Young Stand Monitoring in the Morice TSA: Plot Establishment Report

A Technical Report

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

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EXECUTIVE SUMMARY

Fifty ground plots were established in the Morice Timber Supply Areas (TSA) to monitor young stands. The Young Stands Monitoring (YSM) target population was 15 to 50 year old stands which represent approximately 72,000 ha within a vegetated land base of approximately 1,000,000 ha.

The Phase II ground plot age, height and site index (SI) were compared to the Phase I inventory polygon estimates. For young stands, the Phase I polygon attributes often come from silvicultural records and, for this TSA, SI was taken from the provincial site productivity layer. The inventory ages were unbiased but the inventory height was 2.7 m (or 23%) less than the ground height, a statistically significant difference. The inventory SI from the site productivity layer was 8% in lower than the Phase II ground plot SI. The ground plot leading species and the inventory leading species were the same for 39 of the 50 plots.

The Phase II ground plot basal area, trees per hectare and volume were compared to Phase I inventory estimates generated by TIPSY using the analysis unit assumptions, the Phase I inventory species composition and SI from the provincial site productivity layer. The Phase I inventory basal area was significantly lower than the Phase II ground basal area while the Phase I inventory trees per hectare were slightly higher than the Phase II ground. The Phase I TIPSY-generated volumes were significantly lower than the Phase II ground volumes and the total bias was dominated by attribute bias (rather than model bias). The population is young and the stands are growing rapidly. Although some of the differences are large, they are comparable to the growth from age 30 – 35. As a consequence, the results should be viewed with caution.

These are monitoring plots and the results reported here are based on one measurement. Remeasurements will be used to quantify trends in the differences – whether they increase, decrease or stay the same over time. A key question not addressed here s how differences in young stands will translate to differences at maturity and the effect on wood supply.

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1 Introduction

The British Columbia Ministry of Forests, Lands and Natural Resource Operations Forest Analysis and Inventory Branch (FAIB) has developed a young stand monitoring (YSM) program to monitor the performance of young forest stands, especially those in high risk forest management units. The primary focus of FAIB's YSM is to check the accuracy of the growth and yield assumptions and predictions of key timber attributes in young stands for timber supply review (TSR) in a management unit. That is, the monitoring program will help identify opportunities to improve the accuracy of timber supply forecasting for a management unit.

YSM pilot projects were conducted in the Kootenay Lake and Morice TSAs in 2012/13. The Kootenay Lake YSM report was the starting point for the Morice analysis. These two projects represent the first implementations of the YSM analysis and reporting protocol and, as a consequence, it is anticipated the results from these initial analyses will contain some recommendations regarding future YSM sampling and analysis.

2 Objective

This report summarizes young stand monitoring for the Morice TSA. It is an establishment report, summarizing the initial sampling and analyses. The specific objective of young stand monitoring is (FAIB 2012):

> To check the accuracy of the GY predictions (assumptions) of key timber attributes of young stands used in TSR in a management unit, based on an independent random sample of monitoring plots. The TSR assumptions include stand gross and net volume (gross volume less cruiser-called decay and waste), site index, total age, species composition, pest and disease incidence and operational adjustment factors (OAFs).

In addition to TSR uses, the YSM data can also be used to meet some other objectives, including:

- Characterization of young stand state and trends (e.g., current composition, structure, productivity, health, growth rates, and change),
- Assessment of the accuracy of young stand attributes in the veg-comp-poly inventory file (at the level of population means and totals),
- Provision of a dataset for various special projects, e.g., test/refine site index estimates in the site productivity layer, and various research needs.

The conclusions that can be drawn from a single, initial measurement are limited and should be interpreted with caution. Remeasurement of the ground samples is critical in confirming any observed trends. The OAF assumptions were not evaluated here.

3 Sample Design

3.1 Population

The monitoring unit, the geographic area of interest, is the Morice TSA which is located in north-western British Columbia (Figure 1).

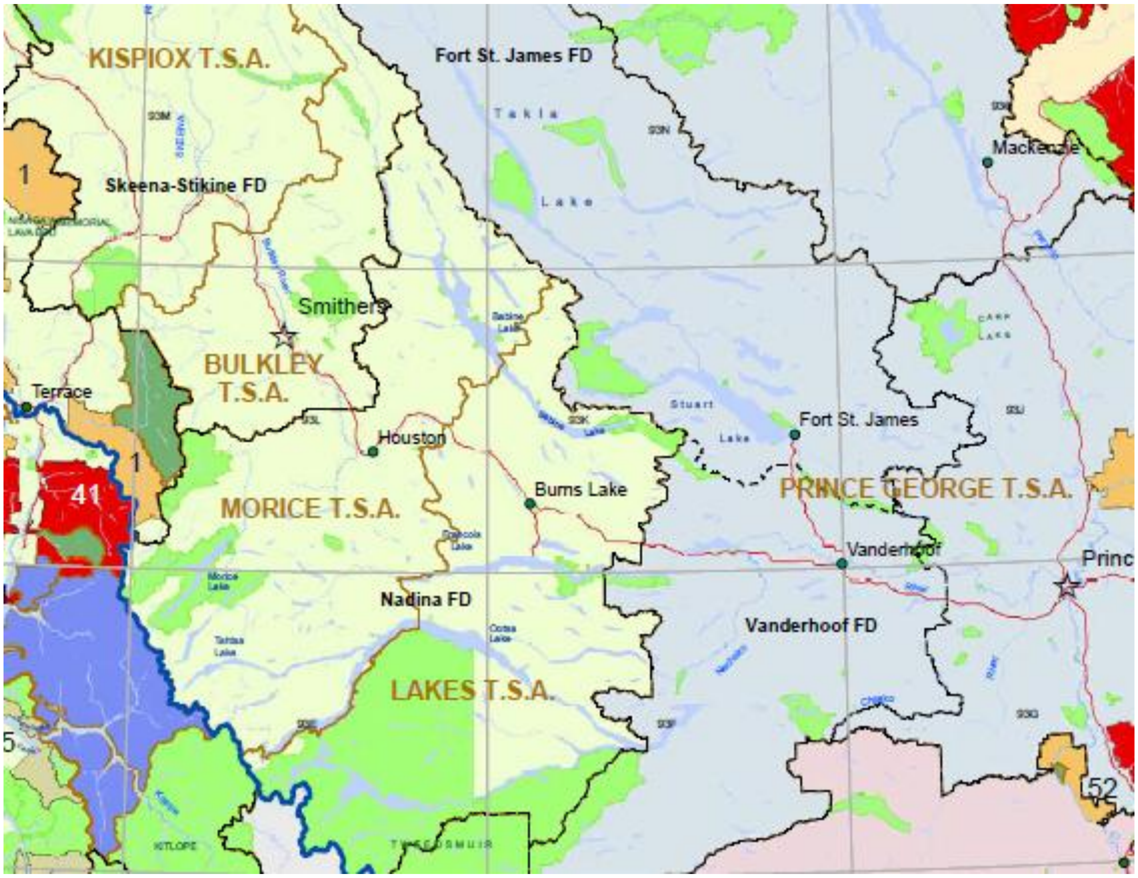


Figure 1. The Morice TSA

The Morice TSA has approximately 1.5 million hectares, approximately 57 percent of which is considered productive forest (Table 1).

Table 1. Morice TSA Land Base Summary (Nona Phillips Forestry Consulting 2012a).

Land Classification	Area (ha)	% of TSA
Total TSA Area	1,501,703	100%
Net-downs	171,707	11.4%
Parks	134,899	9.0%
Private	34,740	2.3%
Indian Reserve	2,068	0.1%
Net Area	1,329,996	88.6%
Non Vegetated	291,212	19.4%
Vegetated	1,038,784	69.2%
Non-treed	180,432	12.0%
Treed	858,352	57.2%

3.2 Target Population

The ground sampling plan is described in Nona Phillips Forestry Consulting (2012a, 2012b).

The YSM target population is composed of 15- to 50-year-old stands within the monitoring unit (Table 2). The population was not restricted to vegetated treed polygons. It includes all stands in the age range (including silvicultural openings with CC < 10%).

Table 2. Species Distribution – Morice TSA, Young Stand Monitoring Population (ages 15-50) (Nona Philips Forestry Consulting 2012a).

	Area	
Tree Species	ha	%
Pine	51,152	70.9%
Spruce	17,232	23.9%
Balsam	2,566	3.6%
Aspen (Cottonwood, ACT)	1,146	1.6%
Birch	6	0.0%
Douglas-fir	4	0.0%
Cedar	1	0.0%
Total	72,107	100.0%

3.3 Sample Selection

The YSM target population was not stratified prior to sample selection.

The sampling design was a systematic sample on a fixed grid. The target was to identify 50 initial sample plots with a minimum of 100 alternates. Trial and error with the grid files provided by the Ministry determined that the 2 kilometre grid yielded 177 points within the Young Stand Monitoring population when the grid was clipped to the immature population shapefile. The grid points were divided by the required number of initial samples (50) giving an interval (n) of 3.54. Every n^{th} sample was an initial sample. The remaining samples (127) were alternates.

The first sample was established on the 2km grid at:

Samp_no	UTM (zone, easting, northing)	FEATURE_ID	MAP_ID	POLYGON_ID
51	09U 651582 5961941	7915334	093E077	13424016

3.4 Plot Design & Establishment

Fifty Plots were established from June-August 2012 following the plot design and establishment CMI protocol version dated March 2012 ver 1.0.1[1]. The CMI plot consists of three nested plots: a 400 m^2 (11.28-m radius) plot for measuring all trees with diameter at breast height (DBH) ≥ 9.0 cm; a 100 m^2 (5.64-m radius) for trees with DBH between 4.0 and 9.0 cm; and a 19.6 m^2 (2.50-m radius) plot for all

[1] http://archive.ilmb.gov.bc.ca/risc/pubs/teveg/nficmp2012/CMI%20Procedures_ver1_2012_Final.pdf

trees at least 1.3 m tall and DBH < 4.0 cm. The sample plots are centered at the grid intersection points.

The average establishment cost for the 50 plots was $1536.50/plot. Access significantly affected sample cost and plots requiring helicopter access were significantly more expensive. Quality assurance was $1154.00/sample.

There were no substitutions. Two plots were moved. Sample 79 was moved 200m east and sample 99 was moved 15m north.

4 Data Compilation

The compiled data are given in Appendix I.

4.1 Phase I Inventory

The Phase I inventory (VRI) must stay current to reflect changes due to disturbances such as harvesting, fire, insect and disease. The update process includes the identification, mapping and description of the changes that occur on the forest landbase. The Vegetation Resource Inventory Management System (VRIMS) is used to maintain and update the VRI.

VRIMS can incorporate new harvest and Free Growing data extracted from the RESULTS (Reporting Silviculture Updates and Land status Tracking System) database. Licensees are mandated to report their silviculture activities to RESULTS annually. In addition, VRIMS provides the tools required to grow and project the trees annually. This data is then posted to the BC Geographic Warehouse and is made available to forest managers and the public.

Generally, the data source for the older polygons in the Phase I inventory is interpretation of aerial photography. The information is updated to the reference year using VDYP7. The YSM population consists of younger polygons and the data are more likely to come from RESULTS.

The provincial site productivity layer provides an alternative source of site index estimates for the YSM population. This layer provides site index estimates for up to 9 species that potentially occur. The intersection of the provincial site productivity layer and the YSM ground plots was provided by the FAIB. Of the 50 YSM ground plots, the ground leading species for four plots did not have an associated site index estimate in the site productivity layer. Three of these were HW leading and the fourth was LW leading.

The Phase I inventory attributes are given in Table 3.

Table 3. The Phase I inventory attributes are defined.

Attribute	Source	Variable Description
Proj_Height_1 Proj_Height_2	Veg_comp_ poly	The average height, weighted by basal area, of the dominant, codominant and high intermediate trees for the leading and second species of each tree layer identified. Projected to January 1, 2012.
Proj_Age_1 Proj_Age_2	Veg_comp_ poly	The average age, weighted by basal area, of the dominant, codominant and high intermediate trees for the leading and second species of each

Attribute	Source	Variable Description
		tree layer identified. See section 4.4 for projection year.
Site index	Provincial site productivity layer	The Site Productivity Dataset is intended to give site index estimates province-wide for commercial tree species. The estimates are based on available ecosystem data (spatial delineations and descriptions) from existing PEM (Predictive Ecosystem Mapping) and TEM (Terrestrial Ecosystem Mapping) datasets, coupled with SIBEC data. In areas where no PEM or TEM data is available, site index estimates are based on biophysical data and species ranges.
$Height_{TIPSY}$	TIPSY	Generated from Proj_Age_1 and site index.
Species composition	Veg_comp_poly	Species composition by Basal Area.
Basal area	TIPSY	Generated using the polygon species composition, SI and the analysis unit assumptions.
Stems/ha	TIPSY	Generated using the polygon species composition, SI and the analysis unit assumptions.
Gross volume	TIPSY	Generated using the polygon species composition, SI and the analysis unit assumptions.
Net merchantable volume	TIPSY	Generated using the polygon species composition, SI and the analysis unit assumptions.

4.2 Phase II Ground (YSM) attributes

The tree level file was used to compile most attributes (Table 4 and Table 5) and to identify veteran trees.

Table 4. The Phase II ground attributes are defined. Attributes refer to live trees only unless noted. L_gvaf, d_gvaf and l_nvaf are the GVAF and NVAF ratios supplied by FAIB.

Attribute	Utilization	Variable Description
Mean height	7.5 cm	Mean Total height of all suitable height trees by species.
Mean age	7.5 cm	Mean Total Age of all suitable trees by species.
Site index	7.5 cm	The SI for each suitable SI tree was computed by SiteTools and the average computed by species.
Species comp.	4.0 cm	Species composition by Basal Area.
Basal area	7.5 cm	Basal area/ha
Stems/ha	7.5 cm	Number of stems/ha.
Gross volume	7.5 cm	Whole stem volume m^3/ha = vol_wsv * l_gvaf
Net merchantable volume	12.5 cm for pine & hardwood 17.5 cm others	Merchantable volume m^3/ha: Gross stem volume less NVAF decay, waste, breakage, top and stump = vol_ntwb * l_nvaf
Mortality	7.5 cm	Whole stem volume m^3/ha (dead trees) = vol_wsv * d_gvaf

Table 5. Descriptive statistics for the Morice TSA ground plots. SE is the standard error of the mean and SE% is standard error as a percent of the mean. All are given at the 7.5cm utilization except net merchantable volume.

Attribute	Statistic				
	Mean	Minimum	Maximum	SE	SE%
Basal area (m^2/ha)	19.0	1.5	67.9	1.6	8%
Stems/ha	1378	100	5954	133	10%
Gross volume (m^3/ha)	94.5	3.5	572.4	12.4	13%
Mortality (Gross volume m^3/ha)	6.1	0.0	191.6	3.9	65%
Net Merchantable Volume (m^3/ha)	43.1	0.0	287.1	7.4	17%

4.3 Ground plot data screening

The data were screened to detect any departures from the intended YSM population. In particular, the data were screened for large, old trees as well as any identified as veterans. Trees with ages greater than 60, DBHs greater than 50 cm and those identified as veterans were examined in further detail. The age and DBH criteria are subjective but appeared to be useful for this TSA. No trees were identified as veterans in the tree file but there were some old, large trees (Table 6). Plots with high volumes were also examined in more detail.

Plot 57 had a total of 70 live trees tallied with an average DBH of 11.8 cm. There were 6 trees with DBH > 20 cm (ranging from 21.0 – 26.3 cm). Three trees were older than 100 years (Table 6). A fourth tree was sampled for age and had a breast height age of 37 and a total age of 43.5. The three old height trees were removed from the summaries.

Plot 91 had one old tree (Table 6) and 7 other trees sampled for age, all within the YSM definitions. Tree 885 was flagged as not a suitable height tree and was removed from the summaries.

For plot 97, there were 13 live balsam trees measured with an average DBH of 35.5 cm (ranging from 9.2 – 62.9 cm). Four trees were sampled for age. One was rotten. The remaining three trees had breast height ages of 47, 79 and 99. The plot had a net merchantable volume of over 300 m^3/ha for trees with DBH > 17.5 cm. Although the trees are large and old, they do not appear to be veterans but rather part of the main canopy. The plot does not represent the young stands that are being monitored. Although the Phase I polygon information meets the immature stratum definition, the plot appears to be in part of the polygon left unharvested. The entire plot was retained.

Table 6. The potential veteran trees are listed. These are trees with DBH > 50 cm, AGE_BH > 60 years and crown class = V.

Sample	Plot	Tree_no	Species	LV_D	DBH	CR_CL	suit_tr	AGE_BH	AGE_TOT	Removed?
57	I	626	BL	L	26.3	D	Y	210	236.5	Yes
57	I	649	BL	L	17.0	C	Y	110	135.5	Yes
57	I	676	BL	L	21.0	C	Y	128	151.5	Yes

Sample	Plot	Tree_no	Species	LV_D	DBH	CR_CL	suit_tr	AGE_BH	AGE_TOT	Removed?
91	I	885	SX	L	26.4	D	N	195	220.5	Yes
97	I	702	BL	L	45.4	C	Y	79	89.5	No
97	I	703	BL	L	62.9	C	Y	99	110.5	No
97	I	707	BL	L	58.7					No
97	I	708	BL	L	47.8	C	Y	98	111.2	No

4.4 Ground sampling year and projection year

The ground sampling occurred from June 7, 2012 to September 20, 2012. Plots measured before July 1, 2012 were assumed to not include the 2012 growing season (ground_year = 2011) and the rest were assumed to include the 2012 growing season (ground_year = 2012). The projection date for the Phase I data was January 1, 2012 and assumed not to include the 2012 growing season. For the samples where ground_year = 2012, the Phase I proj_age_1 was incremented by one year.

4.5 Ground SI and years to breast height for TIPSY

TIPSY requires SI and breast height age (age_bh). First, each ground-sampled age tree was run through SiteTools using the sindex33.dll. SI was predicted from age_bh and height. This was then used to estimate the years to breast height (y2bh). The average age_bh (bhage_avg) and height (htop_avg) were calculated by plot and species. These were then run through SiteTools and an average SI (SI_avg) and y2bh (y2bh_avg) calculated by species and plot.

Ordinarily, growth intercept equations should be used for trees with age_bh < 30. However, these are not available in TIPSY and were not used here.

4.6 Analysis Units

FAIB provided the analysis unit (AU) definitions and yield curve assumptions (Table 7). These AU definitions were used to generate Phase I inventory volume estimates except all balsam polygons were assumed to be natural regeneration.

Table 7. The analysis unit (AU) definitions and assumptions are given.

Species	AU	SI range	Phase I Inventory SI	Site productivity layer SI	Regen delay (years)	OAF 1	OAF 2	Regen method	Regen percent	Initial density
Balsam	100	< 11	9.5	14.8	2	15	5	plant	100	1400
Balsam	101	11 – 14	12.2	15.2	2	15	5	plant	100	1400
Balsam	102	> 14	16.8	15.6	2	15	5	plant	100	1400
Pine	200	< 15	12.9	17.4	2	20	5	plant	100	1400
Pine	201	15 – 18	16.5	18.0	2	20	5	plant	100	1400
Pine	202	> 18	19.8	18.1	2	20	5	plant	100	1400
Spruce	300	< 12	10.3	16.5	2	15	5	plant	100	1400
Spruce	301	12 – 16	14.1	17.6	2	15	5	plant	100	1400
Spruce	302	> 16	18.7	18.0	2	15	5	plant	100	1400

4.7 Predicted (Projected) Yield Estimates

For each sample plot, Phase II ground volumes were compared against two separate sets of TIPSY generated volumes in order to quantify the overall volume bias as well as to partition the total bias into model bias and attribute bias. The whole stem volume uses the 7.5 cm utilization. The utilization for volumes net of decay, waste and breakage depends on the leading species. Pine and hardwood use the 12.5 cm utilization and all other leading species use 17.5 cm.

<u>VOL1</u>: Ground-based whole stem plot volume. The data were screened and residual or veteran trees removed. VOL1 is identical to the ground compiled volume except for the removal of veteran trees. The tree file (Morice_TSA_trees_and_FH_30MAY13.xlsx) was used. It does not include the application of gross volume adjustment factor (GVAF) or net volume adjustment factor (NVAF). These ratios are applied by status (live vs. dead), species, age group and BEC grouping. The GVAF and NVAFs were provided by FAIB and applied to vha_wsv and vha_nwb to obtain NVAF adjusted estimates of whole stem volume and volume net of decay, waste and breakage.

<u>VOL2</u>: TIPSY estimated volumes using ground plot inputs and some analysis unit assumptions. The ground plot inputs include site index and species composition. For each species, the average ground breast height age and site index were computed as described in section 4.5. If SI was not available for the leading species, it was taken from the provincial site productivity layer (the leading specie SI was always available in Morice). If SI was not available for non-leading species, site index conversion equations were used to impute the SI from the SI of the leading species. If no conversion equations exist, the leading species SI was used for non-leading species.

If there was a record of harvesting in the polygon and the leading species was a conifer, the regeneration method was assumed to be planting and the planting density taken from the analysis unit assumptions. Otherwise the regeneration method was assumed to be natural with an initial density of 5,000 stems/ha. If the leading species was balsam, natural regen with an initial density of 5,000 stems/ha was assumed. Each species present in the ground sample was projected as a pure species stand with the appropriate site index, and the regen method and planting density taken from the leading species. If balsam or aspen were a minor component of a plantation, the initial density was taken from the leading species but the regeneration method was set to natural for balsam and aspen. A regen delay of 2 years was used for all runs. TIPSY does not allow for aspen leading stands to have a conifer component so aspen leading plots were projected as pure aspen stands.

The TIPSY total age is the age since disturbance and not necessarily breast height age plus years to breast height. It includes a regen delay, years to breast height and assumes an initial stock height. As a consequence, when the TIPSY total age is equal to the ground age, the TIPSY height will not necessarily march the ground height. And the heights should match since the ground compiler and TIPSY use the same SI (SiteTools) curves. Rather than matching the ground and TIPSY total ages, the ground and TIPSY heights were matched and the corresponding TIPSY volume extracted. This is equivalent to matching the ground and TIPSY volumes at the same breast height age. Generally there is a ground height corresponding to the leading species but often there is no ground height or SI for minor species. In this case, the SI was taken from the site productivity layer and the TIPSY height matched to the ground leading species height. There were some trends in the ground data heights. Generally the heights of primary and secondary species were close with the secondary species being slightly shorter. In general, BL was shorter than PL and AC taller than conifers. There were not enough data to develop rules and the impact of defaulting to the leading species height was assumed to be minor.

The TIPSY volume was computed as the species composition weighted average of the pure species TIPSY volumes.

<u>VOL3</u>: TIPSY estimated volumes using SI from the provincial site productivity layer and Phase I inventory species composition. The TIPSY runs were similar to those for VOL2 except the species composition was taken from the VRI Phase I layer and SI from the site productivity layer. The TIPSY age was matched to PROJ_AGE_1. Again, pure species curves were generated and weighted by the Phase I species composition. Regeneration method and initial density were based on the leading species. If balsam or aspen were a minor component of a plantation, the initial density was taken from the leading species but the regeneration method was set to natural for balsam and aspen. For aspen leading polygons, the minor species were ignored and the sample modelled as a pure aspen stand.

For all TIPSY runs, all other input assumptions were constant by sample (initial density, origin, OAFs, and regen delay).

Total Bias = VOL1 – VOL3
Model Bias = VOL1 – VOL2
Attribute Bias = VOL2 – VOL3

Yield tables, averaged by leading species, are given in Appendix II.

4.8 Height and Age matching

The height and age data matching followed the FAIB (2011) VRI procedures. The Phase II ground data were matched with the corresponding Phase I inventory data for the parent polygon. The Phase II ground plot heights and ages were based on the average values for suitable height trees for the leading species. The objective was to match the Phase II ground leading species to the Phase I inventory leading or secondary species and compare the ages and heights. If a match could not be made at the Sp0 (genus) level, conifer-to-conifer (or deciduous-to-deciduous) matches were allowed. However, conifer-deciduous matches were not acceptable.

The five possible matching cases are as follows:

- Case 1: Phase I inventory leading Sp0 matches the Phase II ground leading Sp0.
- Case 2: Phase I inventory second Sp0 matches the Phase II ground leading Sp0.
- Case 3: Phase I inventory leading species and the Phase II ground leading species are both coniferous or are both deciduous.
- Case 4: Phase I inventory second species and the Phase II ground leading species are both coniferous or are both deciduous.
- Case 5: No match

4.9 Power analysis

The power of a statistical test is the probability of rejecting the null hypothesis when the null hypothesis is false. A type II error occurs when the null hypothesis is rejected when it is true. The probability of a type II error is β so the power is 1 – β. The power is affected by the sample size, the magnitude of the bias and the correlation between the two estimates (in a paired sample). The suggested minimum power level is 0.60 (FAIB 2012).

5 Phase II Ground vs. Phase I Inventory

5.1 Stand Age and Height

A total of 43 plots had matched age and height pairs while 45 matched SI pairs (Table 8). Five out of the 6 plots that were a case 2 match (Phase II ground leading species = Phase I second species) did not have an age and height associated with the second species. Because SI was taken from the site productivity layer, there were estimates of inventory SI for these plots.

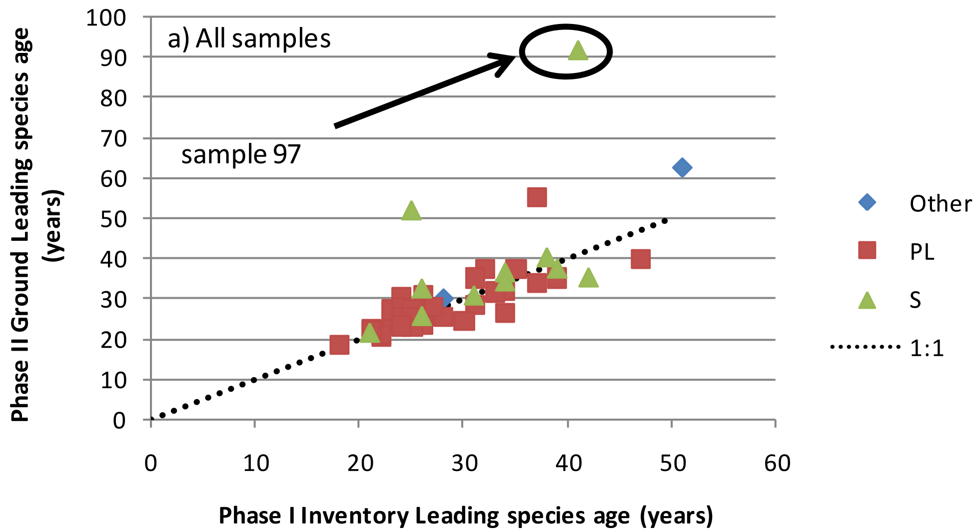
Table 8. The results of the age, height and SI matching.

Case	Number of plots	Age pairs	Height pairs	SI pairs
1	39	39	39	39
2	6	1	1	6
3	3	3	3	0
4	0	0	0	0
5	2	0	0	0
All	50	43	43	45

In general, there was good agreement between the Phase II ground and Phase I inventory ages (Table 9Table 10 and Figure 2). Overall, the Phase I inventory age underestimated the Phase II ground age by 1.7 years and this was dominated by plot 97. As mentioned previously, plot 97 appeared to be located in the residual part of the polygon.

Table 9. The Phase II ground plot and Phase I inventory polygon ages are compared. Statistically significant differences ($p < 0.05$) are shaded.

		Age (years)				
Strata	N	Phase II Ground	Phase I Inventory	Bias	Prob (bias ≠ 0)	Power (1 -β)
A	0					
B	2	52.8	52.0	0.8 ± 9.3	0.946	
P	31	28.7	28.6	0.1 ± 0.9	0.887	
S	10	40.6	33.9	6.7 ± 5.6	0.264	
	43	32.6	30.9	1.7 ± 1.5	0.266	0.960



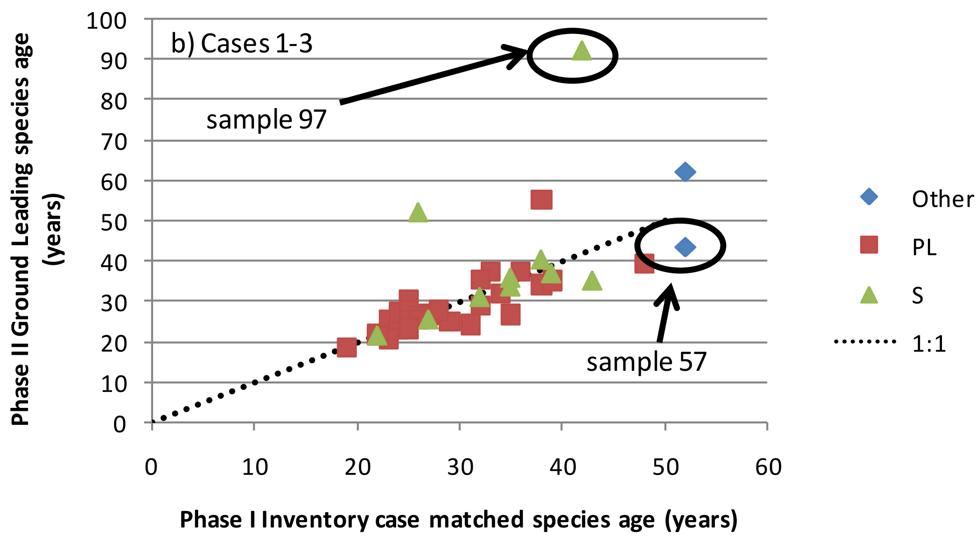
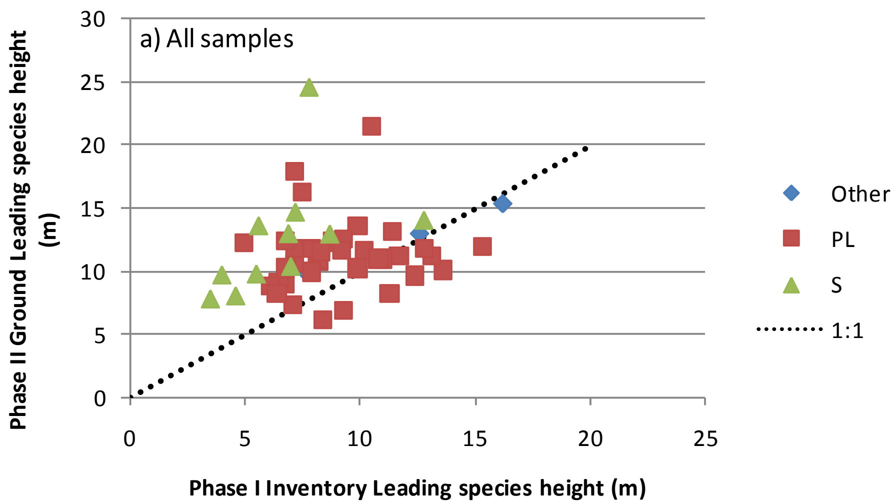


Figure 2. The Phase I inventory and Phase II ground leading species ages are compared (a) and the species matched ages are compared (b). There were no ages taken from the leading species for sample 57. This was the plot where the residual trees were removed.

The relationship between Phase II ground and Phase I inventory height was poor (Figure 3 and Figure 4) with evidence of significant bias (Table 10). The Phase I TIPSY height was also significantly biased and the bias was about half of the Phase I inventory height.

Table 10. The ground plot and the Phase I inventory and Phase I TIPSY-generated heights are compared. Statistically significant differences ($p < 0.05$) are shaded.

	Height (m)						Height (m)					
Strata	N	Phase II Ground	Phase I Inventory	Bias	Prob (bias ≠ 0)	Power (1 -β)	N	Phase II Ground	Phase I TIPSY	Bias	Prob (bias ≠ 0)	Power (1 -β)
A	0						0					
B	2	12.7	12.0	0.7 ± 1.5	0.715		2	12.7	10.6	2.1 ± 0.7	0.191	
P	31	11.0	9.2	1.8 ± 0.6	0.002		34	10.8	9.9	0.8 ± 0.3	0.016	
S	10	13.1	7.5	5.6 ± 1.4	0.004		11	12.6	9.7	2.9 ± 1.2	0.031	
	43	11.6	8.9	2.7 ± 0.6	0.000	0.995	47	11.3	9.9	1.4 ± 0.4	0.001	0.948



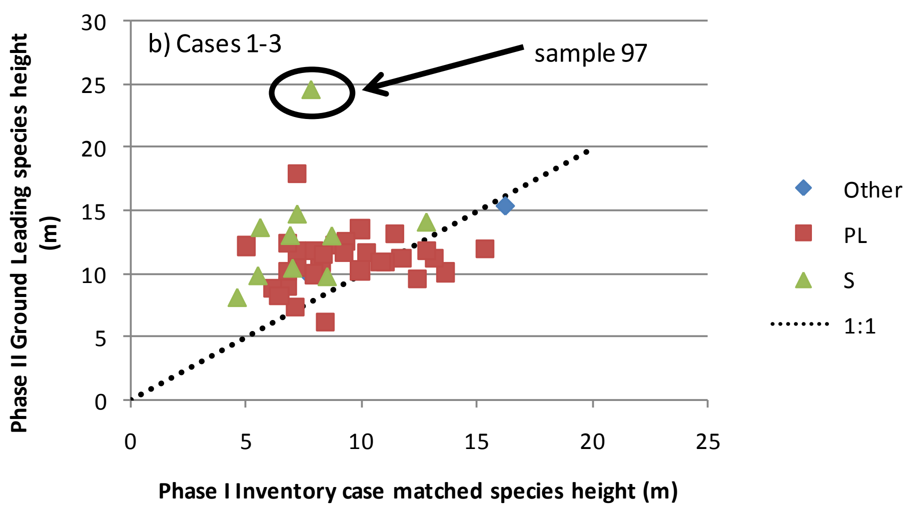


Figure 3. The Phase I inventory and Phase II ground leading species heights are compared (a) and the species matched heights are compared (b).

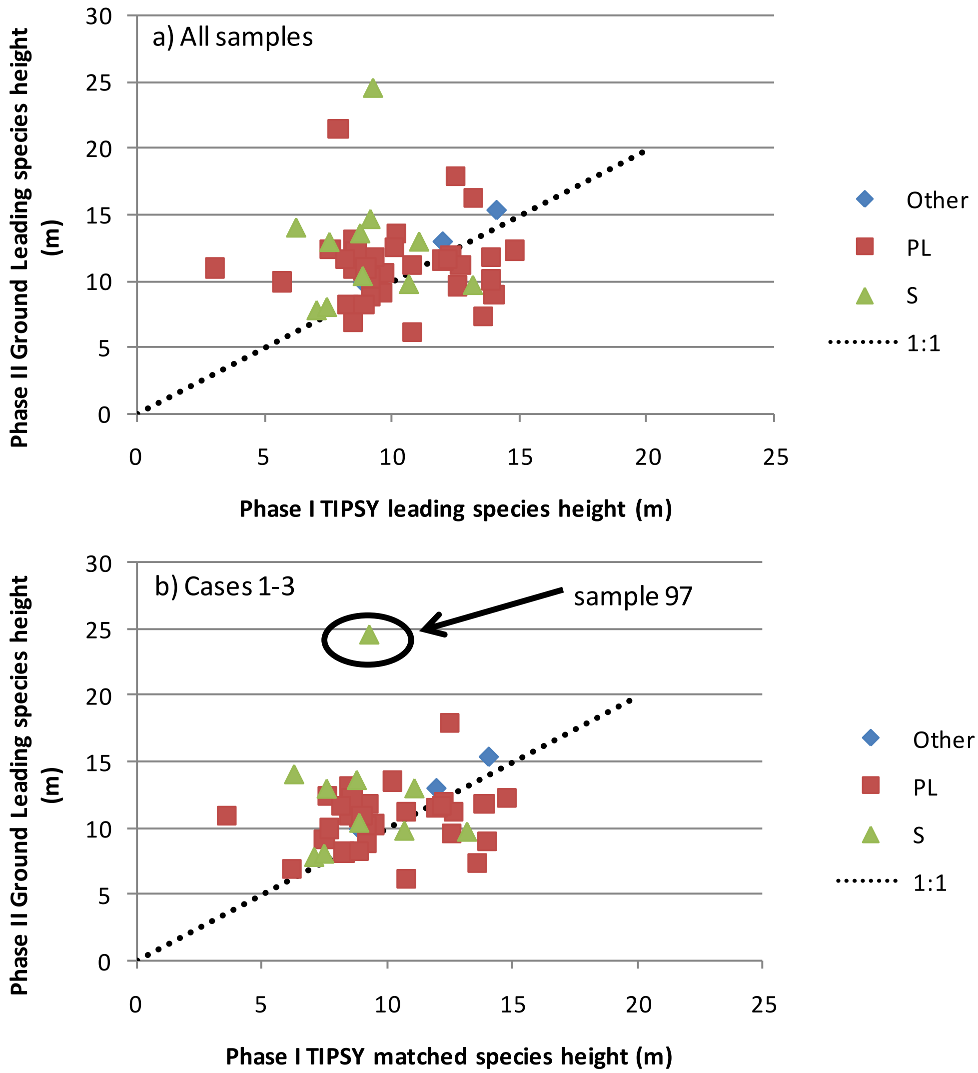


Figure 4. The Phase I TIPSY generated and Phase II ground leading species heights are compared (a) and the species matched heights are compared (b).

5.2 Site index

There was little variation in SI (Figure 5) and evidence of slight but statistically significant underestimation of SI in the Phase I inventory site productivity layer (Table 11). This is consistent with the age (no bias) and height (underestimation) results. Height and age were taken from the Phase I inventory while SI was taken from the site productivity layer so this consistency between height, age and SI is reassuring.

The Phase II ground site index has a higher range and variability than the Phase I SI from the site productivity layer. This may be due in part to the Phase II plot representing a small area while the Phase I inventory polygon representing a larger area.

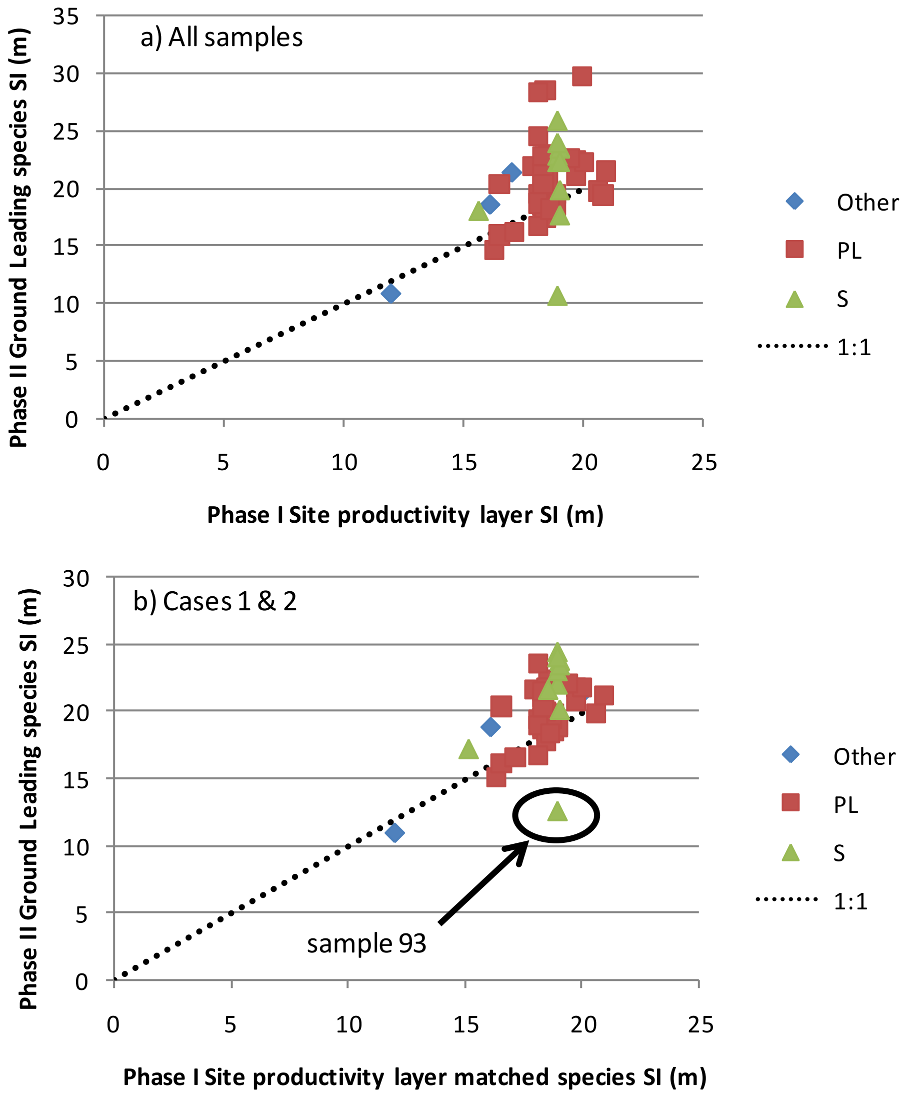


Figure 5. The site productivity layer SI and Phase II ground leading species SI are compared (a) and the species matched SIs are compared (b).

Table 11. The Phase II ground plot and Phase I inventory SI are compared. Statistically significant differences ($p < 0.05$) are shaded.

		SI (m)				
Strata	N	Phase II ground	Phase I site productivity layer	Bias	prob(bias ≠ 0)	Power (1 -β)
A	1	21.3	20.0	1.4 ± 0		
B	2	14.9	14.1	0.7 ± 1.9	0.728	
P	32	19.7	18.5	1.4 ± 0.3	0.000	
S	10	21.2	18.5	2.9 ± 1.1	0.035	
All	45	19.9	18.3	1.7 ± 0.3	0.000	0.994

5.3 Leading Species

Thirty-nine (78%) of the plots had the same Phase I inventory and Phase II ground leading species (Table 12). The weighted Kappa statistic was 0.45 ± 0.12 and is statistically significant, indicating the observed agreement is higher than would be expected by chance.

Table 12. Comparison of leading species labels (4.0 cm utilization level). Cells with the same Phase II ground and Phase I leading species are shaded gray. The agreement is statistically significant.

Phase I inventory	Phase II Ground Plot Leading Species			
leading species	AC or AT	B	PL	S
AC or AT			1	
B		2		
PL	3		29	4
S		1	1	8

5.4 Forest Health

The ground sampling crews did not have specialized training in forest health data collection at the time of ground sampling and the results should be evaluated cautiously.

The average dead standing whole stem volume at YSM plot establishment was 6.1 ± 3.9 m^3/ha, or approximately 5% of the gross volume (live and dead) (Table 5). Sample 68 had 192 m^3/ha of dead volume while the rest of the samples had less than 40 m^3/ha. For sample 68, 6 of the 32 dead trees were pine and the rest were unknown conifer. The cause of mortality was not recorded.

The YSM plots include an assessment of damage agents and severity on individual trees, to assess forest health. Damage agent types include abiotic, disease, insects and animal damage. Only live, non-veteran trees with DBH > 7.5cm were included. By basal area, 36% of the trees had no damage, 31% had damage by unknown agents and the majority of the remaining damage was due to disease (19%) (Figure 6). For pine, the primary damage agent identified was disease and for spruce, it was insects. For hemlock and balsam, the primary damage agent was generally unidentified. Poplar (aspen and cottonwood) had the widest range of damage agents.

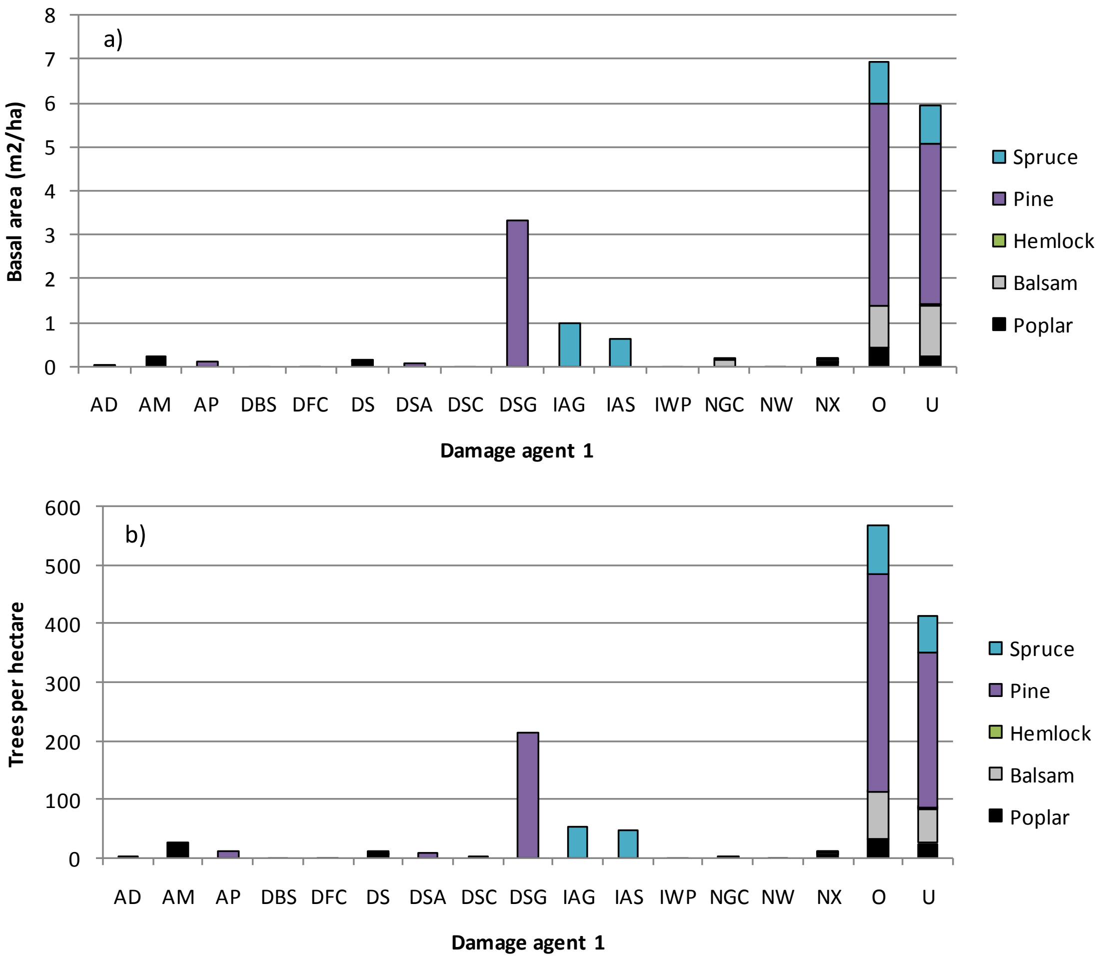


Figure 6. The average basal area (a) and trees/ha (b) are given primary damage agent and species. The first letter indicates the type of damage agent: abiotic (N), disease (D), insect (I), animal damage (A), no damage (O) and unknown (U). The codes are fully defined in Table 13. The summary includes live, non-veteran trees with DBH > 7.5cm.

Table 13. Codes of primary damage agents observed in the Morice TSA YSM.

Agent	Code	Description
Animal	AD	deer
	AM	moose
	AP	porcupine
Disease	DBS	Spruce broom rust
	DFC	Large-spored spruce-labrador tea rust
	DS	stem disease
	DSA	Atropellis Canker (lodgepole pine)
	DSC	Comandra Blister Rust
	DSG	western gall rust

Agent	Code	Description
Insect	IAG	Cooley Spruce Gall Adelgid
	IAS	Green Spruce Aphid
	IWP	lodgepole pine terminal weevil
Abiotic	NGC	Frost crack
	NW	windthrow
	NX	scarring and rubbing
None	O	No detectable abiotic or biotic damage
Unknown	U	Damage evident but causal agent unknown

6 Phase II Ground vs. Phase I TIPSY

The Phase II ground measurements and Phase I TIPSY predictions of basal area, trees per hectare and volume were compared. Separate documents (TIPSY_AUassumptions.docx and Morice_YSM_inTSR_2013jun27.docx) examine the effect of changing the AU assumptions of planting density, regen delay and OAF1 on yield and the persistence of the effects over time.

6.1 Phase II Ground vs. Phase I TIPSY Basal area and TPH

The Phase II ground and Phase I TIPSY basal area (BA) and trees per hectare (TPH) were compared (Table 14). The differences between the Phase II ground and Phase I TIPSY TPH are not significant but the Phase II ground BA is significantly higher than the Phase I TIPSY BA.

Table 14. The ground plot and TIPSY BA and TPH are compared. Statistically significant differences ($p < 0.05$) are shaded. The last row omits samples 78, 97 and 100.

		TPH					BA (m^2/ha)				
Strata	N	Phase II Ground	Phase I TIPSY	Bias	Prob (bias ≠ 0)	Power (1 -β)	Phase II Ground	Phase I TIPSY	Bias	Prob (bias ≠ 0)	Power (1 -β)
A	1	1626	3287	-1661 ± 0			22.6	10.9	11.7 ± 0		
B	2	926	3141	-2215 ± 891	0.244		17.0	20.5	-3.5 ± 7.7	0.728	
P	36	1468	1386	82 ± 197	0.681		18.3	13.2	5.1 ± 2.0	0.015	
S	11	1146	1596	-449 ± 418	0.308		21.2	11.3	9.9 ± 2.3	0.002	
Total	50	1378	1540	-162 ± 185	0.385	0.138	19.0	13.0	6.0 ± 1.6	0.000	0.958
	47	1297	1488	-192 ± 171	0.267		17.4	12.6	4.9 ± 1.4	0.001	

6.2 Phase II Ground (VOL1) vs. Phase I TIPSY Volume (VOL3) – Total bias

The Phase II ground volume (VOL1) and the Phase I TIPSY volumes (VOL3) are not particularly close (Figure 7) and the differences are statistically significant (Table 15 – total bias).

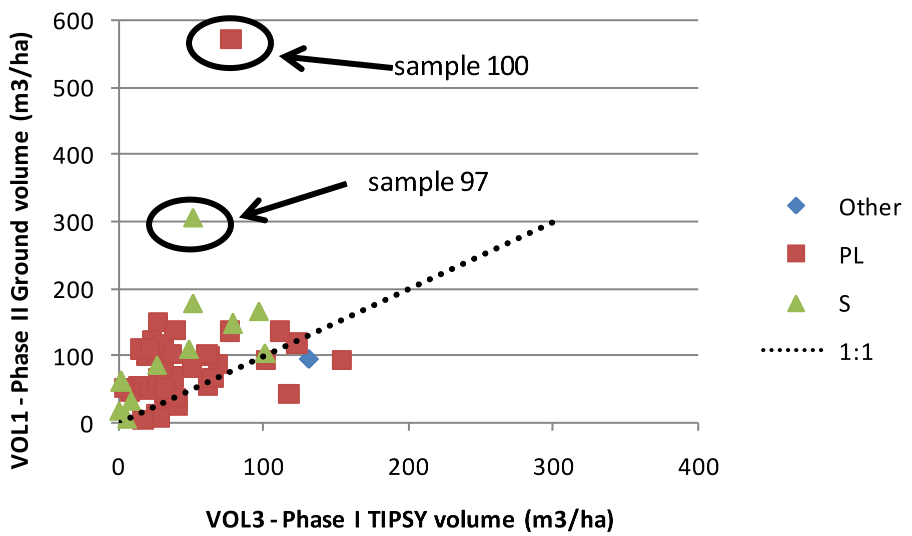


Figure 7. The Phase II ground volume (VOL1) is plotted against the Phase I TIPSY VOL3 predictions. Volumes are whole stem volumes at the 7.5 cm utilization level.

6.3 Phase II Ground (VOL1) vs. AU Volume (VOL2) – model bias

The Phase II ground volumes (VOL1) were compared to the TIPSY volumes using the ground species composition and site index (VOL2) (Figure 8). This is an indication of the model-related volume bias and generally the volumes are close with the exception of samples 78 and 100. The model bias is not statistically significant.

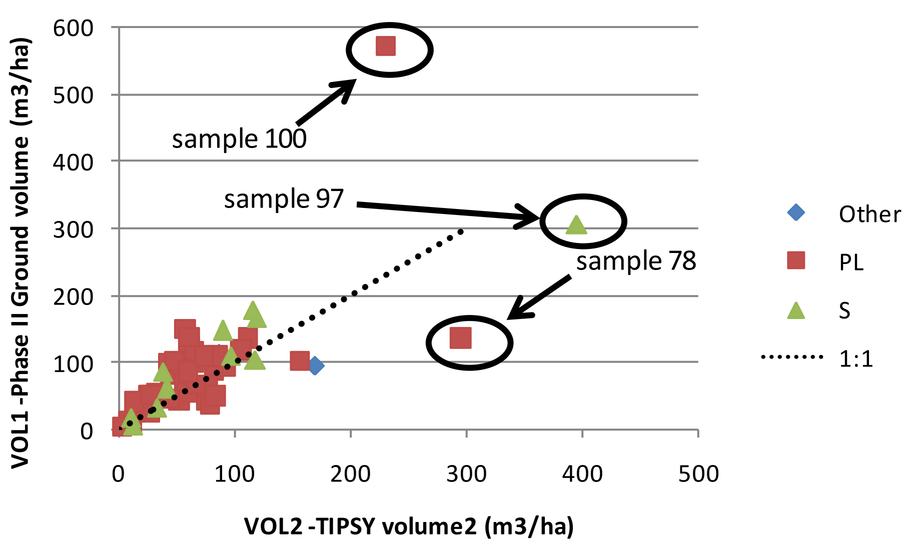


Figure 8. The Phase II ground volume (VOL1) is plotted against VOL2. Volumes are whole stem volumes at the 7.5 cm utilization level.

The Phase II ground leading species for sample 78 is ACT with an associated SI = 29.7m (based on a height of 21.4 m and an age of 30). For sample 100, the Phase II ground trees per hectare was 5,954 at a breast height age of 49 while the maximum stems/ha allowed by TIPSY using the existing stand options and the Phase II ground attributes was 2,054 stems/ha.

6.4 Bias analysis

The results of TIPSY whole stems volume comparisons are given in Table 15 by Phase I leading species. The overall total bias is 46.9 m^3/ha ± 11.9 (one standard error). Most of this bias is due to attribute rather than model bias. Overall the model bias is low and not statistically significant.

Three samples have particularly large biases (Figure 7 and Figure 8). Sample 78 had a considerably higher VOL2 than Phase II ground volume (VOL1) and a very high site index (29.7m). Sample 97 has a Phase II ground breast height age of 81 for the leading species and, although the polygon is part of the YSM population, the sample point is older than the usual range for TIPSY. Sample 100 has an unusually high Phase II ground stems/ha (approximately 6,000 at breast height age 49) and beyond the range allowed by TIPSY for existing stand conditions. Therefore, results are also summarized with these three plots omitted.

Table 15. Comparison of whole stem volume. The utilization level is 7.5 cm. Statistically significant differences are shaded. The last row omits samples 78, 97 and 100.

Strata	N	(m^3/ha)			Bias			prob	(bias ≠ 0)	
		VOL1	VOL2	VOL3	Total	Model	Attribute	Total	Model	Attribute
Hardwoods	1	112.9	84.4	25.0	87.9 ± 0	28.5 ± 0	59.4 ± 0			
Balsam	2	74.2	100.0	75.5	-1.2 ± 33.4	-25.7 ± 43.2	24.5 ± 9.8	0.977	0.658	0.243
Pine	36	90.2	69.3	48.3	41.9 ± 14.9	20.9 ± 11.6	21.0 ± 8.2	0.008	0.081	0.015
Spruce	11	110.8	96.4	42.4	68.4 ± 21.7	14.4 ± 12.9	54.0 ± 29.4	0.010	0.291	0.097
Total	50	94.5	76.8	47.6	46.9 ± 11.9	17.8 ± 9.0	29.2 ± 8.8	0.000	0.053	0.002
	47	79.0	62.1	45.5	33.5 ± 6.6	16.9 ± 4.7	16.5 ± 4.6	0.000	0.001	0.001

The previous volume analysis looked at whole stem volume for DBH ≥ 7.5 cm. The following analysis looks at volume net of decay, waste and breakage. The utilization depends on the leading species. The volumes are about half the whole stems volumes. The bias is again dominated by attribute bias while the model bias is not statistically significant.

Table 16. Comparison of volumes net of decay, waste and breakage. The Statistically significant differences are shaded. The last row omits samples 78, 97 and 100.

Strata	Util	N	(m^3/ha)			Bias			prob	(bias ≠ 0)	
	(cm)		VOL1	VOL2	VOL3	Total	Model	Attribute	Total	Model	Attribute
Hardwoods	12.5	1	59.9	59.1	0.7	59.2 ± 0	0.8 ± 0	58.4 ± 0			
Balsam	17.5	2	30.7	31.7	9.4	21.3 ± 14.0	-0.9 ± 35.2	22.2 ± 21.2	0.370	0.983	0.485
Pine	12.5	36	39.6	40.6	27.0	12.6 ± 6.6	-1.0 ± 5.2	13.6 ± 6.1	0.064	0.850	0.032
Spruce	17.5	11	55.1	54.3	8.0	47.1 ± 24.9	0.8 ± 5.4	46.3 ± 27.1	0.088	0.888	0.118
Total		50	43.1	43.6	21.6	21.5 ± 7.4	-0.6 ± 4.1	22.0 ± 7.5	0.006	0.889	0.005
		47	33.4	31.3	19.9	13.5 ± 4.4	2.1 ± 2.6	11.4 ± 3.5	0.004	0.422	0.002

The power associated with the tests of volume bias (Table 17) is generally above the suggested minimum power level of 0.60 (FAIB 2012).

Table 17. The power of the test of whether the bias components, based on all 50 samples, are statistically different from zero.

Attribute	N	Power (1 - β)		
		Total	Model	Attribute
Whole stem volume	50	0.972	0.493	0.899
Volume net of decay, waste and breakage	50	0.810	0.052	0.820

7 Discussion

The Phase II ground age and Phase I inventory age matched reasonably. Stand height was significantly underestimated in the Phase I inventory but the height generated from the site productivity layer SI was closer to the Phase II ground height. The underestimation of height is consistent with the underestimation of SI in the provincial site productivity layer.

In general, the Phase II ground volume was higher than the Phase I TIPSY generated volumes and the volume bias was dominated by attribute bias. That is, the differences between the Phase II ground and Phase I TIPSY volumes are dominated by differences in the inputs (attributes including species composition and SI) rather than the model predictions (ground compiler vs. Batch TIPSY). VOL1 and VOL2 (model bias) use the same species composition and SIs but VOL1 uses the ground density and does not include OAFs while VOL2 uses the AU initial density and OAFs. VOL1 uses the ground compiler and VOL2 uses TIPSY to generate volumes. VOL2 and VOL3 (attribute bias) use the same AU assumptions of initial density, regen delay and OAFs but VOL2 uses the ground species composition and SI while VOL3 uses the inventory species composition and SI.

Table 18. The results of comparing the Phase II ground plots to the Phase I inventory and AU assumptions are summarized. A down arrow indicates underestimation by TIPSY or the Phase I inventory and an upward arrow indicates over-estimation. The values in brackets are total bias as a percent of Phase II ground attribute mean. An asterisk (*) indicates a statistically significant bias (95% probability).

Attribute	N	Total Bias ± standard error	
		Magnitude	Direction
Total whole stem volume bias (m^3/ha)	50	46.9 ± 11.9 (50%)	↓*
Volume model bias (m^3/ha)	50	16.6 ± 9.0 (18%)	↓
Volume attribute bias (m^3/ha)	50	30.3 ± 8.9 (32%)	↓*
Trees per hectare	50	-162 ± 185 (-12%)	↑
Basal area (m^2/ha)	50	4.9 ± 1.4 (31%)	↓*
Matched age (yrs)	43	2.5 ± 1.5 (8%)	↓
Inventory Stand height (m)	43	2.7 ± 0.6 (23%)	↓*
Site productivity layer height (m)	47	1.4 ± 0.4 (12%)	↓*
Site index (m)	45	1.7 ± 0.3 (8%)	↓*

There are a number of limitations to the approach taken here and contribute to the differences observed between the Phase I inventory and the Phase II ground sample.

Attribute definitions – The Phase I inventory and Phase II ground plots have slightly different definitions of attributes. Some of the Phase I estimates come from silvicultural records and may be collected to different standards, different levels of error checking and different definitions.

Sample Unit – The Phase I inventory sample unit is the polygon and the Phase II ground plot is a 0.04 ha fixed area plot within the polygon. Some of the differences between Phase I and Phase II may arise because Phase II is a subsample of the polygon and may not fully capture some of the within polygon variation considered by photo interpreters when assigning a VRI label to reflect the overall polygon.

VRIMS – VRIMS[2] projects the Phase I inventory to the year of ground sampling which introduces another source of error.

TIPSY – The documentation for TIPSY indicates the following.

> TIPSY retrieves yield tables from its database, customizes the information and displays summaries and graphics for a specific site, species and management regime. Yield tables are available for eight pure even-aged coniferous species of commercial importance in British Columbia, and our two broadleaf hardwoods, red alder and trembling aspen. Other species use a substitute database, along with site index equations specific to that species.
>
> An optional multiple species feature will prorate the yields for up to a maximum of eight species in TIPSY, and five in BatchTIPSY. This option was developed to aggregate stands for the benefit of timber supply planners. TIPSY does not simulate the growth of multiple species stands biologically. The only biological assumption is the site index conversion adjustment among species.
>
> TIPSY projects the growth of managed stands starting at age zero in support of silvicultural planning and timber supply analyses. Users should consider VDYP for even-aged, natural stands and PrognosisBC for ground-based inventories of multi-layered and partially cut stands of mixed species.

Some of the TIPSY runs in this report are certainly outside the recommended use of TIPSY.

8 Recommendations

The sample size is small and the results here are based on one measurement so the results should be viewed with caution. The effects of some of the differences are expected to diminish over time and remeasurements will allow evaluation of this. For example, there are differences between the

[2] http://www.for.gov.bc.ca/hts/vri/vcu/vcuvrims.html

observed Phase II ground trees per hectare and the analysis unit assumptions resulting in differences in immature volumes but these differences are expected to diminish as the stands age and achieve full site occupancy. In contrast, differences in SI are expected to persist and the resulting differences in volume estimates are expected to persist as the stands age.

- The results here should be viewed with caution as the sample size is limited and only one measurement is used.
- Remeasurements should be conducted as planned (every 5 years) to quantify trends and identify whether differences diminish, persist or increase over time.
- Data screening is subjective. Guidelines should be established for identifying residual/veteran trees and whether to include or exclude them from the ground plot compilations and TIPSY runs. Guidelines should be established for including/excluding plots with Phase I attributes that meet the YSM definition but do not meet the YSM definition based on the ground data.

9 List of References

FAIB. 2011. Vegetation Resources Inventory: VRI sample data analysis procedures and standards. Version 1. Dated January 2011. 23p + app.

FAIB. 2012. A framework for implementing young stand growth monitoring in British Columbia – A discussion paper. Version 2.1. Dated January 6, 2012. 37p.

Nona Phillips Forestry Consulting. 2012a. Morice Timber Supply Area – TSA 20 Vegetation Resources Inventory Project Implementation Plan for Volume Audit Sampling, Young Stand Monitoring and Net Volume Adjustment Factor Sampling.

Nona Phillips Forestry Consulting. 2012b. Morice TSA VRI Sample Selection Report.

10 Appendix I – Plot Data Summaries

Table 19. The Plot data summaries are given.

	Phase II Ground								Phase I VRI				Site Prod Layer						TIPSY			
samp	BA 7.5	TPH 7.5	WSV 7.5	WSV dead	Spp1	Ht1	Age _bh1	SI1	Spp1	HT1	Age1	SI	SX	HM	BL	PL	FD	AT	VOL2	VOL3	BA	Ht
51	23.9	901	136	4	PL	13.5	31	18.6	PL	9.9	32	16	18.9		16.1	18.3		15.1	110	77	19.5	12.0
52	34.1	3152	148		PL	10.8	24	18.3	PL	8.2	24	18	18.9		16.1	18.4		15.8	55	27	8.9	8.2
53	19.1	926	118		PL	13.1	28	19.6	PL	11.4	37	16	19.3		17	18.8		14.9	100	123	26.2	14.1
54	24.0	1026	81	0	PL	9.6	28	14.7	PL	12.4	31	20	14.7		14.8	16.3			44	51	14.8	10.2
55	28.2	2477	121		PL	10.9	24	18.6	PL	8.2	24	18	18.9		16.1	18.3		15.3	62	24	7.8	7.9
56	14.5	475	53	22	BL	10.0	46	10.9	B	7.7	51	11	12	12	12	12			35	20	10.4	8.6
57	19.4	1376	96	2	BL	15.4	37	18.6	BL	16.2	51	19.1	18.9		16.1	18.4		17.2	165	131	30.5	13.9
58	25.1	2552	98	3	PL	10.2	21	19.6	PL	9.9	23	21	18.9		16.1	18.3		16.5	43	20	6.9	7.9
59	22.0	2001	86		SX	10.4	22	22.4	S	7	31	19	18.9		15.8	18.1		17.4	35	26	9.0	9.1
60	3.8	450	11		SX	6.8	18	19.2	PL	9.3	24	20	18.9		16.1	18.3		16.7	9	26	8.7	8.4
61	31.0	1401	147	1	SX	13.0	31	20.0	S	6.9	38	15	19		16.5	18.5		17.9	91	78	18.5	12.5
62	8.4	500	42	8	PL	11.9	29	17.5	PL	15.3	39	20	18.9		16.1	18.4		16.5	73	118	25.2	13.8
63	14.8	1701	49		PL	8.9	19	18.5	PL	6.8	23	16	19		16.9	18.8		16.7	27	19	7.2	7.9
64	32.3	1276	167		SX	14.7	29	23.7	S	7.2	39	15	19		16.5	18.5		17.5	120	97	21.6	13.1
65	7.6	725	26	1	SX	8.2	21	18.9	PL	11.3	26	21	18.9		15.8	18.2		16.4	24	40	12.1	9.4
66	21.5	2076	93		PLI	11.2	23	19.8	PL	11.7	31	19	19.2		15.8	20.6	22	18.3	53	102	22.8	13.3
67	9.8	1076	40	1	AT	9.1	17	19.4	PL	6.5	22	16	19.4		16.7	20.8	22.5	18.7	13	33	11.3	9.2
68	1.9	125	6	192	PLI	7.4	19	16.0	PL	7.1	28	14	14.2		14.4	16.5			13	28	11.7	8.4
69	8.0	400	35		PLI	11.6	20	22.3	PLI	9.2	25	19	18.5		16.9	20	20.9	17.3	76	40	13.6	8.7
70	14.4	1726	67		PL	10.6	18	22.4	PL	7.2	24	16	18.2		16.3	19.7	20.5	16.9	60	38	11.7	9.2
71	18.9	1401	87	1	PLI	11.8	21	21.5	PL	7.9	26	16	19.4		16.1	20.9	22.6	18.9	88	69	19.3	10.8
72	14.3	1376	65		PL	11.8	20	23.0	PL	7.2	24	16	19		16.5	18.5	.	15.5	73	28	9.4	8.6
73	10.7	826	42		PLI	10.2	19	21.1	PL	6.8	23	16	18.2		16.2	19.7	20.5	16.9	49	31	10.2	8.7
74	1.5	150	3		PL	6.1	14	16.7	PL	8.4	22	20	18.9		15.8	18.1		16.7	4	17	6.3	7.5
75	18.7	1026	93	45	PLI	12.2	33	16.3	PL	5	47	4	15		14.9	17.1			92	154	29.9	14.8
76	20.8	2151	98		PLI	11.2	19	22.7	PLI	13.1	30	21	18		16.7	19.4	20.1	16.8	66	63	16.7	11.6
77	15.5	1576	54	0	PLI	8.8	16	20.4	PL	6.1	21	16	19.2		16.2	18.4		17	32	14	5.6	7.1

	Phase II Ground								Phase I VRI				Site Prod Layer						TIPSY			
samp	BA 7.5	TPH 7.5	WSV 7.5	WSV dead	Spp1	Ht1	Age _bh1	SI1	Spp1	HT1	Age1	SI	SX	HM	BL	PL	FD	AT	VOL2	VOL3	BA	Ht
78	22.8	1701	136	5	ACT	21.4	30	29.7	PL	10.5	34	16	18.5		16.6	19.9	20.9	17.4	297	112	24.2	13.6
79	20.2	1026	109	1	PL	12.3	22	22.0	PL	8.8	23	20	18.8		15.4	17.9		16.9	81	15	7.7	8.1
80	22.6	1626	113	0	PLI	13.0	24	21.4	AT	12.6	28	20	18.6		16.7	20	20.6	17	84	25	10.9	10.1
81	25.7	1376	117		PLI	11.5	22	20.4	PL	8.3	27	16	14.7		15	16.5			66	31	9.8	8.7
82	13.3	1176	54		S	12.4	28	20.8	PL	6.8	35	11	19		16.5	18.5		16	61	61	15.1	11.3
83	5.6	776	18		BL	7.8	21	18.2	S	3.5	26	16	15.6		15.1	17			10	0	0.1	3.3
84	24.5	2402	101		PL	10.1	20	19.6	PL	13.6	34	20	18.9		15.8	18.1		17.1	46	61	15.9	11.3
85	12.8	1051	66	1	PLI	11.6	25	18.7	PL	10.2	33	16	18.9		15.8	18.1		17.6	69	65	16.7	11.4
86	23.7	1526	111		SX	13.6	28	23.0	S	5.6	34	15	18.9		16.1	18.4		18	96	48	13.1	10.8
87	19.7	1326	105		S	14.1	27	24.1	SX	12.8	42	20.9	18.9		16.1	18.3		16.4	117	101	21.9	13.7
88	16.7	1676	61		PLI	9.7	16	22.4	SX	4	21	20	19		16.5	18.5		17.4	42	2	2.3	5.9
89	12.2	550	49		S	12.5	19	28.6	PL	9.3	24	20	18.9		16.1	18.4		17.3	76	32	10.5	8.9
90	18.6	1626	85		PLI	11.0	20	21.4	PL	11	24	22	18.9		16.1	18.3		18.8	57	32	10.3	9.0
91	31.4	1601	180	1	SX	13.0	25	23.6	S	8.7	34	20	19		16.5	18.5		16.4	116	51	13.5	11.2
92	16.9	1376	101		AT	16.2	21	28.3	PL	7.5	25	16	18.9		15.8	18.1		18.6	145	37	11.5	9.2
93	1.8	100	5		S	8.1	38	10.8	S	4.6	25	19	18.9		16.1	18.4		17.7	11	5	3.4	7.0
94	22.6	1176	109		PL	11.8	18	24.5	PLI	12.8	24	25	18.9		15.8	18.1		17	75	22	8.9	8.6
95	10.6	1051	44		PL	9.9	16	22.8	PLI	7.9	21	20	18.9		16.1	18.4		18	46	8	4.4	6.9
96	9.6	600	33		S	9.8	17	26.0	S	5.5	26	21	18.9		16.1	18.3		18.3	30	8	4.3	7.5
97	39.2	325	306		BL	24.6	81	17.8	S	7.8	41	15	19		16.5	18.6		16.1	394	51	16.4	10.7
98	29.8	2051	138		PLI	11.0	21	20.4	PL	10.8	25	21	18.9		16.1	18.3		16.9	60	39	11.8	9.3
99	17.6	2001	51		PLI	8.2	13	22.8	PLI	6.4	18	20	18.9		16.1	18.3		18.7	20	4	2.9	5.6
100	67.9	5954	572	15	PL	17.9	49	18.2	PL	7.2	37	11	19		16.5	18.6			230	78	19.8	11.5

11 Appendix II – TIPSY-generated yield tables based on the Phase II ground and Phase I Inventory data.

A yield table was generated for each sample plot. The Phase II ground yield table was generated using the Phase II ground species composition and SI and the regen method and planting density taken from the analysis unit assumptions. The Phase I inventory yield table was generated using the Phase I inventory species composition and SI from the site productivity layer, and regen method and planting density take from the analysis unit assumptions and polygon history. The yield tables were averaged by Phase I inventory leading species.

Table 20. The yield tables based on the Phase II ground (YSM) data and the Phase I Inventory data are given by strata and 5 year age class. All attributes are at the 7.5 cm utilization except for Vol_ndwb which is at 12.5 cm for leading species A and P and 17.5 cm for B and S. The means are followed in brackets by the standard error.

Leading speices	Age	N	Phase II Ground					Phase I Inventory				
			Trees/ha	Basal area (m^2/ha)	Top height (m)	WSV (m^3/ha)	Vol_ndwb (m^3/ha)	Trees/ha	Basal area (m^2/ha)	Top height (m)	WSV (m^3/ha)	Vol_ndwb (m^3/ha)
A	5	1	995 (0)	0 (0)	0.8 (0)	0 (0)	0 (0)	2462 (0)	0 (0)	0.5 (0)	0 (0)	0 (0)
A	10	1	970 (0)	0.1 (0)	2.7 (0)	0 (0)	0 (0)	2515 (0)	0 (0)	2 (0)	0 (0)	0 (0)
A	15	1	942 (0)	1.9 (0)	5.3 (0)	1 (0)	0 (0)	2395 (0)	2 (0)	3.4 (0)	0 (0)	0 (0)
A	20	1	920 (0)	7 (0)	8 (0)	20 (0)	6 (0)	2264 (0)	4 (0)	4.7 (0)	1 (0)	0 (0)
A	25	1	906 (0)	14.1 (0)	10.7 (0)	52 (0)	30 (0)	2115 (0)	5.8 (0)	5.9 (0)	7 (0)	0 (0)
A	30	1	897 (0)	21.2 (0)	13.2 (0)	98 (0)	72 (0)	1937 (0)	7.9 (0)	7 (0)	21 (0)	1 (0)
A	35	1	892 (0)	27.3 (0)	15.5 (0)	150 (0)	121 (0)	1813 (0)	9.9 (0)	8 (0)	38 (0)	6 (0)
A	40	1	887 (0)	31.9 (0)	17.5 (0)	199 (0)	167 (0)	1675 (0)	11.6 (0)	9 (0)	58 (0)	14 (0)
A	45	1	878 (0)	35.6 (0)	19.4 (0)	241 (0)	207 (0)	1556 (0)	13.1 (0)	9.8 (0)	76 (0)	25 (0)
A	50	1	866 (0)	38.6 (0)	20.9 (0)	281 (0)	246 (0)	1454 (0)	14.3 (0)	10.7 (0)	94 (0)	36 (0)
A	55	1	847 (0)	41.1 (0)	22.4 (0)	317 (0)	281 (0)	1342 (0)	15.6 (0)	11.4 (0)	113 (0)	53 (0)
A	60	1	823 (0)	43.2 (0)	23.7 (0)	347 (0)	311 (0)	1239 (0)	16.7 (0)	12.1 (0)	131 (0)	69 (0)
A	65	1	793 (0)	44.7 (0)	24.9 (0)	371 (0)	335 (0)	1157 (0)	17.7 (0)	12.7 (0)	147 (0)	86 (0)
A	70	1	762 (0)	46 (0)	25.8 (0)	391 (0)	355 (0)	1081 (0)	18.6 (0)	13.3 (0)	161 (0)	101 (0)
A	75	1	731 (0)	47.1 (0)	26.8 (0)	410 (0)	375 (0)	1008 (0)	19.1 (0)	13.8 (0)	176 (0)	119 (0)
A	80	1	705 (0)	48.1 (0)	27.6 (0)	428 (0)	392 (0)	940 (0)	19.8 (0)	14.3 (0)	191 (0)	138 (0)
A	85	1	677 (0)	49 (0)	28.4 (0)	442 (0)	407 (0)	877 (0)	20.4 (0)	14.7 (0)	205 (0)	155 (0)
A	90	1	647 (0)	49.3 (0)	29 (0)	453 (0)	419 (0)	827 (0)	21 (0)	15.1 (0)	216 (0)	169 (0)
A	95	1	619 (0)	49.5 (0)	29.7 (0)	460 (0)	428 (0)	781 (0)	21.2 (0)	15.5 (0)	226 (0)	182 (0)
A	100	1	594 (0)	49.8 (0)	30.3 (0)	467 (0)	434 (0)	737 (0)	21.6 (0)	15.9 (0)	235 (0)	194 (0)

Leading speices	Age	N	Phase II Ground Trees/ha	Phase II Ground Basal area (m^2/ha)	Phase II Ground Top height (m)	Phase II Ground WSV (m^3/ha)	Phase II Ground Vol_ndwb (m^3/ha)	Phase I Inventory Trees/ha	Phase I Inventory Basal area (m^2/ha)	Phase I Inventory Top height (m)	Phase I Inventory WSV (m^3/ha)	Phase I Inventory Vol_ndwb (m^3/ha)
B	5	2	2280 (430)	0 (0)	0.1 (0.1)	0 (0)	0 (0)	2541 (56)	0 (0)	0.1 (0.1)	0 (0)	0 (0)
B	10	2	4135 (11)	0 (0)	0.6 (0.3)	0 (0)	0 (0)	4183 (15)	0 (0)	0.4 (0.1)	0 (0)	0 (0)
B	15	2	4082 (53)	0.1 (0.1)	1.5 (0.7)	0 (0)	0 (0)	4105 (33)	0 (0)	1.1 (0.2)	0 (0)	0 (0)
B	20	2	3982 (94)	0.7 (0.7)	2.6 (1.2)	1 (1)	0 (0)	4019 (52)	0.1 (0.1)	1.9 (0.4)	0 (0)	0 (0)
B	25	2	3843 (170)	2.4 (2.4)	3.9 (1.9)	4 (4)	0 (0)	3907 (90)	0.4 (0.4)	3 (0.8)	1 (1)	0 (0)
B	30	2	3688 (248)	5.1 (5)	5.3 (2.5)	11 (11)	1 (1)	3768 (143)	1.7 (1.6)	4.3 (1.1)	2 (2)	0 (0)
B	35	2	3543 (314)	8.4 (8)	6.8 (3.1)	23 (23)	4 (4)	3644 (182)	4.1 (3.2)	5.8 (1.5)	5 (5)	0 (0)
B	40	2	3373 (408)	12.6 (10.8)	8.4 (3.5)	42 (42)	10 (10)	3526 (220)	7.4 (4.6)	7.2 (1.8)	14 (14)	1 (1)
B	45	2	3181 (531)	16.8 (13.1)	9.9 (3.9)	65 (64)	21 (21)	3385 (293)	11.4 (6.1)	8.7 (2.1)	30 (25)	3 (3)
B	50	2	3011 (641)	20.6 (14.5)	11.3 (4.2)	90 (82)	36 (36)	3210 (403)	15.9 (7.7)	10.2 (2.3)	52 (40)	6 (6)
B	55	2	2854 (737)	23.8 (14.9)	12.7 (4.5)	114 (100)	55 (55)	3041 (494)	20 (8.4)	11.6 (2.5)	79 (53)	14 (14)
B	60	2	2703 (817)	26.8 (14.8)	14 (4.7)	142 (114)	75 (75)	2867 (559)	23.9 (8.7)	13 (2.7)	107 (62)	25 (23)
B	65	2	2551 (866)	29.1 (14.2)	15.3 (4.8)	167 (123)	95 (93)	2671 (584)	27.7 (8.6)	14.2 (2.8)	138 (68)	38 (31)
B	70	2	2387 (868)	31.8 (12.8)	16.4 (4.9)	193 (125)	115 (107)	2489 (601)	30.9 (8.2)	15.4 (2.8)	169 (74)	56 (40)
B	75	2	2238 (861)	33.9 (11.8)	17.4 (5)	217 (127)	134 (120)	2324 (606)	33.4 (7.2)	16.5 (3)	197 (77)	75 (46)
B	80	2	2099 (841)	35.8 (10.4)	18.4 (5)	241 (128)	157 (130)	2172 (603)	35.9 (6.7)	17.6 (3)	223 (79)	95 (50)
B	85	2	1972 (808)	37.6 (9.5)	19.4 (5)	263 (128)	178 (138)	2034 (592)	37.6 (5.9)	18.6 (3.1)	246 (79)	114 (52)
B	90	2	1858 (769)	38.8 (8.4)	20.3 (5)	284 (126)	198 (142)	1905 (570)	39.1 (5.2)	19.5 (3.1)	269 (77)	134 (51)
B	95	2	1749 (725)	40.1 (7.2)	21.1 (5)	302 (124)	217 (145)	1788 (545)	40.6 (4.5)	20.4 (3.1)	291 (76)	155 (51)
B	100	2	1644 (674)	40.8 (6.4)	21.9 (4.9)	320 (120)	237 (143)	1673 (508)	41.7 (4)	21.2 (3.1)	311 (74)	175 (50)
P	5	36	1319 (129)	0 (0)	0.7 (0)	0 (0)	0 (0)	1354 (54)	0 (0)	0.6 (0)	0 (0)	0 (0)
P	10	36	1552 (177)	0.3 (0.2)	2.6 (0.2)	0 (0)	0 (0)	1637 (158)	0 (0)	2.3 (0.1)	0 (0)	0 (0)
P	15	36	1477 (162)	2.2 (0.4)	5 (0.3)	2 (1)	0 (0)	1584 (153)	1.3 (0.1)	4.3 (0.1)	0 (0)	0 (0)
P	20	36	1403 (147)	6.7 (0.7)	7.5 (0.3)	18 (4)	4 (1)	1530 (145)	4.6 (0.3)	6.5 (0.2)	8 (1)	0 (0)
P	25	36	1318 (127)	12.8 (0.9)	9.9 (0.4)	48 (6)	23 (4)	1464 (132)	10.2 (0.5)	8.7 (0.2)	30 (2)	11 (1)
P	30	36	1233 (106)	18.8 (1)	12.1 (0.4)	84 (9)	53 (7)	1386 (112)	15.9 (0.6)	10.7 (0.3)	58 (3)	32 (2)
P	35	36	1159 (87)	24.3 (1)	14.1 (0.5)	126 (11)	91 (10)	1319 (94)	21.1 (0.7)	12.6 (0.3)	90 (4)	59 (4)
P	40	36	1100 (72)	28.7 (0.9)	15.9 (0.5)	167 (12)	130 (11)	1263 (79)	25.9 (0.7)	14.2 (0.3)	126 (5)	92 (5)
P	45	36	1052 (61)	32.2 (0.9)	17.5 (0.5)	205 (13)	166 (13)	1216 (67)	29.7 (0.7)	15.7 (0.4)	161 (6)	124 (5)
P	50	36	1010 (53)	35.1 (0.8)	18.9 (0.5)	238 (13)	199 (13)	1175 (56)	32.6 (0.7)	17.1 (0.4)	191 (6)	152 (6)

Leading speices	Age	N	Trees/ha	Phase II Ground Basal area (m^2/ha)	Top height (m)	WSV (m^3/ha)	Vol_ndwb (m^3/ha)	Trees/ha	Phase I Inventory Basal area (m^2/ha)	Top height (m)	WSV (m^3/ha)	Vol_ndwb (m^3/ha)
P	55	36	970 (48)	37.3 (0.8)	20.2 (0.5)	268 (13)	229 (13)	1138 (47)	35.1 (0.7)	18.2 (0.4)	219 (6)	177 (7)
P	60	36	934 (45)	39 (0.8)	21.4 (0.6)	293 (12)	254 (13)	1104 (40)	37 (0.7)	19.3 (0.4)	244 (7)	200 (7)
P	65	36	901 (43)	40.3 (0.8)	22.4 (0.6)	316 (12)	277 (12)	1073 (34)	38.6 (0.7)	20.3 (0.4)	266 (7)	221 (8)
P	70	36	869 (41)	41.5 (0.8)	23.4 (0.6)	336 (11)	298 (12)	1041 (29)	39.9 (0.7)	21.2 (0.4)	286 (7)	240 (8)
P	75	36	840 (40)	42.4 (0.9)	24.2 (0.6)	354 (11)	316 (11)	1013 (25)	41 (0.7)	22 (0.5)	304 (7)	257 (9)
P	80	36	811 (40)	43.1 (0.9)	25 (0.6)	369 (10)	332 (11)	985 (21)	42 (0.7)	22.7 (0.5)	320 (8)	273 (9)
P	85	36	784 (39)	43.6 (1)	25.7 (0.6)	382 (10)	346 (10)	957 (18)	42.7 (0.7)	23.3 (0.5)	334 (8)	287 (10)
P	90	36	757 (38)	44 (1)	26.3 (0.6)	394 (10)	359 (10)	931 (16)	43.3 (0.7)	23.9 (0.5)	347 (8)	300 (10)
P	95	36	732 (37)	44.3 (1)	26.9 (0.6)	405 (9)	370 (10)	907 (15)	43.8 (0.7)	24.4 (0.5)	359 (9)	311 (11)
P	100	36	709 (36)	44.5 (1)	27.4 (0.6)	413 (9)	379 (9)	884 (13)	44.2 (0.7)	24.9 (0.5)	370 (9)	322 (11)
S	5	11	1517 (222)	0 (0)	0.6 (0.1)	0 (0)	0 (0)	1477 (161)	0 (0)	0.5 (0.1)	0 (0)	0 (0)
S	10	11	1720 (368)	0.1 (0)	1.9 (0.2)	0 (0)	0 (0)	1772 (363)	0 (0)	1.3 (0.1)	0 (0)	0 (0)
S	15	11	1683 (359)	0.9 (0.3)	3.7 (0.5)	1 (0)	0 (0)	1741 (356)	0.2 (0.1)	2.5 (0.2)	0 (0)	0 (0)
S	20	11	1642 (348)	3.3 (0.9)	5.8 (0.7)	8 (3)	1 (1)	1707 (347)	1.1 (0.2)	4 (0.3)	0 (0)	0 (0)
S	25	11	1602 (333)	7.5 (1.6)	8.1 (0.8)	24 (6)	6 (3)	1668 (334)	2.8 (0.4)	5.8 (0.4)	4 (1)	0 (0)
S	30	11	1566 (320)	13.5 (2.3)	10.4 (1)	54 (12)	21 (7)	1629 (321)	6 (0.7)	7.6 (0.4)	16 (3)	1 (1)
S	35	11	1538 (308)	19.6 (2.8)	12.5 (1)	92 (18)	51 (13)	1598 (310)	10.8 (0.9)	9.4 (0.5)	37 (5)	7 (2)
S	40	11	1500 (289)	25.2 (3)	14.6 (1.1)	135 (22)	87 (19)	1567 (297)	16.2 (1.2)	11.2 (0.5)	67 (8)	23 (5)
S	45	11	1435 (252)	30.3 (3)	16.5 (1.1)	179 (25)	124 (25)	1519 (272)	21.4 (1.3)	12.9 (0.5)	101 (9)	47 (8)
S	50	11	1363 (216)	34.6 (2.9)	18.2 (1.2)	222 (27)	162 (29)	1466 (243)	26 (1.3)	14.5 (0.5)	139 (11)	75 (12)
S	55	11	1293 (183)	38.4 (2.8)	19.9 (1.2)	265 (29)	202 (33)	1406 (209)	30.3 (1.4)	16 (0.6)	177 (11)	106 (15)
S	60	11	1222 (154)	41.4 (2.6)	21.3 (1.2)	305 (31)	242 (34)	1345 (178)	33.5 (1.4)	17.4 (0.6)	212 (12)	134 (17)
S	65	11	1151 (129)	43.8 (2.4)	22.7 (1.2)	340 (31)	278 (35)	1285 (151)	36.3 (1.4)	18.7 (0.6)	245 (12)	162 (19)
S	70	11	1083 (109)	45.5 (2.2)	23.9 (1.2)	370 (31)	310 (35)	1228 (127)	38.8 (1.4)	20 (0.6)	278 (13)	191 (21)
S	75	11	1018 (93)	46.6 (2)	25.1 (1.2)	395 (30)	338 (34)	1175 (106)	41.2 (1.5)	21.1 (0.7)	312 (14)	221 (23)
S	80	11	961 (81)	47.5 (1.8)	26.1 (1.2)	417 (29)	362 (33)	1121 (89)	42.8 (1.5)	22.1 (0.7)	339 (14)	246 (24)
S	85	11	909 (71)	48.1 (1.6)	27.1 (1.2)	436 (28)	384 (32)	1071 (74)	44.2 (1.5)	23.1 (0.7)	363 (14)	269 (26)
S	90	11	862 (64)	48.5 (1.4)	27.9 (1.2)	452 (27)	403 (30)	1022 (64)	45.1 (1.5)	24 (0.7)	382 (15)	286 (27)
S	95	11	817 (59)	48.6 (1.2)	28.7 (1.2)	465 (26)	418 (29)	977 (54)	45.8 (1.6)	24.8 (0.8)	399 (15)	302 (28)
S	100	11	777 (56)	48.7 (1.1)	29.5 (1.2)	477 (25)	432 (28)	931 (48)	46.1 (1.5)	25.6 (0.8)	414 (15)	316 (28)