Change Monitoring Analysis Using CMI Data

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Executive Summary

Change Monitoring Inventory (CMI) plots have been established in several management units (Timber Supply Areas - TSAs and Tree Farm Licenses - TFLs) across the province, including TFL 5, TFL 30, TFL 33, TFL 35, TFL 37, TFL 52, Fort. St. John TSA, Merritt IFPA, Quesnel TSA, Kamloops TSA, Okanagan TSA, 100 Mile House TSA, and Hope IFPA. Some of the TFL CMI plots have been remeasured and change monitoring analysis done. To date, however, no monitoring analyses of CMI data have been done in the TSAs. The objective of the management unit CMI was to monitor (or check) the projected growth or change in timber volume and other tree attributes (e.g., species composition and top height) at a management-unit level.

Re-measured CMI data from 58 plots from three adjacent TSAs in the Interior (Okanagan, 100 Mile House and Kamloops) were used to demonstrate the accuracy of GY predictions for timber supply review (TSR).

The key monitoring analysis results are the following:

- There is evidence of catastrophic mortality between measurements on some plots and it is important to analyze these separately ("decline" subset vs. "growth" subset).
- The ground plot volume growth rates for the "growth" subset ranged from 0.9 m^3/ha/yr in 100 Mile House to 2.2 m^3/ha/yr in the Kamloops TSA.
- For the growth subset, the TSR predicted volumes at the first measurement were slightly higher than the ground plot volumes in the Okanagan (13 m^3/ha or 8%) and in 100 Mile House (11 m^3/ha or 13%).
- For the growth subset, by the second measurement the TSR over prediction of volumes had increased to 21 m^3/ha or 8% in the Okanagan and 53 m^3/ha or 61% higher in 100 Mile House compared to the average ground volume.
- In the Okanagan, the predicted volume growth (3.7 m^3/ha/yr) was higher than the actual growth (2.1 m^3/ha/yr) but was close. For 100 Mile House the predicted volume growth (9.3 m^3/ha/yr) was much higher than the actual growth (0.9 m^3/ha/yr). Note that the Okanagan TSR analysis was undertaken in 2010 vs. 2001 for 100 Mile House.
- Differences between the ground plot plots and the VRI Phase I inventory projected to 2011 are dominated by changes in leading species, particularly within the spruce stratum and mixed species polygons. In general, the differences in site index and stand age are large but with high variability so the differences are not statistically significant. Some of the variability may be due to differences in leading species.

The results from this report suggest that the CMI data can be used for GY monitoring. However, of the original 62 plots, 4 were harvested between measurements and 21 showed evidence of catastrophic mortality between measurements and 22 showed evidence of mountain pine beetle-caused mortality (15 of which had catastrophic mortality). This left 37 growth plots for GY monitoring – a very small sample size from which to draw conclusions or management interpretations. As a result, this report should be used as an example of the types of change monitoring analyses that can be conducted using CMI data rather than as a basis for decision-making.

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List of Abbreviations and Acronyms

BA	Basal Area (of trees)
BC	British Columbia
BCTS	British Columbia Timber Sales
CMI	Change Monitoring Inventory
Dbh	Tree Diameter at Breast Height
FAIB	Forest Analysis and Inventory Branch
FIA	Forest Investment Account
FRBC	Forest Renewal BC
GY	Growth and Yield
MFLNRO	Ministry of Forests, Lands and Natural Resource Operations
MPB	Mountain Pine Beetle
TFL	Tree Farm License
TSA	Timber Supply Area
TSR	Timber Supply Review
WSV	Whole Stem Volume

1. Introduction

Change Monitoring Inventory (CMI) plots have been established in several management units (Timber Supply Areas - TSAs and Tree Farm Licenses - TFLs) across the province since about 2000. These include TFL 5, TFL 30, TFL 33, TFL 35, TFL 37, TFL 52, Fort. St. John TSA, Merritt IFPA, Quesnel TSA, Kamloops TSA, Okanagan TSA, 100 Mile House TSA, and Hope IFPA. Projects for the establishment of these CMI plots were implemented with funding largely from the past FRBC/FIA Landbase Program. Some of these CMI plots, such as those in TFL 35, have been remeasured and change monitoring analysis done. To date, however, no analyses of CMI data have been done in the TSAs.

The objective of the management-unit CMI was to monitor (or check) the projected growth or change in timber volume and other tree attributes (e.g., species composition and top height) at a management-unit level. The purpose of the checking was to determine the accuracy of projections used in timber supply analysis and to identify large differences should they occur.[1] This report illustrates the types of change monitoring that can be conducted using remeasured TSA CMI plots.

2. Objectives

The objectives of this report are to conduct change monitoring analysis of remeasured TSA CMI plots, in particular to:

a) Compile the ground plot data from both first (2006) and second (2011) measurements, and compare data between measurements, and
b) Compare ground plot results of volume, leading species, site index and stand age against management plan assumptions for the monitoring plots.

3. Methodology

3.1 Sample Data

Data from 58 CMI plots in three adjacent TSAs in the Interior of BC (100 Mile House, Okanagan and Kamloops) were used (Table 1). These were chosen because, at the time, they were the only TSAs with remeasured CMI plots.

Table 1. Summary descriptions of the CMI plots by TSA. The age means are followed in brackets by the range. The data are from the first measurement (2006). The summary is for trees with Dbh ≥ 7.5 cm. The area is the area of the target CMI population (a subset of the TSA).

TSA	Project ID	Number of plots (N)	Total Age (years)	Area (ha)	Weight (Area/N)
Kamloops	011M	19	127 (63 - 279)	1,838,689	96773
Okanagan	022M	20	112 (48 - 189)	1,302,270	65114
100 Mile House	DMHM	19	83 (37 - 126)	938,421	49391
Total		58	112 (37 - 279)	4,079,380	

Twenty-four plots had more than 30% lodgepole pine at the time of plot establishment (calculated as the live + dead lodgepole pine basal area (BA) as a percent of total live + dead BA for trees with Dbh ≥ 7.5 cm). Seven other plots had some PL, ranging from 1-13% of the total BA.

[1] *Graphical & Statistical Analysis for Monitoring Estimates of Change at the Management-Unit Level (Version 2.0).* Contract report prepared by J.S. Thrower & Associates Ltd. for the Resources Inventory Branch, BC Ministry of Forests, Victoria, BC. Dated March 31, 2000.

Trees were tallied using the CMI methodology. That is, trees with 4.0 ≤ Dbh < 9 cm were tallied on a 0.01-ha plot and trees with Dbh ≥ 9 cm were tallied on a 0.04-ha plot. Four plots (Samples 011M-0067-MR1, 011M-0073-MR1, 022M-0093-MR1 and DMHM-0127-MR1) were harvested between 2006 and 2011 and were removed from the analysis. One plot (DMHM-0131) had a single large Douglas-fir that was alive in 2006 and dead in 2011. This tree was not identified as a veteran but had a Dbh of 61.3 cm, a breast height age of 379 and a measured height of 23.1 m. The next largest tree had a Dbh of 29.5 cm and the next oldest cored tree had a breast height age of 55 years. This illustrates the importance of identifying veterans in field data collection and the effect it can have on predictions. In this analysis, the large Douglas-fir was changed to a veteran and not included in the main canopy layer.

3.2 Ground plot values

Live and dead plot volume was compiled at the 12.5 cm for lodgepole pine leading plots and 17.5 cm for the remaining plots. The compiled volume was net merchantable volume (NMV: whole stem volume less stump, top, decay, waste and breakage). Ground plot site index, stand age and leading species attributes were taken directly from the VRI compiler output at the two measurement times. Tree top conditions at the two measurement times were compiled manually.

Various components of volume growth were calculated; these components of growth are given in the Appendix (Section 8.1). There were three main types of mortality in the plots – ordinary (or background), catastrophic mortality between measurements and catastrophic mortality prior to plot establishment. The threshold for catastrophic morality between measurements was arbitrarily set at a decrease of more than 8 m^2/ha of BA in the 5 years. The focus here is in survivor growth and mortality so plots are stratified into ordinary and catastrophic mortality using the definitions in Table 2. The plots with catastrophic mortality are given in the Appendix (Section 8.2).

Table 2. Definitions of ordinary and catastrophic mortality.

Strata	Mortality	Definition
Growth	Ordinary	A increase in BA or a decrease of less than 8 m^2/ha in the 5 years
Catastrophic	Catastrophic	A decrease in BA of more than 8 m^2/ha in the 5 years (1.6 m^2/ha/yr)

3.3 Predicted (TSR) volume

The TSR yield curves were obtained for the Okanagan (BC 2010) and 100 Mile House (BC 2001) TSAs. The 100 Mile House TSR curves are from the previous TSR because of some difficulties with TIPSY. The non-pulpwood agreement curves were used. The pulpwood yields are lower than the non-pulpwood yields. Plots were assigned to analysis unit based on the plot information at the time of first measurement including leading species, site index and age. No polygons met the analysis unit age criteria for managed stands (< 30 years old). The volume in 2006 was estimated from the analysis unit and age in 2006. The volume in 2011 was estimated from the analysis unit assignment in 2006 and the age in 2006 + 5 years. The TSR curves give volumes at 5-year age intervals for the Okanagan and 10-year intervals for 100 Mile House. Volumes for intermediate ages for 100 Mile House were linearly interpolated.

The utilization level was 12.5 cm for lodgepole pine leading plots and 17.5 cm for the remaining plots. The ground plot volume was whole stem volume less decay, waste and breakage (vol_dwb).

3.4 Predicted site index and age

Each sample plot falls within a VRI Phase I polygon. The VRI Phase I inventory polygon information for each sample plot was provided by FAIB including the site index and stand age projected to the year 2011 for the growth subset.

3.5 Comparison methods

The FAIB (2012) techniques were used. The ground plot level summaries and TSR estimates were treated as a paired sample and evaluated using a t-test, as were site index and age.

4. Results & Discussion

4.1 Volume comparisons

There were considerable differences between the plots with catastrophic mortality ("decline" plots) and those without ("growth" plots).

Table 3. The average net merchantable volume (m^3/ha) is given by TSA, measurement year and mortality status.

TSA	Status	Growth Component	Growth plots 2006	Growth plots 2011	Decline plots 2006	Decline plots 2011
Kamloops (11 growth plots, 8 decline plots)	Live	Undersize	9	10	15	11
		Survivor	221	232	229	79
		Ingrowth		0		0
	Subtotal Live		230	242	244	90
	Dead	Dead	8	5	40	21
		Mortality		2		60
	Subtotal Dead		8	7	40	81
	Total		238	249	284	170
Okanagan (15 growth plots, 5 decline plots)	Live	Undersize	10	11	14	16
		Survivor	246	256	306	105
		Ingrowth		0		0
	Subtotal Live		256	266	319	121
	Dead	Dead	33	28	31	17
		Mortality		8		95
	Subtotal Dead		33	36	31	112
	Total		289	302	350	233
100 Mile House (11 growth plots, 8 decline plots)	Live	Undersize	14	14	12	8
		Survivor	144	146	268	81
		Ingrowth		0		0
	Subtotal Live		157	160	281	89
	Dead	Dead	38	34	44	34
		Mortality		6		112
	Subtotal Dead		38	40	44	146
	Total		196	200	324	235

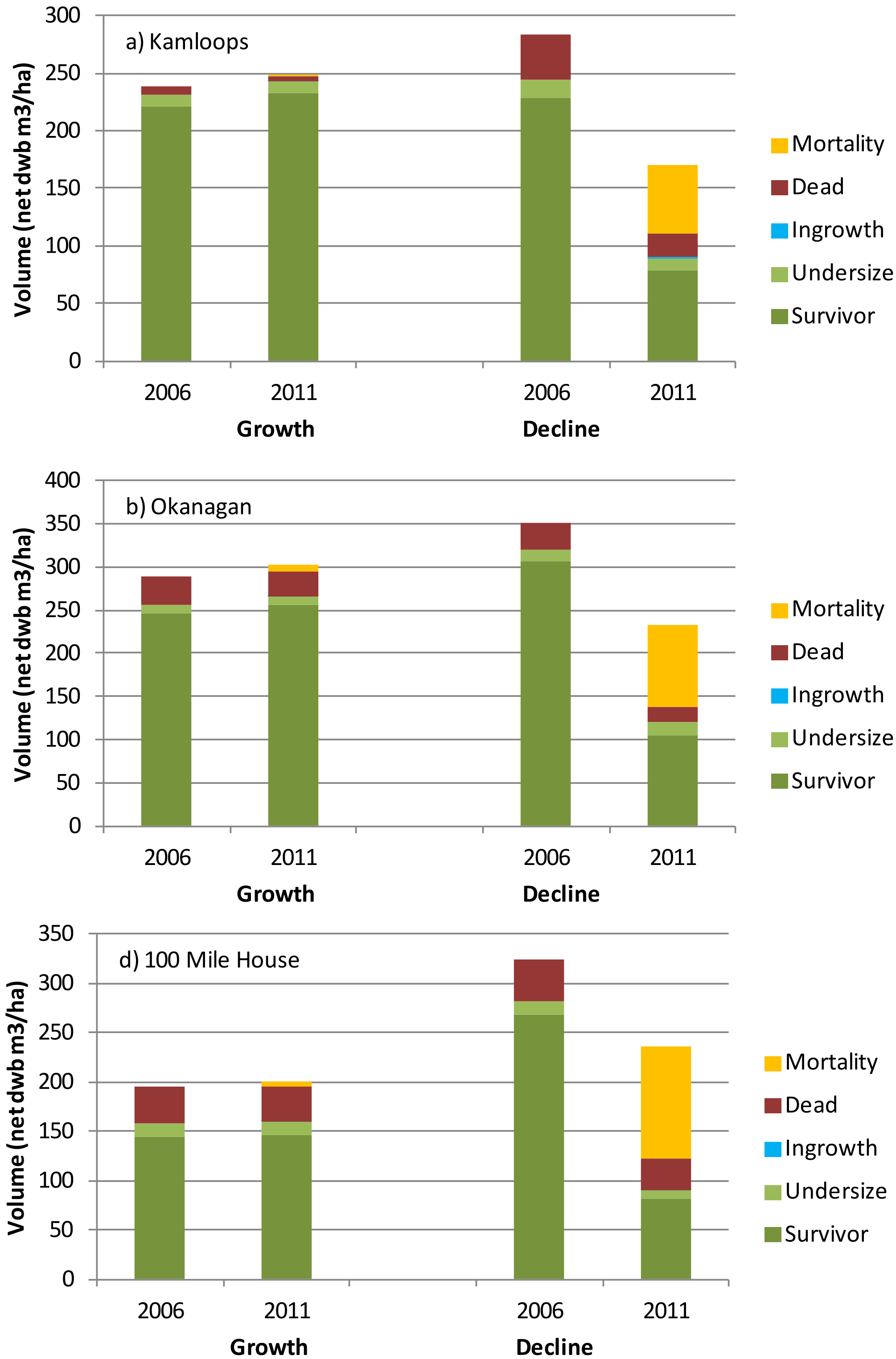


Figure 1. Net merchantable volume by TSA, measurement year and mortality status. There is very little ingrowth.

The following discussion is for the Okanagan and 100 Mile House TSAs only. No plots met the criteria for managed analysis units (age < 30 yrs) and only one plot in the Okanagan and 2 plots in 100 Mile House were less than 50 years old at the time of first measurement. Therefore, the comparison focuses on natural stand yield curves. The one plot in 100 Mile House that was cedar leading had a ground volume of over 700 m^3/ha while the TSR prediction was approximately 230 m^3/ha. The results are shown including this plot and without this plot (no CW).

The differences at the time of plot establishment are small in the Okanagan (13 m^3/ha or about 5%) for the growth subset (Table 4; Figure 2). The differences for 100 Mile House were similar in absolute terms but larger in relative terms (about 11 m^3/ha or about 13% for the growth subset excluding Cw). In the Okanagan, the differences at the second measurement were slightly higher, but in 100 Mile House, the underestimation increased considerably.

For the decline subset, the differences in 2006 were larger than for the growth subset but still not significantly different than zero. However, for the decline subset, the 2011 differences are substantial. The TSR yield curves greatly overestimate the live volume and the differences between the actual volumes and TSR predictions are statistically significant.

Table 4. Ground plot volume and the TSR predicted volume by year separately for the growth and decline plots subsets. Utilization level is 12.5 cm for lodgepole pine leading plots and 17.5 cm for all others. These data are also plotted in Figure 2.

				Volume (m^3/ha)					
TSA	Subset	Year	N	Ground	TSR	Diff (Ground – TSR)	Diff/ Ground (%)	Standard error diff	Paired t-test Prob ($t > t_{obs}$)
Okanagan	Growth	2006	14	259	273	-13.4	-5%	35.8	0.714
		2011		270	291	-21.4	-8%	35.0	0.552
	Decline	2006	4	354	301	53.7	15%	71.5	0.507
		2011		132	307	-175.8	-134%	47.9	0.035
100 Mile House	Growth	2006	11	144	121	22.5	16%	41.4	0.599
		2011		146	165	-18.7	-13%	44.5	0.683
	Growth no Cw	2006	10	83	94	-11.0	-13%	27.0	0.694
		2011		87	140	-53.0	-61%	31.4	0.125
	Decline	2006	8	268	311	-42.2	-16%	45.5	0.384
		2011		81	343	-261.8	-323%	34.7	0.000

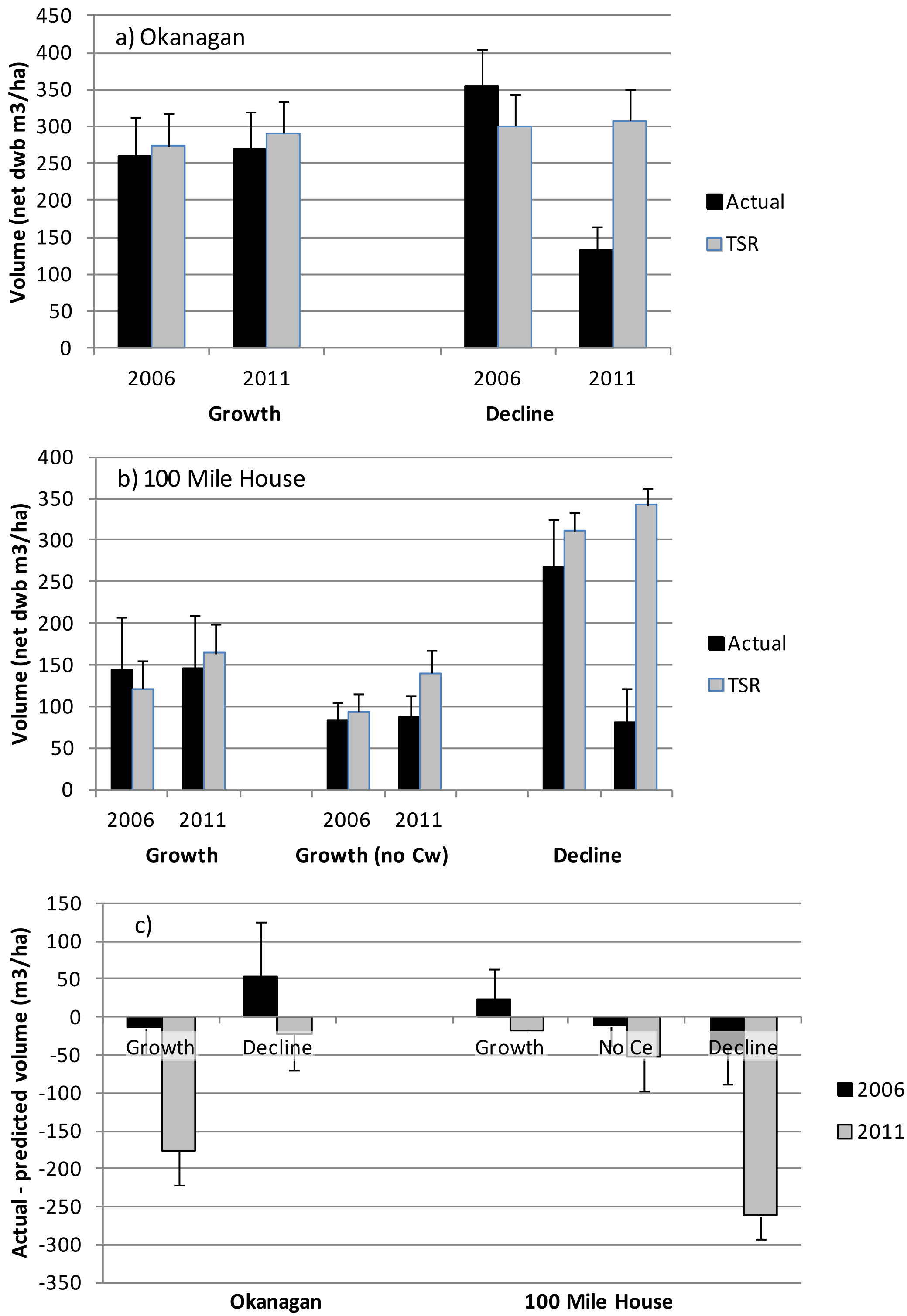


Figure 2. Ground (actual) volume and the TSR predicted volume by TSA, and measurement year separately for the growth and decline plots subsets. Standard error bars are also given. The data are given in Table 4. The differences between the Actual and TSR volumes are given in (c).

There were no obvious trends in prediction errors with age (Figure 3).

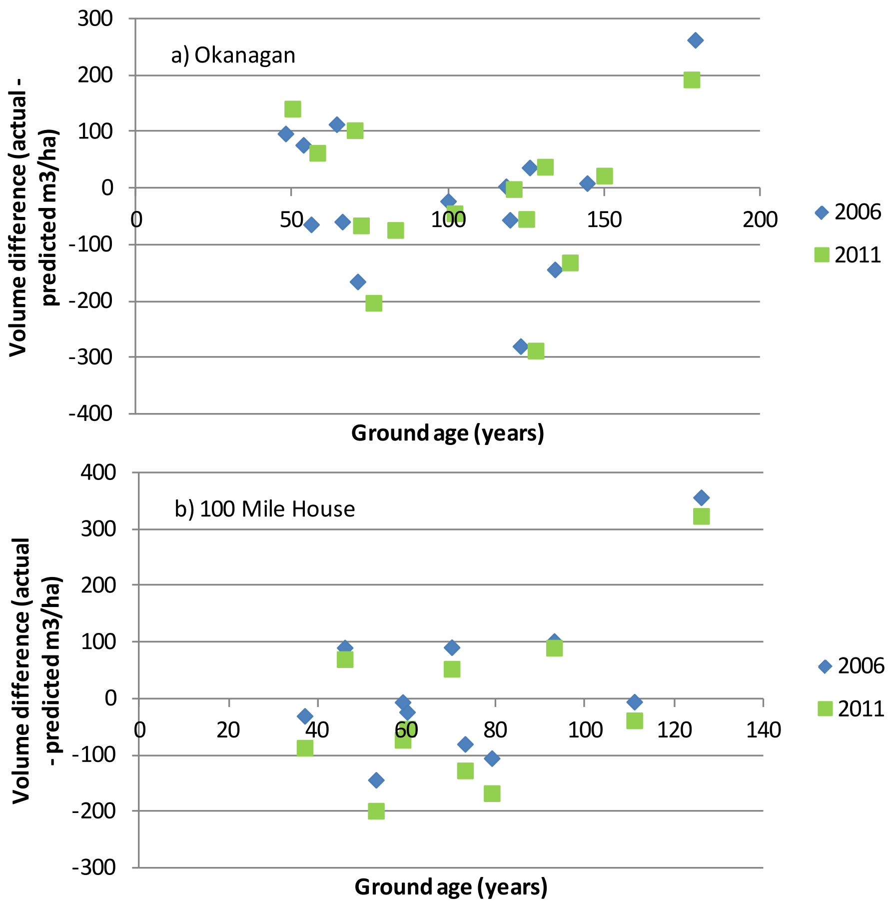


Figure 3. Differences between ground plot and TSR volumes plotted against ground plot age for the growth subset by TSR. The age in 2011 was assumed to be the age in 2006 + 5 years.

For the growth subset (excluding the Cw plot) the ground plot 5-year volume periodic annual increments (PAIs) in the Okanagan (2.1 m^3/ha/yr; Table 5) are approximately double those in 100 Mile House (0.9 m^3/ha/yr; Table 5). In both cases, the TSR yield curves over predict the volume growth.

In the Okanagan, the TSR yield curves overestimated the volume growth of the growth subset by 65% but the difference was not statistically different from zero. In the 100 Mile House, the differences in growth predictions were considerably larger. The growth subset plots had very little growth while the TSR yield curves predicted growth of approximately 9 m^3/ha/yr. The differences were statistically significant in the 100 Mile House growth subset. The growth rates in 100 Mile House were very low compared to those in the Okanagan TSA (Table 5).

Table 5. Ground plot and TSR-predicted periodic annual volume growth by TSA and data subset.

			5 year Volume periodic annual increment (m^3/ha/yr)					
TSA	Subset	N	Ground	TSR	Diff (Ground – TSR)	Diff/ Ground (%)	Standard error diff	Paired t-test Prob ($t > t_{obs}$)
Kamloops	Growth	11	2.24	NA				
	All	7	-33.37	NA				
Okanagan	Growth	14	2.09	3.68	-1.59	-76%	1.39	0.273765
	All	4	-44.53	1.38	-45.91	103%	5.25	0.003143
100 Mile House	Growth	11	0.48	8.72	-8.24	-1726%	1.06	0.000016
	Growth No CW	10	0.92	9.32	-8.41	-916%	1.16	0.000049
	All No CW	7	-38.92	6.33	-45.25	116%	5.58	0.000188

4.2 Changes in leading species

For the growth plots, only one plot changed leading species from 2006 to 2011 - plot 990145. It went from a species composition of PL36At30S30Fd04 to S42At29Pl23Fd06 and had more dead basal area than live. Following Congalton (1991), the leading species were compared in terms of overall accuracy and Kappa estimate (Table 6). The overall agreement was 100% in Kamloops and Okanagan and 91% for 100 Mile house (the Kappa value of 0.8642 indicates good agreement, i.e., no change in leading species on the two occasions).

Table 6. Changes in leading species (by basal area; Dbh ≥ 4.0 cm) between 2006 and 2011 for the growth plots only. Only one plot changed leading species.

	Leading	Leading Species 2011								Overall	Kappa
TSA	Species 2006	BL	CW	FD	HW	LW	PL	PY	S	agreement	
Kamloops	BL	2									
	CW		1								
	FD			4							
	HW				1						
	SX								3	100%	NA
Okanagan	BL	1									
	CW		3								
	FD			2							
	HW				2						
	LW					1					
	PL						1				
	PY							1			
	SX								4	100%	NA
100 Mile House	CW		1								
	FD			5							
	PL						1		1		
	S								3	91%	0.8642

The ground plot and VRI leading species in 2011 are compared in Table 7. In general, there is a greater diversity of leading species in the ground plots than in the Phase I VRI except for 100 Mile House. The overall level of agreement was low. In general, FD and S leading stands tended to have a high proportion of the leading species on the ground (80% or greater proportion of the basal area). The interpretation of FD-leading polygons by VRI photo interpreters is fairly good but the prediction of S leading is poor. The remaining polygons tend to be more mixed in terms of species composition and poor agreement between the ground and VRI is not unexpected. In addition, the ground plot is a limited sample (0.04 ha) within the polygon and, particularly for mixed polygon, differences between the VRI and ground leading species are not unexpected.

Table 7. Ground leading species in 2011 is compared to the VRI leading species for the growth plots only. The Chi-square statistic is given along with the significance level. A low significance level indicates a high level of agreement. A Kappa statistic could not be computed because the number of ground species was not the same as the number of VRI species (except in 100 Mile House).

	VRI Lead	Ground Lead Species								Overall	Chi-square
TSA	Species	BL	CW	FD	HW	LW	PL	PY	S	agreement	
Kamloops	BL	2									
	FD		1	3					1		
	HW				1						
	SX			1					2	55%	24.6 (0.0164)
Okanagan	NA					1					
	BL	1			1				1		
	CW		2								
	FD		1	2				1	2		
	PL				1		1		1	40%	21.8 (0.2420)
100 Mile House	AT								2		
	FD		1	3							
	PL			2			1		1		
	S								1	45%	10.6 (0.305)

4.3 Changes in condition of tree tops

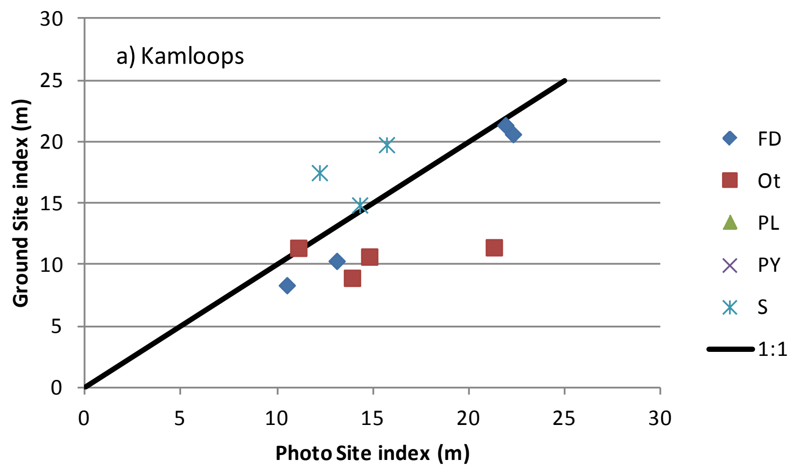
Changes in tree-top conditions were examined (no pest or disease data were available). There was little change in the condition of tree tops over time. Out of a total of 1769 trees, only 71 or 4% changed top condition between 2006 and 2011 (Table 8). Surprisingly, 22 trees went from a broken or dead top to healthy condition.

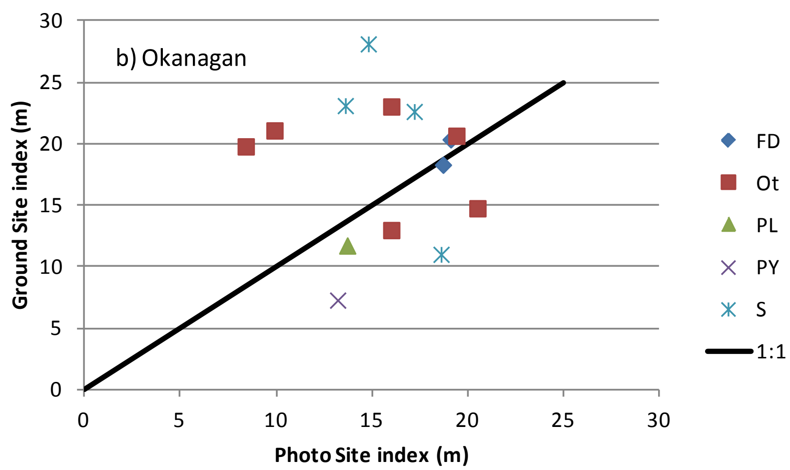
Table 8. Number of trees by tree-top condition and TSA for trees live in 2006 and 2011 using the ground plots.

		All				Growth subset			
	Condition	Condition 2011			%	Condition 2011			%
	2006	Healthy	Broken top	Dead top	unchanged	Healthy	Broken top	Dead top	unchanged
Kamloops	Healthy	468	5	9		308	3	7	
	Broken top	3	34			1	14		
	Dead top			11	97%			6	97%
Okanagan	Healthy	670	8	10		516	8	8	
	Broken top	6	23			2	18		
	Dead top	2		7	96%	1 .		3	97%
100 Mile House	Healthy	470	11	5		348	8	4	
	Broken top	8	11			7	4		
	Dead top	3	1	4	95%	2	1	1	94%

4.4 Site index comparisons

There were differences in site index between the ground measurements and VRI estimates in 2011 for the growth subset (Figure 4). Most of the larger differences were associated with differences in leading species.





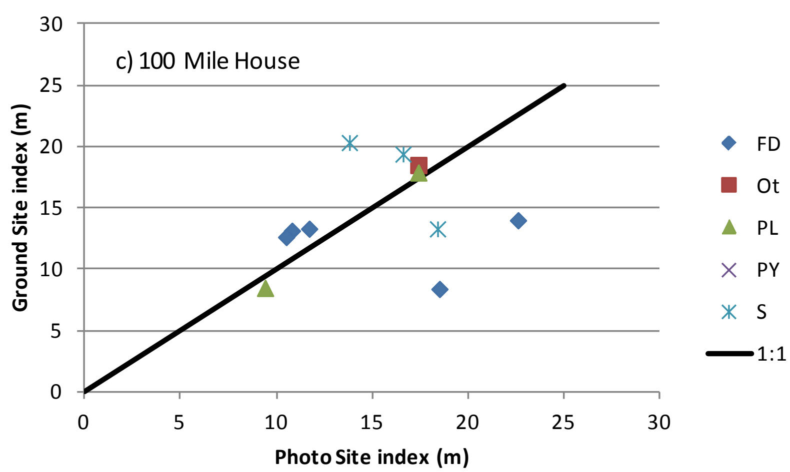


Figure 4. Ground plot site index in 2011 versus the VRI site index in 2011 by TSA and plot leading species. The plots with catastrophic mortality are not included. Most of the large differences in site index are associated with differences in leading species between the ground plot and the VRI inventory.

The average site index for the growth plots are given in Table 9 and Figure 5. The differences between the ground and VRI site index in 2011 are larger than the changes in the ground site index between 2006 and 2011. The variation in the differences is also high so only the change in site index of the FD leading polygons is statistically significant. The Spruce and Other categories tended to have the highest differences with the most variability and are also associated with more differences between the VRI and ground plot leading species.

Table 9. Average site index by TSA and species group for the growth subset. The average difference is followed in brackets by the standard error; N is the number of plots and Sp0 is species group.

			Site index			2011	
TSA	Sp0 2006	N	Ground 2006	Ground 2011	VRI 2011	Difference (Ground – VRI)	Paired t-test Prob ($t > t_{obs}$)
Kamloops	FD	4	15.0	15.2	17.0	-1.8 (0.5)	0.032
	Ot	4	10.6	10.6	15.3	-4.7 (2.1)	0.110
	S	3	17.7	17.4	14.1	3.3 (1.4)	0.145
	All	11	14.1	14.1	15.6	-1.5 (1.3)	0.279
Okanagan	FD	2	19.8	19.3	18.9	0.4 (0.8)	0.696
	Ot	6	18.3	18.7	15.0	3.7 (3.0)	0.271
	PL	1	11.8	11.7	13.7	-2.0 (NA)	NA
	PY	1	7.2	7.3	13.2	-5.9 (NA)	NA
	S	4	20.8	21.2	16.1	5.2 (4.5)	0.338
	All	14	18.0	18.2	15.7	2.6 (1.9)	0.200
100 Mile House	FD	5	12.9	12.3	13.7	-1.4 (2.2)	0.562
	Ot	1	18.5	18.5	17.4	1.1 (NA)	NA
	PL	2	14.2	13.2	13.4	-0.2 (0.7)	0.813
	S	3	17.4	17.7	16.3	1.4 (3.4)	0.722
	All	11	14.9	14.5	14.7	-0.2 (1.3)	0.889

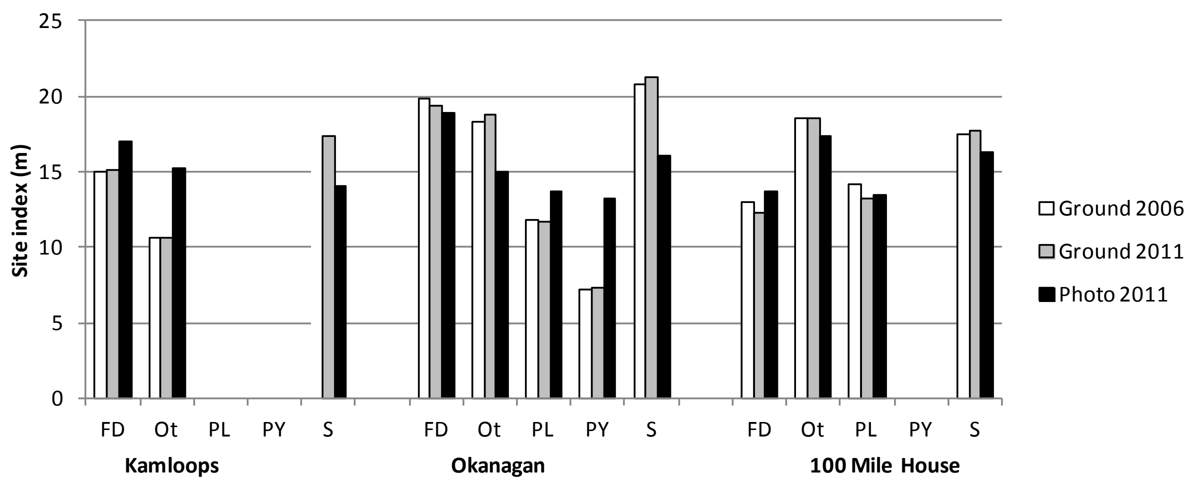


Figure 5. Ground and VRI average site index by TSA and species group.

4.5 Stand age comparisons

The ground and VRI age in 2011 are plotted in Figure 6 and Figure 7 and summarized in Table 10. As with site index, most of the large differences in ground age and VRI inventory age in 2011 are associated with differences in leading species.

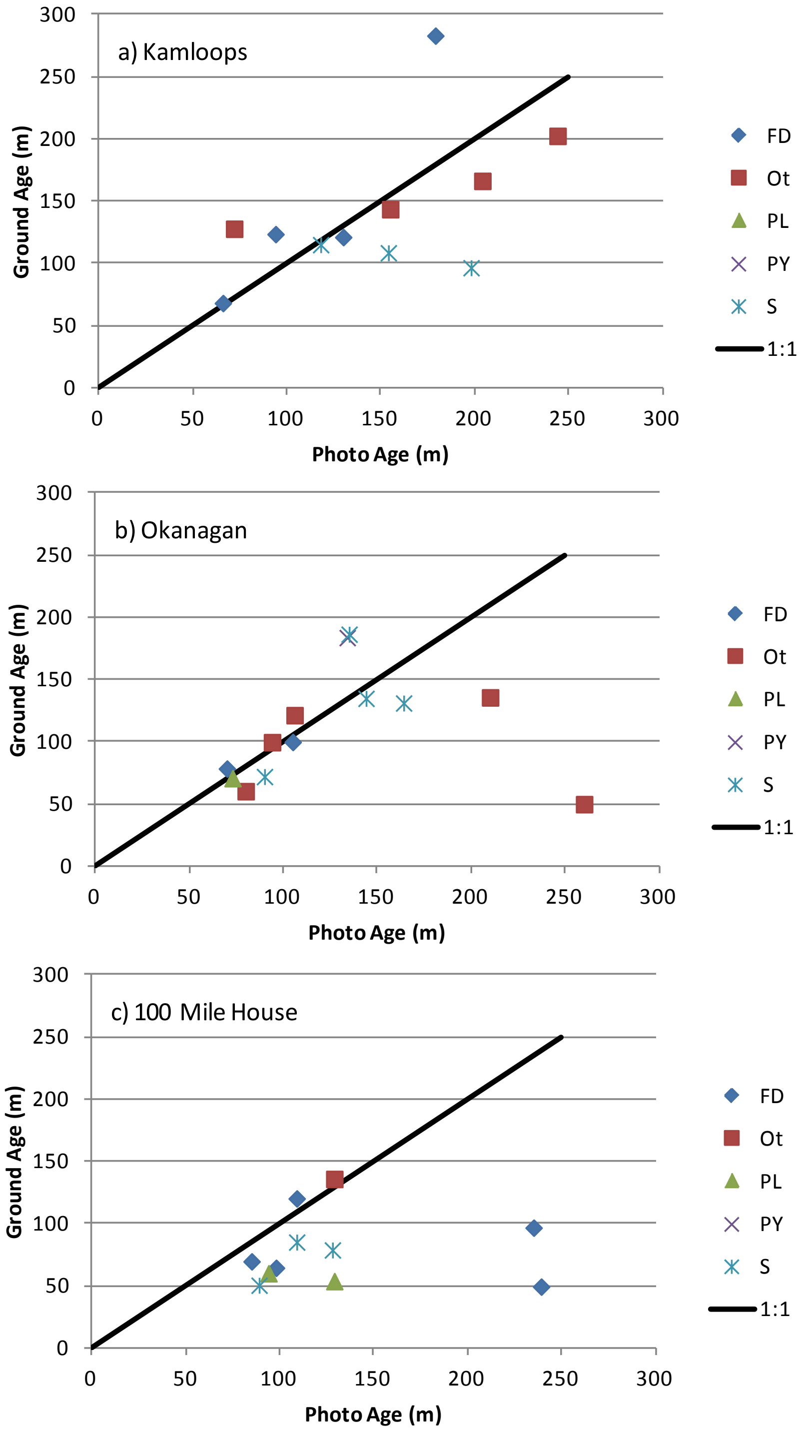


Figure 6. Ground plot age 2011 versus the VRI inventory age in 2011 by TSA and plot leading species. The plots with catastrophic mortality are not included. As with site index, most of the large differences in age are associated with differences in leading species between the ground plot and the VRI inventory.

The differences in age in 2011 between the ground plots and VRI are large with high variability at the leading species level At the TSA level, the differences tend to cancel each other so that the differences at the TSA level in Kamloops and Okanagan are relatively small. Only the differences associated with spruce in 100 Mile House are statistically significant.

Table 10. Average age by species group and TSA for the growth subset. The average difference is followed in brackets by the standard error.

TSA	Sp0 2006	N	Age: Ground 2006	Age: Ground 2011	Age: VRI 2011	2011 Difference (Ground – VRI)	Paired t-test Prob ($t > t_{obs}$)
Kamloops	FD	4	144.6	148.9	117.3	31.7 (25.4)	0.301
	Ot	4	156.2	160.0	168.8	-8.8 (22.5)	0.723
	S	3	101.5	106.7	156.7	-50.0 (28.5)	0.222
	All	11	137.1	141.4	146.7	-5.3 (16.6)	0.755
Okanagan	FD	2	83.2	89.1	87.5	1.6 (6.8)	0.852
	Ot	6	90.0	94.9	150.0	-56.7 (41.4)	0.230
	PL	1	65.2	70.7	73.0	-2.3 (NA)	NA
	PY	1	180.5	183.7	134.0	49.7 (NA)	NA
	S	4	126.3	131.1	133.3	-2.2 (18.5)	0.914
	All	14	104.1	109.0	128.1	-18.6 (18.4)	0.330
100 Mile House	FD	5	75.1	80.1	153.2	-73.1 (38.6)	0.131
	Ot	1	124.7	135.9	129.0	6.9 (NA)	NA
	PL	2	76.3	56.9	111.5	-54.6 (20.7)	0.230
	S	3	65.7	71.5	108.7	-37.2 (7.3)	0.037
	All	11	77.2	78.6	131.3	-52.7 (18.4)	0.017

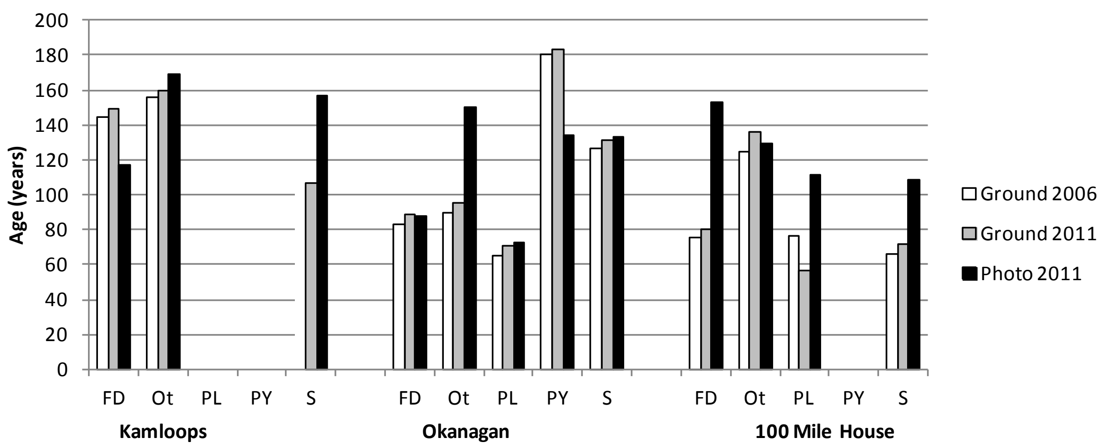


Figure 7. Ground plot and VRI average age by TSA and species group.

5. Summary

Change monitoring analysis of CMI data was implemented in three TSAs. The monitoring analysis requires re-measured ground plots and the available data sets were not ideal. In particular, there was evidence of catastrophic mortality in some plots. Nevertheless, these plots were used to illustrate the monitoring analysis. For most of the analysis, the plots with evidence of catastrophic mortality were excluded or analyzed separately.

The volume growth rates in the ground plots showed small amounts of ingrowth. The growth rates varied widely with TSA. In the 100 Mile House, the TSR growth rate of 9.3 m^3/ha/yr is much higher than the ground plot growth rate of 0.9 m^3/ha/yr. For the Okanagan, the predicted growth (3.7 m^3/ha/yr) was much closer to the ground plot growth rate (2.1 m^3/ha/yr). The main differences on the ground plots between 2006 and 2011 and between the ground plots and TSR and VRI estimates are given in Table 11 for the growth subset.

Differences between the ground plots and the VRI estimate in 2011 are dominated by changes in leading species, particularly within the spruce stratum and mixed species polygons. In general, the differences in site index and leading species are large but with high variability so the differences are not statistically significant. Some of the variability may be due to differences in leading species.

Table 11. Summary of differences by TSA and subset. Differences that are statistically significant at the α = 0.05 are indicated by * and the α = 0.01by **.

TSA	Subset	Attribute	Baseline	Comparison	Differences	
					Absolute	Relative
Kamloops	Growth	Leading species	Ground 2006	Ground 2011	None	
			Ground 2011	VRI 20111	5 of 11	45%
		Tree top condition	Ground 2006	Ground 2011	11 of 339	3%
		Site index	Ground 2011	VRI 20111	-1.5 ± 1.3	-10%
		Age	Ground 2011	VRI 20111	-5.3 ± 16.6	-4%
Okanagan	Growth	volume (m^3/ha)	Ground 2006	TSR 2006	-13.4 ± 35.8	-5%
			Ground 2011	TSR 2011	-21.4 ± 35.0	-8%
		volume periodic annual increment (m^3/ha/yr)	Ground	TSR	-1.59 ± 1.39	-76%
		Leading species	Ground 2006	Ground 2011	None	
			Ground 2011	VRI 20111	9 of 15	60%
		Tree top condition	Ground 2006	Ground 2011	19 or 556	3%
		Site index	Ground 2011	VRI 20111	2.6 ± 1.9	14%
		Age	Ground 2011	VRI 20111	-18.6 ± 18.4	-17%
100 Mile House	Growth (no Cw)	volume (m^3/ha)	Ground 2006	TSR 2006	-11 0 ± 27.0	-13%
			Ground 2011	TSR 2011	-53.0 ± 31.4	-61%
		volume periodic annual increment (m^3/ha/yr)	Ground	TSR	-8.41** ± 1.16	-916%
		Leading species	Ground 2006	Ground 2011	1 of 11	
			Ground 2011	VRI 20111	6 of 11	55%
		Tree top condition	Ground 2006	Ground 2011	22 of 375	6%
		Site index	Ground 2011	VRI 20111	-0.2 ± 1.3	-1%
		Age	Ground 2011	VRI 20111	-52.7* ± 18.4	-67%

6. Conclusion

This report uses CMI plots to evaluate TSR yield curves, site index and age. A significant proportion of the plots had catastrophic mortality and TSR yield curves should not be applied. For the growth subset, the TSR yield curves consistently over-predict growth rates. There was a very small CMI sample size from which to draw conclusions or management interpretations. As a result, this report should be used as an example of the types of change monitoring analyses that can be conducted using CMI data rather than as a basis for decision-making.

7. Literature Cited

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8. Appendix

8.1 Components of growth

Growth was divided into various components.

- Survivor – trees that are merchantable sized (Dbh ≥ 7.5 cm) at time t_1 and alive at time t_2.
- Ingrowth – trees that are unmerchantable or not tallied at time t_1 and alive and merchantable at time t_2.
- Mortality – trees that are merchantable sized (Dbh ≥ 7.5 cm) and alive at time t_1 and dead at time t_2.
- Dead – trees that are a merchantable size (Dbh ≥ 7.5 cm) and dead at time t_1 and time t_2.
- Undersize – trees that are an unmerchantable size (Dbh < 7.5 cm) at and alive at time t_1 and time t_2.
- Ingrowth_small - trees that were not tallied at time t_1 and alive and unmerchantable at time t_2.

The components of growth are summarized for the Kamloops TSA in Table 12. Ingrowth was minor (0.2 m^2/ha of BA in the 5 year interval) in this dataset but would likely be more significant for younger stands. Growth models such as VDYP7 predict the net change attributes. In terms of the growth components, net change is the following:

(eqn. 1) Net change in live merchantable trees = Survivor + Ingrowth – Mortality

It is important to examine the plot data to detect any anomalies. Not surprisingly, the survivor trees grew. Ingrowth has a small QMD so the QMD of S+I is between the QMD for S and I. The trees that died generally shrank a bit. This is pretty typical and a slight decrease in Dbh is a good indicator of imminent mortality (field assessments of crown health are also very good indicators).

Table 12. Basal area (BA), trees per hectare (TPH) and quadratic mean Dbh (QMD) are given by growth component and data subset by TSA.

				2006			2011		
Subset		N	Component	BA (m^2/ha)	TPH	QMD (cm)	BA (m^2/ha)	TPH	QMD (cm)
Growth	Kamloops	11	Survivor (S)	35.4	789	23.9	36.3	762	24.6
			Ingrowth (I)				0.2	36	8.3
			Total Live	35.4	789	23.9	36.5	798	24.1
			Dead	2.8	68	23.0	2.2	68	20.0
			Mortality	0.9			0.6	27	17.2
			Total Dead	3.8	68	26.5	2.8	96	19.3
	Okanagan	15	Survivor (S)	35.1	969	21.5	35.6	877	22.7
			Ingrowth (I)				0.6	118	7.9
			Total Live	35.1	969	21.5	36.1	996	21.5
			Dead	9.2	242	22.0	8.6	242	21.2
			Mortality	2.4			1.8	92	15.7
			Total Dead	11.6	242	24.7	10.3	334	19.9
	100 Mile House	11	Survivor (S)	25.7	910	19.0	24.5	785	19.9
			Ingrowth (I)				0.5	93	8.4
			Total Live	25.7	910	19.0	25.0	878	19.1
			Dead	8.3	200	23.0	7.7	200	22.1
			Mortality	2.6			2.2	125	15.0
			Total Dead	10.9	200	26.4	9.9	325	19.7
Decline	Kamloops	8	Survivor (S)	33.7	1054	20.2	13.7	522	18.3
			Ingrowth (I)				0.2	31	9.3
			Total Live	33.7	1054	20.2	13.9	553	17.9
			Dead	10.2	375	18.6	6.5	375	14.9
			Mortality	20.8			11.9	532	16.8

Subset		N	Component	2006 BA (m^2/ha)	2006 TPH	2006 QMD (cm)	2011 BA (m^2/ha)	2011 TPH	2011 QMD (cm)
			Total Dead	31.0	375	32.4	18.4	907	16.1
	Okanagan	5	Survivor (S)	41.7	1401	19.5	17.2	811	16.4
			Ingrowth (I)				0.4	75	8.3
			Total Live	41.7	1401	19.5	17.6	886	15.9
			Dead	9.2	450	16.2	6.9	450	13.9
			Mortality	25.7			21.0	590	21.3
			Total Dead	35.0	450	31.4	27.8	1041	18.5
	100 Mile House	8	Survivor (S)	37.1	1132	20.4	11.6	382	19.7
			Ingrowth (I)				0.6	94	8.9
			Total Live	37.1	1132	20.4	12.2	475	18.1
			Dead	11.7	575	16.1	9.5	575	14.5
			Mortality	26.7			23.9	751	20.1
			Total Dead	38.4	575	29.2	33.4	1326	17.9

8.2 Plots with catastrophic mortality

Plots with catastrophic mortality between measurements are identified and listed below. These plots are not included in the "growth" subset. Most are pine-leading. The summary is for trees with Dbh ≥ 7.5 cm.

Plot	Leading species 2006	Height (m) 2006	Age 2006	SI (m) 2006	Basal area (m^2/ha) 2006	Basal area (m^2/ha) 2011
110023	PLI	14.8	124	8.3	21.3	4.0
110003	PLI	25.4	129	15.8	34.8	14.9
110009	PLI	22.4	101	15.6	27.1	3.5
110042	PLI	23.8	116	15.4	12.7	3.5
110061	PLI	23.1	89	17.5	34.0	24.4
220047	PLI	24.4	131	14.7	37.2	17.2
220063	PLI	28.3	105	20.6	31.2	14.4
220094	PLI	28.3	134	18.0	47.4	25.0
990133	PLI	17.8	70	15.4	16.7	4.8
990211	PLI	21.1	91	15.7	21.0	5.0
990219	PLI	22.3	126	13.5	34.8	3.3
990238	PLI	17	76	13.8	25.4	2.8
220029	PLI	20.3	123	12.1	47.2	14.9
990203	S	26.9	96	18.5	58.4	20.8
990204	S	31.7	97	22.5	50.2	33.6
220023	SE	14.9	189	4.5	26.1	0.4
990132	S	25.5	118	14.8	38.0	13.2
110044	SX	28.5	205	11.9	59.2	45.3
990138	FDI	19	96	13.7	28.9	0.0
110041	CW	24.6	83	18.2	54.0	3.6
110032	PY	13.9	63	15.1	9.0	0.5