Change Monitoring Inventory on TFL 30: First Measurement Results

Prepared for:

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Project: CFP-013-005

March 15, 2002

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Executive Summary

Canadian Forest Products Ltd. (Canfor) initiated a Change Monitoring Inventory (CMI) program on Tree Farm License (TFL) 30 in 2001 to check that the growth and yield predictions used in timber supply analysis are actually being achieved on the ground. Thirty-five (35) plots were established in post-harvest regenerated (PHR) stands between 15 and 30 years of age. This report presents the first measurement results for these plots. The results of the field sampling were compared to estimates obtained from the yield tables used in Management Plan 9.

Canfor's primary objectives were to monitor the change in mean annual increment (MAI) and site index (SI) in PHR stands. For the first measurement, only yield could be compared. For both MAI and SI, the values observed on the ground were not statistically different from the yield table estimates.

Attribute	Sample Size	Average Residual	Relative Average Residual	Minimum Residual	Maximum Residual	p-value
MAI (m^3/ha/yr)	35	0.0	0%	-2.0	1.6	0.970
SI (m)	12	2.3	10%	-6.1	7.5	0.064

The small sample size limits the statistical power of the first-year measurement analysis. We recommend that Canfor install 35 additional CMI plots in 2002.

Acknowledgements

We thank Joe Kavanagh, *RPF*, Bill Wade, *RPF*, and Kerry Deschamps, *RPF*, of Canadian Forest Products Ltd., who contributed to the success of this project. We also acknowledge the field assistance of Larry Badowski, *RPF* (Ministry of Sustainable Resources Management).

Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

1.1 BACKGROUND

Canadian Forest Products Ltd. (Canfor) implemented a Change Monitoring Inventory (CMI) program on Tree Farm License (TFL) 30 to ensure that growth and yield (G&Y) models used for timber supply analysis provide realistic growth projections for post-harvest regenerated (PHR) stands. TFL 30 (also known as the McGregor Model Forest) is part of an international network of model forests aimed at accelerating the implementation of sustainable forest development practices. Monitoring programs are a key element of model forest management. J.S. Thrower & Associates Ltd. (JST) prepared a sample plan for this CMI program that was approved by the Ministry of Sustainable Resources Management (MSRM) in September 2001.[1]

1.2 CMI PROGRAM GOALS

Canfor's primary objectives for the CMI program are to track the actual mean annual increment (MAI) in net merchantable volume and to monitor site index (SI) estimates in PHR stands. A secondary objective is to monitor plant species richness and abundance in PHR stands. This secondary objective has not been addressed in the first year, but will be addressed in the future.

1.3 REPORT OBJECTIVES

The objectives of this report are:

1. To present the data summary for the CMI plots and the corresponding yield tables.
2. To compare the actual and predicted yield.

1.4 TERMS OF REFERENCE

Joe Kavanagh, *RPF* of Canfor is the project leader. Guillaume Thérien, *PhD* is JST's project manager and analyst. Mike Ciccotelli, *DoT* coordinated the field sampling and quality control. Tim de Grace, *DoT*, Scott MacKinnon, *BNRSc*, Kendra Wood, *BSF*, and Tennessee Trent, *BNRSc* completed the field work.

2. SAMPLING DESIGN

2.1 OVERVIEW

The key features of this CMI sampling design were:

1. Sample plots were randomly located in stands between 15 and 30 years old.
2. Plots were 11.28 m radius (400 m^2) fixed area, centered at the random point.
3. Only timber attributes were measured.

Further details of the sampling design are provided in the sample plan.[1]

[1] J.S. Thrower & Associates Ltd. 2001. Canadian Forest Products TFL 30 Pilot Change Monitoring Inventory. Sample Plan. Unpubl. Report, Contract No. CFP-013-005. September 7, 2001. 11 pp.

2.2 PURPOSE

The purpose of the sample design was to monitor the changes in net merchantable volume and site index in PHR stands. For the first measurement period however, the purpose of the sampling design was to audit the PHR yield tables used for Management Plan (MP) 9.

2.3 TARGET POPULATION

TFL 30, located covers 181,000 ha northeast of Prince George (Appendix I). The target population for the CMI program is all PHR stands. However, in 2001, the program was limited to PHR polygons aged 15 to 30 years (18,177 ha).

2.4 SAMPLE PLOT LOCATION

Thirty-six (36) sample plots[2] were randomly selected from the target population using probability proportional to size (polygon area) with replacement (PPSWR). Prior to selecting the sample, the target population was stratified into three species groups (spruce [Sx], lodgepole pine [Pl], and Others). Sample allocation within stratum was proportional to stratum area. A random point using the provincial 100 m grid was selected within each sample polygon (Appendix II).

2.5 SAMPLE PLOT DESIGN

The plot design followed the MSRM standard CMI protocol for timber attributes (Figure 1).[3] The Main plot was 400 m^2 (11.28 m radius) divided into eight sectors. All trees greater than 9 cm (diameter at breast height [DBH]) were measured and tagged in the Main plot. Trees between 4 and 9 cm DBH were measured and tagged in the Small-tree plot (100 m^2, 5.64 m radius). Trees taller than 0.3 m but less than 4 cm DBH were tallied by species in the Regeneration plot (19.6 m^2, 2.50 m radius).

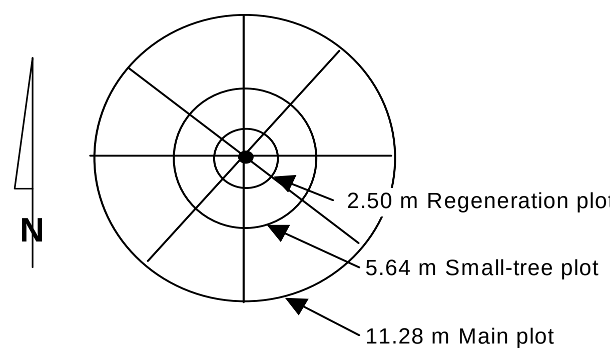

Figure 1. Monitoring sample plot.

[2] One plot (plot 22) was not installed because it had recently been manually and chemically spaced. This plot should be installed in the next field season.

[3] Ministry of Forests – Resources Inventory Branch. 2001. Change Monitoring Inventory. Ground Sampling Procedures for the Provincial Change Monitoring Inventory Program. March 30, 2001. Version 1.1. 203 pp.

3. DATA MANAGEMENT

3.1 DATA ENTRY AND ERROR CHECKING

Field data was entered using the MSRM Vegetation Inventory Data Entry (*VIDE version 1.2.02)* software, as required. VIDE validation reports were generated for each plot to check for completeness and anomalies. Corrections were made accordingly and edited data was submitted to the MSRM for compilation.

3.2 PLOT DATA COMPILATION

Gitte Churlish, *BSc*, compiled the plot data. Modifications to the compiler were necessary to ensure that all site trees could be compiled. The revisions to the standard compilation routine were made under JST's supervision. Descriptive statistics[4] for the 35 CMI plots are provided in Table 1. The range (maximum minus minimum) is relatively large, leading to wide confidence intervals. Detailed plot data are provided in Appendix III.

Table 1. Descriptive plot statistics for the 35 CMI plot locations.

Attribute	n	Mean	Min.	Max.	95% CI
Mean Annual Increment (m^3/ha/yr)	35	0.6	0.0	2.9	[0.3 - 0.8]
Site Index (m)	25	22.9	8.2	48.6	[19.9 - 25.9]
Net Merch Volume (m^3/ha)	35	20.8	0.0	112.1	[10.6 - 31]
Whole-Stem Volume (m^3/ha)	35	46.1	2.3	160.0	[30.0 - 62.1]
Basal Area (m^2/ha)	35	12.3	1.5	34.9	[9.0 - 15.5]
Stems/ha	35	1,747	350	7,555	[1,267 - 2,227]
Height (m)	29	9.4	4.4	19.0	[8.2 - 10.7]
Age (yrs)	35	32	17	135	[24 - 40]

Note: n is the sample size, 95% CI is the 95% confidence interval.

3.3 INVENTORY DATA AND YIELD TABLES

The CMI plot data was compared to the growth and yield model predictions generated by the yield tables for the timber supply analysis for MP 9.[5] All yield tables for these plots were produced with *BatchTIPSY version 2.5r*. A yield table was first generated for each productive site series in the timber harvesting land base based on the silviculture regime used on that site series. A weighted average yield table was then constructed for each forest cover polygon, based on the distribution of site series within the polygon. Descriptive statistics for the 35 yield tables are given in Table 2. Site index and net merchantable volume (first 60 years) for all 35 yield tables are provided in Appendix IV.

Table 2. Yield table statistics for the 35 CMI locations.

Attribute	n	Mean	Min.	Max.	95% CI
Mean Annual Increment (m^3/ha/yr)	35	0.6	0.0	2.7	[0.3 - 0.8]
Site Index (m)	35	21.7	20.0	24.2	[21.4 - 22.0]
Net Merch. Volume (m^3/ha)	35	13.9	0.0	79.4	[7.5 - 20.4]
Whole-Stem Volume (m^3/ha)	35	41.4	4.9	113.7	[28.1 - 54.6]
Basal Area (m^2/ha)	35	8.8	0.9	27.3	[6.4 - 11.2]
Stems/ha	35	2,000	1,277	2,600	[1,900 - 2,101]
Height (m)	35	7.0	3.6	13.4	[6.1 - 7.9]
Age (yrs)	35	20	15	30	[19 - 21]

[4] Descriptive statistics are not for analysis purposes. They simply represent a brief information summary.
[5] J.S. Thrower & Associates Ltd. 2000. Yield Table Summary Report: Canfor TFL 30 – Prince George (MSYTs and NSYTs), Version 2. Unpubl. Report, Contract No. CFP-013-002, December 6 2000, Vancouver. 27 pp.

4. ANALYSIS AND RESULTS

4.1 Overview

The sample design allows the CMI plots to act as a yield audit of the PHR population between 15 and 30 years of age. For the purpose of this project, we compared the CMI plot observations to the predicted observations from the yield tables used in MP 9 using both graphical and statistical analysis.[6] The residuals for all attributes are shown in Appendix V.

4.2 Comparison of Measured and Predicted Attributes

The following sample data were graphically and statistically compared to the yield table estimates:

Primary timber attributes:	Secondary timber attributes:	
▪ MAI ▪ SI	▪ Net merchantable volume ▪ Whole-stem volume ▪ Basal area ▪ Stems/ha	▪ Height ▪ Age ▪ Species composition

For each attribute except species composition, a residual graph showing predicted minus observed estimate versus the yield table age is shown in Appendix VI. In these residual graphs, a positive residual means that the yield table under-estimated the plot observation, while a negative residual indicates that the yield table over-estimated the plot observation. On the residual graphs, a residual observation close to the 0 reference line indicates that the yield table estimate accurately predicted the plot observation. Simple graphical analysis is not possible for species composition. Graphical analysis has no statistical value, its purpose is only to visualize the information.

Descriptive statistics for the residual estimates, as well as t-tests to determine if the average residual (or bias) equals zero, are presented in sections 4.3 and 4.4. The descriptive statistics presented in this report are the absolute bias, the relative bias (the absolute bias divided by the plot average [from Table 1]), the minimum and maximum residuals. The t-test (represented by the p-value) is the statistical tool used to detect statistical difference. If the p-value is greater than 0.05, it means that the average residual is not statistically different from 0 at a 95% confidence level. In this case, any difference between the plot and the yield table estimates is due to the sampling process. For species composition, a confusion matrix for the yield table leading species is presented in section 4.4. A confusion matrix shows how many times the yield table leading species was actually the leading, second, third, or fourth species in the plot.

[6] The ground data can be also compared to the inventory database, but this was beyond the scope of this project.

4.3 PRIMARY TIMBER ATTRIBUTES

4.3.1 Mean Annual Increment

The MAI for both the CMI plots and the yield tables was 0.6 m^3/ha/yr; therefore the MAI bias was 0 (Table 3). The p-value of 0.970 indicates that the bias was not statistically different from 0. In the graphical analysis, the residuals were well distributed around the zero line, and no localized bias could be detected (Appendix VI). This indicates that the yield tables accurately predicted MAI.

Table 3. MAI (m^3/ha/yr) residual statistics.

Statistic	Value
Sample Size	35
Bias - Absolute	0.0
- Relative	0%
Minimum Residual	-2.0
Maximum Residual	1.6
p - value	0.970

4.3.2 Site Index

4.3.2.1 Site Index Computations

The SI of the plot leading species was computed using the method outlined in the MSRM CMI ground sampling procedures (MSRM SI)[3,7] as well as using additional site trees (JST SI) as explained in the sample plan.[1]

4.3.2.2 Yield Table Site Index Bias

The average yield table SI was 21.3 m while the MSRM SI and JST SI were 23.6 m and 22.0 m, respectively. Therefore, the SI bias was 2.3 m for the MSRM SI and 0.7 m for the JST SI (Table 4). This means that SI tended to be under-estimated, but this under-estimation was not statistically significant at a 95% confidence level (the p-values were greater than 0.05). The JST SI yielded four more observations than the MSRM SI, providing a higher precision in the JST than in the MSRM SI estimate.

Table 4. Site index (m) residual statistics.

Statistics	Value	
	MSRM	JST
Sample Size	12	16
Bias - Absolute	2.3	0.7
- Relative	10%	3%
Minimum Residual	-6.1	-6.2
Maximum Residual	7.5	5.7
p - value	0.064	0.354

4.3.2.3 Potential Site Index Bias

The SI estimates used in the MP 9 PHR stand yield tables were derived from the Site Index Adjustment (SIA) project completed by JST for Canfor in 1999.[8] This project provided potential site index (PSI) estimates for the main commercial species (balsam [Bl], Pl, and Sx) for PHR stands. The PSI estimates were applied to the leading species of each yield table. Monitoring the SIA PSI estimates ensures that these PSI estimates are being achieved on the ground.

PSI estimates from the SIA project were compared to both MSRM and JST SI estimates for Bl, Pl, and Sx. One Sx observation was deleted from the analysis because this SI estimate was greater than 45 m (for both the MSRM and JST SI) and is likely the result of measurement error. Deleting that observation had little impact on the overall results of the t-test statistic for Sx. The CMI plot results showed that the Bl PSI estimates were over-estimated, while the Pl and Sx

Table 5. SIA SI (m) residual statistics.

Source	Spp	n	Mean	Min.	Max.	p-value
MSRM	Bl	8	-3.0	-14.0	4.2	0.180
	Pl	7	1.6	-1.9	4.2	0.092
	Sx	10	-1.5	-12.1	4.7	0.425
JST	Bl	12	-1.7	-14.1	3.1	0.266
	Pl	8	0.8	-2.1	3.2	0.291
	Sx	21	0.0	-12.9	4.8	0.986

Note: The total sample size does not add up to 35 because there can be more than one SI observation on a plot.

[7] The MSRM standard uses only the largest diameter tree in a 100 m^2 plot. The JST method uses all suitable dominant or codominant reflecting the growth potential of the site.

[8] J.S. Thrower & Associates Ltd. 1999. Potential Site Index Estimates for the Major Commercial Tree Species on TFL 30. Unpubl. Report Contract No. NWP-041-007. March 31, 2000, Vancouver. 21 pp.

PSI estimates were under-estimated (Table 5). None of the SIA PSI estimates were statistically different from the plot SI estimates at a 95% confidence level (all p-values were greater than 0.05).

4.4 SECONDARY TIMBER ATTRIBUTES

The statistical analysis showed that most secondary timber attributes were under-estimated in the yield tables (Table 6); only stems/ha were over-estimated. For net merchantable volume, whole-stem volume, and stems/ha, this bias was not statistically significant at a confidence level of 95% (p-values were greater than 0.05). The under-estimation for basal area, height, and age was statistically significant (p-values were less than 0.05). The graphical analyses (Appendix VI) showed that residuals were distributed around the zero line with two plots (plots 12 and 35) being outliers on all graphs, except on the graph showing stems/ha.

Table 6. Residual statistics for the secondary timber attributes.

Attribute	Sample Size	Bias		Minimum Residual	Maximum Residual	p-value
		Absolute	Relative			
Net Merch. Volume (m^3/ha)	35	6.9	33%	-63.2	95.2	0.185
Whole-Stem Volume (m^3/ha)	35	4.7	10%	-94.7	132.5	0.559
Basal Area (m^2/ha)	35	3.4	28%	-11.3	23.2	0.030
Stems/ha	35	-253.5	-15%	-1993.7	6226.1	0.314
Height (m)	29	2.1	22%	-7.2	14.9	0.011
Age (yrs)	35	12.2	38%	-6.2	118.6	0.007

The tendency for the models to under-estimate performance was expected because a model under-estimation is more likely than an over-estimation. This is because in young stands large volume over-estimation is not likely, since volume is relatively small and cannot be less than 0. However, the presence of residual trees or an inventory age error could generate a large model under-estimation. In the case of plots 12 and 35, further analysis is needed to determine whether the plot was established in an unrepresentative part of the polygon, if the stand age in the inventory polygon was incorrect, or if residual trees within the polygon were present. In the future, recording anecdotal information about the stand conditions in the vicinity of the plot could help determining if the plot is unrepresentative of the polygon.

Species composition can be defined using many different attributes. The ground-plot species composition was defined using whole-stem volume above a 4 cm utilization level if that volume was greater than 0, or using stems/ha otherwise. For the yield table comparison, species composition was defined in the silviculture regimes. Predicting the leading species with accuracy is important because site index is estimated for the leading species. The yield table and plot leading species were similar in only 14 plots (Table 7). On 13 plots, the yield table leading species was not present in the plot. For 12 of these 13 yield tables where the leading species was not present, the leading species was Pl.

Table 7. Yield table leading species rank on the ground plots.

Ground Rank	No. Plots	%
Leading	14	40.0
Second	5	14.3
Third	2	5.7
Fourth	1	2.9
None	13	37.1

5. DISCUSSION

Table 8. Residual statistics, based on ground age.

Attribute	n	Bias	Minimum Residual	Maximum Residual	p-value
Mean Annual Increment (m^3/ha/yr)	35	-0.9	-4.3	1.7	0.000
Net Merch. Volume (m^3/ha)	35	-47.0	-469.4	39.1	0.011
Whole-Stem Volume (m^3/ha)	35	-82.8	-474.0	54.0	0.000
Basal Area (m^2/ha)	35	-5.8	-41.3	23.1	0.006
Stems/ha	35	-119.5	-1930.7	6226.1	0.634
Height (m)	29	-2.3	-18.1	4.6	0.018

Note: Site index is not affected by a change in age.

All sampled polygon attributes were under-estimated by the yield tables except for MAI and stems/ha. This under-estimation may be due to the inventory age being under-estimated or the presence of residual trees. To study the sensitivity of inventory age on the model under-estimation, the residual analysis was recomputed using plot age instead of inventory age. The bias in this sensitivity analysis was significant in all cases except for stems/ha (Table 8, p-values were less than 0.05). This shows that the actual age of the polygon is a critical attribute in monitoring. It is difficult to assess the magnitude of the impact of inventory age.

The leading species used in the silviculture regimes to define the yield tables was often not present in the plots. We can hypothesize that the silviculture regimes probably reflected future management regimes where spruce weevil will be controlled by planting more Pl than Sx, rather than past regimes where Sx was still a predominant species. Only one set of silviculture regimes were used for existing and future PHR stands. For the next MP, if the hypothesis is correct, separate regimes might be more appropriate for both types of PHR stands. This hypothesis should be investigated further.

The confidence intervals in the different plot attributes were relatively large. The width of the confidence interval is related to the statistical precision of an estimate. Narrow confidence intervals indicate higher precision. Increasing the sample size will increase precision and decrease confidence interval widths.

6. RECOMMENDATIONS

The two main attributes of interest for Canfor, mean annual increment and site index, were not statistically different from the estimates used in MP 9. The small sample size led to wide confidence intervals for both attributes. This partly explains why the yield tables and ground data were not statistically significant. Therefore, we recommend that

Canfor establish another 35 CMI plots in 2002.

Age in the inventory database was significantly lower than the age observed in the ground plots. This can be due to an inventory database error, the presence of residual trees in the sampled polygon, or plots being installed in areas unrepresentative of the sampled polygon. Age was shown to have an important impact on the results. Therefore, we recommend that

Canfor investigate the age difference in the 35 CMI plots installed in 2001.

APPENDIX I – LAND BASE CHARACTERISTICS

Geographic Location

Canfor's TFL 30 is located northeast of Prince George on the McGregor Plateau between Highway 97 on the west and the western foothills of the Rocky Mountains to the east. The TFL covers 181,000 ha (Table 10) of which 157,000 ha (87%) is in the productive forest land base (PFLB).

Table 9. TFL 30 area distribution by land type.

Land Type	Area (ha)	% of TFL	% of Forested
Entire TFL	180,520		
Non-Forested	9,461	5%	
Forested	171,060	95%	
Non-Productive	14,136	8%	8%
Productive	156,924	87%	92%

Forest Cover

Eighty-seven (87) percent of the polygons in the PFLB are either Sx or Bl leading (Table 10). Almost 70% are either SxBl or BlSx stands. Due to the impact of spruce weevil on spruce stands, Canfor will regenerate an increasing portion of the land base in Pl leading stands. Approximately 50% of the TFL is in age class 8 and 9 and only 14% in age class 3 to 6. The current annual allowable cut is 350,000 m^3.

Table 10. TFL 30 PFLB area distribution by leading species and age class.

	Age Class									Total	
Spp	1	2	3	4	5	6	7	8	9	(ha)	(%)
Sx	25,251	7,210	1,750	899	1,126	1,527	5,568	47,473	1,892	92,696	61
Bl	212	1,007	2,636	2,365	4,493	4,220	6,304	18,584	97	39,919	26
Pl	1,728	648	14	112	168	278	955	2,086		5,988	4
Ep	856	1,663	623	89	151	53	158	44		3,637	2
Hw	8	2		34	160	382	814	1,126	305	2,831	2
At	1,448	156	31	32	13	27	92	15		1,815	1
Fd	249	52	18	66	95	71	76	875	119	1,620	1
Sb		27	6	23	124	198	469	412		1,259	1
Ac	57	148	172	30	24	26	53	345	190	1,046	1
Cw	8							195	53	255	0
Total (ha)	*29,817*	*10,913*	*5,250*	*3,650*	*6,354*	*6,784*	*14,488*	*71,156*	*2,655*	*151,066*[1]	
(%)	*20%*	*7%*	*3%*	*2%*	*4%*	*4%*	*10%*	*47%*	*2%*		*100*

[1] There are 5,858 ha non-sufficiently restocked (NSR).

Ecological Description

The TFL is dominated by the Sub-Boreal Spruce (SBS) biogeoclimatic (BGC) zone with small areas of the Interior Cedar-Hemlock (ICH) in the southeast and Engelmann Spruce-Subalpine Fir (ESSF) in the northeast. Approximately 80% of the PFLB is in the SBSvk and SBSwk1 BGC subzones (Figure 2).

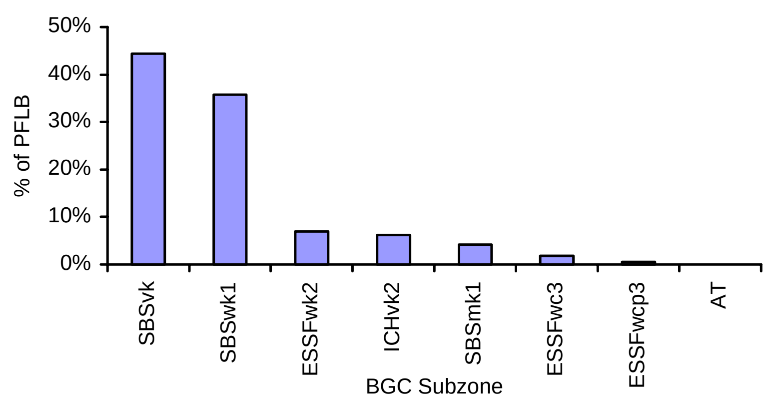

Figure 2. TFL 30 PFLB area distribution by BGC subzone.

APPENDIX II – CMI PLOT LOCATIONS

Table 11. CMI plot locations.

Plot No	Map	Stand	Spp	Northing	Easting	Age (yrs)	Subzone	Area (ha)
1	93I011	4610	Ep	6001188	573017	25	SBSwk1	130.9
2	93J020	1770	At	6006461	543669	16	SBSwk1	119.1
3	93I011	5770	Ep	6000693	573183	27	SBSwk1	55.0
4	93J029	6580	Fd	6010679	545648	27	SBSwk1	17.5
5	93J030	13020	Pl	6007760	562268	23	SBSwk1	16.2
6	93J030	7820	Pl	6009016	556497	20	SBSwk1	7.4
7	93J030	9790	Sx	6016451	563031	15	SBSvk	265.5
8	93J030	12340	Sx	6012114	563844	17	SBSvk	214.9
9	93I021	3490	Sx	6012435	567883	17	SBSvk	174.1
10	93I012	9770	Sx	6000933	588339	20	SBSvk	112.0
11	93I031	7450	Sx	6018314	570740	16	SBSvk	104.5
12	93I021	2560	Sx	6015538	570221	16	SBSvk	100.6
13	93I012	2670	Sx	6003226	584150	16	SBSvk	100.0
14	93I012	90	Sx	6005437	579300	20	SBSvk	71.8
15	93I011	4730	Sx	6002267	573555	20	SBSwk1	66.6
16	93J029	10730	Sx	6006456	543669	15	SBSwk1	62.6
17	93I012	2980	Sx	6001756	583263	26	SBSvk	60.7
18	93J030	7040	Sx	6012355	560561	15	SBSvk	58.4
19	93I021	10960	Sx	6008293	569283	21	SBSwk1	57.1
20	93I021	1850	Sx	6016384	569243	17	SBSvk	49.3
21	93J029	1730	Sx	6013454	541862	25	SBSwk1	48.8
23	93I021	4100	Sx	6011671	569248	17	SBSvk	43.4
24	93J030	4070	Sx	6013194	557286	19	SBSwk1	43.2
25	93J029	11410	Sx	6010518	549270	30	SBSwk1	43.1
26	93I003	7920	Sx	5990962	603760	19	ICHvk2	40.0
27	93J038	4300	Sx	6022312	538424	25	SBSwk1	30.2
28	93I011	2350	Sx	6006048	572017	26	SBSwk1	25.6
29	93J018	860	Sx	6004728	532270	26	SBSmk1	21.9
30	93J039	3820	Sx	6020844	539674	18	SBSwk1	19.0
31	93I021	14710	Sx	6006609	575238	18	SBSvk	14.8
32	93J038	4210	Sx	6021524	538097	17	SBSwk1	14.2
33	93I031	8160	Sx	6017554	572408	17	SBSvk	10.7
34	93J030	11530	Sx	6009200	561633	15	SBSwk1	9.2
35	93J030	6880	Sx	6008623	553507	20	SBSwk1	6.3
36	93I021	3100	Sx	6012056	567359	18	ICHvk2	2.7

APPENDIX III – CMI PLOT STATISTICS

Table 12. Tree attribute summary data by CMI plot.

Plot	MAI	Net Merch.	Whole-Stem	BA		MSRM			JST		
No.	(m^3/ha/yr)	(m^3/ha)	(m^3/ha)	(m^2/ha)	SPH	Ht (m)	Age (yrs)	SI (m)	Ht (m)	Age (yrs)	SI (m)
1	1.3	41.3	124.8	28.3	3,202	12.3	32	23.4	12.6	32	23.2
2	0.6	11.8	23.0	7.7	951	9.1	21	25.4	9.1	19	24.4
3	1.0	29.5	41.3	9.3	751	13.2	31	48.6	13.2	20	43.1
4	1.2	33.1	90.5	21.2	3,352	10.5	27	22.8	11.2	25	22.7
5	0.3	7.5	135.7	34.9	7,555	10.6	23	24.5	10.5	23	23.6
6	0.4	11.0	34.0	10.0	1,251	8.3	31	21.2	8.4	32	20.8
7	0.0	0.0	2.3	1.5	600	4.4	21	24.9	3.9	20	22.0
8	0.3	7.5	19.2	7.1	725		25		7.9	17	
9	0.2	5.3	25.4	10.6	1,676		24		7.7	22	22.5
10	0.0	0.9	7.1	2.6	725	8.5	24	23.3	8.5	19	23.3
11	0.1	3.2	11.3	5.2	650	7.4	31	12.1	5.3	32	12.7
12	0.7	95.8	128.4	20.5	525	19.0	135	15.2	21.1	90	15.1
13	1.6	51.6	86.1	20.9	2,927	13.8	32		13.4	20	
14	1.3	32.3	78.3	20.6	3,202	11.0	24	22.8	12.1	23	23.9
15	0.1	2.8	26.3	10.3	1,726	7.8	22	28.9	7.6	20	27.0
16	0.2	4.4	11.4	4.8	350		24				
17	1.1	24.4	60.8	17.8	2,827	10.8	22		11.5	20	
18	0.1	1.9	12.8	6.0	976	5.7	17	21.4	5.4	16	20.2
19	0.2	6.5	18.3	6.9	826	7.3	27	23.3	7.1	27	22.8
20	0.2	3.8	18.3	8.3	1,426	7.3	24	28.1	7.0	23	25.7
21	0.1	1.6	9.4	3.9	801	6.6	25	15.9	6.0	30	16.5
23	0.0	0.9	5.6	2.9	525		25		5.3	23	22.7
24	0.0	0.3	10.8	5.0	1,101	6.8	22	26.7	6.9	19	24.6
25	0.7	16.2	45.7	16.0	3,052	6.2	24	24.9	6.6	21	23.7
26	0.5	12.6	28.1	10.2	1,376	7.7	26		7.7	29	
27	2.8	112.1	160.0	33.4	2,377	10.9	41	19.4	10.9	36	19.4
28	2.9	65.4	94.4	20.4	1,276	11.9	23	23.5	11.6	25	23.5
29	0.5	13.5	34.5	10.8	2,477	8.6	29		7.3	28	
30	0.0	0.4	10.0	4.6	951		26				
31	0.0	0.5	13.6	7.6	2,952	5.8	23	26.1	5.0	22	20.8
32	0.3	29.4	50.2	12.0	1,801	11.8	109	8.2	11.7	106	7.4
33	0.0	0.9	7.1	3.2	675	6.1	23	18.3	6.1	19	18.2
34	0.2	4.4	28.4	10.6	2,552	7.9	24	25.8	9.1	20	24.2
35	1.4	96.3	154.8	31.9	2,477	16.5	67	17.7	15.3	58	20.6
36	0.0	0.0	3.8	2.1	525		23				

Table 13. Species composition amongst the CMI plots.

Plot No.	Spp1	Spp2	Spp3	Spp4	Spp5	Spp6	Pct1	Pct2	Pct3	Pct4	Pct5	Pct6
1	SXW	EP	PLI	BL			38.9	37.3	14.3	9.5	0.0	0.0
2	PLI	SXW	BL				97.6	2.4	0.0	0.0	0.0	0.0
3	SXW	BL	EP	XC			88.7	7.7	3.7	0.0	0.0	0.0
4	PLI	AT	BL	SXW	ACT	FDI	79.2	15.5	3.9	1.0	0.4	0.0
5	PLI						100.0	0.0	0.0	0.0	0.0	0.0
6	PLI	SB					92.4	7.6	0.0	0.0	0.0	0.0
7	SXW	XC					100.0	0.0	0.0	0.0	0.0	0.0
8	BL	SX	FDI	XC			56.5	43.5	0.0	0.0	0.0	0.0
9	SXW	BL	AT				79.0	10.6	10.4	0.0	0.0	0.0
10	EP	SXW	PLI				86.5	13.5	0.0	0.0	0.0	0.0
11	BL	SXW	XC				73.5	26.5	0.0	0.0	0.0	0.0
12	SXW	BL	XC				72.2	27.8	0.0	0.0	0.0	0.0
13	BL	SXW	HW	ACT			37.4	28.7	27.9	5.9	0.0	0.0
14	EP	ACT	SXW				77.2	21.5	1.3	0.0	0.0	0.0
15	SXW	ACT	AT	BL	XC		100.0	0.0	0.0	0.0	0.0	0.0
16	SXW	BL	EP	XC			100.0	0.0	0.0	0.0	0.0	0.0
17	PLI	EP	ACT	SXW			41.1	24.8	22.2	11.9	0.0	0.0
18	PLI						100.0	0.0	0.0	0.0	0.0	0.0
19	SXW						100.0	0.0	0.0	0.0	0.0	0.0
20	SXW	PLI					100.0	0.0	0.0	0.0	0.0	0.0
21	BL	SXW					100.0	0.0	0.0	0.0	0.0	0.0
23	SXW	BL					69.9	30.1	0.0	0.0	0.0	0.0
24	SXW	FDI	AT	EP			60.0	40.0	0.0	0.0	0.0	0.0
25	BL	SXW					63.6	36.4	0.0	0.0	0.0	0.0
26	SXW	BL					91.9	8.1	0.0	0.0	0.0	0.0
27	BL	SXW	XC				72.9	27.1	0.0	0.0	0.0	0.0
28	PLI	EP	SXW	AT	BL	ACT	60.4	26.1	6.4	4.9	2.0	0.2
29	BL	PLI	SXW				78.9	13.8	7.4	0.0	0.0	0.0
30	SXW	XC					100.0	0.0	0.0	0.0	0.0	0.0
31	SXW	PLI					100.0	0.0	0.0	0.0	0.0	0.0
32	SXW	BL					97.1	2.9	0.0	0.0	0.0	0.0
33	SXW	BL	ACT				99.2	0.8	0.0	0.0	0.0	0.0
34	SXW	EP	AT	BL	ACT		66.9	28.0	4.5	0.6	0.0	0.0
35	SXW	EP	BL	ACT	HW		78.4	10.9	10.7	0.0	0.0	0.0
36	SXW	XC					100.0	0.0	0.0	0.0	0.0	0.0

APPENDIX IV – YIELD TABLE SUMMARIES

Table 14. SI and net merchantable volume (first 60 years) for the yield tables used to model the CMI plots.

Plot No	Site Index (m)	Merchantable Volume - 12.5 cm+ (m^3/ha)						
		0 yrs	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	60 yrs
1	22.8	0	0	9.9	74.3	164.9	244.2	304.4
2	22.9	0	0	12.7	84.1	177.5	257.9	321.1
3	22.0	0	0	6.7	61.0	146.3	223.9	283.6
4	22.0	0	0	4.8	51.7	140.0	220.4	285.6
5	20.0	0	0	6.0	61.0	141.2	215.9	280.1
6	21.0	0	0	9.8	83.3	174.9	251.7	315.2
7	22.2	0	0	0.0	27.2	123.4	226.4	328.7
8	20.9	0	0	1.0	23.1	107.8	205.7	291.1
9	21.2	0	0	1.0	23.2	104.5	195.8	273.8
10	21.2	0	0	1.7	28.0	122.9	228.0	311.9
11	20.7	0	0	1.2	20.3	96.1	184.2	256.9
12	21.3	0	0	1.0	22.9	103.8	194.1	271.7
13	20.9	0	0	1.6	23.6	106.4	200.4	274.2
14	20.7	0	0	1.6	23.0	101.5	189.5	257.9
15	22.3	0	0	8.4	69.3	157.7	235.8	295.2
16	22.2	0	0	6.6	60.6	148.2	227.2	288.7
17	20.4	0	0	1.1	17.9	91.6	181.1	256.4
18	21.1	0	0	1.3	25.8	118.0	221.9	308.7
19	23.0	0	0	13.7	86.8	181.9	263.5	331.0
20	21.4	0	0	1.3	24.7	108.1	199.7	274.7
21	21.2	0	0	4.3	52.4	145.0	232.5	304.5
22	21.0	0	0	1.5	22.7	101.7	190.5	260.6
23	21.2	0	0	1.0	21.6	100.2	189.5	266.4
24	22.2	0	0	8.9	71.9	168.2	254.6	322.9
25	22.9	0	0	11.1	79.4	173.2	254.9	317.7
26	22.9	0	0	1.8	46.3	159.9	269.5	360.3
27	22.3	0	0	10.0	77.9	178.5	268.0	338.1
28	21.8	0	0	7.9	69.4	155.7	232.3	290.3
29	20.6	0	0	3.9	48.7	127.7	202.7	262.1
30	22.4	0	0	10.5	81.5	181.2	269.7	336.6
31	20.4	0	0	1.1	17.1	88.0	174.3	246.3
32	24.2	0	0	17.7	109.6	225.6	321.3	395.1
33	20.9	0	0	0.8	19.5	93.6	180.3	256.6
34	22.4	0	0	11.0	83.0	176.3	255.3	316.9
35	21.8	0	0	4.5	50.1	136.6	216.4	281.5
36	21.7	0	0	1.4	37.4	131.1	223.9	303.5

APPENDIX V – RESIDUAL TABLES

Table 15. MAI residuals for the 35 CMI plots.

Plot No.	Inventory Age (yrs)	Plot MAI (m^3/ha/yr)	Yield Table MAI (m^3/ha/yr)	Residual MAI (m^3/ha/yr)
1	25	1.3	1.7	-0.4
2	16	0.6	0.5	0.1
3	27	1.0	1.7	-0.7
4	27	1.2	1.4	-0.2
5	23	0.3	1.0	-0.6
6	20	0.4	0.5	-0.1
7	15	0.0	0.0	0.0
8	17	0.3	0.0	0.3
9	17	0.2	0.0	0.2
10	20	0.0	0.1	0.0
11	16	0.1	0.0	0.1
12	16	0.7	0.0	0.7
13	16	1.6	0.1	1.6
14	20	1.3	0.1	1.3
15	20	0.1	0.4	-0.3
16	15	0.2	0.2	0.0
17	26	1.1	0.4	0.7
18	15	0.1	0.0	0.1
19	21	0.2	1.0	-0.8
20	17	0.2	0.1	0.1
21	25	0.1	1.1	-1.1
23	17	0.0	0.0	0.0
24	19	0.0	0.4	-0.4
25	30	0.7	2.6	-2.0
26	19	0.5	0.1	0.4
27	25	2.8	1.8	1.0
28	26	2.9	1.7	1.2
29	26	0.5	1.2	-0.7
30	18	0.0	0.5	-0.5
31	18	0.0	0.1	0.0
32	17	0.3	0.7	-0.5
33	17	0.0	0.0	0.0
34	15	0.2	0.4	-0.2
35	20	1.4	0.2	1.2
36	18	0.0	0.1	-0.1

Table 16. Site index residuals for the 35 CMI plots.

Plot No	Inventory Age (yrs)	Yield Table Site Index (m)	MSRM Site Index (m)	MSRM Residual Site Index (m)	JST Site Index (m)	JST Residual Site Index (m)
1	25	22.8			22.0	-0.8
2	16	22.9	25.4	2.5	24.4	1.5
4	27	22	22.8	0.8	22.7	0.7
5	23	20	24.5	4.5	23.6	3.6
6	20	21	21.2	0.2	20.8	-0.2
7	15	22.2	24.9	2.7	22.0	-0.2
9	17	21.2			22.5	1.3
10	20	21.2	25.5	4.2	23.8	2.6
11	16	20.7			18.5	-2.2
12	16	21.3	15.2	-6.1	15.1	-6.2
17	26	20.4	27.9	7.5	26.1	5.7
20	17	21.4	28.1	6.7	25.7	4.3
23	17	21.2			22.7	1.5
28	26	21.8	23.5	1.7	23.5	1.7
31	18	20.4	26.1	5.7	20.8	0.4
33	17	20.9	18.3	-2.6	18.2	-2.7

Table 17. Net merchantable volume residuals for the 35 CMI plots.

Plot No	Inventory Age (yrs)	Plot Net Merch Volume (m^3/ha)	Yield Table Net Merch Volume (m^3/ha)	Residual Net Merch Volume (m^3/ha)
1	25	41.3	42.1	-0.8
2	16	11.8	7.6	4.2
3	27	29.5	44.7	-15.2
4	27	33.1	37.6	-4.5
5	23	7.5	22.5	-15.0
6	20	11.0	9.8	1.2
7	15	0.0	0.0	0.0
8	17	7.5	0.7	6.8
9	17	5.3	0.7	4.6
10	20	0.9	1.7	-0.8
11	16	3.2	0.7	2.5
12	16	95.8	0.6	95.2
13	16	51.6	1.0	50.6
14	20	32.3	1.6	30.7
15	20	2.8	8.4	-5.6
16	15	4.4	3.3	1.1
17	26	24.4	11.2	13.2
18	15	1.9	0.7	1.2
19	21	6.5	21.0	-14.5
20	17	3.8	0.9	2.9
21	25	1.6	28.3	-26.7
23	17	0.9	0.7	0.2
24	19	0.3	8.0	-7.7
25	30	16.2	79.4	-63.2
26	19	12.6	1.6	11.0
27	25	112.1	43.9	68.2
28	26	65.4	44.8	20.6
29	26	13.5	30.8	-17.3
30	18	0.4	8.4	-8.0
31	18	0.5	0.9	-0.4
32	17	29.4	12.4	17.0
33	17	0.9	0.6	0.3
34	15	4.4	5.5	-1.1
35	20	96.3	4.5	91.8
36	18	0.0	1.1	-1.1

Table 18. Whole-stem volume residuals for the 35 CMI plots.

Plot No	Inventory Age (yrs)	Plot Whole-Stem Volume (m^3/ha)	Yield Table Whole-Stem Volume (m^3/ha)	Residual Net Merch Volume (m^3/ha)
1	25	124.8	107.5	17.3
2	16	23.0	34.6	-11.6
3	27	41.3	94.2	-52.9
4	27	90.5	85.9	4.6
5	23	135.7	81.7	54.0
6	20	34.0	30.5	3.5
7	15	2.3	4.9	-2.6
8	17	19.2	7.9	11.3
9	17	25.4	7.8	17.6
10	20	7.1	10.8	-3.7
11	16	11.3	8.0	3.3
12	16	128.4	7.6	120.8
13	16	86.1	9.8	76.3
14	20	78.3	9.5	68.8
15	20	26.3	30.0	-3.7
16	15	11.4	26.8	-15.4
17	26	60.8	43.8	17.0
18	15	12.8	9.4	3.4
19	21	18.3	113.0	-94.7
20	17	18.3	8.8	9.5
21	25	9.4	87.7	-78.3
23	17	5.6	7.3	-1.7
24	19	10.8	30.9	-20.1
25	30	45.7	112.4	-66.7
26	19	28.1	16.5	11.6
27	25	160.0	113.7	46.3
28	26	94.4	101.0	-6.6
29	26	34.5	84.7	-50.2
30	18	10.0	35.6	-25.6
31	18	13.6	7.4	6.2
32	17	50.2	42.4	7.8
33	17	7.1	6.4	0.7
34	15	28.4	32.8	-4.4
35	20	154.8	22.3	132.5
36	18	3.8	14.3	-10.5

Table 19. Basal area residuals for the 35 CMI plots.

Plot No	Inventory Age (yrs)	Plot Basal Area (m^2/ha)	Yield Table Basal Area (m^2/ha)	Residual Basal Area (m^2/ha)
1	25	28.3	19.3	9.0
2	16	7.7	7.5	0.2
3	27	9.3	20.6	-11.3
4	27	21.2	19.5	1.7
5	23	34.9	11.8	23.1
6	20	10.0	10.7	-0.7
7	15	1.5	0.9	0.6
8	17	7.1	2.0	5.1
9	17	10.6	2.2	8.4
10	20	2.6	3.8	-1.2
11	16	5.2	2.0	3.2
12	16	20.5	1.9	18.6
13	16	20.9	2.3	18.6
14	20	20.6	3.9	16.7
15	20	10.3	11.0	-0.7
16	15	4.8	5.6	-0.8
17	26	17.8	9.7	8.1
18	15	6.0	1.7	4.3
19	21	6.9	12.4	-5.5
20	17	8.3	2.5	5.8
21	25	3.9	14.9	-11.0
23	17	2.9	2.1	0.8
24	19	5.0	9.4	-4.4
25	30	16.0	27.3	-11.3
26	19	10.2	5.3	4.9
27	25	33.4	18.0	15.4
28	26	20.4	19.9	0.5
29	26	10.8	17.7	-6.9
30	18	4.6	9.3	-4.7
31	18	7.6	2.4	5.2
32	17	12.0	9.1	2.9
33	17	3.2	1.9	1.3
34	15	10.6	6.4	4.2
35	20	31.9	8.7	23.2
36	18	2.1	4.4	-2.3

Table 20. Stems/ha residuals for the 35 CMI plots.

Plot No	Inventory Age (yrs)	Plot Stems/ha (m^2/ha)	Yield Table Stems/ha (m^2/ha)	Residual Stems/ha (m^2/ha)
1	25	3,202	2,138	1,064
2	16	951	2,081	-1,130
3	27	751	2,139	-1,388
4	27	3,352	2,226	1,126
5	23	7,555	1,329	6,226
6	20	1,251	1,450	-199
7	15	600	1,277	-677
8	17	725	1,862	-1,137
9	17	1,676	1,819	-143
10	20	725	1,991	-1,266
11	16	650	1,889	-1,239
12	16	525	1,833	-1,308
13	16	2,927	2,064	863
14	20	3,202	2,047	1,155
15	20	1,726	2,196	-470
16	15	350	2,335	-1,985
17	26	2,827	1,878	949
18	15	976	1,973	-997
19	21	826	1,671	-845
20	17	1,426	1,922	-496
21	25	801	2,044	-1,243
23	17	525	1,820	-1,295
24	19	1,101	2,137	-1,036
25	30	3,052	2,008	1,044
26	19	1,376	2,600	-1,224
27	25	2,377	2,023	354
28	26	1,276	2,028	-752
29	26	2,477	2,489	-12
30	18	951	2,206	-1,255
31	18	2,952	2,085	867
32	17	1,801	2,084	-283
33	17	675	1,656	-981
34	15	2,552	1,964	588
35	20	2,477	2,232	245
36	18	525	2,519	-1,994

Table 21. Height residuals for the 35 CMI plots.

Plot No	Inventory Age (yrs)	Plot Height (m)	Yield Table Height (m)	Residual Height (m)
1	25	12.3	10.8	1.5
2	16	9.1	6.3	2.8
3	27	13.2	11.2	2.0
4	27	10.5	10.8	-0.3
5	23	10.6	8.9	1.7
6	20	8.3	8.4	-0.1
7	15	4.4	3.6	0.8
10	20	8.5	5.7	2.8
11	16	7.4	4.0	3.4
12	16	19.0	4.1	14.9
13	16	13.8	4.1	9.7
14	20	11.0	5.6	5.4
15	20	7.8	8.1	-0.3
17	26	10.8	7.9	2.9
18	15	5.7	3.7	2.0
19	21	7.3	9.0	-1.7
20	17	7.3	4.6	2.7
21	25	6.6	9.5	-2.9
24	19	6.8	7.4	-0.7
25	30	6.2	13.4	-7.2
26	19	7.7	6.0	1.7
27	25	10.9	10.5	0.4
28	26	11.9	11.0	0.9
29	26	8.6	10.0	-1.4
31	18	5.8	4.5	1.3
32	17	11.8	7.1	4.7
33	17	6.1	4.3	1.8
34	15	7.9	5.8	2.1
35	20	16.5	7.3	9.2

Table 22. Age residuals for the 35 CMI plots.

Plot No.	Plot Age (yrs)	Inventory Age (yrs)	Age Residual (yrs)
1	31.9	25.0	6.9
2	20.5	16.0	4.5
3	30.6	27.0	3.6
4	27.4	27.0	0.4
5	22.7	23.0	-0.3
6	31.2	20.0	11.2
7	20.6	15.0	5.6
8	25.2	17.0	8.2
9	23.5	17.0	6.5
10	23.8	20.0	3.8
11	31.4	16.0	15.4
12	134.6	16.0	118.6
13	31.5	16.0	15.5
14	24.1	20.0	4.1
15	21.9	20.0	1.9
16	23.7	15.0	8.7
17	22.0	26.0	-4.0
18	17.4	15.0	2.4
19	27.1	21.0	6.1
20	24.4	17.0	7.4
21	25.1	25.0	0.1
23	24.8	17.0	7.8
24	22.1	19.0	3.1
25	23.8	30.0	-6.2
26	26.5	19.0	7.5
27	40.7	25.0	15.7
28	22.8	26.0	-3.2
29	29.5	26.0	3.5
30	26.2	18.0	8.2
31	23.2	18.0	5.2
32	108.7	17.0	91.7
33	22.8	17.0	5.8
34	23.5	15.0	8.5
35	67.0	20.0	47.0
36	23.2	18.0	5.2

APPENDIX VI – GRAPHICAL ANALYSIS OF THE TIMBER ATTRIBUTE RESIDUALS

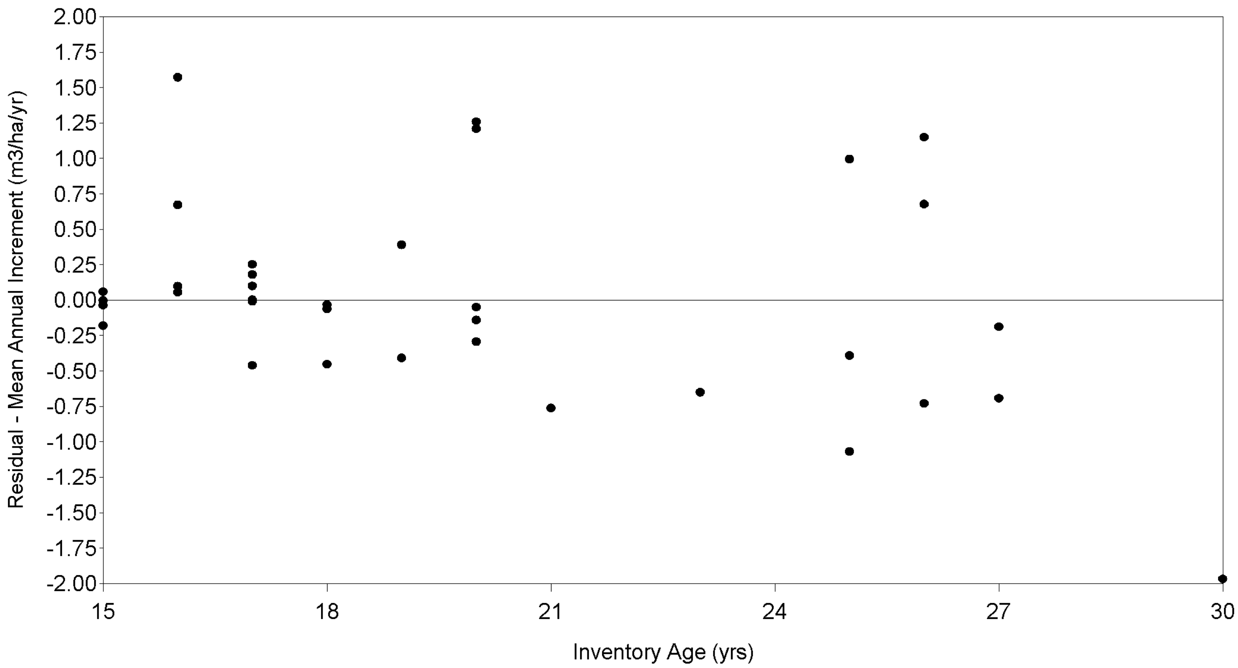

Figure 3. MAI residual versus inventory age for the 35 CMI plots.

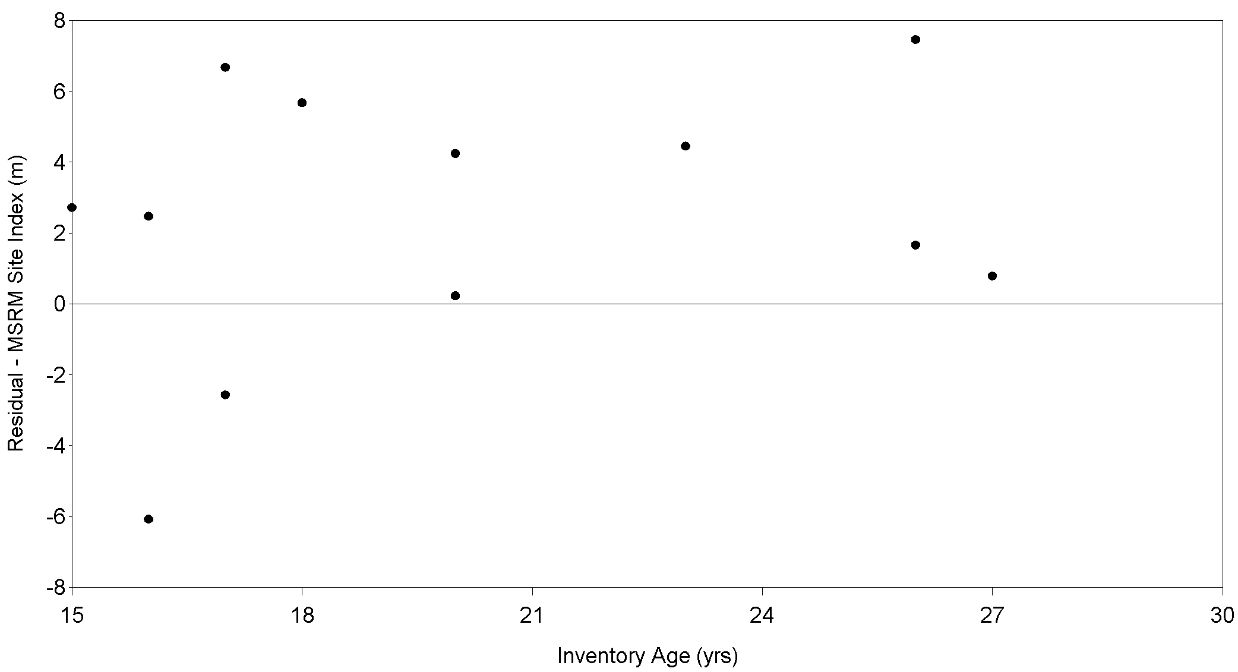

Figure 4. MSRM SI residual versus inventory age for the 35 CMI plots.

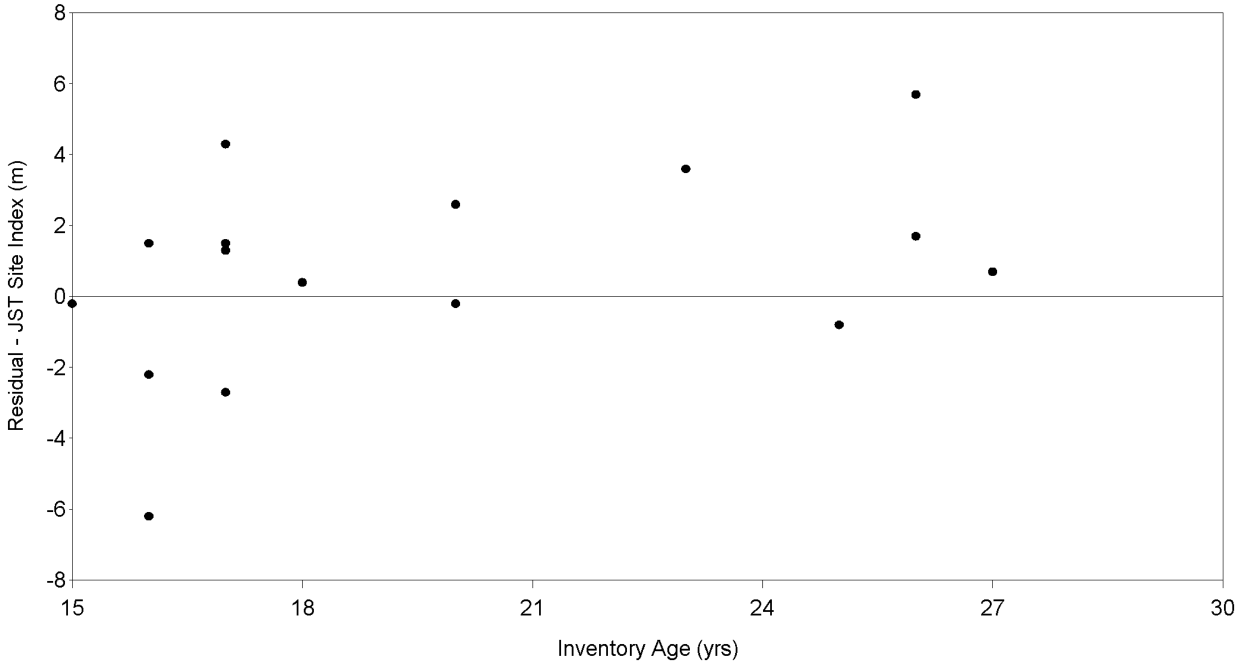

Figure 5. JST SI residual versus inventory age for the 35 CMI plots.

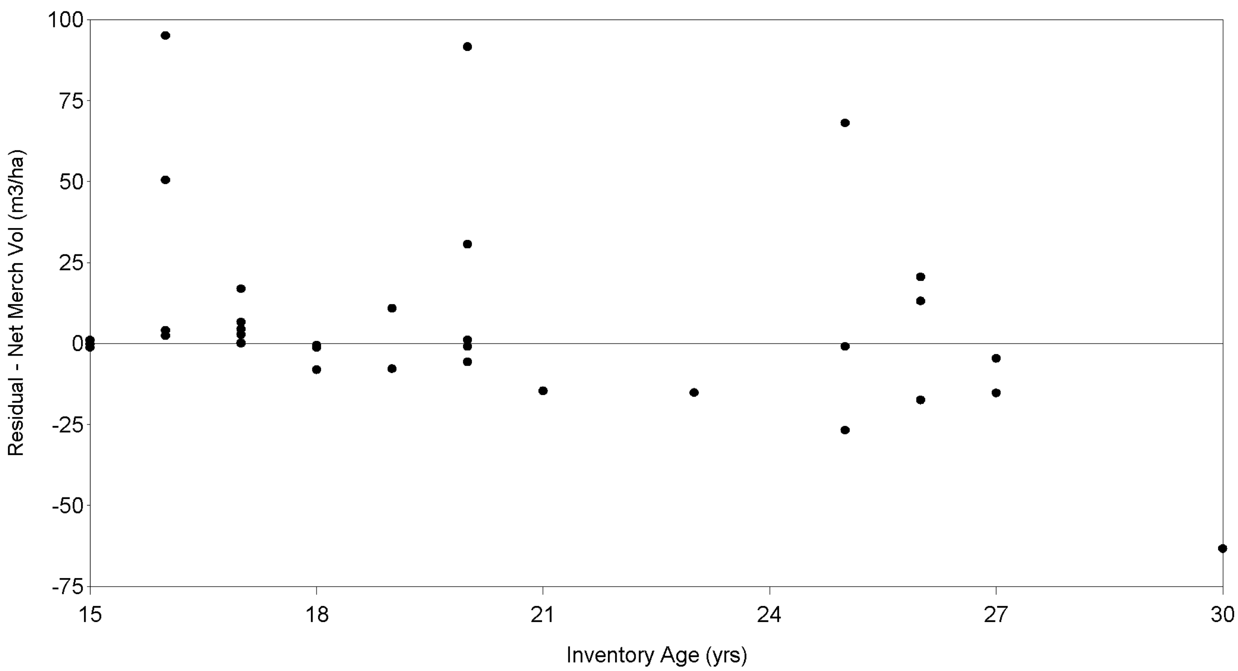

Figure 6. Net merchantable volume residual versus inventory age for the 35 CMI plots.

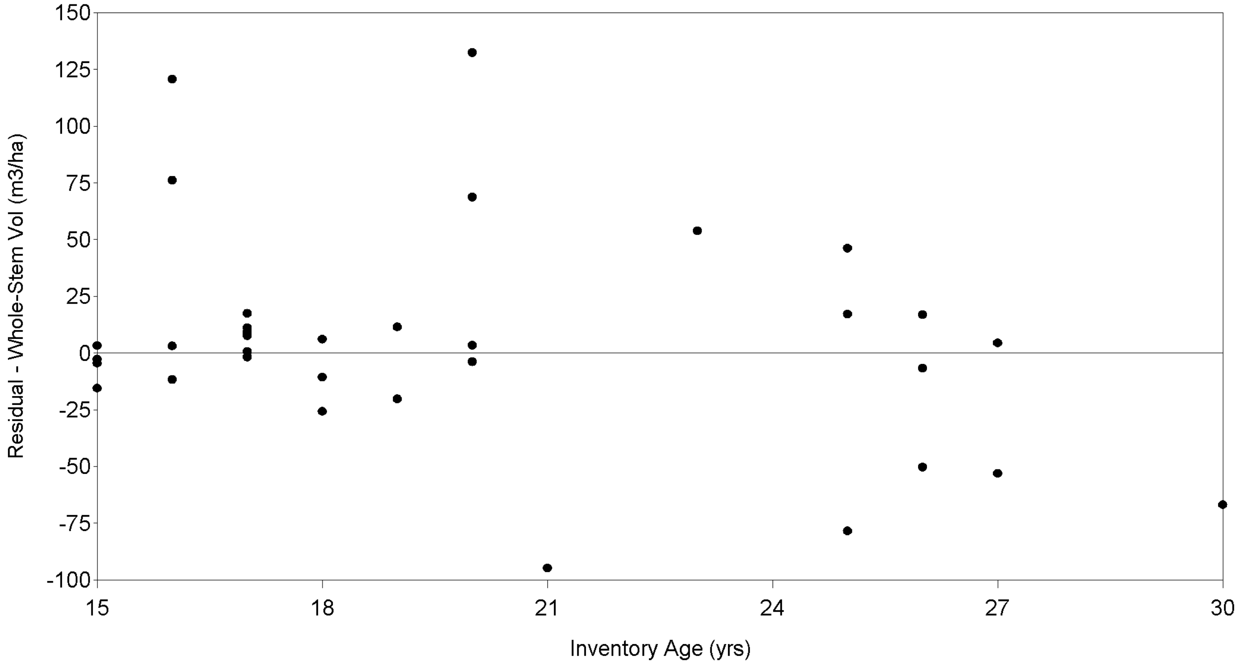

Figure 7. Whole-stem volume residual versus inventory age for the 35 CMI plots.

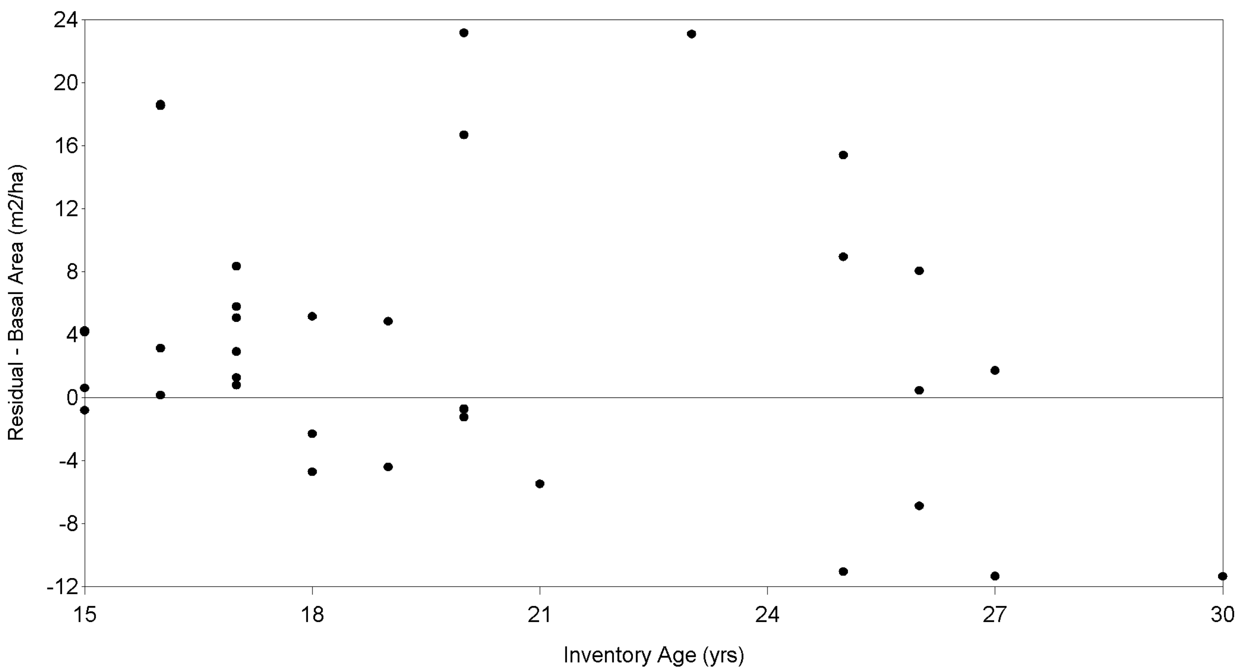

Figure 8. Basal area residual versus inventory age for the 35 CMI plots.

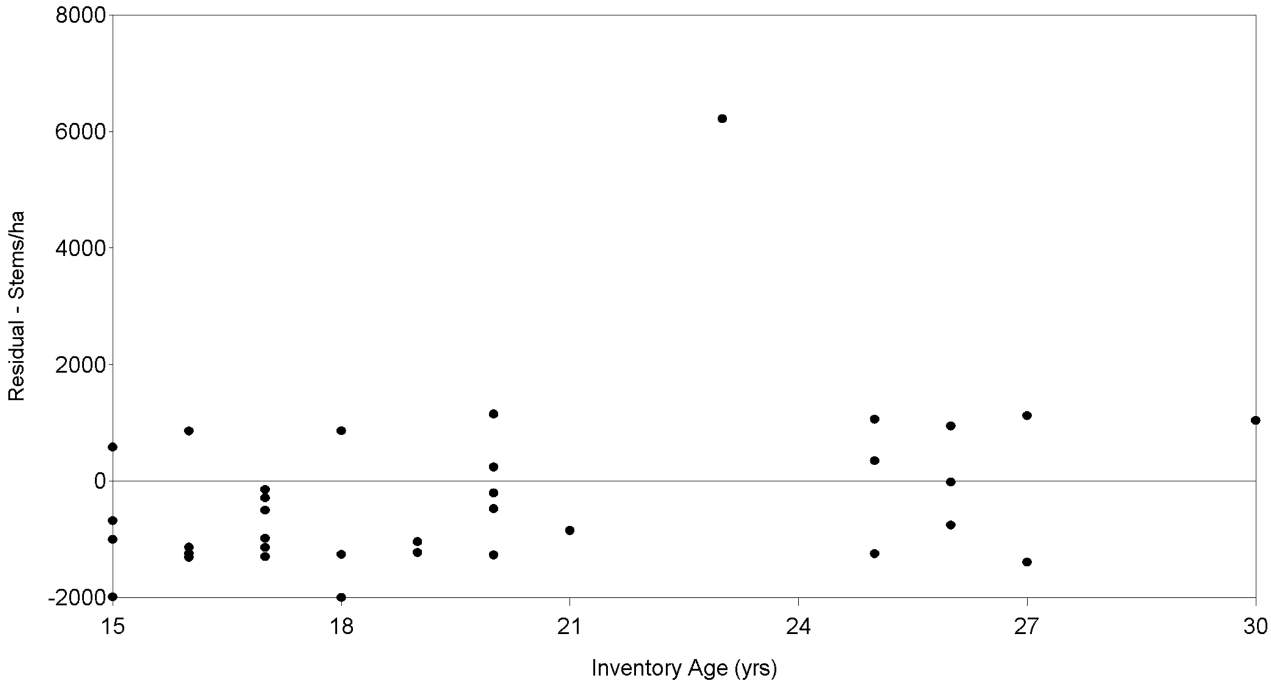

Figure 9. Stems/ha residual versus inventory age for the 35 CMI plots.

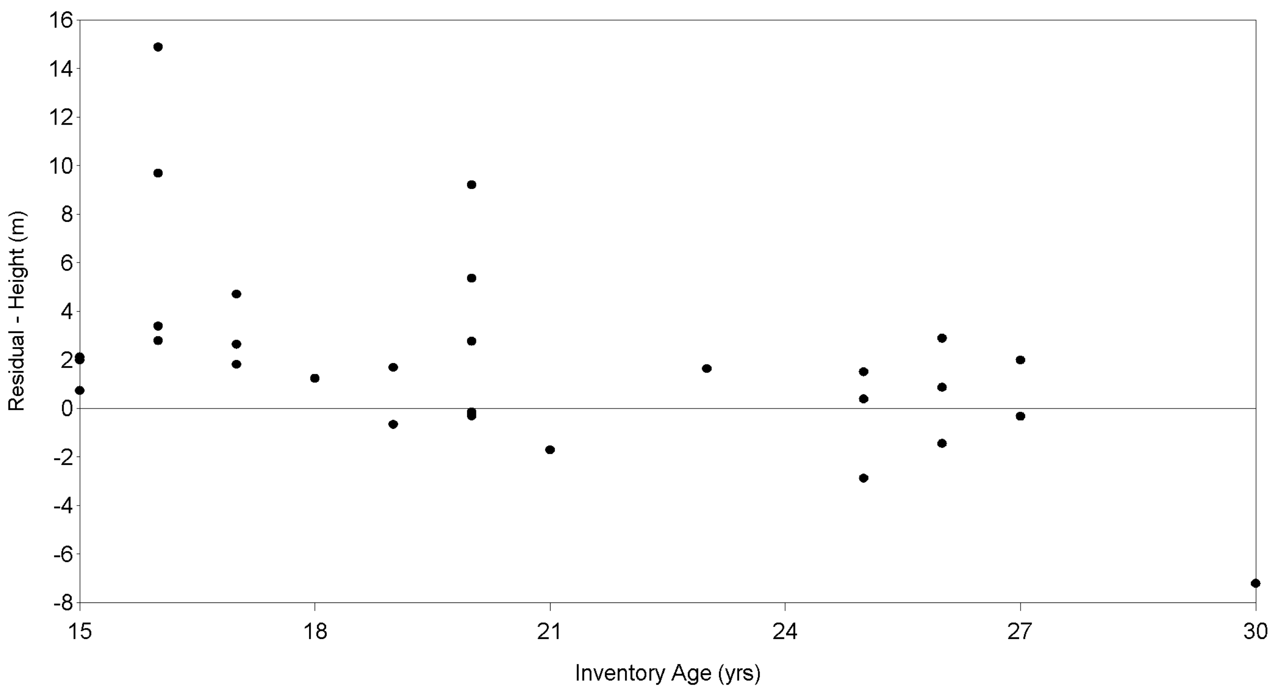

Figure 10. Height residual versus inventory age for the 35 CMI plots.