
TFL 55 Site Index Adjustment

Final Report

Prepared for

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Executive Summary

This Site Index Adjustment (SIA) project provides ground-based estimates of potential site index (PSI) for second growth stands of hybrid spruce (Sx) and interior Douglas-fir (Fd) in the Interior Cedar Hemlock (ICH) and lower Engelmann Spruce Sub-alpine Fir (ESSF) biogeoclimatic zones on Tree Farm Licence (TFL) 55. The statistical adjustment method used in this project is similar to that used in the Vegetation Resources Inventory (VRI) where preliminary estimates are adjusted based on the results of ground sampling. Preliminary PSI estimates were developed using expert knowledge of productivity trends on the TFL and were assigned to each resultant polygon of the forest cover and Predictive Ecosystem Map (PEM) coverages. Eighty-three (83) plot clusters were installed in the ICHvk1, ICHwk1, and the ESSFvc below 1,500 m to provide ground-based estimates of PSI for each of the sample eco-polygons. Finally, a ratio adjustment was applied to the preliminary PSI estimates to reduce potential bias. The results of the statistical adjustment show that the area-weighted adjusted PSI for Sx is 23.1 m and Fd is 23.4 m.

From the results of this project, we recommend that Louisiana Pacific Canada Ltd.:

1. Use the PSI estimates to build managed stand yield tables to support the timber supply analysis for Management Plan 4.
2. Establish a growth & yield monitoring program on the TFL. A monitoring program will provide a broad-level check of growth & yield attributes used in Management Plan 4, identify potential problems with growth & yield model predictions, and help develop more accurate managed stand yield tables for use in subsequent timber supply analyses.
3. Use Ministry of Forests and Range site index conversion equations to estimate the site indexes of other species. Where possible, use Sx as the reference species. If conversion equations do not exist for all species, Site Index Biogeoclimatic Ecosystem Classification (SIBEC) estimates will more closely represent actual growth than the inventory site indexes.

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1. INTRODUCTION

1.1 BACKGROUND

Growth & yield practitioners in BC generally accept that site indexes estimated from old-growth stands underestimate the growth of post harvest regenerated (PHR) stands regenerating on the same sites. This trend has been repeatedly confirmed in projects completed by government and forest licensees throughout BC.^{1,2,3,4} Old-growth site indexes represent conditions of the current stand and reflect historical events (suppression, height growth damage, partial cutting regimes) rather than the potential site productivity. Thus, when old-growth site indexes are applied to future PHR stands in timber supply modeling, the growth & yield of these stands are generally underestimated. In the last timber supply review for Louisiana Pacific Canada Ltd.'s (LP) Tree Farm Licence (TFL) 55, the Chief Forester acknowledged this underestimate of site index:⁵

“ The inventory audit suggests that site indices for immature stands were underestimated in the inventory. While I note the licensee staff have conducted a preliminary review of the data, I encourage them [LP] to continue to refine the site productivity data for young stands on the TFL over the term of this determination. Any additional data can be used for the next timber supply analysis for TFL 55.”

1.2 PROBLEM STATEMENT

The Ministry of Forests and Range (MOFR) has reduced the allowable annual cut (AAC) on TFL 55 by 10% since 1992. A further decrease of 50% is forecasted over the next 25 years. LP believes that this reduced long-term harvest level is lower than the potential that can be supported by the landbase. LP thus initiated this Site Index Adjustment (SIA) project to improve the estimated growth & yield of PHR stands on the TFL.

1.3 OBJECTIVES

The objective of this project was to:

Develop reliable estimates of potential site index (PSI) for second growth stands of spruce (Sx) and Douglas-fir (Fd) in the Interior Cedar Hemlock (ICH) and lower Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic zones on TFL 55.

LP intends to use the PSI estimates to build managed stand yield tables to support the proposed area-based timber supply analysis for Management Plan (MP) 4.

¹ We have completed Site Index Adjustment projects for TFLs 5, 6, 8, 15, 18, 30, 33, 35, 37, 38, 45, 46, 47, 52, 53, 54, the Merritt, Adams Lake, Hope, and Okanagan IFPA areas, and the Fraser TSA.

² Nussbaum, A.F. 1998. Site index adjustments for old-growth stands based on paired plots. Working paper 37. Ministry of Forests Research Program. Victoria, BC. 21 pp.

³ Ministry of Forests. 1997. Site index estimates by site series for coniferous tree species in British Columbia. Site Productivity Working Group, B.C. Min. For. and Forest Renewal BC. 265 pp.

⁴ Second approximation MOF SIBEC estimates are approved for timber supply analysis:
www.for.gov.bc.ca/hre/sibec/index.htm

⁵ Ministry of Forests. 2001. Tree Farm Licence 55. Rationale for allowable annual cut (AAC) determination. B.C. Min. For. Victoria, BC. Effective April 18, 2001. 56 pp.

1.4 PROJECT TEAM

This project was completed, following methods outlined in the MOFR-approved sample plan,⁶ by J.S. Thrower and Associates Ltd. (JST) for Mike Copperthwaite, *RPF* and Fernando Cocciolo, *RPF* of LP. The JST team was Dan Turner, *RPF* (project manager), Guillaume Thérien, *PhD* (senior biometrician), Scott MacKinnon, *FIT* (crew leader), and Tara McCormick, *BSc* (technical support). This report will be submitted to the MOFR Forest Analysis & Inventory Branch for review and approval of results in the upcoming timber supply analysis.



Figure 1. Crew leader Scott MacKinnon measuring the height of a sample tree in plot cluster Fd-1 (DBH=10.8 cm, Height=7.7 m, Age=9 years, and SI=33 m).

⁶ J.S. Thrower & Associates Ltd. 2005. Site index adjustment for Tree Farm Licence 55. Sample plan. Contract report for Louisiana Pacific Canada Ltd. Malakwa, BC. June 30, 2005. 13 pp.

2. METHODS

2.1 SIA PROCESS

This SIA project was completed in three major steps:

1. **Preliminary PSI Estimates** – were developed for Sx and Fd for the forested ecosystems delineated in the Predictive Ecosystem Mapping (PEM) on TFL 55.⁷
2. **Site Index Sampling** – was completed to measure actual site index in PHR Sx and Fd stands at random locations across the operable landbase.
3. **Statistical Adjustment** – the preliminary PSI estimates were statistically adjusted based on the relationship between the predicted and ground-based site indexes.

2.2 TARGET AND SAMPLE POPULATIONS

The target population is the area where the statistical adjustment will be applied based on the results of field sampling. The target population is 19,672 ha (approximately 79% of the operable TFL area, Table 1) and included all areas in the operable productive forest in the ICH and areas below 1,500 m in the ESSFvc.⁸ Sx and Fd were the target species as they are the most important management species on the TFL.⁹

The sample population is a subset of the target population where stand conditions were suitable for estimating the site index of Sx and Fd from height and breast height (BH) age measurements. The sample population was 3,460 ha (18% of the target population) and included Sx-leading polygons between 14-40 years in the ICH and 16-40 years in the ESSFvc, and Fd-leading polygons between 11-40 years of age.¹⁰

Table 1. Area distribution of the target and sample (shaded) populations by leading species and age class.

Ldg Spp	Age Class										Total Area	
	1a*	1b*	2	3	4	5	6	7	8	9	ha	%
Sx	1,509	1,616	1,409	56	153	103	191	112	1,619	2,129	8,897	45
Cw	315		71	0	2	8	32	8	614	2,909	3,961	20
H	197		69	23	14	156	185	255	1,264	1,925	4,089	21
Fd	117	246	189	0	71	68	488	144	138	32	1,493	8
NSR	687										687	3
Decid	99		52	30	18	22	14	28	37		300	2
Bl	19		3	0	1	20	7	4	182	0	235	1
Pl	8						1				9	0
Total	3,187	1,626	1,793	110	260	378	917	551	3,855	6,996	19,672	
%	16	8	9	1	1	2	5	3	20	36		

*Age class 1 was divided into areas too young to sample (1a) and areas old enough to sample (1b).

⁷ Timberline Forest Inventory Consultants Ltd. 2005. Predictive ecosystem Mapping of Tree Farm Licence 55 – Final Report. Contract report for Louisiana Pacific Canada Ltd. Malakwa, BC. November 2005. 21pp.

⁸ The sample plan reported slightly different areas for the target and sample populations (19,821 ha and 3,546 ha, respectively) than given in this report. These area differences resulted from the exclusion of 149 ha in the final analysis, due to missing PEM information.

⁹ Sx-leading silviculture regimes have been the most dominant over the past 20 years, and Fd-leading regimes have become more important in the recent past (pers. comm., Michael Copperthwaite, RPF and Fernando Cocciolo, RPF of LP).

¹⁰ The intent was to sample Sx- and Fd-leading managed stands that were a minimum of 10 and 5 years of age at BH, respectively.

2.3 SAMPLE SIZE & SELECTION

The sample population was divided into two lists based on leading species. The lists were sorted by elevation, and samples were selected using a random start, with probability proportional to area, and with replacement. Sixty (60) Sx-leading sample polygons were systematically selected from the Sx sample population. Once selected, the Sx sample polygon list was randomized. The first 40 plots made up the sample (batch 1), and two additional batches of 10 plots were available, if required. The first 50 Sx samples were completed (first two batches).¹¹

Fifty-six (56) Fd samples were selected. Only 28 Fd-leading polygons were available for sampling. Two plot locations were selected in each of these polygons. The first batch, which included the first plot location per polygon, was completed. The second set of plot locations was randomized, and the first 12 samples were established, for a total of 40 established samples.

Sample plots were randomly located in each of the 116 selected polygons using a 5 m grid in our Geographic Information System (GIS).

2.4 PRELIMINARY PSI ESTIMATES

Preliminary estimates were developed by Tara McCormick and Guillaume Thérien to reflect the potential productivity, expressed as site index, of managed stands growing on TFL 55 (Table 2). Preliminary PSIs were based on SIBEC estimates but were modified to reflect the local conditions on TFL 55 and the expected trends in productivity among site series. Dennis Lloyd, *RPF* (Research Ecologist, MOFR, Southern Interior Forest Region) reviewed the preliminary estimates, and his suggestions were incorporated. The impacts of elevation and aspect on site index were also incorporated into the preliminary PSI estimates (Appendix II).

Table 2. Preliminary PSI estimates by subzone, site series, and species.

Site Series	Sx			Fd	
	ESSFvc	ICHvk1	ICHwk1	ICHvk1	ICHwk1
01	21.0	26.0	26.0	27.0	27.0
02	14.0	17.0	17.0	18.0	18.0
03	18.0	21.0	22.0	22.5	24.0
04	23.0	24.0	23.0	26.0	24.0
05	17.0	23.0	28.0	21.0	29.0
06	12.0	19.0	23.0	15.0	21.0
07		22.5	25.0	17.0	27.0
08		22.5	20.0	15.0	15.0
09		12.0	12.0	10.0	10.0
TP		18.0		15.0	

2.5 RANDOM SAMPLING

Field sampling was completed between July 6 and August 10, 2005 by JST field crews, following methods described in the MOF-approved sample plan (Figure 2).¹² Each sample was a cluster of five 100 m² (5.64 m radius) plots. Site tree selection followed MOF SIBEC standards,^{13,14} thus suitable site trees included the largest diameter, dominant or co-dominant Sx or Fd tree in each quadrant, that was live, standing, and without damage or suppression affecting more than 5% of height growth. Site trees could not be veterans or residuals from a previous stand.

¹¹ The first batch was completed under budget, hence we completed the second batch with the remaining funds.

¹² J.S. Thrower & Associates Ltd. 2005. Site Index Adjustment for Tree Farm Licence 55: Sample Plan. Contract report for Louisiana Pacific Canada Ltd., Malakwa, BC. June 30, 2005. 13 pp.

¹³ The minimum SIBEC age criteria of 10 years at BH was modified to 5 years BH for this project.

¹⁴ Province of British Columbia. 2000. SIBEC Sampling and Data Standards version 5.1. BC Ministry of Forests Site Productivity Working Group. Victoria, BC. <http://www.for.gov.bc.ca/hre/sibec/documents/standards.pdf>

2.6 QUALITY ASSURANCE

Quality assurance (QA) of the field measurements was completed by JST staff to ensure appropriate standards were achieved. Dan Turner, *RPF* completed a random audit of three plot clusters on July 12, 2005 at the end of the first 10-day shift. Bob Cavlek, *FIT* and Tysen LeBlanc, *BNRSc* completed another random audit of five plot clusters on July 27-29, 2005. Both audits showed that plot location, site tree selection, height measurements, and age measurements met all specified standards (Appendix III).

2.7 ANALYSIS

Preliminary estimates of Sx and Fd PSI were statistically adjusted to reduce potential bias in the predicted estimates. The adjustment ratio was computed using the average field PSI and preliminary PSI estimates of each cluster. Separate ratios were computed for Sx and Fd. The ratios were then applied to the eco-polygon based preliminary Sx and Fd PSI estimates to compute the adjusted PSI estimates for the target population.



Figure 2. Crew assistant Shawn Corrigan measuring the DBH of a sample tree in plot cluster Fd-1 (DBH=10.8 cm, Height=7.7 m, Age=9 years, and SI=33 m).

3. RESULTS

3.1 PRELIMINARY PSIs

Application of the preliminary PSIs to the target population resulted in an overall average of 22.4 m for Sx and 23.4 m for Fd (Table 3). Subzone-level PSIs were slightly higher in the ICHwk1 than the ICHvk1 due to the application of the elevation model. Predicted site index ranged from a minimum of 9 m to a maximum of 30 m for both species.

Table 3. Preliminary PSI statistics for the TFL 55 target population.

Subzone	Area ^a		Sx PSI (m)				Fd PSI (m)				Elevation (m)			
	(ha)	%	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
ICHvk1	14,790	78	22.8	11.5	27.0	2.1	23.3	8.5	28.0	2.8	1,088	588	1,450	77
ICHwk1	1,666	9	23.7	12.0	29.0	4.1	24.0	10.0	30.0	5.1	742	580	1,099	45
ESSFvc	2,408	13	18.8	9.2	23.9	1.7	-	-	-	-	1,454	1,280	1,500	13
<i>Total</i>	<i>18,864</i>		<i>22.4</i>	<i>9.2</i>	<i>29.0</i>	<i>2.7</i>	<i>23.4</i>	<i>8.5</i>	<i>30.0</i>	<i>3.1</i>	<i>1,104</i>	<i>580</i>	<i>1,500</i>	<i>96</i>

^a PSI estimates are only applied to forested site series within the target population.

3.2 FIELD PSI

Sx Samples

One hundred and ten (110) Sx trees were sampled in 60 plot clusters. Forty-seven (47) of the plot clusters were Sx-leading and 13 were Fd-leading. Three (3) of the 50 Sx-leading samples were rejected due to unsuitability for site index sampling (Appendix IV).

Sx was sampled with an average of 1.8 trees/cluster (Table 4).

The field site index of Sx ranged from 12.1 to 29.5 m, with an average of 23.3 m (Table 5). Site index was sampled over a range of 640 to 1,500 m in elevation. The average age of Sx sample trees was 14 years at BH. Twenty-two (22) percent of the Sx clusters were <10 years old at BH (Table 6); however, the average field site index of clusters <10 years was very similar to that of clusters ≥10 years old at BH (23.5 and 23.3 m, respectively).

Table 4. Number of trees per cluster.

No. Trees Per Cluster	No. Clusters			
	Sx	%	Fd	%
1	28	47	20	61
2	19	32	8	24
3	9	15	5	15
4	3	5	0	0
5	1	2	0	0

Table 5. Field sample statistics (n = number of sample clusters and SD = standard deviation).

Spp	Subzone	n	Site Index (m)				Elevation (m)				BH Age (yrs)			
			Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Sx	ICHvk1	49	23.5	17.1	29.5	2.6	1,145	701	1,393	187	13	5	22	4
	ICHwk1	4	22.6	12.1	28.9	7.4	796	640	1,054	191	23	7	60	25
	ESSFvc	7	22.2	19.5	26.3	2.2	1,464	1,434	1,500	32	12	8	18	3
	<i>Total</i>	<i>60</i>	<i>23.3</i>	<i>12.1</i>	<i>29.5</i>	<i>3.0</i>	<i>1,159</i>	<i>640</i>	<i>1,500</i>	<i>225</i>	<i>14</i>	<i>5</i>	<i>60</i>	<i>7</i>
Fd	ICHvk1	24	26.6	15.4	38.0	5.2	909	701	1,111	131	15	8	67	11
	ICHwk1	9	23.0	14.2	30.8	6.5	744	657	979	113	24	8	66	24
	<i>Total</i>	<i>33</i>	<i>25.7</i>	<i>14.2</i>	<i>38.0</i>	<i>5.7</i>	<i>864</i>	<i>657</i>	<i>1,111</i>	<i>145</i>	<i>18</i>	<i>8</i>	<i>67</i>	<i>16</i>

Fd Samples

Fifty-one (51) Fd trees were sampled in 33 plot clusters. Thirty-two (32) of the plot clusters were Fd-leading and one was Sx-leading. The remaining eight assessed Fd clusters did not provide Fd observations: four clusters only contained Sx site trees, and four were rejected due to unsuitability for site index sampling (Appendix IV).

Fd was sampled with an average of 1.5 trees/cluster (Table 4).

The field site index of Fd ranged from 14.2 to 38.0 m, with an average of 25.7 m (Table 5). Site index was sampled over a range of 657 to 1,111 m in elevation. The average age of sample trees was 18 years at BH. Eighty-five (85) percent of Fd clusters had ≥ 10 years of height growth over BH (Table 6); however, the 15% of clusters younger than 10 years at BH had a considerably higher average field site index than the clusters ≥ 10 years (30.6 and 24.8 m, respectively).

Table 6. Number of clusters with average BH age < 10 years.

Avg. BH Age of Cluster	No. Clusters			
	Sx	%	Fd	%
5	1	2	0	0
6	0	0	0	0
7	1	2	0	0
8	5	8	4	12
9	6	10	1	3
≥ 10	47	78	28	85

3.3 COMPARISON OF TARGET POPULATION AND SAMPLE

The Sx sample well represents the area distributions of the target population by subzone, elevation class, and BEC site series (Figure 3, Figure 4). As expected, the Fd sample is more concentrated in lower elevation areas of the target population where it is planted and where the Fd PSI estimates will be applied in timber supply modeling. Fd is rarely planted over 1,200 m elevation.¹⁵ The Fd sample was also more concentrated in the submesic site series of the ICHvk1 rather than the zonal site when compared to the target population.

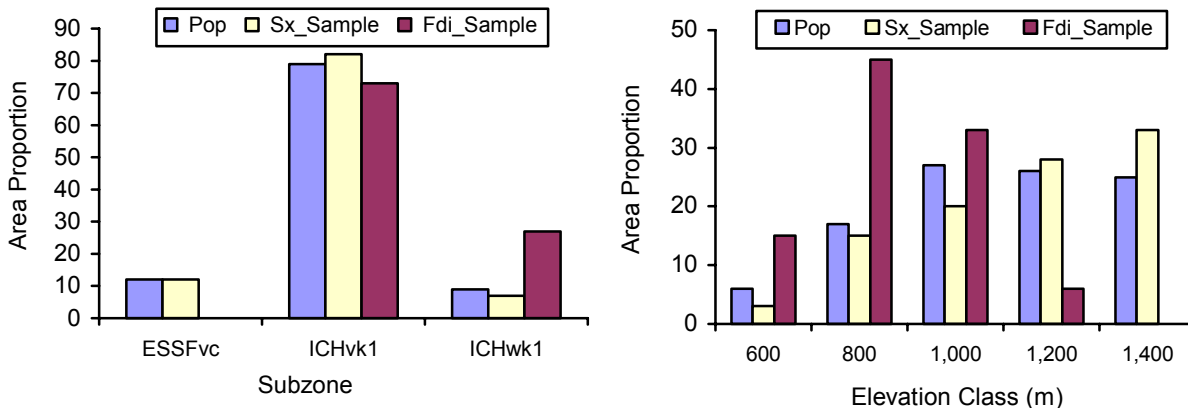


Figure 3. Area distribution of target population and realized Sx and Fd samples by subzone and elevation class.

¹⁵ Pers. Comm. December 2005. Michael Copperthwaite, RPF and Fernando Cocciolo, RPF. LP. Malakwa, BC.

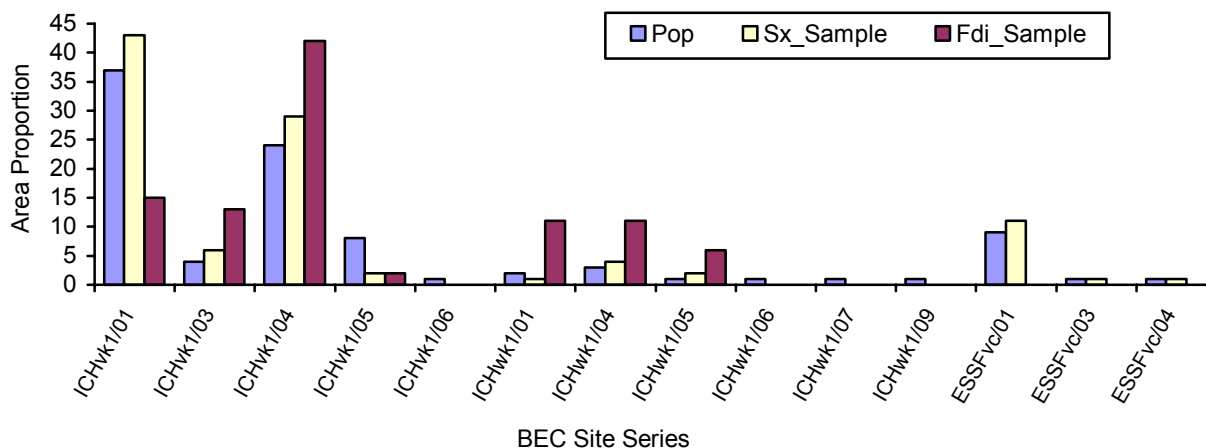


Figure 4. Area distribution of target population and realized sample by BEC site series.

3.4 Sx STATISTICAL ADJUSTMENT

The ratio of means (ROM) adjustment equation showed that the preliminary Sx PSI under-predicted the average field PSI by 3%. The area-weighted mean preliminary PSI of the target population increased from 22.4 m to 23.1 m. The ranges in predicted and field PSI of the sample were similar, 17.5 to 25 m and 17.0 to 29.5 m, respectively. The sampling error of the average adjusted population was ±0.8 m at the 95% confidence level (Table 7, Figure 5), thus much lower the target of ±1.5 m.

Table 7. Sx and Fd adjustment statistics.

	Sx	Fd
No. of plot clusters	60	33
Sample mean prelim PSI (m)	22.6	25.6
Sample mean field PSI (m)	23.3	25.7
ROM	1.030	1.001
R-squared	3.1	19.6
% Sampling Error of ROM	3.5	7.3
Population prelim PSI (m)	22.4	23.4
Population adjusted PSI (m)	23.1	23.4
95% Sampling Error (m)	0.8	1.7
95% Confidence Interval (m)	[22.3][23.9]	[21.7][25.1]

3.5 Fd STATISTICAL ADJUSTMENT

The overall average predicted and field PSIs of the Fd sample were virtually the same: the ROM was 1.001. Therefore, field sampling did not result in an adjustment of the preliminary Fd estimates and the area-weighted mean PSI remained at 23.4 m. Predicted PSI estimates of the sample ranged from 22 to 28 m; whereas the field site index ranged from 14 to 30 m. The sampling error of the mean was ±1.7 m at the 95% confidence level, resulting in a slightly higher sampling error than the targeted ±1.5 m (Table 7, Figure 5).

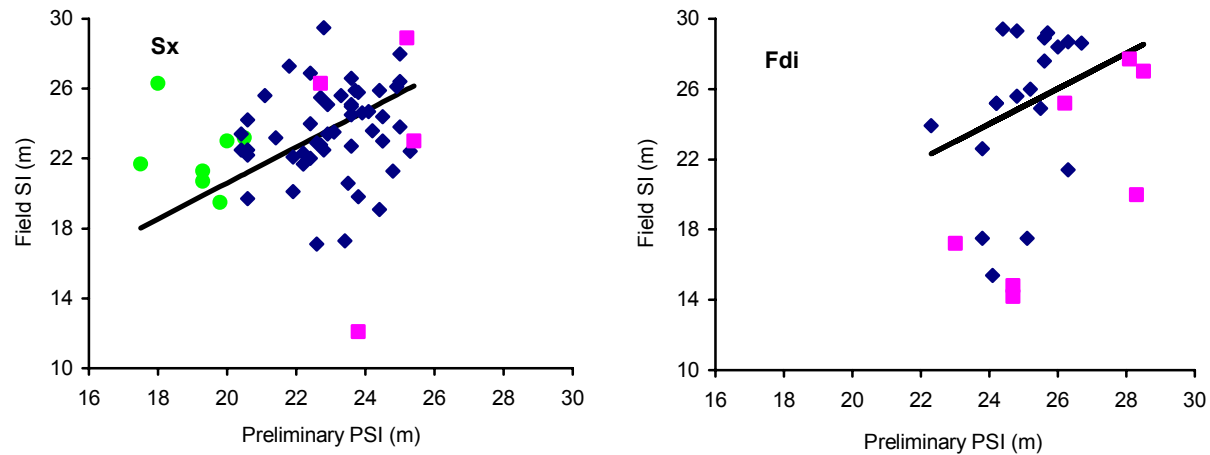


Figure 5. Relationship between average field and preliminary PSI for the Sx and Fd samples (ICHvk1-blue diamond; ICHwk1-pink square; ESSFvk-green circle). The thick black line shows the average PSI for a polygon of a given preliminary SI.

3.6 APPLICATION OF RESULTS

Area-weighted average adjusted PSI estimates can be calculated for the forest cover polygons in the target population based on their component PEM eco-polygons. LP should use the forest cover polygon level PSI estimates for existing and future managed stands in the yield table process.

4. DISCUSSION

4.1 VARIATION BETWEEN PRELIMINARY & FIELD SI

There is variation in the relationship between preliminary and field PSI of Sx and Fd (Figure 5). There are four sources contributing to the variation: within-polygon variation, within site-series variation, model error, and mapping error. The bias from these sources is removed in the SIA process, but the variation is included in the overall sampling error of the adjustment.

a) Within-polygon variation in PSI

The PSI of trees and groups of trees varies among areas within polygons. The within-polygon variation in PSI is probably the most important source of variation contributing to the overall sampling error of the adjustment ratio. Field PSI estimates of Sx and Fd were based on an average of 1.8 and 1.5 trees/cluster, respectively. Estimates were based on a single tree in about 50% of the Sx clusters and 60% of the Fd clusters. This increased the variability of the cluster-level PSI estimates as there is a greater likelihood that the estimated field PSIs reflected individual micro-sites rather than average plot productivity. Using a smaller number of trees in the average field PSI estimate for a plot increases the measurement error at the plot level. This variation in the measurement error is only one component of the unexplained variation.

We investigated the impact of including non-standard site trees in the analysis. These additional trees (“O trees”) were sampled in subplots where the largest diameter site tree was not suitable, and met all SIBEC site tree selection criteria with the exception of being the largest diameter. The number of Sx trees increased by about 50% over the standard analysis and the number of Fd trees nearly doubled (Table 8). Inclusion of non-standard trees resulted in similar ROM adjustment ratios (1.028 for Sx and 0.989 for Fd); however, the sampling error for Fd decreased to ± 1.5 m. The sampling error for Sx remained constant.

Table 8. Number of trees, including non-standard trees, per cluster.

No. Trees	No. Clusters			
	Sx		Fd	
	Standard	Non-Standard	Standard	Non-Standard
Per Cluster				
1	16	16	7	7
2	13	26	7	14
3	13	39	8	24
4	11	44	7	28
5	7	35	4	20
All	60	160	33	93

b) Within site-series variation

The preliminary PSI estimates are developed to reflect the average PSI for each site series. However, site productivity within a site series varies in response to differences in moisture and nutrient availability, as depicted by the edatopic range of the site series. For example, in TFL 55, the observed range of Sx field PSIs on a given site series was between 7 and 10 m.¹⁶ The observed range of Fd field PSI on a given site series was even larger, between 13 to 15 m (Table 9). This variation accounts for some of the differences between predicted and field PSI estimates.

¹⁶ Site series presented in the Table 9 are based on the field classification of clusters. Only clusters located in pure site series were included in the summary. Only site series with >3 clusters were presented.

Table 9. Range of field PSI by field site series.

Field Site Series	Sx Field Site Index (m)						Fd Field Site Index (m)					
	n	Avg	Min	Max	Diff	SD	n	Avg	Min	Max	Diff	SD
ICHvk1/01	24	24.4	19.7	29.5	9.8	2.6	11	28.9	22.6	38.0	15.4	4.3
ICHvk1/04	9	24.3	22.0	29.5	7.5	2.4	6	25.4	17.5	32.0	14.5	5.6
ICHwk1/04							4	20.3	14.2	27.0	12.8	6.7
ESSFvc/01	8	22.2	19.5	26.3	6.8	2.2						

c) Model Error

Model error is the bias in the preliminary PSI estimates at the site series level. The assumption is that the bias is consistent across subzone and site series; hence, one adjustment equation per species is applied throughout the target population. There is a possibility of localized bias where the adjustment is not the same across all areas, but the sample was not large enough for post-stratification of the results. We believe that the potential differences would be small as the preliminary estimates were reasonable between subzones and site series. The overall bias from the model error is removed in the SIA, but the variation of the site-series level bias is included in the overall variation of the adjustment.

Another source of variation due to model error resulted from the possible bias in the Fd growth intercept equation for trees younger than 10 years at BH, as seen in the higher average field PSI in this group compared to trees over 10 years (section 3.2).

d) Mapping Error

Preliminary estimates are applied to the landbase using the site series and aspect modifiers delineated in the PEM and the elevation from TRIM. Mapped attributes for any point or polygon will not perfectly reflect actual conditions on the ground; subsequently, the predicted PSI will also not reflect exactly what is on the ground. This source of variation is included in the overall sampling error for the adjustment, and potential bias from mapping error is removed in the SIA through the statistical adjustment process.

The mapping error is exaggerated on this landbase due to the resolution of some of the mapped units. There was no xeric forested unit typed in the PEM project; consequently, these poorer productivity sites were included in the subxeric mapped unit (the ICHvk1/03 and ICHwk1/04 units). There is a considerable difference in productivity between the two distinct units; thus, lumping them into one unit will add to the observed variation. The effect of this can be observed in the scattergram, where the bias in predicted PSI is larger on clusters where field site index is low (Figure 5).

A third mapping error results from the site series composition is aspatial in the PEM eco-polygon. Ninety-two (92) percent of the eco-polygons in the target population (18,169 ha) are mapped as complex site series in the PEM database. In these eco-polygons, the preliminary PSI estimate is a weighted average of the constituent site series. When a plot is established in one of these polygons, the site series proportions within the 500 m² plot may differ from the site series proportions for the entire eco-polygon. In this sample, 96% plots were located in polygons mapped with complex site series based on the PEM; however, only 25% of the plots were classified as complexes based on the field site series (*i.e.*, 75% of plots were in areas of pure site series within the sampled polygons). Differences in site series distributions within individual polygons will also introduce variation into the relationship between the field measurements and the preliminary PSI estimate.

4.2 COMPARISON OF ADJUSTED PSI & INVENTORY SITE INDEX

The overall average adjusted PSI estimate is 4.2 m (about 22%) higher than indicated in the inventory for both Sx and Fd-leading stands in the target population (Table 10). The upward shift in PSI estimates does not indicate a change in the productivity of the landbase, but rather reflects the bias in the inventory site index. The magnitude of increase over inventory site index, averages by subzone, and the overall average seem reasonable for this landbase and are similar to other SIA projects completed in the BC Interior (Table 11).¹⁷

Table 10. Comparison of inventory and adjusted site index.

Ldg Spp	Subzone	Area (ha)	Site Index (m)		Difference (m) (%)	
			Inventory	Adj PSI	(m)	(%)
Sx	ICHvk1	4,702	18.6	23.2	4.6	25%
	ICHwk1	489	20.8	23.0	2.2	10%
	ESSFvc	1,502	15.8	19.4	3.6	23%
	Sx Total	6,692	18.2	22.4	4.2	23%
Fd	ICHvk1	995	20.1	24.1	4.0	20%
	ICHwk1	344	20.2	25.2	5.0	25%
	Fd Total	1,340	20.1	24.4	4.2	21%

Table 11. Average adjusted PSI by subzone by source.

Landbase	ICHwk1		ICHvk1	
	Sx PSI (m)	Fd PSI (m)	Sx PSI (m)	Fd PSI (m)
TFL 55	23.0	25.2	23.2	24.1
TFL 33	24.9	26.0	-	-
Okanagan wet-belt	-	22.8	-	-
SIBEC ^a	24.0	24.0	24.0	24.0

^a estimate for zonal site

4.3 RISKS & UNCERTAINTY FOR TIMBER SUPPLY

The adjusted PSI estimates are unbiased estimates of site productivity, thus represent a significant improvement over the inventory site indexes (for which no accuracy measure exists). The measure of uncertainty around the average PSI is estimated at ± 0.8 m for Sx and ± 1.7 m for Fd. The MOFR raised concerns over Fd sampling during development of the sampling plan.¹⁸ We acknowledge that there is greater uncertainty in the Fd estimates than the Sx estimates due to the smaller sample size and higher sampling error; however, we believe the estimates are reasonable based on the results from the non-standard analysis and comparisons with Fd PSI estimates from adjacent landbases and SIBEC.⁴

The best method to ensure that PSI estimates obtained from the SIA project adequately measure the site productivity on TFL 55 is to undertake a growth & yield monitoring program. In a growth & yield monitoring program, randomly located permanent sample plots are established and re-measured in targeted stands with a known frequency, such as 5 or 10 years. The monitoring program provides an early warning system if the observed site index estimates deviate from the SIA PSI estimates used in the timber supply analysis. The results of this program could be useful to further justify assumptions around minimum harvest age, green-up, and adjacency in the area-based timber supply analysis.

¹⁷ Other PSI increases resulting from SIA projects completed in the BC Interior include: Merritt TSA at 28%, Adams Lake IFPA at 31%, TFL 33 at 29%, TFL 15 at 29%, TFL 8 at 24%, and TFL 18 at 23%.

¹⁸ Pers. Comm. June 2005. Albert Nussbaum, RPF, MoFR – Analysis Section, Victoria, BC.

5. RECOMMENDATIONS

From the results of this project, we recommend that LP:

1. Use the PSI estimates to build managed stand yield tables to support the timber supply analysis for MP 4.
2. Establish a growth & yield monitoring program on the TFL. A monitoring program will provide a broad-level check of growth & yield attributes used in MP 4, identify potential problems with growth & yield model predictions, and help develop more accurate managed stand yield tables for use in subsequent timber supply analyses.
3. Use MOFR site index conversion equations to estimate the site indexes of other species. Where possible, use Sx as the reference species. If conversion equations do not exist for all species, SIBEC estimates will more closely represent actual growth than the inventory site indexes.

APPENDIX I – STUDY AREA

TFL 55 is located approximately 120 km north of Revelstoke, BC. LP manages their TFL operations from Malakwa and the TFL is administered by the Columbia Forest District office in Revelstoke. The gross area of the TFL is approximately 92,200 ha and is characterized by sharp peaks, glaciers, and deep, narrow, forested valleys. The elevation of the TFL ranges from 600 m to 2,000 m primarily at a western aspect overlooking the Revelstoke Reservoir. The TFL receives almost 1,337 mm of annual precipitation.

The target population is 79% of the operable TFL landbase. The target population is comprised of 62% ICHvk1, 10% ESSFvc, and 7% ICHwk1.

Description	Area (ha)	TFL %	Oper %
Entire TFL	92,864	100	
Inoperable	67,857	73	
Operable	25,007	27	100
ESSFwc2/vv/vcp	663	1	3
ESSFvc >1,500 m	4,523	5	18
Missing PEM label	149	0	1
<i>Target Pop</i>	19,672	21	79
ICHvk1	15,485	17	62
ICHwk1	1,749	2	7
ESSFvc ≤1,500 m	2,438	3	10

APPENDIX II – SITE INDEX MODIFIERS

The following site index modifiers were applied to the preliminary PSI estimates (Table 2) to account for the impacts of aspect and elevation on site index:

PEM Modifier	Criteria			SI Modifier
	Spp	Subzone	Elev. (m)	
k (cool)	Both	All	All	Deduct 2.0 m
w (warm)	Both	All	All	Add 1.0 m
NA	Fd	ICHvk1	>900	Deduct 0.009 m for every meter above 900
NA	Fd	ICHwk1	>800	Deduct 0.009 m for every meter above 800
NA	Sx	ESSFvc	>1,300	Deduct 0.007 m for every meter above 1,300
NA	Sx	ICHvk1	>900	Deduct 0.007 m for every meter above 900
NA	Sx	ICHwk1	>800	Deduct 0.007 m for every meter above 800

APPENDIX III – SIBEC SAMPLING STANDARDS

Data Type	Tolerance
Site tree selection	No error
Height to DBH	actual \pm 5cm
DBH	actual \pm 0.1cm or 1%, whichever is greater
Total tree height	actual \pm 20 cm or 2%, whichever is greater
BH age	if age < 50 no error, otherwise 1year
Notes	must have comments where accepting a damaged sample tree

APPENDIX IV – LIST OF REJECTED SAMPLES

Reason for Rejection	Plot No.	Subzone	Site Series	PEM ID (Polygon_ID)	VRI ID (Mapstand)	Inv.SI (m)	Inv.Age (yrs)
<i>Damage causing >5% height loss was noted on all the potential site trees</i>							
	Fd05	ICHvk1	04(9)03(1)	1000095	83D008_2407	25	21
	Fd30	ICHvk1	04(9)03(1)	1000081	83D008_2405	25	21
	Sx50	ICHvk1	01(7)04(2)03(1)	1003586	82M077_2439	22	39
<i>The growth rates of the potential site trees were impacted by an overstory (suppression)</i>							
	Fd07	ICHvk1	04(8)03(2)	1000270	82M098_1003	21	34
	Fd38	ICHvk1	04(8)03(2)	1000270	82M098_1003	21	34
	Sx09	ICHvk1	01(9)04(1)	1003335	82M077_2431	21	31
	Sx31	ESSFvc	01(10)	1001812	82M087_2034	18	24