Terrace Community Forest Site Index Adjustment Project – Final Report

Presented To: **Terrace Community Forest**
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Executive Summary

Ecora Engineering & Resource Group Ltd. (Ecora) prepared this site index adjustment (SIA) project for the Terrace Community Forest (TCF) as part of the data preparation steps for the upcoming Timber Supply Review (TSR). The objective of the SIA was to conduct unbiased field sampling to validate the existing site index values from the Provincial Site Productivity Layer (PSPL) which estimates site index of commercial species across BC through application of SIBEC and SIA data to areas with existing ecosystem maps, and developing gap filling biophysical models.

This SIA project was completed in three (3) steps:

1. Developing a sample plan that was reviewed and approved by a provincial government technical expert;
2. Conducting unbiased sample selection and field data collection for two selected target species: western hemlock (Hw) and Amabilis fir (Ba); and
3. Conducting post-field data analyses and recommending a suitable method for statistical adjustment of site index values in the PSPL.

The field sampling program produced 87 site index observations for the two target tree species of Hw (47 observations) and Ba (40 observations). Average breast height (BH) age of the site index observations was 31 years and 30 years for Hw and Ba, respectively, while the respective average diameters at breast height (DBH) were 24.2 and 24.7 cm.

Comparison of the field sample site index to PSPL site index resulted in an upward adjustment of 11 % for Hw and 0.7 % for Ba. Adjustment equations were developed separately for three geographical areas (Deep Creek, Kitimat, and Shames) since the site index analyses of samples showed the largest variation between the geographical areas and the lowest variability within a given area. The standard error of samples, at 95% confidence level, was achieved within the desired range (±1.5 m) for both target species with Hw (±1.2 m) and Ba (±1.3 m).

The site index estimates in the project are generally considered conservative, mainly due to the exclusion of a significant portion of the productive landbase for sampling, due to prior application of silviculture treatments.

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Acronyms and Abbreviations

AAC	Annual Allowable Cut
BC	British Columbia
BEC	Biogeoclimatic Ecosystem Classification
BGC	Biogeoclimatic units (zone, subzone, variants)
BH	Breast Height
CF	Community Forest
CMAI	Cumulative Mean Annual Increment
FAIB	Forest Analysis and Inventory Branch
LiDAR	Light Detection and Ranging
MD	Mean Difference
MFLNRORD	Ministry of Forests, Land and Natural Resource Operations and Rural Development
QA	Quality Assurance
QC	Quality Control
SIA	Site Index Adjustment
SIBEC	Site Index and Biogeoclimatic Ecosystem Classification
PSPL	BC Provincial Site Productivity Layer
PEM	Predictive Ecosystem Mapping
TEM	Terrestrial Ecosystem Mapping
TCF	Terrace Community Forest
THLB	Timber Harvesting Landbase
TRIM	Terrain Resources Information Management
TSA	Timber Supply Area
TSR	Timber Supply Review
VDYP	Variable Density Yield Projection
VRI	Vegetation Resources Inventory
TIPSY	Table Interpolation Program for Stand Yields

1. Introduction

1.1 Terms of Reference

Ecora Engineering & Resource Group Ltd. (Ecora) prepared this Site Index Adjustment (SIA) report for the Terrace Community Forest (TCF) Corporation. The Ecora team, comprised of forest inventory, analysis and ecosystem experts with many decades of collective expertise throughout BC, includes Shikun Ran, RPF (project and field crew leader), Jay Greenfield, RPF (project manager), Brad Freeman, M.Sc. (GIS Analyst), Madeline Zhang, TFT (field sampling crew member). Terrace Community Forest is funding the completion of this project.

1.2 Background

Site index, a measure of potential site productivity and defined as ‘the average height that free growing, undamaged top height trees of a given species can achieve in 50 years growth above breast height' (https://www.for.gov.bc.ca/hfp/training/00011/lesson02a.htm), is the most important driver in predicting the growth and yield of future stands for timber supply modeling. It is commonly believed that site index estimates from photo-interpreted height and age of Vegetation Resources Inventory (VRI) that are based on older stands under-estimate the site index of managed stands. When these under-estimated site index estimates are applied to future managed stands in timber supply modeling, the future predicted yield and sustainable harvest level can be significantly understated.

The Terrace Community Forest (TCF) is undergoing a timber supply review (TSR) for a new annual allowable cut (AAC) determination. As part of the process, the TCF has invested in several landscape level inventory projects including Vegetation Resources Inventory (VRI) and Terrestrial Ecosystem Mapping (TEM), which together provide valuable information on updated forest and ecosystem distribution, enabling estimates of site productivity and potential. The TCF has acquired LiDAR (light detection and ranging) data for most of the CF areas (Shames and Deep Creek sections), which provides the ability to greatly enhance the modeling and prediction of ground and vegetation attributes. The LiDAR data was used to verify and update tree height estimations for the VRI.

According to the Kalum VRI Strategic Inventory Plan (LM Forest Resource Solution, 2004), site productivity was an identified forest management issue in the Kalum TSA as it relates to VRI (LM Forest Resource Solution, 2004). In the Kalum TSA Timber Supply Analysis Technical Report (MFLNRO, 2010), the Base Case included a site index adjustment for western hemlock (Hw), based on the findings of Nigh and Love (1997). The report also included a sensitivity analysis with site index adjustments on the other tree species, based on Nigh and Love’s (1998) findings, and found that the harvest level over the latter half of the planning horizon increased (FAIB 2010; Figure 1-1).

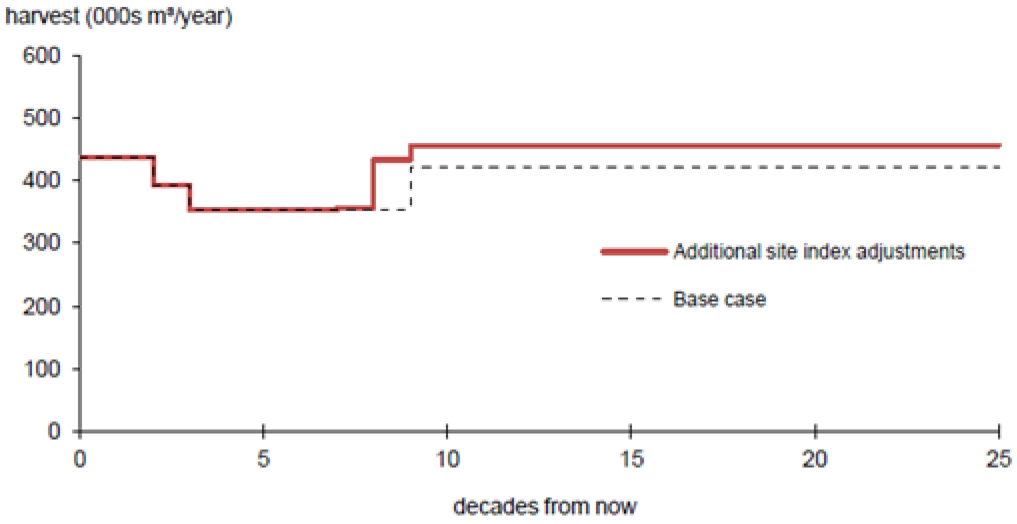


Figure 1-1 **MFLNRO Site Index Adjustment Sensitivity Analysis from the Kalum TSA Timber Supply Analysis**

In British Columbia (BC), data on site index values of a given tree species are obtained through several methods:

- SIBEC (site index and biogeoclimatic ecosystem classification): site trees are measured in a 100m² within an ecologically homogenous site, comprised of a single ecosystem (site series). The sample plots are located through a subjective manner in a sampling population, with a minimum of 7 site trees required for each site unit combination before the results are published.
- SIA (site index adjustment): site trees are measured in a 100m² plot randomly located in a sampling population. The difference between the existing site index (e.g. inventory site index, provincial site productivity layer etc.) and the field-derived site index are calculated and used to generate a statistically valid site index adjustment.
- The BC government has published a 'provincial site productivity layer' (PSPL) based on site index data from SIBEC and SIA projects. The site index values of a given species under a given climate and site are predicted through either a biophysical model (https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr073.htm) or through the SIBEC model. These models incorporate existing TEM, PEM, and other mapping products to obtain site index predictions.

It is commonly believed that site index values from the PSPL, which represents regional generalization, present an improvement over conventional forest inventory site index estimation. However, field observations at operational scale indicate that the PSPL site index values may still underestimate the site productivity of managed stands. Validation of the regional site index values at operational scale is expected to provide valuable insight into site index changes.

1.3 Project Objective

The main objectives of the SIA process were to:

- Develop reliable estimates of site index for managed stands of Western Hemlock (Hw) and Amabilis fir (Ba) in the Terrace Community Forest; and

- Use the improved estimates, with other growth and yield, and silviculture information, to develop managed stand yield tables for use in the ongoing TSR.

1.4 SIA Methods Overview

This project compared existing estimates of site index from the Provincial Site Productivity Layer (PSPL) with measured results from randomly selected ground samples within the managed stands. At each sample point, the difference between the two were compared across the sampling population. The site index differences and bias that are revealed from the data analysis would indicate the necessity for a site index adjustment. Individual adjustments were developed for each of the targeted tree species - western hemlock (Hw) and Amabilis fir (Ba). Other tree species, including Sitka spruce (Ss), western redcedar (Cw) and lodgepole pine (Pl) were also sampled, when presented in the SIBEC plots, but the sample sizes were small.

There are four main components of the Terrace Community Forest SIA project:

1. **Field Sample Plan and Package Development:** to provide specific steps and standards for field sampling. Detailed sample design and sampling procedures were described in the field sample plan (Ecora, 2018).
2. **Field Sampling**: to measure actual site index calculated from height and breast-height age of site trees in suitable stands across the sampling population.
3. **Data Analysis and Site Index Adjustment**: to adjust site index values of the PSPL to improve the site index estimation and remove the prediction bias, and
4. **Reporting and Deliverables**: to document all process and results and discuss the uses and impacts of the adjusted site index values in timber supply analysis (this document).

2. Study Area

2.1 Terrace Community Forest

The Terrace Community Forest (TCF) is situated within the Kalum Timber Supply Area (TSA). The 25,146-ha TCF, comprised of 3 separate blocks or parcels (i.e., Kitimat, Shames, and Deep Creek) within the Kalum Forest District (Figure 2-1). This SIA project requires the Timber Harvesting Landbase (THLB) which will be the target population for site index adjustment.

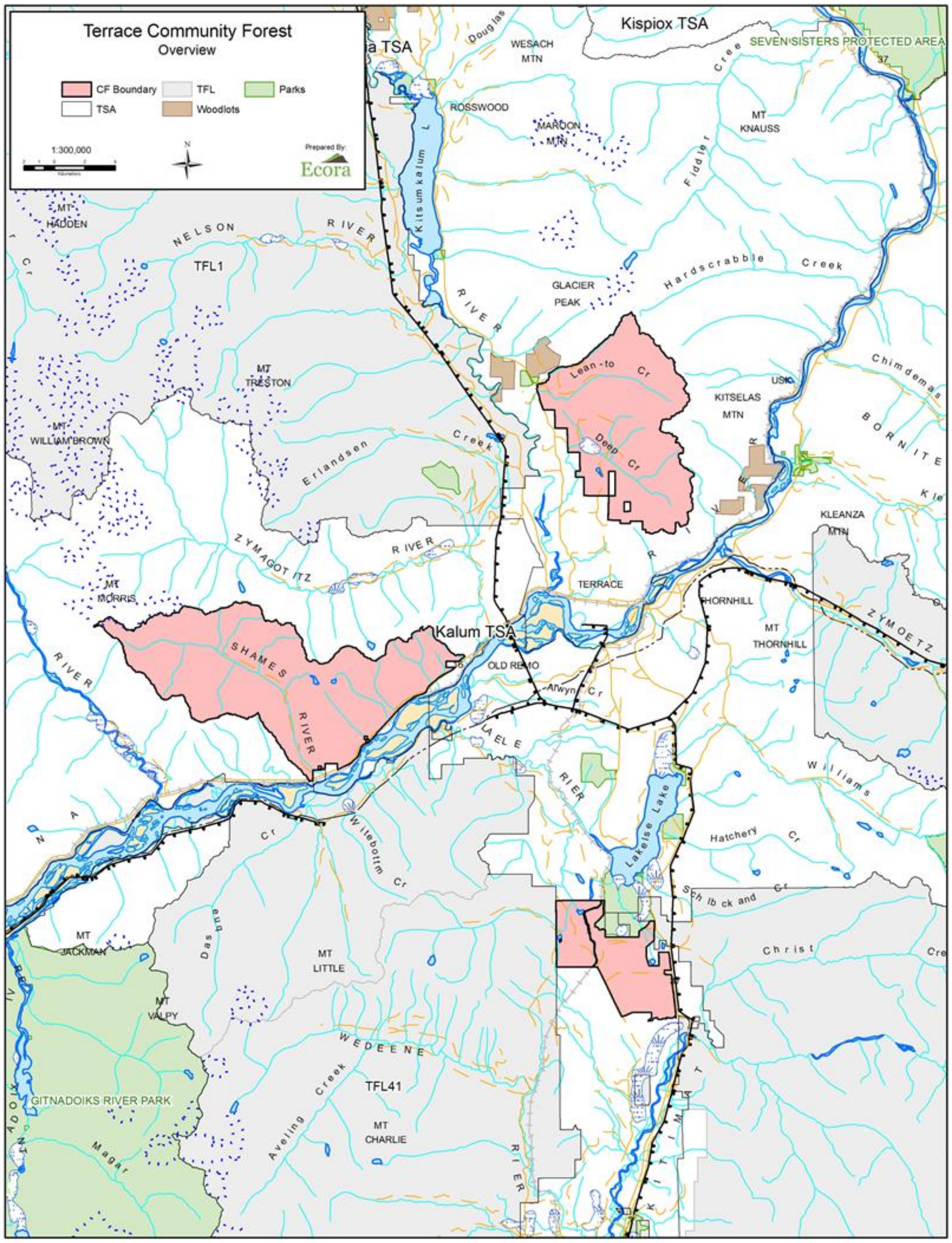


Figure 2-1: Terrace Community Forest Overview

The climate and vegetation within the TCF is broadly described by the provincial biogeoclimatic ecosystem (BEC) classification (Table 2.1). High elevation (parkland and alpine) ecosystems comprise nearly one-quarter (23%) of the total TCF. The majority of the TCF occurs within the coastal western hemlock (CWH) BEC zone. Collectively, the two wet, submaritime variants of the CWH BEC zone (CWHws1 and CWHws2) comprise over 60% and 88%, respectively, of the total TCF landbase and the THLB. The leading tree species and associated area distribution within the TCF are summarized in Table 2.2. The two hemlock species (Hw and Hm) comprise over 80% and 78%, respectively, of the total landbase and THLB, with western hemlock (Hw)-leading stands comprising nearly two-thirds (64%) for both treed landbase and THLB. Other tree species that comprise over 1% of the TCF landbase are Amabilis fir (Ba), Sitka spruce (Ss), and lodgepole pine (Pl). The remaining seven (7) species collectively comprise 2.3% of the TCF.

Table 2.1 Area Distribution (ha) of Biogeoclimatic Units in the TCF

	CWHws1	CWHws2	MHmm2	MHmmp	CMAun	Total
Total Area (ha)	10,685	4,721	4,010	5,021	709	25,146
Total Area PCT (%)	42.5	18.8	15.9	20.0	2.8	100.0

Table 2.2: Area Distribution (ha) of Leading Tree Species in the TCF

	Hw	Hm	Ba	Sx	Pl	At	Dr	Cw	Ep	Ac	Ss	Total
Total Area (ha)	10,331	7,794	1,758	57	372	58	189	65	91	10	357	21,083
Total Area %	49.00	36.97	8.34	0.27	1.77	0.28	0.90	0.31	0.43	0.05	1.70	100.00

2.2 Target Population

The target population for this project was defined as the THLB, comprised of the productive landbase, with net downs for areas deemed inoperable, non-productive or otherwise constrained. The THLB area is 13,460 ha (Table 2.3).

The project focused on development of site index estimates for stands dominated by western hemlock (Hw) or Amabilis fir (Ba), which collectively comprise over 75% of the target population (Table 2-4). When mountain hemlock (Hm) is included, nearly 90% of the THLB tree species are accounted for. Site index estimates for spruce (Ss), western redcedar (Cw) and lodgepole pine (Pl) were also sampled when they occurred within the site index plots.

Table 2.3, 2.4, 2.5 present selected summary statistics of the THLB, including area distributions of BGC units (Table 2-3), leading tree species (Table 2.4). Table 2-5 presents area distributions of target tree species (Hw, Ba) by age class and BGC unit within the THLB.

Tables 2-3 through 2-5 summarize the area and % representation within the THLB by BGC unit, leading tree species, and age class.

Table 2.3 Area Distribution of BGC units Within the THLB

	CWHws1	CWHws2	MHmm2	MHmmp	CMAun	Total
THLB Area (ha)	9,513	2,381	1,224	342	0	13,460
THLB Area PCT (%)	70.7	17.7	9.1	2.5	0	100.0

Table 2.4 Area Distribution of Leading Tree Species within the THLB

	Hw	Hm	Ba	Sx	Pl	At	Dr	Cw	Ep	Ac	Ss	other	Total
THLB Area (ha)	8,659	1,879	1,478	28	351	58	104	62	53	10	375	402	13,460
THLB Area %	64.35	13.96	10.98	0.21	2.61	0.43	0.77	0.46	0.39	0.07	2.79	2.99	100

Table 2.5 Area Distribution of Age Class by BGC Units within the THLB

		Age Class									
BGC Unit		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
CWHws1	Hw (ha)	305	2,441	2,551	103	258	271	142	509	715	7,295
	Hw (%)	4.2	33.5	35.0	1.4	3.5	3.7	1.9	7.0	9.8	100
	Ba (ha)	120	247	426	13	5	5	0	7	30	853
	Ba (%)	14.1	29.0	49.9	1.5	0.6	0.6	0.0	0.8	3.5	100
CWHws2	Hw (ha)	3	335	91	31	2	5	1	162	621	1,251
	Hw (%)	0.2	26.8	7.3	2.5	0.2	0.4	0.1	12.9	49.6	100
	Ba (ha)	17	235	44	17	0	0	0	13	138	464
	Ba (%)	3.7	50.6	9.5	3.7	0.0	0.0	0.0	2.8	29.7	100
MHmm2	Hw (ha)	0	21	0	7	1	3	9	35	38	114
	Hw (%)	0.0	18.4	0.0	6.1	0.9	2.6	7.9	30.7	33.3	100
	Ba (ha)	0	14	0	61	0	0	0	7	51	133
	Ba (%)	0.0	10.5	0.0	45.9	0.0	0.0	0.0	5.3	38.3	100
MHmmp	Hw (ha)	0	0	0	0	0	0	0	0	0	0
	Hw (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ba (ha)	0	0	0	25	0	0	0	0	2	27
	Ba (%)	0.0	0.0	0.0	92.6	0.0	0.0	0.0	0.0	7.4	100
Sub Total	Hw (ha)	308	2,797	2,642	141	261	279	152	706	1374	8,660
	Ba (ha)	137	496	470	116	5	5	0	27	221	1,477
Grand Total	Hw+Ba (ha)	445	3,293	3,112	257	266	284	152	733	1595	10,137
	Hw+Ba (%)	4.4	32.5	30.7	2.5	2.6	2.8	1.5	7.2	15.7	100

3. Methodology

3.1 Sample Design

The primary objective of the sample design is ensuring a sufficient number of field samples can be field-verified in an unbiased manner. The required number of site index observations is sufficiently large in order to achieve a sampling error of ±1.5 m (95% probability) for each of the target species. The sampling error (SE) is a statement of statistical precision of the average site index. Typically, the 95% confidence interval is estimated as two units of SE from the overall average. The goal of achieving a sampling error of ± 1.5 m is also a function of available project resources. Based on past projects and experience, the required sampling error typically requires between 30-40 observations for each of the target species.

3.2 Target and Sample Population

The target population represents the area within which the statistical adjustment will be applied based on the results of the field sampling. The target population for this project is defined as the THLB within the TCF. The sample population is a subset of the target population where stand conditions are suitable for estimating site index of selected tree species. The sample population in this project is defined as the post-harvesting 'managed forest' land base. The managed stands include post-harvesting areas that were both manually stocked and naturally regenerated. The total area of sample population is 1,662 ha, representing about 16% of the target population (10,138 ha) (Table 3.1 and Table 3.2). As specified in Ecora's 2018 field sample plan, stands that were subject to previous silviculture treatments (comprising 2,864 ha) were excluded from the sample population.

The objective of an SIA project is to develop site index estimates for just the managed stands. Although the site index adjustment landbase includes the entire THLB, the adjusted site indices – for use in timber supply analysis – are only applicable to the landbase following scheduled harvesting. The inventory-based site index is applicable for natural (not yet harvested) stands.

Table 3.1 Area Distribution of Target Populations by BGC Units and Target Species

BGC Unit	Leading Species	Target Population (Ha)	Target Population (%)	Sample Population (ha)	Sample Population (%)
CWHws1	Hw	7,295	72.0	986	59.3
	Ba	853	8.4	196	11.8
CWHws2	Hw	1,250	12.3	261	15.7
	Ba	464	4.6	174	10.5
MHmm2	Hw	115	1.1	32	1.9
	Ba	134	1.3	13	0.8
MHmmp	Hw	0	0.0	0	0.0
	Ba	27	0.3	0	0.0
Total	-	**10,138**	**100.0**	**1,662**	**100.0**

Table 3.2 Area Distribution of Sample Populations by Geographical Area

BGC Unit	Leading Species	Target Population (Ha)	Target Population (%)	Sample Population (ha)	Sample Population (%)
Deep Creek	Hw	3,833	37.8	648	39.0
	Ba	376	3.7	13	0.8
Kitimat	Hw	2,497	24.6	187	11.3
	Ba	287	2.8	0	0.0
Shames	Hw	2,330	23.0	444	26.7
	Ba	815	8.0	369	22.2
Total	-	**10,138**	**100.0**	**1,662**	**100.0**

3.3 Sample Size and Allocation

A total of 60 samples comprised the sample population. A stratified random sampling design method was used for the sample allocation. The sample population was stratified by the number of target tree species (2) and number of BGC units (3), such that the sample size for each stratum (BGC unit) is relatively proportional to its size (ha). Table 3.3 presents the final allocation of sample size to each stratum. A total of 59 samples resulted, as there were not enough stands in the MHmm2 variant for Ba selection.

Ideally, the sampling landbase should be stratified into more homogenous units (e.g. on the basis of BGC, site series, elevation, slope gradient etc.) where, within each unit, allocated samples are randomly selected. In practice, this is not possible since strata numbers determine sample sizes; a large increase in strata numbers would significantly increase the sample size, making the project costs unrealistic.

Table 3.3 Sample Distribution by BGC units and Target Tree Species

BGC Units	Target Species	Number of Samples
CWHws1	Hw	15
	Ba	15
CWHws2	Hw	8
	Ba	7
MHmm2	Hw	8
	Ba	6
Total	**-**	**59**

3.4 Sample Selection and Rejection

Within a given sampling stratum, spatial grid points (based on a 100-m grid) from the Provincial Site Productivity Layer (PSPL) was used for random sample selection. Each selected point constituted a sample plot centre. Where an original sample plot was rejected, based on the rejection criteria described below every effort was made to locate a nearby replacement sample. Identification of a replacement sample would be based on assessment of the surrounding area at 25-m distances, in cardinal (N, E, S, W; in order) directions from the original plot centre. If no plot could be successfully located after the four additional attempts, the targeted sample was rejected. The following section further outlines the process for sample rejection.

Sampling process will target trees with a breast height (BH) age between 20 and 80 years. Within the 1,662 grid points comprising the sample population, a set of 59 random points were selected by GIS (numbered 1 through 59; Figure 3-1) based on the sample numbers allocated to the BGC units and target tree species (Table 3.3). The 59 samples constitute the primary samples. A second set of 59 random points was separately selected and constituted the replacement subset. The cluster appearance of the sample distribution (Figure 3-1) is primarily due to stratification of the landbase by BGC and tree species. For example, the MHmm2 has a relatively small landbase. As leading tree species is an additional factor in sample selection, the suitable landbase for sampling is further reduced.

A circular 5.64-m radius sampling plot was generated surrounding each sample location. Prior to field sampling, all proposed sampling plots were manually assessed using high resolution imagery from the recently completed VRI project, a process primarily aimed to help reduce the rate of sample rejection, during the field program. The sampling of random field plot locations is an expensive endeavor; any plot rejections in the field would ultimately increase the overall project cost.

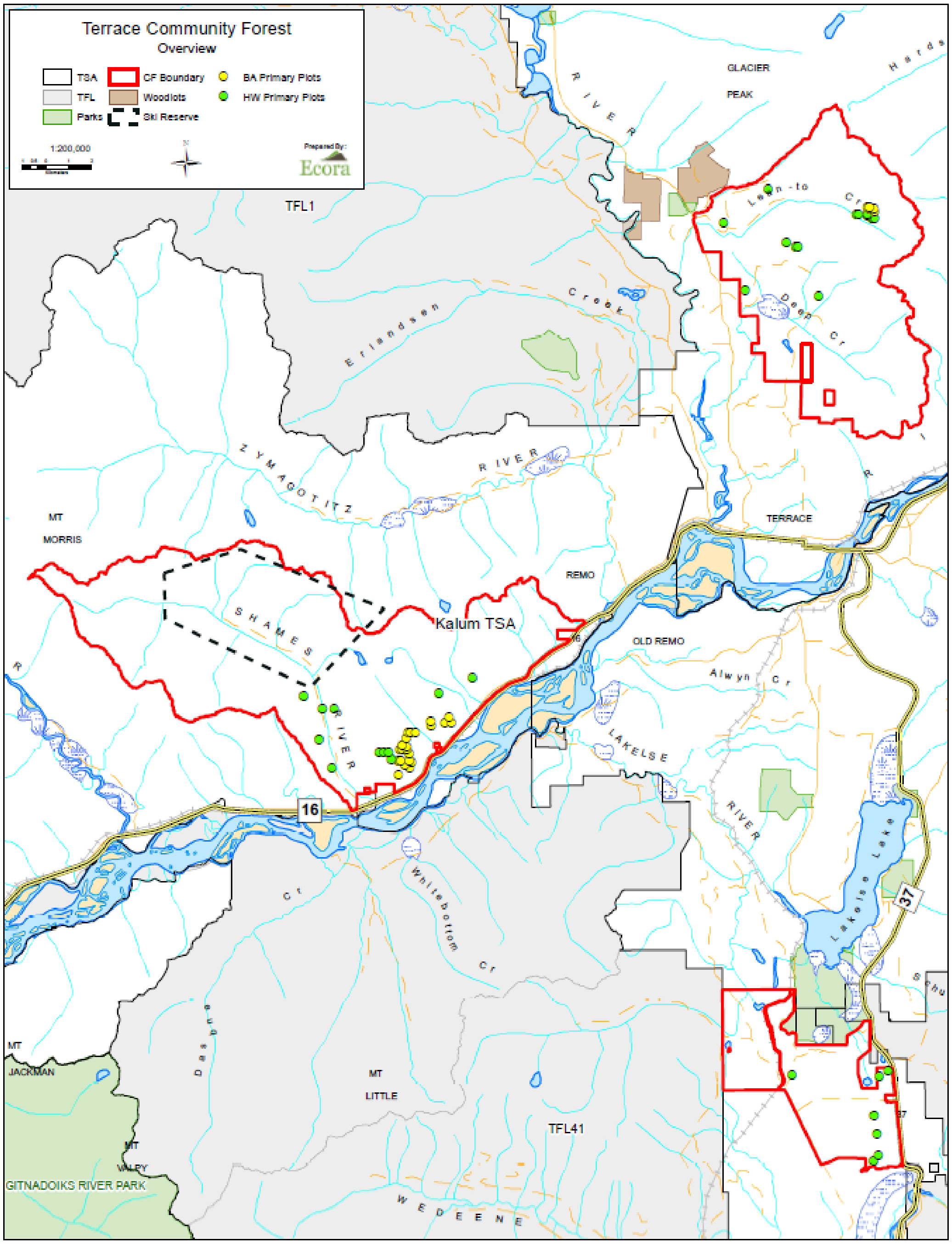


Figure 3-1 Spatial Distribution of Primary Samples by Hw (green) and Ba (yellow)

Sample rejection criteria are outlined below:

1. Sample, or a portion thereof, extends outside of the sampling population (e.g. outside of the TCF boundary, outside of the BGC unit boundary, or within mature stands,

2. Samples are deemed unsuitable for site index sampling; i.e., over-topped by deciduous tree species, or occur in openings including non-treed and sparsely treed areas (e.g., wetlands, brush lands, water bodies, roads, landings etc.),
3. Samples occur within very open (<300 live stems per ha) or very dense stands (>3000 live stems per ha). Within an SI plot, a minimum of 5 live trees is required to be considered a suitable canopy. The criteria for rejecting very dense samples may depend on the stand age and structure.
4. Samples occur in areas with a significant number of veteran trees, suffered with significant natural damages (blow-down, pests, flood, mass movement etc.).
5. Site poses a safety risk; including very steep slopes (>70%), presence of cliffs, hazard trees, excessive blow-down, impassible routes or barriers to all or parts of the sample plot, presence of dangerous wildlife and/or insects (i.e., bears or wasps etc.).
6. Site has no, or very difficult, access. Previous cutblock / spur roads may be completely brushed in, prohibiting truck / ATV access. The sample may be rejected if the GPS distance from a suitable access point to the sample exceeds 1,500m on steep slopes, or 2,500m on gentle or flat terrain. Helicopter was not considered in areas of steep terrain.
7. Sample occurs in multiple layered stands, with the target species restricted to the lower (i.e. intermediate or suppressed) layers.
8. Other reasons identified in the field (e.g., no suitable site trees that adhere to the SIBEC standards etc.).

After a sample was rejected due to above listed reasons, a replacement sample was drawn from replacement samples, in order, within the same BGC unit and targeting the same leading tree.

3.5 Sample Packages

Following the office-based image verification, field maps were produced at 1:4,000 scale and displayed the following information:

- Sample No.
- Plot center and plot boundary
- BGC unit
- TRIM contours (20-m) and water features
- Updated road network
- Orthophoto imagery

Smaller scale overview maps, representing the geographical areas (Kitimat, Shames, and Deep Creek), were also prepared for planning and navigation. A summary sheet of the sample plot attributes was produced, which contained key information for each sample including BGC, site series, leading and secondary tree species from VRI, and site index from the PSPL.

All maps and associated information sheets were loaded into a field iPAD for use in sampling and navigation. The location of the plot center was verified through the use of a GPS unit.

Site tree selection criteria and measurement followed the provincial SIBEC standards (http://www.for.gov.bc.ca /hre/sibec/documents/standards.pdf). All tree cores that include pith were retained; the ages were counted in the office using a microscope, using a 10X magnification lens. The field measurement standards are attached in Appendix 1. The procedures are outlined in Section 3.6.

3.6 Field Procedures

An individual plot may possess either a single or multiple species. In cases of multiple species, each target species (Hw, Ba) as well as other important species (either Cw, Sx, Ss, or Pl) were sampled in the event they meet criteria for 'site tree' selection.

For a given target tree, the largest diameter tree within the dominant or co-dominant layer represents the site tree candidate. Where the largest diameter tree does not meet all site tree criteria, the plot was rejected and subplots (in order: N, E, S, W) were investigated.

For each completed sample, the following information was recorded:

- Project ID (e.g. TCF-SIA)
- Surveyor / crew name(s)
- Sample date and time
- Sample Number or ID
- Sample plot center UTM coordinates
- BEC unit
- Slope (%)
- Aspect (degrees)
- Dominant soil moisture regime
- SIA or SIBEC (indicating Which standards the SI data satisfy)
- Site series and proportions within SI plot boundary
- Number of live stems
- Target tree species
- Diameter at breast height (cm)
- Height (m)
- BH age
- Site index
- Origin (P-planted/N-natural)
- Comments

Any comments pertaining to uncertainty regarding selection of site, plot, and/or sample trees were recorded in the Comments section. A sample of a completed plot card is presented in Appendix 2.

Ideally, site trees would be located in a completely homogenous site, with a single ecosystem (site series) encompassing the entire 5.64-m boundary, and beyond (>10m). However, this is not realized in random selection-based SIA projects. In this project, each field sampling crew included an experienced ecologist who is competent in identifying site units using existing provincial land management handbooks for site identification and interpretation.

3.7 Quality Assurance

Field data collection followed data standards in Appendix 1. Prior to initiation of the field component, the field sample plan, data analysis and statistical adjustment procedures were reviewed and approved by Gordon Nigh, Team Lead - Strategic Analysis, with the MFLNRORD. The field crew adhered to all relevant technical standards during the field sampling.

For consistency and to reduce potential for subjectivity, Ecora assigned one field crew to complete the project. Shikun Ran, RPF, Ecora's senior ecologist who has extensive experience in projects of a similar nature (i.e., SIBEC, SIA, ecosystem inventory etc.), served as the field crew lead. Madeline Zhang, an experienced forest inventory technician (VRI and CMI) was the 2nd crew member. The crew lead reviewed and checked every plot form, on site, for completeness and accuracy prior to leaving a sample plot.

Cored ages were measured in the field and the cores were collected for subsequent age confirmation in the office using a 10X microscope. The office verification is critical due to the significant impact that small errors in age (i.e., one year) could have on the resulting site index estimates.

3.8 Data Compilation and Analysis

After field sampling, the data was entered and compiled for statistical analysis. All collected tree cores were counted under microscope with a 10X lens. Provincial "Site Tools" program was used for SI calculation based on age and height relationships.

The mean site index values and associated standard errors of the samples, for each target tree species, were calculated. The variability in site index of a given tree species was analyzed by BEC and site series, and by geographical areas and by soil moisture classes. The site index of non-target tree species (Cw, Ss, Sx and Pl) was also analyzed, albeit based on limited sample size. The number of samples for the non-target species was small and would not be justified for use in statistical adjustment.

3.9 Statistical Adjustment

Statistical adjustment is a process of comparing the existing site index values from the PSPL with locally collected field data. Through localization, an adjustment ratio was developed for each target species (Hw, Ba). A regression with no intercept method was used to develop the adjustment ratios.

The new, adjusted site index values would be combined with other silviculture information to develop managed stand yield tables for use in the upcoming timber supply analysis.

4. Results

4.1 Site Index from Provincial Site Productivity Layer

This SIA project is based on the use of preliminary site index values from the PSPL that was published by the BC Government. The site index values in the PSPL were produced through the development of a biophysical model (https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr073.htm). The model took advantage of existing data from completed SIBEC and SIA projects and incorporated existing ecological mapping products such as TEM and PEM, as available. Table 4.1 presents average site index values for selected tree species presented in the THLB of the TCF, based on the published data of the PSPL. The average site index is also presented by BGC units and by geographical areas.

Table 4.1 Average Site Index of PSPL by BGC and Geographical Area (THLB)

Site Index /BGC/ Geographical areas	Hw	Ba	Cw	Ss	Sx	Pl
Overall SI (m)	22.3	24.2	19.7	24.7	21.0	20.9
CWHws1 SI (m)	22.8	25.4	20.3	24.5	21.0	21.0
CWHws2 SI (m)	20.5	22.2	17.8	25.4	20.9	20.3
MHmm2 SI (m)	19.0	14.5	17.3	26.0	20.4	19.0
Deep Creek SI (m)	22.5	20.2	20.2	24.9	21.4	21.3
Kitimat SI (m)	22.3	25.2	19.4	24.2	20.3	20.3
Shames SI (m)	22.0	23.1	19.3	24.9	21.1	20.8

4.2 Field Sampling

A total of 51 samples were established in the field. The sampling of all 59 designed plots was stopped when field sampling budget was exhausted and expected numbers of site trees for the target species were achieved. One sample was dropped during the post-field data compilation process. The dropped sample was a replacement sample in Kitimat area and established during the first sampling day due to imminent harvesting of the sample. A total of 50 samples were used for data analysis. Forty-seven of the samples were established at their original sample location, while three samples required an alternative (sub-plot) sample selection. In total, 95 site trees were sampled (Table 4.2).

Table 4.2 Site Tree Distribution and Average Site Index of Samples

Tree Species	Hw	Ba	Cw	Ss	Pl	Total
Number of Site Trees	47	40	5	2	1	95
Average Site Index of PSPL at sample locations (m)	22.2	24.0	19.0	22.3	20.7	-
Average Site Index of Field Measurements (m)	24.7	24.2	20.6	25.8	23.0	-

Twenty samples were rejected, with half of the rejections (10) made in the office during pre-field image assessment, and another 10 samples rejected in the field. Table 4-3 summarizes the rejected samples, with rationale.

Table 4.3 The Distribution of Rejected Samples and Associated Reasons

Reasons for Rejection	No Access	Excessively Steep	Mature Stand	Harvesting/Open	Other	Total
Samples	6	6	3	3	2	20

The rejected samples were replaced with samples on the replacement list, in order, from the same BGC units.

4.3 Site Index Statistics

4.3.1 Site Tree Statistics

Eight-seven (87) site trees of target species were derived from the 50 samples (Table 4.4). As they often grow together, in many of the Hw-leading plots, site tree data was also collected for Ba, and vice versa. The expected range of 30-40 site trees for each of the two-target species (Hw and Ba), as documented in the field sample plan, was exceeded in completion of the 50 samples.

The average diameter at breast height (DBH) for the site trees was 24.2 cm and 24.7 cm for Hw and Ba, respectively. Average breast height (BH) age of the site trees was 30 and 31 years for Hw and Ba. The average

BH age of both target species exceeded 30 years, which is considered good in site index sampling. As the index age of site trees is defined at BH 50 years, the closer a sampled tree is to 50 years of BH age, the better.

Table 4.4 Site Tree Statistics of DBH and BH Ages

Species	n	DBH (cm)				BH Age (years)			
		Average	Min	Max	SD	Average	Min	Max	SD
Hw	47	24.2	9.2	40.6	8.3	30	12	57	10.1
Ba	40	24.7	9.7	48.5	10.2	31	15	55	9.4

Table 4.5 through to Table 4.7 present comparative statistics of the target population and the field sample sizes. For the target population (THLB), area distribution of CWHws1, CWHws2, and MHmm2 accounts for 72.5%, 18.2%, and 9.3% respectively (Table 4.5). By comparison, the distribution of realized site tree samples (Hw + Ba) account for 47.1%, 29.9% and 23.0% respectively for the same three (3) BGC units. In other words, significant under sampling of CWHws1 and oversampling of MHmm2 are evident if areas of BGC units are made for comparison. If the comparison is made by the three geographical areas, the target population areas and site tree sample size distribution is more reasonable (Table 4.5).

Comparison was also made by area distributions of leading tree species (Hw, Ba) within target population and site tree sample size distribution (Table 4.6, Table 4.7). Again, site tree sample size distributions have a better representation by geographical area (Table 4.7) than by BGC units (Table 4.6).

Table 4.5 Comparative Statistics of Target Population Areas and Sample Size Distribution

	CWHws1	CWHws2	MHmm2	Total	Deep Creek	Kitimat	Shames	Total
Population Area (ha)	9,513	2,381	1,224	13,118[a]	5,275	3,222	4,963	13,460[a]
Population Area (%)	72.5	18.2	9.3	100.0	39.2	23.9	36.9	100.0
Sample No	27	13	10	50	22	8	20	50
Sample No (%)	54.0	26.0	20.0	100.0	44.0	16.0	40.0	100.0
Site Tree Sample (Hw+Ba)	41	26	20	87	41	14	32	87
Site Tree Sample (%)	47.1	29.9	23.0	100.0	47.1	16.1	36.8	100.0

[a] the difference of landmass between BGC units and geographical areas is caused by MHmmp, i.e., 42 ha is not included in the table

Table 4.6 Comparative Statistics of Target Population (tree species) Areas and Sample Size Distribution by BGC Units

Population	CWHws1		CWHws2		MHmm2	
	Hw	Ba	Hw	Ba	Hw	Ba
Target Population (%)	84.3	58.8	14.4	32.2	1.3[a]	9.1
Site tree (%)	51.1	47.1	27.7	22.9	21.3	23.0

[a] low Hw percent is due to VRI Hm is not included in the calculation

Table 4.7 Comparative Statistics of Target Population (tree species) Areas and Sample Size Distribution by Geographical Areas

Population	Deep Creek		Kitimat		Shames	
	Hw	Ba	Hw	Ba	Hw	Ba
Target Population (%)	44.3	25.4	28.8	19.4	26.9	55.1
Site tree (%)	46.8	47.5	17.0	15.0	36.2	37.5

4.3.2 Site Index Statistics

Application of field sample tree site index values to the existing PSPL layer resulted in an overall increase of 11% and 0.7% for Hw and Ba, respectively (Table 4.8). R-square values of the regression equations are considered weak, with 0.1134 and 0.0342 respectively for Hw and Ba. However, the standard errors (95% probability) of the sample set site index values are both below 1.5 m, a threshold determined prior to field sampling based on empirical data of previously completed SIA projects in BC.

Scatter gram of site index between the PSPL and field data are displayed in Figure 4.1 (Hw) and Figure 4.2 (Ba).

Table 4.8 Site Index Statistics of Field Samples Within THLB

Species/ Site Index	Sample Size	Average SI (PSPL)	Average SI (Field)	Regression Equation	R-Square	Std. Deviation	Std. Error (95% confi.)
Hw	47	22.2	24.7	Y=1.1106X	0.1134	4.2	1.2
Ba	40	24.0	24.2	Y=1.0065X	0.0342	4.3	1.3

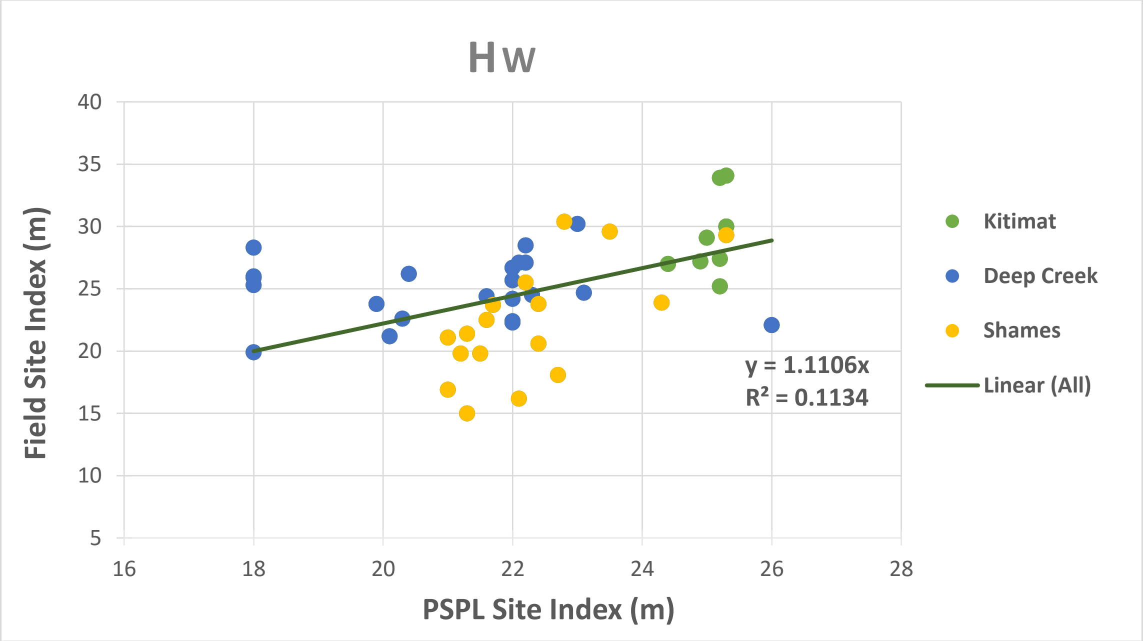


Figure 4.1 Scattergram between PSPL Site Index and Field Site Index: Target Hw

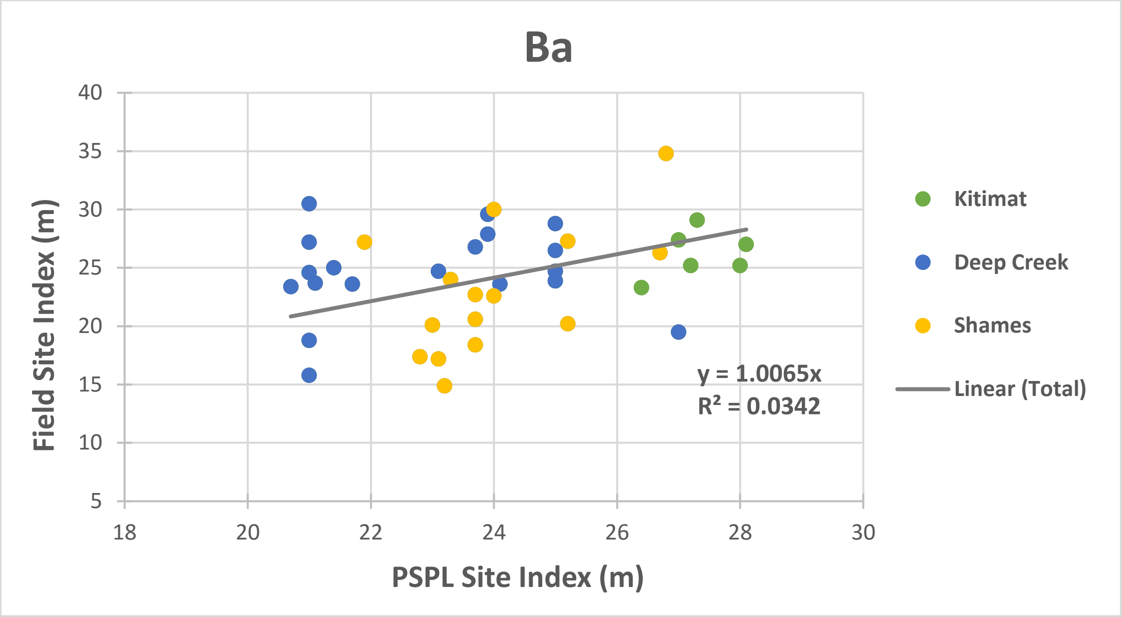


Figure 4.2 Scattergram between PSPL Site Index and Field Site Index: Target Ba

Site index statistics of field samples are also presented: by BGC unit (Table 4.9); by geographic area (Table 4.10); and by site moisture (Table 4.11). Overall, it appears that the standard deviation and errors of samples were smallest (on average) when results were presented by geographical area (Deep Creek, Kitimat, Shames). Standard deviation is a useful measure to quantify the amount of variation of the site index sample set. Standard error is a measure of statistical accuracy of the site index estimate, such that the smaller the standard error, the more accurate the site index estimate.

Table 4.9 Site Index Statistics of Field Samples by BGC Unit

BGC Units	Sample Size	Species/ Site Index (m)	Average SI (PSPL)	Average SI (Field)	Regression Equation	R-Square	Std. Deviation	Std. Error (95% confi.)
CWHws1	24	Hw	23.5	26.0	Y=1.1110X	0.3309	4.6	1.8
	17	Ba	25.4	25.3	Y=0.9933X	0.1676	4.2	2.0
CWHws2	13	Hw	21.1	22.7	Y=1.0730X	0.0818	4.0	2.2
	13	Ba	22.7	23.0	Y=1.0118X	-0.0370	4.3	2.3
MHmm2	10	Hw	20.4	24.2	Y=1.1609X	-2.8080	2.5	1.5
	10	Ba	23.2	24.0	Y=1.0267X	-0.2370	4.7	2.9

Table 4.10 Site Index Statistics of Field Samples by Geographical Area

BGC Units	Sample Size	Species/Site Index (m)	Average SI (PSPL)	Average SI (Field)	Regression Equation	R-Square	Std. Deviation	Std. Error (95% confi.)
Deep Creek	22	Hw	21.1	25.0	Y=1.1747X	-0.8670	2.6	1.1
	19	Ba	22.9	24.7	Y=1.0700X	-0.1810	3.7	1.7
Kitimat	8	Hw	25.1	29.2	Y=1.1670X	0.0817	3.3	2.3
	6	Ba	27.3	26.2	Y=0.9586X	-0.1207	2.0	1.6
Shames	17	Hw	22.3	22.3	Y=1.0022X	0.2662	4.4	2.1
	15	Ba	24.0	22.9	Y=0.9576X	-0.2089	5.4	2.7

Table 4.11 Site Index Statistics of Field Samples by Site Moisture

Sites	Sample Size	Species/Site Index (m)	Average SI (PSPL)	Average SI (Field)	Regression Equation	R-Square	Std. Deviation	Std. Error (95% confi.)
Dry (SNR= 1, 2, 3)	10	Hw	22.0	22.4	Y=1.0115X	-0.0450	4.2	1.9
	6	Ba	21.9	23.7	Y=0.8916X	0.1644	4.5	2.4
Mesic (SMR=4)	23	Hw	22.1	26.3	Y=1.1826X	0.2060	4.0	2.2
	19	Ba	24.1	25.5	Y=1.0476X	-0.6060	3.6	1.3
Moist (SMR=5, 6)	6	Hw	22.8	25.6	Y=1.1279X	0.6235	3.2	2.6
	7	Ba	24.2	27.1	Y=1.1157X	0.3812	3.7	2.7

4.3.3 Site Index Adjustment

Within the THLB, the average site index values of the PSPL are 22.3 m and 24.2 m, respectively, for Hw and Ba (Table 4.1). From the subset of grid points comprising the field sample locations, the average site index of PSPL at sampling points was respectively 22.2. and 24.0 m for Hw and Ba (Table 4.2), which may indicate a good representation of samples to the target population (THLB). However, the average site index of field measurements at sampling points are 24.7 m and 24.2 m for Hw and Ba respectively, which displayed a relatively large increase for Hw (+2.5 m) but a negligible increase for Ba (+0.2 m). The statistical adjustment on these samples used linear regression models with no intercept method, and resulted in an upward adjustment of 11.06% and 0.65% for Hw and Ba respectively (Table 4.8).

Field observations indicated that tree productivity is consistently lower in the Shames geographical area, when compared to the other two areas (Deep Creek and Kitimat). This trend was also supported by site tree sampling and associated statistics (Table 4.10). The relatively poor productivity of the Shames area can be attributed to geological factors, i.e., a poor bedrock type. Discussions with multiple parties, including the client, timber supply analysts, and a government technical expert, it was agreed that a geographic site index adjustment may be justified. The presented regression equations in Table 4.10 will be applied to the PSPL grid points where site index values were estimated by the PSPL biophysical models.

5. DISCUSSION

5.1 Site Index Variation

The large site index variation between the PSPL and field samples, as depicted by the scattergrams in Figure 4.1 and Figure 4.2, may be attributed to a number of factors including climate, site, elevation, geographical area, PSPL modelling error, or sampling error. Potential factors in variability are addressed below.

1. **Climate:** the main climate factors that cause productivity variations are commonly linked to precipitation and temperature. In extreme climates (very dry and hot, or very wet and cold), the survival and growth of most tree species are hampered, resulting in low species diversity and low site productivity, or site index. The BGC units are designed to broadly classify provincial climate into smaller, relatively uniform regional climatic units. As evident in Table 4.9, analysis by BGC unit can reveal significant variations in site index. Within a given biogeoclimatic unit, there is also variation in precipitation and temperature, resulting in local variations in productivity. This is particularly true for the high elevation BGC units (e.g., the MH BEC Zone) where every increase of 100 m in elevation results in a decrease in average temperature, and thus, productivity. Within BGC units at lower elevations, however, the impact of climatic factors on site productivity is commonly considered less significant.

2. **Site:** site factors redistribute climate factors such as water and temperature, thus causing the productivity variations. The prominent site factors include slope gradient and aspect, slope position, soil depth and texture etc. The BEC site units (site series) are designed to characterize sites with relatively uniform site conditions. Table 4.11 presents the site index results by a key site factor, i.e., soil moisture. Site series was used in the preliminary analysis but showed relatively large variation within the zonal (i.e., ‘01’) site series. There are two reasons that site series were not used for the analysis:

    a. The zonal sites for the BGC units within the target population are all, by definition, inclusive of both mesic and submesic relative site moistures. By site series, zonal sites are so dominating on a landscape that there are not enough samples for other site series.

    b. By further separating zonal sites through soil moisture, the variation of site index can be better characterized.

3. **Elevation**: elevation is believed one of the most significant factors in site index variation. In a given range of elevation, site productivity typically decreases as elevation increases. However, BGC units within the target population were mapped using a similar concept as the elevation band. In addition, the elevation impact on site index variation is greatest at high elevations where temperature becomes a limiting factor for tree growth. At lower elevations, where temperature effects are not considered to be a limiting factor, the impact of elevation changes on productivity are much less significant.

4. **Geographical Area**: as evident in the Table 4.10, assessment by geographic area resulted in major site index variations within the sample population. The Shames area has the lowest productivity, while the Kitimat area had the highest productivity. The differences of site index values ranged up to 6.9 m and 3.9 m, respectively, for Hw and Ba. This report recommended the statistical adjustment of site index by geographical area since the results showed the largest variations between areas and the lowest variation within an area (Table 4.10). A major contributing factor for the relatively poor growth throughout the Shames area, as discussed, is attributed to underlying nutrient-poor bedrock types.

5. **PSPL Modelling Error:** The PSPL used a biophysical model to predict site index within a given area, such as a BGC unit. There are certain assumptions made in any modeling approach. Any deviations from the assumed conditions may produce errors predictions. In addition, the biophysical models might have used model input data that are incomplete (e.g., provincial SIBEC) and/or land-based mapping products (e.g., TEM, PEM) that are neither accurate, nor precise. All those errors may contribute to variations of predicted site index values. It is also the precise reason why the predicted values by the model need to be validated and adjusted through collection of local data, even though average values of predicted and locally collected data may be similar within the target population. A good example, in this project, is evident by assessing results for Ba. The average values of the predicted site index and field-derived site index are very similar (Table 4.2), but significant variations do exist when analyzed by BGC unit, geographical area, and site moisture class (Table 4.11, Figure 4.2). Nevertheless, site index values used by the biophysical model are derived from project-specific sources that may not apply well across large landscapes. For example, if a SIBEC data set was collected from an area similar to the Shames area, the application of the values to other, more productive areas such as Kitimat or Deep Creek, would underestimate site index; of course, the opposite also applies.

6. **Sampling Error**: given the unbiased selection of samples, one can assume that the sample population well represents the target population, and adjusted site index values in the sample

set are applicable to the larger target population. However, there are limitations in the sample selection process. First, the sample population is a relatively small subset of the target population (Table 3.1). Within the sample population, further stratification such as BGC units and tree species created difficulty for sample allocation. Ideally, each stratum should have equal or similar numbers of samples that are sufficiently large to meet requirements for statistical rigor. In reality, this is not often possible due to limitations in the available time / resources to conduct such sampling. This sample design adopted a balanced approach, i.e., sample requirement and sample stratum size. During the field sampling, certain stratum had more inherent issues with access and stand suitability. Based on the final realized samples (Hw+Ba) from the field program, the CWHws1 was under-represented while MHmm2 was over-represented (Table 4.5, Table 4.6, Table 4.7). When the comparison was made by geographical area, the Kitimat area was under-represented while Deep Creek was over-represented (Table 4.5). Table 4.6 and Table 4.7 compared target tree species areas within the target population to the realized site tree samples, by BGC units and by geographical area. The under- and over-representations are also evident but the magnitude of misrepresentations by geographical locations is reduced. Since the site index variation is sensitive to geographical area, as discussed above, the over- or under-representation of site tree samples may contribute to an important source of site index variation.

5.2 Impacts on Timber Supply

The site index results through this project are higher than each of the existing site index estimates available for the same landbase (Inventory SI, SIBEC SI and PSPL SI; Table 5.1). When compared to the PSPL, field site index increased by over 11% for Hw, but less than 1% for Ba. This upward adjustment trend also exists for other tree species such as Cw (N=5, +8.7%), Ss (N=2, +15.7%), and Pl (N=1, +11.1%). When the field site index is compared to the existing Inventory and SIBEC site index, the magnitude of increase is much greater (Table 5.1). Using an empirical rule that a relative increase of 1% in site index may lead to a 2% increase in CMAI, these results would demonstrate a significant effect on CMAI, and thus timber supply.

Table Interpretation Program for Stand Yields (TIPSY) is a growth and yield program that provides access to managed stand yield tables. Figure 5.1 shows the potential increase of merchantable volume of DBH class17.5cm with SIA site index when compare to PSPL site index. The example input stand is a western hemlock leading stand with PSPL site index of 22.7 m and a corresponding SIA site index of 25.6 m (+12.6%).

Table 5.1 Site Index Comparison of Multiple Sources by Species within a Given BGC Unit and Geographical Area

Tree Species	Hw				Ba			
BGC Unit & Geographical area	Inventory SI (m)	SIBEC SI (m)	PSPL SI (m)	Field SI (m)	Inventory SI (m)	SIBEC SI (m)	PSPL SI (m)	Field SI (m)
Entire THLB	20.5	19.3	22.2	24.7	20.1	20.4	24.0	24.2
CWHws1	20.9	22.8	23.5	26.0	24.9	24.7	25.4	25.3
CWHws2	18.8	19.1	21.1	22.7	24.9	21.7	22.7	23.0
MHmm2	17.6	11.2	20.4	24.2	17.7	11.2	23.2	24.0
Deep Creek	18.1	16.2	21.1	25.0	22.5	16.7	22.9	24.7
Kitimat	23.2	22.9	25.1	29.2	17.5	25.2	27.3	26.2
Shames	19.4	21.7	22.3	22.3	18.9	23.1	24.0	22.9

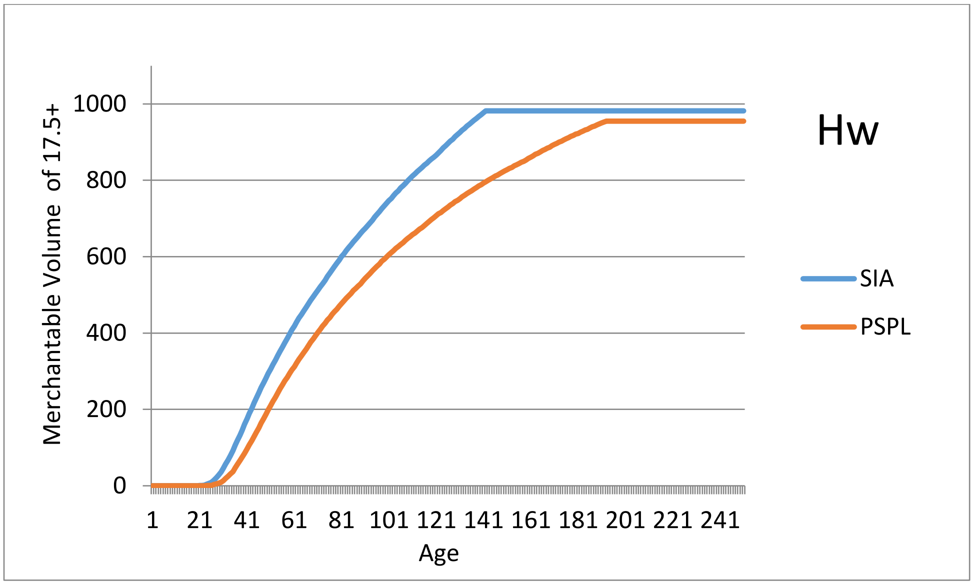


Figure 5.1 Tipsy Yield Curve compare for a Hemlock stand with SIA/PSPL site index

The estimated site index through this project is considered conservative for the target population. A major factor in the potential underestimate of site index is the exclusion of 2,864 ha of land base that had previous silviculture treatments, including spacing and/or fertilization etc. Those areas are typically located in the productive portion of the target population with potentially high site index values, if sampled. Given the project's total sampling population of 1,662 ha (Table 3.1), the excluded portion of the landbase is substantial.

A potentially corrective method for the underestimated site index is to establish a growth and yield monitoring program throughout the target population. In the monitoring program, randomly located permanent sample plots (e.g., change monitoring inventory (CMI) plots) are established and re-measured at a repeated frequency, such as at five (5) or ten (10) year intervals. The monitoring program provides the actual growth and volumes of the target stands and provides the best feedback to the timber supply analysis that uses adjusted site index to project future yield.

References

B.C. Ministry of Forests and Range, 2009. SIBEC Sampling and Data Standards. Version 5.3. http://www.for.gov.bc.ca/hre/sibec/documents/standards.pdf

Gordon D. Nigh, 2017. The Effect of Leader Damage on White Spruce (Picea glauca) Site Tree Height Growth and Site Index. Can J. For. Res. 2017 47(9):1153-1160. https://doi.org/10.1139/cjfr-2017-0056.

Forest Analysis and Inventory Branch, Ministry of Forest, Land, Natural Resources Operation, 2010. Kalum TSA. Timber Supply Analysis Technical Report. Retrieved from: http://data.nrs.gov.bc.ca/TSR_Historical/TSA/Kalum_10/TSR_2011/Technical_Report/10ts10_tech_rep_update1.pdf

Gordon D. Nigh and Bobby A. Love, 1997. Ministry of Forests Research Program. Site Index Adjustment for Old-growth Coastal Western Hemlock Stands in the Kalum Forest District. Retrieved from: https://www.for.gov.bc.ca/hfd/pubs/Docs/wp/wp27.pdf

Gordon Nigh, 2010. A closer look at site index – biogeoclimatic site series correlations: Douglas-fir in the Coastal Western Hemlock Zone, xm2 variant, 01 site series. Retrieved from: http://pubs.cif-ifc.org/doi/pdf/10.5558/tfc86477-4

Gordon D. Nigh, 1998. Ministry of Forests Research Program. Site Index Adjustments for Old-growth Stands Based on Veteran Trees. Retrieved from: https://www.for.gov.bc.ca/hfd/pubs/docs/wp/WP36.pdf

Jim Snetsinger, 2011. Kalum Timber Supply Area. Rationale for Allowable Annual Cut (AAC) Determination. Retrieved from: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/tsr-annual-allowable-cut/kalum_tsa_rationale.pdf

LM Forest Resource Solution, 2004. Kalum Timber Supply Area. Vegetation Resources Inventory Strategic Plan. Retrieved from: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/ground-sample-inventories/vri-audits/planning-reports/tsa-vsip/kalumtsa_vri_vsip.pdf

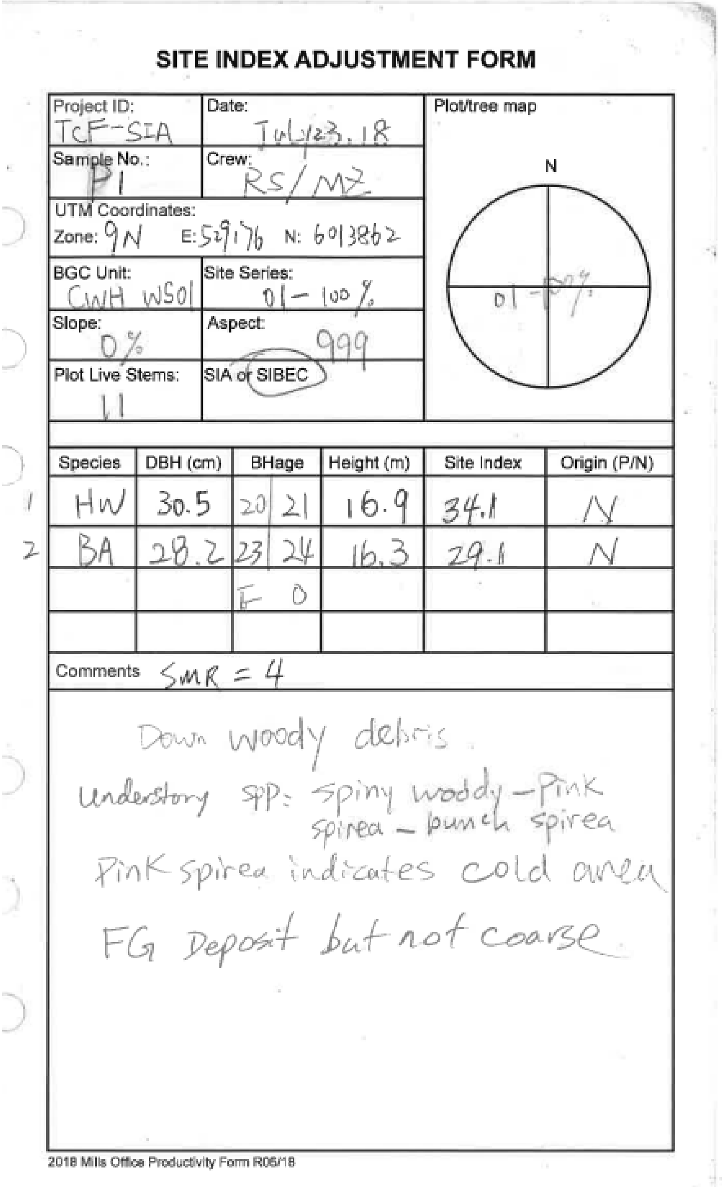
Appendix 1

Field Measurement Standards

Data Type	Standard	Tolerance
Site tree selection	SIBEC version 5.3	No error
Height to DBH	SIBEC version 5.3	≤ 5 cm from actual
DBH	SIBEC version 5.3	≤ 0.1 cm or 1%, whichever is greater
Total tree height	SIBEC version 5.3	≤ 20 cm or 2%, whichever is greater
Breast-height (BH) age	SIBEC version 5.3	Sample must include pith, no error if BH age ≤ 50 years; 1 year if BH age = 50 to 100 years
Notes	SIBEC version 5.3	Must have comments where accepting a damaged sample tree
Subzone		No error, must include notes on transition
Site series		No error, must include composition
Elevation		± 50 m, based on GPS or TRIM
Slope		± 10% from actual
Aspect		± 15 degrees from actual
Soil Moisture		± 1 class
Soil Nutrients		± 1 class

Appendix 2

Sample – Completed Plot Card



SITE INDEX ADJUSTMENT FORM

Project ID: TCF-SIA

Date: July23,18

Sample No.: P1

Crew: RS/MZ

UTM Coordinates:

Zone: 9N E: 529176 N: 6013862

BGC Unit: CWH WS01

Site Series: 01 – 100%

Slope: 0%

Aspect: 999

Plot Live Stems: 11

SIA or [✓ SIBEC]

Plot/tree map

	Species	DBH (cm)	BHage	Height (m)	Site Index	Origin (P/N)
1	HW	30.5	20 | 21	16.9	34.1	N
2	BA	28.2	23 | 24	16.3	29.1	N
			F 0			

Comments SMR = 4

Down woody debris

understory spp: spiny woody – Pink spirea – bunch spirea

Pink spirea indicates cold area

FG Deposit but not coarse

2018 Mills Office Productivity Form R06/18