How to Determine Site Index in Silviculture

Participant's Workbook

1999

Ministry of Forests
Forest Practices Branch

Contents

Appendices

Background Information on the Course

Target Audience

The target audience for this course includes silviculture surveyors, contract administrators, and people developing SMPs or SPs. The course content assumes that participants have a working knowledge of the current silviculture survey system as well as the development of SPs and SMPs.

Prerequisites

- Working knowledge of the Silviculture Survey System.
- Basic understanding of Forest Health issues.
- Basic understanding of Multi-story Stands.

Purpose of this Course

The purpose of this course is to improve forest management in British Columbia by improving the ability of silviculture sureyors to estimate site index – one of the key variables that needs to be considered for effective forest management decision making.

Learning Objectives

By the end of this course, participants should be able to:

- Understand the purpose of estimating site index.
- Know which method of estimating site index is best to use for each species and site.
- Collect site index data that conforms to provincial standards.

Course Format

This course consists of a one day workshop, with half-day class and field sessions. The course workbook summarizes the in-class information, provides site index reference material, and allows participants to add their own notes.

Equipment Required

For In-class Exercises

Site Index reference material
Pencil/pen

For Field Exercises

Personal field gear (Cruiser's vest, rain gear, boots, etc.) plus whatever you can bring from the following list:

Increment borer

5.64 m plot cord

Folding hand saw

Carpenter's measuring tape

Field book

DBH tape

Suunto

30 m tape or loggers chain

Hand lens

Calculator

Pocket knife

References

Silviculture Practices Regulation

Silviculture Surveys Guidebook

Site Index Estimates by Site Series for Coniferous Tree Species in British Columbia

Course Schedule

Classroom Session

8:30	Course and Participants Introduction
8:50	Introduction to Site Index (SI)
9:10	Overview of Methods for Estimating SI
9:25	BEC Method
9:45	Growth Intercept Method
10:15	***Break***
10:35	Advanced Options for Growth Intercept
10:50	Site Index Curve Method
11:10	Site Class Conversion Table
11:15	Decision Key
11:30	Species Conversion Table
11:35	Contract Specifications
11:45	Session Summary
12:00	***Lunch and Travel***
1:00	Field Session

Field Session

12:30	Leave for Field Sites
14:30	Return from Field Sites

Lesson 1 Course and Participant's Introduction

Lesson Objectives

- Review course structure, content and presentation.

Course Objectives

- Introduce the concept of site index.
- Discuss the importance of, and legal requirements for, site index.
- Introduce the various methods of estimating site index for a variety of sites and species.
- Develop the skills to accurately determine site index in the field.

Notes

Lesson 2 Introduction to Site Index

Lesson Objective

Develop understanding of some important site index concepts, the uses of site index, and the legal and systems requirements for site index.

What is Site Index?

Site index (SI) is a measure of potential site productivity – the capacity of an area of land to grow trees of a given species (Figure 2.1). It is 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. Simply, SI is the height of doms at age 50 when they have been able to grow to their full potential. On sites where suppression, repression, or damage have reduced top height growth, SI is best thought of as the top height that would be attained at bh age 50 by unsuppressed, unrepressed, undamaged top height trees.

Top height

Until very recently, top height trees were defined as the 100/ha largest DBH trees of a given species. Now this definition has been changed. The new definition of a top height tree is the "largest DBH tree of a given species in a 0.01 ha plot." This definition makes sure that all the top height trees cannot be located in a cluster in one corner of the hectare.

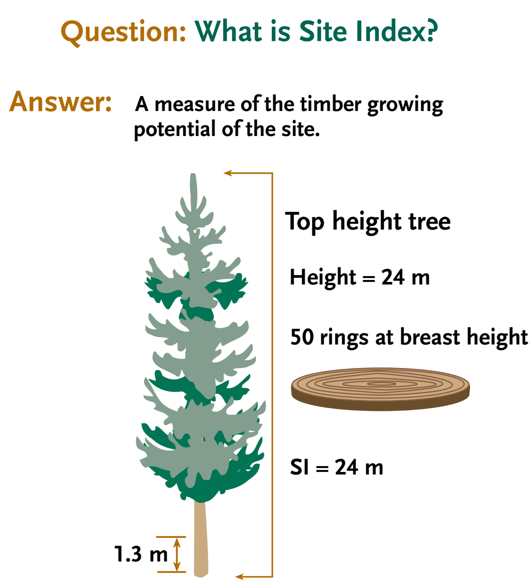


Figure 2.1. What is site index?

Total age, breast height age, and years to breast height

The concept of SI is based on breast height age – not total age. Figure 2.2 illustrates the differences between total age, breast height age, and years to breast height. Total age is the number of years since seed germination. The number of years it took a tree to grow from seed to breast height is termed “years to breast height.” The number of years growth above breast height is termed “breast height age.”

Breast height age is the number of annual growth rings at breast height. Total age is the number of rings at the point of germination.

Breast height is 1.3 m above ground measured from the high side.

This measure of productivity (SI) is based on stand height because stand height is:

- easy to measure
- closely related to stand volume
- relatively independent of stocking density.

SI allows standardized comparisons of productive potential between sites, across a broad range of existing stand conditions.

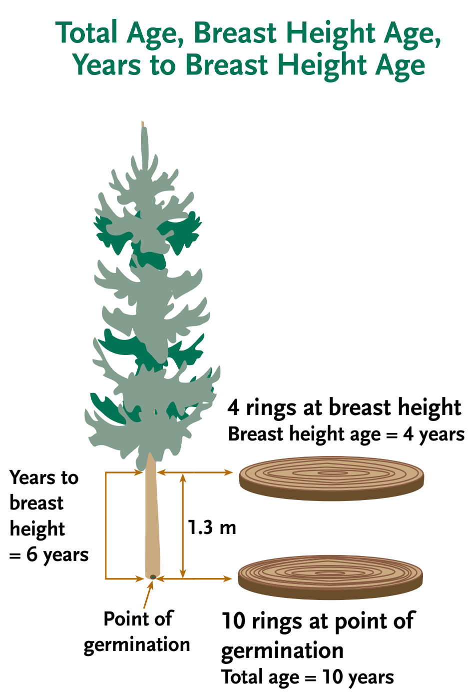


Figure 2.2. Total age, breast height age, and years to breast height.

In the past, site productivity was recorded as a site class (i.e., good, medium, poor).

Typically, SI for different site classes is as follows:

Coast		*Interior*	
Good:	> 35 m	Good:	> 22 m
Med:	20–35 m	Med :	15–22 m
Poor:	< 20 m	Poor:	< 15 m

As can be seen, these classes are very broad. The more accurate the estimate of SI, the more accurate the decisions that rely on that value will be.

Where is SI used?

Site index has many uses in:

- inventory
- silviculture
- timber supply analysis.

Inventory

In inventory, SI is used as a basic descriptor of site quality and used to grow the inventory to keep height and volume estimates current.

Silviculture

In silviculture, accurate estimates of SI are required to adequately describe site quality, formulate appropriate prescriptions, schedule and prioritize treatments and to predict stand growth and yield.

In many cases, site index is the single most important factor determining stand growth and yield. To illustrate how site index affects stand development, Figure 2.3 shows WinTIPSY (version 1.3) output for a coastal Fd stand planted at 1100 stems/ha on site index 25, 30, and 35 m.

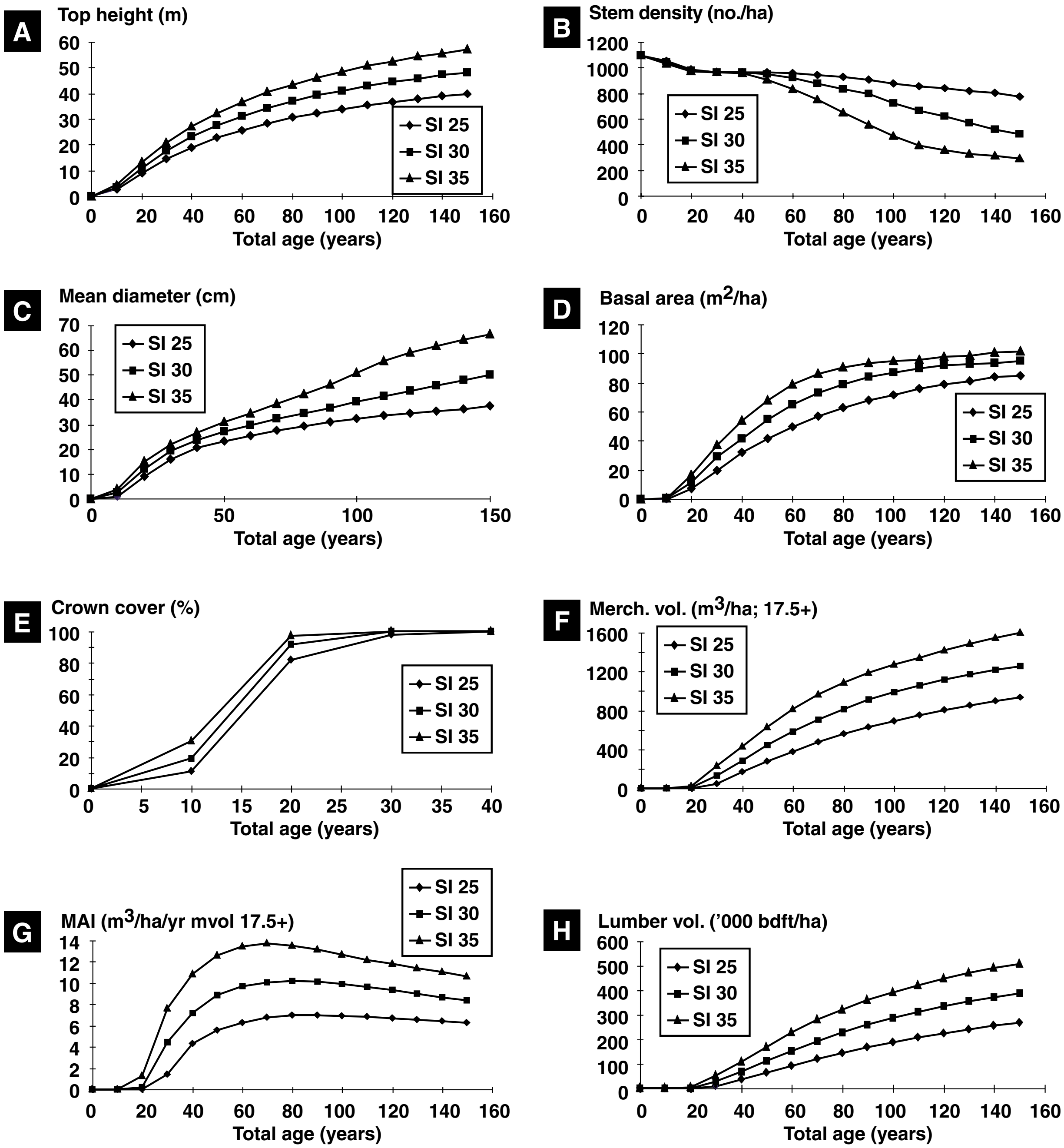


Figure 2.3. Example of the effect of site index on stand development: A) top height; B) trees/ha; C) mean diameter; D) basal area; E) percent crown cover; F) merchantable volume/ha; G) mean annual increment; H) lumber yield. Source: WinTIPSY (ver. 1.3) output for a coastal Fd stand planted at 1100/ha on site index 25, 30 and 35 m.

Timber Supply Analysis

In timber supply analysis, SI is used to estimate years to green-up, size of operable land base, minimum harvestable age, yield of regenerated stands and growth of existing stands.

In many management units, our estimate of future timber supply depends heavily on our site index estimates. In the Kingcome TSA, a sizable portion of the land base is considered inoperable due to low site index (Figure 2.4A). The B.C. Ministry of Forests' analysis shows that timber supply is very sensitive to the size of the harvestable land base (Figure 2.4B). Clearly, accurate site index estimates are essential to ensure that the size of the area inoperable due to low site index is accurately estimated. Site index largely determines the yield expected from regenerated stands. Figure 2.4C shows that the Kingcome TSA timber supply analysis is sensitive to our yield expectations for regenerated stands. Clearly, we must ensure that we have accurate site index estimates so that we can develop accurate expectations for the yield of regenerated stands. Site index partially determines the number of years it will take a stand to reach green-up height. Figure 2.4D shows that our estimate of future timber supply in the Kingcome TSA is significantly affected by our estimates of time to green-up. Clearly, accurate site index estimates are required to increase the accuracy with which we can predict years to green-up.

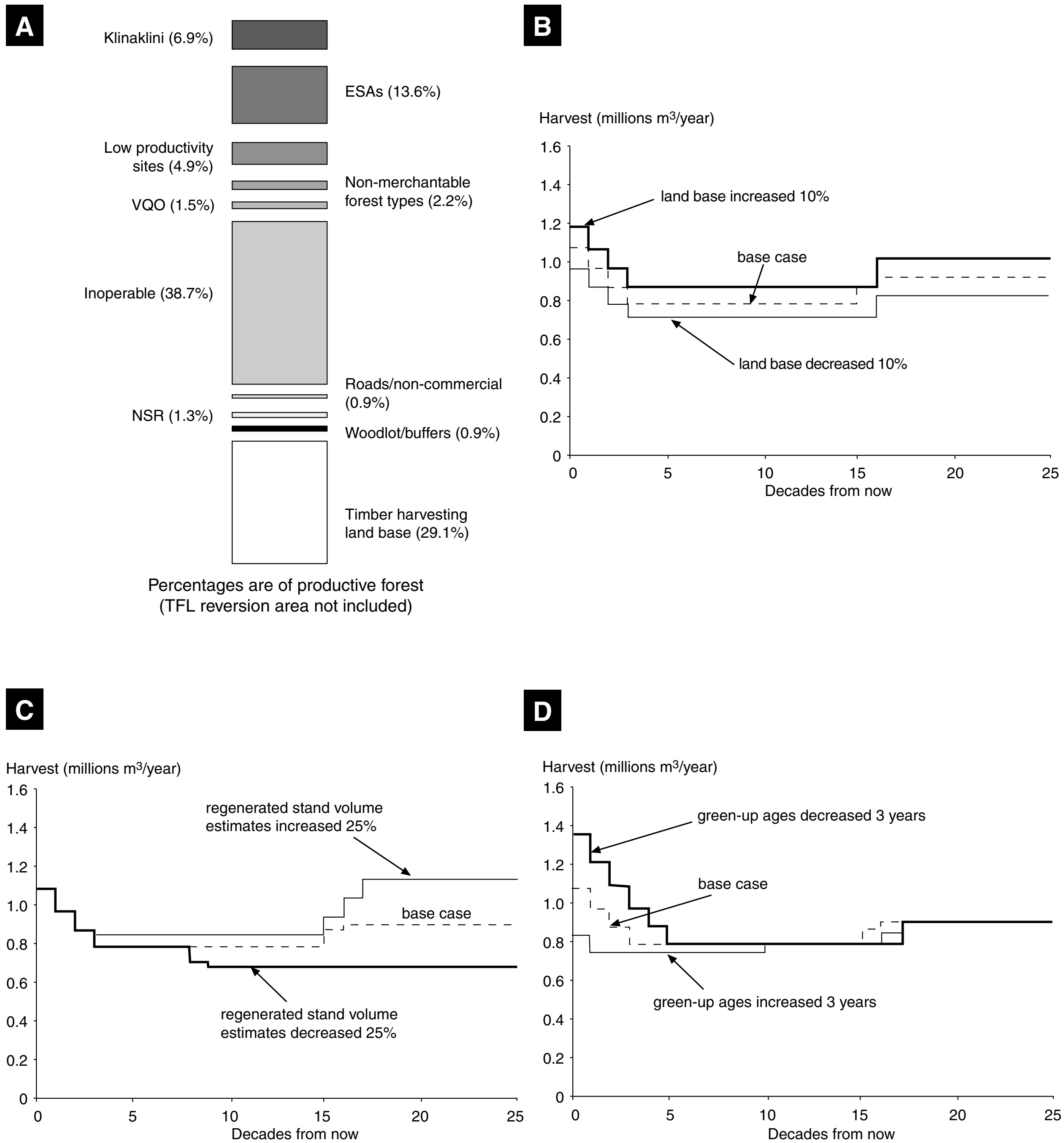


Figure 2.4. Effect of site index on timber supply analysis in the Kingcome TSA: A) portion of land base inoperable due to low site index. Sensitivity of timber supply analysis to B) uncertainty in size of harvestable land base; C) yield of regenerated stands; and D) estimated time to green-up.

In some management units, recent sampling programs have confirmed that site index is underestimated. Figure 2.5 provides an example of two management units where SI was found to be underestimated, improved SI estimates were obtained, and these estimates were used in timber supply analysis. Figure 2.5A shows the change in estimated timber supply in MacMillan Bloedel's TFL 44 after improved site index estimates were obtained. Figure 2.5B shows the change in estimated timber supply in the Lakes TSA after improved site index estimates were obtained.

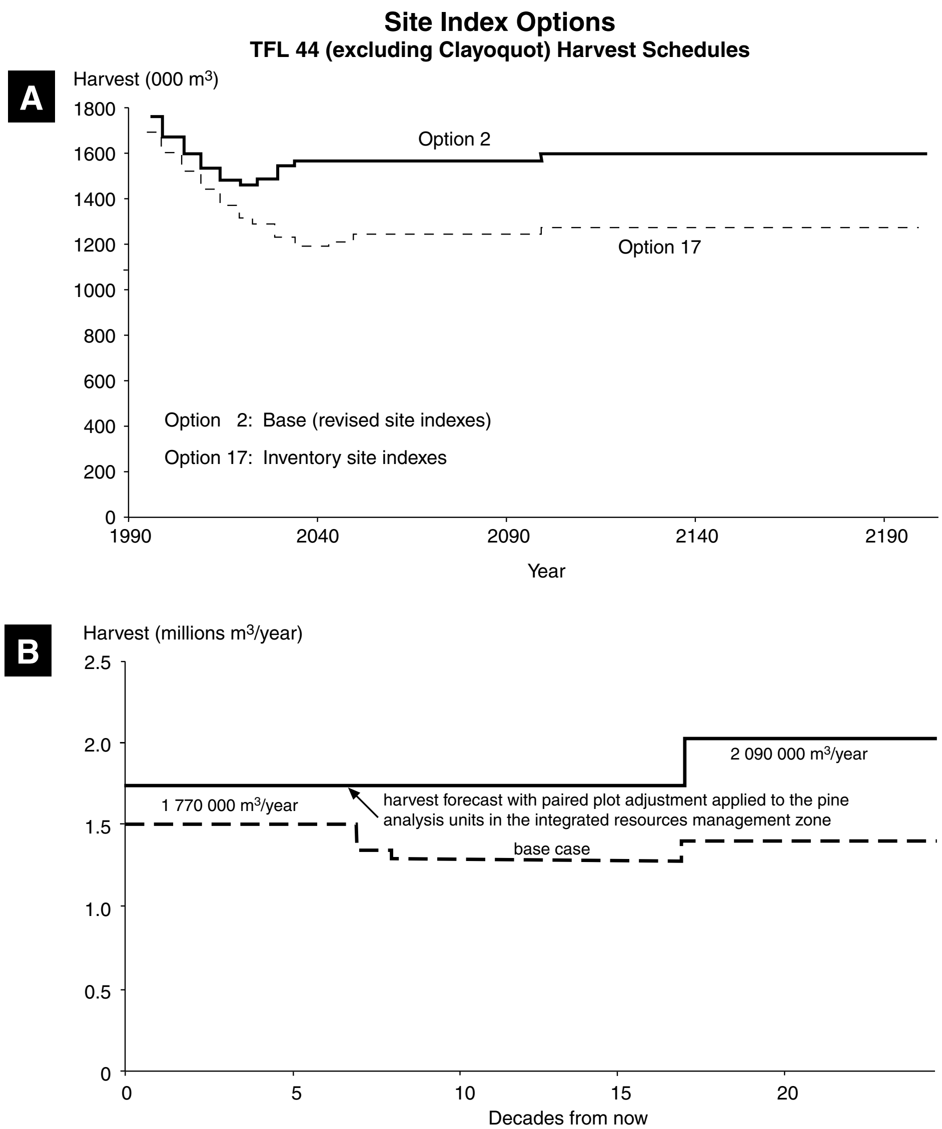


Figure 2.5. Effect of improved site index estimates on estimated timber supply in A) TFL 44 and B) Lakes TSA.

Site Index in Forest Cover Labels

SI is now used on forest cover maps and replaces the site class labels (G, M, P, L).

Figure 2.6 shows the former map labels and the ones currently used.

Old Labels **New Labels**

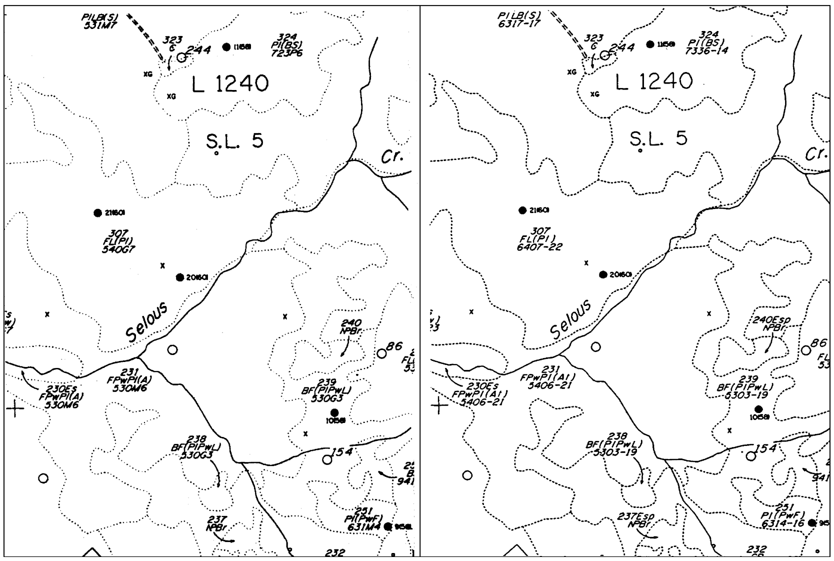


Figure 2.6. Format of old and new forest cover map labels.

Consider these two labels for a polygon (Figure 2.7):

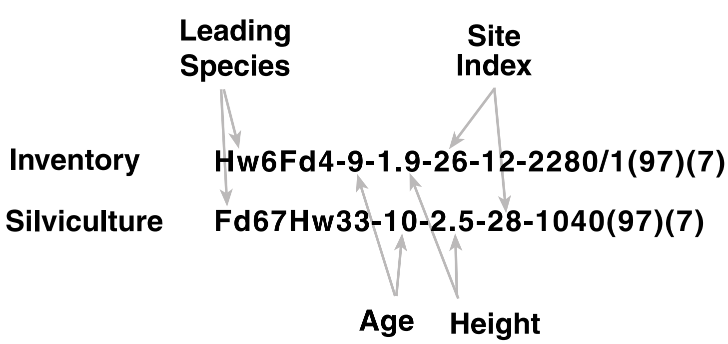


Figure 2.7. Inventory and silviculture labels for a polygon.

Note the following:

1. Site index is only reported for one species in the label – the leading species (Hw in the inventory label and Fd in the silviculture label).
2. If the silviculture and inventory labels have the same leading species, they must have the same site index. If they differ, site index may differ.
3. Age is total age – not breast height age.
4. Height is average height – not top height.
5. The trees sampled for height and age may not be unsuppressed and undamaged.
6. Height and age may be estimated – not accurately measured.
7. In a multi-layered stand, all layers with the same leading species must have the same SI.

Problems with Incorrect Site Index Determinations

It is important to correctly estimate SI. Incorrect SI estimates can lead to a variety of problems, including:

- inappropriate silviculture prescriptions
- inability to accurately schedule and plan for future treatments (as required under SMPs)
- inability to prioritize treatment dollars to the best sites
- incorrect estimates of the growth potential of regenerated stands
- incorrect information in the silviculture and inventory databases
- inaccuracies in the timber supply analysis.

When/Where is SI Recorded?

Site index should be recorded on silviculture prescriptions (SP) and stand management prescriptions (SMP).

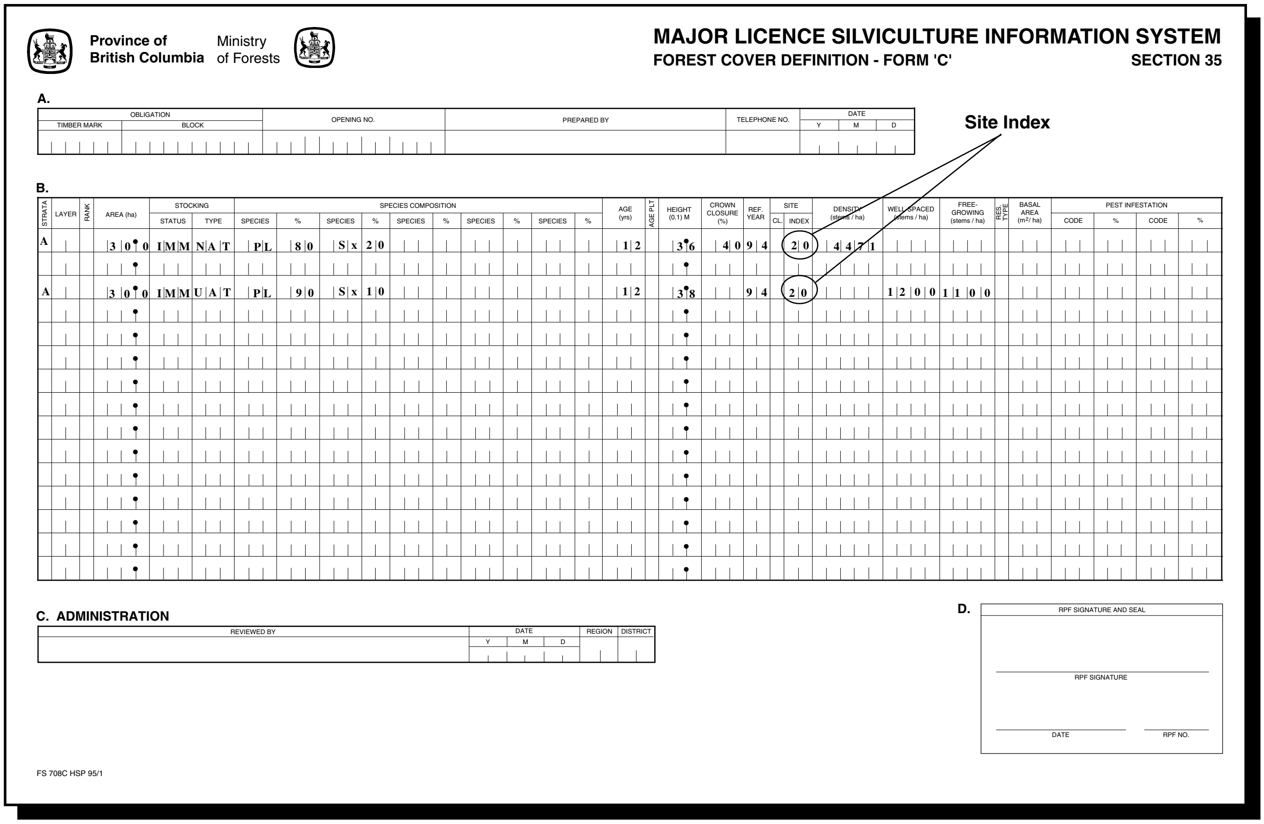
SI must be recorded on all legally required silviculture surveys (e.g., stocking and free growing surveys). All small business, FRBC and government funded silviculture surveys (including I/O and M/O) should provide SI.

SI is required on all MLSIS form C submissions (Figure 2.8). It is required for all ISIS forest cover screen updates (Figure 2.9). SI is required on the FS 810A (Inventory Forest Cover Attribute Form).

FPC and SI

SI is a requirement under the Forest Practices Code. SI is required in both the inventory and silviculture labels in regeneration and free growing survey reports (Silviculture Practices Regulation 25(b) viii and 28(1)(c)). If these labels have different leading species, two unique SI values are required for the stratum.

SI is required (Silviculture Practices Regulation 26(1)(b)(4)) in the survey report that must follow intermediate harvest (e.g., commercial thinning).



Province of British Columbia Ministry of Forests

MAJOR LICENCE SILVICULTURE INFORMATION SYSTEM

FOREST COVER DEFINITION - FORM 'C' SECTION 35

A.

OBLIGATION: TIMBER MARK	OBLIGATION: BLOCK	OPENING NO.	PREPARED BY	TELEPHONE NO.	DATE Y	M	D

Site Index

B.

STRATA	LAYER	RANK	AREA (ha)	STOCKING STATUS	STOCKING TYPE	SPECIES	%	SPECIES	%	SPECIES	%	SPECIES	%	SPECIES	%	AGE (yrs)	AGE PLT	HEIGHT (0.1) M	CROWN CLOSURE (%)	REF. YEAR	SITE CL.	SITE INDEX	DENSITY (stems / ha)	WELL SPACED (stems / ha)	FREE-GROWING (stems / ha)	RES. TYPE	BASAL AREA (m²/ ha)	PEST INFESTATION CODE	%	CODE	%
A			30.0	IMM	NAT	PL	80	Sx	20							12		3.6	40	94		20	4471								
A			30.0	IMM	UAT	PL	90	Sx	10							12		3.8		94		20		1200	1100						

C. ADMINISTRATION

REVIEWED BY	DATE Y	M	D	REGION	DISTRICT

D.

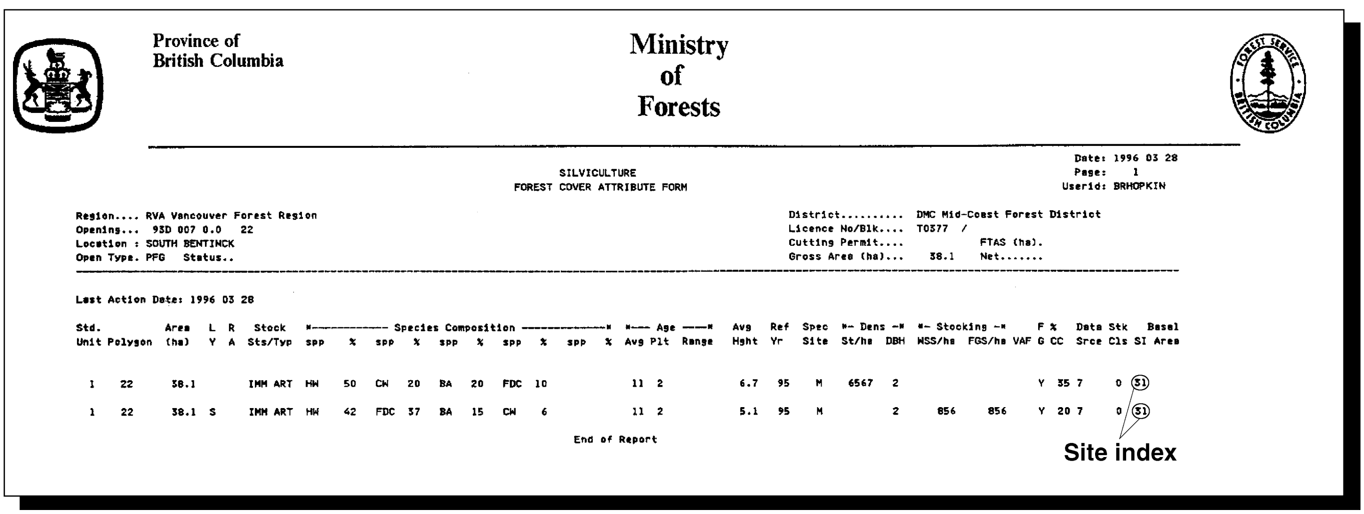
RPF SIGNATURE AND SEAL

RPF SIGNATURE

DATE RPF NO.

FS 708C HSP 95/1

Figure 2.8. MLSIS form C.



Province of British Columbia

Ministry of Forests

Date: 1996 03 28
Page: 1
Userid: BRHOPKIN

SILVICULTURE
FOREST COVER ATTRIBUTE FORM

Region.... RVA Vancouver Forest Region
Opening... 93D 007 0.0 22
Location : SOUTH BENTINCK
Open Type. PFG Status..

District.......... DMC Mid-Coast Forest District
Licence No/Blk.... T0377 /
Cutting Permit.... FTAS (ha).
Gross Area (ha)... 38.1 Net.......

Last Action Date: 1996 03 28

Std. Unit	Polygon	Area (ha)	L Y	R A	Stock Sts/Typ	spp	%	spp	%	spp	%	spp	%	spp	%	Age Avg	Plt	Range	Avg Hght	Ref Yr	Spec Site	Dens St/ha	DBH	Stocking WSS/ha	FGS/ha	VAF	F G	% CC	Data Srce	Stk Cls	SI	Basal Area
1	22	38.1			IMM ART	HW	50	CW	20	BA	20	FDC	10			11	2		6.7	95	M	6567	2				Y	35	7	0	31	
1	22	38.1	S		IMM ART	HW	42	FDC	37	BA	15	CW	6			11	2		5.1	95	M		2	856	856		Y	20	7	0	31	

End of Report

Site index

Figure 2.9. ISIS forest cover report.

SI Source Codes

SI estimates vary in accuracy due, in part, to the method used to estimate SI. The Ministry of Forests data capture software, data files, and data forms are being converted to accept a SI source code along with every SI estimate. The SI source codes are:

A	SI from adjacent stand
C	SI from site index curve
E	SI from Biogeoclimatic Ecosystem Classification
H	SI from stand before harvest
I	SI from growth intercept
M	SI from G, M, P, L site classes
O	SI from provincial SIBEC rollover, Nov. 1998
S	SI assigned by District Silviculture Section

As of March 1999, these codes were fully implemented in ISIS only.

Biased Site Index and Stands Growing Below Potential

Site index is a measure of the site's potential to grow trees. However, the stand that is currently on the site may not express potential, and may not achieve potential, due to:

- overtopping by brush or trees
- excessive establishment density
- damage by insects, disease, snow, etc.
- treatment such as excessive pruning or thinning-out of top height trees.

When these factors have reduced the height growth of top height trees, and when site index is predicted from top height tree height and age, the resulting site index estimate is biased. It underestimates site potential. Some have called this value the "expressed site index" or "indicated site index." "Biased site index" is the term that will be used in this course.

A biased site index should not be entered into the site index field of any form or database, but it may be useful as input to a growth and yield model to estimate the future growth of some types of stands that are growing below their potential. Though this topic needs further research, it appears that this approach is appropriate for stands where height grows smoothly and continuously along a reduced height-age curve – like a stand growing on a poorer site. The best example of this is repressed Pl stands. Height and age measurement in a repressed Pl stand input to a site index curve, yield a site index estimate that is well below true site potential. However, because repressed Pl stands have top height development like lower SI, unrepressed stands, their future growth is best predicted with this biased SI as input to the GY model (Figure 2.10). Biased site index estimates are the best input for estimating the future growth of this special stand type.

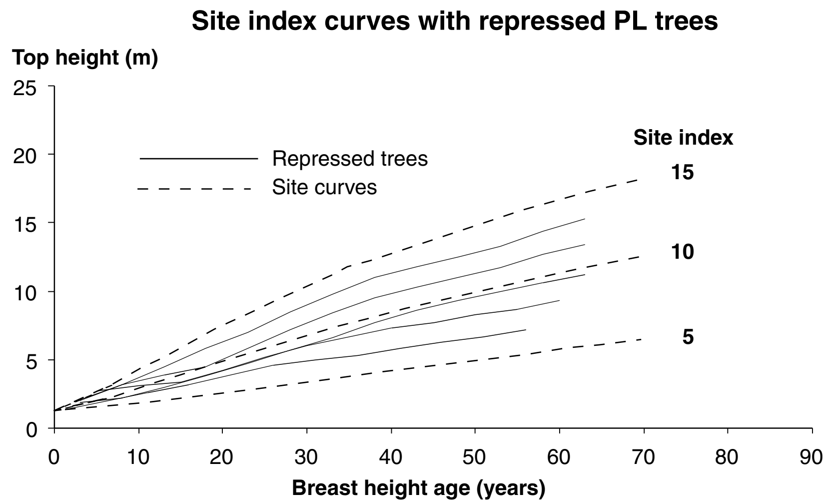


Figure 2.10. Top height growth of repressed Pl. (Source: J. Goudie, B.C. Min. Forests, Research Branch.)

Site Index and Yield

The actual timber yield achieved by a stand depends on many factors. While the SI of the growing site is one important factor, other important factors include species composition, stocking, treatment, and losses to pests, disease, and damage. High SI does not guarantee high yield. For example, high site land with no trees on it, produces no timber volume. Figure 2.11 compares the yield expected from an understocked Pl stand on SI = 20 m with the yield that can be expected with full stocking.

A site may have high growth potential (SI) for conifers, but if deciduous trees establish a thick canopy above the young conifers, the site will produce little conifer volume. A high site may have the potential to grow trees rapidly, but if the trees are killed or repeatedly damaged by pests and disease, little timber volume will accumulate. Figure 2.12 provides a hypothetical example of the different yields that can be achieved by Pl stands on SI = 20 m. Scenario A includes delayed regeneration, inadequate stocking, and heavy brush competition and losses to pests. Scenario B includes patchy but adequate stocking, with some brush competition and moderate losses to pests. Scenario C includes prompt regeneration, full stocking, and no brush competition or losses to pests.

To produce an accurate estimate of yield, a stand growth model requires an accurate description of SI, stocking, species composition, and expected losses to pests and disease. The model user must not focus solely on SI.

Tree Growth Response to Improved Site Quality

Compared to a poor site, a site that is "better" for a given tree species provides the required resources (e.g., light, soil water, soil nutrients, CO_2) and environmental conditions (e.g., temperature, soil aeration) at levels that are closer to optimum for more days of the year. Under these favourable conditions, trees achieve more growth; top height growth is greater and stands attain a greater top height at bh age 50 years. Thus, the site has a greater site index. The increased height growth of trees ***on better sites*** can be understood as a result of four factors (Figure 2.13):

1. ***Resource availability*** – a greater quantity of resources are available per day and there are more days in the growing season.
2. ***Resource capture*** – trees can support more foliage thus capturing more of the available light.

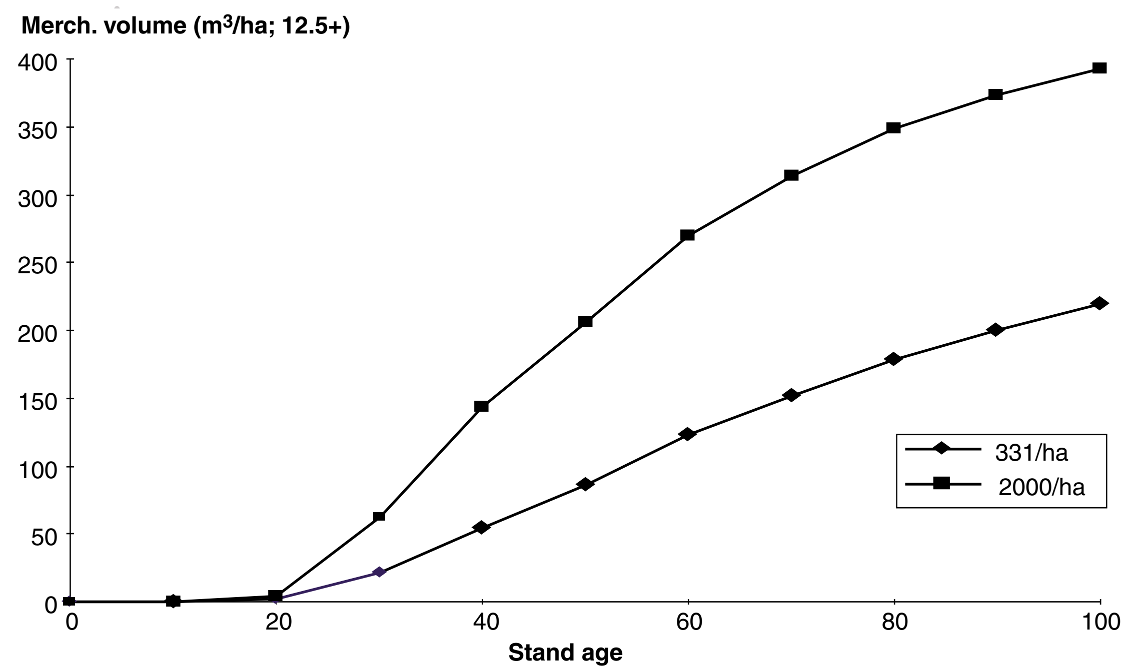


Figure 2.11. Yield predictions for understocked and well-stocked Pl stands on SI = 20 m. (Source: TIPSY 2.1.)

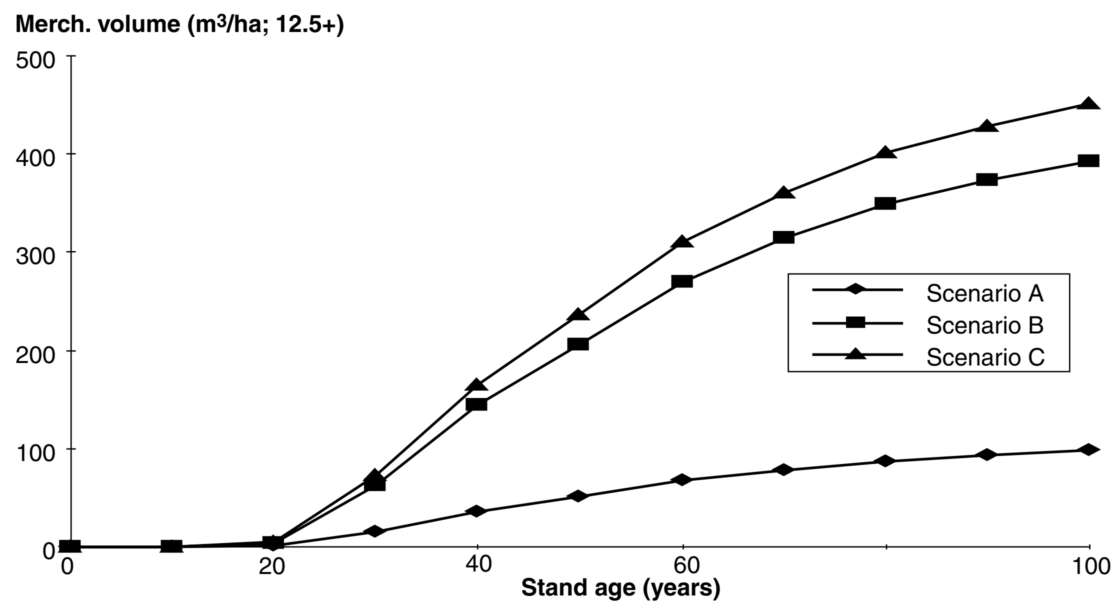


Figure 2.12. Yields of hypothetical Pl stands on SI = 20 under three management scenarios.

3. ***Efficiency of resource use*** – the resources that have been captured are used more efficiently. More photosynthate is produced per unit of resources captured. The efficiency of resource use is greater as:
   a) there are fewer days in the growing season where soil moisture deficit, frosts, air moisture vapour pressure deficits, and other environmental conditions limit photosynthesis; and
   b) improved nutrient levels in the leaves improves the yield of photosynthate per unit of captured light.
4. ***Allocation to roots*** – underground resources (e.g., soil moisture and nutrients) are acquired more easily. Thus, the tree needs to allocate less of its photosynthate to the roots, leaving a greater proportion to be allocated to stem growth. The increased top height growth on better sites is the result of the combined effect of these tree responses to improved site quality.

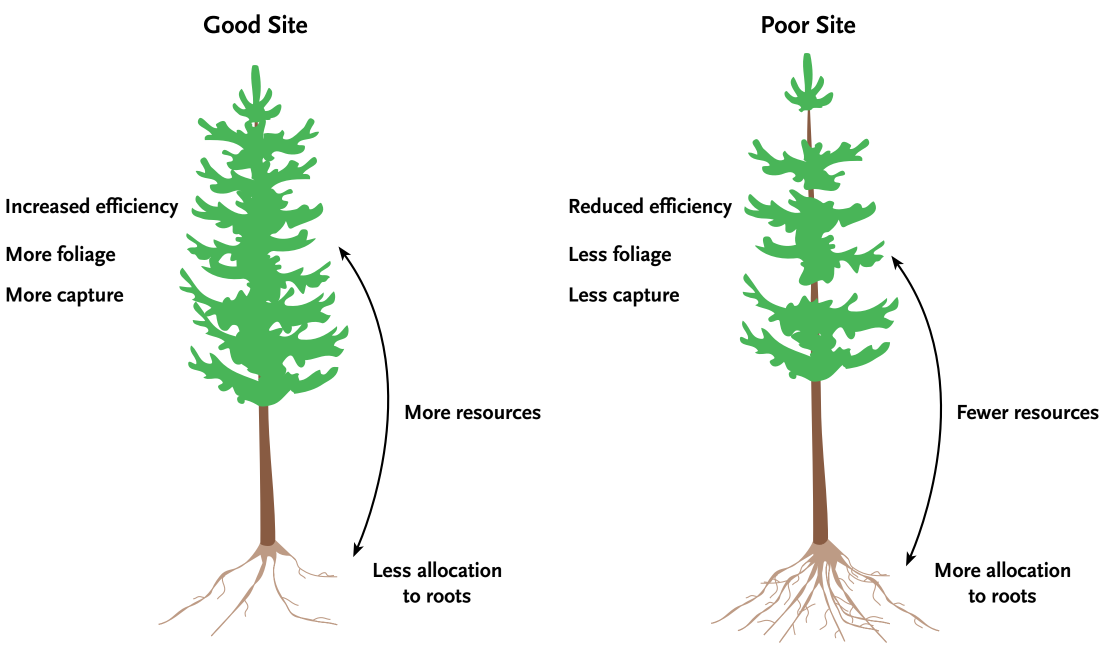


Figure 2.13. Tree height growth is greater on better sites due to greater resource availability, resource capture, efficiency of resource use, and allocation to stem growth.

Lesson 3

Overview of Methods for Estimating Site Index

Lesson Objective

Review the methods for estimating site index.

Methods for Estimating SI

There are several methods for estimating SI. These different methods produce SI estimates that differ in accuracy.

Site index can be determined from field collected data (preferred procedure) or office procedures. However, SI can be very inaccurate if it is determined from office procedures such as:

- entering inventory label height and age into a SI curve
- using the SI value from a nearby area
- converting site class to SI.

There are three methods that use ground collected data. They are accurate and best suited for silviculture work. These methods are:

- **biogeoclimatic ecosystem classification method (BEC)**
- **growth intercept method**
- **site index curve method**

These methods are each suited to specific stages of stand development (Figure 3.1).

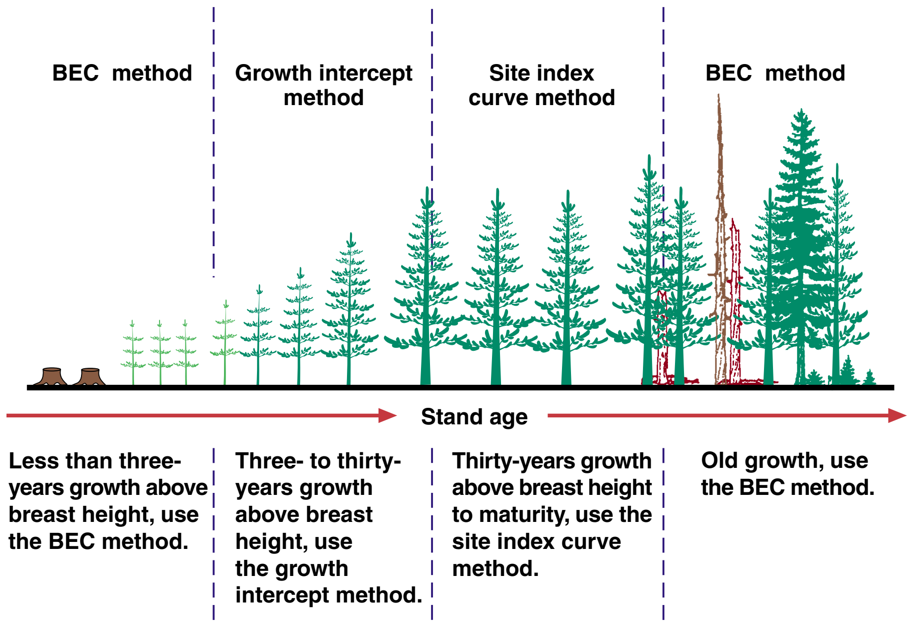


Figure 3.1. SI methods commonly used at various stand ages.

BEC Method

The BEC method (Lesson 4) uses the biogeoclimatic ecosystem classification of a stratum to predict SI. Generally, SI is predicted from subzone and site series.

The BEC method is best used in very young stands, very old stands, and stands not suitable for other methods.

Growth Intercept Method

The growth intercept method (Lessons 5 and 6) uses the height and age of sample trees measured on site to predict SI.

This method is best used on stands that have between 3- and 30-years growth above breast height.

Site Index Curve Method

The SI curve method (Lesson 7) uses the height and age of sample trees measured on site to predict SI.

This method is best used on stands that have between 30- and 140-years growth above breast height.

Site Class Conversion Table

To use the site class conversion table (Lesson 8), the surveyor estimates site class and converts it to SI.

This method of obtaining SI should only be used in those cases where a more accurate method is not available.

Two Useful Tools

1. SI Method Decision Key

A decision key (Lesson 9) has been developed to assist surveyors in determining the appropriate method to use to estimate SI.

2. Species Conversion Table

A species conversion table (Lesson 10) is available to predict the SI for one species from the SI measured on a different species on the same site.

Notes

Lesson 4

BEC Method

Lesson Objective

Learn how to use the BEC method to estimate site index.

BEC Method

With the BEC method, the SI for a stratum is predicted from its subzone and site series. The BEC method is best suited to stands that have less than three-years growth above breast height and older stands not suitable for the growth intercept and site index curve methods (Figure 4.1). The BEC method produces SI estimates of moderate accuracy. When correctly used, the growth intercept and site index curve methods produce more accurate SI estimates.

If a standards unit or strata contains more than one site series, estimate the percent of area by site series and compute an average SI weighted by site series percent.

Previously, the BEC method was available for use in the regional eco-guides of the Vancouver, Nelson and Prince Rupert forest regions. Each region had its own format for presenting the information. A standard format covering the entire province was released in the fall of 1997.

Figure 4.1. Stands suited to BEC include A) recently harvested, and B) old-growth stands.

Old Vancouver Forest Region Format

Each site series in each BEC unit was assigned to a site class (Figure 4.2). There were four site classes (I, II, III, IV). For each class, the available SI data were shown in box plots. Where enough data were available, box plots were given for Ba, Cw, Fd, Hw, and Ss.

For a given species, the box plot showed the minimum, maximum, and median SI in the site class. The median SI was the line in the middle of the box. The box indicated the range in which the middle 50% of the SI data was located.

To obtain SI for a species on a site series, the surveyor determined which site class the site series was in, and then read the median SI out of the appropriate box plot.

Section 6.3 of the Vancouver Forest Region Region eco-guide provides more information on these SI estimates.

Exercise:

Given the following site series, use the old Vancouver Forest Region format for the BEC method to determine SI:

CWHdm/07	Fd
CWHdm/60% 01 and 40% 05	Fd
CWHdm/02	Pl

Old Prince Rupert Forest Region Format

For each site series, the tree species that commonly occur on the site series were placed on a site index scale (Figure 4.3). The scale ran from site index 0 to 40 m. To obtain SI for a species on a site series, the user read the position of the species code on the site index scale. Site index was not provided for species and site series where there was inadequate data. Section 7.2.2 of the Prince Rupert Forest Region eco-guide and footnotes on each table provide more information on these SI estimates.

Exercise:

Given the following information, use the old Prince Rupert Forest Region format for the BEC method to determine SI:

CWHwm/01	Hw
CWHwm/60% 01 and 40% 02	Hw
CWHwm/01	Ba

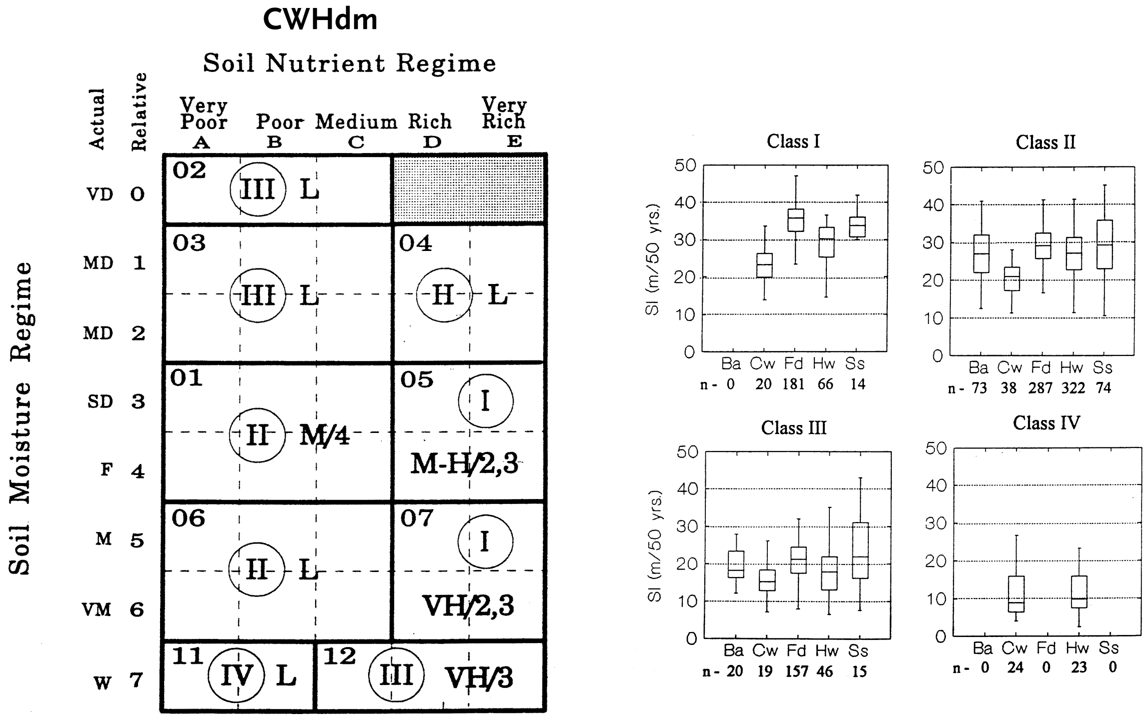


Figure 4.2. Old Vancouver Forest Region format for BEC method – CWHdm.

CWHwm Interpretations Table[a]

Site series	Productivity[b] Site index - ht (m) at 50 yr (0 10 20 30 40)	Limiting factors for productivity and regeneration	Vegetation potential & complexes[c]
01	Hw Ss	Slope stability. Root restrictions on 01b. Deep LFH (Mors) limit nutrient availability on some sites.	Medium ES, FW
02	Hw Ss	Slope stability. Moisture and nutrient deficits. Root restrictions on shallow soils. Wind exposure.	Low ES
03	Hw Ss	Slope stability. Competing vegetation.	High RS, SB, FW
04	Hw Ss	Slope stability. Competing vegetation.	Very High RS, SB, FW, FN
08	Hw Ss	Saturated, mineral soils and wet, peaty LFH restrict rooting, nutrient availability, and productivity. Cemented horizons also restrict rooting.	Medium ES
09	Hw Ss	Saturated, poorly aerated soils limit rooting and productivity.	Medium SB, FN
10	Pl	Saturated, peaty soils severely limit rooting, nutrient availability, and productivity.	Medium ES

[a] Refer to Section 7.2 for an explanation of each category in the table. Interpretations for active fluvial ecosystems (05, 06, 07) are presented on page 7•46 for all CWH subzones.

[b] Site index estimates are based on unpublished Ministry of Forests data; very limited data for the CWHwm.

[c] Vegetation potential and complexes are described in Section 7.2.4, page 7•18.

Figure 4.3. Old Prince Rupert Forest Region format for BEC method – CWHwm.

Old Nelson Forest Region Format

For each site series, average SI was provided for one shade-intolerant tree species that commonly occurred on the site series (Figure 4.4). Site index was not provided if there was inadequate data. Section 3.6.2 of the Nelson Forest Region eco-guide and footnotes on each table provide more information on the SI estimates.

Exercise:

Given the following information, use the old Nelson Forest Region format for the BEC method to determine SI:

MSdk/01	Fd
MSdk/60% 01 and 40% 04	Fd
MSdk/01	Pl

MSdk
Management Interpretations[a]

Site series	Number of plots	Common seedling growth limiting factors[a,b]	Relative tree productivity: Gross volume productivity	Relative tree productivity: Growth class (site index, tree species)	Vegetation potential - common complexes[c]	Road drainage control needs (see cautions[a,d])	Common site sensitivities (see cautions[a,e])	Other prescription considerations
02	3	Dry soil, Cold soil	None to Very low	Poor[f] (15, Fd)	Low - grass	Low	H displacement hazard on moderate slopes	No timber values
03	9	Dry soil, Nutrients	Low	Medium[f] (17, Fd)	Low - dry shrub	Mod.	H forest floor displacement on all sites; H displacement hazard on moderate slopes	Partial cutting recommended; Conserve limited organic matter
04	31	Cold air temp., Dry soil, Cold soil, Nutrients	Low	Medium (16, Fd)	Low - pinegrass	Mod.	H forest floor displacement hazard on all sites; H displacement and mass wasting hazards on steep slopes; H surface erosion hazard on moderate slopes; H compaction hazard on silty soils	Conserve limited organic matter; Special road construction/maintenance on steep slopes; Random machine travel on silty soils when dry or on snowpack
01	52	Cold air temp., Cold soil	Med.	Medium (19, Fd)	Medium - mixed shrub, fireweed, dry alder	High	H compaction hazard on silty soils	Random machine travel on silty soils when dry or on snowpack
05	15	Cold air temp., Cold soil, Nutrients (on clay soils)	Med.	Good[f] (23, Fd)	Medium - mixed shrub, fireweed	High	H-VH compaction hazard on silty and clayey soils; H forest floor displacement hazard on clayey soils	Conserve organic material on clayey soils; Random machine travel on clayey soils on snowpack
06	11	Cold air temp., Cold soil	Med.	Good[f] (21, Fd)	Medium - mixed shrub, fireweed	High	H compaction hazard on silty soils	Windthrow hazard; Water table may rise post harvest; Random machine travel on silty soils on snowpack; Riparian
07	5	Wet soil, Cold soil, Cold air temp.	None or Very low	No data	Medium - sedge	High	H compaction and displacement hazards on organic soils	Nonforested fen and bogs; No timber values; Riparian

[a] **Caution:** Based on sample plot data; some interpretations expected to vary with individual site conditions. Use of original interpretive tools is necessary; these interpretations are presented here to "red flag" common concerns. This table outlines key considerations that should go into management decisions. Rationale and interpretive tools are discussed in Section 3.6.

[b] These include air temperature, soil temperature, vegetation, soil moisture, and soil nutrients; use of SYTEPREP recommended, see Section 3.6.1.

[c] Complexes described in Newton and Comeau (1990).

[d] **Caution:** This is presented here to "red flag" common drainage needs and is not intended to substitute for site specific engineering interpretations, see Section 3.6.4.

[e] **Caution:** Site sensitivity keys must be used with your site data for the PHSP; see Section 3.6.5. VH = very high, H = high, 30 - 45% = moderate slope, >45% = steep slope.

[f] Sample size less than five plots for site index determination.

Figure 4.4. Old Nelson Forest Region format for BEC method – MSdk.

New Provincial Format for the BEC Method

In the fall of 1997, the B.C. Ministry of Forests released the document "Site index estimates by site series for coniferous tree species in British Columbia." This book is known as the SIBEC guide (Site Index – Biogeoclimatic Ecosystem Classification). The SIBEC guide provides BEC method estimates of SI for many of the common species-site series combinations in the province. The SIBEC guide replaces the BEC method SI estimates in the Vancouver, Prince Rupert, and Nelson eco-guides.

In addition to tables of average SI by species, site series, and forest region, the SIBEC guide includes a discussion of:

1. the relationships between SI and soil moisture, soil nutrients, and biogeoclimatic subzone;
2. the accuracy that can be expected from the BEC method and its limitations; and
3. the overall SIBEC program.

SIBEC Guide Tables

Figures 4.5 to 4.7 provide examples of the SIBEC guide tables. When these tables are compared to the previous examples of the old BEC method formats from the Nelson, Vancouver, and Prince Rupert forest regions, it is clear that the new SIBEC guide:

1. provides site index estimates for more species–site series combinations;
2. indicates the reliability of the SI estimates;
3. includes footnotes by the regional ecologists to supplement the tables;
4. provides greater resolution and clarity than the Prince Rupert and Vancouver forest region formats; and
5. provides site index as a class midpoint with 4 m classes in the CDF, CWH, and MH zones and 3 m classes in all other zones.

Vancouver CWHdm

Site series[A]	Name	Bg	Cw	Fd	Hw	Lw	Pl	Pw	Ss
01	Hw – Flat moss	x	**28** *H*	**32** *H*	**32** *H*	x	x	_	x
02[B]	FdPl – Cladina	x	x	**16** *M*	x	x	**16** *L*	x	x
03	FdHw – Salal	x	**20** *L*	**24** *H*	x	_	x	x	x
04	Fd – Sword fern	x	**24** *L*	**28** *L*	x	_	x	_	x
05	Cw – Sword fern	x	**28** *M*	**36** *H*	x	x	x	_	x
06	HwCw – Deer fern	x	**32** *L*	**36** *M*	**32** *L*	x	x	_	x
07	Cw – Foamflower	**40** *L*	**32** *M*	**40** *H*	x	x	x	x	x
08	Ss – Salmonberry	**40** *L*	**32** *L*	x	x	x	x	x	x
09	Act – Red-osier dogwood	**28** *L*	**28** *L*	x	x	x	x	x	x
10	Act – Willow	x	x	x	x	x	x	x	x
11[C]	Pl – Sphagnum	x	**12** *L*	x	x	x	**16** *L*	x	x
12[C]	CwSs – Skunk cabbage	x	**20** *M*	x	**32** *L*	x	x	_	**28** *L*
13	Cw – Salmonberry	**36** *L*	**28** *L*	**36** *L*	x	x	x	x	x
14	Cw – Black twinberry	**28** *L*	**28** *L*	x	x	x	x	x	x
15	Cw – Slough sedge	x	**24** *L*	x	x	x	x	x	x

[A] Restrictions apply to some species. See the appropriate *Establishment to Free Growing* guidebook, April, 1995.

[B] Estimates not applicable to rocky microsites or areas with very thin veneers of soil.

[C] Estimates provided only for elevated microsites.

Site index (m @ 50 yr bh) — **24** *L* — Reliability (*H* = High; *M* = Medium; *L* = Low)

x = Species generally not found on site series; _ = No estimate available

Site Index and Reliability Code **166**

Figure 4.5. New province-wide format for BEC method – Vancouver Forest Region – CWHdm.

Prince Rupert CWHwm

Site series[A,B]	Name	Ba	Cw	Hm	Hw	Pl	Ss	Yc
01	HwSs – Blueberry	**24** *L*	**20** *L*	**24** *L*	**24** *L*	x	**24** *L*	**20** *L*
02	HwSs – Step moss	x	**16** *L*	**20** *L*	**20** *L*	**20** *L*	**16** *L*	**16** *L*
03	SsHw – Oak fern	**28** *L*	**24** *L*	x	**28** *L*	x	**28** *L*	_
04	SsHw – Devil's club	**28** *M*	**24** *M*	x	**28** *H*	x	**32** *M*	_
05	Ss – Salmonberry	**28** *L*	**24** *L*	x	**28** *L*	x	**32** *L*	x
06	Act – Red osier dogwood	**28** *L*	**24** *L*	x	x	x	**32** *L*	x
07	Act – Willow	x	x	x	x	x	x	x
08	Hw – Sphagnum	x	**12** *L*	**16** *L*	**16** *L*	**16** *L*	x	**12** *L*
09[C]	Ss – Skunk cabbage	x	**16** *L*	x	**16** *L*	x	**20** *L*	_
10	Pl – Sphagnum	x	**8** *L*	x	x	**12** *L*	x	**8** *L*

[A] Restrictions apply to some species. See the appropriate *Establishment to Free Growing* guidebook, April, 1995.

[B] Estimates for southern portion of subzone only (South of Iskut–Stikine).

[C] Estimates provided only for elevated microsites.

Site index (m @ 50 yr bh) — **24** *L* — Reliability (*H* = High; *M* = Medium; *L* = Low)

x = Species generally not found on site series; _ = No estimate available

Site Index and Reliability Code **146**

Figure 4.6. New province-wide format for BEC method – Prince Rupert Forest Region – CWHwm.

Nelson MSdk

Site series[A]	Name	Bl	Fd	Lw	Pl	Sx
01	Sxw – Soopolallie – Grouseberry	**15** *H*	**21** *M*	**21** *M*	**18** *H*	**18** *H*
02	Saskatoon – Bluebunch wheatgrass	x	x	x	x	x
03	Pl – Juniper – Pinegrass	**12** *L*	**18** *L*	**18** *M*	**18** *H*	**15** *L*
04	Pl – Oregon-grape – Pinegrass	**15** *M*	**18** *L*	**18** *M*	**18** *H*	**18** *M*
05	Sxw – Soopolallie – Snowberry	**15** *L*	**21** *M*	**21** *M*	**21** *M*	**18** *M*
06[B]	Sxw – Dogwood – Horsetail	**15** *L*	**18** *L*	_	**15** *L*	**18** *L*

[A] Restrictions apply to some species. See the appropriate *Establishment to Free Growing* guidebook, April, 1995.
[B] Estimates provided only for elevated microsites.

Site index (m @ 50 yr bh) — **24** *L* — Reliability (*H* = High; *M* = Medium; *L* = Low)
x = Species generally not found on site series; _ = No estimate available

Site Index and Reliability Code **100**

Figure 4.7. New province-wide format for BEC method – Nelson Forest Region – MSdk.

Relationships Between SI and Soil Moisture, Soil Nutrients, and Biogeoclimatic Subzone

Plant growth is greatest on moist sites. On wetter and drier sites, growth is reduced. Consequently, average SI for a species within a subzone follows a predictable pattern over soil moisture regime (Figure 4.8). The SIBEC guide SI estimates for Fd in the CWHdm reflect the expected relationship (Figure 4.9).

Plant growth increases with soil fertility. Consequently, average SI for a species within a subzone follows a predictable pattern over soil nutrient regime (Figure 4.10). The SIBEC guide SI estimates for Fd in the CWHdm reflect the expected relationship (Figure 4.9).

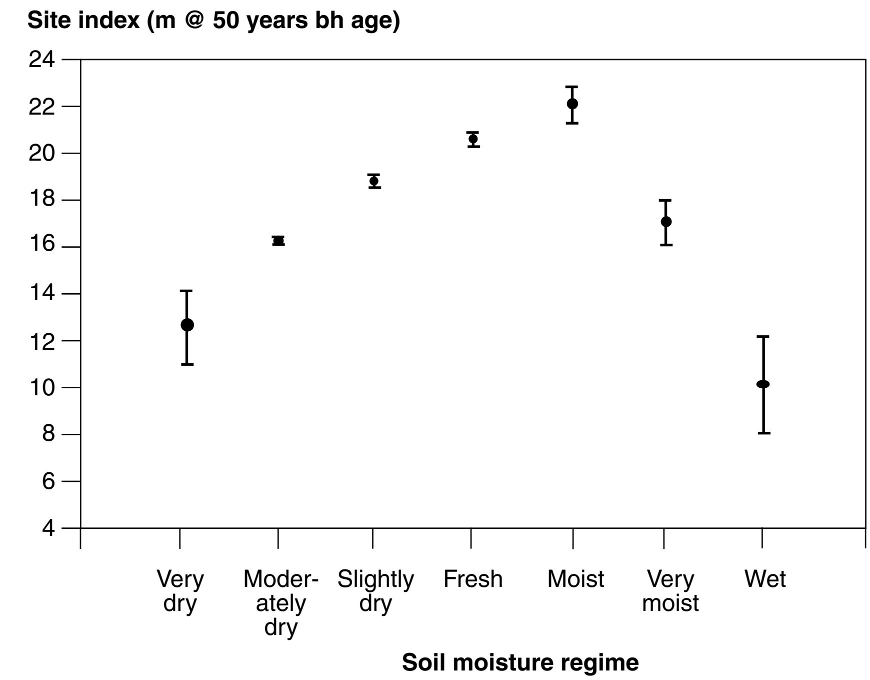


Figure 4.8. Average site index for Pl stands on nutrient poor and medium sites sampled in the SBS by soil moisture regime.

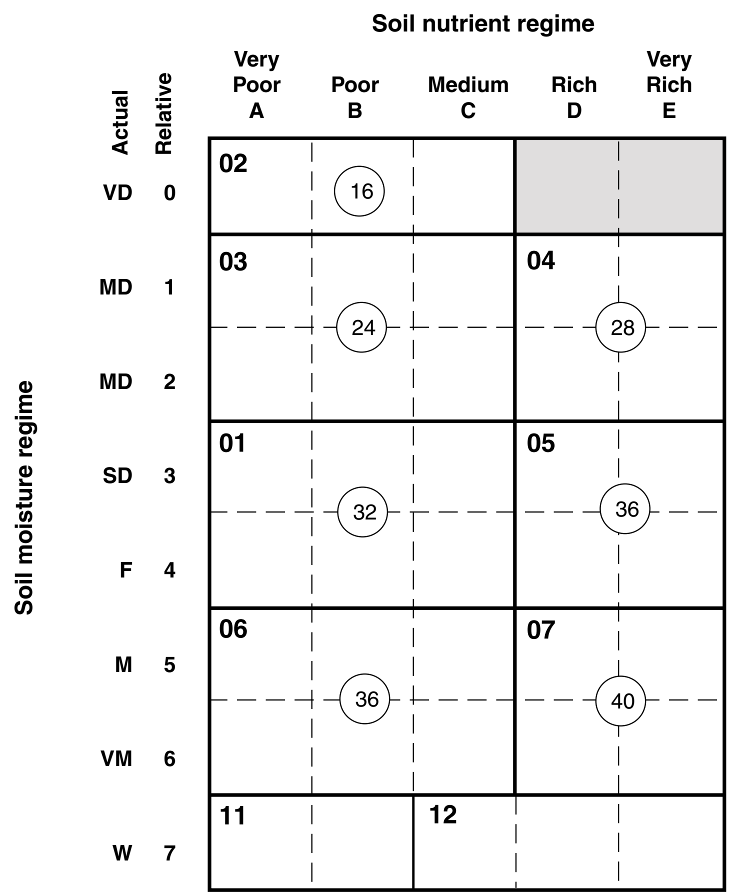


Figure 4.9. SIBEC guide SI estimates for Fd on the CWHdm (Vancouver Forest Region) edatopic grid. Site index values are circled.

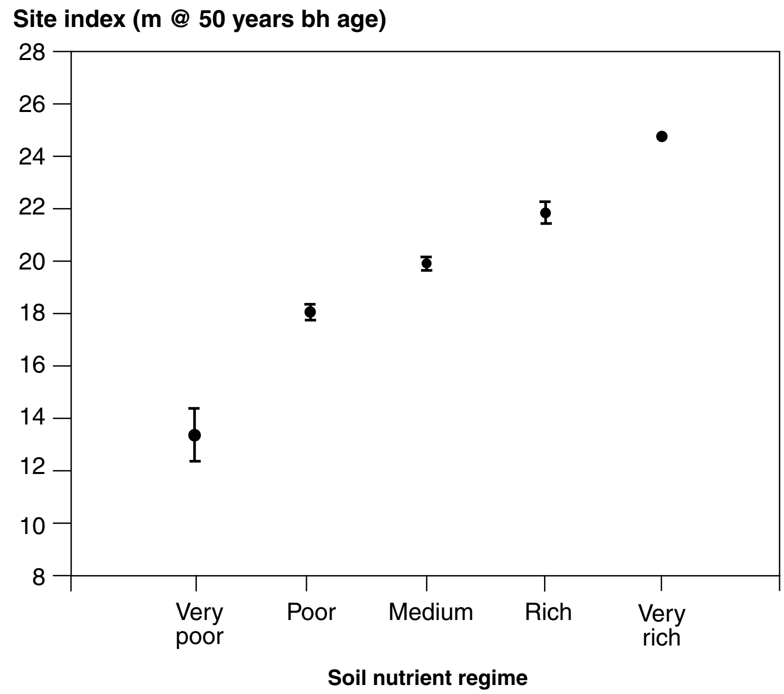


Figure 4.10. Average site index for Pl stands on slightly dry and fresh sites sampled in the SBS by soil nutrient regime.

Notes

Plant growth is partially determined by regional climate. BEC subzones are areas of distinct regional climates. So, we might expect SI to vary in a predictable manner across subzones. However, this is often not the case. Regional climate is a complex mix of numerous important elements such as average summer temperature, length of growing season, timing of precipitation, and so on. These factors often offset one another and, as a result, the average SI for a species on zonal sites may not follow a predictable pattern over BEC subzones (Figure 4.11).

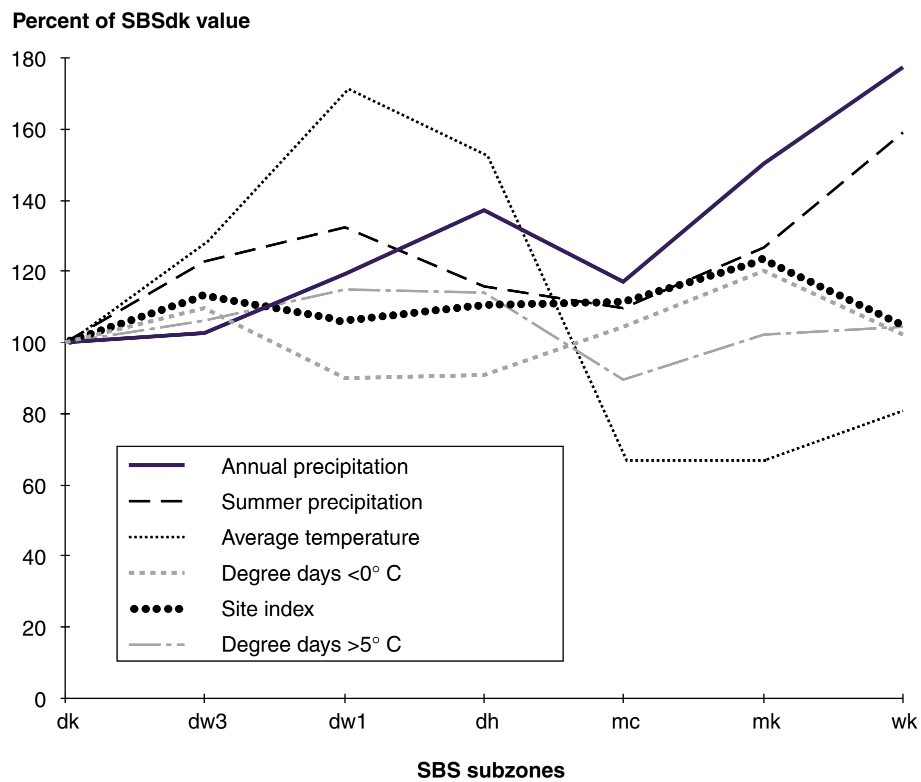


Figure 4.11. Mean Pl site index and five climate variables on zonal sites across SBS subzones expressed as a percent of their value in the SBSdk.

Most tree species display the same general ***pattern of SI*** over soil moisture and nutrient regimes that is illustrated by Pl in the SBS (Figures 4.8 and 4.10). However, species do differ in the ***actual SI level*** on a given site as illustrated by a comparison of Sx and Pl SI over soil moisture regime in the SBS on nutrient poor and medium sites (Figure 4.12).

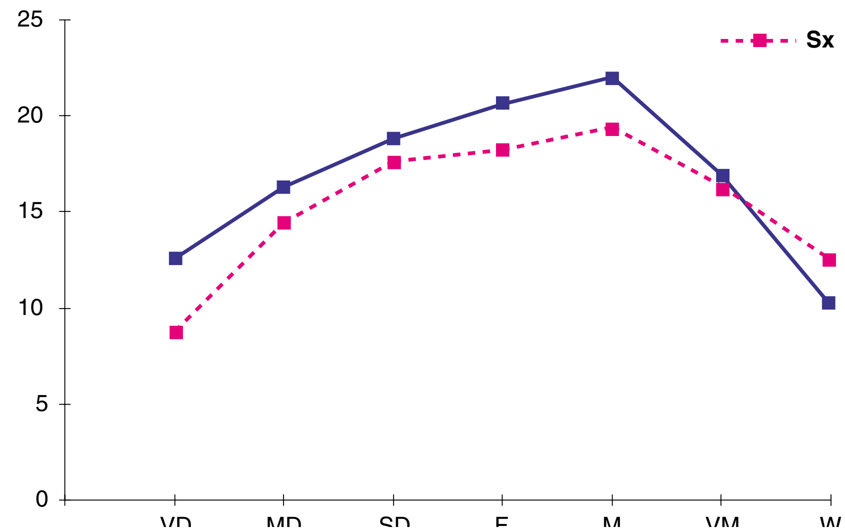


Figure 4.12. Average SI of Sx and Pl over soil moisture regime in the SBS on nutrient poor and medium sites.

SIBEC Guide Accuracy and Limitations

There are several limitations to the site index estimates provided in the SIBEC guide.

1. The SI tables do not provide site index estimates for all species and all sites.
2. The correlation between site index and site units varies from weak to moderately strong across species and sites. As a result, there are inherent limitations to the accuracy that can be obtained when this method is used to determine site index for a given tree species in a given stand.
3. The right site index estimate cannot be obtained without a correct site identification.
4. For some species and sites, the site index database is small and therefore the site index estimates given in the tables are imprecise.
5. The site index database was compiled from sources of varying quality and this contributes to uncertainty in site index.
6. Site index averages are based on data from naturally established, unmanaged stands and site index estimates for managed stands may be different.

Accuracy for Site Index of Single Stand

For many coastal species and sites, site index on two-thirds of individual sites is within 4 or 5 m of the average provided in the tables. In the interior, site index on two-thirds of individual sites is within 3 or 4 m of the average provided in the tables. For example, the average site index for Fd on the CWHxm/01 is given as 32 m in the SISU table. However, the site index for any individual CWHxm/01 Fd stand can easily be 4 or 5 m above or below the average.

When tested against an independent data set of 706 plots, the SI estimates in the SIBEC book were in the correct SI class 35% of the time. In 80% of the stands, the true SI was in the same class as the SIBEC estimate or one class above or one below (Figure 4.13).

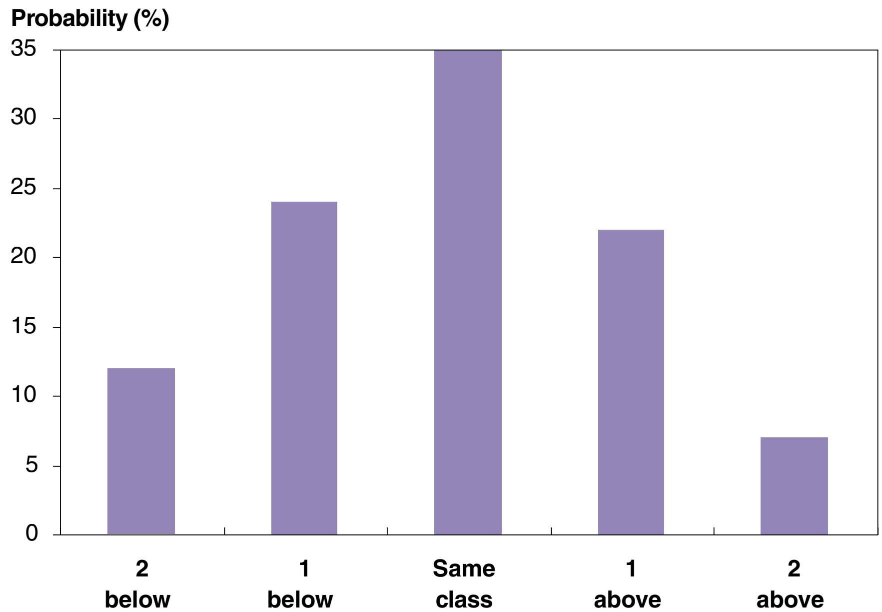


Figure 4.13. Probability that the true stand site index is in the same class as the SIBEC book estimate, or above, or below.

Accuracy for Mean Site Index of Population of Stands

For this application (i.e., estimating mean site index for a group of stands), the BEC method can achieve a high level of accuracy — assuming correct site identification and no bias.

The SIBEC Program

The overall SIBEC program is built around the provincial SIBEC database. One component of the program is SIBEC data collection. SIBEC data collected by ministry staff, licensees and researchers is added to the SIBEC database as it becomes available. Once enough new data accumulates, the SIBEC guide will be revised. The raw SIBEC database is available from:

Del Meidinger
SIBEC Project Leader/Research Ecologist
Research Branch
B.C. Ministry of Forests
Phone: 250-387-6688.

If you collect data suitable for the SIBEC database, you are requested to:

1. use the data collection standards described in the document "SIBEC sampling and data standards."
2. provide your data to the SIBEC database administrator.

Contact Del Meidinger to discuss these issues.

The site index values and reliability codes in the SIBEC guide are available in ASCII file format. Information on the SIBEC Project is available on the Internet at <http://www.for.gov.bc.ca/resinv/G&Y/Projects/spwg/SIBEC/SIBEC1.htm>.

Local SIBEC Tables

Several TFL-based SIBEC projects and numerous SIBEC research studies have been completed in British Columbia. These projects provide estimates of average SI for some sites and tree species. Where these estimates are based on an adequate sample and acceptable methods, these local estimates may be superior to the global esstimates contained in the provincial SIBEC guide.

Lesson 5

Growth Intercept Method

Lesson Objective

Learn how to use the growth intercept method to estimate SI.

Growth Intercept Method

The growth intercept (GI) method predicts SI from height and age measurements taken on carefully selected sample trees. As of March 1999, the GI method is available for the following species:

- interior lodgepole pine
- interior spruce
- coastal hemlock
- coastal Sitka spruce
- coastal Douglas-fir
- interior Douglas-fir
- interior subalpine fir
- interior hemlock

Although the GI method is the best way to estimate SI in many stands aged 3 to 30 years breast height age (Figure 5.1), another method may have to be chosen if the appropriate species tables are not available.

When correctly used, the GI method provides an accurate estimate of SI. However, the required input data (heights and ages) are costly to collect and determining ages may damage crop trees.

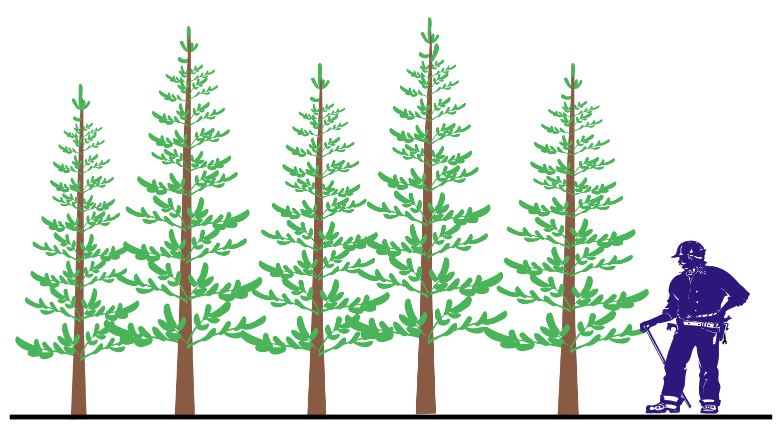


Figure 5.1. Stands suited to GI include many 3- to 30-year-old stands.

The GI method cannot be used in stands where sample trees have been:

- overtopped by trees or brush
- seriously damaged or diseased
- cut out by spacing
- affected in height growth by treatment (e.g., fertilization or thinning shock).

Note: It is best to use the BEC method for the type of stands listed above.

How to Use the GI Method

Once it has been determined that the GI method is the most appropriate for collecting SI data, there are four steps to the growth intercept method of estimating SI:

1. Pre-stratify the opening.
2. Select the site index species for each stratum.
3. Collect growth intercept data on the site index species in each stratum.
4. Compute the average SI for each stratum.

Survey Timing

Because GI data should be collected when the tree is not actively growing, GI data should NOT be collected in the spring or early summer (Figure 5.2). This is especially important for young sample trees.

This limitation can be relieved for species which form annual branch whorls if SI is estimated from partial growth as explained in Lesson 6.

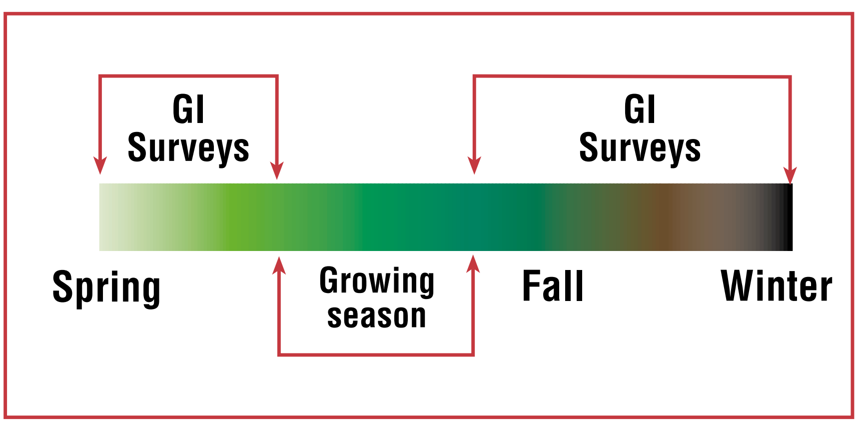


Figure 5.2. Extra caution is required on GI surveys during the growing season.

Number of Plots

As a general recommendation, surveyors plots should be:

- stratum >10 ha: 10 plots well spaced across stratum
- stratum <10 ha: 1 plot/ha.

Within each stratum, survey sample lines should be laid out to achieve uniform coverage of the entire stratum (Figure 5.3).

- **Target – 10 plots/stratum**
- **Maximum – 1 plot/ha**

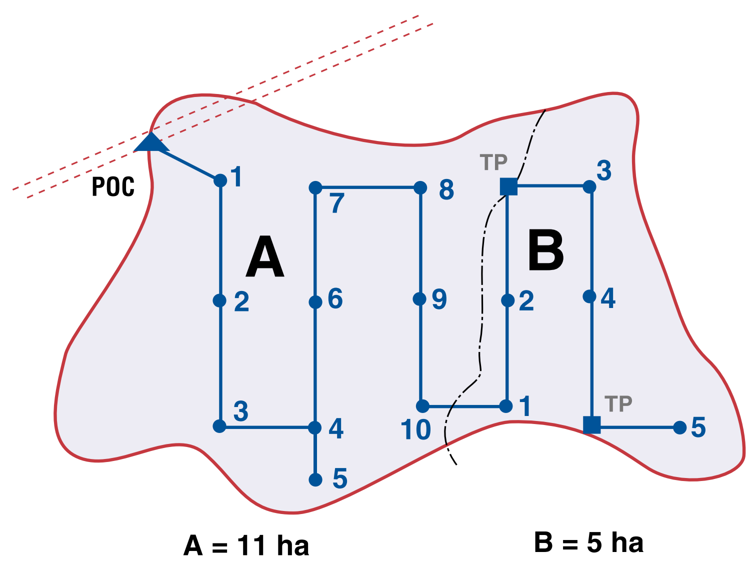


Figure 5.3. A sample grid achieves uniform coverage of the stratum.

1. Pre-stratifying the Opening

Prior to conducting any survey, the opening being surveyed should be divided into homogeneous units (strata). When the opening is stratified for a regular silviculture survey, usually no additional stratification is required to collect GI data.

The **stratification criteria** used for most silviculture surveys (i.e., site series, potential/past treatment, change in leading species, etc.) match the requirements of the GI method. The **stratification process** used for most silviculture surveys (i.e., use maps, air photos and opening file information to do the initial office stratification and confirm the boundaries with a walkthrough) provides enough information on the stratum to use the GI method.

To add GI data collection to a silviculture survey, there are two additional tasks during stratification:

- determine if conditions in the stratum are suitable for collecting GI data
- learn enough about the stratum to select a site index species.

To be suitable for GI data collection, a stratum must be well stocked with acceptable sample trees of the desired SI species (Figure 5.4).

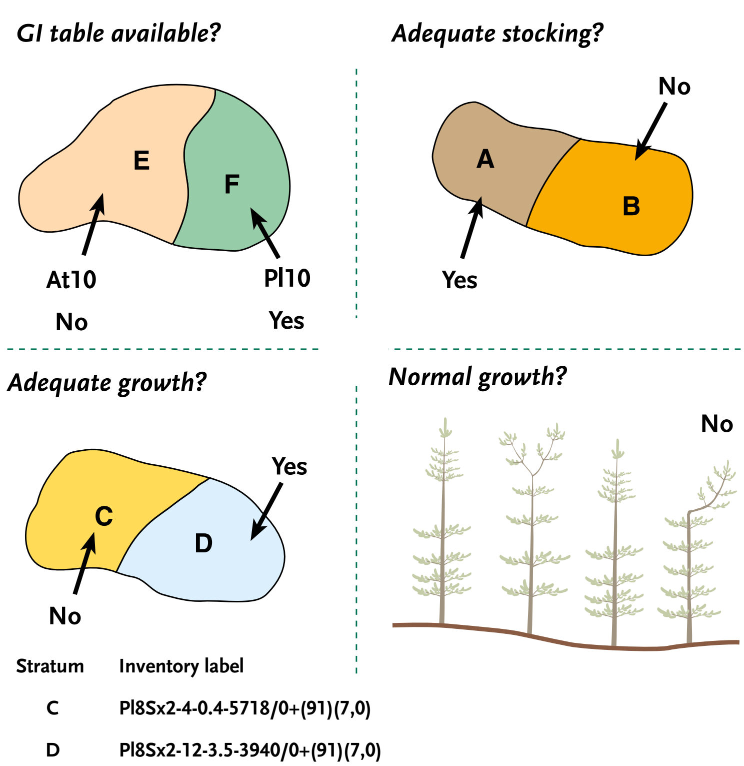


Figure 5.4. Questions to consider in stratification and selection of the site index species.

It may be determined from the office information or the walkthrough that the age of the stand is not appropriate for the GI method or that the appropriate species tables are not available. In this case, the BEC or site index curve method will have to be considered. Use the decision key to decide which method is appropriate to obtain SI (see Lesson 9).

In some cases, the stratification required for a silviculture survey results in many small strata that may differ in history, forest health or stocking status, but do not differ in site productivity and forest cover attributes. In this case, it is possible to sample the many small strata as a single stratum for GI data collection.

During stratification it may be determined that the GI method is not suitable for a portion of the stratum or for the entire stratum. If the entire stratum is not suitable for the GI method, do not collect GI data on the plots falling in that stratum.

If a portion of the stratum is unsuitable for the GI method, either treat the entire stratum as unsuitable and use another method or divide the stratum into two smaller strata. It is not acceptable to put growth intercept plots in unsuitable ground. It is acceptable to use different methods to determine SI for the different strata within an opening.

2. Select the Site Index Species

For each stratum, surveyors have to choose the species that GI data will be collected on. This species is called the site index species.

Normally, the leading species in the stratum's inventory label is chosen as the SI species. This ensures that the SI data collected in the field is compatible with the requirements of forest cover map labels and the inventory database, as well as ISIS and MLSIS.

The inventory component leading species is not an appropriate choice for site index species when it is:

- silviculturally unsuitable
- suppressed, damaged, or diseased
- scheduled to be eliminated through treatment (i.e., spacing or spraying).

Whenever this is the case, the silviculture component leading species should be chosen for the site index species.

The Code requires that SI be provided in both the inventory and silviculture labels. If the inventory and silviculture labels have different leading species, two different SI values are required. Surveyors can either collect GI data on one tree of each species in each plot or they can collect GI data on one species and use the SI conversion table to estimate SI for the other species. SI species conversion is explained in Lesson 10 of this workbook. Obviously, collecting GI data on both species will give higher accuracy.

For a stratum, a tree species is suitable as a SI species if (Figure 5.4):

- the dominant and codominant trees have at least 3-years growth above breast height
- the growth intercept table is available
- more than 500 stems/ha (total trees) are evenly distributed over the entire stratum
- sample tree height growth above DBH reflects site productivity.

Height growth above DBH may not reflect long term site productivity if the stand has experienced wide spread damage, thinning shock, fertilization or brush competition. A stand is not suitable for the GI method if these factors have altered the normal height growth. More research is needed on this subject.

3. Collect Growth Intercept Data

Once the opening has been stratified, the sample lines laid out and a site index species chosen, field data can be collected.

GI information can be collected concurrently with a silviculture survey (stocking or free growing) or during a separate survey.

If GI information is to be collected during a silviculture survey, no new sample lines or plots are required. Surveyors should use the same plot centre for both the GI and silviculture plots.

If sampling using the GI method on its own, surveyors will have to develop sample lines and establish plots strictly for GI information.

In either case, an adequate number of samples are required as discussed earlier.

A 5.64 m radius plot is used to collect SI data using the GI method (Figure 5.5). In this plot, one sample tree is assessed. There are two steps in the process of selecting a sample tree to measure (Figure 5.6):

- identify the largest DBH tree of the SI species
- determine if it is suitable to measure.

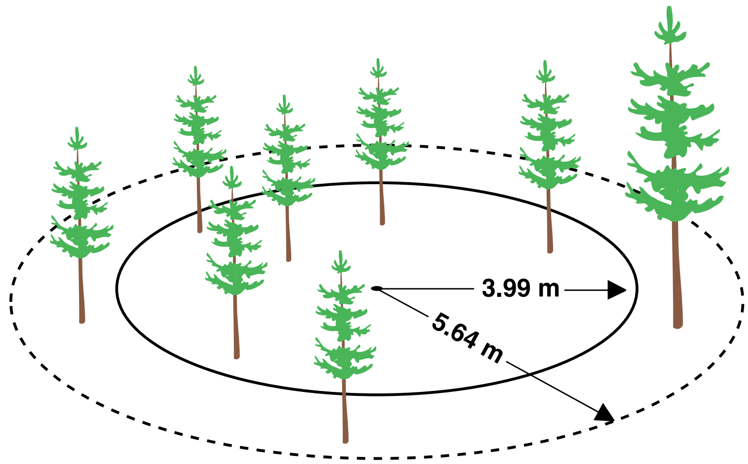
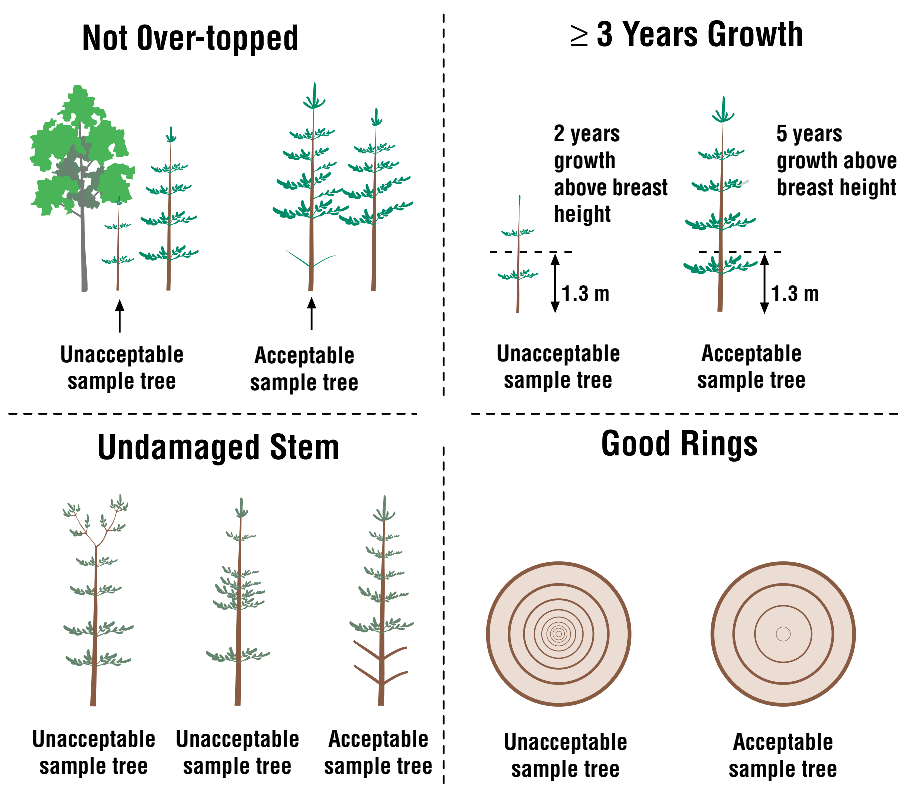


Figure 5.5. A 3.99 m silviculture plot nested within a 5.64 m GI plot.

Step 1: Find the largest DBH plot tree of site index species.

Step 2: If it is acceptable, continue with measurement.



Step 3: If tree is unacceptable, go to next plot.

Figure 5.6. Selecting GI sample trees.

In the plot, the surveyor identifies the largest DBH tree of the SI species. This is the only candidate for sampling in the plot. Then, the surveyor assesses whether this tree is suitable for measurement. To be suitable, the sample tree must have the following characteristics:

- at least 3-years growth above DBH
- undamaged stem with vigorous, uniform annual height growth above breast height
- must be in the dominant or codominant crown class and not over-topped by other trees or brush
- ring width should be vigorous and uniform.

If the plot does not contain a suitable sample tree, do not collect GI information. If dropping plots results in not enough samples for a stratum, then surveyors can offset GI plots using a consistent method.

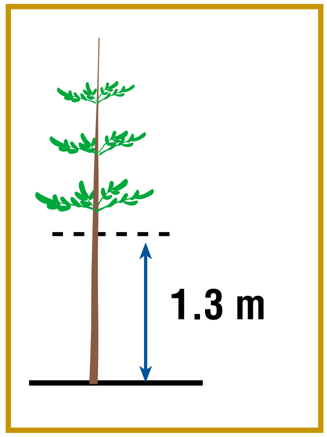
Once the sample tree has been selected, the surveyor should measure the tree as follows (Figure 5.7):

- **Locate breast height** (1.3 m above ground at high side)
- **Measure total tree height from the ground (at high side) to the top of the leader.** For species with a droopy leader, total height is height with the tip straightened up. Height can be measured with:
  - a tape and clinometer (see Appendix 1)
  - a height pole
  - a carpenter's measuring tape.
- **Determine breast height age**. Breast height age is equal to the number of rings at breast height.
  - On small diameter trees, this must be determined by felling the tree at breast height and counting rings.
  - On larger diameter sample trees, an increment borer can be used. The core **MUST** contain the pith. If it does not, redrill the tree.
- It is possible to determine breast height age by counting annual branch whorls above breast height for species that produce obvious branch whorls (see Lesson 6).

  See Appendix 2 for additional tips on accurately determining age.
- **Record the species, height and age above breast height.** Current field cards (FS 658 and FS 748) are not designed to record GI. Surveyors will have to use a separate line under the standard survey data collected on each plot, or record the data on a separate, blank card.

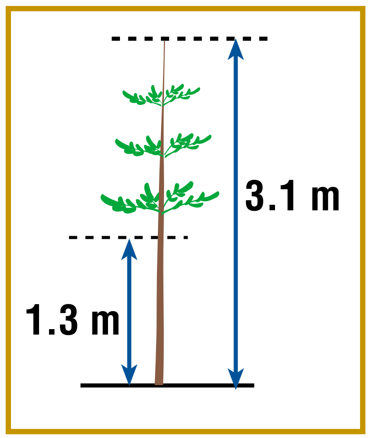
An alternate version of the GI method, not discussed in this course, estimates SI from the distance between branch whorls.

Step 1



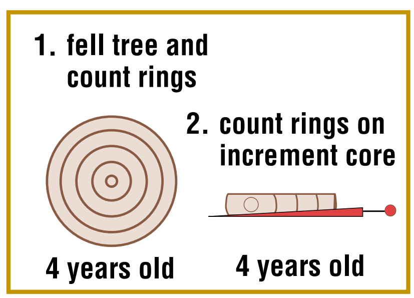
- Locate breast height

Step 2



- Measure total tree height from ground at high side to the top of the leader

Step 3



- Determine breast height age

Step 4

Plot no.	Species	Total height (m)	Breast height age (yr)
1	Pl	3.1	4

- Record the species, height and age above breast height

Figure 5.7. Measurements on GI sample tree.

4. Summary

Once the strata boundaries have been finalized and the data has been collected, use the appropriate table to determine SI for each sample tree (Figure 5.8). The average SI for all of the sample trees site indices is then calculated.

If a sample tree has more than 30 rings at DBH, use the appropriate site index curves to determine its SI.

A complete set of tables is provided in Appendix 3 "Growth Intercept Tables."

Step 1: **Site index is determined for each sample tree in a stratum.**

GROWTH INTERCEPT TABLE

Species: Interior spruce (Sw, Se) **Region:** Interior B.C. **Source:** G. Nigh, 1995b

Breast height age (yr)	Site index (m)															
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Tree total height (m)															
3					1.4	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.2
4					1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
5					1.4	1.5	1.7	1.8	1.9	2.1	2.2	2.3	2.5	2.6	2.7	2.9
6					1.5	1.6	1.8	2.0	2.1	2.3	2.4	2.6	2.8	2.9	3.1	3.2
7				1.4	1.6	1.8	2.0	2.2	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.6
8				1.5	1.7	1.9	2.1	2.3	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
9			1.4	1.6	1.8	2.1	2.3	2.6	2.8	3.0	3.3	3.5	3.7	4.0	4.2	4.4
10			1.5	1.7	2.0	2.2	2.5	2.8	3.0	3.3	3.5	3.8	4.1	4.3	4.6	4.9
11			1.6	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.8	4.1	4.4	4.7	5.0	5.3
12		1.4	1.7	2.0	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.5	4.8	5.1	5.4	5.7
13		1.4	1.8	2.1	2.4	2.8	3.1	3.4	3.8	4.1	4.5	4.8	5.1	5.5	5.8	6.1
14		1.5	1.9	2.2	2.6	3.0	3.3	3.7	4.0	4.4	4.8	5.1	5.5	5.8	6.2	6.6
15		1.6	2.0	2.4	2.8	3.2	3.5	3.9	4.3	4.7	5.1	5.5	5.8	6.2	6.6	7.0

Step 2: **Calculate the average site index for all sample trees per stratum.**

Figure 5.8. Summarizing GI survey data.

Exercise:

Here is data from three GI plots in stratum C of 82F045-001:

Species	Rings	Height	SI
Hw	8	3.5 m	___
Hw	12	4.3 m	___
Hw	10	4.7 m	___

- What is the SI predicted by each sample tree on this coastal site?

Notes

Lesson 6 Advanced Options for Growth Intercept

Lesson Objective

Learn some advanced options for the GI method.

Advanced Options for Using GI Method

The GI method allows for some advanced options that surveyors may find useful. The following options allow surveyors some flexibility in using the GI method.

Measuring More Than One Sample Tree Per Plot

In order to reduce between plot variation, surveyors may wish to measure more than one GI sample tree per plot. Surveyors must increase plot size in order to collect more than one sample tree per plot. The following stipulates the appropriate plot radius for the corresponding number of sample trees:

- 1 tree 5.64 plot radius
- 2 trees 7.99 plot radius
- 3 trees 9.74 plot radius

To compile data when more than one sample tree per plot is measured, SI is estimated for each tree and the SI values are averaged.

Estimating SI from Partial Growth

It is possible to estimate SI from a portion of the total growth above breast height if the SI species has distinct annual branch whorls. This method is less accurate than the method based on ring count and total height. However, it can be used during the growing season. It is also useful for quick reconnaissance work.

To estimate SI from partial growth, surveyors follow these five steps (Figure 6.1):

1. Locate breast height.
2. Select an annual branch whorl below the leader. If the survey is conducted during the growing season, surveyors should measure up to the annual whorl below the currently growing leader. This whorl is called the upper measurement point.
3. Measure the tree height from the ground to the upper measurement point.
4. Determine the number of years growth between breast height and the upper measurement point.
5. Indicate that the measurement is for partial growth on the data collection card.

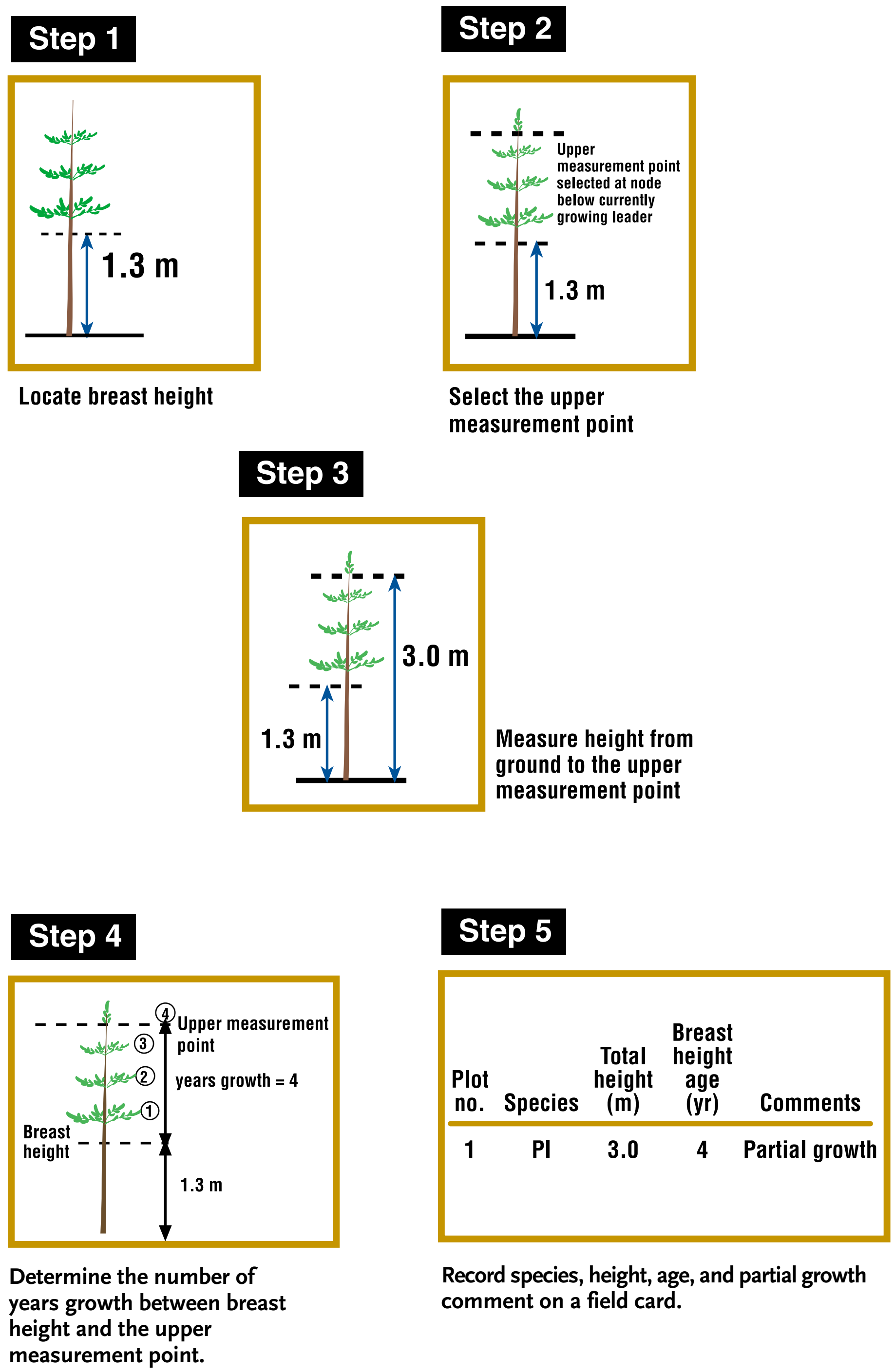


Figure 6.1. Estimating SI from partial growth.

Determining Age by Counting Branch Whorls

If a species produces annual branch whorls, it is possible to determine breast height age by counting whorls above breast height (Figure 6.2). However, mid-year branch clusters and other variations in branch growth may cause silviculture surveyors to make errors in age determination with this method. Therefore, counting rings, not counting whorls, is the recommended way to determine breast height age. On sample trees with seven or fewer years growth above breast height, a count of whorls above breast height is recommended to confirm the age determined by a ring count.

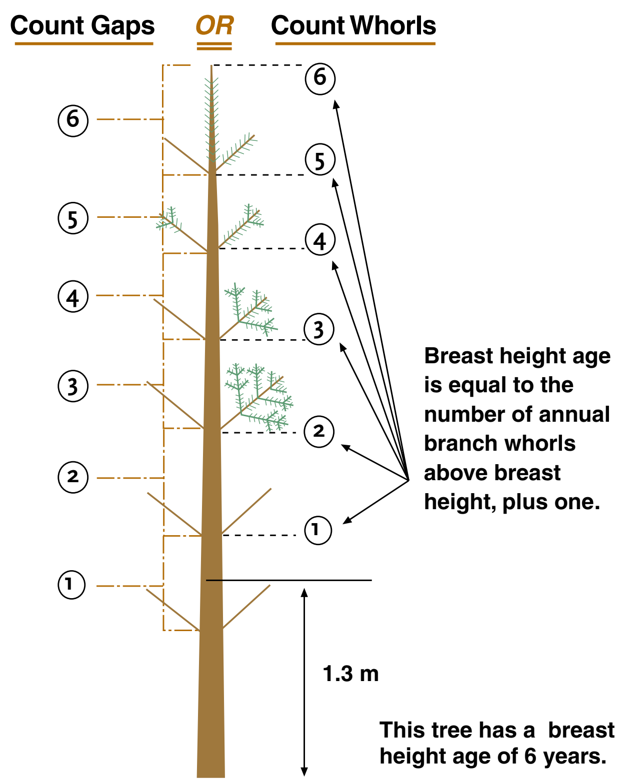


Figure 6.2. Determining age by counting branch whorls.

Species with distinct annual branch whorls

Species	Distinct annual branch whorls
Pl, Sx, Fd, Ss, Bl	Yes
Hw	No

Breast height age can be determined by counting the number of annual branch whorls above breast height plus one (for the annual whorl within the bud at the tip of the leader). Alternatively, you can count stem sections between whorls – starting in the section that contains bh.The shape of individual branches that is created by annual branch growth is used to help distinguish an annual whorl from a mid-year cluster of branches.

Assessing the Reliability of the SI Average

Surveyors can compute confidence limits on the calculated average SI using the FS 1138 card. Site index values are input into the calculations in the same manner that well spaced trees would be, except that the plot multiplier (p) is not used.

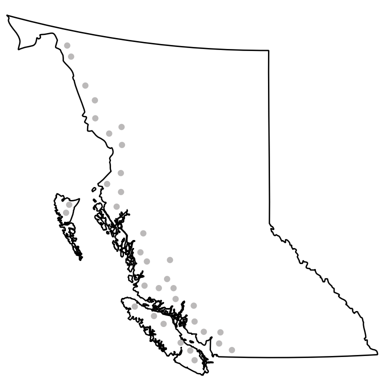
The reliability of the SI average for the stratum can also be assessed by calculating the standard deviation of the plot SI values. Surveyors should use the following as a guide:

Standard deviation of site index (m)	No. of plots required to achieve a reliable SI
1	7
2	18
3	35

Building a growth intercept table

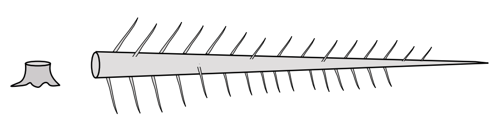
Figure 6.3 provides a simplified illustration of the procedure used to construct a growth intercept table. The first step is to find appropriate plot locations. Plots are located to cover the geographic and site index range of the species. Sample trees are undamaged, unsuppressed top height trees approximately 60–100 years breast height age. Generally, each plot contains 3 suitable top height trees (Figure 6.3A). The second step is to fall and section the top height trees to exactly determine tree height at known ages (Figure 6.3B). Where possible, sectioning is supplemented with measurement at each annual branch whorl. The third step is to relate measured site index to the top height measured at a given bh age (Figure 6.3C). From these regression equations, a growth intercept table is prepared (Figure 6.3D).

A

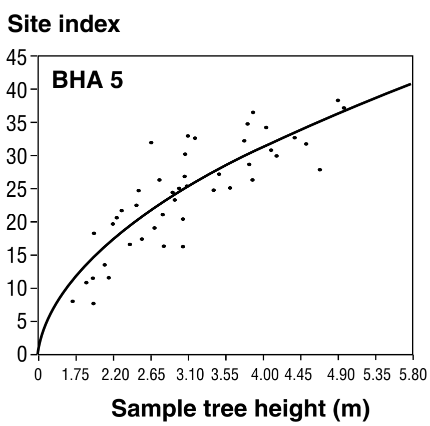


B

Age	5	10	15	…	50
Height	3.3	6.1	9.2	…	28



C



D

GROWTH INTERCEPT TABLE

Species: Western hemlock (Hw) Region: Coastal B.C. Source: G. Nigh, 1995c

Breast height age (yr)	Site index (m) 26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	Tree total height (m)														
3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.6	3.7	3.8	3.9
4	2.8	2.9	3.1	3.2	3.3	3.4	3.6	3.7	3.9	4.0	4.2	4.3	4.5	4.7	4.8
5	3.2	3.4	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.2	5.4	5.6

Figure 6.3. Illustration of the procedure used to construct a growth intercept table: A) find appropriate plot locations; B) section top height trees to re-construct their height growth; C) relate sample tree height to site index at each bh age; D) summarize regression equations in a simple table.

Lesson 7

Site Index Curve Method

Lesson Objective

Learn how to use the site index curve method to estimate SI.

Site Index Curves

The site index curve method predicts SI from height and age measurements taken on carefully selected sample trees. Site index curves are available for the following species:

- Coastal – Fd, Hw, Cw, Ba, Ss, Dr, Act
- Interior – Pl, Sw, Fd, Bl, Cw, Py, Lw, At, Ep, Hw, Pw.

Site index curves and tables for B.C. species are provided in Appendix 8 "Site index curves and tables for B.C."

The site index curve method is best suited to even-aged, pure species, middle-aged stands that are healthy (Figure 7.1). Usually, a stand is not suited to the Site Index Curve method if:

- it is uneven aged
- the sample trees have been overtopped by trees or brush
- it has received partial cutting removing the larger trees
- many of the sample trees are seriously damaged or diseased
- the sample trees are old (age class 8 and 9)
- the sample trees are excessively large or rotten at DBH.

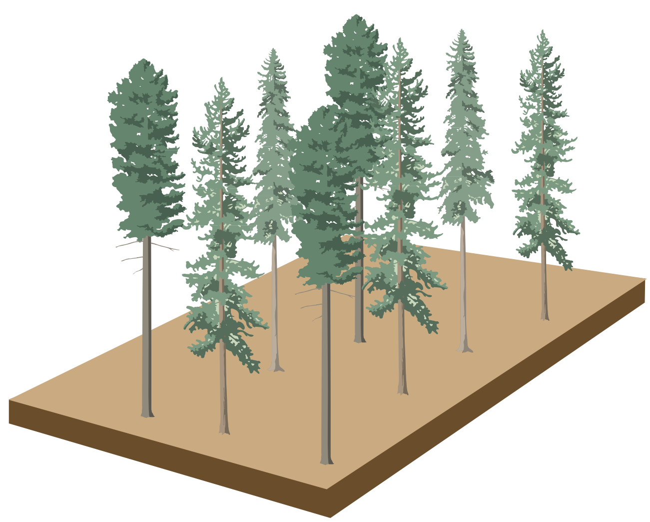


Figure 7.1. Stands suited to site index curves include many 30- to 140-year-old stands.

When correctly used, the site index curve method produces an accurate estimate of SI. However, the required heights and ages can be costly and difficult to accurately measure. Sampling is very similar to the growth intercept method. To use the site index curve method:

1. pre-stratify the opening
2. in each stratum,
   a) select a site index species
   b) collect height and age data on suitable top height sample trees
   c) compute the average SI.

Spread plots across the stratum. In a 5.64 m radius plot, identify the largest DBH tree of the SI species. Measure it for height and age if it meets the following criteria:

- undamaged stem with vigorous, uniform annual height growth above breast height
- dominant or codominant crown class and not overtopped by other trees or brush
- vigorous and uniform ring width from pith to bark.

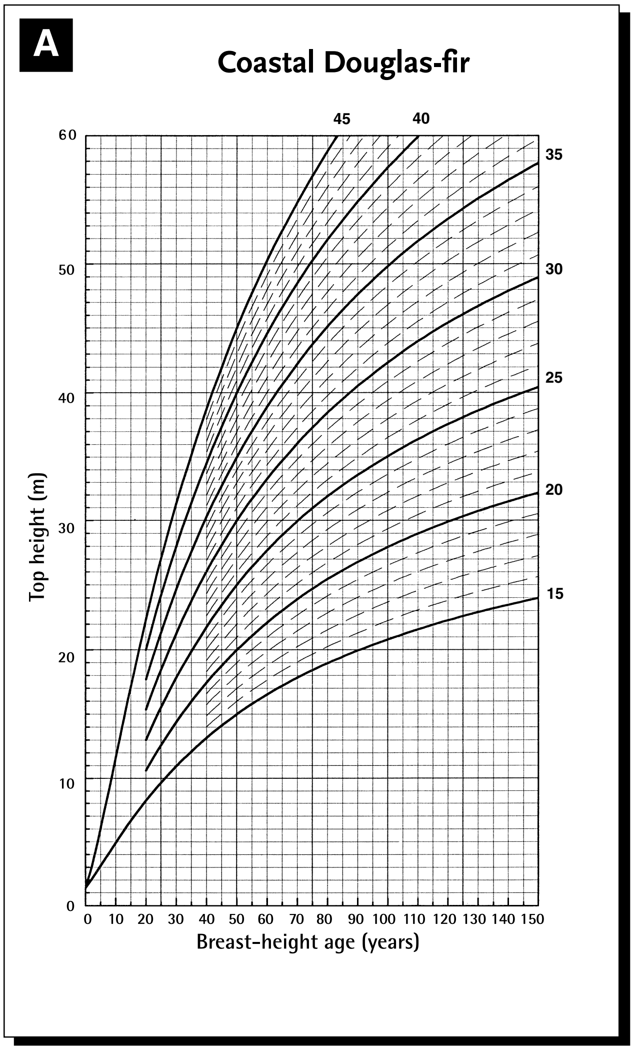
Age is determined at breast height by counting rings on an increment core taken at 1.3 m above ground on the high side (see Appendix 2). Total tree height is usually determined with a suunto and distance tape (see Appendix 1).

For each sample tree, read the corresponding SI from the appropriate SI curve or table.

With the SI curve, the X axis shows the breast height age and the Y axis shows the top height for a given species (Figures 7.2A).

The tables have breast height age down the side, top height along the top, and site index in the body of the table (Figure 7.2B).

Average the SI determined for each sample tree to obtain the average SI for the stratum.



B

Coastal Douglas-fir

Top height (m) 34	36	38	40	42	44	46	48	50	52	54	56	58	60	bh age (years)
Site Index (m)														
-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
-	-	-	-	-	-	-	-	-	-	-	-	-	-	25
49	-	-	-	-	-	-	-	-	-	-	-	-	-	30
43	46	49	-	-	-	-	-	-	-	-	-	-	-	35
39	42	44	46	49	-	-	-	-	-	-	-	-	-	40
36	39	41	43	45	47	49	-	-	-	-	-	-	-	45
34	36	38	40	42	44	46	48	50	-	-	-	-	-	50
32	34	36	38	40	42	43	45	47	49	-	-	-	-	55
31	32	34	36	38	39	41	43	45	47	48	50	-	-	60
29	31	33	34	36	38	39	41	43	44	46	48	49	-	65
28	30	32	33	35	36	38	40	41	43	44	46	48	49	70
27	29	31	32	34	35	37	38	40	41	43	44	46	47	75
27	28	30	31	33	34	36	37	39	40	42	43	44	46	80
26	27	29	30	32	33	35	36	38	39	40	42	43	45	85
25	27	28	30	31	32	34	35	37	38	39	41	42	43	90
25	26	28	29	30	32	33	34	36	37	39	40	41	42	95
24	26	27	28	30	31	32	34	35	36	38	39	40	42	100
24	25	27	28	29	31	32	33	34	36	37	38	40	41	105
23	25	26	27	29	30	31	33	34	35	36	38	39	40	110
23	24	26	27	28	30	31	32	33	35	36	37	38	39	115
23	24	25	27	28	29	30	32	33	34	35	36	38	39	120
22	24	25	26	27	29	30	31	32	34	35	36	37	38	125
22	23	25	26	27	28	30	31	32	33	34	36	37	38	130
22	23	24	26	27	28	29	30	32	33	34	35	36	37	135
22	23	24	25	26	28	29	30	31	32	34	35	36	37	140
21	23	24	25	26	27	29	30	31	32	33	34	35	37	145
21	22	24	25	26	27	28	29	31	32	33	34	35	36	150
21	22	23	25	26	27	28	29	30	31	33	34	35	36	155
21	22	23	24	25	27	28	29	30	31	32	33	34	35	160
21	22	23	24	25	26	28	29	30	31	32	33	34	35	165
20	22	23	24	25	26	27	28	30	31	32	33	34	35	170
20	21	23	24	25	26	27	28	29	30	31	33	34	35	175
20	21	22	24	25	26	27	28	29	30	31	32	33	34	180
20	21	22	23	24	26	27	28	29	30	31	32	33	34	185
20	21	22	23	24	25	27	28	29	30	31	32	33	34	190
20	21	22	23	24	25	26	27	29	30	31	32	33	34	195
20	21	22	23	24	25	26	27	28	29	30	31	33	34	200

Site Index	$\leq$ 16	17-22	23-28	29-35	36-41	42-47	$\geq$48
Years to bh	11	10	9	8	7	6	5

Figure 7.2. Site index curves for coastal Douglas-fir: A) graph format, and B) table format.

Figure 7.3 shows the data that was used to produce site index curves for interior Douglas-fir.[1] Note the following:

1. The top height growth curves are relatively smooth. Top height is a stable, predictable quantity in free growing, undamaged stands. It is partly for this reason that it has become the most common index of site quality in the world.
2. Few plots are over 100 years old. Therefore, the resulting site index curves should not be expected to perform well when applied to stands over 100 years old.
3. None of the sampled stands appear to have suffered top breakage or suppression. Stands with these conditions are not sampled for site index curve construction – therefore, site index curves should not be applied to stands with top height tree damage or suppression.

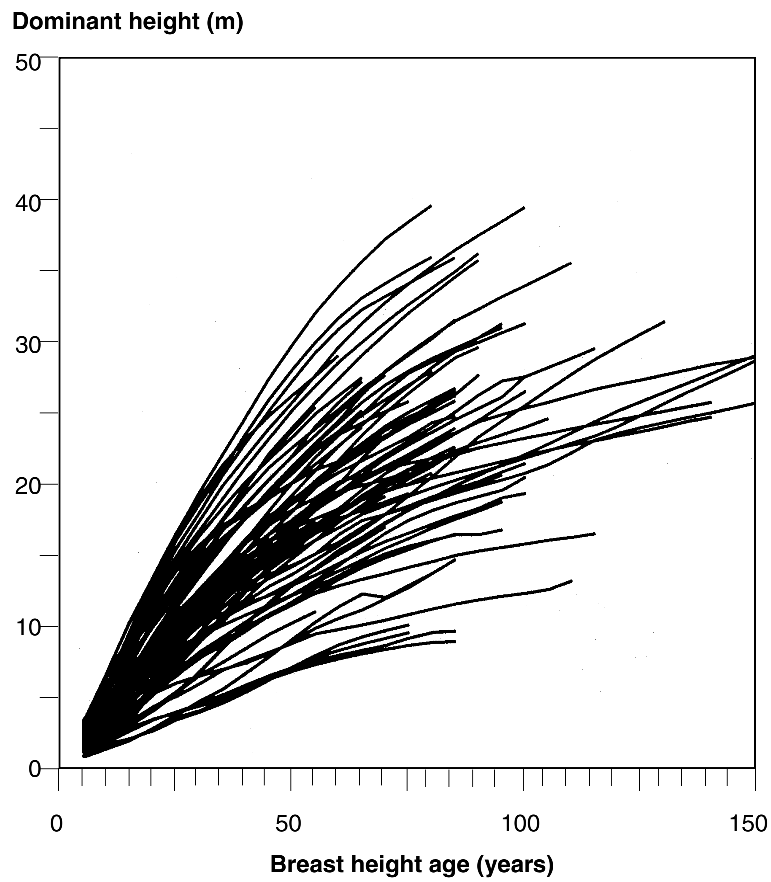


Figure 7.3 Top height over age in 68 interior Douglas-fir plots.

[1] Thrower, J.S. and J.W. Goudie. 1992. Estimating dominant height and site index of even-aged interior Douglas-fir in British Columbia. West. J. of Appl. For. 7(1):20–25.

Site Index Curves and Old Growth

When old-growth stand height and age are input to a site index curve, the resulting site index usually underestimates the true growth potential of the site. Most inventory files and the forest cover map labels contain site index values that were obtained in this way. As a result, the site index estimates for old-growth stands in most inventory files and forest cover map sheets are biased.

Figure 7.4 depicts the relationship between the site index curve estimate of SI for old Pl stands and our best current estimate of the true site potential of these stands.

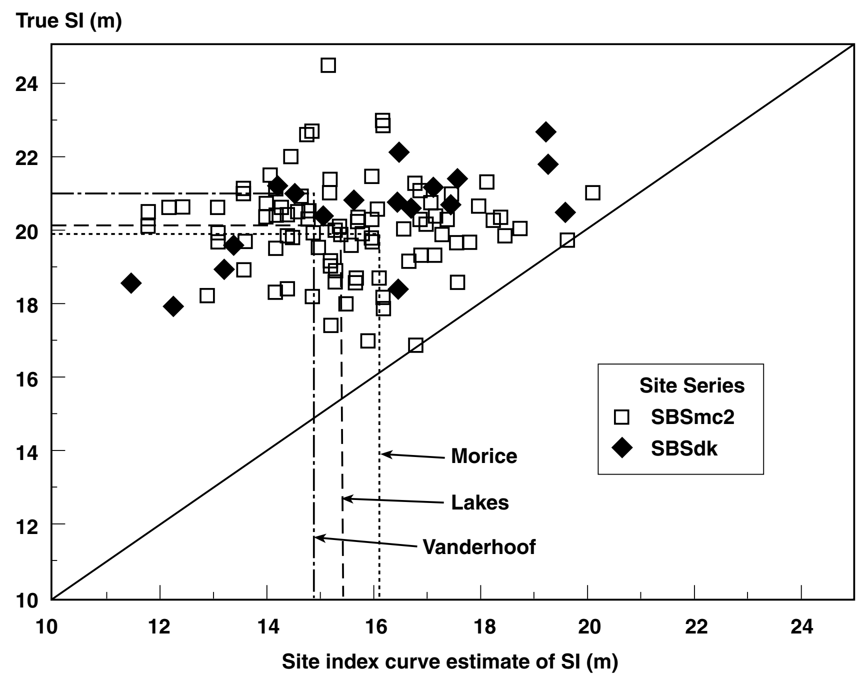


Figure 7.4. Site index curve estimate of SI for old Pl stands compared to our best current estimate of the true site potential.

The poor performance of site index curves, when applied to old stands, is due to several factors. First, the height growth of old stands frequently flattens off more than the height growth assumed by site index curves. Figure 7.5A illustrates this effect in a Ss stand on site index 40 where top height growth stops due to repeated top breakage after the stand is 100 years old. When this stand is 300 years old and its age and height are input to the Ss site index curve, site index is estimated at 25 m.

Height repression is the second factor contributing to site index underestimates in some old stands. Repression, most common in Pl, is when top height growth is slowed by high establishment density. Figure 7.5B shows WinTIPSY (version 2.0) predictions of the effect on Pl top height development of excessive establishment density. When regenerated at 200,000/ha, top height on site index 23 m develops as though the stand was site index 20 m.

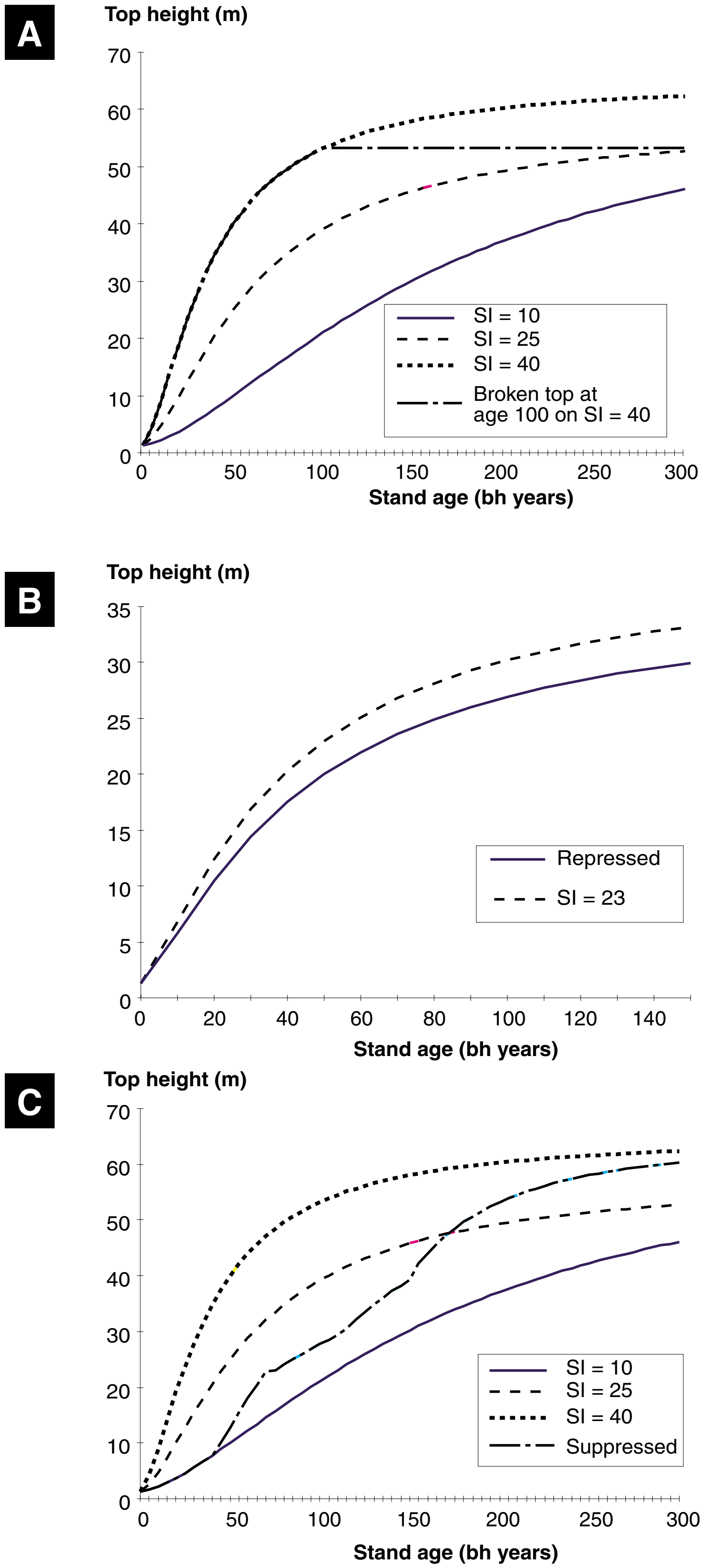


Figure 7.5. Examples of factors that cause underestimates of site index in old stands: A) height growth flatter than site index curve; B) height repression due to high establishment density; C) development under overstorey.

Suppression is the third factor contributing to poor SI estimates in old stands. In some forest types, today's candidate SI sample trees grew up under an overstorey. These trees have reached their dominating position in the stand today from a history of suppression and release as canopy gaps opened and closed above them. Figure 7.5C illustrates this effect as a dominant Ss tree reaches its current canopy position through a repeating cycle of suppression and release. Over the 300 years, site index estimated by site index curves varies from 10 m to almost 40 m.

Exercise:

Use the SI curve for coastal Douglas-fir. If the breast height age of the tree is 105 and the top height is 44 m, what is the SI indicated by this one tree?

Lesson 8

Site Class Conversion Table

Lesson Objective

Learn to not use the site class conversion table.

Site Class Conversion

To use this method, the surveyor estimates site class (G, M, P, or L) and refers to a table to convert site class to SI (Figure 8.1). The resulting SI is very inaccurate. This method should only be used when SI cannot be determined with more accurate methods. A copy of this table is provided in Appendix 6 "Procedures for obtaining site index for silviculture polygons."

The site class conversion table is supplied because it will take several years to replace all of the existing site class values with improved SI estimates. During this transition period, it may be necessary to convert site class to SI for some polygons. Over time, these interim SI values should be replaced with more accurate SI estimates based on appropriate ground sample methods.

A SI value obtained from converting site class is not sufficiently accurate for most silviculture decisions.

The site class conversion table is based on inventory leading species, region of the province (coast, interior or both) and site class.

When forest cover map labels were converted from site class to SI, the site class conversion table was widely applied to young stands.

Other methods that are frequently inaccurate (like the site class conversion table) include assigning to a polygon, the SI determined on an adjacent stand and assigning to a species, the SI determined for another species on the same site.

Inventory Label Leading Species	Region	Good	Medium	Poor	Low
Ac	Province	26	18	9	3
At	Province	27	20	12	4
B, Ba, Bg	Coastal	29	23	14	5
B, Ba, Bg	Interior	18	15	11	5
Bl	Province	18	15	11	5
Cw	Coastal	29	23	15	6
Cw	Interior	22	19	13	5
Dr	Province	33	23	13	6
E, Ea, Ep	Province	27	20	12	4
Fd	Coastal	32	27	18	7
Fd	Interior	20	17	12	5
H, Hm, Hw	Coastal	28	22	14	5
H, Hm, Hw	Interior	21	18	12	4
L, La, Lt, Lw	Province	20	16	10	3
Mb	Province	33	23	13	6
Pa, Pf, Pj, Pl	Province	20	16	11	4
Pw	Province	28	22	12	4
Py	Province	17	14	10	4
S	Coastal	28	21	11	4
S	Interior	19	15	10	5
Ss	Province	28	21	11	4
Sb, Se, Sw	Province	19	15	10	5
Yc	Coastal	29	23	15	6
Yc	Interior	22	19	13	5

Figure 8.1. Site class conversion table.

Exercise:

If the inventory leading species is Hw, the stand is on the coast, and the surveyor estimates it is site class M (medium), what interim SI value should be used?

Lesson 9

Decision Key

Lesson Objective

Learn how to use the decision key to help pick a method for determining SI.

Decision Key

A decision key (Figure 9.1) has been developed to assist surveyors in determining the appropriate method to use to estimate SI (see Appendix 4 "Determining a suitable site index method").

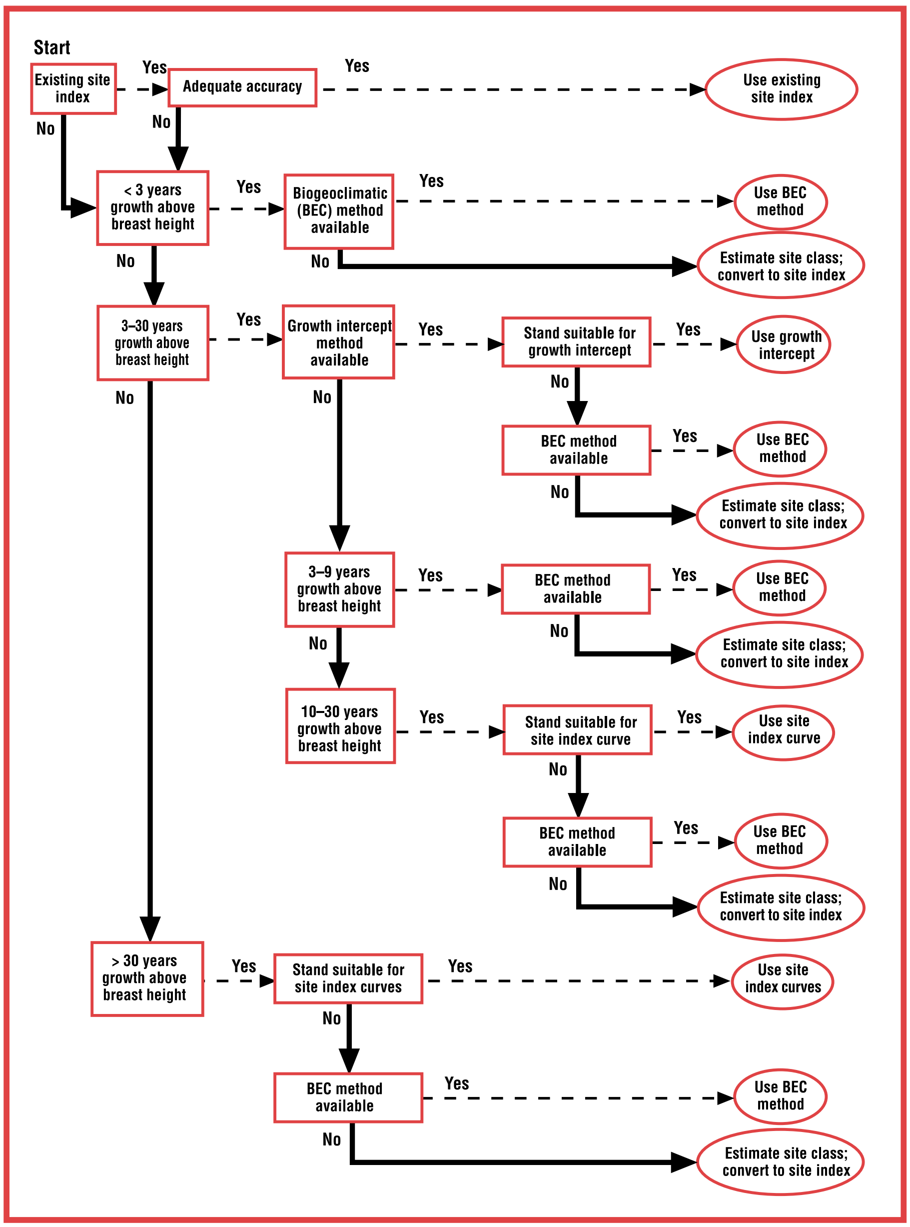


Figure 9.1. Decision key.

For most silviculture polygons (strata), there is more than one method that can be used to obtain SI. These methods differ in their:

1. availability throughout the province
2. suitability for different stand conditions
3. accuracy.

This decision key helps you choose from four methods:

1. BEC method
2. growth intercept method
3. site index curve method
4. estimate site class and convert to SI.

The decision key helps you choose a method by leading you through the following five questions:

1. Is there an existing SI?
2. Is it accurate enough?
3. How old are the sample trees?
4. For the SI species, which SI methods are available?
5. Is the condition of the sample trees suitable for predicting SI from height and age?

Decision Key Exercises

Using the decision key, determine the best method for obtaining SI.

Exercise 1:

Use the decision key to select the method to determine SI:

You must determine SI for a standards unit in a SMP. The stand is 4 m tall Hw in the Vancouver Forest Region. The existing SI comes from the map label of the previous old growth stand. Sample trees are suitable for GI sampling.

Exercise 2:

Use the decision key to select the method to determine SI:

You must determine SI for a standards unit in a SP. The stand is old growth (age class 9) spruce-hemlock in the Prince Rupert Forest Region. The existing SI comes from the forest cover map label. Most sample trees have broken and dead tops and are over 1 m in DBH.

Accuracy of Different Methods

The relative accuracy of the various SI estimation methods is one important consideration when deciding which method to use. An assessment of the accuracy typically achieved by the different methods is built into the decision key. A recent study by Nigh[2] illustrates the typical trends in accuracy achieved by three methods of SI estimation: SIBEC, growth intercept, and site index curves (Figure 9.2). Nigh's study is based on 44 western hemlock plots in the ICH. Though the general trends are typical, the specific error levels and the ages at which one model becomes more accurate than another, differ considerably between species.

2 Nigh, G.D. 1998. A system for estimating height and site index of western hemlock in the interior of British Columbia. For. Chron. 74(4): 588–596.

Some trends in accuracy that are typical for all species are:

1. For the methods based on sample tree height and age (growth intercept and site index curve), accuracy changes with sample tree age.
2. The accuracy of SIBEC is not affected by sample tree age, as the SI estimate is not based on sampling the trees on site.
3. In very young stands, SIBEC is the most accurate method.
4. Once young stands achieve a certain age, the growth intercept method is more accurate than both SIBEC and site index curves.
5. With the growth intercept method, accuracy improves with sample tree age.
6. SI curves can be very inaccurate in young stands.
7. The accuracy of SI curves improves to bh age 50 years and deteriorates thereafter.
8. At some old stand age, SIBEC again becomes the most accurate method.

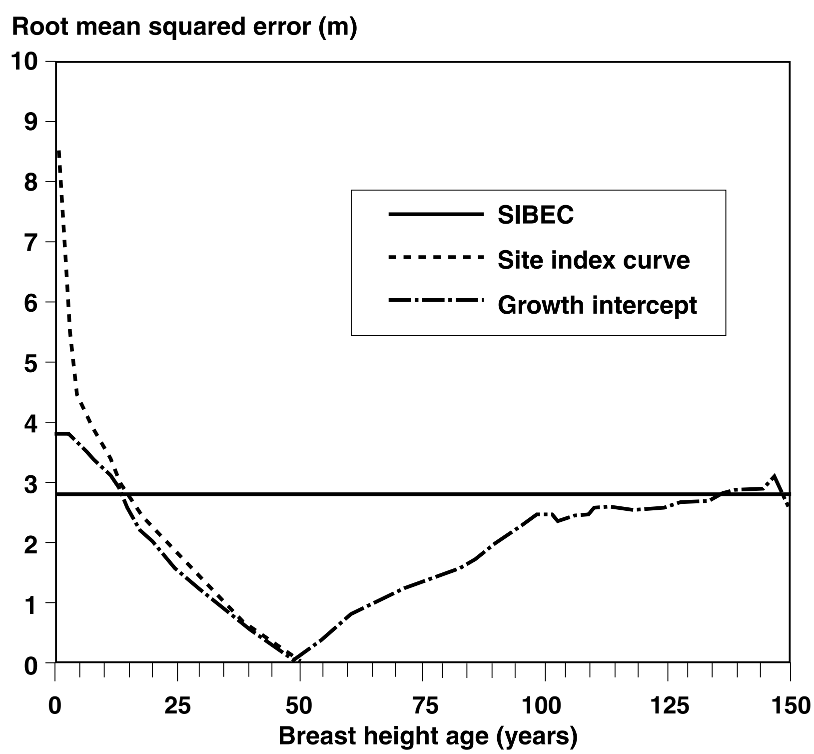


Figure 9.2. Average error in site index estimate over age for SIBEC, site index curves, and growth intercept in Nigh's study of western hemlock in the ICH.

Lesson 10

Species Conversion Table

Lesson Objective

Learn how to use the species conversion table (Figure 10.1).

Site Index Species Conversion

Each species on a site has a unique SI. Site index does not differ by layer, only by species.

It is possible to predict the SI of one species from the SI determined for another species on the same site. Surveyors can use the site index species conversion table to make these predictions.

Conversions may be needed if GI data is collected for a species that is not the inventory component leading species. This could occur if there is no GI table for the inventory species but there is one for the second species on site, or if the leading species has an unacceptable level of damage, disease, or suppression.

The accuracy of the SI value is reduced when the SI species is converted. A SI obtained by converting site index species is more accurate than one obtained from the site class conversion table and, in some instances, better than one obtained with the BEC method. The typical accuracy of the conversion is illustrated in Figure 10.2 which shows the data used to develop the average Ss-Hw site index relationship.

Many, but not all possible, paired species conversions are available to date. A copy of the site index species conversion table is provided in Appendix 5 "Average site index relationships between species." A six-ring field book sized version of the species conversion table is available in the FS 415 series. The FS 415 I is the field card for species conversion.

Site Index Species Conversion

Average site index relationships

Interior Bl Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Pl	10	13	15	17	19	21	23	26	28	30	32
Interior Sx	10	12	14	17	19	21	24	26	28	31	33

Interior Fd Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Hw	6	8	11	13	15	17	20	22	24	27	29
Interior Lw	11	13	15	17	19	21	23	25	27	29	31
Interior Pl	10	12	14	16	19	21	23	25	27	29	31
Interior Sx	7	10	13	15	18	21	23	26	29	32	34

Interior Hw Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Fd	13	15	17	19	21	22	24	26	28	29	31

Interior Lw Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Fd	9	11	13	15	17	19	21	23	25	27	29
Interior Pl	8	10	13	15	17	19	21	23	25	27	29

Interior Pl Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Bl	10	12	13	15	17	19	21	23	24	26	28
Interior Fd	10	12	14	16	18	19	21	23	25	27	29
Interior Lw	12	13	15	17	19	21	23	25	27	29	31
Interior Sx	9	11	13	15	17	20	22	24	26	28	31

Interior Sx Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Bl	10	12	14	15	17	19	21	22	24	26	27
Interior Fd	12	14	15	17	18	19	21	22	24	25	27
Interior Pl	11	13	15	17	19	20	22	24	26	28	30

Coastal Ba Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Hw	17	20	23	26	29	32	35	39	42	45

Coastal Fd Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Hw	13	16	18	21	24	27	29	32	35	37

Coastal Hw Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Ba	13	16	19	22	25	28	31	34	36	39
Coastal Fd	17	20	24	27	30	34	37	40	44	47
Coastal Ss	14	18	21	25	29	33	36	40	44	48

Coastal Ss Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Hw	16	18	21	23	26	28	30	33	35	38

FS 415I HFP 98/11

Figure 10.1. Species conversion table.

Exercise:

Given that you have surveyed an interior stand with Fd leading species but collected information only on Hw (Fd has leader damage), and you determined the average SI for Hw to be 20 m, what would the SI be for Fd?

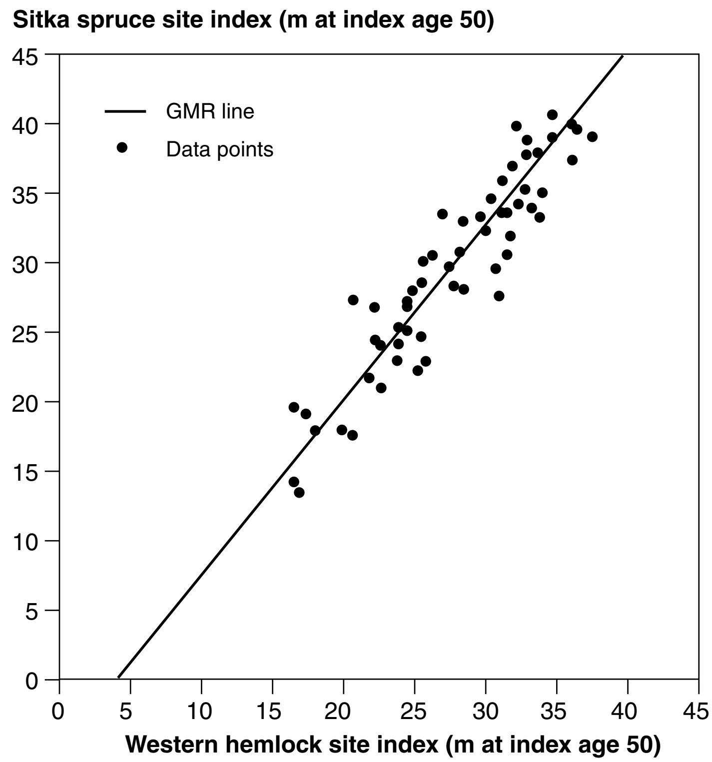


Figure 10.2. Data and fitted regression line for the coastal Ss-Hw site index conversion. (Source: G. Nigh, B.C. Min. Forests, Research Branch.)

Lesson 11

Contract Specifications

Lesson Objective

Consider recommended contract specifications and topics.

Contract Specifications

For surveys using the growth intercept or site index curve methods, the following are recommended contract specifications (Figure 11.1):

- Height: record height to the nearest 10 cm with a maximum error of 5%
- Age: record age to the exact year with
  - no error on trees <10 years
  - maximum 1 year error on trees 10–20 years
  - maximum 5% error on trees >20 years.

  It may be difficult to meet these age standards under some field conditions so flexibility in checking will be required.
- Species: NO error is acceptable.

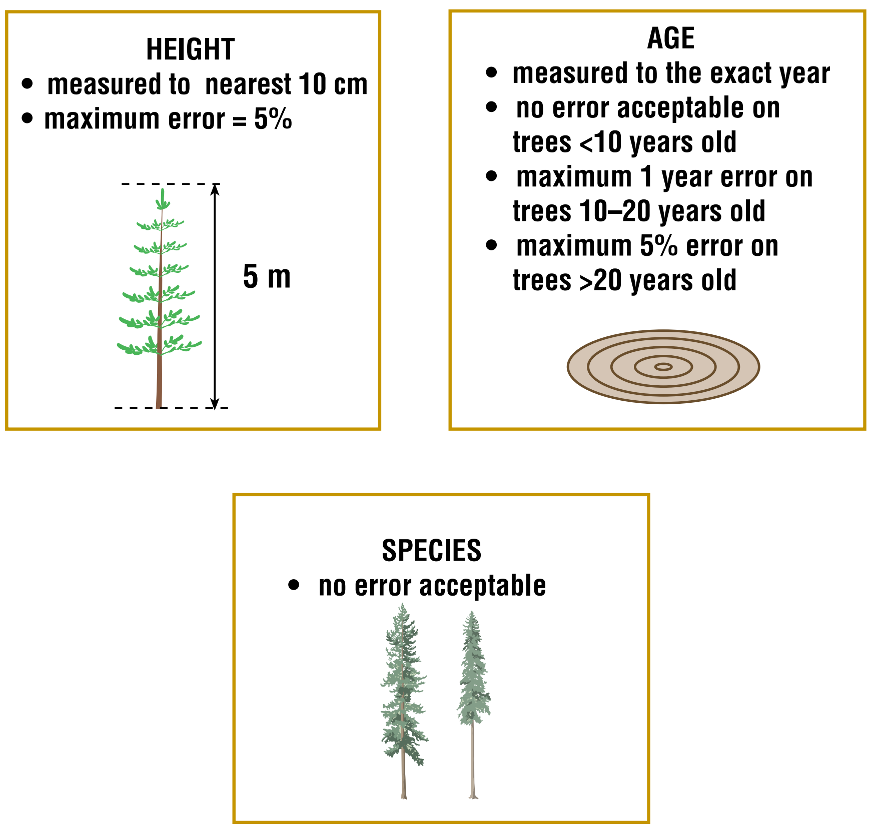


Figure 11.1. Some recommended contract specifications.

In some contracts, it is possible (and useful) to specify the method that should be used to estimate site index. When SI is determined with the growth intercept or site index curve methods, specify the number of plots required.

Recommended Contract Topics

Contract administrators should consider the following topics when developing or implementing contracts:

- recommend that surveyors take this course
- review SI estimation procedures with the contractor at the viewing and again at the pre-work
- ensure surveyors attain first few ages by drilling or cutting to calibrate their eye prior to whorl counting
- consider flagging sample trees as a contract clause.

Provide surveyors with the necessary SI materials:

- SIBEC guide
- GI FS415s and manual
- SI curves
- Decision key
- SI/Site class conversion tables
- SI species conversion tables.

Contract administrators should be prepared to do a GI plot in the field with surveyors.

Tips on how to check a GI survey are provided in Appendix 7.

Lesson 12

Session Summary

Lesson Objectives

Learn where to go for more information and review the information provided in the classroom session.

Where to Go for More Information

As discussed in previous sections, more information is available on SI and the methods for estimating it.

The SI Decision Key lists several sources of information on site index (see Appendix 4).

To discuss site index in silviculture surveys and prescriptions, contact:

Pat Martin
Stand Development Specialist
Forest Practices Branch
Ministry of Forests
Phone: (250) 356-0305
e-mail: pat.martin@gems8.gov.bc.ca

To discuss research into site index, contact:

Gord Nigh
Biometrician
Research Branch
Ministry of Forests
Phone: (250) 387-3093
e-mail: Gordon.Nigh@gems2.gov.bc.ca

For more information on the provincial group that coordinates site productivity developments, visit the Site Productivity Working Group web site:
<http://www.for.gov.bc.ca/resinv/G&Y/Projects/spwg/index.htm>

Field Notes

How to Determine Site Index in Silviculture

Workbook Appendices

Appendix 1. How to Measure Tree Height Using a Suunto and Distance Tape

Very briefly, here is one way to measure tree height with a suunto and distance tape.

1. On the sample tree, accurately locate 1.3 m above ground on the high side. This is breast height (bh).
2. Attach the logger's chain at the centre of the tree at bh or have a crew member hold the end of the distance tape at this point.
3. Walk back from the tree to a location where you can see both the top of the tree and bh. It is often best to go uphill of the tree. Pull the tape tight and straight between the tree and your eye. With the suunto, read the % to tree top. If the reading exceeds 100%, move further away from the tree and repeat. If the tree has a droopy leader, shoot to the top of the droop.
4. Then, from the same location, read the % to bh with the suunto.
5. Record, top shot (% to top), bh shot (% to breast height), slope distance, and bh correction (1.3 m).
6. Calculate horizontal distance using Table 1 or other slope tables. To use Table 1, multiply slope distance by the appropriate factor to get horizontal distance.
7. Combine top and bh shots. If the bh shot is negative, treat both numbers as positive and add top and bottom percents – i.e., +88% top shot, -10% bh shot, combined percentage is 98%. If the bh shot is positive, subtract bottom from top. – i.e., +88% top shot, +10% bh shot, combined percentage is 78%.
8. Multiply the combined percent by the horizontal distance. This produces tree height above bh Add the bh correction (1.3 m) to produce total tree height.
9. For the growth intercept method, if the tree has a droopy leader, add to the calculated height the amount required to obtain total tree height with the tip straightened up.

Table 1. To get horizontal distance, multiply slope distance by this factor.

Percent to bh (%)	Factor	Percent to bh (%)	Factor	Percent to bh (%)	Factor	Percent to bh (%)	Factor
1	1	26	0.968	51	0.891	76	0.796
2	1	27	0.965	52	0.887	77	0.792
3	1	28	0.963	53	0.884	78	0.789
4	0.999	29	0.960	54	0.880	79	0.785
5	0.999	30	0.958	55	0.876	80	0.781
6	0.998	31	0.955	56	0.873	81	0.777
7	0.998	32	0.952	57	0.869	82	0.773
8	0.997	33	0.950	58	0.865	83	0.769
9	0.996	34	0.947	59	0.861	84	0.766
10	0.995	35	0.944	60	0.857	85	0.762
11	0.994	36	0.941	61	0.854	86	0.758
12	0.993	37	0.938	62	0.850	87	0.754
13	0.992	38	0.935	63	0.846	88	0.751
14	0.99	39	0.932	64	0.842	89	0.747
15	0.989	40	0.928	65	0.838	90	0.743
16	0.987	41	0.925	66	0.835	91	0.740
17	0.986	42	0.922	67	0.831	92	0.736
18	0.984	43	0.919	68	0.827	93	0.732
19	0.982	44	0.915	69	0.823	94	0.729
20	0.981	45	0.912	70	0.819	95	0.725
21	0.979	46	0.908	71	0.815	96	0.721
22	0.977	47	0.905	72	0.812	97	0.718
23	0.975	48	0.902	73	0.808	98	0.714
24	0.972	49	0.898	74	0.804	99	0.711
25	0.97	50	0.894	75	0.800	100	0.707

Example:

Percent to top:	+75%
Percent to breast height (bh)	-15%
Slope distance	20 m
Breast height correction	1.3 m

Horizontal distance
= slope distance × factor
= 20 × 0.989
= 19.78 m

Combined percent
= top shot + bh shot
= 75 + 15
= 90%

Height above bh
= horiz. distance × combined percent
= 19.78 × 0.9
= 17.80 m

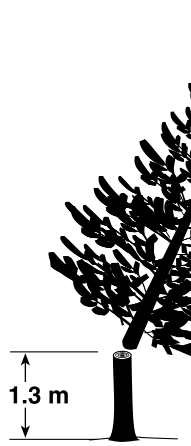
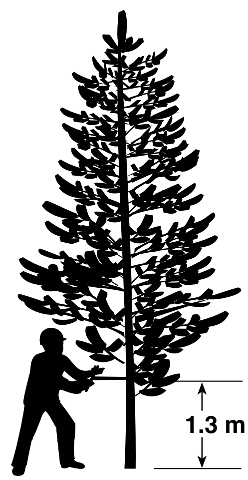
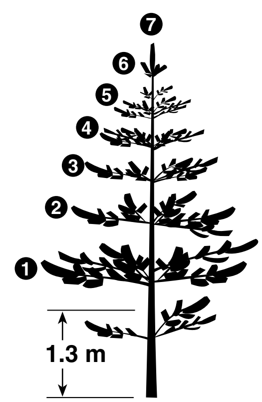
Total height
bh correction+height above bh
= 1.3m + 17.80m
= 19.1 m

Appendix 2. Eight Tips for Accurately Determining Age

Here are 8 tips for accurately determining age.

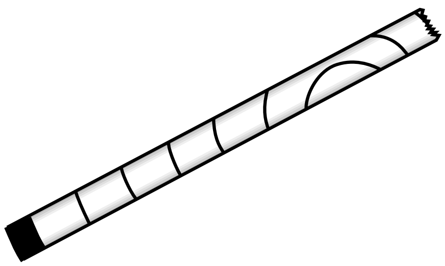
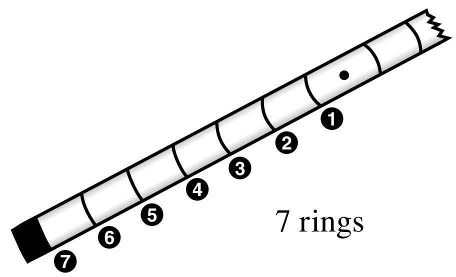
1. Use an accurate method to determine age

There are three methods that can be used to determine the age of a sample tree at breast height: fell the tree at breast height and count rings on the stem cross-section, count rings on an increment core taken at breast height, and count annual branch whorls above breast height. These three methods of determining age differ in accuracy. Generally, it is easiest to get an accurate age by felling the tree and counting rings on the stem cross-section. The method of counting branch whorls is the most difficult method to use to get an accurate age. Counting rings on an increment core is intermediate in difficulty.

Fell tree and count rings	Count rings on increment core	Count whorls
Easy to get correct age	Harder to get correct age	Hardest to get correct age
		

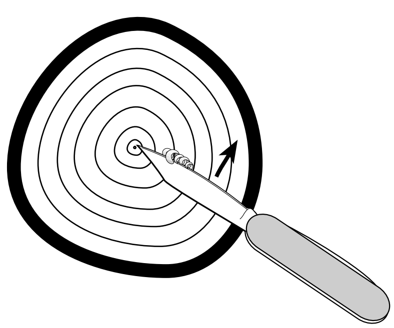
2. Take a quality increment core

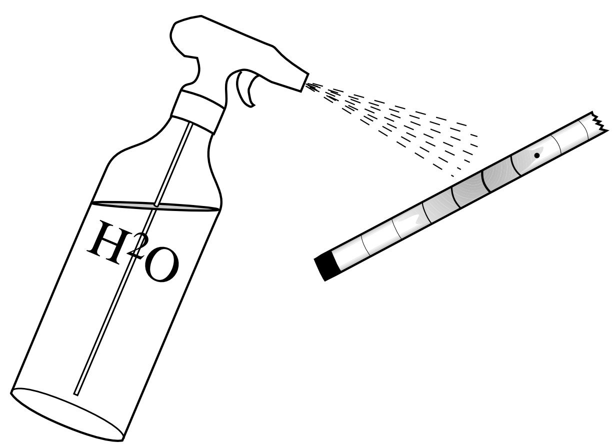
Rings are easiest to count on high quality cores. To obtain high quality cores, keep your increment borer sharp and clean. Hold the borer steady when you begin to drill. Re-drill the tree until you get an increment core that contains the pith. Often you can improve your chances of hitting the pith by aligning the borer with tree center using the branch angles into the pith.

Core does not contain pith.You must re-drill.	Core contains pith. Success.
	

3. Prepare the surface for counting

On both an increment core and a stem cross-section, wetting the surface may make rings more visible. In some cases, colouring the wood with a yellow highlighter pen will make the rings easier to count. Also, shaving a thin layer of wood from the surface will often make rings more visible. If you are felling the tree, use a sharp handsaw to make sure the rings are clear.

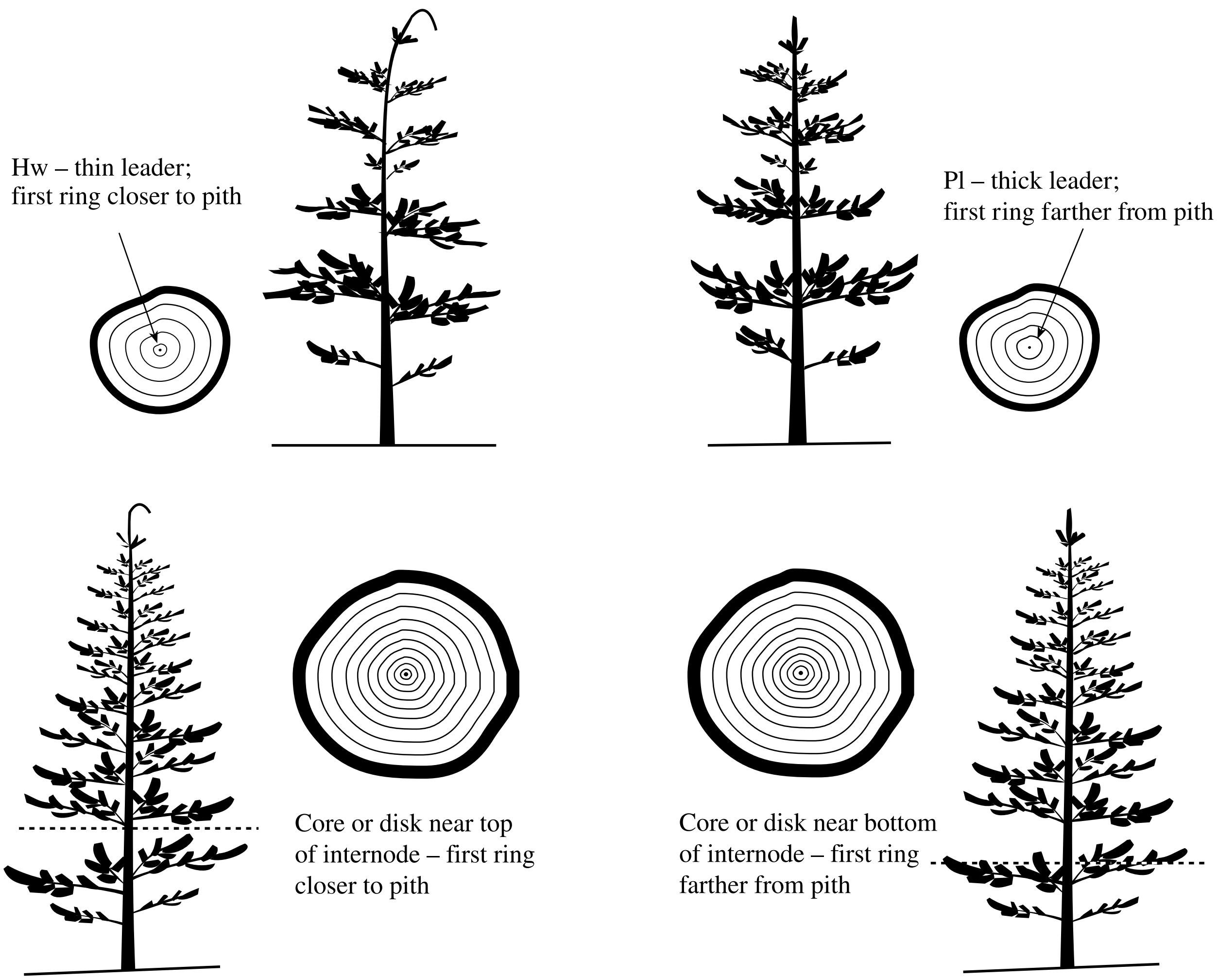




4. Accurately Locate the Pith and First Ring

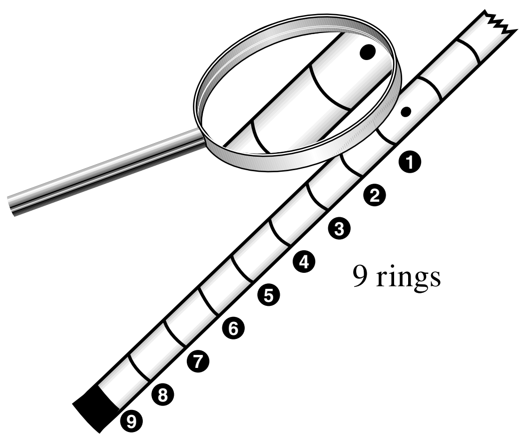
On the increment core (or stem cross-section), locate the pith. Generally, the pith is an oval-shaped area of darker, spongier material. Confirm that you've got the pith by making sure that the rings closest to it form concentric circles around the pith.

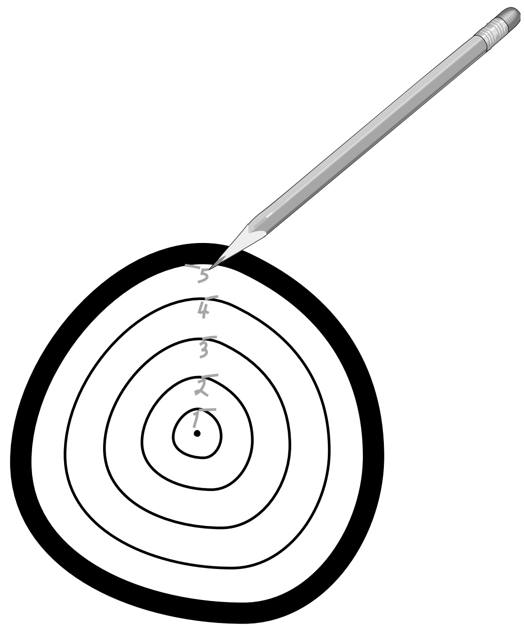
To locate the first ring, consider where the core or cut was taken within the internode. At the top of the internode, little wood has formed so the first ring is very close to the pith. At the bottom of the internode, more wood has formed so the first ring is farther away from the pith. Also, consider the thickness of wood on the leaders of the sample trees. A species with a thick woody leader (such as Pl) will have the first ring well away from the pith.



5. Carefully count rings

To help resolve questions while counting, roll the increment core over to look at all sides. On a stem cross-section, look at rings around the complete surface to help resolve ring counting questions. You may improve your accuracy by using a handlens and marking every fifth or tenth ring with a pencil while counting. Watch out for compression wood 1/2 rings.





5 rings

6. Correctly account for the last ring

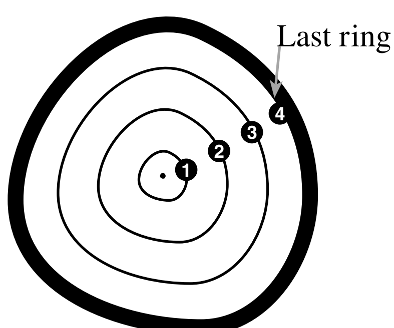
Make sure your method of counting rings takes account of the last ring that is pressed against the inner bark. The method of ring counting that is shown in the diagrams in this document is as follows:

a) Do not count the pith

b) Count from pith to first band of latewood as ring 1

c) Count each subsequent band of latewood as a ring

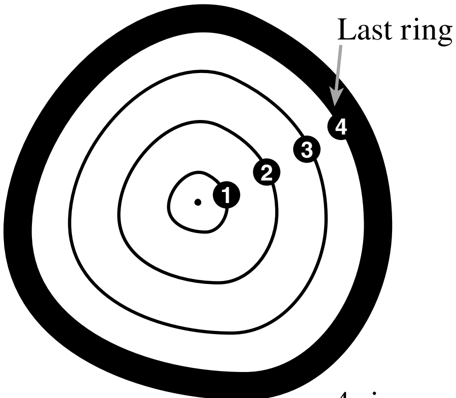
d) Count the last ring pressed against the inner bark.



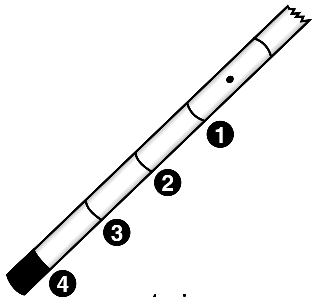
4 rings

7. Double check

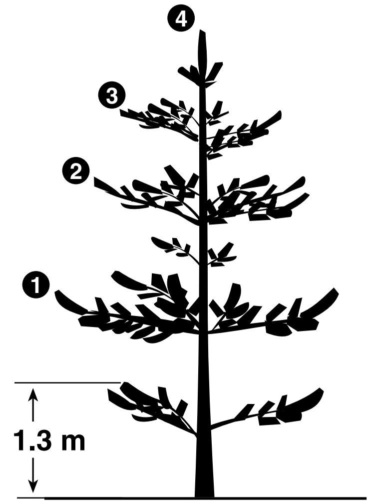
It is useful to double check your age determination every now and again. On small trees it is relatively quick and easy to compare the age determined by counting whorls to the age determined by felling or drilling the tree.



4 rings



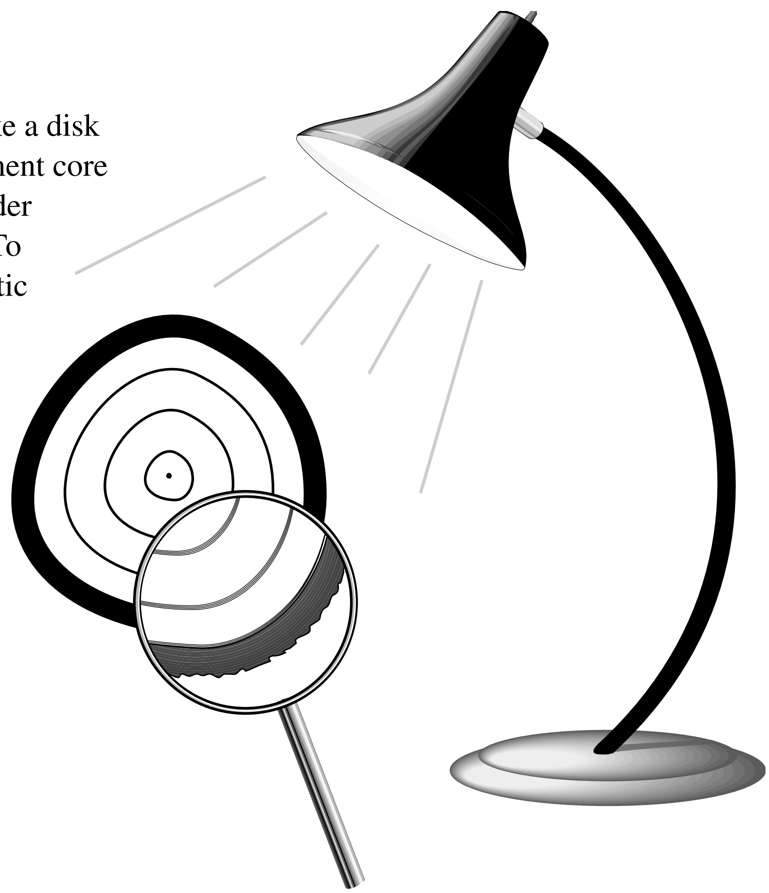
4 rings



4 rings at breast height

8. Office counting

In some cases, you may want to take a disk cut from breast height or the increment core back to the office to count rings under improved light and magnification. To transport cores, place core in a plastic drinking straw and seal the ends of the straw.

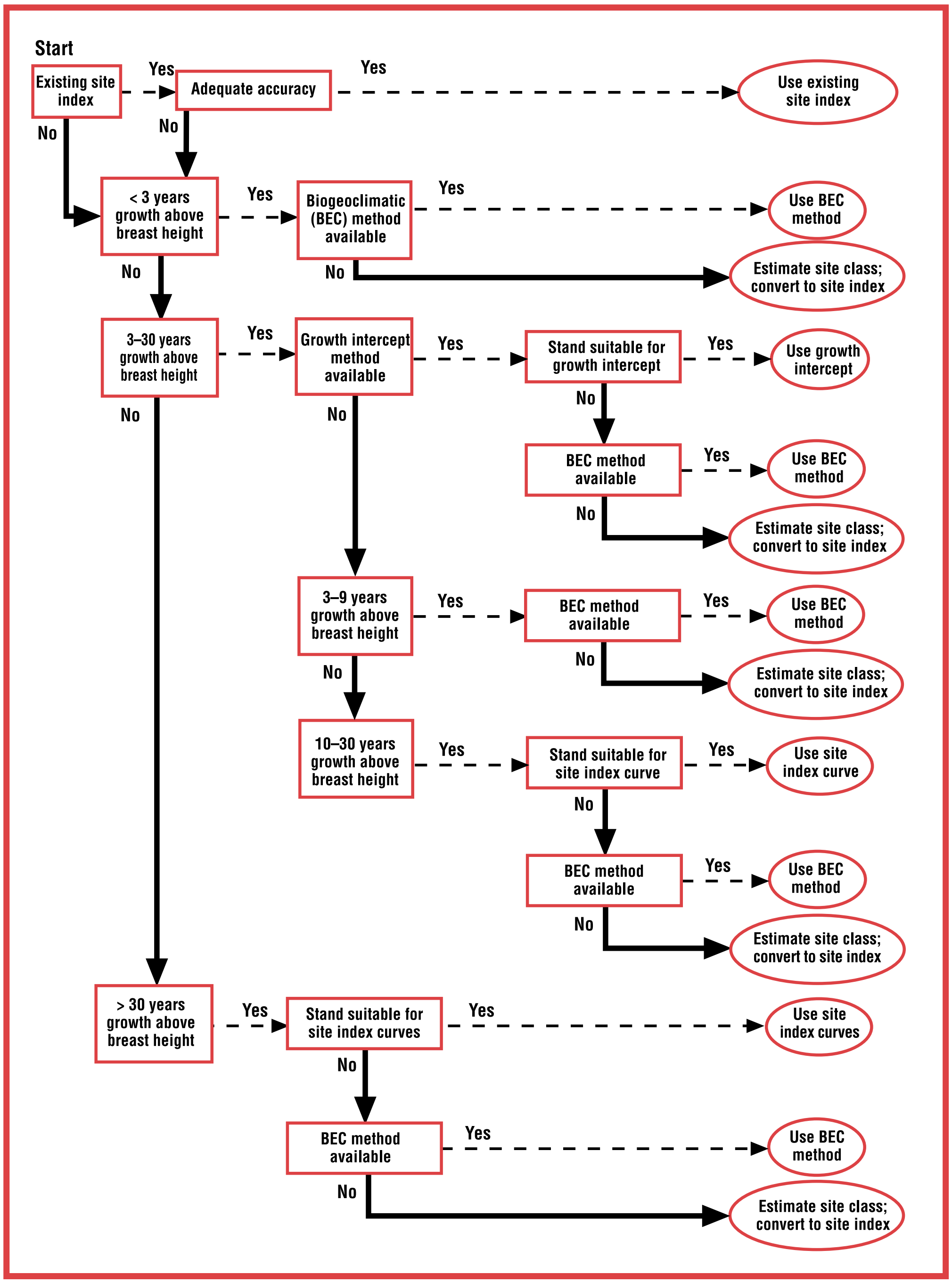


Appendix 3. Growth Intercept Tables

This appendix is available on the Internet at:
http://www.for.gov.bc.ca/hfp/pubs/sicourse/index.htm

Appendix 4. Determining a Suitable Site Index Method

This figure is a decision key to select a recommended method to estimate site index for silviculture polygons and strata. The background required to properly use the decision key follows.



1 Who should use this key?

This decision key is provided for silviculture surveyors who must determine site index for silviculture polygons. The key may also assist other users (e.g., inventory or research crews).

2 Cautions

This decision key will recommend a method to use to determine site index. However, operational concerns not addressed by the key may override this recommendation. These additional concerns include 1) the cost of data collection and the available budget, 2) damaging crop trees when determining age, and 3) combining the recommended method with other surveys planned for the block.

3 Methods to estimate site index

For most silviculture polygons (strata), there is more than one method that can be used to obtain site index. These methods differ in their availability throughout the province, their suitability for different stand conditions, and their accuracy. This decision key assists in selecting from four methods: 1) BEC method, 2) growth intercept method, 3) site index curve method, and 4) estimate site class and convert to site index.

BEC method

With the BEC method, site index is predicted from the Biogeoclimatic Ecosystem Classification (BEC) for the stratum. The surveyor determines the biogeoclimatic unit and site series and then obtains a site index estimate for the selected species from the site index–site unit look-up table.

Growth intercept method

With the growth intercept method, site index is predicted from the height and age of sample trees measured on site. The surveyor measures the heights and ages of a number of sample trees in the stratum and obtains site index from a look-up table.

Site index curve method

With the site index curve method, site index is predicted from the height and age of sample trees measured on site. The surveyor measures the heights and ages of a number of sample trees in the stratum and obtains site index from a look-up table.

Estimate site class and convert to site index

With this method, the surveyor estimates site class and uses a table to convert site class to site index.

4 Documents required

To accurately estimate site index and to properly use the decision key, the following documents are required:

1. The SIBEC guide (Site Index Estimates by Site Series for Coniferous Tree Species in British Columbia).
2. FS 415 growth intercept field cards.
3. A complete set of site index curves and tables.
4. The table to convert site class to site index.

5 Description of each box in the decision key

Existing site index

This box questions whether there is a site index value already available for the stratum. Some strata have site index indicated on the forest cover map label; within ISIS, MLSIS, or a licensee's silviculture information system; or on a note in the opening file.

Adequate accuracy

This box asks if the existing site index is accurate for the purpose of the survey. In general, an existing site index is accurate enough for silviculture uses if it was obtained by careful, on-site application of any of the BEC, growth intercept, or site index curve methods. Usually, an existing site index is not accurate enough for silviculture purposes if it was 1) obtained by converting site class to site index, 2) taken from an adjacent stand, or 3) taken from the forest cover map label (since the site index in the label of most young stands was converted from site class and the site index in the label of most old stands is inaccurate).

Use existing site index

To obtain a site index estimate for the stratum, use the existing site index value.

Less than three years growth above breast height

This box questions if dominant and codominant trees of the selected site index species have completed less than three years growth above breast height.

BEC method available

This box asks if the Biogeoclimatic Ecosystem Classification (BEC) method of predicting site index is available. It is available if the species — site unit combination in the SISU tables of the *Site Index Estimates by Site Series for Crop Tree Species of British Columbia* contains an estimate.

Use BEC method

To obtain a site index estimate for this stratum, use the BEC method.

Estimate site class; convert to site index

To obtain site index for this stratum, estimate site class and convert site class to site index.

3–30 years growth above breast height

This box asks if dominant and codominant trees of the selected site index species have completed 3–30 years growth above breast height.

Growth intercept method available

This box asks if the growth intercept method is available for the selected site index species.

Stand suitable for growth intercept

This box questions whether the stand condition is suitable for the growth intercept method. The growth intercept method is suitable for a stratum if there are enough sample trees, with enough growth, and their growth reflects site potential. Usually, a stand is not suitable if many of the dominant and codominant trees of the selected site index species have been:

1. overtopped by other trees or brush;
2. seriously damaged or diseased;
3. cut out by spacing; or
4. affected in height growth by treatment (for example, fertilization temporarily accelerating height growth or thinning shock temporarily reducing height growth).

Use growth intercept method

To obtain site index for this stratum, use the growth intercept method.

3–9 years growth above breast height

This box asks if dominant and codominant trees of the selected site index species have completed 3–9 years growth above breast height.

10–30 years growth above breast height

This box asks if dominant and codominant trees of the selected site index species have completed 10–30 years growth above breast height.

More than 30 years growth above breast height

This box asks if dominant and codominant trees of the selected site index species have completed more than 30 years growth above breast height.

Stand suitable for site index curve

This box questions if the stand condition is suitable for the site index curve method. The site index curve method is suitable for a stratum if there are enough sample trees with growth that reflects site potential. Usually, a stand is not suitable if:

- it is uneven aged;
- the sample trees have been overtopped by other trees;
- it has received partial cutting removing the larger trees;
- many of the sample trees are seriously damaged (for example, broken or dead tops) or diseased;
- sample trees are very old (age class 8 and 9);
- sample trees are very large or rotten at DBH;
- it is a stand that regenerated densely, particularly lodgepole pine.

Appendix 5. Average Site Index Relationships Between Species

Average site index relationships

Interior Bl Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Pl	10	13	15	17	19	21	23	26	28	30	32
Interior Sx	10	12	14	17	19	21	24	26	28	31	33

Interior Fd Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Hw	6	8	11	13	15	17	20	22	24	27	29
Interior Lw	11	13	15	17	19	21	23	25	27	29	31
Interior Pl	10	12	14	16	19	21	23	25	27	29	31
Interior Sx	7	10	13	15	18	21	23	26	29	32	34

Interior Hw Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Fd	13	15	17	19	21	22	24	26	28	29	31

Interior Lw Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Fd	9	11	13	15	17	19	21	23	25	27	29
Interior Pl	8	10	13	15	17	19	21	23	25	27	29

Interior Pl Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Bl	10	12	13	15	17	19	21	23	24	26	28
Interior Fd	10	12	14	16	18	19	21	23	25	27	29
Interior Lw	12	13	15	17	19	21	23	25	27	29	31
Interior Sx	9	11	13	15	17	20	22	24	26	28	31

Interior Sx Site Index	10	12	14	16	18	20	22	24	26	28	30
Interior Bl	10	12	14	15	17	19	21	22	24	26	27
Interior Fd	12	14	15	17	18	19	21	22	24	25	27
Interior Pl	11	13	15	17	19	20	22	24	26	28	30

Coastal Ba Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Hw	17	20	23	26	29	32	35	39	42	45

Coastal Fd Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Hw	13	16	18	21	24	27	29	32	35	37

Coastal Hw Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Ba	13	16	19	22	25	28	31	34	36	39
Coastal Fd	17	20	24	27	30	34	37	40	44	47
Coastal Ss	14	18	21	25	29	33	36	40	44	48

Coastal Ss Site Index	15	18	21	24	27	30	33	36	39	42
Coastal Hw	16	18	21	23	26	28	30	33	35	38

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This "site index species conversion table" provides the average site index expected for a species when site index is known for another species growing on the same site. The text that follows provides the background to assist in using the table properly.

When will this table be useful?

This table is useful when site index has been accurately determined for one species and it is required for another species. This could occur when the silviculture and inventory labels differ in leading species, and data were only collected on sample trees of one species. Rather than assume that both species have the same site index, use the conversion table to improve the estimate of the site index for the second species.

Why not assume all species on site have the same site index?

You should not assume that the site index determined for one species can be applied to all other species on the site. On any forest site, trees of one species will grow faster or slower than trees of a second species. A site may be good for one tree species, but only fair for a second species. Each species on the site has a unique site index.

How to use the table

To use the table, accurately determine the site index of one species. Find the section in the table that corresponds to this species and look up the site index predicted for a second species on the same site. For example, if site index was accurately determined as 22 m for Sx in an interior stand, find the section of the table labeled "Interior Sx site index." Look across the section heading to find the column for site index 22 m. Look down this column to find that the average site index predicted for Fd on the same site is 21 m.

Cautions

This table provides rough estimates of site index. These estimates are based on the average site index relationship between species. On any individual site, the site index for the second species may differ considerably from the average provided in the table. The most accurate site index for a second species on site is obtained by collecting growth intercept or site index curve data on suitable sample trees of the second species. However, on average, using the conversion table will provide you with better site index estimates than if you simply assume that all species on site have the same site index.

Appendix 6. Procedures for Obtaining Site Index for Silviculture Polygons

This appendix is available on the Internet at:
http://www.for.gov.bc.ca/hfp/pubs/sicourse/index.htm

Appendix 7. Checklist for Evaluating Growth Intercept Data

This appendix is available on the Internet at:
http://www.for.gov.bc.ca/hfp/pubs/sicourse/index.htm

Appendix 8. Site Index Curves and Tables for B.C.

This appendix is available on the Internet at:
http://www.for.gov.bc.ca/hfp/pubs/sicourse/index.htm

Appendix 9. SIBEC Field Cards

This appendix is available on the Internet at:
http://www.for.gov.bc.ca/hfp/pubs/sicourse/index.htm

Appendix 10. How to Obtain Site Index Resource Material

1. SIBEC – book size

You should obtain the 8.5 × 11 inch book-sized version of the complete provincial SIBEC guide.

Publication title	Ordering information
Site index estimates by site series for coniferous tree species in British Columbia	Order from Crown Publications Inc. Order number 661 $6.00

2. SIBEC – field book size

If you work in the field, you'll also find useful a set of waterproof, field-book sized SIBEC tables for your region.

Publication title	Ordering information
Cariboo Forest Region site index – site unit tables	Order from Crown Publications Inc. Order number 662CF $3.50
Kamloops Forest Region site index – site unit tables	Order from Crown Publications Inc. Order number 662KF $3.50
Nelson Forest Region site index – site unit tables	Order from Crown Publications Inc. Order number 662NF $3.50
Prince George Forest Region site index – site unit tables	Order from Crown Publications Inc. Order number 662PGF $3.50
Prince Rupert Forest Region site index – site unit tables	Order from Crown Publications Inc. Order number 662PRF $3.50
Vancouver Forest Region site index – site unit tables	Order from Crown Publications Inc. Order number 662VF $3.50

3. Growth Intercept

You should get a set of waterproof, field-book sized growth intercept tables.

Publication title	Ordering information
FS 415 A; Growth intercept table – Lodgepole pine – Interior B.C.	Order from MoF Admin. Supply No charge
FS 415 B; Growth intercept table – Interior spruce – Interior B.C.	Order from MoF Admin. Supply No charge

FS 415 C; Growth intercept table – Western hemlock – Coastal B.C.	Order from MoF Admin. Supply No charge
FS 415 D; Growth intercept table – Douglas-fir – Coastal B.C.	Order from MoF Admin. Supply No charge
FS 415 E; Growth intercept table – Douglas-fir – Interior B.C.	Order from MoF Admin. Supply No charge
FS 415 F; Growth intercept table – Sitka spruce – Coastal B.C.	Order from MoF Admin. Supply No charge
FS 415 G; Growth intercept table – Subalpine fir – Interior B.C.	Order from MoF Admin. Supply No charge
FS 415 H; Growth intercept table – Western hemlock – Interior B.C.	Order from MoF Admin. Supply No charge

PDF files

Adobe Acrobat format (pdf) files for each of these forms are available at
<http://www.for.gov.bc.ca/ISB/Planning/Forms/index.htm>

4. Site Index Curves

You should get a waterproof, field-book sized set of site index curves.

Publication title	Ordering information
Site index curves and tables for British Columbia – Coastal species	Order from Crown Publications Inc. Order number 978 $20.00
Site index curves and tables for British Columbia – Interior species	Order from Crown Publications Inc. Order number 979 $20.00

5. Site Index Species Conversions

You should obtain a waterproof, field-book sized site index species conversion table.

Publication title	Ordering information
FS 415 I; Average site index relationships	Order from MoF Admin. Supply No charge

PDF files

An Adobe Acrobat format (pdf) file for this form is available at
<http://www.for.gov.bc.ca/ISB/Planning/Forms/index.htm>

6. Decision Key

You may find this waterproof, field-book sized flow chart to select a method to estimate site index useful.

Publication title	**Ordering information**
FS 415 I; Key to help silviculture surveyors select a method to estimate site index.	Order from MoF Admin. Supply No charge

PDF files

An Adobe Acrobat format (pdf) file for this form is available at
<http://www.for.gov.bc.ca/ISB/Planning/Forms/index.htm>

7. SITETOOLS

The SITETOOLS software can be downloaded at no cost from the following internet site:
<http://www.for.gov.bc.ca/cgi-shl/research/gy/softreg.exe>

8. Site Productivity Working Group Web Site

The SPWG web site contains useful site index information.View it at:
<http://www.for.gov.bc.ca/resinv/G&Y/Projects/spwg/index.htm>

How To Order

1. Crown Publications Inc.

To order a publication from the Crown Publications Inc., contact them by:

Tel.: (250) 386–4636
Fax: (250) 386–0221
Mail: Crown Publications Inc.
521 Fort Street
Victoria, BC V8W 1E7
Email: crown@pinc.com

You can place your order over the internet at the following address:
<http://www.crownpub.bc.ca>

2. Ministry of Forests, Administrative Supply

Temporarily, the FS 415 forms are being distributed by Monty Vanden-Bulck, MoF, Forest Practices Branch, (tel.) 250-387-8931, (e-mail) Monty.VandenBulck@gems2.gov.bc.ca.