FOREST PRACTICES

Silviculture Practices Section

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SILVICULTURE NOTE 28

BEHAVIOUR OF SITE INDEX ESTIMATES WHEN A GROWTH INTERCEPT MODEL IS APPLIED IN SURVEYS OF REGENERATED STANDS

Examples from a study of stumped, coastal Douglas-fir stands

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Introduction

Growth intercept models are used widely in British Columbia to estimate site index in young stands. These models were introduced in their current form in 1995 (Nigh 1995). As growth intercept models are relatively new to BC, most silviculturists are unfamiliar with the typical characteristics of the site index estimates produced by these models. In this paper, we use data collected in a recent study to demonstrate some important characteristics of the site index estimates of growth intercept models when they are applied in surveys of regenerated stands.

This paper is intended to help silviculturists using the growth intercept models to:

1. become more familiar with some key characteristics of the models
2. better assess how the models are performing
3. improve the accuracy of site index estimates
4. reduce sampling costs and increase sampling efficiency.

Since 1998, we have studied the performance of growth intercept models in silviculturally treated stands. Our data collection and analysis methods are described in other publications (Nigh and Love 1999, J.S. Thrower and Assoc. 1999, BC Ministry of Forests 2000, Nigh and Martin 2001). In this publication, we avoid a technical presentation. Instead, we provide some simple examples, drawn from a recent study, that illustrate typical properties of the site index estimates when growth intercept models are used in surveys of regenerated stands.

Study stands and methods

The data presented in this paper are taken from a study of the performance of Nigh's (1997) coastal Douglas-fir growth intercept model when applied to stumped sites on southern Vancouver Island. A complete description of the data, methods, and results of this study are provided in a more detailed report by Nemec (2001). In brief, the following methods were used. Eleven openings were identified which had been harvested between 1975 and 1984, stumped, and regenerated to Douglas-fir. In each opening, a stumped stratum was delineated. In each stratum, plots were established on a grid that uniformly covered the stratum at an intensity of approximately 1 plot/ha. At each grid point, the largest dbh Douglas-fir in a 0.01 ha circular plot was identified. This tree was sampled if it was deemed to be a suitable site tree (undamaged, healthy, and unsuppressed). Starting at the annual branch whorl below breast height (bh), a telescoping height pole was used to measure the height to every subsequent annual whorl up the stem until the whorls could no longer be reliably identified (Figure 1). This process recovered the height of the site trees each year as they grew above bh. In addition, on each site tree the current total height and bh age was measured. To each site tree, the coastal Douglas-fir growth intercept model was applied to the recovered height:age pairs to generate a series of site index estimates over time. In addition, the best currently available estimate of site index was obtained from total height and bh age.

Figure 1. Telescoping height pole used to measure the past height of a site tree each year as it grew above bh, based on the location of branch whorls.

Results

Site index estimates vary from plot to plot

In the typical survey, the site index estimates from a growth intercept model vary somewhat from plot to plot. Plot-to-plot variation in estimated site index does not necessarily indicate that there is a problem with the survey or the growth intercept model. This variation results from site quality differences across the stratum and random variation in site tree height growth. Errors in the measurement of site tree height and age, errors in site tree selection, and rounding errors will add to the variation. Figure 2 provides an example of the variability of plot site index values in a survey with 19 plots in one stratum.

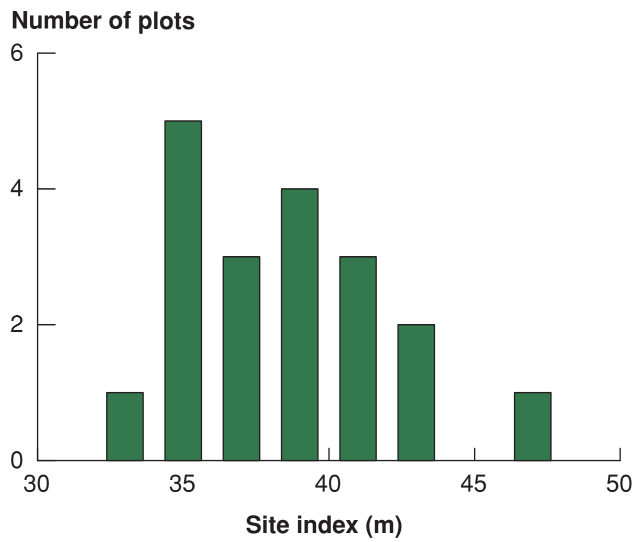

Figure 2. Variation in site index estimates among the 19 plots in the stumped stratum at the Hillcrest site.

The population mean lies somewhere within the confidence interval

After the fieldwork is completed, site index is estimated for each plot and the mean and (sometimes) the 95% confidence interval are calculated. The sample mean is our best estimate of the population mean. No survey measures every site tree in the stratum, so that even after a careful survey, the exact value of the population mean remains unknown. The confidence interval describes the range within which the population mean probably lies.[1]

[1] However, the 95% confidence interval around the sample mean will not encompass the true population mean 95 times out of 100 if the sample data are biased.

For example, 19 site trees were sampled in the stumped stratum at the Hillcrest site. The sample mean site index is 38.5 m, the standard deviation is 3.26 m and the critical ($\alpha = 0.025$) t-value is 2.101. Therefore, the 95% confidence interval is:

$$38.5 \pm 2.101 \quad \frac{3.26}{\sqrt{19}}$$

$$38.5 \pm 1.6$$

The sample data and the 95% confidence interval are displayed in Figure 3.

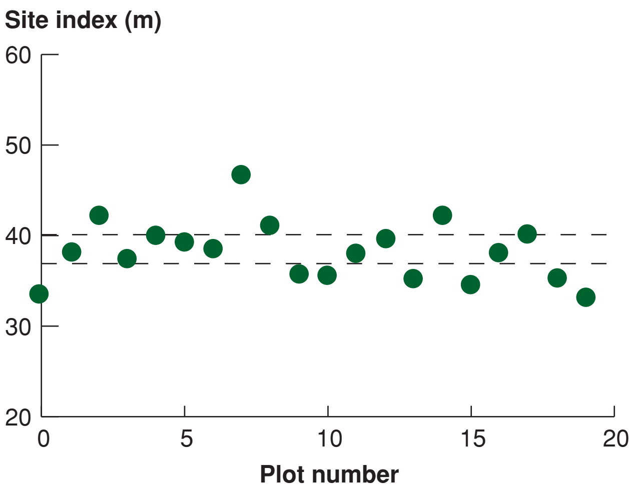

Figure 3. Site index estimates from the 19 plots (circles) in the stumped Hillcrest stratum and the 95% confidence interval on the mean (dashed lines).

Site index estimates from individual site trees vary over time

Ideally, if a tree were a site tree at a young age and it remained a site tree at an older age, measurements of its height and age input to a growth intercept model would return the same site index at both ages. However, due to many factors, including random variation in the height growth pattern of individual site trees, this ideal situation is rarely achieved. Instead, the site index indicated by a single site tree typically varies over time. Figure 4 displays examples of the variety of trends in site index values over time (site tree age) exhibited by site trees on one site. Note that we do not interpret these trends as evidence that site index itself is changing over time; we interpret these trends as random variation.

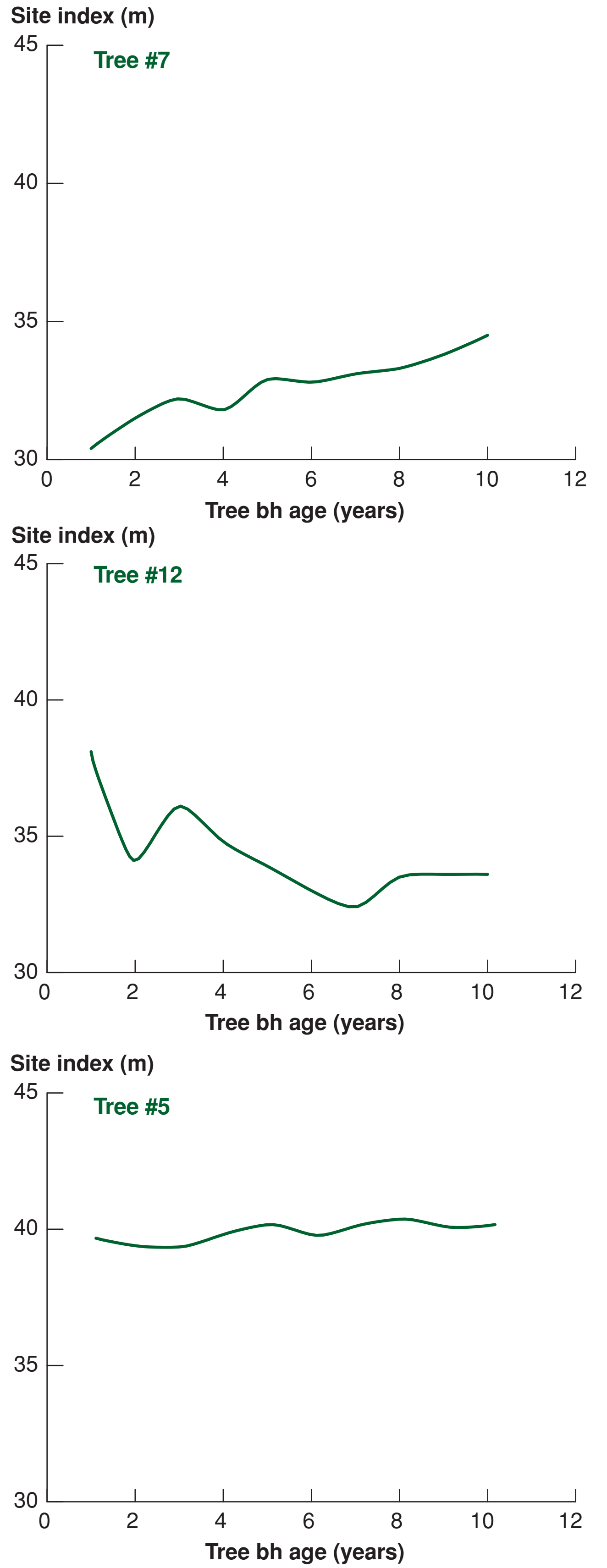

Figure 4. Examples of the trends in site index over time (sample tree age) exhibited by three site trees in the stumped Hillcrest stratum.

Plot-to-plot variation in site index values declines over time

As discussed earlier, every growth intercept survey returns a range of site index values. Typically, the variation in site index estimates is greater when site trees are younger. If a stratum was re-surveyed year after year, the variation in site index estimates would tend to decline over time. This behaviour is illustrated in Figures 5 and 6. Figure 5 displays the trends over time (site tree age) in the site index estimates from the 19 site trees sampled in the stumped Hillcrest stratum. Figure 6 displays the trends over time (site tree age) in the standard deviation of the site index estimates from this stratum.

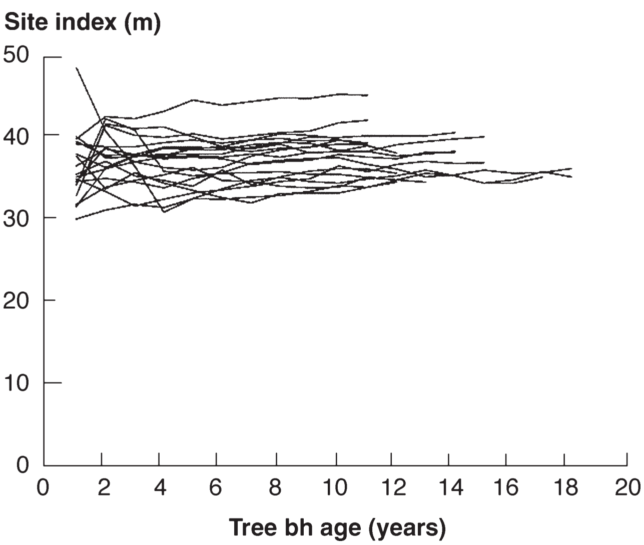

Figure 5. Trends over time (site tree age) in the site index estimates from the 19 site trees sampled in the stumped stratum at the Hillcrest site.

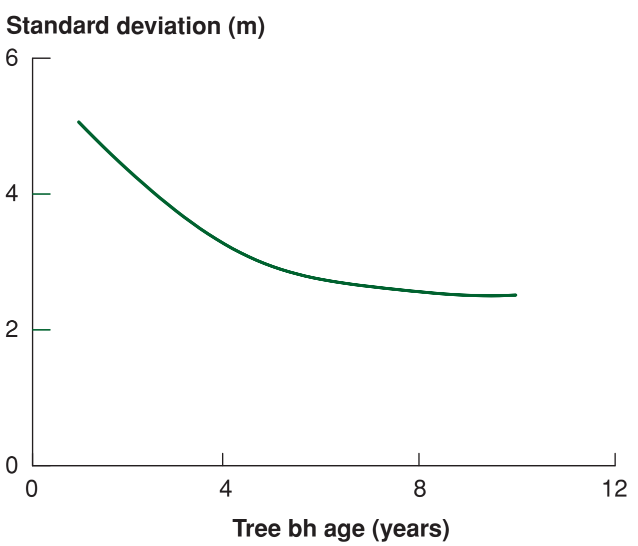

Figure 6. Trends over time (site tree age) in the standard deviation of the site index estimates from the stumped Hillcrest stratum.

Mean site index is often slightly lower when sample trees are very young

We expect site index to be constant on a site (at least over a single rotation), and would like our growth intercept models to return the same site index estimate whether a stand is surveyed at bh age 3 or 23 years. However, the growth intercept models frequently display the behaviour shown in Figure 7—initially slightly lower estimates of site index that increase somewhat when site trees are older. Nigh and Martin (2001) discuss some of the possible causes of this undesirable trend. This trend has been observed in studies of coastal Douglas-fir, interior lodgepole pine, interior spruce, and coastal western hemlock. When a growth intercept model is applied in a stand with very young site trees, the resulting site index estimate is often, but not always, slightly low. If the stand is surveyed repeatedly for several years, the site index estimates will tend to converge to a slightly higher value than the initial estimates. Generally, the site index estimates of growth intercept models appear to stabilize between bh age 5 and 10 years.

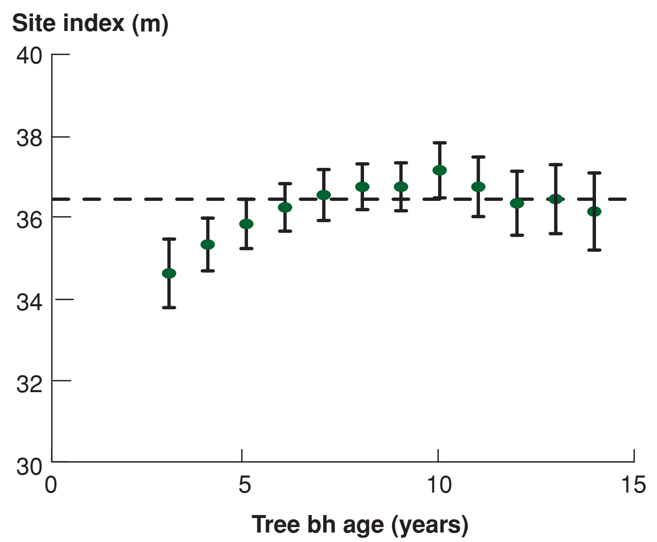

Figure 7. Trends over time (site tree age) in the mean and standard error of site index in the stumped Stamp Falls stratum and the best current estimate of site index (dash line).

Discussion

The site index estimates produced by growth intercept models exhibit certain behaviours that are relevant to silviculturists using these models. The examples presented here were chosen because they are typical of the behaviours that we commonly observe. The site index estimates are most variable when site trees are young. Plot-to-plot variation is less when site trees are older. As a result, compared to older stands, more samples are required in younger stands to achieve a desired level of precision. The site index estimates from individual site trees can vary greatly over time and within a single polygon. A reliable mean site index for a polygon requires, among other things, a sample of adequate size. Other important contributors to an accurate site index estimate are:

- plots evenly distributed over the stratum
- site trees correctly selected
- age and height accurately determined
- site index correctly computed from the appropriate growth intercept model.

In many stands, the growth intercept models slightly underestimate site index when young site trees are sampled. Less commonly, we have observed the site index estimates from growth intercept models to stay constant or increase over site tree age. This bias is frequently observed when site trees are less than 5 years bh age; but it generally becomes insignificant between bh ages 5 and 10 years. Though early bias is an undesirable characteristic, this finding should be considered relative to the accuracy of the alternatives that could be used to estimate site index in young stands. In most cases, these alternatives (e.g., SIBEC and site index from the inventory label of the previous old-growth stand) are much less accurate than the application of the growth intercept models to very young stands. The growth intercept models still provide the most accurate site index estimates in most cases.

In this study, a height pole was used to reconstruct the annual height growth of site trees. There are two important limitations to this method. First, this method is less accurate than falling trees and splitting them lengthwise to identify the locations of the pith scars that delineate the termination of each season's height growth (Figure 8). However, we believe that the height pole method has an accuracy in the lower section of the tree bole that is adequate for monitoring the site index estimates of the Douglas-fir growth intercept model, though the accuracy of the method is inadequate for calibrating a growth intercept model. Second, this method assumes that trees identified as largest dbh and suitable today were also largest dbh and suitable in the past. If in fact some other plot tree would have been selected as the site tree in the past, a bias enters the analysis. This bias (rank change bias) results in overstating the magnitude of the under-estimation of site index at young ages. However, one study in similarly aged stands of coastal Douglas-fir (J.S. Thrower and Associates 1999) found that, 70% of the time, site trees selected today were also site trees in the past. Based on these results and the relatively short

Figure 8. Site tree split lengthwise to identify the pith scars that mark the termination of each season's height growth.

time period over which we reconstruct tree height growth, we believe that if any rank change bias is present in our data, it is insignificant and would not materially alter the data and our interpretations.

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Additional information

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