60

Extension Note

January 2002

Splicing Height Curves

Gordon D. Nigh
and
Ken R. Polsson
B.C. Ministry of Forests
Research Branch
P.O. Box 9519, Stn Prov Govt
Victoria, BC V8W 9C2

SITE PRODUCTIVITY

Abstract

A previous method for splicing juvenile height models with height-age models does not give satisfactory results for coastal Douglas-fir because the two curves have different shapes and are far apart at the splice point. Our new procedure forces the juvenile height curve to be the same as the height-age curve at the pre-determined splice point, and pseudo-data are used to make a smooth transition between the two curves.

Introduction

Recent juvenile height models estimate height from germination up to total age 15, 20, or 25, depending on the species. These models give better estimates of height at young ages and hence give better estimates of the number of years it takes to reach breast height or green-up height. In order to get continuous height estimates from germination up to maturity, the juvenile curves need to be spliced with the height-age models. The juvenile height models can be used stand-alone if height estimates only up to the maximum age of the models are desired; otherwise the spliced version should be used.

In an earlier extension note, four ways of splicing juvenile height curves to height / breast height age curves were discussed, with one method giving better results for lodgepole pine (*Pinus contorta* var. *latifolia* Dougl.) (Nigh 1999). This method uses the following procedure:

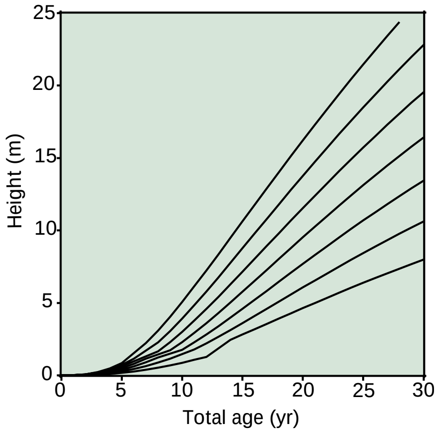
- Estimate heights up to breast height age 0 with the juvenile height model;
- Use the height / breast height age models to estimate heights above breast height age 2;
- Obtain heights between breast height age 0 and 2 by linear interpolation of the heights at breast height age 0 and 2.

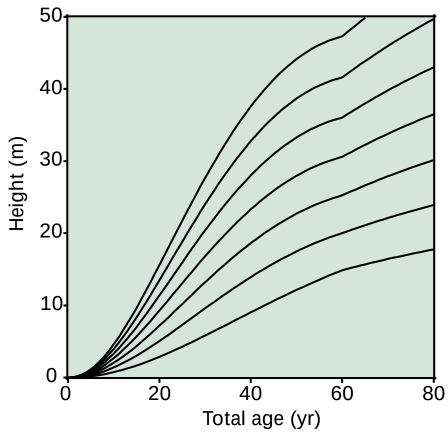
This procedure also gave good results when applied to white spruce (*Picea glauca* (Moench) Voss) (Nigh and Love 2000). The models for lodgepole pine and white spruce gave similar height estimates in the age range in which they were spliced together. When the same method was applied to the coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) juvenile height models (Nigh and Mitchell 2002) and the height–total age models (Bruce 1981), the resulting curve (Figure 1) was distorted at the splice point.

This extension note describes an alternative method to splice the curves that results in smoother and more reasonable height curves for Douglas-fir. This note also presents a years-to-breast-height model that is compatible with the height-age model. Compatibility occurs when the height-age model returns a height of, or close to, 1.3 m if the age and site index from the years-to-breast-height model are used in the height-age model.

BRITISH COLUMBIA

Ministry of Forests Forest Science Program





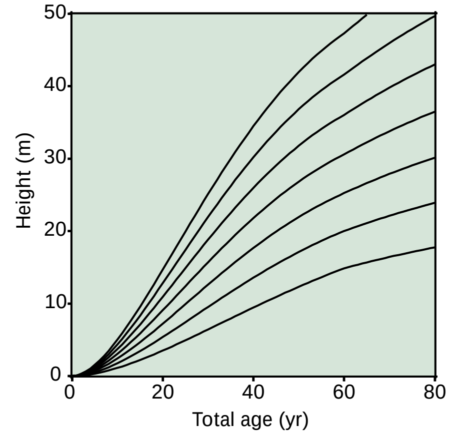


FIGURE 1 *Height models spliced using linear interpolation. Curves for site indices 15, 20, 25, 30, 35, 40, and 45 m.*

FIGURE 2 *Height models spliced by forcing a join point. Curves for site indices 15, 20, 25, 30, 35, 40, and 45 m.*

FIGURE 3 *Height models spliced by forcing a join point and using pseudo-data to smooth the curves. Curves for site indices 15, 20, 25, 30, 35, 40, and 45 m.*

Method

The splicing procedure includes re-fitting the juvenile height model for Douglas-fir so that the model and Bruce's (1981) height model are identical and smooth at a specified age. The age was specified as 60 years (total age) because the two curves were far apart at breast height, which necessitates a long transition period from the juvenile height curve to Bruce's curve. This age was also chosen because it is approximately the index age of 50 years at breast height. The functional form of the juvenile height model is:

$$HT = (a_0+a_1\times SI)\times A^{a_2}\times a_3^{A} \qquad [1]$$

where HT is site height (m), SI is site index (m at breast height age 50), A is total age (yr), and a_0, a_1, a_2, and a_3 are model parameters.

The curves were spliced by extrapolating the range of the juvenile height model from total age 25 to total age 60, and then conditioning it so that it gave the same estimated height as Bruce's model at total age 60. The model was conditioned by inverting equation 1 and expressing parameter a_3 as a function of the other parameters, SI, A, and HT. Variable A is set to 60 and HT is set to the height estimated by Bruce's model at age 60, denoted as HT60. Therefore, the equation for parameter a_3 is:

$$a_3=\left[\frac{HT60\times 60^{-a_2}}{a_0+a_1\times SI}\right]^{1/60} \qquad [2]$$

Using parameter a_3 as calculated in equation 2, model 1 was fit to the juvenile height data (see Nigh and Mitchell 2002). This resulted in a juvenile height curve that joined Bruce's curve at total age 60, but was not smooth (Figure 2).

To improve the smoothness, pseudo-data were generated from Bruce's equation for total ages 45–60, and model 1 (with parameter a_3 from equation 2) was re-fit to the juvenile height data and the pseudo-data. This gave a much improved curve shape (Figure 3) because the inclusion of the pseudo-data in the model-fitting data set caused the curves to follow a shape similar to Bruce's curves between age 45 and 60.

The years-to-breast-height model used in Bruce's curve and the curve based on the juvenile height model are no longer compatible with the spliced curve. Therefore, a new years-to-breast-height model was developed. First, pseudo-data were generated from the spliced curve by determining the years to breast height from the spliced curve for site indices 10–50 m in increments of 2 m. The functional form of the years-to-breast-height model is:

$$YTBH=b_0\times(SI-b_1)^{b_2} \qquad [3]$$

where YTBH is the years-to-breast-height (yr), SI is site index (m at breast height age 50), and b_0, b_1, and b_2 are model parameters. Model 3 was then fitted to these pseudo-data.

Discussion

Juvenile height models were developed in response to a need for good juvenile height, years-to-breast-height, and green-up age estimates. Most height-age models in British Columbia are based on breast height age, yet there is a need for height estimates below breast height. Before juvenile height models were available, heights below breast height were estimated with a quadratic function that was calibrated to give an estimated height of 0 m at total age 0 and a height of 1.3 m at the years to breast height, which is estimated from a years-to-breast-height function. The years to breast height estimates are not as accurate as the juvenile height models because the years-to-breast-height functions were derived from data collected on natural trees. These trees may have had some early suppression, and these data typically consisted of years from stump height (0.3 m) to breast height, with a few years added to account for the time taken to reach stump height from germination. In contrast, the juvenile height models we developed used very accurate data from managed trees, with measured heights right down to the point of germination. Therefore, the juvenile height models will give better height, years to breast height, and green-up age estimates in managed forests.

The coastal Douglas-fir height-age models (Bruce 1981) are the only height-age curves recommended for use in British Columbia that are based on total age. Therefore, there is not the same need for juvenile height models because Bruce's models give height estimates below breast height. However, the juvenile height models we developed should be more accurate because the juvenile height data we used are specific to British Columbia, and the models are localized to a narrower age range.

The juvenile height (HT) and years-to-breast-height (YTBH) models are:

$$HT=(-0.0160+0.00225\times SI)\times A^{1.8667}\times a_3^{A}$$

and

$$YTBH=38.8894\times(SI-6.2975)^{-0.5882}$$

where $a_3=\left[\frac{HT60\times 60^{-1.8667}}{-0.0160+0.00225\times SI}\right]^{1/60}$,

SI = site index (m at breast height age 50), A = total age (yr), and HT60 is the height (m) at total age 60 as estimated from Bruce's (1981) height curves.

The curves for spruce and pine have similar shapes and are close together, so splicing the two curves is straightforward. However, the curves for Douglas-fir are not close together and have different shapes. These differences can be attributed to sampling error, different data collection techniques, and different sample populations. The juvenile height models we developed are based on data taken from operationally managed stands across the range of Douglas-fir in British Columbia, whereas Bruce's curves were developed with data collected from research installations in Oregon, Washington, and British Columbia. Bruce's curves may not accurately represent early height growth of Douglas-fir since he did not have many data from very young stands.

The drawback with splicing the curves using the method described here is that the spliced curves become somewhat subjective over part of their range. Hence, a different curve shape would result by choosing a different splice point. The spliced curve is not fully supported by data since its shape is influenced by the splicing procedure. The impact of the splicing procedure on height estimates is demonstrated graphically in Figure 4. The juvenile height model up to age

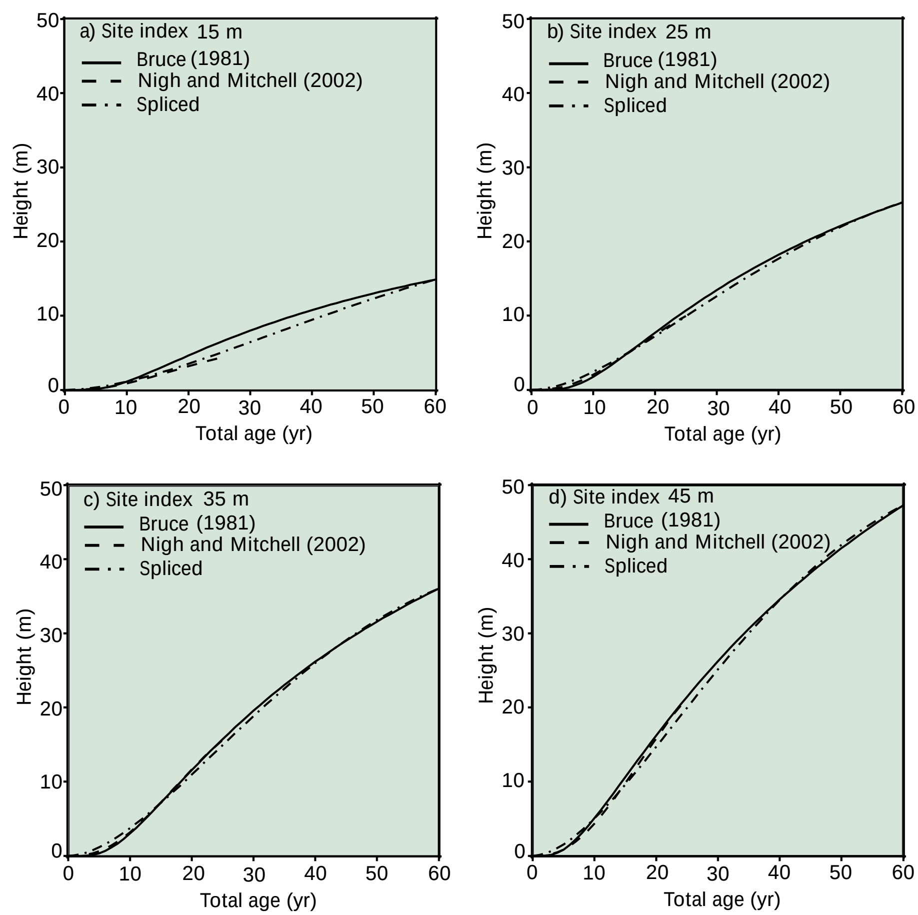


FIGURE 4 *A comparison of Bruce's (1981) curve, the juvenile height model (Nigh and Mitchell 2002), and the spliced curve for site indices 15 (part a), 25 (part b), 35 (part c), and 45 (part d) m.*

25, Bruce's (1981) curve, and the spliced curve for site indices of 15, 25, 35, and 45 m (parts a, b, c, and d, respectively) show that the spliced curves are similar to the juvenile height curves up to age 25. Except for the lower sites, the spliced curves are similar to Bruce's curves above age 25. Therefore, we conclude that the splicing procedure produces acceptable height estimates.

The green-up age model developed in Nigh and Mitchell (in 2002) is not compatible with our spliced curve for Douglas-fir. We did not develop a new green-up age model because there is no need for compatibility. Since green-up age can have a large impact in timber supply analyses, we did not want to compromise the green-up age estimates by using the spliced curves to develop a compatible green-up age model.

Conclusion

The splicing method presented here gave good results when applied to coastal Douglas-fir juvenile height models and height-age models. This method can be applied when the two curves being spliced do not have similar shapes.

Literature Cited

Bruce, D. 1981. Consistent height-growth and growth-rate estimates for remeasured plots. For. Sci. 27: 711–725.

Nigh, G.D. 1999. Smoothing top height estimates from two lodgepole pine height models. B.C. Min. For., Res. Br., Victoria, B.C. Exten. Note 30.

Nigh, G.D. and B.A. Love. 2000. Juvenile height development in interior spruce stands of British Columbia. West. J. Appl. For. 15: 117–121.

Nigh, G.D. and M.G. Mitchell. 2002. Development of height-age models for estimating juvenile height of coastal Douglas-fir in British Columbia. West. J. Appl. For. In prep.

URL: http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En60.htm