On Correcting for Bias in Stem Analysis Data

Gordon D. Nigh, Biometrician

Research Branch

British Columbia Ministry of Forests

31 Bastion Square

Victoria, B. C.

Canada V8W 3E7

Acknowledgements: The author would like to thank James Goudie and Ian Cameron of the B.C. Ministry of Forests Research Branch for reviewing this manuscript and providing helpful comments.

Abstract. Adjustments for sectioning bias in stem analysis data may introduce a bias into fixed intercept height-breast height age models. This bias can easily be removed by allowing the intercept to float or by not adjusting the data. A further bias may be introduced when using the model if the breast height age of the tree is taken to be the ring count at breast height.

On Correcting for Bias in Stem Analysis Data

Introduction

Stem analysis data are frequently used to develop height-age (site index) models which predict height from site index (SI) and age. Often, age is taken to be breast-height age (BHA) because it eliminates "early erratic growth that is poorly related to site quality that occasionally occurs before a tree reaches breast height" (Monserud, 1984).

Stem analysis crosscuts do not always occur exactly at a node; on average, they lie midway between nodes. A bias is present if the nodes are assumed to lie at the crosscuts. Several methods have been proposed to remove this bias when it is desired to know the height of the tree at a given total age. Dyer and Bailey (1987) tested six of these methods and concluded that Carmean's (1972) correction was the most accurate.

This note shows how, in some instances, the bias correction can actually introduce bias into height-BHA equations. It further shows that, to avoid this bias, care must be taken in selecting the appropriate model formulation when developing height-BHA equations from stem analysis data. A further bias is identified which may be present when applying height-BHA curves.

Background

Figure 1 shows a stylized transverse section of a 7-year old tree which has had a constant height growth rate of 1 metre (m) per year since it reached breast height (1.3 m). Since, on average, all crosscuts occur midway between nodes it will be assumed that all cuts (points B and D) in our hypothetical tree occur midway between nodes. BHA is calculated by taking the difference between the number of growth rings at a sectioning point and the number of rings at breast height. Consequently, the age of the tree at breast height is 0. Applying a correction (Carmean's in this example) to section B-D in Figure 1 adjusts the height at BHA 0 to 1.8 m. An alternative and equivalent method of making this correction is to subtract half a year from the BHA. This would make the tree 1.3 m at $-\frac{1}{2}$ years BHA. Note that the magnitude of the adjustment depends on the growth rate, which in turn is a function of site index, i.e., the amount of the adjustment increases as site index increases.

A bias arises when developing height-BHA equations using a fixed intercept model formulation. Fixed intercept height-BHA equations are of the form

$$H = 1.3 + f(BHA, SI)$$

where H is height and f(BHA, SI) is a function which describes the height growth pattern. Function f is asymptotic, that is, it approaches a constant (0) as BHA approaches 0 (it also may approach some maximum value as BHA approaches infinity). Therefore, H approaches 1.3 m as BHA approaches 0. But, as shown above, after applying an adjustment for sectioning bias the height at BHA 0 is 1.8 m. The adjustment for bias actually introduces a bias in the height-BHA model! A brief review of the literature reveals cases where authors have unwittingly introduced this bias, for example, Carmean and Lenthall, 1989; Goelz and Burk, 1992; Ker and Bowling,

1991. Fortunately, this bias is small and it diminishes as BHA increases because the only fixed point in the height-BHA model is at BHA 0.

A further bias may arise when using the height-BHA model. Suppose the 7-year old tree in Figure 1 is measured for total height and BHA. The tree is cored at breast height and 5 rings are counted. Since there are 0 rings at the tip of the tree its BHA is deemed to be 5. However, if the first node above breast height is considered to be BHA 0, then counting nodes up to the tip (Figure 1) indicates that there is only 4 years growth, i.e., the tree really only has a BHA of 4.

Solution

The stem analysis bias can be alleviated in one of two ways: either do not make the adjustment for bias in the stem analysis data or use a floating-intercept formulation of the height-BHA model. Note that in the former case an adjustment will have to be applied for the tip of the tree unless the stem analysis was done in the middle of the growing season. This is opposite to what is usually done: adjustments are made everywhere except the tip (Newberry, 1991). If the latter method is employed, the formulation of the height-BHA curve should be of the form

$$H = (1.3 + b_0 \cdot SI) + f(BHA, SI)$$

where b_0 is a parameter to be estimated. The term $(1.3 + b_0 \cdot SI)$ is the floating intercept so b_0 should be positive to reflect the correlation between the amount of the adjustment and site quality.

The definition of breast height age clouds the issue somewhat because the way is it defined influences the height-BHA model formulation. BHA has been defined to be the difference between the number of rings at a section point and the number of rings at breast height (Alemdag, 1988; Anonymous, 1990). This definition is ambiguous because the point at which a tree has a BHA of 0 can be anywhere between points A and C in Figure 1. It also makes BHA a discrete variable. If BHA 0 is defined to be at either point A or C then a correction for bias should be applied. However, at point A the correction should be downwards instead of upwards and parameter b_0 in the above equation should be negative to be consistent with the correction. In any case, the point at which BHA is 0 should be clearly stated and should be reflected in the model. Often it is difficult to tell exactly how the authors defined BHA, for example, Biging (1985), Cieszewski and Bella (1989), and Thrower and Goudie (1992).

Husch et al. (1972) defines age at the breast height point to be "the number of years the tree has been growing above the point". This definition is unambiguous and makes BHA a continuous variable, as it should be. It has the further advantage that, when developing height-BHA models, an adjustment for sectioning bias only has to be done for the tip of the tree and a simple fixed intercept model can be used. In the application of the model, BHA should be calculated by subtracting one or ½ from the ring count at breast height, depending on whether the tree was measured in the middle of the growing season or after the end of the growing season, respectively.

Conclusion

Adjustments in stem analysis data to remove bias caused by crosscuts falling, on average, midway between nodes actually introduces a bias into fixed intercept height-BHA curves. The easiest method of removing this bias is by using a fixed intercept model without performing any adjustment, except on the last section. Regardless of what definition of BHA and method of removing bias is used, it needs to be carefully thought out and explained. With respect to the application of height-BHA models, a correction has to be applied to the ring count at breast height to correctly determine the BHA of the tree.

Literature Cited

Alemdag, I. S. 1988. Site index equations for white spruce in the Northwest Territories, Canada. For. Ecol. Manage. 23: 61-71.

Anonymous. 1990. Minimum standards for the establishment and remeasurement of permanent sample plots in British Columbia. Forest Productivity Councils of British Columbia. 28 pp.

Biging, G. S. 1985. Improved estimates of site index curves using a varying-parameter model. For. Sci. 31(1): 248-259.

Carmean, W. H. 1972. Site index curves for upland oaks in the central states. For. Sci. 18(2): 109-120.

Carmean, W. H. and D. J. Lenthall. 1989. Height-growth and site-index curves for jack pine in north central Ontario. Can. J. For. Res. 19(2): 215-224.

Cieszewski, C. J. and I. E. Bella. 1989. Polymorphic height and site index curves for lodgepole pine in Alberta. Can. J. For.

Res. 19(9): 1151-1160.

Dyer, M. E. and R. L. Bailey. 1987. A test of six methods for estimating true heights from stem analysis data. For. Sci. 33(1): 3-13.

Goelz, J. C. G. and T. E. Burk. 1992. Development of a well-behaved site index equation: jack pine in north central Ontario. Can. J. For. Res. 22(5): 776-784.

Husch, B., C. I. Miller, and T. W. Beers. 1972. Forest mensuration. 2nd Ed. John Wiley & Sons, Inc. Toronto. 410 pp.

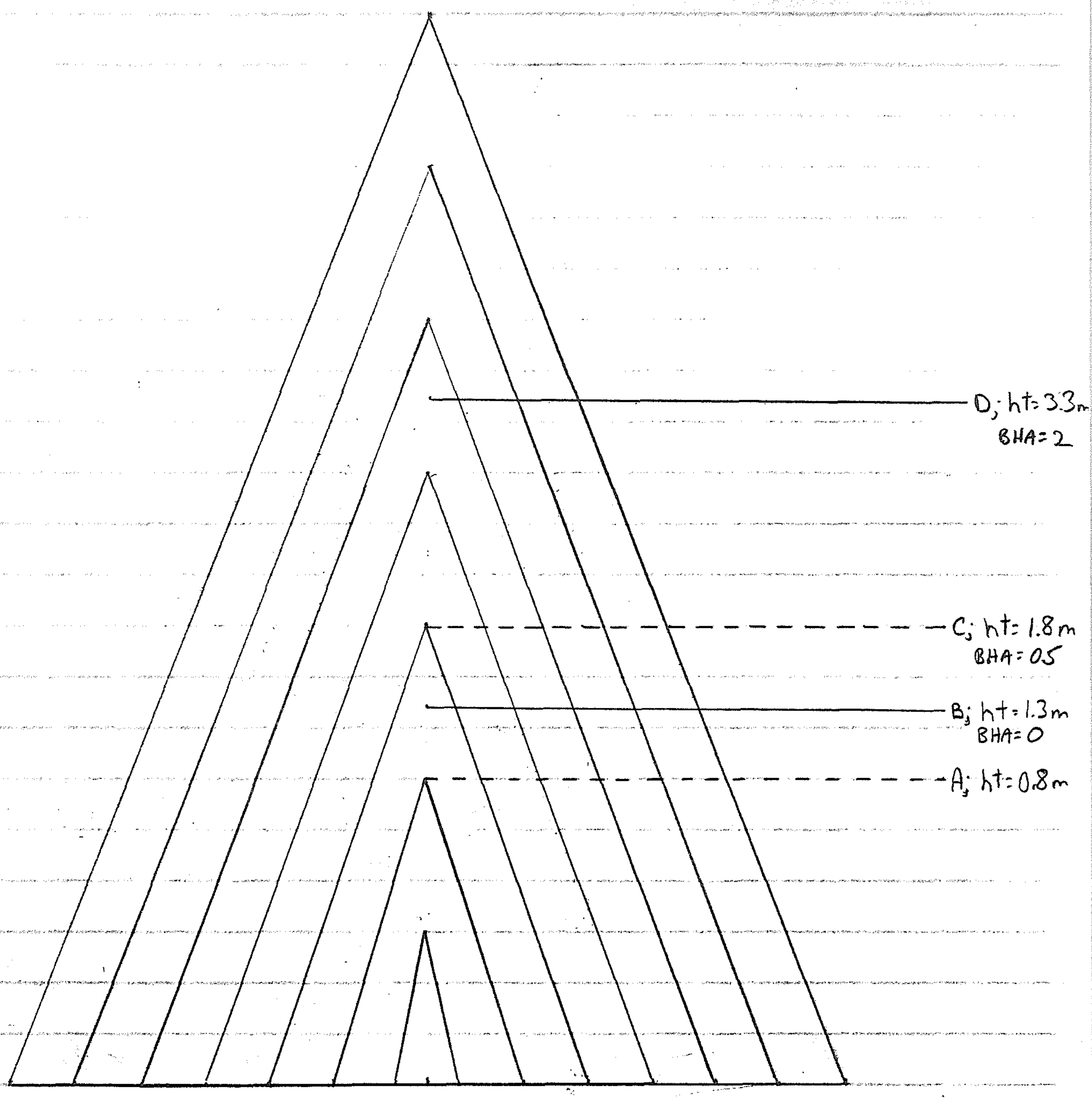
Ker, M. F. and C. Bowling. 1991. Polymorphic site index equations for four New Brunswick softwood species. Can. J. For. Res. 21(5): 728-732.

Monserud, R. A. 1984. Height growth and site index curves for inland Douglas-fir based on stem analysis data and forest habitat type. For. Sci. 30(4): 943-965.

Newberry, J. D. 1991. A note on Carmean's estimate of height from stem analysis data. For. Sci. 37(1): 368-369.

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. Appl. For. 7(1): 20-25.

Figure 1. Stylized transverse section of a 7-year old tree.



D; ht=3.3m
BHA=2
C; ht=1.8m
BHA=05
B; ht=1.3m
BHA=0
A; ht=0.8m