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HEIGHT INTERCEPT FOR ESTIMATING SITE INDEX in young ponderosa pine plantations and natural stands

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Foresters find it difficult to make reliable estimates of site index in young stands of ponderosa pine (*Pinus ponderosa* Laws.). In stands under 20 years old, this estimate of site quality cannot be obtained by conventional methods; in stands above 20 years, small errors in estimating age often create large errors in site index.¹ Furthermore, management decisions, such as planning cultural work in plantations, often must be made where trees suitable for estimating site productivity by standard means are lacking.

Height intercept offers a way of estimating site index in stands too young for conventional methods. This concept is based on the total length of a given number of consecutive internodes beginning at or just above breast height. In 1954, Wakeley² first proposed that 5-year height intercept be used to estimate growth in southern pines. Since then, height intercept has been developed as an independent measure of site productivity for red pine (*Pinus resinosa* Ait.),³ and as a method of estimating site index for stands of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco),⁴ western hemlock (*Tsuga heterophylla* [Raf.] Sarg.)-Sitka spruce (*Picea sitchensis* [Bong.] Carr.),⁵ and eastern white pine (*Pinus strobus* L.).⁶

Like red pine and eastern white pine, ponderosa pine is ideally suited to the height intercept method. Height growth is uninodal. And height growth differences caused by site appear early—by the time the tree reaches breast height.¹

This note reports a method of using height intercept to estimate site index in young, natural stands and plantations of ponderosa pine in northern California.

METHODS

Thirty-five even-aged ponderosa pine stands on the westside Sierra Nevada, southern Cascade Range, Warner Mountains of northeastern California, and

Abstract: Site index is difficult to estimate with any reliability in ponderosa pine (*Pinus ponderosa* Laws.) stands below 20 years old. A method of estimating site index based on 4-year height intercepts (total length of the first four internodes above breast height) is described. Equations based on two sets of published site-index curves were developed. They worked equally well for plantations and natural stands in northern California.

Oxford: 541:174.7 *Pinus ponderosa* (794).

Retrieval Terms: *Pinus ponderosa*; site-index estimation; California (northern); height intercept method; internodal measurement.

interior Coast Ranges were sampled. Nineteen stands were natural, and 16 were plantations. All stands were unthinned, were currently free of insect or disease attack, and showed little previous stem breakage. Stand ages ranged from 16 to 83 years.

Within each stand at least five dominants meeting the usual criteria for a site-index sample tree were selected in a small homogeneous area. Total height and age were obtained for each tree. Planting records gave total age for planted trees. Total age of natural trees was estimated by adjusting age measured at breast height from increment cores for time to reach breast height.⁷

Site index was determined for each area with two sets of site curves, one developed by Dunning and Reineke (D & R),⁸ and the other by Arvanitis, Lindquist, and Palley (ALP).⁹ Neither set of curves was designed for use in the Warner Mountains. I included the Warner Mountains anyway because only three of the 35 plots were located there and because the pattern of height growth on these plots fit the pattern shown in the site index curves. Site indices for stands less than 50 years (age at breast height) were adjusted according to the method described by Powers.¹⁰ Height intercepts one through six were recorded individually to the nearest 0.1 foot for each tree.

RESULTS

The relationship of site index to 6-year height intercept was linear, with no apparent difference between natural and planted stands. Therefore, I combined the data.

How many internodes need to be measured for an acceptable estimate of site index? Most investigators have recommended five. But I was uncertain whether five internodes were the most efficient number for ponderosa pine in northern California. To test this, I compared the coefficients of determination (r^2) of the linear regressions of both D & R and ALP site indices over 1- to 6-year height intercepts (*fig. 1*). The 6-year height intercept accounted for 81 percent of the variation between plots when estimating D & R site index and 74 percent when estimating ALP site index.

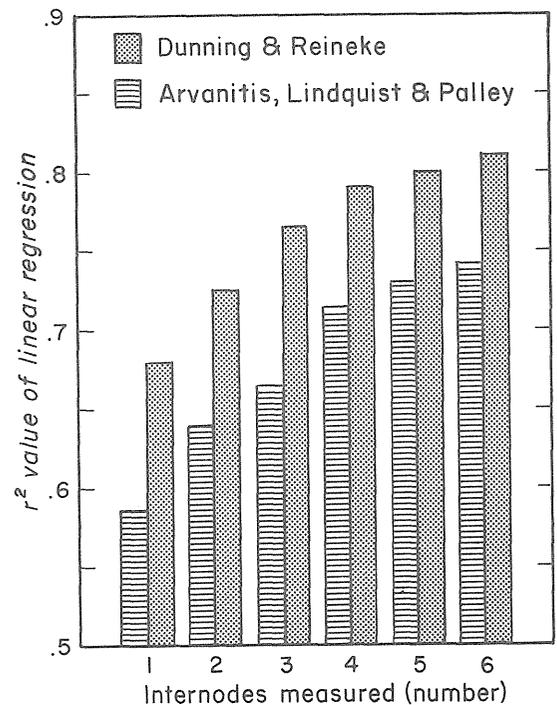
The r^2 values dropped slowly as fewer internodes were measured—down to 79 percent for D & R site index and 72 percent for ALP site index at four

Figure 1—The r^2 values of linear regressions estimating Dunning and Reineke⁸ and Arvanitis, *et al.*⁹ site indices increase only slightly when more than 4-year height intercepts are measured in young ponderosa pine stands in northern California.

internodes. Then the amount of variation explained dropped more quickly. But the drop was less than expected. Surprisingly, when only one internode above breast height was measured, 68 percent of the variation between plots remained accounted for when estimating D & R site index. Apparently, by the time young ponderosa pine reach 4.5 feet in height, their height growth strongly reflects the site potential. Severe brush competition could mask this growth response. In this study, however, all samples were in fully-stocked stands where brush, although present in varying amounts, never had a full crown cover.

Little improvement in estimating either D & R or ALP site index can be expected by measuring more than four internodes (*fig. 1*). Measuring four instead of six internodes makes field measurements easier and lowers the minimum age at which site index can be estimated.

The relationship of 4-year height intercept to D & R site index (*fig. 2*) is preferred over ALP site index (*fig. 3*). Although ALP site index curves are more frequently used, D & R site index curves (base age: 50 years) more accurately describe height growth in stands less than 50 years old.¹⁰ For example, 72 percent of the variation in 4-year height intercept was accounted for by ponderosa pine site index curves developed by ALP (base age: 100 years) compared with 79 percent for D & R curves. But 4-year height intercept still will provide a satisfactory estimate of ALP site index (*fig. 3*).



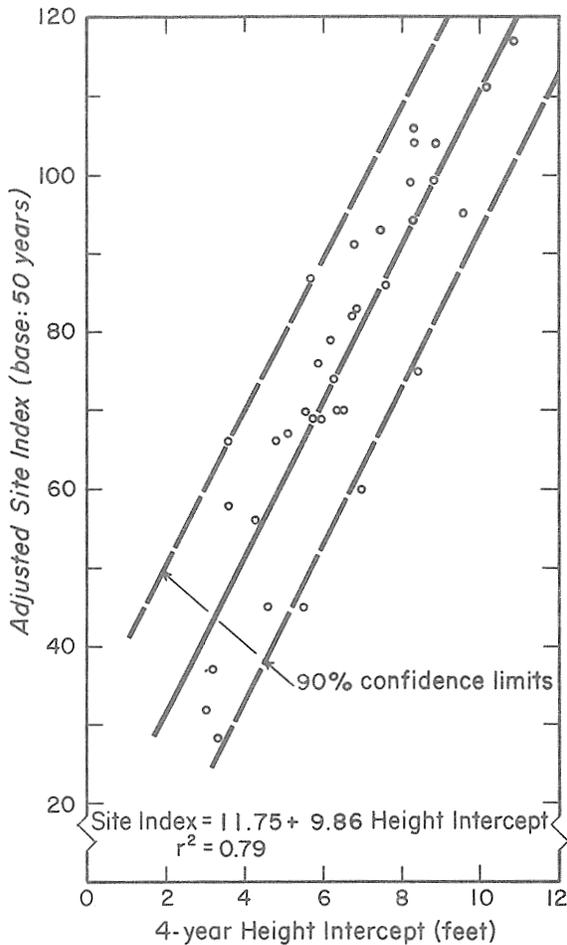
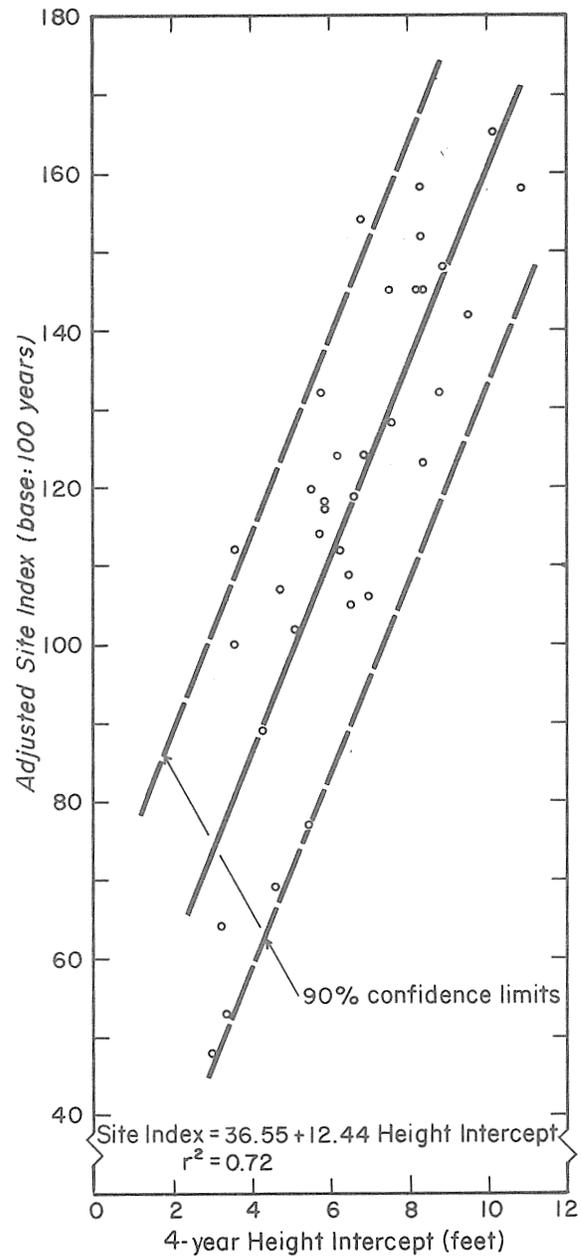


Figure 2—Dunning and Reineke⁸ site index can be estimated closely by 4-year height intercept in young ponderosa pine stands in northern California.

Figure 3—Arvanitis, *et al.*⁹ site index can be estimated by 4-year height intercept in young ponderosa pine stands in northern California.



The predicting equations I developed are:

1. Dunning and Reineke Site Index = $11.75 + 9.86$ H.I.
2. Arvanitis, Lindquist, and Palley Site Index = $36.55 + 12.44$ H.I.

in which H.I. = 4-year height intercept.

Mean square deviation from regression ($Sy.x^2$) was 101.98 for D & R site index and 245.49 for ALP site index.

When estimating D & R site index from 4-year height intercepts, 90 percent of the individual estimates should fall within ± 18 site index units of the true value. Since 4-year height intercept is a less accurate estimate of ALP site index, 90 percent of these estimates should fall within ± 28 site index units of the true value.

APPLICATION

To use the height intercept method of site index estimation:

- Select at least four or five dominant trees within a small, homogeneous area. The number of tree groups

necessary will depend on the variation in site quality and the accuracy needed. Choose vigorous, well-formed trees with no evidence of disease, insect attack or stem damage—trees that, if older, would be candidates for conventional site index estimates.

- Measure the total length (nearest 0.1 foot) of the four internodes beginning with the node at or just above breast height.

- Average the 4-year height intercepts for each group.

- Read site index from *figures 2 or 3*, or calculate it from equations 1 or 2.

Estimates of site productivity will not be precise with this method. Site index, itself, is only an estimate of site productivity. Errors inherent in site index curves are compounded by errors in the height intercept method. Nevertheless, for young stands of ponderosa pine below 20 years of age it offers a way to obtain site index. And for stands at, or slightly above 20 years, height intercept is probably as accurate and certainly easier to obtain than by conventional means. The method appears to work equally well for natural stands and plantations.

NOTES

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