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Site Index: Accuracy of Prediction

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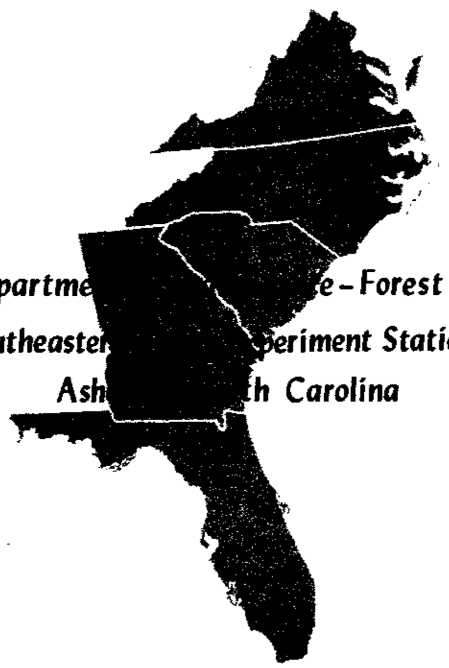
Donald E. Beck

and

Kenneth B. Trousdell



U.S. Departme… e-Forest Service
Southeaste… periment Station
Ash… h Carolina

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Donald E. Beck, Principal Silviculturist
Asheville, North Carolina

and

Kenneth B. Trousdell, Principal Silviculturist
Charleston, South Carolina

With the current forecasts of increasing demands for forest products from a decreasing land base, many foresters are preoccupied with ways to increase productivity. Therefore, it is appropriate that foresters take a look at just how well they are evaluating productivity, or site quality, at the present time. Evaluation of site quality has always been an important part of forest management. As management has intensified, accurate estimates have become increasingly important.

For this discussion, we have restricted ourselves to one measure of site quality. That measure is site index, which is defined as the height reached by a forest stand at a selected index age. It can be debated whether or not site index is the best possible measure of site quality. However, over the years it has proved to be a useful indicator. It is widely used for direct estimates, as well as being used as a base for developing and testing alternative methods. Thus, we will confine ourselves to a discussion of how accurately site index can be estimated at the present time and how the accuracy of these estimates might be improved.

In using site index, many foresters are inclined to talk about increments of one unit or possibly even fractions of a unit, which would imply that they are working with a very precise measurement indeed. However, to our knowledge, no set of site index curves or equations comes packaged with a statement of precision or the accuracy one might expect in application. In fact, one usually has no idea of the size of the error involved in any given estimate of site index. Anything that can affect height growth--and there are many factors--can affect one's estimates of site index. Thus, it is extremely difficult to predict the amount of error in such estimates.

Concern with error in estimates of site index is not new. The possible weaknesses in the site index approach were recognized and discussed at the time of its introduction into this country and have been reviewed periodically since then (3, 5, 6, 7). As long-term records have been accumulated, one finds that there are indeed some major sources of error and, thus, avenues for improvement in estimates of site index.

On the basis of recent work, we think that, if conventional site index curves or equations are being used, the estimates of site index are probably biased--quite possibly, seriously biased. By conventional curves, we mean those developed by constructing a single curve of height over age from temporary plot data and then drawing a series of curves for higher and lower sites, harmonized to have the same shape as the guide curve. The majority of the site index curves in use today were constructed by this method. Two major faults of this method prompt us to say that resulting estimates may be biased: disregard of a possible age-site bias in sampling and the assumption of a constant curve shape. An additional and often-overlooked factor which may contribute substantially to errors in estimating site is the improper use of site curves.

SOURCES OF ERROR

Sampling Bias

First, because of patterns of land abandonment and timber harvest, the mean or guide curve of height over age is often distorted. A sample drawn from either natural or planted stands is unlikely to have a uniform distribution of site quality for all ages. For example, a pattern that has occurred in samples for a number of species is that the young age classes contain a preponderance of good sites and the older age classes have a preponderance of poor sites. A sample such as this could result from a cutting pattern: trees reach harvestable size earliest on the best sites; consequently, stands on the highest quality sites may not be available for sampling. Site index curves derived from this sample would tend to underestimate site index at young ages and overestimate site index in older stands. Figure 1 illustrates a distortion associated with a disproportional sample of site and age.

What size error can occur? From stem analysis in 42 stands of eastern white pine (*Pinus strobus* L.) in the Southern Appalachians, the senior author found that the conventional site curves in use badly underestimated site index in young stands (1). The use of height at age 20 as an input into the existing site curves resulted in underestimates ranging from 8 to 32 feet at index age 50. The average underestimate was 19 feet or nearly two 10-foot site classes. Similarly, in working with loblolly pine (*Pinus taeda* L.), the junior author found that one set of curves commonly used in the Coastal Plain underestimated site index for a sample of 19 stands by an average of nearly 10 feet when height at age 20 was used (8). In younger stands, the errors were greater.

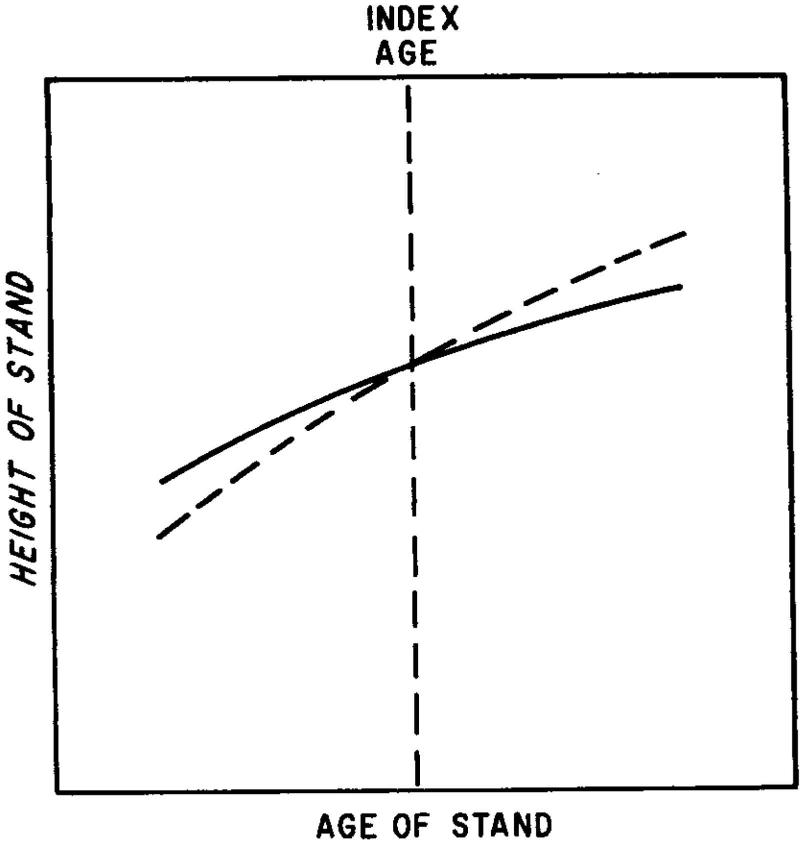

Figure 1.--Disproportional sample of site and age (too many high-quality sites at young age and vice versa) tilts the biased curve (solid line) in comparison with the unbiased curve (dashed line).

Polymorphic Curves

The second major fault of most existing site curves is their inherent assumption that the shape of the height growth curve is the same for all sites. Bull (2) demonstrated in the early thirties that this assumption did not hold in all cases. He showed that the shape of the growth curve varied with site quality in red pine (Pinus resinosa Ait.) plantations, i.e., that it was polymorphic, and, furthermore, that it varied in a definable manner. Similar findings have been increasingly reported for other species in recent years. The degree of diversity in curve shape seems to vary with species and location, but the pattern of growth with changes in site quality is surprisingly similar for many species. Instead of the rates of growth being proportional at all ages for all qualities of sites, as they are usually depicted by conventional curves, the rates of height growth rise rapidly on the best quality sites and then become relatively slow. On the other hand, the growth rates on progressively poorer sites increase more slowly but are maintained for a longer time. In fact, we have found that the rates of height growth for both white and loblolly pines on sites with the poorest site indices are equal to those on sites

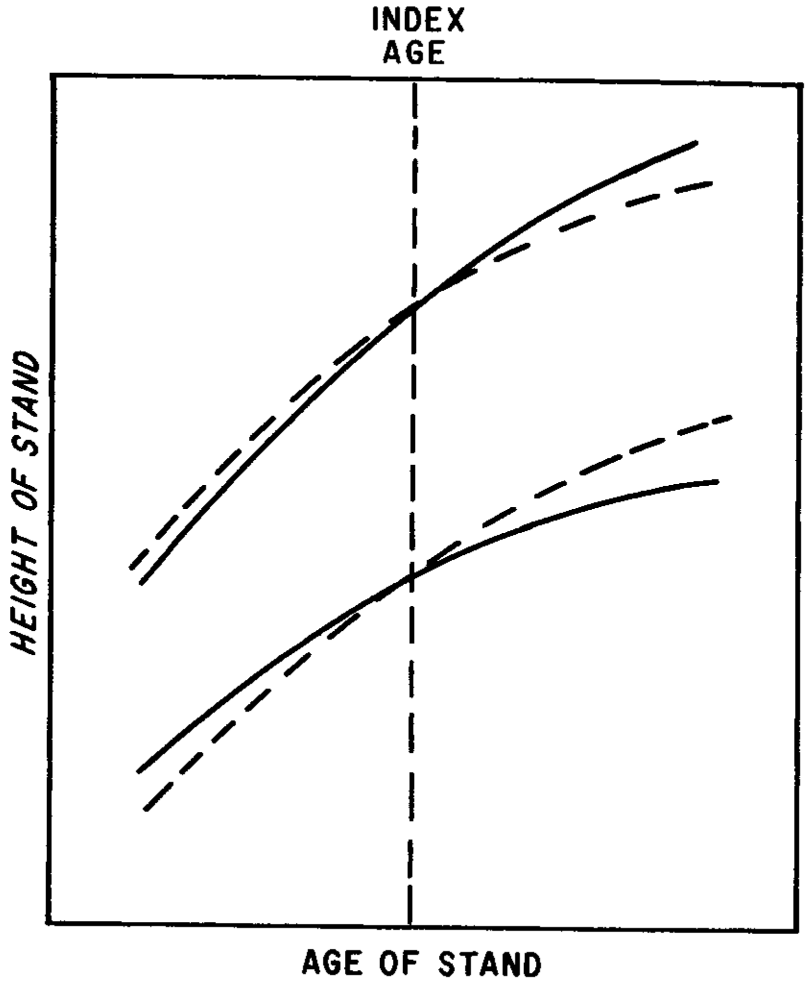

Figure 2.--Curves that assume a proportional relationship (solid lines) are here compared with unbiased, polymorphic curves (dashed lines). As can be seen from the latter, height growth on high-quality sites is rapid at first, but the curves flatten while the stands are still young. In contrast, height growth on low-quality sites is sustained at a slower rate for a longer period.

with the best indices by the time the stands are 50 to 60 years old (fig. 2). Consequently, estimating site index in such stands with site curves that use one similar shape would result in biased estimates.

Given the pattern of growth just described, the size of the bias is likely to be greatest at advanced ages, at 80 to 100 years or older. With present rotations, such bias might be of little but academic interest. However, it can be of some consequence in younger stands. For instance, when height at age 20 was used in the previously mentioned white pine sample, we found that better-than-average sites were overestimated by approximately one site class and below-average sites were underestimated by slightly less than one 10-foot site class if we assumed similar shape for the index curves. There was a similar but smaller bias with the site curves for loblolly pine. These errors, although not as large as those resulting from sampling bias, are nevertheless serious because of the bias.

Improper Use

One additional, and often overlooked, source of error should be mentioned: the manner of selecting trees on which to base estimates of site index. In most cases, estimates of site index have been based on average height of dominants and codominants. Estimates have also been based on heights of other components, such as dominants only, a fixed number of the largest or tallest trees, and a fixed percentage of the largest or tallest trees. There is really no optimum procedure for all species and all situations. Perhaps the main criterion in choosing trees for such estimates is to apply the curves in a manner consistent with their construction. If a set of site curves was developed on the basis of the 10 tallest trees per acre, then they should be applied on a site to trees selected on the same basis. To do otherwise could negate all the refinements that have gone into the construction of the curves.

IMPROVING ESTIMATES

The first two faults with which most existing site index curves are plagued stem from methodology of construction. These faults can be overcome and the resulting estimates of site index made considerably more accurate by adequate samples that correctly determine curve shape from stem analysis or periodic remeasurements and by analytic methods that recognize differences in curve shape on sites with different qualities. The third fault can be overcome by careful application.

When site curves which eliminated sampling bias and allowed different shapes for different levels of site index were applied to the data on white pine, the senior author found that 70 percent of the estimates in 10-year-old stands could be expected to be within 10 feet of actual site index and 92 percent could be expected to be within 20 feet (1). Of course, the shorter the period to index age, the more precise the estimates. For stands 20 years old, 93 percent of the estimates erred by less than 10 feet. Only an occasional estimate was badly in error. Similar results were found for the loblolly pine stands in the Coastal Plain (8).

But even if site curves are perfectly constructed, diversity in growth patterns caused by different combinations of site factors will lead to a certain amount of error in estimation. Foresters know from experience that stands of exactly the same height at index age may not have grown at exactly the same rate at all ages (fig. 3). Thus, generalized site index curves cannot accurately represent the growth of every individual stand, and errors of estimate are inevitable.

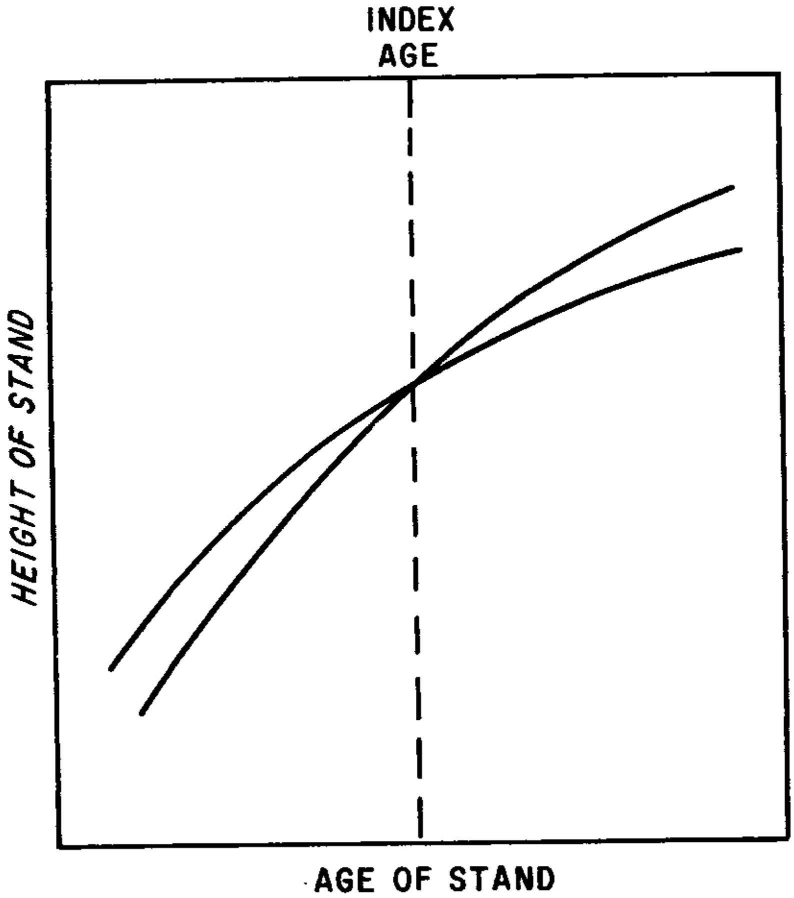

Figure 3.--These two growth curves of identical site index cannot be described without error by a single curve.

The data for white pine in the Appalachian highlands and for loblolly pine in the Coastal Plain represent a wide geographic range, diverse soils, and other environmental factors. Thus, it appears that the improvement that could be obtained in the majority of estimates for these species by recognizing one or a few environmental factors would be relatively small. On the other hand, the literature indicates substantial variation in curve shape (of the type illustrated in figure 3) for some species and for geographical locations (4). Different growth patterns have been associated with specific soil features, vegetative types, and land form categories. For example, Carmean (4) found that height-growth curves for Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) in the Pacific Northwest differed substantially between stands growing on gravels and sands and those growing on soils derived from sandstones and shales. Developing separate sets of site curves for the different soil groups improved estimates of site index.

SUMMARY

It is obvious that site index is not a precise measure of productivity. However, prediction of site index can be improved by using curves that have been developed by stem analysis or other methods that allow detection of true curve form. As a minimum requirement, curves should be used that have been verified by these methods. This one step alone could eliminate a major source of error in many estimates of site index. Additional improvement can be obtained by developing polymorphic site curves that allow the shape of the curve to vary with the quality of the site. For many species, site curves with only this degree of refinement will probably be adequate for most management purposes. In situations where a species grows on two distinctly different sets of soils, it may be profitable to impose a soil classification on the site index system by developing separate sets of curves. Finally, all curves, no matter what their degree of refinement, should be applied in accordance with their construction. Only in this way can maximum accuracy be achieved.

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