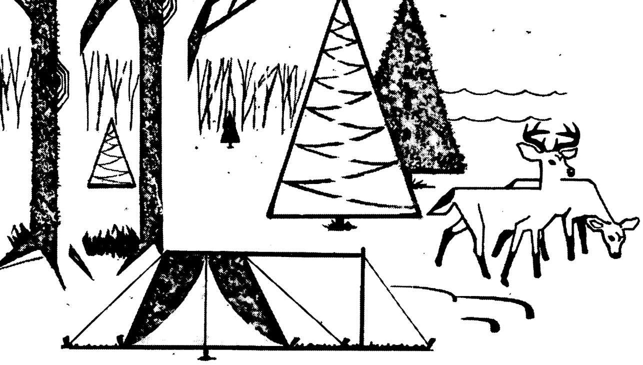

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ERRORS IN SITE INDEX DETERMINATION CAUSED BY TREE AGE VARIATION IN EVEN-AGED OAK STANDS

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ABSTRACT.--Age deviations of individual trees in even-aged oak stands in Missouri caused variations in the height growth patterns and site index estimates of these younger or older trees. A correction factor for site index estimates on these age-deviant trees is given.

OXFORD: 541:552:176.1 *Quercus* spp. (778).
KEY WORDS: light, wind, height growth.

Site index measurement in even-aged oak stands using tree heights, tree ages, and site index curves is usually based on the assumption that height growth (and site index) is independent of the minor variations in tree age (i.e., 10 to 15 yr) normally found in natural even-aged stands. However, height, age, and site index data from such stands of white oak (*Quercus alba* L.), black oak (*Q. velutina* Lam.), and scarlet oak (*Q. coccinea* Muenchh.) in southeastern Missouri show that even these small variations in tree age have a definite and significant effect on height growth patterns of the trees and, consequently, a similarly significant effect on site index measurements made on such trees.

METHODS

Data were taken from 334 1/10- to 2/10-acre plots located in even-aged oak-hickory stands on the National Forests in southeastern Missouri. The stands ranged in age from 30 to 85 yr, although most were 40 to 60 yr old. On each plot breast-height (BH) age and total height were determined on three to eight dominant or codominant trees of at least one of the three oak species. In addition, one to three of these trees were felled and sectioned for stem analysis. For sectioned trees over 50 yr old, site index was determined from individual tree height/age graphs; for trees less than 50 yr old, site index was determined from height, total age, and local site index prediction tables (McQuilkin 1974). For both sectioned and nonsectioned trees, total age was taken as BH age plus 2 yr.

Within most plots, the BH age range of the trees was 5 yr or less, but at least one tree on about a third of the plots differed significantly in age from the mean age of the rest of the trees.

To determine if these age differences were associated with any differences in site index, regressions were computed of the differences between the ages of the younger or older tree(s) and the mean age of the rest of the trees on the plot versus the difference in site index between the younger or older tree(s) and the mean site index of the rest of the trees. Regressions were computed separately by species using data from all plots that had trees differing in age from the mean of the rest of the trees by 4 yr or more.

Of the 334 plots examined, 106 had at least 1 tree with this minimum 4-yr age difference. On most of these plots (92 percent), the age differences were between 4 and 12 yr; the maximum difference was 29 yr. Similar regressions were also computed between height differences and age differences and between d.b.h. differences and age differences on the same trees.

RESULTS

Covariance analyses showed no significant differences among the species regressions, so the data for all three species were analyzed together. In all cases, the regression intercept terms were not significantly different from zero, and were dropped. The final age-site index relation was:

$$\Delta SI = -0.3366 \Delta AGE \qquad [1]$$

in which ΔSI = the site index of the age-deviant tree(s) minus the mean site index of the even-aged trees, and ΔAGE = the mean age of the age-deviant tree(s) minus the mean age of the even-aged trees. Addition of an AGE term (mean age of the even-aged trees) or an AGE x ΔAGE interaction term showed these factors to be nonsignificant--both individually and together. The correlation coefficient for Equation [1] was -0.64. The regression coefficient was highly significant. The negative regression coefficient shows that trees younger than the surrounding even-aged trees will indicate a site index too high by 1 ft per 3 yr of age difference and trees older than the surrounding even-aged trees will indicate a site index too low by the same amount.

Similar regression analyses of the relations between ΔAGE and ΔHEIGHT (mean height of the age-deviant tree(s) minus the mean height of the even-aged trees) and ΔDBH (mean d.b.h. of the age-deviant trees minus mean d.b.h. of the even-aged trees) resulted in:

$$\Delta HEIGHT = 0.2594 \Delta AGE. \qquad [2]$$

$$\Delta DBH = 0.1518 \Delta AGE. \qquad [3]$$

In both of these equations the intercept terms were not significantly different from zero and were dropped. The regression coefficients for both of these equations were highly significant. Equations [2] and [3] show that trees older than the surrounding even-aged trees are also taller and larger in diameter, and that younger trees are also shorter and smaller in diameter.

Height/age graphs were drawn for all plots in which the age-deviant tree was sectioned (figs. 1 and 2). Figure 1 shows

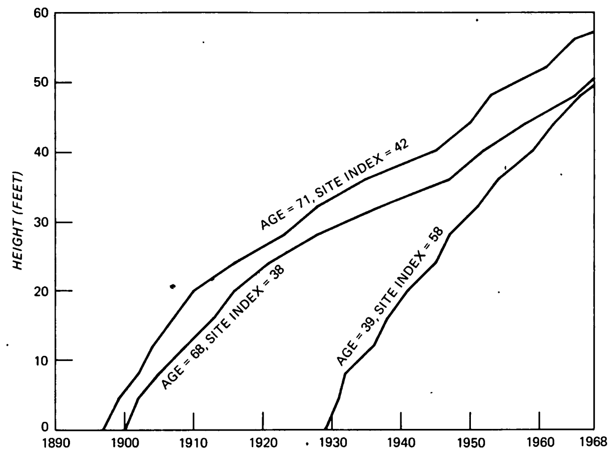

Figure 1.--*Height growth patterns of three adjacent white oak trees of different ages.*

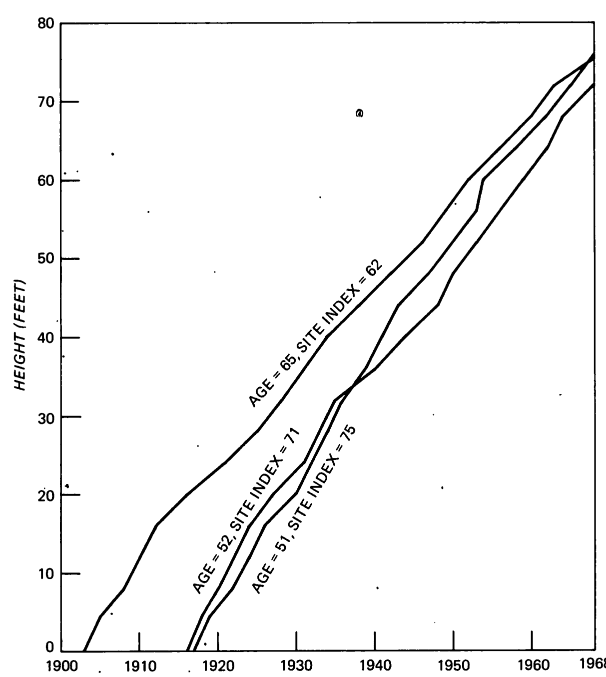

Figure 2.--*Height growth patterns of three adjacent black oak trees of different ages.*

a white oak plot containing one tree younger than the surrounding even-aged trees, and fig. 2 shows a black oak plot containing one tree older than the surrounding even-aged trees. The height/age graphs show that the site index errors of the younger or older trees are due to differences in the height growth patterns of these trees. The younger trees have greater height growth rates until their heights about equal those of the surrounding older trees, and the older trees have slower height growth rates until their heights about equal those of the surrounding younger trees.

Most of the graphs showed that after the tree heights became about equal, the subsequent height growth rates of all the trees tended to be about the same. As stand age increases, the effect of an age difference on site index becomes less and less because of the decrease in height growth rate with increasing age. Theoretically, the regression coefficient in Equation [1] should have been dependent on AGE, i.e., the interaction term AGE x ΔAGE should have been significant. It was not, however, probably because most of the plots (92 percent) were less than 70 yr of age. This factor should be considered, however, for stands over 100 yr old, where site index corrections for minor age differences would probably not be necessary.

DISCUSSION

This negative association between age differences and height growth rate differences is analogous to the relation between oak height growth and stand stocking in which trees tend to be taller in dense stands and shorter in understocked stands (Gevorkiantz and Scholz 1944, Youngberg and Scholz 1949, Gaiser and Merz 1951, Larson 1963, Allen and Marquis 1970, Dale 1972). Obviously, dominance or suppression is not a factor in either of these cases because these factors would tend to produce the opposite effect. The most likely explanation of the negative height growth rate-age relation found in this study (and probably a factor in the height-density relation also) is that differential effects of light and wind on the taller or shorter trees cause differences in height growth rates.

Older, taller trees project up above the main canopy and are more exposed to wind and receive more light on their upper crowns than surrounding shorter, even-aged trees. Conversely, the younger, shorter trees in an otherwise even-aged older, taller stand are less exposed to the wind and the Sun than the surrounding taller trees. The effect of these differences in both light and wind would tend to produce the results found here. Higher light intensity on the upper crowns of taller trees would tend to promote greater crown development at the expense of height growth and, conversely, receiving full sunlight only from directly above would tend to promote greater height growth of shorter trees.

In even-aged stands, windspeed 6 to 10 ft above treetop level may be 50 to 100 percent greater, and windspeed 10 ft below may be 25 to 50 percent less than that at the treetop level (Fons 1940, Geiger 1959, Bergen 1971). Wind affects tree growth by increasing transpiration and mechanical stress. Satoo (1962) found that the usual effect of wind was to increase transpiration, reduce stomatal aperature and photosynthesis, and ultimately to reduce growth. Larson (1963) found that mechanical stress due to wind usually stimulated diameter growth and reduced height growth. Neel and Harris (1971) found that shaking sweetgum (*Liquidambar styraciflua* L.) seedlings 30 sec each day reduced height growth 70 to 80 percent below that of motionless seedlings.

Thus the overall effect of wind on the older, taller trees would be to reduce height growth, while the effect of wind protection on the younger, shorter trees would be to stimulate height growth.

The combined effect on height growth from both these agents (light and wind) would not need to be large--only about 15 percent--to produce the results found in this study.

It must be emphasized that these explanations are speculations only and are offered here in the hope of stimulating further research on the subject.

The implications of these findings are: (1) age-deviant trees such as those described here should either not be used in site index determination unless corrections are made in their site index, (i.e., Equation [1]), and (2) in estimating stand site indexes, scattered individual sample trees should not be used, but rather groups of 2 to 3 adjacent trees to ensure that the sample trees are similar in age to the trees immediately around them.

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