SOIL-SITE RELATIONSHIPS OF THE UPLAND OAKS

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ABSTRACT. Site quality for upland oaks can be estimated directly by using site-index curves, or indirect estimations can be made by using soil-site prediction methods. Presently available harmonized site-index curves may not be suitable for all upland oak species, or may not be suitable throughout their range. New stem-analysis data show that different species of oak have different patterns of height growth; for older ages these patterns are markedly different from patterns predicted by harmonized site-index curves. Soil-site studies for upland oaks are reviewed, and suggestions are made for coordinating these results with soil surveys for forested lands.

INTENSIVE MANAGEMENT of forest land for upland oaks requires precise information about oak site quality. This knowledge is needed so that we can estimate quantity and quality of wood products from specific portions of our forest land. Site quality information also aids us in determining what species of oak to grow and what products to favor on lands of differing productivity. Finally, accurate identification of site quality will better enable us to concentrate intensive management on productive forest lands that are capable of producing large yields of high-grade timber.

SITE-INDEX CURVES

The most widely accepted method for estimating site quality in the United States is direct estimation of site index. Height and age measurements from dominant and codominant trees are used with site-index curves to estimate how tall trees will be at an index age—50 years for upland oaks. Estimated site index is then related to yield tables to estimate growth and yield at various stand ages. The site-index method can easily be used when suitable forest trees are available for the required height and age measurements.

However, suitable trees may be lacking in many upland oak forests because stands may be uneven-aged, poorly stocked, too young, damaged by fire or heavy grazing; or the forests may have been subjected to a variety of past cutting. Satisfactory site-index measurements can be taken only from dominant and codominant trees that have been free-growing and uninjured throughout their lives. Such trees are most commonly found in even-aged oak stands that have not been disturbed by past cutting.

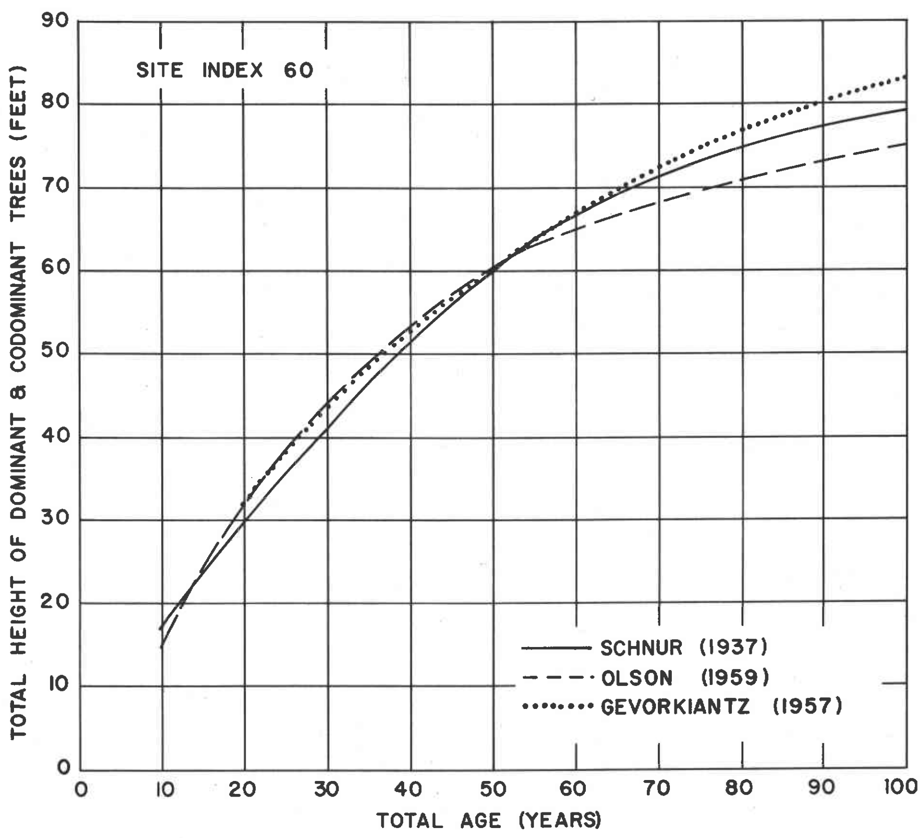
Three sets of harmonized site-index curves are available for upland oaks *(Schnur 1937, Gevorkiantz 1957, Olson 1959)*. These curves show different patterns of height growth when they are compared at the same level of site index (fig. 1); differences are particularly great for older stands. For example, at 100 years of age and at site index 60, the Olson site curves predict that trees will be 75 feet tall, the Schnur curves predict 79 feet, and the Gevorkiantz curves predict 83 feet. Accordingly, when site index is estimated in older-aged stands, these different height-growth patterns result in the lowest site-index values (estimated height at age 50 years) when using the Gevorkiantz curves, intermediate values with the Schnur curves, and the highest values with the Olson curves.

Which set of site-index curves should a forester use for estimating oak site index? Do trees on all sites follow the same pattern of height growth, or do trees on good sites follow a height-growth pattern different from that for trees on poor sites? Are the regionwide oak harmonized curves applicable to all species, all areas, all levels of site, and all soils? Or do we need separate polymorphic site curves for each species of oak and for local portions of the oak region?

We cannot adequately answer these questions now because we do not have sufficient knowledge about height-growth patterns for different oak species growing in different portions of the upland oak region. Until we obtain this specific knowledge, site-index estimates from existing site-index curves can be viewed only as general approximations of oak site quality. Accordingly, when we are uncertain about the applicability of regionwide harmonized site-index curves, we should measure trees as close as possible to 50 years of age. Trees ranging from 35 to 65 years are probably acceptable *(Carmean 1970a)*.

We are faced with a complex problem when we try to precisely describe the vary-

Figure 1.—Harmonized site-index curves for upland oaks show differing height-growth patterns when compared at the same level of site index. Differences are particularly great at older ages.



ing patterns of height growth for different oak species in different areas growing on differing levels of site quality. Answers to this complex problem require mensurational methods more precise than the methods used for constructing harmonized site-index curves. This more precise method is stem analysis or tree sectioning, a procedure that has long been used for diameter, volume, and height-growth studies. The stem-analysis method has been used widely in recent years for constructing site-index curves for many tree species *(Carmean 1970b)*. However, new oak site-index curves based on stem analyses have not yet been published.

Stem analyses for upland oak site-index curves are now under way in the Arkansas and Missouri Ozarks, in eastern Tennessee, and in the southern Appalachians. And considerable stem-analysis data are now available for four species of upland oaks in the Central States. Site-index curves have been prepared for these oak species *(Carmean 1971)*, and some of the findings are given here.

FOR UPLAND OAKS

Briefly, 559 dominant and codominant upland oaks growing on 204 plots in the Central States were felled and sectioned. Ring counts were made at regular intervals on the boles, from the stump to the growing tip of each tree. A wide range of site index was observed (site index 18 to 106), and trees as old as 129 years were sectioned. All plots were located in even-aged stands found in the unglaciated portions of Ohio, Kentucky, Indiana, Illinois, and Missouri. These data were used to compute separate sets of polymorphic site-index curves for black, white, scarlet, and chestnut oaks.

Our new site-index curves reveal definite differences in height-growth patterns for each of the four species of upland oaks (fig. 2). Fairly similar height growth is evident for all species until about 60 years of age, but then the height-growth curves diverge. White oak has relatively slow height growth in early years, but this growth rate apparently is maintained well past 100 years of age. In contrast, black and scarlet oaks initially have more rapid height growth than white oak; however, after 60 years these species show a much more pronounced slowing of height growth. Chestnut oak has a pattern of height growth intermediate between white oak and that of black and scarlet oak. We have found that all these oaks maintain more rapid height growth in later years than predicted by the Schnur *(1937)* and Olson *(1959)* site-index curves. However, our curves for black and scarlet oaks are similar to Gevorkiantz's *(1957)* site curves for red oak in the Lake States.

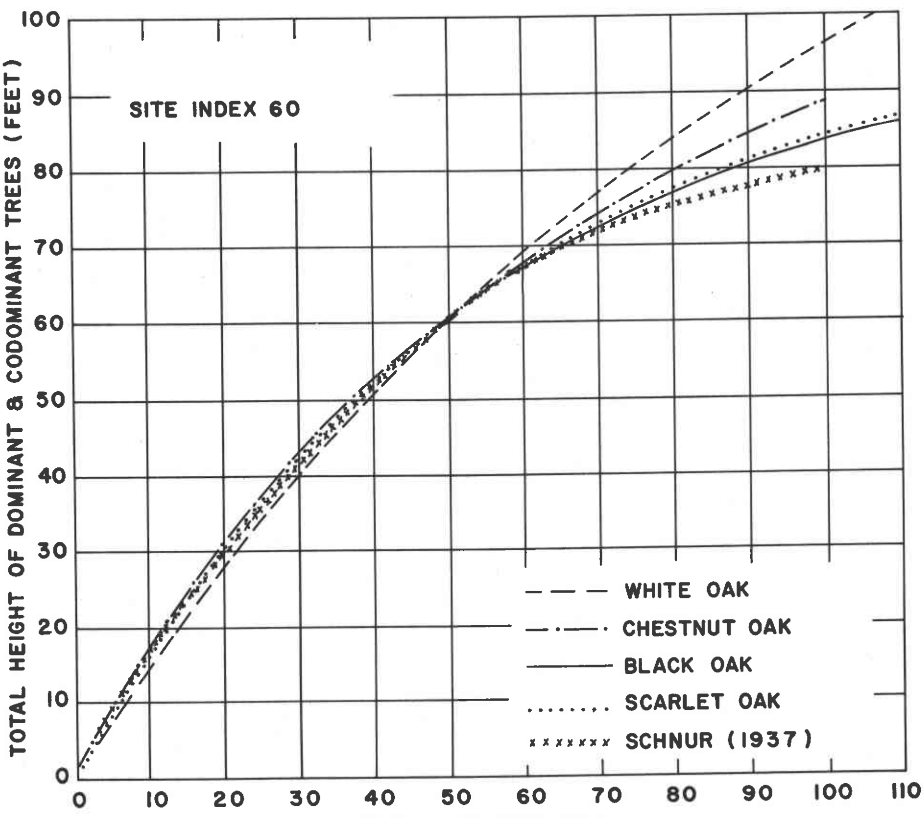
These large differences in tree height-growth patterns (fig. 2) mean that oak site index measured in older stands also will show large differences, depending upon which site-index curve is used. For example, if we find that dominant and codominant trees are 79 feet tall at 100 years of age, then the Schnur curves predict that their height at 50 years (site index) was 60 feet. However, if these trees are white oaks, then figure 2 shows that their growth pattern is much more linear than the pattern predicted by the Schnur curves. Consequently, if white oaks average 79 feet tall at 100 years, than at 50 years their height was much less than the 60 feet predicted by the Schnur curves. If we assume that their height growth will be proportional to the white oak curve in figure 2, then dominant white oaks 79 feet tall at 100 years were probably only 49 feet tall at 50 years instead of 60 feet tall. Likewise, for trees 79 feet tall at 100 years, the curves of figure 2 indicate that chestnut oak was 54 feet, scarlet oak 56 feet, and black oak 57 feet tall at 50 years of age. Obviously the Schnur and Olson curves will overestimate site index when used in older stands, and the amount of this overestimation is different depending upon tree age and upon the species of oak involved.

Site-index estimation is a vital first step in estimating future growth and yield. But our studies show that, if we measure site index in young stands, then estimates of future height growth, and future growth and yield, will differ depending upon the site-index curves we use. For example, if we measure dominant and codominant tree heights in oak stands exactly 50 years of age, then their present height is defined as site index.

But what about height and volume projections for the future? Schnur's site-index curves predict that these trees will be 79 feet tall at 100 years of age regardless of species (fig. 2). However, our studies predict that if trees are 60 feet tall at 50 years of age, then black oak will be 83 feet, scarlet oak 84 feet, chestnut oak 88 feet, and white oak 96 feet tall at 100 years of age. Obviously, tall trees also will produce more volume because tree height, together with tree diameter and number of trees, determines the volume of forest stands. Accordingly, even though white and black oaks may be the same height at 50 years (same site index), at 100 years of age we can expect stands containing mostly white oak to have taller trees and more volume than stands containing mostly black oak.

Of course, when several species of oak are growing together on the same plot, their average height at 50 years will vary depending upon species of oak. We can assume for discussion purposes that dominant and codominant white oaks will be perhaps 5 feet shorter than black oaks at 50 years of age—that is, black oak will indicate site index 60 and white oak site index 55. Probably the site index 60 black oak will grow as shown in figure 2, and the site index 55 white oak will grow proportional to the pattern shown for white oak in figure 2. Accordingly, even though white oak is 5 feet shorter than black oak at 50 years, we estimate that dominants and codominants of both species will be 75 feet tall at 77 years. Thereafter, the white oak will surpass the black oak until at 100 years we

Figure 2.—Tree height-growth patterns for four species of upland oaks reveal decided differences in growth for older ages. Also shown is the Schnur *(1937)* site-index curve for upland oaks.



estimate the white oaks will average 88 feet and black oaks 83 feet in total height.

Our results indicate that we must carefully evaluate the accuracy and applicability of all regionwide harmonized site-index curves. More intensive management of the future will require more precise evaluations of land productivity for forest trees than has been possible by using older generalized site-index curves. In many cases we may find that a single set of site-index curves cannot adequately express the different growth patterns for tree species that have wide geographical ranges, or that grow on land having a wide range of climate, soil, and topography.

SPECIES COMPARISON

Many even-aged oak stands suitable for site-index measurements may not contain the particular oak species, or other hardwood species, for which site-index estimates are desired. Dominant and codominant trees of several oak species may be present, but no usable trees of the particular desired species may occur. For such stands we can estimate site index by using the tree species that are actually present. Then species-comparison graphs can be used to convert site index of the measured trees to site index of other desired tree species. Species-comparison graphs and site-index ratios have been published for upland oaks and other hardwoods *(Doolittle 1958, Nelson and Beaufait 1956, Olson and Della-Bianca 1959, Trimble and Weitzman 1956)*. These studies usually indicate that, at 50 years of age, scarlet and northern red oaks will be the tallest trees, black and chestnut oaks will be intermediate in height, and white oaks will be the shortest trees.

Species-comparison graphs are very useful for extending the application of direct site-index measurements. However, we should bear in mind that comparisons are based only on tree height at one point in time—namely, 50 years of age. But if tree heights are only compared at 50 years, then we might conclude that scarlet oaks or black oaks are faster growing and more productive than white oaks. On the other hand, if the index age for oaks was 100 years, as for certain western trees, then species-comparison graphs would show that white oak was the tallest tree, and consequently, white oak might be judged as the most productive species.

These differences in patterns for tree height growth indicate that we also should compare heights of oaks both before and after the index age of 50 years. In addition, comparisons should be made for both volume and value of yield throughout the lifetime of each species of tree considered for management. Such comparisons might better help us select the species of tree, and most valued product, for management at each level of site quality.

For example, these broader comparisons might reveal that scarlet and black oaks grow faster and produce greater volumes than white oak in early years. Thus these species might be preferable for short pulpwood rotations on poorer sites not capable of producing large trees of veneer and high-quality sawlogs. On the other hand, white oak apparently surpasses the growth of scarlet and black oaks in later years, and thus seems able to eventually attain a larger size and greater volume than other oaks. Accordingly, this more rapid later growth may mean that white oak is better suited for long rotations on better sites where quality veneer and sawlogs are the most desirable products.

SOIL-SITE RELATIONSHIPS

Measurements of site index from standing trees are very satisfactory whenever suitable stands and trees are present for the required tree height and age measurements. But the land may be devoid of trees; or trees may have been injured by fire or heavy grazing; stands may be very young; they may be uneven-aged; or indiscriminate cutting may have removed the free-growing dominant and codominant trees needed for direct site-index measurements. Therefore soil-site methods of site-quality estimation are needed that are applicable to all forest land regardless of the composition or condition of existing vegetal cover.

Much information has been accumulated about the relationships between forest site quality and features of soil, topography, and climate *(Coile 1952, Ralston 1964)*. A recent article also has summarized the various soil-site studies for eastern hardwoods *(Carmean 1970a)*. This article lists a total of 19 separate soil-site studies for upland oaks, so this summarization will not be repeated here.

Most soil-site studies describe the relationship between site index and associated features of soil, topography, and climate. These studies not only identify the important features of site, but also include regression coefficients that express the magnitude of site change associated with each of the significant features of site. Site features pinpointed by these studies are then used to compute site-prediction tables for the field estimation of site quality. These site-prediction tables, developed for a particular area and tree species, provide a means for estimating site quality of all forest lands regardless of the composition or condition of existing vegetal cover.

The review of eastern hardwood soil-site studies *(Carmean 1970a)* reveals certain general trends about the soil and topographic features usually associated with changes in oak site quality. Soil conditions most important are soil depth, soil texture and stone content, and soil drainage--that is, those soil properties ". . . which influence the quality and quantity of growing space for tree roots" *(Coile 1952)*. In general, oak site quality improves as soil depth increases, and trees seem to be most affected by depth changes in the surface soil layers where the majority of tree roots are concentrated. Usually medium-texture soils are the best sites, and site quality decreases for both coarse-texture and for fine-texture soils. Site quality usually decreases as stone content increases, and sometimes as drainage becomes poorer.

Topographic features most important are slope position, aspect, and slope steepness. The best sites usually are found on lower slopes, on north and east aspects, and on gentle concave-shaped slopes. Poorer sites usually are found on narrow ridges, on upper slopes, on south and west aspects, and on steep convex-shaped slopes. These topographic features apparently are closely related to microclimate, soil, and moisture conditions that are important for tree growth.

Even though we can generalize about soil and topographic features related to oak site quality, we find that soil-site studies show considerable variation in site features found to be important. Features important in one area may be unimportant in another. Sometimes a feature may show positive trends in one area and a negative correlation with site quality in another area. Reasons for these variable results may include growth differences between oak species, differences in study areas, and different methods used in statistical analyses *(Carmean 1970a)*.

Because of these differing results between areas we should exercise caution in attempting to apply results developed in one region to a different region. Soil-site prediction methods are applicable only to the particular area studied and, further, to the particular soil and topographic conditions observed within the study area. For example, results obtained for upland oaks in Ohio should not be applied in other states where soil, topography, and climate are different. Likewise, within a particular study area, results for upland soils should not be applied to bottomland soils or to other soil conditions not included in the original site study. Oak soil-site correlations developed from studies of undisturbed forest soils may not be applicable to oaks planted on soils disturbed by agriculture or heavy grazing.

Even so, when nearby regions are similar in soil, topography, and climate, then results from one region probably can be safely applied to the other region. However, results should be applied with caution until trials are made to test the applicability of these results. Of course, when regions have contrasting differences in soil, topography, and climate, then it is unlikely that results from one region can be applied to another.

The fairly large number of soil-site studies for upland oaks *(Carmean 1970a)* may appear impressive at first glance. However, bear in mind that upland oaks cover a very large area that is extremely diverse in soil, topography, and climate. Furthermore, upland oaks include many species that frequently respond in different ways to these varying conditions of soil, topography, and climate. Accordingly, it soon becomes apparent that large gaps in our knowledge exist for many important areas and for many important species of upland oak. For example, the Northeast, the Lake States, and the glaciated portions of the Midwest have received relatively little study.

Site evaluation based upon soil-site methods permits us to estimate site quality only for the local spot in the landscape where we may happen to measure the significant features of soil, topography, and climate. Thus site evaluation still is a point observation comparable to point observations of site index using trees themselves. Still to be resolved is the problem of abstracting these point observations into an area classification of the landscape. Here is where forest managers can best use the skill and knowledge possessed by soil surveyors. Closer coordination between soil-site research and soil survey can provide land-classification knowledge and techniques useful in forest land management. Research can pinpoint the features of soil and topography important in classifying site quality, and soil surveyors can then incorporate this knowledge into soil surveys to obtain more useful inventories of forest lands.

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