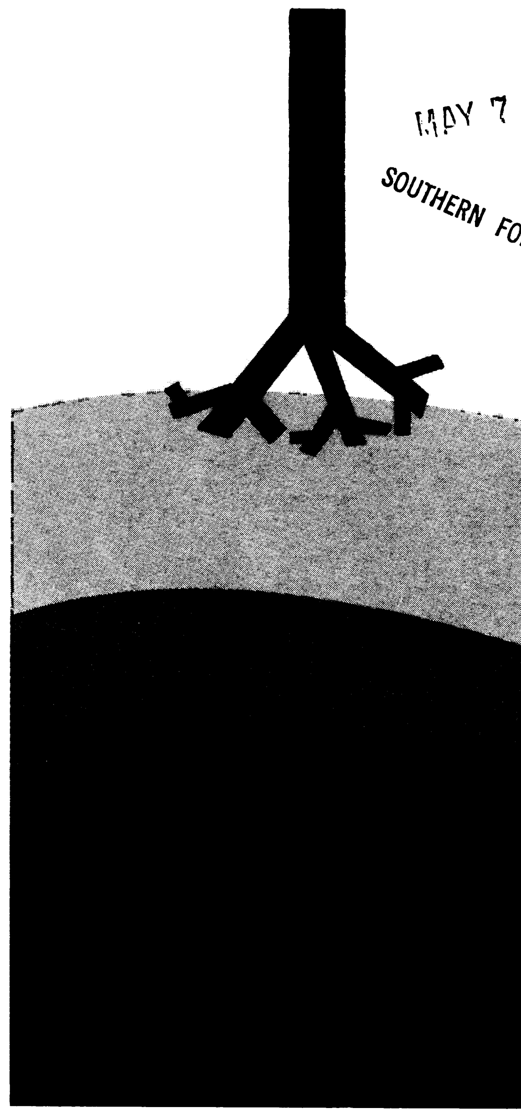
USDA Forest Service
Research Paper NC-86
1973

NC-86
RP
cop 2

SOME SOIL PHASES IN THE MISSOURI OZARKS HAVE SIMILAR SITE INDEXES FOR OAKS



MAY 7 1973
SOUTHERN FORE[illegible]ENT STATION
LIBRARY

Richard F. Watt &
Michael E. Newhouse

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service — U.S. Department of Agriculture
Folwell Avenue
St. Paul, Minnesota 55101
(Maintained in cooperation with the University of Minnesota)

Manuscript approved for publication November 20, 1972

THE AUTHORS: Richard F. Watt is a Principal Plant Physiologist at the Station's field office in Columbia, Missouri. The office is maintained in cooperation with the University of Missouri. Michael E. Newhouse is an Assistant Professor at Virginia Polytechnic Institute & State University, Blacksburg, Virginia. Dr. Newhouse was formerly a Soil Scientist for the Station.

Some Soil Phases in the Missouri Ozarks Have Similar Site Indexes for Oaks

Richard F. Watt and Michael E. Newhouse

The classical and most widely used method of estimating forest site quality is to use the growth of the trees themselves as an integrator of the site's growth factors and microclimate. This method is based on the logical belief that the reaction of the tree over its lifetime is the surest indicator of the long-term levels of moisture, nutrients, heat, and light available. Heights and ages of several dominant and codominant trees are determined, and, by reference to height-age curves, the height of the tree at some standard age — the site index — is calculated. Naturally, trees selected for site index measurements must have grown without suppression or serious injuries that might have affected normal height-age relationships. When such trees are not present, we must resort to indirect methods of site index determination. These can be based on physical factors, such as soils, topography, and climate, or the presence and growth of other plants believed to indicate the site's ability to support the tree species in question.

Soils and topography, separately or combined, are often used to estimate site quality, because they are stable factors of the landscape that are relatively undisturbed by man's activities. Although soil types were found to be significantly correlated with site index of loblolly pine and shortleaf pine in Texas (Chandler *et al.* 1943), site index of black oak in southeastern Ohio varied too widely within soil series to have practical use in forest management (Carmean 1961). A number of additional studies (Graney and Ferguson 1971, Hannah 1968, Hartung and Lloyd 1969, Ike and Hupuch 1968, Smalley 1967, VanLear and Hosner 1967, and Yawney and Trimble 1968) have shown topography to be more important than soil classification in the indirect determination of site quality for hardwoods and conifers.

In this report, we will discuss one phase of a study designed to relate specific soil and topographic characteristics to site quality for black and white oaks in the Central Ozarks of Missouri. The results showed that soil series and phases, as presently defined, cannot be used as indicators of site quality for these tree species.

METHODS

This study was confined to the Salem Plateau of the southeastern portion of the Missouri Ozarks, an area of well dissected karst terrain heavily wooded with oak-hickory stands. Except for relatively small areas of colluvial slopes, the soils are residual and thin; they generally contain a large amount of chert, an insoluble silica stone left from the weathering of the parent material. Parent material is sedimentary rock from formations of the Lower Ordovician and Cambrian systems, largely cherty limestones and dolomites with some bands of sandstone in the Roubidoux formation. The low levels of phosphorus and potassium in the parent material, in conjunction with the long weathering period, have produced soils low in fertility and pH. Pleistocene loessal deposits approximately 3 feet thick have been largely eroded away, except for shallow remnants on the gentler slopes and level ridgetops. Hard, dense fragipan layers are found at shallow depths in some soil series. These fragipans limit penetration of roots and are slowly permeable to air and water.

A total of 179 black oak and 125 white oak plots was established in fully stocked, even-aged oak-hickory stands in the Ozarks of southeastern Missouri. On each plot five or more dominant or codominant trees were selected for site-index determinations. Three of these were felled for sectioning, height measurement, and detailed observations of height-growth patterns. The others were bored at breast height for ring counts; their total heights were determined optically. Care was taken to select only healthy trees that had grown without periods of suppression or damage. A number of trees that appeared normal externally were rejected later due to abnormalities disclosed by sectioning.

Equal numbers of plots were selected on the basis of aspect, slope position, and slope steepness for each soil phase and for both pan and nonpan soils. These topographic classes were selected after preliminary analysis of the partially completed sampling. This distribution of plots over the main topographic variables makes comparison of the pan and nonpan groups statistically valid.

Using a small backhoe, one to four soil pits were dug on each plot to a depth of at least 4 feet, bedrock permitting, and the large exposed profiles were then described by soil scientists. Bulk samples were taken for laboratory analysis of the chemical and physical properties of the soil horizon. Field descriptions and laboratory measurements were used to place each plot in the correct soil family, series, and phase. Independent verifications were later provided by a third soil scientist.[1]

RESULTS

The site index and soil phase analysis showed no statistical or practical difference in the average site quality of the seven soils studied. For example, the lowest average site index for black oak is 61.7 feet on the Clarksville cherty silt loam, and the highest is 65.1 feet on the Coulstone cherty loam. The range of differences for average white oak site indexes are equally small (fig. 1).

Another major result, unexpected on the basis of our knowledge of the general physical characteristics of the two soil groups, was the almost identical site index averages and ranges for the pan and nonpan soils (table 1). A third finding was the uniformly lower site indexes obtained when white oak rather than black oak was used as the site-index species.

Table 1. —*Summary of nonpan and pan soil data for black and white oak plots*

Item	Nonpan soils	Pan soils
BLACK OAK		
Average site index	63.0	63.4
Standard deviation	± 4.4	± 7.2
Range	52-75	52-73
Number of plots	107	72
WHITE OAK		
Average site index	55.9	55.7
Standard deviation	± 5.2	± 5.4
Range	45-70	45-65
Number of plots	65	60

When the total range of site index for all soil phases is compared with the range for the individual soils, even more emphasis is placed on the impossibility of relating soils to site quality for growth of trees. For example, the total range of site index for all soils was 28 feet. The range of site index for most individual soil phases approaches this total range. Obviously, if all site indexes found in the study can also be found on most soil phases, it is impossible to predict site index from soil phases alone.

The fragipan soils have a dense, impervious layer 12 to 36 inches below the surface that restricts the downward movement of roots and moisture except for the occasional structural crack. Thus, pan soils are physiologically shallow and would be expected to be of lower site index than the nonfragipan soils (Krusekopf 1963). But, in fact, both pan and nonpan soils have nearly identical site index (table 1). How can this paradox of similar site index on soils of different effective depths be explained?

[1] *Soil descriptions for 125 black oak plots were made by John Millet, Soil Scientist, now with USDA Forest Service, Grants Pass, Oregon; descriptions for 54 black oak plots and 125 white oak plots were made by the junior author; verifications of a selected sample were made by Mack Miller, Soil Scientist, USDA Forest Service, Rolla, Missouri.*

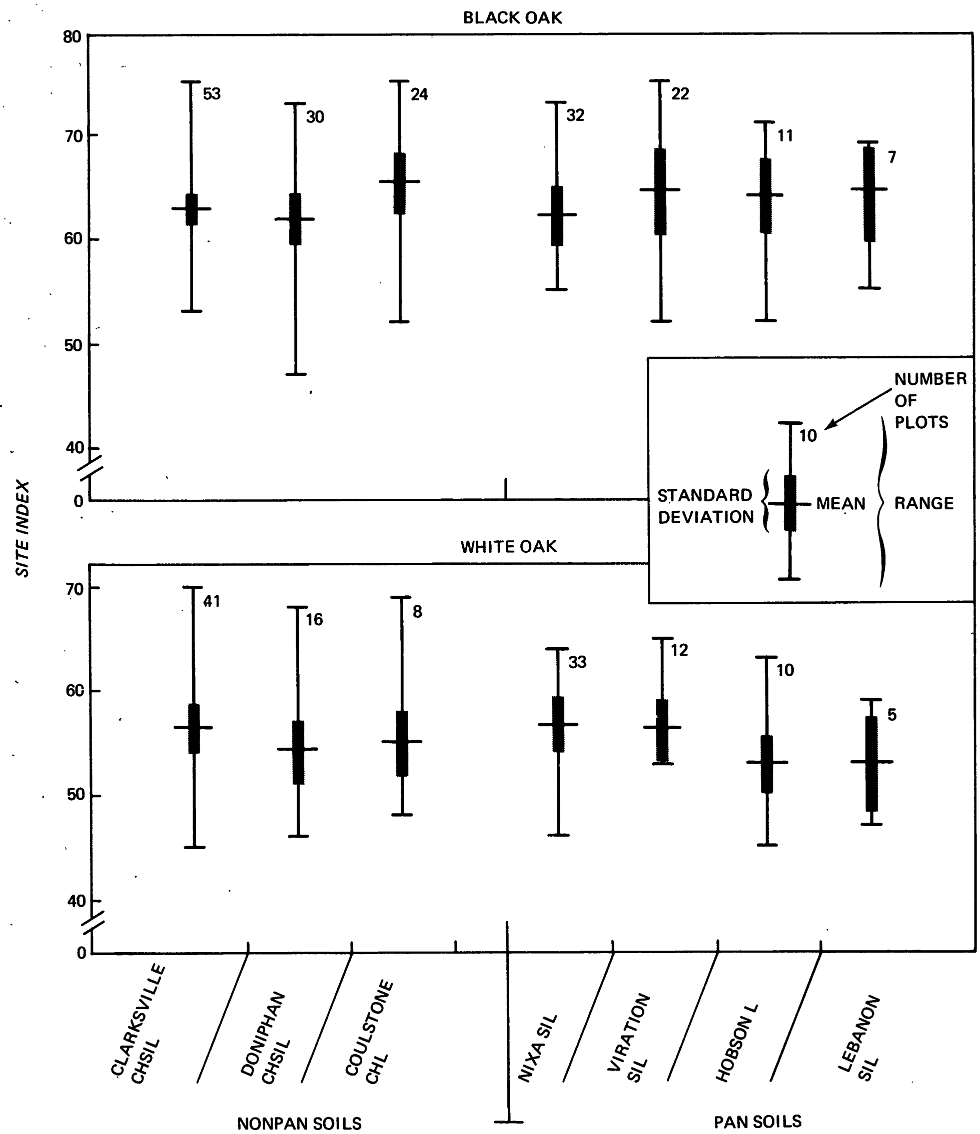


Figure 1. — *Site index for seven Ozark soils – mean, range, and standard deviation. CHSIL = cherty silt loam; CHL = cherty loam; SIL = silt loam; L = loam.*

Examining the available moisture capacity of the two groups may help to provide an answer, since moisture availability during the growing season may be a growth-limiting factor in this region of periodic hot, dry weather. Available soil moisture (the difference between moisture capacity at ⅓ and 15 atmospheres) was determined for the separate horizons with a pressure plate and pressure membrane apparatus. After making corrections for the presence of the chert fragments, the values were used to calculate available moisture either in the upper 36 inches of the profile or above the fragipan, as appropriate. These are the soil depths with the bulk of the tree roots.

The difference in available moisture between pan and nonpan soils to the depths calculated above was not as great as expected:

Soil phase	*Inches available water to pan or 36 inches*
Pan:	
Nixa silt loam	3.1
Viration silt loam	4.3
Lebanon silt loam	3.6
Hobson loam	3.1
Nonpan:	
Doniphan cherty silt loam	4.7
Clarksville " " "	4.2
Coulstone cherty loam	3.8

This additional moisture may be depleted in a short period during the summer months, for oak stands in Arkansas removed 0.19 inches of water per day from the upper 4 feet of the soil profile during a 6-week period (Zahner 1955). Thus, the small amount of additional water available in the nonpan soils is relatively unimportant. When the same data are averaged by site index classes, it is apparent that available moisture has little relationship to site quality:

Site Index Class	*Inches available water to pan or 36 inches*
50	3.8
51-55	4.0
56-60	3.8
61-65	3.8
66-70	4.0

Although fragipans have structural cracks that are occasionally penetrated by roots, moisture below the pan is probably of little help to the tree because of the slow percolation rate of water through the pan during periods of moisture recharge.

Foresters have often noted that young dominant and codominant white oak trees are frequently shorter than associated dominant and codominant members of the red oak group. The comparison of white and black oak site index for similar soils shows that this is indeed a well-founded observation; site index of white oak is 7 feet lower than site index for black oak. The difference in height growth between these two species has been well-documented using sectioned trees of both species from the Central States, including a good representation from Missouri (Carmean 1972). Carmean's site index curves indicate that black oak grows more rapidly than white oak during the early years, just as in our study.

CONCLUSIONS

This preliminary analysis of measurements from 300 sample plots indicates that soil phases, as presently described for the Missouri Ozarks, cannot be used to determine the site indexes for oak. As we have shown, a given soil phase will include a wide range of site qualities; average site qualities of the soil phases studied were essentially similar. This failure of soil classification to indicate the supply of soil growth factors has been found in other studies with oak.

Because soils research and taxonomic classification have historically been oriented toward agricultural uses, considerably more is known about the features that influence shallow-rooted, annual agricultural crops than about those that influence long-lived, relatively deep-rooted trees. Consequently, soils series used for intensive agriculture have been defined more narrowly than those describing soils on rough land suited only for extensive uses (Kellogg 1958). Carmean (1961) indicated that certain soil and topographic features closely related to the growth of forest trees in Ohio vary widely within soils types and soil mapping units, but are not included in their definition. Topographic features such as steepness and degree of erosion are sometimes included, but often in terms too general to be useful for forest site evaluation.

The wide range of slopes and aspects occupied by a given soil in Missouri suggests that the variability in site quality found in this study may be traced to factors not delineated in current soil classifications. As the relationships between forest soils and tree growth are studied more intensively, the way should be open for revision of soil mapping units to reflect to a greater extent the soil's ability to support tree growth.

Many physical characteristics, such as steepness of slope, aspect, soil texture, and depth, are important modifiers of site quality and may be used to improve estimates based solely upon soil phases (Carmean 1970). For example, working with Clarksville soils in a single county in the Ozarks, Hartung and Lloyd (1969) showed that topographic exposure could be used to give a better estimate of the soil's ability to support tree growth.

Preliminary analysis of the data in this study has disclosed that a combination of topographic features and some edaphic characteristics will provide the best estimate of site quality for sites that do not have trees suitable for direct site-index determination.

LITERATURE CITED

Carmean, Willard H. 1961. Soil survey refinements needed for accurate classification of black oak site quality in southeastern Ohio. Soil Sci. Soc. Am. Proc. 25: 394-397.

Carmean, Willard H. 1970. Site quality for eastern hardwoods. *In* The silviculture of oaks and associated species. USDA For. Serv. Res. Pap. NE-144, p. 36-56. Northeast. For. Exp. Stn., Upper Darby, Pa.

Carmean, Willard H. 1972. Site index curves for upland oaks in the Central States. For. Sci. 18: 109-120.

Chandler, R. F., Jr., P. W. Schoen, and D. A. Anderson. 1943. Relation between soil types and the growth of loblolly and shortleaf pine in east Texas. J. For. 41: 505-506.

Graney, David L., and Edwin R. Ferguson. 1971. Site-quality relationships for shortleaf pine in the Boston Mountains of Arkansas. For. Sci. 17: 16-22.

Hannah, Peter R. 1968. Topography and soil relations for white and black oak. USDA For. Serv. Res. Pap. NC-25, 7 p. North Cent. For. Exp. Stn., St. Paul, Minn.

Hartung, Robert E., and William J. Lloyd. 1969. Influence of aspect on forests of the Clarksville soils in Dent County, Missouri. J. For. 67: 178-182.

Ike, A. F., Jr., and C. D. Huppuch. 1968. Predicting tree height growth from soil and topographic site factors in the Georgia Blue Ridge Mountains. Ga. For. Res. Counc. Pap. 54, 11 p.

Kellogg, Charles E. 1958. A look at future forest soils problems. First North Am. For. Soils Conf. Proc., East Lansing, Mich. Mich. Agric. Exp. Stn. Bull., p. 1-5.

Krusekopf, H. H. 1963. Forest soil areas in the Ozark regions of Missouri. Univ. Mo. Agric. Exp. Stn. Res. Bull. 818, 28 p.

Smalley, G. W. 1967. Soil-site relations of upland oaks in North Alabama. USDA For. Serv. Res. Note SO-64, 6 p. South. For. Exp. Stn., New Orleans, La.

VanLear, David H., and John F. Hosner. 1967. Correlation of site index and soil mapping units. J. For. 65: 22-24.

Yawney, Harry W., and G. R. Trimble. 1968. Oak soil-site relationships in the ridge and valley regions of West Virginia and Maryland. USDA For. Serv. Res. Pap. NE-96, 19 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Zahner, Robert. 1955. Soil moisture depletion by pine and hardwood stands during a dry season. For. Sci. 1: 258-265.

☆U.S. Government Printing Office: 1973 — 761-444

SOME RECENT PUBLICATIONS
OF THE
NORTH CENTRAL FOREST EXPERIMENT STATION

Fire Weather and Behavior of the Little Sioux Fire, by Rodney W. Sando and Donald A. Haines. USDA For. Serv. Res. Pap. NC-76, 6 p., illus. 1972.

Canoeist Suggestions for Stream Management in the Manistee National Forest of Michigan, by Michael J. Solomon and Edward A. Hansen. USDA For. Serv. Res. Pap. NC-77, 10 p., illus. 1972.

The Changing Market for Hardwood Plywood Stock Panels, by Gary R. Lindell. USDA For. Serv. Res. Pap. NC-78, 7 p., illus. 1972.

Size of Oak Advance Reproduction: Key to Growth Following Harvest Cutting, by Ivan L. Sander. USDA For. Serv. Res. Pap. NC-79, 6 p., illus. 1972.

An Improved Growth Intercept Method for Estimating Site Index of Red Pine, by David H. Alban. USDA For. Serv. Res. Pap. NC-80, 7 p., illus. 1972.

Projecting the Aspen Resource in the Lake States, by William A. Leuschner. USDA For. Serv. Res. Pap. NC-81, 32 p., illus. 1972.

Improve Forest Inventory With Access Data—Measure Transport Distance and Cost to Market, by Dennis P. Bradley. USDA For. Serv. Res. Pap. NC-82, 21 p., illus. 1972.

Canadian Forest Products Shipped Into the North-Central Region, by Eugene M. Carpenter. USDA For. Serv. Res. Pap. NC-83, 22 p., illus. 1972.

Aspen Symposium Proceedings. USDA For. Serv. Gen. Tech. Rep. NC-1, 154 p., illus. 1972.

A Method of Evaluating Crown Fuels in Forest Stands, by Rodney W. Sando and Charles H. Wick. USDA For. Serv. Res. Pap. NC-84, 10 p., illus. 1972.

ABOUT THE FOREST SERVICE . . .

As our Nation grows, people expect and need more from their forests — more wood; more water, fish, and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U.S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.