SITE PRODUCTIVITY OF OAKS IN RELATION TO SOIL TAXONOMIC UNITS IN NORTHERN ILLINOIS

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The predictive value of soil taxonomic units (11 soil series) was tested for classifying forest sites in northern Illinois. Productivity of black, white and northern red oak types was expressed as periodic growth in cubic feet per acre over 23-years. Differences in productivity were less within soil series than between soil series.

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INTRODUCTION

One of the first steps necessary for intensive forest management is to determine forest site quality. With such information for each unit of land, foresters can better determine what species to grow and what species combination will give the most satisfactory results. While direct measurement of the current productivity of a given site is possible where standing trees of the appropriate age are present, the limited range for extrapolation of site evaluation thus obtained severely curtails its usefulness.

Many site evaluation studies have been conducted, but comparatively few concern the upland oak species, especially when the broad distribution and importance of oak species is taken into consideration. In addition, upland oaks include many species that frequently respond differently to differing conditions (Carmean 1971).

Soil taxonomic units have been tested as site quality indicators for tree growth by a number of researchers. For example, Carmean (1961) showed that site indexes of black oak (*Quercus velutina* Lam.) vary widely within upland soil series in southern Ohio. He found site indexes related to depth of surface soil, subsoil stoniness, slope position, slope aspect and steepness, and stated that soil series could not be used for accurately estimating potential productivity. He suggested using the above factors to modify soil series and define new soil types and phases in order to attain better accuracy in site predictions. Van Lear and Hosner (1967) tried to correlate the growth of yellow-poplar (*Liriodendron tulipifera* L.) to five soil types in southwestern Virginia but found no difference between any of the soil mapping units. The lack

of correlation was presumed to be caused by the variation of site index within the allowable range of soil features in each mapping unit. Phillips and Markely (1963) found site indexes of sweetgum to range from 2 to 23 feet in eight soil series. They implied that recognition of drainage phases and water table would have appreciable improved estimates.

Shetron (1972) found differences in site quality among some soil series for northern red oak (Quercus rubra L.) in Michigan but could find no difference in site quality for sugar maple (Acer saccharum Marsh.) between the 12 soil series studied. He suggested that these 12 soil series could be combined into one group for productivity purposes.

Watt and Newhouse (1973) phased the soil series in 300 plots of white (Quercus alba L.) and black oak in the Missouri Ozarks according to aspect, slope position, and slope steepness. No differences were found among site indexes of the phases created.

Soil series alone are at times too heterogeneous to serve as a basis for evaluating timber productivity. In most studies only the soil series are considered and phases are not differentiated. Phasing the soil series, families, and even the subgroups has been suggested to increase the accuracy of soil units as site predictors (Carmean 1961; Ralson 1964). However, growth data on soil series representing a range of soil conditions is essential for a sound grouping of soil taxa into productivity units.

This paper reports the results of using 11 soil series as predictors of forest site quality in northern Illinois.

MATERIALS AND METHODS

Source Materials and Location of Study Area

The source materials used in the study are forest productivity and soils data from Sinnissippi Forest in northwestern Illinois. Sinnissippi Forest is a private enterprise of about 2,400 acres that has been under management since the early 1900's and intensive management during the past 35 years. It is located in Ogle County, Illinois, bounded on the north and west by the Rock River. Sinnissippi Forest is part of the Oak Hickory Region (Braun 1950) located near the westernmost part of the eastern deciduous forest. Black oak and white oak usually in mixed stands predominate on the uplands. Northern red oak occurs only on the better sites, usually in mixed stands with white oak.

The surficial geological deposits of the area of study consist of sand dunes, outwash, valley trains, alluvial deposits, loess, as well as sandstone and limestone bedrock. Till is not extensive in the area but occurs in isolated spots usually overburdened by loess.

The continental location of the area, together with the latitude, makes for hot summers and cold winters. The average frost-free period is from 160 to 170 days long. Killing frosts have, however, occurred as late as the first part of June and as early as the first part of September (Page 1949).

Field Work and Soil Characteristics

In 1948, several hundred circular 1/5-acre study plots were established in the forest to conduct forestry research and to aid in managing the forest. A total of 108 of these plots were selected for the present study. Only plots that were well stocked, at least during one of the three time spans covered by the four inventories, were considered. Further screening was based on species composition, age of the stand, and soil characteristics. Only plots with mixed oak stands of 91 to 110 age class and with uniform soils were chosen.

The soil survey was conducted during the summers of 1971, 1972, 1973, and 1974. Soil borings using a hand probe or soil auger were made at three points within each plot to determine the soil series present and to assess uniformity. Only plots having uniform soils of the particular soil series of interest were chosen. Soil series specifications as given by the U. S. National Cooperative Soil Survey (1966-1975) were used to determine the range in soil characteristics allowed for any soil series studied. Eleven soil series were selected for this study. Their classification and general characteristics are given in tables 1 and 2 (USDA 1974).

Table 1. Classification of the eleven soil series included in this study.

Soil series	Subgroup	Family
Alvin	Typic Hapludalfs	Coarse-loamy, mixed, mesic
Bloomfield	Psammentic Hapludalfs	Coarse-loamy, mixed, mesic
Boone	Typic Quartzipsamments	Mesic, uncoated
Camden	Typic Hapludalfs	Fine-silty, mixed, mesic
Dickinson	Typic Hapludolls	Coarse-loamy, mixed, mesic
Eleva	Typic Hapludalfs	Coarse-loamy, mixed, mesic
Lamont	Typic Hapludalfs	Coarse-loamy, mixed, mesic
Martinsville	Typic Hapludalfs	Fine-loamy, mixed, mesic
Plainfield	Typic Udipsamments	Mixed, mesic
St. Charles	Typic Hapludalfs	Fine-silty, mixed, mesic
Whalan	Typic Hapludalfs	Fine-loamy, mixed, mesic

Table 2. Characteristics of the eleven soil series included in this study.

Soil series	Lithology	Drainage	Permeability	Some salient profile characteristics
Alvin	Sandy material	Moderately well	Moderate to moderately rapid	15 to 18% clay in upper 20" of argillic horizon
Bloomfield	Sandy material over loamy material	Well to somewhat excessive	Moderately rapid to rapid	Lamellae or continuous. B horizon at >35" but <60"
Boone	Sandy material over sandstone	Excessive	Very rapid	No pedogenic horizon other than A1
Camden	Silty material over stratified loamy material	Well to moderately well	Moderate	24 to 40" of silty material over stratified material
Dickinson	Sandy material over loamy sand and sand	Well to sometimes excessive	Moderately rapid to rapid	Mollic epipedon
Eleva	Sandy material over sandstone	Well	Moderate to moderately rapid	Sandstone bedrock between 20 and 40"
Lamont	Sandy material over loamy sand and sand	Well	Moderately rapid	10 to 15% clay in upper 20" of argillic horizon
Martinsville	Loamy material >60"	Well	Moderate	18 to 22% clay in upper 20" of argillic horizon
Plainfield	Sandy material	Excessive	Rapid	Deep sands, no textural bands within 60"
St. Charles	Silty material over stratified loamy material	Moderately well to well	Moderate	40 to 60" of silty material over loamy material
Whalan	Loamy material over limestone	Well	Moderate (slow in clayey horizon)	Lithic contact between 20 to 40"

Forestry Data Collection and Manipulation

Stand data were collected in four inventories conducted in 1949, 1954, 1963 and 1972. Forest type, site quality, species, age, diameter at breast height and disposition (fate of previously measured trees which included both mortality and trees harvested) were used for the purpose of this investigation. All three oak species occurred on all sites. The species composition on the best sites were northern red oak and mixed oaks stands; on the medium sites were white oak and mixed oaks stands; and on the poor sites were white oak, black oak and mixed oak stands. Total heights of representative trees were used to develop volume equations. These equations were specifically developed for Sinnissippi Forest, for each forest type, age class, and site quality, by the least squares methods from the D^2H equation of Gevorkiantz and Olsen (1955).

Growth expressed in cubic feet per acre per year was used in the present study as a measure of soil productivity. Gross growth, cut, mortality, ingrowth, and survivors growth were calculated for each plot and growing period.

An analysis of variance of the 11 soil series based on yield in cubic feet per acre per year was executed to establish differences in population means. A completely randomized design was chosen with soil series as treatments and yields as the dependent variable. A Fisher's Least Significant Difference test was calculated to detect differences between treatment means (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Tree Growth and Soil Series

Analysis of variance showed highly significant differences among the 11 soil series. The results of the test for the 99% confidence level are summarized in table 3.

No statistical difference was found among yield means of the Plainfield, Boone, Whalan, Eleva, Lamont and Bloomfield soil series. These series are ranked from lowest to highest in the same sequence as listed in the preceding sentence. Judging from the typical soil characteristics of these soil series, it was expected to obtain a somewhat different sequence. Soil series Bloomfield was expected to fall closer to the lower part of the sequence together with Boone and Plainfield. A possible explanation for this particular result is that Bloomfield soils have either lamellae with cumulative thickness of more than six inches between 35 and 60 inches or a continuous B horizon between the same depths. Lamont soils have greater water holding capacity and higher nutrient levels above 60 inches than Bloomfield soils. However, the lamellae or the continuous B horizon in Bloomfield soils often extend beyond 60 inches, providing extra moisture and nutrients to the trees. This

additional usable root growing space is more than likely responsible for the greater growth found in Bloomfield soils than in Lamont soils. The presence of textural bands or finer textured layers (pedogenic or non-pedogenic) in sandy soils has been recognized as a factor favorably influencing tree growth. White and Wood (1958) report an increase in red pine growth in soils with textural bands over soils with no textural bands. Hannah (1969) obtained a progression in soil productivity of 50, 70 and 90 metric tons per hectare on a sequence of sandy soil, without thinly developed bands, with bands, and with till-like prominent bands, respectively.

The Boone soil series had a higher mean yield than Plainfield although the two soils are texturally similar. Boone soils have less than five percent weatherable minerals which should affect tree growth from the nutrient status aspect. In the area of study, some silty material (possibly loess) often found mixed with the residual sand, was most likely responsible for the better growth found in the Boone than in the Plainfield series.

The Whalan soil series illustrates the importance of rooting depth in relation to tree growth. Although this soil has a well-developed B horizon, its total maximum depth to consolidated material was found to be 28 inches. In addition to being a shallow soil, it has a layer high in clay above the bedrock, which may inhibit growth of tree roots. Both of these soil characteristics were found to be detrimental to upland oak growth in southern Ohio (Carmean 1971).

Table 3. Mean, standard deviation and range of tree growth for each soil series.

Soil series	Number of plots	Mean[1/]	Standard deviation	Range
		----- Cubic feet per acre per year -----		
St. Charles	8	68.9 e	15.1	47.3-86.5
Martinsville	12	66.0 e d	12.8	46.6-93.4
Alvin	14	64.1 e d c	11.3	51.8-86.5
Dickinson	8	63.3 e d c	15.0	46.7-94.5
Camden	6	61.5 e d c b	7.2	52.4-74.2
Bloomfield	8	61.5 e d c b a	14.8	35.6-72.4
Lamont	10	52.3 d c b a	11.8	30.8-71.1
Eleva	7	49.0 c b a	12.2	33.6-65.9
Whalan	7	46.7 b a	10.9	31.5-65.8
Boone	12	45.5 a	14.1	24.8-76.3
Plainfield	16	42.4 a	13.3	20.5-68.7

[1/]Means followed by the same letter are not statistically different at the 99 percent confidence level.

No statistical differences were found among Bloomfield, Camden, Dickinson, Alvin, Martinsville and St. Charles series in the upper portion of the rank (Table 3). The Dickinson soil series has a rather high mean considering its sandy texture. Dickinson soils developed under prairie vegetation and have the thickest A1 horizons of all soils in this study. The importance of the A1 horizon has been recognized and emphasized, especially when dealing with sandy soils (Ralson 1964). The thick A1 horizon present in Dickinson soils overshadows the fact that the characteristics of the rest of the profile is conducive to rather low tree growth potential.

Alvin and Martinsville soils are similar in many respects and both developed in glacial outwash. However, Martinsville soils are finer textured than Alvin as is the underlying substratum. The higher mean yield of the Martinsville soils can be attributed to a thicker B horizon with a higher clay percentage than in Alvin soils.

There is a general trend of increasing yields with increasing percentages of clay and silt in the subsurface horizons of Plainfield, Lamont, Bloomfield, Alvin and Martinsville soils. This particular sequence of soils covers sandy soils having B horizons that increase in expression and thickness in the same order as listed above. It is interesting to note that tree growth increases gradually in the same order. Apparently, characteristics used in the delineation of these soil series reflect factors important to upland oaks growth. Camden soils have lower mean yields than Alvin soils and also have the narrowest range in yield of all soils considered. Although no complete explanation of this result can be offered, incomplete sampling of the range of Camden soils may have occurred since this soil series had the lowest sampling frequency.

It has been reported that soil series have not been defined narrowly enough to serve as site quality predictors for tree growth and that variation of tree growth within soil series may be greater than between soil series (Carmean 1971). It appears that these relationships are aggravated if climatic variations occur within the broad distribution of a particular soil series and/or if significant growth variations exist due to topography. In the present study the variation of yield between soil series was found to be greater than within soil series. Topographic variables did not affect yield significantly and climate can be considered constant throughout the study area. Therefore, some of the soil characteristics used in defining the soil series are reflected in the soil productivity presented by these soil series. In a local situation as found in this study where climate and topography are relatively uniform, taxonomic units as broad as soil series can be related to tree yield. Overlapping yields between soil series represents the response of the trees to various combinations of factors affecting tree growth. These combinations of factors occur within the allowable range of soil characteristics of a given soil series. This should be expected since it would be virtually impossible to account for all these combinations in defining soil series.

The accuracy of yield predictions based on soil series is also affected by the way yield is measured and expressed (Ralson 1964). For example, if height is used as a measure of yield, soil properties used in defining soil series may not affect height growth the same way they will affect volume growth. After a given age, height of an oak tree may remain constant while other expressions of yield (i.e., volume or basal area increments) may continue to increase. Also, trees normally grow taller on deep soils than on shallow soils. But trees on shallow soils can develop rather sizeable diameters provided the distribution of rainfall is favorable. Other factors such as plant competition, genetic variation, etc., may also contribute to the inability of soil series to predict yield. Unless all known factors external to soil taxonomic units contributing to variation in yield are taken into account, the accuracy of yield prediction based on soil series will decrease.

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