GROWTH OF WHITE OAK (*QUERCUS ALBA* L.) IN RELATION TO SOIL AND SITE PROPERTIES IN EASTERN KENTUCKY

C. W. Honeycutt, R. L. Blevins and R. F. Wittwer[1/]

Abstract.--This study was conducted in the Appalachian Mountains in eastern Kentucky with the objective of relating basic soil properties and other measured site characteristics to the growth of white oak (*Quercus alba* L.). A range of three soil series and three slope positions were investigated.

A white oak height prediction equation was developed based on data from 39 sites. It was found through stepwise multiple regression analysis that the most important variables for predicting height were, in decreasing order of importance: age, nitrogen content of the A horizon, the product of the A horizon thickness and a transformation of aspect, slope position, and thickness of the B horizon. This general equation accounted for 62 percent of the variation in tree height. Of the three soil series and slope positions investigated, white oaks grow best on the Shelocta series and the lower 1/3 slope position. Favorable properties of the Shelocta soil include the silt loam texture, high CEC, and relatively high organic matter and nitrogen contents. The lower 1/3 slope positions had thicker A horizons and contained the highest nitrogen content.

Keywords: Prediction equations, site index, soil series, slope position, organic matter, organic nitrogen.

INTRODUCTION

A number of foresters and soil scientists have directed their research towards the use of soil and site variables as a means of estimating site quality. These soil-site studies may be especially beneficial on lands where no trees near index age are present, such as on recently cutover areas, or they may also be useful in predicting height growth of a more desirable species if species conversion is to be attempted.

[1/] Research Assistant in Agronomy, Professor of Agronomy, and Associate Professor of Forestry, University of Kentucky, Lexington, Kentucky.

The investigation reported in this paper (82-3-8-140) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director. This study was supported in part by the McIntire-Stennis Cooperative Forestry Research Program.

The most recent comprehensive review of soil-site research has been compiled for several tree species by Carmean (1975). Most documented soil-site studies in the United States have been performed since the 1930's.

Trimble and Weitzman (1956) investigated relationships of soils and topography to site indices of mixed upland oaks (Quercus spp.) in mountainous northeastern West Virginia and western Maryland. Regression analysis showed that oak site index was closely related to aspect, position on the slope, slope percent, and depth of soil to bedrock.

Studies in the unglaciated region of southeastern Ohio by Carmean (1965), resulted in multiple regression equations that accounted for about 80% of the variance in height of black oak (Quercus velutina Lam.). Carmean (1965) found that better black oak sites occurred on lower slopes and cove areas and on soils with thicker surface horizons and site index decreased with increased stone content in subsoil.

In a soil-site study of scarlet oak (Quercus coccinea Meunchh.) and black oak (Quercus velutina Lam.) in the southern Appalachians, Doolittle (1957) examined twenty soil and topographic variables through multiple regression in developing a tree height prediction equation. His final equation included depth and percent sand in the A horizon, which were significant at the 0.01 level, and the slope position, which was significant at the 0.05 level. These three variables accounted for 96 percent of the total variation in site index and the depth of the A horizon alone accounted for 91 percent of the variation.

On the Cumberland Plateau of northern Alabama, Smalley (1967) found height growth of white oak to be related to slope position and total slope length. Height growth of mixed red oaks (Quercus spp.) was related to slope position and aspect. No soil factors were found to be significantly related to tree height for either group of oaks after these topographic variables and tree age had been taken into account.

Auchmoody and Smith (1979) developed a mixed upland oak soil-site productivity equation for well drained, upland soils in northeastern West Virginia. Forty-six independent variables were originally tested, and six were found to be significantly related to site index at the 0.05 level: slope shape, thickness of the A1 horizon, slope gradient, aspect, precipitation, and position on the slope. Their final equation was tested against independent data from 61 soil-site plots, and results showed a correlation of 0.83 between predicted and observed site indices, significant beyond the 0.01 level.

The objectives of this study were: 1) to measure the basic morphological, chemical, and physical properties of three major forest soils in eastern Kentucky; 2) to relate soil properties and other measured site characteristics to the growth of white oak (Quercus alba L.); and 3) to formulate a tree height prediction equation for white oak using soil and site factors.

METHODS

Study Area

The study area lies within the Cumberland Plateau commonly known as the Mountains and Eastern Coalfields region of Kentucky (Fenneman, 1938). Approximately two-thirds of the study sites were located in the University of Kentucky's Robinson Forest in Breathitt and Knott Counties. The remaining sites were located in Jackson County, mostly within the Daniel Boone National Forest.

The region has a humid continental climate that varies widely in temperature and precipitation within a given year. Average annual air temperature is 14°C and average annual precipitation is 117 cm. Approximately 55 cm of the precipitation comes during the 170-180 day frost-free growing period.

The geologic strata of Robinson Forest consists of alternating layers of acid sandstones, siltstones, and shales of the Breathitt Formation of the Pennsylvanian period. The area is characterized by a maze of winding narrow-crested ridges and deep narrow valleys (McFarlan, 1943). The geology of Jackson County also consists of acid sandstones, silt-stones and shales mainly of the Breathitt Formation, with some inclusions of the Lee and Pennington Formations of the Pennsylvanian and Mississippian periods, respectively. The topography of Jackson County is very similar to that of Robinson Forest, with the exception that ridgetops are much broader in Jackson County.

Three soil types were investigated in this study. The most commonly sampled soil type was a Shelocta silt loam which formed in colluvium and is classified as a fine-loamy, mixed, mesic Typic Hapludult. Also found on the steep valley walls was the Rigley sandy loam, a coarse-loamy, mixed, mesic Typic Hapludult which formed in colluvium from acid siltstone, sandstone, and only a minor component of shale. The third soil type was a Wernock variant loam which was sampled on the broad ridgetops in Jackson County. The Wernock variant soil is pending correlation by the Soil Conservation Service, USDA.

Field Sampling and Laboratory Analyses

Soil, site, and topographic factors were evaluated or measured in 39 pure and mixed stands of white oak. Selection of sites were based on the following criteria: 1) the site was representative of one of three major soil series which occurred in the area; 2) the trees were between 30 and 70 years of age; 3) the trees occupied dominant or codominant canopy positions; 4) the trees had not been perceptibly damaged by wind, fire, disease, etc.; and 5) the site was relatively uniform in slope, aspect, and slope position. The Shelocta and the Rigley series were found on the lower 1/3 and middle 1/3 slope positions owing to their colluvial nature of formation. The Wernock variant was only found on the broad ridgetop position, suggesting that this soil was formed in residuum. A representative profile of each of the three soils investigated was selected for the purpose of obtaining a more detailed characterization of the physical and chemical soil properties.

A soil pit was dug at each site and soil samples were taken from each genetic horizon for laboratory analysis. Soils were air-dried and ground to pass a 2 mm sieve. Soil pH of each horizon was determined on a 1:1 soil to water paste using Beckman glass and calomel reference electrodes. Total nitrogen was determined for all A horizons and for the surface 30 cm of each site by a macro-Kjeldahl method described by Allison (1965). Organic matter content was determined for all A horizons by the Walkley-Black method for organic carbon (Allison, 1965).

Slope shape was evaluated by visual observation and numerically coded. Approximate slope length and position on the slope were also evaluated and recorded. Slope position was expressed as the percent of the distance from the stream to the adjacent ridge plus one. Thus the lower 1/3 slope position was given a value of 2, the middle 1/3 a value of 1.67, the upper 1/3 a value of 1.33 and the broad ridgetop a value of 1. This approach avoids the use of zeroes on the ridgetops. Elevation was determined from topographic maps.

Prior to the use of aspect in linear regression, the azimuth of aspect was transformed to a straight-line function. The authors elected to use the traditional value of 45° azimuth from north as the optimal aspect (Lloyd and Lemmon, 1968) for tree growth. Consequently, aspect was expressed as cosine (aspect - 45°) + 2. This rectification assigns a value of +3 to 45° and +1 to the 180° reading, while avoiding the use of negative numbers and zeroes. The seven sites sampled on broad ridgetops in Jackson County were described as having "neutral" aspects and were therefore given an intermediate value of two.

Basal area was determined at the plot center with a 10 factor wedge prism, since these stands were classified as second-growth saw-timber (Avery, 1975). A minimum of four white oak trees which met the previously outlined site criteria were measured for the following features; the diameter at breast height (1.4 m from ground line) was measured with a diameter tape; total tree height was measured with a Haga altimeter; age was determined with an increment borer; three years were added to arrive at the total age since the increment core was extracted at breast height. These height and age measurements were used to determine the site index of each site based on Schnur's (1937) site index curves for upland oak.

Nineteen soil, topographic, and stand variables were analyzed by the stepwise regression procedure as described by Draper and Smith (1966). The 0.05 significance level was used throughout the analysis; however, the reciprocal of tree age was forced into each regression equation regardless of its significance. Nineteen variables and transformations of variables were chosen for analysis based upon their significance reported in the literature or because preliminary trend analysis indicated a relationship to tree height. Two stand variables, tree age and basal area, were included as independent variables in the regression. Eight soil features were also analyzed. Topographic factors analyzed during the regression included aspect, elevation, percent slope, and three transformations of slope position (lower 1/3, middle 1/3, and broad ridgetop). Additional transformations were the product of the A horizon thickness and the percent organic matter in the A horizon, the product of the A horizon thickness and aspect,

and the product of the A horizon thickness and the percent nitrogen in the A horizon.

RESULTS AND DISCUSSION

Average values of soil and site factors for each soil series and slope position are given in Table 1. Variables of significance include eight soil features and one stand variable (basal area).

Table 1. Average values of soil and site factors for each soil series and slope position.

	Averages for Soil Series			Averages for Slope Positions		
	Shelocta	Rigley	Wernock Variant	Lower 1/3	Middle 1/3	Broad Ridgetop
Percent Slope	45	55	6	49	47	6
Thickness of A horizon (cm)	12	16	5	15	11	5
Thickness of B horizon (cm)	91	81	75	89	85	75
pH of A horizon	5.10	4.87	4.61	5.05	5.00	4.61
pH of B horizon	5.05	5.07	4.89	5.01	5.13	4.89
Organic matter content of A horizon (%)	1.76	1.18	2.61	1.64	1.50	2.61
Nitrogen content of A horizon (%)	0.13	0.09	0.12	0.13	0.10	0.12
Nitrogen content of surface 30 cm (%)	0.08	0.06	0.06	0.08	0.06	0.06
Basal area (m^2/ha)	23	25	24	25	23	24

Following the development of the general height prediction equation, the data were analyzed separately for each soil series and slope position investigated. White oak height prediction equations were subsequently developed for each situation as a means of comparing their associated site qualities.

Soil Properties

The profile chosen to be representative of the Shelocta soil was located on the lower 1/3 portion of an east-facing slope. The Rigley profile was also sampled on a lower slope position but was on a south-facing slope. The Wernock variant was only found on the broad ridgetop slope positions, and its aspect was therefore considered to be neutral.

Physical and chemical properties of the representative profiles are given in Table 2. Particle size analysis of the representative profiles indicated that the Shelocta soil was finer in texture than the Rigley and

Table 2. Physical and chemical characteristics of a representative profile of the Shelocta, Rigley and Wernock variant soils.

Soil Horizon	Depth (cm)	Sand	Silt	Clay	O.M.	N	pH	Exchangeable Ca^{++}	Exchangeable Mg^{++}	Exchangeable K^{+}	Exchangeable Na^{+}	CEC	Exch. Acidity
		%						(meq/100 g)					
Shelocta													
A1	0-7.5	13.3	64.0	22.7	3.44	0.25	5.8	0.65	0.32	0.47	0.07	16.5	0.53
B1	7.5-20	18.6	54.2	27.2	0.99	0.10	6.1	0.61	0.31	0.37	0.05	15.5	0.21
B21t	20-48	17.2	53.7	29.1	0.27	0.06	5.1	0.43	0.43	0.26	0.05	13.7	1.98
B22t	48-69	15.3	59.1	25.6	0.10	0.05	5.3	0.25	0.41	0.19	0.04	10.5	4.36
B23t	69-91	11.6	61.2	27.2	0.11	0.05	5.0	0.23	0.41	0.18	0.04	9.3	5.06
B24t	91-107	12.4	60.2	27.4	0.13	0.05	5.0	0.18	0.44	0.17	0.07	10.2	6.28
B3	107-130+	15.8	59.7	24.5	0.14	0.05	5.0	0.25	0.48	0.28	0.09	11.7	5.48
Rigley													
A1	0-5	70.2	18.5	11.3	0.99	0.07	5.0	0.81	0.42	0.31	0.16	5.3	2.40
A2	5-18	69.8	18.2	12.0	0.44	0.05	5.0	0.27	0.23	0.24	0.07	4.7	2.58
B1	18-36	68.2	18.8	13.0	0.56	0.03	5.0	0.29	0.16	0.16	0.05	4.2	2.44
B21	36-81	68.3	19.4	12.3	0.22	0.03	5.2	0.12	0.31	0.15	0.05	3.6	2.16
B22	81-107+	70.3	19.4	10.3	0.09	0.02	5.2	0.14	0.53	0.16	0.07	3.1	1.95
Wernock Variant													
A1	0-5	43.6	43.5	12.9	2.25	0.11	4.4	0.37	0.18	0.18	0.06	8.2	4.43
B1	5-20	41.1	46.1	12.8	0.56	0.03	4.9	0.11	0.07	0.08	0.08	3.6	2.76
B21t	20-41	35.6	43.3	21.1	0.23	0.03	5.1	0.18	0.28	0.12	0.10	6.2	5.09
B22t	41-71	39.6	39.0	21.4	0.14	0.02	4.9	0.10	0.53	0.10	0.12	7.0	5.45
B3	71-89	56.3	28.3	15.4	0.08	0.02	5.1	0.06	0.15	0.04	0.10	3.7	2.98

Wernock variant soils. The Wernock variant was classified as a loam, and the Rigley soil fell into the sandy loam textural class.

The A horizon of the Shelocta soil contained appreciably more organic matter than either the Wernock variant or the Rigley, while the Rigley contained the least organic matter of all three soils. This same trend was displayed in percent nitrogen contents for all three representative profiles.

The Shelocta soil had a dramatically higher cation exchange capacity (CEC) throughout its entire profile than either the Wernock variant or the Rigley. In scanning all three representative profiles, it becomes evident that cation exchange capacities agree closely with contents of clay and organic matter for each profile and among soil profiles. The soil with the highest clay and organic matter, i.e. Shelocta, had the highest CEC. The representative profile having the lowest contents of clay and organic matter was the Rigley, which also had the lowest CEC.

With the exception of the surface 20 cm, the pH values for all three profiles were about the same; however, the A1 and B1 horizons of the Shelocta soil had considerably higher pH values than the other two representative profiles. The most dramatic difference in pH values occurred between the A1 horizon of the Wernock variant soil (pH=4.4) and the B1 horizon of the Shelocta soil (pH=6.1).

The representative profile of the Rigley series contained a higher percent base saturation than either the Shelocta or Wernock variant. Although the Shelocta generally had higher amounts of exchangeable bases in each horizon, the lower total CEC of the Rigley profile accounted for the higher percentage base saturation. Considerable variability exists in the levels of exchangeable acidity within a representative profile. However, the control horizons show the Wernock variant to have the highest level of exchangeable acidity and the Rigley to have the lowest.

General Height Prediction Equation

The following white oak height prediction equation was derived by stepwise regression analysis of the soil, topographic and stand data from all 39 study sites.

$$Y = 3.43289 - 20.47568(X_1) + 0.00409(X_2) + 1.58643(X_3) - 0.05054(X_4) - 0.00219(X_5),$$

where

Y = Predicted logarithm of total tree height (meters),
X_1 = 1/age (years),
X_2 = [cosine (aspect - 45°) + 2] [thickness of A horizon (cm)],
X_3 = Nitrogen content of A horizon (%),
X_4 = Middle 1/3 slope position,
X_5 = Thickness of B horizon (cm).

Each of the significant variables with the exception of age, appears to either directly or indirectly related to moisture regime, soil fertility, or soil depth of a given site. The significance level for each variable and the cumulative R^2 values are given in Table 3.

Table 3. Variables, significance levels, and the cumulative multiple coefficients of determination (R^2) values for the general tree height prediction equation for all 39 sites.

Variable	Significance Level	Cumulative R^2
1/age	0.0001	0.186
[cosine (aspect - 45°) + 2] [A horizon depth (cm)]	0.0001	0.343
Nitrogen content of A horizon (%)	0.0001	0.527
Middle 1/3 slope position	0.0001	0.591
Thickness of B horizon (cm)	0.0009	0.620

Age as an independent variable (X_1) was the largest contributing factor for explaining variation in tree height (R^2 = 0.186). This relationship between height and age is largely consistent; although incongruities may exist in very young and very old stands of timber. Other researchers (Della-Bianca and Olsen, 1961; McClurkin, 1963; Carmean, 1965; Hannah, 1968; Yawney and Trimble, 1968) have reported that tree age is highly correlated with height of oaks.

Another important independent variable (X_2) in this study was a transformation of aspect and thickness of the A horizon. Aspect alone was not a significant variable in the general height prediction equation. However, the product of A horizon thickness and aspect transformation was found to contribute towards the explanation of the variation in tree height (R^2 = 0.16).

Aspect exerts its influence on tree growth by its effect on microclimate, soil moisture, and soil development. In general, soils on northern and eastern aspects are cooler, have higher moisture and organic matter contents, and usually show less soil development than soil on south and west facing slopes (Finney et al., 1962; Franzmeier et al., 1969; Hutchins, 1972; Hanson, 1977). Thickness of the A horizon soil layer is also frequently related to tree height. A thick A horizon results in a greater volume of soil material and, more importantly, more organic matter; hence higher soil CEC that enhances root development an is more efficient in storing and making available both nutrients and water to the trees. The more favorable rooting medium translates into a potential for more rapid above-ground growth.

Percent nitrogen in the A horizon (X_3) explained an additional 18.4 percent of the variance. Inclusion of this variable limits the use of the height prediction equation because field tests for nitrogen are generally

less accurate than laboratory analyses. However, the contribution to the prediction equation provided by this variable seems to merit its use and inclusion.

The middle 1/3 slope position (X_4) was observed in the general prediction equation to have a negative coefficient suggesting that trees located on the mid-slopes have poorer growing conditions than those on lower 1/3 slope and broad ridgetop positions. In application of this equation, X_4 = 1.67 when the model is used on the middle 1/3 slope position. This variable is simply dropped from the equation on the other slope positions.

The last variable (X_5) to enter into regressions was thickness of the B horizon which explained an additional 2.9 percent of the variance. The negative relation between B horizon thickness and tree height is caused by the inclusion of data from the more shallow Wernock variant. Even though the B horizon is slightly thinner than Rigley and Shelocta, it has chemical and physical soil properties (Table 2) more favorable for white oak growth.

Prediction Equation by Soil Series

Data obtained from the three soil series were analyzed separately by stepwise regression procedure to develop a tree height prediction equation for each soil series. These equations were calculated and their multiple coefficients of determination (R^2) are provided in Table 4. The means of all significant variables were entered into each regression equation, and these equations were then compared among soil series by a general linear hypothesis test as described by Searle (1971).

White oaks on the Shelocta series have slightly higher site indices than those on the Wernock variant. Table 5, however, reveals that this is not a significant difference. Analysis of the representative profiles showed the Shelocta to have a higher CEC and higher organic matter and nitrogen contents in the A horizon than the Wernock variant. However, nine of the 22 sites sampled on the Shelocta series were located on the middle 1/3 slope position, and trees on these sites generally had lower site indices than those on the Wernock variant. Thus the observed similarity between these two soils in white oak site quality may at least be partially explained by the dispersion of the data collected.

The Shelocta series was associated with significantly higher quality of white oak sites than did those on the Rigley series. While both of these soils are formed in colluvial material, the Rigley is described as being coarse-loamy and the Shelocta as fine-loamy. The higher sand content of the Rigley is to a certain degree synonymous with lower water holding capacity few exchange sites, less nutrient source and subsequently with a greater leaching loss of nutrients. Table 1 also shows the Rigley to have the lowest organic matter and nitrogen contents of the three soils studied. This same trend was observed to exist during the analysis of the representative profiles.

Although higher site indices of trees were generally found on the Wernock variant than on the Rigley series, the general linear hypothesis test in Table 5 reveals that the differences between these two prediction

Table 4. Multiple coefficients of determination (R^2) and regression equations for tree height prediction equations developed for each soil series and slope position.

Soil Series and Slope Position	Regression Equations	R^2
Shelocta	$Y = 3.46 - 20.7476(X_1)^* + 0.0576(X_2) + 1.4454(X_3) - 0.0032(X_{10}) + 0.0036(X_6)$	0.71
Rigley	$Y = 2.6421 + 3.5109(X_1) + 0.2220(X_4) + 0.0080(X_5) + 0.0120(X_7) - 0.0991(X_8) - 0.6551(X_9)$	0.77
Wernock variant	$Y = 3.3752 - 23.3231(X_1) - 0.0032(X_7) - 0.2155(X_8) + 0.2971(X_{10})$	0.69
Lower 1/3	$Y = 2.5984 - 14.2648(X_1) + 0.1088(X_{11}) + 0.0139(X_{12}) - 0.1146(X_8) + 6.9963(X_{14}) - 0.1633(X_4)$	0.71
Middle 1/3	$Y = 1.5471 - 21.5452(X_1) + 0.5064(X_9) - 0.0529(X_{13}) + 1.3405(X_3) + 0.0713(X_{15})$	0.69
Broad ridgetop	$Y = 3.3752 - 23.3231(X_1) - 0.2155(X_8) + 0.2971(X_9) - 0.0032(X_7)$	0.69

* Where variables

X_1 = 1/age
X_2 = Lower 1/3 slope position
X_3 = N content of A horizon
X_4 = O.M. content of A horizon
X_5 = Elevation
X_6 = Thickness of B horizon
X_7 = Thickness of A+B horizon
X_8 = pH of A horizon
X_9 = pH of B horizon
X_{10} = Cosine (aspect - 45°) + 2 x (A horizon depth)
X_{11} = Cosine (aspect - 45°) + 2
X_{12} = Basal area (m^2/ha)
X_{13} = Thickness of A horizon
X_{14} = N content of top 30 cm
X_{15} = Depth of A horizon x % of O.M. of A horizon
X_{16} = Depth A horizon x % N of A horizon
X_{17} = Depth A horizon x cosine (aspect - 45°) + 2

Table 5. Comparisons of regression equations for each soil series and slope position by the general linear hypothesis test.

Regression Comparison	Significance Level
Shelocta > Rigley	0.0002
Wernock variant = Rigley	0.0823
Shelocta = Wernock variant	0.5561
Lower 1/3 > Middle 1/3	0.0001
Lower 1/3 > Broad Ridgetop	0.0028
Broad Ridgetop > Middle 1/3	0.0001

equations are not significant ($p = 0.08$). The less suitable physical and chemical properties of the Rigley soil and the more favorable properties of the Wernock variant have already been discussed.

Prediction Equations by Slope Position

Each of the white oak sites was classified into one of three slope positions, namely lower 1/3, middle 1/3, or broad ridge-top. Although numerous attempts were made to locate white oak sites on the upper 1/3 slope position only a few stands of white oak were located at this position and most of those fell beyond the upper age limit of 70 years. Furthermore, many of the white oaks at this slope position occurred as scattered individuals and were not grouped close enough to be objectively considered as inhabitants of a homogeneous site. Each of the three slope positions was analyzed separately by stepwise regression and three different tree height prediction equations were subsequently developed.

Soils on the lower slope positions generally had thicker A horizons (Table 1) than those on the other two slope positions and this is conducive to development of a larger and more effective root system. Soils on the lower 1/3 slope position also had higher nitrogen contents in the A horizons and in the surface 30 cm than those on the middle 1/3 and broad ridgetop slope positions (Table 1). The higher N content would be expected since these soils have a high organic matter content and a more favorable moisture regime which encourages greater microbial activity. Other authors have reported nitrogen to be significantly related to growth of oaks (Lunt, 1939; Jones and Curlin, 1968; Ward and Bowersox, 1970; Bowersox and Ward, 1972).

Table 5 shows trees on broad ridgetop slope position to have a significantly higher site index than the middle 1/3 slope position. At first glance, this appears to be contradictory to the findings of many authors (Lunt, 1939; Einspahr and McComb, 1951; Carmean, 1965). However, these studies were done in geographic areas where the ridges were characteristically very narrow-crested. The ridgetops that were sampled in Jackson County were broad with an average gradient of only 6.4%. Many of the apparently productive farms in the county are located on these ridgetops.

Although slope gradient was not a significant factor in the height prediction equations for any of these three slope positions, it is the variable which most closely represents the differences between the broad ridgetops and the other two slope positions. The middle 1/3 and the lower 1/3 slope positions had average slope gradients of 47 and 49 percent, respectively. Considerable amounts of surface runoff and subsurface lateral flow may occur on these steeper slopes. Furthermore, the only soil sampled on these broad ridgetops was the Wernock variant, whose favorable properties for tree growth have already been noted in the comparisons among representative profiles and soil series.

SUMMARY AND CONCLUSIONS

The Shelocta series was generally the most favorable soils for growth of white oak and the Rigley series the least favorable. The best white oak stands were found on the lower 1/3 slope positions. These sites generally had thicker A horizons which are conducive to a more extensive and effective root system and more nutrient availability. Soils on the lower 1/3 slope position also had the highest soil nitrogen contents, while the trees on the broad ridgetop position had intermediate site qualities.

A general tree height prediction equation was developed for white oak by the stepwise regression procedure. The five most important variables for predicting white oak height were, in decreasing order of importance: age, nitrogen content of the A horizon, the product of the A horizon thickness and the coded aspect, slope position, and the thickness of the B horizon. The equation developed accounted for 62 percent of the variation in tree height. The R^2 for the general equation is less than values reported from other studies of the Appalachian area (Auchmoody and Smith, 1979; Carmean, 1965; Carmean, 1967; Hannah, 1968; Trimble and Weitzman, 1956). Age alone accounted for approximately 19 percent of the variation in tree height, which was almost one-third of the variation explained by the model.

Prediction equations developed for each soil series and slope position accounted for a larger percent of variation. For example, the equation developed for the Rigley series accounted for 77 percent of the variation in tree height. This suggests that when a data set is confined to a given soil series or slope position, less variability is usually found to exist and accurate results are generally more tangible.

From the general height prediction equation, prediction tables may be developed for more rapid site quality decisions and also to avoid repeated computational procedures. However, when the site can be qualified in a more specific way, such as by soil series or slope position, it is suggested that these individual equations be used since they explain a greater percentage of the variation in tree height.

LITERATURE CITED

Allison, L.E. 1965. Organic carbon. In C.A. Black, ed., Methods of Soil Analysis, Part 2, Monograph 9. American Society of Agronomy, Madison, Wisconsin.

Auchmoody, L.R., and H.C. Smith. 1979. Oak soil-site relationships in northwestern West Virginia. USDA/FS Res. Pap. NE-434.

Avery, T.E. 1975. Natural resources measurements. 2nd ed. McGraw-Hill Book Company, New York. 339 pp., illus.

Bowersox, T.W., and W.W. Ward. 1972. Prediction of oak site index in the ridge and valley region of Pennsylvania. Forest Sci. 18:192-195.

Carmean, W.H. 1965. Black oak site quality in relation to soil and topography in southeastern Ohio. Soil Sci. Soc. Amer. Proc. 29:308-312.

Carmean, W.H. 1967. Soil survey refinements for predicting black oak site quality in southeastern Ohio. Soil Sci. Soc. Am. Proc. 31:805-810.

Carmean, W.H. 1975. Forest site quality evaluation in the United States. Adv. Agron. 27:209-269.

Della-Bianca, L., and D.F. Olson, Jr. 1961. Soil-site studies in Piedmont hardwood upland forests. For. Sci. 7:320-329.

Doolittle, W. 1957. Site index of scarlet and black oak in relation to southern Appalachian soil and topography. For. Sci. 3:114-124.

Draper, N.R., and H. Smith. 1966. Applied regression analysis. John Wiley and Sons, Inc., New York. 407 pp.

Einspahr, D., and A.L. McComb. 1951. Site index of oaks in relation to soil and topography in northeastern Iowa. J. For. 49:719-723.

Fenneman, N.M. 1938. Physiography of the eastern United States. McGraw-Hill Book Company, Inc., New York and London.

Finney, R.R., N. Holowaychuk, and M.R. Heddleson. 1962. The influence of microclimate on the morphology of certain soils of the Allegheny Plateau of Ohio. Soil Sci. Soc. Amer. Proc. 26:287-292.

Franzmeier, D.P., E.J. Pedersen, T.J. Longwell, J.G. Byrne, and C.K. Losche. 1969. Properties of some soils in the Cumberland Plateau as related to slope aspect and position. Soil Sci. Soc. Amer. Proc. 33:755-761.

Hannah, P.R. 1968. Topographic and soil relations for white and black oak in southern Indiana. USFS Res. Paper NC-25, 7 pp.

Hanson, C.T. 1977. Relationship of soil and site characteristics to soil moisture regimes in a forested watershed. M.S. Thesis, Univ. of Kentucky, 99 pp.

Hutchins, R.B. 1972. The influence of microclimate on the soil and vegetation of steep forested slopes in eastern Kentucky. M.S. Thesis, Univ. of Kentucky.

Jones, H.C., and J.W. Curlin. 1968. The role of fertilizers in improving the hardwoods of the Tennessee Valley. In Forest fertilization-theory and practice. TVA, Knoxville, Tenn. p. 185-190.

Lloyd, W.J., and P.E. Lemmon. 1968. Rectifying azimuth (of aspect) in studies of soil-site index relationships. In Tree growth and forest soils, ed. by C.T. Youngberg and C.B. Davey. Third North American Forest Soils Conference, Corvallis, Oregon.

Lunt, H.A. 1939. Soil characteristics, topography, and lesser vegetation in relation to site quality of second-growth oak stands in Connecticut. J. Agr. Res. 59:407-428.

McClurkin, D.C. 1963. Soil-site index predictions for white oak in north Mississippi and west Tennessee. For. Sci. 9:108-113.

McFarlan, A.C. 1943. Geology of Kentucky. Univ. of Kentucky, Lexington, 531 pp.

Schnur, G.L. 1937. Yield, stand, and volume tables for even-aged upland oak forests. U.S.D.A. Tech. Bull. 560, 88 pp.

Searle, S.R. 1971. Linear models. John Wiley and Sons, Inc., New York.

Smalley, G.W. 1967. Soil-site relations of upland oaks in north Alabama. U.S.F.S. South. For. Exp. Sta., Res. Note 64, 6 pp.

Trimble, G.R., Jr., and S. Weitzman. 1956. Site index studies of upland oaks in the northern Appalachians. For. Sci. 2(3):162-173.

Ward, W.W., and T.W. Bowersox. 1970. Upland oak response to fertilization with nitrogen, phosphorus, and calcium. For. Sci. 16:113-120.

Yawney, H.W., and G.R. Trimble. 1968. Oak soil-site relationships in the ridge and valley region of West Virginia and Maryland. U.S.F.S. Res. Paper NE-96, 19 pp.