SITE QUALITY RELATIONSHIPS FOR SHORTLEAF PINE

David L. Graney[1]

ABSTRACT

Existing information about site quality relationships for shortleaf pine (*Pinus echinata* Mill.) in the Southeastern United States is reviewed in this paper. Estimates of site quality, whether from direct tree measurements or indirect estimates based on soil and site features, are only local observations for many points on the landscape. To be of value to the land manager, a system of site quality evaluation based on identifiable units of the landscape must be devised. Physiographic site classification systems may provide the basis for reliable site quality evaluation in the Southeast.

INTRODUCTION

Shortleaf pine has the widest range of the southern pines. Its botanical range is greater than 400,000 square miles and extends over 22 states. It grows naturally on most upland soils and physiographic divisions of the Southeastern United States.

Shortleaf pine is adapted to a variety of soil and site conditions resulting in considerable variation in productivity throughout its range. Site indexes at age 50 can vary from more than 100 feet on deep, well-drained sandy loams of stream bottoms of the Upper Coastal Plain to nearly 30 feet on shallow, rocky, or clayey soils in the western portions of the Ozark and Ouachita Mountains (Murphy and Beltz 1981, Graney 1974, Graney and Burkhart 1973).

Yield and tree quality of shortleaf pine vary greatly with site quality. To gauge returns from silvicultural treatments and to select a species for management on a given site, forest and managers need reliable site quality estimates for shortleaf pine and major associated species. Information about site quality relationships for shortleaf pine is limited mainly to the eastern and western portions of its range (Carmean 1975). Few, if any, additional results on shortleaf pine site quality have been published since the mid-1970's.

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[1]Dr. Graney is principal silviculturist at the Silviculture and Hydrology Laboratory maintained at Fayetteville, Arkansas, by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the University of Arkansas.

Site quality is usually expressed as site index (the height of the dominant and codominant trees at an index age of usually 25 or 50 years), which can be measured either directly by site curves or species comparisons or indirectly by soil-site relationships and by soil survey or site classification methods.

DIRECT MEASUREMENT

Site Index Curves

With the site index curve method of direct estimation, height and age measurements from free-growing dominant and codominant trees are compared with published site index curves or tables to estimate how tall the trees were or will be at the index age. The site index curve method is both simple and accurate when suitable trees and stands exist for measurement and reliable site index curves and tables are available.

In addition to the regional natural stand shortleaf pine curves in Miscellaneous Publication 50 (USDA Forest Service, 1929), local site index curves have been developed for natural shortleaf pine stands in the Piedmont (Coile and Schumacher 1953), the Ouachita Mountains of Arkansas and Oklahoma (Graney and Burkhart 1973), and the Ozark Highlands of southern Missouri (Nash 1963, Graney and Popham[2]). Site index curves have also been developed for shortleaf pine plantations in southern Illinois (Gilmore and Metcalf 1961, Gilmore 1979), the Interior Uplands of Tennessee, Alabama, and Georgia (Smalley and Bower 1971), and the Ozark Highlands of southern Missouri.[2] The importance of accurate localized curves has been indicated by several studies showing that height growth patterns for pine and hardwoods may vary considerably by species, locality, soil condition, and site index class (Carmean 1972, Graney and Burkhart 1973, Graney 1976, Zahner 1962).

Significant errors caused by inaccurate curves are most likely in very young or very old stands. If uncertainty exists as to the reliability of regionwide or local harmonized curves, site index measurement trees as near the index age as possible should be selected to minimize errors. Also, using trees appreciably younger or older than the main stand could cause errors in site index estimates, because such trees often have height growth patterns different from those of the main stand.

Graney and Burkhart (1973) found that height growth patterns for natural shortleaf pine stands in the Ouachita

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[2]Graney, D. L. and Popham, T. Site index curves for shortleaf pine in Missouri. Unpublished manuscript.

Mountains differed from those indicated by the curves of Coile and Schumacher (1953) and of Miscellaneous Publication 50 (USDA Forest Service, 1929) and that the pattern of growth varied by site index class. For site index classes 40, 60, and 80, the local curves and the regional curves agreed fairly well for all sites and ages older than 50 years. For younger ages, the Ouachita Mountain and Miscellaneous Publication 50 curves are similar for poor sites, but Miscellaneous Publication 50 curves tend to overestimate site index on medium to good sites. The curves of Coile and Schumacher (1953) underestimated site index for all site index classes at stand ages of 35 years or less.

Site index curves (25-year base) constructed from tree section data representing 200 shortleaf pines in 99 plantations in southern Missouri were compared with curves for plantations in the Interior Uplands (Smalley and Bower 1971) and with 25-year base curves for natural stands in the Ouachita Mountains (Graney and Burkhart 1973). Except for poor sites, both the Interior Uplands and Ouachita Mountains curves produce accurate estimates in Missouri plantations between ages 15 and 30. However, for younger and older plantations, errors of 3 to 5 feet could occur. On medium to good sites, the rate of height growth declined more rapidly in Missouri plantations than for the pines in the other regions. This decline in rate of height growth should be carefully considered when making long-term projections of plantation yields. For example, the mean site index (25-year base) of the 99 plantations sampled in southern Missouri was 5.5 feet greater than the mean of 76 natural stands sampled on similiar sites in the same area. When plantation heights at age 25 were projected to age 50, the average site index for plantations was nearly 10 feet higher than the measured site index for the 50-year-old natural stands, and many plantations were assigned the unlikely site index of 80 to 85 feet.

Species Comparisons

Many even-aged stands are suitable for site index measurement, but they may not contain shortleaf pine in the dominant or codominant crown classes. In some areas, the shortleaf pine site index can be estimated by measuring the site index of existing species and then using comparison graphs or equations to determine the site index of shortleaf pine. Such graphs or equations are available for shortleaf pine and several associated species in the Piedmont of Virginia, North Carolina, and South Carolina (Olson and Della-Bianca 1959) and the Southern Appalachians (Doolittle 1958). Equations comparing shortleaf and loblolly pine in mixed stands have been developed for the Piedmont of North Carolina (Coile 1948) and the Coastal Plain of northern Louisiana and southern Arkansas (Zahner 1957, 1958). All comparisons have shown that, except on poor sites, the site index for shortleaf pine growing in mixed stands tends to be lower than the site index of associated pine and hardwood species. Site index differences between shortleaf and loblolly in mixed stands are usually 10 to 15 feet on better sites in the Carolina Piedmont area and 0 to 10 feet, depending on the soil and site condition, in the western part of the range (Walker and Wiant 1966). In the Arkansas and Missouri Ozarks, where summer droughts and high soil moisture deficits are common, the shortleaf pine site index equals or exceeds values for associated oak species on all but the best sites. On sandy soils common to the broad, gently sloping ridges in the Boston Mountains of Arkansas, the site index of shortleaf pine averages 6 to 10 feet higher than the site index of white, black or northern red oaks (*Quercus alba* L., *Q. velutina* Lam., *Q. rubra* L.) (Graney 1976).

INDIRECT METHODS

Where suitable site index trees are not available, land managers need methods to estimate site quality that can be used regardless of species composition or existing stand conditions. Soil-site techniques, soil survey, and site classfication methods have received the most emphasis as indirect methods of site quality estimation.

Soil-Site Relationships

The most recent comprehensive review of forest site quality evaluation in the United States listed 24 papers on soil-site relationships for shortleaf pine and associated species (Carmean 1975). However, even with the wealth of information contained in this summary, site relationships for the species are not well understood, because shortleaf pine covers a wide geographic range that includes extreme variation in physiography, soils, and climate. The soil-site studies, however, have provided some general trends concerning the soil and topographic site features most often associated with differences in shortleaf pine site quality. Most upland tree species respond similarly to the same general site conditions although the degree of response for any one site factor can vary widely among species and with other interacting soil, topographic, or climatic conditions.

Soil features most often correlated with shortleaf pine site quality are surface soil thickness; depth to a restricting, mottled, or less permeable horizon; surface soil texture; subsoil texture; and subsoil consistency. The surface soil is generally considered to be most favorable for fine root development and absorption of nutrients and moisture. The relationship between surface soil thickness and site quality is usually curvilinear; where surface soils are shallow, small increases in surface soil thickness can cause large increases in site quality. Coile (1948) found that shortleaf pine site index increased rapidly as the thickness of the A horizon of North Carolina Piedmont soils increased from less than 1 inch to 6 or 8 inches. The site index changed little with increases in thicknesses greater than 8 inches. For well-developed Coastal Plain soils in Louisiana and Arkansas, Zahner (1957, 1958) found that shortleaf pine site index increased with increases in surface soil thickness up to 20 inches, then declined for thickness greater than 20 inches.

The best shortleaf pine sites are usually on well-drained, medium-textured soils. Texture and stone content affect the levels of available moisture, nutrients, drainage, and aeration. Thus, coarse-textured soils generally have lower site qualities because soil moisture holding capacity and nutrient levels are limited. Medium-textured soils make good sites because they have adequate available moisture and nutrient levels, good soil structure, internal drainage, and sufficient aeration, all of which favor root development. Fine-textured soils generally have adequate soil moisture and nutrients, but they are often of lower site quality because they commonly have a dense clay subsoil with poor structure, internal drainage, and aeration. In the southern Piedmont, the incidence of littleleaf disease (<u>Phytophthora</u> <u>cinnamomi</u> Rands) is associated with fine-textured, plastic subsoils having poor internal drainage (Copeland 1949).

Topographic features affecting shortleaf pine site quality are aspect, slope steepness, slope position, slope shape, and elevation. The best shortleaf pine sites are generally on north- or east-facing, gently sloping, concave, or lower slope positions, whereas poor sites are on narrow ridges and south- or west-facing, steep, convex upper slopes. Topographic features are often closely correlated with soil depth and profile development, amounts of available soil moisture and nutrients, and microclimate (Carmean 1975,; Lee and Sypolt 1974). Generally, on rough hilly and mountainous terrain, topographic features are more closely correlated with site quality; on more level terrain, soil variables are more important in determining site quality.

On mountainous terrain, aspect is strongly correlated with shortleaf pine site quality. In the Ozark-Ouachita Mountains the site index of shortleaf pine on north aspects averaged 4 to 7 feet higher than on south aspects (Graney 1976, Hartung and Lloyd 1969). In the Georgia Blue Ridge Mountains, shortleaf pine site index averaged 10 to 20 feet higher on north than on south aspects (Ike and Huppuch 1968).

Slope position and slope shape are related to many of the soil properties that have been correlated with shortleaf pine quality. Midslopes, lower slopes, and concave slopes generally have deep, colluvial soils with a relatively thick surface horizon. Upper slope soils are usually shallow and have a relatively thin surface horizon. In mountainous areas with "bench and bluff" topography, upper and lower slopes alternate along the entire length of mountain slopes. In such situations, site quality changes significantly within a distance of a few feet, and slope shape and slope position must be integrated to accurately define the relationship between site quality and topographic features (Graney 1976, 1977).

In the mountains of western Arkansas and northern Georgia, shortleaf pine site index was significantly lower at the higher elevations. Site index of shortleaf pine at elevations higher than 2,000 feet in the Boston and Ouachita Mountains of Arkansas and Oklahoma averaged 4 feet lower than site index on lower mountain slopes (Graney and Ferguson 1971, Graney 1976). In the Blue Ridge Mountains of northern Georgia, the shortleaf pine site index at 3,000 feet elevation averaged about 9 feet less than site index of pines growing at 1,800 feet (Ike and Huppuch 1968). In western Arkansas, higher elevation sites have shorter growing seasons, and a greater proportion of shallower, residual soils than are observed for the lower elevation sites.

Throughout the Ozark-Ouachita Highlands, site index for shortleaf pine in mixed pine-oak or oak-pine stands is significantly lower than it is for relatively pure shortleaf stands on either old-field or non-old-field sites (Graney and Ferguson 1971, 1972; Graney 1974, 1976). On equivalent sites, stands with only shortleaf pine in the overstory averaged 5 to 10 feet higher in site index than in mixed pine-hardwood stands. In southern Missouri, site index for pure shortleaf pine plantations averaged more than 5 feet greater than for plantations where hardwoods had not been effectively controlled.

One major source of error for indirect estimation of site index comes from using soil-site prediction equations and tables from outside the specific geographic area; the soil and topographic conditions used for equations and tables should be similar to those of the soil-site study. Errors can also occur if site prediction equations do not accurately represent the true correlations between site conditions and site index in the study area. Few soil-site prediction equations have been tested with independent sets of soil-site data to determine whether equations produce reasonable estimates of site quality within the study area.

The coefficient of determination (R^2) and standard error of the estimate have generally been the measure of success for a derived equation. However, these statistics simply show how well the equation fits that particular data set without indicating how well the equation will predict for other data sets.

Soil-site equations have shown mixed success in predicting site index for stands not used to derive the equations. Equations for bottomland hardwoods in the lower Mississippi Valley (Broadfoot 1969) and black oak in the Missouri Ozarks (McQuilkin 1976) were inaccurate when tested with additional plot data from within the study areas. But shortleaf pine soil-site equations for the Ozark Plateaus of southern Missouri and northern Arkansas, the Boston Mountains of Arkansas, and the Ouachita Mountains of Arkansas and Oklahoma produced accurate predictions on check plots (Graney and Ferguson 1971, 1972; Graney 1974, 1976). Such conflicting results indicate that all soil-site equations, both new and existing, should be adequately tested for reliability before general use as site quality predictors.

Soil Survey

Although soil surveys for agricultural lands have been made for more than 75 years, not much attention has been given to forest lands until recently. In most States, modern soil maps are now prepared for both agricultural and forested lands.

Most modern soil survey reports include an average site index or a range in site index values for each soil series. When these average site index values are based on many measurements over the range of site conditions common to a given soil, comparisons of average values can provide general productivity levels for a given tree species on different soils or for a number of species on the same soil series. Often, however, average site index values for various species and soils are based on few actual site index measurements, and estimates of productivity can be misleading.

A greater problem in using soil taxonomic unit site index averages arises from the often excessive variation in site index within a given soil series (Carmean 1961, 1975; Graney 1976, 1977). Much of the site index variation is caused by wide variations in the soil or topographic factors within the soil series. Features such as depth of surface soil, subsoil texture, aspect, slope position, and slope shape, which are often strongly correlated with site quality, could be incorporated in determining phases of established soil series. Based on soil-site studies in southeastern Ohio, Carmean (1967) suggested topographic phases that could aid in defining differences in oak site quality. Hartung and Lloyd (1969) found that a correlation for aspect explained much of the shortleaf pine and oak site index variation within the Clarksville soil in southern Missouri. Although the range in soil and site characteristics for individual soil series has been narrowed substantially in recently published soil surveys, even the best soil survey maps are unreliable for strict office or computer site quality estimates (Harding and Baker 1983).

A National Forest soil survey in southeastern Missouri (Gott 1975) is a good example of an attempt to incorporate soil-site information into a soil survey. Mapping intensity was medium, and mapping units were slope phases of each soil type. Species productivity estimates were presented by landsite groups, which were determined by soils, topographic position, aspect, and microclimate. Site quality estimates for each species and landsite group could be refined as additional site index and soil-site information becomes available.

Physiographic Site Classification

Although foresters and soil scientists have studied soil-site relationships of shortleaf pine and associated species for nearly 50 years, no reliable techniques have been developed for evaluating potential site quality for an individual site or management unit. Much information has been accumulated on soil and site factors influencing shortleaf pine site quality; however, site evaluations based on soil-site equations or soil taxonomic units have rarely been successful.

A site classification system should be relatively simple, practical, and applicable to all sizes and classes of ownership. The scale and intensity of delineations should be appropriate for a wide variety of management objectives (Smalley 1984b). The recent physiographic site classifications for the Interior Uplands (Smalley 1978, 1979, 1980, 1982, 1983, 1984a, 1984b), Alabama-Mississippi (Hodgkins et al. 1979), and Louisiana (Evans et al. 1983) represent significant advances toward effective classification of shortleaf pine site quality.

The classification system described by Smalley (1984b) involves stratification of the landscape according to the hierarchal significance of physiography, geology, soils, topography, and vegetation. The basic management units, landtypes, are visually identifiable areas that have similar soil and productivity and have resulted from similar climatic and geologic processes. Each landtype is described in terms of nine elements that relate geographic setting, soils, moisture, fertility, and most common wood vegetation. Each landtype is evaluated in terms of productivity for selected species and species desirability for timber production. Also, each landtype is rated for soil-related problems that may affect forest management operations. The site classification system was designed to allow foresters and other resource professionals to make onsite determinations of site productivity and should provide a site-dependent framework for forest management planning.

CONCLUSIONS

Estimates of site quality, whether from direct tree measurements or indirect estimates based on soil and topographic features, are simply local observations for many points on the landscape. To be of value to the land manager, a system of site quality evaluation based on some identifiable unit of the landscape must be devised. The system should include all available knowledge of soils, site index, and soil-site relationships for each species that can be reasonably managed in a given area. Some precision in site quality estimation might be sacrificed, but such a system would have the advantage of identifying a manageable portion of the landscape. The physiographic site classfication efforts in Louisiana, Alabama-Mississippi, and the Interior Uplands provide an excellent foundation on which to build.

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Symposium Coordinator

R. Larry Willett
Extension Forester
Arkansas Cooperative Extension Service
Monticello, Arkansas

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