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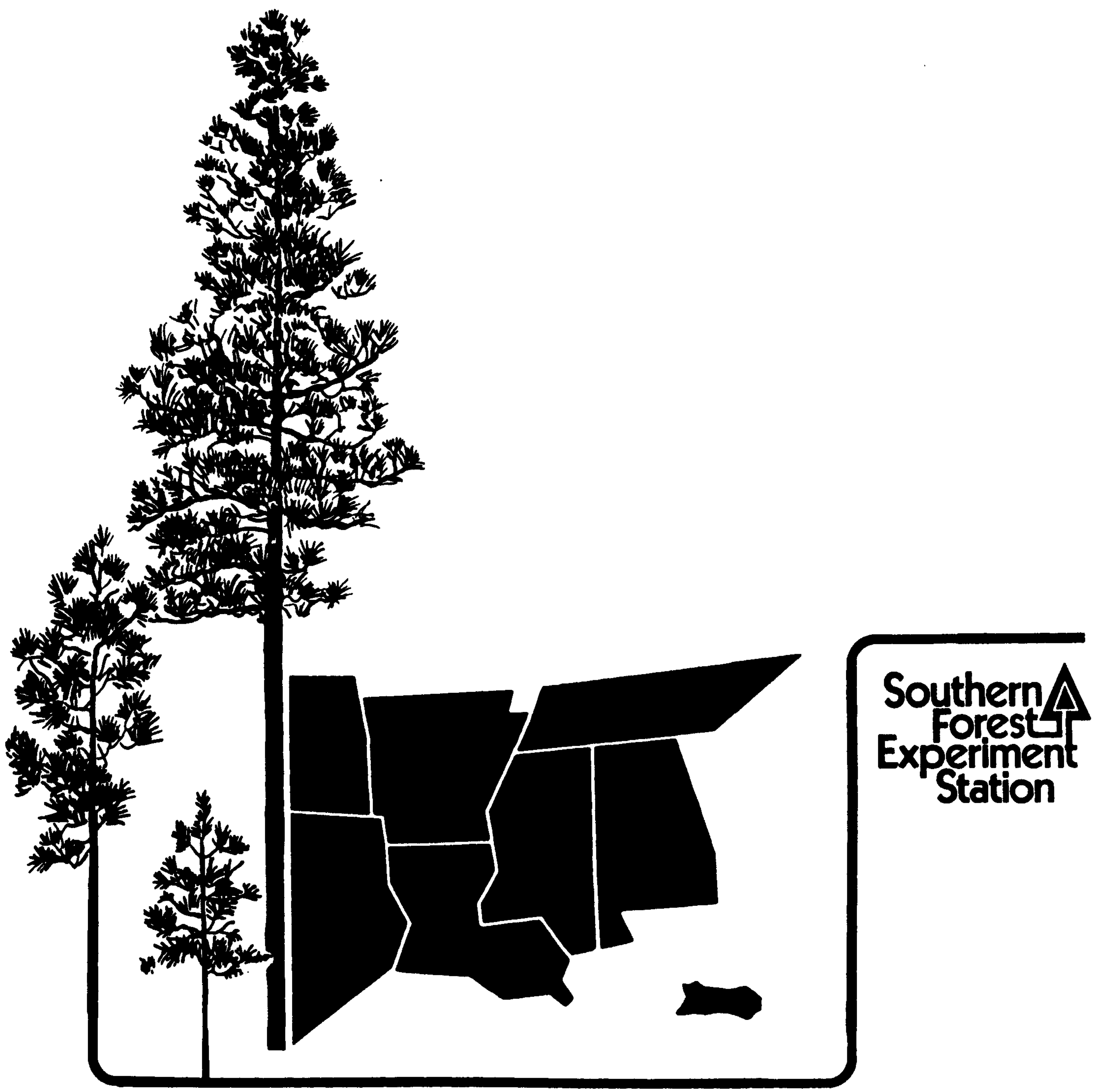

SITE EVALUATION FOR HARDWOODS

John K. Francis[1]

Abstract.--Foresters evaluate sites for an indication of potential growth and yield, for an ecological descriptor, and to correctly match the hardwood species to be planted with sites suitable for them. Site indexes measured directly from trees on the site are the preferable means of quantifying site. Because this method is not always possible, other means based on soil and environmental features can be used to predict site index.

Additional keywords: Site index, species-site matching, soil-site prediction.

Speaking anthropomorphically, site evaluation is a constant activity of hardwood trees. Young trees, usually several species, soon arise after almost any kind of harvest or destruction of the original stand. Once rooted, the trees cannot move to more favorable environments. Individuals that are competitive and well suited to the site survive and grow while the many that are a little out of tune with the environment or in unfavorable positions must die.

Since the best adapted of the hardwood regeneration will eventually dominate the stand, why should foresters bother to evaluate sites? There are several reasons. Suppose a forester must grow a certain species of hardwood to supply a mill. Because most hardwoods are site sensitive, the forester must choose sites on which the species will grow well. How does he do it? By site evaluation. In another situation, the forester may have an old field to plant. He must choose the best adapted of several commercial species for that site. Because there presently is no existing stand to guide him, he must use some form of site evaluation.

Site evaluation can also give an indication of potential yield, a value needed for planning purposes. Site is quantified in terms of site index, the average height of the dominant and codominant trees in a stand at a specified age (usually 50 years). Because yield is more sensitive to stand density than is height growth, we are not yet able to accurately predict yield from site index. High site index is, however, an indication of high potential yield and low site index an indication of low potential yield. Krinard and Johnson found nearly five times as much volume in 18-year-old planted sweetgum at site index 110 compared to site index 80.[2]

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[2] Krinard, R. M., and Johnson, R. L. 18-year development of sweetgum plantings on two sites. (Manuscript accepted for publication in *Tree Planters Notes*.)

Site index can also be a useful ecological descriptor. For example, a site index of 125 for cottonwood not only indicates a very good site for growing cottonwood but also a soil with medium texture, abundant supply of bases, relatively low bulk density throughout, and abundant rain or an external source of water.

ESTIMATES OF SITE INDEX FROM TREES AND VEGETATION

The simplest way to obtain site index is to measure the heights and determine the ages of trees on the site being evaluated. If the tree measured is older or younger than 50 years, a site index curve should be used to estimate the height at 50 years. Hardwoods for which site index curves are available are listed in table 1.

Table 1.--Site index curves available for southern hardwood species.

Species	Source area	Author	Year
Cottonwood	IL, IN, KY, MO	Neebe and Boyce	1959
	LA, MS	Alexander	1976
	AR, KY, LA, MS, TN	Broadfoot	1960
Sweetgum	AL	Lyle and others	1975
	AR, LA, MS, TN	Broadfoot and Krinard	1959
Sycamore	LA	Briscoe and Ferrill	1958
Cherrybark oak	AR, AL, LA, MS, TN	Broadfoot	1961
Water oak	AR, AL, LA, MS, TN	Broadfoot	1963
Nuttall oak	AR, AL, LA, MS, TN	Broadfoot	1969
White oak	OH, KY, IN, IL, MO	Carmean	1971
Green ash	AR, AL, LA, MS, TN	Broadfoot	1969
Swamp blackgum	GA	Applequist	1959
Tupelo-gum	GA	Applequist	1959

Age can be determined from stand records, by counting the rings on an increment core, or from a cross section obtained by cutting the tree. Most of the problems associated with obscured or false rings can be avoided by shaving the surface to be examined and using magnification if needed. The rings of a few species such as sweetgum are faint and difficult to count. A 1-percent phloroglucinol stain in alcohol followed by treatment with 50-percent hydrochloric acid will often make the rings stand out nicely, especially under fluorescent lighting.

Site index estimates are frequently subject to errors. Faulty measurement of height or determination of age is sometimes the cause. A common and subtle source of error is that the trees chosen for measurement do not represent the true growth potential of the site. The trees may have been suppressed at an early age; damaged by storms, insects, or disease; or growing on unrepresentative microsites. To avoid these errors when choosing site index trees, look for uniform growth rings, clean, undamaged tops, and an average microsite. Determine the site index of three to five trees (more if high precision is required), and calculate the average.

Sometimes the species of interest is not present on the site. It is sometimes possible to determine the site index by comparison with that of another species using comparative site index curves. At present, comparative site index curves are available for cottonwood, green ash, cherrybark oak, water oak, willow oak, and Nuttall oak based on the site index of sweetgum (Broadfoot 1970). Occasionally, the site index of one species can be assumed to approximate the site index of another. The site indexes of sugarberry and hackberry, and willow oak and water oak are apparently so similar that they were estimated by the same soil-site criteria by Baker and Broadfoot (1979).

Site indexes and other indexes of site value could conceivably be projected from the presence and size of plant indicator species. No such system for southern hardwoods has yet been devised. However, most hardwood foresters are aware of and use some plant indicators in making judgments about sites. For example, a seasoned forester would know better than to plant cherrybark oak or yellow-poplar, which requires well drained sites, on land now occupied by buttonbush and swamp-privet. Nonplant indicators such as soil color, wetness, and elevation are likewise useful.

ESTIMATES OF SITE QUALITY BASED ON SPECIES TRIALS

The lack of suitable trees to measure in natural stands suggests the possibility of evaluating sites by planting a species or a number of species and observing their growth. This approach offers the ultimate "ground truth" for the potential of plantations but has a few drawbacks. Species-site trials are costly, they take many years to produce answers, and they relate only to sites similar to the ones on which the trials were conducted. Also, the results may not apply well to natural stands. A number of species-site trials are in progress around the country.

SITE INDEX PREDICTION WITH SOIL-SITE EQUATIONS

Soil-site equations rely on observed correlations between height growth and environmental variables, particularly soil variables, to predict site index. Equations for southern hardwoods were developed by Broadfoot (1969) for sweetgum, water oak, willow oak, Nuttall oak, green ash, and cottonwood. Other authors present equations for sweetgum (Phillips and Markley 1963, Phillips 1966); yellow-poplar, white oak, southern red oak, cherrybark oak, and sweetgum (Hebb 1962); swamp blackgum and tupelo (Applequist 1959); and willow oak (Beaufait 1956). Of the above equations, only Broadfoot's (except for cottonwood) were tested against data not used to develop the relationship. No equation in the previously cited papers was able to account for more than 67 percent of the variation in site index.

Because of their complicated nature, soil-site equations have not been widely used by practicing foresters. Their greatest use has been as a test of the researcher's understanding of species-site relationships. Broadfoot (1969) admits that "the relationships between [bottomland] soil characters and height growth seem to defy quantification." He cited numerous difficulties, including extreme variability of alluvial soils, absence of unabused stands to work with, and lack of "measurable variables that faithfully express soil moisture and nutrient availability during the growing season, physical condition including root growing space, and soil aeration."

SITE INDEXES ASSOCIATED WITH SOIL SERIES

An elaborate system of soil classification has been developed under the leadership of the Soil Conservation Service. What could be more natural than to document the site index range of each soil series? The difficulty is that soil series are not based on features necessarily associated with yield, even agricultural yield (Coile 1959). Consequently, considerable range in site index is possible within a soil series. It is imperative that a person using soil series-site association systems be able to identify soil series correctly and, if soil properties are transitional to other series, to interpolate the site index range appropriately.

A word of caution about using soil survey maps to identify soil series on forest tracts: the older soil surveys used many series which are now defunct or have been modified. Forested areas often were not mapped or were mapped in such an extensive way that inclusions of sizable areas of contrasting soil types were missed or ignored.

Broadfoot (1976) prepared a guide for 40 important Midsouth soils which gives site index ranges, recommended species for planting and management, and important soil properties. This is the guide I use most often in my soil-site work. Because the soils cited are of the Midsouth, the guide is probably not very useful in the Southeast. The Soil Conservation Service has published "Soil Survey Interpretations for Woodlands" for each physiographic provenance. They give site index averages and ranges, recommended species for planting, and management hazards for each soil series covered. Broadfoot was the source of some of the information on bottomland hardwoods in these publications.

A PRACTICAL SYSTEM

Not being tied to mathematical functions, a practical (empirical) system's only requirement is that it works. The one effective system for predicting the site index of bottomland hardwoods was developed by Jim Baker and Walter Broadfoot (1979). Fourteen species are covered: sycamore, swamp chestnut oak, yellow-poplar, cherrybark oak, pecan, green ash, sugarberry, hackberry, sweetgum, Nuttall oak, willow oak, Shumard oak, cottonwood, and water oak.

Tree growth is considered to be dependent on four soil factors: (1) physical condition, (2) available moisture, (3) nutrient availability, and (4) aeration. It was assumed that each factor was responsible for a certain portion of site index. Using cottonwood as an example, soil physical condition is assigned 35 percent of the potential height growth, available moisture 35 percent, nutrient availability 20 percent, and aeration 10 percent (fig. 1). Each of these factors is split into several subfactors, each of which has a "Best," "Medium," and "Poor" level. A score is specified for each level. The sum of the scores for the 23 subfactors yields an estimate of site index.

Beginning with estimates of how each option ought to be weighted, the authors adjusted and readjusted the values until the system would predict the site index within 5 feet of the measured site index of plots on file 95 percent of the time.

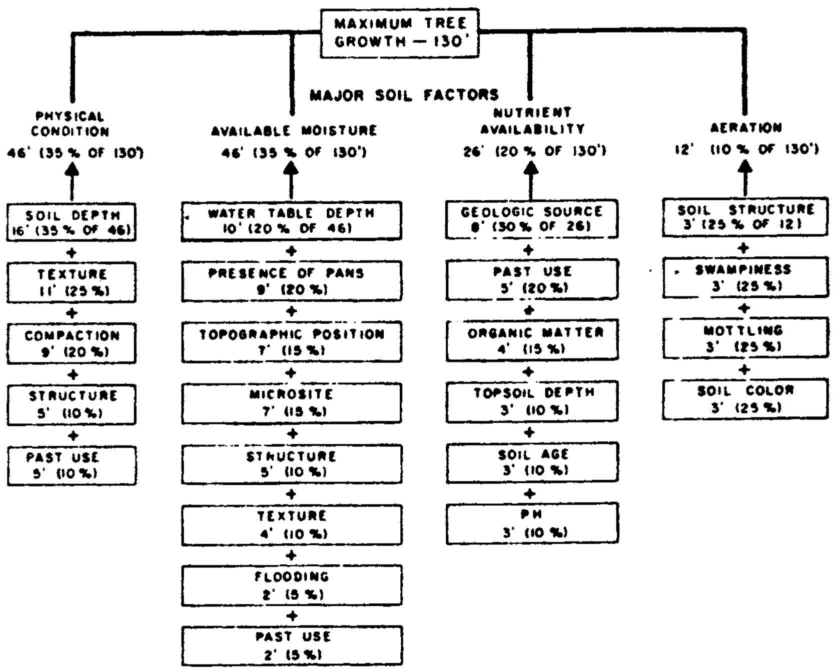

Figure 1.--Contribution of various soil-site properties to the four major soil factors and to cottonwood growth (maximum growth expected on an ideal site at age 30).

The system is straightforward and easy to understand. A difficulty that has caused concern to many potential users is that fairly sophisticated determinations of some soil properties are required--or at least must be estimated. Of particular concern are texture, compaction, water table depth, organic matter content, and pH. Use of this system may require purchasing a field kit for pH, sending in a few samples for organic matter analysis, and taking a little training in recognizing soil and topographic features. Fortunately, an error in estimating a factor or two will not result in a large error in site index.

SITE EVALUATION TOOLS NEEDED

Our present inventory of site index curves should be expanded. Only a small fraction of our commercial species is covered. In some cases those species covered are based on small numbers of samples or represent limited geographic areas. More comparative site index work would be helpful. It may prove impossible to predict site index by the presence and size of indicator species, but it would be immensely useful to document indicator species that associate with various critical environmental features. Soil series-site index association systems probably should be more widely used because soils series are so widely accepted as management units. The systems need to be refined and extended to more soil series representing broader areas of the South.

The Baker-Broadfoot system is a good one for the species covered in the South and Southeast. The system was created to fill the need for something nontechnical for the practicing forester to use. There have been numerous requests for an even simpler system. However, for each reduction in the sophistication of the input, there is usually a reduction in the precision of the output. Perhaps what is needed is a system with nontechnical inputs that separates sites capable of rapid growth from those incapable of it.

Whatever the need for systems, real progress in site evaluation can be based only on increased understanding of the relationships between tree growth and soil-environmental properties. Particularly needed is a more complete understanding of the effects of flooding, soil density, moisture, and aeration. A little work in these basic areas is under way, but much more is needed.

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