

# Estimating Site Index From Tree Species Composition in Mixed Stands of Upland Eastern Hardwoods: Should Shrubs be Included?

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**Abstract**—Site index is the most widely used method for site quality assessment in hardwood forests of the eastern United States. Its application in most oak (*Quercus* sp. L.) dominated stands is often problematic, however, because available sample trees usually do not meet important underlying assumptions of the method. A prototype method for predicting site index from tree species composition has shown promising results in the southern Appalachian Mountains. The objective of this study was to determine if upland oak site index was associated with two common understory shrubs: mountain laurel (*Kalmia latifolia* (L) and spice bush (*Lindera benzoin* (L) Blume). Regression analysis indicated that including these shrubs in the model increased  $r^2$  from 0.63 to 0.67. Predicted upland oak site index decreased by 5.4 ft if mountain laurel was present on a sample plot and increased by 7.4 ft if spice bush was present. Results from this exploratory study conducted in a small watershed should be validated elsewhere, but the findings do suggest that estimates of upland oak site index using the species composition method can be improved by observing the presence of mountain laurel and spice bush.

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**Keywords:** mesophytic, site quality, soil moisture, upland oaks, xerophytic, yellow-poplar.

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## Introduction

The productive capacity of forest stands strongly influences the response to silvicultural treatments (Smith 1962). Except for short rotation plantation biomass culture, however, estimation of forest site productivity by direct measurement of product yields is generally not feasible. Indirect estimation of forest site quality using site index is the method most used in upland hardwoods (Spurr and Barnes 1973). Beck and Trousdell (1973) provide a thorough description of the method, particularly its underlying assumptions and limitations. Estimation of site index in mixed hardwoods is often problematic, however, because suitable sample trees are generally lacking particularly on intermediate and lower quality sites, resulting in biased estimates of site quality. Also, site index is a timber measure and cannot be readily adapted for other applications, such as ecological studies or assessment of wildlife habitat. Replacement of conventional site index estimation with an alternate method is particularly desirable for ecosystems where oaks (*Quercus* sp. L.) are a dominant component of the overstory because many stands lack trees suitable for determination of site quality. One such alternative method to site index is a procedure reported by Whittaker (1956) for arraying stands on environmental gradients based on composition of the tree stratum.

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Forest productivity in the southern Appalachian Mountains is associated primarily with temperature and moisture gradients (Whittaker 1966) and somewhat with fertility. Whittaker (1966) reported that "... an index of site moisture conditions based on weighted averages of stand composition..." was highly correlated with forest production. He subdivided the topographic-soil moisture gradient within an elevation zone into four soil moisture classes (mesic, submesic, subxeric, and xeric) and assigned a weight (0, 1, 2, or 3) to each class. Each tree species was assigned to a soil moisture class based on its modal frequency of occurrence along the gradient. Whittaker used the average weight of the frequency of each species present >1 in diameter at breast height (dbh) as an index of the soil moisture conditions for a site. The index, which was a means for quantifying the relative position of sites on the moisture gradient, was highly correlated with primary forest production for vegetative communities occupying environments ranging from xeric to mesic in the Great Smoky Mountains National Park (GSMNP) (Whittaker 1966). The simplicity of such a site classification system is appealing for several reasons: it can be applied with data typically collected from sample plots in a systematic inventory of stand conditions, it is easily adapted to other ecosystems with their associated species, and the system can be extended to other environmental gradients of temperature and nutrients.

Whittaker's (1966) methods were used in a previous study (McNab and Loftis, in press) to array forested sites along a moisture gradient that was quantified with a moisture regime index (MRI) calculated from arborescent vegetation present on each plot. Results of that study indicated that upland oak site index was correlated with the MRI. Shrubs were not included in that study, but a number of species occur in the Southern Appalachians and appear to be associated with sites of varying environmental conditions (Stupka 1964). Whittaker (1966) reported about a dozen shrubs species were common in the GSMNP and reported the "... distributions of undergrowth species do not appear closely related to those of dominant [tree] species." The independence of tree and shrub species distributions observed by Whittaker (1966) suggests that each form of vegetation was responding to different environmental conditions and could account for different sources of variation that affect site quality. My study investigated the question: Are common species of forest shrubs associated with forest site quality? This study is an extension of a previous study of site quality that was based only on tree species (McNab and Loftis, in press). The purpose of this exploratory study was primarily to determine if additional study on this topic is warranted and not to develop an application for immediate use by managers.

## Methods

### *Study Area*

The study was conducted in the Bent Creek Experimental Forest; a 6,000-ac watershed located about 10 miles southwest of Asheville, North Carolina. This area is characterized by short, mild winters and long, warm summers; elevation ranges from 2000 to 4000 ft. Annual precipitation averages about 45 in and is evenly distributed throughout the year. Geologic formations consist of gneisses and schists of Precambrian Age that have weathered to form a complex, dissected land surface consisting of ridges and coves. Soils, which consist mainly of Ultisols with lesser areas of Inceptisols, are generally deep (>40 in), highly acidic (pH<5.5) and range in moisture regimes from xeric to hydric.

The arborescent canopy of xeric to subxeric sites on upper slopes and ridges typically consists of communities dominated by scarlet oak (*Quercus coccinea*

Muenchh.), white oak (*Q. alba* L.) chestnut oak (*Q. prinus* L.), and black oak (*Q. velutina* Lam.). Typical mesophytic species occurring on moist slopes and coves include yellow-poplar (*Liriodendron tulipifera* L.), northern red oak (*Q. rubra* L.), white ash (*Fraxinus americana* L.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), cucumbertree (*Magnolia acuminata* L.), and black locust (*Robinia pseudoacacia* L.). Midstory species include, dogwood (*Cornus florida* L.), blackgum (*Nyssa sylvatica* Marsh.), sourwood (*Oxydendrum arboreum* (L.) DC.); shortleaf pine (*Pinus echinata* L.) or pitch pine (*P. rigida* L.) may occur on disturbed dry sites. Various hickory species occur on dry and moist sites. Red maple (*Acer rubrum* L.) is usually present on sites of all moisture regimes. American chestnut (*Castanea dentata* L.) was a major component of most stands before it was lost as a canopy species as a result of the introduced blight disease (*Cryphonectria parasitica*) in the 1920s; it was typically replaced by oaks (*Quercus* spp. L.) on many sites. Common shrubs of dry sites include mountain laurel (*Kalmia latifolia* L.) and deerberry (*Vaccinium staminium* L.); moist sites support rosebay rhododendron (*Rhododendron maximum* L.) and spicebush (*Lindera benzoin* (L.) Blume). More than 250 trees, shrubs, and vines are native to this area of the southern Appalachian Mountains (Stupka 1964).

Principal types of disturbance in the watershed have resulted from natural and human causes. Most stands in Bent Creek Experimental Forest have been affected by past land-use. Extensive areas of gentle slopes were cleared for agricultural purposes from 1800 until about 1900, when land abandonment resulted in conversion to pine-hardwood mixtures on dry sites and yellow-poplar on moist sites. Stands on areas of steeper slopes, which were not cultivated or cleared for pasture, were typically burned to promote sprouting for woodland grazing by livestock, and periodically harvested for timber by high grading. Following acquisition of the watershed by the USDA Forest Service around 1915, timber stand improvement work was done in selected areas to reduce stocking of non-commercial species such as red maple, sourwood, and dogwood. Lightning-caused fires are seldom a source of extensive disturbance in this humid region.

### **Field Plots and Vegetation Inventory**

I used field data from several earlier silvicultural studies installed in the experimental forest for my exploratory investigation. Three requirements were necessary for the previously collected data to be suitable for use: (1) inventory of all tree and shrub species present on each plot, (2) accurate estimation of site index for stands on each sample plot, and (3) the sample plots represented the range of site qualities in the experimental forest. Field data from two previous studies satisfied these requirements: one study dealing with prediction of site index for xerophytic upland oaks and the other study to investigate growth and yield of mesophytic yellow-poplar after thinning. In the site index study, Doolittle (1957) established 114, 0.2-acre plots in even-aged stands of upland oaks ranging in age from 30 to 120 years. Arborescent and shrub vegetation in the sapling and tree strata had been re-inventoried by species in 1970 (unpublished data on file). Vegetation on this group of plots is typically described as xerophytic. The yellow-poplar growth and yield study consisted of 34, 0.25-ac plots that had been established in even-aged stands, ranging in age from 30 to 76 years, for which site index had been determined (Beck and Della-Bianca 1970). Vegetation associated with this group of plots is characterized as mesophytic. I pooled the inventories from these two studies to obtain a data set consisting of 148 sample plots that extended over the range of site qualities present on upland sites in the Bent Creek Experimental Forest.

Site index relationships developed by Schnur (1937) for upland oak stands in the central hardwood region were used as the standard measure of timber productivity. I converted yellow-poplar site index to upland oak site index using the relationship presented by Doolittle (1958). Upland oak site index overlapped between the two groups of plots characterized by composition of the arborescent vegetative community (Stupka 1964):

<b>Group of plots (Source of data)</b>	<b>Range of oak site index (ft)</b>
Mesophytic (Beck and Della-Bianca 1970)	71 - 95
Xerophytic (Doolittle 1957)	36 - 87

Across all 148 plots, oak site index averaged 65 ft. The plots established for the growth and yield study are dominated by yellow-poplar and other mesophytic species and are considered representative of high to moderately productive stands on mesic and submesic sites. The plots established for the site index study are dominated by oaks and other xerophytic species and are considered representative of moderate to low productivity on xeric and subxeric sites.

Woody perennial vegetation on each sample plot was recorded by species in two physiognomic groups of plants (i.e. tree or shrub) and two size classes (i.e. overstory or midstory). A tree was a plant with a well-defined stem carrying a definite crown; shrubs were plants without a well-defined stem (Helms 1998). Each tree on a sample plot was recorded by species in two arbitrary size classes: overstory (>4.5-in dbh), or midstory (0.01 to 4.5 in dbh). Each shrub was recorded by species without regard to size. The number of tree and shrub species present on each plot was determined for each size class from the inventory data.

### **Moisture Regime Index**

Following the rationale of Whittaker (1956) I subdivided the apparent soil moisture gradient on upland sites in the Bent Creek watershed into four classes: xeric, subxeric, submesic, and mesic. A fifth class, hydric, was not included in this study because the tree species of interest do not occur on soils of that moisture regime. The xeric class of sites was typically associated with upper slopes of ridges; mesic sites occurred on lower slopes of valleys. The subxeric and submesic classes were on sites perceived as somewhat less dry or less moist than xeric or mesic, respectively. I assigned each tree species occurring in the watershed to a moisture regime class based on its perceived modal position (i.e. distributional center) along the gradient (e.g. post oak (*Quercus stellata* Wangenh.), xeric; chestnut oak, subxeric; northern red oak, submesic, etc). Soil moisture deficits would likely develop on xeric sites in the mid to late growing season and on subxeric sites during the late season of most years. On the submesic class of sites, soil moisture deficits would occur occasionally during the mid to late growing season and on mesic sites, lack of moisture for plant growth would likely occur only rarely during an interval of 30 years. Each moisture class was assigned a weight, ranging from 1 to 4 (e.g. xeric = 1; subxeric = 2; etc), which represented the perceived relative availability of soil moisture for plant growth during the frost-free season. Moisture class weights were refined by assigning half values to some species where their modal position appeared to occur between two classes (e.g. scarlet oak = 1.5; white oak = 2.5, etc).

The combined information provided by all tree species present on a sample plot is used to determine the location of the site on the moisture gradient. The numerical location of the plot (e.g. site) on the moisture gradient, which ranges in magnitude from 1 to 4, is defined as the moisture regime index (MRI). The plot MRI is calculated as the average moisture weight of all species present on the plot:

$$\text{MRI} = \sum(\text{Species}_i * \text{MW}_i + \dots + \text{Species}_j * \text{MW}_j) / \text{N species}$$

where: MRI is moisture regime index, species is each tree species present, MW is moisture weight value for each species (values 1 to 4), and N is number of species used in calculation of the index.

Because MRI can be calculated with various combinations of vegetation size classes and frequencies of occurrence, I used the method of calculation reported as best in an earlier study (McNab and Loftis, in press). I combined the midstory and overstory size classes for each plot and calculated MRI using tree species represented by more than one individual ( $N > 1$ ). I evaluated the effect of shrubs on estimation of site index by including them as binary variables (e.g. 0 or 1) in regression analyses, where a species was present on ten or more sample plots.

## Data Analysis

I used a completely randomized design where sample plots had been established previously in stands meeting criteria for study of timber productivity and without regard to topographic or soil characteristics.

**Regression model without shrubs**—Simple linear regression was used to determine the relationship of upland oak site index with MRI by the model:

$$Y_i = \alpha + \beta X_i + \varepsilon$$

where  $Y_i$  are observed values of upland oak site index,  $\alpha$  and  $\beta$  are population parameters,  $X_i$  are observed values of MRI, and  $\varepsilon$  is unexplained error.

**Regression model with shrubs**—A Spearman rank correlation test was used to determine the relationship between the frequencies of occurrence of the inventoried tree and shrub species in relation to the xeric (oak dominated) plots and the mesic (yellow-poplar dominated) plots. T-tests were used to determine if site index was significantly associated with the presence of each species of shrub. For those shrubs significantly associated with oak site index, multiple regression was used to determine the combined effect of moisture regime index and shrub species by the relationship:

$$Y_i = \alpha + \beta X_i + \beta Z_i + \varepsilon$$

where  $Y_i$  are observed values of upland oak site index,  $X_i$  are observed values of MRI,  $Z_i$  are species of shrubs absent or present (represented as 0 or 1),  $\alpha$  and  $\beta$  are population parameters, and  $\varepsilon$  is unexplained error. Relative performance of the two types of models (e.g. site index estimated from MRI without shrubs, and with shrubs) was evaluated using the proportion of variation of the dependent variable explained by the independent variables (adjusted  $r^2$ ). Statistical tests of significance were made at the probability level of 0.05.

## Results and Discussion

Thirty-one arborescent species were present with frequency of occurrence of  $n > 1$  stems on the 148 sample plots (table 1) and were used in calculation of MRI for each plot. Although dry-site and moist-site species occurred on plots of all moisture regimes, their frequencies of occurrence were generally consistent with the perceived soil moisture conditions (e.g. xerophytic oaks tended to dominate plots characterized by xeric and subxeric soil moisture regimes). Spearman

**Table 1**—Arborescent species present (>0.05 inch dbh) on plots, moisture weight assigned to each species, and their frequencies of occurrence (percent of total plots sampled) in two studies installed previously for investigations of productivity for xerophytic and mesophytic vegetation types in the Bent Creek Experimental Forest.

Common name	Scientific name	Moisture weight	Plot moisture regime	
			Xerophytic <sup>a</sup>	Mesophytic <sup>b</sup>
----- Percent -----				
Post oak	<i>Quercus stellata</i>	1.0	1	0
Virginia pine	<i>Pinus virginiana</i>	1.0	0	6
Scarlet oak	<i>Quercus coccinea</i>	1.5	75	0
Black oak	<i>Quercus velutina</i>	2.0	60	32
Black gum	<i>Nyssa sylvatica</i>	2.0	32	21
Chestnut oak	<i>Quercus prinus</i>	2.0	71	15
White pine	<i>Pinus strobus</i> L.	2.0	0	18
Persimmon	<i>Diosporis virginiana</i>	2.0	1	0
Sassafras	<i>Sassafras albiurnn</i>	2.0	2	15
Shortleaf pine	<i>Pinus echinata</i>	2.0	32	9
Sourwood	<i>Oxydendrum arboreum</i>	2.0	86	56
Southern red oak	<i>Quercus falcata</i>	2.0	2	0
Hickory spp	<i>Carya</i> spp.	2.3	0	62
Holly	<i>Ilex opaca</i>	2.5	0	3
White oak	<i>Quercus alba</i>	2.5	80	32
Red maple	<i>Acer rubrum</i>	2.5	74	82
American beech	<i>Fagus grandifolia</i>	3.0	3	3
Black locust	<i>Robinia pseudoacacia</i>	3.0	37	71
Dogwood	<i>Cornus florida</i>	3.0	42	47
Frazier magnolia	<i>Magnolia fraserii</i>	3.0	0	6
Mulberry	<i>Morus alba</i>	3.0	0	3
Northern red oak	<i>Quercus rubra</i>	3.0	31	35
Black cherry	<i>Prunus serotina</i>	3.5	0	3
Cucumber	<i>Magnolia acuminata</i>	3.5	2	0
Eastern hemlock	<i>Tsuga canadensis</i>	3.5	3	21
Hornbeam	<i>Ostrya virginiana</i>	3.5	1	0
Sweet birch	<i>Betula lenta</i>	3.5	3	74
Yellow-poplar	<i>Liriodendron tulipifera</i>	3.5	39	100
Black walnut	<i>Juglans nigra</i>	4.0	0	3
White ash	<i>Fraxinus americana</i>	4.0	4	26
Yellow birch	<i>Betula lutea</i>	4.0	0	3

<sup>a</sup> 114, 0.2-ac plots situated in stands dominated by oaks.

<sup>b</sup> 34, 0.25-ac plots situated in stands dominated by yellow-poplar.

$r = 0.49$  ( $n = 31$ ,  $p < 0.01$ ), however, indicated a moderate similarity of tree species occurrence between the two sets of plots.

Six species of shrubs were present on the sample plots, but the principal species were mountain laurel and spice bush (table 2). There was little correlation between shrub species occurring on the two sets of plots (Spearman  $r = 0.11$ ,  $n = 6$ ,  $p > 0.05$ ). Four shrubs were present on less than ten plots, leaving only mountain laurel and spice bush present with frequency judged adequate for analysis. These two species rarely occurred on the same plot.

**Table 2**—Shrub species present on sample plots, and their frequencies of occurrence (percent of total plots sampled) in two studies installed previously for investigations of productivity of xerophytic and mesophytic vegetation types in the Bent Creek Experimental Forest.

Common name <sup>a</sup>	Scientific name	Plots sampled	Plot moisture regime	
			Xerophytic <sup>b</sup>	Mesophytic <sup>c</sup>
		<i>N</i>	----- Percent -----	
Mountain laurel	<i>Kalmia latifolia</i> (L.)	32	25	2
Spice bush	<i>Lindera benzoin</i> (L., Blume)	21	6	47
Rhododendron	<i>Rhododendron maximum</i> (L.)	2	2	0
Flame azalea	<i>R. calendulaceum</i> (Michx., Torr.)	4	3	3
Deerberry	<i>Vaccinium stamineum</i> (L.)	1	0	3
Black huckleberry	<i>Gaylussacia baccata</i> (Wang., K. Koch)	6	4	0

<sup>a</sup> 95 plots had no shrubs and two or more species occurred on 13 plots.

<sup>b</sup> 114 plots were located in stands dominated primarily by oaks.

<sup>c</sup> 34 plots were located in stands dominated primarily by yellow-poplar.

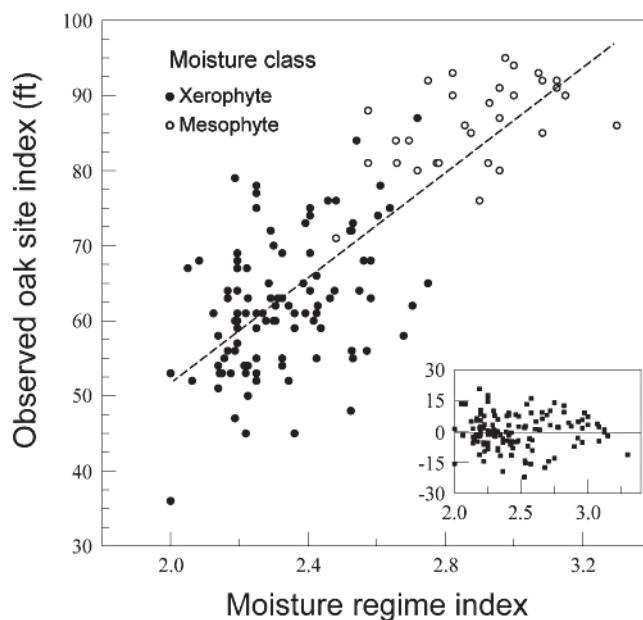
### Site Index Model With Shrubs Excluded

Regression analysis of site index as a function of the moisture index produced the relationship:

$$\text{Oak SI (ft)} = -21.972 + 36.524 * (\text{MRI})$$

where SI is site index (50 years) in feet for mixed oaks and MRI is moisture regime index based on midstory and overstory tree species with plot density >1. This equation has an r<sup>2</sup> of 0.63 and mean square error of 8.10 ft. The MRI variable was highly significant (p<0.001).

The distribution of upland oak site index in relation to moisture regime index without shrubs is shown in figure 1. The simple regression model fitted the field data reasonably well, and the pattern of residuals from the regression appeared to be uniformly distributed, suggesting a prediction equation with little bias.



**Figure 1**—Observed site index measured on 148 sample plots (plotted points) dominated by either xerophytic or mesophytic species and predicted site index (dashed line) in relation to the moisture regime index. The inset shows residuals (actual - predicted) of predicted site index in relation to the moisture regime index.

Observed site index varied by about  $\pm 20$  feet from predicted values for the xerophytic plots and about  $\pm 10$  feet from the mesophytic plots, however, suggesting that other variables might explain part of the variation in site index not accounted for by the tree species and their perceived association with a moisture gradient.

Site fertility could account for additional variation of site index not explained by moisture (Kimmins 1987), but relatively little has been reported on the effects of nutrients on height growth for most tree species. Gilmore and others (1968) found yellow-poplar height was better correlated with soil pH than nutrients. Carmean (1975) reported that for various species of oaks, fertility (particularly pH) had a stronger influence on the distribution of some species (e.g. chinquapin oak (*Quercus muehlenbergii* Engelm.) than on height growth.

### **Site Index Model with Shrubs Included**

The two predominant shrubs were each associated with oak site index (table 3). Compared to plots with no shrubs, average oak site index was lower by 8.2 ft where mountain laurel was present ( $t = -3.70$ ,  $P < 0.003$ ) and site index was higher by 19.6 ft on plots where spice bush was present ( $t = 7.48$ ,  $P < 0.001$ ). Regression analysis of moisture regime index and the two significant shrub variables produced the following relationship:

$$\text{Oak SI (ft)} = 15.564 + 21.918 * (\text{MRI}) - 5.432 * (\text{KALA}) + 7.368 * (\text{LIBE})$$

where: SI is site index (50 years) in feet for mixed upland oaks, MRI is moisture regime index calculated from tree species, KALA is absence (0) or presence (1) of mountain laurel, and LIBE is absence (0) or presence (1) of spice bush. This equation has an  $r^2$  of 0.67 and mean square error of 7.7 ft. All variables were highly significant ( $p < 0.001$ ). The relationships between observed and predicted upland oak site index for the two models is shown in figure 2. The practical importance of the shrub variables is to reduce upland oak site index predicted from MRI by 5.4 feet if mountain laurel is present or increase site index by 7.4 feet if spice bush is present (fig. 3).

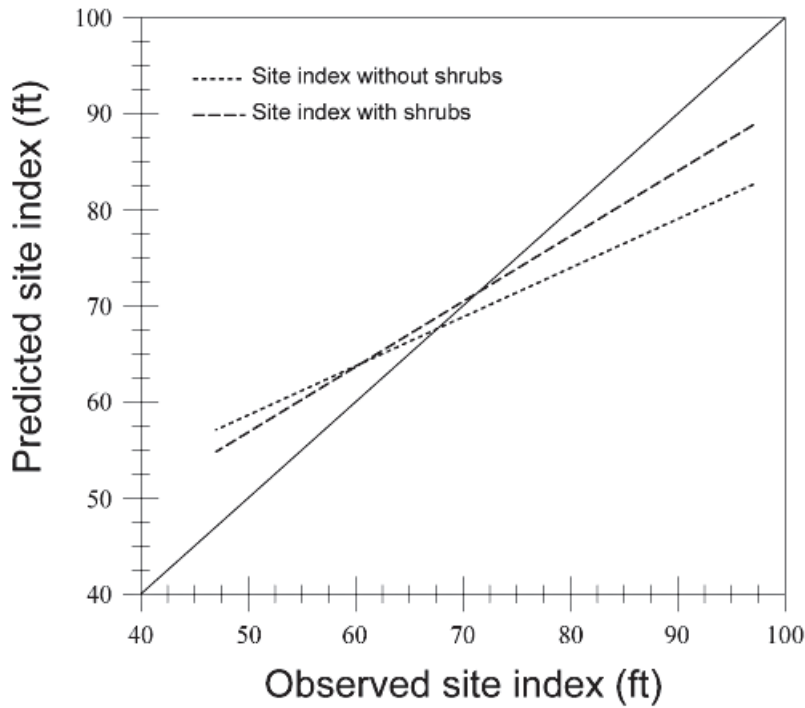
**Table 3**—Mean and SD of upland oak site index observed on sample plots where either mountain laurel, spice bush, or neither species, was present in the Bent Creek Experimental Forest.

Shrub present	Sample plots	Upland oak site index	
		Mean	SD
	N	-----feet-----	
None	95	66.8	11.2
Mountain laurel	32	58.6 <sup>a</sup>	9.4
Spice bush	21	86.4 <sup>b</sup>	8.7
All	148	67.8	13.2

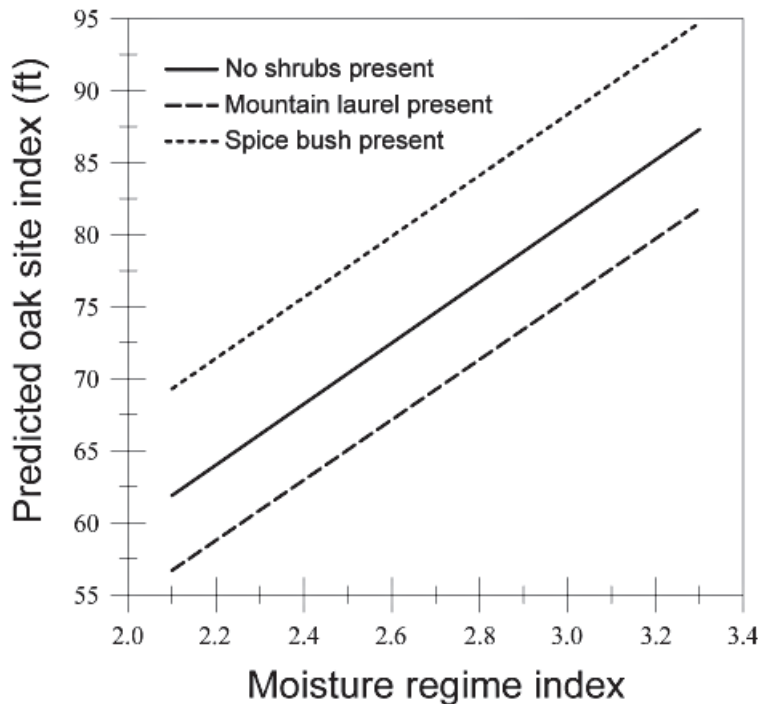
<sup>a</sup>Significantly lower compared to plots where the species was not present.

<sup>b</sup>Significantly higher compared to plots where the species was not present.





**Figure 2**—Relationships between observed and predicted upland oak site index for two models: (1) site index as a function of moisture regime index without shrubs (dotted line) and (2) site index as a function of moisture regime index with the occurrence of two shrubs (dashed line). Both models under predict site index on high quality sites (SI > 70) and over predict site index on lower quality sites. The diagonal line represents perfect fit between observed and predicted upland oak site index.



**Figure 3**—Relationship between moisture regime index and predicted upland oak site index in relation to the presence or absence of two species of shrubs in the Bent Creek Experimental Forest.

Results of this exploratory study in a small watershed suggest that both trees and shrubs are beneficial for estimating site index from species composition. These findings are not surprising because shrubs have different rooting zones compared to trees and may have different environmental requirements for their establishment, growth, and reproduction (Kimmins 1987). Including shrubs with MRI for estimation of site index was an unplanned part of the overall study that resulted from serendipitous observations in the study area. Mountain laurel, normally a dry-site species, occurred as scattered plants in several yellow-poplar stands that had become established on sites with low site index, which were located on moist flood plains. This unusual composition of tree and shrub vegetation provided a clue to the value of non-arborescent data for assessment of site quality. A number of shrub species are common in this region, mostly xerophytic species, although several mesophytic species occur also, such as rosebay rhododendron (*Rhododendron maximum* L.) and sweet shrub (*Calycanthus floridus* L.). Additional study is needed to determine the value of other shrubs for estimation of site quality based on species composition. These results should be applicable within similar temperature regimes of the southern Appalachian Mountains, similar to where my study was conducted.

Application of the method requires several considerations by the resource manager. First, an adequate design must be derived for adequate inventory of the stand. A systematic grid of sample points is recommended similar in intensity to that used for estimation of the timber resources. Next, the tree species list must be completed for the area of application. The lists of trees in table 1 and shrubs in table 2 are limited to species encountered in the study area, which is about a third of the species occurring throughout the southern Appalachian Mountains. Finally, moisture weights assigned to each species must be adjusted for the region in which the method will be applied. The location of some species on the moisture gradient could change somewhat if the area of application is near the limits of the natural range or if there are compensating factors for the area, such as temperature or fertility. For example, Whittaker (1956) assigned northern red oak a value weight of 4.0 for submesic in the overstory. In my area of application, which is somewhat lower and drier, northern red oak was assigned a value of 3.5. As this example illustrates, one strength of the MRI method of site classification is the ease by which it can be adapted and extended to other areas.

In summary, results of this exploratory study demonstrate that at least two species of shrubs may be useful for classification of forest site productivity in the southern Appalachian Mountains. More specifically, I found that upland oak site index is associated with the moisture regime index and the occurrence of either mountain laurel or spice bush. An equation based only on the moisture index accounted for 63 percent of the variation in oak site index on sample plots in the study area. Including the presence of either mountain laurel or spice bush accounted for an additional four percent of variation in site index. Although this system of site classification has been under intermittent development for over ten years, this is the first formal test of the method using nonarborescent species. The relationships with shrubs should be evaluated for application beyond the limited area of this test. Many shrubs occur throughout the Southern Appalachians, and the benefits of using other species for estimation of site index should be tested. Considerable additional work is needed to refine the system and particularly to establish a direct relationship of the moisture regime index with site quality based on volume increment.

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