United States
Department of
Agriculture

Forest Service

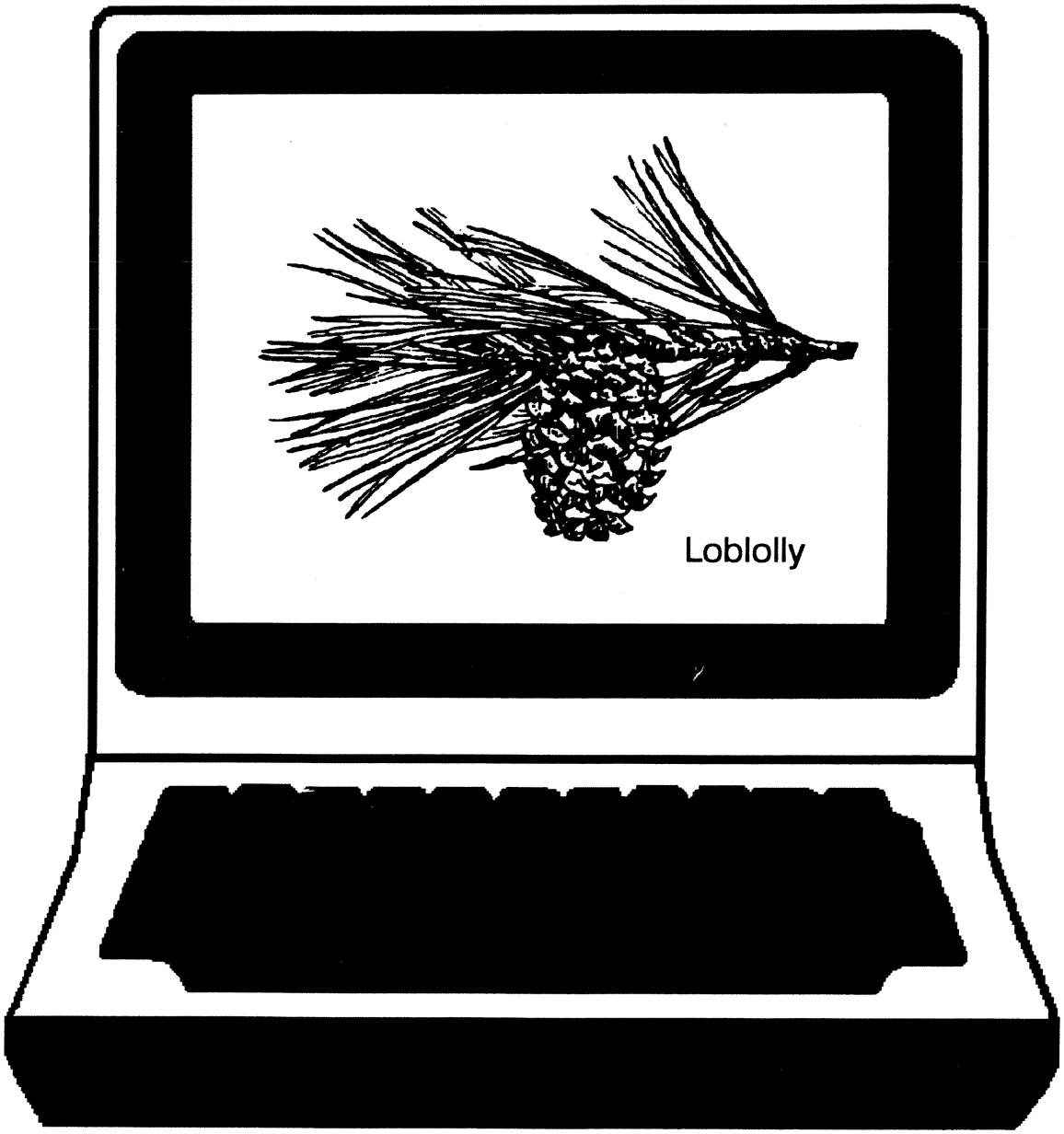
**Southern Forest
Experiment Station**

New Orleans,
Louisiana

General Technical Report
SO-81

PTSITE—A New Method of Site Evaluation for Loblolly Pine: Model Development and User's Guide

Constance A. Harrington



SUMMARY

A model was developed to predict site index (base age 50 years) for loblolly pine (*Pinus taeda* L.) on the Southern Coastal Plain. The model, named PTSITE, was based on soil characteristics, site location on the landscape, and land history. The model was constrained so that the relationship between site index and each soil-site variable was consistent with what was known about the biology of the species. The model was quantified empirically with information available from the literature or other sources and with data collected for this study from 50 stands. Because of the way the model was developed, the PTSITE model is an example of a knowledge-based or expert system. The final model was tested with data reserved by the author for testing and with data from other organizations. For the original set of 50 stands, the difference between site index estimated from tree ages and heights and site index predicted by the model averaged 1.7 feet with the chi-square test of accuracy, indicating that site index prediction should be within ± 4 feet ($p<0.05$). PTSITE was modified to predict site index for a 25-year base age; site index predictions were judged to be within ± 3 feet ($p<0.05$) for these younger stands.

Testing the model with reserved data from an additional 13 stands sampled by the author indicated that the model was consistent in its accuracy. In addition, soil-site data from two other sources were used to provide another test of the accuracy of the PTSITE model. These additional data sets did not have values for all variables; thus, some of the information used in the predictions was based on estimates. Despite probable errors introduced by estimation, the model performed quite well with two independent data sets.

The PTSITE model is available as an IBM-compatible interactive computer program that can be requested from the author. Supplemental information is provided in an appendix to assist users in operating the program and in understanding the structure of the underlying model.

ACKNOWLEDGMENTS

Financial support and field assistance in the collection of most of the soil and site data were provided by the Southern Region of the National Forest System. Assistance from the following soil scientists is gratefully acknowledged: Neal R. Babik (Kisatchie National Forest), William L. Barnhill (Soil Conservation Service, retired), Don C. Dagnan (National Forests in Mississippi), Arthur Goddard (National Forests in Alabama), Dennis Law (National Forests in South Carolina), Dan M. Manning (National Forests in North Carolina), Rodney Peters (National Forests in Texas), and M. L. Weeks (National Forests in Mississippi). Some additional funding was provided by the Fusiform Rust Team of the Southern Forest Experiment Station. Appreciation is also extended to the Soil Conservation Service for providing plot data from their Soil Woodland data base and to Douglas M. Crutchfield, Westvaco, and Marilyn Buford, Southeastern Forest Experiment Station, for providing data used in verifying the model. Finally, the programming assistance of Bettina M. Casson and Kirby F. Sneed (Southern Forest Experiment Station) is deeply appreciated.

January 1991

CONTENTS

INTRODUCTION 1
FIELD AND LABORATORY METHODS 2
MODEL CONSTRUCTION 3
MODEL VERIFICATION 6
USING THE PTSITE PROGRAM 8
MODEL APPLICABILITY 9
PROGRAM AVAILABILITY 11
LITERATURE CITED 11
Appendix A—Additional information to help users respond to the questions and requests for information of the PTSITE program 13
Appendix B—Definitions and ranges for program variables 23
Appendix C—Example of sample output 27

PTSITE—A New Method of Site Evaluation for Loblolly Pine: Model Development and User's Guide

Constance A. Harrington

INTRODUCTION

Knowledge of site quality for each unit of land to be managed is an important criterion for modern forest management. Although other measures of site quality have been proposed, site index is the measure most commonly used in the United States. Site index is the mean height of upper-crown-class trees that have been free to grow in an even-aged stand at a specified index age. Most modern growth and yield models require site index (or a related measure of site quality) as input to their prediction systems. In addition, site index often needs to be estimated for land not currently in timber production. Based on the estimated site index value, decisions are made on which species to plant or whether to plant at all. It is, however, very difficult to accurately assess site index in stands that are uneven-aged, of mixed species, very young or very old, or on sites where the tree species of interest is not growing.

Several methods have been developed for predicting site index for a species when it cannot be directly measured (Mader 1965). The most common methods are: (1) prediction of site index from a mathematical equation using measured soil and site characteristics as independent variables, (2) association of site-quality classes with soil series or soil mapping unit, and (3) prediction of site quality from the presence or growth of other plant species. Prediction of site index by use of soil and topographic characteristics in a multiple regression equation was popular in the United States beginning in the 1930's; good reviews of the subject are available from several sources (Carmean 1975, Coile 1952, Ralston 1964). These classical soil-site studies were useful in identifying the soil and site characteristics that influence tree growth (Hodgkins 1956). However, the biological interpretation of many of the equations developed in classical soil-site studies was often obscure, and the applicability of these equations was usually limited to small uniform areas. In addition, the equations developed in most mathematical soil-site studies were not verified with independent data (McQuilkin 1976). This type of mathematical soil-site study has been criticized on both mathematical and biological grounds (Broadfoot 1969, Hodgkins 1959, Lloyd and Lemmon 1970) and is currently used much less than in the past.

Use of soil series, soil mapping units, or other plant species has been useful in distinguishing among broad classes of productivity, but in most cases these approaches have not yielded the desired precision for predicting site index (Harding and Baker 1983, Mader 1965, Youngberg and Scholz, 1949). Over the years, many modifications and refinements have been made in these types of studies. For example, McKee (1977) demonstrated that a substantial amount of the variation in site index values among plots could be accounted for by the chemical and physical properties of soils if the plots were first grouped by soil series. However, this type of approach is not practical when sites representing many soil series need to be evaluated because it requires that the soil series be known for each site and that the significant relationships between site index and the soil-site factors be determined for each soil series of interest. Smalley (1979) divided sites into landtypes within selected geographic areas; this landtype classification system incorporated several physiographic features, could be used in areas where soil series had not been mapped, and provided information on soil-based management considerations as well as productivity for each landtype. However, a landtype classification system is unlikely to yield the precision in site index estimates required for some forest management decisions. Storie and Wieslander (1948) stratified sites into soil profile groups, then evaluated site quality for four California conifers on the basis of several site factors. This approach was usable over a wide range of site conditions, but their timber soil ratings were more in terms of site-quality classes than of specific site index values.

Baker and Broadfoot (1977, 1979) published field guides to evaluate site quality for southern hardwoods that combined both subjective and objective approaches to site-quality evaluation. These researchers first identified, and later quantified, the specific

Constance A. Harrington, previously research forester at the Forestry Sciences Laboratory, Southern Forest Experiment Station, USDA Forest Service, Monticello, AR 71655, is now research forester, Forestry Science Laboratory, Pacific Northwest Research Station, USDA Forest Service, Olympia, WA 98502. This research was done in cooperation with the Department of Forest Resources and Arkansas Agricultural Experiment Station, University of Arkansas at Monticello.

soil-site properties that influenced site quality for a particular species. The approach used was different from past work in that: (1) the values used in quantifying these models were constrained by the authors' knowledge of the silvics of the species involved, (2) it was not necessary to know soil series to use these models, and (3) the number of soil-site characteristics evaluated by these models was high enough to allow accurate prediction (±5 ft) over a wide range of site conditions. The Baker-Broadfoot field guides were later made available in the form of a computer program (Harrington and Casson 1986). A Baker-Broadfoot type of approach to site-quality evaluation was used by Harrington (1986) to develop a field guide for evaluating red alder (*Alnus rubra* Bong.) in the Pacific Northwest.

A site quality evaluation system for loblolly pine (*Pinus taeda* L.) is presented in this paper. This system was based on a Baker-Broadfoot type of site model in that the basic framework of the model was derived from an understanding of the site requirements of the species, and the relationship between each variable and site index was constrained to be biologically reasonable. The model, named PTSITE, was quantified with concepts from the literature, published and unpublished data sets, and with data specifically collected for this purpose in 50 loblolly pine stands in the Southern Coastal Plain. The PTSITE model was tested with data from 13 additional stands that were reserved from the original model development and with similar soil-site data collected by other organizations. The 50-year version of the model was converted to a 25-year version with data from 11 additional younger stands. A computer program based on the PTSITE model was then produced for use on IBM-compatible personal computers.

FIELD AND LABORATORY METHODS

Even-aged, well-stocked stands of loblolly pine were selected for sampling in the Atlantic Coastal Plain (fig. 1). A deliberate attempt was made to sample a wide range of soil conditions and productivity (table 1). The mean and range in site index values are similar to the regional mean and range in site index values reported for loblolly pine in a large range-wide sample of stands (USDA FS 1976). Most sampled stands were pure loblolly pine. When mixed-species stands were sampled, the other species were not in a crown position or of an age to have suppressed past height growth of pines. Within each stand, a 0.25-acre temporary plot was established. Plot boundaries were kept away from roads and did not cross any obvious stand boundaries or changes in stand or site conditions. On side slopes, plots were laid out along the contour to avoid crossing slope-position categories within a plot boundary.

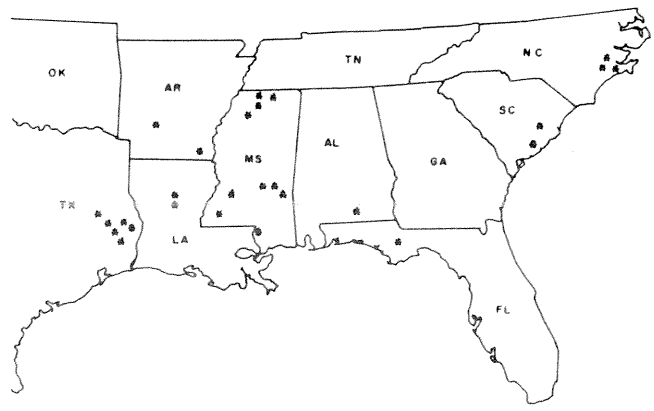


Figure 1.—*General location of loblolly pine stands used in the development and testing of the PTSITE model. In most cases, several sites were sampled at each location.*

On each plot, seven dominant or codominant trees were selected to be measured for site index. These trees were apparently healthy and free from past height damage. The trees were bored with an increment borer to determine age at breast height; total height was measured with an altimeter. The rings on the cores were counted in the laboratory; any trees having cores showing signs of suppression were deleted from the sample. Site index at a 50-year base (SI_{50}) was calculated from the equations of Farrar (1975), which were based on Miscellaneous Publication 50 (USDA FS 1976). For natural stands, 3 years were added to age at breast height to estimate total age (as recommended in USDA FS 1976); for older plantations, the breast-height age correction factor was reduced to 2 years. (The reasonableness of this correction factor was verified with groundline increment cores from several stands). Most stands were 35 to 60 years old. Site index (25-year base) was calculated for stands ≤30 years old with the equations in Golden and others (1981). These younger stands were used only to convert the model from a 50-year prediction system to a 25-year prediction system; they were not used in quantifying or testing the original (50-year) model.

Physiographic data collected for each plot included aspect, percent slope, and position on the slope (fig. 2). Mean depth to the water table during the growing season was estimated for sites along rivers or streams and for areas of poor drainage. Frequency of flooding and depth to a perched water table during winter months were estimated from physiographic position, soil characteristics, and local knowledge. Site descriptions also included mention of site-specific or microsite topography such as the presence of intermittent or ephemeral stream channels, small depressional areas (hummocks and hollows), and larger bowl-shaped depressions. Plot elevations were determined from topographical maps.

Table 1.—*Mean and range in selected site characteristics for plots used in the development of the PTSITE model*

Characteristic	Mean	Range
Site index at age 50 (*ft*)	94	68–122
Slope (*percent*)	4	0–25
Drainage class	3.6	1–7
Elevation (*ft*)	282	20–360
Surface soil (*0–6 in*):		
pH	4.9	4.0–6.5
Organic matter (*percent*)	3.9	0.9–18.2
Phosphorus (*ppm*)	2.5	0.5–9.9
Thickness A1 or Ap (*in*)	4.9	0.5–24
Texture of subsoil	NA*	sand-clay

*NA = not applicable

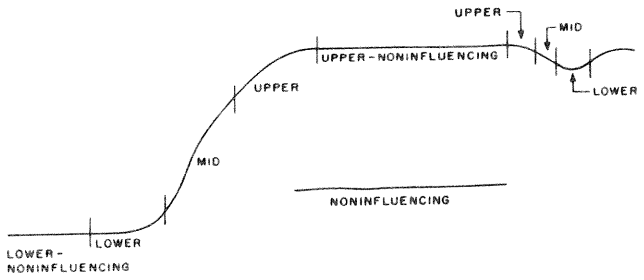


Figure 2.—*Slope-position categories used in the PTSITE model. The category "noninfluencing" should be selected when there is no real change in topography in the area around the site being evaluated. See appendix A for additional information on slope position categories.*

Mean precipitation (annual and for selected time periods) and water deficit (precipitation minus evapotranspiration) values were assigned to each plot on the basis of published maps (USDA FS 1969 and U.S. Department of Commerce 1968).

At each plot, a detailed soil profile description was made by a soil scientist. Soil profiles were described to a minimum of 60 inches (or to an impenetrable layer). Profile descriptions included depth, color (including mottles), texture, structure, consistence, pH, presence and size of pine roots, and percentage of rock fragments in each horizon. The presence of stratification within the profile was also noted. Effective rooting depth was estimated for each site. Field determinations of texture were spot-checked in the laboratory using the hydrometer method (Bouyoucos 1962), with sodium hexametaphosphate being used as a dispersing agent, to ensure that individual soil scientists were not introducing a systematic bias into the data. Representative soil samples were taken from each horizon. Samples were air-dried and sieved to remove organic materials and rock fragments. Samples from each horizon were analyzed for pH (standard glass electrode, 1:1 volume ratio of distilled water and soil) (USDA Soil Conservation Service 1972). Representative samples from each horizon were also sent to Ward Laboratories, Kearney, Nebraska, for analysis of Walkley-Black organic carbon (Allison 1965), double-acid extractable phosphorus (also called Mehlich 1 phosphorus) (Olson and Sommers 1982), and total Kjeldahl nitrogen (Jackson 1958).

Samples to determine the bulk density of the soil were collected from three arbitrarily selected locations in the plot. At each location, two samples were collected from the surface horizon and two collected from the top B or C horizon (or in the E horizon if the depth to a B or C horizon was greater than 20 inches). Thus, a total of 12 samples were collected in each plot. Samples were taken with care to avoid crossing horizon boundaries; in addition, samples crossing large roots or animal burrows were discarded and new samples taken. Samples of known volume (5.5 in^3) were extracted in metal cores using a drop-hammer sampler; care was taken to avoid compacting the core during sample collection. Ovendry weights (constant weight at 220 °F) were determined in the laboratory, and bulk density was calculated. It was necessary to dig small soil pits to collect bulk density samples from the subsoil. Depth of the surface horizons was measured in these small pits and at the spot where the complete profile description was being made; this allowed the variability of the depth of the surface horizons to be measured and provided a check on the uniformity of the soil across the plot. If there was any indication that more than one soil series was present, several spots were checked with a soil auger to allow the plot boundaries to be relocated so that each plot encompassed only one series.

MODEL CONSTRUCTION

The goal of this project was to incorporate what was known about site quality for loblolly pine into a general site-prediction model. Development of this type of knowledge-based or expert system incorporated published[1] and unpublished observations on the silvics of the species by foresters and forestry researchers in the Southern United States. General observations and conclusions were supplemented by several types of data sets, which allowed specific relationships to be quantified.

Actual construction of the model was accomplished in stages. First, a general theoretical model that listed

[1]See Fowells (1965) and Wahlenberg (1960) for general information on the silvics of loblolly pine. More recent literature can be accessed by consulting Hu and others (1983).

the soil and climatic characteristics that could influence tree growth was developed. This was a subjective listing, but it was based on results from many published studies (e.g., Baker and Broadfoot 1977, 1979; Carmean 1975; Coile 1952). Next, a subset of these variables was selected on the basis of the following criteria: (1) variables theoretically considered to be the most important ones in influencing height growth, (2) variables that exhibited a meaningful range across the sampled sites, and (3) variables that were fairly independent of (that is, poorly correlated with) other selected variables. The goal at this stage of model construction was to reduce the number of variables to a manageable level without deleting classes of variables that could be important.

The next stage of model construction was to quantify the relationship between site index and each variable being considered. The first step was to determine what levels of each variable were associated with the highest values for site index. This was accomplished by examining the data graphically and via statistical analyses such as discriminant analysis. Graphical analyses included boundary-line analysis, which reveals the maximum values associated with various levels of a variable (Evanylo and Sumner 1987, Webb 1972). This was helpful in determining the general shape of the relationship and the amount of the range in site index values that may be attributable to that variable. When possible, data from sources other than the plots measured for this study were used to determine the preliminary values assigned to the various levels of each variable. For example, data from 1,086 plots in the Soil Conservation Service (SCS) soil woodland data base were used to initially quantify the effects of soil drainage class, soil order, and texture of the surface horizon of the soil. (These were values recorded on individual plots and were **not** averages by soil series.) For example, the relationship between site index for loblolly pine and soil drainage class was plotted for the SCS soil woodland plots (fig. 3). Separate boundary lines were drawn for sites that had been coded as being on stream terraces or floodplains and for upland sites. When sites were not near rivers and streams (the solid line), poorly drained, moderately well-drained[2], or well-drained, sites could achieve a maximum site index of about 110 feet; very poorly drained sites a maximum value of about 95 feet; somewhat excessively drained sites a maximum value of 90 feet; and excessively drained sites a maximum value of 80 feet. The differences between the heights of the solid and dashed lines of figure 3 for moderately well to excessively drained sites were taken as an indication of the effect of subsurface irrigation. These differences were then used as guides in selecting the values initially assigned to the drainage classes and the values for extra water (a variable that included factors such as distance to a water table during the growing season). However, the actual values assigned did not correspond directly to the differences in the maximum values observed because it was evident that other variables being evaluated (e.g., soil texture) would be partially correlated with drainage class.

General relationships between each variable and site index were constrained to be consistent with what is known about the silvics of the species (cf., Fowells 1965) and general published relationships between plant growth and specific variables. Interrelationships between variables were also required to be consistent with what was known. For example, bulk density was not evaluated alone but only in the context of soil texture (Daddow and Warrington 1983) and structure, and phosphorous values were evaluated in relation to soil drainage class (cf., Tiarks and Shoulders 1982). Apparent inconsistencies or "quirks" in the measured data or in other data used in model construction were not allowed to influence the structure of the model. If there was no biological reason to explain an odd shape in the relationship between site index and the variable being considered, the odd shape or quirk was ignored in defining the guiding shape of that relationship.

Model quantification began by assigning the characteristics associated with the highest levels of site index (sites with $SI_{50} \geq 115$ ft) a value of zero. Then the amount of reduction in site index associated with other levels of the variable was estimated. The final weights assigned to the individual levels were determined empirically; more than 400 runs of the basic program were made before deciding on the values in the final model. The implied relationship between site index and each variable was always constrained to be biologically reasonable. For example, if evaluation of a preliminary run indicated that changing the variable weights in a manner **inconsistent with the shape of the guiding relationship** would improve the predictive ability of the model, such changes were **not** made.

The starting maximum value used in the model for SI_{50} was 122 feet. The values of some variables or combinations of variables were assumed to have additive effects; thus, the theoretical maximum value that the model can predict is 136 feet. This theoretical maximum value is a hypothetical condition that may not exist in the Southern Coastal Plain; however, a large range-wide study (USDA FS 1976) reported sampling one natural stand in the 130-foot site index class, so this value may not be completely unrealistic.

When the model with the first group of selected variables predicted site index from the site characteristics to within ± 15 feet of the value estimated from tree measurements, the original group of variables was

[2]The apparently lower value of maximum site index achieved on somewhat poorly drained sites was judged to be an artifact due to insufficient sample size.

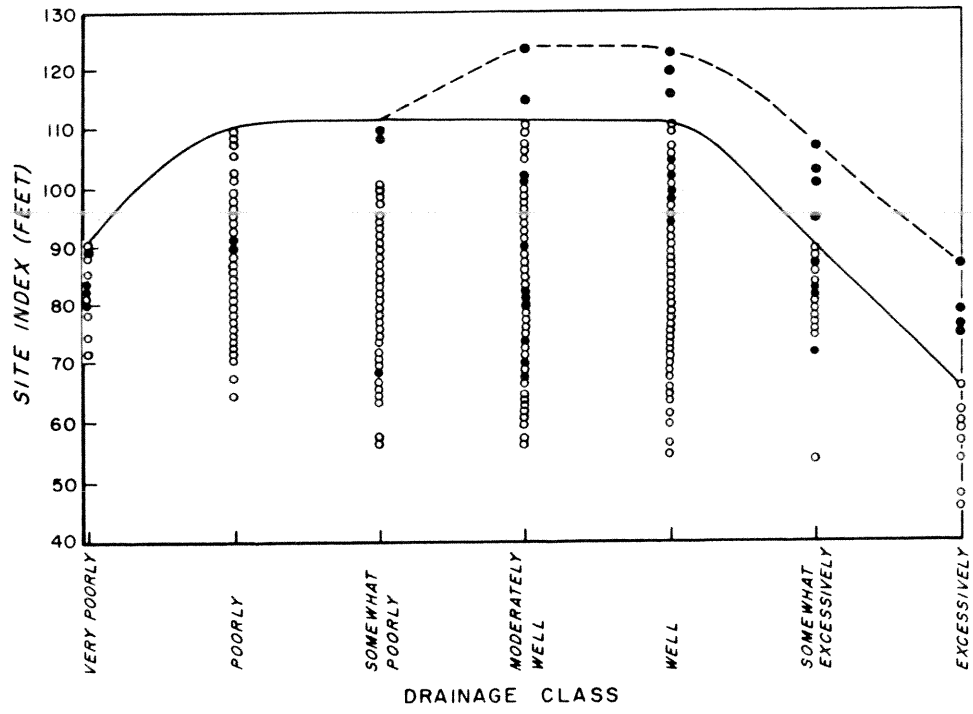


Figure 3.—*Relationship between site index at age 50 and soil drainage class for plots from a Soil Conservation Service data base for loblolly pine. Boundary lines represent the theoretical maximum value of site index for each drainage class and physiographic position.*

reevaluated. Particular care was taken to evaluate whether or not plots with certain characteristics were underpredicted or overpredicted. The second round of model fitting included two new variables—aspect and previous land use. These variables had not qualified for the original group of variables because most plots were classified into only one or two categories of these variables. Thus, the effects of these variables were difficult to quantify until some of the other site variables had been accounted for. The third round of model quantification resulted in adding three more variables to the previous group. The first of these new variables coded for the depth, thickness, and texture of buried or stratified sandy layers; the second assessed frequency and timing of flooding; and the third coded for past erosion. These new variables were only important on a few sites but needed to be incorporated into the final model to improve its overall predictive ability. The final model was named PTSITE, the PT portion of the name coming from the scientific name of loblolly pine (*Pinus taeda*).

The variables included in the final model are listed in table 2. The ranges in site index values associated with the possible range in variable values are given in appendix B, which also indicates which site characteristics are associated with the most and least favorable model values.

The model includes one climatic variable—mean annual water deficit. Water deficit is the difference between precipitation and potential evapotranspiration. The value used in the model is based on long-term records and does not incorporate any measure of year-to-year variability. Although the value is expressed as **annual** water deficit (based on the usual pattern of precipitation and evapotranspiration in the Southern Coastal Plain), all of the mean annual water deficit occurs during the growing season. Thus, this variable is actually assessing water deficit during the growing season. The values of water deficit used in the model were regional values appropriate for average sites and were not calculated on the basis of site-specific characteristics. Characteristics that influence the actual value for water deficit on a specific site (such as soil texture) are accounted for in other parts of the program.

The original version of PTSITE predicted site index for a base age of 50 years. A second version was developed to predict site index for a base age of 25 years. The model for base age 25 was developed primarily by scaling down the variable effects by a factor[3] of one-

[3]This scaling factor was based on a rule-of-thumb used by some foresters—convert a 50-year site index value for loblolly pine to a 25-year value by multiplying the 50-year value by two-thirds (0.67).

Table 2.—*Information needed to run PTSITE, a model for predicting site index of loblolly pine from soil and site characteristics*

Main category and specific information needed
Physical properties of soils:
Texture of surface horizon
Texture of subsoil
Buried sand or stratified layers
Bulk density of first subsoil horizon
Thickness of A1 or Ap horizon
Thickness of E horizon (if present)
Depth to first subsoil horizon
Effective rooting depth
Structure of surface and subsoil horizons
Consistence of surface and subsoil horizons
Rock fragments in rooting zone
Soil properties influencing nutrient availability:
pH of surface soil (0–6 inches)
Change in pH from surface soil to pH at 12 inches
Extractable phosphorus in surface soil
Organic matter in surface soil
Soil order (from Soil Survey Staff 1975)
Site location on the landscape and in relation to climate:
Slope position and percent slope
Aspect
Drainage classification
Access to extra water
Water deficit*
Occurrence of flooding
Land history:
Previous land use
Erosional history

* The user is asked for county (or parish) and State name for site to be evaluated; an internal file provides the actual values for water deficit.

third (0.33). However, several variables were weighted differently in the version of the model for younger stands. Some variables were given the same weight in the 25-year model as in the 50-year model. These "full-effect variables"—previous land use, past erosion, parent material, and thickness of the E horizon—were considered to have a proportionately greater effect on early growth than on later growth of the stand. Thus, the effect of these variables was not scaled down in conversion to a younger index age. Values for two other variables, aspect and soil order, had proportionately less impact in the younger stands than in the older stands and were scaled down by a factor of 0.50. The conversion from the 50-year model to the 25-year model also incorporated a "drainage conversion" factor to account for the difference in height growth patterns of trees on sites that differ in soil drainage classification. For example, trees on imperfectly drained sites have proportionately poorer height growth at young ages and attain greater height at older ages than trees on better drained sites having the same site index (cf., Golden and others 1981, Pienaar and Shiver 1980).

MODEL VERIFICATION

The final model of PTSITE fit the original data set well (table 3). The correlation coefficient between site index predicted from PTSITE and site index predicted from tree height and age was 0.98 for the initial group of 50 plots used in quantifying the model (fig. 4). Based on the chi-square test of accuracy (Freese 1960), the model was judged to predict site index within ±4 feet ($p<0.05$). More than half the sites were predicted within ±2 feet. The portion of the model predicting 25-year site index achieved a similar level of accuracy, with the predictions being within ±3 feet ($p<0.05$).

PTSITE also fit the reserved data set with the same level of accuracy (±4 ft., $p<0.05$, chi-square test of accuracy) as the original data (table 3, fig. 4). The reserved data included sites from North Carolina to Texas and drainage classes somewhat poorly drained, moderately well drained, and well drained. Thus, the model was tested and verified with independent data that were representative of many loblolly pine sites in the Southern Coastal Plain.

Soil-site data from Westvaco and from the USDA Forest Service's Southeastern Forest Experiment Station (SEFES) were made available to the author for the purpose of testing the PTSITE model. The data in these two data sets were from coastal South Carolina and included poorly drained to moderately well drained drainage classes and a wide range in values for extractable phosphorus. Thus, these data sets provide an additional test of the model's predictive ability.

The Westvaco and SEFES data sets did **not** contain information on bulk density, access to extra water, or soil structure or consistence; they did have slightly different coding systems for slope position. These data sets also had information on fewer trees per plot for site index calculation than the author's original and reserved data sets. For the purposes of this evaluation, bulk density values were assumed to be at optimal levels. Access to extra water, soil structure, and soil consistence were estimated from soil textures, position on the landscape, and soil series descriptions (each plot had been classified into soil series or soil mapping unit). In addition, the values for extractable phosphorus in the data set from SEFES were obtained using a different analysis procedure (Bray 2 in Jackson 1958). The values for extractable phosphorus were assumed to be roughly equivalent to what would have been obtained using the double-acid (Mehlich 1) procedure based on the results in Tiarks (1982). This assumed equivalence in phosphorus values may have introduced a bias into the predictions; however, it was apparent that having approximate values for phosphorus would be better than not having any information on this variable.

Considering that information was missing for some variables and had to be estimated and that there were

Table 3.—*Predictive ability of PTSITE for several data sets**

Data source and age for site index	Number of plots	Location	ΔSI		R	Accuracy of site index class (± ft) prediction					
			Mean[†]	ABS[‡]		1	2	3	4	5	10
						Percentage of plots					
Original data											
50-year base	50	Southwide	0.10	1.7	0.98	28	58	88	100	100	100
Reserved data											
50-year base	13	Southwide	0.05	1.7	0.96	31	62	92	100	100	100
Reserved data											
25-year base	11	Mostly Mississippi	−0.01	1.5	0.97	36	73	100	100	100	100
Westvaco[§]											
50-year base	4	South Carolina	1.50	1.5	0.99	50	100	100	100	100	100
25-year base	3	South Carolina	1.10	1.9	0.71	33	67	100	100	100	100
SEFES[§,‖]											
50-year base											
Forested sites	16	South Carolina	−1.38	1.7	0.95	21	71	79	93	93	100
Old-field sites	15	South Carolina	−2.61	5.2	0.73	24	24	29	29	53	94

* All data came from the Southern Coastal Plain; ΔSI is the difference between site index estimated from tree heights and ages and site index predicted by the PTSITE model.

[†] Mean of positive and negative values of ΔSI numbers.

[‡] Mean of absolute values of ΔSI numbers.

[§] Some variables were not measured on these plots; see text for details.

[‖] SEFES = Southeastern Forest Experiment Station.

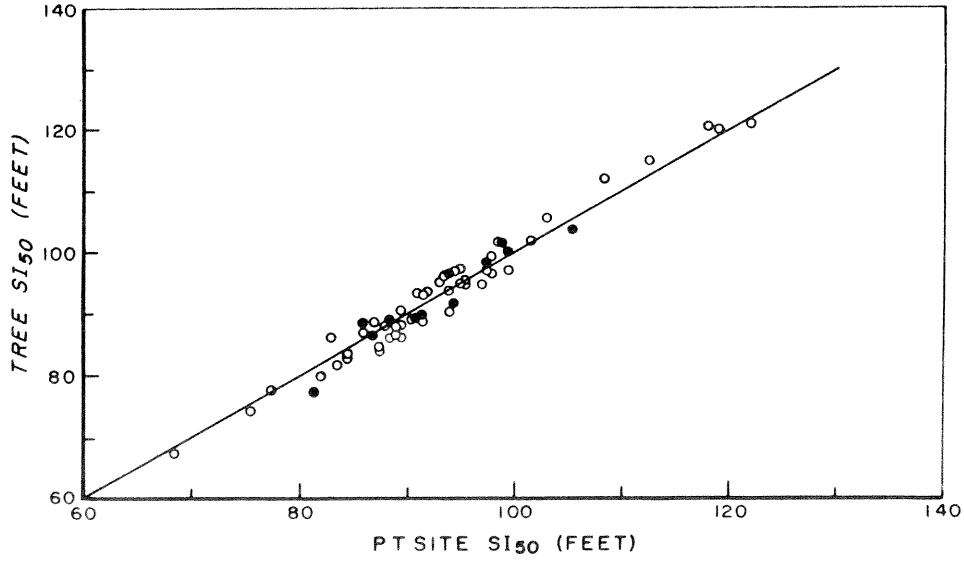


Figure 4.—*Relationship between site index at age 50 (SI_{50}) calculated from tree heights and ages (Tree SI_{50}) and SI_{50} predicted by PTSITE; diagonal line indicates where the two values for SI_{50} would be equivalent.*

differences in data collection and coding systems, the plots from the Westvaco and SEFES data sets were predicted quite well by the model. Because of differences in the procedures used to collect the data, these plots did not provide as rigorous a test of the model as the plots in the reserved data set; however, they may be indicative of the accuracy that users might achieve when using available soil-site data that were not collected specifically to run through the PTSITE model.

The Westvaco plots were generally underpredicted (mean change in site index was positive), which may have been caused by errors in assigning slope position and access-to-extra-water codes. Several of the possible alternative codes would result in slightly higher prediction values. On the other hand, site index values for the plots from SEFES were generally overpredicted by the model, which may indicate that there is a consistent difference in phosphorus values obtained by the different extraction procedures.

The correlation coefficient between measured and predicted site index for the previously forested plots in the SEFES data set (0.95) was similar to the values obtained in analyzing the data sets collected by the author. The lower correlation obtained for the old-field sites may indicate that past agricultural use altered the physical properties of soils to the extent that it was inaccurate to assume that bulk density values were at optimum levels or that the typical values for soil structure, soil consistence, and rooting depth associated with the soil series were appropriate. The 25-year-base plots from the Westvaco data set also had lower correlation than the plots in the author's data; however, with only three plots in the group and a small range in the values being predicted, that statistic is probably not very meaningful.

USING THE PTSITE PROGRAM

An interactive computer program was developed from the PTSITE model. The program, also named PTSITE, is run on IBM and IBM-compatible machines. The version of the program available at the time this user's guide was prepared (version 10-89) has a menu format. The program is accessed by keying in the name of the program, PTSITE, and pressing the <RETURN> (or <ENTER> or <NEW LINE>) key. The program prompts the user to answer questions or requests for information regarding various soil and site characteristics (table 2). Most answers can be selected from a multiple choice format. Menus "pop up" with the possible choices as they are needed (fig. 5). To respond to each question or request for information, the user should press the number key associated with the appropriate answer and then press the <RETURN> (or <ENTER> or <NEW LINE>) key. The program can be terminated at any point by pressing control F1 (i.e., by holding down the <CONTROL> key and pressing the F1 key). Some questions require information to be keyed in rather than just selecting a category. Examples of this type of question are site name or number, county (or parish) and State location, values for depth of specific horizons, and bulk density. Some questions are asked only if the answer to a previous question falls into a specific category; thus, some questions do not appear on every run of the program.

A question will be repeated if the response is not a reasonable answer. For example, if a multiple choice question offers the user the choices of 1 to 5 and the user inputs 35, the question will be asked again. On most computers an inappropriate answer is also signaled by a beep. PLEASE READ THE SCREEN CAREFULLY!! Users should also be careful when keying in county (or parish) names and State abbreviations because the program will not recognize misspellings.

Certain answers will trigger a warning message indicating that an unusual or possibly unsuitable value has been selected. In most cases the user is then given the opportunity to change the answer. Additional information on running the program is provided in appendix A, which explains how to answer each question and provides suggestions on how to collect information or answer questions dealing with unusual or unfamiliar characteristics. Users should read appendix A before running the program.

Many of the questions require users to use their judgment in selecting the answer. Users must be careful to accurately evaluate the conditions on each site. If users "know" that the site being evaluated is a "good site" or a "bad site," they may tend to choose more favorable or less favorable characteristics than are warranted. Careful evaluation of each characteristic is essential for accurate site evaluation.

When all the questions on site characteristics have been answered, the user is given the opportunity to change any of the values before running the program. Each of the input variables is numbered on the screen (fig. 5). For example, if users want to change the value input for texture of the surface horizon, they should press 11 (and press <RETURN>) upon seeing the message at the bottom of the screen that reads: "Enter variable number you want to change (0 for site ID) or press F1 to process." The menu of choices corresponding to texture of the surface horizon will appear, and users can select another value. There is no limit to the number of variables that can be changed; however, changes can be made only when all of the questions have been answered initially. When users are satisfied with all the values, the F1 key should be pressed to process the program.

After the F1 key is pressed, the user is given the choice of having the output from the program sent to a

```
SITE:  Crossett Experimental Forest, Compartment 3, Stand 7

  1.  COUNTY                    ASHLEY     2.  STATE                    AR
  3.  SLOPE POSITION                2      4.  PERCENT SLOPE             1
  5.  ASPECT                        0      6.  PAST LAND USE             2
  7.  PAST EROSION                  1      8.  DRAINAGE CLASS            3
  9.  FLOODING                      1     10.  EXTRA WATER               25
 11.  TEXTURE OF SURFACE           14     12.  TEXTURE OF SUBSOIL        14

            Select a value for the texture of the surface horizon.

 (1) Sand                    (9)  Coarse sandy loam        (17) Clay loam
 (2) Coarse sand            (10)  Sandy loam               (18) Silty clay loam
 (3) Fine sand              (11)  Fine sandy loam          (19) Sandy clay
 (4) Very fine sand         (12)  Very fine sandy loam     (20) Clay
 (5) Loamy coarse sand      (13)  Loam                     (21) Silty clay
 (6) Loamy sand             (14)  Silt loam                (22) Muck or peat
 (7) Loamy fine sand        (15)  Silt
 (8) Loamy very fine sand   (16)  Sandy clay loam

Enter variable number you want to change (0 for site ID) or  press F1 to process
```

Figure 5.—*Appearance of data on the screen and one of the "popup" menus from the PTSITE program.*

printer[4] or saved in a file. An example of a sample output is included in appendix C. If the option of saving to a file is selected, the program will ask for the path[5] and file name. File names can be any combination of alpha or numeric characters (up to a maximum of eight characters); however, file names cannot **begin** with a number or contain blank spaces or punctuation characters.

After the decision has been made as to where to send the output from a run of the program, users are then given the choice to: (1) evaluate another site, starting with the values from the last run; (2) evaluate another site, but delete the old values; or (3) exit the program. Selecting option 1 enables users to make another run of the program without having to input all the variables again. For example, if a user wanted to run the program for the same soil but on two different slope positions, the program would first be run with one of the values for slope position; at the end of the first run; option 1 would be selected. The other value for slope position would be input for variable 3, and F1 would be pressed to process the new value. If several variables need to be changed for the new run, it is probably safer for users to select option 2—that way incorrect values cannot be inadvertently retained from the previous run.

MODEL APPLICABILITY

The PTSITE model was developed with data from stands of loblolly pine in the Southern Coastal Plain from North Carolina to Texas. Sites were not sampled in the Piedmont or in the floodplains of major river systems such as the Mississippi River. In addition, all sites sampled were within the native range of loblolly pine (Fowells 1965). The program should not be relied upon outside this geographic area until local users determine the applicability of the program to their site conditions.

An attempt was made to sample a wide range of soil conditions and site indices. Not all possible conditions were sampled, however, and the user is cautioned from relying on the model's prediction for unusual or non-typical conditions until the model can be tested under

[4]If the user selects the option of sending the output to a printer and a printer is not attached, the program will print an error message. If the print option is selected and a printer is attached but not online, the output will be lost. The popup menu includes a reminder to the user that the printer must be online.

[5]The path is the drive where the user wants the output file to be stored (e.g., A:). If the user does not specify a path, the file will be saved on the current drive. If the user does not specify a file extension, the program will add an extensions of .pts to the file name (e.g., Jones.pts).

those conditions. For example, only a few sites had pH values below 4.0 or above 6.5, and no samples were taken on sites that had slopes greater than 30 percent or that were on very deep sands or deep organic soils. In addition, samples were not taken on sites that had problems with sodium toxicity[6] or with known nutrient deficiencies other than phosphorus or nitrogen. The model may be modified in the future, and the author would welcome input on how the model performed under different conditions.

The program was developed on the basis of plots located on apparently uniform site conditions. Plot boundaries were laid out to avoid changes in slope, aspect, drainage, or other visible site conditions. The greatest accuracy in prediction of site index will be achieved when users limit their evaluations to areas of similar uniformity. It may be helpful to first roughly map areas that appear to be uniform and then to sample within each area. Sampling intensity should vary with the user's need for accuracy; however, soil characteristics can be extremely variable, and in some areas several point determinations may be required to accurately assess potential site index.

The PTSITE model was developed with data from stands that were considered to accurately represent the potential site quality of the area. Stands having uneven-aged structure or a significant component of upper-canopy hardwoods were not included. Trees showing evidence of major top damage or ring patterns indicating a period of early suppression were deleted, and uniformity in tree ages within a stand was one of the criteria used for selecting plots to be used in model development or testing. In addition, very young or very old stands were not included because of the possible errors in accurately estimating site index from such stands.

The PTSITE model can be used to provide estimates of **potential site index** in stands having the criteria mentioned above—uneven-aged structure, upper-canopy hardwoods, suppression, or damage, as well as stands that are very young or very old. In fact, a soil-based prediction system like PTSITE is the only way to accurately estimate potential site index for most of these stand conditions. Users are cautioned, however, to follow the same criteria for stand and tree selection described above when **testing** the applicability of the model in new situations.

Most stands used in developing the model had regenerated naturally; however, some of the stands had been planted in the 1930's by the Civilian Conservation Corps. Stands used in scaling down the 50-year model to a 25-year model were also of both natural and artificial origins.

Actual or apparent changes in site quality associated with forest management practices such as thinning are not included in the model. However, if a forest management practice such as intensive site preparation significantly alters long-term soil properties, the change in these properties should result in a change in the site index predicted by PTSITE. Thus, the model can be run with different values for depth of the A1 horizon, percentage of organic matter, phosphorus concentration, bulk density, past use, or erosion to determine its sensitivity to changes in those factors[7]. Some users may wish to use PTSITE as a rough method of predicting or monitoring the effects of management practices on long-term productivity. For example, if onsite investigation or other information indicates that a certain site preparation practice reduces depth of the A horizon and organic matter content of the surface soil, the change in the value of site index predicted by the model could be used as a measure of the change in site productivity.

The PTSITE model was developed and tested with data from mature stands where soil characteristics would be quite stable. For example, organic matter in the top 6 inches of a very sandy soil may decrease sharply when the overstory is removed and the soil surface opened up to full sun. Then, as the regeneration increases in size and crown closure occurs, organic matter contents will increase. In contrast, extractable phosphorus levels will be quite high immediately after fertilization, then will decrease and eventually level off at a new equilibrium value. Thus, users are cautioned not to overestimate or underestimate the long-term effects of a management practice on site productivity based on a soil characteristic that is changing over time. For most variables, measurements made 10 or more years after disturbance will probably provide estimates close to equilibrium values. Measurements made before that time may need to be modified on the basis of experience or specific information on the behavior of a soil variable over time.

The PTSITE model does not take genetic variability of loblolly pine into account. Actual increases in the measured site index may be realized when specific plant materials are present. These increases may result from higher overall growth rates associated with some genotypes or from using genotypes having tolerances for specific conditions. The program can be used to rank sites in order of potential site index; however, how accurately the program will predict actual site index under a variety of forest management practices is unknown. Users having some knowledge of programming can add or alter sections of the PTSITE

[6]Some soils having suspected high sodium levels were analyzed, but sodium levels were not high enough to be a problem.

[7]See the sections in appendix A on past land use, access to extra water, and organic matter for additional ideas on how to handle specific management practices.

model so that its predictions are in line with their experience. The basic framework of the model is expected to remain intact, but additional modules could be added to take other site conditions or specialized plant materials into account.

PROGRAM AVAILABILITY

A copy of the PTSITE program may be obtained by contacting the Southern Forest Experiment Station, P.O. Box 3516, Monticello, AR 71655 (501-367-3464). Requests by mail should include the user's name, address, and telephone number as well as a blank **formatted** diskette (3.5- or 5.25-inch). The requester's name **MUST** be on the diskette. Unless otherwise specified, a compiled version of the program will be provided. Upon request, a program listing or an interpreted version of the program is available. The interpreted program version can be changed by the user; however, to actually run an interpreted program, users must have a BASIC interpreter software program available on their computer. The compiled program can be run without additional software but cannot be altered.

LITERATURE CITED

Allison, L.E. 1965. Organic carbon. In: Black, C.A., ed. Methods of soil analysis. Agronomy. Madison, WI: American Society of Agronomy: 1367–1378. Vol. 9, pt. 2.

Baker, James B.; Broadfoot, W.M. 1977. A practical field method of site evaluation for eight important southern hardwoods. Gen. Tech. Rep. SO-14. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 31 p.

Baker, James B.; Broadfoot, W.M. 1979. A practical field method of site evaluation for commercially important southern hardwoods. Gen. Tech. Rep. SO-26. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 51 p.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agronomy Journal. 54: 464–465.

Broadfoot, W.M. 1969. Problems in relating soil to site index for southern hardwoods. Forest Science. 15: 354–364.

Carmean, Willard H. 1975. Forest site quality evaluation in the U.S. Advances in Agronomy. 27: 209–269.

Coile, T.S. 1952. Soil and the growth of forests. Advances in Agronomy. 16: 329–398.

Daddow, Richard L.; Warrington, Gordon E. 1983. Growth-limiting soil bulk densities as influenced by soil texture. WSDG Rep. WSDG-TN-00005. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Watershed Systems Development Group. 17 p.

Evanylo, G.K.; Sumner, M.E. 1987. Utilization of the boundary line approach in the development of soil nutrient norms for soybean production. Communications in Soil Science and Plant Analysis. 18(12): 1379–1401.

Farrar, R.M., Jr. 1975. Southern pine site-index computing program. Res. Note SO-197. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 8 p.

Fowells, H.A., comp. 1965. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture. 761 p.

Freese, Frank. 1960. Testing accuracy. Forest Science. 6(2): 139–145.

Golden, M.S.; Meldahl, R.; Knowe, S.A.; Boyer, W.D. 1981. Predicting site index for old-field loblolly pine plantations. Southern Journal of Applied Forestry. 5(3): 109–114.

Harding, R.B.; Baker, R.D. 1983. The soil survey and its value in the ad valorem taxation of privately owned timberland. Southern Journal of Applied Forestry. 7(4): 204–208.

Harrington, Constance A. 1986. A method of site quality evaluation for red alder. Gen. Tech. Rep. PNW-192. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

Harrington, Constance A.; Casson, Bettina M. 1986. SITEQUAL—a user's guide. Computerized site evaluation for 14 southern hardwood species. Gen. Tech. Rep. SO-62. New Orleans, LA: U.S. Department of Agriculture, Southern Forest Experiment Station. 13 p.

Hodgkins, Earl J. 1956. Testing soil-site index tables in southwestern Alabama. Journal of Forestry. 54(4): 261–266.

Hodgkins, Earl J. 1959. Forest site classification in the Southeast. In: Proceedings, 8th annual symposium on southern forest soils; 1958 June; Baton Rouge, LA. Baton Rouge, LA: Louisiana State University Press: 34–48.

Hu, Shih-Chang; Lilieholm, R.J.; Burns, Paul Y. 1983. Loblolly pine: a bibliography, 1959–1982. Res. Rep. 2. Baton Rouge, LA: School of Forestry and Wildlife Management, Louisiana State University Agricultural Center. 199 p.

Jackson, M.L. 1958. Soil chemical analysis. Englewood Cliffs, NJ: Prentice-Hall, Inc. 498 p.

Lloyd, W.J.; Lemmon, P.E. 1970. Rectifying azimuth (of aspect) in studies of soil-site index relationships. In: Tree growth and forest soils; proceedings of the

3rd North American forest soils conference; 1968 August; Raleigh, NC. Corvallis, OR: Oregon State University Press: 453–558.

Mader, D.L. 1965. Where are we in soil-site classification? In: Applications of soils information in forestry. Washington, DC: Society of American Foresters and Soil Conservation Society of America: 25–32.

McKee, W.L. 1977. Soil-site relationships for loblolly pine on selected soils. In: Proceedings 6th southern forest soils workshop; 1976 October 19–21; Charleston, SC. Atlanta, GA: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Southeastern Area: 115–120.

McQuilkin, Robert A. 1976. The necessity of independent testing of soil-site equations. Soil Science Society of America Journal. 40: 783–785.

Olsen, S.R.; Sommers, L.E. 1982. Phosphorus. In: Page, A.L., ed. Methods of soil analysis; pt. 2. Chemical and microbiological properties. Agronomy Monogr. 9, 2d. ed. Madison, WI: American Society of Agronomy and Soil Science Society of America: 403–430.

Pienaar, Leon V.; Shiver, Barry D. 1980. Dominant height growth and site index curves for loblolly pine plantations in the Carolina flatwoods. Southern Journal of Applied Forestry. 4(1): 54–59.

Ralston, C.W. 1964. Evaluation of forest site productivity. International Review of Forestry Research. 1: 171–201.

Smalley, Glendon W. 1979. Classification and evaluation of forest sites for timber production: introduction of a new system for classifying forest sites based on the physical features of the landscape. In: Proceedings of a forest soils and site quality workshop; 1979 May 8–9; Auburn, AL. Auburn, AL: Auburn University: 28–47.

Soil Survey Staff. 1975. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. Agric. Handb. 436. Washington, DC: U.S. Department of Agriculture. 754 p.

Storie, R. Earl; Wieslander, A.E. 1948. Rating soils for timber sites. Soil Science Society of America Proceedings. 13: 499–509.

Tiarks, A.E.; Shoulders, E. 1982. Effects of shallow water tables on height growth and phosphorus uptake by loblolly and slash pines. Res. Note SO-285. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 5 p.

Tiarks, Allen E. 1982. Phosphorus sorption curves for evaluating phosphorus requirements of loblolly pine (*Pinus taeda*). Communications in Soil Science and Plant Analysis. 13(8): 619–631.

U.S. Department of Agriculture, Forest Service. 1969. A forest atlas of the South. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station and Southeastern Forest Experiment Station. 27 p.

U.S. Department of Agriculture, Forest Service. 1976. Volume, yield, and stand tables for second-growth southern pines. Misc. Publ. 50. Washington, DC: U.S. Department of Agriculture. 202 p.

U.S. Department of Agriculture, Soil Conservation Service. 1972. Soil survey laboratory methods and procedures for collecting soil samples. Soil Surv. Invest. Rep. 1. Washington, DC: U.S. Government Printing Office. 63 p.

U.S. Department of Commerce. 1968. Climatic atlas of the United States. Asheville, NC: U.S. Department of Commerce. 80 p.

Wahlenberg, W.G. 1960. Loblolly pine: its use, ecology, regeneration, protection, growth, and management. Raleigh, NC: School of Forestry, Duke University. 603 p.

Webb, R.A. 1972. Use of the boundary line in the analysis of biological data. Journal of Horticultural Science. 47: 309–319.

Youngberg, C.T.; Scholz, H.F. 1949. Relation of soil fertility and rate of growth of mixed oak stands in the driftless area of southwestern Wisconsin. Soil Science Society of America Proceedings. 14: 331–332.

Appendix A

—Additional information to help users respond to the questions and requests for information of the PTSITE program

General note—Questions or requests for information listed below that are preceded by an asterisk (*) are asked only if the answer to a previous question or request for information fell into a specific category. Thus, some questions will not appear in every run of the program. Screen prompts appear in bold-face type.

What is your site name or number?
A site identification in the form of a name or number is optional; any combination of letters, numbers, spaces, or special characters can be used, up to a maximum of 256 characters or spaces. If users do not wish their output to be labeled, they should press <RETURN> (or <ENTER> or <NEW LINE>) when this question is asked.

Input county (or parish) name:
Input the two-letter State abbreviation:
The user should first enter the county or parish name (press <RETURN> after the name). Use of uppercase or lowercase letters is acceptable. Next, the user should enter the two-letter State abbreviation (the program will prompt the user). This information on county (or parish) and State names will appear on the output as an additional site identifier. The program also checks a supplemental file (included with the program) to determine whether loblolly pine is native to that county (based on the range map in Fowells 1965). If loblolly pine is not native, a warning message is triggered, and the user is given the option of changing the site location or continuing with the same location. The warning message is also triggered if the county (or parish) name or State abbreviation is spelled incorrectly (e.g., Arkansas is AR not AK). Counties or parishes named for saints are spelled ST with no punctuation (e.g., ST CLAIR, ST TAMMANY, OR ST JOHNS). Spaces are optional between words in a county or parish name if the common spelling uses spaces (e.g., either REDRIVER or RED RIVER, or ST FRANCIS or STFRANCIS will work, but RICH LAND for RICHLAND will not). When in doubt, the spaces should be left out.

The supplemental file also contains the mean annual water deficit values[1] for each county or parish in the Southern United States (based on the map in USDA FS 1969). The program uses water deficit in conjunction with the codes for access to extra water in evaluating site quality. Water deficit values are not included for States where loblolly pine is not native nor for central or western Oklahoma or Texas. If a water deficit value is not available for the county (or parish) selected, a warning message is triggered, and the user will be given the choice of selecting another county or exiting the program.

The supplemental file (psite.dat) contains State names arranged in alphabetical order. If the user is evaluating a site with a State code near the end of the alphabet, the program will pause for several seconds while it checks the file. This delay is reduced if the program is run on a hard drive rather than on a disk drive. If users do not know what a hard drive is, they should ask a computer programmer or specialist for assistance.

Select a value for slope position of the site from the following list:
(1) Lowerslope
(2) Lower noninfluencing
(3) Midslope
(4) Upper noninfluencing
(5) Upperslope and ridgetop
(6) Noninfluencing (flatwoods)

Users can refer to figure 2 for assistance in categorizing slope position. **This is an important variable and should be assessed carefully.** Sites characterized as noninfluencing, lower noninfluencing, or upper noninfluencing should have slopes ≤5 percent. Noninfluencing (without a modifier) should be selected when there is no major change in topography in the area (such as flatwoods). The categories upper noninfluencing or lower noninfluencing should be selected for sites having slopes ≤5 percent that have an obvious position in relation to the surrounding topography. The information on slope position is used to assess relative water movement. Sites in depressional areas or with a bowl-shaped topography should be classified as having a "lower" position if the user perceives them as gaining moisture from adjoining areas, regardless of their elevational relationship to the overall topography of the area. Similarly, sites on terraces located in midslope positions should be classified as lower if the user believes these sites are likely to have a net gain in soil moisture due to down-slope water movement. Small differences in elevation can alter the appropriate slope position code if the differences would influence water movement. For example, a large flatwoods area would generally be coded as noninfluencing; however, there may be: (a) depressional areas within the larger area that should be coded as lower or lower noninfluencing if they are in moisture-gaining positions or (b) elevated flats that should be coded as upper noninfluencing if they are in moisture-losing positions. It may be helpful to examine a topographical map having small contour intervals to pick out areas likely to be moisture gaining or losing.

[1]Water deficit is the difference between mean annual precipitation and mean annual potential evapotranspiration; the values for water deficit in the psite.dat file are in millimeters.

Select a value for percent slope from the following list:

(1) 0–2
(2) 3–5
(3) 6–8
(4) 9–11
(5) 12–15
(6) 16–19
(7) 20–29
(8) >=30

Users should select the percent-slope category that best fits the site being evaluated. The program is fairly sensitive to percent slope, so users should be as accurate as possible. They should select the value for the average slope of the general lay of the land in the area of interest rather than the value for the maximum slope. This is particularly important in eroded areas having gullies. It is also important to separate areas on terraces or steps or in bowl-shaped topography from those on nearby side slopes. The model was developed with data primarily from sites having gentle slopes; the program will print a warning message if category 8 (slopes ≥30 percent) is selected.

***Select a value for aspect from the following list:**

(1) South or Southwest
(2) All others

This request only appears if percent slope is greater than 5. Future versions of the program may break aspect into more codes; additional codes were not warranted with the low number of Coastal Plain sites having steep slopes.

Select a value for past land use from the following list:

(1) Previously forested
(2) Farming or pasture (include sites open and bare at time of regeneration)

Past land use can have both negative and positive effects on growth of the current (or planned) forest stand. Negative effects such as compaction, erosion, and loss of organic matter are addressed in other parts of the program. This part of the program is primarily concerned with assessing the **amount of early competition**, particularly hardwood competition, **present during stand establishment** and early growth. Thus, sites on fresh alluvium or sites having site preparation and vegetation control sufficient to markedly reduce hardwood competition would fall into category 2.

Please characterize past erosion on the site:

(1) None or slight (include sites with uniform sheet erosion)
(2) Moderate, rill erosion or slightly gullied (often with irregular depths of A horizon on sideslopes)
(3) Major, gullies >2 feet and <5 feet deep
(4) Severe, gullies >5 feet deep

This part of the program categorizes rill and gully erosion induced by human activity. Sheet erosion is not included here because its effects are accounted for in the sections on depth of the A horizon and effective rooting depth. The model was not tested with data from any sites having severe gully erosion; thus, site evaluation for severely eroded sites should be considered as approximate.

Select a value for drainage class from the following list:

(1) Very poorly drained
(2) Poorly drained
(3) Somewhat poorly drained
(4) Moderately well drained
(5) Well drained
(6) Somewhat excessively drained
(7) Excessively drained
(8) Permanently swampy or flooded

These drainage classes (except for 8) are the same as the standard soil drainage classes used by the Soil Conservation Service (SCS). Users should select the most appropriate drainage class for the specific site being evaluated rather than the average drainage class that might be associated with the soil series or mapping unit for the area. If users are not familiar with drainage classes or other soil terminology, they should contact their local SCS office for assistance.

Select one of the following descriptions that best describes the timing and duration of flooding:

(1) Never flooded
(2) Flooded winter only or if in early spring only for a few days
(3) Frequently flooded in late spring or summer, flood waters can cover the tops of seedlings for more than a week during the growing season
(4) Continuously flooded

Users should select the category that the best describes the timing of flooding (if any) on the site. Sites continuously flooded are unsuitable for loblolly pine; selection of this category will trigger a warning message, and the user will be given the choice of selecting a new category. Sites subject to flooding for more than a week during the growing season will be difficult to regenerate; a warning message to that effect will appear on the output.

Select one or two of the following categories for access to extra water from the following list (if two characteristics are selected, input the value as a two-digit number with the smaller digit first—17 rather than 71):

(1) Water table during the growing season of 6-10 feet
(2) Water table during the growing season of greater than 10 feet
(3) Water table during the growing season at 5 feet or less
(4) Seasonally perched water table, water table =>2 feet during winter months
(5) Seasonally perched water table, water table <2 feet during winter months
(6) Microsite relief, mounds and depressions
(7) Intermittent or ephemeral stream channels on plot
(8) Bowl-shaped topography

The listed characteristics can markedly influence soil moisture and thus site quality. The possible categories for access to extra water describe summer water tables (choices 1–3), winter water tables (choices 4 and 5), and characteristics associated with microsite relief (choices 6–8). The user should carefully select the one or two characteristics considered to be most important in influencing soil moisture. The user can input information on both summer and winter water tables; for example, a code of 25 would indicate that the water table during the growing season is deeper than 10 feet and that the site has a perched water table[2] during the winter months within 2 feet of the surface. The characteristics selected for access to extra water modify the values assigned for soil drainage; some characteristics also modify the values for water deficit.

Users should carefully consider the possible characteristics for each site to be evaluated. Several of the extra water characteristics can be affected by management activities. The effects of some activities, such as ditching, are obvious, while the effects of other activities are more subtle and need to be carefully considered. For example, road construction activities can alter water movement patterns and, in some situations, can create bowl-shaped topography. The effects of bedding can be accounted for by selecting "Intermittent or ephemeral stream channels on plot" (choice 7) and the appropriate water table category. On bedded plots, the drainage classification will also need to be changed to reflect the altered water relations, and the value for effective rooting depth will need to be increased.

[2]A perched water table is a saturated layer that is separated from ground water (the true water table) by soil or rock layers that are not saturated. Perched water tables often develop during the winter on sites having well-developed fragipans or other soil layers of low permeability. County soil surveys (available from most local SCS offices) include information on the type and depth of water tables commonly associated with a soil series or association. **Caution**—SCS soil surveys categorize sites having deep water tables as having a water table greater than 6 feet (their deepest category). **Unless** the selected site is on a stream terrace or in a floodplain, users should assume that this means that the water table during the growing season is deeper than 10 feet (category 2), rather than at 6–10 feet (category 1).

Select a value for texture of the surface horizon from the following list:

(1) Sand
(2) Coarse sand
(3) Fine sand
(4) Very fine sand
(5) Loamy coarse sand
(6) Loamy sand
(7) Loamy fine sand
(8) Loamy very fine sand
(9) Coarse sandy loam
(10) Sandy loam
(11) Fine sandy loam
(12) Very fine sandy loam
(13) Loam
(14) Silt loam
(15) Silt
(16) Sandy clay loam
(17) Clay loam
(18) Silty clay loam
(19) Sandy clay
(20) Clay
(21) Silty clay
(22) Muck or peat

Users should first enter the one- or two-digit code for the texture of the uppermost or surface horizon (below an organic horizon or litter layer if present). Sand size should be carefully considered as the model distinguishes between textures based on sand size; for example, sand and fine sand are rated differently.

The program will then request that the user select the code for the dominant texture of the subsoil horizons in the main rooting zone (the same list of codes will appear). Most soil profiles are finer textured as depth increases or have little change in texture in the profile; the presence of sand or sandy loam layers below a finer textured subsoil horizon will be addressed in a separate question.

The program will then prompt the user to enter the code for the texture of the horizon where bulk density was measured. **If bulk density was not measured,** users should input a value of 0 (zero).

***What is the bulk density in the main rooting zone of the subsoil?**

Bulk density should be measured in the first or top subsoil horizon unless the depth to the subsoil is

greater than 20 inches. If the depth to the subsoil is greater than 20 inches, bulk density should be measured at a depth of 10 to 15 inches. Horizon boundaries should not be crossed when measurements are being taken. Bulk density should be expressed in grams per cubic centimeter (g/cm^3) and the value input to the nearest 0.05 if possible (e.g., 1.35). The values used in the program were derived from samples taken with a core sampler. The bulk density values associated with deductions in site index vary by soil textural class and the strength of the soil structure.

If the user indicated that bulk density was not measured (by inputting a 0 [zero] when asked for the texture of the horizon where bulk density was measured), the program will skip over the question on bulk density. When bulk density is not input, the program assumes that bulk density in the rooting zone was at an optimum level.

Most accurate site determinations are made when all variables, including bulk density, are measured rather than estimated. If necessary, an experienced user can roughly estimate bulk density from soil texture, organic matter, and consistence. Use of the growth-limiting bulk density values based on soil texture (Daddow and Warrington 1983) can indicate approximate upper limits for bulk density values in structureless soils. Average bulk density values can sometimes be obtained from soil interpretation records available from the SCS. Obtaining accurate bulk density values is probably most important when the user knows or suspects that previous practices associated with soil compaction have occurred, for example, if the area was farmed for many years or had a lot of heavy equipment use on it. However, **please note** that some soils—especially silt loams, silty clay loams, and sandy clay loams—may have higher than optimum bulk densities independent of human activities. If users or others wish to measure bulk density for a site and have not taken this measurement before, a local Cooperative Extension or SCS office can be contacted for assistance.

Is most of the soil profile stratified?

(1) Yes, it is stratified

(2) No, it is not stratified

This question sets apart sites that have soil profiles consisting of numerous thin layers of deposited material. Stratified soil profiles are usually on stream terrace sites or in floodplains. These profiles are an indication that little in-place soil development has occurred; thus, stratified soils are usually classified as Entisols or Inceptisols. Most soil profiles are **not** stratified; if there is doubt as to whether the profile being evaluated is stratified, the answer "(2) No. . ." should be selected. The user should not answer "(1) Yes. . ." if only one horizon in the profile is stratified.

If the top subsoil horizon is *not* a sand or sandy loam, is there a sand, loamy sand, or sandy loam horizon below it?

(1) Yes, there is a sand, loamy sand, or sandy loam horizon below a finer textured B horizon

(2) No, there are no buried or stratified sand layers (includes soils that are sandy throughout)

Some profiles will not be adequately characterized by surface and subsoil texture because of the presence of deeper horizons that are much sandier than horizons closer to the surface. These include soils with buried horizons, some bisequal soils, and soils with some stratified, mixed, or layered horizons. If the answer to the question is "(2) No. . .," the program skips down to the question on structure. If the answer is "(1) Yes. . .," two or three additional questions will follow to determine the depth and texture of the sandier horizon or layer.

***Please characterize the soil using the following list as to the texture and location of the sandy layer:**

(1) Within 30 inches of the surface, texture changes from a finer texture to sandy loam

(2) Within 30 inches of the surface, texture changes from a finer texture to a sand or a loamy sand

(3) Within 60 inches of the surface, texture changes from a finer texture to a sandy loam

(4) Within 60 inches of the surface, texture changes from a finer texture to sand or loamy sand

(5) Pickup in sand content occurs at =>60 inches

This request for information only appears if the answer to the previous question was "(1) Yes. . . ." The purpose of this request is to determine the texture of the sandy layer and where in the profile it occurs.

***How thick is the sandy loam layer before a finer textured horizon is encountered?**

***How thick is the sand or loamy sand layer before a finer textured horizon is encountered?**

***What texture are the horizons below the sandy loam layer?**

***Characterize the profile from the sand or loamy sand layer on down.**

***Is the sand below 60 inches stratified, mixed, or layered?**

Depending on the response to the previous query on the location and texture of the sandy layer, one of these

five requests for information[3] will appear on the screen.

***Please indicate whether the soil profile has any of the following characteristics:**

(1) Many, moderately thick, continuous, clay bridges or films on sand grains
(2) Discontinuous or patchy clay bridges or films on sand grains
(3) Alternating bands of same textural class but different colors
(4) Alternating bands of different textural classes (e.g., sl, ls, sl, ls)
(5) Presence of one or more finer textured layers at least 3 inches thick
(6) No special features present

This request for information appears if information previously provided by the user indicated the soil was a well-drained or excessively drained sand. If the user selects answers 1 through 5, the following question is asked:

***At what depth do the special sand characteristics first occur?**

(1) <65 inches
(2) 65–85 inches
(3) >85 inches

This query will appear on the screen when the user selects answers 1–5, indicating the presence of special characteristics in deep sands that should be taken into account in predicting site index.

Select a value for the structure of the surface soil from the following list. (Use a two-digit code with one digit coming from each list; for example, weak blocky structure would be coded as 23.):

(1) Structureless	**(1) Platy**
(2) Weak	**(2) Prismatic**
(3) Moderate	**(3) Blocky**
(4) Strong	**(4) Granular or crumb**
	(5) Single-grained
	(6) Massive

This part of the program characterizes the strength and type of structure in the surface soil using standard codes. The user will then be requested to characterize the structure in the main rooting zone of the subsoil, and the list of choices will be presented again.

[3]To conserve space, the response choices provided for these requests are not listed here. The response choices are provided in a multiple-choice format.

In addition to its effect as an independent variable, structure is also used in evaluating bulk density.

Select a value for consistence of the surface soil from the following list:

(1) Loose
(2) Very friable
(3) Friable
(4) Firm
(5) Very firm
(6) Extremely firm
(7) Cemented

Consistence of moist soil should be characterized for the surface horizon. If cementation or brittleness is present in the surface 6 inches, the consistence of the A horizon should be coded as "(7) Cemented." The consistence of the subsoil should also be characterized using the same codes (the program will prompt the user for this information).

What is the average thickness of the A1 or Ap horizon (in inches)?

The thickness of the surface (topsoil) horizon should be input. Only A1 and Ap horizons should be counted (i.e., do not include A2 or E horizons). The user should input the value to the nearest 0.5 inch if the horizon thickness is less than 2 inches (e.g., 1.5). If the horizon thickness is more than 2 inches, values can be rounded to the nearest inch. Thickness of the A1 or Ap horizon should be checked at several locations across the site and an average value used. If an A1 or Ap horizon is not present, the user should enter a value of 0. If an A/E horizon is present, the user should add two-thirds (0.67) of the thickness of the A/E horizon to the thickness of the A1 or Ap horizon. For example, if the site has a 2-inch-thick A horizon and a 3-inch-thick A/E horizon, input the thickness of the A horizon as 4 [i.e., $2 + (\frac{2}{3})(3) = 4$].

The model evaluates topsoil thickness in relation to soil order and slope position. Shallow topsoil depth will be most detrimental to site quality when soil horizons are well developed (e.g., Ultisols) and sites are in midslope or upperslope positions.

What is the depth to the first B horizon (or subsoil) in the soil profile (in inches)?

The answer to this question is used in conjunction with slope position and with the change in texture between the surface soil and subsoil to calculate a correction factor to the texture value for the surface horizon. Note—use depth to the first C horizon when evaluating young soils without B horizons.

How thick is the E horizon (in inches)?
The E horizon (formerly called the A2 horizon) has been leached and is usually lighter in color than the underlying B horizon. If an E (or A2) horizon is not present, users should enter a value of 0 (zero). Users should include all E horizons **above** the first B horizon; that is, the thickness of an E1 horizon and an E2 horizon are added together if both are present. A B/E horizon should not be included unless it has the same texture as the E horizon above it and differs from the B horizon below. Buried E horizons should not be included because they are accounted for in another section of the program.

Estimate percentage of rock fragments in the A horizon(s), express as a percentage, not as a decimal.
This request requires the user to categorize the percentage of soil volume in the topsoil occupied by rock fragments. The values should be input as whole numbers and as 0 (zero) if no rock fragments are present. The program also requests the user to estimate the percentage of rock fragments in the subsoil (the program will prompt the user for this information).

Please estimate the maximum effective rooting depth for loblolly pine (in inches) using the following list:

(1) <=15
(2) 16–20
(3) 21–25
(4) 26–30
(5) 31–35
(6) 36–40
(7) 41–45
(8) 46–60
(9) >60

Effective rooting depth is the **maximum** general depth of root penetration and **not** the depth where **most** of the root system is located. Effective rooting depth should be measured from the level of the root collar to the depth of maximum root penetration. Estimating maximum rooting depth is fairly easy if the site is being evaluated using a large soil pit and if mature loblolly pine trees are present on the site. Effective rooting depth is probably similar for many tree species, so rooting depth for loblolly pine could be estimated from rooting depth of sweetgum, *Liquidambar styraciflua* L., or slash pine, *P. elliottii* Engelm. var. *elliottii*, (for example) if loblolly pine were not on the site. Tree species have low rooting densities compared to grasses or many agricultural plants; thus, the person doing the estimating should be careful not to underestimate rooting depth based on roots seen when using an auger.[4]

If roots from mature trees are not present on the site, rooting depth must be estimated from soil characteristics (and personal experience). Loblolly pine roots do penetrate into and through some horizons having cemented pans. Thus, rooting depth should not be taken as the depth to the top of the first horizon having cementation or brittleness. If better information is not available, effective rooting depth for sites with well-developed pans can be estimated by adding 10 inches to the depth of the first horizon that has a well-developed pan. (Horizons having only partial or moderate pan development should be included in the estimation of rooting depth). Tree rooting is restricted by firm or very firm clay layers; however, effective rooting depth should not be estimated as the depth to the top of the clay layer because: (a) the clay layer will supply some water to overlying soil layers via capillary rise and (b) some rooting will probably be formed in the clay layer along ped faces[5] or in the areas where organic materials are decomposing. Estimating effective rooting depth as the depth to a clay layer would imply that the clay layer is as inert as rock. Thus, to determine an equivalent value for effective rooting depth when other information is not available, the user should add 15 inches to the depth of the clay layer when the consistence of the clay is firm or 10 inches when the consistence is very firm. For example, if a very firm clay layer begins at 20 inches, one can assume that effective rooting depth is 30 inches (category 4, 26–30 inches).

Effective rooting depth is evaluated in conjunction with soil drainage classification. One should be careful not to underestimate rooting depth on bedded sites or when microtopography is present. On poorly or very poorly drained sites having microrelief (natural or artificial), most trees will be on the high spots. One should keep this relationship in mind when estimating effective rooting depth (i.e., remembering to measure from the root collar).

Very shallow rooting depths (1) ≤15 inches, will trigger a warning message that the site is unsuitable for loblolly pine. The user will be given the option of selecting another value for rooting depth or exiting the program.

[4]When medium-size roots are present in an auger sample, this is usually an indication that fine roots are present at greater depths.

[5]Peds are the natural units of soil structure, such as a block or granule. A ped face is the surface of this structural unit.

Select a value for soil order from the following list:

(1) Entisol or Inceptisol
(2) Alfisol or Ultisol
(3) Spodosol
(4) Vertisol
(5) Histosol
(6) Mollisol

These soil orders are those used in USDA Soil Taxonomy (Soil Survey Staff 1975). If the area is mapped by soil series, soil association, or soil mapping unit, the appropriate order can probably be determined from that information. It is **not** necessary to know soil series. Soil order is used in the model as an indication of weathering (i.e., nutrient availability). In addition to its use as an independent variable, soil order is also used to evaluate the effects of both topsoil depth and percentage of organic matter on site quality.

The model was developed and tested primarily with data from Entisols, Inceptisols, Alfisols, Ultisols, and Spodosols. Selection of other soil orders will trigger warning messages to be printed on the program output. The warning message for Vertisols is that trees may have form problems, especially on side slopes, due to the presence of shrink-swell clays. Selection of Histosols results in a warning message that model values for organic soils should be viewed as preliminary. Selection of Mollisols results in a message that the model has not been tested with data from Mollisols.

Select a value for average pH of the surface soil (from 0 to 6 inches):

(1) <3.5
(2) 3.5–3.89
(3) 3.9–4.29
(4) 4.3–5.59
(5) 5.6–6.79
(6) 6.8–7.59
(7) 7.6–8.49
(8) >= 8.5

First, the user should select a value for pH (measured in water) for the surface soil. If the top horizon is less than 6 inches thick, the pH value should be weighted according to the depths of the horizons in the zero to 6 inch layer. Soil pH is used as an indication of nutrient availability. Very low or high pH values (i.e., choices 1 or 8) will trigger a warning message that the site is unsuitable for loblolly pine. The user is given the choice of changing the pH value for the site or exiting the program.

Next, the user should select a value for average pH of the soil at 12 inches (the program will prompt the user). This information is used to identify sites with major pH changes in the portion of the profile where heavy rooting occurs. Most sites exhibit little change or a small decrease in pH with depth. Sites that have been limed may exhibit a major drop in pH below the surface layer. In contrast, some sites change from acidic to basic because of differences in parent material. Although the program asks for the pH at 12 inches, users should use their judgment in responding. For example, if a major change in pH occurs between the surface soil and a horizon that begins at 14 inches, the pH value from the horizon beginning at 14 inches is probably a better choice than the value at exactly 12 inches. On the other hand, even major changes in pH that occur deep in the profile are probably not significant in their effects on nutrient availability.

Select a value for extractable phosphorus concentration of the surface soil (0 to 6 inches) from the following list:

(1) <0.5
(2) 0.5–0.9
(3) 1.0–1.3
(4) 1.4–1.7
(5) 1.8–2.1
(6) 2.2–3.0
(7) 3.1–5.0
(8) 5.1–7.0
(9) 7.1–10.0
(10) 10.1–15.0
(11) 15.1–25.0
(12) 25.1–50
(13) >50
(14) I have no idea

The values for extractable-phosphorus concentration (phosphorus soluble in dilute hydrochloric acid and sulfuric acid, Olsen and Sommers 1982—also known as double-acid phosphorus or Mehlich-1 phosphorus) are expressed in parts per million (ppm). The program evaluates phosphorus values in relation to drainage class. If extractable P is not known for the site being evaluated, values from similar sites in the area or published values from the soil series can be used as an estimate if the same chemical analysis procedure was used. However, some soil series[6] have wide ranges in P concentrations; use of average values for these series may markedly reduce the accuracy of the site index prediction. In addition, for imperfectly drained sites, the PTSITE model predicts greater changes in site index based on P concentration than changes based on any other variable. Thus, the user is strongly encouraged to obtain site-specific information on extractable P if accurate estimates of site index are desired. If no

[6]Soils with the widest range in P values appear to be located primarily on the eastern half of the Atlantic Coastal Plain.

information is available on P concentration, the user can select "I have no idea" option. The program will then give the user the choice of having the program select a "BEST GUESS" value for P concentration or exiting the program. "BEST GUESS" values are based on averages by drainage class and should be considered as only very approximate values.

Users or others who would like to obtain a value for extractable phosphorus but have not collected soil samples before should use the following procedure: collect soil from the 0- to 6-inch layer at several (5 to 10) spots in the area of interest. Remember to remove the organic layer before taking the sample. An easy way to take the samples is with a push probe. (Many county Cooperative Extension or SCS offices have push probes that can be borrowed). Remove any roots, other organic material (such as needles, leaves, and twigs), and rock fragments (with a 2-mm sieve or by picking the pieces out by hand). Thoroughly mix together the soil from the different sampling spots. Let the sample air-dry, and then send a representative subsample to a laboratory for analysis.

Cooperative Extension agents have access to a soil testing service, so users or others interested should contact their local Extension office for more information. The Extension office will specify how much soil to send, and they may provide shipping containers for this purpose. **Remember** to specify that the laboratory is to use the double-acid extractable-phosphorus procedure (also known as Mehlich 1) and ask that the results be reported in parts per million (ppm).[7] Users will probably also want to have the laboratory analyze the sample for organic matter content. If suitable soil analyses[8] are not available through the local Extension office or through one's organization, the local Extension agent should be asked to check with a soils specialist, or one can contact the soils department in a nearby college or university and ask for the name of a reliable laboratory.

***Select a value for the percentage of organic matter in the surface soil (from 0 to 6 inches) from the following list:**

(1) <1
(2) 1–1.9
(3) 2–3.9
(4) 4–6.9
(5) 7–9.9
(6) >=10

Choices are given for percentage of organic matter content in the top 6 inches of soil. If the user has values for individual horizons, a weighted value for the top 6 inches of surface soil should be used. Organic matter content is evaluated in relation to soil order. Concentrations of 1.5 to 2.5 percent are common on well-drained forest sites when soil orders are not Spodosols or Histosols. If the user indicated in the question on soil order that the soil is a Histosol, the model assumes that the organic matter content of the soil is high and skips over this part of the program. Sites having fresh alluvium, a history of agricultural use, or intensive site preparation will probably have lower values. Organic matter in piles or windrows should not be considered as part of the site.

Users may want to have the soil tested at a laboratory for organic matter content. They should refer to the discussion above on phosphorus for the procedure to be used in collecting the samples. If the user wants to obtain accurate values for organic matter determinations, it is especially important that roots, charcoal, and other organic material be carefully removed before analysis.

Select a value for the parent material of the soil from the following list:

(1) Coastal Plain sediments (or organic materials)
(2) Loessal material deposited over Coastal Plain sediments (loess less than 4 ft thick)
(3) Silty alluvium
(4) Thick loessal deposits (loess greater than 4 ft thick)

This information on parent material helps characterize the general fertility of the soil. In addition, thin loess deposited over Coastal Plain sediments is much less favorable for tree growth than thick loess deposits because of both the thinner layer of nutrient-rich material and the presence of fragipans that commonly develop when this combination of materials is present (particularly on sites having slow internal water movement). Sites having thickness of loess at approximately 4 feet should be classified only as "(4) Thick loessal deposits. . ." if a pan is not present within 4 feet of the surface. If the user indicated that the soil order is a Histosol, the program assumes the parent material is organic and skips this portion of the program.

[7]Users having extractable-phosphorus values in units of pounds per acre or pounds per acre-furrow-slice should divide by 2 to convert to parts per million.

[8]For example, some laboratories are primarily set up for analyzing nutrient requirements for agricultural crops and may not be able to provide information on double-acid extractable phosphorus.

Appendix B

—Definitions and ranges for program variables

a1orval—Evaluation of the thickness of A1 or Ap horizon in relation to soil order and slope position. Possible values range from 0 (any A horizon thickness value if soil order is Entisol or Inceptisol or an A horizon at least 5 inches thick if any other order) to −7.5 (A horizon less than 1 inch thick, soil order not Entisol or Inceptisol, and midslope or upperslope positions).

aspval—Evaluation of aspect in relation to percent slope. Possible values range from 0 (aspects other than south or southwest) to −3 (south or southwest aspects when slope is ≥20 percent).

consval—Evaluation of soil consistence. Possible values range from 0 (any consistence if rooting depth is more than 40 inches) to −6 (rooting depth less than 40 inches with firm soil consistence) to −13 (rooting depth less than 40 inches and A horizon is cemented, or cementation occurs in the top 6 inches of soil).

drconv—Conversion factor based on drainage class used to convert 50-year site index predictions to 25-year predictions. Values range from +5 (excessively drained) to −6 (very poorly drained).

drexval—Evaluation of soil drainage class and access to extra water. Possible values range from +5 (moderately well or well drained with summer water table at 6 to 10 feet and intermittent stream channels present) to −8 (excessively drained with no special features).

drppval—Evaluation of extractable phosphorus in relation to soil drainage class. Possible values range from +4 (P>50 ppm, any drainage class) to −16 (P<0.5 ppm **and** drainage class is very poor). Within a drainage class the relationship between phosphorus class and drppval is exponential.

eroval—Evaluation of past gully erosion. Possible values range from 0 (no or slight erosion) to −10 (severe gully erosion).

floodval—Evaluation of frequency and timing of flooding. Possible values range from +2 (flooded in winter or early spring) to −10 (flooded in late spring or summer). Continuous flooding will result in the site being judged unsuitable for loblolly pine.

omorval—Evaluation of organic matter in relation to soil order. Possible values range from 0 to −8. Low amounts of organic matter are considered less detrimental when the soil order is an Entisol or an Inceptisol than when it is one of the other possible orders for mineral soils. Histosols are automatically assigned a value of 0 for omorval.

orval—Evaluation of soil order. Possible values range from 0 (Entisols or Inceptisols having a soil texture that is not sand[1]) to −12 (Spodosols) and −17 (Histosols). Several soil orders result in warning messages being printed on the output.

phval—Evaluation of surface pH. This value is modified if pH changes with depth. Possible values range from 0 to −12. The highest values of phval are assigned for sites with pH values between 4.39 and 5.5. Phval can also result in the site being judged unsuitable for loblolly pine (pH <3.5 or pH >8.5).

pmval—Evaluation of soil parent material. Possible values range from +6 (thick loess deposits) to 0 (Coastal Plain sediments or organic parent material).

puval—Evaluation of past land use. Possible values range from +4 (agricultural past use or intensive competition control) to 0 (past land use was forest).

rfval—Evaluation of rock fragment content. Possible values range from 0 to −8. No deduction is made unless rock content in the A horizon or average rock content in the soil profile is equal to or greater than 20 percent.

rtdval—Evaluation of effective rooting depth. This is done separately for each drainage class. Possible values range from 0 to −15. Extremely shallow rooting depths (less than 15 inches) will result in the site being judged unsuitable for loblolly pine.

sbandval—Evaluation of special features in deep, well-drained sands that improve site quality. The type of feature and the depth in the soil profile where the feature is first observed are used in the evaluation. Values range from 0 (no special features) to +5 (one of the following occurring within 65 inches of the soil surface: continuous clay films on sand grains, layers of alternating texture, or presence of at least one finer textured layer at least 3 inches thick).

slslval—Evaluation of slope position and percent slope. Possible values range from 0 to −20. Sites in lower or lower noninfluencing slope positions having slopes of 0 to 2 percent receive the best rating. Sites in upperslope positions having slopes greater than 25 percent receive the worst rating. Slope position is also considered in the evaluation of a1orval.

stratval—Evaluation of stratified soil profile. Possible values are +3 (stratified) and 0 (not stratified).

stval—Evaluation of soil structure. Possible values range from 0 (granular or crumb structure) to −6 (massive, with clayey subsoil texture). Structure is also considered in the evaluation of texsval.

tckeval—Evaluation of thickness of the E horizon. Possible values range from 0 to −5. Any E horizons less than 6 inches thick are assigned a value of 0. The value for tckeval is constrained so that the sum of texaval and tckeval is equal to or greater than the most negative value possible for texaval.

texaval—Evaluation of texture of the surface horizon. Possible values range from 0 to −13. Soil textures receiving the highest values for texaval are fine

[1]The purpose of this textural restriction is to separate sands that have low nutrient-holding capacity from other young soils that generally have higher nutrient-supplying abilities.

sandy loam, very fine sandy loam, loam, silt loam, and silt. Soil textures receiving the lowest values are sand and coarse sand.

texcval—Evaluation of change in texture from the surface horizon to the subsoil. This is evaluated in relation to depth to subsoil, texture of the topsoil, and slope position. Possible values range from +5 (sites having sandy topsoil, much finer textured subsoil close to the surface, and in midslope or upperslope positions) to −2 (sandy clay or sandy clay loam subsoil when surface soils are not sandy).

texsand—Evaluation of the presence of a sand or sandy loam horizon below the first subsoil horizon. Possible values range from 0 to −12. Thick, coarse-textured horizons close to the soil surface are more detrimental than thin, finer textured horizons deep in the profile.

texsval—Evaluation of bulk density of the subsoil with soil texture and structure taken into account. Possible values range from 0 to −8. For a given bulk density and soil texture class, the values of texsval are higher (i.e., less negative) when soil structure is strongly developed.

wdval—Evaluation of the effects of water deficit. The value is modified by the codes used for access to extra water. Possible values range from 0 to −8. Mean annual water deficits of less than 2 inches are optimum. Wdval is lowest for sites having water deficits of 4 inches or more and seasonally perched water tables close to the soil surface during the winter.

Appendix C

—Example of sample output

The meaning of the numerical codes used in the listing of the program inputs (the top section of the output) can be determined from appendix A. Negative values for program variables (listed at the bottom section of the output) indicate which variables are considered to be at suboptimum levels. Program variables are defined in appendix B.

PTSITE
Soil-site Prediction System for Loblolly Pine
Site ID—Crossett Experimental Forest, Compartment 3, Stand 7

Input Values

County	ASHLEY	State	AR
Slope position	6	Percent slope	1
Aspect	0	Past land use	1
Past erosion	1	Drainage class	3
Flooding	1	Extra water	25
Texture of surface	14	Texture of subsoil	14
Texture for bulk density	14	Bulk density	1.2
Stratification	N	Presence of sand layer	N
Structure of the surface	24	Structure of the subsoil	23
Consistence of the surface	2	Consistence of the subsoil	3
Thickness of A1 or Ap	4	Depth to subsoil	4
Thickness of E horizon	0	Surface rock content	0
Subsoil rock content	0	Effective rooting depth	4
Special features in sands	N	Soil order	2
pH surface	4	pH subsoil	4
Extractable phosphorus	4	Organic matter	3
Parent material	2	Water deficit	50

Site index (50-year) = 93 feet
Site index (25-year) = 63 feet

Program Variables

a1orval	−1	aspval	0
consval	0	drconv	−1.5
drexval	−2	drppval	−5
eroval	0	floodval	0
omorval	0	orval	−9
phval	0	pmval	2
puval	0	rfval	0
rtdval	−6	sbandval	0
slslval	−4	stratval	0
stval	0	tckeval	0
texaval	0	texcval	0
texsand	0	texsval	0
wdval	−3		

Harrington, Constance A. 1991. PTSITE—a new method of site evaluation for loblolly pine: model development and user's guide. Gen. Tech. Rep. SO-81. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 28 p.

A model, named PTSITE, was developed to predict site index for loblolly pine based on soil characteristics, site location on the landscape, and land history. The model was tested with data from several sources and judged to predict site index within ±4 feet ($p<0.05$). A computer program for IBM-compatible personal computers was developed based on the model; the program is available by request.

Keywords: computer programs, expert systems, models, *Pinus taeda*, site index, site quality.