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Site Class and Site Index:

Two Estimates of Site Quality for the Southern Research Station Forest Inventory and Analysis Program

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Abstract—Information on site quality, the capacity of forested land to grow wood, is an important component in forest inventories. Site index and site class are two variables that describe forest site quality. Site index is usually defined as the average total height that the dominant and codominant trees in fully stocked, even-aged stands will attain at key ages. Site class is a classification of forest land in terms of the capacity to grow repeated crops of industrial wood. This classification is based on the maximum mean annual increment, in cubic feet per acre, of natural, well-stocked, even-aged stands of species suitable to the local site. This paper documents and describes the equations, methods, and data used by the Forest Inventory and Analysis program of the U.S. Department of Agriculture Forest Service, Southern Research Station, to estimate site index and site class for forest inventories conducted in the Southern United States.

Keywords: Site class, site index, forest inventory, growth and yield, Southern United States.

Introduction

In timber management, site quality refers to the capacity of a location to grow wood, information that is important for nearly all forest management activities. Rotation length, thinning schedules, and species composition are just a few of the decisions influenced by site quality. A host of abiotic and biotic processes affect site quality. Many abiotic factors such as soils, topography, and climate change slowly. On the other hand, biotic factors such as genetic composition and competing vegetation can change quickly. Spurr and Barnes (1973) point out that biotic and abiotic processes constantly modify each other and cause site quality to be quite dynamic. This makes site quality difficult to measure.

While many methods of evaluating site quality have been developed, site index is the most widely used indicator of site quality for timber in the United States. Site index is usually defined as the average total height that the dominant and codominant trees in fully stocked, even-aged stands will attain at key ages (Husch and others 1982).

Site class is a classification of forest land in terms of the capacity to grow repeated crops of industrial wood. This classification is based on the maximum mean annual increment (MAI), in cubic feet per acre, of natural, well-stocked, even-aged stands of species suitable to the local site.

Because some description of site quality is an important part of forest inventories, the national Forest Inventory and Analysis (FIA) program of the Forest Service, U.S. Department of Agriculture, uses site class and site index to describe forest site quality. This paper documents the data and methods used by the Southern Research Station FIA program (SRS FIA) to obtain site class and site index estimates in forest inventories in 13 States (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia), as well as the Commonwealth of Puerto Rico and the Territory of the U.S. Virgin Islands.

Southern Tree Species Site Classes and Site Indices

The site classes and site indices used by SRS FIA have been compiled from several decades of forest growth and yield research from across the Southern United States. The SRS FIA site classes and the MAI range for each class are presented in table 1. Josephson (1962) calculated the maximum MAI from yield tables for several important timber species or species groups in the United States. In some cases, yields were reduced to account for a large proportion of non-growing stock material included in the yield tables. For each species, the maximum MAI was plotted against site index. The site index corresponding to the lower limit of each site class was read from this graph. Site class could be determined by comparing the site index to the site class minima (Scott and Voorhis 1986).

Putnam and Broadfoot (1965) followed the same type of procedure for water oak (*Quercus nigra*), cherrybark oak (*Q. pagoda*), and eastern cottonwood (*Populus deltoides*). Table 2 presents the list of SRS FIA site tree species and the associated yield studies.

Field Data Collection

Site tree data are required for every forested condition on an FIA plot. (Note that we will use the term "condition" in reference to the practice of subdividing FIA plots based on criteria described in the FIA National Core Field Guide [USDA Forest Service 2018a].) The SRS FIA field crews typically record data for one site tree, with a maximum of two site trees, for each forested condition on a portable

Table 1—Southern Research Station Forest Inventory and Analysis site classes and the mean annual increment (MAI) range for each class in cubic feet per acre

Site class code	Maximum MAI range for class *(ft³/acre)*
1	≥225
2	165–224
3	120–164
4	85–119
5	50–84
6	20–49
7	<20

Table 2—Species with yield table and site index curve and equation references for Southern Research Station Forest Inventory and Analysis site trees

Species	Yield table reference	Site index curve and equation references
Softwoods		
Loblolly pine (*Pinus taeda*)	Schumacher and Coile 1960	Schumacher and Coile 1960
Longleaf pine (*Pinus palustris*)	Schumacher and Coile 1960	Schumacher and Coile 1960
Sand pine (*Pinus clausa*)	Schumacher and Coile 1960	Schumacher and Coile 1960
Slash pine (*Pinus elliottii*)	Schumacher and Coile 1960	Schumacher and Coile 1960
Shortleaf pine (*Pinus enchinata*)	Schumacher and Coile 1960	Schumacher and Coile 1960
Pond pine (*Pinus serotina*)	Schumacher and Coile 1960	Schumacher and Coile 1960
Virginia pine (*Pinus virginiana*)	Schumacher and Coile 1960	Carmean and others 1989
Atlantic white-cedar (*Chamaecyparis thyoides*)	Korstian and Brush 1931	Carmean and others 1989
Eastern white pine (*Pinus strobus*)	Frothingham 1914 as cited in Parresol and Vissage 1998	Parresol and Vissage 1998
Hardwoods		
Sweetgum (*Liquidambar styraciflua*)	Winters and Osborne 1935	Carmean and others 1989
Yellow-poplar (*Liriodendron tulipifera*)	McCarthy 1933	Carmean and others 1989
Upland oaks (*Quercus* spp.)	Shunur 1937	Wiant 1975
Water oak (*Quercus nigra*) growing on bottomland sites	Putnam and Broadfoot 1965	Carmean and others 1989
Cherrybark oak (*Quercus pagoda*)	Putnam and Broadfoot 1965	Carmean and others 1989
Eastern cottonwood (*Populus deltoides*)	Putnam and Broadfoot 1965	Carmean and others 1989

data recorder (PDR). A single site tree can be recorded for multiple forested conditions if the differences between those conditions are not based on differences in site productivity, such as reserved status or ownership. A site tree must be an acceptable species that has been dominant or codominant through its life and free from damage. In addition, for the Eastern United States, site trees must be between 15 and 100 years old (ideally 20 to 70 years old) and the diameter at breast height (d.b.h.) >5.0 inches.

Trees outside the forest inventory subplot are selected as site trees whenever possible. But trees that are part of the current inventory sample within the subplot boundaries may be chosen if necessary. For new site trees, the field foresters record the species and measure d.b.h., tree length, tree age at diameter (determined by an increment sample), and any relevant notes about the site tree. Optionally, they might also note the nearest subplot number, azimuth to that subplot center, and horizontal distance to that subplot center for site trees outside of subplots, information that would be collected for trees that are within subplots. For a site tree that has been previously measured, the PDR presents the field foresters with its species, d.b.h., and total length of the tree. The field foresters then enter the updated tree measurements and the tree's total age.

Site trees may not be available for some forested conditions, in which case the field forester assigns site class based on experience. On plots where site trees from the prior survey are no longer present to be remeasured due to disturbances, treatments, or mortality and there are no new site trees available, the field crew copies the species, d.b.h., total age, and total height of those site trees from the prior survey.

The data recorder checks the species, d.b.h., total age, and total height of all site trees for data entry errors. After completion, field data are transmitted to the SRS FIA office where all data are edited and checked again as part of data processing by the FIA National Information Management System (NIMS).

Determination of Site Index and Site Class

Figures 1–15 (see pages 4-11) present the southern regional site index equations, site class curves, and sources used by SRS FIA. The site class curves are reproduced from the southern regional version of the National Core Field Guide (USDA Forest Service 2018a).

Site index formulations were chosen for compatibility and accuracy when compared to the original site index and yield studies. The index age for eastern cottonwood is 30 years while the index age for all other species is 50 years. Site class for each tree is determined by comparing the site index to the site class minima established by Josephson (1962). Some equations that appear here are the back-transformed version of originally log-transformed equations.

The site class assigned to the condition is the best indicated by the different site trees. The site index for the plot is the highest site index within the best site class. Thus, site index and site class assignments are made from a single site tree. For example, if a yellow-poplar (*Liriodendron tulipifera*) with a site index of 115 (based on the tree being 30 years old and 115 feet tall) and a sweetgum (*Liquidambar styraciflua*) with a site index of 119 (based on the tree also being 30 years old and 119 feet tall) occurred on the same condition, site index and site class would be based on the yellow-poplar since the site class for the yellow-poplar (site class 2) is better than the site class for sweetgum (site class 3). The site class in this example would be 2 and site index would be 115.

For those conditions where no site trees were recorded, site index is estimated based on the site class and physiographic class assigned by the field forester (table 3). Generally, the assigned site indices are simply the midpoints of the site class for a widespread species compatible with the physiographic class. However, for the extremely poor and extremely good sites, the assigned site indices are either the extremes published in the original studies or are just beyond the extremes found by Josephson (1962).

Table 3—Southern Research Station Forest Inventory and Analysis site index assignments by physiographic class and site class (for 30 years' growth for cottonwood and 50 years' growth for all other species, in feet) for conditions without site trees

Physiographic class	Site class						
	1	2	3	4	5	6	7
1[a]	105	104	95	79	63	46	37
2[b]	120	110	102	87	70	55	50
3[b]	120	110	102	87	70	55	50
4[b]	120	110	102	87	70	55	50
5[b]	120	110	102	87	70	55	50
6[c]	136	135	122	97	77	61	50
7[d]	115	107	94	81	67	54	47
8[d]	115	107	94	81	67	54	47
9[d]	115	107	94	81	67	54	47
10[d]	115	107	94	81	67	54	47
11[d]	115	107	94	81	67	54	47
12[d]	115	107	94	81	67	54	47
13[d]	115	107	94	81	67	54	47

[a] Based on shortleaf pine.
[b] Based on loblolly pine.
[c] Based on yellow-poplar.
[d] Based on water oak.

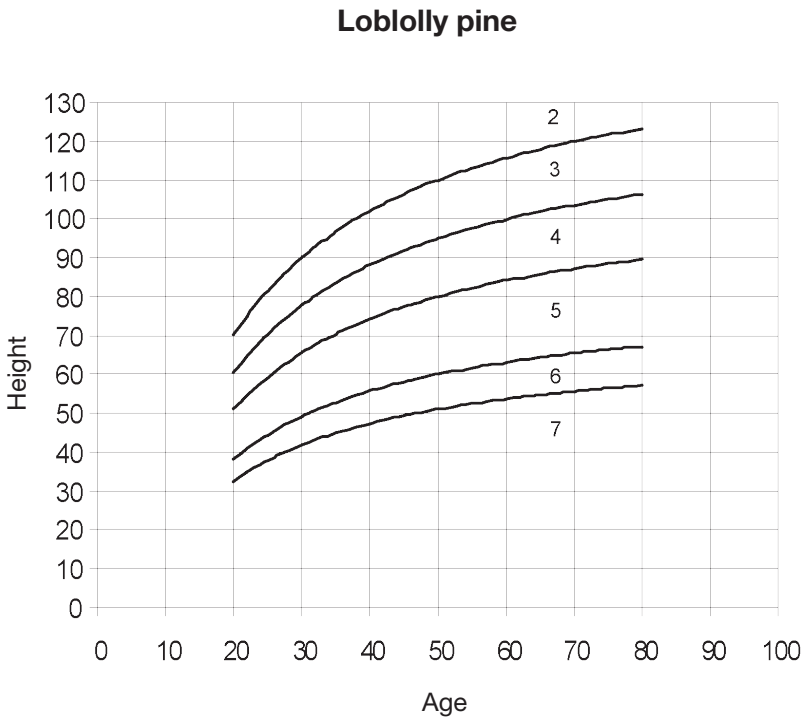

Figure 1—Loblolly pine (*Pinus taeda*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, and H = total height (Schumacher and Coile 1960).

$$SI = 10^{6.528\,(1/A\,-\,1/50)\,+\,\log(H)}$$

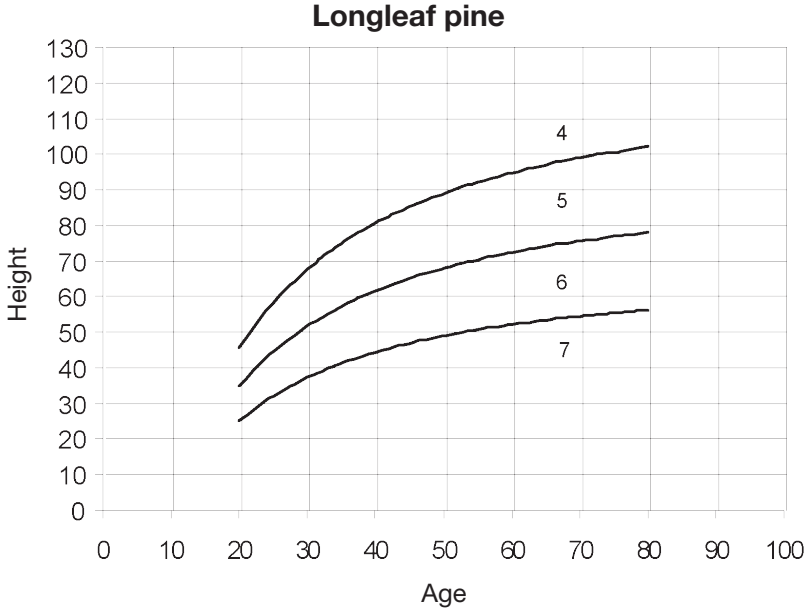

Figure 2—Longleaf pine (*Pinus palustris*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, and H = total height (Schumacher and Coile 1960).

$$SI = 10^{6.33645(1/A\,-\,1/50)\,+\,44.550(\,(1/A)^2\,-\,(1/50)^2\,)\,+\,\log(H)}$$

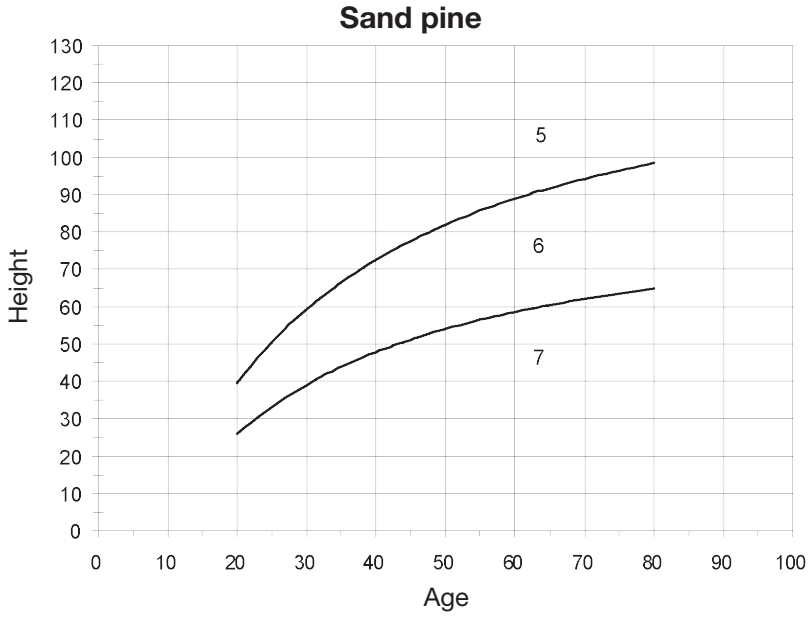

Figure 3—Sand pine (*Pinus clausa*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI =site index, A = total age of tree, and H = total height (Schumacher and Coile 1960).

$$SI = 10^{10.557(1/A - 1/50) + \log(H)}$$

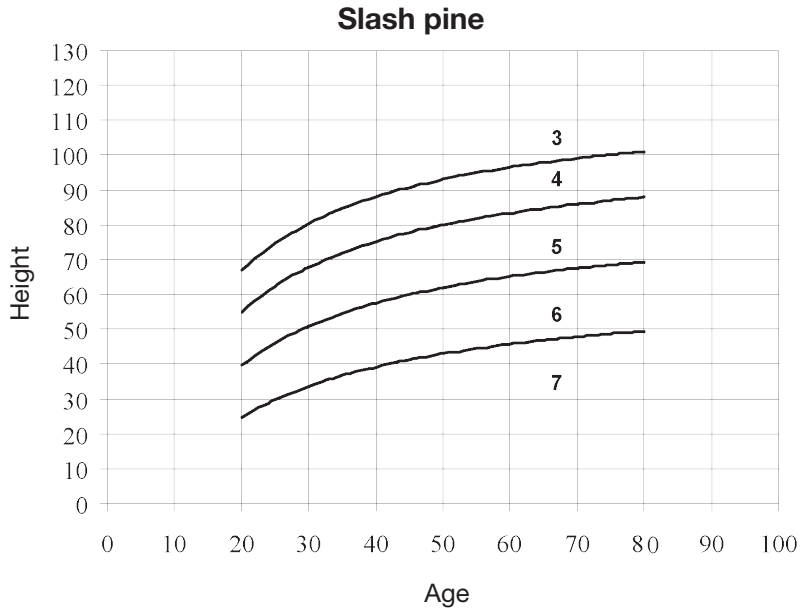

Figure 4—Slash pine (*Pinus elliottii*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, and H = total height (Schumacher and Coile 1960).

$$SI = 10\left(\frac{\log(H) + \frac{2.907}{A} - 0.4781}{0.8057 + \frac{9.7172}{A}}\right)$$

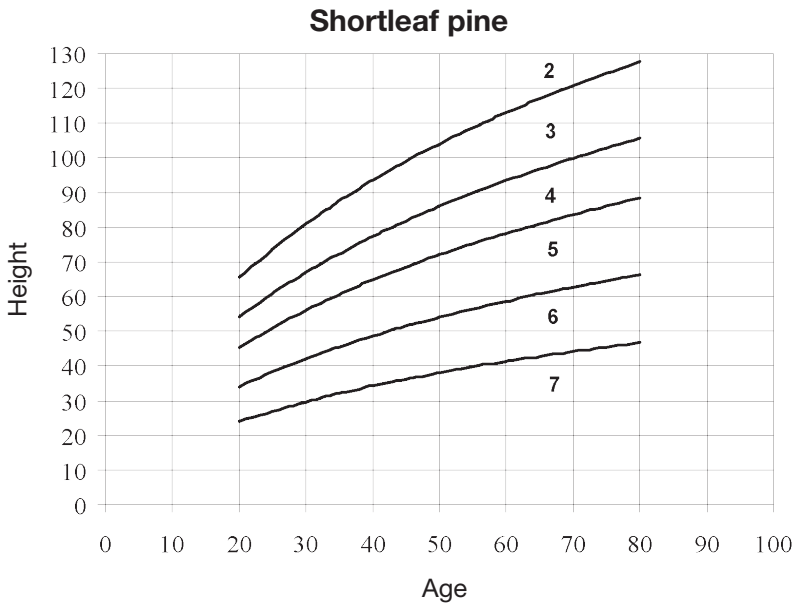

Figure 5—Shortleaf pine (*Pinus echinata*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, and H = total height (Schumacher and Coile 1960).

$$SI = 10^{-4.9525(1/A - 1/50) + 42.3588((1/\sqrt{A}) - (1/\sqrt{50})) + \log(H)}$$

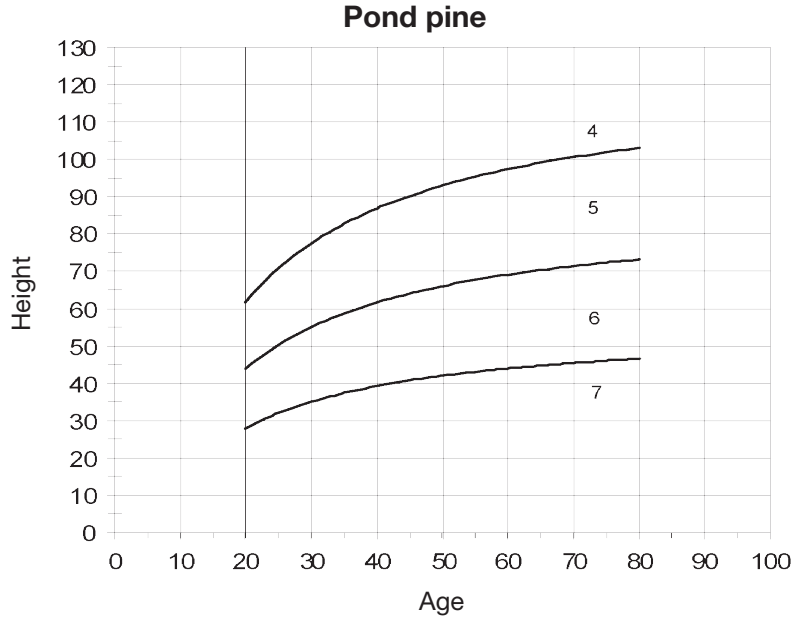

Figure 6—Pond pine (*Pinus serotina*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, and H = total height (Schumacher and Coile 1960).

$$SI = 10^{5.940(1/A - 1/50) + \log(H)}$$

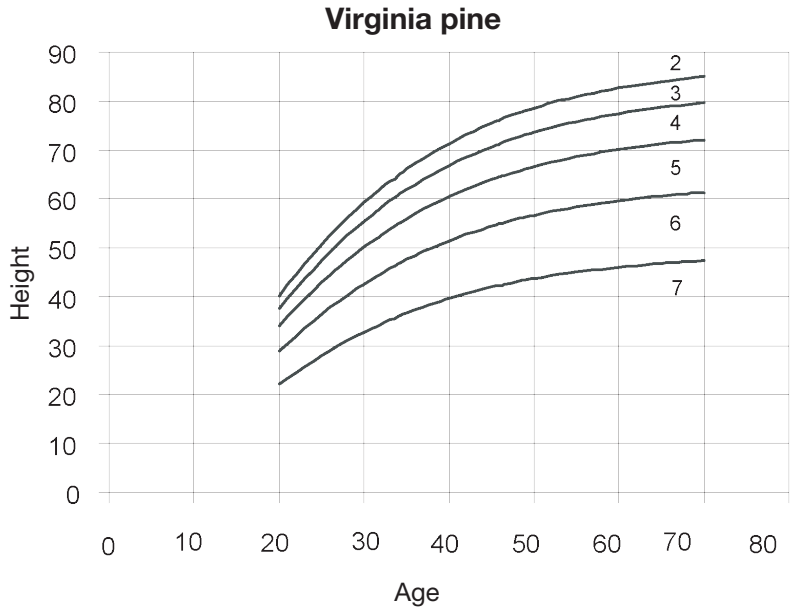

Figure 7—Virginia pine (*Pinus virginiana*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Carmean and others 1989, which cites Chaiken and Nelson 1959 and Nelson and others 1961 as the original data sources).

$$SI = 0.8421\,H^{1.0090}\left(1 - e^{-0.0490A}\right)^{-2.1682H^{-0.0762}}$$

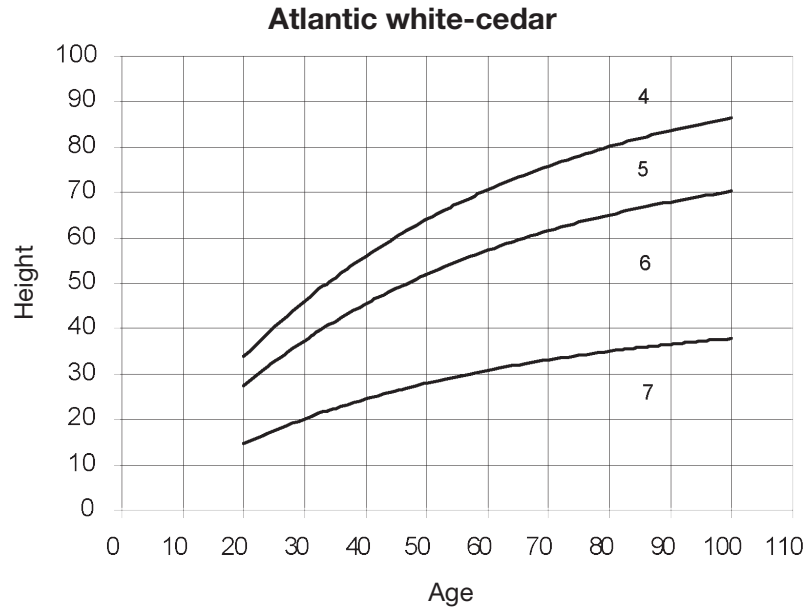

Figure 8—Atlantic white-cedar (*Chamaecyparis thyoides*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = Site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Carmean and others 1989, which cites Korstian and Brush 1931 as the original data source).

$$SI = 0.6528H^{1.000}\left(1 - e^{-0.0213A}\right)^{-1.0243H^{-0.0046}}$$

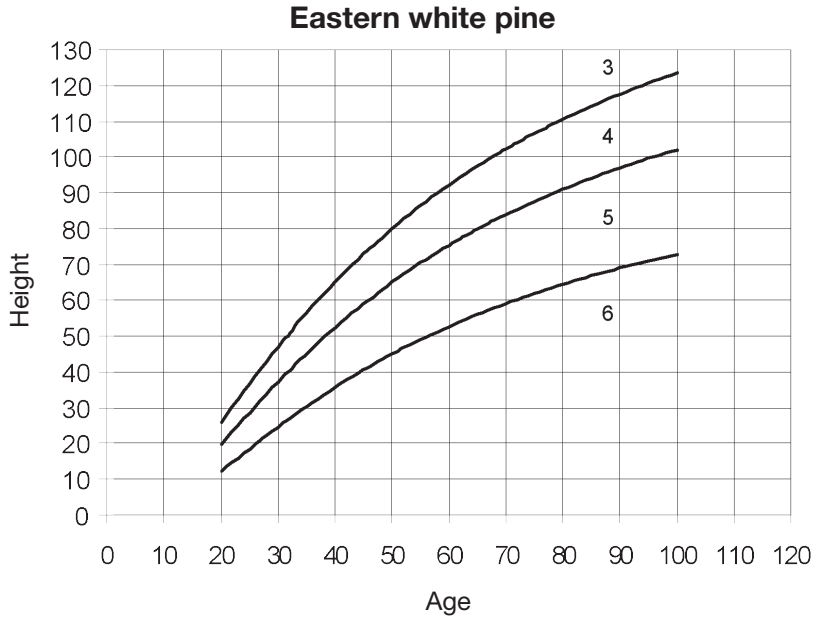

Figure 9—Eastern white pine (*Pinus strobus*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = Site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Parresol and Vissage 1998).

$$SI = e^{\left(1.1881\, e^{\frac{-8.6188}{A}}\right)\left(\ln(H) + \frac{74.7099}{A} - 2.0862\right) + 0.5920}$$

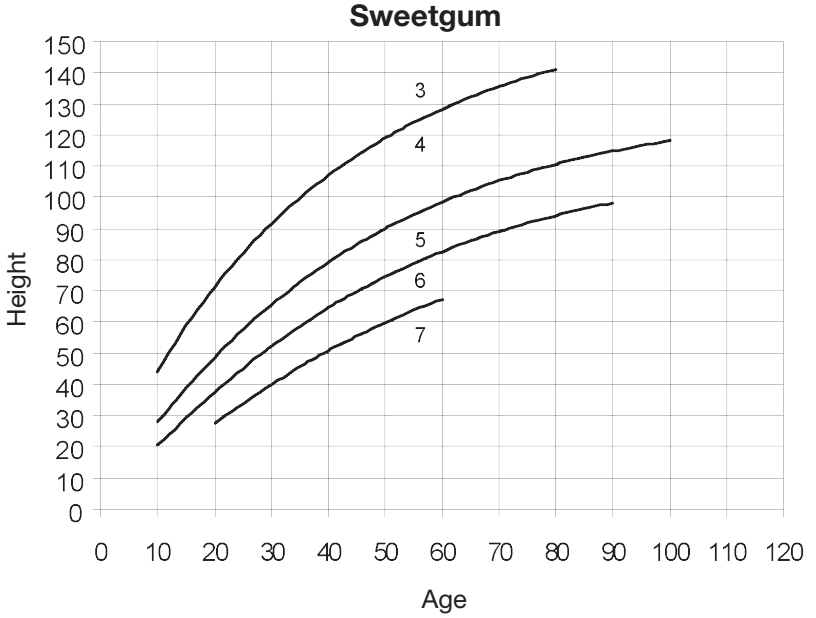

Figure 10—Sweetgum (*Liquidambar styraciflua*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Carmean and others 1989, which cites Winters and Osborne 1935 as the original data source).

$$SI = 0.0055\, H^{1.6414}\left(1 - e^{-0.00026A}\right)^{1.7678H^{-0.2712}}$$

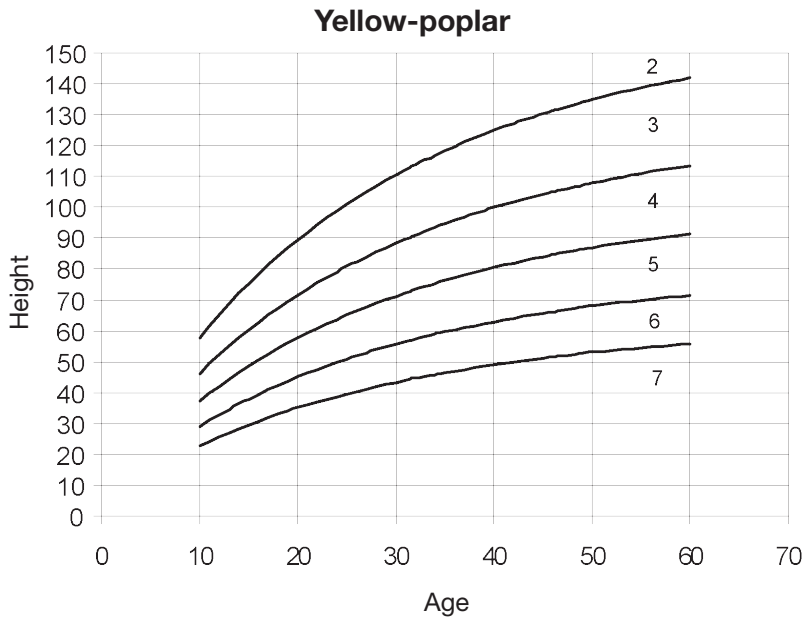

Figure 11—Yellow-poplar (*Liriodendron tulipifera*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Carmean and others 1989, which cites Beck 1962 as the original data source).

$$SI = 0.8323\, H^{1.0051}\left(1 - e^{-0.0352A}\right)^{-0.9706H^{-0.0303}}$$

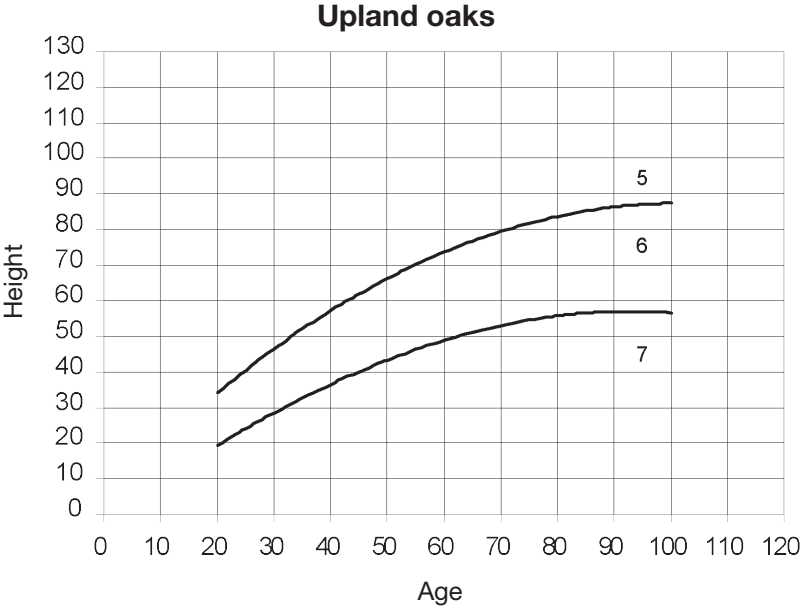

Figure 12—Upland oaks (*Quercus alba, Q. coccinea, Q. falcata, Q. imbricaria, Q. palustris, Q. prinus, Q. rubra, Q. stellata,* and *Q. velutina*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, and H = total height (Wiant 1975).

$$SI = 62.7 + 8.37\left(\frac{H - \left(81.63249 - 0.00786\left(100 - A\right)\right)^2}{4.09382\, A^{0.29} - 4.40767}\right)$$

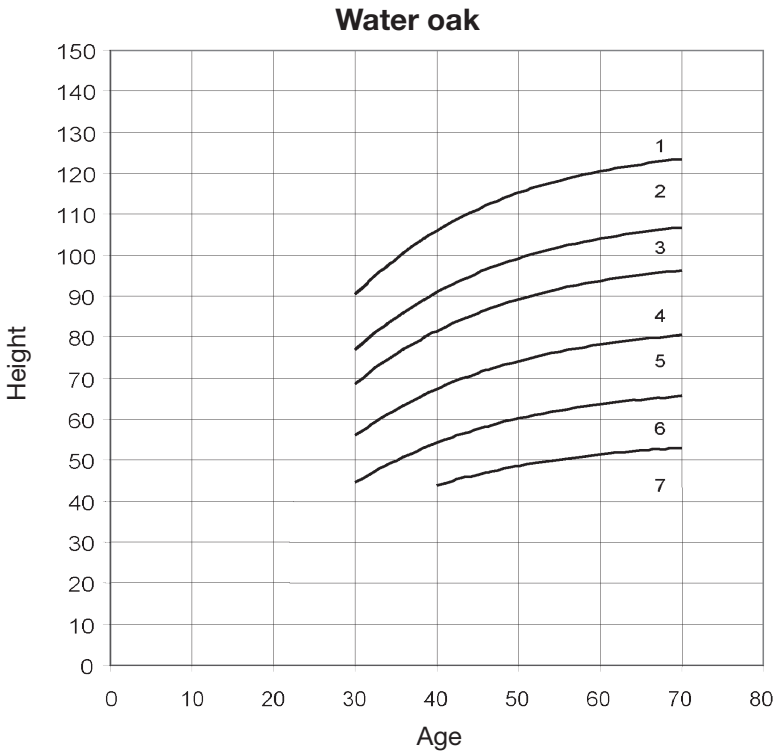

Figure 13—Water oak (*Quercus nigra*; also representing other southern bottomland oaks) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Carmean and others 1989, which cites Broadfoot 1963 as the original data source).

$$SI = 0.0055\, H^{1.6414}\left(1 - e^{-0.00026A}\right)^{1.7678H^{-0.2712}}$$

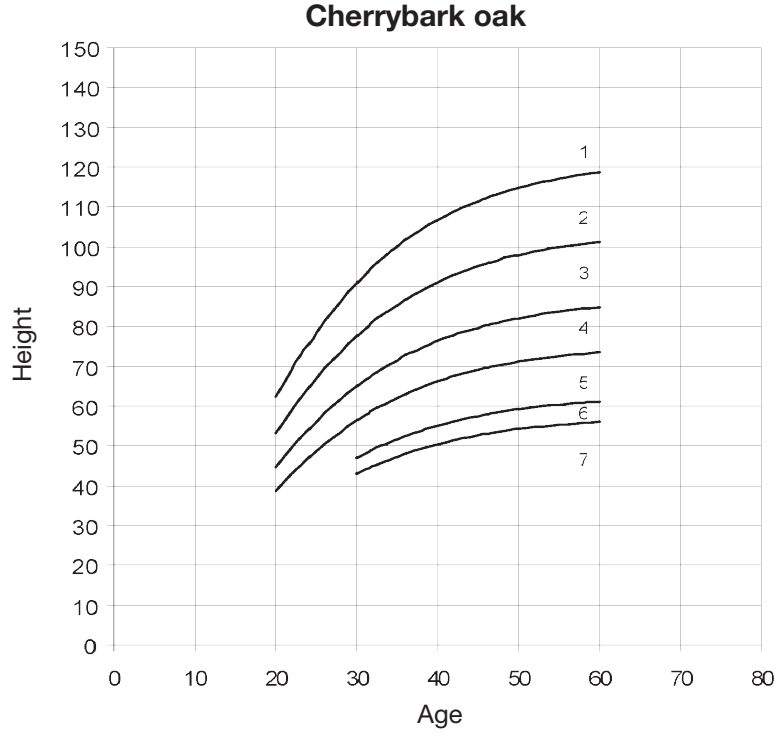

Figure 14—Cherrybark oak (*Quercus pagoda*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Carmean and others 1989, which cites Broadfoot 1961 as the original data source).

$$SI = 0.9452\, H^{0.9987}\left(1 - e^{-0.0762A}\right)^{1.8868H^{-0.0861}}$$

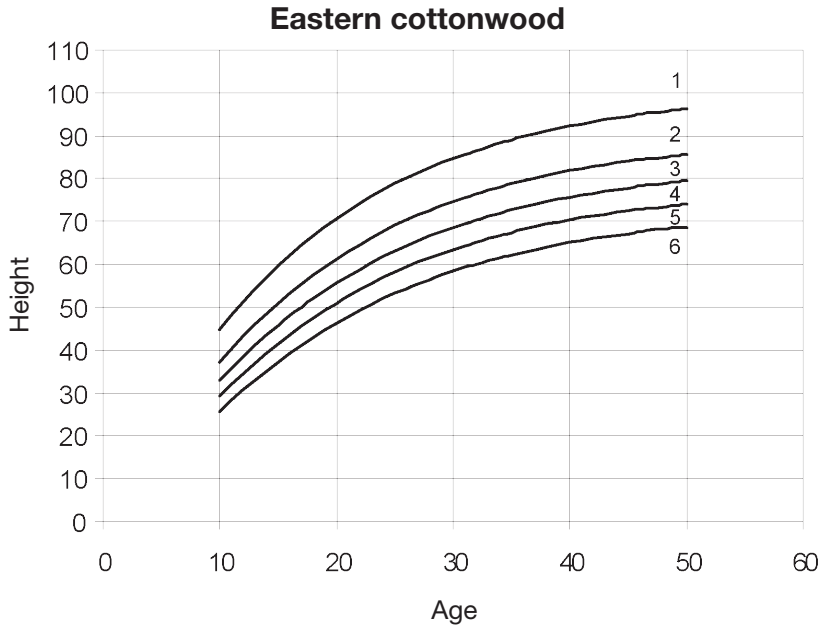

Figure 15—Eastern cottonwood (*Populus deltoides*) site index equation and site curves used by Southern Research Station Forest Inventory and Analysis, where SI = site index, A = total age of tree, H = total height, and e = base of the natural logarithms (Carmean and others 1989, which cites Broadfoot 1960 as the original data source).

$$SI = 0.4754\, H^{1.1190}\left(1 - e^{-0.0429A}\right)^{5.6452H^{-0.4912}}$$

Availability of Data

The site index and site class assigned by SRS FIA provide utility for many data users. However, some users may wish to use other site index equations or other criteria for productivity estimates. All SRS FIA site tree data are available from the national FIA database which can be queried using online tools (https://www.fia.fs.fed.us/tools-data/index.php). The names and a short description of all site tree attributes are found in the appendix.

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APPENDIX

Site tree attributes from the FIA database, version 8.0. Detailed definitions for the attributes listed below can be found in "The Forest Inventory and Analysis Database: Database Description and User Guide for Phase 2. Version 8.0" (USDA Forest Service 2018b).

Attribute	Descriptive name
CN	Sequence number
PLT_CN	Plot sequence number
PREV_SIT_CN	Previous site tree sequence number
INVYR	Inventory year
STATECD	State code
UNITCD	Survey unit code
COUNTYCD	County code
PLOT	Plot number
CONDID	Condition class number
TREE	Tree number
SPCD	Species code
DIA	Diameter
HT	Total height
AGEDIA	Tree age at diameter
SPGRPCD	Species group code
SITREE	Site index for the tree
SIBASE	Site index base age
SUBP	Subplot number
AZIMUTH	Azimuth
DIST	Horizontal distance
METHOD	Site tree method code
SITREE_EST	Estimated site index for the tree
VALIDCD	Validity code
CREATED_BY	Created by
CREATED_DATE	Created date
CREATED_IN_INSTANCE	Created in instance
MODIFIED_BY	Modified by
MODIFIED_DATE	Modified date
MODIFIED_IN_INSTANCE	Modified in instance
CYCLE	Inventory cycle number
SUBCYCLE	Inventory subcycle number

Vissage, John S.; Greer, Travis R., Jr.; Brandeis, Thomas J. 2019. Site class and site index: two estimates of site quality for the Southern Research Station Forest Inventory and Analysis Program. e-Res. Note SRS-025. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 13 p.

Information on site quality, the capacity of forested land to grow wood, is an important component in forest inventories. Site index and site class are two variables that describe forest site quality. Site index is usually defined as the average total height that the dominant and codominant trees in fully stocked, even-aged stands will attain at key ages. Site class is a classification of forest land in terms of the capacity to grow repeated crops of industrial wood. This classification is based on the maximum mean annual increment, in cubic feet per acre, of natural, well-stocked, even-aged stands of species suitable to the local site. This paper documents and describes the equations, methods, and data used by the Forest Inventory and Analysis program of the U.S. Department of Agriculture Forest Service, Southern Research Station, to estimate site index and site class for forest inventories conducted in the Southern United States.

Keywords: Site class, site index, forest inventory, growth and yield, Southern United States.

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