UNIVERSITY OF GEORGIA
Warnell School of Forestry & Natural Resources

WSFNR-25-16A

September 2025

Comparisons of site index and mean annual increment for slash and loblolly pine in the southeastern United States Coastal Plain

E. David Dickens[1], Professor of Forest Productivity; *David Clabo[1],* Associate Professor of Silviculture Outreach; Dehai Zhao[1], Senior Research Scientist; Michelle Thompson[2], Climate Science Communication Specialist; Daniel Markewitz[1], Professor of Soil Site Productivity; and Bronson P. Bullock[1], Professor of Forest Biometrics & Quantitative Timber Management

[1] *UGA Warnell School of Forestry and Natural Resources*

[2] *United States Department of Agriculture Southeast Climate Hub and Clemson* University

SUMMARY

Forest managers and private forest landowners use site index (SI) estimates to predict productivity and growth of primarily single or similar tree species groups for natural and planted stands. Publicly available SI estimates are crucial for non-industrial private forest landowners to make management decisions. There have been great steps forward in artificial regeneration and forest management since productivity estimates were last updated for loblolly and slash pine in the southeastern US Coastal Plain. Two studies were conducted by the Natural Resources Conservation Service (NRCS) and the University of Georgia to determine current site index estimates by soil characteristics in the Coastal Plain physiographic region for two important timber species: loblolly and slash pine. Soils provide trees with two of the three essential requirements: water and nutrients with the third essential requirement being sunlight. This paper describes both studies and how the productivity (SI and mean annual increment) of slash and loblolly pine differ based on soil profile characteristics and an indicator of soil fertility to address the two of three essential requirements of trees..

INTRODUCTION

The southeastern U.S. is America's wood basket, and the majority of forestland is privately owned. As of 2019, 86% of forests in the southeastern U.S. are privately owned (Oswalt and others, 2019). Two-thirds of privately owned forests were owned by non-industrial private forest landowners (NIPFLs) in 2013 (Butler & Wear, 2013). These forests are also economically significant to the region. The South is the greatest timber-producing region in the U.S. and has accounted for more than 65% of total U.S. pulpwood production over the past 30 years (Howard and Liang, 2019).

There are many significant timber species in the Southeast, but the two most important commercial timber species are loblolly pine (*Pinus taeda*) and slash pine (*Pinus elliottii*) (Zhao and others, 2019). Loblolly pine is the most commercially important forest species in the southern U.S. Loblolly pine is favored on a variety of sites due to its fast growth and form/disease resistance improvements accumulated through efforts by tree improvement programs. It is the dominant species on over 61 million acres in 12 southeastern U.S. states, and its native range stretches from eastern Texas along the east coast and north into Delaware (Figure 1) (USDA Forest Service, 2025). Loblolly pine is a fast-growing species, with an estimated maximum mean annual increment culminating between stand ages 20 and 24-years of about 7 tons ac^{-1} yr^{-1} under operational management and 10+ tons ac^{-1} yr^{-1} for intensively managed stands (Fox and others, 2007; Zhao and Kane, 2012; Kinane, 2014; Zhao and others, 2019).

Slash pine (*Pinus elliottii*) is not as prevalent on the landscape as loblolly pine due to its slower growth rate and smaller native range. However, slash pine is valued for its tolerance to drought, fire, and poor soil fertility (Lohrey and Kossuth, 1990). It is also relatively fast-growing and is used for specific timber products like poles, as is loblolly pine. It is naturally found most frequently in poorly drained areas and along streams, yet it is a soil generalist similar to loblolly pine and has been planted on a wide variety of sites in the Coastal Plain. Its northern range is limited by average winter low temperatures and ice/snow events. The native range of slash pine is less extensive than loblolly's range, spreading from Texas along the Gulf Coast to Florida, and along the Atlantic Coast to South Carolina (Figure 2). It has been planted extensively outside of its native range. Slash pine is not as fast-growing as loblolly pine but still has a maximum estimated mean annual increment culminating between stand ages 20 and 24 years of 5.0 tons ac^{-1} yr^{-1} under operational management to 8.0 tons ac^{-1} yr^{-1} under intensive management (Zhao and Kane, 2012; Zhao and others, 2019).

Forest management has become more specialized with technological advancements over the past 70+ years. Genetically improved families for both loblolly and slash pine have been introduced after decades of tree improvement programs, seedling quality and consistency have improved, fertilization can drastically increase volume growth on some sites, and there are now better ways to control competing vegetation and manage for limiting physical soil factors such as poor internal drainage or compaction on forest lands. All these factors have led to an increase in productivity and a decrease in rotation ages. These factors have affected forest management broadly, but the effects are more concentrated on industrial forest land, as costs can be prohibitive to NIPFLs.

Figure 1: ***The native range of loblolly pine*** **(Pinus taeda).** Map courtesy of Baker and Langdon (1990).

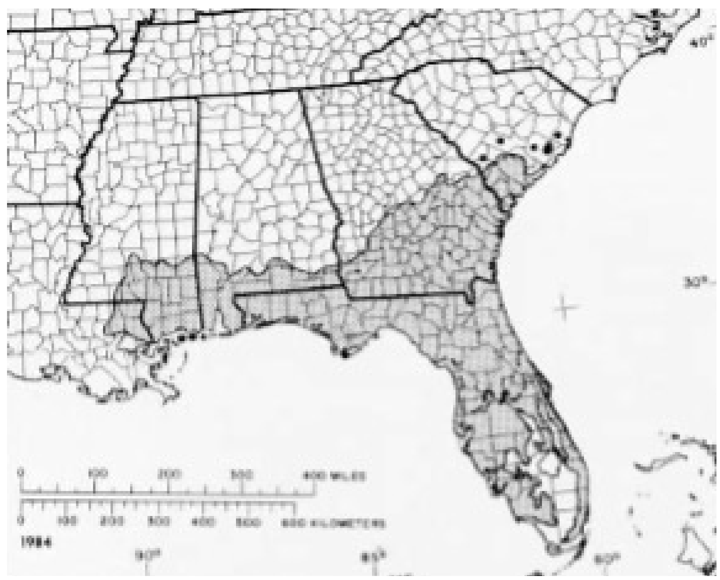

Figure 2: ***The native distribution of slash pine (Pinus elliottii).*** Map courtesy of Lohrey and Kossuth (1990).

Part of planned forest management involves using the most accurate information to inform land use decisions. Site index (SI) is a measure of site productivity and is commonly used to estimate actual or potential productivity (in terms of average height) for a single species or groups of similar tree species for a defined period of time (typically 50 years for naturally regenerated stands and 25 years for planted stands). The SI value is expressed as the average height (a measure of productivity) of a certain number of dominant and codominant crown class trees at an index age (e.g., 25 years for pine plantations) (Geyer and Lynch, 1987). Site index alone is not a perfect estimation of site productivity because it does not reflect the natural variation in stand productivity over time. Mean annual increment (MAI) is the total weight or volume of a stand up to a given age divided by that age. It is valid for unthinned stands and is affected by planting density or trees per acre (tpa) and survival over time.

Publicly available estimates of SI and MAI are very useful to NIPFLs and forest managers. This information aids in decision-making decisions on what species to plant, how frequently to harvest, and allows managers to predict future stand growth. Estimates of SI and MAI for loblolly and slash pine in the Coastal Plain were originally created in 1929 by the U.S. Forest Service and were later updated for slash pine stands in Georgia by the U.S. Forest Service Southeastern Forest Experiment Station, in the late 1950s and early 1960s and the early 1950s for loblolly pine by researchers at Duke University (U.S. Department of Agriculture, 1929; Coile and Schumacher 1953a; Coile and Schumacher 1953b; Bennett and others, 1959; McGee, 1961). Currently, the U.S. Department of Agriculture's Natural Resources Conservation Service's (NRCS) Web Soil Survey is the most convenient way to access forest productivity data based on these estimates (NRCS, 2019). Even though they are updated, these estimates are outdated and do not reflect improved management practices and species genetic improvements. Two studies were conducted by the University of Georgia and NRCS to update SI and MAI estimates for loblolly and slash pine by soil groupings in the Coastal Plain region. Site index and MAI for this study are grouped by the University of Florida's Cooperative Research in Forest Fertilization (CRIFF) soil classification system (Jokela and Long, 2018) with subgroups within two of the CRIFF soil groups. This method sorts Coastal Plain soil types depending on their drainage classes, presence/ depth to an argillic (Bt) horizon, and presence/absence to a spodic (Bh) horizon. The original system includes eight soil categories, which are depicted in Figure 3.

Both studies used a modified version of the CRIFF soil classification system, which split groups "B" and "F" into three subgroups each (Dickens and others, 2024; Zhao and others, 2024a). The subgroups were categorized based on the depth to the argillic (Bt) horizon. If the Bt horizon was greater than 20 through 40", it was grouped as B1 or F1, >40-60" to Bt horizon was classified as B2 or F2, and >60-80" to Bt horizon was either B3 or F3, although B3 includes soils that do not have a Bt horizon within 80" but do have the same drainage classes as the other B subgroups. This modification was incorporated into the CRIFF soil classification system because the depth to the Bt horizon is a factor in slowing water infiltration and is more nutrient-dense than sandier textured overlying E or A horizons (if either are present, especially on the F subgroups.) The modified CRIFF soil groups are A, B1, B2, B3, C, D, E, F1, F2, F3, and G. Soils belonging to the CRIFF H group were not included in the studies due to their unsuitability for pine growth. Soils were classified into the modified CRIFF soil groups by soil drainage class, the presence/ depth of an argillic (Bt) horizon, and presence/absence of a spodic (Bh) horizon. Depth to seasonal high-water table and depth to chroma ≤2 (a gray soil color produced by reduced iron indicating a wet soil condition for part of the year) were also tallied in each plot. The modified CRIFF system is described visually in Figure 4. Soil profile delineation was conducted by NRCS soil scientists and to a lesser extent by UGA personnel.

To address the second of of the two essentual requirements for tree, we sampled surface (0-6") soil and used an soil extraction procedure (Mehlich1; M1) this procedure is considered to mimic plant available nutrients. Phosphorus (P) is the most immobile of the macro-nutrients in the soil and there is a strong correlation between Mehlich 1 - phosphorus (M1-P) and loblolly and slash pine growth on somewhat to very poorly drained soils. We found that there was a strong correlation within certain soil groups, (Figure 5 and Table 2) including better drained soils and surface soil M1-P. Generally, when the M1-P range was wide M1-P values were a significant part of site index predictions within soil groups.

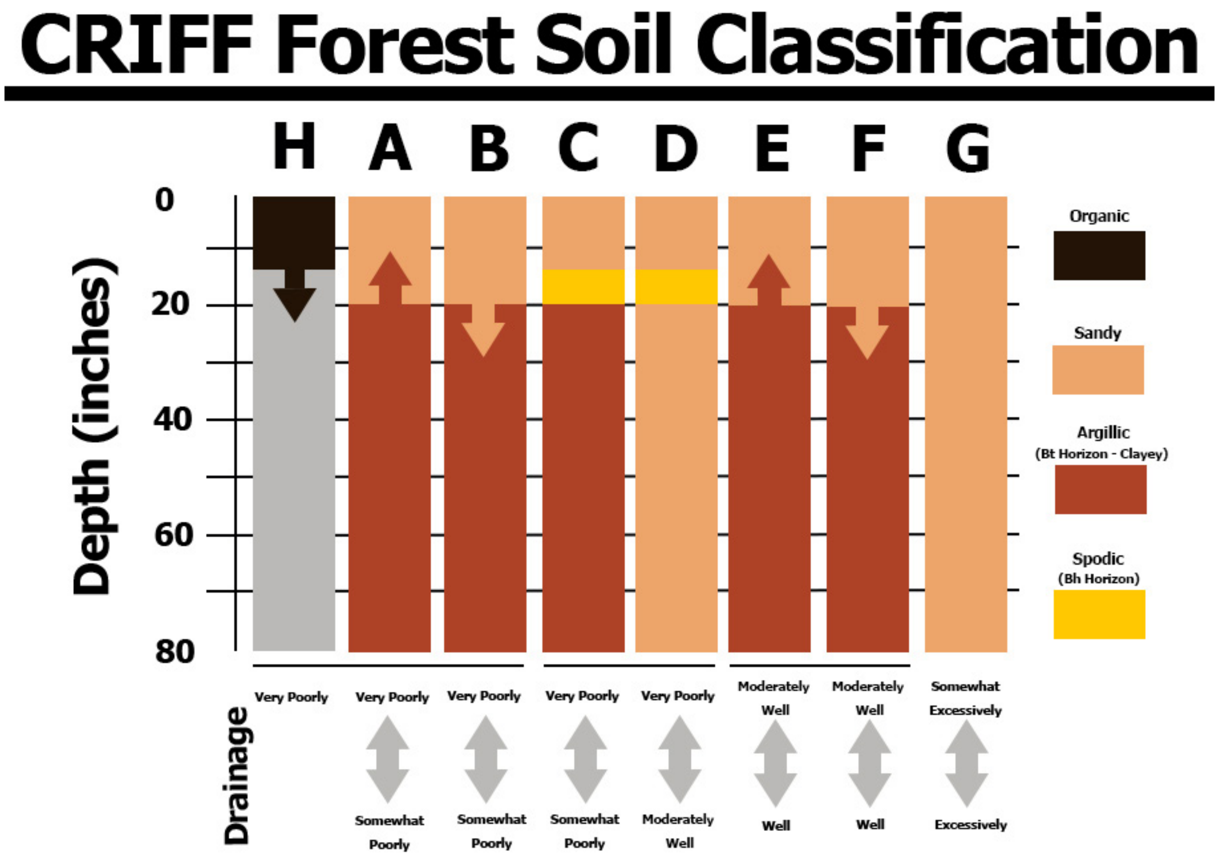

Figure 3: *The University of Florida's Cooperative Research in Forest Fertilization (CRIFF) forest soil classification system is depicted. This method of classifying soils was specifically created for soils in the Coastal Plain region of northern Florida and southern Georgia. The figure was redrawn from Jokela and Long (2018).*

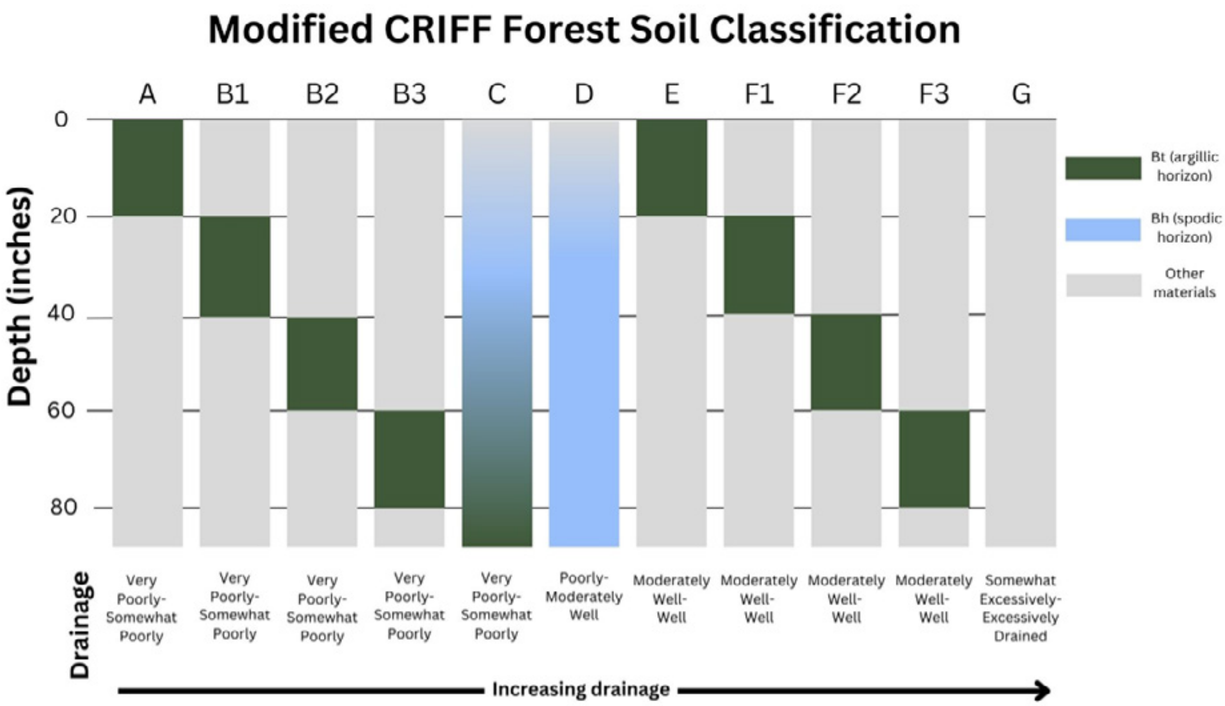

Figure 4: *The modified University of Florida Cooperative Research in Forest Fertilization (CRIFF) soil classification system used for the site index and mean annual increment analyses. Soils are sorted by increasing drainage. Argillic (green) and spodic (blue) horizon depths are noted.*

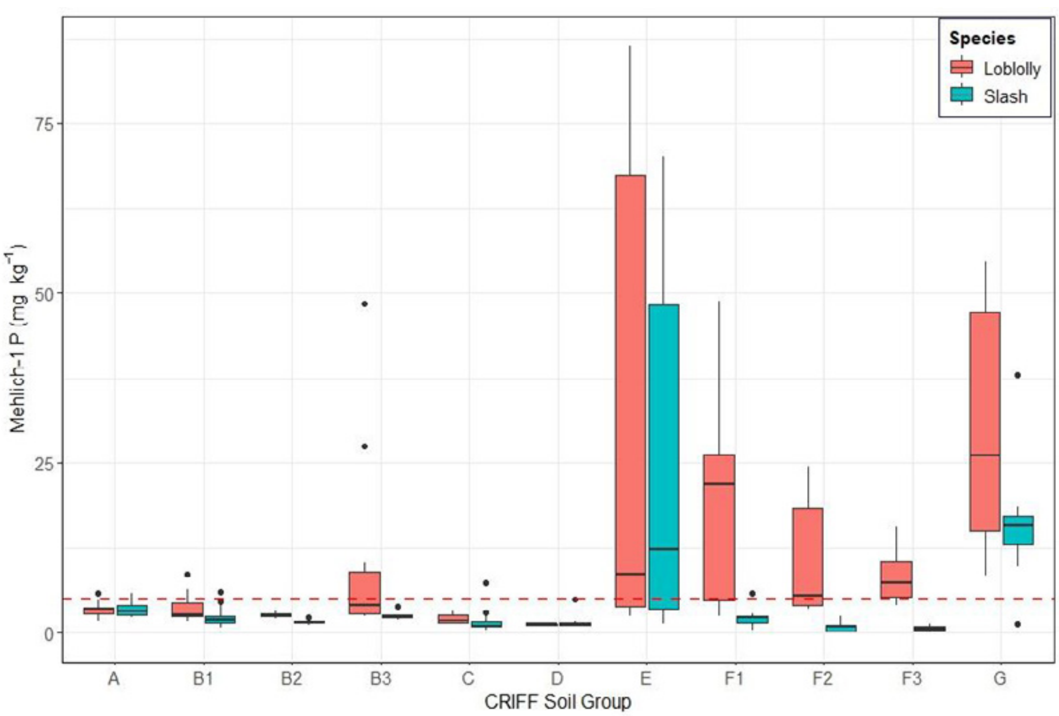

Figure 5: *Concentrations of surface (0-6") soil extractable P (Mehlich-1 P; M1-P) measured in loblolly and slash pine plots in the NRCS study. The dotted line represents minimum sufficiency level of 5 mg/kg for CRIFF soil groups A, B and sometimes C.*

METHODS

Study area

Both studies were conducted in southern Georgia. 126 plots were measured for the loblolly pine study, and 157 plots were inventoried in the slash pine study. Most plots for both studies are located on privately owned land, but some were on state-owned land or industry-owned forest land. Plot locations for both studies are depicted in Figure 6. Pink circles represent loblolly pine NRCS plots while blue triangles represent slash pine NRCS plots measured for the study.

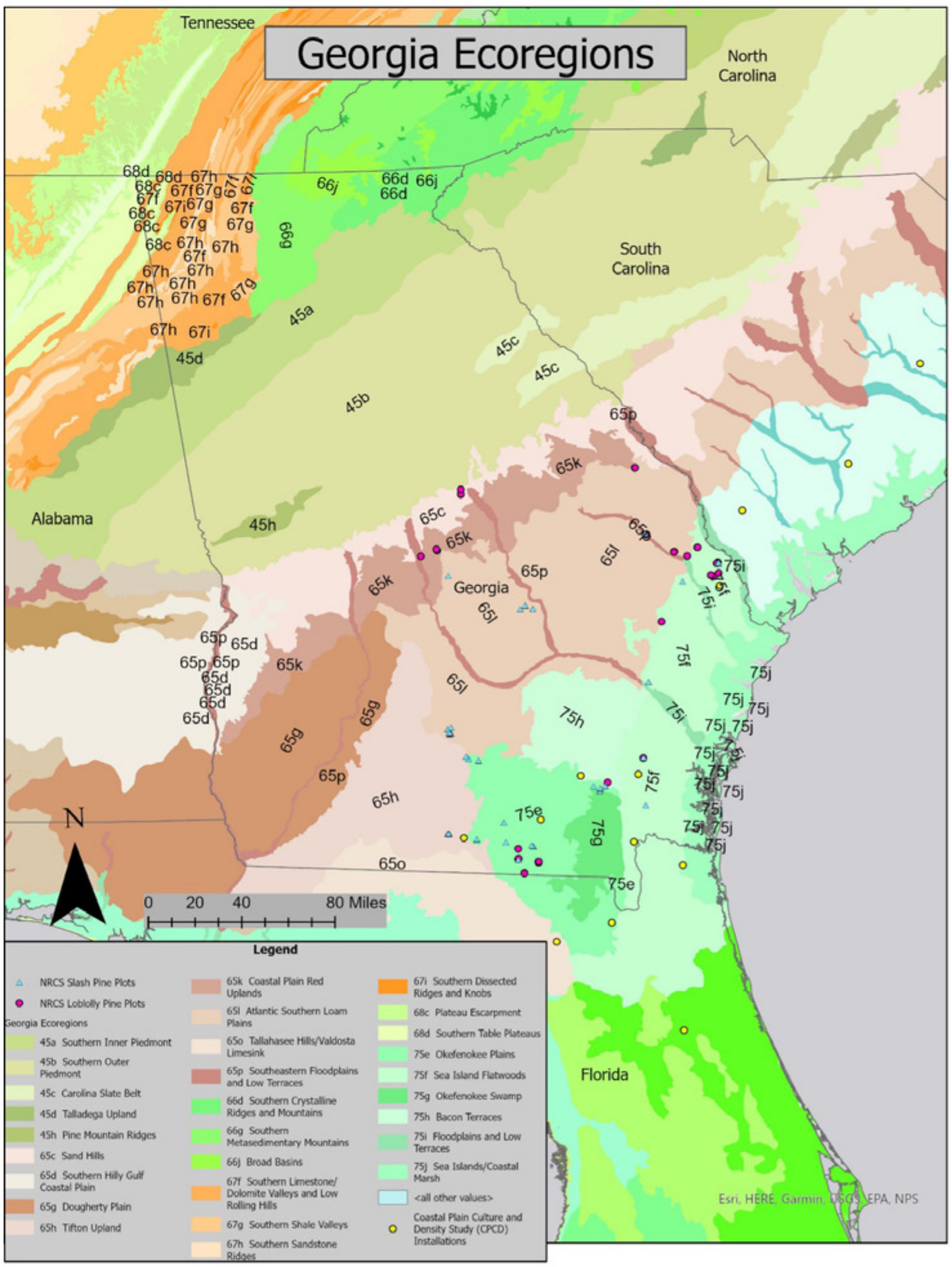

Figure 6: *Map of the study areas with inventoried slash pine Natural Resources Conservation Service (NRCS) plots marked as blue triangles and loblolly pine plots marked as pink circles. University of Georgia Plantation Management Research Cooperative Coastal Plain Culture and Density (CPCD) study installations are marked as yellow circles. All NRCS study plots were located in Georgia. Georgia Ecoregions are overlaid with loblolly and slash pine NRCS/CPCD plots and installations (Griffith and others, 2001).*

The stands used in these studies were located on six different Major Land Resource Areas (MLRAs). These MRLAs are characterized by their hydrology, soil types, climate, vegetation, and land use types. The six MLRAs included: Southern Coastal Plains Sand Hills, Coastal Plain Red Uplands and Tifton Upland, Atlantic Southern Loam Plain/ Vidalia Upland, Sea Island Flatwoods and Okefenokee Plains. Each ecoregion, its environmental conditions, and the percentage of plots for each study in each ecoregion are depicted in Table 1.

Table 1: The Major Land Resource Areas (MLRAs) in which plots were established for the loblolly and slash pine studies. Landform characteristics for each MLRA are included along with the percentage of plots for each study that are located within the MLRA.

		Loblolly pine	Slash pine
Ecoregion	**Landform characteristics**	**Percent of plots in ecoregion**	**Percent of plots in ecoregion**
Southern Coastal Plains sand hills	Dissected landscape consisting of primarily low nutrient soil with some loam or clay soils	7.4%	0%
Coastal Plain red uplands and Tifton upland	Well-drained loamy/ sandy surface layer soils with red subsoils	15.7%	7.6%
Atlantic southern loam plain/ Vidalia upland	Flat to gently rolling topography with fine textured soils	20.7%	35.1%
Sea Island flatwoods	Flat plains with mostly poorly drained spodosol soils, but some better drained ultisols soils	33.9%	24.2%
Okefenokee plains	Flat plains and low terraces with somewhat-poorly to poorly drained soils; spodosols are common.	22.3%	33.1%

Plot characteristics

There are significant differences between loblolly and slash pine sites. Figure 7 shows examples of both species' plots with different locations, soil types, woody competition, and tree planting density (tpa).

For more information on plot characteristics for each study, please refer to the two 2025 papers: *Loblolly pine site index and mean annual increment estimates by soil classification in the Coastal Plain* and *Slash pine site index and mean annual increment estimates by soil classification in the Coastal Plain.*

Figure 7. Eleven-year-old high-density (1,489 trees per acre; tpa) loblolly pine plot on a Cooperative Research in Forest Fertilization (CRIFF) E soil in Baldwin County, GA, with minimal competing woody vegetation (left photo) versus an eleven-year-old moderate-density (558 tpa) slash pine plot on a CRIFF A soil with significant woody competition in Berrien County, GA (right photo).

Field measurements

For information on the field measurements of both studies, please refer to the two 2025 papers: *Loblolly pine site index and mean annual increment estimates by soil classification in the Coastal Plai*n and *Slash pine site index and mean annual increment estimates by soil classification in the Coastal Plain*.

Site productivity

Site productivity was calculated in the same manner for both studies. The SI was estimated by the average height of dominant and codominant trees at 25 years old. Trees were considered dominant or codominant if they had a DBH greater than the average DBH of stems in an unthinned stand or were among the tallest 80% of trees in thinned stands. Observed mean loblolly and slash pine SI means are found in Figure 7.

The equations used for the loblolly and slash pine SI estimations were developed by the University of Georgia's Plantation Management Research Cooperative (PMRC) (Borders and others, 2014). The following explanatory variables were used in the model: modified CRIFF soil group, concentrations of surface (0-6") soil Mehlich 1 P, presence/depth to an argillic horizon, presence/depth to a spodic horizon, and presence/ depth to a seasonal high-water table, and presence/depth to a soil chroma ≤ 2 (a light gray color indicating reduced iron, wet soil condition). These variables were used in the regression analyses to determine their significance in explaining SI.

The MAI by species (green weight tons ac^{-1} yr^{-1}) was calculated using estimated (predicted) site index from NRCS plots and base site index from CPCD study plots starting at stand age five years at five year increments up to age 20 years (just before the first thinning) using actual CPCD study data through stand age 20- or 24-years (operational management and 600 tpa for loblolly pine and 900 tpa for slash pine). The PMRC loblolly and slash pine growth and yield models were used for analyses (Borders and others, 2004; Logan, 2005; Borders and others, 2014). These models estimated green weight (green weight tons ac^{-1} yr^{-1}) MAIs at ages 10, 15, and 20 years by modified CRIFF soil group for three different surviving tpa values at age 5-years (500, 600, and 700 tpa) using updated whole-tree green weight equations by Zhao and others (2024b).

RESULTS

The regression analyses for both species found two significant predictor variables, which were CRIFF soil group and surface soil P levels. While the productivity of both species was correlated with SI, loblolly and slash pine performed differently on the 10 soil groups. Loblolly outperformed slash pine on all but two soil groups. On soil group A, loblolly pine's SI was 2.3 ft greater than slash, 13.5 ft more on B1, 22.6 ft more on B2, 6.5 ft higher on B3, 5.6 ft greater on soil group C, 10.8 ft taller for soil group E, and 12.1, 16.4, and 10.8 ft greater on soil groups F1, F2, and F3 respectively. Slash pine performed better on CRIFF D (spodosols without an underlying argillic) and G (somewhat excessively and excessively drained primarily sandy textured soils with no argillic horizon within 80") soils, with 8.2 ft and 6.2 ft increases, respectively. Site index values are shown in Figure 8 for both loblolly and slash pine, by CRIFF soil group.

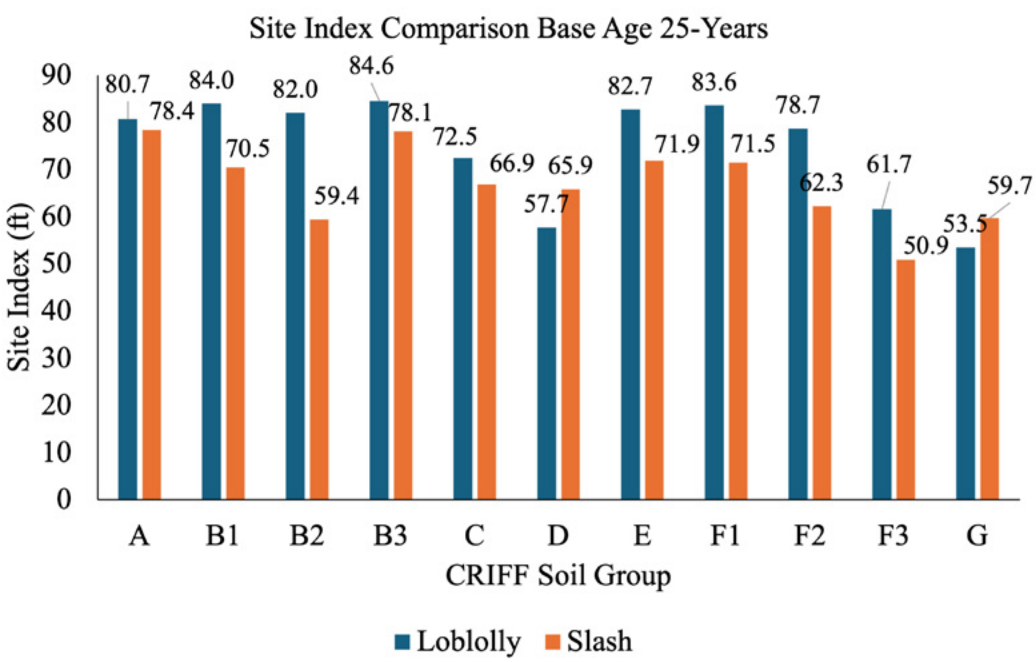

Figure 8: *A comparison of the observed average site index (SI) in feet between slash pine and loblolly pine by modified Cooperative Research in Forest Fertilization (CRIFF) soil groupings. Site index values for loblolly pine are from Zhao and others, (2024a) and SI for slash pine are from Dickens and others, (2024).*

Comparing the observed mean SI values of loblolly and slash pine provides interesting insight. Slash pine had better productivity on D and G soils when compared to loblolly. Loblolly far outperformed slash pine on B1, B2, B3, E, F1, F2, and F3 soil groups by a range of 10.8 to 22.6 ft. For soil groups A, B3, and C, loblolly was only slightly better (by a range of 2.3 to 6.5 ft), meaning that both slash and loblolly pine could be the preferred species although fertilization can improve loblolly's SI more so than slash pine on at least soil groups A and C. Slash pine SI values had greater variability for all soil groups, making productivity estimates less predictable. Loblolly and slash pine had differences in productivity on the same soil types, which can yield management insights for decision making. Table 2 shows the preferred species for each CRIFF soil group based on estimated SI results.

Table 2: The preferred pine species for each modified Cooperative Research in Forest Fertilization (CRIFF) soil group depending on the estimated site index (SI) value.

Modified CRIFF soil group	Preferred species
A	Either
B1	Loblolly pine
B2	Loblolly pine
B3	Loblolly pine
C	Either
D	Slash pine
E	Loblolly pine
F1	Loblolly pine
F2	Loblolly pine
F3	Loblolly pine
G	Slash pine (longleaf is best choice w/o fertilization; Jokela and Long, 2018)

The mean annual increment (MAI) estimates (measured in green tons $ac^{-1}yr^{-1}$) were simulated using the growth and yield model systems for slash and loblolly pine based on average estimated SI (Logan 2005, Borders et al., 2004, 2014). This means that differences in MAI between species and soil type are proportional to the differences in SI between species and soil type, i.e., trends in SI values are shared with values for MAI.

Additionally, MAI estimates included three different tree densities (500, 600, and 700 tpa) based on survival at stand age five-years. Mean annual increments for loblolly and slash pine were estimated at ages 15 and 20 years by soil group. The estimated growth was linear, so the MAI values for older and more dense stands are proportional to younger and less dense stands by species and soil group. Slash pine MAI ranged from 2.6 tons $ac^{-1}yr^{-1}$ at stand age 15 years (500 tpa, soil groups B2 and F3) to 7.4 tons $ac^{-1}yr^{-1}$ at stand age 20 years (700 tpa, soil group B3 and A). Loblolly MAI values are between 1.9 tons $ac^{-1}yr^{-1}$ at stand age 15 years (500 tpa, soil group G) to 8.4 tons $ac^{-1}yr^{-1}$ at stand age 20 years (700 tpa, soil group B3). As with SI, slash pine MAI only outperformed loblolly pine MAI on CRIFF soil groups D and G. The highest MAI values were among loblolly pine stands on soil groups B1, B3, E, and F1. Mean annual increment values by species, soil type, tree density, and stand age are depicted in Figure 9.

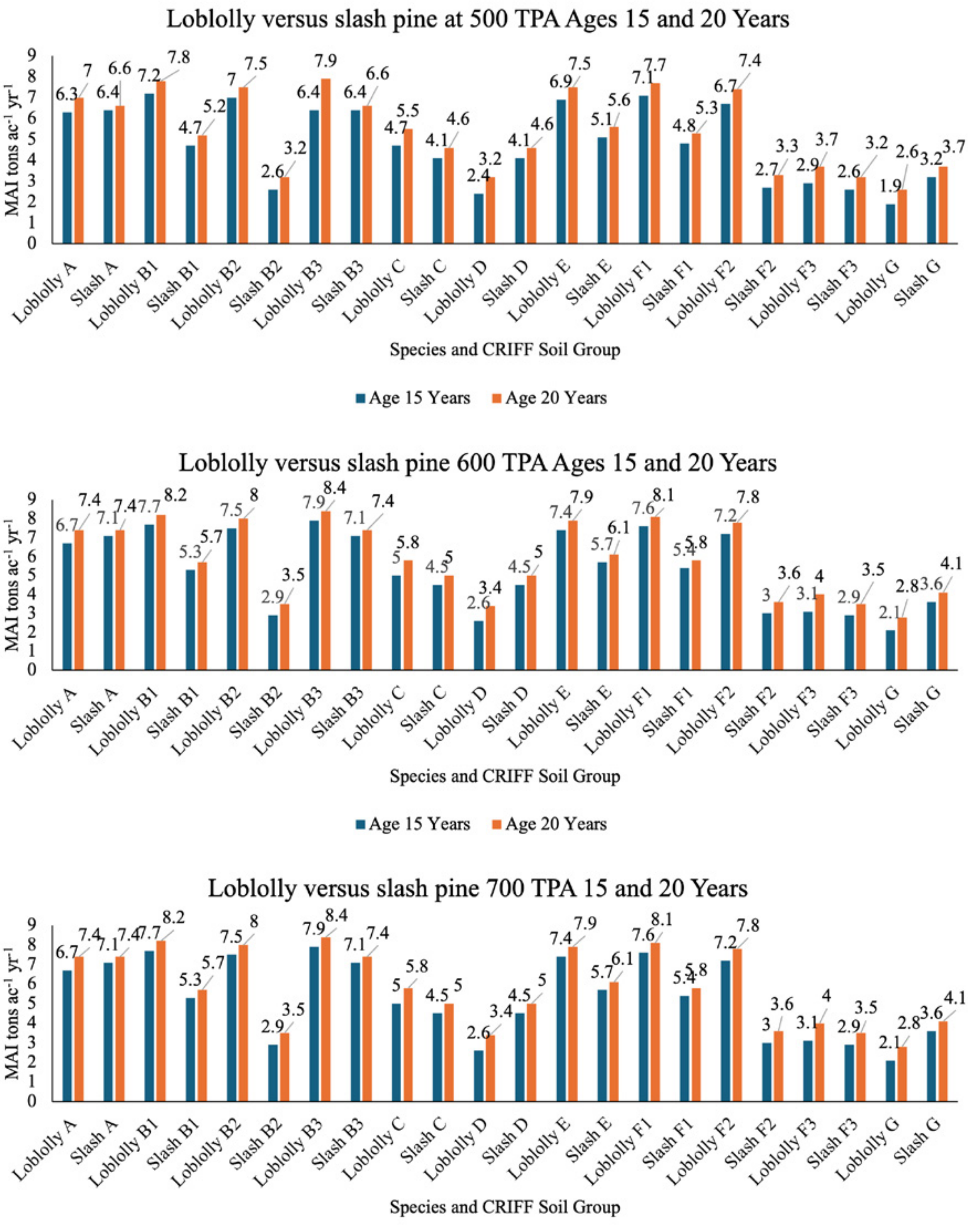

Figure 9: *Mean predicted annual increment values (green tons ac^{-1} yr^{-1}) for loblolly and slash pine by soil group. Values for 15-year-old stands are shown in blue and 20-year-old stands are in orange.*

The amount of available P (M1-P) in the surface soil (0-6") had differing effects on SI by soil group and species. Slash pine had very few correlations between soil M1-P levels and observed mean SI. Only a portion of plots on soil groups B3 and E soils on sites with a history of fertilization showed any correlation for slash pine. Loblolly pine stands had more and stronger relationships between soil M1-P levels and SI. Soil groups B1, B2, E, F1, F2, and G had statistically significant correlations for M1-P availability and observed mean SI. All other soil groups had no clear correlations between soil M1-P values and SI (Table 3). All statistically significant correlations between soil M1-P and SI were positive for all soil groups and both species, meaning that a higher availability of soil P led to greater growth. However, the magnitude of growth improvement varied by soil M1-P levels, species, and soil group. Much of the lack of significant relationship of surface soil M1-P correlation to SI by pine species was due to soil groups that had a narrow range and low values for MI-P (e.g., slash pine soil group A had 10 plots with a M1-P range from 2.3 to 5.8 ppm and loblolly on soil group A had 12 plots with a M1-P range of 1.7 to 5.8 ppm).

Table 3: Detected correlations between soil phosphorus (M1-P) values and stand site index (SI) by species and soil group. Correlations between M1-P and SI are recorded as a binary variable with Y for yes (correlation detected) and N for no (no statistically significant proof of a correlation).

Species	Soil Group	M1-P Correlation with SI (Y= yes, N= no)
Loblolly Pine	A	N
	B1	Y
	B2	Y
	B3	N
	C	N
	D	N
	E	Y
	F1	Y
	F2	Y
	F3	N
	G	Y
Slash Pine	A	N
	B1	N
	B2	N
	B3	Y
	C	N
	D	N
	E	Y
	F1	N
	F2	N
	F3	N
	G	N

CONCLUSIONS

This study shows that, based on the modified CRIFF soil groups, either loblolly or slash pine may be preferred for new plantings, though on most sites, loblolly pine would be the optimal species choice to increase wood production or carbon storage on all soil groups except A (similar SI with a 2.3 ft difference in observed SI means in favor of loblolly over slash pine), D and G groups. In general, loblolly had faster growth than slash pine. Loblolly's average site index across all soil groups at 25 years was 74.7 ft, 7.8 feet greater than the average slash pine value of 66.9 ft. Loblolly pine mean annual increment was 1.1-, 5.5-, and 4.4-tons ac^{-1} yr^{-1} greater than slash on average for the three simulated stand ages. However, in certain scenarios, slash pine may be the more productive species. On CRIFF soil groups D and G, slash pine had average MAI values of 4.7- and 3.0-tons ac^{-1} yr^{-1}, respectively. This exceeded loblolly's MAI by 2.2- and 0.9-tons ac^{-1} yr^{-1}, respectively. The observed average SI values at base age 25 years of slash pine on soil groups D and G were 65.9 and 59.7 ft, while observed average loblolly SI values were 57.7 and 53.5 ft. Slash pine outperformed loblolly pine on soil groups D and G by 8.2 and 6.2 ft, respectively. Longleaf pine (*Pinus palustris*) is considered the best pine species to plant on somewhat excessively to excessively drained, primarily sandy textured soils with no argillic horizon within 80" of the surface and low fertility (Jokela and Long, 2018, Dickens and others, 2024). Different site productivity estimates for loblolly and slash pine may yield valuable management information, depending on local climate conditions, the soil type, and desired growth/yield.

The modified CRIFF B and F groups can provide more precise information for species selection and productivity ratings than the original CRIFF B and F groupings. The modified F grouping for loblolly pine showed important productivity differences for F1 (83.6 ft SI) and F2 (78.7 ft SI) compared to F3 (61.7 ft SI); illustrating that the deeper to the top of the Bt the lower the SI. For slash pine, F1 (71.5 ft SI) had a major productivity increase compared to F2 (62.3 ft SI) and F3 (50.9 ft SI) which were similar. Modified groupings for CRIFF B were less important for loblolly pine as site index and MAI values were similar. Slash pine B1 (70.5 ft SI) tended to be much more productive than B2 (59.4 ft SI) while B3 (78.1 ft SI) experienced productivity increases due to the type of B3 soils that were inventoried (Typic Fluvaquent—with black, organic matter rich soils to 12 to 30 inches) from a limited plot sample size.

The results of this study provide updated SI and MAI estimates for non-industrial private forest landowners. Accurate SI estimates are a valuable tool to estimate site productivity, plan for the future, and select the best species for a given site. This information will help forest managers make informed decisions based on the soil series that are present on their property. The modified CRIFF soil grouping method allows forest owners to apply this information on their own land in a targeted manner.

ACKNOWLEDGMENTS

Special thanks to the many landowners who gave UGA and NRCS personnel access to their properties to collect field data. In addition, thanks go to Dee Pederson and her team with NRCS for their work collecting soils information. Funding for this project was provided by NRCS agreement NR204310XXXXC035. Partial funding of this project was provided by USDA Institute of Food and Agriculture project number SC-2022-10900.

SOURCES

Baker, J.B., and Langdon, O.G. 1990. *Pinus taeda* L. Loblolly Pine. in: Burns, R. M. and Honkala, B. H., tech. coords. Silvics of North America. Volume 1, Conifers. Washington, DC: USDA Forest Service. pp. 497-512

Borders, B., Harrison, W.M., Zhang, Y., Shiver, B.D., Clutter, M., Cieszewski, and Daniels, R.F. 2004. Growth and yield models for second rotation loblolly pine plantations in the Piedmont/Upper Coastal Plain and Lower Coastal Plain of the southeastern U.S. UGA/PMRC Technical Report 2004-4. 67 p.

Borders, B., Zhao, D., Wang, M., and Kane, M. 2014. Growth and yield models for second/third rotation loblolly pine plantations in the Piedmont/Upper Coastal Plain of the southeastern U.S. UGA/PMRC Technical Report 2014-1. 49 p.

Butler, B.J., and Wear, D.N. 2013. Forest Ownership Dynamics of Southern Forests. In: Wear, D.N.; Greis, J.G. (eds.). The Southern Forest Futures Project: Technical Report. Gen. Tech. Rep. SRS-GTR-178. Asheville, NC: USDA-Forest Service, Southern Research Station. 103-121.

Coile, T.S., and Schumacher, F.X. 1953a. Site index of young stands of loblolly and shortleaf pines in the Piedmont Plateau region. *Journal of Forestry* 51(6): 432-450.

Coile, T.S., and Schumacher, F.X. 1953b. Relation of soil properties to site index of loblolly and shortleaf pines in the Piedmont region of the Carolinas, Georgia and Alabama. *Journal of Forestry* 51(10): 739-744.

Dickens, E.D., Zhao, D., Clabo, D.C., Markewitz, D., Bullock, B.P., and Pederson, D.C. 2024. Soil-based assessment of site productivity for southern pine plantations in the coastal plain of the southeastern US: (II) slash pine. Forest Ecology and Management 566, 122093. https://doi.org/10.1016/j.foreco.2024.122093

Fox, T.R., Jokela, E.J., and Allen, H.L. 2007. The development of pine plantation silviculture in the southern United States. *Journal of Forestry* 105(7): 337-347.

Geyer, W.A., and Lynch, K.D. 1987. Use of site index as a forestry management tool. *Transactions of the Kansas Academy of Science* (1903-). 90(1/2): 46–51. https://doi.org/10.2307/3628111

Griffith, G.E., Omernik, J.M., Comstock, J.A., Lawrence, Foster. T., 2001. Ecoregions of Georgia. Corvallis, OR. U.S. Environmental Protection Agency (map scale: 1: 1,500,000).

Howard, J.L., and Liang, S. 2019. U.S. timber production, trade, consumption, and price statistics. 1965-2017. Res. Pap. FPL-RP-701. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 96 p.

Jokela, E.J., and Long, A.J. 2018. Using soils to guide fertilizer recommendations for southern pines. Univ. Florida, IFAS Extension, Gainesville, FL. 13 p.

Kinane, S.M. 2014. Consortium for accelerated pine production studies (CAPPS) 25 years of intensive loblolly pine management. Master's thesis. University of Georgia Warnell School of Forestry & Natural Resources, Athens, GA. 337 p.

Logan, S.R., 2005. Growth and yield models for slash pine plantations in the Southeastern Coastal Plain. UGA/Plantation Management Research Cooperative Technical Report 2005-3. 27 p.

Lohrey, R.E.; Kossuth, S.V. 1990. *Pinus elliottii* Engelm. Slash Pine. In: Burns, Russell M.; Honkala, Barbara H., technical coordinators. Silvics of North America. Volume 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 338-347. [13396]

USDA Forest Service. 2025. Forest inventory and analysis one-click state fact sheets 2022-2024. Washington, DC: U.S. Department of Agriculture, Forest Service. Available at: https://research.fs.usda.gov/products/dataandtools/forest-inventory-and-analysis-one-click-state-factsheets.

USDA NRCS. (2019, July 31). Web Soil Survey Home. Web Soil Survey. https://websoilsurvey.nrcs.usda.gov/app/

Oswalt, S.N., Smith, W.B., Miles, P.D., Pugh, S.A., coords. 2019. Forest Resources of the United States, 2017: A technical document supporting the Forest Service 2020 RPA Assessment. Gen. Tech. Rep. WO-97. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 223 p. https://doi.org/10.2737/WO-GTR-97

Zhao, D., and Kane, M. 2012. Differences in growth dynamics of loblolly and slash pine plantations in the southeastern United States. *Forest Ecology and Management* 281: 84-92.

Zhao, D., Bullock, B.P., Montes, C.R., Wang, M., Greene, D., Sutter, L. 2019. Loblolly pine outperforms slash pine in the southeastern United States – A long-term experimental comparison study. *Forest Ecology and Management* 450, 117532. https://doi.org/10.1016/j.foreco.2019.117532.

Zhao, D., Dickens, E.D., Clabo, D.C., Markewitz, D., Bullock, B.P., Pederson, D.C., 2024a. Soil-based assessment of site productivity for southern pine plantations in the coastal plain of the southeastern US: (I) loblolly pine. *Forest Ecology Management* 564, 122054. https://doi.org/10.1016/j.foreco.2024.122054

Zhao, D., Bullock, B.P., Wang, M., and Dickens, E.D. 2024b. Whole-tree green density equations for loblolly and slash pine trees. *Forest Science* 70(4): 271-282. https://doi.org/10.1093/forsci/fxae020