COMPARISON OF PLANTED LOBLOLLY, LONGLEAF, AND SLASH PINE DEVELOPMENT THROUGH 10 GROWING SEASONS IN CENTRAL LOUISIANA—AN ARGUMENT FOR LONGLEAF PINE

James D. Haywood, Mary Anne S. Sayer, and Shi-Jean Susana Sung[1]

Abstract—Two studies were established in central Louisiana to compare development of planted loblolly (*Pinus taeda* L.), longleaf (*P. palustris* Mill.), and slash (*P. elliottii* Engelm.) pine. Study 1 was on a Beauregard silt loam, and Study 2 was on Ruston and McKamie fine sandy loams. After 10 growing seasons, stocking ranged from 1,165 longleaf to 1,606 loblolly pines per ha in Study 1. Slash (9.8 m) and loblolly (8.9 m) pine trees had similar average total heights, and both were taller than longleaf pine (5.3 m). Volume production was comparable between slash (134 m^3/ha) and loblolly (111 m^3/ha) pine, and longleaf pine (24 m^3/ha) had the least volume per ha. In Study 2, stocking ranged from 1,907 longleaf to 2,356 slash pines per ha. Slash (11.2 m) and loblolly (10.8 m) pine trees had similar average total heights, and both were taller than longleaf pine (9.2 m). Volume production was similar between slash (181 m^3/ha) and loblolly (162 m^3/ha) pine, and both produced more volume per ha than longleaf pine (96 m^3/ha). Although outcomes in growth and yield among species were similar in both studies, the magnitude of differences between longleaf versus loblolly and slash pine was greater in Study 1 than Study 2 for several reasons. While longleaf pine had the poorest growth and yield, its early development normally lags behind that of other southern pines, and longleaf pine grew sufficiently well to warrant consideration if other values are taken into account, which are herein discussed.

INTRODUCTION

Through much of the 20th century, land managers had serious problems regenerating longleaf pine (*Pinus palustris* Mill.); thus, many managers favored loblolly (*P. taeda* L.) and slash (*P. elliottii* Engelm.) pine over longleaf (Croker 1987). Despite past favoritism, longleaf pine might be as productive as loblolly or slash pine by age 20 to 25 years on some sites provided there is good survival and an absence of brown-spot needle blight (caused by *Mycosphaerella dearnessii* Barr.) that can arrest seedling growth (Derr 1957, Kais and others 1986, Schmidtling 1987, Shoulders 1985).

More specifically, longleaf pine has a grass-stage of seedling development, during which there is little above-ground stem growth, whereas loblolly and slash pine do not. The grass stage can continue for the first 3 to 6 years after planting (or longer under adverse conditions) as the root system develops (Harlow and Harrar 1969). On silt loam soils in central Louisiana, planted longleaf pine seedlings typically remain in the grass stage (seedlings being no more than 12 cm tall) for 1 to 6 years unless other factors continue to stunt growth (Haywood 2005, 2007; Haywood and others 2012).

Controlling competition by herbicidal and mechanical means for site preparation and after planting loblolly and slash pine are widely accepted practices in the southern United States (Moorhead and others 2012). Similarly, to establish longleaf pine seedlings, some type of vegetation management program is usually necessary because brush outgrows young longleaf pine seedlings and saplings (Haywood 2009a, Haywood and Grelen 2000, Haywood and others 2001).

Prescribed fire is commonly used in longleaf pine plantations to control vegetative competition even when the pines are seedling-sized—a practice that would be avoided in managing other southern pine species. However, fire is not essential for growing longleaf pine seedlings provided other vegetation management practices are used to control competition (Haywood 2005, 2007). In fact, intensive vegetation management employing herbicides was the best treatment for increasing height growth of planted longleaf pine in central Louisiana rather than prescribed fire (Haywood 2011), and intensive vegetation management has benefited both slash and loblolly pine development as well (Haywood and Tiarks 1990; Haywood and others 1994, 2003; Tiarks and Haywood 1981).

Presently, there is an interest in restoring longleaf pine across its native range in the southeastern United States that is partly focused on increasing its acreage from 1.4 million to 3.2 million ha (3.4 to 8 million acres) by 2024 (America's Longleaf 2009). The Longleaf Partnership Council estimated that in 2012 there were 1.7 million ha (4.2 million acres) of forest

[1]Supervisory Research Forester and Research Plant Physiologists, respectively, USDA Forest Service, Southern Research Station, Pineville, LA 71360.

Citation for proceedings: Holley, A. Gordon; Connor, Kristina F.; Haywood, James D., eds. 2015. Proceedings of the 17th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–203. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 551 p.

dominated by longleaf pine, and it has been proposed by state organizations that there will be 2.4 million ha (6 million acres) of longleaf pine by 2027 (Gaines 2012). To achieve either of these outcomes will require forests, pastures, and croplands to be reforested or converted to longleaf pine. The principal method will be to plant longleaf pine seedlings.

Given that one can successfully establish longleaf pine plantations, should one choose longleaf pine rather than loblolly or slash pine? To help answer this question, two studies in central Louisiana were established to compare the survival, growth, and yield of these three southern pines through 10 growing seasons. Results are directly applicable to management of planted pines in the West Gulf Coastal Plain and southeastern United States in general.

METHODS

Study Site Descriptions

Study 1 is located on the Kisatchie National Forest (KNF) in central Louisiana at 53 m above sea level on a gently sloping (1 to 3 percent) Beauregard silt loam soil (fine-silty, siliceous, superactive, thermic Plinthaquic Paleudult) (Kerr and others 1980). The natural pine and mixed hardwood forest cover was clearcut harvested in the mid-1980s, and the site was sheared and windrowed in 1991. Prescribed fire was applied in March 1993 and 1996 to the low cover of herbaceous and scattered woody vegetation that developed after windrowing. Vegetation, which was dominated by bluestem grasses (*Andropogon* spp. and *Schizachyrium* spp.), was rotary mowed in fall 1996 before plot establishment.

Study 2 is on two soil complexes on the KNF. The first one at 55 m above sea level is comprised of Ruston fine sandy loam (fine-loamy, siliceous, semiactive, thermic Typic Paleudult) with a slope of 1 to 10 percent (Kerr and others 1980). The other complex at 66 m above sea level is comprised of McKamie fine sandy loam (fine, mixed, superactive, thermic Vertic Hapludalfs) with a slope of 1 to 10 percent. Before harvesting, Study 2 was a closed canopy, mature, loblolly pine-hardwood forest. The understory vegetation was mostly hardwood trees, shrubs, vines, and scattered shade tolerant herbaceous plants.

The two study sites are within the humid, temperate, coastal plain and flatwoods province of the West Gulf Region of the southeastern United States (McNab and Avers 1994). The climate is subtropical. From 1997 through 2007, December had the lowest average mean temperature of 10.3 °C, and August had the highest average mean temperature of 28.3 °C (National Climatic Data Center 2012). Annual precipitation averaged 1456 mm with 1045 mm during the growing season, which included the months of March through November. Both studies are on uplands suitable for restoring longleaf pine forests (Turner and others 1999).

Treatment Establishment

In both studies, research plots were established in a randomized complete block design of four blocks with three treatments (three pine species) each (Steel and Torrie 1980). Study 1 was installed in fall 1996. Each of the 12 research plots measured 39 by 39 m and contained 16 rows of 16 seedlings arranged in 2.4- by 2.4-m spacing. The center 100 seedlings (10 rows of 10 seedlings each) formed the measurement plot of each research plot. The three southern pines studied, loblolly, longleaf, and slash pine, were randomly assigned to different plots within each block. Blocking was based on slope.

Study 2 was installed in fall 1997 as at Study 1 with the following exceptions: each of the 12 research plots measured 29 by 29 m and contained 16 rows of 16 seedlings arranged in 1.8- by 1.8-m spacing. Blocking was by soil complex (two blocks on each complex) and topographic location within each complex.

For both studies, seeds for all three species were supplied by the Stuart Seed Orchard, KNF, LA, and were open-pollinated native Louisiana parent trees. Seedlings were grown in containers by Forest Service personnel in Pineville, LA. Study 1 was planted in March 1997, and Study 2 was planted in March 1998. Both studies utilized dibbles with tips of the correct size and shape for the 3.8-cm wide and 14-cm deep root plugs.

In April 1997, sethoxydim (2-[1-(ethoxyimino) butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] was banded over the rows of planted pine seedlings to control bluestem grasses on all 12 plots at Study 1. In April 1998, sethoxydim was again applied, and hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione] was banded over the rows of planted seedlings for general herbaceous plant control. Within the 0.9-m bands, the rate of sethoxydim was 0.37 kg active ingredient (ai)/ha, and for hexazinone, the rate was 1.12 kg ai/ha. In addition, triclopyr ([(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid) at 0.0048 kg acid equivalent/liter was tank mixed with surfactant and water and applied as a directed foliar spray to the scattered hardwood trees and shrubs in April 1998 and 1999.

At Study 2, hexazinone was banded over the rows of planted pine seedlings in April 1998 on all 12 plots; sethoxydim was not needed for bluestem grass control. The triclopyr tank-mix was applied as a directed foliar spray to hardwood trees and shrubs in April 1998 and June 1999.

Brown-spot needle blight on the longleaf pine seedlings became a concern at Study 1. To control the disease, prescribed fire was applied to only the longleaf pine plots in May of the third growing season. Byram's fire intensity averaged 278 kJ/s/m of fire front, which was a low fire intensity for grass-dominated fuels in central Louisiana (Haywood 2009a, 2011). Prescribed fire was not needed for brown-spot needle blight control at Study 2.

Measurements and Data Analysis

Total tree heights were measured with a calibrated pole through eight growing seasons at Study 1 and seven growing seasons at Study 2. Thereafter, a laser instrument (Criterion 400 Survey Laser, Laser Technology, Inc., Centennial, CO) was used. The change in measurement equipment is evident in the shape of the total tree height curves for loblolly and slash pine in figures 1 and 2. Tree d.b.h. was measured with a diameter tape after 8 through 10 growing seasons at Study 1 and 7 through 10 growing seasons at Study 2. Total height and d.b.h. were used to calculate outside-bark stem volume of loblolly pine with Baldwin and Feduccia's (1987) formula, longleaf pine with Baldwin and Saucier's (1983) formulas, and slash pine with Lohrey's (1985) formula.

For each study, number of living pines per ha after 10 growing seasons; average total height, basal area, and volume per tree; and pine basal area and volume per ha were compared among loblolly, longleaf, and slash pine with a randomized complete block design model at $\alpha = 0.05$ using SAS Statistical Software (SAS Institute Inc. 1985). If there were significant species differences, mean comparisons were made with Duncan's Multiple Range Tests at $\alpha = 0.05$ (Steel and Torrie 1980).

RESULTS

At Study 1, longleaf pine seedlings began emerging from the grass stage in the third growing season (25 percent emergence), and 74 percent were in height growth by the end of the fourth growing season. This trend is shown in figure 1 by the relative flatness of the height curve for longleaf pine at ages 1 to 3 years compared to the other two pine species. Ninety-nine percent of the surviving longleaf pines were in height growth by age 8 years. The remaining 1 percent of the longleaf pines were perhaps planted too deep or were overtopped by competing vegetation.

Sixty-four percent of the longleaf pine seedlings at Study 1 were infected with brown-spot needle blight at age 2 years, and to control the disease, a prescribed fire was applied in May of the third growing season. At the end of the third year, only 4 percent of the longleaf pines were evidently infected with brown-spot. The percentage of brown-spot infection remained below 5 percent through seven growing seasons; disease incidence was not recorded thereafter.

Partly because of a high percentage of brown-spot needle blight and slow rate of height growth initiation at Study 1, average height, basal area, and volume per tree were significantly lower for longleaf pine than for loblolly and slash pine after 10 growing seasons (fig. 1). Volume per slash and loblolly pine averaged 85 and 69 dm^3/tree, respectively, and was 20 dm^3/tree for longleaf pine (probability [P] > F-value [F] < 0.0001). There were no statistically significant differences in average height, basal area, and volume per tree between loblolly and slash pine based on Duncan Multiple Range Test comparisons.

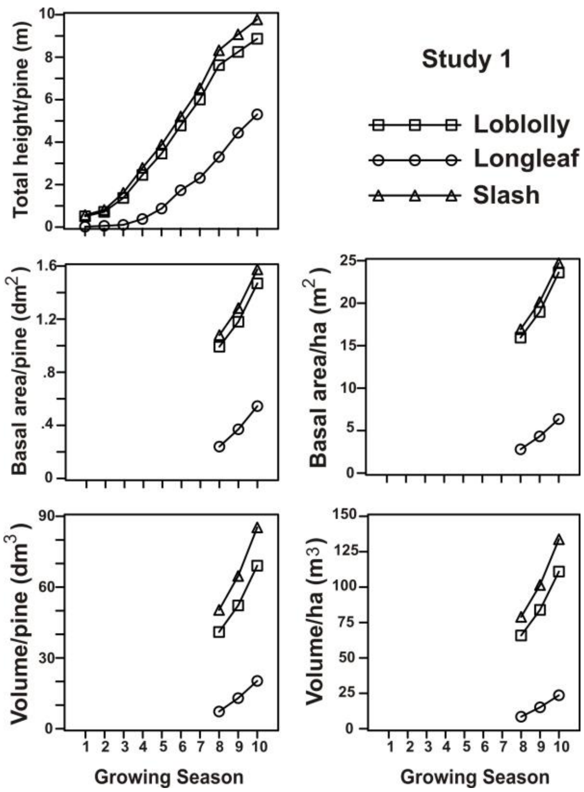

Figure 1—Comparing total height, basal area, and volume per tree and basal area and volume per ha among loblolly, longleaf, and slash pine planted on a Beauregard silt loam soil through 10 growing seasons.

Pine stocking was also significantly greater for loblolly (1,606 trees/ha) and slash (1,569 trees/ha) pine than for longleaf pine (1,165 trees/ha) ($P > F < 0.0001$) with no significant difference between loblolly and slash pine in Study 1. As a result of the differences in stocking and average tree size, basal area and volume per ha were also significantly greater for loblolly and slash pine than for longleaf pine (fig. 1). Volume per ha was 134 and 111 m^3/ha for slash and loblolly pine, respectively, and was 24 m^3/ha for longleaf pine ($P > F < 0.0001$). There were no significant differences in basal area and volume per ha between loblolly and slash pine.

A different longleaf pine growth pattern occurred in Study 2 (fig. 2). On these sandy loam soils, 36 percent of the longleaf pine seedlings emerged from the grass stage in the first growing season. Ninety-seven percent were in height growth after 2 years, and all surviving longleaf pine seedlings were in height growth after 3 years. The quick height initiation is evident in figure 2. In addition, brown-spot needle blight infected only 1 percent of the longleaf pine seedlings through age 4 years.

Despite the rapid height initiation and low disease incidence among longleaf pine in Study 2, average height, basal area, and volume per tree were still significantly greater for loblolly and slash pine than for longleaf pine after 10 growing seasons (fig. 2). Volume per slash and loblolly pine averaged 78 and 73 dm^3/tree, respectively, and was 51 dm^3/tree for longleaf pine ($P > F = 0.0074$). There were no significant differences in average height, basal area, or volume per tree between loblolly and slash pine.

Pine stocking was not significantly different among the three pine species after 10 growing seasons ($P > F = 0.0564$) in Study 2. Stocking was 2,356; 2,259; and 1,907 trees/ha for slash, loblolly, and longleaf pine, respectively. However, as a result of the differences in average tree size and the small differences in stocking, basal area and volume per ha were also significantly greater for loblolly and slash pine than for longleaf pine (fig. 2). Volume per ha of slash and loblolly pine were 181 and 162 m^3/ha, respectively, and was 96 m^3/ha for longleaf pine ($P > F = 0.0019$). There were no significant differences in basal area and volume per ha between loblolly and slash pine.

DISCUSSION

Longleaf pine growth and production were less than for loblolly and slash pine on both study sites through 10 growing seasons. This is not surprising as the development of young longleaf pines normally lags behind that of other southern pines. However, this does not mean that landowners should avoid longleaf pine and choose loblolly or slash pine if the alternative values that longleaf pine produce are desired. These alternatives, which do not necessarily involve management of federally listed threatened or endangered species, would include: (1) hurricane tolerance; (2) growth on droughty, low-nutrition sites; (3) contributes to habitat diversification for wildlife and game animals; (4) being the pine species of choice in arson-prone areas; (5) conveys sustainable forestry certification; (6) increases product quality and diversity; and (7) need not require special management.

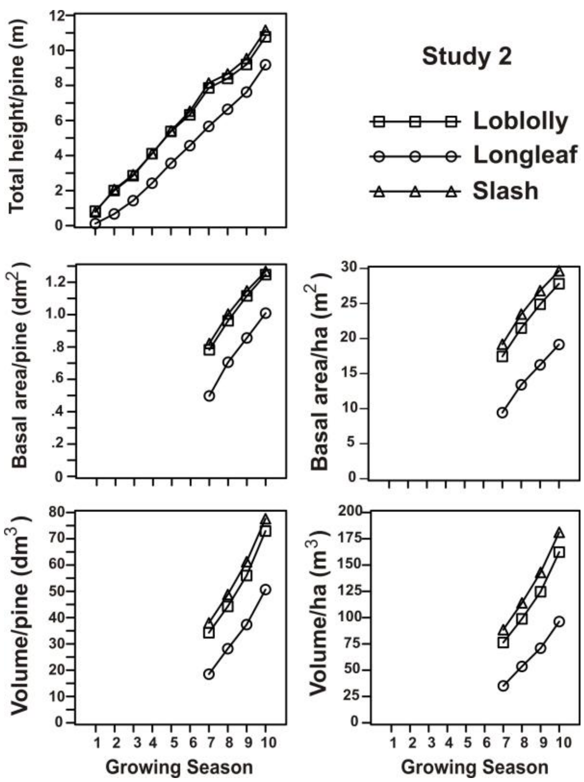

Figure 2—Comparing total height, basal area, and volume per tree and basal area and volume per ha among loblolly, longleaf, and slash pine planted on Ruston and McKamie sandy loam soils through 10 growing seasons.

The tolerance of longleaf pine to hurricane-force winds was reported by Johnsen and others (2009) wherein longleaf pine stands damaged by Hurricane Katrina suffered less mortality than loblolly pine stands and less loss in overstory basal area than loblolly or slash pine stands. The poor growth of intensively managed, short-rotation loblolly and slash pine on sites similar to Study 1 is believed to result from phosphorus deficiencies that greatly reduce stand growth and yield in subsequent rotations (Haywood and Tiarks 2002). Longleaf pine has lower phosphorus and nitrogen requirements than loblolly and slash pine and lower calcium and magnesium requirements than loblolly pine (Dickens and Moorhead 2009). Thus, sites such as Study 1 might be good candidates for longleaf pine reforestation if 25- to 30-year multiple rotations are planned, and management options do not include nutrient amendment. In addition, longleaf pine is better adapted to soil water deficit compared to the other southern pines (Barrett 1995), and once longleaf pine seedlings are established, they tolerate severe to extreme drought conditions (Haywood 2005, 2007).

Longleaf pine is also highly resistant to pine beetles and fusiform rust (*Cronartium quercuum* f. sp. *fusiforme*) (North Carolina Forest Service 2012, The Longleaf Alliance 2012).

Kerr and others (1980) reported that the McKamie soil series in Study 2 has a site index at base age 50 years of 25.9 m (85 feet) for both loblolly and longleaf pine. Therefore, Study 2 is a site where longleaf pine might be recommended for reforestation based on its predicted growth rather than being tolerant of soil resource limitations. In addition, total height growth patterns through age 10 years for loblolly and longleaf pine were similar to those reported by Schmidtling (1987) on an unfertilized, well-drained, upland fine sandy loam in southern Mississippi. In his study, longleaf pine was taller than loblolly pine by age 25 years. This suggests that longleaf pine may be overlooked by forest managers as a reforestation species of choice for sites where it could grow better than expected (Shoulders 1985). For example, longleaf pine was reported to have a site index of 21.3 m (70 feet) at base age 50 years on Smithdale sandy loams (fine-loamy, siliceous, subactive, thermic Typic Hapludults) in central Louisiana (Kerr and others 1980). However, in recent work, the site index of longleaf pine on a Smithdale soil was measured to be 26.2 m (86 feet) at age 50 years (Haywood 2009b), which is similar to the expected site index for loblolly and slash pine on this soil series (Kerr and others 1980).

Because longleaf pine stands can be prescribed burned even as seedlings (Haywood 2005, 2007), the maintenance of an open understory of herbaceous plants and low brush with fire can provide a forest habitat for wildlife different from nearby, unburned stands. This diversity in forest cover should increase game management options and improve the value of property to be leased for hunting. Open forest structure can also be aesthetically pleasing and the rich understory cover typical of longleaf pine forests provides biological diversity that is sought by some landowners. Furthermore, longleaf pine is a forest type that has historic and cultural value for many (North Carolina Forest Service 2012, The Longleaf Alliance 2012, Way 2012). As long as the longleaf pine overstory is not allowed to become too dense, these desirable attributes can be maintained with fire (Haywood 2012, Wolters 1981). In addition, the tolerance of longleaf pine to fire is why it is the pine species of choice for planting in arson-prone areas.

Because a longleaf pine forest can be biologically diverse, its restoration on a portion of a landowner's property may help them obtain sustainable forestry certification. In today's markets, products derived from longleaf pine can be more valuable than products from other southern pines (The Longleaf Alliance 2012). For example, although the market for pulpwood, lumber, and other solid wood products has declined in recent years, the market for utility poles has not fluctuated significantly (The Longleaf Alliance 2012). Longleaf pine stands produce a high percentage of poles, and since poles are a more valuable product than pulpwood and sawtimber, longleaf pine may afford a stronger economic position than loblolly or slash pine. True, the pole market is small relative to the sawtimber market, but the volume of longleaf pine being brought to market is also small. Thus, longleaf pine provides investment security and reduces risk to landowners because the volatility of the longleaf pine market is low.

Besides wood products, longleaf pine stands produce other preferred market goods such as pine straw for landscaping and weaving of high quality baskets, native herbs, high-end furnishings and furniture, and forage for livestock (Haywood 2012, North Carolina Forest Service 2012, The Longleaf Alliance 2012). Some landowners are adverse to the use of prescribed fire, but prescribed burning is not necessary in longleaf pine stands provided the eventual loss of the herbaceous plant community is not a concern (Haywood 2009a, 2011). Thus, no special management practices are needed to grow longleaf pine. This could be convenient for landowners who only wish to reforest with longleaf pine due to poor soil quality, arson problems, to reduce market risk, or for alternative products because longleaf pine can be established and managed similarly to a landowner's loblolly or slash pine.

In summary, "beauty is in the eye of the beholder". Longleaf pine is not a likely choice for landowners only interested in maximizing wood fiber production. However, landowners who desire values other than wood fiber production may want to add longleaf pine to their suite of crop trees given that it grew well on both study sites, although not as well as loblolly or slash pine.

LITERATURE CITED

America's Longleaf. 2009. Range-wide conservation plan for longleaf pine. http://www.americaslongleaf.org/resources/conservation-plan. [Date accessed: October 30, 2012].

Baldwin, V.C., Jr.; Feduccia, D.P. 1987. Loblolly pine growth and yield prediction for managed West Gulf plantations. Res. Pap. SO-236. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 27 p.

Baldwin, V.C., Jr.; Saucier, J.R 1983. Aboveground weight and volume of unthinned, planted longleaf pine on West Gulf forest sites. Res. Pap. SO-191. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 25 p.

Barrett, J.W. 1995. Regional silviculture of the United States. 3rd ed. New York: John Wiley & Sons, Inc. 643 p.

Croker, T.C., Jr. 1987. Longleaf pine. A history of man and a forest. Forestry Rep. R8-FR-7. Atlanta, GA: U.S. Department of Agriculture Forest Service, Region 8. 37 p.

Derr, H.J. 1957. Effects of site treatment, fertilization, and brownspot control on planted longleaf pine. Journal of Forestry. 55: 364-367.

Dickens, E.D.; Moorhead, D.J. 2009. Sample loblolly, longleaf, and slash pine foliage for nutrient analysis. Bethesda, MD: Society of American Foresters. The Forestry Source. 14(9): 14.

Gaines, G. 2012. Report of the Longleaf Partnership Council state assessment and projections for longleaf pine August 2012. Atlanta, GA: America's Longleaf, Longleaf Partnership Council, Assessment and Reporting Team. 4 p.

Harlow, W.M.; Harrar, E.S. 1969. Textbook of dendrology. New York: McGraw-Hill Book Co: 81-84.

Haywood, J.D. 2005. Effects of herbaceous and woody plant control on *Pinus palustris* growth and foliar nutrients through six growing seasons. Forest Ecology and Management. 214: 384-397.

Haywood, J.D. 2007. Influence of herbicides and felling, fertilization, and prescribed fire on longleaf pine establishment and growth through six growing seasons. New Forests. 33: 257-279.

Haywood, J.D. 2009a. Eight years of seasonal burning and herbicidal brush control influence sapling longleaf pine growth, understory vegetation, and the outcome of an ensuing wildfire. Forest Ecology and Management. 258: 295-305.

Haywood, J.D. 2009b. Influence of pine straw harvesting, prescribed fire, and fertilization on a Louisiana longleaf pine site. Southern Journal of Applied Forestry. 33(3): 115-120.

Haywood, J.D. 2011. Influence of herbicides and felling, fertilization, and prescribed fire on longleaf pine growth and understory vegetation through ten growing seasons and the outcome of an ensuing wildfire. New Forests. 41: 55–73.

Haywood, J.D. 2012. Frequency and season of prescribed fire affect understory plant communities in longleaf pine stands. In: Butnor, J.R., ed. Proceedings of the 16th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-156. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 137-143.

Haywood, J.D.; Goelz, J.C.; Sword Sayer, M.A.; Tiarks, A.E. 2003. Influence of fertilization, weed control, and pine litter on loblolly pine growth and productivity and understory plant development through 12 growing seasons. Canadian Journal of Forest Research. 33: 1974-1982.

Haywood, J.D.; Grelen, H.E. 2000. Twenty years of prescribed burning influence the development of direct-seeded longleaf pine on a wet pine site in Louisiana. Southern Journal of Applied Forestry. 24(2): 86-92.

Haywood, J.D.; Harris, F.L.; Grelen, H.E.; Pearson, H.A. 2001. Vegetative response to 37 years of seasonal burning on a Louisiana longleaf pine site. Southern Journal of Applied Forestry. 25(3): 122-130.

Haywood, J.D.; Sung, S-J. S.; Sword Sayer, M.A. 2012. Copper root pruning and container cavity size influence longleaf pine growth through five growing seasons. Southern Journal of Applied Forestry. 36(3): 146-151.

Haywood, J.D.; Tiarks, A.E. 1990. Eleventh-year results of fertilization, herbaceous, and woody plant control in a loblolly pine plantation. Southern Journal of Applied Forestry. 14(4): 173-177.

Haywood, J.D.; Tiarks, A.E. 2002. Response of second-rotation southern pines to fertilizer and planting on old beds—fifteenth-year results. In: Outcalt, K.W., ed. Proceedings of the 11th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-48. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 497-502.

Haywood, J.D.; Tiarks, A.E.; Snow, G.A. 1994. Combinations of fungicide and cultural practices influence the incidence and impact of fusiform rust in slash pine plantations. Southern Journal of Applied Forestry. 18(2): 53-59.

Johnsen, K.H.; Butnor, J.R.; Kush, J.S. [and others]. 2009. Hurricane Katrina winds damaged longleaf pine less than loblolly pine. Southern Journal of Applied Forestry. 33(4): 178-181.

Kais, A.G.; Cordell, C.E.; Affeltranger. C.E. 1986. Benomyl root treatment controls brown-spot disease on longleaf pine in the southern United States. Forest Science. 32(2): 506-511.

Kerr, A., Jr.; Griffis, B.J.; Powell, J.W. [and others]. 1980. Soil survey of Rapides Parish, Louisiana. Baton Rouge, LA: U.S. Department of Agriculture Soil Conservation Service and Forest Service. 87 p. and 114 maps. In cooperation with: the Louisiana Agriculture Experiment Station

Lohrey, R.E. 1985. Stem volume, volume ratio, and taper equations for slash pine in the West Gulf region. In: Shoulders, E., ed. Proceedings of the 3rd biennial southern silvicultural research conference. Gen. Tech. Rep. SO-54. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 451-459.

McNab, W.H.; Avers, P.E. 1994. Ecological subregions of the United States: section descriptions. WO-WSA-5. Washington, DC: U.S. Department of Agriculture Forest Service. 267 p.

Moorhead, D.J.; Dangerfield, C.W.; Beckwith, J.R. 2012. Opportunities for intensive pine plantation management. http://www.bugwood.org/intensive/98-002.html. [Date accessed: October 30, 2012].

National Climatic Data Center. 2012. U.S. Department of Commerce, NOAA satellite and information service. http:// http://www1.ncdc.noaa.gov/pub/data/cirs/. [Date accessed: October 30, 2012].

North Carolina Forest Service. 2012. Longleaf pine forest – superior economic, environmental, and historical values. Longleaf Leaflet No. 2. Raleigh, NC: North Carolina Forest Service. http://ncforestservice.gov/publications/LongleafLeaflets/LL02.pdf. [Date accessed: October 30, 2012].

SAS Institute, Inc. 1985. SAS user’s guide: statistic. 5th ed. Cary, NC: SAS Institute Inc. 956 p.

Schmidtling, R.C. 1987. Relative performance of longleaf compared to loblolly and slash pines under different levels of intensive culture. In: Philips, D.R., comp. Proceedings of the 4th biennial southern silvicultural research conference. Gen. Tech. Rep. SE-42. Asheville, NC: U.S. Department of Agriculture Forest Service, Southeastern Forest Experiment Station: 395-400.

Shoulders, E. 1985. The case for planting longleaf pine. In: Shoulders, E., ed. Proceedings of the 3rd biennial southern silvicultural research conference. Gen. Tech. Rep. SO-54. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 255-260.

Steel, R.G.D.; Torrie, J.H. 1980. Principles and procedures of statistics a biometrical approach. 2d ed. New York: McGraw-Hill Book Company. 633 p.

The Longleaf Alliance. 2012. Restoring and managing longleaf pine. http://www.longleafalliance.org/. [Date accessed: October 30, 2012].

Tiarks, A.E.; Haywood, J.D. 1981. Response of newly established slash pine to cultivation and fertilization. Res. Note SO-272. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 4 p.

Turner, R.L.; Van Kley, J.E.; Smith, L.S.; Evans, R.E. 1999. Ecological classification system for the national forests and adjacent areas of the West Gulf Coastal Plain. Nacogdoches, TX: The Nature Conservancy and Stephen F. Austin State University. 305 p.

Way, A. 2012. Longleaf pine ecosystem. The new Georgia encyclopedia, land and resources/environment/conservation and management/environmental history section. http://www.georgiaencyclopedia.org/nge/Home.jsp. [Date accessed: October 30, 2012].

Wolters, G.L. 1981. Timber thinning and prescribed burning as methods to increase herbage on grazed and protected longleaf pine ranges. Journal of Range Management. 34(6): 494-497.