Comparing 16-year-old shortleaf and loblolly pine growth and yield on a north Mississippi afforested site

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Abstract

This analysis compares the growth and yield of 16-year-old shortleaf pine (*Pinus echinata* Mill.) and loblolly pine (*Pinus taeda* L.) planted on retired fields near Holly Springs in north Mississippi. The 1-0 bareroot shortleaf seedlings were planted in early March of 2005, while bareroot 1-0 loblolly pine 2nd-generation seedlings were planted during the third week of March in 2005. For both species, the site was subsoiled. Within the plantations of each species, four plots were established for each species and total height and diameter at breast height (dbh) were measured. Volumes were then estimated using appropriate combined-variable volume equations. Loblolly pine had substantially greater growth rates relative to shortleaf pine, producing on average across the four plots (n = 4) 48.4 m^{-2} of basal area ha^{-1}. This basal area was 42.6% greater than the 34.0 m^{-2} of basal area ha^{-1} observed within the shortleaf pine. For merchantable volume, defined as all trees with a dbh of 10.16 cm and greater up to a diameter-outside bark (dob) of 5.08 cm, the loblolly pine m^{-3} volume ha^{-1} of 424 was 2.36 times greater than that of shortleaf pine. Merchantable volumes were converted to tons and a revenue of $3.61 was assumed per ton of pulpwood. A theoretical 3rd row thinning with no logger select of the remaining rows was conducted – hence the thinning was assumed to remove 33% of the standing merchantable yield. Loblolly pine had a stumpage value of $97.39 ha^{-1} which was 136% greater than the shortleaf pine economic value of $41.23 ha^{-1}.

Keywords

Pinus; *Pinus echinata*; *Pinus taeda*; Subsoiling; Ripping

Contents

1 Introduction

Shortleaf pine (*Pinus echinata* Mill.) is native to much of the western half of the southeastern United States as well as southern Missouri (Little 1971; Guldin 2019). Currently, the area occupied with stands dominated by loblolly pine (*Pinus taeda* L.) greatly exceeds shortleaf pine dominated stands. For instance, in the western states of the southeastern US, including Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas, loblolly dominates on around 16.5 million ha and shortleaf dominates on around 1.74 million ha. However, historically, shortleaf pine had a larger range, in fact it has the largest range of any southern pine species. Over the last 30 to 40 years, this extensive shortleaf pine ecosystem has lost over 50% of its former area (Clabo and Clatterbuck 2015; Guldin 2019). Changes in timber management practices, altered fire regimes, massive pine beetle outbreaks in poorly managed stands, disease, and land use changes have contributed to this rapid decline. As a result, faster growing loblolly pine plantations have replaced much of the area once occupied by this ecosystem, plus the lack of fire has led to an increased abundance of shade-tolerant hardwood species (Guldin 2019) and less fire-dependent loblolly pine in natural stands. Land conversion for agricultural production and urban expansion has also contributed to the reduction in the area once occupied by the shortleaf pine ecosystem.

Coordinated efforts are beginning to restore the shortleaf pine ecosystem such as by groups like the Shortleaf Pine Initiative. Restoring this ecosystem will likely entail different approaches, including the underplanting of shortleaf pine (Schnake et al. 2021), but restoration will also involve the use of plantations (Guldin 2019). Although a more open woodland setting may be the ultimate goal by the majority of landowners and agencies, timber production will help to offset the initial conversion and regeneration costs. Other components of these ecosystems such as understory vegetation, biological diversity, wildlife habitat, recreation, etc., are also highly desired. Thus, managers need growth and yield estimates to examine financial returns and how wildlife, water quality, etc., may be impacted when establishing and tending shortleaf pine plantations.

According to a recent Forest Inventory and Analysis (FIA) estimate (USDA Forest Service 2022), and when including Missouri, there are 103,197 ha of shortleaf pine dominated plantations in the western half of the southeastern United States, while northwestern Arkansas and southeastern Oklahoma have considerable amounts of naturally-regenerated stands (Table 1). But shortleaf pine stands are also relatively abundant in Mississippi, the majority being of naturally-regenerated origin.

As noted earlier, a significant factor contributing to the substantial reduction in shortleaf pine dominated stands on the landscape is direct, and purposeful, conversion to other cover types following initial harvesting, predominately conversion to loblolly pine generally through the use of plantations. Loblolly pine generally has faster growth rates (Williston 1958, 1963; Branan and Porterfield 1971; Watson et al. 1973; Smalley 1986; Williston 1985; Schubert et al. 2004; Lynch et al. 2016) than shortleaf pine that usually leads to greater financial returns. However, shortleaf pine is generally considered to outgrow loblolly pine by age 50 (Smalley 1986; Clabo and Clatterbuck 2015).

There are some advantages to establishing shortleaf rather than loblolly pine though. For instance, it often has better stem form (Will et al. 2013) that will increase volume production and it is particularly resistant to fusiform rust (*Cronartiiumquercuum* f. sp. *fusiforme*) (Clabo and Clatterbuck 2015). Additionally, this species is generally less negatively affected by ice, snow, and cold temperatures relative to the other major southern pines (Will et al. 2013; Clabo and Clatterbuck 2015). With time, shortleaf pine forests can attain higher standing basal areas ha^{-1} (Smalley 1986).

Table 1. Hectares of shortleaf pine forest types as defined by the USDA Forest Service Forest Inventory and Analysis (FIA) program (USDA Forest service 2022). FIA has two forest type classifications where shortleaf pine is a dominant species – shortleaf pine (FORTYPCD = 162) and shortleaf pine/oak (FORTYPCD = 404).

	Natural		Planted		Total
State	Shortleaf	Shortleaf/Oak	Shortleaf	Shortleaf/Oak	ha
Alabama	45152	46475	1256	-	92883
Arkansas	470428	306472	35261	3771	815932
Louisiana	14977	11675	-	-	26653
Mississippi	66477	68568	4219	3468	142733
Missouri	62037	122728	34748	3870	223383
Oklahoma	206069	184025	10781	-	400874
Tennessee	20270	53883	3628	-	77780
Texas	102277	51540	2195	-	156012
Total	987687	845366	92088	11109	
Total	1833053		103197		1936250

1.1 Review of growth and yield studies comparing shortleaf pine to loblolly pine plantations

Many studies have compared directly growth and yield when planting these two species. Some examples are provided in this paper. In northern Virginia at age 21 (Bashore and Marler 1955), loblolly had lower survival but was greater in diameter and height, basal area, and merchantable volume. For old-field plantations established in western Tennessee at a planting density of 2990 seedlings ha^{-1} when 19-years-old (Huckenpahler 1950) and 29-years-old (Williston 1959), similar to Bashore and Marler (1955), survival was less but diameter, height, basal area, and merchantable volumes were greater for loblolly pine. Marler (1963) presented survival rates of many shortleaf and loblolly pine plantations on privately owned land established from 1959 to 1962 on both cutover and old-field sites in Virginia. Results for shortleaf were only from the Mountain and Piedmont regions. Loblolly pine generally had higher survival rates.

In the Piedmont of South Carolina (Branan and Porterfield 1971) at age 13, when planted at a density of 1683 seedlings ha^{-1}, loblolly pine had greater survival and basal area ha^{-1} and had taller trees on average than shortleaf pine. In southeastern Louisiana plantations (Wakeley 1969), 34-year-old loblolly pine exceeded 30-year-old shortleaf pine growth and yield. In southwestern Alabama, in age 18 plantations planted at 2990 seedlings ha^{-1}, loblolly had 21% greater volume ha^{-1} relative to shortleaf pine (Watson et al. 1973). Up to age 30 in south-central Tennessee (Schubert et al. 2004), loblolly pine had substantially greater m^3 volume to a 10.16 cm dob (diameter outside-bark) for plantations established at densities of 2990, 1329, 746, and 479 seedlings ha^{-1}. Dipesh et al. (2015) reported that up to age 10 at four sites in southeastern Oklahoma, planted loblolly pine had greater survival, basal area ha^{-1}, and greater height growth than planted shortleaf pine when both species were established at a density of 1344 seedlings ha^{-1}. Hooker et al. (2020; 2021) reported results from a study examining loblolly versus shortleaf of West Gulf Coast provenance machine-planted containerized seedlings planted at a density of 1495 ha^{-1}. At age 3, loblolly had greater heights and survival rates than shortleaf.

Some studies though have showed that shortleaf pine exceeded loblolly pine growth and yield. For all studies, shortleaf pine only exceeded loblolly pine at older ages. In a species comparison/provenance trial in southern Illinois (Rink and Wells 1988), at age 37, shortleaf pine had greater volumes ha^{-1}relative to loblolly pine. This was observed despite loblolly pine having greater height because of substantially greater shortleaf pine survival rates. Within East Texas (Ting and Chang 1985), 19-year-old loblolly had greater diameter and height growth relative to 21-year-old shortleaf but slightly less basal area because loblolly had lower survival rates. Both plantations were established at a density of 2244 seedlings ha^{-1}. In 31-year-old plantations in southern Illinois (Arnold 1981), shortleaf pine had greater total volumes ha^{-1} than loblolly pine for planting densities of 2990 and 6729 seedlings ha^{-1}, but lower volumes ha^{-1} for planting densities of 1077 and 1683 seedlings ha^{-1}. In fact, at age 25 for the 6729 planting density ha^{-1}, shortleaf pine total volume exceeded that of loblolly pine (Arnold 1978). This is most likely reflective of the fact that shortleaf pine can generally carry higher basal areas ha^{-1} (Smalley 1986). Without herbicide treatments to control undesirable vegetation and modern fire suppression efforts, shortleaf pine would likely have greater survival rates relative to loblolly pine. Thus, when comparing growth and yield under those conditions between loblolly and shortleaf pine, unlike today on many sites, results may be more favorable for shortleaf.

The objective of this paper is to provide a review of growth and yield comparisons of shortleaf and loblolly pine plantations within the southeastern United States and to present results from an afforestation of a former pastureland within northern Mississippi. First-year survival results were reported within Kushla (2009; 2010) and first-year ground-line diameter (GLD) and total tree height were also reported in Kushla (2009).

2 Material and methods

2.1 Study site description

The study site is on the Mississippi Agriculture and Forestry Experiment Station near Holly Springs, Mississippi (Kushla 2009; 2010). The current station was established in 1947. The terrain is gently undulating (2–5% slope) on the edge of the loess hills of Mississippi. The predominant soils include Grenada, Providence, and Loring silt loams (USDA Soil Conservation Service 1972). All these soils are Alfisols having fragipans about 0.61 m deep with relatively high native fertility. Average annual temperature ranges from around 16.7 to 21.1°C, average annual precipitation ranges from around 145 to 183 cm, and the frost-free period annually ranges from about 250 to 315 days (Soil Survey Staff 2022).

Subsoil treatments were completed in December 2004 before tree planting. A 50.8-cm ripping shank was pulled by a tractor on 3.05-m planting centers. For shortleaf, bareroot 1-0 seedlings were planted on the retired farmland March 7 and 8, 2005. The shortleaf seedlings were machine planted on a spacing of 3.05 m x 2.13 m for a density of 1537 seedlings ha^{-1}. For loblolly pine, bareroot, 2nd generation (Weyerhaeuser), 1-0 seedlings were machine planted on the retired farmland March 21, 2005 on a spacing of 3.05 m x 2.13 m for a density of 1537 seedlings ha^{-1}. The distinct planted treatment areas for each species were at least 1 ac in size.

Both species had a first-year herbaceous weed control treatment consisting of a combination of herbicide application and mowing the 1st year. Herbicide was applied in April 2005. A tank mix of 4-oz Arsenal AC (BASF) product and 2-oz of Oust XP (Dupont) product (2.0 oz a.i. imazapyr + 1.5 oz a.i. sulfometuron methyl, respectively) per sprayed acre was applied over the planted trees in a 1.22-m band. The sprayer volume was calibrated to 20 gal ac^{-1}. In addition, the lanes between the rows were mowed three times during the growing season on treated areas. Mowing was an attempt to provide extended weed control through the growing season.

For this analysis (Kushla 2009; Kushla 2010), plots for both species were only located on the subsoiling treatments. Both plantations are considered to be 16 years old (trees were 17 years old from seed).

2.2 Data

For both species, four 0.02-ha (1/20th acre) circular plots were established. Total tree height and diameter at breast height (dbh) were measured in late December of 2021 within the four shortleaf plots and during mid-February of 2022 within the four loblolly plots. For shortleaf pine and loblolly pine, total cubic foot volumes and merchantable volumes to a 5.08-cm diameter outside bark (dob) were estimated using equations presented by Smalley and Bower (1968a,b), respectively. These equations were chosen since equations were estimated using the same statistical procedure and hence there is no impact of parameter estimation methodology on the estimated volumes between species.

Dominant height (ft) was defined as the average height of the tallest 50% of surviving shortleaf pine or loblolly pine trees (for a particular species, other species within plots were not selected). There were very few, and some cases no other, tree species in these plots besides the specific trees planted.

3 Results and discussion

At age 16 loblolly pine is clearly outperforming shortleaf pine (Tables 2 and 3). Loblolly pine not only has larger diameter trees on average, but also greater survival. Basal area ha^{-1} is 42% greater for loblolly pine, while for total volume ha^{-1} loblolly is 2.35 times greater. Dominant height is substantially greater for loblolly pine, it actually is somewhat difficult to identify the tops of individual trees within the loblolly pine plantation. The H/D ratio is substantially greater for loblolly pine relative to shortleaf pine; resulting from the substantially greater stand density of loblolly pine (Valinger and Fridman 1997; Harrington et al. 2009). For the same diameter, loblolly pine would be expected to be taller. In addition, this ratio is an indication that the loblolly pine trees are under extreme competition for limited amounts of light (Harrington et al. 2009). Given the high H/D ratio for loblolly pine, and excessive stand density for this age, thinnings should be moderate at most and not severe to avoid potential issues with windthrow and ice storms (Bragg et al. 2003) that can occasionally occur in this region of Mississippi (e.g. Halverson and Guldin 1995, Bragg et al. 2003).

Table 2. Summary measurements by species across the four replications (*n* = 4 for each species). Observations, measurement ages, and summary statistics of dominant height, trees ha^{-1}, quadratic mean diameter, basal area ha^{-1}, arithmetic mean height, and the height-diameter ratio (H/D Ratio). Where: Stdev – standard deviation, Min – minimum, and Max – Maximum.

	Dominant height (m)				Trees ha^{-1}				Quadratic Mean Diameter (cm)			
Species	Mean	Min	Max	Stdev	Mean	Min	Max	Stdev	Mean	Min	Max	Stdev
Loblolly	19.0	17.2	20.1	1.24	1,458	1,384	1,532	63.8	20.5	19.2	21.8	1.17
Shortleaf	11.3	10.8	11.9	0.47	1,236	1,137	1,285	69.9	18.7	17.9	19.3	0.64
	Basal Area ha^{-1} (m^2)				Arithmetic Mean Height (m)				H/D Ratio			
Species	Mean	Min	Max	Stdev	Mean	Min	Max	Stdev	Mean	Min	Max	Stdev
Loblolly	48.4	43.4	53.5	5.3	17.4	15.3	19.1	1.60	87.5	79.4	94.3	6.75
Shortleaf	34.0	32.1	35.6	1.5	10.3	9.6	10.8	0.55	57.2	51.5	60.7	3.97

Table 3. Summary measurements by species across the four replications (*n* = 4 for each species). Observations, measurement ages, and summary statistics of total m^3 volume ha^{-1} and merchantable m^3 volume ha^{-1}. Merchantable volume is to a 5.08-cm top diameter-outside bark (DOB) for trees with a dbh of 10.16 cm and greater. Where: Stdev – standard deviation, Min – minimum, and Max – Maximum.

	Total m^3Volumeha^{-1}				Merchantable m^3Volumeha^{-1}			
Species	Mean	Min	Max	Stdev	Mean	Min	Max	Stdev
Loblolly	427.6	340.4	494.8	73.6	424.0	338.1	492.3	74.2
Shortleaf	182.1	166.3	198.6	15.7	179.5	164.4	195.6	15.7

Stands of both species are in immediate need of a thinning. This is most particularly true for loblolly pine. Pulpwood market conditions are extremely poor in northeastern Mississippi. From a stand density study perspective, the lack of thinning is advantageous. However, both species are in danger of being attacked by the southern pine beetle (SPB - *Dendroctonus frontalis* Zimmermann). We used the following equation recommended by the Mississippi Forestry Commission[1] for a first commercial thinning (age 12 and older) to estimate the SPB hazard rating.

[1] SPB Hazard Rating = $6.92 + 2.004 * BA_P - 46.4058 * R$

Where:

BA_P – pine basal area per acre at breast height (4.5 feet above the ground in English units), and

R –10-year radial growth at 4.5 feet above the ground (breast height in English units), inches.

The Mississippi Forestry Commission is the state-funded agency that helps landowners within the state of Mississippi conduct forest management on their property and that helps them to identify issues with their forests and trees. For the equation, since we don't have 10-year radial increments at dbh (R), we just divided the current quadratic mean diameters (QMD) by 16, and then divided the diameters by two to obtain the average annual radius. Although not exact, this assumption is reasonable, and since the stand densities are so high, this inexact assumption probably doesn't impact much the hazard rating category of each species.

Across the four plots of each species when averaged, loblolly has a SPB hazard rating of 418 while shortleaf pine has a SPB hazard rating of 294. Scores of 233 and higher are assigned to the Very High rating category, as expected given our data and the stand conditions, both plantations are highly susceptible. Within Mississippi at the current time across all counties, to reduce the probability of SPB infestation, the Mississippi Forestry Commission is offering a subsidy to landowners who cannot financially thin their pine trees.

To compare the current financial value of the two species, a simple economic analysis will be conducted where a thinning operation is conducted at the current time. Due to the high density and issues with trees toppling or breaking, every 3rd row will be thinned, but we will assume no logger select of theremaining rows. Thus, for simplicity, we can simply divide the predicted yields by three. To convert merchantable m^3 volumes (up to 5.08-cm dob) as reported in Table 3 to weights, it was assumed that each cubic-foot of wood (following conversion to cubic feet) when converted to tons of wood and bark weighs 66 lbs for both species (based on Clark et al. 2006).

Hence, for loblolly pine there is estimated to be 448 Mg ha^{-1} (200 t per acre) and for shortleaf pine there is estimated to be 191 Mg ha^{-1} (85 t per acre). A pulpwood revenue per ton of \$3.61 was used to determinepotential financial values for both species (Measells 2022, 1st quarter). Thus, at the current time, if a 3rd row thinning with no logger select was conducted for both species, the loblolly and shortleaf pine plantations would be worth \$240.65 (66.661 * 3.61) and \$101.88 (28.221 * 3.61) per acre, respectively. This equates to \$594.66 and \$251.75 ha^{-1}.

Although the financial returns from the shortleaf pine first thinning are less than those from loblolly pine, there are some potential financial advantages of shortleaf pine. As mentioned previously, shortleaf pine can carry higher densities (Smalley 1986), and thus by age 40 and certainly by age 50 this species will often exceed loblolly pine in sawlog volume/weight and perhaps ply logs. Currently, in northeastern Mississippi, sawlog stumpage on average is \$30.12 per ton, which is 8.34 times greater in value than the pulpwood stumpage value of \$3.61 per ton (Measells 2022). Additionally, shortleaf pine has a high potential to produce poles, which often demand a higher stumpage value relative to all other markets commonly observed in Mississippi. Across the state of Mississippi, average pole stumpage is \$39.26 per ton while average pine sawlog stumpage is \$27.92 per ton, hence pole stumpage is 40.6% greater. Currently, there is not a strong market for poles in the northeastern region of Mississippi, all facilities are located in southern Mississippi. However, if enough haare reforested with shortleaf pine and with time, perhaps pole facilities and markets can be established in this part of Mississippi. Thus, under ideal conditions, it is not so much that across a rotation that loblolly out produces shortleaf, but rather, on many sites, it is a matter of what age shortleaf attains or exceeds loblolly pine yields.

Shortleaf pine's slower growth may actually be beneficial from a wildlife habitat perspective. The shortleaf pine stand, although the canopy is essentially closed, still has some understory vegetation production (both herbaceous and woody, but particularly woody), but the loblolly pine is closed canopy and has very minimal, and in most locations, no understory production. The loblolly pine plantation is extremely dense and dark. Thus, shortleaf pine's delayed crown closure may be beneficial for those landowners interested in not only timber revenues, but hunting as well (Wigley 1986). The practice of thinnings will also further the benefits of shortleaf pine relative to loblolly pine. Beyond that, generally speaking, for the same amount of overstory basal area, the smaller needles of shortleaf pine may permit more light to be transmitted through the crown, resulting in relatively greater understory production.

Due to the wildlife benefits of shortleaf pine relative to loblolly pine, landowners may be able to charge higher hunting lease rates for a longer length of time within 10-to-20 year old unthinned shortleaf plantations, prior to using thinnings to increase light, moisture, and nutrients to the understory (Dr. Daryl Jones, Program Coordinator Natural Resource Enterprises (NRE), Mississippi State University, Personal Communication 2022). If applicable to a landowner's situation, with time as the hardwood component develops within these shortleaf plantations, and a more mixed pine-hardwood stand condition exists, higher lease rates are likely possible as well. Of course, these statementsare highly dependent on specific site and market conditions and situations.

4 Conclusions

The shortleaf pine plantation is developing well, however, the loblolly pine plantation is producing at an excessively high rate. As noted in Fox et al. (2007), we as foresters over the last 75 or so years have greatly enhanced our silvicultural ability to produce southern yellow pine volume, particularly loblolly pine. The observed growth rates of loblolly in our study are an indication of that. Currently, inflation is increasing at high rates, and fuel costs are high, and thus reforestation costs are increasing. This is coupled with extremely poor pulpwood markets in the northeastern part of Mississippi, and less than desirable chip-n-saw and sawtimber markets in this region. Additionally, logging costs are also increasing which should continue to produce low stumpage values. Thus, the extremely high growth rates for loblolly pine observed in our study will help to compensate landowners. Shortleaf pine may offer advantages in terms of wildlife habitat since stand development is slower, the potential for landowners to charge higher hunting lease rates, and there may be more financial incentive programs to restore once dominant shortleaf pine ecosystems.

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