Assessing Income and Risk of Incorporating Pine Straw Production into Slash Pine Plantations

T. Eric McConnell

Abstract

Slash pine plantation economic returns from both timber and pine straw producing perspectives were compared. Bare land values (BLVs) were calculated for site index 65 (base age 25) across three discount rates (4%, 5%, and 6%), three planting densities [545 (8 by 10 ft), 623 (7 by 10 ft), and 726 (6 by 10 ft) trees per acre], and two sets of timber prices (30-year and 10-year averages). Timber yields were obtained from the Cutover Slash Growth and Yield Simulator. Straw yields were estimated stochastically using a two-parameter Weibull distribution based on findings from a summary of pine straw yields and economic benefits in loblolly, longleaf, and slash pine stands. Straw production at an estimated average of 198 bales per acre (13 by 13 by 26 inches) improved net economic returns across all discount rates and planting densities. Increasing discount rates expectedly lowered BLVs. The BLVs varied much less across spacings, with planting at 7 by 10 ft being the preferred option. From 159 to 164 bales per acre were needed for pine straw operations to break even when planting 623 trees per acre depending on the discount rate. The distance from the average BLV to the 90th percentile was greater than the distance from the average BLV to the 10th percentile across strategies. This implied a greater potential existed for pine straw harvesting to improve BLV, but risk associated with a pine straw enterprise could reduce net income levels below simply choosing to forgo this activity.

Alternative southern pine forest products markets currently include harvesting needles for mulch along with a renewed and more inclusive carbon market for small landowners (Stainback and Alavalapati 2002, Dyer et al. 2012, Tanger et al. 2023). Harvesting resin for biofuel production and establishing a water-yield payment system provide additional promise (Susaeta et al. 2014, 2016b), but they are still in exploratory phases. These options for nontimber income are desirable in the current economic environment for managed timberland to be considered a worthy investment. Southern pine sawtimber price in Mississippi, e.g., had declined by –4.99 percent annually since 2010, while pulpwood price declined even further, by –8.72 percent (McConnell et al. 2021). Volatility has increased in that state's sawtimber market over the same period. This means the most valued product in plantation management was not only trending downward, but it was also experiencing wider price swings than were observed in earlier time periods.

Pine straw offers landowners an established marketplace to gain additional income from southern pine timberland. Straw is prepared and harvested generally during a stand's early growth period from canopy closure up to the first thinning (Dickens et al. 2018). It offers early income that can occur as often as annually, and because of its timing, it is less subject to discounting. This can be critical to landowners for offsetting undiscounted establishment costs, particularly those who are either wary of, or do not qualify for, cost sharing or income tax deductions (Bullard and Straka 1988; Tanger et al. 2020).

Loblolly pine (*Pinus taeda* L.), slash pine (*P. elliottii* Engelm.), and longleaf pine (*P. palustris* Mill.), have been planted on nearly 30 million acres in the South where the three species' home ranges overlap (USDA Forest Service 2023). Loblolly pine plantings comprise 81 percent of this acreage, followed by slash pine at 15 percent, and longleaf pine at 4 percent. Loblolly pine's dominance was driven by the geographic expanse of its home range, its adaptability to variable site conditions, and its responsiveness to management (Baker and Langdon 1990). Slash pine's natural home range is the more limited of the southern pines (Lohrey and Kossuth 1990). It has been planted beyond that range, predominantly westward into central Louisiana and eastern Texas and less so northward into North Carolina and

Assistant Professor, Department of Forestry, Mississippi State University, Mississippi State, Mississippi (eric.mcconnell@msstate.edu). This paper was received for publication in January 2023. Article no. 23-00003.

Forest Prod. J. 73(3):209–218.
doi:10.13073/FPJ-D-23-00003

Tennessee. Current plantings on private timberland approach 4.5 million acres (USDA Forest Service 2023). The geographic expanse of longleaf pine's historical home range approached that of loblolly pine, but plantings today are driven more by ecological restoration than timber production (Dyer et al. 2012).

Consumer preference for pine straw, however, is opposite to producer preference for timber production (Dickens et al. 2012). Longleaf pine straw is preferred for its needles' superior color retention and durability over slash pine, which is then followed by loblolly pine. It would require significant financial incentives to entice landowners to switch to longleaf pine plantation production, though (Susaeta and Gong 2019). Both longleaf and slash pines' needles fall after 2 years, whereas loblolly pine requires 3 or 4 years (Dyer et al. 2012). Slash pine possessed greater foliage density and foliage biomass per hectare than did loblolly pine over a 21-year study (Zhao et al. 2019).

Although loblolly pine generally outperformed slash pine in total timber yield over Zhao et al.'s (2019) study period, slower growth can improve wood quality. Slash pine's material advantages over loblolly pine include higher wood specific gravity, and consequently strength (Forest Products Laboratory 2010). The species provides these gains without the delayed wood development (grass) stage that the likewise dense longleaf pine must biologically endure. This ultimately delivers an economic advantage over longleaf pine in terms of rotation age that can maximize timberland's productive value (Straka 2010).

Susaeta et al. (2016a) estimated land value planted in slash pine along the southeastern coastal plain using a whole stand growth and yield model, which was complemented by a pine straw production model. They found timber and straw production together at their averages improved land value. Dickens et al. (2012) obtained mixed results in a field study of independent sites for slash pine in Georgia. One site that incorporated straw production improved net annual income US$23 per acre, while another lost –US$17 per acre. The site with negative income was already approaching self-thinning at the study's outset, which the authors referenced as a potential contributing factor to that result.

Southern pine straw revenue has rapidly increased while timber stumpage has not (Center for Agribusiness and Economic Development 2022). Slash pine's commercial importance for both timber and straw necessitate further study for forest managers and landowners to better understand how pine straw economically integrates into traditional slash pine plantation timber management. This is particularly true along the less studied western portion of the species' home range. The objective of this study was to apply the Cutover Slash (CSLASH) Growth and Yield Simulator from bare ground to final harvest under intensive plantation management. Three planting densities at three discount rates were evaluated, with and without pine straw harvesting. Two sets of timber prices based on short- and long-term averages were applied to estimated timber yields. Pine straw harvesting occurred annually from the initial harvest to thinning. Maximum bare land value was the criterion assessed across treatments; this was recognized as each treatment combination's financial maturity. Straw yields were estimated stochastically using published data on slash pine (Dickens et al. 2012). Resampling from the straw yield distribution provided upper and lower production levels to clarify straw production's ability to improve timberland returns.

Methods

The CSLASH simulator is a distance-independent, individual tree, growth and yield system developed by Matney (1996) to better understand slash pine management on cutover lands in the Gulf South (available for download from Mississippi State University's Forest and Wildlife Research Center). Discounted cash flow tables were set up for planting densities of 545 (a spacing of 8 ft within a row and 10 ft between rows), 623 (a spacing of 7 ft within a row and 10 ft between rows), and 726 (a spacing of 6 ft within a row and 10 ft between rows) trees per acre at three real discount rates of 4 percent, 5 percent, and 6 percent. Site index was considered above average along the West Gulf at 65 feet at 25 years across all treatment combinations (Zarnoch and Feduccia 1984). A natural hardwood component comprising 5 percent of basal area was included in each stand's early years. Stands were modeled to include one fourth-row and low thinning to a residual basal area of 75 ft^2/acre when basal area reached 120 ft^2/acre. A regeneration harvest occurred when bare land value was maximized. Bulk density was entered as an outside-bark average of 55.3 lb/ft^3. This value was derived from a green basis specific gravity of 0.54 and bark percentage volume of 18 percent (Smith and Miles 2009) at 50 percent green basis moisture content. One cord's weight was 5,200 pounds per Mississippi statute. Pulpwood diameter limits were 4.6 inches at breast height and a 3-inch top; Chip-N-Saw diameter limits were 7.6 inches at breast height and a 6-inch top; sawtimber diameter limits were 11.6 inches at breast height and a 7-inch top.

Maggard's (2021) most recent publication on the costs of forestry practices in the US South, which were reported in 2020 dollars, were adjusted for inflation using the producer price index for all commodities (WPU00000000; US Department of Labor 2023, https://www.bls.gov/ppi/) to 2022 constant dollars to better reflect the cost surges experienced nationally since 2020. The timber-only strategy consisted of a one-pass mechanical operation plus burn at US$186 per acre, which was followed by planting in Year 0. Seedlings were $0.17 each and planted at $106 per acre. Herbaceous weed control was applied in Year 1 at $71 per acre. A hardwood control operation was conducted the same year of the thinning at $99 per acre. Fertilization was excluded from the timber-only strategy. Ad valorem taxes assumed Cushing's and Newman's (2018) $4.62 per acre average for Mississippi. Annual consulting forester management costs of $5.00 per acre and sales commission of 8.5 percent were approximated across all tract sizes and sale types per Wright and Munn (2016).

Two sets of timber prices—both adjusted for inflation to 2022 third quarter constant dollars per the producer price index for all commodities—were analyzed using data from Timber Mart-South (Norris Foundation 2019) and the Mississippi Timber Price Report (Mississippi State University Extension 2021). First were 30-year average timber prices, which were $11.04, $29.75, and $48.81 per green ton for pulpwood, Chip-N-Saw, and sawtimber, respectively Second were 10-year average prices per green ton of $8.61 for pulpwood, $19.13 for Chip-N-Saw, and $31.20 for sawtimber. Bare land values (BLV) were calculated in real dollars per acre before taxes:

$$\mathrm{BLV} = \frac{\mathrm{NPV} \times e^{rT}}{e^{rT} - 1} \quad (1)$$

where BLV was bare land value, NPV was net present value of the first timber rotation, e was the base of the natural logarithm, r was the real discount rate, and T was the rotation age that maximized BLV. The BLV signifies the most that can be paid for bare land to produce timber under the proposed strategy. The BLVs were calculated for each timber price, planting density, and discount rate combination from age 25 to 42 (age 42 was the maximum age allowed by CSLASH). The upper portions of Tables 1, 2, and 3 illustrate the timber-only strategies for the 545, 623, and 726 trees per acre planting scenarios, respectively.

The timber plus pine straw approach followed the same activities for Years 0 and 1 as well as annual management costs, taxes, and consulting forester commission on timber sales. Timber product prices were equal also. Pine straw management activities were assumed to begin no earlier than crown closure, which typically occurs between ages 6 and 10 years, and ended at the thinning operation. The first activity began 3 years prior to the first straw harvest with an understory burn ($32/acre). This was followed by mowing ($40/acre), an herbaceous weed application ($71/acre), hardwood control ($98.97/acre), and fertilization ($127/acre). Fertilization cannot be incorporated into CSLASH; thus, it had to be assumed to simply offset nutrient removal due to strawing, nothing more or less. The year before the first harvest, mowing and herbaceous weeding were repeated.

Straw harvesting generally occurs annually, but harvest cycles range from twice annually to once every 5 years (Dickens et al. 2020). Annual harvesting was assumed because it is the more prevalent practice across the slash pine home range. Herbaceous weed spraying ($71/acre) occurred concurrently with straw harvesting. An additional intermediate fertilization ($127/acre) was included as appropriate because this was recommended when straw is harvested for ≥8 consecutive years (Dickens et al. 2020). A final fertilization treatment occurred at the year of thinning. Pine straw price was estimated at $1.06 per rectangular bale of an average size of 13 by 13 by 26 inches from a nonscientific survey of local retailers with a stumpage factor of 0.24 per dollar output applied (McConnell et al. 2016). The lower portions of Tables 1, 2, and 3 illustrate the pine straw management activities incorporated into the timber strategies for the 545, 623, and 726 trees per acre planting scenarios.

Pine straw yields were simulated by fitting a two-parameter Weibull distribution to the findings from Dickens et al. (2012) for slash pine straw harvesting in Georgia and South Carolina:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x}{\alpha}\right)^{\beta-1} e^{-\left(\frac{x}{\alpha}\right)^{\beta}} \quad (2)$$

$$f(x) = 1 - e^{-\left(\frac{x}{\alpha}\right)^{\beta}} \quad (3)$$

Equation 2 is the Weibull distribution's probability density function and Equation 3 is the cumulative density

Table 1.—Slash pine plantation timber-management strategy using 545 seedling per acre (8 by 10-ft spacing) on a site-index 65-feet tract at 25 years.

Year[a]	Activity	Cost (US$)	30-yr revenue (US$)	10-yr revenue (US$)	Unit
Timber					
0	Mechanical site prep 1 pass + burn	$186.09			acre
0	Seedlings @ 545	$96.49			acre
0	Planting	$105.93			acre
Annual	Taxes	$4.62			acre
Annual	Management	$5.00			acre
1	Herbaceous weed	$70.72			acre
21	Hardwood control	$98.97			acre
21	Thin pulpwood		$11.04	$8.61	ton
21	Thin Chip-N-Saw		$29.75	$19.13	ton
21	Commission	8.5% of sale			acre
21	Hardwood control	$98.97			acre
At max BLV	Harvest pulpwood		$11.04	$8.61	ton
At max BLV	Harvest Chip-N-Saw		$29.75	$19.13	ton
At max BLV	Harvest sawtimber		$48.81	$31.20	ton
At max BLV	Commission	8.5% of sale			acre
Pine straw harvesting					
10	Understory burn	$32.26			acre
11	Hardwood control	$98.97			acre
11	Mow	$40.00			acre
11	Herbaceous weed	$70.72			acre
11	Fertilization	$127.21			acre
12	Mow	$40.00			acre
12	Herbaceous weed	$70.72			acre
16	Fertilization	$127.21			acre
21	Fertilization	$127.21			acre
13 to 20	Herbaceous weed	$70.72			acre
13 to 20	Straw harvest		$1.06	$1.06	rectangular bale

[a] BLV is bare land value.

Table 2.—Slash pine plantation timber-management strategy using 623 seedling per acre (7 by 10-ft spacing) on a site-index 65-feet tract at 25 years.

Year[a]	Activity	Cost (US$)	30-yr revenue (US$)	10-yr revenue (US$)	Unit
Timber					
0	Mechanical site prep 1 pass + burn	$186.09			acre
0	Seedlings @ 623	$110.19			acre
0	Planting	$105.93			acre
Annual	Taxes	$4.62			acre
Annual	Management	$5.00			acre
1	Herbaceous weed	$70.72			acre
19	Hardwood control	$98.97			acre
19	Thin pulpwood		$11.04	$8.61	ton
19	Thin Chip-N-Saw		$29.75	$19.13	ton
19	Commission	8.5% of sale			acre
19	Hardwood control	$98.97			acre
At max BLV	Harvest pulpwood		$11.04	$8.61	ton
At max BLV	Harvest Chip-N-Saw		$29.75	$19.13	ton
At max BLV	Harvest sawtimber		$48.81	$31.20	ton
At max BLV	Commission	8.5% of sale			acre
Pine straw harvesting					
8	Understory burn	$32.26			acre
9	Hardwood control	$98.97			acre
9	Mow	$40.00			acre
9	Herbaceous weed	$70.72			acre
9	Fertilization	$127.21			acre
10	Mow	$40.00			acre
10	Herbaceous weed	$70.72			acre
14	Fertilization	$127.21			acre
19	Fertilization	$127.21			acre
11 to 18	Herbaceous weed	$70.72			acre
11 to 18	Straw harvest		$1.06	$1.06	rectangular bale

[a] BLV is bare land value.

Table 3.—Slash pine plantation timber-management strategy using 726 seedling per acre (6 by 10-ft spacing) on a site-index 65-feet tract at 25 years.

Year[a]	Activity	Cost (US$)	30-yr revenue (US$)	10-yr revenue (US$)	Unit
Timber					
0	Mechanical site prep 1 pass + burn	$186.09			acre
0	Seedlings @ 726	$128.41			acre
0	Planting	$105.93			acre
Annual	Taxes	$4.62			acre
Annual	Management	$5.00			acre
1	Herbaceous weed	$70.72			acre
16	Hardwood control	$98.97			acre
16	Thin pulpwood		$11.04	$8.61	ton
16	Thin Chip-N-Saw		$29.75	$19.13	ton
16	Commission	8.5% of sale			acre
16	Hardwood control	$98.97			acre
At max BLV	Harvest pulpwood		$11.04	$8.61	ton
At max BLV	Harvest Chip-N-Saw		$29.75	$19.13	ton
At max BLV	Harvest sawtimber		$48.81	$31.20	ton
At max BLV	Commission	8.5% of sale			acre
Pine straw harvesting					
7	Understory burn	$32.26			acre
8	Hardwood control	$98.97			acre
8	Mow	$40.00			acre
8	Herbaceous weed	$70.72			acre
8	Fertilization	$127.21			acre
9	Mow	$40.00			acre
9	Herbaceous weed	$70.72			acre
16	Fertilization	$127.21			acre
10 to 15	Herbaceous weed	$70.72			acre
10 to 15	Straw harvest		$1.06	$1.06	rectangular bale

[a] BLV is bare land value.

function. The scale parameter was α, β was the shape parameter, e was the base of the natural logarithm, and x was rectangular bales of straw harvested per acre. Bales were computed from Dickens et al. (2012) assuming a weight of 17.5 pounds per bale. Parameters $\alpha = 225.444$ and $\beta = 2.503$ were estimated using maximum likelihood (Fig. 1). One thousand yields per acre were randomly sampled from this distribution, sorted from low to high, and averaged. Straw yields were then found at the 10th and 90th percentiles (100th and 900th ranked values). These values were entered as straw yields for each timber plus straw management strategy to provide prospective ranges for BLV under an integrated timber and/or nontimber product system. Break-even pine straw yields were lastly determined by iteratively entering average yields into the discounted cash flow schedules until the BLVs for the timber-plus-straw system equaled the timber-production-only regime.

Results

Timber production only

CSLASH predicted a thinning at age 21 when planting 545 trees per acre, which produced 8.3 tons of pulpwood and 23.6 tons of Chip-N-Saw per acre. The regeneration harvest at age 37 yielded 2.0 tons of pulpwood, 15.3 tons of Chip-N-Saw, and 115.3 tons of sawtimber per acre when the discount rate was 4 percent. Harvest occurred one year earlier at age 36 with a 5 percent discount rate; yields were 3.8, 19.8, and 105.3 tons of pulpwood, Chip-N-Saw, and sawtimber. Maximum BLV occurred at age 34 with a 6 percent discount rate when yields were 3.5, 32.4, and 84.0 tons of pulpwood, Chip-N-Saw, and sawtimber. Timber-only BLVs were $1,165, $570, and $219 at discount rates of 4 percent, 5 percent, and 6 percent when timber prices were entered at their 30-year averages (Fig. 2).

Thinning occurred at age 19 when planting 623 trees per acre, which produced 12.1 tons of pulpwood and 19.7 tons of Chip-N-Saw per acre. When considering timber only, regeneration harvesting occurred at age 37 at a 4 percent discount rate with yields of 2.3, 24.2, and 115.7 tons of pulpwood, Chip-N-Saw, and sawtimber. Harvesting took place at age 35 when the discount rate was 5 percent based upon yields of 4.3 tons of pulpwood, 34.6 tons of Chip-N-Saw, and 95.0 tons of sawtimber per acre. The BLV maximized at age 34 with a 6 percent discount rate when per acre yields were 3.6 tons of pulpwood, 41.8 tons of Chip-N-Saw, and 83.6 tons of sawtimber per acre. Timber-only BLVs when timber prices were entered at their 30-year averages were $1,214, $600, and $240 at discount rates of 4 percent, 5 percent, and 6 percent (Fig. 2).

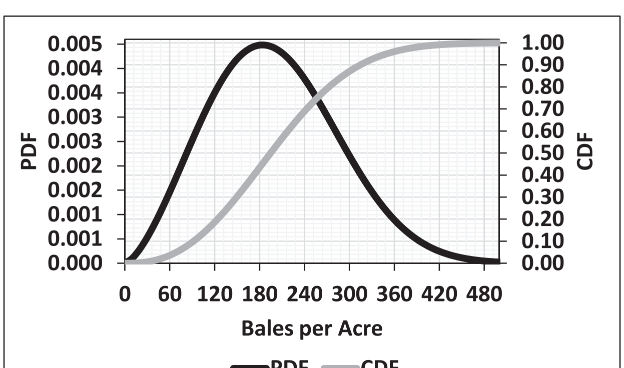

Figure 1.—Probability (PDF) and cumulative (CDF) distributions generated by a two-parameter Weibull distribution fitted to pine straw yields published by Dickens et al. (2012) for slash pine plantations in Georgia and South Carolina.

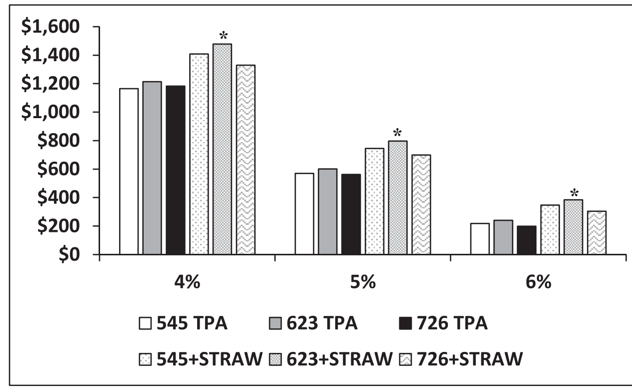

Figure 2.—Bare land values, 2022 dollars per acre, of three timber production only (trees per acre (TPA), solid columns) systems as compared with timber production plus pine straw (TPA + Straw, patterned columns). Plantings were either 545, 623, or 726 slash pine seedlings per acre at 4 percent, 5 percent, and 6 percent real discount rates. Timber product prices were 30-year averages in 2022Q3 US dollars. Average straw yield was 198 bales per acre. Straw price was $1.06 per rectangular bale. Each asterisk marks the preferred management regime within each discount rate.

Planting 726 trees per acre at establishment produced a predicted thinning at age 16, which yielded 16.2 tons of pulpwood and 9.7 tons of Chip-N-Saw per acre. The regeneration harvest at age 37 for discount rates of 4 percent as well as 5 percent. This yielded 2.8 tons of pulpwood, 42.8 tons of Chip-N-Saw , and 112.2 tons of sawtimber per acre. Harvest occurred at age 31 at a 6 percent discount rate with yields of 1.8 tons of pulpwood, 84.5 tons Chip-N-Saw, and 43.6 tons of sawtimber per acre. Timber-only BLVs were $1,182, $563, and $199 at discount rates of 4 percent, 5 percent, and 6 percent using 30-year average timber prices (Fig. 2). The results pointed to planting 623 trees per acre at each level of discount rate.

The 10-year average pine pulpwood price was –22.0 percent lower than the 30-year average price. Chip-N-Saw over the past 10 years averaged –35.7 percent less than its 30-year average price, while sawtimber's 10-year average price was –36.1 percent below its 30-year average price. Holding all costs constant therefore resulted in BLVs falling as well (Table 4). The preferred density for establishing the plantation remained 623 trees per acre at each discount rate. The lower stumpage price levels led BLV to be maximized later in some cases but not all. The key takeaway from varying the stumpage price levels was learning the slash pine plantation management regimes studied here were not cost effective at a 6 percent discount rate when shorter term, 10-year average timber prices were applied; all BLVs were negative. This signified these operations should not be undertaken because they would fail to meet the required rate of return, 6 percent in this instance.

Timber plus straw production

An integrated timber and pine straw production system would conduct an understory burn 10 years after 545 trees

Table 4.—Bare land values using two sets of pine timber product prices. The 10-year average covered from the fourth quarter of 2012 to the third quarter of 2022. The 30-year average covered from the fourth quarter of 1992 to the third quarter of 2022. Trees per acre represents the number planted at stand establishment; "+ straw" is a management regime consisting of both timber and pine straw production.

	Real discount rate								
	4%			5%			6%		
Trees per acre	10-yr average timber prices (US$)	30-yr average timber prices (US$)	% difference, 10 yr from 30 yr	10-yr average timber prices (US$)	30-yr average timber prices (US$)	% difference, 10 yr from 30 yr	10-yr average timber prices (US$)	30-yr average timber prices (US$)	% difference, 10 yr from 30 yr
545	$433.86	$1,164.70	–62.7%	$91.11	$570.36	–84.0%	–$111.36	$218.69	–150.9%
623	$463.13	$1,214.08	–61.9%	$105.98	$600.68	–82.4%	–$102.60	$240.31	–142.7%
726	$435.14	$1,181.90	–63.2%	$77.00	$562.92	–86.3%	–$136.59	$198.58	–168.8%
545 + Straw	$677.44	$1,408.28	–51.9%	$266.22	$745.29	–64.3%	$17.13	$347.98	–95.1%
623 + Straw	$725.26	$1,477.95	–50.9%	$299.88	$796.68	–62.4%	$42.84	$384.59	–88.9%
726 + Straw	$582.27	$1,329.04	–56.2%	$212.43	$698.35	–69.6%	–$35.75	$304.24	–111.8%

per acre were planted at establishment. Straw harvests would begin at age 13 and continue to age 20 ($n = 8$). The BLVs at 4 percent, 5 percent, and 6 percent, which were based upon an average yield of 198 bales per acre determined by the Weibull distribution, were $1,408, $745, and $348 per acre for both timber and straw at 30-year average timber prices (Fig. 2). These BLVs per acre at each discount rate were all greater than those where timber alone was produced—$244 at 4 percent (a 20.9% improvement), $175 at 5 percent (a 30.7% improvement), and $130 at 6 percent (a 59.1% improvement), respectively. Pine straw management did not change the year BLV was maximized across all discount rates.

A stand planted with 623 trees per acre would begin preparing for the first harvest at age 8. Straw harvesting would commence at age 11 and continue to age 18 ($n = 8$). The BLVs at 4 percent, 5 percent, and 6 percent were $1,478, $797, and $385 per acre for both timber and straw at 30-year average timber prices (Fig. 2). The BLVs were maximized at 37 years at 4 percent, 35 years at 5 percent, and 34 years at 6 percent discount rates. These ages were identical to those when timber alone was produced. The BLVs per acre including pine straw were all greater than those where timber alone was produced, $264 at 4 percent (a 21.7% improvement), $196 at 5 percent (a 32.6% improvement), and $144 at 6 percent (a 60.0% improvement), respectively.

Activities to prepare for the first pine straw harvest began at age 7 when 726 trees were planted per acre. Six rather than eight straw harvests occurred from ages 10 to 15. The BLVs when applying 30-year average timber prices at 4 percent, 5 percent, and 6 percent, were $1,329, $698, and $304 per acre for both timber and straw (Fig. 2). The maximum BLVs occurred at age 37 for both the 4 percent and 5 percent discount rates (no change in rotation length) and age 31 for the 6 percent discount rate (no change in rotation length). The BLVs per acre including pine straw improved over producing timber alone, $147 at 4 percent (a 12.4% improvement), $133 at 5 percent (a 24.1% improvement), and $106 at 6 percent (a 53.2% improvement). The conclusion based on these results was to plant 623 trees per acre at each level of discount rate when jointly considering slash pine timber and straw production.

Using the lower 10-year average prices while holding all costs and the price of pine straw constant also resulted in BLVs falling but not to the degree they did under a timber-only regime (Table 4). Straw production at 4 percent discount, e.g., provided about 10 percent support to BLV at lower stumpage price levels, as the BLVs fell from –51.9 percent to –56.2 percent across the established stand density levels versus from –61.9 percent to –63.2 percent when straw production was excluded. The support rose exponentially with the discount rate. Rotation length was unaffected when including pine straw harvesting. The main finding from varying the stumpage price level was learning the 545 and 623 planting densities for timber plus straw management regimes were in fact cost effective at a 6 percent discount rate. Those BLVs were positive, meaning they returned the required rate of return, 6 percent, plus $17.23 or $42.84 per acre. Planting 726 slash pine per acre was still not advisable with pine straw included.

Bare land values generated from simulated straw yields

One thousand simulations from the Weibull distribution produced the earlier stated average of 198 bales of straw per acre (Fig. 1). This was bounded on the lower end at the 10th percentile, which was 96 bales per acre, and the 90th percentile of 313 bales per acre. At 313 bales per acre BLVs ranged from $714 per acre at 6 percent discount when planting 726 trees per acre to as high as $2,189 per acre when planting 623 trees per acre at 4 percent discount when timber prices were at their 30-year averages (Fig. 3). The BLVs calculated with 10-year average timber prices plus 313 pine straw bales per acre varied from $373 to $1,440 per acre across planting densities and discount rates (Fig. 4).

The range of BLVs at these straw yields were not of equal magnitude at any discount rate and trees per acre combination. Table 5 illustrates this using the 30-year average timber prices to calculate BLV. The BLV at average pine straw yield was always a shorter distance to the BLV associated with the lower straw production level than the upper level. The same was found for BLVs calculated using 10-year timber prices only at lower BLV values. This suggested BLV had greater potential to exceed the average than fall below it.

However, the BLV linked with the lower straw production level at each discount rate and trees per acre combination always fell below the point estimate for BLV of a timber-only system, regardless of timber prices (Figs. 3 and 4). This indicated environmental, organizational,

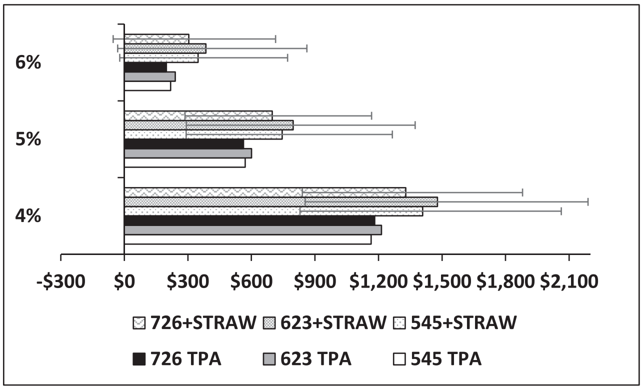

Figure 3.—Bare land values, 2022 dollars per acre, for timber-only and timber production plus pine straw systems. Lower and upper bars on the timber plus straw systems represent bare land values at 10th and 90th percentiles when stochastically estimating pine straw yields. Plantings were either 545, 623, or 726 slash pine seedlings per acre at 4 percent, 5 percent, and 6 percent real discount rates. Timber product prices were 30-year averages in 2022Q3 US dollars. Straw price was $1.06 per rectangular bale.

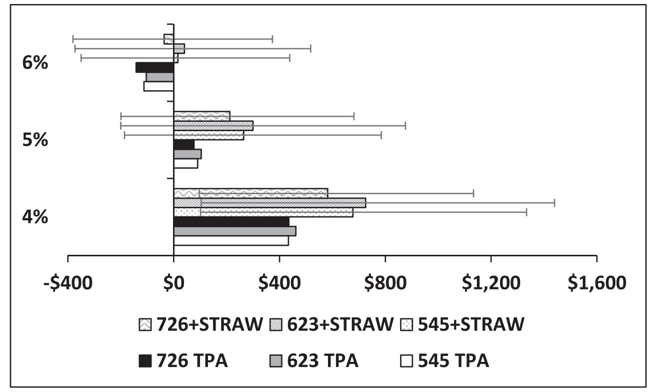

Figure 4.—Bare land values, 2022 dollars per acre, for timber-only and timber production plus pine straw systems. Lower and upper bars on the timber plus straw systems represent bare land values at 10th and 90th percentiles when stochastically estimating pine straw yields. Plantings were either 545, 623, or 726 slash pine seedlings per acre at 4 percent, 5 percent, and 6 percent real discount rates. Timber product prices were 10-year averages in 2022Q3 US dollars. Straw price was $1.06 per rectangular bale.

management, and/or other unseen factors could reduce income levels below simply choosing to forgo pine straw management all together. Managing slash pine plantations for pine straw cannot be justified at these low harvest levels. Pine straw average yields per the discounted cash flow schedules needed to be $\geq$159 bales per acre to break even with the preferred planting density of 623 trees per acre using both sets of average timber prices at the 4 percent and 5 percent discount rates, which was located at the 34th percentile. At the 6 percent discount rate, an average of 164 bales per acre was required at 623 trees per acre to not negatively affect the overall forest investment; this was found at the 36th percentile. The entire forestry investment would be lost if yields were to average abnormally low levels, such as the 10th percentile of 96 bales per acre, when discounted at rates of at least 6 percent using 30-year average timber prices and as low as 5 percent with 10-year average timber prices (Figs. 3 and 4).

Discussion

Discounted cash flows found that slash pine plantations managed for timber alone were worthy of investment if a landowner were to take a longer range view of stumpage price trends. All planting densities produced positive BLVs at each discount rate at the 30-year averages of timber prices. This signified each timber-only investment not only produced a return that recovered all costs and earned the designated rate of return, but it also generated additional income across all future rotations that summed to at least US$199 and up to US$1,214 per acre (Fig. 2).

Landowners more pessimistic regarding timber prices returning to those seen from the late 1990s to 2008 might

Table 5.—Simulated average bare land values of three timber production plus pine straw systems. Percentile values represent bare land values when pine straw harvests were at the respective production level percentile. Distance from average was found by subtracting the average from the respective percentile value. Plantings were either 545, 623, or 726 slash pine seedlings per acre at 4 percent, 5 percent, and 6 percent real discount rates (DR). Timber product prices were 30-year averages in 2022Q3 US dollars. Straw price was $1.06 per rectangular bale. TPA is trees per acre.

4% DR	545 TPA	Distance from average	5% DR	545 TPA	Distance from average	6% DR	545 TPA	Distance from average
10% lower	$829.22	−$579.06	10% lower	$291.80	−$453.49	10% lower	−$21.81	−$369.79
Average	$1,408.28		Average	$745.29		Average	$347.98	
90% upper	$2,063.00	$654.72	90% upper	$1,265.39	$520.10	90% upper	$770.77	$422.79
4% DR	**623 TPA**	**Distance from average**	**5% DR**	**623 TPA**	**Distance from average**	**6% DR**	**623 TPA**	**Distance from average**
10% lower	$853.51	−$624.44	10% lower	$292.65	−$504.03	10% lower	−$31.63	−$416.22
Average	$1,477.95		Average	$796.68		Average	$384.59	
90% upper	$2,189.24	$711.29	90% upper	$1,372.99	$576.31	90% upper	$1,861.88	$477.29
4% DR	**726 TPA**	**Distance from average**	**5% DR**	**726 TPA**	**Distance from average**	**6% DR**	**726 TPA**	**Distance from average**
10% lower	$840.29	−$488.75	10% lower	$286.39	−$411.96	10% lower	−$52.88	−$357.12
Average	$1,329.04		Average	$698.35		Average	$304.24	
90% upper	$1,880.08	$551.04	90% upper	$1,167.28	$468.93	90% upper	$714.03	$409.79

consider 10-year price averages instead. Doing so will generally capture one to two business cycles. These particular 10-year timber-product price averages encompassed the postrecessionary industrial reorganization seen in US southern production forestry (McConnell et al. 2021), as well as the maturity of many acres of timberland enrolled in the Conservation Reserve Program (Assogba and Zhang 2022). This has resulted in an oversupply that will take time to overcome. Slash pine plantations alone still generated net income at these price levels for discount rates of 4 percent and 5 percent, but they failed to do so at 6 percent discount.

Expectedly, the discount rate influenced BLV more than planting density. The optimum rotation is quite sensitive to changes in the discount rate, but it is robust to wide ranges of unit costs and revenues (Lundgren 1966). Within discount rates, BLVs did not differ more than $50 per acre as a result of planting density. Point estimates of BLV concluded that planting 623 seedlings per acre, or a spacing of 7 feet within rows and 10 feet between rows, was ideal. Rotation age would vary with 30-year timber price averages from 34 years at 6 percent discount to 35 years at 5 percent discount and 37 years at 4 percent discount. Ten-year average timber prices extended the rotation length because they are lower, but only slightly so (Yin and Newman 1995). Rotation age would lengthen to 37 years at 5 percent discount and 38 years at 4 percent discount. The negative BLV at 6 percent discount precluded discussing timber production as a land use option.

Economic theory states that bare timberland's productive value equals the discounted present value of all future net income. Commonly, per unit costs and revenues are held at constant levels because of the significant challenge to predict prices from one rotation to another, let alone to infinity. Admittedly, the 30-year average stumpage prices were optimistic relative to those seen in more recent years (McConnell et al. 2021). South Mississippi's timber markets where slash pine plantations reside are more competitive than those in north Mississippi, which provide better stumpage price support in that area (Mississippi State University Extension 2021). Still, the BLVs calculated here from a productivity perspective using 30-year average stumpage prices were found to overlap with recent market-based transactions following an ad hoc review of cutover bare timberland sales in Mississippi.

Incorporating straw production into slash pine plantation management proved worthwhile at average levels of straw harvest. Pine straw production in these cases improved timberland's productive value from 12.4 percent to 60.0 percent over just managing for timber alone using 30-year average timber prices. At 198 bales per acre, BLVs increased for all planting densities at each discount rate. The higher planting density of 726 trees per acre only achieved six straw harvests as a result of the earlier thinning age. Eight straw harvests were completed for the other two plantings, and they subsequently achieved higher BLVs. Planting 623 trees per acre again produced the higher average BLV at each discount rate. Incorporating pine straw production into slash pine plantation management using either 30-year or 10-year average stumpage prices did not affect the rotation length.

Considering a timber-plus-pine-straw system based on 10-year average stumpage prices importantly resulted in positive BLVs for planting densities of 545 and 623 trees per acre at a 6 percent discount rate, with 623 still being the preferred planting strategy. This carries particular relevance with the federal funds effective rate—the key interest rate looked to by financial institutions in the United States—increasing from 0.05 percent in April 2020 to 4.83 percent by April 2023 (Board of Governors of the Federal Reserve System 2023). Landowners who react in kind to these rate increases by requiring a higher rate of return on their forest investment up to 6 percent would find a timber and pine straw regime at 623 trees per acre to be acceptable—at average production levels.

However, with production comes risk. Unfortunately, one study limitation was the inability to account for timber production variability. Growth and yield simulators usually only return averages based on user inputs into the simulator's models. Results from Dickens et al. (2012), however, provided the opportunity to investigate ranges of pine straw production. The Weibull distribution was a good candidate to fit those results. It is flexible with a definable distribution at small sample sizes (McGarrigle et al. 2011). Figure 1 highlights a slight right skewness in the Weibull probability distribution curve, which illustrates that straw production could approach and even exceed 350 bales per acre. Risk taking individuals would consider, "how many bales could I *possibly* harvest?" Using the 90th percentile of 313 bales per acre as a guide, they could improve BLV from $1,214 per acre when planting 623 trees per acre to produce just timber at 4 percent discount to as much as $2,189 per acre with the addition of pine straw net income at optimistic harvest levels using 30-year average timber prices. A more pragmatic level may be the 3 to 10-year high average yield reported by Dickens et al. (2012). In that case, average yield was 253 bales per acre. At 623 trees per acre, BLV based on 30-year average timber prices would range from $613 per acre at 6 percent discount to $1,816 per acre at 4 percent discount; with identical conditions but instead BLVs calculated with 10-year average, then timber prices were $269 per acre and $1,064 per acre, respectively.

Risk-averse landowners would be more cautious. First, their timber enterprise may be managed at a higher level of discount as compared with risk-neutral or risk-taking individuals. They might consider a 4 percent discount rate, or perhaps even one of 5 percent, to be inadequate for a 30+ year investment (Bullard et al. 2002). Second, the unknown of entering a slash pine straw market—setting aside consumer preferences and focusing solely on straw yields—would induce them to think, "how many bales would I *at least* need to harvest?" If straw harvesting averaged less than 159 bales per acre, then BLV across all combinations of discount rate and planting density was less than the BLV point estimate calculated across timber-only regimes, as indicated by the error bars in Figures 3 and 4. Pine straw production would not pay its way. This is critically important because Dickens et al.'s (2012) 3 to 10-year low average was 129 bales per acre—a losing proposition with these discounted cash flow schedules. This emphasizes the need for forest managers to understand forest products markets, site quality, and productivity, as well as forest stand dynamics.

The CSLASH simulator is unfortunately not capable of explicitly considering fertilization's biological impacts on timber and straw production. Dickens et al. (2020) reviewed the literature on pine straw production, focusing on raking and fertilization treatment effects on both straw and timber yields. Fertilization on cutover lands tended to aid slash pine straw production more than on old agricultural field sites. Ogden and Morris (2004) found neither straw raking nor fertilization significantly affected straw yield within unthinned slash pine plantations planted on oldfields. Concerns regarding soil nutrition and the impact on wood production are often voiced when considering a pine straw operation. Annual straw harvesting is more deleterious than raking and baling on a more staggered basis. Lopez-Zamora et al. (2001) found slash pine diameter growth suffered from annual straw raking, but the negative effect was absent on 2- and 4-year harvest cycles. Ogden and Morris (2004) found no wood yield effect from fertilizing unthinned slash pine plantations on oldfield sites. This could mean either the fertilizer did not promote additional timber growth, or it offset removing soil nutrients by harvesting pine straw.

The implications of positive BLVs signified producing timber from slash pine plantations following the outlined management regimes were worthy investments for those considering production forestry at 30-year average timber prices. Net income levels were generated above and beyond designated rates of return at all planting densities, with 623 trees per acre being preferred (a 70-ft^2 spacing of 7 by 10 ft). Those who may instead consider the more recent 10-year stumpage trends to be a clearer indicator of the future would find slash pine plantation management acceptable at discount rates of both 4 percent and 5 percent but not 6 percent; 623 trees per acre would still be the favored planting option. Landowners may improve their net returns where markets support producing slash pine straw at regional averages for costs of forest operations, pine straw yield, and woods-run straw price per bale. This was particularly true for two planting strategies that surpassed break even at a 6 percent discount rate when timber revenues were based on 10-year average prices. But pine straw yield variability suggested this parlay was not without risk. Returns could either exceed $2,000 per acre, fall below those predicted from simply forgoing straw production altogether, or be completely lost.

Conclusions

Incorporating pine straw production into slash pine plantation management was investigated at three discount rates and planting densities. The sensitivity of BLV to timber prices was assessed by employing both 30-year and 10-year price averages for pine pulpwood, Chip-N-Saw, and sawtimber. Slash pine plantations were worthy investments based on all the modeled scenarios using 30-year average prices. Timber-only regimes ranged in BLV from $199 per acre at 6 percent discount rate when planting 726 trees per acre to $1,214 per acre when planting 623 trees per acre at 4 percent discount rate. Acceptable investments were also found with 10-year timber prices but only at discount rates of 4 percent and 5 percent. Increasing the discount rate expectedly lowered BLV across all planting densities. Differences in BLV due to planting density were much narrower. Planting 623 trees per acre at establishment was the preferred option between discount rates.

Including slash pine straw production at average levels of yield per acre raised average BLVs for all combinations of discount rate and planting density. Those values were higher than average BLVs where only timber was produced across all discount rates and tree spacings. The discount rate and planting density effects were similar to those of timber-only systems. Cautiously considering more conservative stumpage prices and a higher 6 percent discount rate at average timber and straw production levels critically pushed two management regimes beyond break even. Establishing a stand at 623 trees per acre was also the preferred option between discount rates across timber price averages.

Stochastically estimating straw yields provided some means of placing bounds around BLV and assessing the production risk of a straw enterprise. Although the potential for obtaining higher returns exceeded generating lesser returns at the averages, the lower straw production levels pushed all BLVs below those where only timber was produced. Consistently baling low levels of slash pine straw can not only reduce net returns, but it can also turn an entire forest investment into a losing proposition at higher desired discount rates. Diversifying into allied production systems can help buffer forest landowners from inflation, timber price trends, and volatility. But those systems come with their own set of risks that should be recognized and respected before venturing into them.

Acknowledgments

This publication, a contribution of the Forest and Wildlife Research Center, Mississippi State University, was supported by the USDA National Institute of Food and Agriculture, McIntire Stennis project 1025007. Thank you to those who took the time to review this manuscript. Your contributions helped tremendously.

Literature Cited

Assogba, N. P. and D. Zhang. 2022. The conservation reserve program and timber prices in the southern United States. *Forest Pol. Econ.* 140:102752.

Baker, J. B., and O. G. Langdon. 1990. *Pinus taeda* L. loblolly pine. *In:* Silvics of North America: 1. Conifers. R. M. Burns and B. H. Honkala, (Tech. coords.). USDA Forest Service Agriculture Handbook 654, Washington, D.C. pp. 497–512.

Board of Governors of the Federal Reserve System (US). 2023. Federal Funds Effective Rate [FEDFUNDS], retrieved from FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/FEDFUNDS. Accessed May 2, 2023.

Bullard, S. H., J. E. Gunter, M. L. Doolittle, and K. G. Arano. 2002. Discount rates for nonindustrial private forest landowners in Mississippi: How high a hurdle? *South. J. Appl. For.* 26(1):26–31.

Bullard, S. H. and T. J. Straka. 1988. Structure and funding of state-level forestry cost-share programs. *North. J. Appl. For.* 5(2):132–135.

Center for Agribusiness and Economic Development. 2022. Georgia farm gate value report 2021. Report #AR-22-01, University of Georgia, Athens. 176 pp.

Cushing, T. L. and D. Newman. 2018. Analysis of relative tax burden on nonindustrial private forest landowners in the southeastern United States. *J. Forestry* 116(3):228–235.

Dickens, E. D., D. J. Moorhead, C. T. Bargeron, L. A. Morris, L. A. Ogden, and B. C. McElvany. 2012. A summary of pine straw yields and economic benefits in loblolly, longleaf and slash pine stands. *Agroforest. Syst.* 86(3):315–321.

Dickens, E. D., D. J. Moorhead, L. A. Morris, and C. T. Bargeron. 2018. Pine straw yields and economic benefits when added to traditional wood products in loblolly, longleaf, and slash pine stands. Warnell School of Forestry & Natural Resources, University of Georgia, Athens. 8 pp.

Dickens, D., L. Morris, D. Clabo, and L. Ogden. 2020. Pine straw raking and growth of southern pine: Review and recommendations. *Forests* 11:799.

Dyer, J. F., R. Barlow, G. J. Keever, and W. Morse. 2012. Market demands and characteristic preferences for pine straw in Alabama. *J. Environ. Hort.* 30(1):1–7.

Forest Products Laboratory. 2010. Wood handbook—Wood as an

engineering material. US Department of Agriculture Forest Products Laboratory FPL-GTR-190, Madison, Wisconsin. 508 pp.
Lohrey, R. E. and S. V. Kossuth 1990. *Pinus elliottii* Engelm.: Slash pine. *In:* Silvics of North America: 1. Conifers. R. M. Burns and B. H. Honkala (Tech. coords.). USDA Forest Service Agriculture Handbook 654, Washington, D.C. pp. 338–347.
Lopez-Zamora, I., M. L. Duryea, C. M. Wild, N. B. Comerford, and D. G. Neary. 2001. Effect of pine needle removal and fertilization on tree growth and soil P availability in a *Pinus elliottii* Engelm. var. elliottii stand. *For. Ecol. Mgt*. 148(1–3): 125–134.
Lundgren, A. L. 1966. Estimating investment returns from growing red pine. USDA Forest Service Research Paper NC-2, North Central Forest Experiment Station, St. Paul, Minnesota. 48 pp.
Maggard, A. 2021. Costs & trends of southern forestry practices, 2020. FOR2115. Alabama Cooperative Extension System, Auburn University, Auburn. 6 pp.
Matney, T. 1996. Cutover slash growth and yield model. Forest and Wildlife Research Center, Mississippi State University, Mississippi State. https://www.fwrc.msstate.edu/software.php. Accessed July 5, 2022.
McConnell, T. E., C. Altizer, and B. Pickens. 2016. The pine straw industry of North Carolina: A preliminary contributions analysis. *In:* Proceedings of the 2016 Meeting of the International Society of Forest Resource Economics, Forest economics and policy in a changing environment: How market, policy, and climate transformations affect forests, G. E. Frey and P. Nepal (Eds.). US Department of Agriculture Forest Service Gen. Tech. Rep. SRS-218, Southern Research Station, Asheville, North Carolina. pp. 132–136.
McConnell, T. E., B. Kanieski da Silva, C. Sun, and S. Tanger. 2021. Forest to mill timber price trends and volatility for Mississippi timber products. *Forest Prod. J*. 71(2):177–187.
McGarrigle, E. J. A. Kershaw, Jr., M. B. Lavigne, A. R. Weiskittel, and M. Ducey. 2011. Predicting the number of trees in small diameter classes using predictions from a two-parameter Weibull distribution. *Forestry* 84(4):431–439.
Mississippi State University Extension. 2021. Mississippi timber price report, various quarters. Mississippi State University. http://extension.msstate.edu/content/timber-prices-2013-present. Accessed July 13, 2022.
Norris Foundation. 2019. Timber Mart-South quarterly price data for Mississippi. University of Georgia, Athens. http://timbermart-south.com/msprices.html. Accessed April 5, 2019.
Ogden, E. A. and L. A. Morris. 2004. Effects of annual pine straw removal and mid-rotation fertilization on pine growth in unthinned plantations. *In:* Slash pine: Still Growing and Growing! E. D. Dickens, J. P. Barnett, W. G. Hubbard, and E. J. Jokela (Eds.), Proceedings of the Slash Pine Symposium. US Department of Agriculture, Forest Service Gen. Tech. Rep. SRS-76, Southern Research Station, Asheville, North Carolina. pp. 90–97.
Miles, P. D. and W. B Smith. 2009. Specific gravity and other properties of wood and bark for 156 tree species found in North America. US Department of Agriculture, Forest Service Res. Note NRS-38, Northern Research Station, Newtown Square, Pennsylvania. 35 p.
Stainback, G. A. and J. R. R. Alavalapati. 2002. Economic analysis of slash pine forest carbon sequestration in the southern US. *J. Forest Econ*. 8(2002):105–117.
Straka, T. J. 2010. Financial breakeven point for competition control in longleaf pine (*Pinus palustris* Mill.) reestablishment. *New Forest*. 40:165–173.
Susaeta, A., D. R. Carter, S. J. Chang, and D. C. Adams. 2016a. A generalized Reed model with application to wildfire risk in even-aged Southern United States pine plantations. *Forest Pol. Econ*. 67(2016):60–69.
Susaeta, A. and P. Gong. 2019. Economic viability of longleaf pine management in the southeastern United States. *Forest Policy Econ*. 100(2019):14–23.
Susaeta, A., G. F. Peter, A. W. Hodges, and D. R. Carter. 2014. Oleoresin tapping of planted slash pine (*Pinus elliottii* Engelm. var. *elliottii*) adds value and management flexibility to landowners in the southern United States. *Biomass Bioenerg*. 68(2014):55–61.
Susaeta, A., J. R. Soto, D. C. Adams, and D. L. Allen. 2016b. Economic sustainability of payments for water yield in slash pine plantations in Florida. *Water* 8(9):382. https://doi.org/10.3390/w8090382
Tanger, S., S. Dicke, J. Henderson, and D. Gaddis. 2020. Paying for a new forest without cost-share funding. Mississippi State University Extension Publication 2420 (POD-10-20), Mississippi State University, Mississippi State. 8 pp.
Tanger, S., B. Kanieski da Silva, A. D. Polinko, T. E. McConnell, and M. E. McDill. 2023. Estimating stand-level carbon supply curves for loblolly pine and Douglas-fir plantations. *J. Forest*. 121(2):125–134. https://doi.org/10.1093/jofore/fvac036
US Department of Agriculture (USDA) Forest Service. 2023. EVALIDator 2.0.6. USDA Forest Service Forest Inventory and Analysis. https://apps.fs.usda.gov/fiadb-api/evalidator. Accessed March 14, 2023.
Wright, W. C. and I. A. Munn. 2016. 2013 fees and services of Mississippi's consulting foresters. Forest and Wildlife Research Center, Research Bulletin FO460, Mississippi State University, Mississippi State. 36 pp.
Yin, R. and D. H. Newman. 1995. Optimal timber rotations with evolving prices and costs revisited. *Forest Sci*. 41(3):477–490.
Zarnoch, S. J. and D. P. Feduccia. 1984. Slash pine plantation site index curves for the West Gulf. *South J. Appl. For*. 8(4):223–225.
Zhao, D., B. P. Bullock, C. R. Montes, M. Wang, D. Greene, and L. Sutter. 2019. Loblolly pine outperforms slash pine in the southeastern United States—A long-term experimental comparison study. *Forest Ecol. Mgt*. 450(2019):1–15.