AN ECONOMIC COMPARISON OF SLASH AND LOBLOLLY PINE UNDER VARIOUS LEVELS OF MANAGEMENT IN THE LOWER ATLANTIC AND GULF COASTAL PLAIN

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Abstract—Nonindustrial private forest (NIPF) landowners have perceived reduced product market availability and increased price uncertainty since late 1997 in the southeastern United States. Lower Atlantic and Gulf Coastal Plain NIPF landowners seek management options utilizing two commonly available pine species, loblolly (*Pinus taeda* L.) and slash (*Pinus elliottii* Engelm.), to enhance feasibility, profitability, and cash-flow of production forestry enterprises. At the same time, NIPF landowners desire heightened flexibility across time required to achieve marketable forest products. This paper examines feasibility, profitability, and cash-flow of 24-year rotation management options affecting wood-flow for slash and loblolly pine plantations. Modeled treatments include thinning, fertilization, and pine straw harvests under alternative levels of productivity and current (2004) product prices. Calculated financial measures of profitability include net revenue and internal rate of return using the Georgia Pine Plantation Simulator (GaPPS 4.20) growth and yield model developed at The University of Georgia Warnell School of Forest Resources.

INTRODUCTION

Nonindustrial private forest (NIPF) landowners in the lower Atlantic and Gulf Coastal Plain from South Carolina to Mississippi question whether to plant slash or loblolly pine on cut-over and old-field sites. They also question making moderate to relatively large investments for intensive forest management under the current and anticipated stumpage prices and future economic uncertainty. To address these questions, we used the Georgia Pine Plantation Simulator (GaPPS 4.20) growth and yield model developed by Bailey and Zhao (1998). The majority of stand and tree data to develop the GaPPS growth and yield models for slash and loblolly were in the 10- to 25-year age classes. Therefore, we used a 24-year rotation age that had a mixed product class distribution of pulpwood and chip-n-saw (CNS). Generally, culmination of merchantable volume mean annual increment occurs for both species on average to good sites and moderate levels of management by age 20 to 25 (Pienaar and others 1996). Longer rotation ages are often financially attractive but will not be addressed in this paper.

METHODOLOGY

Common Assumptions

The rotation age was set at 24 years for slash and loblolly pine plantations. Net revenue (NR, sum of all revenues minus all costs in 2004 dollars) and internal rate of return (IRR) were calculated. Calculation of IRR assumes intermediate cash-flows are reinvested in the scenario at the IRR, not the discount rate. A discount rate of 8 percent was used for intermediate or annual costs and returns. Fire protection cost was set at \$2 acre^{-1}year^{-1}, stand management at \$2 acre^{-1}year^{-1}, and property taxes at \$5 acre^{-1}year^{-1}. Thus, the total annual costs for each year of the rotation were \$9 acre^{-1}. This value cost goes in the transaction table as an annual cost during the rotation. The present value of this net, annual cost flow is \$94.75 during the 24-year rotation. Results are reported in constant dollars, before taxes. It is assumed that land is already owned.

Site Preparation and Planting Costs

Three site preparation and planting (SP+PL) costs rise in increments of \$125 acre^{-1} (\$125, \$250, and \$375 acre^{-1}). These costs represent the following site preparation and planting scenarios: The low site preparation and planting cost of \$125 acre^{-1} could include machine planting and the use of a post plant herbicide to control herbaceous weeds on an old-field site, glyphosate at 1 gallon acre^{-1}, or prescribe burning (low level) site preparation and roughland planting on a cutover site. The moderate (\$250 acre^{-1}) establishment cost could include a mechanical site preparation treatment, burn and plant, or a herbicide, burn, plant, and herbaceous weed control (Dubois and others 1999). The high (\$375 acre^{-1}) establishment cost could include a combination of chemical and mechanical site preparation as can be the case on many flatwoods cutover sites.

Site preparation options and associated costs vary extensively by location, prior stand history, harvesting utilization, landowner objectives, monies available, and anticipated future stumpage value and demand. The assumption used was that level of site preparation intensity was matched to level of competition control needed so that wood-flows were comparable within site productivity levels, after site preparation and planting.

Product Class Specifications

The three product class specifications are: (1) pulpwood (PW) at a d.b.h. of 4.6 to 9 inches to a 3 inch top, (2) CNS at a d.b.h. of 9 through 12 inches to 6 inch top, and (3) sawtimber (ST) with a d.b.h. > 12 inches to a 10 inch top (inside bark) (table 1).

Georgia stumpage prices, reported through Timber Mart-South© (TM-S 2004) for first quarter, year 2004 average, were used in this analysis for loblolly and slash. Prices were the net of property taxes at harvest (2.5 percent) and the net of marketing costs (8 percent). The low TM-S prices for pulpwood and CNS were used for thinning prices and average TM-S prices for pulpwood, CNS, and ST are used for the clearcut. Cash and net-converted prices are found in table 2.

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Table 1—Product class specifications for pulpwood (PW), chip-n-saw (CNS), and sawtimber (ST)

Product/Item	PW	CNS	ST
Small end diameter (*inches*)	3	6	10
Minimum length (*feet*)	5	8	8
Length increment (*feet*)	1	4	8

Table 2—Product prices, cash and net (net of property taxes and marketing costs) per cord stumpage prices used in the profitability analysis of slash and loblolly scenarios, Georgia State average, price per ton (1stQ TM-S 2004)

Item, price level	Cash or net	Pulpwood	Chip-N-Saw	Saw-timber
		- - - - - - - - *$ ton^{-1}* - - - - - - - -		
Low	Cash	5.04	21.36	35.91
	Net	4.51	19.12	32.14
Medium	Cash	6.42	25.80	40.97
	Net	5.75	23.09	36.51

Species Specific Assumptions

The slash pine scenarios assumed 500 living trees per acre (TPA) at age 5. A base mean annual increment of 2.09 cords acre^{-1}year^{-1} (5.77 tons acre^{-1}year^{-1}) at age 24 without fertilization or thinning was assumed. The base slash scenario woodflow was approximately 15 percent less than base loblolly woodflow (Shiver and others 1999) at age 24. The assumed fertilizer applications increased merchantable volume by an average of 0.50 cord acre^{-1}year^{-1} (1.38 tons acre^{-1}year^{-1}) for 8 to 10 years following treatment (Jokela and Stearns-Smith 1993).

The loblolly pine survival was also assumed to be 500 TPA at age 5. The base mean annual increment for loblolly was assumed to be 2.35 cords acre^{-1}year^{-1} (6.48 tons acre^{-1}year^{-1}) through age 24 without fertilization or thinning. The base loblolly woodflow was approximately 15 percent greater than the slash base woodflow (Shiver and others 2000) at age 24. The assumed fertilizer applications increased merchantable volume by an average of 0.65 cord acre^{-1}year^{-1} (1.79 tons acre^{-1}year^{-1}) for 8 to 10 years (NCSUFNC 1998).

FOREST MANAGEMENT ACTIVITIES

Thinning

The thinning scenarios include no thinning or one thinning at 15 years (scenario # 2, 6 through 9). Total woodflow of scenario with thinning is approximately 95 percent of total woodflow of scenario without thinning for slash and loblolly without fertilization. Residual basal area (RBA), after thinning (fifth row with selection from below) is set at 65 square feet acre^{-1}.

Fertilization

A fertilizer and application cost of $100 acre^{-1} for slash and loblolly per application at age 6 and 16 was assumed. Fertilization with 150 and then 200 N + 40 P (as diammonium phosphate and urea) per acre was part of this scenario to maintain pine straw production rates (Dickens 1999), to enhance wood volume (NCSUFNC 1998), and to change product class distribution (Dickens 2001, Peinaar and Rheney 1996). Fertilization timing at age 6 was 2 years prior to the initiation of straw raking (just prior to canopy closure). The second application, 10 years later, was just after a thinning (thinning scenario) and after the response (wood and straw) to the first application has become negligible. The periodic fertilizer application costs are converted to present values (PV) in year 1, then re-computed as annual equivalent values (AEV). These AEVs were then put in the transaction table as annual expense cash-flows (table 3).

Scenarios with fertilization for both loblolly and slash pine were set-up as follows: (#3) to delay fertilization cost, (#4) to maintain or enhance pine straw production from canopy closure (age 6 only), (#5) to maintain pine straw production (age 6 and 16) through the rotation with a higher annual revenue, (#6) to change product class distribution and put extra growth on best trees after thinning (age 16 only), (#7 and #8) to maintain or enhance pine straw production from just prior to canopy closure (age 6 only) to the first thinning, and (#9) to maintain or enhance pine straw production from just prior to canopy closure (age 6) to the first thinning and to change product class distribution and put extra growth on best trees after thinning (age 16).

Pine Straw

The pine straw income assumptions included were as follows: $50 and $100 acre^{-1} year^{-1} raking income for the slash and loblolly scenarios has been noted in south (slash) and central (loblolly) Georgia between 1998 and 2003 (Doherty and others 2004). Pine straw is raked starting in year 8 (approximating canopy closure) for slash and loblolly pine. Periodic pine straw income was converted to present values (PV) in year 1, then re-computed as AEVs at the discount rate of 8 percent. These AEVs were then put in the transaction table as annual income cash-flows (table 4). There was an associated clean-up cost to get the stand rakeable of $70 acre^{-1} ($20.43 present value and $1.94 AEV acre^{-1}) where pine straw was raked after the thinning (scenario #9). Scenarios that included pine straw income for both species are numbers 4, 5, and 7 through 9 (table 5a, 5b).

Table 3—Fertilizer costs, $100 acre^{-1} per application cost levels, expressed as present values and annual equivalent values (AEV), as used in the profitability analysis for 24 year slash and loblolly scenarios

Rotation	Applied	Present value of a periodic cost	Annual equivalent value of the periodic cost
- - - - *years* - - - -		*$ acre^{-1}*	$ acre^{-1}year^{-1}
	6	63.02	5.99
24	16	29.19	2.77
	6, 16	92.21	8.76

Table 4—Pine straw periodic per acre income levels expressed as present values and annual equivalent values (AEV) as used in the profitability analysis of slash and loblolly pine scenarios over a 24 year rotation

Item rotation	Thin scenario	Periodic income acre^{-1}year^{-1}, raked	Present value of periodic income	AEV of periodic income
		- - - - - - - - - - $ acre^{-1} - - - - - - - - - -		$ acre^{-1}year^{-1}
24 years	Thin at age 15	50 & 0[a]	140.64	13.36
		100 & 0[a]	281.28	26.72
		100 & 50[b]	351.64	33.40
	No thin	50[c]	239.11	22.71
		100[c]	478.21	45.42

[a] With thinning, pinestraw raked in years 8 through 14.
[b] With thinning, pinestraw raked in years 8 through 14 and 17 through 23.
[c] With no thinning, pinestraw raked in years 8 through 23.

Scenarios for the 24-year Rotation

The following are the nine slash (table 5a) and loblolly (table 5b) pine scenarios:

1. No thinning, no pine straw income, and no fertilization
2. Thin (at age 15 to 65 square feet acre^{-1}), no pine straw, no fertilization
3. No thin, fertilize at age 16, no pine straw
4. No thin, fertilize at age 6 and rake pine straw from age 8 through age 23 at $50 acre^{-1}year^{-1}
5. No thin, fertilize at ages 6 and 16 and rake pine straw from age 8 through age 23 at $100 acre^{-1}year^{-1}
6. Thin, fertilize after the thinning (age 16), no pine straw
7. Thin, fertilize at age 6 and rake pine straw at $50 or $100 acre^{-1}year^{-1} from age 8 through 14
8. Thin, fertilize at age 6 and rake pine straw at $50 or $100 acre^{-1}year^{-1} from age 8 through 14
9. Thin, fertilize at ages 6 and 16, and rake pine straw at $100 acre^{-1}year^{-1} in years 8 through 14 and $50 acre^{-1}year^{-1} in years 17 through 23.

RESULTS

NR and IRR Ranges

NR ranged from $1,187 (base slash pine scenario with highest site preparation and planting cost) to $4,171 per acre (loblolly with pine straw at $100 acre^{-1}year^{-1}, no thin, fertilize twice, and lowest site preparation and planting cost; table 5a, 5b). Ranking of scenarios by NR within a SP+PL level were as follows: 5 > 9 > 8 > 4 > 7 > 6 > 3 > 2 > 1 for both loblolly and slash pine. NR for slash pine (growing at approximately 15 percent less than loblolly) were 15 to 20 percent less than corresponding loblolly scenarios (table 5a, 5b).

IRR for both species and all scenarios (54 scenarios in all) had a very wide range, between 5.48 and 6.16 percent (base slash and loblolly scenarios with highest site preparation and planting cost, respectively) to 24.64 and 24.96 percent (slash and loblolly pine scenarios with the lowest site preparation and planting cost, no thin, fertilize twice, and rake straw at $100 acre^{-1}year^{-1} from age 8 through 23, respectively) using the aforementioned assumptions (table 5a, 5b). Ranking of scenarios by IRR within a SP+PL level were as follows: 5 > 9 > 8 > 4 > 7 > 6 > 3 > 2 > 1 for both loblolly and slash pine. Generally, these levels of forest management are economically justifiable in these cases, even using low to medium first quarter 2004 stumpage prices (TM-S 2004) for Georgia.

Impact of Thinning on NR and IRR

Thinning increased total harvest revenues and NR by $350 (slash) to $409 acre^{-1} (loblolly) compared to the unthinned counterpart. Thinning slash and loblolly pine stands increased IRR by 1.19 to 1.59 percent (slash, table 5a) and by 1.35 to 1.87 percent (loblolly, table 5b) over unthinned, unraked stands (scenario #1 versus 2).

Impact of Pine Straw Income on NR and IRR

The pine straw income prior to thinning (age 8 through 14) increased NR by $641 to $1,010 acre^{-1} ($350 and $70 is not pine straw income) in the thinned scenarios (scenario #7 and #8) over the thin, no pine straw scenario (scenario #2). When pine straw was raked before and after the thinning, (scenario #9) NR increased by $1,515 to $1,721 ($780 acre^{-1} in net straw income) over the thin, no pine straw scenario (#2) for slash and loblolly, respectively (table 5a, 5b). In unthinned stands, pine straw income and fertilization (age 8 though 23) increased NR by $1,168 to $2,480 acre^{-1} for both species ($700 and $1400 acre^{-1} in net straw income) (table 5a, 5b).

The addition of pine straw income for slash pine in the unthinned scenarios (#4 and #5) increased base scenario (#1) IRR from 5.48 (at $375 acre^{-1} SP+PL), 6.96 (at $250 acre^{-1} SP+PL), and 9.30 (at $125 acre^{-1} SP+PL) percent to 8.77, 10.95, and 15.16 percent at the $50 acre^{-1}year^{-1} pine straw income rate in unthinned stands (table 5a). Raising the annual pine straw income to $100 acre^{-1}year^{-1} from age 8 through 23 increased internal rates of return to 12.27 (at $375 acre^{-1} SP+PL), 15.71 (at $250 acre^{-1} SP+PL), and 24.64 (at $125 acre^{-1} SP+PL) percent (table 5a).

In thinned slash pine stands, pine straw income increased IRR from 6.67, 8.28, and 10.89 percent (thin, no straw; scenario #2) to 8.53, 10.46, and 13.83 percent, for three $375, $250, and $125 acre^{-1} SP+PL costs, respectively when $50 acre^{-1}year^{-1}

Table 5a—A comparison of slash pine plantation management scenarios[a] under a 24-year rotation and their effect on net revenue and internal rate of return (IRR), with site prep and plant (SP&PL) cost of $125, $250, and $375 acre^{-1}

Treatment					SP&PL @ $125		SP&PL @ $250		SP&PL @ $375	
Scenario # fertilize @ year	Thin year 15	Pine straw	PW	MIA[b] tons, cords	Net revenue[c]	IRR[d]	Net revenue[c]	IRR[d]	Net revenue[c]	IRR
		$ acre^{-1}	*percent*		*$ acre^{-1}*	*percent*	*$ acre^{-1}*	*percent*	*$ acre^{-1}*	*percent*
1 N	N	N	60	5.77, 2.09	1,437	9.30	1,312	6.96	1,187	5.48
2 N	Y	N	46	5.55, 2.01	1,787	10.89	1,662	8.28	1,537	6.67
3 Y, 16	N	N	48	6.28, 2.28	1,912	10.19	1,787	7.96	1,662	6.53
4 Y, 6	N	50[e]	52	6.28, 2.28	2,805	15.16	2,680	10.95	2,555	8.77
5 Y, 6, 16	N	100[e]	43	6.82, 2.48	3,686	24.64	3,561	15.71	3,436	12.27
6 Y, 16	Y	N	40	6.16, 2.23	2,162	11.51	2,037	9.00	1,912	7.43
7 Y, 6	Y	50 & 0[f]	43	6.16, 2.23	2,447	13.83	2,322	10.46	2,197	8.53
8 Y, 6	Y	100 & 0[f]	43	6.16, 2.23	2,797	18.12	2,672	12.87	2,547	10.31
9 Y, 6, 16	Y	100 & 50[g]	38	6.57, 2.38	3,302	19.42	3,177	13.80	3,052	11.12

Table 5b—A comparison of loblolly pine plantation management scenarios[a] under a 24-year rotation and their effect on net revenue and internal rate of return (IRR), with site prep and plant (SP&PL) cost of $125, $250, and $375 acre^{-1}

Treatments					SP&PL @ $125		SP&PL @ $250		SP&PL @ $375	
Scenario # fertilize @ year	Thin year 15	Pine straw	PW	MIA[b] tons, cords	Net revenue[c]	IRR[d]	Net revenue[e]	IRR[d]	Net revenue[c]	IRR[d]
		$ acre^{-1}	*percent*		*$ acre^{-1}*	*percent*	*$ acre^{-1}*	*percent*	*$ acre^{-1}*	
1 N	N	N	60	6.48, 2.35	1,701	10.04	1,576	7.66	1,451	6.16
2 N	Y	N	46	6.24, 2.26	2,110	11.91	1,985	9.18	1,860	7.51
3 Y, 16	N	N	48	7.15, 2.59	2,173	10.76	2,048	8.50	1,923	7.05
4 Y, 6	N	50[e]	52	7.15, 2.59	2,871	15.62	2,746	11.42	2,621	9.24
5 Y, 6, 16	N	100[e]	43	7.94, 2.88	4,171	24.98	4,046	16.24	3,921	12.85
6 Y, 16	Y	N	40	6.99, 2.53	2,481	12.44	2,356	9.81	2,231	8.17
7 Y, 6	Y	50 & 0[f]	43	7.68, 2.78	2,751	14.63	2,626	11.16	2,501	9.18
8 Y, 6	Y	100 & 0[f]	43	7.68, 2.78	3,101	18.83	2,976	13.51	2,851	10.91
9 Y, 6, 16	Y	100 & 50[g]	38	7.68, 2.78	3,831	20.56	3,706	14.83	3,581	12.08

[a] Uninflated, 8% discount rate, before income taxes, GaPPS v 4.20.
[b] MAI = Mean Annual Increment of wood growth, Tons & Cords ac^{-1}yr^{-1}.
[c] Net Revenue = Harvest revenue(s) – SP+PL cost – (annual cost x 24 yrs) – fert cost(s) – clean up cost + pine straw revenues (2004 $).
[d] IRR = internal rate of return of the investment scenario (percent).
[e] With no thinning, pinestraw raked years 8 through 23.
[f] With thinning, pinestraw raked years 8 through 14.
[g] With thinning, pinestraw raked years 8 through 14 and 17 through 23.

pine straw revenue was realized from age 8 through 14 (scenario #7, table 5a). Pine straw raking in the slash scenario prior to thinning only (age 8 through 14) at $100 acre^{-1}year^{-1} produced internal rates of return of 10.31, 12.87, and 18.12 percent (scenario #8). Pine straw raking in the slash scenario prior to thinning (age 8 through 14) at $100 acre^{-1}year^{-1} and after the thinning (ages 17 through 23) at $50 acre^{-1}year^{-1} produced internal rates of return of 11.12, 13.80, and 19.42 percent (scenario #9).

The addition of pine straw income for loblolly pine in the unthinned scenarios (#4 and #5) increased base scenario (#1) internal rates of return from 6.16 (at $375 acre^{-1} SP+PL), 7.66 (at $250 acre^{-1} SP+PL), and 10.04 (at $125 acre^{-1} SP+PL) percent to 9.24, 11.42, and 15.62 percent at the $50 acre^{-1}year^{-1} pine straw income rate in unthinned stands (table 5b). Raising the annual pine straw income to $100 acre^{-1}year^{-1} from age 8 through 24 increased internal rates of return to 12.85 (at $375 acre^{-1} SP+PL), 16.24 (at $250 acre^{-1} SP+PL), and 24.98 (at $125 acre^{-1} SP+PL) percent (table 5b).

In thinned loblolly pine stands (scenario #2), pine straw income increased internal rates of return from 7.51, 9.18, and 11.91 percent to 9.18, 11.16, and 14.63 percent, for three $375, $250, and $125 acre^{-1} SP+PL costs, respectively when $50 acre^{-1}year^{-1} pine straw revenue was realized from age 8 through 14 years (scenario #7, table 5b). Pine straw raking in the loblolly scenario prior to thinning only (age 8 through 14) at $100 acre^{-1}year^{-1} produced IRR of 10.91, 13.51, and 18.83 percent (scenario #8). Pine straw raking in the loblolly scenario

prior to thinning (age 8 through 14) at $100 acre^{-1}year^{-1} and after the thinning (ages 17 through 23) at $50 acre^{-1}year^{-1} produced IRR of 12.08, 14.83, and 20.56 percent (scenario #9).

Impact of Fertilization on NR and IRR

In the unthinned scenarios, NR increased by $470 to $475 acre^{-1} with fertilization at age 16 (scenario #3) compared to the no fertilization (scenario #1) for both species (table 5a, 5b). In the thinned scenarios, fertilization just after thinning (scenario #6) increased NR by $370 to $375 acre^{-1} compared to the thin only (scenario #2) (table 5a, 5b) for loblolly and slash pine.

Fertilization in unthinned slash pine stands with 200 N + 40 P acre^{-1} at age 16 ($100 acre^{-1} cost in year 16), increased IRR by about 1 percentage point across the three SP+PL levels (scenario #1 vs #3, table 5a). Fertilization at age 16 IRR (scenario #3) was about 0.10 to 0.70 percentage points below the thin only scenario (#2). The combination of thinning slash pine at age 15 and fertilization at age 16 (scenario #6) improved IRR by 0.62 to 0.76 percent over the thin only (scenario #2).

Fertilization in unthinned loblolly pine stands with 200 N + 40 P acre^{-1} at age 16 ($100 acre^{-1} cost in year 16), increased IRR by a 0.74 to 0.89 percentage point across the three SP+PL levels (scenario #1 versus #3, table 5b). Fertilization at age 16 IRR (scenario #3) was about 0.46 to 1.15 percentage point below the thin only (scenario #2). The combination of thinning loblolly pine at age 15 and fertilization at age 16 (scenario #6) improved IRR by 0.53 to 0.65 percent over the thin only (scenario #2).

Impact of Establishment Costs on NR and IRR

The impact of establishment costs (site preparation and planting; SP+PL) was straight-forward: net revenues differing by increments of $125 acre^{-1} within a scenario by species. Establishment cost impact on the time-value of money, though, was large.

Within a management level scenario, the impact of establishment costs was large enough to illustrate the importance of choosing the right SP+PL for a given site. The impact of SP+PL on IRR became larger as management inputs increased for both species. For example: The base slash pine scenario (#1) of no thinning, no fertilization, and no straw had IRRs of 5.48, 6.96, and 9.30 percent, differences of 1.48 and 2.34 percentage points. Slash pine scenario #5 had IRRs of 12.27, 15.71, and 24.64 percent, differences of 3.44 and 8.93 percentage points compared to the base scenario (#1, table 5a). The impact of SP+PL in the loblolly scenarios showed the same trend as the slash pine scenarios.

Impact of Management Inputs on NR and IRR

Generally, increasing management, whether through a thinning or with fertilization or clean-up for pine straw after a thinning with their associated costs, increased NR and IRR for both species. Thinning improved NR by $350 to over $400 acre^{-1} for slash and loblolly pine, respectively (table 5a, 5b). Fertilization increased NR by $350 to $475 acre^{-1} over the unfertilized scenario counterparts. Adding pine straw increased NR by a wide range (from $350 to $1,400 acre^{-1}; table 5a, 5b). In each case NR increased with increasing forest management within a given SP+PL level for both species.

The exception was scenario #3 (fertilization at age 16, no thinning, and no straw). The IRR for scenario #3 for slash (table 5a) and loblolly (table 5b) was lower by 0.14 to 1.15 percentage point than scenario #2 (no fertlization, thinnning, and no straw). Thinning (scenario #2) improved IRRs for both species by 1.19 to 1.87 percent over the unthinned scenario (#1; table 5a, 5b).

Adding pine straw income greatly improved IRRs for both species, by 2.24 to 4.97 percent for slash pine (scenario #4 vs #3) and 2.19 to 4.86 percent for loblolly (scenario #4 versus #3) at the $50 acre^{-1}year^{-1} from age 8 through 23 (no thinning; table 5a, 5b). The $100 acre^{-1}year^{-1} pine straw revenue from age 8 through age 23 further improved IRRs by 3.50 to 9.48 percent for slash pine (scenario #5 vs #4) and by 3.61 to 9.36 percent for loblolly pine (scenario #5 vs #4) over the $50 acre^{-1}year^{-1} income rate.

SUMMARY

Wood Flow, Fertilization Responses, and Pine Straw

The productivity levels at age 24 for slash [2.09 cords acre^{-1}year^{-1} (5.77 tons acre^{-1}year^{-1})] and loblolly [2.35 cords acre^{-1}year^{-1} (6.48 tons acre^{-1}year^{-1})] are very realistic on most cut-over sites with chemical site preparation and post-plant herbaceous weed control (Pienaar and Rheney 1996) and is conservative on most old-field sites. Exceptions would be problem soils such as deep sands (Typic Quartzipssamments) of the Sand Hills or shallow, rocky soils of the Piedmont physiographic region.

These scenarios illustrate, given the aforementioned base growth rates for slash pine and loblolly pine, that establishment expenditures must be carefully considered. In many cases the establishment phase decisions (site preparation type, timing, quality, site preparation effects on near- or long-site productivity, woody and herbaceous weed control efficacy, species selection, seedling genetics and size, seedling survival) can improve growth rates above those used here, therefore improving rates of return.

The average increase in wood production for slash [0.50 cord acre^{-1}year^{-1} (1.37 tons acre^{-1}year^{-1})] and loblolly [0.65 cord acre^{-1}year^{-1} (1.79 tons acre^{-1}year^{-1})] is consistent with published reports (Jokela and Stearns-Smith 1993, Martin and others 1999, NCSFNC 1999) with nitrogen plus phosphorus fertilization at ages 6 and 16. No increase in pine straw income per acre was assumed with fertilization. Fertilization studies (Blevins and others 1996, Dickens 1999) illustrate that pine straw production can be increased by an average of 40 to 50 percent over unfertilized stands on marginal-fertility soils. Fertilization was included in the pine straw production scenarios to maintain straw production as nutrients are removed/displaced with each raking.

When wood value only is considered, loblolly produced more wood of greater value and a higher NR and IRR with the aforementioned assumptions. Recent studies (Shiver and others 1999) have shown that loblolly will grow more wood than slash on a number of soils where both species are grown. Loblolly's superior wood volume yields do not necessarily equate to higher per acre or per unit wood stumpage prices. Clark and Daniels (2004) noted that slash pine yielded

more number one lumber, had a slightly greater (4 to 11 percent greater) density, and 4 percent less moisture content than loblolly pine growing in the same stand.

DISCUSSION

NIPF landowners have attractive forest management options with both slash and loblolly pine even when at low to medium stumpage prices. Generally, increasing forest management activities (thinning, fertilization, adding pine straw) increased rates of return at the wood growth increments used.

If an internal rate of return of ≥ 8 percent is a landowner goal with the stumpage prices used (Georgia first quarter 2004, TM-S 2004) and the wood production rates of 2 cords $acre^{-1}year^{-1}$ or better, then that can be achieved with thin scenario (#2) for both loblolly and slash pine at the lower two site preparation and planting establishment costs. At the highest SP+PL level, an IRR of ≥ 8 percent was achieved only when pine straw pine straw income at ≥ \$50 $acre^{-1}year^{-1}$ was realized for both species (scenarios 4, 5, 7 through 9, table 5a, 5b).

If an IRR of ≥ 10 is a landowner objective under the aforementioned assumptions, then pine straw production to achieve \$100 $acre^{-1}year^{-1}$ for both loblolly and slash pine is required at the highest SP+PL level. A ≥ 10 percent IRR can be realized at the moderate SP+PL cost with the rake at \$50 $acre^{-1}year^{-1}$, fertilize once, and thin or no thin scenarios (#4 and #7) for both species (table 5a, 5b). At the lowest SP+PL cost, all scenarios but scenario #1 for slash pine had an IRR > 10 percent.

An IRR of ≥ 12 percent is realized at the highest SP+PL level when \$100 $acre^{-1}year^{-1}$ pine straw income, no thinning, and fertilize twice is realized for slash and loblolly pine and at the \$100 $acre^{-1}year^{-1}$ pine straw income, fertilize twice, thin, clean-up, and rake at \$50 $acre^{-1}year^{-1}$ to clearcut scenario (#9) for loblolly. At the moderate SP+PL level, a IRR of ≥ 12 percent was realized with the rake at \$100 $acre^{-1}year^{-1}$, fertilize twice, no thin (scenario #5) or rake at \$100 $acre^{-1}year^{-1}$ prior to thinning, fertilize, thin and rake or no-rake straw (scenarios #8 and #9) for loblolly and slash pine (table 5a, 5b).

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