Financial Analysis of Mid-rotation Fertilization in Lower Coastal Plain Slash Pine Plantations

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Summary

To evaluate the economic implications of mid-rotation fertilization we have estimated internal rates of return (IRR) and marginal rates of return (ROR) for several starting scenarios projected into the future using the Martin *et al.* (1999) models. Economic gains due to increased growth rates were measured against the cost associated with mid-rotation fertilization. Our results indicate that fertilization with N and P consistently increases the maximum IRR over all site indices and densities investigated. We found that evaluating the IRR in isolation can be misleading. Such would indicate that there is little or no gain in fertilizing with N-only in soil group B, but evaluation of the marginal ROR values show that fertilization with N will return 5.4% or better on the one-time investment. The results also demonstrate that the optimum economic rotation age (OER) tends to be reduced by mid-rotation fertilization. In all cases investigated, fertilization with N and P produced marginal one-rotation ROR values of 14% or greater.

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Introduction

Intensive silvicultural management of southern pines has become the new standard in southern forestry. Managers now commonly fertilize established slash pine (*Pinus elliottii* Engelm. var. *elliottii*) plantations with a combination of nitrogen (N) and phosphorus (P) to increase pulpwood and solid wood yields. Forest researchers studying the impact of forest fertilization in established stands (>6 yr old) consistently report a positive impact on stand growth development. Jokela and Stearns-Smith (1993) reported that cumulative growth responses of southern pine stands fertilized with N and P at mid-rotation averaged 43% more basal area and 39% more volume than the unfertilized control plots 8 years later. Although it is well established that mid-rotation fertilization will increase growth rates and future volumes, it is not clear if this intensive treatment is economically feasible. In order to evaluate this feasibility, land managers require the ability to accurately determine changes in stand density, diameter distribution, and volume growth resulting from forest fertilization.

Bailey *et al.* (1989) developed a system of equations to predict survival, basal area growth, dominant height growth and diameter distributions for slash pine following mid-rotation fertilization. Their system was fit using data from mechanically site-prepared plantations (e.g., CRIFF[1] B100 and B200 series) established during the 1970's on flat-planted sites. Although the modeling approach was sound and the model unbiasedly represented the data, limitations in those studies lead to a conclusion that responses in contemporary plantations are higher than represented by their models. Using data from studies with larger measurement plots (e.g., CRIFF 400 series) and in better quality plantations Martin *et al*. (1999) recently developed a new system of growth and yield models for slash pine plantations fertilized at mid-rotation on a variety of soil types in the lower Coastal Plain. Their system includes models to predict:

1. dominant height,
2. surviving trees per acre,
3. basal area per acre,
4. diameter distributions,
5. individual tree diameter growth, and
6. individual tree height.

The diameter growth models can be used to predict future stand diameter distributions based on an initial diameter distribution or tree list, and an individual tree height equation. With these models we can evaluate expected changes in stand density and volume following mid-rotation fertilization of contemporary slash pine plantations.

Methods

To evaluate the economic implications of mid-rotation fertilization it is necessary to consider both the economic gains due to increased growth rates and the costs associated with

[1]CRIFF, the Cooperative in Forest Fertilization Program at the University of Florida was established in the 1960's and supported by the Forestry and Soil Science Departments in cooperation with forest product companies and the chemical industry.

mid-rotation fertilization. In this study we have estimated internal rates of return (IRR) [i.e. the discount rate that gives a bare land value (BLV) of zero] for several starting scenarios projected into the future using the Martin *et al*. (1999) models. Optimum economic rotation ages (OER) were determined for each soil and treatment combination by finding the age of maximum IRR. To determine OER and its associated IRR, the equation:

$$\frac{SY_r - R - T(1+i)^{r-a_t}}{(1+i)^r - 1} - R - \frac{A}{i} = 0$$

where Y_r=yield (tons/ac) at the end of the rotation,

S=stumpage price ($/ac),

R=regeneration cost ($/ac),

T=treatment cost ($/ac),

r=rotation age (yr),

a_t=age at time of treatment (yr),

A=annual ad valorem tax and administration cost ($/ac), and

i=inflation-free interest rate,

was solved for i at every possible rotation age in 1-year increments to determine the value of r=OER that gave a maximum value for i=IRR. We also calculated the marginal rate of return (ROR) on the investment in mid-rotation fertilization using the following equation:

$$ROR = \left(\frac{S(Y_F - Y_U)}{T}\right)^{\frac{1}{(r-a_t)}} - 1$$

where Y_F= yield (tons/ac) for the fertilized stand at the OER indicated by the fertilized stand,

Y_U=yield (tons/ac) for the unfertilized stand at end of the OER indicated by the fertilized stand,

ROR=inflation-free marginal rate of return,

r=OER as indicated by the fertilized stand,

and all other variables are as defined previously.

For the marginal ROR we ignore the costs associated with stand establishment and consider them Asunk@. Although the OER is usually different for unfertilized and fertilized stand, the OER for the fertilized stand was used to determine the length of time (yr) between the incurrence of fertilization costs and additional income attributed to this investment.

We obtained site preparation, seedling, planting and fertilization costs from Dubois et al. (1997) and current wood product prices from the Timber Mart-South Report (1998).

Site preparation treatment (Shear-Rake-Pile-Bed)	$165.65/ac
Seedlings	$31.18/thousand
Machine planting	$48.69/ac
Annual ad valorem tax and administration cost	$4.50/ac
Mid-rotation fertilization with N or N and P	$54.95/ac
Average Coastal Plain pulpwood stumpage	$11.66/ton
Average Coastal Plain chip-n-saw stumpage	$32.13/ton

Product weights were calculate for pulpwood (trees $ 4 in. to a 2 in. top outside bark (o.b.)) and for chip-n-saw (trees $ 8 in. to a 6 in. top o.b.) with an individual tree merchantable weight equation presented by Pienaar *et al.* (1996). To account for possible defects in chip-n-saw size trees, 30% of the chip-n-saw volume was allocated to pulpwood.

The Martin *et al.* (1999) models accept initial information at one of three different levels: a tree list, a diameter distribution or whole stand summary variables. For this analysis we assumed that only whole stand summary variables are available at the initial age. We assumed an initial age of 15 yr with site indices of 50, 60, and 70 and densities of 350, 550, and 750 trees per acre at age 15. To approximate seedling costs, we used the Martin *et al.* (1999) survival function to estimate original planting densities. Initial basal area was predicted with an equation in the Martin *et al.* (1999) system.

Results

Our results show that fertilization with N or N and P consistently increases the maximum IRR over all site indices and densities, except for N-only fertilization on site index 50, soil group B (Table 1). However, the examination of maximum the IRR in isolation can be misleading. Such would indicate that there is little or no gain in fertilizing with N-only in soil group B, but evaluation of the marginal ROR values (Table 2) indicate fertilization with N will return 5.4% or greater on the one-time investment. This contradiction can be explained by the differences in evaluating the investment in terms of an infinite series of rotations compared to just a one-time application during one rotation. The comparison of maximum IRR values may ›water down= the economic gains due to fertilization because of the costs associated with establishment, while the marginal ROR just considers the one-time investment of mid-rotation fertilization during one rotation. These results demonstrate that the OER tends to be reduced by mid-rotation fertilization. For example, a stand with site index 60 in soil group D and an initial density of 550 trees/ac would have a maximum IRR of 7.9% if unfertilized, if fertilized with N and P the maximum IRR increases to 8.7%. The OER decreases from 26 years to 23 yr (Table 1).

Conclusions

Mid-rotation fertilization decreases the OER and increases the maximum IRR. The marginal ROR for one rotation tended to be highest for soil group D, for higher site index values, and for higher stand density. In the most responsive cases, annualized marginal ROR values from fertilization with N and P at age 15 are consistently greater than 20%. In all cases investigated, fertilization with N and P produced a marginal one-rotation ROR of 14% or greater.

In this analysis we accounted for both the cost and benefits associated with mid-rotation fertilization and found a clear economic benefit from this silvicultural practice in contemporary slash pine plantations.

Table 1. Economic and yield results from a comparison of mid-rotation fertilization alternatives for slash pine plantations. The treatments are: 1. no fertilization, 2. fertilization with N, and 3. fertilization with N and P.

Site Index 50										
		Soil Group								
		B			C			D		
		Treatment			Treatment			Treatment		
		1	2	3	1	2	3	1	2	3
350 trees/ ac	Max IRR (%)	4.9	5.0	5.7	5.0	5.3	5.7	4.9	5.3	5.7
	OER (years)	30	29	29	29	29	28	30	30	28
	Income ($/ac)	971	1048	1256	933	1128	1187	977	1211	1200
	Pulp (tons/ac)	47.3	48.1	50.6	46.5	48.6	49.7	45.1	46.9	47.6
	Chip-n-Saw (tons/ac)	13.1	15.2	20.7	12.1	17.5	18.9	14.1	20.7	20.1
550 trees/ ac	Max IRR (%)	5.5	5.5	6.1	5.5	5.7	6.1	5.4	5.7	6.1
	OER (years)	30	29	28	30	29	27	29	30	28
	Income ($/ac)	1173	1225	1370	1173	1300	1296	1098	1395	1371
	Pulp (tons/ac)	72.1	73.1	76.1	72.1	74.4	74.4	67.6	72.5	73.4
	Chip-n-Saw (tons/ac)	10.3	11.6	15.0	10.3	13.4	13.3	9.6	17.1	16.0
750 trees/ ac	Max IRR (%)	5.9	5.8	6.5	5.8	6.0	6.5	5.8	6.0	6.4
	OER (years)	29	28	26	28	28	26	29	29	27
	Income ($/ac)	1266	1309	1354	1203	1371	1352	1255	1451	1434
	Pulp (tons/ac)	91.4	92.4	94.5	89.1	94.8	94.5	88.9	93.7	94.4
	Chip-n-Saw (tons/ac)	6.2	7.2	7.8	5.1	8.3	7.8	6.8	11.2	10.4

Table 1. Continued.

Site Index 60										
		Soil Group								
		B			C			D		
		Treatment			Treatment			Treatment		
		1	2	3	1	2	3	1	2	3
350 trees/ ac	Max IRR (%)	7.2	7.4	8.1	7.3	7.6	8.1	7.1	7.6	8.0
	OER (years)	27	24	24	27	25	25	28	26	24
	Income ($/ac)	1516	1380	1591	1528	1555	1712	1589	1657	1574
	Pulp (tons/ac)	58.5	55.8	58.1	58.6	57.2	59.1	56.8	56.1	55.7
	Chip-n-Saw (tons/ac)	25.9	22.7	28.4	26.3	27.6	31.8	28.8	31.2	28.8
550 trees/ ac	Max IRR (%)	7.9	8.1	8.7	7.9	8.2	8.7	7.9	8.2	8.7
	OER (years)	26	25	24	25	26	24	26	25	23
	Income ($/ac)	1723	1769	1872	1601	1982	1878	1712	1840	1721
	Pulp (tons/ac)	88.2	88.2	89.2	86.1	90.5	89.7	85.3	86.0	85.1
	Chip-n-Saw (tons/ac)	21.6	23.0	25.9	18.6	28.9	25.9	22.3	26.0	22.7
750 trees/ ac	Max IRR (%)	8.4	8.5	9.1	8.4	8.7	9.2	8.4	8.6	9.1
	OER (years)	24	25	23	25	24	24	25	24	24
	Income ($/ac)	1688	2009	1931	1835	1905	2118	1828	1909	2106
	Pulp (tons/ac)	109.3	116.8	114.9	113.6	114.4	119.1	110.3	111.3	115.7
	Chip-n-Saw (tons/ac)	12.9	20.2	18.4	15.9	17.8	22.7	16.9	19.0	23.5

Table 1. Continued.

Site Index 70										
		Soil Group								
		B			C			D		
		Treatment			Treatment			Treatment		
		1	2	3	1	2	3	1	2	3
350 trees/ac	Max IRR (%)	9.6	9.8	10.4	9.6	10.0	10.4	9.5	9.9	10.4
	OER (years)	23	22	22	23	22	22	23	22	21
	Income ($/ac)	1889	1915	2128	1894	1963	2133	1877	1950	1927
	Pulp (tons/ac)	64.2	64.1	65.5	64.5	64.4	65.5	62.3	62.0	61.8
	Chip-n-Saw (tons/ac)	35.5	36.4	42.5	35.5	37.7	42.6	35.8	38.2	37.5
550 trees/ac	Max IRR (%)	10.5	10.7	11.3	10.5	10.8	11.3	10.5	10.8	11.3
	OER (years)	22	22	22	22	22	21	22	22	21
	Income ($/ac)	2130	2341	2600	2131	2392	2335	2126	2389	2341
	Pulp (tons/ac)	97.2	99.0	101.4	97.7	99.4	98.6	95.1	96.8	96.5
	Chip-n-Saw (tons/ac)	31.0	36.9	44.1	30.9	38.4	36.9	31.7	39.2	37.8
750 trees/ac	Max IRR (%)	11.1	11.3	11.9	11.1	11.4	11.9	11.0	11.4	11.8
	OER (years)	21	20	21	21	21	21	21	21	21
	Income ($/ac)	2217	2176	2674	2228	2466	2670	2214	2454	2662
	Pulp (tons/ac)	124.6	122.7	131.9	124.9	127.9	131.7	122.6	125.9	129.0
	Chip-n-Saw (tons/ac)	23.8	23.2	35.3	23.9	30.3	35.3	24.4	30.7	36.0

Table 2. The marginal rates of return on the investment in mid-rotation fertilization for slash pine plantations harvested at the OER indicated by the fertilized stand.

			Soil Group					
			B		C		D	
			N	N and P	N	N and P	N	N and P
Site Index 50	350 trees/ac	Marginal ROR (%)	6.1	13.7	9.5	14.4	10.2	14.9
		OER (years)	29	29	29	28	30	28
	550 trees/ac	Marginal ROR (%)	5.4	14.9	9.4	15.7	10.5	15.1
		OER (years)	29	28	29	27	30	28
	750 trees/ac	Marginal ROR (%)	5.6	16.7	9.0	16.5	9.5	15.9
		OER (years)	28	26	28	26	29	27
Site Index 60	350 trees/ac	Marginal ROR (%)	13.4	24.0	15.8	21.8	15.7	23.8
		OER (years)	24	24	25	25	26	24
	550 trees/ac	Marginal ROR (%)	12.5	24.8	15.3	25.0	16.5	27.3
		OER (years)	25	24	26	24	25	23
	750 trees/ac	Marginal ROR (%)	12.8	27.4	16.6	25.8	17.5	25.7
		OER (years)	25	23	24	24	24	24
Site Index 70	350 trees/ac	Marginal ROR (%)	19.7	33.1	23.3	33.2	23.3	37.7
		OER (years)	22	22	22	22	22	21
	550 trees/ac	Marginal ROR (%)	21.2	35.9	25.0	40.0	25.1	40.7
		OER (years)	22	22	22	21	22	21
	750 trees/ac	Marginal ROR (%)	26.4	42.3	27.7	41.5	27.9	41.9
		OER (years)	20	21	21	21	21	21

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