Fertilization Options for Longleaf Pine Stands on Marginal Soils with Economic Implications

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Abstract

Literature is scarce pertaining to the economic benefits and biological response to one-time fertilization in early to mid-rotation longleaf (*Pinus palustris* Mill.) pine stands. Over 100,000 acres of new longleaf CRP acres have been planted in the SE United States in the last 2-3 years. Many non-industrial private forest (NIPF's) landowners are interested in fertilizing their existing longleaf pine stands to increase pine straw production, wood volume and value. Pine straw which is used for mulch in landscaping, is a multi-million dollar industry in the SE. Forest landowners can generate annual cash flows once a stand is old enough to produce straw (fresh brown pine needles or the litter layer of the forest floor). Longleaf is the preferred southern pine species to rake. Slash is second in preference and loblolly is third. Older studies have shown little growth response and therefore value to fertilization of longleaf stands in terms of extra wood volume grown. This study uses 4 year data from an inorganic and organic fertilization trial in a young and a mid-aged longleaf stand on deep sands to determine the economic benefits of inorganic and organic fertilization at various costs/acre, extra pine straw bales per acre, and extra wood grown. This information may prove useful in assisting NIPF's in determining the economic benefits of fertilizing their longleaf stands on marginal soils.

Key words: Non-industrial private forest (NIPF) landowners, longleaf (*Pinus palustris* Mill.) pine, feasibility, cash flow, profitability, fertilization, pine straw production, and net present value (NPV).

Introduction

Forest soils are generally marginal in fertility and southern pine plantations often respond to fertilization (Wells and Crutchfield 1974, Wells and Allen 1985, Jokela et al., 1991). Pine straw production is a multi-million dollar industry in the SE US (Morris et al. 1992). Little work has been done to determine the beneficial use of biosolids (treated municipal sewage sludge) to increase longleaf (*Pinus palustris* Mill.) pine straw and wood volume production. Furthermore, the literature is scarce on quantifying the magnitude and duration of longleaf pine straw and wood volume production response to side-by-side trials of inorganic fertilizer versus biosolids.

A forest land application of inorganic fertilizer and lime stabilized biosolids project was initiated in 1995 on the Sand Hills State Forest in South Carolina. The main objective was to determine the magnitude and duration of longleaf pine straw and wood volume production response to these two fertilizer materials on deep sands. This paper will address the biological and economic effect of fertilizer forms and biosolids application level (compared to untreated control plots) on pine straw and wood volume production through four growing seasons after application on marginal soils.

Methodology

The study areas are located on the Sand Hills State Forest in the Sand Hills physiographic region of South Carolina. Two sites were located; a 1963 and 1986 established longleaf stand. The soil series on each site, the Alpin soil series (Typic Quartzipsamments or deep sand), was delineated and verified by a NRCS soil mapper prior to plot installation. The 1963 planted site previously supported a scattered natural pine stand with a heavy turkey oak understory. This stand was cleared and planted to watermelons for one year, then planted to longleaf in 1963. The prior stand in the 1986 planted longleaf site was a 38-year-old slash pine stand that was clearcut in 1984-85. Site preparation on this site was disking and v-blading prior to planting. South Carolina Forestry Commission bareroot longleaf seedlings were planted at both sites. The experimental design was randomized complete block design with two replications in the younger stand and three replications in the older stand. One-half acre gross treated plots were installed with a 40-foot untreated buffer around each plot. One-quarter acre permanent measurement plots were then installed in the center of each gross treated plot. Eight plots were established in the 1986 planted (8 x 9 feet spacing) stand and twelve plots in the older stand that was thinned twice. All trees within each permanent measurement plot (0.25 acres each) were aluminum tree tagged (at 4.5 feet above groundline), measured for dbh (measured just above each tree tag for consistency from year to year with a d-tape) and total height (height pole in the young longleaf stand and clinometer in the older stand) in March 1995, February 1997, and March 1999. Volume per tree and per acre (total, inside bark) was estimated by using the following longleaf volume equations (Baldwin and Saucier 1983):

a. 1963 planted stand (dbh > 5 inches)

$$\log V = -2.77009 + 1.04013\log(D^2H)$$

b. 1986 planted stand (dbh < 5 inches)

$$\log V = -2.39317 + 0.91019\log(D^2H)$$

where V = volume (ft^3)
D = dbh (in)
H = ht (feet)

Volume per acre was calculated by multiplying volume/tree by the mean trees/acre in the 1963 planted (191 TPA) and 1986 planted (458 TPA) stands. A conversion factor of 0.7378 was used in the older stand to convert from total volume (ib) to chip & saw volume (6" top). Baseline litter layer (fresh brown needles of the forest floor from 6 random 12"x12" grids) were taken in February 1995 prior to plot treatment and each winter thereafter (February 1996, 97, 98, and 99). Litter layer dry weights were used as a relative measure of pine "straw" production. Pine straw bales per acre were estimated by year from each treatment by dividing the litter layer dry weight per acre (in pounds) by 25 (assumes 25 pounds/bale on a dry weight basis, Blevins, et al., 1996). Each plot received one of the following randomly assigned treatments in may 1995: control (no fertilizer treatment), N+P+K fertilizer (@ 1500 lbs/ac or 150 lbs N, 150 lbs P_2O_5,and 150 lbs K_2O), a low biosolids level (2.0 dry tons/ac; 130 lbs TKN, an estimated 53 lbs plant available-N, 69 lbs P_2O_5, 7 lbs K_2O and 1200 lbs Ca per acre), and a high biosolids level (3.2 tons/ac; 210 lbs TKN, an estimated 85 lbs plant available-N, 110 lbs P_2O_5, 11 lbs K_2O, and 1900 lbs Ca per acre). A subsequent fertilizer application was made May-June 1999 after 4 year data was collected.

Economic Analysis

An 8% discount rate was used to determine net present value (NPV). An up-front cost of $55/acre in the 1986 planted stand (less nitrogen needed) and $83/acre in the 1963 planted stand (more N) for the fertilizer and application was assumed. These prices are obtained in May 2001 from GA and SC local distributor prices for DAP, urea, and muriate of potash and the cost/pound for a SE applicator to aerially apply the inorganic fertilizer. These prices are close to those reported by Dubois et al. (1998) for fertilization. Biosolids application was assumed to be $20/ton for the material plus application. The low biosolids level material+ application cost was $40/acre and the high biosolids level material +application cost was $64/acre.

The extra pine straw and extra wood grown over the 4 year period with fertilization will have an estimated value and NPV will be solved. Historically the Sand Hills State Forest has been paid by the acre for straw raking rights to the highest bidder. They have been averaging $80 /acre (with a range of $75 to $100/acre) per raking in unfertilized longleaf stands between 1995 and 2001. Another form of payment for the raked straw is by the bale. Good bale counts must be made or the landowner may receive less money per acre with "by bale" sales than if the straw is sold by the acre. Bale prices of $0.50 and $1.00 were used in the analysis for the extra pine straw grown in February 1997, 98 and 99. These are current noted prices for both SC and GA for longleaf pine straw. The pine straw sales on a "per bale" basis is the economic analysis option used in this paper. It is not well established that landowners are receiving the percent extra income (compared to unfertilized stands) on a per acre basis with fertilization. Longleaf stumpage prices used in the analysis were $21/cord for extra pine pulpwood grown with fertilization in the young stand and $79/cord for the extra chip&saw wood grown in the older stand (TMS 2000).

Results - Fertilization Effect on Tree Growth

Fertilization of the 1963 established longleaf stand with N+P+K (@ 1500 lbs/ac of 10-10-10) increased four year (1995 to 1999) diameter growth by 50% (0.3"), height growth by 63% (1.2'), and volume per acre by 55% (2.0 cds/ac) over the control (Table 1). The biosolids at the low level increased four year diameter growth over the control by 50% (0.3 inches), height growth by 21%, and volume/acre by 50% between 1995 and 1999. The biosolids at the high level increased four year diameter growth between 1995-99 by 50% and volume/acre by 25% over the control but height increment was less than the control (Table 1). The extra volume/acre (total, ib) grown between 1995 and 1999 in the fertilized versus control plot trees was 2.0, 1.8 and 0.9 cds/acre for the N+P+K, low, and high biosolids, respectively in the 1963 planted stand. Fertilization of the 1986 longleaf pine stand with both the N+P+K fertilizer and the biosolids at the high level increased four year diameter growth by 29% and 14% over the control, respectively (Table 2). Four year height growth in N+P+K fertilized and biosolids plots was equal to or lower than that of the control plots. This height growth reduction in the N+P+K and low biosolids plots is due in part to tree losses from tractor damage biosolids plots, late winter 1996 ice damage, and excessive foliage production in the N+P+K plots of the more dominant trees. Four year volume per acre growth in the N+P+K and biosolids plots was only 0.1 to 0.5 cords/acre greater than the control. Four year BA/ac increment was 11, 36, 27, and 33 ft^2 for the control, N+P+K, low, and high biosolids, respectively indicating that a target rotation age may be realized sooner with fertilization.

Fertilization Effect on Pine Straw Production

There was no significant litter layer (pine straw) production increase in the fertilized plots the first winter after application (February 1996, Tables 3 and 4) in either longleaf stand. Litter layer dry weights from the inorganic fertilizer treatment were 90% and 83% greater than the control two and three winters after application (February 1997 and 1998), respectively in the 1963 established longleaf stand (Table 3). The biosolids treated plots litter layer dry weights were 49% and 50% (low biosolids) and 60% and 62% (high biosolids) greater than the control

two and three years after application, respectively in the 1963 established longleaf stand. Litter layer dry weights from the inorganic fertilized plots were 48% and 93% greater than the control two and three winters after application, respectively in the 1986 established stand (Table 4). The biosolids treated plots litter layer dry weights were 53% and 28% (low biosolids) and 86% and 97% (high biosolids) greater than the control two and three winters after application, respectively in the same stand. Fourth year litter layer dry weights from the fertilized plots were 27% to 35% greater than the control in the older stand but essentially the same in the young stand.

Table 1. Mean diameter (dbh), total height, volume per acre, and four year growth increment (NGrow[1] is estimated chip&saw four year growth increment) in the 1963 established longleaf stand on an Alpin soil.

	Dbh(in)			Height(ft)			Volume/acre (cords)			
	---Year—			----Year----			---Year---			
Trt	95	99	Grow	95	99	Grow	95	99	Grow	NGrow[1]
Cont	7.4	8.0	0.6	50.1	52.0	1.9	15.8	19.4	3.6	2.7
N+P+K	7.3	8.2	0.9	49.6	52.7	3.1	15.7	21.3	5.6	4.2
Low Bio	7.3	8.2	0.9	51.1	53.4	2.3	16.2	21.6	5.4	4.0
High Bio	7.3	8.2	0.9	51.1	51.2	0.1	16.2	20.6	4.5	3.3

Trt= treatments; Cont = control (no treatment), N+P+K (10-10-10 @ 1500 lb/ac), Low Bio (2 dry tons biosolids /ac), High Bio. (3.2 dry tons biosolids/ac). Stand was thinned twice, most recently in 1994 to 50 ft^2 BA/ac.

Table 2. Mean diameter (dbh), total height, volume per acre, and four year growth increment in the 1986 established longleaf stand on an Alpin soil.

	Dbh(in)			Height (ft)			Volume/acre (cords)		
	----Year----			----Year----			----Year----		
Trt	95	99	Grow	95	99	Grow	95	99	Grow
Cont	3.1	4.5	1.4	17.1	30.7	13.6	2.6	8.6	6.0
N+P+K	2.8	4.6	1.8	16.0	28.1	12.1	2.0	8.3	6.3
Low Bio	3.0	4.5	1.5	16.9	30.3	13.4	2.4	8.5	6.1
High Bio	3.0	4.6	1.6	17.0	30.6	13.6	2.4	8.9	6.5

Trt= treatments; Cont = control (no treatment), N+P+K (10-10-10 @ 1500 lb/ac), Low Bio (2 dry tons biosolids/ac), High Bio. (3.2 dry tons biosolids/ac).

Table 3. Mean pine straw[1] production estimates in a 1963 planted longleaf pine stand, Alpin soil, on the Sand Hills Forest in Chesterfield county, South Carolina

	-----------------------------Year-------------------------------				
Treatment	96	97	98	99	Total
		-------Bales/acre---------			
Control	66	80	88	99	333
N+P+K	59	152(72[2])	161(73)	126(27)	498(165)
Low Bio	70	119(39)	132(44)	129(30)	450(117)
High Bio	53	128(48)	142(54)	134(35)	457(124)

[1]Pine straw = forest floor litter layer dry weight □ 25. Assumes a bale of pine straw is 25 lbs dry weight and 100% rakeable site. This stand was thinned twice, most recently in 1994 prior to fertilization (May 1995). Stand had approximately 50 BA/ac at fertilization.
[2]() bales above the control

Table 4. Mean pine straw[1] production estimates in a 1986 planted longleaf pine stand, Alpin soil, on the Sand Hills State Forest in Chesterfield county, South Carolina

	-------------------------------Year-------------------------------				
Treatment	96	97	98	99	Total
		-------Bales/acre---------			
Control	67	71	100	153	391
N+P+K	53	105(34[2])	193(93)	153(0)	504(113)
Low bio	78	109(38)	128(28)	164(11)	479(88)
High Bio	66	132(61)	197(97)	159(6)	554(163)

[1]Pine straw = forest floor litter layer dry weight □ 25. Assumes a bale of pine straw is 25 lbs dry weight and 100% rakeable site. This stand was planted @ 8x9 feet with an average of 458 stems/acre at fertilization (May 1995).
[2]() bales above the control

Economic Analysis Results

The 1995 costs were $55/acre for N+P+K fertilization in the young stand, $83/acre for N+P+K in the older thinned stand, $40/acre to apply 2 dry tons biosolids, and $64/acre to apply 3.2 dry tons biosolids (Table 5). The extra pine straw (@ $0.50 and $1.00/bale) produced in years 1997, 98, and 99 and extra wood value (@ $21/cd or $79/cd) in 1999 were the returns. Pine straw revenues were discounted by $(1.08)^2$ for 1997 extra straw production, by $(1.08)^3$ for 1998 extra straw production, and by $(1.08)^4$ for 1999 extra straw production for both the younger unthinned stand and the older thinned stand (Tables 7 and 8). The extra wood grown in the young stand was negligible (0.1 to 0.5 cords/acre) with fertilization (Table 2). Therefore only extra pine straw revenues in the young stand were used in solving for NPV @ 8%. The older thinned stand produced an estimated 0.66 to 1.48 extra cords/acre of chip&saw wood between 1995

Table 5. Cost per acre (1995) for longleaf stand fertilization by treatment on the Sand Hills State Forest

Treatment	Stand (yr planted)	Cost/ac ($)
N+P+K	1963 / 1986	83 / 55
Low Bio	both stands	40
High Bio	both stands	64

Table 6. Extra wood grown and $/acre revenues (@ $79/cd) in the 1963 planted longleaf stand on the Sand Hills State Forest, SC between 1995 and 1999.

Treatment	cords/ac	1999 $/acre	discounted $/acre
N+P+K	1.48	117	86
Low Bio	1.33	105	77
High Bio	0.66	52	39

Table 7. Extra pine straw[1] produced versus control plots with May 1995 fertilization by treatment and discounted @ 8% value/acre in the 1963 planted longleaf stand (thinned twice) on a deep sand on the Sand Hills State Forest, SC

Treatment	$/bale	1997 bales[1]	discount $/acre	1998 bales[1]	discount $/ac	1999 bales[1]	discount $/ac	Total disc $/ac
N+P+K	0.50	72	30.86	73	28.97	27	9.78	69.61
	1.00		61.73		57.95		19.56	139.24
Low Bio	0.50	39	16.72	44	17.46	30	10.87	45.05
	1.00		33.44		34.93		21.73	90.10

High Bio	0.50	48	20.58	54	21.43	35	12.68	54.69
	1.00		41.15		42.87		25.35	109.37

Table 8. Extra pine straw[1] produced versus control plots with fertilization (May 1995) by treatment and discounted @ 8% value/acre in the 1986 planted longleaf stand on a deep sand on the Sand Hills State Forest, SC

Treatment	$/bale	1997 bales[1]	discount $/acre	1998 bales[1]	discount $/ac	1999 bales[1]	discount $/ac	Total disc $/ac
N+P+K	0.50	34	14.57	93	36.19	0	0	50.76
	1.00		29.15		73.83		0	102.98
Low Bio	0.50	38	16.29	28	11.15	11	4.04	31.48
	1.00		32.58		22.28		8.09	62.95
High Bio	0.50	61	26.15	97	38.50	6	2.20	66.86
	1.00		52.30		77.00		4.41	133.71

and 1999 with fertilization. Economically the N+P+K fertilizer and both biosolids levels produced positive NPV's in the 1963 planted stand (Table 9) whether pine straw was sold for $0.50 or $1.00/bale. Positive NPV's are due to a relatively large estimated increase in wood volume (0.66 to 1.5 chip&saw cords/acre), and pine straw production (117 to 165 extra bales/acre) between 1995 and 1999. The wood value @ $79/cord for chip&saw in the older stand also helped NPV's. The younger stand's NPV's were close to zero (Table 9) for all fertilizer levels when the extra pine straw income at $0.50/bale was realized in 1997, 98, and 99. Per acre NPV's when the extra pine straw income was $1.00/bale were $23 (low biosolids), $48 (N+P+K), and $70 (high biosolids, Table 9) in the younger stand. Discounted extra pulpwood grown (0.1, 0.3, and 0.5 cords/ac) between 1995 and 1999 from the fertilized plots would have only contributed $1.54 (low biosolids), $4.55 (N+P+K), and $7.72 (high biosolids) to NPV's in the younger stand.

Table 9. Net present value (@ 8%) for extra wood grown (1963 stand only) and extra pine straw (PS) produced by treatment in two fertilized longleaf stands (deep sands)on the Sand Hills State Forest, SC

Treatment	**$/bale**	**1963 stand wood+PS**	**1986 stand PS**
N+P+K	0.50	73	-4
	1.00	142	48
Low Bio	0.50	82	-9
	1.00	127	23
High Bio	0.50	29	3
	1.00	83	70

Summary and Conclusions

Fertilization using traditional inorganic fertilizer materials or biosolids in young and semi-mature longleaf stands growing on deep sands in this case was generally economically beneficial (using the aforementioned discount rate, costs, return prices, and estimated wood volume and pine straw production gains). The higher price/bale for pine straw gave all scenarios in both stands a positive NPV at 8%.

The primary economic incentive to fertilize young longleaf stand in this case is enhanced pine straw production. Fertilization (inorganic or organic) did reduce the age at which the young longleaf stand could have pine straw raked by one to two years. It is feasible that the litter layer may have been rakeable one or two years earlier if fertilization was initiated sooner. Fertilization increased pine straw bale production by 127 (N+P+K) and 158 (high biosolids) bales/acre over the control between 1997 and 1998 in the 1986 planted stand. Basal are growth between 1995 and 1999 was 2 to 3 times greater in the fertilized versus control plots in the younger stand potentially reducing the rotation age by 2-3 years. The estimated volume gains were small during the four year period. The small volume gain was also in the lower valued product class in the younger stand.

The economic incentive to fertilize the older (thinned twice) longleaf stand was two-fold in this case; to enhance pine straw production and an estimated 0.66 to 1.5 wood volume gain in a more valuable product class (chip&saw) in four years. Net present values (wood+straw) of $29 to $82/acre at the lower bale price and $83 to $142/acre at the higher bale price from the older thinned twice are attractive.

Approximately 15% to 20% of the longleaf pine in the 1986 planted stand N+K+P plots (@ 150 lbs N, P_2O_5, and K_2O/ac) became top-heavy, bent over, and never recovered. This loss is apparently due to the large increase in foliage production and the stems not able to take the extra weight. Due to the 15% to 20% losses, only 75-100 lbs of N per acre (plus 25 lbs P/ac and 50 lbs K/ac) would be recommended for these younger longleaf stands on these deep sands. The older longleaf stand (32-years-old at fertilization) had no losses due to increased foliage production at 150 lbs N/ac fertilizer level.

Subsequent biosolids applications at higher N and P levels (plus associated macro- and micro-nutrients) may increase incremental growth in the older stand to similar levels as the N+P+K inorganic fertilizer level but may not be cost effective. If another cost (i.e., herbicide application, stump cutting and cut stump treatment, or debris removal) is incurred to clean-up the stand for pine straw raking then NPV's will be reduced. The amount of rakeable stand can also effect the bale/acre production and NPV.

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