Outreach
Warnell School of Forestry & Natural Resources
UNIVERSITY OF GEORGIA

Economics of Fertilization in Longleaf Pine Stands

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INTRODUCTION

Forest landowners, at some point in the life of their longleaf pine stands, may wonder if fertilization may be of value. There are a number of questions that need to be addressed to make a sound decision. These include: (1) Is the decision purely economic (obtaining an economic return from fertilization that will more than out-weigh the cost over a period of time; typically four to eight years)? (2) Is there a concern that nutrients are being removed or displaced from pine straw raking and harvesting trees and that fertilization can replace those nutrients and maintain site productivity, stand health and growth? (3) Are there nutrients that are limiting growth enough that fertilization can dramatically improve wood growth (and pine straw production where of value)? (4) What tools can be used to figure out if a stand is nutrient deficient? (5) What nutrients are needed, how much of each nutrient, and what form of nutrients are available (inorganic fertilizers, animal manures, etc.)? (6) What is the cost of fertilization? (7) What is the growth and pine straw response to fertilization? (8) How long will the fertilization response last? (9) What are the current (pine straw) and anticipated (wood) prices per unit? (10) Are one-time, split, or interval fertilizer applications needed? This paper will address the economics of longleaf fertilization using four studies; two studies on old-field sites with moderate to high fertility (former crops were a rotation of annual crops with annual fertilization and no woody competition initially) and two studies on cutover pine-hardwood sites (former crops were pines and hardwoods) with low fertility and excessively drained sandy soils (with woody competition). Refer to the recent longleaf fertilization paper on bugwood.org that addresses many of the longleaf fertilization questions listed above (Dickens and others 2017).

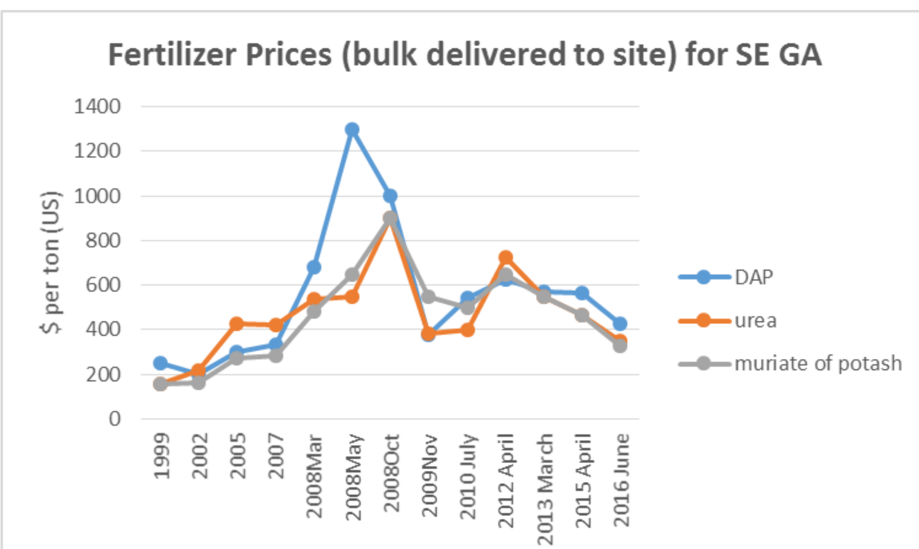

Figure 1. Nitrogen (N) as DAP and urea, phosphorus (P) as DAP, and potassium (K) as Muriate of potash fertilizer prices in SE Georgia from 1999 through June 2016

EXAMPLES OF LONGLEAF FERTILIZATION ECONOMICS

A. Former old-field site longleaf planted fertilization studies in South Georgia

The two old-field December 1986 planted (at 605 TPA), unthinned longleaf stands are located in Screven and Tift County, Georgia. The former crops were a rotation of corn, cotton, soybeans or peanuts and a winter grain with annual N, P, and K fertilization. The University of Georgia Warnell School of Forestry and Natural Resources faculty (David Dickens and Dave Moorhead) installed side-by-side replicated plots to determine if a split (1/2 dose of NPK 3 years apart; at ages 17 and 20 years old) or a single NPK dose would improve pine straw production and wood growth prior to a first thinning enough to justify the cost of these single or split applications (NPK application totals were 150 N + 50 P + 50 lbs K per acre).

Results at both old-field planted sites were as follows. (1) Merchantable wood tons per acre gains (4 year increment), when averaged across the two sites four years after initial fertilizer treatments, were zero or negligible for the single and split NPK treatments (34 and 32 tons per acre, respectively) compared to the control (32 tons per acre, Tables 1 and 2). (2) There was an average pine straw yield gain of 28 bales per acre per year with the ½ + ½ NPK and full NPK treatments at the Screven County site, and a 25 bale per acre per year average gain with the same treatments at the Tift County site. At $0.80/bale (coastal Georgia 2015-16 prices) for the extra straw produced with the ½ + ½ NPK or full NPK treatment through six years (initially, there was no fertilizer benefit one year after initial application, because needles stay on pines 18-24 months) there was a pine straw financial benefit of $112 per acre at the Screven County site and $100 per acre at the Tift County site. Using current June 2016 fertilizer prices, an NPK fertilizer plus application cost would be approximately $167 per acre, so in both cases there was not enough extra pine straw produced to cover the current cost of the fertilizer on these two old-field sites. Since these two old-field planted longleaf stands would most likely be thinned (versus clearcut), even if there were significant wood growth and value gains, only 1/3 to ½ of the fertilizer benefit would have been recovered from the thinned wood, and the balance of the fertilizer cost would not be recovered in the final wood harvest. Typically, mid-rotation fertilizer responses for loblolly, longleaf and slash pine peak four years after application and dissipate after eight years, so a clearcut is needed within a four to eight years after fertilization if a landowner wants to capture 100 percent of the mid-rotation fertilizer benefit.

Table 1. Trees per acre, diameter at breast height (dbh or 4.5 feet above groundline), basal area and merchantable tons per acre (4 yr increment) for December 1986 unthinned, old-field planted longleaf pine plots at the Screven County, Georgia site (Bonneau and Blanton soils) through age 17- and 21-years-old

	Trees per acre		dbh (inches)		Basal area (ft^2/ac)		Tons per acre (4yr increment)	
Treatment	-- Age (years) ---							
	17	21	17	21	17	21	17	21
Control	325	303	8.37	9.24	121	135	84	120 (36)
Split NPK	303	273	8.47	9.52	114	125	83	114 (31)
Full NPK	328	305	8.32	9.24	120	136	86	118 (32)

Table 2. Trees per acre, diameter at breast height (dbh or 4.5 feet above groundline), basal area and merchantable tons per acre (4 yr increment) for December 1986 unthinned, old-field planted longleaf pine plots at the Tift County, Georgia site (Albany and Leefield soils) through age 17- and 21-years-old

	Trees per acre		dbh (inches)		Basal area (ft^2/ac)		Tons per acre (4yr increment)	
Treatment	-- Age (years) ---							
	17	21	17	21	17	21	17	21
Control	320	303	7.97	8.80	114	126	82	110 (28)
Split NPK	317	310	7.96	8.84	113	129	80	113 (33)
Full NPK	360	350	8.26	9.09	127	146	99	135 (36)

B. Longleaf fertilization studies on low fertility, cut-over sites with excessively drained sandy soils in South Carolina

Two longleaf fertilizer studies were installed on the Sand Hills State Forest in Chesterfield, South Carolina on sandy, excessively drained, low fertility, cut-over sites. One was in a 9-year old un-thinned plantation (planted in 1986) and another in a 32-year old (planted in 1963) longleaf plantation which had been thinned twice.

Photo 1 shows a longleaf pine stand that was fertilized twice (once at age 32 and again at age 36 years) with NPK. In this case, fertilization was needed twice in a 10 year period due to the deep excessively drained sands where inorganic fertilizers can easily leach well down into the soil profile and past the feeder root zone. On better soils (i.e., sandy loams with a restrictive clay layer within 50 inches of the surface) NPK fertilization may only be needed once to enhance pine straw production for four to six years and wood gains for four to eight years.

In the older, twice thinned (age 20 and 31 years old) longleaf stand the pine straw yield response to NPK fertilization improved by 135 bales per acre in the first four years and by an estimated 150 bales per acre in the following six year period. Additionally, the extra wood grown (30% chip-n-saw, 40% sawtimber and 30% poles) from the two NPK applications, through age 42, was 12.7 tons/acre (Table 3). Using recent (2015) Georgia pine stumpage prices of $20/ton for chip-n-saw (CNS), $30/ton for sawtimber (ST) and $50/ton for poles (P), and a proportionate price across the product classes of $33/ton, times 12.7 tons of incremental wood response to NPK fertilization, the increased CNS+ST+P wood value was $419 per acre but pulpwood value was decreased by $36 per acre (3 tons less versus the control during the 10 year period @ $12/ton, Table 3) for a net wood gain with NPK fertilization of $383/acre. The additional pine straw, 285 bales/acre at $0.90 per bale (SC 2015-16 prices) yields $257/acre incremental straw value (an annual $25.70 in years 2 through 10 increase versus the control). The total wood plus straw value increase is $640/acre. Using 2015 fertilizer prices for 250 lbs DAP (45 N + 50 P), 230 lbs urea (105 N) and 100 lbs potash (50 lbs K) per acre and a $0.10/lb cost to apply, the total cost of the two NPK fertilizations was $334/acre. Costs per acre for each application are $40 urea, $53 DAP, $16 potash and $58 to apply ($167 per application x 2 applications). In this case where pine straw and wood values are high and fertilizer costs are relatively low there is a large NPK fertilization benefit. The rate of return for the incremental fertilization response in longleaf wood (income at the end of the 10 year period) and pine straw (annual income starting in year 2 through 10) over the 10 year period is 11.8%. This is a 1.9-fold increase in return versus cost and a positive net revenue increase of $306/acre. In other cases where incremental wood and/or straw responses may be less, fertilizer costs higher, or where pine straw raking and income is not part of stand management, fertilization may not be financially attractive.

Table 3. Mean trees per acre, dbh, height, and tons per acre by treatment from 1995 (age 32 years) through 2005 (age 42 years) for the 1963 planted longleaf stand (thinned in 1983 and 1994 and fertilized in May 1995 and May 1999) on the Sand Hills State Forest in Chesterfield County, SC (Alpin soil).

Year	Treatment	Trees/ acre	Dbh (in)	Total height (ft)	Merchantable tons/acre (10 yr MAI)	Pulpwood tons/acre	Chip-n-saw, sawtimber + poles tons/acre
1995	control	196	7.50	50.1	36.3	27	9.3
	NPK	177	7.30	49.7	31.6	24	7.6
2005	control	195	8.70	55.2	53 (1.67)	17	36
	NPK	175	9.37	57.6	58 (2.64)	11 (-3 vs C)	47 (+12.7 growth vs C)

The young, unthinned longleaf stand (age 9 – 19 years old) in South Carolina that was fertilized twice in a ten year period did not provide a large enough economic response to fertilization to justify the costs. The incremental wood response to fertilization was approximately ½ ton per acre per year, which was essentially pulpwood. Pulpwood is historically lower in value than sawtimber or poles by 2- to 4-fold. Nor did fertilization yield enough incremental pine straw to justify the cost of NPK fertilization, with an average of 30 bales per acre per year over the ten year period, but with no pine straw gain in year one. The incremental fertilization wood response harvested in a thinning plus the incremental pine straw yield response for the two NPK applications was $273 per acre. This included $243 in pine straw for 270 incremental bales at $0.90/bale (an annual income starting in year 2 through year 10) plus $30 in incremental pulpwood at $12/ton on the 2.5 tons harvested (in year 10 of the study or at age 19 years) in a thinning of the 5.1 tons gained by fertilization. With a first thinning at age 19, only 1/3 to ½ of the incremental wood value would be realized, so the fertilizer benefit is mostly in the pine straw response in this young longleaf stand.

In this young, unthinned longleaf stand case, the lack of large economic response was due to: (1) a much lower stumpage price for pulpwood, (2) fertilization provided only just over ½ ton per acre per year of incremental wood, (3) only 1/3 t o1/2 of the extra wood grown was captured in the thinning (versus a clear-cut which captures 100% of the wood gain) ,and (4) the $194/acre cost for two NPK (75 N + 25 P + 50 K) applications. The rate of return for the incremental wood value captured in the thinning and pine straw value versus the two NPK application costs is 3.5%. This is a 1.4-fold increase in value (a $194 cost and a $274 per acre return), or a net gain of $79/acre, which for many forest landowners may not be an adequate net revenue increase to justify the cost, irrespective of investment risk.

Table 4. Mean trees per acre, dbh, height, and merchantable tons per acre by treatment from age 9 years old (1995) through age 19 years old (2005) for the 1986 planted longleaf stand (fertilized in May 1995 and May 1999) on the Sand Hills State Forest in Chesterfield County, SC (Alpin soil).

Year	Treatment	Trees/ acre	Dbh (in)	Total height (ft)	Merchantable tons/acre (10 yr MAI)
1995	control	476	3.1	17.1	0.10
	NPK	556	2.8	16.6	0.30
2005	control	378	6.3	46.6	50 (4.99)
	NPK	382	6.8	44.4	56 (5.57)

SUMMARY

When fertilizing any southern pine species, land use history is an important factor in determining if a given stand will respond to a single, split or repeated applications. Typically (based on our 12 old-field fertilization studies since 1995), fertilization does not pay on sites recently in agriculture, pasture or hay cutting because of moderate to high inherent fertility from the former land use. There are many important factors in deciding whether to fertilize a pine stand including: (1) a determination of nutrients needed using diagnostic tools (leaf area index estimates, soil, and foliage sampling), then fertilizer materials and amounts needed (NP or NPK typically; see Dickens and others 2017 *Longleaf Pine Stand Fertilization*, bugwood.org), (2) current application costs and fertilizer prices for di-ammonium phosphate (DAP 18-46-0) or mono-ammonium phosphate (MAP 11-52-0), urea (46-0-0), and potash (0-0-60), (3) expected growth response period (typically 4 to 8 years depending on soils and stand age and stocking), (4) anticipated future stumpage prices for the projected products grown, (5) anticipated increase in pine straw bales per acre and price per bale (where pine straw is raked), and (6) anticipated incremental wood gains in thinning and final harvest as a result of fertilization.

The two old-field planted longleaf NPK fertilization studies in Georgia indicated that fertilization was not financially attractive using 2005 through 2016 fertilizer prices and pine straw and stumpage values when using merchantable tons per acre wood growth and pine straw yields. In our 10 other old-field fertilization studies using traditional one-time, split or interval fertilization applications of inorganic NP, NPK, NPKMgS, NPKMgSCuB, poultry litters or land applicable biosolids in loblolly and slash pine stands, there have not been large enough fertilizer benefits with extra wood grown and/or extra pine straw to justify fertilization using recent (2005-2016) fertilizer prices, pine stumpage values and pine straw values.

The 32 year old, twice thinned longleaf stand growing on a low fertility, cut-over, excessively drained sandy soils did respond adequately to justify two applications of NPK in a 10 year period to be financially attractive (11.8% rate of return, a 1.9- fold increase in value, and a net revenue of $306/acre). The younger longleaf stand on the same soil series and same land use history had a low rate of return (3.5%), produced a net revenue gain of $79/acre over the 10 year period, and was not as financially attractive as the older stand.

Alternative fertilizer materials such as animal manures and biosolids that are classified as land applicable may be economically justifiable to use and offer pine growth benefits. These organic materials act as slow release fertilizers, which on excessively drained sandy soils of low fertility can have a longer response benefit than traditional inorganic fertilizer materials. If pine straw is not part of the income stream and a landowner is only going to get a wood gain from fertilization, the pine stumpage price(s) for the extra wood has to be high for longleaf pine as longleaf is the least responsive to NP or NPK mid-rotation fertilization when compared to loblolly and slash pine.

In practice, to choose which stands to fertilize, stands are ranked from those potentially most capable and probable (cut-over, low fertility sites) to realize a financial gain in a five to 10 year period to the least probable of responding (old-field, pasture and hay field, moderate to high fertility sites). The problem lies in anticipating what wood values will be at time of harvest, and prices may be higher or lower than at time of fertilization. If a stand is to be thinned after fertilization not all the financial benefit from fertilization is realized until final harvest. If a landowner can double their revenue (versus cost) from incremental wood and straw produced in six to nine years after fertilization, then they realize an 8% to 12% rate of return (this assumes all extra wood and straw revenues are realized at the end of the time period, higher rates of return are realized when pine straw extra income is considered on an annual basis). For example, it costs $135/ac for a single NPK application and the landowner gets an extra $270 in pine straw and wood at the end of eight years, then he/she made a 9% rate of return for investment in fertilization using the "rule of 72" (money doubles every 8 years = 9% rate of return, every 6 years = 12% rate or return, every 9 years = 8% rate of return, every 12 years = 6% rate of return).

Photo 1. A forty-two year old longleaf stand in South Carolina growing on an excessively well drained, deep, sandy soil (Alpin soil series) that was NPK (150 N + 50 P + 50 K) fertilized twice in a 10 year period, improving both pine straw production and sawtimber and pole production.

Citation:

Dickens, E.D., D. J. Moorhead, 2017, and P. Minogue. Economics of Fertilization in Longleaf Pine Stands University of Georgia Warnell School of Forestry and Natural Resources – Center for Invasive Species and Ecosystem Health. BW-2017-05. 6 p.