Planting longleaf pine at

WIDE SPACINGS

| David B South

ABSTRACT

When the landowner's objective is to maximize the net present value of a longleaf pine (*Pinus palustris* P. Mill. [Pinaceae]) plantation, most tree planting recommendations can be placed into 1 of 2 schools of thought. Those from the "plant-'em thick" school recommend planting more than 1483 longleaf pine trees/ha (600/ac). Some from this school say the extra costs associated with establishment will result in more profit when selling pulpwood, chip-n-saw, sawtimber, pine straw, and poles. When the landowner's objectives include producing chip-n-saw, sawtimber, wildlife, and maximizing profits, some from the "plant-'em thin" school recommend planting less than 1235 trees/ha (500/ac). For example, some might recommend planting 1100 container-grown seedlings/ha (445/ac). Most longleaf pine articles published prior to the turn of the century are from the "plant-'em thick" school. In contrast, this paper provides landowners with some of the logic for planting longleaf pine seedlings at wide spacings.

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KEY WORDS
Pinus palustris, economics, planting density, stocking, wood quality

NOMENCLATURE
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Figure 1. (top) An example of a "plant-'em thin" stand of longleaf pine. Container seedlings were hand-planted at 920 trees per hectare (TPH) (372/ac) in December 2000 (photo taken in October 2005). Seedling survival was 73%. At age 5, a sample of trees had a diameter at breast height of 7.1 cm (2.8 in) and height was 4.1 m (13.4 ft). Photo by Steven Hudson

Figure 2. (bottom) An example of a "plant-'em thick" stand of longleaf pine. Bareroot seedlings were machine-planted at 1794 TPH (726/ac) in January 1996 (photo taken in November 2004). At age 8 the survival was 69%, and the stand had an average diameter at breast height of 9.6 cm (3.8 in) and average height of 6.9 m (22.6 ft). Photo by Steven Hudson

The spacing of planted longleaf pine (*Pinus palustris* P. Mill. [Pinaceae]) seedlings affects not only the growth and development of the stand but also the economic returns. Wahlenberg (1946) wrote that "the spacing of trees in plantations depends on the survival expected and on economic considerations, such as costs of establishment, major products, market for thinnings, and effects of stand density and crown differentiation on natural pruning of the stems. The tendency has been to space too widely." He said that 2988 trees per hectare (TPH) (1210/ac) were generally recommended, and that 3556 TPH (1440/ac) were "considered advisable where pulpwood thinnings can be made." If the stand was not going to be thinned and was planted for timber production, he recommended 1680 to 2241 TPH (680 to 907/ac). In contrast, for naval stores he suggested 747 or 1076 TPH (303 or 434/ac).

Over the years, the recommended planting density for longleaf pine seedlings has decreased. At the beginning of the 20th century in Europe, the number of trees outplanted varied between 2471 and 98 840 TPH (1000 to 40 000/ac) (Schenck 1907). Some foresters recommended planting 2965 longleaf pine seedlings per ha (1200/ac) (Ware and Stahelin 1948; Wakeley 1954; Dennington and Farrar 1983), while others (Muntz 1954; Hamilton 1956) recommended higher stocking because of historically low seedling survival. As seedling quality improved, recommended planting rates fell, and by the end of the 20th century some were planting less than 1557 TPH (630/ac) (Sasnett and others 1990; Sirmon 1990). Currently, most managers of longleaf pine want to manage for wildlife and (or) sawtimber and target a stocking level of 494 to 1483 TPH (200 to 600/ac) (Boyette 1996).

Today, there are 2 schools of thought regarding the number of longleaf pine seedlings that should be planted when the landowner's main objectives are to increase the net present value of the stand and to manage for wildlife. Some say these objectives will be met by planting seedlings "thin" (Figure 1), while others recommend seedlings be planted close together (Figure 2). Those from the "plant-'em thick" school might recommend planting 1483 to 3556 TPH (600 to 1440/ac), whereas the "plant-'em thin" school might recommend 740 to 1235 TPH (300 to 500/ac) (Franklin 1997).

SAWTIMBER PRODUCTION

When stands are not thinned, sawtimber production at a given age will be related to the number of trees planted. For example, 2 longleaf pine growth and yield models (WinYield [Hepp 1996] and SiMS03 [ForesTech 2005]) indicate that planting 625 to 1111 TPH (253 to 450/ac) will produce more sawtimber at age 30 than planting 1600 to 2066 TPH (648 to 836/ac). This is because the higher stocking rates will delay the time required for trees to reach a sawtimber diameter at breast height (DBH). For example, on some sites, it may take 14 additional years for a stand planted at 2066 TPH (836/ac) to achieve the same amount of sawlogs as a 625 TPH (253/ac) stand (Figure 3). Even when stands are commercially thinned, a stand with 292 TPH (118/ac at harvest age 39) might provide more sawtimber and pole volume than a stand with 1030 TPH (417/ac) at harvest (Kush and others 1998).

PINE STRAW PRODUCTION

Pine straw is a popular mulch with homeowners and landscapers. The demand for this mulch has been high and the returns from pine straw production are greater than those obtained from intermediate pulpwood thinnings. Some landowners might expect a net profit of US$ 200 to $300 per ha ($81 to $121/ac) every other year (Pickens 2005). When pine straw production is the primary objective, then stands with basal areas of 23+ m^2/ha (100+ ft^2/ac) will result in more pine straw production than stands with 11 m^2/ha (48 ft^2/ac) or less (Rayamajhi and Kush 2001).

Spacing will affect the time required for a plantation to reach a basal area of 23 m^2/ha. According to one growth and yield program (SiMS03), planting 741 TPH (300/ac) on good sites will take approximately 4 additional years to reach a basal area of 23 m^2/ha as compared with 1977 TPH (800/ac). Therefore, those who wish to plant longleaf pine on wide spacings should realize that pine straw production will be delayed for several years.

POLE PRODUCTION

The production of poles is of interest to many landowners because the stumpage value might be US$ 27/Mg ($24.50/ton) greater than for sawtimber. Therefore, some recommend relatively long rotations, relatively dense stands, and multiple thinnings to produce a high percentage of straight poles (approximately 1/100 cm (1/100 in) from butt to tip of pole). In most naturally regenerated stands, the production of poles is greatest at ages of 50 to 60 y (Williston and others 1990). Because it takes a 25-m (82-ft) tree to make a 24-m (78-ft) pole, only a few trees will make poles by age 25 y. In one 46-y-old stand, the volume of poles was about the same from 14 to 28 m^2/ha (61 to 122 ft^2/ac) of basal area. In general, larger diameter poles are produced at 14 m^2/ha whereas more, smaller-diameter poles were produced at 28 m^2/ha. Establishing 3706 TPH (1500/ac) and leaving the stand unthinned can greatly reduce the production of poles as many trees will not reach the minimum DBH by age 39 y. Thus, in some cases 39-y-old stands with more than 700 TPH (280/ac) will have fewer valuable poles than stands containing 200 to 600 TPA (81 to 242/ac) (Kush and others 1998; Figure 4).

LOGGING COSTS

The distance to the mill affects the number of longleaf pine seedlings to plant. The greater the transportation cost per weight of wood, the fewer the trees planted per hectare. This is because the sawtimber price and pulpwood price increases as transportation cost per unit weight increases. On average, about two-thirds of the value of pulpwood at the mill is attributable to the cost of harvesting and trucking to the mill (Figure 5). At some distant locations, however, transportation costs can eat up all the value of pulpwood. Therefore, it makes more sense to grow mostly sawtimber and poles if the longleaf pine plantation is far from a pulp mill.

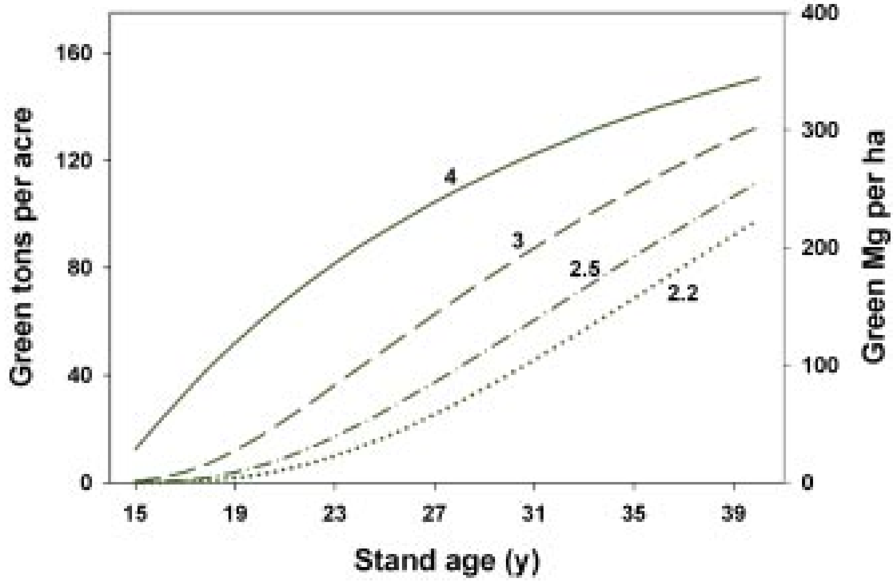

Figure 3. Predicted effect of tree spacing on sawtimber harvest of an unthinned, longleaf pine plantation using SiMS03. Spacing 4 m apart = 625 TPH; 3 m apart = 1111 TPH; 2.5 m apart = 1600 TPH; 2.2 m apart = 2066 TPH; Site index = 21.3 m (base age 25 y). (4 = 253/ac; 3 = 450/ac; 2.5 = 647/ac; 2.2 = 836/ac).

SEEDLING QUALITY

In earlier times, "the production of high-quality bareroot seedlings was dif-

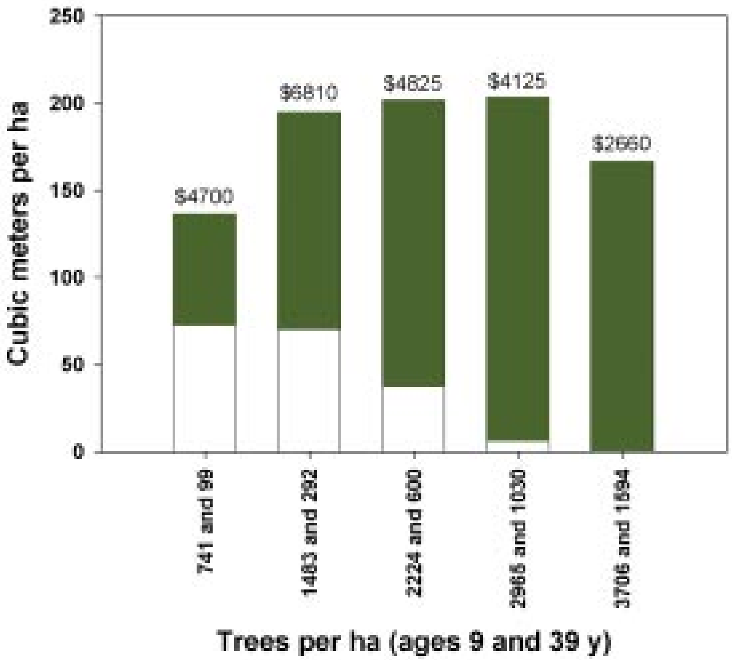

Figure 4. Merchantable volume production from longleaf pine as affected by stocking levels at age 9 y and 39 y (from Kush and others 1998). Solid green bars represent merchantable volume at harvest and white bars represent merchantable volume from thinnings (pulpwood plus chip-n-saw). At the final harvest, merchantable logs were placed into 4 product classes: poles, sawlogs, chip-n-saw, and pulpwood. US$ values above each bar represent total harvest value of merchantable logs (thinnings plus final harvest) per ha.

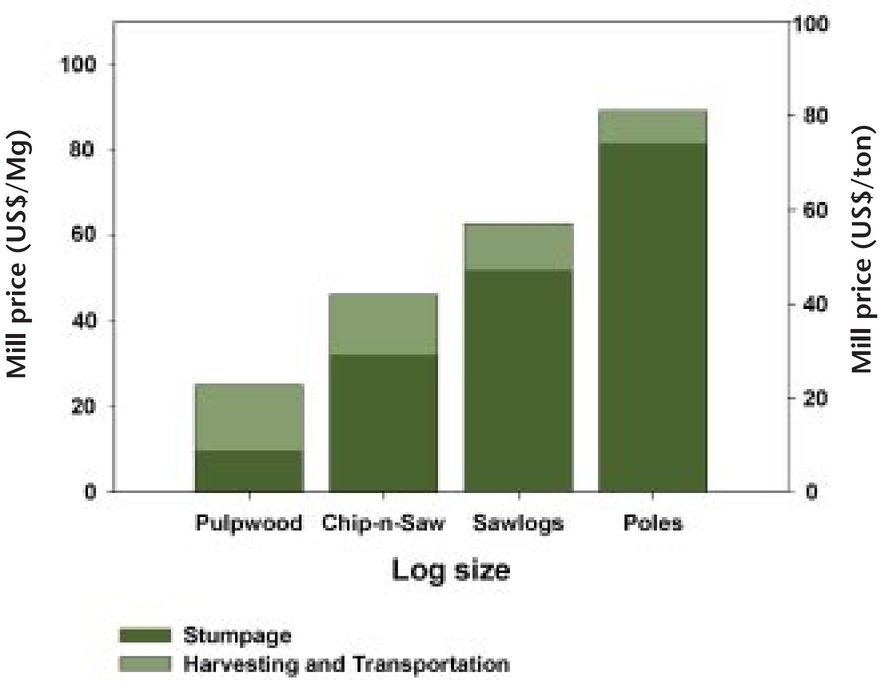

Figure 5. Stumpage value and mill value of longleaf pine pulpwood, chip-n-saw, sawlogs, and poles. Typically, about 2/3 of the mill value of pulpwood is attributed to harvesting and transportation costs. Only about 1/12 of the mill value of poles is attributed to harvesting and transportation costs.

ficult and management practices and site conditions precluded longleaf pine establishment" (Sword Sayer and others 2005). Plantation failures were, in part, due to "the use of small, poor quality seedlings" (Croker 1990). Low-performing bareroot seedlings were common because nursery managers often produced seedlings with small roots and small root-collar diameters. During the first half of the 20th century, nursery managers often aimed for a target seedbed density of 323 to 538/m^2 (30 to 50/ft^2) (Wakeley 1935). Hand planters preferred seedlings produced at these densities because longleaf pine with small roots could be easily planted in small planting holes (Figure 6). Nursery managers also liked this type of seedling because it required much less bed space than sowing for 64 to 86/m^2 (6 to 8 /ft^2) (Hatchell and Muse 1990; South 1993). As a result of various nursery practices (such as sowing late, inadequate fertilization, inadequate lateral pruning, high seedbed densities, lifting frozen seedlings), various planting practices (such as planting bareroot stock too shallow [Wakeley 1954; Croker 1990]), and adverse site conditions (such as a sudden hard freeze), thousands of hectares of longleaf pine plantations failed. Fortunately, seedling quality has increased since the 1950s and now nurseries provide both morphologically improved bareroot longleaf pine stock and container stock. Both result in greater seedling survival than longleaf pine seedlings produced during the first half of the 20th century.

WILDLIFE BENEFITS

Wildlife habitat is one of the primary objectives of landowners who manage longleaf pine (Boyette 1996). Therefore, a spacing of 1100 TPH (445/ac) will be more beneficial to browsers than a spacing of 2200 TPH (890/ac) (Allen and others 1996; Yarrow and Yarrow 1999). Longleaf pine in an open stand can produce about 952 kg/ha/mo (850 lb/ac/mo) of forage compared to 504 kg/ha/mo (450 lb/ac/mo) in a moderately dense stand (Smith and others 1955). Therefore, some wildlife habitat incentive programs require planting less than 1235 TPH (500/ac).

SAWLOG QUALITY

Form class is an important component of sawlog quality. Some believe the form class of longleaf pine would be affected if trees grew shorter when planted 4 m (13 ft) apart. It has been known for some time, however, that height of dominants and co-dominants of longleaf pine is not usually affected by stand density (Ware and Stahelin 1948; Russell and Derr 1956). A stand with only 300 TPH (121/ac) at age 25 is not shorter on average than a stand with 660 TPH (267/ac) (Table 1). Similarly, a stand with about 741 TPH (300/ac) at age 20 is not shorter on average than stands with more than 1977 TPH (800/ac) (Farrar 1985).

WOOD QUALITY

In general, the quality of lumber produced from naturally regenerated stands of longleaf pine and slash pine (*Pinus elliottii* var. *elliottii* Englm. [Pinaceae]) is better than that produced from loblolly pine (*Pinus taeda* L. [Pinaceae]) (Campbell 1964). This also holds true when comparing plantation-grown pines. When planted at 1075 TPH (435/ac), the specific gravity of longleaf pine (0.56) is greater than that of loblolly pine (0.51) (Clark and Schmidtling 1989).

Specific gravity of longleaf pine is closely related to the strength of the lumber. For longleaf pine, lower stocking rates do not result in wood of significantly lower specific gravity (when trees of equal age are compared). When comparing longleaf pine with 1.6 rings per cm to trees with 2.2 rings per cm (4 to 5.6/in), the specific gravity was 0.55 and 0.56, respectively (Bray and Paul 1930), suggesting that "strength and width of rings are not closely related" (Wahlenberg 1946). Koch (1972) stated "that growth rate of plantation trees, when manipulated by changing environmental or silvicultural conditions, may not be closely correlated with wood specific gravity." Megraw (1985) compared pine trees of the same age and concluded "there is no inherent relationship between growth rate and specific gravity." For example, Table 1 shows that specific gravity was not significantly affected by a silvicultural treatment that doubled stocking levels and thereby decreased diameter growth. Even though the percentage of juvenile wood was increased by the soil cultivation treatment (as a result of faster early diameter growth), the overall specific gravity at age 25 was not reduced. In addition, although lower stocking reduces the number of rings per cm, tree spacing has a minimal effect on the percentage of basal area in juvenile wood (Table 2).

KNOTS

Knots are the major cause of degrade in lumber. Because knot size is important for lumber strength, it is surprising how little information is available on the effect of stocking on knot size of plantation longleaf pine. For longleaf pine, knot size appears to be slightly related to stand density. In some stands, doubling the stocking of longleaf pine might only reduce average knot size by 0.8 cm (0.3 in). A 30-y-old stand with 865 TPH (350/ac) might have only 6% of the knot diameters exceeding 2.5 cm (1 in) in the first log (Paul 1938). The number of knots in the first log of longleaf pine is generally less than in loblolly pine stands, especially when prescribed fires are used to assist in pruning longleaf pine branches.

ECONOMICS

Establishment costs are lower when both rows and trees are spaced farther apart. For example, when tree outplanting costs US$ 0.22 per seeding (seedling plus planting), the overall planting cost will be reduced by US$ 328/ha ($133/ac) when planting 747 TPH instead of 2241 TPH (302 instead of 907/ac). When rows are spaced 4.9 m (16 ft) apart instead of 3 m (10 ft) apart, the cost of subsoiling prior to outplanting might be reduced by US$ 54/ha ($22/ac). Therefore, when the landowner has a limited amount of capital to invest (or when seedlings are in short supply), more hectares can be planted when trees are spaced farther apart.

Figure 6. This longleaf pine seedling was planted at the John Day field in south Alabama as part of the South-wide Seed Source Study. The seedling was planted by researchers in January 1953 and the plantation subsequently failed. This seedling had few lateral roots and was easily planted in the small planting hole. Wakeley (1935) said that "Slash is the easiest of the southern pines to plant, followed by longleaf."

Photo courtesy of USDA Forest Service

The effect of compound interest has an influence on planting recommendations. Although a 50-y-old longleaf pine pole is worth more at the mill than an equal mass of 30-y-old chip-n-saw logs, the effect of a 6% discount rate makes the discounted value of the 30-y-log higher (Figure 7). This fact is sometimes overlooked by some who favor planting many longleaf pine seedlings in order to produce 50-y-old poles with a minimal amount of taper.

Landowners who are willing to accept a lower discount rate (for example, 2% to 4%) can justify longer rotations than those who desire a 5% or 6% return on their investment. In some cases, a 5% discount rate can be used to justify rotation lengths of 36 to 41 y (Busby and others 1993), whereas a 4% rate might justify a 50-y rotation (Cubbage and Hodges 1990).

When conducting an economic analysis for longleaf pine, 7 factors should be included: 1) stumpage price for pulp, chip-n-saw, sawlogs, poles, and pine straw; 2) hunting leases; 3) volume production for each product; 4) establishment costs; 5) rotation length; 6) discount rate; and 7) risks due to southern pine beetles, hurricanes, fire, and so on. All 7 factors should be considered before selecting the proper spacing and harvest age for meeting the landowner's economic objectives.

Caulfield and others (1992) found that with loblolly pine, the land expectation values generally increased as the outplanting density decreased to 740 TPH (300/ac). Teeter and Somers (2005) reported similar findings for longleaf pine plantations (Figure 8).

WHY PLANT LONGLEAF THICKLY?

There are several possible explanations as to why some recommend planting more than 1483 longleaf pine seedlings per ha (600/ac). These include: 1) using traditional tree planting recommendations that date back 50 y or more; 2) assuming a low price ratio between long-leaf pine sawtimber and pulpwood ($S/P); 3) expecting low initial survival when outplanting bareroot seedlings; 4) not taking into account the value of an "open stand" to wildlife species; 5) assuming planting 2965 TPH (1200/ac) will produce more sawtimber in 30 y; 6) assuming logging costs do not vary with log size; 7) assuming everyone's land is close to a mill; 8) assuming that the average branch size of longleaf pine grown at low densities will reduce stumpage values; 9) assuming that outplanting 1100 TPH (445/ac) will result in an increase in taper and a reduction in wood specific gravity; 10) assuming planting 1100 TPH will result in shorter trees than trees planted at 3000 TPH (1214/ac); 11) assuming the discounted value of poles will always be greater than the discounted value of chip-n-saw logs; 12)

TABLE 1

The effect of soil cultivation on final stocking, diameter at breast height (DBH), height, specific gravity, and juvenile wood percentage of 25-y-old longleaf pine plantation (Clark and Schmidtling 1989).

Treatment	Final stocking number/ha (number/ac)	Average DBH cm (in)	Average height m (ft)	Specific gravity	Percentage of basal area in juvenile wood
Cultivation	660 (267)	15.5 (6.1) a [Z]	14.6 (48) a	0.58 a	52 a
No cultivation	301 (122)	18.5 (7.3) b	16.8 (55) a	0.57 a	19 b

[Z] Values within a column followed by the same letter do not differ at the 0.05 level of probability (Duncan's Multiple Range Test).

TABLE 2

The effect of spacing on predicted diameter at age 10 (DBH year 10), at age 30 (DBH year 30), rings per cm (at groundline), and predicted percentage of basal area in juvenile wood (at DBH) according to WinYield model for old-field longleaf pine plantation (Site index = 21.3 m [70 ft] base age 50 y).

Initial stocking number/ha (number/ac)	DBH year 10 cm (in)	DBH year 30 cm (in)	Rings per cm (in)	Percentage of basal area in juvenile wood [z]
494 (200)	8.6 (3.4)	24.4 (9.6)	2.4 (6.2)	12.8
988 (400)	7.4 (2.9)	23.1 (9.1)	2.6 (6.6)	10.3
1482 (600)	6.9 (2.7)	21.8 (8.6)	2.8 (7.0)	10.2
1977 (800)	6.9 (2.7)	21.6 (8.5)	2.8 (7.0)	10.3

[Z] Assumes rings 11 and greater represent mature wood.

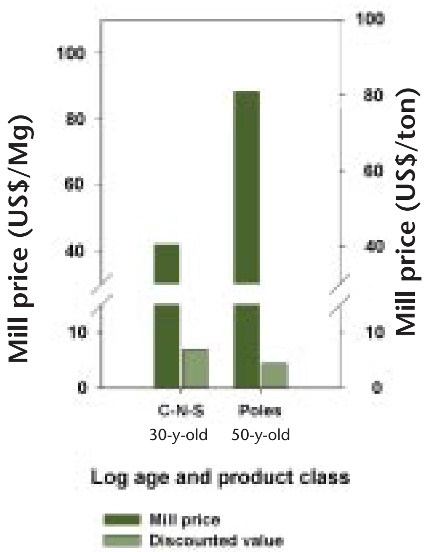

Figure 7. The price paid for poles at the mill may be twice that of chip-n-saw logs (c-n-s). However, when these values are discounted to year zero using a 6% interest rate, 30-y-old c-n-s logs (at time of planting) are worth 60% more than 50-y-old poles.

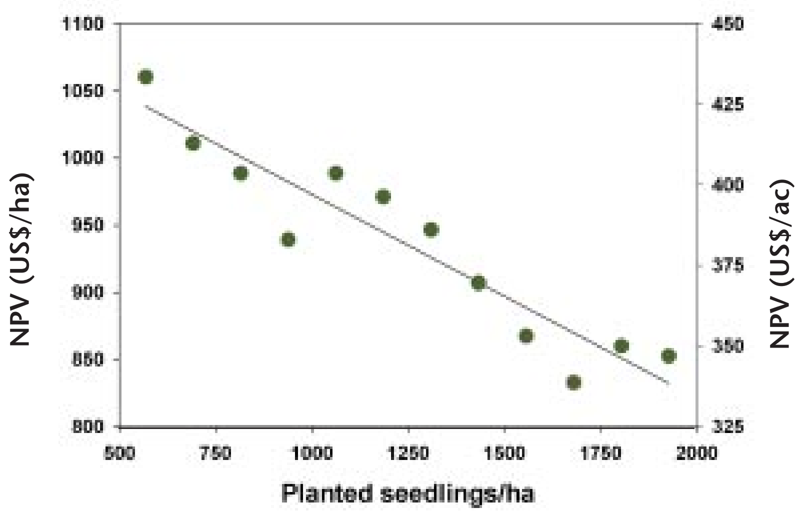

Figure 8. An example of a net present value (NPV) analysis for longleaf pine (7% discount rate and a site index of 27.4 m [90 ft; base age 50 y]). Factors excluded from this analysis were: risk, hunting leases, pole production, pine straw production and value of forage to wildlife species (Teeter and Somers 2005).

assuming the government will be paying for most of the establishment costs; and 13) ignoring economic analyses that indicate wider spacings increase the net present value of stands.

SUMMARY

There are several advantages to planting less than 1235 longleaf pine seedlings per ha (500/ac). Not only are establishment costs and logging costs (per Mg) reduced but also the net present value of the stand can be increased because of earlier production of chip-n-saw and sawtimber. Vehicle access and wildlife forage are increased when rows are spaced farther apart. Income from pine straw can be obtained although wide row spacing will reduce bale production for several years. When the landowner's primary objective is to establish longleaf pine in a manner that maximizes the stand's net present value, the decision on "how many trees to plant" is relatively straightforward. A holistic economic analysis should be conducted and used to guide the decision. In many cases, however, the decision is not based on economics but instead is based on factors such as aesthetics, outdated or misinformed opinions and peer pressure.

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AUTHOR INFORMATION

David B South
Professor
School of Forestry and Wildlife Sciences and Alabama Agricultural Experiment Station
Auburn University, AL
36849-5418
southdb@auburn.edu