Effects of Five Silvicultural Treatments on Loblolly Pine in the Georgia Piedmont at Age 20

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ABSTRACT: *Age 20 data from a designed experimental study installed on 24 plots at one location in the Lower Piedmont in Jones County, Georgia, were used to evaluate the effect of six silvicultural treatments on survival, growth, and yield of cutover site-prepared loblolly pine plantations in the Georgia Piedmont. The following silvicultural treatments were included in the study: (1) clearcut only, (2) clearcut with all residual trees greater than 1 inch dbh removed by chainsaw, (3) shear and chop, (4) shear, rootrake, burn, and disk, and (5) shear, rootrake, burn, disk, fertilize, and herbicide. Treatment significantly affected all tree and stand characteristics at age 20. The shear, rootrake, burn, disk, fertilize, and herbicide treatment ranked best in all categories with the exception of survival and basal area, which were highest for the shear, rootrake, burn, and disk treatment. The shear and chop treatment was not significantly lower than the most intensive treatment in any measured category. South. J. Appl. For. 28(1):35–40.*

Key Words: Southern pine, fertilizer, herbicide, and site preparation.

Few long-term studies on the effects of site preparation and silviculture in terms of survival, growth, and yield for loblolly pine (*Pinus taeda* L.) on cutover sites had been conducted when this study began in 1981. Most earlier studies in the Piedmont reported results at young ages (Berry 1979, Haines and Davey 1979), or focused only on mechanical site preparation treatments (Brender and Nelson 1952). Pine silviculture in the South, especially the regeneration investment, is a risky long-term proposition that requires knowledge of expected long-term results from alternative treatments for rational consideration between alternatives for all classifications of practitioners.

This study compares average survival, diameter at breast height (dbh), total tree height, basal area, and merchantable weight in a loblolly pine stand after 20 yr for five different treatments that represent varying levels of site preparation and silviculture. In addition, an economic analysis is performed on the age 20 data, and financial returns of the five treatments are compared. The resulting information can benefit foresters, private forest landowners and land managers in the Piedmont as they make important decisions about how to manage their forestlands. The purpose of the study is to determine the benefits of various intensities of site preparation and silviculture to the survival and growth of loblolly pine in the Piedmont of Georgia.

Materials and Methods

The study site is located on an 84 ac tract in the lower Piedmont in Jones County, Georgia. The preharvest stand of naturally regenerated loblolly pine was mixed with dogwood (*Cornus florida* L.) and sweetgum (*Liquidambar styraciflua* L.). It was cut in 1981, and following the site preparation treatments, the area was hand-planted with improved first generation loblolly pine seedlings in January 1982 on a spacing of 6 ft by 10 ft (726/ac). Site index for the study site was based on the previous stand and averaged 80 ft (base age 50 yr).

The following six treatments were implemented from fall 1981 to spring 1982 on 2 ac plots:

1. Clearcut only (CC): no site preparation,
2. Clearcut with all residual trees greater than 1 inch dbh removed by chainsaw (SAW) in August 1981,
3. Shear and chop (SC): shearing was conducted by KG blade and plots were chopped by a rotary drum with a single pass of a D-7 tractor from September to November 1981,

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4. Shear and chop with herbicide (SCH): in addition to shearing and chopping as in treatment 3, 0.5 cc Velpar Gridball pellets (hexazinone) were applied in a 2 ft by 2 ft grid at a rate of 40 oz ai/ac in March 1982.

5. Shear, rootrake, burn, and disk (SRBD): residual vegetation was sheared and rootraked into piles in September to October 1981 and burned. Most of the materials in the windrows were consumed, and the remaining debris and ash were scattered with a bulldozer blade. Plots were disked with an offset harrow to a depth of 6–10 in,

6. Shear, rootrake, burn, disk, fertilize, and herbicide (SRBDFH): site preparation was the same as described in treatment 5, with the addition of ammonium nitrate fertilizer 100 elemental lb. N/ac broadcast by hand in March 1983. Oust herbicide was then applied using backpack sprayers at rate of 6 oz ai/ac in April 1983.

The original study design was six treatments arranged in a randomized complete block with five replications for a total of 30 plots. The five blocks were located by topographic position to avoid obvious site-quality differences and to ensure reasonable uniformity within blocks. Each 2 ac treatment plot contained a 0.2 ac internal measurement plot. Since 1996, six plots were impacted by southern pine beetle activity and were removed by salvage. Oddly enough, the six plots affected were representative of each treatment, and the pine beetles favored no single treatment.

Survival for the SCH treatment was significantly reduced due to approximately 3 in. of rain falling in a short period soon after the herbicide application. This distributed a large quantity of hexazinone on the soil surface and killed about 35% of the planted pines. Surviving pines were injured and suffered growth loss. Pines were interplanted the following winter. Interplanting is generally considered to be ineffective (Wakeley 1968, Dennington 1986), but was used in this case in an attempt to salvage treatment four for the study. Unfortunately, interplanting again did not work well, and as a result of these problems the SCH treatment was dropped from this analysis. Therefore, the data used for analysis totaled 20 plots at age 20, and only 5 treatments are valid for this study.

Field measurements were made annually for the first 5 yr, and again after the eighth, tenth, twelfth, and twentieth growing seasons. Tree heights were measured to the nearest foot using Haglof Vertex III hypsometers, and diameters were measured to the nearest 0.1 in using Haglof Mantax aluminum calipers. Merchantable green weight per tree was estimated using equations from Clark and Saucier (1990) for trees larger than 4.5 in. dbh to a 2 in. top diameter outside bark (dob). Plot weights were expanded to per acre weights. Results at age 1 (Edwards 1986), age 5 (Edwards 1990), and age 10 (Edwards 1994) are available. The effects of site preparation on diameter distribution and basal area of pines and hardwoods at age 1 was examined by Harrington and Edwards (1998). Clark and Edwards (1999) examined the effects of site preparation treatments on wood properties at age 15. Projected economic return using age 10 measurements for six site preparation treatments was examined by Dangerfield and Edwards (1994).

An analysis of variance (ANOVA) was conducted to test for significant differences in dbh, height, basal area, merchantable weight, and survival at age 20. The skewness, kurtosis, and range of the treatment diameter distribution were also tested. Duncan's multiple range test was used to determine whether differences among means were significant at the 0.05 level. Data analysis was performed using the SAS statistical package (SAS 1990).

Results and Discussion

Average DBH

After 20 growing seasons, all treatments with site preparation had greater diameters than the control plots (Table 1). The dbh ranking was the same at age 20 as it has been at all previous measurement ages, although the 0.4 in. advantage the SRBD treatment had over the SC treatment at age 13 has diminished to less than 0.1 in. (Figure 1). The SRBDFH treatment, the most intensive treatment, had an average diameter almost 2.5 in. larger than that of the control plots. Even the SAW treatment, the lowest intensity site preparation treatment, increased average diameter by almost 1 in. over the control plots at age 20, indicating that residual hardwoods after harvest severely impacted dbh growth on the control treatment. The SC treatment increased average diameter by about 2 in. over the control plots and was not significantly smaller than the two most intensive treatments. The growth in average dbh for the SC treatment was as large as for any more intensive treatment.

Average Height

All treatments have a greater average height than the control plots at age 20 (Figure 2). This trend has been seen at each previous measurement age. Average heights follow a generally increasing trend as treatment intensity increases, although the SRBD treatment is shorter than the SC treatment, but not significantly. There is approximately a 15 ft increase in average total height from the control plots to the most intensive treatment at age 20. Just the removal of hardwood stems associated with the SAW treatment increased average height by 7.5 ft over the control treatment. The SC treatment

Table 1. Average tree and stand characteristics values at age 20 by treatment. Treatments with the same letter (a,b,c) are not significantly different at alpha = 0.05 level.

	Treatment				
Variable	CC	SAW	SC	SRBD	SRBDFH
Dbh (in.)	4.71c	5.48bc	6.42ab	6.48ab	6.99a
Height (ft)	44.2b	51.7ab	55.4a	54.1a	59.4a
Basal area (ft^2/ac)	52.4b	50.4b	122.5a	153.4a	150.1a
Merch. weight (tons/ac)	25.1b	31.7b	84.8a	103.4a	113.8a
% survival	53.5bc	37.8c	70.3ab	88.5a	74.3ab

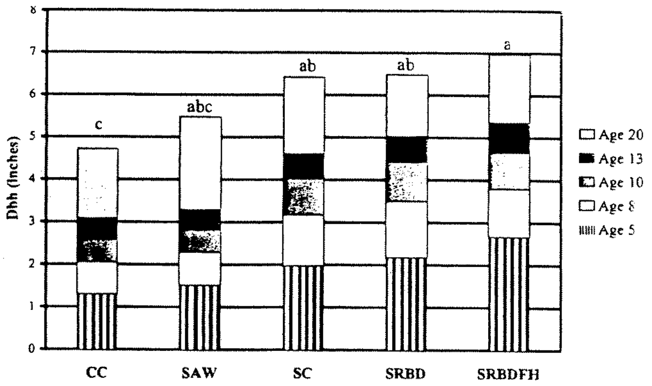

Figure 1. Average dbh by silvicultural treatment for five ages of stand development in a loblolly pine plantation in the Georgia Piedmont. Different letters indicate significant differences between treatment means at age 20.

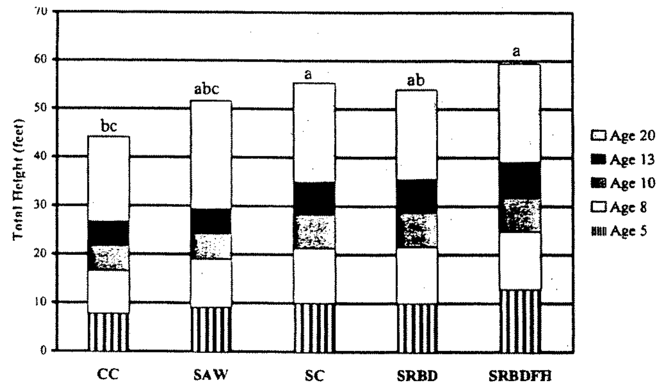

Figure 2. Average height by silvicultural treatment for five ages of stand development in a loblolly pine plantation in the Georgia Piedmont. Different letters indicate significant differences between treatment means at age 20.

has the second tallest average height and was not significantly shorter than the most intensive treatment. Many studies have shown no differences in average height by density for density ranges from about 600 to 1200 (Pienaar and Shiver 1993). With higher stem counts and hardwood competitors, there is an obvious effect on height from pine and hardwood density combined.

Average Survival

Average survival does not follow the general trend seen on all other variables. The SRBD treatment had the highest rate of survival at 88.5%, although it was not significantly higher than the SC and SRBDFH treatments. Though not significant, the SRBDFH treatment has had a lower survival rate than the SRBD treatment since the stand was 8 yr old (Figure 3). Other studies have noted the positive impact on survival from disking in the Georgia Piedmont (Knowe et al. 1992, Shiver et al. 1990). The SAW treatment had the lowest average survival at 37.8%, which was 15% lower than the control plots. The SAW treatment has experienced 30% mortality since age 13, when it had a survival rate of 76%. The development of hardwoods sprouting after the chainsaw treatment may have influenced this increased mortality rate. Other treatments averaged 10% mortality during the same time period. The two low intensity treatments had lower survival throughout the study, and the gap in trees per acre has widened as intertree competition has intensified.

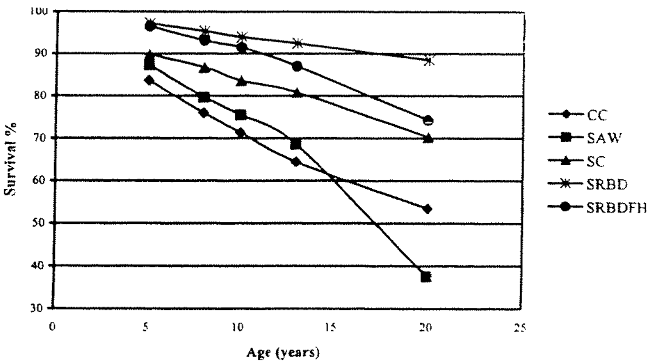

Figure 3. Average survival by silvicultural treatment for five ages of stand development in a loblolly pine plantation in the Georgia Piedmont.

Average Basal Area

All treatments, with the exception of the SAW treatment, have significantly higher basal area per acre than the control plots (Figure 4). The SAW treatment's low basal area was a result of the high mortality these plots experienced between the ages of 13 and 20. The SRBDFH treatment's slightly lower basal area than the SRBD treatment's basal area was at least partially due to the SRBD treatment having approximately 14% better survival than the SRBDFH treatment. This was not the case at age 10 when the SRBDFH treatment had a slightly higher basal area than the SRBD treatment, and the SRBDFH treatment had a survival rate only 3% lower than the SRBD treatment. The SC treatment had almost 2.5 times the average basal area of the SAW or CC treatments. It was also not significantly lower than the two most intensive treatments even though the absolute difference is about 25 ft^2/ac. The fact that 25 ft^2/ac is not significantly different is an indication of the variability in basal area in these plots. It seems likely that the SRBD and SRBDFH treatments have reached, or are very near, their asymptotic basal area on this site. That asymptote could possibly be raised by more intensive woody brush competition control and/or fertilization later in the rotation rather than just at planting.

Average Merchantable Green Weight

Average merchantable green weight follows a general increasing trend with increasing intensity of site preparation

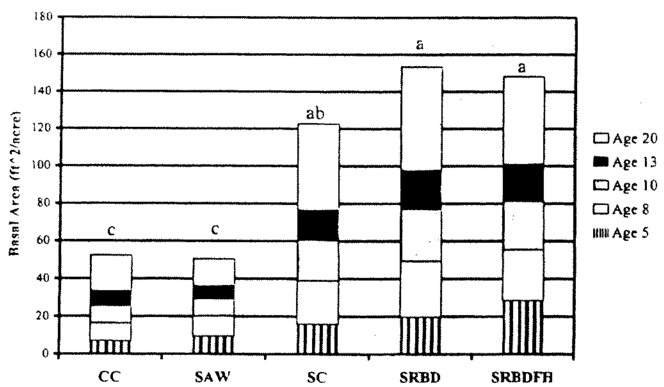

Figure 4. Average basal area by silvicultural treatment for five ages of stand development in a loblolly pine plantation in the Georgia Piedmont. Different letters indicate significant differences between treatment means at age 20.

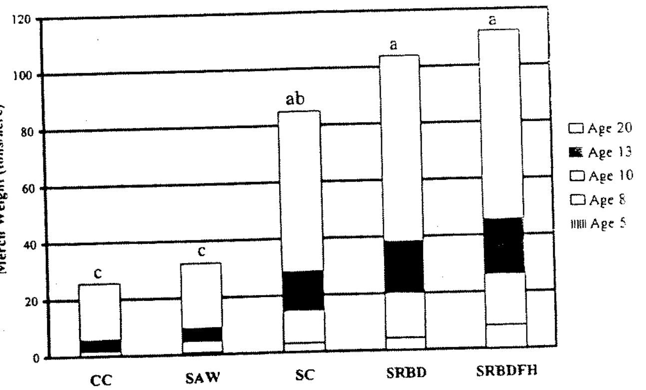

Figure 5. Average merchantable green weight by silvicultural treatment for five ages of stand development in a loblolly pine plantation in the Georgia Piedmont. Different letters indicate significant differences between treatment means at age 20.

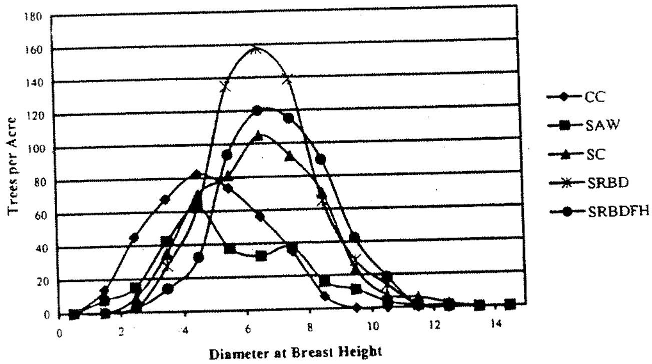

Figure 6. Diameter distribution by silvicultural treatment at age 20 for a loblolly pine plantation in the Georgia Piedmont.

(Figure 5). The CC and SAW treatments had approximately the same total green weight, probably due to a trade-off between better survival and better dbh growth. Over 20 yr, their growth was no better than a naturally regenerated pine stand. Landowners reluctant to spend money on site preparation should probably opt for natural regeneration instead. The three most intensive treatments showed a significant increase in total green weight over the two least intensive treatments. The SC treatment showed an increase in total green weight of almost 2.5 times more than the SAW treatment, and 3.5 times greater than the CC treatment. The SRBDFH treatment had the greatest total green weight of all treatments, about three times more than the CC or SAW treatments, though not significantly higher than the SC or SRBD treatments.

Diameter Distribution

Figure 6 shows the diameter distribution of each treatment at age 20. The average skewness, kurtosis, and range of diameter distributions for each treatment are shown in Table 2. Treatment did not significantly affect skewness, kurtosis, or the range, although a general decreasing trend in the range can be seen as site preparation intensity increases. This implies that as site preparation intensity increases, variability in dbh is slightly reduced. Logically, the variability of dbh by treatment should depend on the age of the measurement. At young ages, the dbh variability is reduced for more intensive treatments. As stands approach their asymptotic basal area larger trees continue to grow and smaller trees shift to survival mode rather than growth mode and the dbh range increases. This should be happening to the more intensive treatments by age 20.

Economic Analysis

Land managers considering various site preparation and silvicultural treatments should be interested in how these five treatments rank economically. To help answer this question, an economic analysis was performed. Yields were based on calculated merchantable tons at age 20. Product green weights were calculated for pulpwood with a minimum dbh of 4.5 in. to a 2 in. top, and chip-n-saw with a minimum dbh of 7.5 in. to a 6 in. top. Any portion of the tree above 6 in. to a 2 in. top on a chip-n-saw tree was included in the pulpwood weights. Pulpwood and chip-n-saw weights by treatment are shown in Table 3.

Economic Assumptions

Stumpage prices were based on North Georgia averages obtained from Timber Mart–South (2003). Product prices used were \$5.69/ton for pine pulpwood and \$23.04/ton for pine chip-n-saw. Current costs for silvicultural treatment combinations were obtained from personal communication with consulting foresters in the study area. The CC treatment had no site preparation or silvicultural treatment costs. The SAW treatment's cost was estimated at \$100/ac. Due to the lack of current cost data on this treatment, this is an estimated

Table 2. Average skewness, kurtosis, and range of the diameter distribution for each site preparation treatment for loblolly pine plantations in the Georgia Piedmont at age 20.

	Treatment				
Variable	CC	SAW	SC	SRBD	SRBDFH
Skewness	0.396	0.538	0.262	0.201	0.018
Kurtosis	0.499	−0.065	0.072	−0.013	−0.239
Range	11.5	10.8	10.7	8.8	9.4

Table 3. Merchantable pulpwood and CNS weights by treatment at age 20.

	Treatment				
Product	CC	SAW	SC	SRBD	SRBDFH
Pulp	22.7	19.8	53.8	72.4	65.9
CNS	2.4	11.9	31.1	31	47.9

cost based on costs associated with precommercial thinnings. The SC treatment cost was set at $175/ac, the SRBD treatment had a cost of $200/ac, and the SRBDFH treatment had a cost of $265/ac. Seedling prices of $26.14/ac (726 TPA) are based on the Georgia Forestry Commission's 2002–2003 price list. Planting costs were set at $39.70/ac as reported by Dubois et al. (2003). Annual tax and administration costs were assumed to be $4.00/ac/yr.

Evaluation Criterion

Net present values (NPV) were calculated to analyze the returns from the five site preparation and silvicultural treatments. NPV is the present value of revenues minus the present value of costs. A general formula for NPV is:

$$NPV = \sum_{y=0}^{n}\left[\frac{R_y}{(1+i)^y} - \frac{C_y}{(1+i)^y}\right]$$

where

R_y = revenues in year y,

C_y = costs in year y,

n = number of years in investment, and

i = discount rate.

Real discount rates of 5, 8, and 11% were chosen to investigate the effect of varying hurdle rates on treatment combination selections.

Economic Results and Discussion

Figure 7 shows NPVs for the five treatments at three different discount rates. Assuming a discount rate of 5%, the most intensive treatment has the highest NPV at $113.73. The SAW treatment has the lowest NPV at $–69.25. This is due to the high cost of the treatment relative to the small increase in volume that results. The SC treatment has a NPV of $95.39, just under $20 less the most intensive treatment. The SRBD treatment, the treatment with the most intensive site preparation only treatments, has a NPV of $109.41. This is only $4 less the most intensive treatment.

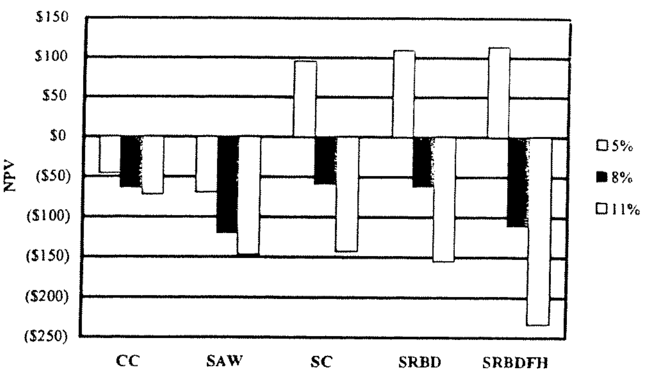

Figure 7. Net present values for five treatments at three discount rates at age 20 for a loblolly pine plantation in the Georgia Piedmont.

When an 8% discount rate is assumed, the ranking of the five treatments change. The treatment with the highest NPV becomes the SC treatment. The two most intensive treatments, SRBD and SRBDFH, now have NPV's of –$61.75 and –$111.16, respectively. The increased volumes at age 20 do not make up for the high initial costs of these treatments at planting when a higher discount rate is assumed. The SAW treatment again has the lowest NPV at –$120.38.

When an 11% discount rate is assumed, the most intensive treatment has the lowest NPV at –$233.09. All treatments at this discount rate are negative. The best NPV at an 11% discount rate is the CC treatment, at –$71.79.

Conclusions

It is evident that increasing site preparation intensity causes an increase in average DBH, height, basal area, and green weight. The SAW treatment did not significantly improve upon any measured variable over the control plots. The SC treatment was a good performer in all cases. The SRBD and SRBDFH treatments were the best performers in most cases. Though these treatments were considered intensive in 1981, neither had a chemical treatment to control unwanted hardwoods. The low asymptotic basal areas of these treatments are at least partially due to sharing space with hardwoods. In addition, the herbaceous weed control treatment of the SRBDFH has much less impact in growth in the presence of hardwoods (Quicke et al. 1999). The fertilizer would have had more effect later in the rotation than at planting. In terms of present value, the most intensive treatment, SRBDFH, had the highest NPV assuming a 5% discount rate. If the discount rate is increased to 8% or 11%, the best performing treatment becomes the SC and CC treatments, respectively.

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