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YIELDS, STAND STRUCTURE AND ECONOMIC CONCLUSIONS

Based on a 22-year-old Site Preparation Study with planted loblolly and longleaf pines

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ABSTRACT

In October, 1960, a site preparation study was planted with 726 trees per acre to loblolly and longleaf pine on loblolly site index 65 (base age 25) land in Polk County, Georgia. Data from nine replications of each species established following each of four site preparation methods indicates that age-22 yields (inside bark to a 2-inch top) are significantly less for longleaf (1203 cu ft/ac) than for loblolly (3094 cu ft/ac). Analyses of site preparation effects were restricted to loblolly. Across the four site preparation treatments, (1) shear and pile, (2) disk, (3) bed, and (4) subsoil and bed, loblolly survival was excellent and ranged from 81.8 to 88.5 percent. Dominant height averaged from 52.4 to 51.1 feet across treatments. Volume yield for the subsoil and bed treatment (3352 cu ft/ac) was significantly greater than for bed (3064 cu ft/ac), shear and pile (2999 cu ft/ac) and disk (2962 cu ft/ac). An economic analysis based on yields indicates that none of the other three treatments applied after shearing are likely to be cost effective.

INTRODUCTION

Increasing demand for wood products has forced the forest products industry to address the problem of establishing productive forests on marginal sites. Artificial regeneration of southern pine species is the only practical method on such sites as site conditions and residual stocking are often inadequate for natural regeneration. The value of mechanical site preparation in controlling competing vegetation and enhancing growth and survival of crop trees is widely recognized and well documented. However, management decisions on which particular site preparation technique to employ and what species to plant are often dictated by local custom or personal preference of the forest manager. In order to make intelligent decisions toward optimizing wood production, the forest manager needs better information on site preparation and the establishment of southern pines.

Site preparation information currently available is from research on pine stands of age ten years or less. Side by side comparisons of older stands provide some useful guidelines, but well replicated, statistically sound studies of older stands have not been reported.

In this paper we report the results from a research project designed to examine the long term effects of site preparation treatments on loblolly pine *(Pinus taeda* L.*)* and longleaf pine *(Pinus palustrus* Mill.*)*. The objective of this study was to evaluate differences due to four site preparation treatments in stand structure, volume yields and growth patterns in stands 22 years old. Only with good yield data from such experiments can any true economic differences due to site preparation treatments be evaluated. These results will help fill the information void by providing what is probably the oldest site preparation information yet reported.

Procedures

The study site is located in Polk County near Cedartown in Northwest Georgia. The area is typical of the Valley and Ridge Physiographic Province in which it is located. This region is characterized by long sharp ridges and broad flat valleys. These ridges once supported scattered stands of loblolly pine, longleaf pine, and shortleaf pine *(Pinus echinata* Mill.*)*. These stands exhibit a well developed understory of hardwoods, generally of the oak-hickory type.

Polk County has a moist temperate climate with average minimum daily temperature of 30 degrees F. in February and average maximum daily temperature of 89 degrees F. in August. Mean summer temperature is 78.5 degrees F. with extremes of 42 to 107 degrees F. Mean winter temperature is 43.5 degrees F. with extremes of -7 to 85 degrees F. Average rainfall is approximately 52 inches annually, most of which comes in the form of quick intense showers. Winter precipitation comes in the form of sleet, snow and all-day rains.

The experiment was originally designed to help determine the feasibility of converting upland oak-hickory types to stands of loblolly and longleaf pine. It was initiated in October, 1960, by the Georgia Forest Research Council in cooperation with the University of Georgia School of Forest Resources and Rome Plow Company of Rome, Georgia. The objectives were to evaluate the effects of mechanical site preparation on survival of planted seedlings and on establishment of direct seeded stands. Results of the planting survival tests were reported in a thesis by Whitehead (1962).

The land clearing began in October, 1960, and was completed in mid November. Most of the work was done with a Caterpillar D-8H tractor and Rome K/G clearing blade. Hardwood cover was sheared at ground level with the tractor and clearing blade and pushed along with logging slash from a pine harvesting operation into windrows. These windrows were oriented along the slopes to serve as terraces and pushed into gullies and ravines when possible.

The experiment as originally established consisted of two separate studies. One area was allocated for testing the effects of four site preparation treatments on survival of planted loblolly and longleaf pine seedlings. The remaining area was used for testing the effects of site treatments on establishment of seedlings by direct seeding. We selected the area used to test survival of planted seedlings for our growth and yield study. The average site index (base age 25) for loblolly pine plantations on the area is 65 feet.

The experimental design employed is a randomized complete block split plot design with nine replications or blocks. Whole plots 120 by 200 feet in size received site preparation treatments and were subdivided into 60 by 100 feet subplots for species treatments. Site preparation treatments were assigned randomly to plots within blocks and species were assigned randomly to subplots within plots.

Site preparation treatments were designed to take into account a wide range of intensities of mechanical methods. The treatments, in order of increasing intensity, were:

1. Control - No treatment other than the shear-pile operation used in land clearing.
2. Disking - Following clearing (method 1 above), shallow furrows were plowed on cleared sites at ten-foot intervals with two-disk gang harrows. Furrows were plowed rather shallow to avoid erosion on slopes.
3. Bedding - Following clearing, ridges 8 to 10 inches high were plowed at ten-foot intervals with a disk ridger followed by a packing wheel to settle the beds.
4. Subsoiling and bedding - Following clearing, heavy duty 36-inch subsoiling standards with 30-inch lifter wings were pulled at a depth of 24 inches in rows ten feet apart. Beds were then prepared directly over the subsoiling rips as in method 3 above.

Care was taken to avoid running whole plots up and down slopes when possible. Each subplot, 36 for each species, was planted with one hundred seedlings (726 trees/acre) of good health and vigor. Longleaf Grade 2 and loblolly Grades 1 and 2 seedlings of 1-0 stock were used for the species treatments. Seedlings were machine planted except in areas where difficulty was encountered in getting the planting shoe in the ground. These areas were hand planted. Exact uniformity of spacing in the rows was not possible as it was necessary to search for a spot to plant the seedling. This is to be expected when regenerating any rocky site.

The experimental area was first revisited in March of 1982. It was evident at that time that survival on the longleaf treatments was considerably poorer than on any of the loblolly treatments. Some of the longleaf subplots had fewer than five stems remaining. Loblolly had generally expressed complete crown closure, and in some cases there remained a surviving stem at virtually every planted spot. Holes in the stand created by poor longleaf survival and woods roads created an edge effect in adjacent trees. The original replication markers were still present although plot and subplot corners could not be located.

Plot and subplot re-establishment and measurement began in June and were completed in September, 1982. Rectangular subplots of varying sizes were established using a 150 ft. fiberglass tape and a right angle prism. Variable size subplots were necessary as species treatment boundaries were sometimes unclear due to mortality of boundary trees. It was also necessary to disallow trees and rows of trees adjacent to forest openings and woods roads in order to avoid any bias introduced by edge effect. When possible, the whole 60 by 100 ft. original subplot was re-established for measurement.

Diameter at breast height (dbh) to the nearest 0.1 inch was measured and recorded for every pine stem on each subplot. Total height to the nearest foot was measured with a Suunto hipsometer for the first tree and every fifth tree thereafter in each one-inch dbh class. This lead to an approximate 25-percent subsample of total heights in each diameter class on each subplot. All hardwood stems were tallied into one-inch dbh classes. In addition, three trees from each subplot, two dominant or co-dominant trees and one in a lower crown class, were felled and subjected to stem analysis. These trees were cut into four foot bolts, each of which was measured for ring count, inside bark diameter, outside bark diameter, and radius of the ring nearest the center.

Various stand structure and yield statistics were calculated and converted to a per-acre basis for comparisons between species and among site preparation techniques. Statistics calculated for both pine and hardwood were stems per acre, basal area, quadratic mean diameter, arithmetic mean diameter, standard error of the arithmetic mean diameter, and average height of dominant stems. Smalian's formula was used to calculate cubic foot volumes of trees felled by stem analysis. The volume to basal area ratio for the felled trees on a subplot was then applied to subplot basal area per acre to obtain an estimate of volume per acre. Total stem volume inside and outside bark and volume inside and outside bark to a 2-inch top were calculated for comparisons of volume yields.

The procedure reported by Newberry and Pienaar (1978) was applied to the stem analysis data to determine height-age pairs for each cut point on each felled tree. A non-linear least squares fit of the data was made with the model

$$H = b_o e^{b_1 A^{b_2}}$$

where H = height
A = age

and b_o, b_1, and b_2 are parameters.

This lead to the conclusion that b_2 = -0.3356 was acceptable. Thus, interpolative equations were fitted to all the data on each subplot with the model

$$1n(H) = B_o + B_1 A^{-0.3356},$$

where 1n(H) is the natural logarithm of H, and B_o and B_1 are regression coefficients. Height growth patterns based on heights at ages 10, 15, and 20 years, maximum height growth rate, and age of maximum growth rate were determined for the dominant and co-dominant trees by subplot with these interpolative equations.

Analysis of variance and Duncan's multiple range test were used to test for significant site preparation and species effects.

An example of a heavy crawler tractor performing intense site preparation on a cutover site. The blade is used to knock down residuals while the trailing chopper chops the residue.

Low quality hardwood and other logging residue are pushed into windrows for burning prior to planting.

RESULTS

Loblolly vs. longleaf. At 22 years of age, it was no big surprise that loblolly yields were significantly higher than longleaf:

Variable	Loblolly	Longleaf
	----means of all subplots----	
Volume (cu ft/ac, inside bark, 2-in top)	3094	1203
Trees/acre	618	357
Survival (percent)	85.1	49.2
Basal area (sq ft/ac)	159	66
Mean dbh (in)	6.9	5.8
Average dominant height (ft)	53	48

Since loblolly is generally the preferred species, and these results support such a preference, we confined our subsequent analyses to the loblolly data. No analyses were made to test the site preparation effects on longleaf yields.

Site Preparation Effects for Loblolly

Site preparation method definitely affected stand structure and yields of planted loblolly on this site:

	Site Preparation Method			
Variable	(1) Shear and Pile	(2) Disk	(3) Bed	(4) Subsoil and Bed
	--------means of all subplots-----			
Volume (cu ft/ac, inside bark, 2-in top)	2999	2962	3064	3352
Trees/acre	619	617	594	643
Survival (percent)	85.3	85.0	81.8	88.6
Basal area (sq ft/ac)	156	153	159	168
Mean dbh (in)	6.8	6.8	7.0	6.9
Average dominant height (ft)	53	52	52	54

The subsoil and bed treatment applied following shearing and piling gave significantly higher yields. There were no significant differences among methods (1) through (3) in yields or any of the other variables. We think the higher yields with method (4) resulted from the increase in survival with subsoiling. As evidence of this, tests with mean dbh and standard error of mean dbh revealed no difference in the diameter distributions. However, the stand density (basal area) is significantly higher for method (4).

Differences in average dominant height, although small, lead us to question whether or not the site index curve is affected by site preparation. With the interpolative equation fitted to stem analysis data for each subplot, various parameters of the site index curve were calculated and averaged by treatment:

Site Index Curve Parameter	(1) Shear and Pile	(2) Disk	(3) Bed	(4) Subsoil and Bed
	--------means of all subplots--------			
Height (ft) at age:				
ten	30.4	31.6	30.8	31.7
fifteen	42.2	43.2	41.7	43.5
twenty	51.9	51.7	50.6	53.1
Maximum growth rate (ft/yr)	3.7	4.0	4.0	3.9

No significant differences in these parameters were detected. The age of maximum growth rate in height was two to three years in all cases.

Economic Analysis

To investigate the relative cost effectiveness of these site preparation methods, we derived the following minimum and maximum costs with data from Moak and others (1980):

Site Preparation Method	Cost Minimum	Cost Maximum
	----------$/acre----------	
(1) Shear and pile	77	107
(2) Shear, pile and disk	105	145
(3) Shear, pile and bed	97	143
(4) Shear, pile, subsoil and bed	143	197

Planting was assumed to cost $30 per acre regardless of the site preparation method and seedling costs were assumed to be $13 per acre.

In order to calculate incomes, volume yields were grouped into two product classes, pulpwood and chip-N-saw. Chip-N-saw volume was defined as that in trees 8-inches dbh and greater. A conversion of 70 cubic feet of wood per cord was used to express yields in cords:

Site Preparation Method	Yield Pulpwood	Yield Chip-N-Saw
	----------Cords----------	
(1) Shear and pile	27	16
(2) Shear, pile and disk	29	13
(3) Shear, pile and bed	25	18
(4) Shear, pile, subsoil and bed	29	18

Values were based on Timber Mart-South reports for zone 2 (middle) in Georgia. We used $23 per cord for pulpwood and $45 per cord for chip-N-saw.

After-tax internal rates of return were determined assuming 46% ordinary and 28% capital gains tax rates, $4 per acre per year for ad valorem taxes and annual administration costs, and an infinite series of rotations with a rotation age of 22 years. Rates of return were plotted (Fig. 1) for the full range of site preparation costs given above by each of the four methods.

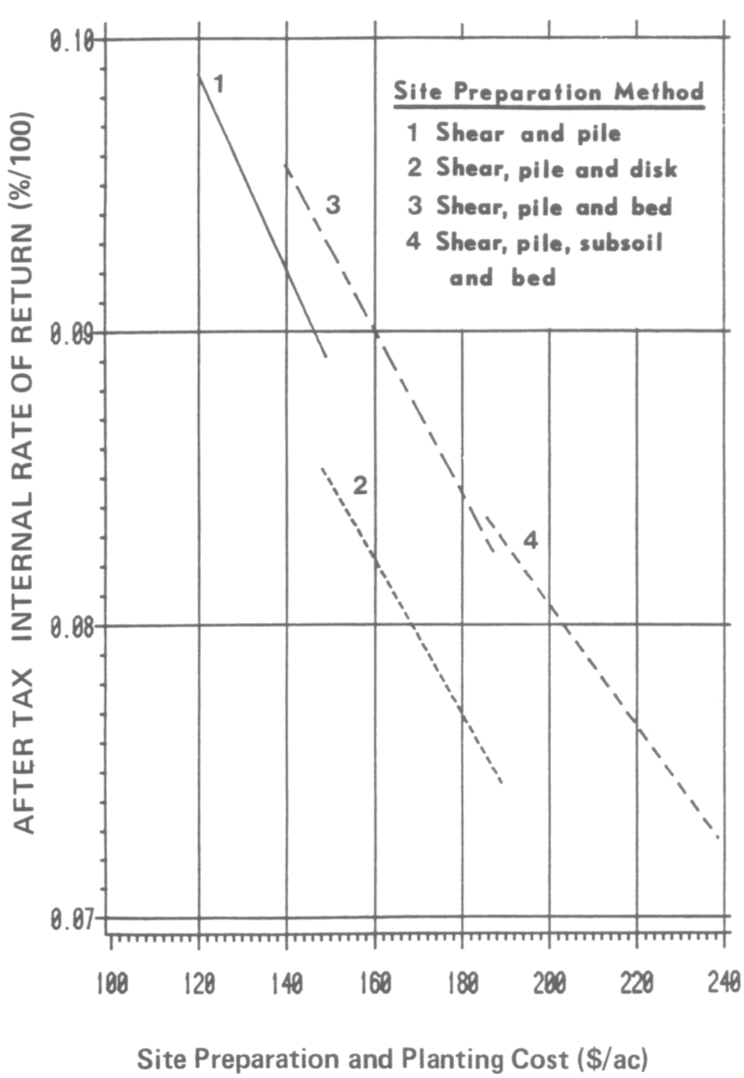

Figure 1.--After tax internal rate of return over total site preparation and planting costs for four site preparation methods. Yield data were from plantations of loblolly pine grown on site index 65-feet land to a 22-year rotation age.

CONCLUSIONS

From this study, which is, of course, specific to one site, we concluded that no significant increase in yield resulted from disking or bedding when applied after clearing with a KG blade (shearing). However, due to an increase in survival on this somewhat rocky site, subsoiling did increase yields. An economic analysis (Fig. 1) supports a conclusion that none of these three treatments--disking, bedding, subsoiling--were cost effective when applied after shearing. After tax internal rates of return ranged from 8.9% to 9.9% for the shear and pile method whereas they ranged from 8.2% to 9.6% for the next best treatment, bedding. At the average, or midrange, values for costs, the internal rate of return was highest for shear and pile with no additional treatments.

Artificial regeneration of southern pine is the only practical method of regeneration on areas where site conditions and residual stocking are inadequate for natural regeneration.

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