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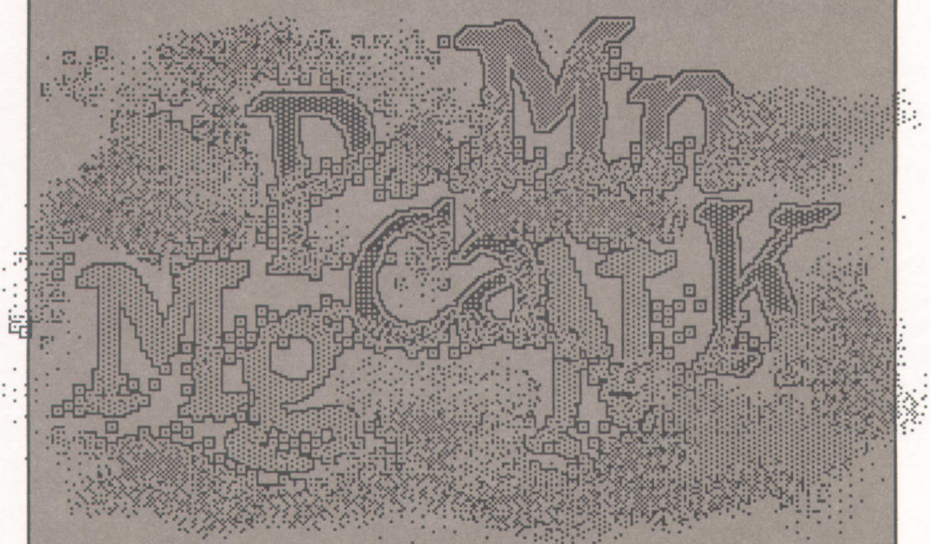
EFFECT OF SOIL REMOVAL AND HERBICIDE TREATMENT ON SOIL PROPERTIES AND EARLY LOBLOLLY PINE GROWTH



CONTENTS

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Effect of Soil Removal and Herbicide Treatment on Soil Properties and Early Loblolly Pine Growth

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INTRODUCTION

OVER THE PAST few decades, forestry and the forest products industry have increased their economic importance in Alabama. This has involved intensifying forestry operations, including the use of large, heavy machinery for harvesting and site preparation. In the South, mechanical site preparation treatments are used primarily to facilitate planting operations and to reduce competition. However, mechanical treatments may severely impact a site (*4, 19, 22*).

During harvesting and mechanical site preparation, the litter layer is commonly removed or destroyed and the surface soil may be compacted. With raking and piling, the surface soil layers may be severely disturbed or pushed into windrows (*10, 21*). This not only physically displaces soil, but bares the soil surface to potential damage from raindrop impact and possible accelerated erosion (*5, 30*).

Many southern pine plantation establishment systems employ some form of mechanical site preparation, which may result in surface soil displacement. However, observation of site-prepared areas indicates that the degree of soil movement is highly variable. Factors such as the amount and nature of rooted vegetation, topography, the quantity and size of stumps and logging debris, soil texture, and soil moisture all affect the degree of soil movement. The major causes of surface soil

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disturbance, however, are the size and design of the machinery used and the skill and care of the machine operator.

Early studies of raking and piling (a popular site preparation system used during the 1950's, 1960's, and 1970's) showed that pine seedling growth and survival could be increased through intensive treatment. Survival increases of 15 to 38 percent were found on raked and piled areas in the Florida sandhills (*11, 13*), while a 33 percent increase in seedling height was found by McMinn in south Florida (*20*). Increases in survival and seedling height were partially attributed to competition reductions.

Other research indicates that although early survival and growth may be improved by raking and piling, long-term site productivity may have been reduced. Glass (*10*) reported that a 25-year-old raked and piled loblolly pine plantation where 1 inch of soil was lost had a site index (base age 50) 8 to 10 feet lower than adjacent nonraked and piled plantations. Coile and Schumacher (*3*) found a 2-inch reduction in the surface soil depth could reduce loblolly pine 50-year site index 3 to 15 feet.

It has generally been accepted that surface soil loss from forest or agricultural land will negatively impact site productivity. However, most investigations into soil loss effects have been conducted on agricultural land which frequently remains bare for long periods of time or on forest land in mountainous areas. Since some soil movement and exposure are inevitable with mechanical site preparation, an important issue is the relationship between the degree of soil movement and potential negative impacts on site productivity. This study was established to determine the effects of surface soil loss on soil properties and on loblolly pine seedling establishment by simulating the levels of soil loss normally occurring during intensive mechanical site preparation.

METHODS

Five sites were selected for study, two in the Piedmont and three in the Hilly Coastal Plain regions of Alabama (*14*). Sites 1 and 2 were Piedmont old field situations, with site 1 being on a gently sloping upper hillside and site 2 on a lower hillside. Soils on both sites were members of the Gwinnett sandy clay loam series (clayey, kaolinitic, thermic Typic Rhodudult) having a sandy clay loam Ap surface horizon 2 to 5 inches thick over a clay subsoil 7 to 23 inches thick. Both Piedmont old field sites had been fertilized and limed during the mid-1970's while used as pasture, but no additions had been made in the 3 years prior to this study. Sites 3, 4, and 5 were in the Hilly Coastal Plain. Site 3 was used as deer range in wildlife research, but had not been fertilized in over 30 years, while site 4 was a recently cutover loblolly pine stand and site 5 was composed of log decks (loading areas) used during the harvest of site 4. Soils on all three Coastal Plain sites are in the Marvyn loamy sand series (fine-loamy, siliceous, thermic Typic Hapludult) with a loamy sand Ap surface horizon 4 to 8 inches thick over a sandy loam Bl horizon 7 to 15 inches thick. Slopes on all five sites were less than 5 percent. Since sites 1 and 2 were both Piedmont old fields on the same soil series located near each other, they were combined for analysis, resulting in six replications for this "previous use" class, while the other three areas each had three replications. Also, due to land area restrictions on the Piedmont old fields, one replication was installed without a control plot.

Vegetation on the Piedmont old fields was composed primarily of Coastal bermudagrass (*Cynnodon dactylon*), asters (*Asteraceae*), and sedges (*Cyperaceae*), with scattered small sweetgum (*Liquidambar styraciflua* L.), dogwood (*Cornus florida* L.), sumac (*Rhus copallina* L. and *Rhus glabra* L.), and oaks (*Quercus* spp.). The Coastal Plain old field contained primarily these same species, along with blackberry (*Rubus* spp.) and privet (*Ligustrum* spp.). Vegetation on the cutover area included oaks, sweetgum, asters, sedges, smilax (*Smilax hispida* Muhl.), sassafras (*Sassafras albium* Nutt.), and loblolly pine.

Three levels of surface soil removal were studied on each site: a control where no soil was removed, a 1-inch removal ("light"), and a 3-inch ("heavy") removal. Three replications, each containing a control and the two levels of soil removal, were installed in a randomized complete block design on each site. The two soil removal treatments were installed using a D-7 crawler tractor. Treatment areas were 40 feet × 75 feet, with 20-foot × 67-foot measurement plots. During the winter of 1981, the treatment areas were hand planted with 1-0 loblolly pine seedlings at a 6- × 8-foot spacing.

After planting, the treatment areas were split and one-half of each treated with a tank mix of glyphosate (Roundup®), trichlopyr (Garlon®), and oxyflurfen (Goal®) during May of the first season and glyphosate alone during May of the second year. Herbicide rates were 2.44 pounds glyphosate, 3.34 pounds trichlopyr, and 1.67 pounds oxyflurfen acid equivalent per acre. The pine seedlings were covered during herbicide applications.

Surface bulk density and soil chemical levels were determined on each plot immediately after planting and at the end of each of the first three growing seasons. Surface soil bulk density was found by collecting five randomly placed 3-inch × 3-inch cylindrical cores from each plot. At each sampling time, three points were randomly selected where the upper 12 inches of soil was collected for chemical analysis in four consecutive 3-inch increments, using a specially designed soil sampling tube (*28*). The three chemical analysis points on each plot were composited by depth increment prior to soil analysis. Total nutrient concentration for the surface 12 inches was found by summing the incremental values. The depth increments compared are based on post-treatment soil conditions, since this is the rooting environment of planted seedlings.

The soil samples were analyzed for extractable calcium (Ca), magnesium (Mg), potassium (K), and manganese (Mn) using 1.0 *N* ammonium acetate (pH 7.0) and atomic absorption spectrophotometry; extractable soil phosphorus (P) was determined using a dilute fluoric acid extracting solution (Bray #2) and the chlorostannous-reduced molybdophosphoric blue color method (*16*). Nitrogen determinations were by block digestion and colorimetric assay (*15*). Soil organic matter content was determined using the Walkley-Black procedure.

Total seedling heights and survival were determined at the end of each of the first three growing seasons. Seedling ground line diameter (GLD) was taken after the second and third seasons. From GLD and total seedling height, stem volume for each seedling was calculated as an index of potential biomass. During July of the second season, nonpine vegetation was estimated as percent cover using a point intercept approach along three systematically placed lines on each plot.

General linear models procedures (GLM) of SAS were used to perform analyses of variance since the study design was not balanced (*8*). When significant differences were observed (0.05 percent level), Duncan's New Multiple Range Tests were performed to compare the means.

RESULTS AND DISCUSSION

Effects on Nonpine Vegetation

Surface soil removal and herbicide treatments were both generally effective in reducing the quantity of nonpine vegetation. Soil removal alone did not reduce the levels of herbaceous cover, table 1. However, where the soil removal and herbicide treatments were used in combination, there were significant reductions of 30 percent and 36 percent in the levels of herbaceous cover for the light and the heavy removal treatments, respectively. This implies that the herbaceous reductions were due to herbicide applications and not the removal treatments, although average vegetation levels on the spray-only controls do not support this. The lack of herbaceous reduction on the spray-only is due primarily to an increase in the bermudagrass levels on the Piedmont old fields where herbaceous cover doubled during the first two seasons. The chemical rates used were not high enough to kill bermudagrass, and in fact released it. Removing the Piedmont old fields from the analysis results in an average herbaceous cover on the spray-only controls of 18 percent, supporting the theory that most of the herbaceous reductions were due to the herbicide applications.

Woody stems (most commonly sumac, sweetgum, dogwood, and oaks) were greatly reduced by the soil removal treatments. Woody cover ranged from 21 percent to 11 percent to 9 percent for the control, light, and heavy removal treatments respectively, table 1. During soil removal, roots, stems, stumps,

TABLE 1. EFFECT OF SOIL REMOVAL AND SPRAY TREATMENTS ON COMPETING VEGETATION AFTER TWO GROWING SEASONS

Spray and soil removal treatment	Competition, percent of total cover				
	Grasses and forbs	Vines	Woody vegetation	Total[1] competition	Coastal Plain[2] total competition
Nonspray					
Control	42.6 A[3]	29.0 A	21.4 A	93.1 A	91.4 A
1-inch removal	46.0 A	18.2 AB	10.6 B	74.8 B	76.8 AB
3-inch removal	39.1 A	17.4 AB	9.0 B	65.6 BC	64.4 B
Spray					
Control	39.9 A	7.9 AB	6.6 BC	54.4 C	32.2 C
1-inch removal	12.8 B	2.9 C	2.4 C	18.1 D	12.0 D
3-inch removal	6.1 B	3.8 C	.9 C	10.9 D	12.0 D

[1]All sites.
[2]Coastal Plain sites only.
[3]Means with the same letter are not significantly different at the 0.05 level.

and seeds were physically removed from the study areas similar to removal which occurs during raking and piling operations. When herbicides were used in combination with soil removal, most of the woody vegetation was eliminated from the treated areas.

Total nonpine cover was reduced from 93 percent to below 75 percent by the soil removal treatments alone, table 1. However, they were most effective when applied in combination. Nonpine competition levels were directly related to the intensity of the soil removal/spray treatment combination. Total cover decreased as soil removal/spray treatment intensity increased. The nonspray control had the highest degree of vegetation cover. The light soil removal alone significantly

TABLE 2. EFFECTS OF SOIL REMOVAL AND HERBICIDE SPRAY TREATMENTS ON COMPETING VEGETATION AFTER TWO SEASONS, BY PREVIOUS LAND USE

Spray treatment	Soil removal treatment[1]	Competition, percent of total cover			
		Grasses and forbs	Vines	Woody vegetation	Total competition
Piedmont old field					
Nonspray	Control	47.4 B[2]	29.3 A	19.6 A	96.3 A
Nonspray	1-inch removal	38.9 B	21.9 A	11.1 AB	71.9 B
Nonspray	3-inch removal	40.4 B	14.2 AB	12.7 AB	67.3 B
Spray	Control	80.4 A	3.5 B	10.2 AB	94.1 A
Spray	1-inch removal	22.9 BC	3.3 B	1.0 B	27.1 C
Spray	3-inch removal	3.3 C	4.3 B	1.2 B	9.2 C
Coastal Plain old field					
Nonspray	Control	8.6 B	61.7 A	29.6 A	99.9 A
Nonspray	1-inch removal	33.3 AB	40.7 AB	14.8 B	88.8 AB
Nonspray	3-inch removal	20.4 AB	34.0 AB	9.9 B	64.2 B
Spray	Control	41.8 A	22.9 AB	1.3 B	66.1 B
Spray	1-inch removal	15.0 AB	7.2 B	.7 B	22.9 C
Spray	3-inch removal	10.5 B	9.1 B	.0 B	19.6 C
Coastal Plain cutover					
Nonspray	Control	40.1 AB	24.7 A	22.8 A	87.7 A
Nonspray	1-inch removal	42.6 A	3.7 A	8.0 B	54.4 B
Nonspray	3-inch removal	21.4 AB	24.7 A	6.8 B	53.1 B
Spray	Control	2.6 A	6.6 A	10.5 AB	19.6 C
Spray	1-inch removal	1.3 B	.0 A	6.5 B	7.8 C
Spray	3-inch removal	3.9 AB	.0 A	1.3 B	5.2 C
Coastal Plain log deck					
Nonspray	Control	71.6 A	.0 A	14.8 A	86.4 A
Nonspray	1-inch removal	76.5 A	2.5 A	8.1 AB	87.1 A
Nonspray	3-inch removal	72.8 A	.0 A	3.1 B	75.9 A
Spray	Control	7.9 B	1.3 A	2.0 B	11.1 B
Spray	1-inch removal	2.0 B	.7 A	2.6 B	5.3 B
Spray	3-inch removal	9.8 B	1.3 A	.0 B	11.1 B

[1]n=3 for all treatments on the Coastal Plain sites, n=5 for the Piedmont old field controls, and n=6 for the Piedmont old field removal treatments.

[2]Means within a use with the same letter are not significantly different at the 0.05 level.

reduced competing vegetation (20 percent), while the heavy removal resulted in a 28 percent reduction. However, use of soil removal and herbicides in combination resulted in an additional 40 percent and 60 percent reduction (over soil removal alone) in nonpine cover.

Vegetation patterns were found to be similar for all four previous land uses, table 2. Nonsprayed controls had the highest nonpine competition level, while the sprayed removal treatments had the lowest. The Piedmont and Coastal Plain old fields had higher competition levels than did the Coastal Plain cutover and log deck sites.

Soil removal also significantly reduced the level of competing vegetation with the amount of total nonpine reduction similar on all sites. Total cover reductions of up to 35 percent occurred due to soil removal alone and averaged 17 percent on the light and 28 percent on the heavy removals, table 2. In addition, total competition decreased on each site as the level of soil removal increased. Increasing the depth of soil removal removed more of the roots and seeds which could sprout. This was particularly evident by the reduction in woody vegetation on the scraped areas.

Effects on Loblolly Pine Seedlings

The soil removal treatment/site interaction was nonsignificant for pine seedling survival or growth after three growing seasons. Therefore, all five study sites were pooled for the seedling analyses.

Soil removal increased seedling survival after three seasons, table 3. Survival was increased 17 percent and 27 percent by

TABLE 3. EFFECT OF SOIL REMOVAL AND SPRAY TREATMENTS ON TOTAL SEEDLING HEIGHT, SURVIVAL, AND VOLUME AFTER THE THIRD GROWING SEASON

Spray and soil removal treatment	Mean seedling height	Seedling survival[1]	Ground line diameter	Mean seedling volume/acre
	In.	*Pct.*	*In.*	*Cu. Ft.*
Nonspray				
Control	54 C	58.3 B	1.02 C	148 D
1-inch removal	55 BC	75.0 AB	1.26 BC	203 CD
3-inch removal	56 BC	85.0 A	1.27 BC	228 CD
Spray				
Control	63 ABC	58.3 B	1.52 AB	332 BC
1-inch removal	71 A	75.6 AB	1.65 A	491 A
3-inch removal	65 AB	77.8 AB	1.61 A	448 A

[1]Means with the same letter are not significantly different at the 0.05 level.

the light and heavy removals, respectively, similar to survival increases previously reported where intensive mechanical site preparation had been used. Stafford et al. (*23*) reported loblolly pine survival increases of 18 percent following raking and piling at three Piedmont sites. Grelen (*11*) similarly reported a 20 percent increase in slash pine (*Pinus elliottii* Engelm.) survival following intensive site preparation in the Florida sandhills. Herbicide use had no effect on loblolly pine seedling survival after three seasons.

A direct relationship was found between the soil removal treatment and seedling height, ground line diameter (GLD), and volume after three seasons, table 3. In general, as treatment intensity increased, seedling growth also increased. Soil removal alone significantly increased mean seedling volume 38 percent and 55 percent for the light and heavy removal treatments, respectively. However, when herbicides were used in conjunction with soil removal, seedling height and volume were affected the most. Volume increases exceeding 200 percent occurred on the removal areas when compared to nonsprayed controls. Mean seedling height and GLD were also increased but to a lesser degree.

Three-year-old loblolly pine height and volume were found to be negatively correlated with the nonpine vegetation cover, table 4. Generally, as nonpine vegetation increased, seedling growth decreased, a previously reported relationship (*1, 2, 17*).

Past research has reported that reducing competing vegetation drastically influences the quantity of water available to tree seedlings. Water depletion rates have been reported to be much higher on areas with heavy competition (*7, 24, 29, 31*). The reduction in competition resulting from soil removal

TABLE 4. CORRELATIONS OF LOBLOLLY PINE SEEDLING HEIGHT AND VOLUME AFTER THREE GROWING SEASONS, WITH THE PERCENT COVER OF VARIOUS NONPINE COMPETITION CLASSES AFTER TWO SEASONS

Pine measurement	Correlation with competition			
	Grasses and forbs	Vines	Woody vegetation	Total competition
Seedling height	-0.2605 *	0.1651	0.0825	-0.0952
Average seedling volume	-0.2611 *	-0.0911	-0.1679	-0.3043 **
Total seedling volume	-0.2402 *	-0.0519	-0.1696	-0.2670 *

* Significant at the 0.05 level.
** Significant at the 0.01 level.

and herbicide treatment leads to the inference that the moisture available to the planted seedlings was increased.

Increases in young seedling growth and survival have been found on other areas where severe soil disturbance has occurred. On a sandhills site in northwest Florida (*11*), slash pine seedlings on raked and piled areas (much of the topsoil in windrows) were taller and had higher survival after two seasons than those on control plots. Lantagne and Burger (*18*) reported that intensive site preparation on sandy loam soils resulted in better survival and growth of loblolly pine after one season.

Effect of Soil Removal on Soil Chemical Properties

Herbicide use had no effect on soil chemical properties in the upper 12 inches of soil or on surface bulk density after three seasons, table 5. At no time during the 3 years of study did herbicide application significantly alter soil properties. Therefore, the split plots were pooled for all soil analyses.

Soil removal significantly reduced concentrations of organic matter and all nutrients except Mg in the upper 12 inches after three seasons, table 6. Although there was no difference between the light and heavy removal treatments, as more soil was removed, nutrient levels tended to decrease; most of this decrease occurred during the removal of the surface inch.

Surface soil removed during treatment was high in organic matter. The light removal treatment reduced the organic

TABLE 5. EFFECT OF HERBICIDE TREATMENT ON SOIL CHEMICAL PROPERTIES IN THE UPPER 12 INCHES OF SOIL AND SURFACE BULK DENSITY AT THE END OF THE THIRD GROWING SEASON

Soil removal and spray treatment	Soil nutrients/acre						Soil organic matter	Soil bulk density
	Ca	Mg	K	Mn	P	N		
No soil removal (control)	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*g/cc*
Nonspray	1,030 A[1]	235 A	159 A	70 A	13 A	2,179 A	1.54 A	1.13 A
Spray	1,020 A	228 A	152 A	59 A	14 A	2,124 A	1.55 A	1.16 A
1-inch removal								
Nonspray	882 A	230 A	127 A	52 A	10 A	1,428 A	.97 A	1.24 A
Spray	900 A	224 A	127 A	48 A	11 A	1,464 A	.90 A	1.31 A
3-inch removal								
Nonspray	773 A	200 A	127 A	41 A	9 A	1,199 A	.80 A	1.32 A
Spray	868 A	205 A	135 A	50 A	8 A	1,149 A	.63 A	1.34 A

[1]Means within a treatment with the same letter are not significantly different at the 0.05 level.

TABLE 6. CHANGE IN SOIL NUTRIENTS AND ORGANIC MATTER IN THE UPPER 12 INCHES OF SOIL THROUGH TIME FOR EACH SOIL REMOVAL TREATMENT

Soil removal treatment and time of treatment	Soil nutrients/acre						Soil organic matter
	Ca	Mg	K	Mn	P	N	
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*
No soil removal (control)							
At planting	919 BC[1]	241 A	163 A	42 C	12 C	2,048 AB	1.26 B
After 1 season	876 C	228 A	158 A	46 BC	12 C	1,834 B	1.16 B
After 2 seasons	963 B	221 A	158 A	53 AB	15 A	1,984 AB	1.16 B
After 3 seasons	1,025 A	232 A	156 A	61 A	13 B	2,152 A	1.55 A
1-inch removal							
At planting	812 B	261 A	154 A[1]	37 C	9 A	1,692 A	.93 A
After 1 season	900 A	240 B	154 A	40 C	8 B	1,349 B	.77 B
After 2 seasons	913 A	219 B	136 B	45 B	10 A	1,226 C	.80 B
After 3 seasons	891 A	227 B	127 B	50 A	10 A	1,446 B	.93 A
3-inch removal							
At planting	774 B	237 A	137 A	34 C	8 A	1,284 A	.71 A
After 1 season	745 B	232 A	137 A	37 BC	8 A	1,145 B	.64 AB
After 2 seasons	802 AB	205 B	136 A	40 B	9 A	980 C	.60 B
After 3 seasons	821 A	203 B	131 A	45 A	9 A	1,174 AB	.72 A

[1]Means within a treatment with the same letter are not significantly different at the 0.05 level.
[2]Control n=14; 1-inch removal n=15; 3-inch removal n=15.

content 26 percent at planting when compared to the controls and the heavy removal reduced it by 44 percent, table 6. These reductions were 40 percent and 54 percent for the light and heavy removals, respectively, after three seasons.

Although not significantly different from the light removal, the heavy removal treatment had the lowest nutrient concentrations after 3 years. Removing 1 inch of soil reduced nitrogen (N) concentration 33 percent. An additional 2-inch soil removal (total of 3 inches of soil removed) reduced N an additional 273 pounds per acre, a total reduction of 45 percent. Similarly, after 3 years, P was reduced 27 percent and 33 percent and Ca 13 percent and 20 percent for the light and heavy soil removal treatments, respectively. Potassium and Mn also were significantly reduced by soil removal, but to lesser degrees than N, Ca, or P. Therefore, where the surface soil layers were removed, nutrients needed by the planted seedlings were also reduced.

Examination of the nutrient concentrations through the first three seasons shows three separate patterns of change occurring, table 6. Calcium and Mn both increased through the study on the removal treatments. Their increases are thought to be associated with release from feldspars and other minerals, abundant on the study areas. These minerals were exposed during treatment application, resulting in more rapid weathering that released Ca and Mn.

Nitrogen, however, dropped during the first 2 years on both removal treatments and then increased during the third. Since in forest situations most soil N is associated with organic material, the early N losses are related to organic residue decomposition and subsequent N loss due to volatilization or leaching. By the third season, developing vegetation increased soil organic matter and consequently soil N.

The decrease in soil organic matter has several other detrimental effects on forest sites. Besides the loss of nutrients through decomposition, a reduction in soil organic matter may reduce soil structure and water holding capacity. This reduces the water available to young seedlings and therefore may reduce early growth.

On any sandy site, a significant organic matter reduction may substantially reduce soil cation exchange capacity (CEC). Organic matter in the surface layers supplies a large portion

TABLE 7. EFFECT OF SOIL REMOVAL ON SOIL NUTRIENT CONCENTRATIONS AND ORGANIC MATTER FOR EACH DEPTH AT PLANTING AND AFTER 3 SEASONS

Soil depth[1]	Soil removal treatment	Soil nutrients/acre						Soil organic matter
		Ca	Mg	K	Mn	P	N	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*
At planting								
	Control	308 A[2]	71 AB	46 A	14 A	4 A	860 A	1.97 A
1	1-inch removal	232 B	75 A	44 A	12 B	3 B	680 B	1.36 B
	3-inch removal	213 B	57 B	27 B	10 C	3 B	390 C	1.07 C
	Control	222 A	61 A	40 A	11 A	3 A	481 A	1.33 A
2	1-inch removal	203 AB	62 A	39 A	10 A	3 A	386 B	1.07 A
	3-inch removal	178 B	65 A	35 A	10 A	3 A	333 B	.71 B
	Control	192 A	56 B	37 A	10 A	3 A	367 A	.96 A
3	1-inch removal	187 A	64 A	38 A	8 AB	2 B	330 A	.68 B
	3-inch removal	178 A	57 AB	35 A	7 B	2 B	287 B	.55 B
	Control	198 A	53 A	39 A	8 A	3 A	340 A	.76 A
4	1-inch removal	190 A	60 A	33 A	8 A	1 B	297 AB	.60 B
	3-inch removal	175 A	58 A	34 A	7 A	2 AB	273 B	.50 B
After 3 seasons								
	Control	322 A	69 A	44 A	18 A	4 A	819 A	2.08 A
1	1-inch removal	208 B	49 B	29 B	14 B	4 A	423 B	1.10 B
	3-inch removal	173 B	40 B	29 B	12 B	3 B	323 B	.84 B
	Control	254 A	59 A	39 A	16 A	4 A	566 A	1.63 A
2	1-inch removal	207 B	52 AB	29 B	12 B	3 B	386 B	1.05 B
	3-inch removal	186 B	38 B	30 B	12 B	2 B	292 B	.79 B
	Control	230 A	53 A	36 A	14 A	3 A	408 A	1.33 A
3	1-inch removal	238 A	61 A	34 A	12 AB	3 B	325 B	.85 B
	3-inch removal	219 A	61 A	36 A	11 B	2 B	284 B	.64 B
	Control	218 A	52 B	36 A	12 A	3 A	360 A	1.15 A
4	1-inch removal	238 A	67 A	36 A	12 A	3 AB	313 AB	.73 B
	3-inch removal	242 A	63 A	36 A	11 A	2 B	275 B	.62 B

[1]Soil depths: 1 = 0 to 3 inches, 2 = 3 to 6 inches, 3 = 6 to 9 inches, and 4 = 9 to 12 inches.
[2]Means within a soil depth/time category with the same letter are not significantly different at the 0.05 level.

of the CEC sites (*12*). Reducing the organic matter level 26 percent on the light removal and 44 percent on the heavy removal treatment (1.26 percent to 0.93 percent to 0.71 percent) undoubtedly resulted in a CEC reduction, since 25 to 40 percent of the CEC sites are normally organic in nature. With the low CEC levels throughout much of the South (less than 10 milliequivalents per 100 grams of soil), the loss of organic exchange sites is important. By reducing soil CEC, the soil's ability to retain mobile nutrients is also reduced, thus leaching may result. Magnesium and K both show steady decreases where soil removal has occurred, probably due to leaching.

The loss of mobile nutrients is further supported by examination of the incremental samples. At planting, the highest Ca, Mg, and K levels on the controls and both removal treatments occurred in the surface soil layer and the concentrations decreased as depth increased, table 7. In contrast, after three seasons, the pattern had reversed on both the removal treatments; the highest Ca, Mg, and K levels were found in the lower soil layers, while the surface layer concentrations had decreased. The reduction in nutrient concentrations in the surface layers would be reduced in part due to vegetation absorption. However, the large increases (over the initial concentrations) at the lower depths, which occurred only on the removal plots, are most readily attributable to leaching. The areas where the surface soil was removed had less vegetation, thus reducing the cycling of nutrients through vegetation and possibly increasing soil water percolation through reduced transpiration and interception loss. The control plots showed little downward movement of the mobile nutrients.

After three seasons, all land uses showed the control areas had higher nutrient concentrations than the removal treatments, table 8. On the old fields and the cutover sites, Ca, Mg, and N concentrations were significantly reduced by soil removal. The nutrients were removed primarily during soil removal treatment, and in the cases of the mobile nutrients, additional losses occurred due to leaching. The log deck areas showed little change in nutrient concentration. Apparently this is due to the severe disturbance occurring during their use as decks. The soil was "churned" by skidders and loaders, mixing the surface layers.

High variation in nutrient concentration occurred between

TABLE 8. EFFECT OF SOIL REMOVAL ON SOIL NUTRIENT CONCENTRATIONS AND ORGANIC MATTER IN THE UPPER 12 INCHES OF SOIL AT THE END OF THE THIRD GROWING SEASON, BY PREVIOUS LAND USE

Soil removal treatment	Soil nutrients/acre						Soil organic matter
	Ca	Mg	K	Mn	P	N	
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*
Piedmont old field							
Control	1,790 A[1]	513 A	216 A	106 A	5 A	3,056 A	1.85 A
1-inch removal	1,673 AB	485 AB	176 A	81 B	3 AB	1,856 B	1.25 AB
3-inch removal	1,463 B	431 B	185 A	75 B	2 B	1,380 B	.89 B
Coastal Plain old field							
Control	1,248 A	154 A	200 A	63 A	29 A	2,454 A	1.58 A
1-inch removal	668 B	83 B	167 A	52 A	24 A	1,357 B	.87 B
3-inch removal	797 B	86 B	157 A	45 A	25 A	1,147 B	.60 B
Coastal Plain cutover							
Control	331 A	40 A	92 A	19 A	11 A	1,348 A	1.40 A
1-inch removal	202 B	31 B	60 B	15 A	8 A	1,010 B	.59 B
3-inch removal	167 B	31 B	57 B	13 A	6 A	821 B	.50 B
Coastal Plain log deck							
Control	220 A	31 B	74 A	23 A	14 A	1,145 A	1.17 A
1-inch removal	219 A	51 A	60 A	22 A	12 A	1,149 A	.70 A
3-inch removal	216 A	35 B	69 A	19 A	8 A	1,141 A	.72 A

[1]Means within a land use with the same letter are not significantly different at the 0.05 level.

former uses, table 6. The old fields were found to have higher nutrient concentrations than the other areas. On these sites, even the most intensive removal treatment had higher concentrations than the controls on the cutover and log deck sites. Because of high variation within a use, however, no significant differences among sites could be ascertained.

Examination of the former forest land uses shows that the controls on the cutover sites have nutrient concentrations similar to those reported in other southern pine plantations. Loblolly pine plantations on an east Texas sandy site had 273 pounds Ca, 18 pounds P, and 1,357 pounds N per acre in the surface 12 inches (*27*). Similarly, Switzer et al. (*26*) found N levels of 1,742 pounds per acre in the surface 6 inches on a Mississippi clay loam soil. After three seasons, soil removal resulted in nutrient concentrations below these reported levels.

Surface Bulk Density

Soil removal significantly increased soil bulk density, table 9. The D-7 tractor used in soil removal compacted the treatment areas, increasing bulk density. This is similar to bulk

TABLE 9. TREATMENT EFFECTS ON SURFACE SOIL BULK DENSITY AT EACH SAMPLING TIME ACROSS ALL SITES

Soil removal treatment	n	Soil bulk density
		g/cc
At planting		
Control	14	1.46 C[1]
1-inch removal	15	1.56 B
3-inch removal	15	1.63 A
After 1 season		
Control	14	1.31 C
1-inch removal	15	1.48 B
3-inch removal	15	1.55 A
After 2 seasons		
Control	14	1.21 C
1-inch removal	15	1.31 B
3-inch removal	15	1.41 A
After 3 seasons		
Control	14	1.14 C
1-inch removal	15	1.27 B
3-inch removal	15	1.33 A

[1]Means within a time with the same letter are not significantly different at the 0.05 level.

density increases commonly occurring during site preparation (*9, 25*). After three seasons, bulk densities on the light and the heavy removal treatments were still significantly higher than the controls, although the values had significantly decreased.

During the first three growing seasons, the relative drop in bulk density was not affected by soil removal treatment. Bulk density reductions from the initial measurements to the end of the third season are similar (near 0.30 gram per cubic centimeter) for the control and both removal treatments. Vegetal root growth is thought to be the primary cause of the bulk density reductions.

Previous land use exhibited little effect on soil bulk density patterns, but did affect the degree of change, table 10. Both the old fields and the cutover forest site were significantly compacted during soil removal. However, soil removal on the log decks caused only slight bulk density increases. The former log decks, which were heavily compacted during harvesting, had the least increases (1.61 grams per cubic centimeter to 1.72 grams per cubic centimeter), while the Piedmont old fields (lowest initial bulk density) showed the largest increases. Previous land use had no effect on the recovery rate as all areas showed similar recovery patterns.

TABLE 10. EFFECT OF SOIL REMOVAL TREATMENT ON BULK DENSITY BY EACH PREVIOUS LAND USE AT PLANTING AND AT THE END OF THIRD GROWING SEASON

Time	Soil removal treatment	n	Soil bulk density
			g/cc
Piedmont old field			
	Control	5	1.36 B[1]
At planting	1-inch removal	6	1.46 AB
	3-inch removal	6	1.57 A
	Control	5	.99 B
After 3 seasons	1-inch removal	6	1.18 A
	3-inch removal	6	1.24 A
Coastal Plain old field			
	Control	3	1.48 B
At planting	1-inch removal	3	1.63 A
	3-inch removal	3	1.68 A
	Control	3	1.19 B
After 3 seasons	1-inch removal	3	1.31 AB
	3-inch removal	3	1.42 A
Coastal Plain cutover			
	Control	3	1.47 A
At planting	1-inch removal	3	1.59 A
	3-inch removal	3	1.62 A
	Control	3	1.19 B
After 3 seasons	1-inch removal	3	1.36 A
	3-inch removal	3	1.40 A
Coastal Plain log deck			
	Control	3	1.61 A
At planting	1-inch removal	3	1.67 A
	3-inch removal	3	1.72 A
	Control	3	1.30 A
After 3 seasons	1-inch removal	3	1.30 A
	3-inch removal	3	1.35 A

[1]Means within a land use and time with the same letter are not significantly different at the 0.05 level.

Bulk density on the control plots also significantly decreased through time. The controls on the cutover and log deck sites were compacted during harvesting, while the old fields were compacted by grazing animals. These compaction causes have been well documented (*6, 22*). As with the removal treatments, bulk density decreases were largely due to vegetative root growth loosening the soil.

SUMMARY AND CONCLUSIONS

Surface soil removal and herbicide treatment resulted in significant loblolly pine seedling survival and growth increases after three seasons. The intensive treatments reduced nonpine vegetation, thereby increasing moisture available to the young seedling. Pine growth increases following both woody and herbaceous competition reductions have been previously documented (*2, 17*).

After three seasons, significant reductions in Ca, K, Mn, P, N, and organic matter concentrations occurred where topsoil was removed. In addition, Ca, Mg, and K appeared to be moving through the upper soil profile during the study period. Nitrogen levels of southern forested areas have been reported to range between 1,750 and 2,500 pounds per acre in forest stands on flatwoods soils (Arenic Paleudults and Ultic Haploquads) and various clay loam soils, respectively (*21, 26*). The N concentration on the control plots falls within this range, but the concentrations on the soil removal treatments are both below these reported values.

Soil bulk density increased due to the removal of surface soil. Use of a D-7 crawler to scalp 1 inch or 3 inches of soil compacted the remaining soil and reduced soil organic matter (reducing soil structure). By the end of the third growing season, bulk densities had decreased relatively consistently on all treatments.

During the 1950's, scalping 1 to 3 inches of surface soil was used to reduce competition, resulting in increased early survival and growth. The possible long-term problems that scalping could create were largely ignored. This study supports these older findings, i.e., competition reduction does increase seedling growth. Although severe site damage occurs during scalping, this damage has little effect on loblolly seedling growth during the first three seasons when soil moisture is the limiting growth factor. However, when the soil nutrient and organic matter changes are considered, it is quite likely that the early seedling growth gains on scalped areas will be temporary, particularly where heavy removal occurs. The significant nutrient and organic matter reductions (to levels below those typically found on southern forest sites) imply a reduction in total site productivity. This reduction may become evident later in the rotation (25-40 years), when vegetal site occupation reaches a point where nutrient supplies become limiting to tree growth.

An implication of the soil, competition, and tree growth data taken together is that interpretation of the important effects of site manipulation on forest growth may be misleading if based solely on early seedling responses. Changes in the basic resource, the soil, indicate that long-term results may be the reverse of the short-term ones.

Intensive vegetation management procedures are a necessary part of southern forestry, particularly during regeneration. However, the use of intensive mechanical treatments may severely damage a forest site, resulting in surface soil loss. Therefore, on many sites consideration must be given to utilizing either a less intensive mechanical treatment (e.g. chopping) or the use of chemicals along with burning to reduce competing vegetation. The quantity of soil lost from forest areas must be reduced to insure long-term site productivity.

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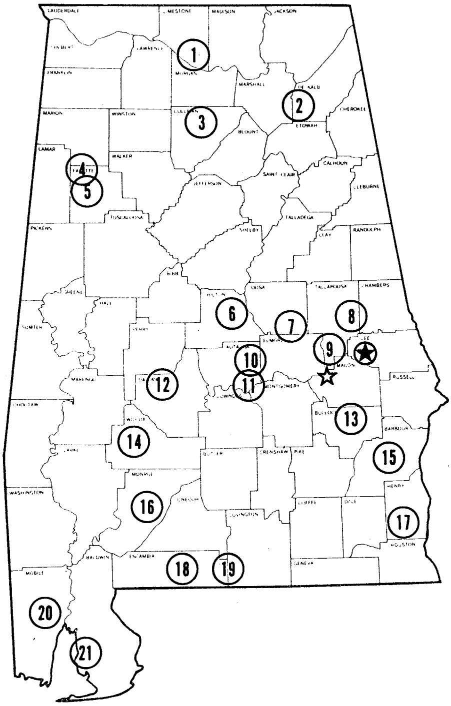

Research Unit Identification

⊛ Main Agricultural Experiment Station, Auburn.
☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Chilton Area Horticulture Substation, Clanton.
7. Forestry Unit, Coosa County.
8. Piedmont Substation, Camp Hill.
9. Plant Breeding Unit, Tallassee.
10. Forestry Unit, Autauga County.
11. Prattville Experiment Field, Prattville.
12. Black Belt Substation, Marion Junction.
13. The Turnipseed-Ikenberry Place, Union Springs.
14. Lower Coastal Plain Substation, Camden.
15. Forestry Unit, Barbour County.
16. Monroeville Experiment Field, Monroeville.
17. Wiregrass Substation, Headland.
18. Brewton Experiment Field, Brewton.
19. Solon Dixon Forestry Education Center, Covington and Escambia counties.
20. Ornamental Horticulture Substation, Spring Hill.
21. Gulf Coast Substation, Fairhope.