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IMPACTS OF VARIOUS INTENSITIES OF SITE PREPARATION ON PIEDMONT SOILS AFTER 2 YEARS[1/]

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Abstract.--Six levels of site preparation were applied to replicated 0.8-hectare plots at the Hitchiti Experimental Forest on the Piedmont Plateau in central Georgia. Treatments ranged in intensity from handclearing to shearing and chopping to rootraking and disking with fertilization and herbicides. Soils were sampled before treatment applications and after 1 and 2 years. Composited bulk samples from 0-15 and 15-60cm were analyzed for texture, pH, organic matter, and available phosphorus, calcium, magnesium, potassium, and sodium. Six core samples (0-6cm) per plot were used to determine bulk density, available moisture holding capacity, and total pore space. The early trends of soil impacts are: 1) soil organic matter and available nutrients are not different among treatments; 2) pH of surface soils increased slightly with increasing intensity of treatment in the first year; and 3) bulk density significantly decreased with disking while pore space increased.

INTROOUCTION

The renewable nature of the forest resource depends on the conservation and continued productivity of the soil resource. Intensive mechanical site preparation in the rolling Piedmont needs to be examined both from the aspect of adverse impacts on sustained productivity and from longterm benefits to tree growth and volume production. Very few investigations have attempted to delve into these two crucial areas. Several presentations at this conference will discuss results of such investigations and thus make sizeable contributions to this vacant area of research. The objective of the research in this paper was to monitor changes in nutritional and physical soil properties that can influence establishment and early growth of a tree crop. Results from 2 consecutive years following site preparation will be presented. Extensive interpretation of results is not yet possible due to the paucity of comparable studies.

METHODS

Study Area

The study area is a 34-ha tract located on the Piedmont at the Hitchiti Experimental Forest, managed by the USDA Forest Service, 20 miles north of Macon, Georgia. The harvested stand was principally composed of loblolly pine (*Pinus taeda* L.) with a lesser component of mature and sapling-sized hardwoods, mainly sweetgum (*Liquidambar styraciflua* L.) and dogwood (*Cornus florida*.L.l. The pre- and post-harvest vegetation.was sampled and described by Edwards (19821. The average site index for loblolly pine was 80 at 50 years. The pre-harvest stand was naturally regenerated on eroded cotton fields that were abandoned in the 1930's.

Soils were comprised of five series which occurred as eroded phases on this undulating terrain, and were typical Piedmont clayey ultisols except for the alluviated soils on the lower slopes:

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Series	Family	Subgroup
a. Cecil	clayey kaolinitic thermic	Typic Hapludults
b. Davidson	clayey kaolinitic thermic	Rhodic Paleudults
c. Vance	clayey mixed thermic	Typic Hapludults
d. Wilkes	loamy mixed thermic	Typic Hapludults
e. Congaree	fine-loamy mixed, nonacid thermic	Typic Udifluvents

Soil series in the study area are influenced by topography and are positioned relative to three broad ridges. The ridges run generally to the southeast from a main curving ridge that is the west and northwest boundary. Wilkes series occur on the long slopes, Congaree series are along stream sides, and the others are on the uplands. The two intermittent streams separating the ridges have broad, flat streamside zones that drain into a perennial stream forming the south and southwest boundaries. Marshy areas have been excluded from the study area.

Design and Treatments

In the spring of 1980, the merchantable pines were harvested with no hardwood removal. The site laid over for a year. In the spring of 1981, a randomized complete block design was established using approximately 0.8-ha (2-a) plots with five blocks, each 4.8 ha (12 a), and six treatments.

The five blocks were located by topographic position. Two blocks were on well-drained ridges, two were positioned on side slopes, and one was located along the upland portions of an intermittent gulley and stream system. Within each block, two to three soil series occurred. Although these series were similar, much variation in surface texture and organic matter was encompassed in the study area.

The following site preparation treatments were applied:

1. Check (no site preparation)--Plots were harvested only.
2. Handclear--All trees greater than 2.5 cm d.b.h. were felled with a chainsaw in August 1981.
3. Shear and chop--Shearing was performed with a D7-sized tractor and a KG-blade in September 1981. Chopping was done with a single pass of a single drum chopper. Application was from September to November 1981. No burning was performed on treatments 3 and 4 due to poor weather conditions.
4. Shear, chop, and herbicide--In addition to the shearing and chopping of treatment 3, ½ cc Velpar® Gridball™ pellets with 10 percent active ingredient of hexazinone were applied in a grid pattern at a rate of 28 kg/ha (25 lbs/a) in March 1982. Heavy rains after application and poor infiltration caused the herbicide to smear across the plots, yielding almost total first-year control of both herbaceous and wody plants, including planted pines. Approximately 80 percent bare ground was observed on these plots during the 1982 growing season.
5. Shear, rootrake, burn, and disk--Shearing and rootraking into windrows occurred in September 1981. Good burns of the windrows were achieved in October 1981. The remaining debris and ash were scattered over the plots with a dozer blade; then, the plots were disked with an offset harrow to a depth of 15-20 cm in October 1981.
6. Shear, rootrake, burn, disk, fertilize, and herbicide--Site preparation was the same as treatment 5. In addition, ammonium nitrate (34-0-0) was applied by hand at 336 kg/ha (300 lbs/a) in March 1983, and Oust® Weed Killer with 75 percent sulfometuron methyl was applied at a rate of 0.56 kg/ha (0.5 lbs/a) in April, using backpack sprayers. Herbaceous weed control was essentially 100 percent during most of the 1983 growing season.

Improved loblolly pine seedlings (1-0 stock), obtained from the Georgia Forestry Commission nursery, were planted by hand in January and February 1982 on a spacing of 1.8 x 3 m (6 x 10 ft). Seedling growth data has not been included in this presentation.

Sampling

Composited bulk soil samples were collected for analyses of nutrients, organic matter, and texture; and undisturbed core samples were extracted for bulk density, pore space, and available water determinations. Sampling occurred in May of 1981, 1982, and 1983, which was before site preparation treatments (after harvesting) and during the first and second growing seasons, respectively. May was considered an appropriate month for sampling because available nutrients should be at a maximum level by then to sustain uptake for the ensuing growing season. Annual sampling was repeated along two diagonal transects established across the plots, and sampling points were located every 7.6 m (25 ft). At each point, tube samples were collected and composited from the 0- to 15-cm (0- to 6-in) and 15- to 60-cm (6- to 24-in) depths. This yielded two composited bulk samples by depth per plot. At randomly selected sample points, which changed by year, six core samples (132 cm^3) per plot were extracted from the upper 6 cm. Thus, 60 composited samples and 180 core samples were collected and analyzed annually.

Analyses

Composite samples were prepared for analyses by air drying, crushing or grinding, and sieving to pass a No. 10-mesh sieve (2-mm openings). Soil nutrients were extracted from duplicate 5-g subsamples using a weak double-acid solution (Mehlich 1953), which yielded a determination of the readily available nutrients. Phosphorus analyses were made according to Watanabe and Olsen (1965), and cations (Ca, Mg, K, Na) were determined by atomic absorption spectroscopy. Organic matter was read as carbon on a carbon analyzer and converted to organic-matter content using a constant. A 1:1 soil-water mixture was used to read pH. Particle-size distribution was determined by the hydrometer method. For determining total pore space and available water-holding capacity, core samples were attached to ceramic disks, soaked to saturation, and then weighed. Following the weighing procedure, they were resoaked. Next a ground-silica slurry was used to attach the core-plus-disk to a pressure plate and a 1/3-atm run preceded a 15-atm run. Then the samples were oven dried (OD). Total pore space in cubic centimeters was calculated by subtracting the OD soil weight from the saturated weight. Available water was calculated by subtracting the soil weight at 15-atm tension from that at 1/3-atm tension. Bulk density was calculated by dividing the OD weight of soil by the ring volume.

An analysis of variance procedure for repeated-measures designs was used to compare physical and nutritional soil properties by treatment, block, year, and treatment x block. In the analyses of the physical properties, treatments were grouped (1 and 2, 3 and 4, 5 and 6) because of their similar treatment due to like equipment passes. Analyses were also performed by pooling the 2 years following treatment and are presented when significant. Probabilities less than 0.05 were considered significant. Percent values were analyzed by using arcsine transformations. Treatment and block means were compared within each year using Duncan's Multiple Range Tests.

RESULTS

Fertility Changes

Site preparation treatments, ranging from an untreated check to very intensive tillage treatments, resulted in no significant differences in soil organic matter (OM) or in available phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) when compared within sample years (fig. 1 and 2). Yearly shifts in mean nutritional properties occurred irrespective of treatment during the 2 years after application.

The logical pairs of similar mechanical passes (1+2, 3+4, 5+6) do not indicate similar responses of nutritional levels; however, the weed control additions to treatments 2, 4, and 6 could have changed uptake and mineralization rates and thus separated such similarities. In this context, it is of interest to note that of all the treatments, the lowest levels in surface soils of OM, P, and Mg, although not significant, occurred on treatment 4 following the total vegetation control in the first growing season. Also, the herbaceous weed control on treatment 6 in the second growing season did not result in increases or decreases in available nutrients, except increased P (0 to 15 an) and decreased Na (0 to 15 cm), which were not significant but apparent.

Significant differences were found in soil pH in the second and first-plus-second years, for the 0- to 15-cm depth (table 1). The pH of the soil tended to increase with increases in intensity of cultural treatment, which was not as evident at the 15- to 60-cm depth.

Block differences were significant for OM for both depths, with one upland block having the highest amounts and the block along an intermittent stream having the lowest. The same upland block had a significantly higher average pH following treatments for the 0- to 15-cm depth. The only other block difference was in the second year; a side-slope block had significantly higher Ca (both depths) and lower K (0- to 15-cm depth).

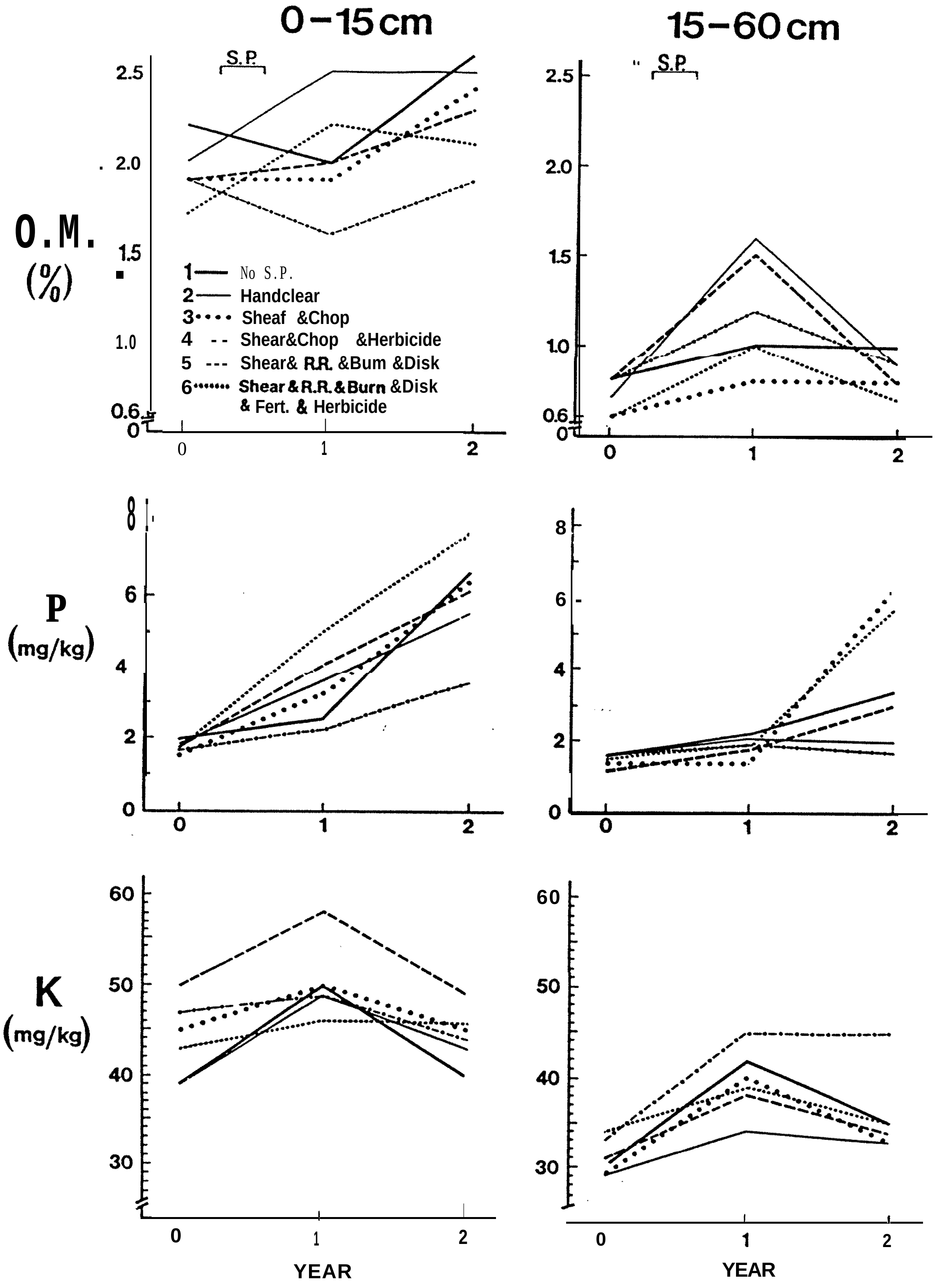

Figure 1. Organic matter and available phosphorus and potassium in soils sampled at two depths and for one and two years after site preparation (S.P.) treatments.

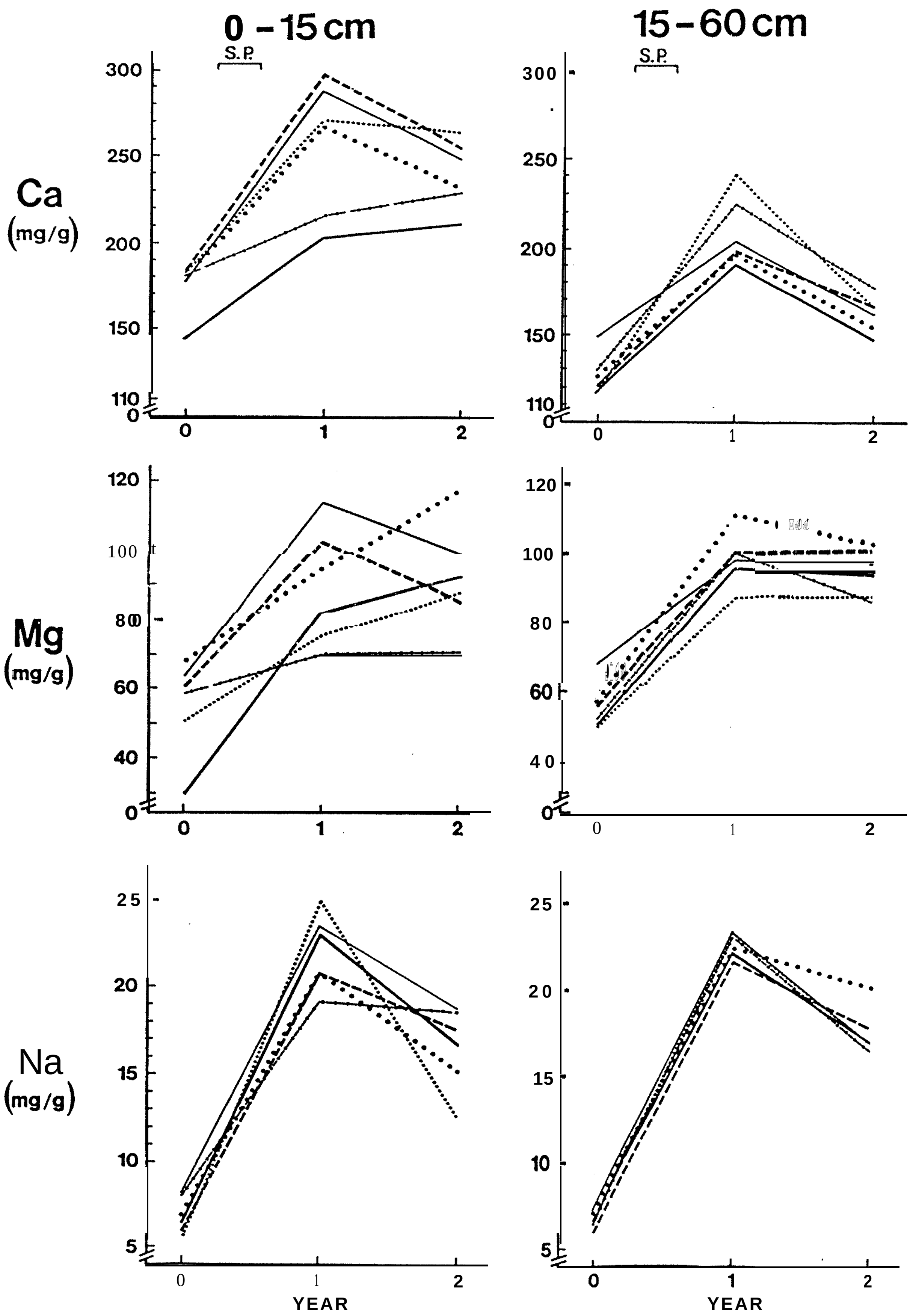

Figure 2. Available calcium, magnesium, and sodium in soils sampled at two depths before and for one and two years after site preparation (S.P.) treatments.

Table 1.--Soil pH means presented by treatment, sampling depth and year after site preparation.[1]

	0 - 15 cm				15 - 60 cm			
Treatment	Before	1st Yr	2nd Yr	1st+2nd Yr	Before	1st Yr	2nd Yr	1st+2nd Yr
No. S.P.	4.69	4.88	5.11a	5.00a	4.71	5.03	5.26	5.15
Handclear	4.76	4.91	5.12a	5.02a	4.80	5.09	5.30	5.18
Shear + chop	4.75	4.97	5.17ab	5.07ab	4.73	5.20	5.40	5.17
S+C+Herbicide	4.78	4.99	5.33 b	5.16 bc	4.78	[illegible]	5.37	5.30
S+RR+Burn+Disk	4.81	5.09	5.31 b	5.20 c	4.81	5.10	[illegible]	5.24
S+RR+Burn+Disk +Fert.+Herbicide	4.70	5.06	5.26ab	5.16 bc	4.68	5.06	5.30	5.18

[1] Means in a column followed by no letter or the same letter are not significantly different at the 0.05 level.

Available nutrients, organic matter, and pH changed significantly during the three sampling years (table 2). The summed values for all treatments generally show an increase for the year following site preparation treatments, and synchronized increases or decreases in the second year. Since the nontreated plots (treatment 1) follow the same trends as the site-prepared plots, these shifts are either a response to harvesting or merely to naturally occurring yearly changes in these soil properties. The 2 consecutive years of phosphorus and magnesium increases appear to be a response to harvesting and not to naturally occurring yearly changes. The same can be stated for the steady rise in pH for two years.

Physical Changes

Bulk density in the surface soils decreased with disking and was significantly less than bulk densities after chopping in the first year (table 3). Neither site preparation treatment differed significantly from the nontreated plots. A steady yearly decrease in bulk densities is apparent in the overall means, which became significantly different in the second year. As with available nutrients, this shift may be due to a harvesting response and less likely due to natural yearly changes.

Available water did not vary significantly by treatment, but there was a somewhat elevated water-holding capacity in the first year for the chopping and disking treatments. Yearly means were also significantly greater in the first year after treatment, due to all treatment means being higher.

Total pore space was significantly increased by the tillage treatments of rootraking and disking, and differences were evident for the 2 years. There also appears to be an increase in overall yearly means, probably due to the contributions to the yearly means by the disking treatments and possibly a harvesting response.

Decreases in clay and silt corresponding to increases in sand were significant in the second year following site preparation treatments (table 4). No treatment differences were significant, so these changes could also be considered a harvesting response or probably sampling variations. These changes in textural composition only resulted in minor changes in textural class designations.

DISCUSSION

Fertility Changes

Soil fertility did not vary significantly by treatment. This finding must be assessed with a full understanding of the limitations of this study. The spatial variation in soil nutrients is large and thus the limitations in sample size and intensity are ever present obstacles in this type of research. Field variation is compounded in the rolling terrain of the Piedmont due to frequent series changes and past cultural practices that have depleted topsoil by varying amounts. Still, the observed patterns of nutrient levels presented in figures 1 and 2, for the most part, show similar responses from year to year, especially in the 15- to 60 cm soil depth. These similar patterns support the idea that sampling intensity was adequate.

Table 2.--Overall yearly means of available nutrients, pH, and organic matter by sampling depth and years after site preparation treatments.

Depth	Time	OM	P	K	Ca	Mg	Na	pH
cm	yr	%	----------------------	------	mg/kg	------	---------------------	
0 - 15	B	1.9a[1]	1.7a	43a	175a	59a	6.8a	4.7a
	1	2.0a	4.1b	50b	257b	90b	16.8b	5.0b
	2	2.3b	5.9c	44a	240b	92b	22.0c	5.2c
15 - 60	B	0.7a	1.5a	31a	128a	56a	7.7a	4.7a
	1	1.2b	1.9a	39b	209b	99b	22.7b	5.1b
	2	0.9a	3.7b	36b	162c	104c	20.1b	5.3c

[1] Means within a sampling depth and in a column followed by the same letter are not significantly different at the 0.05 level.

Table 3.--Means of physical properties of samples collected before and during the first and second growing seasons after site preparation treatments.

Mechanical Treatments	Before	1st Yr	2nd Yr	1st Yr + 2nd Yr
		BULK DENSITY (g/cm^3)		
None	1.28	1.26ab	1.18	1.22ab
Shear+Chop	1.34	1.33a	1.19	1.26a
Shear+R.R.+Disk	1.30	1.22b	1.16	1.19b
	1.31A	1.27A	1.18B	
		AVAILABLE WATER-HOLDING CAPACITY (% by vol)		
None	4.7	5.6	5.5	5.5
Shear+Chop	4.9	6.0	4.7	5.4
Shear+R.R.+Disk	4.7	6.1	5.2	5.6
	4.7A	5.98	5.1A	
		PORESPACE (%)		
None	47	47a	49a	48a
Shear+Chop	45	46a	47a	47a
Shear+R.R.+Disk	46	49b	50b	50b
	46A	47B	498	

[1] Treatment means listed in a column followed by no letter, or the same lower-case letter are not significantly different at the 0.05 level. Likewise, overall means in a row followed by the same upper-case letter are not significantly different at the 0.05 level.

Table 4.--Overall means of soil texture analyzed before, and one and two years after site preparation treatments

Particle Size	0 - 15 cm			15 - 60 cm		
	Before	1st Yr	2nd Yr	Before	1st Yr	2nd Yr
	------------percent------------			------------percent------------		
Sand	49a[1/]	47a	596	37a	37a	48b
Silt	25a	24a	15b	23a	23a	18b
Clay	26a	29a	25a	40a	40a	34b
Texture Class	sandy clay loam	sandy clay loam	sandy clay loam	clay loam	clay loam	sandy clay loam

[1/] Means within a sampling depth and in a row followed by the same letter are not significantly different at the 0.05 level.

Lantagne (1984), in a similar study in the Piedmont, also found no treatment differences in the same fertility properties when analyzed by year. He noted a general trend of increasing organic matter and available phosphorus in the surface soils for all treatments. These same trends are also evident in figures 1 and 2. Increased organic matter in surface soils should translate to heightened available nutrients as mineralization occurs. Banker et. al. (1983) also reported a general increase in available macro-nutrients, especially P, following rootraking treatments in the Georgia Piedmont. Campbell (1973) found that phosphorus and calcium increased significantly during the first year after disking but not after chopping. In Texas, Stransky et. al. (1983) found that phosphorus increased mainly after burning. Treatments 5 and 6 of the current study, which included disking and burning, had the highest phosphorus levels in the first year, though not significantly different.

Another limitation of this study is that critical comparisons of within-plot variation are not obtainable because samples were composited by plot. Although this is a common procedure (also used by Lantagne 1984, Banker et. al. 1983, Stransky et. al. 1983 and Campbell 19731, the changes in microsite can not be assessed with such data, especially changes in the distribution of fertility as they may influence evenly spaced pine seedlings. Redistribution of topsoil and organic matter characterizes most site preparation treatments, particularly windrowing and bedding. But composited samples merely provide an assessment of the average fertility for a treatment, combining the high and low values. Thus, the variation in fertility, that especially should occur with windrowing, is masked. Glass (19761 examined windrows on a Piedmont site in North Carolina and found that the 0- to 6-cm layer had 340% more phosphorus, 325% more calcium, 117% more magnesium, 36% more potassium, 21% more organic matter, and 20% more sodium than the inter-windrow layer. Concentrated topsoil and nutrients have also been reported for windrows in the flatwoods (Morris et. al. 1983). Thus, further studies are needed to describe microsite variation and changes in. frequency of fertility levels as they influence early pine establishment.

The slight increases in pH, found with increasing intensity of site preparation (table 1), should translate into increased availability of macro-nutrients (Pritchett 1979). As acidity or hydrogen-ion concentrations decrease, exchangeable macro-nutrients (N, P, K, Ca, Mg, and Mg) become more available and mineralization rates of organic matter are increased.

The absence of an uncut control stand is another limitation of this study, because yearly changes under untreated conditions in both fertility and physical properties can not be ascertained. The changes in overall yearly means for most properties and for both depths in table 2 must be assumed to be caused by a combination of the harvesting influence, site preparation treatments, and natural year-to-year changes. For the most part, the unprepared treatment 1 shows the same pattern of change (fig. 1 and 2) and thus lends more weight to the harvest influence.. Removal of the overstory canopy at harvest adds logging debris and changes all input variables to the soil by increasing precipitation and decreasing litterfall, while temporarily decreasing transpiration and nutrient uptake. For a plot-average study approach, these changes due' to harvest may mask the site preparation impacts. Obviously, an ecosystem approach. with careful descriptions of the nutrient budgets and how they vary on microsites, Is required to fully understand the complex processes taking place after site preparation treatments.

Physical Properties

The decreases in bulk density and increases in pore space found with disking have been shown to improve growth of loblolly pines (Hatchell, 1970; foil and Ralston 1967). Root growth is enhanced because of the prevalence of accessible pores and the absence of resistance found in compacted soils. Campbell (1973) also reported that chopping did not increase average bulk density when compared to the untreated check, but disking did result in a significant decrease.

Available water-holding capacity was not drastically altered by the mechanical treatments. Banker and co-workers (1983) showed that infiltration was decreased by rootraking on a Piedmont site. However, if infiltration is altered by treatments, then the amount of soil water recharge is altered and deserves closer study. Again, there is some indication that overstory removal during harvest may influence the soil physical properties, since decreases in bulk density from year one to year two and changes in available water occurred irrespective of treatment.

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