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CLEARCUTTING AND SHEARING ON A SALINE SOIL IN EAST TEXAS: IMPACTS ON SOIL PHYSICAL PROPERTIES¹

Mingteh Chang, Alexander K. Sayok, and Kenneth G. Watterson²

Abstract—Soil samples, or in-situ measurements, were collected at seven occasions and at six depths to study the impact of three forest conditions on soil physical properties of a saline soil in E. Texas. Soil bulk density, % of silt plus clay at the surface horizons, soil water content, soil water retention, and depth to groundwater increased following intensive site preparation. Differences in these properties between the commercial clearcutting and undisturbed forest were small. The wet soil conditions created in the intensive preparation site are not likely to be responsible for the failure of artificial pine regeneration. In areas where site preparation may cause standing water on the surface, all plants and stumps should be left intact after marketable timber is removed.

INTRODUCTION

Commercial clearcutting is the most common type of forest disturbance in East Texas (McWilliams and Lord, 1988). Following clearcutting, sites are usually mechanically prepared for forest regeneration by chopping, shearing, piling, bedding or some combination of these activities. Because of the intensity of site disturbance, these activities have caused concern about their impacts on soil physical (Lal and Cummings, 1979; Gent et al., 1983) and chemical properties (Mroz et al., 1985; Snyder and Harter, 1985), nutrient losses (Clayton and Kennedy, 1985; Muda et al., 1989) and erosion problems (Beasley and Granillo, 1988; Chang et al., 1982; Miller, 1984; Riekerk, 1983).

There are more than 120,000 hectares (ha) of somewhat poorly drained, upland saline soils in central East Texas (between Sam Rayburn Reservoir in the NE and Lake Livingston in the SW). The soils contain a high concentration of aeolian sediments derived from volcanic ash and deposited over impervious mudstone high in pyroclastic sediments. Vegetation is dominated by mature loblolly (*P. taeda*) and shortleaf (*P. echinata*) pines with scattered hardwood species. After clearcutting the forest, artificial pine regeneration on these soils is extremely difficult (three attempts in some areas). Examination of scattered pine seedlings naturally regenerated in clearcut sites show J-shaped root-systems at about 15 cm below the surface with little lateral-root development. It is not clear if the poor root systems and mortality of pine seedlings are due to high water tables caused by the removal of vegetation, salt concentrations toxic to seedlings, nutrient imbalance near the surface, or combinations of all three.

A project was initiated in 1988 to study the effects of forest harvesting and site preparation on soil physical and chemical properties along with soil, water and element losses on a poorly drained saline soil in East Texas. Such information is essential in developing artificial regeneration techniques for southern pine species and for managing nonpoint sources of water pollution. Results of the research on sediment-loss and element movement have been reported by Chang et al. (1992) and Sayok et al. (1993a and 1993b); the objective of this report is to discuss the results of the work related to soil physical properties.

METHODS AND PROCEDURES

Study Area

The study was conducted during the water years 1989 and 1990 in the Davy Crockett National Forest near Apple Springs, Texas, about 200 km north of Houston and 250 km southeast of Dallas. The area has a humid subtropical climate with prevailing winds from the southerly directions. Summer storms typically occur afternoon and are of high intensity, low frequency, and short duration. The normal (1951-80) annual precipitation and temperature at Lufkin Airport, about 22 km NE of the study area, is 1,054 mm and 19 °C, respectively. Precipitation recorded at the study site was 1,245 mm for the 1989 and 1,349 mm for the 1990 water years. Topography of the area is characterized by gently rolling hills with slopes ranging from 2-10%. The soil of the study site is Fuller fine sandy loam, a member of the fine loamy siliceous, thermic family of Albic Glossic Natraqualfs. The saline nature of these soils was derived from volcanic ash blown from the Cook Mountain Formation during the Eocene Epoch and deposited on siltstones or

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mudstones. Ocean water inundated the area and compacted the volcanic ash, and silty materials were blown from the west to settle on top of the compacted ash.

Vegetation was dominated by loblolly pine and shortleaf pine with a mixture of post oak (*Q. stellata*), red oak (*Q. falcata*), white oak (*Q. alba*), Sweetgum (*L. styraciflua*), and hickories (*Carya spp.*). Merchantable trees ranged from 30 to 55 years of age in 1988 with an average height 28.5 m, DBH 25 cm, site index 27 m, and basal area 21.81 m² ha⁻¹.

Treatment

Three treatments were employed in the study: 1) undisturbed forest with full crown closure as a control, 2) commercial clearcut with all merchantable timber removed, other vegetation left intact, and 3) clearcut, all vegetation removed, stumps sheared with V-blade D6 crawler tractor, and debris windrowed; vegetation was prevented from regrowth, by shearing, with no disturbance to the soil for two years. All treatments were randomly located within an area of 3.24 ha with each treatment separated by about 90 m and a small 1st-order drainage ditch. They all had the same soil and comparable site conditions in terms of vegetation, slope, aspect, and climatic characteristics. The size of each treatment plot was about 0.5 ha; the harvest was conducted on July 23-24, and shearing on August 26, 1988.

Soil Measurements

Soil physical properties examined in the study included texture, bulk density, moisture retention, hydraulic conductivity, moisture content, and depth to groundwater. Soil samples were collected using a Soilmoisture #200-A soil core sampler along three slope positions centrally located at each treatment site and at six different depths from surface (0-15, 15-45, 45-60, 60-85, 85-100, and 100-120 cm). These samples, taken about two months before (June 1988) and at five different times after treatments (September and December of 1988, February and July of 1989, and January 1990), were used for determinations of texture (Day, 1965), bulk density (Blake, 1965), soil moisture retention (Richards, 1965) and saturation hydraulic conductivity (Falling-Head Permeameter; Soiltest Inc., 1979) in the laboratory. The bulk density and hydraulic conductivity were run on undisturbed samples. Since the effect of logging and its associated activities on soil texture is generally confined within the surface 40 cm depth (Burger and Pritchett, 1984), only were samples collected at the 0-15 and 15-45 cm depths two months before and five months after the treatment used in the soil texture study.

Weekly soil moisture contents at four soil depths were monitored using Campbell Pacific Nuclear (CPN) #503 Hydroprobe, a neutron scattering moderation device, through three access tubes installed in the soil of each

plot to a depth of 0.90 m. At the beginning of the study, the rating curve of Hydroprobe furnished by CPN was re-calibrated to reflect the concentration of soil hydrogen ions at the study site (Sayok, 1991). Three groundwater wells, each 2.0 m deep and 73 mm in diameter slitted PVC pipe, were installed in the center of each plot (5.53 m apart each other). Water table levels were measured weekly using a Soilmoisture handheld water-level indicator, Model K654A. These depths to groundwater table were later converted into elevations of groundwater table for comparisons.

Data Analysis

Data collected from these soil samples and field measurements were employed to show differences in soil physical properties among the three forest site conditions through simple comparisons of sample means, ranges, coefficients of variation, or graphical illustrations. Differences in soil properties were also examined through analysis of variance and Student's *t*-test. Soil properties measured before treatments were used as references for each site. Since there were no replicates employed in this study, results of analyses could only be inferred to the study site. It was assumed that any differences in soil properties were attributable to the site treatment, other effects such as slope, aspect, and climatic variations were negligible through careful selection of the study site and random arrangement of site treatments.

RESULTS

Soil Texture

Percent sand composition was the most affected by the treatment, especially in the sheared plot and in the surface 15 cm. Changes in silt and clay caused by the treatments were small (Table 1).

Clearcutting and shearing caused an increase in silt plus clay content (or a decrease in sand) about 9% in the 0-15 cm and 5% in the 15-45 cm depths , compared to 3% and 5% respectively of the clearcutting without site preparation. These changes in the clearcut plot, in view of the variation of soil texture in the undisturbed forest or among the three plots before treatments, seem to be within the range of site variation, but that in the sheared plot are somewhat substantial. Apparently, the use of a D6 Caterpillar Crawler tractor in site preparation had a great mixing effect on soils in the surface 45 cm depth. The effect of site preparation on particle size distribution may consequently affect bulk density and soil water holding capacity. No statistical analysis was performed on these changes in the present study due to small sample size.

Bulk Density

Prior to treatments, average bulk density (BD) was 1.02 g cm⁻³ at the 0-15 cm depth, and 1.43 g cm⁻³ at the 15-

Table 1— Means and ranges (in parenthesis) of percent sand, silt, and clay two months before and five Months after forest treatments on a saline soil near Apple Springs, Texas

Depth,	<u>Undisturbed Forest</u>		<u>Commercial clearcut</u>		<u>Clearcut & sheared</u>	
	Before	After	Before	After	Before	After
<u>0-15 cm</u>						
Sand	78.1 (73.8-80.4)	81.3 (79.6-83.0)	82.3 (79.4-86.2)	79.0 (73.2-82.4)	80.3 (79.0-81.6)	71.6 (67.8-77.6)
Silt	13.1 (09.2-20.6)	13.6 (13.2-17.2)	14.9 (11.2-17.6)	15.8 (13.0-25.2)	18.0 (17.0-19.8)	24.7 (19.8-27.6)
Clay	8.8 (05.6-10.6)	5.1 (03.2-07.0)	2.8 (02.6-03.0)	5.2 (01.6-06.3)	1.7 (01.2-02.6)	3.7 (01.0-04.6)
<u>15-45 cm</u>						
Sand	79.3 (76.8-81.2)	76.3 (73.0-82.2)	82.5 (79.4-85.4)	77.7 (73.0-82.0)	78.1 (76.4-79.6)	72.7 (67.8-77.0)
Silt	11.2 (08.0-15.4)	17.7 (13.0-20.8)	13.4 (10.8-17.4)	17.0 (14.8-25.0)	18.9 (17.6-20.4)	22.4 (19.0-27.6)
Clay	9.5 (03.6-14.0)	6.0 (04.2-07.2)	4.1 (03.2-05.4)	5.3 (00.8-05.8)	3.0 (02.8-03.2)	4.9 (01.0-06.0)

45 cm depth of the three treatment sites with a greater site variation at the surface level (coefficient of variation 0.17 versus 0.07). These values are within the range for most soils in East Texas (Stransky, 1976). However, compared to Fuller soils in Angelina County (Dolezel, 1988), the BD at the study site (Trinity county) is lower by 0.53 and 0.19 g cm⁻³ for the 0-15 and 15-45 cm depths, respectively.

After treatments, BD increased with severity of site disturbance, but was gradually reduced with depth and time. Two months after treatments, BD in the sheared plot increased as much as 50% (from 1.00 to 1.50 g cm⁻³) at the 0-15 cm depth, and only about 3% (from 1.49 to 1.53 g cm⁻³) at the 15-45 cm depth. However, the increase in the clearcut plot was about 33% and 12% for the two respective depths. Eighteen months after treatment, BD in the surface 15 cm depth of the sheared and commercial cleared plots was still 0.46 and 0.23 g cm⁻³, respectively, greater than that before the treatment (Figure 1).

The rate of BD recovery depends upon soil texture, degree of disturbance, equipment, and climatic conditions. It has been reported to range from one year in a rubber-tired skidder operation on a relatively dry, coarse-textured soil in Minnesota (Mace, 1971) to 48 years on a landing site in Virginia Coastal Plain (Hatchell and Ralston, 1971). Assuming a constant BD decreasing rate in the study area, it would take about 15 and 5 years for the BD at the surface 15 cm depth of the sheared and cleared plots, in that order, to resume its pretreatment levels.

Studying the effect of soil compaction on loblolly-pine growth in a sandy loam soil, Mitchell et al. (1982) found

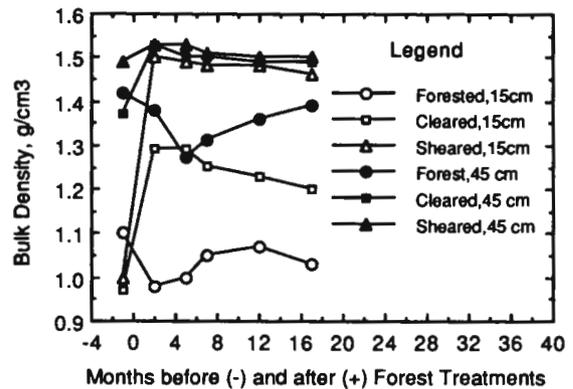


Figure 1 -- Changes in soil bulk density with time due to various forest treatments on Fuller soils near Apple Springs, Texas.

that the root development could be mechanically impeded when BD exceeded 1.4g cm⁻³. The present study showed that BD at both depths(0-15 and 15-45 cm) in the sheared plot and at the 15-45 cm depth in the cleared plot exceeded the 1.4 g cm⁻³ level. A tornado occurred on January 19, 1990 up-rooted a large loblolly-pine in the study area. Soil BD under the up-rooted tree ranged from 1.26 to 1.75 g cm⁻³. Of the 20 core samples collected at the depth (about 60 cm) where the downward growth of the root system was blocked, 11 had BD values equal to or greater than the 1.4 g cm⁻³ critical limit. The roots were found to grow laterally at this depth.

Soil Water Retention

Due to differences in soil texture and organic matter content, the amount of water retained at a particular pressure (tension) varies considerably from one soil to another. Forest harvesting and site preparation reduce canopy coverage and disturb forest floor and surface soil which may cause a mixing effect on soil mechanical composition and enhance organic matter decomposition, consequently affecting soil water retention.

Under six different pressure conditions, the mean amounts of water, in g g^{-1} , retained in the soils of the three study plots collected five months after treatments are given in Figure 2. These means were calculated from nine soil samples collected at three slope positions. The results showed that water retention for soils at the surface and bottom levels of the sheared plot was greater than that of the forested and cleared plots when they were under the 33 kPa pressure, but the forested plot was greater than the cleared and sheared plots when the soils were under the pressure 100 kPa or greater. Soil water available to plants at the 15 cm depth was 0.11 g g^{-1} for the sheared plot, compared to 0.041 and 0.073 g g^{-1} for the undisturbed forest and cleared plots, respectively.

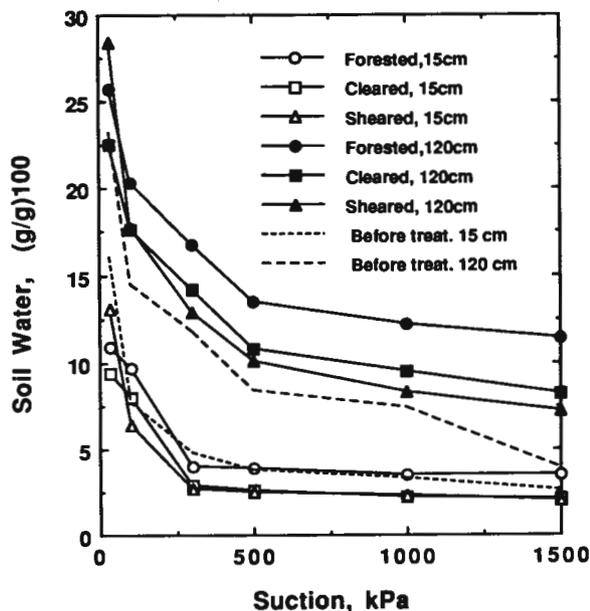


Figure 2 -- Soil water retention curves at the 15 and 20 cm depths of the Fuller soil before and five months after the treatment near Apple Springs, Texas.

At 33 kPa, water retention in the sheared plot was 0.130 g g^{-1} at the 15 cm depth versus 0.109 g g^{-1} and 0.094 g g^{-1} in the forested and cleared plots, respectively. At the 120 cm depth, water retention was 0.284 g g^{-1} in the sheared plot versus 0.257 and 0.226 g g^{-1} . As indicated in a previous section, clearcutting and shearing caused

an increase in clay and silt content of almost 10% at the 15 cm depth (Table 1). In a companion study, Sayok (1991) also showed that there was a leaching of organic matter with time in the soil profile of the treatment plots. These might contribute to the greater moisture retention in the surface horizon of the sheared plot.

Soil Water

Soil water content (SWC) in the study area consistently increased with increasing degree of forest cover removal and with increasing depth below the surface. It was also higher in winter (November-April) than in summer (May-October) half-year. This trend reflects the great loss of soil water near the ground surface due to evapotranspiration.

The mean SWC of the whole soil profile (0-105 cm) during the first post-year period (October 1988 - September 1989) were 0.278 , 0.309 , and 0.349 g cm^{-3} for the undisturbed, clearcut, and sheared plots, respectively (Figure 3). In other words, the commercial clearcut and shearing treatments caused an increase in annual SWC for the whole soil profile by 0.031 (11%) and 0.071 g cm^{-3} (26%), respectively, as compared to the undisturbed forest plot. The effect was more

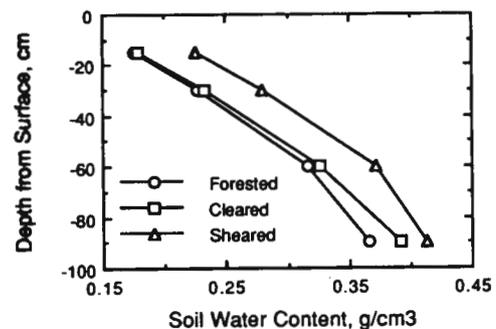


Figure 3 -- Mean soil water contents in the Fuller soil under three forest conditions in the Davy Crockett National Forest near Apple Springs, Texas.

significant for soil at surface levels and in the summer, based on Duncan's multiple range test at the 0.05 alpha level. For instance, summer SWC in the sheared plot at the 15 cm depth was greater than the undisturbed plot by 38% (0.070 g cm^{-3}), but winter SWC at the surface level was greater by 28% (0.057 g cm^{-3}). The maximum difference in daily SWC between the sheared and forest plots during the study period was about 0.172 g cm^{-3} (75%) observed at the 15 cm soil depth. Chang et al. (1983) reported differences in average SWC between sheared and forest plots on a Woodtell soil in Nacogdoches, Texas by as much as 0.135 g cm^{-3} (46%). The present study was conducted in a very wet period. Annual precipitation in the first post-treatment year (October 1988- September 1989)

at the study site was higher than the normal annual precipitation (1951-80) recorded at Lufkin, 22 km NE of the study area, by 191 mm (18%). The great amount of precipitation in the present study might cause the treatment effect on SWC to be less than that reported for the Woodtall soil.

Groundwater Table

Based on 101 weekly observations made between March 6, 1989 and February 25, 1991, groundwater tables in the sheared plot were always the highest among the three treatments, followed by the clearcut and then undisturbed forest plots. The average groundwater elevation in the sheared plot was 29.16 m (shown as depth from surface), higher than the cleared and forest plots by 0.72 and 1.72 m, respectively. This trend persisted throughout the entire period, no matter if it was in a cold season or in a rain-recharged period. Apparently, this is attributed to the differences in evapotranspiration caused by canopy density among treatments.

Expressing the occurrence of groundwater table as percentage of time that a given water table is equal to or greater than the indicated depths from surface, Figure 4 shows that these percentages decreased most rapidly at the forest site and most slowly in the sheared plot. During the summer half-year (May - October), for example, 18.7% of the time in the forest plot the groundwater table was 105 cm deep or less from the surface but it was 28.3% for the cleared plot and 31.4% for the sheared plot. The chances of having a high groundwater table were always greater in the sheared plot than that of cleared and forest plots, regardless of season of the year.

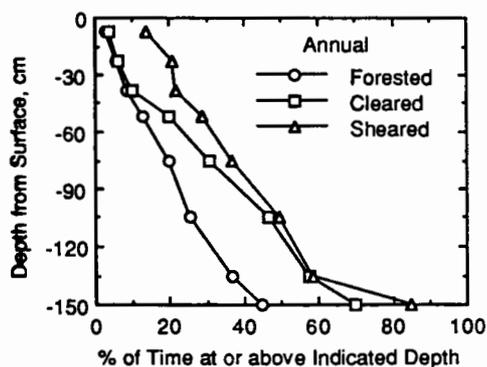


Figure 4 -- Average percent of time in March 1989 through February 1991 that the groundwater was equal to or above the indicated depths of three forest conditions near Apple Springs, Texas.

DISCUSSION AND CONCLUSIONS

The drainage in the Fuller soil is very slow although its texture is loamy sand in the surface horizon and fine sandy loam in the subsurface horizons. Laboratory

analysis using soil samples collected before treatments showed the average saturated hydraulic conductivity to be 6.01 cm hr⁻¹ at the 0-15 cm depth, much slower than 71.01 and 17.70 cm hr⁻¹ at the 0-7.5 and 7.6-15.2 cm depths, respectively, reported for a soil of similar texture, Rains (typic Paleaquult, fine loamy, siliceous, thermic family), in the Lower Coastal Plain of North Carolina (Gent et al., 1983; Figure 5). Apparently, other factors such as compaction, bulk density, soil structure, macropores, and salt concentrations might play an important role in affecting the hydraulic conductivity.

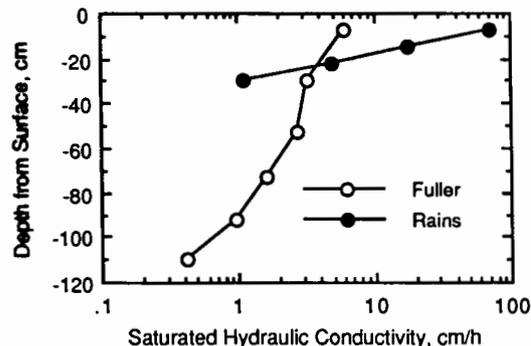


Figure 5 -- The saturated hydraulic conductivity for the Fuller and Rains soils.

Conventionally, the saline soils in many agricultural areas is reclaimed by use of water drainage through the soil profile. Slow hydraulic conductivity precludes this approach in the study soil. Also, on the sheared plot all trees were cut, all stumps and shrubs were sheared, and all debris were raked into windrows. Not only was soil bulk density increased because of compaction and mixing effects of the mechanical operations, but the reduction in plant transpiration and interception also caused increases in soil water content, soil water retention, and height of groundwater table. During the two-year study period, 29% of the time the groundwater table in the sheared plot was within the surface 60 cm depth, while it was only 14% in the forested plot. Average soil water content at the 15 cm depth in the sheared plot was 0.226 g cm⁻³ for the two years period, or about about 0.15 g g⁻¹. This water is held in the soil equivalent to a force less than 33 kpa (field capacity; Figure 2).

Generally, loblolly pines grow well in upland soils as well as in floodplains, bottom-lands, or poor drainage sites (Baker and Langdon, 1990). Studies conducted in Georgia showed that one-year-old loblolly pine seedlings planted in 3.66 x 7.32 m in diked and ditched pots began to die 101 days after initiation of flooding to 10 cm depths. When flooded water was kept at the soil surface and at 10 cm depth above the surface, the

survival rates were 93% and 61% at the end of 206 days, respectively (Walker et al., 1961). At the end of 579 days, the survival rates were still as high as 67% and 44% for the two respective inundated levels (Walker, 1962). Thus, waterlogged sites may make loblolly-pine regeneration impossible (Walker, 1980), but as long as seeds are germinated or seedlings are planted with buds above water, they should be able to survive flooding for one or two growing seasons. At that time, climatic conditions may change and groundwater level and soil water content may be lowered due to regrowth of vegetation, consequently creating a more favorable condition for seedling growth and development.

Although clearcutting and site preparation created a site with a groundwater table close to the surface and a water content saturated or almost saturated, there was no standing water on the soil surface. Moreover, annual precipitation during the two study years was 191 (18%) and 295 (28%) mm greater than the normal. The groundwater table and soil water content should be lower in normal years. Thus, it is unlikely that the wet conditions normally encountered in the study area would cause the failures in artificial pine regeneration. Salt movement following clearcutting and site preparation may increase salt concentrations to levels that are toxic to seedlings; this hypothesis needs to be examined.

Clearcutting without site preparation did not significantly affect the soil physical properties. In areas such as valleys, flat terrains, or concave sites where forest clearcutting with site preparation may cause a standing water on the surface, all plants and stumps should be left intact after marketable timber is removed.

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