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Soil Compaction Absent in Plantation Thinning

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SUMMARY

We examine the effects on soil bulk density by using a TH-105 Thinner Harvester and two forwarders in a mechanically thinned slash pine (*Pinus elliottii* Engelm.) plantation. Points in the machine tracks were sampled before and after harvesting at depths of 5 and 10 cm (2 and 4 in) for moisture and bulk density. Both the standard gravimetric method and a Troxler Model 3411 nuclear moisture-density gauge were used. Sample points were trampled at least seven times by wheels, each exerting a pressure in excess of 120.7 kPa (17.5 lb/in^2), but we detected no compaction at depths sampled. Soil water content was 13 percent during thinning.

Additional keywords: tree harvesters, thinning, soil compaction, soil density, plantation.

INTRODUCTION

Use of large logging equipment and the development of skidders permit year-round operations in most southern forests. As a result, the potential for site damage-compaction, puddling or displacement-has increased. But the effects of large equipment on the properties of forest soils have not been documented fully. In this study we evaluate the effects of the TH-105 Thinner Harvester' on soil compaction in a plantation thinning operation.

Increases in density resulting from compaction are greatest near the soil surface (Craul 1975): little compaction occurs below about 20 cm. The degree of compaction is greatest at the point with the most passes. Weaver and Jamison (1951) reported that the greatest increases in bulk density occurred during the first four passes.

Moehring and Rawls (1970), studying the effects of logging traffic in a 40-year-old even-aged loblolly pine stand during wet and dry soil moisture conditions, concluded that in dry weather neither tree growth nor physical soil properties were altered significantly by logging traffic. However, in wet weather, deep ruts on skid trails, compaction, and root damage were apparent. Drainage was impeded, and tree growth was reduced greatly. Resulting root damage decreased tree vigor and resistance to insect damage. Bulk density of soil in the skid ruts increased 13 percent.

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Soil recovery after logging operations takes many years and depends on intensity of compaction. Hatchell (1969) detected no trend toward recovery from compaction on eleven soil types in the Atlantic Coastal Plain one year after logging. Under normal conditions, about 18 years is required for bulk density on log decks to return to that of undisturbed soil.

Omberg (1969) reported that soil compaction was minor when logging residues covered the ground, providing a mat for vehicular movement. This condition can occur when, for example, a harvesting machine delimbs a tree and the branches fall ahead of it.

Standard methods for monitoring soil bulk density are core sampling or radiation. Donnelly (1976) compared bulk densities measured by volumetric core samples with measurements for a nuclear surface-density probe. The latter slightly overestimated soil moisture and slightly underestimated soil bulk density. Hassan (1977), working with a light organic soil, found that a Troxler Model 3401 surface moisture-density gage gave much higher soil bulk density estimates than those obtained by the core sample method. Both methods are employed in our study.

PROCEDURE

The study site, provided by International Paper Company, Baldwin Timberlands, Bay Minette, Alabama, was in an 18-year-old slash pine plantation in the Coastal Plain of southern Alabama. Soils of the Bowie-Tifton-Sunsweet association predominated with a loamy sand topsoil about 10 cm (4 in) deep over a sandy clay loam subsoil. The site is generally flat, and a recent prescribed burn had left the mineral soil exposed in places. Soil moisture in the O-10 cm layer at harvesting averaged 13 percent by weight.'

The TH-105 harvester has 3 rubber-tired wheels and a single steering wheel at the rear. During thinning the machine straddles the row to be harvested while the felling head grasps a tree, shears it, pushes it forward, and lifts the butt end through a delimbing ring, feeding the stem toward the rear of the machine through a bucking shear. The stem is severed into bolts 2.13 m (7 ft) long, which fall into a cradle. When the cradle is full, about 1.2 m^3 (⅓ cord), it is lowered to the ground and the bolts are dumped for pickup by a forwarder. As the TH-105 moves down a row, tops and branches are deposited on the ground in front of the harvester. Trees in adjacent rows are selectively thinned.

The TH-105 weighs 9545 kg (21,000 lb) loaded. Assuming that the weight is evenly distributed, each tire supports a static load of 3100 kg (7,000 lb). The front tires of the harvester have a footprint of 2,480 cm^2 (400 in^2), indicating that the machine exerts a pressure of about 120.7 kPa (17.5 lbs/in^2) on the ground. The front tires track between tree rows while the rear steering tire treads on top of, or close to, the line of stumps. During harvest the machine moves over the same soil area at least three times, because it has to reverse with the felled tree to prevent it from hanging up in adjacent crowns. As a result, the TH-105 compressed each sample point with a pressure of at least 120.7 kPa (17.5 lb/in^2) a minimum of three times.

Pulpwood bolts were transported to the road by two forwarders. Each machine has a capacity of 7.2 m^3 (2 cords) loaded, about 12,300 kg (27,000 Ibs). The forwarders tracked the same path as the TH-105 and passed over each sample point with two wheels at least twice.

The plantation had 1722 trees/ha (697 trees/acre) before thinning and 1104 trees/ha (447 trees/acre) after. Average height of 18 randomly selected trees was 10.1 m (33 ft); average d.b.h. was 12.95 cm (5.1 in).

A rectangular area 31 tree-rows wide and 122 m (400 ft) long, encompassing 0.93 ha (2.3 acres), was marked for the study. Fourteen randomly located plots were established, each containing three sample points: one in the left tire track, one in the right track, and one in the undisturbed area between adjacent thinned rows. At each point, undisturbed 44 cc (2.7 in") soil core samples were taken before and after harvesting from 5 cm and 10 cm (2 and 4 in) depths and placed in moisture-tight containers. For comparison with the gravimetric method, the Troxler surface moisture-density gage was used at or near the same points to obtain direct readings of bulk density and moisture at the same depths.

Samples were weighed at the Auburn laboratory and cores oven dried at 105°C. Bulk density and moisture percentages of each sample were calculated using the formulae:

$$\text{Bulk density} = \frac{\text{oven dry weight of soil (g)}}{\text{volume of soil (cc)}}$$

$$\text{Moisture Percentage} = \frac{\text{wet weight (g)} - \text{oven dry weight (g)}}{\text{oven dry weight(g)}} \times 100.$$

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Table 1.—Mean bulk density values (g/cm^3) measured by soil cores[1] and by Troxler[2] before and after thinning at 5 cm and 10 cm depths

	Before thinning				After thinning			
	5 cm		10 cm		5 cm		10 cm	
	Grams per cubic centimeter							
	Core	Troxler	Core	Troxler	Core	Troxler	Core	Troxler
Left wheel track	1.51 (±0.11)	1.23 (±0.08)	1.67 (±0.09)	1.31 (±0.11)	1.52 (±0.11)	1.22 (±0.10)	1.65 (±0.10)	1.29 (±0.08)
Right wheel track	1.54 (±0.09)	1.21 (±0.08)	1.62 (±0.10)	1.29 (±0.06)	1.50 (±0.14)	1.27 (±0.06)	1.66 (±0.08)	1.34 (±0.06)
Undisturbed	1.49 (±0.12)	1.22 (±0.07)	1.66 (±0.12)	1.29 (±0.08)				

[1] Core bulk density values are mean of 14 observations.
[2] Troxler bulk density values are mean of 8 observations.

Table 2.—Mean soil moisture percentage values[1] measured by soil cores and by Troxler before and after thinning at 5 cm and 10 cm

	Before thinning				After thinning			
	5 cm		10 cm		5 cm		10 cm	
	Percent							
	Core	Troxler	Core	Troxler	Core	Troxler	Core	Troxler
Left wheel track	11.3 (±2.7)	15.1 (±3.6)	11.9 (±2.5)	14.0 (±3.1)	15.0 (±2.7)	21.4 (±3.4)	14.8 (±1.7)	20.1 (±3.7)
Right wheel track	12.3 (±4.3)	16.3 (±5.1)	12.6 (±3.0)	15.0 (±4.8)	17.9 (±5.2)	20.2 (±3.4)	15.4 (±2.9)	19.4 (±3.4)
Undisturbed	12.7 (±2.6)	15.2 (±3.3)	13.3 (±2.3)	14.9 (±2.8)				

Core and Troxler moisture values are mean of 8 observations.

RESULTS AND DISCUSSIONS

We detected no damage to the soil. Little disturbance to the soil surface occurred, and no tire ruts appeared. There was little tire-to-soil contact anywhere since tree tops and branches formed a mat over the soil surface. Soil bulk density measurements confirmed that little soil disturbance had occurred.

Mean bulk density values of the soil measured either gravimetrically or with the Troxler before and after thinning did not differ significantly (α = 0.05) (table 1). However, standard deviation was greater by the former method (0.08 to 0.14) than by the latter (0.06 to 0.11) (table 1).

Bulk density at 5 cm (2 in) was significantly lower (**r** = 0.05) than at 10 cm (4 in) because bulk density increases with soil depth (Donnelly 1976). However, the TH-105 had no detectable impact on bulk density in the subsoil at 10 cm, even though the subsoil texture is finer than the surface texture.

Troxler bulk densities averaged 0.30 g/cc (18 lbs/ft^3) lower than corresponding gravimetric determination. We assume the lower readings are a characteristic of its calibration. Soil moisture estimates with the Troxler averaged 3 percent and 5 percent greater than gravimetric means before and after harvesting (table 2).

Several factors probably contributed to the lack of detectable differences after thinning. Of major importance was the low soil moisture content (13 percent). Soil moisture and texture have considerable influence on the degree of compaction. Another mitigating factor was the layer of tops and branches deposited on the soil surface during the delimbing cycle. Tires seldom came into contact with the mineral soil surface. This layer of logging debris served to distribute the machine weight over a larger area and decrease compaction.

CONCLUSIONS

A TH-105 Thinner Harvester used with two forwarders to thin a slash pine plantation caused no detectable soil damage. Moderate ground pressure together with the distribution of branches on the soil in front of the machine contributed to the absence of soil compaction. The Troxler 3411 nuclear moisture density meter consistently overestimated soil moisture by 3 to 5 percent and underestimated soil bulk density by 0.3 g/cc (18.7 lbs/ft^3) compared to the gravimetric method.

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