Reprinted from the SOUTHERN JOURNAL
OF APPLIED FORESTRY
Vol. 5, No. 4 November 1981

Site Preparation Effects on Soil Bulk Density and Pine Seedling Growth

J. J. Stransky

ABSTRACT. Soil bulk density was sampled the first and third growing seasons after site preparation and pine planting on three clearcut pine-hardwood forest sites in eastern Texas. Bulk density was measured 10 cm below the surface of mineral soil using a surface moisture-density probe. Plots that had been KG-bladed and chopped had significantly higher bulk density than those that were burned or left untreated. After 5 years the survival, height, and diameter growth of pines averaged highest on the mechanically treated plots, probably because competition from other woody stems was much less than in the untreated and burned plots.

Bulk density is an index of soil compaction. An increase in bulk density tends to reduce root penetration, aeration, infiltration, and percolation. Thus, increases in bulk density reflect changes in soil physical properties that affect the growth of plants.

In forestry, site preparation for tree planting often involves heavy mechanical equipment that may compact the soil, especially in wet weather. The compaction could affect species composition of plant communities, reduce plant vigor, and inhibit pine seedling growth. Presumably, soil compaction may become more of a problem with increasing use of heavy logging and site-preparation equipment.

Objectives of this study were to measure and compare soil bulk density and the growth of planted pines on 3 pine-hardwood clearcut forest sites that had been prepared by various site treatments for pine planting. One of the sites had previously been cultivated; the others had always been forested.

International Paper Company and Temple-Eastex Incorporated provided land and assisted in establishing the study.

MATERIALS AND METHODS

Study Sites

All three study sites are in eastern Texas within the westernmost extension of the loblolly-shortleaf pine-hardwood forest type that covers nearly 28 million hectares (ha) in the South. All sites supported mature pine-hardwood stands prior to clearcutting in the fall of 1972.

The sites were selected to represent the common soil series in the Texas middle coastal plain. Their topography ranges from nearly level to gently sloping. The summers are hot and humid and the winters mild. The growing season is about 240 days. Annual rainfall averages about 130 cm.

Site 1

This study site is within the Stephen F. Austin Experimental Forest near Nacogdoches. The area has not been cleared for agricultural use and has not been grazed for the past 25 years. Soils belong to the Bernaldo-Elysian complex and the Sacul series, which are moderately well-drained soils with fine sandy loam surface horizons.

Prior to clearcutting the forest consisted mainly of loblolly pines (*Pinus taeda* L.) averaging 70 years old. These were interspersed with some hardwoods up to 100 years of age, mostly sweetgum (*Liquidambar styraciflua* L.), winged elm (*Ulmus alata* Michx.), southern red oak (*Quercus falcata* Michx.), and post oak (*Quercus stellata* Wang.).

Site 2

The tract is owned by International Paper Company near Wells, in Cherokee County. The area was cleared for cultivation around 1890 and remained so until about 1930. The abandoned land was invaded by pines. At time of being clearcut the stand averaged 45 years in age. The principal tree species were shortleaf pine (*Pinus echinata* Mill.), sweetgum, post oak, and blackjack oak (*Quercus marilandica* Muenchh.).

Soils belong mostly to the Fuquay and Kirvin series, which are well-drained soils with loamy sand and sandy loam surface horizons.

Site 3

This area is owned by Temple-Eastex, Inc., near Jasper, in Jasper County. The land has never been cleared for agricultural crops, but it has been grazed by livestock. The soils belong to the Bernaldo-Elysian complex and the Sacul series—similar to site 1 soils.

Loblolly pine was prominent in the uncut forest and averaged about 45 years of age. Southern red oak, water oak (*Quercus nigra* L.), blackgum (*Nyssa sylvatica* Marsh.), and sweetgum were prevalent hardwoods.

Treatments and Design

The study had randomized block design consisting of three adjacent blocks and 4 site treatments on each of the 3 sites. Individual site treatment plots were 0.6-ha squares. Merchantable trees were cut and removed from the study areas during the dry August and September of 1972. The following site-preparation treatments were applied to wet soils during February and March 1974 on site 3, and to dry soils during August and September 1974 on sites 1 and 2:

Control—no site preparation, all woody stems greater than 2.5 cm d.b.h. were cut.

Burn—all stems greater than 2.5 cm d.b.h. were cut and burned with the logging slash by headfires.

Chop—logging slash and all standing stems were cut with a Marden chopper and burned.

KG—all stems were cut with a KG blade, and the logging slash was raked off the plots and burned. Sites 1 and 2 were also cultivated to a depth of about 30 cm with a heavy-duty disk after having been KG-bladed.

The sites were handplanted with 1-0 (1-year-old, nursery-grown) loblolly pine seedlings at 2.4 by 3 m spacing. Site 3 was planted in mid-March 1974, and Sites 1 and 2 in February and March 1975.

Sampling Procedures

Soil bulk density was sampled in a sphere centered 10 cm below the mineral soil surface because previous investigation indicated that compaction most likely occurs at that level (Stransky 1976). Also, experience had shown that readings below the soil surface were more accurate than at the soil surface. On the chopped plots the ridges between chopper blade indentations served as reference points.

A Troxler Model 2451 Surface Moisture-Density Probe was used for sampling soil bulk density. On each of the three sites, triplicate readings were taken near the center of each treatment plot; a total of 27 samples per treatment for each sampling date. Sites 1 and 2 were sampled in January 1976 and 1978; site 3 was sampled in December 1974 and in January 1977; 1 and 3 growing seasons after site treatments.

Pine-seedling survival was tallied on 150 trees per treatment (50 trees per plot) in randomly selected rows at all 3 sites at the end of the first and the fifth growing season after planting. Tree heights and diameters (d.b.h.) were measured after the fifth growing season, along with observations on crown class and insect damage. The number and height of competing trees were tallied 5 growing seasons after site preparation on sites 1 and 3, but not on site 2.

For all data, differences among treatments were tested by analysis of variance and by Duncan's multiple range test at the 0.05 level of significance.

RESULTS AND DISCUSSION

Soil Bulk Density

One year after site preparation, soil bulk density of the KG-bladed plots was significantly higher than of the control and burned plots, but not higher than of chopped plots (Table 1). Three years after site preparation, bulk density on both the chopped and KG-bladed plots was still significantly higher than on the control and burn treatments.

Differences of bulk density between sites and the site x treatment interactions were nonsignificant, indicating that the treatment effects were similar within the range of soil conditions tested. Disking of the KG plots on sites 1 and 2 did not give different results from the undisked site 3.

Generally, the first-year bulk density values were slightly higher than the third-year values. However, mean changes were not significantly different among treatments, indicating no detectable recovery of the compacted soils during the 3-year period (Table 1).

Table 1. Mean soil bulk density and changes in bulk density 1 and 3 growing seasons after site preparation on the 3 sites.

Location	Site treatment			
	Control	Burn	Chop	KG
	grams/cc			
	One growing season after site preparation			
Site 1	1.29	1.29	1.35	1.41
Site 2	1.23	1.26	1.34	1.37
Site 3	1.34	1.28	1.29	1.42
Mean	1.29	1.28	1.33	1.40[1]
	Three growing seasons after site preparation			
Site 1	1.26	1.31	1.35	1.34
Site 2	1.26	1.25	1.29	1.34
Site 3	1.25	1.25	1.34	1.40
Mean	1.26	1.27	1.33	1.36[1]
	Changes in bulk density between first and third growing season			
Site 1	−.03	+.02	.00	−.07
Site 2	+.03	−.01	−.05	−.03
Site 3	−.09	−.03	+.05	−.02
Mean	−.03	−.01	.00	−.04[1]

[1] *Values connected by the same line are not significantly different at the 5-percent level.*

After 9 annual burns on a loess soil, Moehring *et al.* (1966) measured (at the 5 to 10 cm depth) the same bulk density on burned and unburned areas (1.34 g/cc). While obtained in soils of different texture, this value is about the same as that of the KG and chopped plots in the present study.

Georgia and Virginia soils, compacted by repeated cropping, measured 1.45 g/cc and 1.43 g/cc, respectively, above the plow layer which was at 18 cm soil depth (Brady 1974). These data are similar to the KG treatment of the study reported here.

Table 2. Survival of planted pines after 5 growing seasons.

Location	Site treatments			
	Control	Burn	Chop	KG
	Percent			
Site 1	55	63	83	91
Site 2	52	41	64	73
Site 3	63	85	90	97
Mean	57	63	79	87[1]

[1] *Values connected by the same line are not significantly different at the 5-percent level.*

Table 3. Height of planted pines after 5 growing seasons.

Location	Site treatments			
	Control	Burn	Chop	KG
	cm			
Site 1	285	290	355	410
Site 2	299	251	321	331
Site 3	306	305	370	311
Mean	297	282	349	351[1]

[1] *Values connected by the same line are not significantly different at the 5-percent level.*

Moehring and Rawls (1970) attributed inferior pine seedling growth to soil compaction that resulted from wet weather logging with heavy equipment. Hatchell and Ralston (1971) postulated that recovery from compaction through natural processes may take as long as 18 to 40 years. Cultural methods, such as disking, may accelerate the recovery process (Moehring 1970).

Pine Survival and Growth

Pine-seedling survival, heights, and diameters averaged greatest on the KG plots (Tables 2, 3, and 4). The relatively superior growth of pines under this treatment was attributed to the low height of competing woody vegetation (Table 5) and to the low density of hardwoods (Table 6). Several studies have shown that the early growth advantages gained through site preparation are maintained for a long period in the life of the young stand, possibly through its entire expected rotation (Stransky 1964, Schultz 1975).

Growth of pines averaged second best on the chopped plots. Here again, the generally good growth of pine seedlings was ascribed to the sparsity of other woody stems. The lesser density and height of competing hardwoods on site 3 (double-chopped) is probably the reason why pine seedlings

Table 4. Diameter of planted pines after 5 growing seasons.

	Site treatments			
Location	Control	Burn	Chop	KG
	cm			
Site 1	3.2	3.2	4.6	5.7
Site 2	3.5	3.1	4.2	5.2
Site 3	2.4	2.9	4.4	3.2
Mean	3.0	3.1	4.4	4.7[1]

[1] *Values connected by the same line are not significantly different at the 5-percent level.*

Table 5. Average height of hardwood trees after 5 growing seasons.

	Site treatments			
Location	Control	Burn	Chop	KG
	cm			
Site 1	183	166	164	105
Site 3	225	203	136	147
Mean	204	184	150	126[1]

[1] *Values connected by the same line are not significantly different at the 5-percent level.*

made greater height growth here than on site 1 (single-chopped).

Survival, height, and diameter growth were least on the burned and control plots having greater densities of overtopping hardwoods than the mechanical site treatments. Within the burned plots on site 3, survival and growth were relatively good because the plots were burned under very favorable wind and fuel-moisture conditions, and many of the hardwoods were killed. In contrast, as a result of poor burning conditions on sites 1 and 2, woody plant competition (number and height of hardwoods overtopping the pines) remained quite similar to the control plots, and the survival and growth of pines were relatively poor.

Generally, pine-seedling survival was less on the dry sandy soils of site 2 than on the other 2 sites. Pine seedlings on sites 1 and 2 were planted in 1975, a year when growing-season rainfall was below average. As a consequence, their survival rate was less than seedlings planted on site 3 in 1974, a year when growing-season rainfall was above average.

Nantucket tipmoth (*Rhyacionia frustrana* Comstock) severely damaged the growing tip of pines on all three sites. On the average, 76, 73, and 74 percent of seedlings were damaged on sites 1, 2, and 3. Sixty-nine percent of seedlings were damaged on the mechanized-treatment plots, 71 per-

Table 6. Average number of hardwood trees after 5 growing seasons.

	Site treatments			
Location	Control	Burn	Chop	KG
	M/ha			
Site 1	13.17	11.20	11.12	4.98
Site 3	9.92	7.95	6.34	4.94
Mean	11.54	9.57	8.73	4.96[1]

[1] *Values connected by the same line are not significantly different at the 5-percent level.*

cent on controls, and 89 percent on burned plots. It is possible that the initial rate of infestation was the same with all site treatments, but the more vigorous trees on chopped and KG-bladed plots appeared to have outgrown the visible signs of tipmoth damage by the fifth growing season.

Even though the soil bulk density was increased by KG-blading and chopping, the short-term effects, if any, on pine-seedling survival and growth were largely masked by the overall positive responses of the seedlings to reduced competition from other woody plants.

Literature Cited

Brady, N. C. 1974. The nature and properties of soils. Macmillan Publ. Co., N.Y. 8th ed. 639 p.

Hatchell, G. E., and C. W. Ralston. 1971. Natural recovery of surface soil disturbed by logging. USDA For. Serv. Tree Planters' Notes 22:5–9.

Moehring, D. M. 1970. Forest soil improvement through cultivation. J. For. 68:328–331.

Moehring, D. M., and C. W. Rawls. 1970. Detrimental effect of wet weather logging. J. For. 68:166–167.

Moehring, D. M., C. X. Grano, and J. R. Bassett. 1966. Properties of forested loess soils after repeated burns. USDA For. Serv. Res. Note SO-40, 4 p. South. For. Exp. Stn., New Orleans, LA.

Schultz, R. P. 1975. Intensive culture of southern pines: Maximum yields on short rotations. Iowa State Jour. Res. 49 (3) Pt. 2:325–337.

Sransky, J. J. 1964. Site preparation effects on early growth of loblolly pine. USDA For. Serv. Tree Planters' Notes 64:4–6.

Stransky, J. J. 1976. Vegetation and soil response to clearcutting and site preparation in east Texas. Ph.D. Dissertation, Texas A&M Univ. 193 p.

J. J. Stransky is with the Southern Forest Experiment Station, USDA Forest Service, Nacogdoches, Texas. Study conducted in cooperation with the School of Forestry, Stephen F. Austin State University, Nacogdoches.