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TIME CHANGES IN SOIL DENSITY FOLLOWING COMPACTION UNDER AN OAK FOREST

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Soil compaction resulting from logging, recreation and grazing activities can be damaging to on-site biota, and a cause of increased surface runoff and erosion. However, compacted soil may recover over time by natural means in the absence of additional compaction. The primary objective of this study was to determine the rate at which artificially compacted soil approached its original uncompacted state by natural means as indexed by bulk density measurements.

Initial data were collected at intervals over a 4 1/2-year period starting in November 1962, and were analyzed and reported earlier.[2] Additional data were obtained at the end of a subsequent 4 1/4-year period and are presented here. Information from the initial report, which details the experimental and analytical approaches utilized in the study, is briefly summarized and incorporated below where needed for background and continuity. Thus, this final report includes results spanning a total period of 8 3/4 years.

Methods

The study site was a protected and mature oak stand bordering Lake Vadnais near St. Paul, Minnesota.[3] Soil texture varied from a sandy loam to a loamy sand in the surface three feet. The A_1 horizon was five to seven inches thick and very dark gray to black. The soil was gravel free in the surface 15 inches.

Ten 17- by 22-foot plots were artificially compacted in November 1962 after leaf fall using a gasoline-powered, construction-type tamper. The plots received no further compaction treatment. Ten additional plots of the same size were left undisturbed as controls. The plot layout was a randomized block design.

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2/ Thorud, D. B. and S. S. Frissell. 1969. Soil rejuvenation following artificial compaction in a Minnesota oak stand. Minnesota Forestry Research Notes. No. 208. 4 p.

3/ The St. Paul Water Department permitted this study to be done on land under its jurisdiction.

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The oven-dry bulk density of the 0- to 3-inch zone was used as the primary measure of initial compaction effects and the subsequent rate of recovery, as determined with a 347 cc Utah sampler. The 0- to 3-inch zone was sampled seven times during the 8 3/4-year study. Samples were obtained from the 6- to 9-inch zone in May 1963 and again in August 1971 to determine the magnitude and duration of compaction effects at greater depth. The 9-to 12-inch zone was sampled once in May 1963.

On measurement dates for the 0- to 3-inch zone, two samples were obtained and averaged to represent each compacted and each uncompacted plot. Thus, ten plot means were obtained for compacted soil and ten for uncompacted soil. An exception to this technique occurred in November 1962 when the plot means were based on four samples per plot. For the 6- to 9-inch and the 9- to 12-inch zones, two samples were obtained from each compacted and uncompacted plot, and likewise averaged to give ten plot means for each soil condition and depth.

The statistical significance of differences between compacted and uncompacted soil for each sample date and depth zone were evaluated using a t-test (a = 0.05) for unequal variance and unpaired observations.

Results

The compaction treatment caused statistically significant increases in bulk density of 0.31, 0.14 and 0.07 g per cc for the 0- to 3-, 6- to 9- and 9- to 12-inch zones, respectively. The average bulk densities for uncompacted soil at these depths were 1.14, 1.42 and 1.48 g per cc.

By May 1967, the bulk density in the 0- to 3-inch zone had declined from an initial value of 1.45 g per cc (November 1962) to 1.24 g per cc which was still 0.08 g per cc greater than uncompacted soil at this time (Table 1). However, by August 1971 the bulk density of the compacted soil had decreased to 1.17 g per cc and was no longer significantly different from that of the uncompacted soils. These results indicate that recovery occurred sometime during the interval between 4 1/2 and 8 3/4 years following the compaction treatment. The uncompacted soil appeared to remain relatively stable as indexed by the nearly constant estimates of bulk density during the entire study period (Table 1); a consistency which may indicate a degree of uniformity in the sampling techniques utilized.

Table 1. The average bulk density of compacted and uncompacted soil in the 0- to 3-inch zone between November 1962 and August 1971.

Date	Compacted Soil	Uncompacted Soil	Difference
		(g per cc)	
Nov. 1962	1.45 ± 0.05[1/]	1.14 ± 0.07	0.31*
May 1965	1.34 ± 0.06	1.14 ± 0.04	0.20*
Nov. 1965	1.33 ± 0.06	1.18 ± 0.04	0.15*
May 1966	1.26 ± 0.06	1.16 ± 0.04	0.10*
Oct. 1966	1.27 ± 0.04	1.16 ± 0.04	0.11*
May 1967	1.24 ± 0.06	1.16 ± 0.04	0.08*
Aug. 1971	1.17 ± 0.04	1.16 ± 0.04	0.01

1/ 95% confidence limit

* Significant at a = .05

The compaction treatment increased the bulk density of the 6- to 9-inch zone by 0.14 gm per cc, as measured in May 1963. In August 1971, a difference of 0.14 gm per cc was again measured, and found to be statistically significant (Table 2). Thus, the increased bulk density of this zone following treatment appeared to remain unchanged throughout the 8 3/4-year period. The uncompacted soil appeared to have a relatively constant bulk density as indexed by measurements made at the initiation and end of the study period (Table 2).

Table 2. The average bulk density of compacted and uncompacted soil in the 6- to 9-inch zone in May 1963 and in August 1971.

Date	Compacted Soil	Uncompacted Soil	Difference
		(g per cc)	
May 1963	1.56 ± 0.03[1/]	1.42 ± 0.05	.14*
Aug. 1971	1.54 ± 0.03	1.40 ± 0.04	.14*

1/ 95% confidence limit

* Significant at a = .05

Discussion and Conclusions

During the initial phase of the study, relatively frequent measurements in the 0- to 3-inch zone permitted a more detailed analysis of seasonal changes in bulk density than was possible for the concluding phase. In the latter period, only one measurement was made at the beginning and one at the end of a 4 1/4-year interval. Measurement intervals during the initial phase were designed to help identify causal factors relating to recovery as indexed by seasonal changes, but the results were inconclusive. However, a statistically significant decrease of 0.07 g per cc occurred during the winter of 1965-66 which suggests that perhaps freezing and thawing may reduce the bulk density of compacted soil. The initial report provides additional details relating to analysis of seasonal changes.[4/]

Bulk density decreased in the surface three inches of soil as a result of natural causes from 1.45 g per cc to a pretreatment level of 1.17 g per cc over an 8 3/4-year period. Thus, a more-or-less complete recovery of the compacted soil evidently occurred in this zone in terms of the parameter measured, which in turn suggests that soil water and aeration phenomena likewise improved with time. However, recovery in terms of bulk density does not necessarily indicate recovery in terms of other soil properties that may have been changed by treatment.

In the 6- to 9-inch zone, the compaction effects apparently persisted unchanged during the entire study period, suggesting no improvement due to natural causes. However, the bulk density in this zone was initially increased by only ten percent as a result of treatment, in contrast to the 27 percent increase observed in the 0- to 3-inch zone. In terms of ecological and hydrological implications, the small increase in density at the lower depth may be less important than the more severe increase observed in the surface zone; further, the comparative significance of a lack of recovery in the 6- to 9-inch zone may likewise be lessened accordingly. It is fortunate and perhaps not coincidental that recovery agents appear to be most effective where compaction effects are most severe.

Information of the type obtained in this study could be of value to land managers. As recreation activity and other resource uses increase, soil compaction and related phenomena may become critical site management problems. This study suggests that a rest-rotation system may be one feasible form of corrective treatment if a site can be taken out of use for, say, four to eight years, assuming that surface compaction is the main problem, and that factors causing natural recovery (freezing and thawing, animal activity, etc.) and other conditions are comparable to those characterizing the present study. If compaction at greater depth is a problem, an alternative mechanism for correction may be necessary, since no improvement was detected after an almost 9-year "rest" period.

Data on the time required for the density of compacted soil to return to acceptable levels under a "rest" system for other geographic areas and conditions may provide additional useful information for land managers who are concerned with correcting site deterioration resulting from land use.

4/ Op cit, p. 1.