Minnesota Forestry Research Notes

No. 208
October 15, 1969

SOIL REJUVENATION FOLLOWING ARTIFICIAL COMPACTION IN A MINNESOTA OAK STAND

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Soil deterioration resulting from recreation use, logging and grazing has long been considered damaging to on-site vegetation, and a cause of increased surface runoff and erosion. However, compacted soil may rejuvenate by natural means in the absence of further compaction. The objectives of this study were to determine the time required for artificially compacted soil to approach its original uncompacted state and if possible, to identify factors that cause rejuvenation.

Methods

The study site was an undisturbed oak stand bordering Lake Vadnais near St. Paul.[2] The stand was composed largely of northern pin oak (*Quercus ellipsoidalis* Hill), with white oak (*Quercus alba* L.), bur oak (*Quercus macrocarpa* Michx.) and northern red oak (*Quercus rubra* L.) intermixed. The average dbh of mature oaks was 17 inches. The flora was similar to the oak-dominated xeric forests of southern Wisconsin (1).

Soil texture varied from a sandy loam to a loamy sand in the surface three feet (Table 1). This description is based on particle size analyses made utilizing the hydrometer technique. 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 with a gasoline-powered tamper in November 1962 after leaf fall. Each plot was traversed three times at a uniform pace with the tamper, which delivers between 500 and 700 blows per minute. This process compacted the soil and litter, and exposed bare soil in spots. The plots received no further compaction treatment. Ten 17- by 22-foot plots were left undisturbed as controls. The plot layout was a randomized block design.

The bulk density of soil in the 0- to 3-inch zone was used as an index of initial compaction and subsequent rate of rejuvenation. Sampling was done periodically with a 347 cc Utah sampler. Immediately after compaction in 1962,

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[2] Our thanks to the St. Paul Water Department for permitting this study on land under its jurisdiction.

Published by the School of Forestry, University of Minnesota, St. Paul, Minnesota 55101, cooperating with the Division of Forestry, Minnesota Conservation Department, and Forest Industries of Minnesota

four samples were obtained in each of the ten compacted plots, and four in uncompacted soil adjacent to each compacted plot. The uncompacted soil was not obtained in plots on this first sampling date. The four samples for each plot location and soil condition were averaged to give ten means for compacted soil and ten for uncompacted soil. On subsequent sampling dates, two samples were obtained in each compacted plot and two in each uncompacted plot, except for May 1963 when only compacted soil was measured. These values were averaged to give ten plot means for compacted soil and ten for undisturbed soil. To determine the initial magnitude of the compaction treatment at greater depth, 20 additional samples were obtained from the 6- to 9-inch zone and 20 from the 9- to 12-inch zone in each plot type during the spring of 1963.

Table 1. Average percent sand and silt for three compacted and four uncompacted plots.[1/]

Depth (inches)	Percent Sand		Percent Silt	
	compacted	uncompacted	compacted	uncompacted
0- 6	75	78	19	17
6-12	76	79	17	16
12-24	71	76	20	16
24-36	72	78	15	14

[1/] The clay content can be estimated by subtracting the sum of sand and silt from 100 percent.

The periodic sampling of the 0- to 3-inch zone was intended to give a measure of the rate at which compacted soil rejuvenated and to identify the seasons during which rejuvenation occurred. The latter objective was explored by sampling in the fall after most biological activity had ceased but before soil freezing had begun; and by sampling in the spring after thawing but before the onset of biological activity. If significant decreases occurred during the fall-spring interval, winter phenomena such as freezing and thawing may have caused the soil improvement. If decreases occurred during the summer interval, biological activity or wetting and drying might be the causes. This sampling scheme was followed prior to the spring of 1963 and from November 1965 until May 1967.

Two types of statistical tests were performed. First, for each sampling date the statistical significance of differences between compacted and undisturbed soil was evaluated using a t-test ($\alpha = .05$) for unequal variance and unpaired observations. Secondly, the statistical significance of changes in bulk density during each interval between sampling dates was evaluated with a t-test ($\alpha = .05$) based on paired observations. Plots were used as a basis for pairing, since the same plots were sampled at the beginning and end of each interval.

Results and Discussion

The compaction treatment caused statistically significant increases in bulk density of .31, .14, and .07 g per cc for the 0- to 3-, 6- to 9- and 9- to 12-inch zones. The average bulk densities for undisturbed soil at these depths were 1.14, 1.42, and 1.48 g per cc. The increase due to compaction was consistent with bulk density changes reported for soils subjected to recreational trampling (2, 3) and grazing (4). However, this compaction treatment was imposed instantaneously, with the result that subsurface biota, such as roots, were possibly not damaged as severely as would occur with long-term trampling.

A gradual improvement in compacted soil was noted in the 4 1/2-year period following treatment. The bulk density in the 0- to 3-inch zone dropped from an initial value of 1.45 g per cc to 1.24 g per cc by May 1967 (Table 2). However, the effect of compaction was still statistically significant on this date. A linear projection of the histogram for compacted soil in Figure 1 indicates that the equivalent of undisturbed soil conditions could possibly be achieved by 1969, a total time lapse of six years. The undisturbed soil remained relatively stable as indicated by the nearly constant bulk density (Table 2).

Table 2. The average bulk density of compacted and uncompacted soil in the 0- to 3-inch zone from November 1962 to May 1967.

Date	Compacted soil	Uncompacted soil	Difference
		(g per cc)	
Nov. 1962	1.45 ± .05 1/	1.14 ± .07	.31*
May 1965	1.34 ± .06	1.14 ± .04	.20*
Nov. 1965	1.33 ± .06	1.18 ± .04	.15*
May 1966	1.26 ± .06	1.16 ± .04	.10*
Oct. 1966	1.27 ± .04	1.16 ± .04	.11*
May 1967	1.24 ± .06	1.16 ± .04	.08*

*Significant at α = .05

1/ 95% confidence limit

Evaluations of seasonal changes in the bulk density of compacted plots were inconclusive (Figure 1). The changes were not statistically significant during two summers (1965 and 1966) and two winters (1962-1963 and 1966-1967) that could be individually isolated. However, a statistically significant decrease of .07 g per cc occurred during the winter of 1965-1966. This suggests that perhaps freezing and thawing can reduce the bulk density of compacted soil. Frozen soil was observed to a depth greater than three inches during three winters including the 1965-1966 season, and it exceeded 30 inches during the first. Freezing in the surface three inches can also be assumed for the two winters when it was not measured. The statistically significant decrease in bulk density of .13 g per cc from May 1963 to May 1965 could not be attributed to either season because two winters and two summers were included.

Conclusions

Although the attempt to identify seasonal changes in bulk density was inconclusive, some significant information on natural rates of recovery from soil compaction was obtained. Bulk density decreased, as a result of natural causes, from 1.45 to 1.24 g per cc over a 4 1/2-year period in the surface three inches. This final value was only .08 g per cc (7%) higher than undisturbed soil which remained nearly constant.

Information of the type obtained in this study could be of value to recreation land managers. As recreation use increases, soil compaction and related phenomena become critical site management problems. A rest-rotation scheme may prove to be the simplest and least expensive corrective treatment. Data on the time required for soils in varied geographic areas to return naturally to an acceptable bulk density are essential to the development of such management programs. As an example, this study indicates that near normal bulk density could be attained in five or six years. Perhaps a recreation site on a similar soil could be rejuvenated by withdrawal from use for this time period. More information on the natural recovery rate of compacted soils will also allow future comparisons of this method with artificial rehabilitation techniques.

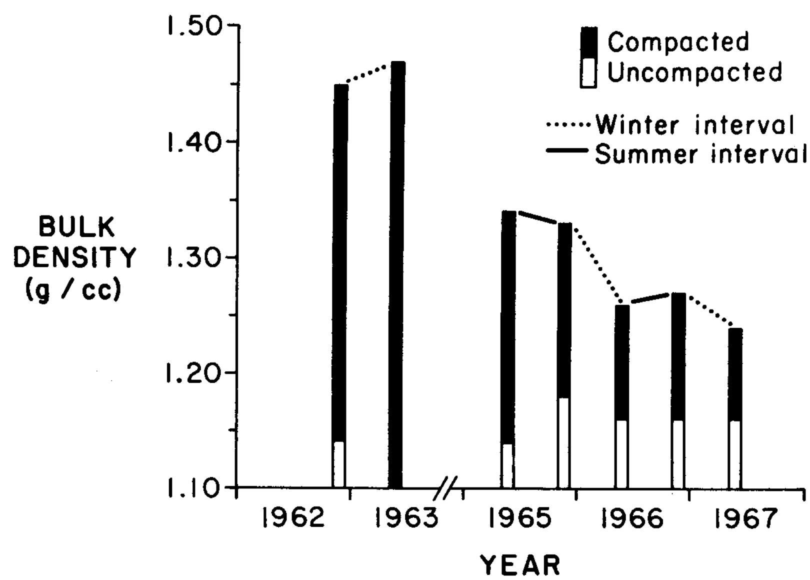

Figure 1. Average bulk density of the 0- to 3-inch zone for compacted and uncompacted soil.

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Published as Sci. Jour. Ser. Paper No. 7078 of the Univ. of Minn. Agr. Expt. Sta.