NATURAL RECOVERY OF SURFACE SOILS DISTURBED IN LOGGING

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Foil and Ralston (3) reported that compaction treatments applied to soil core samples greatly reduced the growth of loblolly pine *(Pinus taeda L.)* seedlings. In recent studies, severe compaction, puddling, and soil displacement were found after logging loblolly pine stands in the Atlantic Coastal Plain, and substantial reduction in loblolly pine establishment and early growth was observed on disturbed parts of medium- and fine-textured soils (5). In this forest area, many forest soils are poorly drained, and logging under wet conditions and with heavy equipment intensifies the damage to soils (fig. 1).

Perry (10) reported that, in a 26-year-old loblolly pine plantation in Durham County, N.C., the yield of individual trees planted in ruts of an abandoned woods road was only 46 percent as much as that for trees on adjacent land. He estimated that 40 years would be required for the infiltration capacity in severely compacted ruts to attain the capacity of normal soil.

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Soils compacted by agricultural equipment have improved in physical condition after cycles of wetting and drying during winter (2). Wittsell and Hobbs (14) found that compacting a silt loam soil reduced wheat yields the first year, but no residual effects were noted in the following crops; they attributed a reduction in bulk density of compacted soils to freezing, thawing, and moisture changes, Total pore space of surface soil is increased upon slow freezing as ice lenses, which are fed by capillary movement from below, grow in size, and cause displacement and bulking of the soil (7).

Biotic factors are important in natural recovery of compacted soil. Deep-rooted plants, such as kudzu and alfalfa, increase the percolation rate of the entire soil profile and also increase the noncapillary pore space (13). Grass roots appear to have a beneficial effect on soil structure, and earthworms 'tend to breakdown soil aggregation (H).

Restoration of compacted soils in forest and open areas has been studied by burying compacted soil cores with several additives (4, 12). During a 2-year period, a platy structure formed in the compacted cores as a result of wetting and drying, and plant

Figure 1.—Severe soil disturbance on this log deck resulted from use of skidding equipment on a medium-textured soil at high moisture content.

roots entered cracks in the cores. The recovery process was much slower for compacted cores buried in the forest than in open areas, possibly the result of less moisture and less pronounced temperature changes in the forest.

In this study we used bulk density as an index in evaluating the changes in the physical conditions of soils disturbed by logging in the lower Atlantic Coastal Plain. To estimate the period that effects persist after logging, the bulk density of surface soils was determined on disturbed and undisturbed parts of areas logged at different dates.

Methods

Long-term recovery trends for soils disturbed in logging were determined from examination of surface conditions on disturbed and undisturbed parts of 15 areas near Franklin, Va., which had been logged at different dates over a 19-year period. Plots were selected in each area to sample undisturbed soil, primary skid trails, and log decks or loading sites. Maps showed the location of skid trails and log decks on the older logging areas. Soil profiles were examined to ascertain that each area represented a single soil type.

Bulk densities of surfaces of log deck, primary skid trail, and undisturbed soil were measured in August and September 1965 using a Nuclear-Chicago P22 density probe, P21 moisture probe, and model 2800 scaler. Nine determinations per plot were made with the density probe and three per plot were made with the moisture probe. Two-thirds of the readings were taken in skid trail ruts, and the other one-third came from the middle of the skid trail. Dry density was

TABLE 1.—*Type of skidding equipment used in logging during a 19-year period on 15 logging areas and bulk densities of disturbed and undisturbed soils measured in August and September 1965*

Time of logging	Type of skidding equipment	Bulk density of surface soil		
		Log deck	Primary skid trail	Undisturbed soil
		G./cm.³	G./cm.³	G./cm.³
June-July 1965	Rubber-tired and crawler	1.35	1.43	1.00
Nov. 1964-Feb. 1965	Rubber-tired and crawler	1.59	.75	.63
June-July 1964	Rubber-tired and crewler	1.34	1.21	.85
Jan.-Mar. 1963	Rubber-tired and crawler	1.15	1.31	.83
Jan.-Mar. 1963	Rubber-tired and crawler	1.15	.98	.86
Dec. 1962-Jan. 1963	Rubber-tired and crawler	1.33	.88	.78
Nov. 1959-Mar. 1960	Crawler	1.25	.93	.82
June-Sept. 1959	Rubber-tired and crawler	1.23	1.31	.92
June-Sept. 1958	Crawler with wheel arch	1.35	1.15	1.03
May-June 1955	Crawler with wheel arch	.91	.76	.93
June-July 1954	Crawler with wheel arch	1.01	1.07	.83
Feb.-Mar. 1954	Crawler with wheel arch	.98	1.20	.95
June-Aug. 1950	Crawler with wheel arch	.99	1.10	.70
July-Aug. 1947	Crawler with wheel arch	.89	.75	.87
Mar.-May 1946	Crawler with wheel arch	1.02	.96	.96

computed as average wet density registered with the surface density probe, less the average surface moisture content expressed as grams per cubic centimeter.

Results and Discussion

Comparison of bulk densities of surface horizons of log decks, primary skid trails, and undisturbed soils on the 15 areas logged at different periods suggested that disturbed soils tended gradually to "recover" to normal, undisturbed densities (table 1). In estimating the period required for soils to recover naturally to their undisturbed densities, two assumptions were made : (1) there is a linear relationship of recovery of disturbed soils with time; and (2) all soils recover at the same rate throughout the recovery period. The texture of surface soil on the 15 logging areas was classified as follows: loam, 4 areas; silt loam, 2 areas; silty clay loam, 8 areas; and clay loam, 1 area.

Density of undisturbed soil was subtracted from the density of disturbed soil to serve as a dependent variable in regression analyses made to estimate the period for complete recovery after logging disturbance. It appears that under average conditions surface soils on log decks return to normal densities in 18 years (fig. 2). Bulk densities on log decks observed 1 to 5 years after logging were much less variable and generally higher than densities on skid trails (table 1). Concentration of skidding equipment on log decks compacted soils to uniformly high densities, whereas, some skid trails with lighter traffic were not compacted to as high a density. Although bulk density on primary skid trail minus normal soil did not show a significant correlation, the recovery trend appears to be similar to that observed for log decks (fig. 2), but additional replication would have permitted a more reliable interpretation of this relationship. Also, if the number of trips and moisture content of soil during disturbance had been known, the reliability of the estimate of recovery could have been improved because these fatcors have an important influence on the degree of compaction caused by skidding (9).

Analyses of trends toward recovery after logging disturbance were based on the hypothesis that the difference between bulk densities of disturbed and undisturbed soils is solely a function of time since logging. However, the type of skidding equipment also was related to time-crawler tractors and arches were used on the older logging areas while later logging was without arches and with rubber-tired tractors (table 1). Because the use of arches may have reduced the degree of initial disturbance (6) and since rubber-tired tractors produce a greater pressure on soil surface than do crawler tractors, a period of recovery longer than that indicated by the older logging areas may be required under current logging practices, i.e., tree-length skidding with rubber-tired

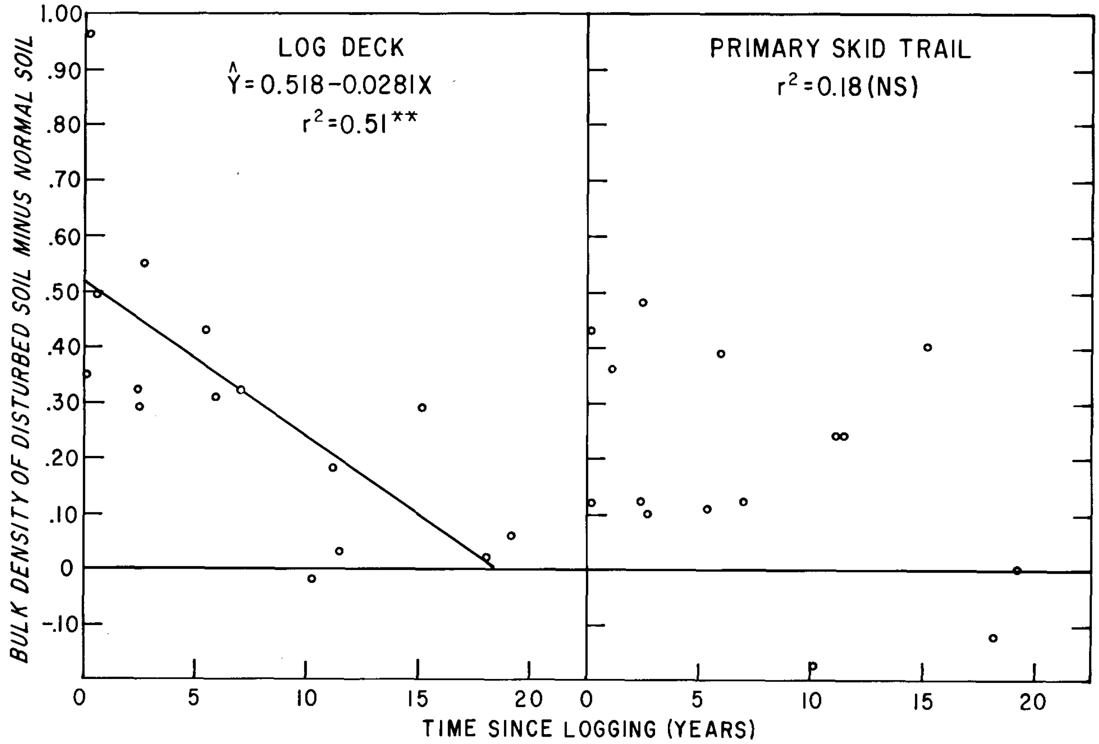

Figure 2.—Surface bulk density of disturbed soil minus normal soil density as related to time since logging.

tractors. Recovery of the most severely disturbed soils, e.g., woods roads and parts of logging areas withstanding numerous trips on wet soils, may require a much longer recovery period than 18 years. The 40-year estimate of the recovery period for an abandoned woods road made by Perry (10) appears realistic for soils having extreme disturbance.

Because recovery is slow on soils having severe disturbance in logging and because pine establishment and early growth is greatly reduced on medium- to fine-textured soils that are severely disturbed, steps should be taken to reduce such damage. In dealing with problem areas, forest managers must avoid, minimize, or correct damage effects. Development of logging plans based on trafiicability of given soils (1) and diversion of logging operations to sandy soils during wet periods are examples of the avoidance principle. Another approach is development of harvesting equipment of low-bearing pressure to minimize the compaction of soils. To reduce the area of damage on heavy soils, skidding should be concentrated on the fewest possible number of trails. Cultural measures, such as disking of log decks and primary skid trails, should reduce the recovery period required for return of natural soil conditions (8).

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