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Soil Bulk Density Recovery on Compacted Skid Trails in Central Idaho[1]

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ABSTRACT

In west-central Idaho, the bulk densities of soil in major skid trails were compared with those of adjacent undisturbed soil in order to determine rates of recovery. Five study sites on each of two soils, one formed from granitic material (mixed, frigid, Typic Xeropsamments) and the other from volcanic material (fine-loamy, mixed Dystric Cryochrepts), provided two chronosequences (five 5-yr periods) of time since logging. Bulk density was measured at 5.1-, 15.2-, and 30.5-cm depths. The percent increase in bulk density of soil on a skid trail over that on an adjacent undisturbed area was greater in the volcanic than the granitic soil, but recovery rates (slope of the regression line) for the two soils were not significantly different. Linear regression models showed a significant ($p < 0.05$) recovery trend for all depths except the 15.2-cm depth on the volcanic site. Except for the surface 5.1 cm of the granitic soil, none of the bulk densities in skid trails had returned to the undisturbed values in the 23 yr since logging.

Additional Index Words: **Inceptisols, Entisols, forest soils, logging, volcanic soils, granitic soils, soil compaction.**

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COMPACTION OF FOREST SOILS is a major effect of ground-based timber harvesting. Undisturbed forest soils typically have high porosity and low bulk density and are easily compacted by logging equipment. Compaction has been shown to have a long-term negative impact on tree growth rates (Froehlich, 1979; Wert and Thomas, 1981). However, because natural soil processes tend to slowly loosen compacted soil, the effect does not persist.

The most rapid rate of complete recovery so far reported (Mace, 1971) was 1 yr after tree-length skidding with rubber-tired skidders on relatively dry, coarse-textured soils in Minnesota. The low initial 7% increase in bulk density in the 5.1- to 15.2-cm layer on medium-use skid trails was reduced to undisturbed levels in one winter. More heavily used trails showed minimal improvment at the same depth.

Also in Minnesota, Thorud and Frissell (1976) traced the recovery of mechanically compacted sandy loam and loamy sand soils. The 0- to 7.6-cm depth recovered within 8.5 yr, but no change was detected in the 15.2- to 22.9-cm soil layer. From regression of data taken within the first several years after logging, Dickerson (1976) estimated recovery of sandy soils compacted by logging in northern Mississipi at 12 yr.

Hatchell and Ralston (1971) measured the densities of compacted and undisturbed soils on 15 areas logged over a 19-yr period in the Virginia Coastal Plain and concluded that surface soils on landings recover to undisturbed densities in 18 yr. Data from primary skid trails had greater scatter, and no statistically significant recovery trend was found. Data were taken with a surface nuclear density probe by the backscatter technique; thus, the soil depth measured was probably

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Table 1. Mean and standard deviation of soil bulk density and the percent difference between values for skid trails and undisturbed soils.

		Granitic site						Volcanic site					
		Skid trail		Undisturbed				Skid trail		Undisturbed			
Depth	Age class	x†	s	x†	s	Difference		x†	s	x†	s	Difference	
cm	yr	Mg m^{-3}					%	Mg m^{-3}					%
5.1	0–5	1.41	0.18	1.12	0.17	0.29**	25.9	1.29	0.16	0.89	0.10	0.40**	44.5
	5–10	1.42	0.19	1.28	0.13	0.20**	16.3	0.98	0.17	0.73	0.14	0.25**	34.7
	10–15	1.26	0.14	1.19	0.13	0.08NS	6.5	0.86	0.13	0.68	0.08	0.18**	25.8
	15–20	1.30	0.12	1.21	0.10	0.09*	7.3	0.98	0.18	0.71	0.11	0.26**	36.5
	20–25	1.35	0.17	1.39	0.11	−0.04NS	−3.0	0.93	0.11	0.81	0.10	0.12*	15.4
15.2	0–5	1.52	0.11	1.23	0.07	0.30**	24.2	1.43	0.18	0.98	0.12	0.45**	46.2
	5–10	1.52	0.13	1.30	0.08	0.25**	19.5	1.11	0.13	0.80	0.08	0.31**	38.0
	10–15	1.48	0.14	1.21	0.11	0.27**	22.3	0.97	0.09	0.71	0.06	0.27**	37.5
	15–30	1.45	0.13	1.26	0.13	0.18**	14.6	1.19	0.20	0.82	0.08	0.36**	44.1
	20–25	1.54	0.08	1.37	0.09	0.18**	12.9	1.06	0.11	0.84	0.07	0.22**	26.1
30.5	0–5	1.55	0.14	1.27	0.08	0.29**	22.7	1.51	0.13	1.06	0.15	0.46**	43.3
	5–10	1.57	0.13	1.36	0.10	0.21**	15.1	1.18	0.15	0.93	0.14	0.25**	26.9
	10–15	1.52	0.12	1.28	0.10	0.24**	18.7	1.11	0.12	0.80	0.13	0.32**	39.6
	15–20	1.53	0.12	1.33	0.11	0.20**	15.2	1.25	0.19	0.92	0.08	0.33**	4.8
	20–25	1.48	0.10	1.37	0.09	0.11**	7.9	1.08	0.11	1.03	0.15	0.05NS	4.8

*,** Significant at the 0.05 and 0.01 levels, respectively. NS = Nonsignificant.
† n = 18 for all samples.

only the surface 10 to 15 cm. Perry (1964) projected recovery of skid trails at about 40 yr in the North Carolina Piedmont. In the Oregon Coast Range, Wert and Thomas (1981) found that the bulk density of skid trails at 20- to 30-cm depths was significantly higher than that of adjacent undisturbed soils 32 yr after logging. The surface several centimeters of soil had apparently recovered to their original density.

The purpose of the present study was to determine the extent and rate of natural recovery from compaction on skid trails on two soils in west central Idaho. Bulk density of skid trails was compared to that of undisturbed forest soil on sites logged 1 to 23 yr before measurement.

METHODS

The project area near McCall in west central Idaho contains soils formed on granitic and volcanic material. Five study sites on each of two soil parent materials were selected, one in each of the time since logging classes 0 to 5 yr, 5 to 10 yr, 10 to 15 yr, 15 to 20 yr, and 20 to 25 yr. The granitic sites are located 24 km southeast of McCall in the Kennally Creek drainage, and the volcanic sites 32 km northwest of the McCall in the Weiser River drainage. Both are in ground-skidded partial-cut areas.

The granitic sites are on 10 to 45% slopes, elevation 1580 to 1620 m, underlain by highly fractured and highly weathered Idaho Batholith granite. The soils are a mixed, frigid Typic Xeropsamments. Vegetation is a mixed conifer forest dominated by Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], ponderosa pine (*Pinus ponderosa* Dougl.), and grand fir (*Abies grandis* Dougl.).

The volcanic sites are on 10 to 35% slopes, elevation 1280 to 1620 m, underlain by well-fractured and moderately weathered Columbia River Basalts. The soils are a fine-loamy, mixed Dystric Cryochrepts. Vegetation is a mixed conifer forest dominated by Douglas-fir, grand fir, and lodgepole pine (*Pinus contorta* Dougl.).

Six sample points were systematically located at 3.05-m intervals along each of three skid trails selected within each study site. Careful selection minimized differences in disturbance level both within and among age-class sampling. Areas with high surface rock content, buried organic matter, or evidence of excavation or piling were excluded.

Bulk density was measured within skid trails and in undisturbed areas. Measurements were taken with a double-probe nuclear densimeter (Campbell Pacific Nuclear stratagauge[3]) at three depths: 5.1 cm, 15.2 cm, and 30.5 cm. Soil moisture samples collected at each measurement location were ovendried at 105°C for 24 h in order to determine gravimetric water content; readings were used to correct bulk densities to a dry weight basis.

Differences in the absolute bulk density of skid trails and undisturbed areas were the criteria used to characterize soil recovery. Paired t-tests were conducted to detect these differences for both soils at each depth.

Regression analysis was used to determine evidence of recovery from compaction over time. The percent increase in bulk density of soil on a skid trail over that on the adjacent undisturbed area was analyzed as a function of age since logging. Linear models were tested for each depth and soil. Analysis of variance was used to determine whether volcanic and granitic sites showed different responses to compaction.

RESULTS AND DISCUSSION

The percent difference between bulk density of soils in skid trails and undisturbed areas varied among age classes and depths on both soils. The average bulk density values for each of the five age classes are shown in Table 1. Soil on the granitic site showed highly significant differences ($p < 0.01$) for all age classes and depths except the three oldest classes at 5.1 cm. The volcanic site also showed highly significant differences for nearly all ages and depths. The chronological trend in the percent difference (Fig. 1) shows that, despite low R^2 values, time since logging is significantly ($p < 0.05$) related to difference in bulk density of both soils at all depths except 15.2 cm in the volcanic site, for which the slope of regression line was not significantly different from zero. Curved and linear models were tested for each depth and soil, but linear models were more significant.

Analysis of variance showed that the difference in

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[3] Mention of trade names does not constitute endorsement by Oregon State University to the exclusion of other products that may be suitable.

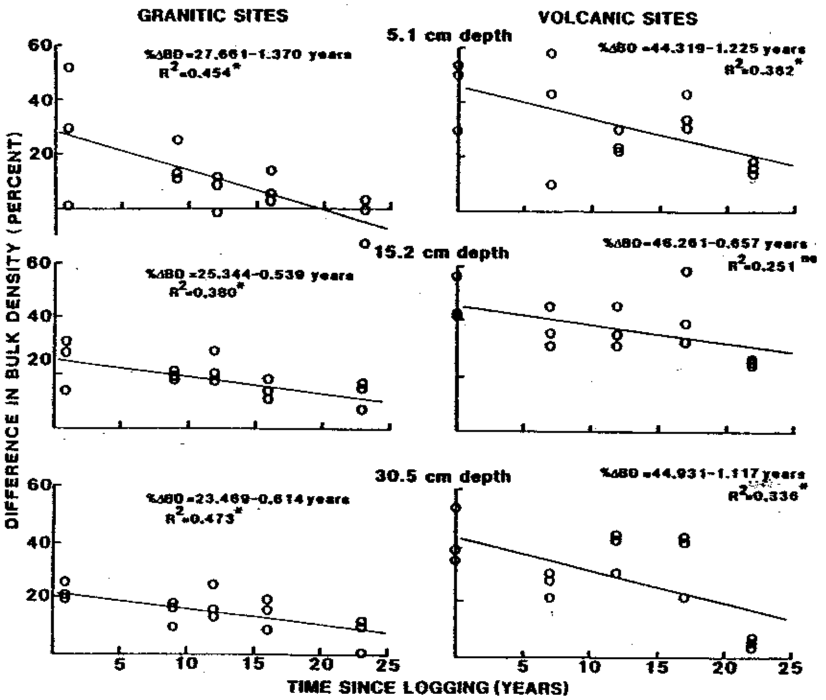

Fig. 1. The percentage difference in bulk density of soils (% BD) in skid trails and in undisturbed areas related to the number of years since logging on granitic and volcanic sites (NS indicates nonsignificant and * indicates significant at the 0.05 level).

density of skid-trail and undisturbed soil was significantly greater ($p < 0.01$) in the loam-textured soil formed on volcanic material than the loamy sand-textured soil formed on granitic material (Table 1).

The influence of soil type on rate of recovery from compaction was also tested by comparing the regression equations developed for each combination of soil and depth. Such comparisons provide a means to determine differences between the initial compaction level and recovery rates of the two soils. The initial percentage difference in bulk density of skid-trail and undisturbed soils was significantly greater for the volcanic site than for the granitic site. Initial percentage increase in bulk density after compaction on the volcanic site was nearly twice that found on the granitic site; however, no significant differences were found between recovery rates (slope of the regression lines) of the two soils.

Only the 5.1-cm depth on the granitic site recovered within the time frame measured. The slopes of the regression lines indicate that recovery of the surface layer is faster than at the 15.2- and 30.5-cm depths. Thorud and Frissell (1976), and Wert and Thomas (1981) also reported earlier recovery at the soil surface than at greater depths. The volcanic site is expected to take longer than the granitic site to recover from soil compaction because of greater initial level of compaction and nonsignificantly different rates of recovery.

Despite some differences in soil type and differences between depths, the soils in this study clearly are very slow to recover from soil compaction. Given the long-term tree growth losses caused by soil compaction (Froehlich, 1979; Wert and Thomas, 1981) and slow natural recovery rates, a method of minimizing the effect of soil compaction is appropriate. Minimizing the area covered by skid trails and tilling to loosen the soil are possible alternatives for retaining or restoring forest soil productivity.

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