



1-31-1988

Potential soil compaction forty years after logging in northeastern California

Robin S. Vora

U.S. Fish and Wildlife Service, Brunswick, Georgia

Follow this and additional works at: <https://scholarsarchive.byu.edu/gbn>

Recommended Citation

Vora, Robin S. (1988) "Potential soil compaction forty years after logging in northeastern California," *Great Basin Naturalist*: Vol. 48 : No. 1 , Article 17.

Available at: <https://scholarsarchive.byu.edu/gbn/vol48/iss1/17>

This Article is brought to you for free and open access by the Western North American Naturalist Publications at BYU ScholarsArchive. It has been accepted for inclusion in Great Basin Naturalist by an authorized editor of BYU ScholarsArchive. For more information, please contact scholarsarchive@byu.edu, ellen_amatangelo@byu.edu.

POTENTIAL SOIL COMPACTION FORTY YEARS AFTER LOGGING IN NORTHEASTERN CALIFORNIA

Robin S. Vora¹

ABSTRACT.—Surface-bearing pressure in newer logging skid trails compared to the 40+-year-old trails was approximately 60% greater as measured by a cone penetrometer. Surface soil compaction from tractor skidding may last 40 years or more, as evidenced by the fact that skid trails of that age were 20% more resistant to the penetrometer than areas adjacent to trails. No relationship was found between dry-bulk density (measured with a balloon apparatus) and surface-bearing pressure.

The resistance of the soil surface to root penetration will affect the ability of a newly germinated seedling to survive. Root-penetration resistance is a function of soil density. Soil-bearing pressure can be correlated to root-penetration resistance because bearing pressure is also a function of soil density, as well as other factors, including moisture content, soil type, and strength parameters of friction and cohesion (Ayers and Perumpral 1981).

Alexander (1985) stated that soil compaction is an increase in the density of a soil as the result of applied loads or pressure. A potential consequence of soil compaction could be reduced site productivity. Increases in soil bulk density can result in physical barriers to root penetration, reduced gaseous transfer (soil aeration), and reduced availability of water and nutrients to the roots. Soil compaction can also produce hydrologic impacts such as reduced infiltration capacity, decreased hydraulic conductivity (subsurface permeability), and reduced soil moisture retention. Peak surface water flows can increase, thus increasing surface erosion and topsoil loss.

In a study on the Tahoe National Forest (200 km S of Blacks Mountain), Froehlich et al. (1980) found that soil densities increased rapidly during the first few passes of any loaded logging equipment, with 60% of the compaction occurring after 6 trips. The increase in soil density after 20 trips was accompanied by a 43% reduction in soil macroporosity, an 80% reduction in saturated hydraulic conductivity, and a 67–78% reduction in

water infiltration capacity. Air permeability of the surface soil decreased rapidly during the first few passes of the machines. Soil compaction, or change in bulk density, in that experiment was described by a regression equation that included an exponential expression for number of trips and a second term for soil-penetration resistance; these two variables defined 54% of the variance in the density data.

There is a negative correlation between seedling height growth and soil density for several conifer species (Froehlich and McNabb 1984). In a later study also on the Tahoe National Forest, Helms and Hipkin (1986) found that soil bulk density increased by 43, 30, and 18% on a landing, a skid trail, and areas adjacent to skid trails, and mean tree volume and initial survival volume per unit area were reduced by 69, 55, and 13%, respectively. Trees in areas of highest bulk density grew 43% less at age 1 and 13% less at age 15 than those in areas of lowest bulk density.

The eastside pine type of northeastern California contains numerous stands of timber that have been logged over the past 40 years. Skid trails are prominent in both the older and the more recent cuts; often relatively few conifers are growing in the skid trails. Reasons for this may include soil compaction from logging activity, seed periodicity and timing in relation to ground disturbance associated with that activity, climatic factors, biotic factors (seed-eating rodents), ground cover, and competition by other vegetation. An exploratory study was conducted to see if soil

¹U. S. Fish and Wildlife Service, Room 334, Federal Building, Brunswick, Georgia 31520.

compaction could be a reason for slow recovery of logging skid trails in the eastside pine type of northeastern California.

STUDY AREA

The Blacks Mountain Experimental Forest, located in the eastside pine type of northeastern California (Fig. 1), contains experimental units harvested under various cutting methods. Some units were cut about 40 years ago (Hallin 1959), and others were cut and thinned during the past 5–10 years. Four of these units were studied, and these are hereafter designated by year of cutting and an identifying number. Timber harvest on two of them was undertaken in 1939 and 1942, with 80% of all trees larger than 30 cm diameter-breast-height (dbh) removed; there has been no use of the skid trails in those units since that time. In the other two units, all trees larger than 46 cm dbh were removed in 1979–80. Elevations ranged between 1,750 and 1,875 m. Slopes were 0–15%, with northwest aspects. Mean annual precipitation varied from 23 to 74 cm and averaged 46 cm during the period 1935–53 (Hallin 1959). Soils in the four units were similar. Storie et al. (1940) described the soils as being a reddish brown loam with a granular surface structure and neutral in reaction. The subsoil was clay loam. The texture was stony loam, with most of the soils being shallow—15–45 cm to lava bedrock, and possibly up to 90 cm deep in parts of one unit (39-6).

METHODS

A 30° cone penetrometer was used to estimate bearing pressure. The cone had a diameter of 2.715 cm and a height of 5.067 cm. The penetrometer was pushed into the ground to the base of the cone and pressure on the scale was recorded. The scale reading was correlated with known weights on a cement floor in a laboratory and the following equation was developed:

Bearing pressure (kg/cm^2) = $-0.14 + 1.29 \times (\text{scale reading})$ ($R^2 = .997$, $\text{MSE} = 2.03$, $n = 16$).

In-place soil bulk density was measured with a rubber-balloon apparatus (AASHTO 1978 Test Method T-205—density of soil in-place by rubber-balloon method). Soil was

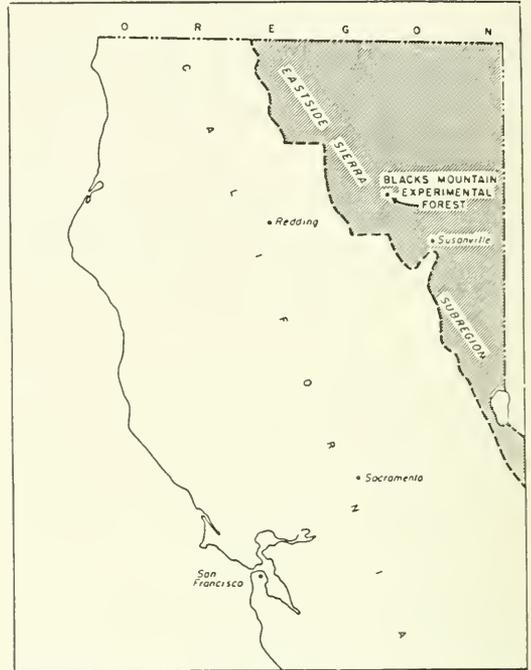


Fig. 1. Location of Blacks Mountain Experimental Forest and the eastside Sierra subregion in northern California (Hallin 1959). Copied with permission of the U.S. Forest Service.

scooped out of a hole 12–16 cm deep and weighed. It was later dried in the lab at 105 C for 24 hrs. The difference in weights was divided by the dry weight to calculate moisture content. The volume of the hole was estimated using a balloon filled with water. The volume of water needed to fill the balloon was recorded. Wet and dry in-place densities of the soil were calculated.

Cone penetrometer readings were taken on and off the skid trails in each of the four units by random wandering throughout the units. Between 30 and 53 points were measured in each unit on skid trails, and the same number were taken in undisturbed areas.

Bulk density and soil moisture were measured at sample points in two of the old units and in the 1980 logging site (39-6, 42-2, and 80T-1). Three points were located in skid trails and three in adjacent, undisturbed areas in each unit. These plots were located 120–150 m from the landing (about one-third of the average maximum skidding distance). Moisture content was estimated at these 18

points and in a similar manner at 6 additional points in the fourth unit (79T-1). Penetrometer readings were taken at each of these bulk density points. Average soil moisture content was 20% (range 11–26%) in August 1984 when the field work was done. Correlations between penetrometer readings and bulk density estimates were analyzed with regression analysis. Potential impacts of tractor skidding and time since skidding on bearing pressure, bulk density, and soil moisture content were examined by an exploratory two-way Analysis of Variance (ANOVA) (SAS 1982). The independent variables were bearing pressure, bulk density, and soil moisture; and the dependent variables were tractor skidding (on and off skid trail), time since skidding activity (40 or 5 yrs), and interaction between these two variables. The residuals were tested for the null hypothesis that they were a random sample from a normal population, using the Shapiro-Wilk statistic, *W*. The probability $< W$ ranged between 0.62 and 1.0 for the dependent variables (i.e., they were normally distributed). The interaction between tractor skidding and time since skidding was insignificant for the three variables ($P = .07-.82$).

RESULTS AND DISCUSSION

No relationship was found between dry-bulk density (measured with a balloon apparatus) and surface-bearing pressure (measured with a cone penetrometer); the coefficient of determination (R^2) was calculated at 0.015 ($P = .63$). The sample size of 17 was too small to make any definite conclusions. The penetrometer was not measuring bulk density to the same depth as the balloon apparatus; thus it is likely that surface compaction, measured by the penetrometer, may differ from that measured when a portion of the subsurface is included (balloon apparatus).

Mean bulk density on skid trails was 0.98 g/cm^3 (0.88–1.20 g/cm^3), and 0.81 g/cm^3 (0.77–0.85 g/cm^3) off skid trails. ANOVA did not show these differences to be significant ($P = .25$) for this small sample.

Froehlich et al. (1980) suggest that compaction should be measured as the average change in density in the surface 20 cm when the concern is for planted seedlings. That volume of soil serves as their root environment

TABLE 1. Effect of tractor skidding on bearing pressure.

Analysis of variance (SAS 1982)			
Source	df	F value	P>F
Skid trail	1	7.35	0.04 (significant)
Age of cut	1	3.02	0.14

for several years and provides the principal nutrient stores for feeder roots of older trees as well. The balloon apparatus is better than the penetrometer for estimating bulk density to 20 cm depth, and it is actually measuring in-place bulk density. The penetrometer gives an approximate measure of soil-bearing pressure, which is only partially a function of soil density. Measurement of penetrometer resistance to a depth of 15–20 cm may have provided a basis for comparing bearing pressure (soil strength) with bulk density (H. A. Froehlich, Oregon State University, personal communication 21 November 1985).

There was no planting done in the experimental units. Surface compaction would impact natural establishment of plants from seed, and this is perhaps better measured with the penetrometer. Penetrometer resistance in the newer trails compared to the 40+-year-old trails was approximately 60% greater (5.01 vs. 3.06 kg/cm^2). However, an ANOVA test did not show this difference (age of cut) to be significant ($P = .14$), a result of having performed only two replications of each main effect (Table 1).

ANOVA test results were significant only for the effect of tractor skidding on bearing pressure ($P = .04$, Table 1). Again, sample sizes were not large enough for this to be a confirmatory test. The 95% confidence limits for bearing pressure (kg/cm^2) overlapped (Table 2):

On skid trail: 4.03 $kg/cm^2 \pm 2.04$ kg/cm^2 (1.99–6.07)

Off skid trail: 2.52 $kg/cm^2 \pm 0.22$ kg/cm^2 (2.30–2.74)

It also remains to be shown whether an increase in surface-bearing pressure from 2.5 kg/cm^2 to 4.0 kg/cm^2 is significant from the standpoint of natural plant establishment. Even after 40 years the older trails were approximately 20% more resistant to the penetrometer than areas adjacent to trails (Table 2, units 39-6 and 42-2).

TABLE 2. Bearing pressures based on penetrometer readings.

Experimental unit	Off skid trail			On skid trail		
	n	Mean (kg/cm ²)	Std. dev.	n	Mean (kg/cm ²)	Std. dev.
39-6	30	2.64	0.96	30	2.56	0.69
42-2	51	2.41	0.96	51	3.56	1.72
80T-1	49	2.35	1.14	49	4.44	1.73
79T-1	53	2.65	0.91	53	5.58	2.02
Mean of units	4	2.52	0.14	4	4.03	1.28

ACKNOWLEDGMENTS

I am very grateful to Earl Alexander, Gordon Keller, and Robert Powers of the U.S. Forest Service, Henry Fröhlich of Oregon State University, and John Helms of the University of California at Berkeley for their assistance.

LITERATURE CITED

- AASHTO. 1975. Standard method of test for density of soil in-place by the rubber-balloon method. AASHTO: T205-64(1974).
- ALEXANDER, E. B. 1985. Principles and review. Pages 1-74 in *Soil disturbance and compaction in wildland management*. USDA For. Serv., Region 5, Earth Res. Monogr. 8.
- AYERS, P. D. AND J. V. PERUMPRAL. 1981. Moisture and density effects on cone index. Amer. Soc. Agric. Engineers summer meeting. Paper No. 81-1047. St. Joseph, Michigan. 15 pp.
- FROELICH, H. A., J. AZEVADA, P. CAFFERATA, AND D. LYSNE. 1980. Predicting soil compaction of forested land. Final Project Rept. under Coop. Agreement 22S, USDA U.S. For. Serv. PNW and Missoula Equipment Development Center. 120 pp.
- FROELICH, H. A. AND D. H. McNABB. 1984. Minimizing soil compaction in Pacific Northwest forests. Pages 159-192 in E. L. Stone, ed., *Forest soils and treatment impacts*. Dept. For., Wildl., and Fish., University of Tennessee, Knoxville.
- HALLIN, W. E. 1959. The application of unit area control in the management of ponderosa-Jeffrey pine at Blacks Mountain Experimental Forest. USDA For. Serv., Washington, D.C. Tech. Bull. 1191. 96 pp.
- HELMS, J. A., C. HIPKIN, AND E. B. ALEXANDER. 1986. Effects of soil compaction on height growth of a California ponderosa pine plantation. *Western J. Appl. For.* 1(4): 104-108.
- HELMS, J. A. AND C. HIPKINS. 1986. Effects of soil compaction on tree volume in a California ponderosa pine plantation. *Western J. Appl. For.* 1(4): 121-124.
- MCDONALD, P. M. 1983. Climate, history, and vegetation of the eastside pine type in California. Pages 1-16 in T. F. Robson and R. B. Standiford, eds., *Management of the eastside pine type in northeastern California*, proceedings of a symposium. N. California Soc. Amer. For. SAF 83-06. Arcata, California.
- ROY, D. F. 1983. Natural regeneration. Pages 87-102 in T. F. Robson and R. B. Standiford, eds., *Management of the eastside pine type in northeastern California*, proceedings of a symposium. N. California Soc. Amer. For., SAF 83-06. Arcata, California.
- STATISTICAL ANALYSIS SYSTEM (SAS). 1982. *SAS user's guide: statistics*. 1982. 3d edition. SAS Institute Inc., Cary, North Carolina. 545 pp.
- STORIE, R. E., W. W. WEIR, AND R. C. COLE. 1940. Soil survey of Blacks Mountain Experimental Forest. Div. of Soils, University of California at Berkeley. On file at USDA For. Serv., PSW Expt. Sta., Redding, California.