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Soil Compaction and Initial Height Growth of Planted Ponderosa Pine

P. H. Cochran and Terry Brock

Abstract

Early height growth of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) seedlings planted in clearcuts in central Oregon was negatively correlated with increasing soil bulk density. Change in bulk density accounted for less than half the total variation in height growth. Although many other factors affect the development of seedlings, compaction has reduced the rate of height growth.

Keywords: Soil compaction, soil bulk density, increment (height), ponderosa pine.

Introduction

Soil compaction during logging and related operations and subsequent reduction in tree growth is a continuing concern among land managers. Pertinent issues include the degree of compaction from use of certain types of equipment on different soil types under varying soil water contents, the length of time necessary for a compacted soil to return to the noncompacted condition, and the reduction in productivity related to the compaction.

This note reports rates of height growth for ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) seedlings planted in two clearcuts with varying degrees of compaction at individual planting sites. Cause of the compaction is not known.

The Study Area

The two small clearcuts (9.3 and 10.5 ha in size with closest edges between clearcuts about 67 m apart) were part of the Switchback Timber Sale administered by the Sisters Ranger District, Deschutes National Forest. They are located in sections 3 and 4, T12S, R9E, Willamette Principal Meridian. The topography slopes gently to the south; slopes exceed 3 percent in only 10 percent of the area. The mean annual precipitation is 100 cm, and the mean annual temperature is 6 °C. The soil is a deep, well-drained mountain soil formed from old Mount Jefferson ash 50 to 60 cm thick over residuum or colluvium from volcanic rocks. A soil survey of the area is underway, and this soil has been tentatively classified as a fine loamy mixed Andeptic Cryoboralf.

In creation of the clearcuts, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.), and ponderosa pine were first removed. Skidding and yarding was done between February and April 1974; slash was piled by use of tractors in late fall 1974. Incense-cedar (*Libocedrus decurrens* Torr.) and other stems infected by mistletoe were removed in 1977. Slash from this second entry was piled in the fall and winter of 1977, and 2-0 ponderosa pine seedlings were planted on a 2.4- by 2.4-m spacing in the spring of 1978. Seedlings were protected from animals

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P. H. COCHRAN is a soil scientist, Silviculture Laboratory, Pacific Northwest Forest and Range Experiment Station, 1027 N.W. Trenton Avenue, Bend, Oregon 97701. TERRY BROCK is a soil scientist, Deschutes National Forest, Pacific Northwest Region, Bend, Oregon.

by cages of rigid vexar placed around the seedlings in the fall of 1978. An examination of the plantation in March 1981 indicated that the vexar cages were in poor condition, and they were removed in the fall of 1981.

Methods

Maps of the two clearcuts were gridded, and 19 grid intersects (12 in clearcut 1 and 7 in clearcut 2) were randomly picked as starting points for a sampling transect. The direction of each transect was then established by randomly choosing an azimuth.

The selected grid intersects were located in the field by pacing, and a 30.5-m tape was laid out in the azimuth direction. All planted trees within a distance of 1.2 m perpendicular to the tape were measured for total height. None of the transects intersected, and no tree was measured twice. Length of the leaders for 1983 and internode lengths for 1982 were also measured. Damage from vexar cages distorting the main stem was also recorded as absent (1), low (4), moderate (7), or high (11); the numbers expressed the estimated degree of damage. A bulk density sample centered 15 cm from the base of the seedling toward the tape was taken from the 10- to 20-cm depth by use of a cylinder 10 cm in diameter and length. Samples were ovendried at 105 °C for at least 48 hours and were weighed with rocks and without.

Ten additional bulk density samples were taken at the 10- and 20-cm depth in undisturbed locations within 9 m of the borders of the clearcuts. Four samples were taken around clearcut 1 and six samples around clearcut 2; these samples were processed like the samples taken next to the seedlings.

An adjusted bulk density for each sample was determined by first calculating the volume of the rock in the sample from the weight of the rock and its particle density (2.64 g/cm^3). The adjusted bulk density is the dry weight of the soil without rocks divided by the cylinder volume minus the volume of rocks. Total heights, periodic annual height growth for 1982 and 1983, adjusted bulk density, and vexar damage were averaged for each transect. Multiple weighted regression techniques were then used to relate average height and average height growth for each transect to the average adjusted bulk density and the average vexar damage for that transect. Weighted regressions were used because each transect did not have the same number of trees because of mortality. Weights for each average transect value were the number of trees measured for that transect.

Results

No relationship was found between estimated damage caused by the vexar cages and either total height or height growth for the 1982 and 1983 growing seasons. Many of the stems were distorted in the first 30 cm of height by the vexar cages, and susceptibility to snow breakage in the future should be monitored.

Bulk density values for the 10 samples taken in undisturbed areas adjacent to the clearcuts ranged from 0.99 to 1.07 g/cm^3 and averaged 1.02 g/cm^3. When the sample values were adjusted for rock content, the range was 0.81 to 0.94 g/cm^3, and the average was 0.88 g/cm^3.

On the 19 transects in the clearcuts, 77 samples were taken next to seedlings that were measured for total height and height growth for 1982 and 1983. Detrimental compaction (Howes and others 1983) is here regarded as more than a 15-percent increase in soil bulk density. By this standard, unadjusted bulk densities greater than 1.17 g/cm^3 (1.02 g/cm^3 x 1.15) and adjusted bulk densities greater than 1.01 g/cm^3 (0.88 g/cm^3 x 1.15) are considered detrimental. Of the 77 unadjusted samples 34 (44.2 percent) were greater than 1.17 g/cm^3, and of the adjusted samples 29 (37.7 percent) were

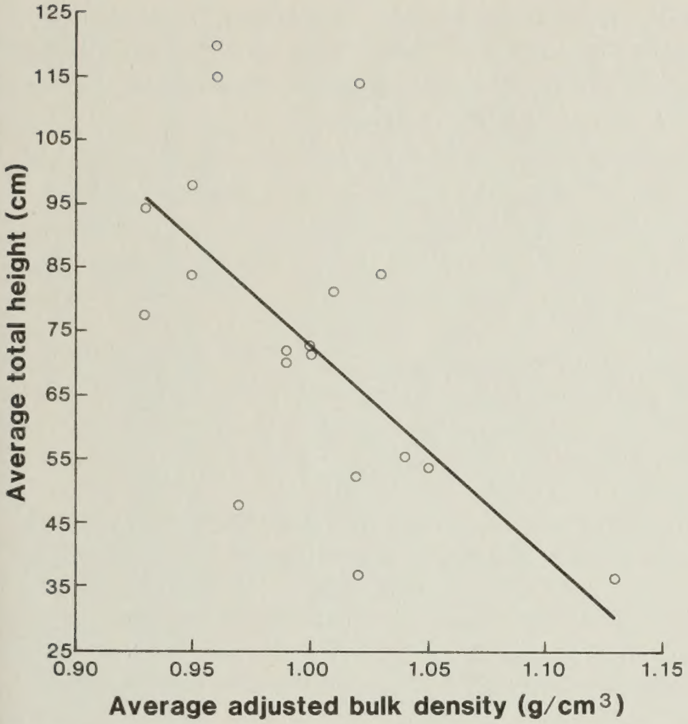

Figure 1.—Average total height vs. average adjusted bulk density for each of the 19 transects. Weighted regression techniques were used to calculate the regression.

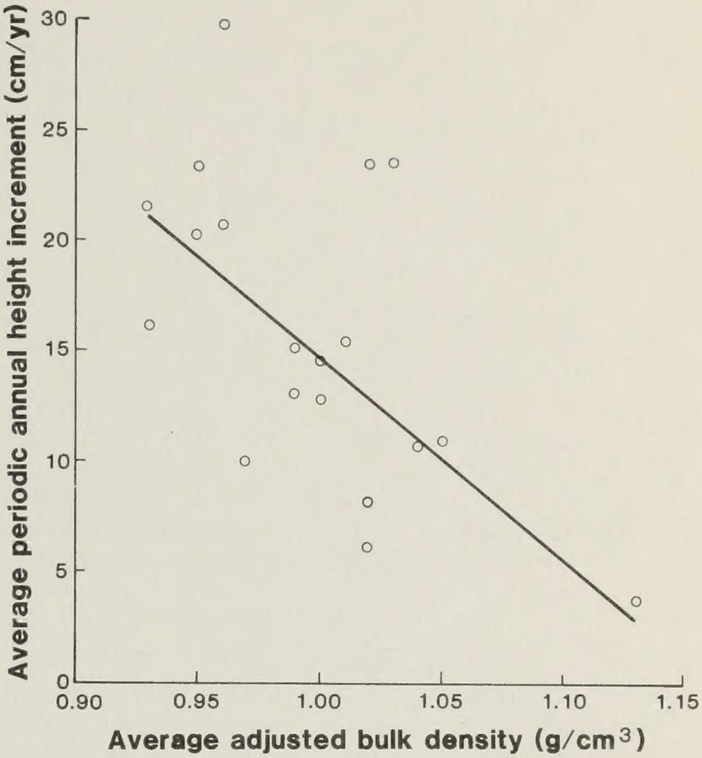

Figure 2.—Average periodic annual height increment during 1982 and 1983 vs. average adjusted bulk density for each of the 19 transects. Weighted regression techniques were used to calculate the regression.

greater than 1.01 g/cm³. Of the 19 transects 7 (36.8 percent) had average unadjusted bulk densities greater than 1.17 g/cm³ and average adjusted bulk densities greater than 1.01 g/cm³.

Total height and periodic annual height growth for 1982 and 1983 were negatively correlated with increasing values of adjusted bulk densities (figs. 1 and 2) and unadjusted bulk densities. All the regressions expressing these correlations are statistically significant at the 5-percent level of probability even though the r^2 values are 0.5 or less (table 1). The low r^2 values for these regressions indicate that other factors influenced total height and height growth besides bulk density. The nature of these factors and their influence on height growth are subject to speculation; however, the significance of the regressions shows that soil compaction has reduced the height growth of the trees.

Table 1—Equations expressing average total height in centimeters (y_1) or average periodic annual height increment for 1982 and 1983 in centimeters (y_2) as functions of average unadjusted bulk density (x_1) and average adjusted bulk density (x_2) for the 19 transects

Equation	r^2	Standard error
		Centimeters
$y_1 = 441.6 - 321.96\,x_1$	0.50	32.57
$y_1 = 401.5 - 328.80\,x_2$	.43	35.04
$y_2 = 107.8 - 81.17\,x_1$	.46	8.93
$y_2 = 105.7 - 90.98\,x_2$	.47	8.86

Conclusion

Compaction, measured by changes in soil bulk density, reduced height growth for the 5-year period after planting. The scatter of the data points caused by the influence of unmeasured variables tends to mask the influence of compaction, but the negative influence of compaction is real. How long the negative influence will continue is unknown. An additional study, planned to test the effect of tillage of compacted areas on growth rates, will also attempt to determine the length of time growth rates are reduced on compacted areas that are not tilled.

Metric and English Units of Measure

When you know:	Multiply by:	To find:
Centimeters (cm)	0.394	Inches
Grams per cubic centimeter (g/cm^3)	62.4	Pounds per cubic foot
Hectares (ha)	2.469	Acres
Celsius (°C)	1.8 then add 32	Fahrenheit (°F)

Literature Cited

Howes, Steve; Hazard, John; Geist, Michael J. Guidelines for sampling some physical conditions of surface soils. R6-RWM-145. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; **1983.** 34 p.