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Yarding-Method and Slash-Treatment Effects on Compaction, Humus, and Variation in Plantation Soils

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Abstract

Soil penetration-resistance and soil-humus frequency were measured on 86 progeny-test plantations in southwestern Oregon to determine the effects of yarding method and slash treatment on soil compaction and humus, and a disturbance index was calculated for each plantation. Compaction and humus loss were more severe on tractor-yarded, machine-piled plantations than on cable-yarded, broadcast-burned plantations. Machine piling and burning of slash did not increase compaction or humus loss significantly more than broadcast burning on tractor-yarded plantations. Within-plantation variation in soil compaction was greater on tractor-yarded, broadcast-burned plantations than on tractor-yarded plantations from where stumps were removed.

Keywords: Yarding method, slash treatment, soil compaction, organic matter, disturbance.

Introduction

Harvest of a forest stand always affects the soil, but those effects vary with the yarding method used. Subsequent slash disposal to reduce fire hazard and prepare the harvested area for planting also affects the soil to a greater or lesser degree, depending upon the methods used. Because plantation survival and growth may be affected, comparisons of the effects of yarding methods and slash treatments on soil are important. Such comparisons are common in the literature, but most of them involve either yarding methods or slash treatments in isolation and not the combination of yarding method followed by slash treatment that usually occurs during the conversion of a mature stand to a plantation.

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Krag and others (1986) used exposed mineral soil as an index of soil disturbance and found that disturbance was significantly greater on ground-skidded than on cable-yarded cutovers in southeastern British Columbia. Tractor yarding compacted a greater area than cable yarding in a study conducted in the Oregon Cascades, and the compaction was greater on areas affected by tractor than those affected by cable yarding (Dyrness 1965). Cable-yarding systems in which the entire length of a log is in contact with the soil during transport may not cause major reductions in infiltration capacity or major increases in soil bulk density (Cummins and others 1984), but they tend to disturb surface soil and remove humus. Heavy equipment may compact soils by vertical loading and may modify soil-surface characteristics by mixing and altering the thickness of the A-horizon (Helms and Hipkin 1986). The soil compaction is long lasting (Froehlich 1979, Froehlich and others 1985, Wert and Thomas 1981).

Slash is usually broadcast burned or machine piled and burned in the Pacific Northwest. Broadcast burning affects the soil surface by removing organic matter (Austin and Baisinger 1955, Little and others 1986). More than the surface may be affected when slash is machine piled before burning, however, and substantial quantities of topsoil may be piled along with the slash (Glass 1976); underlying soil in the B-horizon may be exposed and compacted by the tractors used. In extreme cases, where minimum soil variation and uniform spacing are sought for progeny-test plantations—used for identifying superior seedlings—even stumps are removed during the machine-piling operation. Stump removal is controversial, however, and some plantation owners think that soil variation is increased, not decreased, by removing stumps in a progeny-test plantation.

We measured soils on many progeny-test plantations in western Oregon during a 5-year study of the effects of yarding method and slash treatment on plantation growth, and the results presented here are based on 3 years of field work. Our objectives were limited to soil effects in this portion of the study. They include a comparison of several common yarding and slash treatment combinations to determine which (if any) differ with respect to soil compaction and humus, to assess the effect of stump removal on soil variation, and to create a disturbance index that may be useful in relating the effects of yarding and slash treatment to plantation growth.

Methods

The soil-compaction and soil-humus data presented here were obtained on progeny-test plantations in Coos, Curry, Douglas, Jackson, and Josephine Counties, Oregon, between June 1984 and June 1987. All plantations measured during that period were classified by yarding method and slash treatment. Four yarding-slash treatment categories with more than 10 plantations per class were selected for comparison: cable yarding plus broadcast burning (26 plantations), tractor yarding plus broadcast burning (15 plantations), tractor yarding plus machine piling and burning (31 plantations), and tractor yarding plus machine piling and burning plus stump removal (14 plantations). More detailed variations in yarding method and slash treatment (that is, designated skid trails versus logger's choice and machine piling onsite versus machine piling offsite) were ignored in establishing these categories.

Soil compaction was measured indirectly by sampling with a proving ring penetrometer to determine the average soil penetration-resistance on each plantation. Soil resistance to penetration is increased by compaction (Donnelly and Shane 1986). Total penetration-resistance encountered in the top 20 centimeters (8 in) was determined at 150 to 200 systematically located points on each plantation. Average rock-free resistance on each plantation was adjusted for differences in soil texture and season of measurement with the method described by Minore (1986), and the plantation averages thereby obtained were used in calculating a mean soil penetration-resistance for each yarding-slash treatment category.

Within-plantation variation in penetration resistance was compared among treatment categories with a slightly modified version of Levine's test (Snedecor and Cochran 1980). A mean absolute deviation was computed for the rock-free penetration resistance measurements obtained on each plantation. Those mean absolute deviations were then analyzed in a one-way analysis of variance. Tukey's procedure was used to isolate differences among treatments.

The presence or absence of humus in the top 20 centimeters (8 in) of soil was determined at every penetrometer sampling point by examining the color of the soil on the flat top of the penetrometer cone after each measurement of soil resistance. If any of that soil was darkened by organic matter, humus was judged to be present. Humus frequency was calculated for each plantation by summing the number of points containing humus, dividing that sum by the total number of points, and expressing the result as a percentage. A mean soil-humus frequency was then calculated for each yarding-slash treatment category.

A disturbance index was calculated for each plantation by dividing the average penetration-resistance by humus frequency and multiplying the result by 100:

$$\text{Disturbance index} = \frac{\text{average penetration-resistance}}{\text{humus frequency}} \times 100.$$

Humus frequencies were transformed to arc sines. Completely random analyses of variance were then used to compare the four yarding-slash treatment categories with respect to mean soil penetration-resistance, humus frequencies, and disturbance indexes. When the analyses of variance demonstrated significant differences among means (significant F values at $P < 0.05$), Tukey's HSD test was used for pairwise multiple comparisons.

Mean soil penetration-resistance differed significantly ($P<0.01$) among the four yarding-slash treatment categories (table 1). Cable yarding plus broadcast burning resulted in less compaction than tractor yarding plus machine piling. The tractor-yarded categories did not differ significantly among themselves with respect to penetration resistance, however; machine piling and even stump removal resulted in only small increases in penetration resistance on plantations that had been yarded by tractor.

Within-plantation variation in penetration resistance also differed significantly among the categories listed in table 1 ($P<0.05$). The tractor-yarded, broadcast-burned plantations had significantly more variation in soil penetration-resistance than the tractor-yarded, machine-piled-and-burned plantations from which stumps were removed ($P<0.05$).

Humus frequency declined with treatment intensity, and the percentages shown in table 1 differ significantly among categories ($P<0.01$). Plantations that were cable yarded and broadcast burned retained significantly more humus than those that were tractor yarded and machine piled ($P<0.05$).

Disturbance indexes, like the penetration-resistance means and humus frequencies used in constructing them, differed significantly among categories ($P<0.01$). They increased with yarding and slash-burning intensity and indicate that the soil on tractor-yarded, machine-piled plantations was significantly more disturbed than the soil on cable-yarded, broadcast-burned plantations ($P<0.05$).

Table 1—Effects of yarding method and slash treatment on soil penetration-resistance and its variation, soil-humus frequency, and a disturbance index^a

Yarding method and slash treatment	Mean soil penetration- resistance	Mean within-plantation variation in penetration-resistance	Soil- humus frequency	Disturbance index	Plantations
	<i>Kilograms per square centimeter^b</i>	<i>Kilograms per square centimeter^b</i>	<i>Percent</i>		<i>Number</i>
Cable yarding + broadcast burning	9.98a	4.24ab	84.2a	11.97a	26
Tractor yarding + broadcast burning	11.83ab	4.42a	74.7ab	16.83ab	15
Tractor yarding + machine piling and burning	12.74b	4.02ab	66.2b	22.65bc	31
Tractor yarding + machine piling and burning + stump removal	13.19b	3.26bc	56.4b	29.77c	14

^a Based on 150 to 200 systematically located measurement points on each plantation. Values in the same column followed by a different letter are significantly different ($P<0.05$).

^b To convert to pounds per square inch, multiply by 14.223.

Conclusions

Cable yarding results in less soil compaction than tractor yarding, and broadcast burning of slash results in less soil compaction than machine piling of slash. If tractors are used in yarding, however, the resulting soil compaction is usually great enough to make subsequent differences in slash treatment insignificant with respect to further compaction. Nevertheless, some slash treatments do remove significant amounts of humus, and both machine piling and stump removal result in the redistribution and probable loss of large amounts of soil organic matter.

Tractor yarding followed by broadcast burning increases the variation in soil density within a plantation. Tractor yarding followed by machine piling and stump removal decreases that variation. Stump removal, therefore, may be a useful tool if plantation uniformity is desired without regard to probable site degradation. That uniformity is attained by decreasing the number of uncompacted growing sites, however, and it may be undesirable if optimal seedling growth is desired.

Soil disturbance is accompanied by compaction and loss of humus. The index presented here combines these variables to express the amount of disturbance in a single number that can be used to compare disturbed areas. This index should be useful in relating soil disturbance to seedling growth.

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