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Soil Surface Condition

Following Tractor and High-Lead Logging in the Oregon Cascades

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Abstract. Soil surface condition and bulk density were investigated after tractor and high-lead logging. Surface area of four clearcut units was classified into four disturbance classes. High-lead and tractor areas had about the same proportion of the slightly disturbed and deeply disturbed classes (approximately 23 percent and 9 percent, respectively). The tractor-logged area had about three times more area within the compacted class than did the high-lead (27 vs. 9 percent) and a corresponding decrease in the amount in the undisturbed class (36 percent of the tractor area vs. 57 percent after high-lead logging). Surface soil bulk densities of samples from undisturbed and slightly disturbed areas were the same as prelogging values. Values for both the deeply disturbed and compacted classes were significantly higher, indicating a decrease in soil porosity. Compaction caused by tractor logging undoubtedly results in some increase in runoff and erosion. However, these undesirable effects are minimized if slopes do not exceed 20 to 30 percent and skidroads are located on the contour.

LOGGING OPERATIONS cause surface soil disturbance ranging from removal of the protective organic litter to complete removal of topsoil. Amounts of erosion and stream sedimentation following logging may vary directly with the degree of disturbance caused by timber removal. Therefore, it is important for forest land managers to have some knowledge of relative amounts of disturbance caused by different methods of logging.

Old-growth Douglas-fir in the Pacific Northwest is generally logged in clearcut units by either tractor or high-lead methods. In areas of gentle slopes, most loggers prefer tractor yarding, but on slopes greater than 30 to 35 percent, high-lead logging is generally recommended. During the past several years, considerable controversy has arisen over the relative amounts of soil disturbance caused by logging. Some have maintained that tractor logging should never be allowed in critical watershed areas, even on gentle slopes, because of excessive disturbance. Others have asserted that damage caused by tractor logging is negligible if it is done during the dry season, when soils are not easily compacted.

The extent of soil disturbance caused by logging has been investigated by several workers in the Pacific Northwest. Steinbrenner and Gessel (*3*) studied tractor-logged areas in western Washington and found 26 percent of the total area occupied by tractor skidroads. Wooldridge (*4*) compared soil disturbance by skyline-crane logging with that by conventional tractor skidding. In the tractor-logged area, 29.4 percent of the ground surface was disturbed, while only 11.1 percent was disturbed in the skyline area. A comparison of logging methods in eastern Oregon and Washington by Garrison and Rummell (*2*) showed that exposure of mineral soil averaged 20.9 percent in tractor-logged areas, 15.2 percent of the total area where cables were used, and 11.8 percent in horse-logged areas.

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The Study

This study was designed to assess and compare effects of high-lead and tractor logging on soils with similar undisturbed surface conditions in the H. J. Andrews Experimental Forest, Blue River, Ore. (*1*). The study area is located in the western Cascades about 40 miles east of Eugene, Ore.

Three high-lead cutting units were chosen having areas of 13, 20, and 28 acres (Fig. 1). Logging was completed in January 1963 and was largely carried out during wet weather. The timber stand was old-growth Douglas-fir with a mixture of some younger western hemlock. Slopes in the three units were steep, ranging from 20 to 80 percent and averaging about 55 percent.

Only one tractor-logged cutting unit was available—a 10-acre area on which logging was completed in October 1963. Tractor operations were carried out during the dry season when soil moisture content was at a minimum. The timber stand included 100-year-old Douglas-fir, western hemlock, and western redcedar interspersed with scattered overmature Douglas-fir. Most of the unit was virtually level except for a drainageway and two short ridges. Slopes along the drainage range from 10 to 20 percent and the short ridge sideslopes were about 40 percent. No skidroads were constructed on these sideslopes.

A principal objective of the study was to determine the extent of soil surface disturbance after yarding. The following four soil surface disturbance classes were set up and described.

1. Undisturbed.—Litter still in place and no evidence of compaction.
2. Slightly disturbed (Fig. 2). Three conditions fit this class:
   (a) Litter removed and undisturbed mineral soil exposed;
   (b) Mineral soil and litter intimately mixed, with about 50 percent of each; and
   (c) Pure mineral soil deposited on top of litter and slash to a depth of 2 inches.
3. Deeply disturbed. — Surface soil removed and the subsoil exposed. The soil surface is very seldom covered by litter or slash (Fig. 3).
4. Compacted. — Obvious com-

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Fig. 1.—General view of two of the high-lead cutting units used in this study.

Fig. 2.—Slightly disturbed soil surface condition after high-lead logging.

paction due to passage of a log or mobile equipment. The soil surface under large cull logs is assumed to be in this condition.

The percentage of the total clear-cut area in each disturbance class was determined by means of point sampling along transects. Point observations were made at 10-foot intervals along six randomly located transects crossing each cutting unit.

Slash density classes were also recorded at 10-foot intervals. Sample observations were made on square-foot areas, located by using the soil disturbance observation points as centers. Slash classes are as follows:

1. Heavy — Entire square foot covered with slash at least 1 foot deep.
2. Light—Ten percent or more of the area covered with slash less than 1 foot deep.
3. Absent — Total slash cover less than 10 percent.
4. Cull log—Log over 12 inches in diameter.

Another objective of the study was to determine to what extent physical properties of the surface soil were changed in the four disturbance classes. Bulk density was chosen as a criterion because it offered a convenient measurement of the extent of alteration of physical soil properties caused by logging. Bulk density samples were collected with a core sampler from the surface 2 inches of soil before logging and from areas representing each soil surface disturbance class after logging. Twenty samples were collected from each soil condition, a total of 100 per logging method.

To insure maximum uniformity of surface soil conditions, only one soil type was sampled for each logging method. In the high-lead area, the soil sampled was the Andrews[1] series, a fine-textured, moderately deep, reddish-brown soil derived largely from residual red breccia. In the tractor area, the soil is classified as the Carpenter[2] series, a moderately deep, medium-textured soil derived from glacial till. Both Andrews and Carpenter soil have shotty and porous, reddish-brown surface horizons.

[1]Provisional series, not yet correlated.
[2]Ibid.

Results

A total of 1,800 individual observations of soil disturbance and slash density were made on four cutting units. The three high-lead cutting units were remarkably uniform with respect to soil disturbance (Table 1). The most extensive disturbance occurred in unit L141, with a total of 38 percent of the area deeply or slightly disturbed. The difference among high-lead units, however, is not great, since comparable figures for the other two are 31 and 25 percent.

Largest differences between tractor and high-lead logging are in the proportion of the logged area within the undisturbed and compacted classes (Fig. 4). The per-

Fig. 3.—Deeply disturbed soil surface condition after high-lead logging.

TABLE 1.—PERCENT OF TOTAL CUTTING UNIT AREA IN FOUR SOIL SURFACE DISTURBANCE CLASSES AND FOUR SLASH CLASSES

Classes	High-lead			Tractor
	Unit L222	Unit L141	Unit L221	Unit L522
Soil surface disturbance:				
Undisturbed	58.1	50.7	62.7	35.6
Slightly disturbed	21.0	24.5	18.9	26.4
Deeply disturbed	9.6	13.6	5.8	8.9
Compacted	9.6	7.1	10.7	26.8
Total[1]	98.3	95.9	98.1	97.7
Slash:				
Heavy	32.3	25.5	23.0	25.4
Light	34.7	37.0	41.3	42.6
Absent	23.6	29.6	24.5	26.4
Cull log	10.0	7.9	11.9	6.3
Total[2]	100.6	100.0	100.7	100.7

[1]The areas represented by the difference between the totals and 100 percent are nonsoil areas, i.e., stumps, rocks outcrops, and stream bottoms.

[2]May total more than 100 percent because "cull log" plus one of the other three classes were sometimes recorded at a single point.

centage of the area in the slightly and deeply disturbed classes is approximately the same for both logging methods. Tractor logging caused appreciable increase in the proportion of area described as compacted (26.9 percent vs. 9.1 percent for high-lead) and a corresponding decrease in the proportion of undisturbed area (35.6 vs. 57.2 percent for high-lead). Most compaction in the tractor-logged unit was on skidroads where surface soil had been stripped off and bare subsoil compacted by passage of the tractor.

Compaction in the high-lead units was generally quite different. There it was caused by skidded logs; disturbance other than compaction (e.g., surface soil removal) was, in many cases, not very extensive. The compacted areas were usually in shallow troughs of surface soil, at least partially covered by scattered litter and slash.

In the tractor-logged area, skidroads occupied approximately 28 percent of the total area. This compares very closely with the 26 percent reported by Steinbrenner and Gessel (*3*).

Distribution of slash left on the ground following logging was about equal for the two methods (Table 1). Data indicate that slash was fairly well distributed in all units, with only about 25 percent of the area free of slash.

Bulk density in the surface 2 inches of soil was seriously altered in only two disturbance classes—deeply disturbed and compacted (Table 2). Bulk density values for undisturbed and slightly disturbed classes are similar to prelogging values for both methods of yarding. Apparently, slight disturbance has little effect on physical characteristics of the surface soil and largely involves removal of protective litter. Greater bulk densities found in deeply disturbed areas are usually due to exposure of the denser subsoil. In addition to this type of disturbance, tractor logging results in the deposition of large amounts of loose soil, such as skidroad berms. These deposits, although classed as deeply disturbed, have a much lower bulk density than is characteristic for this disturbance class after high-lead logging. As a consequence, bulk density values in the deeply disturbed class averaged lower for tractor logging than for high-lead.

Discussion and Conclusions

Tractor logging caused more surface soil disturbance than did high-lead logging. Almost all increased disturbance was in the form of compaction—the tractor-logged unit had about three times more area in the compacted disturbance class than did the high-lead units. Bulk density sampling indicated that compaction significantly decreases porosity of the surface soil. In the tractor-logged area, undisturbed soil had approximately 77 percent pore space, while compacted soil averaged only about 63 percent.

Extensive compaction may, in some cases, result in serious erosion and site deterioration. The decrease in pore space likely causes a substantially lower infiltration rate and larger amounts of surface runoff. In addition, most compacted soil in tractor-logged areas occurs in bare skidroads which serve to channel runoff water. Although skid trails in high-lead areas are also trough shaped, they are frequently protected by some litter and scattered slash. Steinbrenner and Gessel (*3*) found that a 15-percent increase in the bulk density of skidroad soils resulted in 93-percent loss in permeability.

Erosion danger posed by compaction was considerably modified by slope and orientation of skid trails. For example, tractor skidding in this study was carried out on slopes of less than 20 percent and skidroads followed the contour wherever possible. As a result, runoff velocity tended to be reduced and sediment transported only short distances. Where tractor skidroads are placed up and down steeper slopes, erosion damage is much greater.

Some workers have noted a relationship between poor survival and growth of tree seedlings and soil compaction. Youngberg (*5*) found a highly significant decrease in the growth of planted Douglas-fir seedlings on compacted tractor roads as compared with seedlings in other cutover locations.

Areas in the slightly disturbed

TABLE 2.—MEAN SOIL BULK DENSITY VALUES BEFORE AND AFTER LOGGING ON THE H. J. ANDREWS EXPERIMENTAL FOREST, 1963

Method	Prelogging	Undisturbed	Slightly disturbed	Deeply disturbed	Compacted
	gm./cc.				
High-lead	0.712(±0.070)[1]	0.753(±0.084)	0.785(±0.138)	0.990(±0.114)	0.952(±0.179)
Tractor	0.657(±0.077)	0.603(±0.126)	0.584(±0.118)	0.772(±0.114)	0.975(±0.182)

[1]Standard deviation.

class may be more susceptible to soil movement than is indicated by their bulk density measurements. It is possible that soil disturbance may affect structural properties of the soil which are not measured by bulk density. Furthermore, susceptibility to soil movement may be increased simply by removal of the protective covering of organic matter although bulk density remains unchanged.

It was interesting to note that a high proportion of the cutting unit area was completely undisturbed or only slightly disturbed. On high-lead units, the undisturbed class occupied at least 50 percent of the area, while the combined undisturbed and slightly disturbed classes averaged 79 percent. In the tractor unit, these two classes totaled 62 percent of the area. Thus, over much of these typical cutting units, physical conditions of the surface soil were affected very little, no matter which logging method was used. It does not necessarily follow, however, that because of the relatively small area of seriously disturbed soil, watershed damage will be negligible. Fortunately, "sore spots" which result in serious stream siltation generally occupy only a small fraction of a total watershed area, especially if they are located near stream channels.

The results of this study indicate that although tractor logging causes more soil disturbance than high-lead, the difference is not very great when tractors are used during the dry season on gentle slopes. Under these conditions, damage to the site would probably not be considered excessive except in cases where special problems of soil instability or reforestation exist.

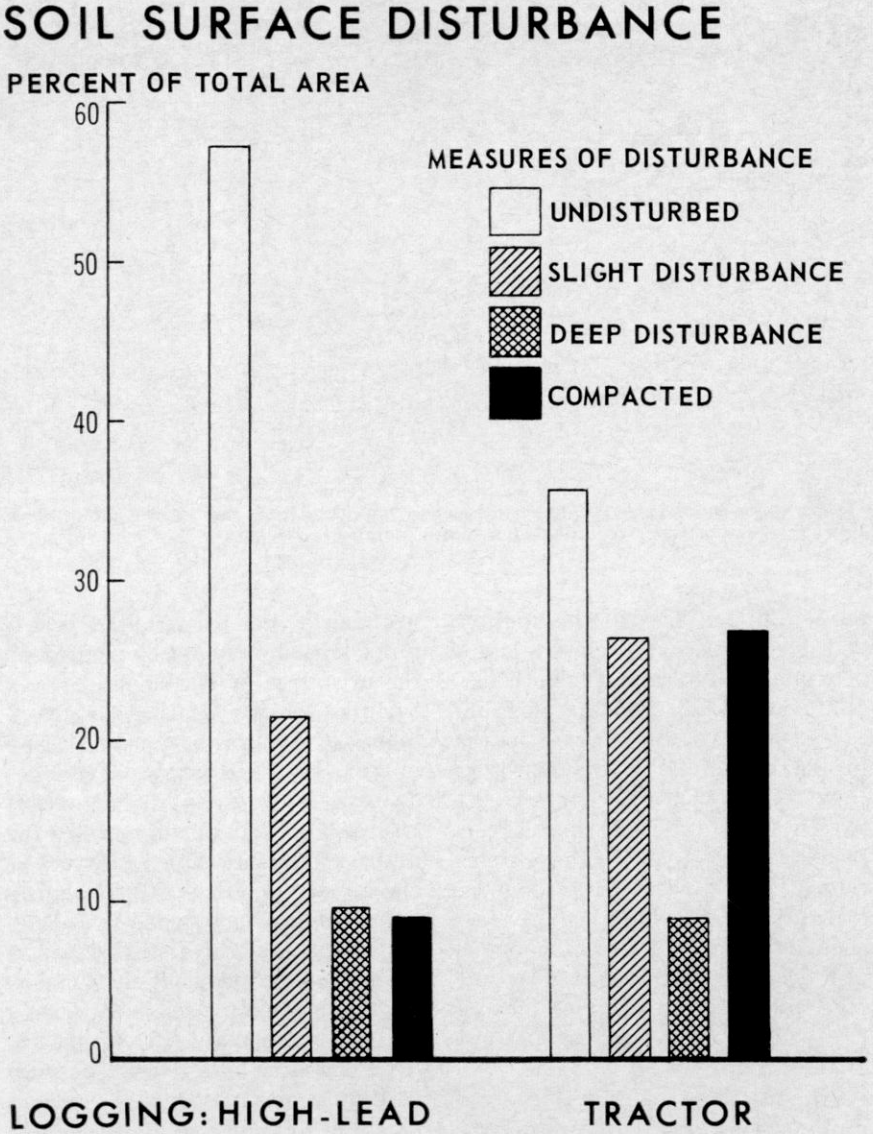

Fig. 4.—Surface soil disturbance following high-lead and tractor logging.

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