SOME EFFECTS OF LOGGING AND SLASH BURNING ON PHYSICAL SOIL PROPERTIES IN THE CORVALLIS WATERSHED

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Foreword

This study was conducted by C. T. Dyrness as part of the requirements for the Master of Science degree, Oregon State College. Dr. C. T. Youngberg of the College's Department of Soils, provided supervision and guidance for the study. Robert H. Ruth of the Pacific Northwest Forest and Range Experiment Station's Willamette Research Center (maintained at Corvallis, Oregon in cooperation with the School of Forestry, Oregon State College) joined in planning the project and in preparation of this report. The study was conducted on the Siuslaw National Forest.

Mr. Dyrness did the field work and laboratory analyses during the 1955-56 school year. He was assisted by a contribution of funds from the Division of Watershed Management Research, Pacific Northwest Forest and Range Experiment Station.

R. W. Cowlin,
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C. T. Dyrness, C. T. Youngberg, and Robert H. Ruth[1]

INTRODUCTION

Many persons question the wisdom of harvesting timber in forested drainages that supply municipal water. In the Douglas-fir region of the Pacific Northwest there are examples of logging that support this viewpoint but others as well that tend to refute it. Some municipal water supplies have been damaged and yet in other cases relatively little harm has been done.

No unqualified statement can be made about logging in municipal watersheds. Much depends upon physical conditions characterizing each individual area. One of the most important of these is soil and the way it reacts to disturbance.

This is a study of three soil types following logging and slash burning in a watershed supplying the city of Corvallis, Oregon.[2] Until recently the forest cover in this watershed, chiefly mature Douglas-fir, remained undisturbed. In 1951 a severe windstorm followed by a Douglas-fir bark-beetle epidemic sharply increased the normal rate of mortality, leaving patches of dead trees totaling

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1/ The authors wish to express their appreciation to R. G. Peterson and L. D. Calvin of the Oregon Agricultural Experiment Station for guidance in statistical analysis of data used in this report.

2/ The Corvallis watershed includes Rock and Griffith Creeks, both flowing from the eastern slopes of Marys Peak in the Oregon Coast Range. The watershed area used in this study is entirely within the Siuslaw National Forest.

roughly 60 million board-feet. In 1953 a logging program was begun to salvage some of this timber and to reduce the serious fire hazard created by concentrations of dead material. In three years, 23 miles of road have been constructed and timber worth one-half million dollars in stumpage value has been salvaged from areas where beetles had centered their attack. Removal of these concentrations has resulted in a scattering of small clearcut areas.

PURPOSE AND SCOPE

This study was designed to evaluate some physical properties of the soil following logging and slash burning. It is not an attempt to assess the full effects of these two types of disturbance. Measurements were limited to properties of soil frequently associated with erodibility: content of sand, silt and clay, aggregation, and percentages of organic matter. A combination of these factors, plus moisture equivalent determinations, was used to arrive at an index of erosion.

Investigations were limited to three cutover areas with different soil types. Results are generally applicable to other soils belonging to the Reddish-Brown Latosol great soil group in the Oregon Coast and Cascade Ranges. However, variables such as soil moisture condition, slope gradient, aspect, and method of logging will also influence reactions to logging and slash burning in any given location.

OTHER STUDIES

Other workers in the Douglas-fir region have explored the influence of logging and slash burning on soils, using somewhat different approaches to the problem. Recently, Tarrant studied the effect of slash burning on rate of water percolation, size of pore spaces, and bulk density of soils in two separate areas.[3/] He found that severe burning lowers the rate of moisture movement, while light burning does not seriously alter the soil in this respect. He showed further that severe burning occurred on less than 5 percent of the total logged and burned area included in his study.

3/ Tarrant, Robert F. Effect of slash burning on some physical soil properties. Forest Sci. 2:18-22, illus. 1956.

Another study dealing with disturbance to soil by tractor logging in the Douglas-fir region was reported in 1955 by Steinbrenner and Gessel.[4/] They were interested in compaction as measured by permeability rates, bulk density, and pore space. Soils of nine cutover areas logged by tractors in southwestern Washington, when compared with adjacent uncut timber stands, showed a 35 percent loss in permeability rate, a 2.4 percent increase in bulk density and a 10 percent reduction in macropore space. Tractor skid roads covered 26 percent of the logged areas. Their contribution to total disturbance is indicated by the results from tractor roads alone. Here permeability rates were reduced 93 percent, bulk density increased 15 percent, and macroscopic pore space reduced 53 percent.

METHODS

In the Corvallis watershed, three selected cutting units, logged with a high-lead system followed by slash burning, were sampled during the spring and fall of 1955 to determine:

1. Extent and distribution of recognizable surface soil conditions in each clearcut unit.

2. Some of the characteristics of soils associated with these surface conditions.

The three clearcut units examined vary in size from 10 to 27 acres (figs. 1, 2 and 3). They are described as follows:

Cutting unit	Logged	Burned	Soil description
3	1953	1953	Blachly loam
4	1954	1954	Melbourne clay
10	1954	1955	Olympic clay

Although the burns were of different ages, the effects of fire were readily apparent in all three units.

4/ Steinbrenner, E. C., and Gessel, S. P. The effect of tractor logging on physical properties of some forest soils in southwestern Washington. Soil Sci. Soc. Amer. Proc. 19:372-376. 1955.

Figure 1.--Clearcut unit 3 in July 1956, three years after logging and slash burning. Soil is Blachly loam. (F. S. Photo 481316)

Figure 2.--Clearcut unit 4 in July 1956, two years after logging and slash burning. Soil is Melbourne clay. (F. S. Photo 481318)

Figure 3.--Clearcut unit 10 in July 1956, two years after logging and one year after slash burning. Soil is Olympic clay. (F. S. Photo 481322)

Figure 4.--Timber stand and understory vegetation in undisturbed condition adjacent to unit 10.

Soil samples to a depth of two inches were collected at 50-foot intervals along randomly located transects within the clearcut areas and in adjacent uncut timber (fig. 4). Condition of the surface soil was noted at 10-foot intervals along the transects in the clearcuts and classified as follows: (1) lightly burned, where the surface litter is charred by the fire but not completely removed; (2) severely burned, where the litter has been completely removed and the mineral soil left with a brick-red color; (3) disturbed-unburned, where there is evidence of disturbance during logging but no visible effect of fire; (4) undisturbed, where surface condition is identical to that found in undisturbed timber, having no evidence of disturbance either by logging or by fire. This classification system is similar to that described by Tarrant[5] except for the addition of the disturbed-unburned category.

From the 80 to 90 soil samples collected in each clearcut, 60 were randomly selected for laboratory analysis. This allowed 12 samples for each of the five soil conditions (undisturbed, disturbed-unburned, lightly burned, severely burned, and uncut timber). Laboratory determinations were made for each of the 180 soil samples as follows:

1. Mechanical analysis to determine content of sand, silt, and clay by a modified Bouyoucos hydrometer method.

2. Moisture equivalent determinations by the standard Briggs-McLane centrifuge method.

3. Aggregate analysis, following the procedure as outlined by Yoder.[6]

4. Total organic matter determinations by the rapid dichromate oxidation method (modified by Walkley and Black).

5/ Op. cit.

6/ Yoder, R. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. Agronomy Jour. 28:337-351. 1936.

With the exception of the aggregate analysis, all of the above determinations were carried out according to the procedures adopted by the Forest Soils Committee of the Douglas-fir Region.[7/]

RESULTS

Almost half the area in the three clearcuts remained untouched by fire (fig. 5). Most of the remainder was classed as lightly burned, leaving eight percent of the area in the severely burned category.

Results varied considerably between the three clearcuts. It was found, for example, that the percentage of severely burned soil surface ranged from 1.3 percent on unit 3 to 16.1 percent on unit 10. As the graph shows, the slash fire on unit 3 resulted in a very mild burn, while unit 10 burned much hotter than average.

Mechanical analysis of the 180 soil samples revealed no consistent change in soil texture as a result of logging and burning for most of the area within the clearcut units (table 1). In the Blachly loam of unit 3, statistical analysis indicated no significant difference in texture of the soils in the unit and under adjacent timber. This was true even for severely burned soil. In units 4 and 10 neither logging disturbance nor light burning had important effects on the soil texture classes measured. Severe burning, however, was associated with a significant reduction in the clay and silt-plus-clay fractions and an increase in sand in the top two inches of soil.

Extreme heat may explain the alteration of soil texture in the severely burned areas of units 4 and 10. Increase in sand accompanied by the loss of silt and clay suggests the fusion of clay particles. It would be reasonable to assume that the resultant newly formed particles would be very stable as the result of complete dehydration. These products of heat fusion apparently were so resistant to dispersion that they were included in the portions described as sand.

The sandier soil in unit 3 was affected differently by severe burning than were the clay soils of other units. It is probable that the aggregates resulting from clay fusion were relatively small and silt-sized. Evidence for this is the lower clay percentages and the increase in silt content of severely burned samples.

7/ Forest Soils Committee of the Douglas-fir Region. Sampling procedures and methods of analysis for forest soils. Col. of Forestry, Univ. of Wash. 38 pp. (Processed.) 1953.

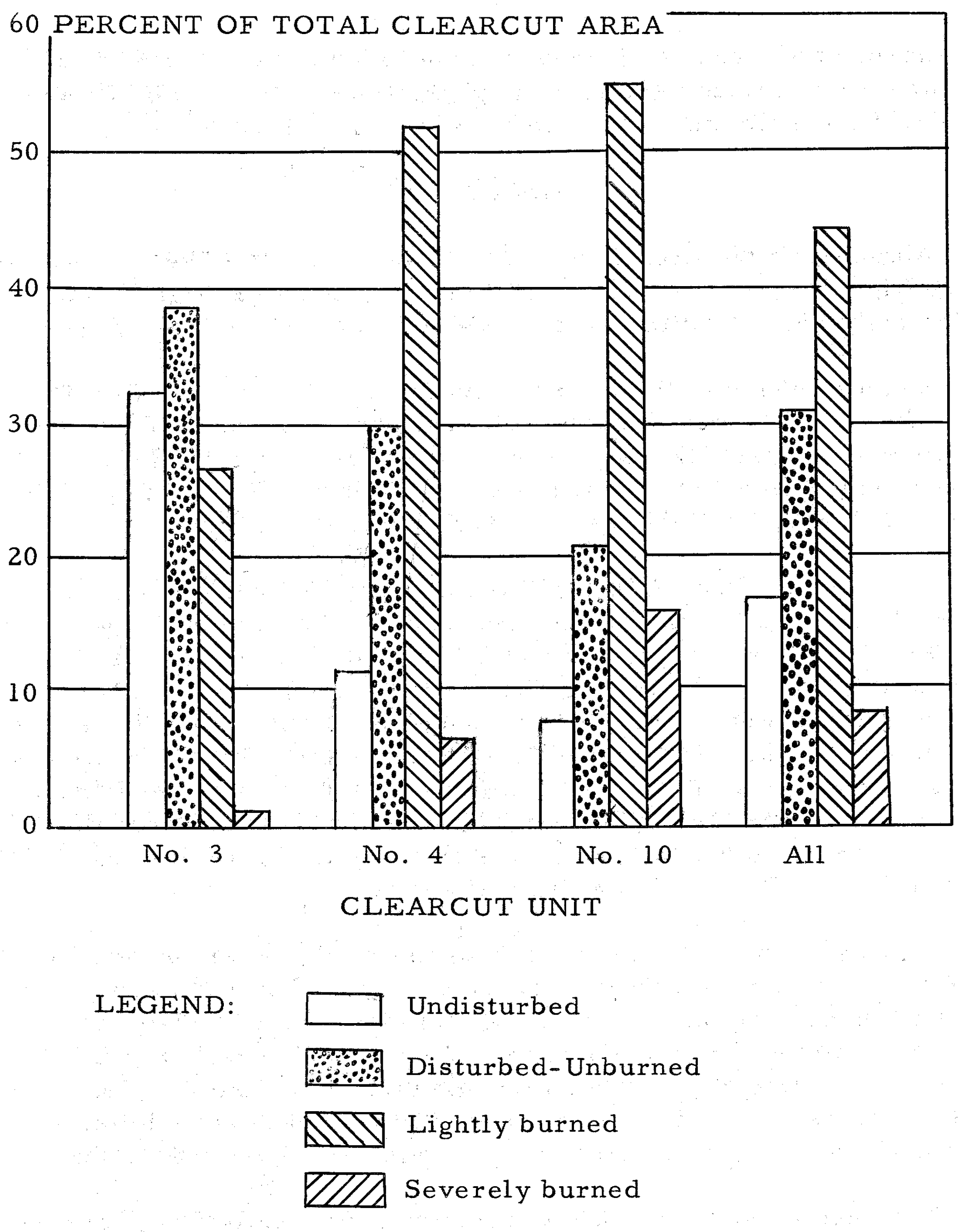

Figure 5.--Soil surface conditions following logging and slash burning in three clearcut units, Corvallis watershed.

Table 1.--Clay and silt-plus-clay fractions in the top two inches of soil in three clearcut units and under adjacent timber stands, Corvallis watershed

Soil texture class & surface condition	Clearcut unit 3	Clearcut unit 4	Clearcut unit 10	Unit average
Clay (2 microns)	-------	Percent	-------	
Timber	27.0	45.8	47.6	40.1
Undisturbed	25.2	48.3	49.4	41.0
Disturbed-unburned	24.3	45.8	46.0	38.7
Lightly burned	25.2	42.3	46.1	37.9
Severely burned	23.8	1/ 39.9	1/ 37.8	1/ 33.8
All conditions	25.1	44.4	45.4	38.3
Silt-plus-clay				
Timber	55.8	70.8	83.3	70.0
Undisturbed	53.9	72.0	85.2	70.4
Disturbed-unburned	53.1	69.0	84.4	68.8
Lightly burned	56.7	66.7	84.2	69.2
Severely burned	57.9	1/ 62.1	1/ 66.6	62.2
All conditions	55.5	68.1	80.7	68.1

1/ Decrease significant at 1 percent probability level.

Organic matter in the top two inches of soil was essentially the same in the clearcuts as in the check areas, except for the severely burned soil (table 2). Severe burning reduced organic matter to about 40 percent of the amounts in soil under the timber.

It was also found that severe burning lowered the level of total soil aggregation (table 3). On the remaining 92 percent of the clearcuts, however, there was no significant difference in soil aggregation from the check areas.

Table 2.--Percentage of total organic matter in the top two inches of soil in three clearcut units and under adjacent timber stands, Corvallis watershed

Soil surface condition	Clearcut unit 3	Clearcut unit 4	Clearcut unit 10	Unit average
	Percent			
Timber	12.4	9.3	10.7	10.8
Undisturbed	12.6	8.6	12.2	11.1
Disturbed-unburned	12.5	10.2	10.9	11.2
Lightly burned	12.3	2/ 12.3	10.4	11.7
Severely burned	1/ 3.0	1/ 5.2	1/ 4.5	1/ 4.2
All conditions	10.6	9.1	9.7	9.8

1/ Decrease significant at 1 percent probability level.

2/ Increase significant at 5 percent probability level.

Table 3.--Percentage of aggregates (0.1-5.0 mm) in the top two inches of soil in three clearcut units and under adjacent timber stands, Corvallis watershed

Soil surface condition	Clearcut unit 3	Clearcut unit 4	Clearcut unit 10	Unit average
	-------------	Percent	--------------	
Timber	34.9	44.1	79.1	52.7
Undisturbed	36.1	49.6	78.6	54.8
Disturbed-unburned	33.5	41.9	72.8	49.4
Lightly burned	35.1	39.1	77.7	50.6
Severely burned	29.1	1/ 30.4	1/ 65.8	1/ 41.8
All conditions	33.7	41.0	74.8	49.9

1/ Decrease significant at 1 percent probability level.

Lowered aggregation in the severely burned soils may be largely due to the removal of colloidal organic matter by fire. Many aggregates in surface soils depend on colloidal organic matter as their cementing agent and its loss leads to disintegration. Although fusion of particles appears to occur at high temperatures, this process apparently fails to offset breakdown of naturally formed aggregates which is occurring simultaneously.

Results of the moisture equivalent determinations likewise indicated that the ability of the surface soil to retain moisture is significantly lessened by exposure to intense heat (table 4). Other treatments had no consistent effect on moisture equivalent values in this study. Reduced moisture equivalent values in severely burned soils may be attributed to the slightly coarser texture they acquire and to loss of organic matter.

Table 4.--Moisture equivalent values for the top two inches of soil in three clearcut units and under adjacent timber stands, Corvallis watershed

Soil surface condition	Clearcut unit 3	Clearcut unit 4	Clearcut unit 10	Unit average
	-------	Percent moisture	-------	
Timber	34.6	41.1	45.7	40.5
Undisturbed	35.0	40.9	46.5	40.8
Disturbed-unburned	33.4	38.8	43.1	38.4
Lightly burned	36.3	38.4	45.7	40.1
Severely burned	32.6	1/ 36.3	1/ 36.9	1/ 35.3
All conditions	34.4	39.1	43.6	39.0

1/ Decrease significant at 1 percent probability level.

EFFECTS ON ERODIBILITY

In considering the possibility of erosion in any area, first need is to determine the inherent erodibility of the soil itself. This information can be obtained prior to logging and can be very useful in prescribing precautions to be taken.

An analysis of undisturbed soils adjacent to the clearcut units in the Corvallis watershed revealed that the soils are naturally quite resistant to erosion. They have a high percentage of water-stable aggregates attributable to generous amounts of colloidal clay, organic matter and iron oxides. Although no measurements were taken, the porous and granular nature of the surface soil suggests a rapid infiltration rate and a minimum of runoff, even during heavy rains.

Erosion ratios were determined for soil samples from the severely burned and lightly burned areas of cutting unit 10 as well as from the adjacent timber. The initial step was to determine the resistance of silt and clay to dispersion. Each sample was shaken in water to obtain a measure of aggregate stability, which was expressed as a dispersion ratio. This index of dispersion was then divided by a ratio of clay content to moisture equivalent, which gave the erosion ratio. Middleton, who originated the procedure, maintains that erosion-ratio values are an accurate index of the relative erodibility of the soil.[8/] Mean ratio values obtained for the three soil conditions were as follows: timber, 3.01; lightly burned, 4.19; and severely burned, 9.97.

Middleton found that soils having an erosion ratio greater than 10 were most frequently susceptible to erosion and those with a smaller ratio were virtually nonerodible. Mean values for the above three conditions would indicate that the ratio increases with the degree of burn. Still, erodibility of the soil is not seriously increased by burning, at least insofar as it is assessed by this method.

Perhaps one of the most important factors contributing to the low rate of soil erosion in the Corvallis watershed is the pattern of rainfall. Total precipitation is high but--in a manner typical of the Douglas-fir region--it usually falls as light, gentle rain and quickly enters the soil. Infiltration capacity of the soil mantle is seldom surpassed; consequently the amounts of surface runoff and soil erosion are small.

Results of this study show that light burning had very little effect on the physical soil properties that were investigated. In each case results obtained for lightly burned soils were not significantly different from those for undisturbed soils.

Physical properties of the surface soil located in the disturbed-unburned portions of the clearcut showed evidence of some alteration, due primarily to compaction. This occurred mainly on skid trails which comprised a large portion of the area classed as disturbed-unburned in the average clearcut unit. Structural breakdown from compaction may have been responsible for lowering of both moisture equivalent and percentage aggregation values.

8/ Middleton, H. E. Properties of soils which influence soil erosion. U. S. Dept. Agri. Tech. Bul. 178, 16 pp. 1930.

Results from undisturbed soils agree closely with those in adjacent undisturbed timber. The undisturbed parts of the clearcut are apparently still as resistant to erosion as the soil located in the surrounding timber. Presence of a vegetative cover and a thick layer of litter has, so far, prevented the disintegration of structure needed to maintain rapid infiltration rates.

Surface litter is a very important factor in the control of soil erodibility. Severely burned areas were all completely bare of organic litter, thus exposing the soil surface to the beating and destructive action of rain. With no organic layer to absorb the impact of falling rain drops, aggregates are broken down, soil thrown into suspension, and the natural porosity of the soil quickly diminished. This, in turn, causes a decrease in permeability of the soil, and more runoff and erosion result.

Several factors, however, tend to minimize the danger of soil erosion in severely burned areas:

1. Often a crust was present on the soil surface of the severely burned areas. It appeared that this crust provided some protection against soil movement.

2. The severely burned soil condition occurred almost entirely in small scattered areas. This tended to reduce the importance of the increased erodibility.

3. Very few severely burned areas were located on steep slopes where erosion would be more apt to occur. Most were found on gentle slopes and benches where topography was more conducive to slash accumulation.

CONCLUSIONS AND DISCUSSION

Physical soil properties measured in this study did not differ significantly among 4 of the 5 surface conditions sampled. Only in the severely burned condition was there found a consistent and significant departure, indicating that intense heat altered the character of the surface soil. Physical properties of soil in undisturbed, disturbed-unburned, and lightly burned portions of the clearcuts remained closely similar to those under adjacent timber stands.

Severe burn, the one surface condition where soil was seriously affected, occupied only a small portion of the cutover areas in the watershed. In this study it involved an average of only 8 percent of the three units examined. This is probably higher than the average for the Douglas-fir region, as indicated by Tarrant's measurements. In unit 10, where 16.1 percent of the area was classed as severely burned, the slash fire was exceptionally hot.

The amount of severely burned soil present following broadcast slash burning depends largely upon three factors: (1) the amount of slash to be burned, (2) its distribution, and (3) the moisture status of the slash, litter, and soil at the time of burning. If, for example, the slash is well distributed over the entire area, the danger of exposing the soil to extremely high temperatures in localized areas is lessened considerably. Furthermore, the level of wood utilization affects the amount of the severely burned soil condition. It is to be expected that in the future it will be economically feasible to utilize many of the logs that are now rejected. Since many of the severely burned areas resulted from prolonged fire in cull logs, increased utilization will decrease the occurrence of the severely burned soil condition.

In recent years it has been the practice to burn soon after a fall rain. Burning the slash as soon as it dries out but when the litter and soil are still moist results in far less damage to the soil. Severely burned soil is limited to areas immediately beneath large accumulations of slash, and even here the effects of the fire penetrate the soil to a limited depth. Spring and early summer burning have the same effect if soils are moist.

This study can be considered only a partial evaluation of the effects of logging and slash burning on soils in the Douglas-fir region. Soil tests were not intended to be a complete investigation of the soil changes which occur. Furthermore, only three types of soil were examined. These are known to occur throughout the Coast and Cascade Ranges in Oregon and Washington, so, while limited in scope, results of this study are applicable over a substantial part of the Douglas-fir region. Still, to assess fully the effect of logging and slash burning, other soils associated with the Douglas-fir type will need to be sampled and subjected to comprehensive tests.