

Effects of Slash Burning on Some Soils of the Douglas-Fir Region

ROBERT F. TARRANT

Effects of Slash Burning on Some Soils of the Douglas-Fir Region¹

ROBERT F. TARRANT²

ABSTRACT

The studies summarized in this paper indicate that effects of slash burning vary with different soils and locations in the Douglas-fir region and also within an individual clear-cut and slash-burned area. Although severe burning damages some soil properties, the soil surface affected by severe burning usually represents only a small portion of the total area logged and burned. As low-grade materials are utilized more fully, a reduction can be expected in the volume of heavy fuels left after logging. This will decrease even more the small amount of soil surface damaged by severe burning.

In weighing the effects of slash burning on soil properties, consideration must first be given to the relative amounts of lightly burned, severely burned, and unburned soil surface. This is necessary to avoid the possibility of assigning to an entire area, the effects of only the most severe burning treatment.

It is also emphasized that findings of these studies apply only to intentional slash burns and should not be construed as applying to areas affected by repeated wildfires.

THOUSANDS of acres of logging slash are burned annually in the Douglas-fir region to reduce the hazard of accidental fires. That broadcast burning does reduce the volume and hazard of fuels on clear-cut areas is seldom questioned. However, under the increasing application of sustained yield forestry, which demands protection and improvement of the basic asset—forest soil—many people have questioned the advisability of slash burning. They see a possibility of soil damage.

Theoretically, a case can be made against the practice of slash burning. Theory suggests that broadcast burning can destroy soil organic matter, and along with it the micro-organisms that contribute to good soil health. Destruction of incorporated organic matter can be shown to reduce soil permeability, increasing chances for erosion, decreasing aeration and moisture-holding properties important to tree growth, and altering generally the chemical nature of the soil.

Until rather recently, such theory has not been tested under Douglas-fir region conditions. Consequently, many generalizations have been made. The subject of slash burning, as it affects the soil, is one in which controversy has always been present. Since 1948, however, studies of the effects of slash burning on soil properties and the resulting impact on tree growth and watershed

conditions have been under way in the Douglas-fir region.

Studies have included both field and laboratory soil tests as well as related observations of germination and growth of seedlings in the greenhouse and under natural conditions. Information has been gathered on both physical and chemical soil properties under various degrees of burning and on germination and growth of seedlings in relation to soil properties. All of the work has been aimed at determining the ultimate effects of slash burning on future tree growth and watershed values. Also, some progress has been made in answering two questions that, in the author's opinion, represent the heart of the problem: (1) What are the effects of different degrees of burning? and (2) What portions of a clear-cut area are burned to varying degrees in a slash fire? This paper summarizes some of these studies.

Intensity of Slash Fires

Throughout this series of studies, three classes of surface soil condition were recognized.

Unburned condition is that surface condition which for one reason or another escaped the fire. Some areas are unburned because logging disturbance has removed all fuel including surface litter. Others may have too small an amount of litter to carry fire. Local weather conditions may also stop fire spread.

Light burn is defined as that surface condition in which fire has charred the surface of organic litter but has not removed all litter from the soil surface. This condition occurs where large fuel is absent but a heavy surface litter is present to carry fire. Clear-cut areas that have burned rapidly and well usually show large areas of blackened surface; these charred areas sometimes are said to be "hard burned," but the term is in error, so far as soils are concerned, according to results of these studies.

Severe burn is defined as that surface condition in which fire has removed all organic litter from the ground surface and in addition has baked the mineral soil to a highly colored, crusty state. This type of burn occurs beneath large pieces or accumulations of fuel which burn at high temperatures for comparatively long periods of time.

¹Presented before Div. V-A, Soil Science Society of America, Davis, Calif., Aug. 17, 1955. Received Aug. 8, 1955.

²Soil Scientist, Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S.D.A., Portland, Oreg.

The intensity of slash burning is far from uniform over any single cutting area, and it is on this point that confusion arises concerning the effects of slash burning. We hear or read statements such as: "Slash burning destroys humus and nitrogen." "Slash burning destroys soil aggregation." The fallacy in such statements stems from the application of a generality, without qualification as to the proportion of an area on which the fire has an effect.

An intensive line sampling of 10 representative clear-cut and burned areas gave these results:

| Surface condition | Percent of total area |
|-------------------------------|-----------------------|
| Unburned..... | 47.1 |
| Light burn..... | 46.9 |
| Severe burn..... | 2.8 |
| Non-seedbed (rock, etc.)..... | 3.2 |

Other workers have made a comprehensive study of slash burning throughout the Douglas-fir region. Their findings, as yet not released, agree closely with the foregoing figures. We can conclude that the extent of severe burn rarely exceeds 5% of the area and in most cases is less. This maximum figure of 5% of severely burned soil surface is supported also by recent studies in California (11).

These figures are important because they provide a definite base on which to apply findings of soil studies. Citing the worst effects of burning as a generality is probably the greatest single reason why foresters today cannot agree as to the true effects of slash burning on the soil.

Physical Properties

The most important physical properties of forest soils are those affecting soil moisture. Moisture relations affect not only tree growth but also watershed quality. A study was made to evaluate the influence of various degrees of burn on several important physical soil properties.

Two soils of different textures were selected for study, a pumicy sandy loam and a sandy clay loam. Plots were established on areas burned the previous year, and undisturbed soil cores were taken in steel cylinders. Unburned, light burn, and severe burn surfaces were intensively sampled. In the laboratory, determinations were made of percolation rate, macroscopic and microscopic pore volume, and bulk density (1).

Severe burning was clearly found to reduce macroscopic pore volume and percolation rate below the levels in unburned soil as shown in figure 1. Microscopic pore volume and bulk density, in contrast, were both increased by severe burning. Direction of the change was the same in both soils; and the magnitude of change, when expressed as a percent of unburned soil, was remarkably consistent. Total pore space was reduced as a result of severe burning in the pumicy sandy loam but unchanged in the sandy clay loam.

When changes in soil properties after burning are expressed as a percentage of the corresponding value for unburned soil, it was found that decrease in percolation rate after severe burning about equals decrease in macroscopic pore volume; that increase in microscopic pore volume is almost identical under both light and severe burn; and that change in bulk density (except for severely burned sandy clay loam) is about matched by an equal but opposite change in total pore

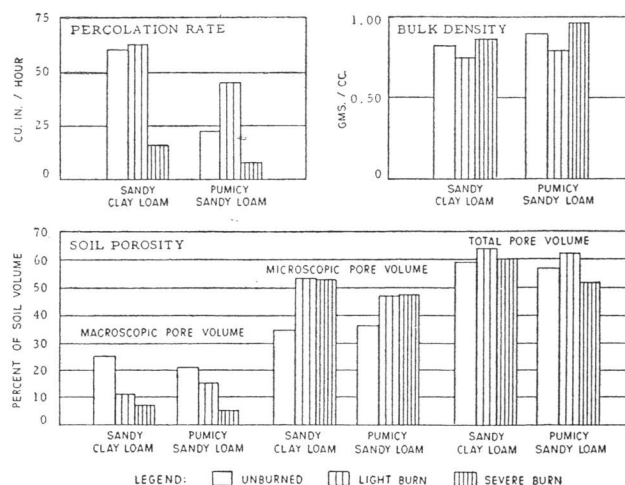


FIG. 1.—Changes in physical soil properties after slash burning.

volume. In lightly burned soils, only the relationship between percolation rate and macroscopic pore volume fails to conform to recognized principles of soil water movement.

Although severe burning seriously lowered percolation rate in the two soils analyzed, the over-all influence of slash burning on soil moisture properties of the cutting areas studied was of minor importance. If severe burning were applied uniformly over a large area, increased surface runoff and erosion would be expected. However, since severe burn occurs only in small, scattered patches, usually totaling less than 5% of the cutting area, the net effect is not considered highly detrimental. Concern is also lessened by the continuing improvement in wood utilization that has been evident in recent years. Eventually loggers may remove most of the large material which now provides fuel for severe burns.

Chemical Properties

Probably the most discussed change in soil conditions after burning is that of soil reaction. We know from earlier studies that "Slash burning tends to change, temporarily at least, the duff and surface soil from an acid to an alkaline condition, but how long this change continues is not known (3)." Accordingly, a study was made in which the trend of pH during the 4 years following slash burning was studied (7). Several relationships were noted (see table 1) as follows:

1. *Significant differences in soil pH were found between unburned and light burn, unburned and severe burn, and between light and severe burn.* The amount of change in soil pH is evidently related to severity of burn. This finding substantiates an earlier laboratory study (6). To minimize change in pH during slash burning, the fire should apparently be light enough so that only part of the litter is consumed.

2. *pH decreased significantly with an increase in time since burning.* One year after burning, pH of burned soil was neutral or slightly acid. Three years after burning, the soils had not returned to their original level of acidity, but even severely burned soils were well within the acid range found naturally in the Douglas-fir region. Perhaps a new humus layer will have to form before severely burned soils will fully regain their original pH value.

Table 1.—Average pH on clearcuttings in Douglas-fir by time since slash burning and intensity of burn.

| Time since burning | Severe burn | Light burn | Un-burned | Adjacent timber |
|-----------------------------------|-------------|------------|-----------|-----------------|
| Cascade Head Experimental forest | | | | |
| Fresh burn 1948 | 7.2 | 7.1 | 4.4 | — |
| One year 1949 | 5.8 | 5.6 | 4.5 | — |
| Two years 1950 | 5.8 | 5.2 | 4.4 | — |
| Four years 1952 | 5.0 | 4.6 | 4.3 | — |
| Wind River Experimental Forest | | | | |
| Fresh burn 1953 | 7.6 | 6.8 | 5.3 | 4.2 |
| One year 1952 | 7.0 | 6.0 | 5.2 | 4.8 |
| Two years 1951 | 6.4 | 5.5 | 5.2 | 4.8 |
| Three years 1950 | 6.0 | 5.0 | 4.8 | 4.0 |
| H. J. Andrews Experimental Forest | | | | |
| Fresh burn 1953 | 7.4 | 7.1 | 5.2 | 4.5 |
| One year 1952 | 7.1 | 6.5 | 5.2 | 4.9 |
| Two years 1951 | 6.1 | 5.5 | 5.0 | 5.0 |
| Three years 1950* | 6.5 | 6.0 | 5.1 | 5.1 |

*This clearcutting was included in the study because it was the only 3-year-old burn in the locality. The soil is derived from andesite and is less acid than the agglomerate soils which characterize other areas studied on the H. J. Andrews Experimental Forest. Nevertheless, the basic relationship among the three intensities of burn remains the same.

3. *The rate of change in soil pH after burning is related to severity of the burn.* With increasing time after burning, pH decreased more on lightly burned than on severely burned areas.

Another study of the effect of heat on soil pH was made in which soils were heated in muffle furnaces (6). From this study, it was found that the greatest change in pH takes place at temperatures below 900°F. It is also at temperatures below 900°F. that duration of exposure to heat exerts an effect on the increase in soil reaction. Isaac and Hopkins (4) found that at a depth of 1 inch below the forest floor (about the same depth as the soils were sampled in this study), the heat generated under a heavy pile of Douglas-fir slash was 608°F. Our later study shows that this temperature would be sufficient to make a significant change in soil reaction. The findings of Isaac and Hopkins lend additional strength to the recommendation that slash fires should move rapidly through light concentrations of fuel if changes in soil reaction are to be avoided.

Still another study, as yet not completed, was made of the effects of slash burning on other chemical properties of the soil. Preliminary indications are that:

1. Light burning stimulates nitrification, but severe burning strongly reduces nitrogen content of the soil.

2. Light burning increases the amount of acid soluble P_2O_5 and exchangeable potassium. Severe burning increases even more greatly the available supply of these nutrients.

3. Light burning has no appreciable effect on cation-exchange capacity, but severe burning reduces this property strongly.

This study will eventually relate the chemical effects of burning to seed germination and seedling growth, and will provide more direct evidence of effects of slash burning on forest productivity than a consideration of chemical data alone.

Germination and Growth of Douglas-fir Seedlings

Wood ash and its accompanying alkalinity have sometimes been cited as being harmful to germination

of tree seed on slash-burned forest land. One experiment (2) indicated that "...there was absolutely no germination where ash was added to the unburned soil." Reasons given for this hindrance to germination included increased pH of the soil, hardening of the ash layer, and exclusion of oxygen and high concentration of the nutrient solution.

In contrast, experiments at the University of Washington (10) indicated that Douglas-fir seed germinated successfully under controlled pH conditions ranging from strongly acid to strongly alkaline.

These contradictory reports prompted the inclusion of further tests in our program of research on the effects of slash burning on soil and regeneration. To test the effects both of high pH and wood ash, Douglas-fir seed was germinated in three different media: artificially heated soils, an ash-sand mixture of varying concentration, and soils from slash-burned areas.

Reaction of these three germinating media ranged from pH 4.5 to pH 9.8. Despite the great range of pH, there was no evidence of a relation between soil reaction and germination rate of Douglas-fir seed (see figure 2). Of course, the fact that a seed may germinate under a great variety of pH conditions does not necessarily mean that further growth will also be satisfactory. These tests do indicate, however, that relatively high pH, within limits found after slash burning (7), does not prevent germination of Douglas-fir seed (8).

Interest in the effects of slash burning on soil is focused on the ultimate effects on tree growth. It is important, therefore, to relate seedling growth to intensity of burn. In such a study (9), more than 400 natural Douglas-fir seedlings, including both 1- and 2-year-old trees, were dug and their height and root length measured. This sample of seedlings was taken from unburned, lightly burned, and severely burned soil surfaces on two experimental forests.

At the Wind River Experimental Forest, no significant differences were found in either seedling height or root growth between the various degrees of burn or

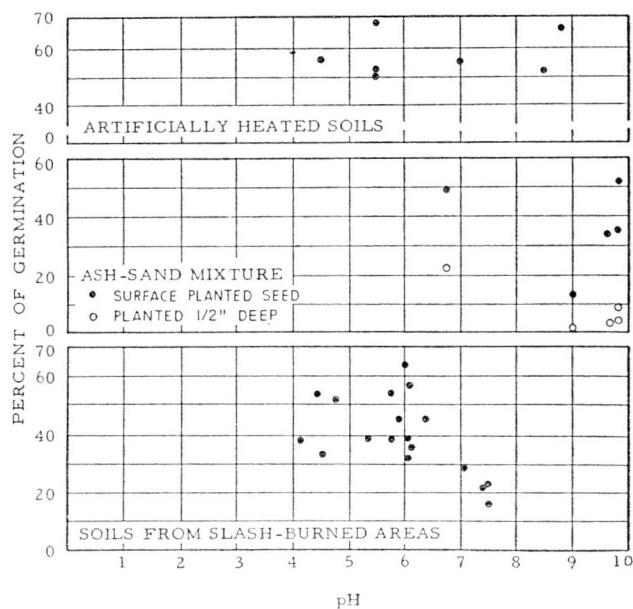


FIG. 2.—Relation of seed germination to pH in three different germinating media.

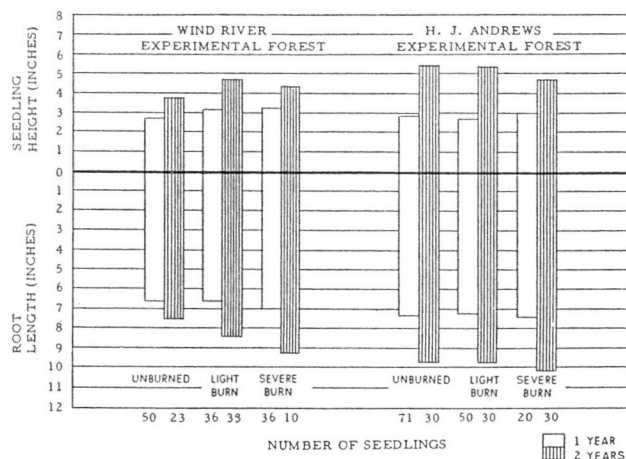


FIG. 3.—Average height and root growth of natural Douglas-fir seedlings after slash burning.

unburned soil (see figure 3). At the H. J. Andrews Experimental Forest, height growth of 1-year-old seedlings was significantly greater on severely burned soil than on unburned soil. For 2-year-old seedlings, height growth was significantly greater on lightly burned than on unburned soil.

These findings indicate that growth of young Douglas-fir seedlings, at least under field conditions represented by the two study areas, was not inhibited by slash burning. In making this statement, we emphasize that the data do not cover possible effects of slash burning on germination, seedling survival, and seedling growth after the first 2 years. These effects, which could be equally important, are the subject of a more intensive study currently under way.

Biological Properties

An interesting sidelight of the germination studies was the disclosure that seedlings in the media of higher pH suffered heavy damping-off losses a day or two after emergence. It has long been established that near-neutral or alkaline soil reaction favors the development of damping-off organisms (5). Perhaps premergence damping-off is responsible for low germination

rates on some severely burned soils. Further tests of the relation between soil reaction and damping-off under field conditions are now in progress.

A study was made in which natural Douglas-fir seedlings growing on slash-burned areas were critically examined for mycorrhizae. The following significant differences were observed:

One year after the burn, 65% of 1-year-old seedlings on unburned soil had external mycorrhizae. On burned soil, only 40% of 1-year-old seedlings were mycorrhizal. The second year after burning, 100% of 2-year-old seedlings on unburned soil had mycorrhizae, but only 79% on burned soil.

Mycorrhizae were deeper in the burned soil in the case of 1-year-old seedlings, but for 2-year-old seedlings, there were no differences in depth of mycorrhizae between burned and unburned soils.

Literature Cited

1. Forest Soils Committee of the Douglas Fir Region. Sampling procedures and methods of analysis for forest soils. Univ. Wash., Seattle. Processed (1953).
2. Gayle, W. B., and Gilgan, W. W. The effect of slash burning on germination and primary survival of lodgepole pine and Douglas-fir. Univ. British Columbia Forest Club Res. Note No. 2. Processed (1951).
3. Isaac, Leo A. Reproductive habits of Douglas-fir. Charles Lathrop Pack Forestry Foundation, Washington, D. C. (1943).
4. ——— and Hopkins, Howard G. The forest soil of the Douglas-fir region and changes wrought upon it by logging and slash burning. *Ecology* 18:264-279 (1937).
5. Lutz, Harold J., and Chandler, Robert F., Jr. *Forest soils*. John Wiley and Sons, New York, N. Y. (1946).
6. Tarrant, Robert F. Effect of heat on soil color and pH of two forest soils. U. S. Forest Serv., Pacific Northwest Forest and Range Exp. Sta. Res. Note No. 90 (1953).
7. ———. Effect of slash burning on soil pH. U. S. Forest Service, Pacific Northwest Forest and Range Exp. Sta. Res. Note No. 102 (1954).
8. ———. Soil reaction and germination of Douglas-fir seed. U. S. Forest Service, Pacific Northwest Forest and Range Exp. Sta. Res. Note No. 105 (1954).
9. ——— and Wright, Ernest. Growth of Douglas-fir seedlings after slash burning. U. S. Forest Service, Pacific Northwest Forest and Range Exp. Sta. Res. Note No. 115 (1955).
10. Thrupp, A. C. Effect of seed-ash characteristics and treatment of seed and soils upon coniferous seed germination. Unpublished doctoral dissertation, College of Forestry, University of Washington (1939).
11. Vlamis, J., Schultz, A. M., and Biswell, H. H. Burning and soil fertility. *Calif. Agric.* 9 (3):7 (1955).