Accelerated mass wasting after logging and slash burning in western Oregon

R. C. MERSEREAU and C. T. DYRNESS

ABSTRACT—Clearcut logging and slash burning in a steep 237-acre watershed in western Oregon resulted in increased rates of soil movement, especially on slopes unprotected by organic debris. During the first growing season after burning, soil movement, which largely occurred as dry ravel, was most pronounced on 80-percent slopes (versus 60-percent), on south aspects (versus north), and in areas having little plant cover (versus well-vegetated areas). By the second growing season after burning, rapid invasion by vegetation essentially halted soil movement on all slopes except extremely stony talus areas.

SOIL movement may decrease site productivity significantly either by removing the more productive surface soil or by covering the surface with less productive material. During the dry season, soil movement also is a substantial source of stream sediment, although its effect on site deterioration often is overlooked because it is not always obvious and frequently does not appear to involve large amounts of soil.

Research in southern California has shown that dry-season debris ravel on steep slopes results in substantially more erosion than wet-season movement (*1*). In the Pacific Northwest, dry-season debris movement on steep slopes may be an important cause of mortality among planted Douglas-fir seedlings (3).

Our study was conducted in a clearcut 237-acre watershed in the H. J. Andrews Experimental Forest, located on the west side of Oregon's Cascade Range. The climate is typically wet with mild winters and dry, cool summers. Precipitation averages 88 inches a year, about 90 percent of which falls mainly as rain from October through April. Rainfall intensities are seldom high enough to cause overland flow on these soils.

Watershed slopes average about 65 percent. There are several nearly vertical rock outcrops as well as steep downward-trending ridges between tributary drainages. Soils tend to be shallow, stony, and extremely permeable; they transmit water rapidly.

The watershed was skyline logged from 1962 to 1966. Logging debris was broadcast burned in the fall of 1966. A soil condition survey in the spring of 1967 revealed the slash burn to be about average for the region. The survey also revealed considerable surface soil movement, especially on steeper slopes where most organic debris had been burned. A limited sampling of erosion was undertaken to provide rough estimates of soil movement in the watershed and to determine variations in the rate of soil movement resulting from climatic events, slope steepness and aspect, and amount of vegetative cover.

Study Methods

Two soil collection boxes, 8 feet long by 1½ feet wide, were located in each of five slope-soil condition classes—one on a north-facing slope and one on a south-facing slope (Figure 1). The five classes were (1) 80-percent slope, soil bare with obvious movement; (2) 80-percent slope, soil disturbed[1] but with some vegetation; (3) 60-percent slope, soil bare and moving; (4) 60-percent slope, soil disturbed but with some vegetation; and (5) 80-percent talus slo[pe] composed of platy fragments of and[e]site or welded tuff. Undisturbed are[as] in the watershed were not sample[d] under the assumption that no mea[s]urable soil movement would occ[ur] there.

The collectors were placed just b[e]low ridge tops and other topograph[ic] breaks so it would be possible to d[e]fine the contributing areas. The[se] areas were corrected for slope so a[ll] areal measurements would be on [a] horizontal basis. Size of contributin[g] areas ranged from about 0.01 to 0.0[?] acre.

To estimate total soil movement i[n] the watershed, total area within eac[h] sampled class was estimated using [a] planimeter on aerial photographs.

Precipitation during such collectio[n] period was taken from records f[or] five rain gauges located near the e[x]perimental area.

Results

Rates of soil movement were a[p]preciably higher on 80-percent slop[es] than on 60-percent slopes (Table 1). An average total catch by the fo[ur] boxes on each slope class (excludin[g] two collectors on the talus material) was 89.6 cubic feet per acre on 80-percent slopes and 20.6 cubic feet p[er] acre on 60-percent slopes.

During the first growing seaso[n] after slash burning, more surface so[il] moved on bare slopes than on vege[tated] slopes—at least half again a[s] much on three of four plot sets. Th[e]

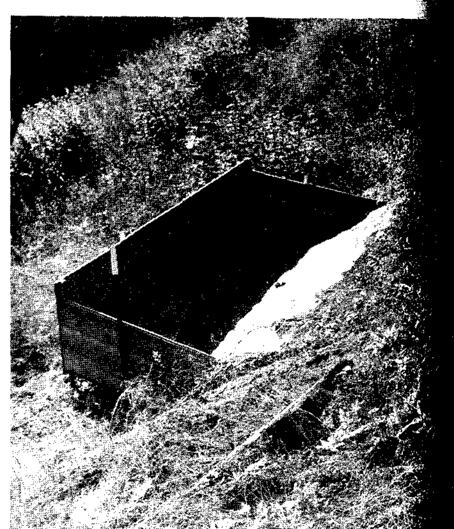

Figure 1. Soil collection box on an 80-perce[nt] south-facing slope 2 years after slash burni[ng] (October 1968).

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[1]Disturbed condition ranged from forest litter removed and bare mineral soil exposed to deep disturbance involving complete removal of surface soil.

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The collectors were placed just below ridge tops and other topographic breaks so it would be possible to define the contributing areas. These areas were corrected for slope so all areal measurements would be on a horizontal basis. Size of contributing areas ranged from about 0.01 to 0.06 acre.

To estimate total soil movement in the watershed, total area within each sampled class was estimated using a planimeter on aerial photographs.

Precipitation during such collection period was taken from records for five rain gauges located near the experimental area.

Results

Rates of soil movement were appreciably higher on 80-percent slopes than on 60-percent slopes (Table 1). An average total catch by the four boxes on each slope class (excluding two collectors on the talus material) was 89.6 cubic feet per acre on 80-percent slopes and 20.6 cubic feet per acre on 60-percent slopes.

During the first growing season after slash burning, more surface soil moved on bare slopes than on vegetated slopes—at least half again as much on three of four plot sets. The

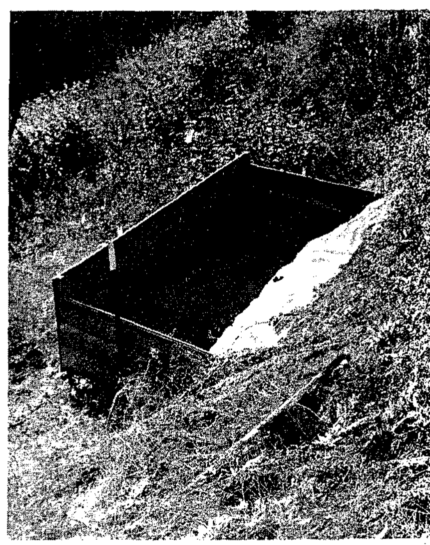

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Table 1. Cun
ning July 7, 1

Collection Date
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9-13-67
10-26-67
2-13-68
4-10-68
5- 8-68
6-19-68
9-10-68

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Table 1. Cumulative volume of soil and rock debris caught in 10 collectors on 60- to 80-percent slopes over an 18-month period beginning July 7, 1967.

Collection Date	80-Percent South		80-Percent North		60-Percent South		60-Percent North		80-Percent Talus	
	Bare[a]	Vegetated	Bare	Vegetated	Bare	Vegetated	Bare	Vegetated	West	North
	cu ft/a									
8- 3-67	32.0	33.5	5.0	5.0	22.7	0	4.4	2.1	34.8	95.2
9-13-67	73.8	54.4	50.0	11.7	40.9	0	4.4	2.1	45.2	289.6
10-26-67	95.9	71.2	54.0	11.7	52.3	0	4.4	2.1	55.6	332.1
2-13-68	111.9	113.7[b]	58.5	13.3	63.3	0.7	7.4	3.2	83.4	400.9
4-10-68	116.8	144.2	61.2	14.9	71.2	0.7	7.4	3.2	107.7	453.7
5- 8-68	118.0	148.3	61.7	16.2	71.2	0.7	7.4	3.2	112.9	477.5
6-19-68	118.0	152.4	—[c]	16.2	71.2	0.7	7.4	3.2	116.3	490.7
9-10-68	118.6	158.6	—[c]	19.5	71.2	0.7	7.4	3.2	116.3	502.7

[a]Prototype collector installed May 11, 1967. Total catch from May 11 to July 7 was 190.3 cubic feet per acre. Remaining nine collectors were installed July 6 and 7, 1967.
[b]Large increase caused by small landslide in the center of the contributing area.
[c]Collector accidentally destroyed and contributing area greatly disturbed.

one exception resulted from a small landslide on the 80-percent south vegetated plot (Table 1).

By the end of the summer of 1967, bare plots averaged about 5-percent vegetative cover. Cover on vegetated plots ranged from 30- to 40-percent. However, rapid invasion of vegetation (mainly *Epilobium paniculatum*) in 1968 eliminated much of this difference. By the end of the 1968 growing season, plant cover averaged 50 percent on bare plots and 75 percent on vegetated plots. The stabilizing effect of the vegetation is shown in table 1. During the entire 1968 growing season, little soil movement occurred, even on 80-percent slopes.

Slope aspect seemed to have almost as much effect on soil movement as steepness. Soil losses on south slopes averaged 87.3 cubic feet per acre as opposed to 23.0 cubic feet per acre on north slopes. The fact that south slopes tend to dry out more quickly probably accounts for this difference. The soils apparently are less cohesive when dry. Thus dry-season movement tends to be considerably higher than wet-season movement. Data from the bare 80-percent south plot show that soil movement totaled 265 cubic feet per acre during a 4-month period with little rain (3.56 inches) compared with 44 cubic feet per acre during a 7½-month period with 61 inches of rain.

Three factors—slope steepness, aspect, and vegetative cover—obviously operate together, not separately. Thus soils subject to movement because of steep topography show a much greater degree of instability when they also are bare and/or on a south-facing slope. Soil movement on bare south slopes surpassed movement on vegetated north slopes by eight times. On 80-percent south slopes, 26 times as much movement occurred as on 60-percent north slopes. Movement on 80-percent bare slopes exceeded movement on 60-percent vegetated slopes by 46 times.

Stratification of the watershed placed about 73 percent of its area in the sampled classes, about half facing south and half facing north. By expanding the data to all similar areas, total soil movement within the watershed for the 16-month sampling period was estimated. The total was 12,378 cubic feet, the equivalent of 0.014 inch over the entire watershed (Table 2).

The fact that almost three-fourths of the estimated soil and rock movement in the watershed originated from talus slopes emphasized the extremely unstable nature of these areas (Table 2). Consisting mainly of platy rock fragments, these areas were unstable before logging and supported a rather low number of tree stems per acre. Logging and burning apparently increased this instability, especially on the north-facing plot (Table 1). Because of the continuing instability and stony soil, reforesting these areas will be a slow process.

Table 2. Watershed area and estimated total surface soil moved in the experimental watershed by sampled class, July 1967 to September 1968.

Slope/Aspect/ Condition Class	Watershed Area (a)	Volume (cu ft)
80% south-bare	5.1	604
80% south-vegetated	9.4	1,494
80% north-bare	5.1	314
80% north-vegetated	9.4	184
60% south-bare	6.5	468
60% south-vegetated	58.3	41
60% north-bare	6.5	49
60% north-vegetated	58.3	187
80% talus	14.6	9,037
Total	173.2[a]	12,378

[a]About 27 percent or 64 acres of the watershed was not included in the sampled classes, being rock outcrop, undisturbed, or slopes less than 60 percent.

Conclusions

Slash burning on steep slopes contributes to surface soil movement by removing litter and vegetation which help stabilize the soil. After clearcutting, but before slash burning, about 12 percent of the watershed was bare mineral soil (3). After burning, 55 percent of the watershed area was bare mineral soil. Because of rapid revegetation, however, serious soil movement occurred only during the first growing season.

In the first 2 months of operation, one prototype collection box caught over 190 cubic feet of material per acre. In the next 16 months, when all 10 collectors were in use, the same box caught only 118 cubic feet of material per acre (Table 1). Thus of the total soil movement measured on this plot, 62 percent was measured before the other nine collectors were installed. If we apply these percentages to all collectors, less than 40 percent of the total soil movement occurring after burning was measured. Future studies of this sort, therefore, should be initiated as soon after burning as possible.

Whenever steep south slopes are logged, care should be taken to preserve as much vegetation as possible. On any steep, unstable area, other means of slash disposal, such as clean yarding or chipping and returning slash to the slope, should be considered as alternatives to broadcast burning.

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Spoils change and tree growth on coal-mined spoils in Kansas

WAYNE A. GEYER and NELSON F. ROGERS

ABSTRACT—Tree growth on coal-mine spoils in Kansas illustrates the potential for growing commercial timber on these areas. Black locust, bur oak, sycamore, loblolly pine, and shortleaf pine performed best after 22 years. Total tree height increased 2 feet from the lower to middle to upper portions of slopes; aspect had no effect on growth. Wood density of loblolly and shortleaf pine was lower than in the South. Leveling spoils reduced tree growth and form. After 20 years, pH and the percentage of soil-size particles in spoils had increased; phosphorus had decreased.

COAL-MINED areas must be returned to productive uses. Establishing adaptable vegetation that is capable of producing commercial crops is one way of using these land resources wisely. Other possible uses include recreational areas, industrial sites, and real estate development.

Mining of bituminous coal since the mid-1800s has created nearly 45,600 acres of disturbed land in eastern Kansas (*9*). Historically, surface mining has been the predominant method of coal removal, and all active operations now are above ground.

Quality coal, good markets, extensive land ownership, and level topography enable electric shovels and draglines to expose multiple seams of coal up to 60 feet deep over large tracts of land. Parallel ridges of overburden or spoil result, some 40 feet high and a mile long. Kansas law now requires all newly mined areas to be partially leveled.

The deposited overburden—a mixture of sedimentary rock, surface and subsurface soil, and coal particles—represents a new medium for plant growth. Characteristically, it is diversified within relatively small areas. Site conditions depend upon parent material of the new surface layer, mining methods, whether or not banks were graded, and the extent of erosion. (*5*).

The study reported here was designed to evaluate the commercial timber-producing potential of coal-mined land in Kansas. It was initiated in 1947 by the Central States Forest Experiment Station on land owned by numerous coal companies.

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Study Methods

Six tree planting sites were selected on ungraded spoils from three different coal seams. Three sites were mined recently (4 years before planting) and three relatively recently (11 years before planting). All were mined from 1930 through 1946, a period of peak coal production to that time. A seventh, leveled-spoil site was planted also.

Vegetative cover, based upon a visual estimate of the density of natural cover during the first growing season, varied from 5 to 95 percent on the seven sites (*2*). Five sites fell in the 25-to-40-percent range.

A five-acre plantation was established on each site during the spring of 1947. Each plantation was divided into 70-foot-square plots (42 per area) in which 100 trees of a single species were planted with three replications. Thirteen species, both native and nonnative to Kansas, were planted: black cherry (*Prunus serotina* Ehrh.), black locust (*Robinia pseudoacacia* L.), black walnut seed (*Juglans nigra* L.), bur oak seed and seedlings (*Quercus macrocarpa* Michx.), eastern redcedar (*Juniperus virginiana* L.), green ash (*Fraxinus pennsylvania* Marsh.), jack pine (*Pinus banksiana* Lamb.), loblolly pine (P. *taeda* L.), pitch pine (P. *rigida* Mill.), ponderosa pine (P. *ponderosa* Laws.), shortleaf pine (P. *echinata* Mill.), Virginia pine (P. *virginiana* Mill), and sycamore (*Platanus occidentalis* L.), All species came from suppliers in the central United States, mostly 1:0, nursery stock, except bur oak (1:1) and jack pine and ponderosa pine (2:0). The bur oak and walnut seed were from sources in eastern Kansas.

Survival and height were evaluated after the sixth growing season (*2*), in addition to diameter, basal area, and volume after the 22nd season. Measurements were limited to the interior 36 trees on each plot, excluding overtopped trees, to obtain an indication of commercial potential. Data were subjected to statistical analysis of variance (multiway) techniques.

Physical and chemical properties of spoils were determined from samples collected (0-to 12-inch depth) in 1947 at a series of points 35 feet apart on a single line across a plantation. Twen-