Logging, Infiltration Capacity, and Surface Erodibility in Western Oregon

Michael G. Johnson and Robert L. Beschta

360

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ABSTRACT—Infiltration capacity and erodibility were measured three to six years after portions of forested watersheds in western Oregon had been logged. Overall values on the logged portions did not differ significantly from values on unlogged portions. Areas that had been heavily disturbed—skid trails, cable log paths, and places where slash had been windrowed by tractors and then burned—had reduced infiltration capacity and increased surface erodibility but also had partially recovered to prelogging conditions.

On undisturbed forested watersheds in the mountains of western Oregon, infiltration capacities (the rate at which rain or melted snow enters a thoroughly wetted soil) are high, usually exceeding precipitation rates. Overland flow therefore is uncommon (Rothacher et al. 1967; Harr 1976, 1977). Logging activities, however, often alter the soil surface and reduce infiltration capacities. Thus yarding and skidding may compact soil; burning of slash may form nonwettable layers in the soil; and raindrop splash may erode soil particles, which in turn may plug macropores.

With infiltration capacities reduced, overland flow may contribute to increased peak flows such as those observed after logging at the Coyote Creek watersheds in southwestern Oregon's Cascade Mountains (Harr et al. 1979). Accelerated surface erosion after logging, accompanied by increased stream sedimentation and turbidity, were also observed at Coyote Creek (R. L. Fredriksen, personal communication, 1978, Pacific Northwest Forest and Range Experiment Station, Corvallis).

In the study reported here, we attempted to learn how various harvesting practices affected infiltration capacity and surface erodibility at Coyote Creek and other experimental watersheds in western Oregon. The measurements were made some years after the logging had been completed.

Study Areas and Methods

Four contiguous experimental watersheds, ranging from 128 to 171 acres, were studied at Coyote Creek in the South Umpqua Experimental Forest approximately 40 miles southeast of Roseburg (*fig. 1*). Three Hi-15 watersheds, ranging from 32 to 55 acres, were studied in the H. J. Andrews Experimental Forest about 45 miles east of Eugene (*fig. 2*). These experimental forests are managed by the Willamette and Umpqua national forests in cooperation with the Pacific Northwest Forest and Range Experiment Station, USDA Forest Service.

Because the Pacific Ocean moderates the climate, both study areas have wet, mild winters and dry, warm summers. Annual precipitation averages 48 inches at Coyote Creek and 92 inches on the Hi-15 watersheds,

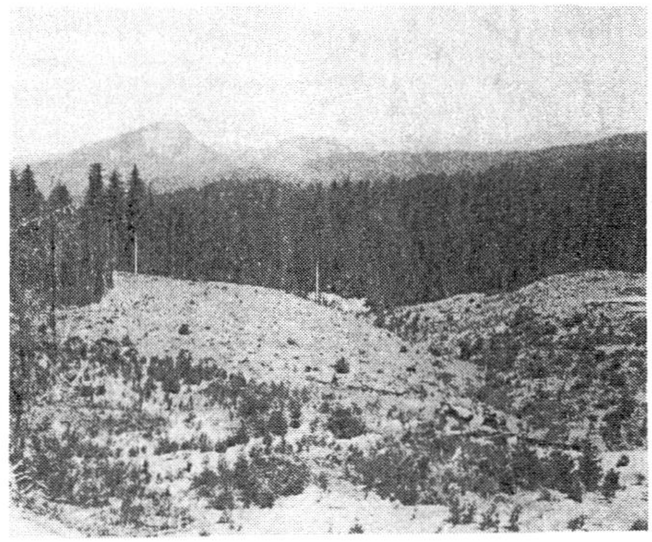

Figure 1. Watershed 3 at Coyote Creek in western Oregon. Six years before photo was taken, area in left center was tractor-skidded, with slash windrowed and burned.

with 80 to 90 percent of the total falling during the autumn and winter (Harr et al. 1979). Rainfall intensities average about 0.12 inch per hour during the fall and winter but may reach 0.24 to 0.51 inch per hour (Rothacher et al. 1967). Although summer precipitation is low at both areas, storms of high intensity but short duration occasionally occur at Coyote Creek. For example, during the late spring of 1977, a storm lasting 5 to 10 minutes had an intensity of 3.15 inches per hour.

Soils at Coyote Creek are a mixture derived from basalt, red and green breccias, agglomerates, and tuffs; scattered rhyolitic breccia and agglomerate soils are also present. Soils formed from andesite cover the Hi-15 watersheds. Both study areas have slope gradients of 20 to 80 percent. At Coyote Creek, the dominant Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) intermingles with ponderosa pine (*Pinus ponderosa* Laws.), sugar pine (*Pinus lambertiana* Dougl.) and incense cedar (*Libocedrus decurrens* Torr.). Overstory tree species on the Hi-15 watersheds are old-growth Douglas-fir mixed with western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and western redcedar (*Thuja plicata* Donn ex D. Don).

The Coyote Creek watersheds had been harvested in the late spring and summer of 1971, the Hi-15 areas in the summer of 1974. Harvesting treatments are outlined in the caption for *figure 2*. At Coyote Creek they consisted of (1) shelterwood harvest with tractor skidding, (2) clearcutting with cable yarding, (3) clearcutting with tractors used for skidding and for windrowing slash, and (4) undisturbed. A fifth treatment had been

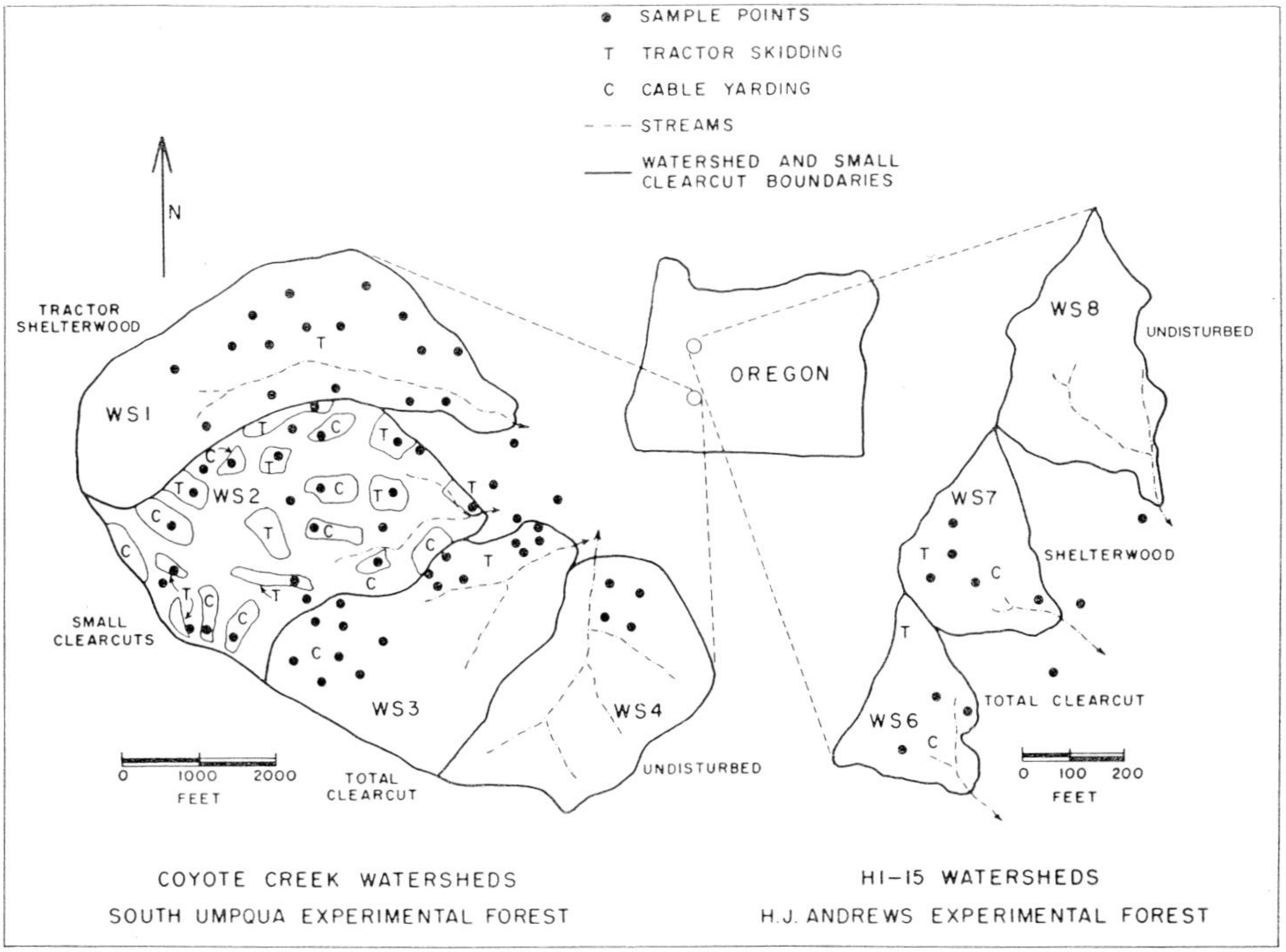

Figure 2. Location of sampling sites on the Coyote Creek watersheds and the Hi-15 watersheds in western Oregon. In watershed 1, at Coyote Creek, a shelterwood cut removed 50 percent of the basal area; logs were skidded by tractors. In watershed 2, 20 small patchcuts ranged from 1.6 to 3.5 acres and comprised 30 percent of the total area; logs in 10 clearcut patches were tractor-skidded while logs in the remaining 10 patches were yarded by a mobile, high-lead cable system. Cull logs and slash in all units were burned. Timber on 77 percent of the totally clearcut watershed 3 was cable-yarded, and slash piles on landings were later burned; on the remaining 23 percent, timber was skidded with tractors, slash was windrowed, and piles were burned two years later. Watershed 4, areas outside the lower perimeter of watersheds 2 and 3, and the leave-strips between the patchcuts on watershed 2 were undisturbed. Of the Hi-15 watersheds, watershed 6 was totally clearcut; 90 percent of the area was yarded with a portable, high-lead cable system, and the logs on the remaining area were skidded by tractor. Cull logs and slash were burned in the spring of 1975. In watershed 7, a shelterwood cut removed 60 percent of the basal area. Timber on the lower one-third of the watershed was yarded by a high-lead cable system, while the remainder was skidded by tractor. Watershed 8 and areas adjacent to watersheds 6 and 7 were unlogged and undisturbed.

applied at Hi-15, shelterwood harvest with cable yarding.

In the summer of 1977, infiltration capacities and surface erodibilities on plots were assessed with an infiltrometer similar to that used by Meeuwig (1971). The infiltrometer is a rainfall simulator that uniformly applies water at a controlled rate to approximately 4 square feet of soil surface. Simulated rainfall was applied at a rate of 3 to 7 inches per hour on prewetted plots and continued for 10 to 20 minutes until the rate of infiltration (that is, capacity) became constant. To determine infiltration capacity, runoff (overland flow) was collected at the downhill edge of the application area and subtracted from the amount of rainfall applied. Although the simulator may overestimate actual capacities on wildland watersheds (Meeuwig 1971), it can effectively index changes in infiltration capacity and surface erodibility. Surface erodibility was measured by determining the concentration of suspended sediment in runoff water from each plot (Johnson 1978).

Because of the documented increase in peak flows and sedimentation at Coyote Creek, sampling was more intensive there than on the Hi-15 watersheds. Within each treatment, sample points—16 at Coyote Creek but only 2 or 3 at Hi-15—were randomly located, and two plots were established at each point. Twenty-five to fifty percent of the sample points within each treatment fell on places that had been severely disturbed during logging.

Effects on infiltration capacity and surface erodibility were evaluated with a one-way analysis of variance for a completely randomized design, and t-tests were used to appraise differences between treatments at the

0.10 level of probability. Infiltration data were normally distributed, but erodibility data were highly skewed and required a transformation to normalize the data prior to statistical analysis.

Results

Average infiltration capacities for logged watersheds at Coyote Creek were generally similar to those for undisturbed areas (*fig. 3*). However, capacities were significantly reduced on watershed 3 because of tractor logging, tractor windrowing of slash, and burning of slash on soils of high clay content. Nowhere else on the Coyote Creek watersheds did we find soils with such a massive subsurface clay. We do not know if compaction by tractors contributed to this tight subsoil, but the severe surface disturbance during skidding, windrowing, and slash burning did reduce the infiltration capacity. The reduction probably indicates a surface sealing resulting from the high percentage of bare ground (41 percent compared to only 1 percent for undisturbed sites), as well as irregular and discontinuous resistance to wetting.

Harvesting significantly increased surface erodibility only on the tractor-logged sites of watersheds 2 and 3. Increased sediment concentrations in watershed 2 were attributed to the skid trails that comprised 50 percent of the sample points (*fig. 3*). Apparently, tractor logging had removed the upper several inches of the soil horizon, and little vegetative or litter cover remained. Because tractors were extensively used on 23 percent of watershed 3 for both skidding and windrowing of slash, most of this area had a highly disturbed soil surface. As a result, the simulated rainfall and overland flow easily eroded silts and amorphous clays from disturbed breccia soils.

Regression analysis was also used to relate infiltration capacities and sediment concentrations to surface conditions (litter characteristics, vegetative cover, and percent of slope) and soil properties (bulk density, moisture content, porosity, and air permeability). Correlation coefficients (r) were generally low; percentage of bare ground had the highest correlation with infiltration (−0.41) and sediment concentration (+0.64). Both correlations were significant. The low correlations with other independent variables probably reflect the large variability in point measurements. Furthermore, interactions between the variables prevented regression analysis from identifying specific cause-and-effect relationships.

At the Hi-15 watersheds, harvesting did not significantly affect infiltration. (Because the area was small and the numbers of sample points limited, the tractor-yarded portion of watershed 6 was excluded from this analysis.) Similarly, sediment concentrations were not significantly increased. In fact, concentrations significantly decreased on the cable-yarded portion of the shelterwood cut on watershed 7 (*fig. 3*), indicating a reduced potential for surface erosion after logging. These results indicate that surface erodibility is not a problem on the Hi-15 watersheds three years after treatment.

As at Coyote Creek, infiltration capacities and sediment concentrations correlated poorly with surface and soil properties. Infiltration capacity correlated best with percentage of live vegetative cover ($r = +0.65$), and sediment concentration correlated best

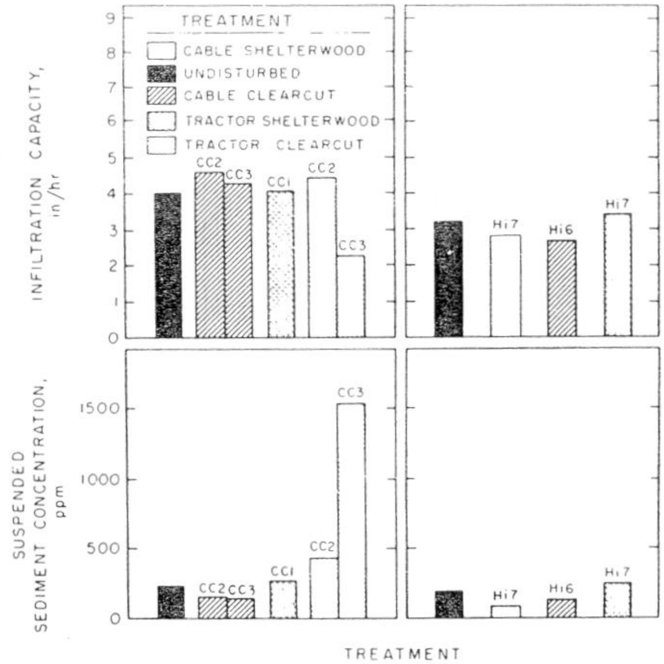

Figure 3. Infiltration capacity and surface erodibility of western Oregon watersheds logged by various methods. CC = Coyote Creek watersheds logged in 1971, Hi = Hi-15 watersheds logged in 1974. Measurements were made in summer 1977.

with percentage of rock cover ($r = +0.46$). (Only the former correlation was significant.) At both the Coyote Creek and Hi-15 locations, surface conditions (percentages of bare ground, vegetative cover, or rock) were the most important variables influencing infiltration and erodibility.

Both treated and undisturbed watersheds at Coyote Creek had significantly higher infiltration capacities than did the Hi-15 watersheds. These differences are undoubtedly related to soil characteristics (texture, structure, and parent material) and surface conditions (bare soil, vegetation, and a resistance to wetting). Furthermore, Coyote Creek had three more years to recover after timber harvesting.

Surface erodibility at the two locations also differed significantly. Although erodibilities were similar for undisturbed points at both areas, comparable logging treatments generally increased erodibility more at Coyote Creek than on the Hi-15 watersheds.

Mean infiltration capacities of skid trails and cable log paths (*fig. 4*) usually were significantly lower than the treatment averages (*fig. 3*). Because sites in skid trails generally had the least vegetative cover and the most soil exposure, dislodged silt and clay particles could readily seal macropores at the surface. Also, water-repellant soil surfaces may partially explain the lower infiltration capacities.

The infiltrometer generally overestimates actual infiltration capacities. For example, raindrops striking the soil at terminal velocity may infiltrate more slowly than simulated raindrops falling 2 feet from the infiltrometer, particularly where mineral soil is exposed. Even so, this study does not indicate that reduced infiltration capacities from soil disturbance and compaction by logging six years ago have increased peak flows on the Coyote Creek watersheds. Skid trails, however, may be influencing subsurface flows and, hence, the

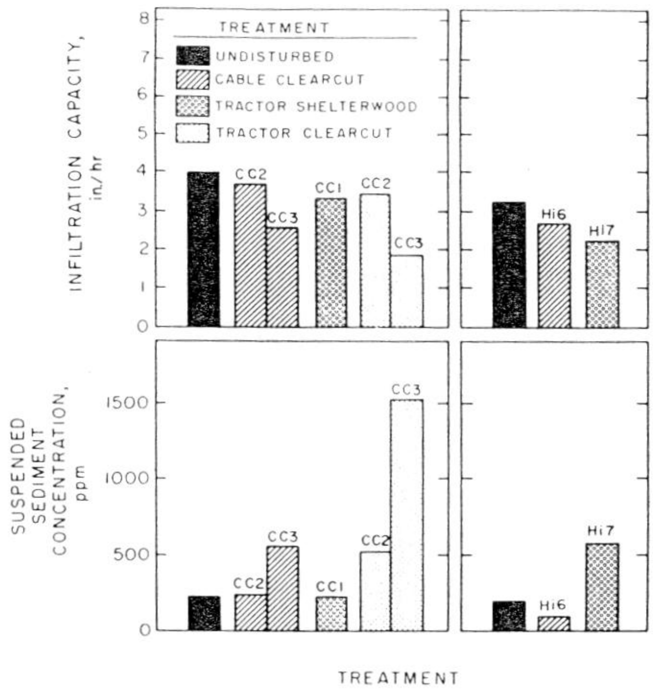

Figure 4. Infiltration capacity and surface erodibility of skid trails and cable log paths in western Oregon watersheds logged by various methods. CC = Coyote Creek watersheds logged in 1971. Hi = Hi-15 watersheds logged in 1974. Measurements were made in summer 1977.

water delivery to stream channels. Furthermore, unmonitored secondary roads on the treated Coyote Creek watersheds may be contributing to increased peak flows there.

Sediment concentrations from infiltration plots on skid trails and paths at Coyote Creek (*fig. 4*) exceeded the treatment averages (*fig. 3*) except for the tractor-skidded portion of watershed 3. Sediment concentrations on watershed 3 were attributed to the severe surface disturbance and burning over the entire area.

To investigate possible recovery of infiltration capacities and reductions in surface erodibility of skid trails, we also studied a nearby area that had been logged in the summer of 1977. During the fall of that year, we selected skid trails on soils similar to those in several tractor-skidded units of watershed 2, which had been harvested in 1971. The infiltration capacities were 1.7 inches per hour for the new skid trails and 3.3 inches per hour for the six-year-old trails on watershed 2. Sediment concentrations from skid trail plots were 5,400 ppm in the recently harvested area and 850 ppm in watershed 2; these values suggest a partial recovery on the latter. In watershed 2, the greater infiltration capacity and lower surface erodibility probably resulted from a combination of factors—freezing and thawing, shrinking and swelling, increased biological activity, and reestablishment of vegetative cover—that loosened soils and generally improved their hydrologic properties.

On the Hi-15 watersheds, surface erodibility increased on skid trails in the tractor-skidded portion of the shelterwood cut (*fig. 4*), and sediment concentrations averaged nearly three times those of plots in undisturbed areas. On cable-logged paths in watershed 6, however, sediment concentrations were less than the treatment averages. These results suggest that general surface disturbance and burning on watershed 6 caused greater sediment concentrations than did the paths created by cable yarding.

Effects on Soil and Water Can Be Minimized

This study was not begun immediately after harvesting, when effects of soil disturbance would normally be most pronounced. If logging did influence infiltration capacity and erodibility at the Coyote Creek and Hi-15 watersheds, the effects had almost disappeared after three to six years, except on the highly disturbed Coyote Creek watershed 3. Where soils had been severely compacted, the surface layer removed, or logging slash burned with a hot fire, infiltration capacity was less and erodibility was greater than on unlogged areas, although some recovery appeared to have occurred.

Undesirable changes in forest soils can be reduced by minimizing the extent of severe disturbance—for example, by yarding with cables instead of tractors, by restricting the area in skid trails, and by broadcast burning of slash instead of windrowing. With such precautions, and if the study watersheds are representative of others in the Pacific Northwest, it appears that logging will cause little long-term damage. Obviously, preventing undue soil disturbance will not only conserve site productivity but will also help to minimize downstream problems of water quality. ■

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THE AUTHORS—Michael G. Johnson—formerly a graduate research assistant, Oregon State University, Corvallis—is a hydrologist for the Coconino National Forest, USDA Forest Service, Flagstaff, Arizona. Robert L. Beschta is assistant professor of forest hydrology, School of Forestry, Oregon State University. This study was made possible by a grant from the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Corvallis. Paper 1355, Forest Research Laboratory, Oregon State University.