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Effects of Tractor Logging on Soils and Vegetation in Eastern Oregon

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ABSTRACT

Soil characteristics were investigated on a mixed conifer forest stand in Oregon's Blue Mountains. The most recent logging had occurred on the site 6 yr previously; 1 yr after harvest, slash was machine-piled and burned. Five classes of ground disturbance including a control were identified, based on degree of soil and ground cover disruption. Bulk density of the disturbed classes was not significantly different from control areas. Infiltration and saturated hydraulic conductivity rates on both disturbed and control areas were high relative to projected storm intensities. Soil organic matter content in the upper 3 cm of disturbed areas was markedly below that of control areas. Understory vegetation production on seeded skid trails was 66% above that of control areas; however, below ground biomass of control areas, vegetated with native rhizomatous species, was three times that of skid trails.

Additional Index Words: **volcanic ash soils, compaction, soil organic matter, skid trails, vegetative cover, logging disturbance.**

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THE 8.1 MILLION HECTARES of forest east of the Cascade Mountains in Oregon and Washington (Denham, 1960) are a source of quality timber (Gedney, 1963) and provide crucial forage for domestic livestock, as well as large numbers of deer (*Odocoileus heminus hemionus*) and Rocky Mountain elk (*Cervus elaphus nelsoni*) (Skovlin et al., 1976). Though eastside forests are extensively logged, studies concerning the effects of timber harvesting on soils and understory vegetation have been few. Garrison (1961) and Young et al. (1967) reported tractor logging—the primary method of logging on the eastside—detrimentally affected yield and composition of forage species on several sites in the region. In eastern Oregon, Froehlich (1979) found reduced growth of ponderosa pine (*Pinus ponderosa* Laws.) in compacted tractor skid trails 16 yr after logging. Physical and chemical properties of some undisturbed forest soils in the northern Blue Mountains were documented by Geist and Strickler (1978).

The purpose of this study was to evaluate ground disturbance resulting from tractor logging and residue disposal on a mixed conifer forest stand in eastern Oregon. Site factors examined included: (i) areal extent of several forms of ground disturbance; (ii) degree of soil compaction, soil water conductance, and soil organic matter distribution within these ground disturbance types; and (iii) production of above and below ground herbaceous biomass on undisturbed areas and seeded skid trails.

Study Site

The study was conducted on an east-facing 1.5-ha site, at 1700-m elevation, on the Malheur National Forest in the southern Blue Mountains. Average annual precipitation is 760 mm, most of which falls as snow between October and May. The site is representative of the mixed conifer-pinegrass, ash soil community type (Hall, 1973), which is regionally extensive. Prior to logging, ponderosa pine, grand fir [*Abies grandis* (Dougl.) Lindl.] and Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] composed the overstory. Principal understory species on visually undisturbed portions of the site are pinegrass (*Calamagrostis rubescens* Buckl.), elk sedge (*Carex geyeri* Boott), and heartleaf arnica (*Arnica cordifolia* Hook.). These three rhizomatous species often combine to form a dense turf, to the exclusion of other species.

The soil is a loamy skeletal, mixed Typic Xerochrepts, characterized by a shallow (8-cm avg) silt loam surface layer derived from volcanic ash overlying cobbly silt loam derived from basalt. Soil depth avg 60 cm. A similar soil condition (i.e., a shallow ash layer overlying residual soil), occurs on approximately one-fourth of the Malheur National Forest (T. Sullivan, 1980, personal communication).

Original stand timber volume was about 37 thousand board feet/ha (MBF) (209 m^3/ha). Some commercial timber was removed from the site in the late 1950s. In August 1974, harvesting by crawler tractor reduced the remaining overstory to 20% of its original volume. In summer of 1975 slash was machine-piled and burned. Tractors were allowed to operate off primary skid trails in an effort to scarify the soil surface for tree regeneration.

At completion of the entry, 3 to 4 kg/ha each of orchardgrass (*Dactylis glomerata* L.), mountain bromegrass (*Bromus marginatus* Nees.), and intermediate wheatgrass [*Agropyron intermedium* (Host) Beauv.], and 1 kg/ha of timothy (*Phleum pratense* L.) were drilled into skid trails and other areas of major disturbance. Success of grass establishment of skid trails was considered representative of seedlings on similar sites in the region. Cattle grazed the site annually but were excluded in the year of sampling.

MATERIALS AND METHODS

Data were collected in the summer of 1980. Disturbance on the cutover was separated into five classes: (*Skid trails* were obvious primary tractor routes. *Berms* were characterized by heavy deposition where soil had been formed into mounds at least 10-cm high. *Fire rings* were areas in which the soil surface was altered by slash piling and burning. *General disturbance* areas were other places where some kind of ground disruption had occurred. Controls were assigned to areas where ground disturbance was not visually apparent; these areas were characterized by a strong predominance of native vegetation and an intact litter layer. All visual disturbance was assumed to have been caused by the 1974 to 1975 entry.

The experiment was set up as a restricted randomized design consisting of four blocks. Areal extent of each disturbance class was determined by the line-intercept method. A set of transects were arranged at regular intervals across the site in each block. A set consisted of 10 transects, 40-m long and spaced 8-m apart.

Along these same transects "potential" plots of 0.5-m^2 area were established at 4-m intervals. Each potential plot was field checked and assigned a disturbance classification.

Within each block, three plots for each disturbance class

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Table 1. Means and standard deviations for bulk density, saturated hydraulic conductivity (SHC), and infiltration values of logging disturbance classes.

Characteristic	Skid trail	Berm	Fire ring	General	Control
			Bulk density, Mg/m^3		
3.2 cm	0.78 ± 0.12 a*	0.66 ± 0.17 a	0.72 ± 0.14 a	0.69 ± 0.14 a	0.68 ± 0.16 a
10.8 cm	0.85 ± 0.20 ab	0.72 ± 0.18 a	0.81 ± 0.13 ab	0.86 ± 0.13 ab	0.89 ± 0.08 b
18.4 cm	0.86 ± 0.23 a	0.89 ± 0.15 a	0.85 ± 0.13 a	0.93 ± 0.14 a	0.92 ± 0.12 a
			Infiltration, cm/h		
1st run	19.0 ± 15.5 a	99.6 ± 189.2 a	14.5 ± 8.4 a	23.4 ± 23.4 a	48.0 ± 43.4 a
2nd run	15.5 ± 15.2 a	54.6 ± 77.5 b	13.2 ± 11.4 a	17.0 ± 16.3 a	34.5 ± 29.7 ab
			SHC, cm/hr		
	6.7 ± 4.1 a	23.6 ± 28.5 a	14.6 ± 19.7 a	12.2 ± 9.4 a	19.7 ± 11.9 a

* Numbers in rows followed by the same letter are not significantly different at the 0.10 level.

were randomly chosen from this pool of potential plots; thus, 12 plots per disturbance class were selected for measurement across the four blocks. Bulk density was sampled with hammer-driven corers (Blake, 1965). Because two corers with different core height (3.5 cm with a 71.5 cm^3 volume; 6.0 cm with a 131.3 cm^3 volume) were used, core depths are reported at midpoints: 3.2, 10.8, and 18.4 cm. Soil cores with excessive fracturing (due to dry conditions) or with excessive rock content were rejected. Saturated hydraulic conductivity (SHC) was determined by the constant head method (Klute, 1965) on cores taken at 3.2 cm. Infiltration was measured on two runs by a double-ring infiltrometer (Bertrand, 1965). Because prior sampling disturbed the plots, infiltration was measured adjacent to the plots. Percent organic matter (0–3, 3–6, 6–9, 9–12, 12–24 cm depths) was determined by the Walkley-Black method (Allison, 1965). Analysis of variance and Duncan's procedure were used to test mean differences of soil properties among disturbance classes (treatments) at the 0.10 probability level.

Plant production and composition were measured by double sampling-weight estimate technique (Pechanec and Pickford, 1937; Wilm et al., 1944) on 40 potential plots across the four blocks in both the skid trails and control areas. Herbaceous vegetation was clipped by species at the growing season peak, oven dried at 65°C, and weighed. Shrubs and tree seedlings were scarce and therefore not measured. On a subsample of three plots within each treatment block combination, below ground biomass was sampled with a 7.0-cm diam corer, driven to 10 cm. This depth was based on observation that nearly all roots and rhizomes of understory species on both disturbed and control areas were concentrated with the surface 10 cm. Samples were washed, oven-dried at 65°C, weighed, and ashed. Ash weights were subtracted from dry weights to gain ash-free values. Mean treatment differences of above and below ground biomass production were tested with Student's unpaired "t" procedure.

RESULTS AND DISCUSSION

Forty-three percent of the site exhibited some form of soil disturbance. Areas of general disturbance, skid trails, berms, and fire rings occupied 23, 10, 8, and 2% of the site, respectively. Froehlich (1979) noted tractor trails commonly occupy 25% or more of a harvested site. Tractors "wandering" during harvest and slash disposal may have distributed more of their total impact into other disturbance areas, keeping primary skid trails to a minimum.

The ash-over-residual soil condition was apparent from bulk density means for descending depths. The surface soils density of 0.68 Mg/m^3 for control plots closely matched 0.67 Mg/m^3 reported by Geist and Strickler (1978) for the upper 15 cm of ash-derived soils in the northern Blue Mountains (Table 1). For the same depth interval these authors reported a density of 0.89 Mg/m^3 for residual soils of basalt origin, matching the figure found in this study for control plots at the 10.8-cm depth.

Table 2. Means and standard deviations for organic matter content, g/kg, of logging disturbance classes.

Depth, cm	Skid trail	Berm	Fire ring	General	Control
0–3	92 ± 23 a*	123 ± 50 a	80 ± 71 a	127 ± 79 a	199 ± 63 b
3–6	76 ± 22 a	103 ± 50 a	78 ± 47 a	69 ± 22 a	76 ± 40 a
6–9	63 ± 23 a	109 ± 67 b	55 ± 36 a	53 ± 36 a	47 ± 22 a
9–12	54 ± 26 ab	73 ± 37 b	48 ± 30 a	37 ± 18 a	31 ± 8 a
12–24	43 ± 33 ab	39 ± 19 ab	50 ± 41 b	27 ± 9 a	23 ± 4 a

* Numbers in rows followed by the same letter are not significantly different at the 0.05 level.

Present guidelines for Region 6 of the U.S. Forest Service define soil compaction as a 15% or greater increase in bulk density above original conditions (J.M. Geist, 1981, personal communication). No compaction was evident among the disturbed classes when bulk density values were compared to the control class. Coefficients of variability for bulk density values were relatively low, indicating sample sizes were adequate. The lack of stronger evidence of soil compaction on the site is somewhat surprising. The compactibility of volcanic ash has been noted by others. Compaction may have been minimized by logging under very dry soil conditions when soils approached a powdery state.

Saturated hydraulic conductivity (SHC, i.e., soil permeability) could be considered the minimum infiltration rate expected of a soil (Vomocil and Flocker, 1961). Infiltration and SHC rates for disturbed and control plots generally exhibited high coefficients of variability, indicating a larger sample size was needed for sensitive statistical comparisons (Table 1). Projected precipitation of a 1-h storm with a 100-yr return period in the area is 2.5 cm (National Oceanic and Atmospheric Administration, 1949–1978). Flood-type infiltrometers like the one used in this study tend to overestimate natural infiltration (Wilm, 1941); however, soils on the site—including skid trail soils—appeared capable of absorbing most of the precipitation reaching it, thus curtailing erosion from overland flow.

Organic matter was considered an important fertility index since the nutrient base of many Blue Mountain soils is largely in the form of organic matter (Geist and Strickler, 1978). The disproportionately high amount of organic matter in the upper 3 cm of soils in the control plots may have been due to the large quantity of plant biomass, i.e., living and dead roots and rhizomes, occupying this zone (Table 2). Some surface organic material was apparently transferred and buried in berms and fire rings; tree needles and other identifiable organic material were sometimes visible in the excavated profiles of these two disturbance classes. The effects of logging on loss and redistribution of organic material in Blue Mountain soils, and the consequent effect on plant growth, deserve further research attention.

Seeded skid trails produced 66% more above ground herbage per unit area than the control areas (551 and 332 kg/ha, respectively). In spite of the greater above ground production, skid trails had only 32% of the root and rhizome production of the control areas (1300 and 4100 kg/ha, respectively). Thirty percent of the total biomass of skid trails was above ground, compared with only 7% for control areas.

Vegetation composition of skid trails was 90% graminoids and 10% forbs on a dry-weight basis. Ninety percent of skid trail production was composed of seeded species. Orchardgrass and intermediate wheatgrass accounted for 65% of the herbaceous yield on skid trails. Composition of control areas was 83% graminoids—almost entirely pinegrass and elk sedge—and 17% forbs.

In summary, these data suggest soil density, water conductance, and organic matter—properties important to plant growth—were not severely altered by logging and slash disposal, when compared to control portions of the site. Within five years after skid trails were seeded with introduced species, above ground production of skid trails had substantially surpassed that of the control area, dominated by native species. However, since skid trails covered only a tenth of the logged area, the additional herbage contributed by the skid trails to the overall forage base of the site was comparatively minor.

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