Richard J. Vogl
Department of Botany
California State College
Los Angeles, California
and
Calvin Ryder
Department of Botany
University of Montana
Missoula, Montana

Effects of Slash Burning on Conifer Reproduction in Montana's Mission Range

Montana forests are usually harvested by clear-cutting 40- to 80-acre sites. These cuts occur in merchantable stands, or sometimes in timber damaged or thrown by wind. After removal of the marketable conifers, the remaining bent and broken trees, stumps, bark, brush, and litter are bulldozed into piles (Fig. 1). Bulldozing scarifies the soil, thereby preparing a mineral seedbed for seeding from the surrounding forest. The slash piles are usually burned in the fall following logging. The primary purpose of piling and burning slash is to reduce, in an efficient and safe manner, the fire hazard created by the post-logging fuels (Isaac, 1963; DeSilvia, 1965; Beaufait, 1966). These slash fires are often intensely hot because of the prodigious amounts of fuel (Figs. 2, 3) (Davis, 1959; Daubenmire, 1959).

The purpose of this study was to determine the effects of burning large slash-piles on subsequent conifer reproduction. This was accomplished by sampling the vegetation invading burned slash piles and comparing it with adjacent unburned sites.

Most studies evaluating the effects of slash burning have been concerned with soil changes produced by these hard burns (Isaac and Hopkins, 1937; Tarrant, 1954; Austin and Baisinger, 1955; Wright and Tarrant, 1957, 1958; Dyrness *et al.,* 1959; Wright and Bollen, 1961). Few studies (Morris, 1958, 1960; Yerkes, 1960; Dyrness, 1965) have evaluated the effects of slash burning on the vegetation, particularly on Montana conifers.

Study Area

The study area is located in the north or glaciated portion of the Mission Mountains in Flathead National Forest (Fig. 4), where the range flanks the east shore of Flathead Lake. The logged sites are located in the mountains between Yellow Bay-Mission Wells and the mouth of the Swan River.

The nearest U.S. Weather Station is about 16 miles south at Polson, Montana (Fig. 4), on the edge of Flathead Lake. The January and July average temperatures recorded there are 24° F and 67.7° F, respectively. Average annual precipitation is 14.6 inches (U.S. Department of Agriculture, 1941). The study area, however, is 2,000 feet higher than Polson and deviates from the above measurements. A comparison of three climatic factors was made between the shore of Flathead Lake at 2,913 feet elevation and the study area at 5,600 feet, during July 1965. Maximum-

Figure 1. Mission Mountain logging site prepared for fire hazard reduction with the construction of slash piles which will be burned in the fall.

Figure 2. Slash piles are often heaped high with logs, branches, brush, stumps, and litter. These heavy fuels produce extremely hot fires that bake soils and create a deep ash residue.

Figure 3. Two years after slash burning, charred logs, stumps, and sparse conifer reproduction mark the former piles.

minimum temperatures recorded at the lower elevation were 91° F and 50° F, and 93° F and 37° F at the higher station. The study area received 133% more precipitation and had 40% less evaporation than the lake site during this month. These measurements support the generalization that the study area was wetter and had more extreme temperatures than the lakeshore locations.

Eight logging sites were selected. The number of years since these openings had been cleared and slash burned ranged from two to 15 with an average of 8.8 years. The sites varied in elevation from 4,750 to 5,600 feet, with an average of 5,247 feet. Slope angle ranged from two to 25°, with an average of 10°. Exposures were from 0-45° and 180-360°, with an average of 243° southwest exposure. Soils were Brown Podzolic (Nimlos, 1963).

Methods

Conifer reproduction was sampled by density counts in m^2 quadrats. Quadrats were laid out in pairs, one placed randomly in a burned slash site, the other placed adajacent to the slash pile on an unburned site. Forty pairs, or 80 m^2 quadrats, were used to sample burned piles in each of the eight logged sites.

In addition to counting the number of different tree species in each quadrat, the heights and diameters of randomly selected trees were taken in the burned and unburned portions of the most recent and oldest logged sites. The per cent cover of all plant types in each quadrat was also estimated. In four of the post-logging sites, the per cent frequency of occurrence of shrubs and herbs was taken. Soil samples were obtained from the top four inches of either scarified soils in unburned areas or charred and ash-covered soils on the burned sites in each logged clearing. These were analyzed by the laboratory of the J. H. Mitchell Co., San Gabriel, California.

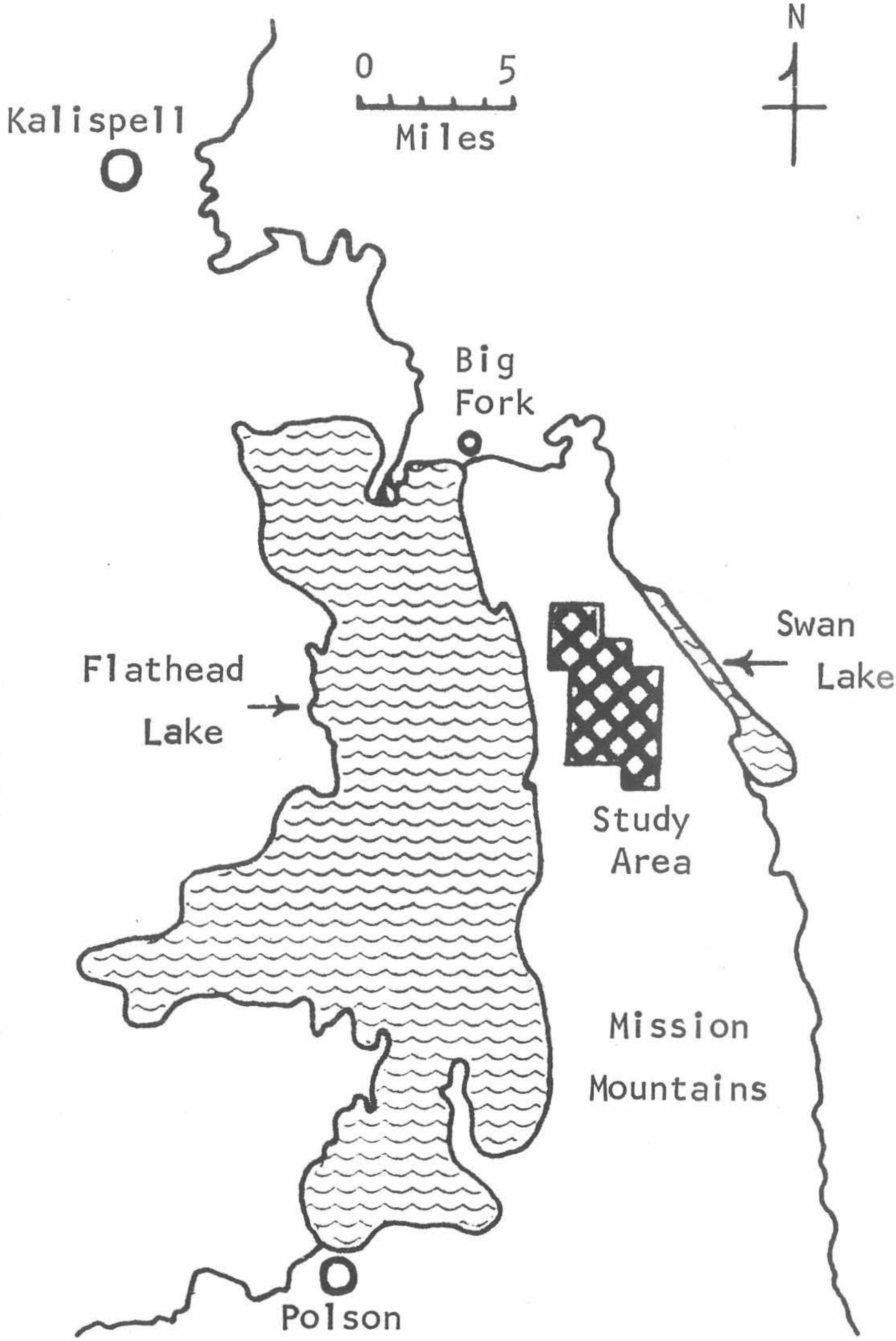

Figure 4. Location of the study area in the north end of the Mission Mountains, Montana.

Soil pits were dug in representative areas. Water infiltration rates were compared between burned and unburned sites by placing open-ended cylinders one inch into the soil in four of the logged areas. Rates were determined by measuring the time required for 12 oz. of water to be completely absorbed by the soil.

Results and Discussion

The most important conifer were alpine fir (*Abies lasiocarpa*), western larch (*Larix occidentalis*), and Engelmann spruce (*Picea engelmannii*), associated with smaller amounts of lodgepole pine (*Pinus contorta*) and Douglas fir (*Pseudotsuga menziesii*). Density counts of the reproduction of these conifers differed between the burned and unburned sites. The differences produced by burning the heavy slash accumulations were expressed as percentage decreases from the adjacent unburned sites for each species in all stands (Table 1). There was an overall average of 80% less reproduction on the severely burned sites than on the unburned areas. Reductions in conifer stocking ranged from an average of 72% less for Engelmann spruce to 89% less for lodgepole pine on burned sites. Unburned areas had an average density of 1,763 seedlings and saplings per acre, whereas the burned slash piles averaged only 324 per acre. These average densities ranged from 139 Douglas fir per acre in the unburned and 38 in the burned, to 4,085 alpine fir per acre in the unburned and 708 in the burned locations. All the density differences produced with burning were highly significant at the 99% level (0.01%) using Student's "t" test for paired data (Simpson *et al.,* 1960). The variation between species in a treatment was considered to be a reflection of species importance in the study locale and not due to differences in species reactions to fire.

TABLE 1. Average densities of conifers on unburned and burned sites in all stands. Differences between tree densities on burned and unburned soils are expressed as per cent decrease or change.

Species	Average tree desity per acre		Per cent change
	Unburned	Burned	
Abies lasiocarpa	4,085	708	−83%
Larix occidentalis	2,618	417	−84
Picea engelmannii	1,391	392	−72
Pinus contorta	569	63	−89
Pseudotsuga menziesii	139	38	−73

Conifer reproduction densities on burned sites varied with the number of years lapsed since burning. Recently burned piles contained baked soils which were layered with ash which was often blown or washed into deep pockets. Scattered throughout the ash were charcoal bits and chunks which were commonly laminated into a surface crust. Only seven seedlings of two species, alpine fir and larch, were present two years after burning, whereas 60 seedlings representing five species were counted in adjacent unburned quadrats. Burned sites, still evident 15 years after treatment, contained all of the species found in the unburned locations (Fig. 5), but only 47 (or 84.8% fewer) conifers occurred in the 15-year-old burned quadrats compared with 309 in the unburned sample. Comparison of the two- and 15-year-old burned sites showed that only a slight change (3.5% increase) in conifer reproduction occurred in 13 years, indicating that the suppressive effects on conifer reproduction persist for at least 15 years.

Figure 5. Slash pile site 15 years after burning is still evident by log remains and conspicuous fireweed (*Epilobium angustifolium*). Vigorous conifer saplings ring the burned pocket. Unlogged forest in the background.

In addition to the conifer density differences between the burned and unburned sites, growth rates were compared from randomly selected trees in both locales. The average height and basal diameter of the common trees occurring in the two- and 15-year-old sites are given in Table 2. Differences in the conifer growth rate between the burned piles and adjacent unburned sites were not apparent two years after logging, but had become obvious 15 years later. The overall average height was 3.0

TABLE 2. Average heights and basal diameters of the common conifers growing on burned and unburned portions of the most recent and oldest sites.

			2 years after logging and burning			
	Unburned			Burned		
Species	No.	Avg Height	Avg Diameter	No.	Avg. Height	Avg Diameter
Douglas fir	7	1.7 ft	0.9 inches	8	0.5 ft	0.5 inches
Subalpine fir	26	1.7	0.8	15	0.5	0.4
Engelmann spruce	16	0.5	0.4	18	0.5	0.3
			15 years after logging and burning			
	Unburned			Burned		
Douglas fir	11	13.9 ft	4.4 inches	20	2.2 ft	0.5 inches
Subalpine fir	13	12.9	3.4	11	2.0	0.4
Engelmann spruce	13	11.2	3.4	19	2.2	0.5
Larch	29	18.5	3.2	26	4.2	1.1
Lodgepole pine	18	12.4	3.0	9	4.6	1.6

ft with an 0.8 inch diameter 15 years after burning, whereas all trees in the unburned site averaged 13.8 ft tall and 3.4 inches in diameter. Thus, during 15 years, conifers growing on the burned sites produced little more than one-fifth the growth of those on unburned soils.

Cover. The average per cent cover estimates for all vegetation types were based on 320 pairs of m^2 quadrats for all eight stands (Table 3) (Fig. 6). The greatest difference between the two types of sites was the lesser tree cover in the burns. The burned sites also contained less shrub cover. Herb, moss, and liverwort cover was greater in the burned than in the unburned locations. Although individual plant types differed between burned and unburned areas, the total cover, or conversely, the amount of bare ground, was similar. However, the burns appeared to have much less cover because the inconspicuous mosses and liverworts had increased (50%) with burning which compensated for the reduction in the conspicuous tree and shrub cover. Even 15 years after logging, the burned sites were still distinct openings in the young forest (Fig. 5).

TABLE 3. Average per cent cover for each vegetation type in unburned and burned sites and per cent differences between sites. Totals exceed 100% because of overlap in the various vegetation strata. (Each set of averages based on 320 pairs of m^2 quadrats).

	Average per cent cover		
Vegetation type	Unburned	Burned	Per cent change
Trees	9.4%	2.7%	−71%
Shrubs	13.9	7.7	−45
Herbs	36.8	44.2	+20
Mosses & liverworts	15.9	23.9	+50
Bare ground	35.3	34.0	− 4
Totals	111.3%	112.5%	

Shrubs and Herbs. Using the average per cent frequency data, the shrubs and herbs on four burned and unburned sites were arbitrarily divided into categories devised to assess species responses to slash burning. Each species was classified as a decreaser, neutral, increaser, invader, or retreater, depending upon its response to fire (Table 4). Decreasers were species with an average per cent frequency decrease of 12.5% or more in the burned sites than in the unburned. Neutral species had less than an average 12.5% frequency increase or decrease when compared with unburned average frequencies. Increasers were species with 12.5% or greater average frequencies in the burned sites. Species sampled only in burned piles were classed as invaders, and those absent in the burn samples were classed as retreaters.

Decreaser or neutral species were mainly characteristic of undisturbed spruce-fir-larch forest understories and were species that usually grow on a shady, litter-covered forest floor. Even species like *Xerophyllum tenax* and *Arnica diversifolia* that usually thrive or persist in forest openings were unable to quickly recolonize the burned sites once their root systems were destroyed.

Increasers consisted of weeds such as *Cirsium* sp., *Achillea millefolium, Anaphalia marqaritacea,* and *Bromus vulqaris,* or aggressive fire-followers such as *Marchantia polymorpha, Funaria hygrometrica,* and *Epilobium* spp. (Reid *et al.,* 1963; Daubenmire, 1959; Hoffman, 1966). The most important invader was *Verbascum thapsus,* a weedy biennial common to over-grazed or highly disturbed sites. Some of the retreater species might have been fire sensitive, and thus were eliminated with burning.

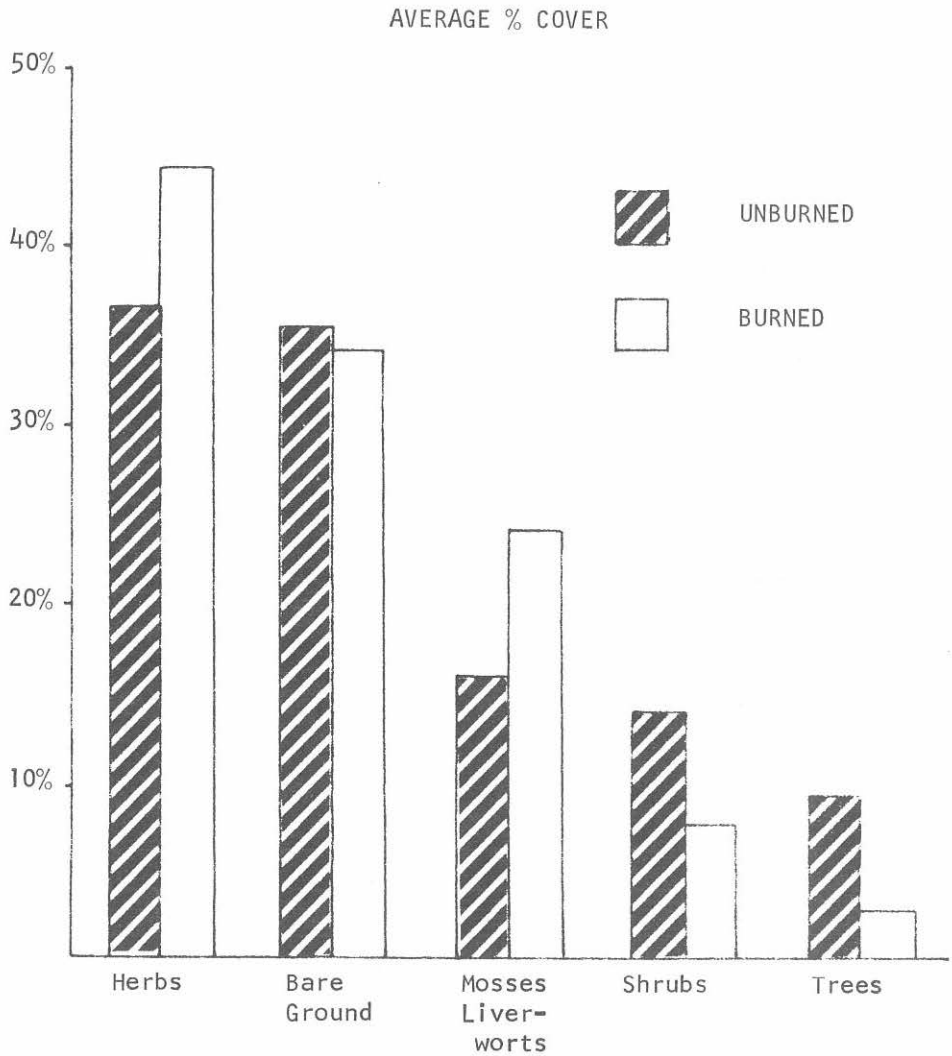

Figure 6. Comparisons of average per cent cover between unburned and burned sites for each vegetation type.

Soil Changes. Burning converted the slightly acid soils to neutral or nearly alkaline (Table 5). Isaac and Hopkins (1937), Tryon (1948), Tarrant (1954), and Austin and Baisinger (1955) found similar pH increases with burning. The saturation percentage, which is a measure of soil texture and water holding capacity, and, similarly, the water retaining capacity of the burned soils were higher. Possibly this resulted from the additions of ash and charcoal in the burn, and conversely, from the reduction of organic matter by bulldozer scarification in the unburned soils. Tryon (1948) found that charcoal improved the water and air content of soil, and served as a mulching agent, particularly in heavy or clayey soils like those encountered in this study.

The fertility assay showed larger amounts of nutrient minerals in the burned soils

TABLE 4. Shrubs, herbs, mosses, and liverworts catagorized according to their response to fire as reflected in average per cent frequency changes or differences.

	Average per cent frenquency
INCREASERS	
Herbs	
Cirsium sp.	+24.4%*
Liverworts	
Marchantia polymorpha	+21.3 *
NEUTRALS	
Shrubs	
Spiraea splendens	+ 1.3
Pachystima myrsinities	+ 0.6
Herbs	
Achillea millefolium	+10.0 *
Epilobium adenocaulon	+10.0 *
Epilobium halleanum	+10.0 *
Antennaria racemosa	+ 7.5
Epilobium anqustifolium	+ 6.3
Anaphalis margaritacea	+ 5.6
Bromus vulgaris	+ 5.6
Senecio triangularis	+ 5.6
Mosses	
Funaria hygrometrica	+ 1.3
DECREASERS	
Shrubs	
Ribes lacustre	–25.6 *
Vaccinium membranaceum	–23.1 *
Herbs	
Xerophyllum tenax	–25.0 *
Arnica diversifolia	–19.4 *
Carex sp.	–17.5 *
Tiarella unifoliata	–15.0 *
NEUTRALS	
Shrubs	
Sambucus melanocarpa	– 5.6
Salix sp.	– 3.1
Vaccinium scoparium	– 1.3
Menziesia glabella	– 0.6
Lonicera utahensis	0.0
Rubus parviflorus	0.0
Herbs	
Clintonia unifolia	– 6.9 *
Viola sp.	– 6.3 *
Thalictrum occidentale	– 2.5
Hieracium albertinum	– 1.9
Osmorhiza purpurea	– 1.9
Fragaria virginiana	– 1.8
Taraxacum officinale	– 0.6
Zigadenus elegans	0.0
INVADERS	
Herbs	
Verbascum thapsus	15.6
Antennaria rosea	1.3
RETREATERS	
Shrubs	
Alnus sinuata	2.5
Arctostaphylos uva-ursi	0.6
Symphoricarpos albus	0.6
Herbs	
Galium triflorum	6.9
Spergularia rubra	1.3
Veratrum viride	0.6

* Species showing a significant change with burning at the 95% level using the Sign Test (Dixon and Masey, 1957).

(Table 5). The higher electrical conductivity of the burned soils indicated a slight increase in soil salinity. The greatest change produced by burning was a more than doubling of the amounts of calcium, magnesium, and sodium salts. Increase of these salts indicated a tendency toward alkali or saline alkali conditions which may lead to structural deterioration as well as salinity difficulties. Large amounts of sodium salts tend to disperse soil aggregates, creating hardpans impermeable to air and water movement. This, in turn, may affect the wettability, infiltration, and runoff of the baked soils (Osborn *et al.,* 1967).

TABLE 5. Summary of physical and chemical analyses of unburned and burned soils.

	Unburned soils	Burned soils
pH	6.5	7.6
Saturation percentage	84.0%	97.3%
Water retaining capacity	89.8%	99.7%
Electrical conductivity (millimhos/cm^3)	0.6	1.0
Ca - Mg (me./liter)	3.7	8.7
Na	12.0 ppm	28.0 ppm
K	340.0 ppm	430.0 ppm
N	27.6 ppm	37.7 ppm
P	11.0 ppm	13.0 ppm
B	1.4 ppm	1.5 ppm

TABLE 6. Average time, in seconds, that 12 ounces of water infiltrated the soils of unburned and burned sites. The range of times at each site is listed in parentheses .

Years since logging and burning	Water infiltration rates	
	Unburned	Burned
2	52 (23-83) sec.	462 (45-520) sec.
3	76 (22-150)	417 (240-675)
10	103 (40-270)	213 (60-530)
15	83 (35-130)	344 (130-520)
Grand average	78.5 sec.	359.0 sec.

Water infiltration was compared on four of the logged sites (Table 6). Each site was sampled with eight paired trials, one member of the pair placed randomly in the burn and the other placed in the adjacent unburned soil. The soils under the burned slash piles absorbed the 12 oz. of water 4.6 times more slowly than the surrounding unburned scarified soils. Even 15 years after burning, water uptake was still obviously slower on the burned soils.

Other physical soil changes included those in texture and color. The surface soil in the burns was usually a powdery buff clay, while the upper unburned soil layer was normally coarser brown to gray clay. The subsurface layer of burned soil was deep yellow to reddish brown in color and aggregated into assorted-sized lumps, while the corresponding unburned layer consisted of a lighter colored glacial flour mixed with till. Soil pits dug in the logged sites revealed that the upper one ft. of each burned soil profile had been affected by the heat of the slash burns, as indicated by altered soil color and texture. Similarly, Davis (1959) stated that soil heating from prolonged burning on heavier soils tended to bake particles into larger aggregates and change the colloidal state. This, he suggested, may retard conifer invasion. Shannon (1953) noted that water infiltration rates decreased with the increased severity of a burn. In the present study, erosion channels had developed downslope from former slash piles as a result of increased runoff, and the slowest water infiltration rates were obtained on slash sites in which rainwater had caked fine ash and charcoal into a surface crust. Friedrich (1955) also found that ash and fine soil were often washed together to produce an impervious layer. Isaac and Hopkins (1937) concluded that slash burning was not advantageous for tree regeneration because it damaged surface soil conditions. Austin and Baisinger (1955) and Wright and Bollen (1961) observed that hard burns were characterized by a deepened soil color and a change in physical structure which resulted in sites with little or no vegetation.

The increases of *Marchantia* liverworts and *Funaria* moss after burning were also indicative of altered soils (Table 4). Daubenmire (1959) suggested that the success of these species is due to their low nitrogen requirements, which allows them to grow without higher plant competition the first few years after burning. Hoffman (1966) also stated that the distribution of *Funaria* is related to fire disturbance. He found that it grew well on soil previously heated between 200° and 300° C, but grew poorly or not at all on soils heated to higher temperatures. The abundance of *Funaria* on portions of the more recent burned sites might indicate that their soils reached the above temperatures. The high temperatures generated by this austere burning may have also destroyed or inhibited mycorrhizal fungi essential to conifers.

Not all kinds of fires produce detrimental physical soil changes like those in the present study. Scott and Burgy (1956), for example, found that burning California brushlands actually improved peremeability, aggregation, and infiltration. Zwolinski (1966) stated that Arizona pine watersheds were unaffected by surface and duff fires. Hartesveldt and Harvey (1967) obtained the best Sierra redwood (*Sequoiadendron giganteum*) seedling establishment where understory brush had been piled and burned.

Conclusions

The effects of burning heavy accumulations of slash on conifer reproduction in Montana's Mission Mountains are similar to those obtained elsewhere in the Pacific Northwest. The lower densities and slower growth of conifers on the burned slash pile sites are attributed to the altered physical structure of the soils. This resulted from high temperatures and additions of ash and charcoal. This soil damage has persisted for 15 years and may remain even longer.

Although conifer growth and densities were less on the burned sites, the present fire hazard reduction methods might benefit wildlife management and recreation, since burning large slash piles could be an effective way to create semi-permanent openings. These openings would help break up an otherwise continuous forest and provide conditions favorable for both big game and upland birds by producing edges and pockets of vegetation at younger and varied stages of succession.

But, if the primary consideration is timber production, with an emphasis on sustained yields, the present slash disposal method should be altered or replaced. This is particularly important when slash piles occupy a considerable portion of post-logging sites (Figs. 1, 3). Windrowing of slash results in less dense collections which should reduce fire temperatures and thus minimize soil damage. The present method could also be improved by breaking up and spreading the pockets of burned soil, slash, and ash with a bulldozer.

Another effective means of reducing the fire hazard created by slash is broadcast burning. This is accomplished by leaving the slash where it has fallen, redistributing heavy accumulations, lopping slash to ground level, felling standing snags, establishing a perimeter firebreak, igniting, and subsequently burning the entire cut area (Beaufait, 1966). Broadcast burning tends to approximate a naturally occurring wildfire and produces a minimum number of hot spots and deep ash deposits as compared to slash pile burning. Isaac and Meagher (1936) and Isaac (1943) observed that some of the finest conifer stands in the Northwest originated on areas burned in wildfires.

Montana conifer stands receive less rainfall and are more subject to drought than stands farther west. Conifer seeds and seedlings, particularly the more mesic spruce and fir species, perish readily during dry and hot periods. Isaac (1943) and McCulloch (1942) pointed out the value of a cover layer to provide partial shade and retain moisture to help nurse seedlings, particularly in drier regions and on south-facing slopes. Charred logs and intact stumps scattered throughout a burn, as well as a quickly recovering intact herbaceous layer, would help provide this nurse cover for seedlings during adverse conditions.

Broadcast burning might cost less than the present method because it is achieved without the use of heavy equipment traversing the entire logged site, scarifying, removing stumps, and piling debris. Prescribed burning removes most of the accumulated organic matter, thereby preparing a mineral seedbed without the need or cost of mechanical scarification (Lyon, 1966). This investigation indicates that scarification is highly successful in producing bumper densities of conifer reproduction (Table 1). In fact, some of the high densities on the unburned sites represent overstocking which has been, or will have to be thinned by hand to prevent stagnation. Broadcast prescribed burning, however, would help to produce more moderate stockings, since burning is not as uniform or mechanical as a bulldozer in affecting the total seedbed, and since the burned, but unconsumed, scattered stumps, logs, and branches would physically prevent occupancy by seedlings.

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