Effects of Slash Burning in Overmature Stands of the Douglas-Fir Region

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Abstract. Following clearcutting of old-growth coniferous forests in western Washington and Oregon, pairs of burned and unburned plots were established to determine the effects of normal fall slash burning. Fires consumed nearly all fine fuel, left nearly all logs, and severely burned less than 6 percent of the soil surface. Five years after burning, the estimated rating of fire spread on the burned plots was 27 percent of that on the unburned, and estimated resistance to control was 67 percent. Difference in rate of spread ended at 16 years; difference in resistance to control ended at 12 years. Burning changed species composition of brush and herbage, reduced brush cover for a few years except where *Ceanothus* sp. invaded, but did not affect total herbaceous cover. Burning did not affect ultimate quantity of natural stocking with commercial conifers that became established after logging. ***Forest Sci. 16:258-270.***

Additional key words. *Pseudotsuga menziesii*, fire control, fire effects, natural regeneration.

THE ESTABLISHED management system of clearcutting the tall, dense, overmature forests of the Douglas-fir region of western Oregon and Washington usually leaves great quantities of debris after all merchantable wood is removed. Limbs up to 10 inches through, masses of small limbs and needles, thick slabs of bark, short chunks of broken trunks, long logs riddled by heart rot, shattered remains of large snags, and moss-coated windfalls of the past 50 years cover most of the ground (Fig. 1). In areas where the stands contained much rot and other defect, the slash may total 100 tons or more per acre.

FIGURE 1. *One-year-old unburned slash from an overmature Douglas-fir stand forms a nearly complete cover. The two large logs on the left were about 30 inches in diameter.*

National Forests of the Douglas-fir region contain about 3 million acres of stands more than 150 years old (USDA Forest Serv. 1963). Most logging on National Forests for at least the next 50 years will be in these stands. Patches, usually of about 30 to 60 acres, are clearcut. In the past, the slash on most of them has beeen burned under prescribed conditions to reduce fire hazard, prepare seedbed or planting site, and reduce brush competition with tree reproduction.

Some foresters have doubted the efficacy of slash burning for the stated purposes Recent concern with the possible contribution of slash burning to air pollution has further stimulated reviews of the benefits and harm of burning.

In 1946 the writer began the present study of effects of operational slash burning on hazard, natural restocking established after logging, and brush and herbaceous cover. The study was gradually extended to some

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60 pairs of burned and unburned plots. Results were reported (Morris 1958) for a period that included seven growing seasons for the oldest plots; this final report includes 16 seasons.

Earlier studies of the effects of slash burning on fire hazard, natural restocking, and cover were made in areas at elevations lower than most of the National Forests of the Douglas-fir region (Kienholz 1929; Ingram 1931; Isaac 1940, 1943; Munger and Matthews 1941); in these areas, climate, vegetation, slash, and severity of burning generally differed from those of our study area.

After the present study began, Yerkes (1960), Dyrness (1965), and Steen (1966) described composition and changes in density of ground cover following logging and slash burning in two restricted localities. DeKeijzer and Hermann (1966) found no significant effect of charcoal seed beds on germination of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seed, but Hermann and Chilcote (1965) found that charcoal and hard-burned soil gave greater germination and survival.

Methods

The writer selected plots within National Forest commercial logging units to be burned in the normal slash disposal process. Forest managers burned most tracts in fall after the duff had been soaked by rain and as soon after rain as fine fuels were dry enough to carry fire. Such fires usually consume only part of the duff depth (Aufderheide and Morris 1948). The plots of each pair were similar in slash, slope, aspect, soil, and distance to tree seed source. Both plots usually lay within several hundred feet of a stand of mature trees.

Fifty-three pairs of plots were in the Cascade Range and nine were in the mid-coastal strip of Oregon (Fig. 2). On most of the plots more than half of the log volume had been Douglas-fir. The principal associated commercial species were western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Pacific silver fir (*Abies amabalis* (Dougl.) Forbes), Noble fir (*A. procera*

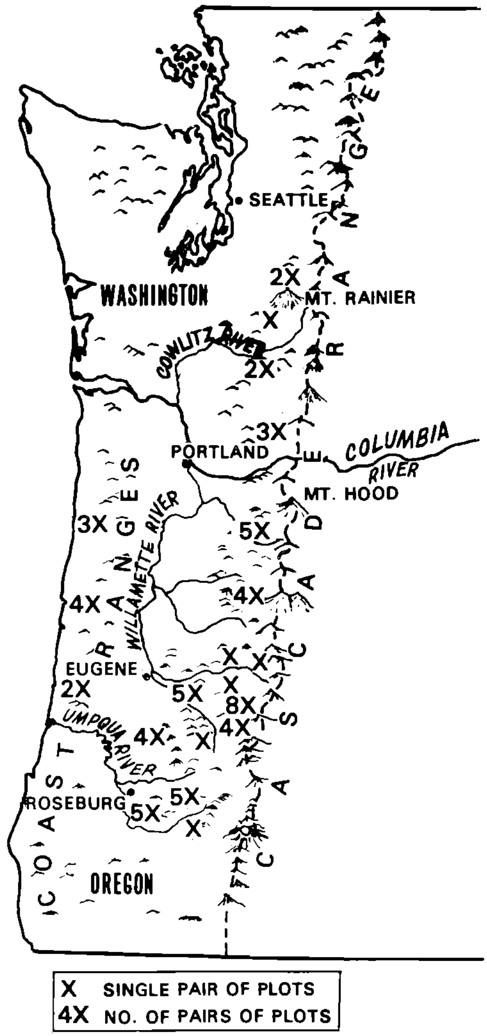

FIGURE 2. *Locations of 62 pairs of burned and unburned slash plots in the Douglas-fir region of western Oregon and Washington.*

Rehd.), and along the coast, Sitka spruce (*Picea sitchensis* (Bong.) Carr.).

Elevation was 1,400 to 4,200 ft in the Cascades and 500 to 800 ft in the coastal strip. Slopes averaged 22 percent on the Cascade plots and 48 percent on the coastal plots. Half of the pairs had a south to west aspect but three or more faced each of the other cardinal and semicardinal directions.

Surface soil on half of the plot pairs was loam with small concretions locally called "shot." Only one-fourth of the pairs had stony or rocky soils, and only one-tenth had sandy soils. Soil depth was estimated as 4 ft or more on nearly all plots.

Initially a larger number of pairs was selected but losses to fire and rejections for insufficient burning were great. Plots to be left unburned received no protection other than cleared strips created by logging. Burned plots less than two-thirds blackened, and unburned plots with burned spots were rejected. From plots tentatively selected between 1946 and 1951, 62 pairs were permanently established. Most pairs were re-examined annually to 1953, and 57 were examined again in 1962.

In the first growing season after burning, the examiner placed durable, tall stakes at the corners of each rectangular plot, which was at least 82.5 × 132 ft and between one-fourth and one-half acre in area. With one of the longer sides as a base line divided into five equal parts, he located a line transect at right angles across the plot from a random point within each part, and staked the transect ends. The examiner recorded the intervals of transect intercepted by different categories of fuel, plant cover, and exposed mineral soil (Table 1). More than one category could be recorded for the same spot. On the burned plot he also recorded the intervals of transect intercepted by any of four classes of severity of burn defined as follows:[1]

1. Unburned.

2. Light burn—duff, crumbled rotten wood, or other woody debris partly burned but not down to mineral soil; or where these were absent before the fire, logs not deeply charred.

3. Moderate burn—the foregoing materials consumed or logs deeply charred but mineral soil under the ash not changed in color.

[1] Morris, William G. Working plan for a study of the comparative effects on stocking and growth of coniferous reproduction following no burning, light burning, medium burning, and severe burning of logging slash after clear cutting in the Douglas-fir region, 1947. (Unpublished manuscript on file at Pacific Northwest Forest & Range Exp. Sta., USDA Forest Service, Portland, Oregon.)

TABLE 1. Average ground coverage by several classes of material on 58 pairs of burned and unburned plots in the first season after slash fire.

(*In percent*[1])

Material	Burned	Unburned
Chunks of wood and bark, limbs, or crumbled rotten wood:		
Covering more than 90 percent of the ground	10	25
Covering less than 90 percent of the ground	38	35
Branches resting above the ground and bearing adequate fine twigs to make appreciable shade for seedlings	1	23
Logs larger than 11 inches in diameter	12	13
Live crowns of brush	3	12
Dense stands of herbs	11	15
Mineral soil	50	22

[1] Since most classes of material were not mutually exclusive, average percentages total more than 100.

4. Severe burn—top layer of mineral soil changed in color, usually to reddish; next one-half inch often blackened from organic matter charred by heat conducted through the top layer.

In the first growing season after burning and each year that a plot was reexamined, two or more contiguous 66-ft-square subplots for recording fire hazard were measured from the initial corner of the main plot, and each of these was divided into quarters. Using Forest Service Region 6 (Oregon and Washington) standards for classifying fuels (USDA Forest Serv. Reg. 6, 1968), the examiner classified the probable rate of spread of a tongue of fire by the route that would give the highest rate of spread across each quarter of a subplot. He also classified resistance to control with hand tools along the easiest practicable route across each whole subplot. The classes have relative numerical values 1 to 125 for rate of spread and 1 to 8 for resistance to control. Average values of rate of spread and resistance to control were then determined for the whole plot.

In the second growing season after burning and at later reexaminations, we established 25 temporary 4-milacre circular subplots in a restricted random sampling pattern related to that of the line transects. For each subplot, we tallied commercial species of conifer seedlings at least 6 inches tall. For several years, we tallied separately those obviously established before logging, but in later years when the advance seedlings could not be readily distinguished, we tallied all as one class.

For each 1-milacre quadrant of a subplot we estimated the proportion of available growing space covered by a vertical projection of the shrub or brush canopy and the proportion of brush cover contributed by each species constituting one-fifth or more of the total. Similarly we estimated the coverage and species composition of the herbaceous canopy independently of the brush canopy.

Results

Plot Surfaces and Slash. The analysis of severity of burn is based on 49 pairs of plots in the Cascade Range and 9 in the coastal strip. Four Cascade pairs not established until the second season after the burn are omitted because a year of plant growth partially obliterates surface conditions on a burn. Each plot percentage was based on a minimum 412.5 ft of line transect.

In many spots the fire reduced the quantity of wood, bark, limbs, or rotten wood from "covering more than 90 percent of the ground" to "covering less than 90 percent of the ground" (Table 1). Slash fires consumed nearly all branches that bore sufficient twigs to make appreciable shade (Fig. 3), but scarcely affected the quantity of wood in large logs. Fires reduced live crowns of brush and increased the area of exposed mineral soil, including that covered by an ash layer.

FIGURE 3. *Slash burning usually removes the small pieces of slash but leaves logs mostly intact except where they are crossed or shattered. Only small spots of soil are severely burned (center foreground).*

Less than 6 percent of the average burned plot area was severely burned and more than 50 percent was lightly burned:

	Percentage burned	
	Cascade Range	*Coastal strip*
Severe burn	5.8	0.1
Moderate burn	22.2	14.2
Light burn	55.4	75.2
Unburned	16.6	10.5

The greatest area of severe burn found on any plot was 31 percent. On most plots severe burn appeared only in small scattered patches, usually where logs or stumps had produced prolonged, intense heat.

Hazard Rating. In the first season after burning, the rate-of-spread rating on the burned plots was only 5 percent of that on the unburned (Fig. 4*A*). Rate of spread continued to be significantly[2] lower on the burned plots until the 16th year, but the difference diminished with time: It was 27 percent of the unburned in the fifth season and 80 percent in the 14th.

Figure 4*A* indicates the trends in rate of spread. The shape of the trend in the period having no plot records (stippled area in this and succeeding charts) is unknown. Moreover, since the plots were established over a period of several years, a given plot is not included in all charted points, and this unequal sampling complicates interpretation of the trend lines. A separate analysis of only 36 pairs of plots that were repeatedly rated in the first, third, and one of the seasons from the 12th to the 16th

[2] Hereafter the term "significant" indicates the 0.05 level of probability in a *t* test. Unless stated otherwise, differences between burned and unburned treatments are for paired plots.

seasons showed essentially the same conformation as Figure 4*A*. Therefore, Figure 4*A* probably represents a real trend in which rate of spread on unburned areas decreases rapidly for a few years and then decreases very slowly, whereas that on burned areas increases slowly for about 13 years. The hump at 12 or 13 seasons for both curves is due to variations among plots.

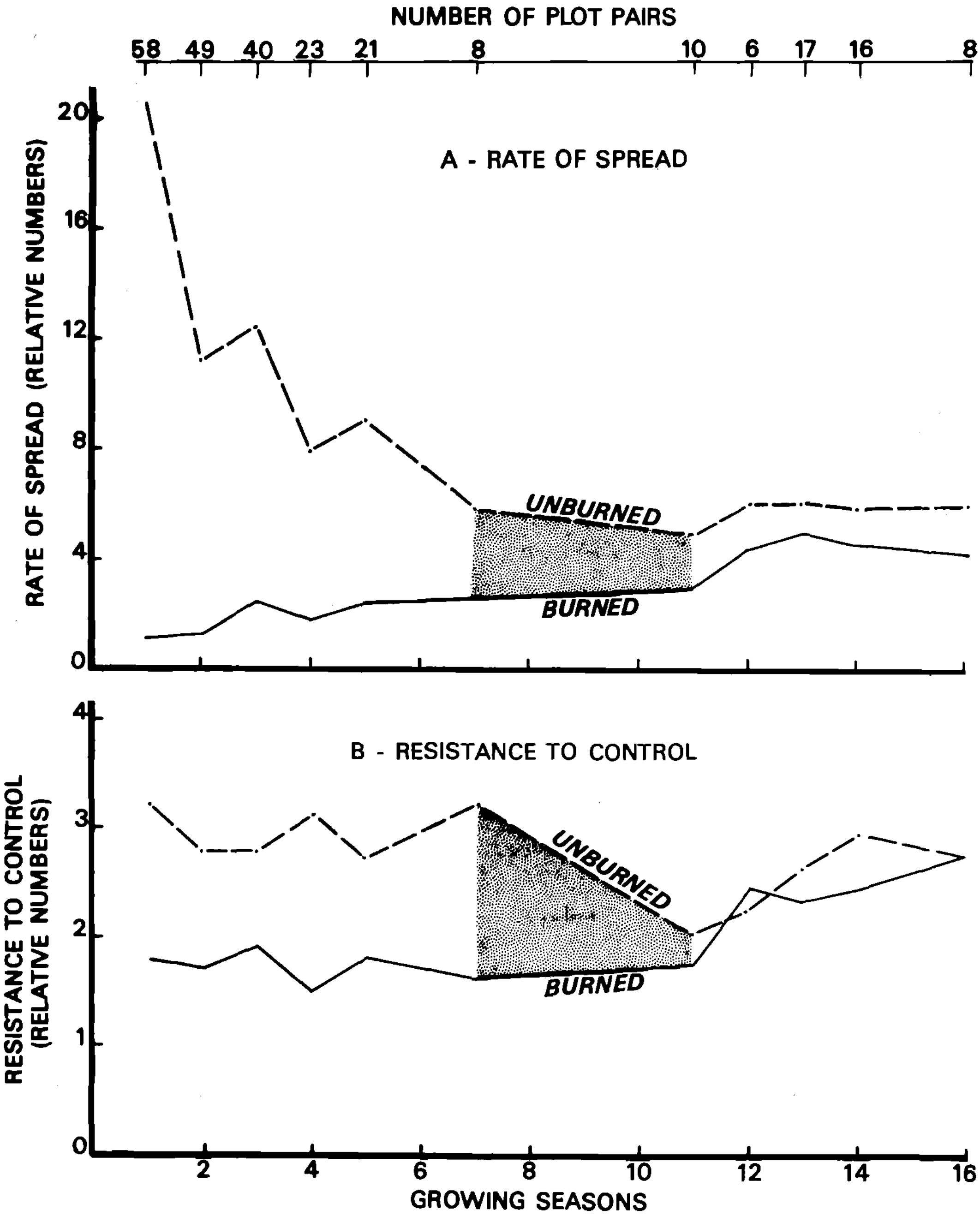

FIGURE 4. *Rate of spread (A) and resistance to control (B) on burned and unburned plots by growing seasons after treatment.*

The trends conform to observations of slash fire behavior. A second fire, a year after the initial fire on a burned slash area, spreads much slower than the first because fine fuels have been removed, and most remaining units of coarse fuel are separated where they previously touched. However, fine fuels added by growth of herbaceous cover and weathering or sloughing of the surfaces of coarse fuels soon increase rate of spread. On burned areas, the net effect is a slow increase in rate of spread and eventually a gradual decrease when a canopy of brush and young tree crowns has been closed long enough to shade out lower vegetation.

In a similar period on unburned areas, smaller twigs and branches fall from the slash to the ground, become compacted, and rot. A canopy of brush, young trees, and herbs grows over the slash, keeps it more moist during drying weather, and protects it from wind. For the August conditions assumed in our ratings the canopy likewise offsets the hazard of fine fuels added by dead leaves and herbaceous material. The net effect on unburned areas is first a rapid decrease in rate of spread, and then a slower decrease.

Resistance to control on unburned plots significantly exceeded that on burned plots in the first 11 years except in the seventh (Fig. 4*B*). In the fifth year, resistance to control on burned plots was 67 percent of that on unburned plots, or about the same as in the preceding years.

Trends in resistance to control suggested by Figure 4*B* were checked, as for Figure 4*A*, by analyzing the 36 pairs of plots represented in seasons 1 and 3, and in one season from 12 to 16. Ratings of burned areas in the 12th to 16th seasons averaged significantly greater than in the first or third seasons. Resistance to control on unburned plots did not change significantly during the period of study.

The increase in resistance to control on burned areas paralleled increase in brush density, which gradually became an important part of resistance to control. Presence of slash on unburned plots caused higher resistance to control from the start, and a moderate increase in brush was offset by amelioration of slash conditions that affect resistance.

Although the plots were not rated before logging, estimates from fuel-type clas-ifications of similar undisturbed stands indicate that they probably had an average numerical rating equal to about 1 for rate of spread and 1 to 2 for resistance to control.

Natural Restocking. Stocking was appraised in terms of percentage of 4-milacre plots stocked with one or more seedlings, at least 6 inches tall, of a commercial conifer (Fig. 5).

Advance seedlings were not included in stocking tallies up to the fifth season after plot treatment because we wanted to determine effect of slash burning on restocking established after logging. About half of the plot pairs had advance seedlings, mostly western hemlock and Pacific silver fir. If these had been included, values in the third to fifth seasons would have been about 10 percent higher for unburned plots and about 1 percent higher for burned plots. Eventually the advance seedlings could not be readily distinguished in the field and so are included in stocking for seasons 11 to 16.

Owing to the time interval between logging and suitable drying and burning weather, a few pairs of plots were not treated until one or more growing seasons after logging. In compiling the stocking tallies for a given number of years since plot treatment, those for the burned plots were numbered from time of slash burning; unburned plots were numbered from time of logging in the earlier years and from time of burning for the 11th to 16th seasons. (Records were unavailable to show stocking in the later years according to time since logging and time since burning.) Since restocking may increase greatly in any 1 year during the first few years, an extra year of restocking for one treatment may greatly affect the comparison of burned and unburned plots in this early period. Later, the restocking increases slowly, and an extra year has little effect on the comparison.

In general, burning did not significantly affect stocking in either the coastal strip or

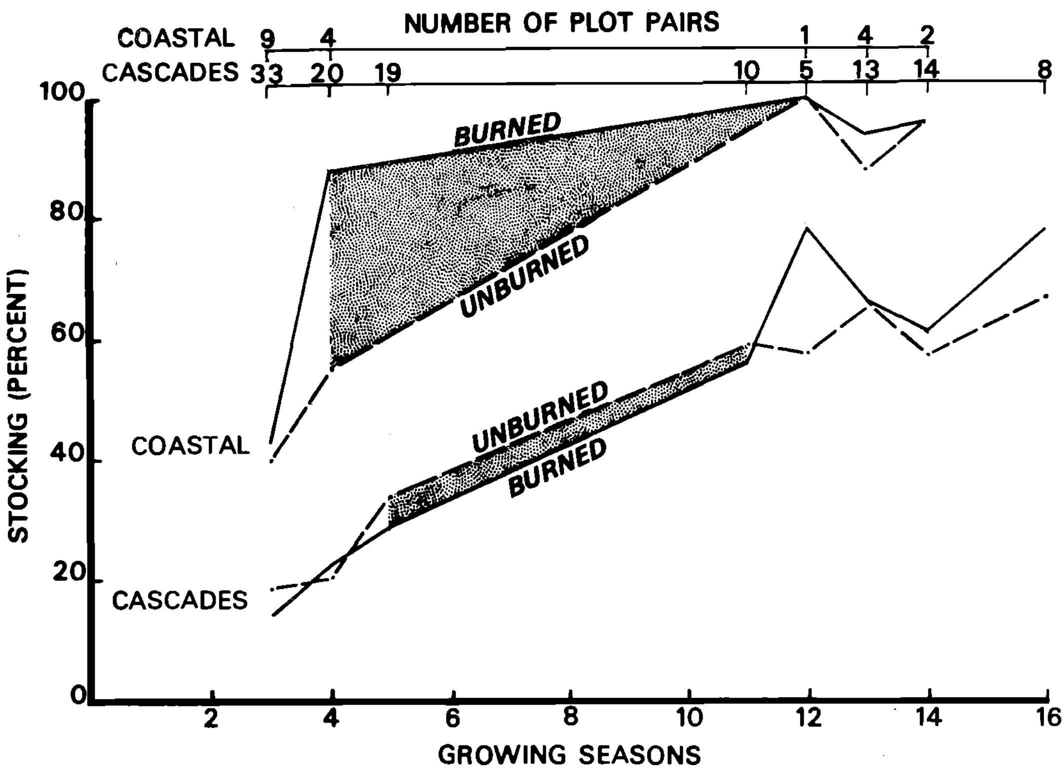

FIGURE 5. *Percent of stocked 4-milacre areas on burned and unburned plots, by growing seasons.*

Cascade Range. The only significant difference between burned and unburned plots was in the Cascades for season 12.

Although interpretation of stocking trends, as mentioned under hazard ratings, is complicated by incomplete repetition of plot records, the generally rising trends in Figure 5 are considered real because records of individual plots showed similar trends.

The average Cascade plot restocked slowly with postlogging seedlings (Figs. 5, 6). Records for early years of the study included at least 1 year of good seed production in the locality of most plots. According to stocking classes customarily used in the Douglas-fir region, medium stocking is 40 to 70 percent (Cowlin 1932). The Cascade plots were still in the medium class after 11 to 16 years; the coastal plots reached this class in about the fourth year. On burned plots, stocking was significantly greater in the coastal area than in the Cascades throughout the 16 years; on unburned plots it was greater in the coastal area for the average of the period beginning with the 11th year. More prompt restocking in the coastal area was probably due to a greater proportion of the prolific western hemlock in the nearby stand and to a more favorable climate.

In 1953, we recorded kind of seedbed surface on which all seedlings were growing on 17 pairs of Cascade plots and 5 pairs of coastal plots. On unburned Cascade plots, 49 percent of the seedlings grew on mineral soil. Since mineral soil covered only 25 percent of the surface of these plots when established, occurrence of seedlings on mineral soil was about twice as great as would be expected if surface had no influence. On burned plots, 64 percent of the seedlings grew on mineral soil, which covered 53 percent of the surface. On coastal plots, however, seedlings showed no preference for mineral soil. Here, seedlings were mostly western hemlock and Sitka spruce, both of which established

FIGURE 6. *Fourteen years after burning, some plots (top) were completely restocked, but a few (bottom) produced little more than fireweed.*

readily on organic surfaces; in the Cascades seedlings were mostly Douglas-fir, which commonly prefers a mineral seedbed.

Brush Cover. Brush covered unburned plots significantly more than burned plots for five growing seasons after burning in the Cascades, but for only three seasons on the coastal strip (Fig. 7). On unburned plots, brush on the coast significantly exceeded that in the Cascades for the first five and the 13th seasons. On burned plots, brush did not differ between the two locations. In both locations, brush cover generally increased until seasons 11 to 16.

Species of brush varied with burning treatment and geographic location. Scarcely any sticky laurel (*Ceanothus* sp.) grew on unburned plots, but much grew on burned plots (Table 2). In one locality southeast of Eugene, Oregon, indicated by eight pairs of plots in Fig. 2, the *Ceanothus* canopy alone on burned plots exceeded the total brush canopy on unburned plots. Western rhododendron and salal grew mainly on unburned plots. Nearly all of the *Ceanothus* and most of the rhododendron grew south of the midpoint of the Cascade group of plots (Fig. 2). Besides the species listed in Table 2, 13 others ranked either first or second on one or more of the Cascade plots. Brush species tallied on the plots totaled 39.

Herbaceous Cover. Area covered by herbaceous growth on burned plots did not differ significantly from that on unburned plots (Fig. 8).

Herbaceous cover in the coastal strip exceeded that in the Cascades for the first 5 years of comparison but not during the last 2 years. The trends in both locations suggest increasing cover during the first 12 years and then a decrease, which probably resulted from the cumulative effects of more competition from brush and conifer restocking.

Several outstanding differences in occurrence of herbaceous species were related to burning treatment and geography (Table 2). American twinflower grew only on unburned areas. South of the midpoint of the Cascade group of plots, wood groundsel predominated on burned plots in the second season but decreased to a minor species by the third season—the first season shown in Table 2. Annual willow-herbs grew abundantly in the first to fifth seasons but not in the 11th to 16th seasons after burning. Western brake-fern grew abundantly in the 11th to 16th but not in the third to fifth seasons. Whipple-vine grew only in the southern one-third of the Cascade group. On the unburned coastal plots, no one species ranked higher than the others in the third to fifth seasons.

In addition to the species listed in Table 2, 11 others ranked either first or second on one or more Cascade plots. Herbaceous species tallied on all plots totaled 72.

Discussion

This 16-year study shows what can be expected, on an average, over a large part

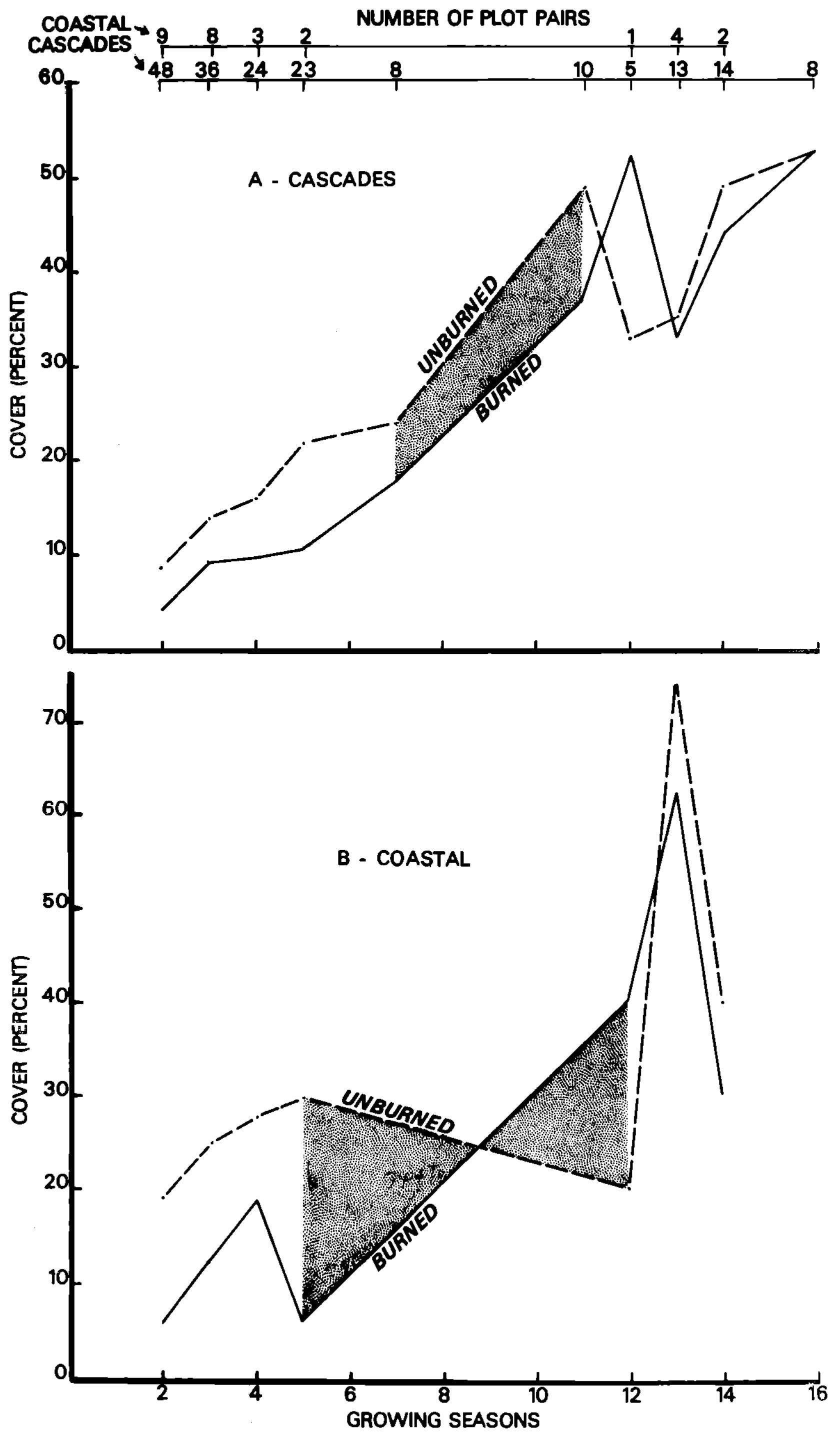

FIGURE 7. *Percent of available growing space covered by a vertical projection of the brush crowns on burned and unburned plots in different growing seasons after a slash fire.*

TABLE 2. Rank of prevailing species[1] in the plant cover on burned and unburned plots in two periods after slash burning. Rank[2] depends on number of plots in which a species ranked first or second in percent of ground shaded; number 1 is highest rank.

Subregion and plant species	3d–5th seasons		11th–16th seasons	
	Burned	Unburned	Burned	Unburned
Brush species				
Cascades:				
Vine maple (*Acer circinatum* Pursh)	1	1	2	1
Sticky laurel (*Ceanothus velutinus* Dougl. and var. *laevigatus* T. & G.)	2	—	1	—
Western rhododendron (*Rhododendron macrophyllum* G. Don.)	4	2	4	2
Salal (*Gaultheria shallon* Pursh)	—	3	—	3
Thimbleberry (*Rubus parviflorus* Nutt.)	—	—	3	4
Elderberry (*Sambucus glauca* Nutt., and *S. callicarpa* Greene)	3	—	—	—
Western blackcap (*Rubus leucodermis* Dougl.)	5	4	—	—
Oval-leafed huckleberry (*Vaccinium ovalfolium* J. E. Sm.)	—	5	—	—
Bitter cherry (*Prunus emarginata* (Dougl.) Walp.)	—	—	5	5
Coastal:				
Thimbleberry (*Rubus parviflorus* Nutt.)	1	1	1	1
Salmonberry (*R. spectabilis* Pursh)	2	1	3	3
Red huckleberry (*Vaccinium parvifolium* J. E. Sm.)	—	2	2	2
Blue huckleberry (*V. ovalfolium* J. E. Sm.)	—	3	—	—
Salal (*Gaultheria shallon* Pursh)	3	3	2	2
Elderberry (*Sambucus glauca* Nutt., and *S. callicarpa* Greene)	3	—	—	—
Vine maple (*Acer circinatum* Pursh)	—	3	4	—
Rustyleaf (*Menziesia ferruginea* J. E. Sm.)	—	3	—	4
Herbaceous species				
Cascades:				
Fire-weed (*Epilobium angustifolium* L.)	1	2	1	1
Western dewberry (*Rubus vitifolius* C. & S.)[3]	2	1	2	2
American twinflower (*Linnaea borealis* L. var. *americana* (Forbes) Rehd.)	—	3	—	3
Western brake-fern (*Pteridium aquilinum* (L.) Kuhn var. *pubescens* Underw.)	—	—	3	4
Whipple-vine (*Whipplea modesta* Torr.)[3]	4	5	4	5
Pea (*Lathrus* sp. (Tourn.) L.)	—	—	4	—
Willow-herb (*Epilobium paniculatum* Nutt., and *E. minutum* Lindl.)	3	4	—	—
Wood groundsel (*Senecio sylvaticus* L.)	5	—	—	—
Coastal:				
Western sword-fern (*Polystichum munitum* (Kaulf.) Presl.)	1	1	1	1
Western brake-fern (*Pteridium aquilinum* (L.) Kuhn var. *pubescens* Underw.)	1	3	2	2
Australian fire-weed (*Erechtites prenanthoides* DC.)	1	3	—	—
Oregon oxalis (*Oxalis oregana* Nutt.)	—	2	—	3
Western dewberry (*Rubus vitifolius* C. & S.)	—	—	3	—
Fire-weed (*Epilobium angustifolium* L.)	1	—	—	—
Phacelia (*Phacelia* sp. Juss.)	1	3	—	—
Deer-fern (*Struthiopteris spicant* (L.) Weis.)	—	3	4	3
Pearly-everlasting (*Anaphalis margaritacea* (L.) B. & H.)	1	—	—	—

[1] Names are those listed by Peck (1961).

[2] Two or more species may have equal rank in the same period after the same treatment.

[3] Although this species has a woody stem, it was included in the herbaceous records because it is part of the lowest layer of cover.

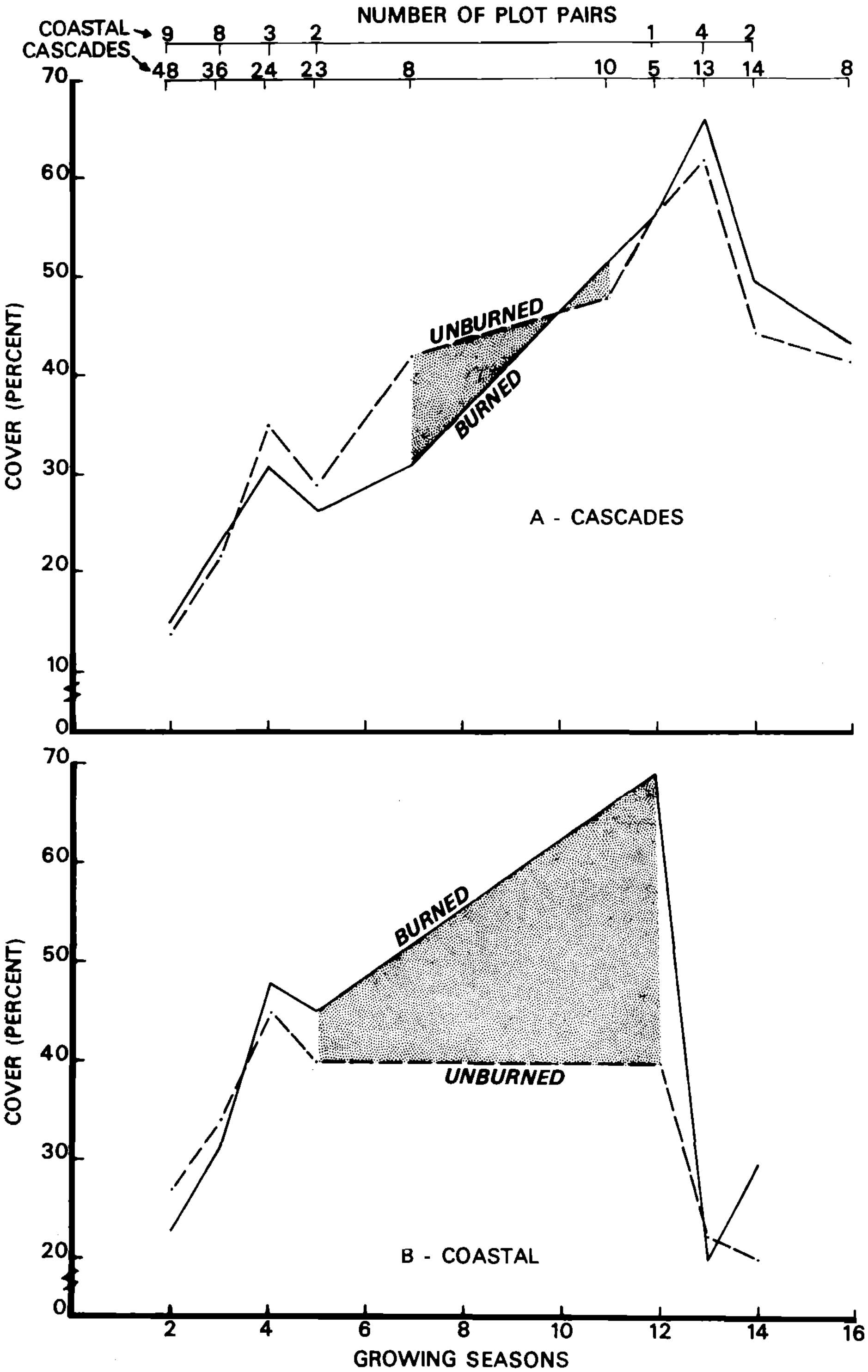

FIGURE 8. *Percent of available growing space covered by a vertical projection of the herbaceous plant crowns on burned and unburned plots in different growing seasons after a slash fire.*

of the higher elevations of western Oregon and Washington if slash from clear-cutting overmature stands is left or burned with moderately intense fires in fall after some rain. The following conclusions apply to those conditions:

1. Slash fires greatly reduce probable rate of spread and resistance to control of subsequent fires for 5 years and significantly reduce rate of spread alone for 15 years. Burning with greater or less fire intensity will produce results different from our averages. Fires that we studied consumed virtually all fine twigs supported above the litter but scarcely affected the quantity of wood more than 11 inches in diameter. More intense slash fires would have further decreased rate of spread in the first several years and appreciably decreased resistance to control.

Our findings regarding rate of spread and resistance to control on burned and unburned plots differ from those of Munger and Matthews (1941). They concluded that rate of spread on burned and unburned tracts became equal about 6 years after cutting or 5 years after burning, and then decreased on both. We found that rate of spread on unburned plots remained higher than on burned plots for at least 14 years (Fig. 4*A*). They showed that resistance to control on unburned tracts decreased for 8 years after burning, but on burned tracts it increased up to the 16th year, at which time both became practically equal. However, we found little change in the first 7 years. Since the Munger and Matthews study areas were mostly at lower elevations, more luxuriant growth of herbaceous cover with its annual crop of dead fuel may have caused the higher rate of spread values for burned tracts. Likewise, greater growth of brush at the lower elevations may have caused a greater increase in resistance to control.

A further difference between the two studies, however, was in the method of rating hazard. Munger and Matthews rated hazard on numerous milacre spots. We estimated rate of spread by the most probable path across 33-ft-square plots and rated resistance to control by the easiest practical route for a fireline across 66-ft-square plots. Given a normal, patchwise distribution of slash, our method would result in a greater rate of spread and less resistance to control than their method.

2. Slash fires eliminate some herbaceous species and encourage others, do not affect total herbaceous growth, usually reduce brush competition for several years, but stimulate establishment and growth of sticky laurel (*Ceanothus* sp.) in the southern Cascade Range. Slash burning evidently is an effective management tool to reduce competition of brush with tree seedlings in localities of the Douglas-fir region where *Ceanothus* does not grow abundantly after a fire.

3. Quantity of well-distributed natural stocking by commercial conifers established after cutting does not differ significantly between burned and unburned areas. Big differences in stocking sometimes occurred, but our observations do not explain them.

Since nearly all of the plots were on moderately deep soils that were seldom rocky, they do not indicate probable results of burning on thin or extremely rocky soils, which are generally recognized as much more susceptible to fire damage.

Our findings on effect of burning on restocking varied from those of several other studies. Three studies reported more stocking on unburned plots (Isaac 1943, Lavender *et al.* 1956, Munger and Matthews 1941), but three others reported more on burned plots (Berntsen 1955, Bever 1954, Worthington 1953). Results of the several studies may not be comparable with our studies because of differences in climatic zones, slash, ground cover, severity of burning, seed crops, and quantity of advance restocking. Most of these studies, moreover, included some unburned slash that was accidentally left despite a general practice of burning all slash that was sufficiently dry or that occurred in sufficient quantity per unit area. These unburned samples may have been in spots that were more moist or shady or that had less slash than the burned samples. If enough vigorous advance seedlings of a suitable species survive the logging to fully stock the area, restocking time is increased by slash burning. Only four unburned plots in our study had medium or better stocking by advance seedlings.

Our data on effects of burning on restocking apply specifically to natural restocking on clearcut units. Recently, many similar areas have been planted immediately after burning to reduce the delay that is common in restocking by natural seeding. Interlaced logs, tangles of branches, and deep beds of rotten wood or solid wood and bark, characteristic of much unburned slash in this region, greatly obstruct or completely block tree planting. Forest managers generally observe that planting is much easier and distribution of the planted trees is more uniform after adequate slash burning.

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