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UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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SLASH DISPOSAL IN THE WESTERN YELLOW PINE FORESTS OF OREGON AND WASHINGTON[1]

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INTRODUCTION

More than 100,000 acres of western yellow pine forest is cut annually in eastern Oregon and Washington, and this amount is yearly becoming greater. Ninety per cent is privately owned land from which ordinarily all the merchantable trees are logged; the remainder is publicly owned land (chiefly national forests and Indian reservations) from which the timber is ordinarily removed by the more gradual method of selective logging.

[1] The region referred to in this bulletin includes the areas in Washington and Oregon on the east slope of the Cascade Range and adjacent mountains and plateaus from Canada to California, the western foothills and slopes of the Cascades south of the Umpqua River, and the Blue Mountains and the Okanogan Mountains of eastern Oregon and eastern Washington, respectively. It includes the type in which western yellow pine (*Pinus ponderosa*) is the principal tree and the fir-larch type, or "north-slope type" in which Douglas fir (*Pseudotsuga taxifolia*), white fir (*Abies concolor*), lowland white fir (*A. grandis*), and western larch (*Larix occidentalis*) are prominent. Other associates of western yellow pine are lodgepole pine (*Pinus contorta*), sugar pine (*P. lambertiana*), western white pine (*P. monticola*), and Shasta red fir (*Abies shastensis*) in varying proportions. Parts of the adjoining States have similar conditions. The terms used by the lumber industry for *P. ponderosa* are "California white pine" in southern Oregon, and "pondosa pine" elsewhere in the region covered by this bulletin.

The removal of the virgin forest inevitably leaves the ground littered with needles, branches, unmerchantable chunks, and tops. These increase greatly the hazard of forest fires, and it becomes a problem of large economic importance to abate or to control the menace from fires on this great acreage of slashing. This has deeply concerned lumbermen and foresters for some time, not only in this forest region but in all regions where heavy accumulations of conifer slash, or logging débris, are subject to seasons of prolonged dry weather.

On the national forests and Indian reservations in the western yellow pine type in this region it has been the general practice for many years to require the operator to pile and burn the slash resulting from logging, but this method of eliminating the hazard has not been adopted on private lands because of its cost. Prior to the enactment of State forest-fire laws no effort was made to dispose of slash on private lands. Where slashings burned, accidental fires were the cause. The first slash-disposal laws were intended primarily for the Douglas fir region, west of the Cascade Range in both States, and their application to the pine forests east of the Cascade Range resulted in wholesale broadcast burning, which here practically spells forest devastation.

In Oregon the first forest fire law that concerned slash disposal (enacted in 1911) provided that: "All persons, firms, or corporations engaged in logging * * * in this State, shall each year burn their annual slashing [2] * * *." This had the effect of compelling broadcast burning because operators were not willing to use more expensive methods of complete disposal of their slash. In recognition of the unwisdom of this provision as it applied to pine forests, the law was revised in 1925 to provide that—

> where only a portion of the forest crop is removed and in the opinion of the forester such burning is unnecessary, or will create a fire hazard, he may relieve by written authorization such person, firm, or corporation from the above requirements with respect to part or all of the operation area * * *.[3]

Many timber operators are now taking advantage of the revised law to employ partial-burning methods.

In Washington the first forest fire laws were enacted in 1903, but slash disposal was not insisted upon in the pine region until 1921. The present law provides that—

> any and all cut-over land or slashings in the State of Washington covered wholly or in part by inflammable débris * * * shall if so declared by the supervisor of forestry, constitute a fire hazard, and the owner or owners * * * are hereby required to abate such hazard under the general direction of the supervisor of forestry.[4]

This law is flexible in that the abatement of the slash nuisance can be interpreted to mean remedial measures other than burning. However, the mistaken idea that burning was the only solution of the slash menace has rendered broadcast slash burning the common practice. Only within the last few years has there been a tendency for private owners to do less burning, and instead to give their slashings intensive protection from accidental fires.

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[2] Sec. 8962, ch. 14, General Laws of Oregon, 1921.
[3] Sec. 21, ch. 281, General Laws of Oregon, 1925.
[4] Sec. 5807 of Remington's Compiled Statutes, as amended by the Legislature of the State of Washington in house bill No. 356, Mar. 20, 1929.

The best treatment of western yellow pine cut-over lands following logging has been a matter of considerable discussion for years. As early as 1907 the Forest Service published a circular entitled "Suggestions for the Disposal of Brush in the National Forests" (*4*) [5] in which it recognized the need for flexibility in western yellow pine slash disposal by recommending that piling and burning should be done where the fire hazard was high, but that lopping should be the practice where the soil was loose or dry and in need of protection to insure reproduction. In 1917, the senior author (*10, p. 40*) offered the opinion that in the western yellow pine region of Oregon—

> in exceptionally dry situations where reproduction is scanty and has difficulty in becoming established, as on the pumice soils of the Klamath-Deschutes divide, it may be better forest management to scatter the brush. * * * At all events, fire lines or strips on which all the brush is burned should be built, so that should a fire get into the débris it could be confined to a small area.

Chapman (*2*), Pearson (*11*), and Woolsey (*18*) have commented on the desirability of leaving slash to benefit the forest. Woolsey stressed the importance of the construction of fire lines that would be of assistance in the suppression of fires where slash is lopped or pulled. In 1923, the State Board of Forestry of California (*1*) recommended to private operators a system of partial disposal of slash on fire lines for the western yellow pine region of California. Show (*14*) in 1926 went a step further and pointed to the desirability of following partial disposal on private lands with intensive protection for about 10 years. J. W. Girard and W. C. Lowdermilk, in an unpublished report prepared in 1922, define the purpose of slash disposal as twofold:

> Namely, the reduction of the fire hazard to the safety point and the favoring of a complete restocking to the desired species. * * * The objective in the reduction of fire hazard is to dispose of sufficient of the logging slash to make possible the effective fighting of fire on the tract during the fire season.

The trend of thought has been toward developing a method of slash disposal which would strike a balance for each class of ownership between the conflicting factors of safety from fire, good silviculture, and minimum cost.

Until recently slash on private lands has been treated wholly with a view to the cheapest effective abatement of the fire hazard without thought for the continued productivity of the land. This is unfortunate since most of the land now being logged is not only nonagricultural, but in fact well suited to continuous timber growing in conjunction with forest grazing. (Plate 1.) It is very desirable, therefore, that in the course of logging there be employed economically sound methods of slash disposal which will be advantageous for the continued productivity of the land and at the same time reduce the fire hazard.

In order to get facts concerning various methods of slash disposal and the comparative advantages of each for various conditions, the Forest Service commenced a field study in 1925,[6] the results of

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[5] Italic numbers in parentheses refer to Literature Cited, p. 57.

[6] The field work was planned and executed by the junior author, who devoted almost his entire time to the study for two years. One hundred and fifteen representative areas constituting nearly 7,500 acres were examined intensively, and this was supplemented by extensive observations on new and old cut-over lands and by conference with many individuals interested in this problem.

which are presented here. This was primarily an analytical, fact-finding study to ascertain and weigh the elements that influence slash-disposal practices and to study the results of these practices. It had also the very definite objective of determining the form of slash disposal that would best fit each set of physical conditions and each class of ownership, whether public or private.

Field work extended over two field seasons on the Deschutes, Crater, Whitman, and Wallowa National Forests and the Klamath Indian Reservation, in Oregon; on the Chelan, Wenatchee, and Rainier National Forests and the Colville Indian Reservation, in Washington, and on the private lands of several lumber companies[7] in both States. Cordial cooperation on the part of all agencies concerned with the slash problem did much to simplify the field work.[8]

PHYSICAL CONSIDERATIONS GOVERNING SLASH DISPOSAL

QUANTITY AND CHARACTER OF SLASH

Although all the débris resulting from logging, including tops, cull logs, and small trees which have been knocked over, is known as "slash," in conducting slash-disposal operations only material under 4 inches in diameter is taken into consideration, and therefore the limited interpretation of the term will be the one understood in this bulletin.

The quantity of slash fuel obviously has a very direct bearing on the treatment of the area. Where the cutting is light and the slash sparse, methods of disposal may be employed which would be wholly inadequate were the slash heavy. But the quantity of western yellow pine slash can not be measured altogether by the volume of the stand. It varies with the age and character of the trees cut. The limbs of mature pines are usually gnarly and larger in diameter than those of young trees (so-called "bull pines"), which are also less severely infected by mistletoe than mature pine, and hence contribute less witches'-broom to the slash. The maximum quantity of slash per thousand feet of logs cut results from logging in sparse stands on poor sites, where limbs are heavy and numerous, and mistletoe is common.

With an increase in the volume of timber per acre (Table 1), the volume of slash per thousand board feet decreases. A. C. McIntyre's studies in the Southwest pointed to a similar relationship.

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[7] These included Shevlin-Hixon Lumber Co., and Brooks-Scanlon Lumber Co., at Bend, Oreg.; Oregon Lumber Co., and Baker White Pine Lumber Co., at Bates, Oreg.; Gardinier Lumber Co., at Austin, Oreg.; Bowman-Hicks Lumber Co., at Wallowa, Oreg.; Pelican Bay Lumber Co., at Klamath Falls, Oreg.; Stoddard Lumber Co., at Perry, Oreg.; Owen-Oregon Lumber Co., at Butte Falls, Oreg.; East Oregon Lumber Co., at Enterprise, Oreg.; and the Cascade Lumber Co., at Casland, Wash.

[8] Acknowledgment is due many individuals for their assistance, especially J. S. Boyce, Yale University; W. H. Long, Bureau of Plant Industry; Fred R. Moffat, Indian Service; Norman Jacobson, Western Forestry and Conservation Association; R. D. Moore and J. H. Meister, Shevlin-Hixon Lumber Co.; the late H. E. Allen, Brooks-Scanlon Lumber Co.; E. R. Aston, Biles-Coleman Lumber Co.; B. B. Colwell, Cascade Lumber Co.; B. Moorehead, Baker White Pine Lumber Co.; and A. C. McIntyre, Pennsylvania State College.

TABLE 1.—*The relation of total gross volume of the stand to the volume of slash per acre and per thousand board feet*[1]

Gross volume per acre (M feet b. m.)	Volume of piled slash		Gross volume per acre (M feet b. m.)	Volume of piled slash	
	Per acre	Per M feet b. m.		Per acre	Per M feet b. m.
	Cubic feet	*Cubic feet*		*Cubic feet*	*Cubic feet*
4	2,480	620	16	3,040	190
6	2,592	432	18	3,132	174
8	2,696	337	20	3,200	160
10	2,780	278	22	3,280	149
12	2,880	240	24	3,336	139
14	2,954	211			

[1] Based on 16 sample plots; data curved.

The intensity of utilization practiced by the logging operator naturally affects the volume and character of the slash, and the ensuing fire hazard. Where small poles, posts, or cordwood are cut following the removal of the saw logs, the slash is correspondingly reduced in quantity and placed in smaller masses closer to the ground. Were such utilization of branch wood for fuel, chemical by-products, etc., economically practicable here, as it is in some parts of Europe, the problem of slash disposal would not be acute.

Of the various species associated with western yellow pine, the most common are lodgepole pine, Douglas fir, white fir, and western larch. Douglas fir and white fir have heavy crowns, the branches crowding close together and extending far down the bole. Also because the limbs are finer than those of western yellow pine, a larger proportion of them enters into the slash volume. Measurements of Douglas fir slash indicate the volume to be two to three times that of pine in a similar stand. Larch has an open crown made up of fine, widely separated branches bearing sparse, small needles; its slash volume is perhaps even less than that of pine. Lodgepole pine, because of its long crown, produces a heavy volume of slash, much of which is dry and inflammable when cut, owing to the persistence in large quantity of dead lower limbs.

Needles of western yellow pine and lodgepole pine persist on the twigs and tops for at least two and often four years, but Douglas fir and white fir needles fall generally by the end of the first year. Needles of larch, which are naturally deciduous, drop in a few months.

DISTRIBUTION OF SLASH

The distribution or arrangement of slash affects the fire hazard quite as much as does its volume. The distribution of similar volumes of slash may differ greatly because of difference in falling, logging, and utilization practices. Figure 1 compares the distribution of slash of different densities on 27 sample plots typifying a variety of logging methods and stand conditions in three districts of this region. The ground area occupied by slash varies with the method of logging, irrespective of volume of slash. Power logging

results in the greater scattering of slash, as illustrated by plots Nos. 10 and 11. The board-foot volumes cut on these plots are practically

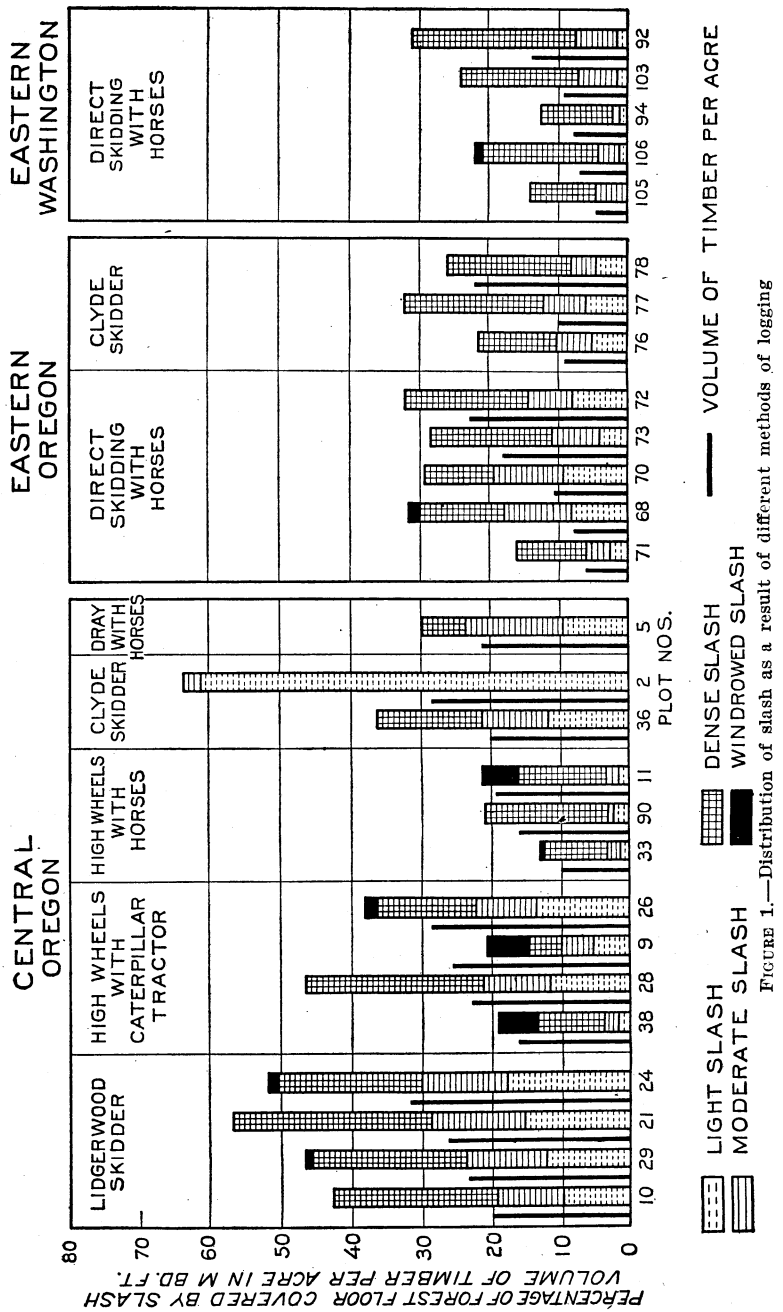

FIGURE 1.—Distribution of slash as a result of different methods of logging

the same, yet the Lidgerwood skidder-logged plot has twice as much area of forest floor covered with slash as the horse-logged plot.

In horse logging in the heavier stands of timber, some slash must be thrown from the wheel roads and skid trails, resulting in considerable windrowing, as in plot No. 11.

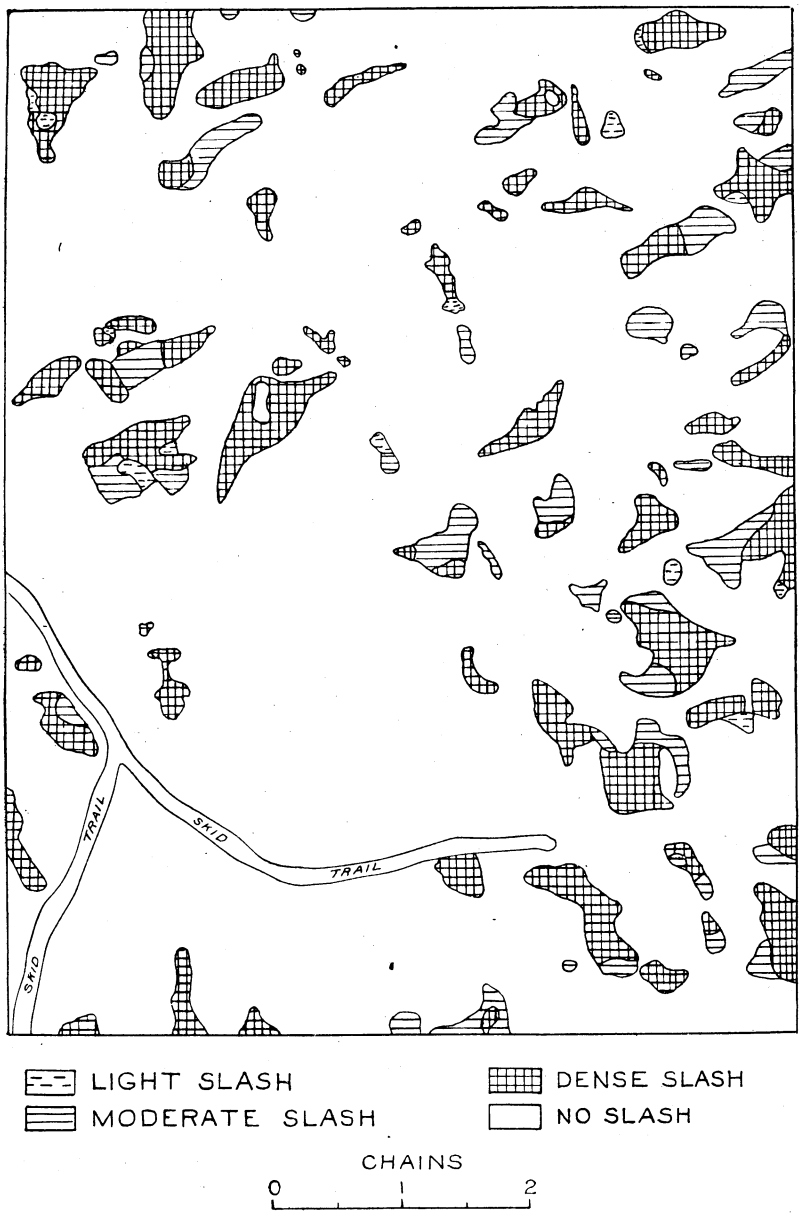

FIGURE 2.—Area logged by direct skidding with horses (plot 105 of fig. 1)

Figure 1 illustrates the wide variation in the arrangment of slash that is so important a consideration in rating the fire hazard of

various slashings. Figures 2 and 3 show graphically for horse-logged plot 105 and for skidder-logged plot 24, the extremes of

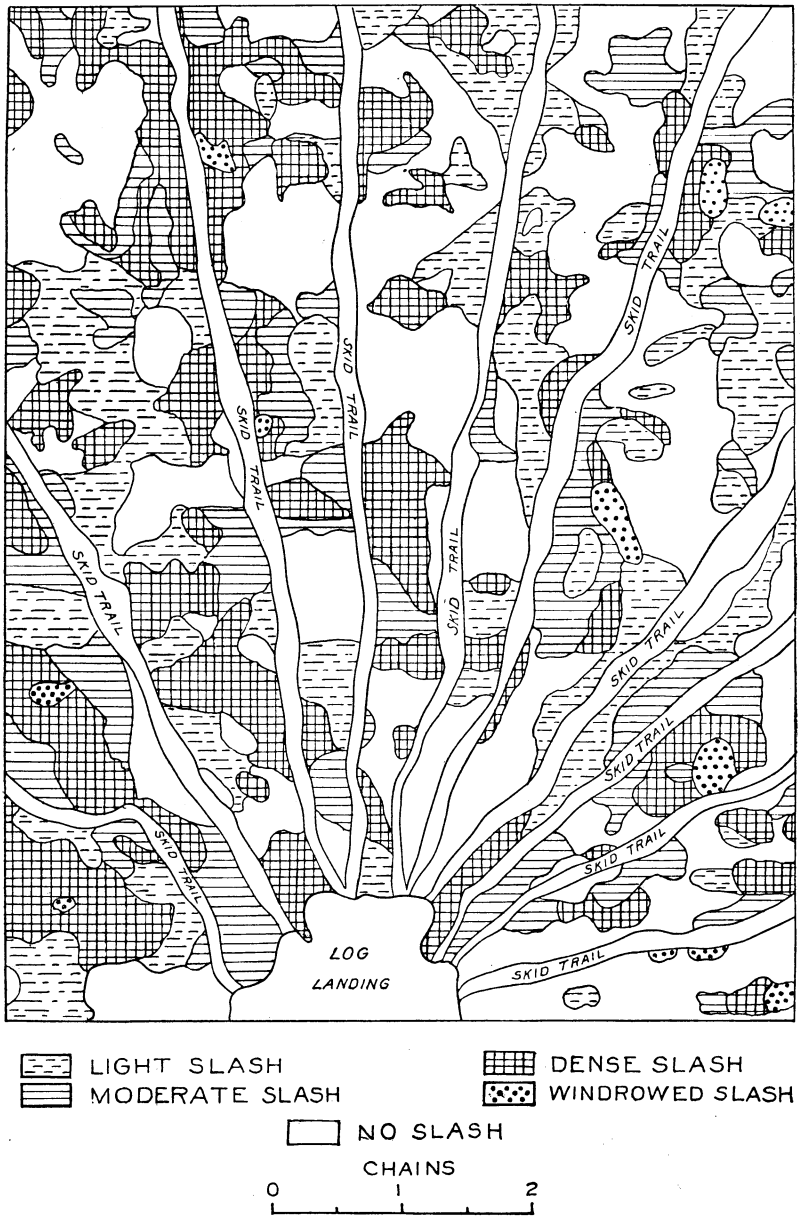

FIGURE 3.—Area logged by Lidgerwood skidder (plot 24 of fig. 1)

distribution of slash under contrasting methods of logging and timber stand.

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Seedlings and saplings which start under the protection of mature western yellow pine will form the nucleus of a second crop if proper methods of logging and slash disposal are used

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A, One year after cutting; the needles are dry and still attached to the limbs. Slash in this condition is readily inflammable and spreads fire rapidly; B, three years after cutting; most of the needles have fallen to the ground. After the needles have dropped from the twigs fire does not spread so rapidly as in newly cut slash

RATE OF DECAY

That the fire hazard from slash is transitory is an accepted fact. But as to the duration of the hazard there is difference of opinion. Long's investigations (*8*) in the Southwest give some information. In a study in eastern Oregon in which the writers cooperated with J. S. Boyce, and of which the results have not been published, Boyce found that at the end of the first year the needles had turned to a light, red-brown color but were still attached to the twigs. (Pl. 2, A.) The second year about 80 per cent of the needles had dropped, and by the end of the third year the needles had practically all fallen, except on occasional tops. (Pl. 2, B.) At that time all the twigs up to one-fourth inch d. i. b.[9] were very soft and broke readily, many up to one-half inch d. i. b. were decayed and broke easily, and some decay and considerable blue stain were evident in those up to 1 inch d. i. b. A year later all the needles had dropped except for an occasional bunch. Western red rot, the most rapid of all rots attacking western yellow pine slash, was by then abundant in the tops and was extending into attached branches. At the end of the seventh year, all needles had dropped and nearly all branches up to 1 inch d. i. b. were on the ground, although an occasional top had most of its branches down to one-half to one-fourth inch d. i. b. still attached. The material already fallen had broken into pieces 2 to 12 inches long. Western red rot had largely completed its work on the cull logs, tops, and large limbs. Broken and severed branches were decaying very slowly.

Thereafter it was difficult to recognize much change in the slash from year to year. The twigs and smaller branches had completely broken down and were broken into small pieces on the ground or had completely disappeared. (Pl. 3, A.) Western red rot had almost entirely completed its work. Many of the smaller tops had decayed completely, leaving only remnants of the branches. Where branches were still attached decay had left only a slender core of firm wood. By the fifteenth year, all branches had fallen to the ground, except those dead or partially dead and with part of the bark gone at the time of cutting. Many tops were completely decayed, with only traces left, while others were destroyed by decay and secondary insects to the point where only a thin shell of firm wood remained. (Pl. 3, B.)

In comparing lopped and untreated slash Boyce found that lopped slash decays more slowly, because the severed limbs dry out too rapidly to be attacked by western red rot. Piled slash, particularly in large piles, also decays very slowly, the branches in the center of the piles still retaining their needles after 15 years and remaining relatively sound.

From the examination of a small quantity of material it appears that deterioration of slash of white fir, lodgepole pine, western larch, and probably Douglas fir is slower than that of western yellow pine.

As decay and disintegration proceed, combustibility diminishes. The slash hazard in western yellow pine cuttings of the region is considered to have decreased materially after 5 years, still more after

[9] D. i. b.=diameter inside bark.

10 years, and after 15 to 20 years to have practically disappeared. These old cuttings, however, may have other sources of fire hazard not present in the virgin woods, such as grass, sapling thickets, underbrush, punky cull logs, tops, and stumps, but the hazard from the slash proper, i. e., the material under 4 inches in diameter, is practically neutralized after about 15 years.

EFFECTS OF SLASH ON FOREST REPRODUCTION

Studies in the Southwest (*12*), in California (*14*), and one in eastern Oregon by R. H. Weidman, all indicate the importance of advance reproduction [10] in the management of the western yellow pine type. In eastern Oregon advance reproduction was found to compose ordinarily from 53 to 98 per cent of the young growth 10 to 30 years after cutting. The establishment of subsequent reproduction is a slow process, depending upon the coincidence of an adequate seed supply and a season favorable to germination and survival of the tender seedlings. This may occur only once in several years, so that a full stand of subsequent reproduction may not follow logging for 10 to 40 years, even where there is a source of seed.

Inasmuch as there is ordinarily in this region an abundance of advance reproduction in the virgin forest which will develop into a satisfactory second-growth forest if spared from logging and slash-disposal damage, it is obviously desirable to so manage the logging and slash hazard that the seedlings and saplings already established may survive and form the nucleus of a second crop. In choosing a method of slash disposal on land which it is desirable to keep forested, it is of utmost importance to adopt one which will favor the advance reproduction, just as far as is compatible with other objectives. Should there be no advance reproduction, the method might well be quite different from what would be good practice where there was a thicket of saplings and seedlings.

The effect of undisposed slash upon advance reproduction and upon subsequent reproduction may be one of the major considerations in deciding upon the method of disposal for any area. It must be known, for example, to what extent dense slash may obstruct seedlings already established or prevent the starting of any subsequent reproduction, and whether, on the other hand, a light covering of slash may prove beneficial in conserving surface soil moisture or in protecting against grazing animals.

Table 2 gives figures based on a study made three or four months after logging, when the effect of the slash upon the seedlings was apparent. This examination of 1,455 seedlings on 167 hundredth-acre transects gives some idea of the immediate effect of slash of different densities upon the existing seedlings.

[10] The term "advance reproduction" is applied to the seedlings and saplings that become established under the protection of the virgin forest prior to cutting. The term "subsequent reproduction" is applied to the reproduction that starts after logging.

TABLE 2.—*The immediate effect of slash of different densities on advance reproduction*

Height class and slash density	Distribution of seedlings by different stages of suppression		
	Free [1]	Bent [2]	Covered [3]
0.01 to 0.5 foot seedlings:	*Per cent*	*Per cent*	*Per cent*
Light slash	69	20	11
Moderate slash	53	20	27
Dense slash	24	24	52
Windrows	0	10	90
0.51 to 1 foot seedlings:			
Light slash	72	26	2
Moderate slash	38	49	13
Dense slash	22	40	38
Windrows	0	13	87
1.01 to 3 foot seedlings:			
Light slash	76	24	0
Moderate slash	71	29	0
Dense slash	34	50	16
Windrows	0	57	43
3-foot to 3.6-inch (d. b. h.) seedlings: [4]			
Light slash	87	13	0
Moderate slash	73	27	0
Dense slash	47	43	10

[1] Seedlings with leaders free and no mechanical obstruction of stem by slash.
[2] Seedlings with leaders free but stem bent, the bending usually in evidence at base.
[3] Seedlings completely covered by slash, foliage yellow, probably killed
[4] No data on windrows in this class.

It is clearly evident that the greatest loss of reproduction occurs among the smaller seedlings. Also, the loss in a given height class increases as the density of the slash becomes greater. Since the percentage of survival is thus dependent on the size of the reproduction and the distribution of slash, no average figure can be given for seedling loss in slash. The smothering of seedlings by undisposed slash is generally in the nature of a thinning rather than complete destruction over extensive areas, and therefore such losses will seldom be inimical to good forest management.

Even among the smallest seedlings (0.01–0.5 foot) the values of Table 2 applied to dense slash distribution, as on plot 24 of Figure 1, show a loss of only 15 per cent of the entire number of that class of seedlings. Assuming all reproduction to be over 3 feet in height and the slash to be light, as on plot 94 (fig. 1), a seedling loss of only 1 per cent is indicated. These two examples illustrate the approximate maximum and minimum amounts of reproduction that might be smothered by undisposed slash immediately after logging.

It is also interesting to know to what degree seedlings suffer permanently from being bent by slash. Accordingly 1,429 seedlings of various heights in slash of different densities, 7 to 12 years after logging, were examined and classified; the results are given in Table 3. The largest proportion of normal seedlings occurs where the slash is the lightest, and here the proportion of bent and crooked seedlings is not enough to be a serious injury to the future stand. In the dense slash the proportion of both bent and crooked seedlings runs from 33 to 38 per cent, which is not particularly serious considering that the patches of dense slash cover ordinarily a relatively small part of an area. As might be expected, with an increase in the height of the

seedlings there is a slight decrease in the proportion of seedlings deformed by mechanical interference from the slash.

TABLE 3.—*The effect of slash on the form of advance reproduction 7 to 12 years after logging*

Height class and slash density	Distribution of seedlings by different results of suppression		
	Normal seedlings [1]	Bent seedlings [2]	Crooked seedlings [3]
0.01 to 0.5 foot seedlings: [4]	*Per cent*	*Per cent*	*Per cent*
Light slash	90	5	5
Moderate slash	80	12	8
Dense slash	64	19	17
0.51 to 1 foot seedlings:			
Light slash	92	5	3
Moderate slash	91	3	6
Dense slash	62	24	14
1.01 to 3 foot seedlings:			
Light slash	95	2	3
Moderate slash	92	6	2
Dense slash	67	19	14

[1] Seedlings normally developed with no mechanical injury to stem.
[2] Seedlings bent, usually at base, with leader free.
[3] Seedlings badly obstructed by slash, crooked in the form of an S.
[4] Height of seedling the year of cutting.

The effect of slash on seedling growth was also studied. Casual observation led to the belief that a slash cover quickened height growth, but the careful measurement of many seedlings failed to show any consistent effects of slash on increment either one way or the other. In general, seedlings in the slash, both advance and subsequent, grew at the same rate as those in the open. Even on south slopes, where the sheltering effect of slash should be beneficial, no consistently better growth of the seedlings in the slash was found.

There is theoretical reason to believe that a slash cover should favor the establishment of subsequent reproduction by conserving soil moisture, by creating desirable seed-bed conditions, by affording shade to the young seedlings, and by protecting them from trampling and browsing animals (*3*). In the Southwest, Pearson (*12*) found that slash is generally beneficial except where there is a rank herbaceous vegetation. In the Pacific Northwest data are inadequate, and definite conclusions are therefore impossible. However, some observations are available from a group of permanent sample plots on the pumice soils of central Oregon, on half of which the slash was piled and burned and on the other half left undisposed as it fell. Here at the end of the third growing season, the survival of subsequent seedlings was 19 per cent on the piled-and-burned area and 37 per cent on the slash-covered area. Moreover, the germination on the latter was nearly twice as great as on the former, so that the net advantage was more than 3 to 1 in favor of the slash-covered area.

FIRE-HAZARD CONSIDERATIONS

Since the principal purpose of slash disposal is the reduction in the fire hazard, the severity or character of the fire hazard on any particular area very largely influences the method of slash disposal

that should be chosen. It should be recognized that there are several factors besides the volume of slash itself that affect the hazard on cut-over lands. An understanding of these will help the timberland manager to appraise conditions on his own property and plan his protective operations accordingly.

FUELS OTHER THAN SLASH

On any cut-over land more or less inflammable material other than débris from the felled trees serves as fuel for the accidental fire. This may be in the form of dry grass which has not been grazed down, an undergrowth of bushes, an accumulation of needles, standing snags, or fallen dead trees. Hence when these natural forest fuels are present in quantity a more intensive system of slash disposal may be necessary than where slash is the only abundant fuel. The areas with a heavy undergrowth of brush, or mock chaparral, present a particularly difficult problem, under any system of disposal. In certain localities where the annual fall of needles accumulates to a depth of a couple of inches or so before decomposition, it is the ground cover of needles, rather than slash, that is the dangerous tinder fuel and accordingly must be considered in deciding upon the treatment of the area after logging.

METHOD OF LOGGING

Some kinds of logging leave the slash very much in patches, others scatter it more evenly, and some power logging smashes it up very much and partly covers it with mineral soil. Some logging methods leave wide roads and trails, scraped clean of slash and other fuels, thus lessening the hazard by making fire control easier. Table 4 gives, for five principal types of logging, the percentages of the total area in primary roads or skid trails and the average width of these trails.

TABLE 4.—*Proportion of logging area in skid trails and average width of skid trails*

Logging method	Area in trails	Width of trails	Logging method	Area in trails	Width of trails
	Per cent	*Feet*		*Per cent*	*Feet*
Lidgerwood steam skidder	9.2	10	Clyde steam skidder	28.7	30
Caterpillar with high wheels	9.5	15	Horses (direct skidding)	3.6	3
Horses with high wheels	6.6	9			

The character of these skid trails varies with the type of soil and the nature of the plants in the ground cover. In loose soils, trails made by power logging remain barren of vegetation for several years, but horse logging usually kills only a part of the vegetation, and the trails become overgrown in a few years. On stiff soils, such as those of the Blue Mountains, where there is an almost continuous sod of grass and weeds, even power logging fails to scrape the surface bare of all vegetation, and trails there are hence less effective as fire lines than those on loose soils.

CAUSES OF FIRES

Some regions are more predisposed to fires than others, both from human risks and from lightning, and the forester should appraise the local chances of fire before he decides upon a slash-disposal policy. Knowing the causes, he can perhaps help to lessen the number of fires that start, and the treatment of the slash areas can be intensified to fit the risks.

The logging operation itself is of course an extraordinary risk, especially where steam power is used. The greatest fire danger lies along railroad lines, near loaders and donkey engines, and about the woods workers themselves. Slash areas contiguous to active logging operations are therefore particularly subject to fire; this is a transitory condition ending when the operation moves on, but must be provided for in the plan for the care of slash areas. It should of course be considered the obligation of the logging department to prevent the starting of fires and to control those which might start contiguous to the operation; this cost should not be a charge against slash disposal or logged-off land treatment.

The risk of fires on current logging operations, in comparison with that on cut-over land away from the operation where no phase of logging is under way and where some of the slash had been piled and burned and some not, is shown rather strikingly in the records of the three national forests in Oregon that have had the most lumbering activity through a term of years. On the Whitman National Forest (1911–1926) the average on current logging areas was 88.7 fires for each 100,000 acres, but on older cut-over land 1.5 fires. On the Wallowa National Forest (1915–1926) the averages were, respectively, 52.8 and 1.6 fires, and on the Crater National Forest (1917–1926) 73.5 and 8.2. These figures indicate that the risk is from 9 to 59 times as great on the logging operation as on the cut-over land away from it.

LOCAL CLIMATE

The climatic conditions of any region not only have an important bearing upon the degree of hazard of a slashing and the season when it is hazardous, but also circumscribe the period when slash may be burned safely. Even within the pine region of Oregon and Washington there is variation in the length and intensity of the fire season and in the nature of the slash-burning season. At higher altitudes the snows come earlier and last longer and shorten the period when slash piling may be done currently with logging. Some localities seem to have much more weather suitable for swamper burning than others. At best there are but a few weeks for safe spot burning or burning piled slash between the time in the spring when slashings become dry enough to burn and yet not too dry, and again in the fall from the time they will burn safely until they are too wet to burn. The susceptibility to high winds and their direction during the fire season are factors to reckon with. Those choosing slash-disposal methods should appreciate these local climatic factors and plan accordingly.

The length of the fire-hazard season has a bearing upon the probable effectiveness and cost of methods that involve intensive protection in lieu of complete burning. It makes a great deal of difference whether this protection must be given for three or six months each year. The fire history of four national forests typical of this region indicates that 94 to 98 per cent of the fires occur between the middle of June and the last of September. (Fig. 4.) The forester will do well to study local fire history and fire factors in estimating what each method of slash disposal will cost in terms of a given standard of safety.

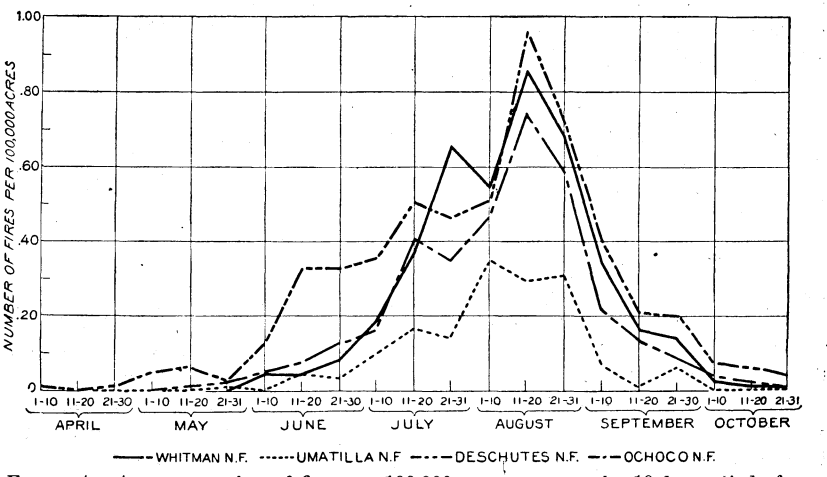

FIGURE 4.—Average number of fires per 100,000 acres per year by 10-day periods for four national forests for the period 1908–1920

SLOPE AND ASPECT

Recognition of the influence of slope and aspect upon the behavior of fires is a distinct aid in planning slash disposal. Methods of slash treatment that might be cheap and effective in a plateau country would be wholly out of place on long hillsides. It has been found in California (*13*) that the percentage of fires reaching class C size varies directly with the percentage of slope, as does the size of the average fire. Roughly, fires on 5 to 15 per cent slopes were two and a half times as large as those on 0 to 5 per cent slopes; on slopes of 15 to 30 per cent they were nearly twice as great as on those of 5 to 15 per cent; and on 30 to 60 per cent slopes they were twice as great as on 15 to 30 per cent slopes. The same report shows a distinct relationship between the size of fires and aspect; it was found that the percentage of class C fires on south slopes was about twice as great as on north slopes.

The discriminating forester may often find it advantageous to apply one method of treatment to the level land and another method to the slopes, or one system to the dry or windward exposures and another to the moist or lee hillsides, even within the same operation. By employing a method that fits the conditions of each situation, he attains uniform results.

FOREST TYPE

This study deals primarily with the western yellow pine type proper, in which that species is predominant, but this type is intermingled with patches of fir, larch, and lodgepole pine, usually on north slopes; this mixed type presents quite a different fire hazard from the pine. Although the fir, larch, and lodgepole pine occur naturally on the more moist sites, these sites are apt to carry a heavy undergrowth and accumulation of dead wood and duff that complicate slash disposal after logging. These areas of mixed conifers on the north slopes deserve special consideration in making a slash-disposal plan and perhaps a treatment quite distinct from that in the pure pine areas.

EFFECTS OF SLASH ON SOIL

Although no systematic investigation of the effect of slash on the soil was made in the present study, it may be said with assurance that the leaving of slash has a favorable effect upon the physical condition of the soil and its liability to erosion, in contrast to the results of burning. The addition of organic matter to the soil through the decomposition of the slash helps to make the soil more friable, particularly if it is a heavy soil. Furthermore, a covering of humus increases its water-absorbing capacity. These effects can be expected to be beneficial to forest production in the long run and are not to be overlooked in planning a slash-disposal policy.

When erosion, either of the sheet or gully type, is well advanced, as on soils underlain at a shallow depth by bed rock or a layer of semipermeable heavy clay, undisposed slash can have a part in holding the soil and ground cover in place, and making conditions more favorable for absorption of precipitation. Particularly on slopes of over 20 per cent, where the surface cover has been broken by roads or skid trails, slash can be a direct deterrent of erosion, if disposed with this purpose in mind.

SLASH IN RELATION TO INSECTS [11]

Slash serves as a breeding place for two general types of forest insects, beneficial and destructive. The beneficial insects are those which hasten decomposition, or which are predacious or parasitic upon the destructive species. In the destructive group are the bark beetles and bark borers which breed in slash and are also capable of attacking and killing living trees.

The insect menace to living timber from slash-breeding insects is a subject of some controversy among entomologists. However, the findings of the Bureau of Entomology as applied to the type under consideration confirm the observations of the writers on this point, namely, that slash usually does not constitute an insect hazard of any great economic importance to near-by living trees.

In the western yellow pine type of Oregon and Washington only three genera of bark beetles and bark borers need be considered, the Dendroctonus beetles (*Dendroctonus brevicomis*, *D. monticolae*, and *D. valens*), the pine engraver beetles (*Ips oregoni*, *I. emarginatus*,

[11] This section prepared by F. P. Keen, Bureau of Entomology.

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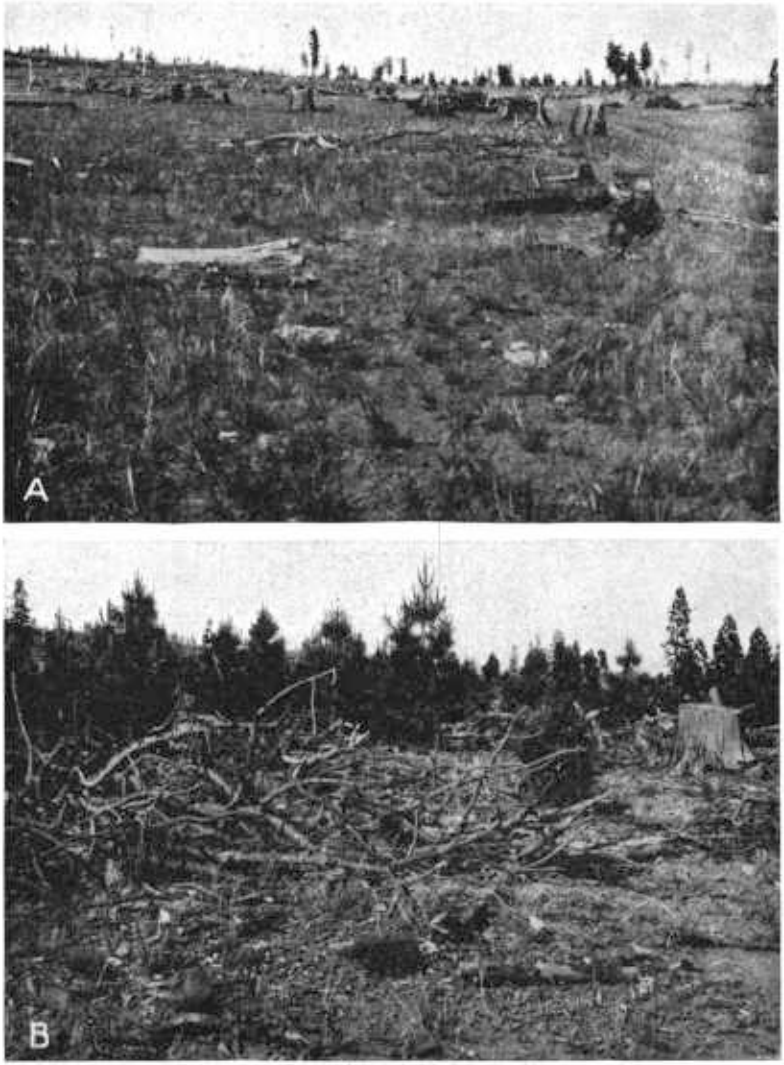
A, Eight years after cutting; the twigs and smaller branches are broken down completely and the larger limbs are punky with decay. Slash in this condition ignites less readily and makes a less flashy fire than fresh slash; B, fifteen years after cutting; the slash is no longer a fire hazard since the small inflammable material has united with the soil and the large material is riddled with decay and insects. A thrifty stand of young growth has been preserved by adequate fire protection



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A, Broadcast burning results in forest denudation. Ten years after logging and broadcast burning this area is still barren of any forest growth; B, spot burning leaves patches of young growth unburned. Ten years after logging the advance reproduction in the unburned spots is making a forest cover of prospective value

I. confusus, etc.) and the pine flatheaded borers (*Melanophila gentilis*, etc.). These are the only insects in the region which breed successfully in logging débris and also attack and kill standing trees.

All of these beetles are strongly attracted to logging areas, where they attack not only the stumps, felled logs, and slash but the standing trees as well. No practicable method of slash disposal will avoid this attractive influence of the cutting areas nor the resultant damage.

The Dendroctonus beetles and the pine flathead borers breed in the stumps and larger felled logs (usually over 6 inches in diameter) both merchantable and cull. As logging progresses the insects attracted to the merchantable logs are removed from the woods, and are no longer a menace. The remaining insects, which have been attracted to cull logs and stumps, do not breed very successfully in this class of material, and it has been found that the emerging progeny is far below the number produced in standing trees; hence the net result is unfavorable to an increase of beetle population in the logging area. It has been noted frequently that logging areas in which cutting has been continuous are freer from beetle damage than virgin forest areas. Furthermore since these beetles breed principally in material larger than that ordinarily removed as slash, it is obvious that no method of slash disposal entirely removes the material which harbors them.

The engraver beetles of the genus Ips and other small bark beetles of little economic importance breed principally in the smaller material removed in slash disposal. They breed readily and successfully in this material, and frequently their progeny emerges and kills large patches of reproduction, saplings, or the tops or limbs of old living trees. It is generally only for a lack of fresh slash that such trees are selected, as when logging operations are interrupted. Usually a continuous supply of green slash will absorb all of the emerging progeny and forestall any injury to living trees. While the destruction of reproduction may be considerable, the outbreaks as a rule are of short duration and rarely persist for more than one season. J. A. Beal, who has done some recent work on this problem, reports that scattered slash left exposed to the sun breeds very few pine engraver beetles, while shaded slash, such as that in piles, breeds great quantities. Thus the menace to young trees, which these engraver beetles present, suggests scattering the slash rather than placing it in piles, since disposal of the slash by burning usually can not be accomplished before the beetles have emerged.

A circular of the Bureau of Entomology on this subject (*15, p. 7*) concludes—

> that in the light of our present information, no special methods of slash disposal need be recommended to avoid insect damage to western yellow pine, except in the case of sporadic cutting or when logging operations cease. In such cases infested slash material should be destroyed before the broods of insects emerge.

SLASH IN RELATION TO FUNGI

Numerous fungi are found in western yellow pine slash and cull logs, of which the following might be dangerous to living trees: *Polyporus ellisianus*, *Trametes pini*, *Polyporus schweinitzii*, and *Fomes laricis*. However, fruiting bodies of any of these fungi are

rare on cut-over lands in the Northwest pine region. As Hubert (*5*) and Weir (*16*) point out, this is due to the unfavorable moisture conditions in the western yellow pine type where drying, except in shady moist situations, is so excessive as to preclude the production of sporophores.

SLASH FROM THE STANDPOINT OF RANGE MANAGEMENT

The loss in forage values from undisposed slash is in proportion to the quantity of palatable vegetation thereby covered or kept out of the reach of grazing animals. Only where the slash is very dense will the vegetation go unutilized, and Figure 1 indicates that this probably would represent not over 27 per cent of the area and generally much less.

Slash interferes with the handling of herded livestock, like sheep, but not so much with other animals, nor is this difficulty permanent, for it decreases as the slash ages. The burning over of the ground incident to slash-burning operations has some effect, usually unfavorable, on the density, composition, and palatability of the forage. This effect is proportional to the area touched by fire and is naturally inconsiderable with methods such as piling and burning and swamper burning, but material in broadcast burning.

Because the effect of slash on grazing is transitory and localized, range management would seldom be a determining factor in deciding upon the method of slash disposal.

ECONOMIC CONSIDERATIONS GOVERNING SLASH DISPOSAL

There are several considerations other than physical conditions that have a controlling influence on the choice of the method of slash disposal to be used in any particular lumbering operation. The most important of these are the ultimate use of the land and the cost of disposal; of lesser import are logging convenience and the preservation of natural beauty along roads and trails.

ULTIMATE USE OF THE LAND

If the land under consideration is distinctly adapted to growing field or orchard crops and the owner intends to convert it to that use, his chief concern will be to get rid of the slash and all residual forest growth as cheaply as possible. Ordinarily this would imply broadcast burning. But practically all of the western yellow pine cut-over lands in Oregon and Washington and the lands yet to be cut over are more suitable for growing forest crops than for agriculture. It is very much in the public interest, as well as in the interest of the owner, that such lands continue to be productive of forest crops and be not allowed to become denuded of useful growth. Hence slash disposal on lands chiefly valuable for timber production ought to be in harmony with, or at least not inconsistent with, the reforestation requirements of western yellow pine. This should be so whether the owner is definitely committed to a policy of continuous production or has no intention of holding the land for successive crops.

The Federal Government on the national forests and the Indian reservations, the States on their lands, and certain private owners as well, can be expected to practice a method of slash disposal which will favor reforestation and leave the land safe for the new crop. Such owners will be willing to expend enough on slash disposal to accomplish these objects, but whether the owners are individuals or the Government, they will expect the investment in slash disposal to return ample benefits.

Owners of pine timberland who have no expectation of holding the tract for a second crop, but who contemplate disposing of it as best they can when their operation is concluded, naturally do not want to invest heavily in intensive slash disposal merely to promote reforestation. But such owners can always do something to foster the young growth, without extra expenditure and in the course of protecting their operations against fire, if it be nothing more than to avoid destroying the reproduction.

At present there is little market for cut-over land, and it is priced low. There is some sale to stockmen purely for grazing purposes. The Federal Government is taking some of it in exchange for stumpage to round out the national forests, giving preference to land that is well restocked with small trees. It is to be expected that timber operators who contemplate continuous production will later be in the market for cut-over land with second growth upon it.

Since regulated grazing is not incompatible with reforestation in this region, this logged land can well serve a dual purpose—furnishing range for stock and growing timber. It would seem therefore that it would be to the financial advantage of stockmen or other owners who did not contemplate holding the land for timber production to take some little care to see that the timber-producing values on the area are not impaired, realizing that the time is not far distant when the ultimate buyer will pay a premium for having a new timber crop started on the land.

The recommendations to be given later take into consideration both classes of owners—those who are willing to make some expenditure for slash disposal to promote reforestation over and above necessary precautions to protect the operation, and those who are unwilling to make any slash-disposal investment for reforestation but who, nevertheless, do not want to destroy any future or salvage values the land and the growth upon it might have.

COST OF SLASH DISPOSAL

There is a wide range in the cost of slash disposal from practically nothing per acre for broadcast burning to as much as $6 to $10 per acre for complete piling and burning. The law in both Oregon and Washington, in requiring the abatement of the fire hazard, does not specify any method of disposal but accepts broadcast burning as satisfactory. Hence the owner is free to use any method he chooses that will abate the fire danger to his neighbor's property; he must use his judgment as to how much he is willing to pay to get security from fire for himself and his neighbor, to

leave his land in productive condition, and to realize on whatever forest and forage values there may be after logging.

The managers of public forests like the national forests and Indian reservations have considered that an expenditure of several dollars an acre is justified in the endeavor to leave logged-off lands in a desirable and safe condition. Private owners so far, with a few exceptions, have not thought it economical to spend more than a few cents an acre on slash disposal. It would be easy to demonstrate that to make no provision for slash disposal is as unbusinesslike as to go without insurance, and also that a crude cheap method, such as broadcast burning, is destructive of forest values far in excess of the cost of a more intensive method. Any owner, whether private or public, must use nice judgment to decide what degree of intensity of slash disposal will bring him the largest returns in insurance against losses from fire and loss of operating time; and in increased prospects for a second crop.

CONSIDERATIONS OF LOGGING CONVENIENCE

Only where horse logging is employed does the presence of slash hamper the skidding; it also increases the chances of injury to the animals. It has been estimated that horse-skidding costs are 10 to 20 per cent less when slash is burned before rather than after skidding. With steam-power logging, and to a lesser degree with caterpillar-tractor logging, the presence of undisposed slash offers no obstacle to bringing in the logs. The choice of a slash-disposal method, therefore, is of real consequence only with horse logging.

AESTHETIC CONSIDERATIONS

Slash is unsightly, particularly during the first few years, when the brown needles are still attached to the twigs. Along highways and close to recreational areas, appearance may be of sufficient consequence to decide the method of slash treatment to be used, apart from other considerations.

METHODS OF TREATING SLASH

For the purpose of this discussion seven methods of slash treatment, some of which may be still further subdivided, may be recognized, all of which are practiced more or less in the Pacific Northwest and most of them in other parts of the western yellow pine region as well. They are broadcast burning, spot burning, piling and burning, swamper burning, no burning, strip burning with intensive protection, and partial piling and burning with intensive protection. Each will be described in turn and its advantages and disadvantages discussed.

BROADCAST BURNING

DESCRIPTION

Disposal of slashings by broadcast burning consists in leaving the débris exactly as it lies after logging and then, at a time when the fire will spread, firing the area along one or more edges and allow-

ing it to run at will over the area to be burned. The only preliminary preparation, if any, is to construct fire lines around, or partly around, the area to be treated, to keep the fire from felled timber, uncut forest, or camps. This method is practiced either spring or fall, when the débris is dry enough to allow free running of the fire from one patch of slash to the next, across logging trails and all. Although broadcast burning should not be done at the height of the dry season, nevertheless it is not unusual for the fire, augmented by a high wind or unexpected dry weather, to spread uncontrolled beyond its intended boundaries. This method has been generally employed in this region by operators on private lands as the cheapest means of getting rid of the slash fire menace, ignoring or subordinating all other considerations. Fortunately in recent years other methods have been coming into use on private lands.

The cost of burning slashings by this method is almost negligible. The principal expense is in the preparation of fire lines at which to stop the fire; this item varies with conditions. The entire cost of the operation is usually between 1 and 5 cents per acre—rarely as much as 10 cents, unless the fire gets out of bounds and has to be fought.

EFFECT ON FOREST GROWTH

The effect of broadcast burning on advance reproduction and trees that may have been left standing is inevitably disastrous. Since the actual burn covers most of the area a corresponding portion of the seedlings, saplings, and small trees are killed or damaged. Table 5, based on the examination of 161 hundredth-acre quadrats on three broadcast burned plots, gives statistics on damage to reproduction.

TABLE 5.—*Effect of broadcast burning on advance reproduction as shown on burned and unburned quadrats*

Plot No.	Seedlings per acre		Quadrats having reproduction		Area upon which reproduction was killed	Basis, quadrats
	Burned quadrats	Unburned quadrats	Burned	Unburned		
	Number	*Number*	*Per cent*	*Per cent*	*Per cent*	*Number*
43	0	339	0	50	55	64
44	4	860	2	92	91	56
93	39	659	9	71	58	41

The effect of the broadcast burning is very plain. Only a few seedlings survived on the burned areas. The percentage of the area upon which all reproduction was killed is indicative of the completeness of the burn. Where most of the slash was consumed, as high as 91 per cent of the total area of reproduction was killed. Where the fire did not run freely, only 55 per cent of the reproductive area was burned over. On two plots examined in less detail and not included in Table 5, 85 and 94 per cent, respectively, of the areas having reproduction were reached by the flames.

Plate 4, A, shows vividly, for an area logged 10 years before, the destructive effect of broadcast burning on forest growth.

The damage to forest growth larger than "reproduction" is also considerable even in trees over 12 inches in diameter, as was shown by strip surveys across broadcast burns upon which all reserved trees were recorded. The results are presented in Table 6.

TABLE 6.—*The effect of broadcast burning on reserved trees of western yellow pine*

Plot No.	Trees killed		Plot No.	Trees killed	
	Under 12 inches d. b. h.	Over 12 inches d. b. h.		Under 12 inches d. b. h.	Over 12 inches d. b. h.
	Per cent	*Per cent*		*Per cent*	*Per cent*
43	80	0	17	100	0
44	76	79	18	91	0
93	31	27			

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FIGURE 5.—Broadcast burning encourages erosion. The burning of the slash, needles, and surface litter robs the soil of its natural protective covering, and gullying is apt to result

The variation in damage from broadcast burning, which in the case of trees under 12 inches in diameter is from 31 to 100 per cent on the plots studied, is due to the behavior of the fire. On a hot, windy day, when the slash burns fiercely, the fire is especially destructive of the forest growth, both small and large. Even under the best conditions broadcast burning of slashings kills so large a proportion

of the advance growth and reserve trees that it is inimical to effective natural reforestation. It is a method that has no place in the management for continuous production of the western yellow pine lands of this region.

Moreover, broadcast burning seems to be unfavorable to the establishment of subsequent reproduction, partly, no doubt, because of the reduction of the seed supply. For example, on 120 hundredth-acre quadrats selected at random in a 10-year-old broadcast burn not one seedling was found that had originated since the fire. Any method of burning is disadvantageous to the soil, robbing it of its duff and humus cover, encouraging erosion (fig. 5), and hastening soil compacting; and broadcast burning spreads these destructive influences over the widest possible area, inevitably contributing to the difficulties of subsequent reproduction. Brush growth, particularly of the species that sprout well after fire, is liable to become denser after broadcast burning, and if the brush becomes too dense this also means less favorable conditions for forest growth.

The effect of a broadcast slash burn is like that of a forest fire; it reduces the density of the forage plants and replaces valuable species with those of inferior quality. How this actually happened in one locality in southern Oregon is shown in Table 7 by data gathered by L. P. Brown.

TABLE 7.—*The effect on forage of broadcast burning of cut-over lands*

Character of vegetation	Condition before burning	Condition after burning
	Per cent	*Per cent*
Surface covered	80	85
Density	15	5
Palatability	40	20
Composition of forage:		
Grass	20	2
Weeds	35	20
Browse	45	78

The striking fact brought out in Table 7 is the change in the composition of the forage after burning. The browse constitutes 78 per cent of the vegetation after burning, as compared with 45 per cent before the fire, while the percentage of grass decreased from 20 to 2. The reduction in density by two-thirds and of palatability by a half is of particular significance in its effect upon the carrying capacity of the range. Observations on extensive areas in different parts of the region bear out the conclusions reached on this one area, namely, that broadcast burning decreases the density of forage at the same time that it lowers its quality.

EFFECT ON FIRE HAZARD

A broadcast slash fire always gives some immediate relief from fire danger by removing at least the needles and grass fuels, and it may clean the ground so thoroughly of inflammable material that there will be little danger of fire for a few years, or until a new supply of dry grass, needles, and brush has accumulated. Often, however, the reduction in fire hazard by broadcast burning is merely temporary

and more apparent than real. The slash itself may be burned up, but in the wake of the fire, particularly in the mixed type of the north slopes, thickets of saplings and small trees that are killed but not consumed remain to give fuel to a later accidental fire. (Fig. 6.) Again, if the broadcast burning results in increasing the quantity of

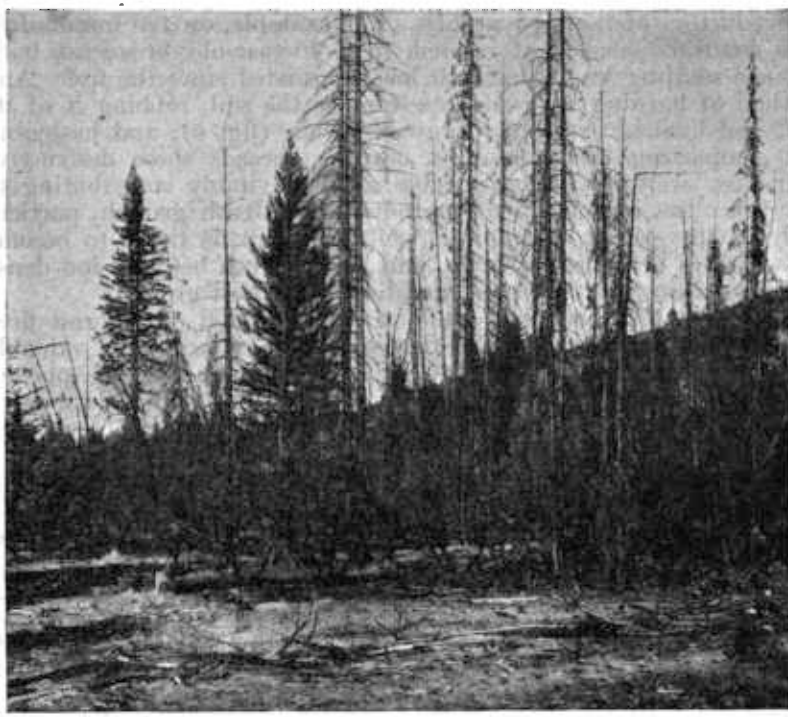

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FIGURE 6.—Broadcast burning may actually intensify the fire hazard by increasing the amount of inflammable fuel, as on this broadcast burn, where the fire killed the clumps of saplings but did not consume them, leaving them to feed future fires

inflammable bushes its beneficial effect in hazard reduction is soon overcome. It sometimes happens, too, that the slash is too wet or too green to burn clean; the needles burn, but the twigs and branches are only charred and thereafter decay more slowly than if untouched by fire.

SPOT BURNING

DESCRIPTION

Spot burning is a modified form of broadcast burning in which only the heaviest patches of slash are fired and the flames are not allowed to spread over the entire area. There is no special handling of the slash, but it is ignited heap by heap as it lies. To prevent the fires from spreading completely over the whole area and resulting in a broadcast burn, certain precautions are taken. For one thing the burning is done when the slash is not excessively dry and when weather conditions are such that the fires will burn well enough in heavy slash but will not spread where the fuels are scant. The heaps of slash are ignited on the leeward side, or the firing is started

on the uphill side of the area. Occasionally short fire lines may be constructed to isolate patches of slash. Late afternoon or evening burning makes possible better control than burning during the heat of the day. Spot burning, like broadcast burning, is done both spring and fall, but rather more in the fall.

It is a common method in use on private lands where the operator has some interest in sparing the residual forest values and wishes to avoid the undesirable consequences of broadcast burning, and yet is not prepared to use the more expensive methods of disposal discussed later. Spot burning is accepted by the State foresters as satisfactory compliance with the State law for the disposal of slashings even though only a fraction of the gross amount of slash is burned up. It is a relatively inexpensive operation, costing on an average from 10 to 20 cents per acre.

EFFECT ON FOREST GROWTH

The results of spot burning are very much the same as those of broadcast burning, except in degree. Each spot burn is in effect a miniature broadcast burn on which destruction of slash, reproduction, forage, and organic-soil cover is complete. In most cases the fire is confined to about a third of the surface. The damage to seedlings and saplings will be proportional to the occurrence of reproduction on the areas covered by the spot fires, and this is quite variable. A detailed study of five spot-burned tracts shows that the fire overran 19 to 77 per cent of the total area of reproduction and on an average killed the seedlings and saplings on about 38 per cent of the area of reproduction. (Pl. 4, B.) If more than 45 per cent of the area of reproduction is run over by fire it can hardly be called spot burning.

Damage to advance reproduction from attempted spot burning ranges, therefore, all the way from practical devastation to a minor loss; but it is considerably less disastrous to the reserve trees both above and below 12 inches in diameter than is broadcast burning, because the fire does not gain such momentum. A survey of three spot-burned plots shows practically no trees over 12 inches in diameter killed by the fire and generally less than 10 per cent of the smaller trees of all species.

The effect of spot burning on soil and forage is as disastrous as that of broadcast burning on the areas burned over. The danger in employing this method lies in the possibility that the spot fires may get out of control and develop into a devastating broadcast burn.

EFFECT ON FIRE HAZARD

Spot burning is more efficient as a means of hazard reduction than broadcast burning if judged by area burned over, since by spot burning the heaviest and most inflammable patches are burned, thereby lessening very much the risk of fire starting on the rest. If in addition the spot burning is done with discrimination, and the areas most exposed to fire, such as along railroads, highways, and trails, are cleaned up thoroughly, a maximum security against fire will be attained with a minimum of area burned over. Examination of two extensive areas of spot burning showed that in one case where 47 per cent of the forest floor had been burned over, only 3.6 per cent of it

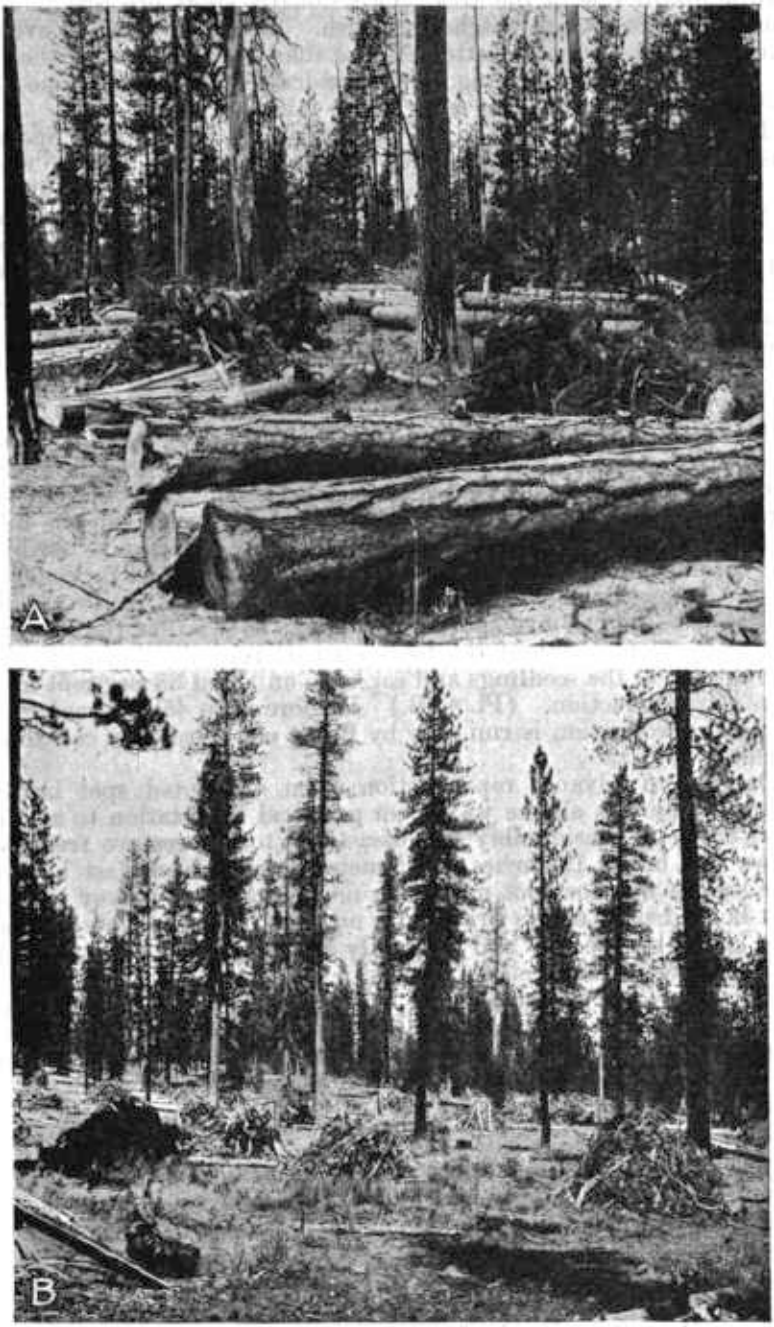

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FIGURE 7.—Piling of slash prior to logging (A) facilitates skidding but precludes the use of logging roads or skid trails for the placement of the piles (B), as is possible when slash is piled after logging

was still covered with slash; in the other case, where 19 per cent had been burned over, only 11.3 per cent of the surface was slash covered after the fire. In both cases, however, about a third of the remaining slash was in heavy accumulations.

PILING AND BURNING

DESCRIPTION

The method of slash disposal called piling and burning consists in piling all the twigs and branches under 4 inches in diameter, including those cut from the unmerchantable top, in compact conical piles and then burning these piles as soon thereafter as it is safe to do so. Next to swamper burning this method accomplishes a maximum reduction in slash hazard with a minimum damage to the

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FIGURE 8.—Light snow on the ground is an ideal condition for burning well-piled slash

forest, but at considerable expense. The piling is ordinarily done by laborers employed especially for this purpose, who work by contract or by the day. The work is carried on concurrently with logging, except during the period of deep snows when piling is impracticable. (Fig. 7.) The burning is confined to a short period between the too-dry and the too-wet season, either in spring or fall, but chiefly the latter.

This has been the standard method of slash disposal on public lands in the western yellow pine type for many years, and most of the slash on the national forests and Indian reservations of eastern Oregon and Washington has been so piled and burned. Only to a limited extent has it been employed on private lands.

Even under the most efficient supervision it is usually a few weeks from the time falling is done before the slash can be piled, and then it may be months before it is burned, especially if burning is done only in the fall. (Fig. 8.) Meanwhile the slash has dried out and

become an increasing fire hazard, even after it is piled. This method, therefore, does not abate the fire hazard immediately; there is a period of a few weeks to several months when the hazard is high, and this occurs at the very time when the risk from the active operation is close at hand. This necessitates especially intensive protection on current logging operations until the slash hazard is abated.

The piling and the burning are two separate and quite distinct operations. For satisfactory disposal both jobs must be well done. The technic of both operations was given much study to learn in what ways this method of slash disposal could be carried out most effectively and efficiently. In the Appendix (p. 50) the technic of both processes is discussed in considerable detail.

This is an intensive method of logged-land treatment and therefore expensive. On the basis of wages prevailing in 1927, 1928, and 1929 piling alone was found to cost all the way from $0.30 to $1.43 per thousand feet of timber cut, depending on the character of the débris, the topography, and the quality of the work expected, with an average at the then current wages of about $0.40. Where the job can be contracted the cost is usually 10 to 20 per cent less than that of the day-labor system. Under the most favorable conditions of slash a contract price of 30 cents a thousand feet seems to be so low that the contractor can not do a thoroughly good piece of work and make money. At the other extreme it was found that in a stand where there was a large amount of heavy slash and knocked-over thickets of young growth that added to the débris, a contract price of $1.25 a thousand feet did not enable the contractor to do an acceptable job and make fair wages.

In a stand of 12,000 to 15,000 board feet per acre on slopes up to 20 per cent, a man will pile the slash from 12,000 to 16,000 board feet per day. At $0.40 per thousand a daily wage of $4.80 to $6.40 will be earned. On that basis, the rate per thousand for heavier stands should be less, and for lighter stands more. The following sliding scale for slash piling in pure yellow pine on gentle slopes on the basis of Table 1 should apply: For stands under 8,000 feet, board measure, per acre, 70 cents per thousand feet of logs; for stands of 8,000 to 12,000 feet, 55 cents; for stands of 12,000 to 15,000 feet, 40 cents; for stands of 16,000 to 20,000 feet, 35 cents. Where Douglas fir and white fir make up an appreciable part of the stand the rate should be increased proportionally. Topography and amount of undergrowth should also be taken into consideration in arriving at a fair rate for piling.

The cost of burning the piles is usually about 4 or 5 cents per thousand feet of logs, but may be as little as 1½ cents or as high as 10 cents, depending upon the condition of the piles and the weather.

EFFECT ON FOREST GROWTH

Properly conducted burning of piled slash kills but a very small percentage of the advance reproduction (Table 8), only an occasional tree 4 to 11 inches in diameter, and none of larger size. However, it is always risky business using fire in the woods, and occasionally

the fires do get temporarily out of control, running from pile to pile and sweeping into the crowns of reserve trees, with resultant damage that on a small scale is comparable to that from a broadcast burn. The better the piling and the better the judgment used in burning, the fewer the accidents. No data were gathered on the number of piled and burned areas that suffer from fire running wild, but it is not large.

The damage to reproduction and small trees is not proportional to the area of burned spots, because the advance seedlings and saplings are not distributed uniformly and the piles are intentionally placed where there is the least reproduction. Furthermore, the destruction of reproduction on occasional spots only 8 or 10 feet across can not be considered to reduce seriously the productive capacity of the forest, especially if the logging damage to reproduction has not been high and the area between piles is reasonably well stocked with young trees.

Table 8, based on 15 typical plots in piled and burned slash, shows that the area of reproduction killed varies widely from 0.5 to 17.3 per cent of the total area of the plot, with an average of 4.6 per cent. From 2.8 to 28 per cent of the forest floor is burned over, averaging 9.4 per cent, but some of this (4.9 per cent of the area burned) carried no reproduction.

TABLE 8.—*Area of reproduction killed and of ground space burned over by piling and burning slash, in percentage of total area*

Plot No.	Area of reproduction killed		Burned area originally lacking reproduction	Total burn	Plot No.	Area of reproduction killed		Burned area originally lacking reproduction	Total burn
	Burned	Covered by slash				Burned	Covered by slash		
	Per cent	*Per cent*	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*	*Per cent*
61	0.5	0.1	4.2	4.7	15	2.4	1.2	2.6	5.0
53	.5	.1	2.3	2.8	8	3.9	.2	1.8	5.7
54	.6	.6	3.2	3.8	46	5.0	.0	8.9	13.9
81	.7	.1	2.5	3.2	20	6.0	.1	3.9	9.9
60	1.0	.0	10.1	11.1	97	11.7	.0	7.4	19.1
83	1.7	1.1	2.4	4.1	50	12.7	.4	2.2	14.9
67	2.2	.0	3.0	5.2	58	17.3	.2	10.7	28.0
57	2.2	.1	7.6	9.8					

Where a reserve tree is killed it is usually by flames from a burning slash pile sweeping into its crown. Indirect damage by fire eating into the base of a tree to start a new or to enlarge an old fire scar ordinarily occurs only when the ground cover is dry enough to carry the fire over the surface.

Table 9 lists the direct damage to reserve trees under 11 inches d. b. h. on five areas examined by strip surveys covering 10 to 20 per cent of the total area. There is no record of a tree above 11 inches being killed. These plots show but a small loss, the percentage varying from 0.7 to 3.3 per cent of the total number of 4 to 11 inch trees, or in other words from one tree to every 20 acres to one tree to every 3½ acres.

TABLE 9.—*The damage to reserve trees between 4 and 11 inches d. b. h. from piling and burning, expressed in number and percentage of trees killed per acre*

Plot No.	Trees undamaged	Trees killed	Trees killed	Basis, area	Plot No.	Trees undamaged	Trees killed	Trees killed	Basis, area
	Number	*Number*	*Per cent*	*Acres*		*Number*	*Number*	*Per cent*	*Acres*
85	7.64	0.05	0.7	378	84	5.88	0.13	2.2	415
36	10.08	.20	1.9	240	59	8.20	.28	3.3	140
55	12.77	.26	2.0	560					

Analyzing this loss by size of tree shows that about 3 per cent of the 4-inch trees are killed, 2 per cent of the 5 and 6 inch trees, and 1 per cent or less of the larger trees up to the 11-inch class. The smaller trees with foliage coming closer to the ground and with thinner bark naturally have the higher mortality. On four other plots, aggregating 1,660 acres, which were burned when the weather conditions were dangerously unfavorable, the damage to 4 to 11 inch trees averaged 13.3 per cent. These latter areas demonstrate the unsatisfactory silvicultural results of piling and burning when not properly supervised.

It is important to bear in mind that the data on loss of seedlings and small trees given in Tables 8 and 9 were all taken on logging operations where care was exercised to keep destruction of the young growth to the minimum. Where the piling and burning method is used without strict supervision of the laborers in both operations, or where the timberland owner is more interested in saving money on the job than in saving the young growth, or where the weather suddenly turns dry before the burning can be suspended, the losses may easily be very much greater than those here given. Slipshod piling and poorly timed burning can give results almost as destructive as spot or broadcast burning. The discussion in the Appendix (p. 50) on the technic of piling and of burning shows the methods that must be applied if damage to forest growth is to be kept reasonably small. It defines the standard of proper piling and burning, which is substantially what the Forest Service established for the timber sales on the national forests of Oregon and Washington.

The effect of piling and burning on the establishment of subsequent reproduction varies from beneficial to decidedly unfavorable. Pearson found (*12*) that where vegetation grows so rank as to be a serious competitor with reproduction, the destruction of the plant growth is a positive benefit, and that almost invariably the burned spots restock better than the grassy areas. However, on heavy soils where the destruction of herbaceous vegetation is accompanied by packing of the soil, the effect is harmful.

The findings in the Southwest can be supplemented by observations made in this region on national forest cut-over lands 5 to 15 years after logging. On clay soils reproduction becomes established very slowly on the burned spots, whereas on light, loamy soils seedlings come in very abundantly when seed supply and moisture conditions are favorable. On pumice soils, which are deficient in organic matter, burning seems to discourage reproduction.

EFFECT ON SOIL AND FORAGE

The area of ground surface actually touched by the fire with properly conducted piling and burning is so small that the direct effect on soil texture and herbage is much less harmful than under the broadcast-burning method, for example, where a high percentage of the forest floor is scorched. However, piling and burning, in common with all methods of complete burning of the slash, has the minor disadvantage of consuming the organic débris from the tree tops that otherwise would be returned to the soil; with some soils this might have a material effect on forest productivity. Likewise this method is not appropriate in the occasional cases when it is imperative to preserve the slash cover as a retardant of erosion.

A detailed study of grazing conditions in southern Oregon before and after slash disposal shows that piling and burning the slash does not appreciably change the composition of the forage or its palatability percentage. The surface area and density of vegetation were somewhat reduced by logging and slash disposal.

EFFECT ON FIRE HAZARD

Piling and burning is a very effective method of getting rid of the fire menace of the logging débris, but the drawback is that it does not give prompt relief. Inevitably much of the slash is not piled immediately, and in that condition it is a hazard as soon as it dries out. Since the fire danger is not abated by piling alone, the piled slash is subject to uncontrolled conflagrations and remains a menace until burned.

Since burning operations are ordinarily conducted only once or at most twice a year, inevitably the recent cut-over areas on which the slash is piled are no better off than those where slash is left untouched, in that they are not freed of the fire hazard for several months. Furthermore, it seems to be impossible on large operations to get all the slash burned during the first burning season after it is piled, either because of unfavorable weather conditions or because the slash is too green. This means that some must be held through a second dry season before it is burned.

In the ordinary execution of burning piled slash, occasional piles are purposely left unburned either because they are too close to saplings or reserved trees or because they fail to ignite. These are not a fire hazard of consequence since they usually occur singly or scattered. On 15 sample plots of piled and burned slashings it was found that on more than half of the areas 90 per cent or more of the slash was burned, the minimum number burned being 62 per cent of the piles and the maximum 100 per cent.

A well-executed job of piling and burning removes very effectively the hazard created by the presence of logging slash. Whatever hazard remains is that resulting from the usual needles, grass, and undergrowth, as in any conifer forest, and from the small quantity of slash left unburned. For a period of several years three national forests (the Crater, Wallowa, and Whitman) having a large area of cut-over land had only 0.01 per cent run over by fire annually

out of the total area upon which the slash has been piled and burned. This indicates a high degree of immunity.

SWAMPER BURNING

DESCRIPTION

Swamper burning, or progressive burning, as it is sometimes called, has been described in detail elsewhere by the junior author (*17*). Briefly, it consists in piling and burning the slash in one operation. A fire is started with dry or pitchy wood by a swamper (or by the log bucker) and as soon as it is burning well the freshly cut limbs are thrown on, the smaller ones first. If the fire has the proper start the green limbs will ignite satisfactorily and burn up cleanly. A single fire will serve quite a radius and may be kept burning several hours.

Swamper burning can be done even in the rain; it works well when there are a few inches of snow on the ground. Whether it would on a large scale in deep snows has not yet been demonstrated. However with other species, such as white and Norway pine in the Lake States (*19*) and spruce in Alberta, swamper burning in the regular winter snows is usual. The great drawback, especially from an administrative standpoint, is that this method can be employed only in wet weather, or when the ground is snow covered, for fear of the fires spreading. Its application is thus limited to a part of the fall, winter, and spring, necessitating a flexible slash-disposal organization. In large operations there is some objection to this method on the part of laborers, because of the smoke that sometimes is disagreeable when they are at work.

Nice judgment is needed in the placement of the fires, which should be away from reproduction, reserve trees, and felled logs that might be burned. And they should be placed so as to take care of the maximum of slash from one or several trees with the minimum of handling.

Swamper burning has been practiced in connection with logging operations in eastern Oregon and Washington only in a very small way and, so far as known, only on the national forests. It has been quite generally employed in some localities by cordwood cutters or others buying small quantities of Government stumpage. Recently it has been tried experimentally on several major logging operations.

The actual cost of swamper burning seems to be a little more than that of piling and subsequently burning the piles, because of the time consumed in starting the fires and the greater average distance the branches must be carried. However, there is a saving in skidding costs, particularly when horses are used, that may be an offsetting advantage. Estimates have placed the saving of skidding costs where horses are used at 10 to 20 per cent. One operator found that when he adopted swamper burning (in contrast to piling and burning after logging) his skidding costs dropped 25 cents per thousand feet. The instances of swamper burning where cost records were kept indicate a range from $0.40 to $1.50 per thousand board feet, with an average in pure pine cuttings of about $0.55 to $0.60 per thousand, or perhaps 10 per cent more than piling and burning.

A modification of swamper burning proposed by J. W. Girard and W. C. Lowdermilk in 1922, and called by them "forced burning" consists in piling and simultaneously burning the slash after the logs have been removed. This practice is naturally limited to a short season when burning is safe and when the débris is not buried in snow. It has most of the advantages of swamper burning before skidding if it is done prior to the first fire season after felling the trees except that it does not facilitate skidding. In an experiment conducted by Girard and Lowdermilk it was found to cost about 10 cents more a thousand feet of logs than the method of piling and burning in separate operations. Despite the possible higher cost, they hold that certain advantages favor its use on the flatter tracts. The slash is disposed of once for all; the hazard is not carried through a fire season; and if a fire accidentally runs and spreads a considerable crew is on hand to suppress it. These advantages they appraise as being worth 10 to 20 per cent of the costs.

EFFECT ON FOREST GROWTH

Swamper burning, because so small an area of the forest floor is touched by fire, affects reproduction, reserved trees, soil, and forage less than any other method that attempts to burn all the débris. On one tract where the cut was about 11,000 feet per acre, only 2.1 per cent of the surface was burned, or about half as much as would have been covered by fire with the piling and burning method under favorable conditions for burning. Injury to advance reproduction is limited to the few fire spots. Injury to reserved trees is unusual and with proper placement of the piles ought always to be negligible.

EFFECT ON FIRE HAZARD

Swamper burning is the most effective of all methods in removing the fire hazard of the slash. Its great advantage is that during the period when it can be practiced safely the slash is burned as fast as it is created and security from the disposal operation accrues immediately. In this respect there is a decided advantage over other burning methods, in all of which the slash is left on the ground adjacent to the operation—generally during the summer months—for periods varying from a few weeks to a year or more. Ordinarily the clean-up from swamper burning is not quite as complete as that from piling and burning, because some limbs are pinned down by the logs and so fail to get on the fires, but this material should not be plentiful enough to constitute any fire hazard.

NO BURNING

NO TREATMENT WHATSOEVER

One method of treating logged-off land is to make no disposal whatsoever of the slash. This was a common practice on private lands prior to the time that the State foresters under the authority of the forest-fire laws began to require that the menace of these unburned slashings be abated in some way. Without special provision

to prevent accidental fires such areas are left liable to conflagrations that may be exceedingly destructive of residual forest values.

It is surprising that any such slash-strewn areas escape burning; yet in examining the older cuttings in eastern Oregon and Washington where there had been no slash disposal and not much systematic fire patrol, as at present, it was found that on a considerable acreage there had never been a fire. As an example of this, R. H. Weidman reported in 1924 an area in the Blue Mountains of Oregon, of which only about 0.6 per cent has been burned over annually in the course of two or three decades. This area of 30,000 acres was logged in the preceding 20 or 30 years, was traversed by wood-burning locomotives, and had received no protection except the ordinary compulsory patrol that all forest lands have received in recent years. The virgin forest within the national forest in the same region, with systematic protection, has an annual burned-over acreage of 0.2 per cent. This is a striking fact, and the conclusion can not be avoided that in parts of this region slash areas of moderate extent are controllable hazards.

From the silvicultural point of view, slash left undisposed is, of course, a benefit to the soil, to reproduction, and to forage values. It also represents no initial cost; but the control of accidental fires and the damage that they do may be very expensive. The chief objection to no disposal is that it does not satisfy the primary requirement of forest management, namely, that logged-off lands be made safe for reforestation. Except as it is practiced over small areas broken up with fire lines and supplemented by intensive protection, as discussed later, no disposal can not be recommended for this region.

LOPPING, PULLING, OR PILING WITHOUT BURNING

Lopping, pulling, and piling without burning are methods of treating slash that have been tried in other regions, but none of them to any extent in the Pacific Northwest. Lopping consists in cutting all limbs from the top of the tree and either letting them lie as they fall or scattering them evenly over the ground. This practice has been used to some degree on public lands, with several objects in view, such as (1) to hasten decay of the slash by bringing it close to the ground, (2) to decrease the fire hazard by getting the tree-top slash close to the ground and scattered, (3) to obtain maximum beneficial effect of slash to soil and seedlings by distributing it, and (4) to improve the appearance of the cutting. The fallacy of the first objective was shown by Long (*8*), who found that slash decayed just as rapidly, if not more so, when attached to the tree top as when lopped off and in contact with the ground. This was corroborated by Boyce in the Northwest. Whether lopping practice gives any safety against fire is problematical. Certainly its advantages over those of leaving the slash wholly untreated are not marked and for this region would not seem to justify the cost (20 or 25 cents per thousand feet board measure cut on the average), except in cases where there is some special objective, such as the control of erosion.

Pulling is a method which has been used to some extent on public lands in the Southwest, but never in the Northwest so far as known. It consists in dragging, usually with horses, the entire unutilized top of the tree into openings far from reserved trees or reproduction.

The objects of this method are to get the bulk of the slash where it would do the minimum of damage to the forest if it got afire and to distribute the slash where it will be of maximum benefit in preventing erosion and in affording protection to subsequent reproduction. It is particularly appropriate in a forest with many openings and with a low fire hazard. This not being the condition in the Northwest, it is not a practice that would appear to have any place here, since it would not give security from fire, and its other benefits would not justify the expense. Its cost is said to vary from 15 to 35 cents per thousand board feet.

Piling of slash without burning has been suggested as a means of disposal that would avoid the danger and injury of fire, yet have some of the advantages of piling and burning. Occasionally, after slash has been piled where the forest growth is dense, it has been deemed better to leave the slash unburned in spite of the hazard than to suffer the damage to reserve trees or reproduction that would be inevitable were the piles to be burned. However, experience of the Forest Service shows that piling without burning creates a real hazard that persists for many years, as slash in piles decays very slowly. The method does not accomplish the purpose sought, and is not recommended.

STRIP BURNING WITH INTENSIVE PROTECTION

DESCRIPTION

This method consists of two operations, (1) broadcast burning strips 100 to 300 feet wide along roads, railroad grades, ridges, or other strategic places to break up the slashing into small blocks upon which there is no disposal of the débris whatever, and (2) extraordinary precautions for a few years to prevent fires in the undisposed slash. Strip burning with intensive protection has been adopted by some operators in Oregon and neighboring States, as a means of avoiding the devastation of general broadcast burning or spot burning and yet controlling the fire hazard at small expense. It is a compromise measure in that its purpose is to make the area safer for reforestation by devastating a part of it. The Oregon State Board of Forestry accepts this system of fire lines and intensive protection as complying with the law for abating the slash hazard.

The strips to be burned are usually defined by fire trails raked clear of débris 6 to 10 feet wide, or constructed with caterpillar tractor and drag or fire-line plow. When the burning season comes the strips between the trails are fired. Attention to these fires is necessary to prevent their spreading broadcast over the slashing, as has sometimes happened. In open pine woods the broadcast-burned strips should act as fairly effective barriers to surface fires for three or four years, but they become increasingly less effective as grass, weeds, and needles accumulate. Some of these isolation strips, even after they have been burned hard, carry a good deal of fuel in the form of saplings and bushes killed but not consumed by the flames, and if there is much of this material the effectiveness of the strips as firebreaks is of short duration. More expensive methods of fireproofing these strips will then be necessary.

The burned strips will not in themselves stop a fire. Under a brisk wind on a dry day a fire will cross one of these strips, either by flying embers or on the ground after the strip has grown up to grass and weeds. Obviously, a network of burned lanes would be quite useless unless there were a protective organization to use the lanes as vantage points in fighting fires. There must be a detection, communication, and suppression system that will stop accidental fires when they reach the isolation strips, if not before. An integral part of the system should be a network of auto roads, ordinarily following the abandoned railroad grades, that will make all parts of the area quickly accessible. The methods of protection employed are similar to those current on logging operations in the region, except that they are intensified to prevent the starting of fires and to confine those that do start to the minimum acreage of unburned slash. The organization suitable for the protection of tracts of unburned or only partly burned slashings is discussed in more detail later.

The cost of isolation strips depends upon their frequency, upon the density of débris and forest growth through which they run, and the care with which they are built. On the central Oregon plateau (*6*) the cost is from $0.50 to $3 per acre for the area actually burned, or 4, 10, or 15 per cent of this for the area actually protected, according to the proportion of the area occupied by strips.

The cost of the protection system is proportional to its intensity and will vary a good deal from tract to tract. In the final pages of this publication a model set-up of a protective system is outlined, which is estimated to cost about 14 cents per thousand feet cut, or $2.14 per acre during a 15-year period. This is a desirable standard but is higher than private operators who are using this method are allowing for their slash areas.

A moderately effective protective system, installed wholly for protecting these slash areas, might cost 5 to 8 cents per acre annually the first 5 years and 3 to 5 cents the succeeding 10 years. During the 15-year period the expenditure would vary from 55 to 90 cents per acre for protection. The combined cost of strip burning (at an average of 20 cents an acre) and protection would then be from $0.75 to $1.10 per acre, or 5 to 7.5 cents for each thousand feet of timber cut. It is hardly equitable to consider all of this as the cost of this method, since, regardless of the system of disposal, some protection must be given for some years to the freshly cut areas and the older cut-overs.

Jacobson (*6*) recommends this method where the cut-over area is accessible and not too steep and rough, and finds that when roads are so cleared out as to make the land accessible, and well-organized protection is thereafter maintained, it proves to be the cheapest and most dependable of all methods.

EFFECT ON FOREST GROWTH

Since this method is merely a combination of broadcast burning and of no disposal, its effect is exactly the same as that of each of these methods on the respective areas treated by each. The strips occupy from 5 to 30 per cent of the total area, and on them the initial loss in reproduction may be from 55 to 91 per cent. (Table 5.) Off

the strips where the slash is left, that is on 70 to 95 per cent of the area, there is no damage to reproduction or reserve trees. Losses from subsequent fires are possible, but these would depend upon the effectiveness of the protective system.

EFFECT ON FIRE HAZARD

When most of the slash is left unburned the chance of fire starting is reduced very little. But the chances of accidental fires being held to a small area are good under this method, provided the strips are numerous and well burned and the protective organization is alert and well equipped.

It is quite impossible to measure the fire hazard on such areas or to compare it quantitatively with that on areas treated by other methods. The experience of one large operation in the region under consideration serves, however, as rather eloquent evidence of what is possible on a tract eminently suited to this method where the organization has been earnest and efficient. In the six years 1925–1930 this company had in their slash 60 fires, which covered a total area of 129 acres before being controlled. During this period there was created each year about 8,000 acres of fresh slash, or an average area of unburned slash for the period of 24,000 acres, on which the burned strips comprised about 5 per cent of the area. This indicates that only about 0.14 per cent of the cut-over area burned accidentally per year. The fire history by years on the cut-over lands of this company, including both those strip burned and those freshly logged, is given in Table 10.

TABLE 10.—*Fire history of 24,000 acres of unburned slash under intensive protection including 5 per cent broadcast burned strips, 1925–1930*

Year	Fires	Acreage burned	Percentage of area protected that burned annually	Year	Fires	Acreage burned	Percentage of area protected that burned annually
	Number	*Acres*	*Per cent*		*Number*	*Acres*	*Per cent*
1925	24	20	0.50	1929	3	5	0.02
1926	13	8	.07	1930	3	61	.10
1927	10	14	.07				
1928	7	21	.07	Total or average	60	129	.14

The largest fire on company lands where this method of slash disposal was in effect was one of 60 acres; most of the fires were held to very small size. There was a larger fire in 1927 but it started in unpiled slash on national-forest land, burned over about 100 acres here, and then spread to uncut timber and land upon which the slash had been piled and burned, where it was controlled.

PARTIAL PILING AND BURNING WITH INTENSIVE PROTECTION

DESCRIPTION

Partial piling and burning with intensive protection is similar to strip burning with intensive protection, except that upon the isolation strips or lanes the slash is piled instead of being fired

broadcast, and additional precautions are taken as needed to make these lanes highly fire retardant. The same extraordinary precautions to prevent fires within a suitable term of years are required. It is a system which has recently been tried in an experimental way on a few national-forest timber sales in California and Oregon and by one private operator in California.[12]

By this method the slash on designated strips of variable width, such as along main-line or spur railroads, automobile roads, creeks, ridges, and near camps or other especially hazardous places, is piled immediately after logging and burned at the first opportunity. Further precautions may be taken to make these strips highly fire retardant, such as chopping out the small trees and bushes, piling and burning them with the slash, pruning the small trees to a few feet above the ground, or plowing a fire trail on each edge of the strip.

The character of the stand, the topography, and the local fire hazard will determine how thoroughly these lanes should be cleaned up to make them serve their purpose. Swamper burning might well be employed on these isolation strips to make them immediately effective as fire lines. The strips would be so located as to break up the area into blocks of 75 to 150 acres and would comprise perhaps 15 to 20 per cent of the tract. The proportion of the area in strips might be less or considerably more, according to the hazard. On the territory off the strips the slash would be left wholly undisposed, exactly as the logger left it.

Grazing of areas of partially disposed slash is considered to be particularly desirable as a fire-control measure, because stock tends to lessen the accumulation from annual plants and shrubs and to break up the slash and so hasten disintegration.

The fire-retarding effectiveness of the strips differs considerably, depending on whether the débris is piled and burned or is broadcast burned. If 100 per cent of the strip is overrun by fire the chances are less that an accidental fire could in the next few years creep through the surface litter across the strip than if only 5 or 10 per cent of the surface of the strip is burned, as in piling and burning. On the other hand, broadcast burning of the strips does not make as thorough a job of cleaning up the slash as piling does. Also broadcast burning must be done when the woods are drier than they need to be for burning piled slash, and it therefore involves more risk. Perhaps the most important consideration is that the broadcast fire kills saplings, seedlings, and undergrowth without consuming them, and leaves this material as possible fuel for later fires. Piling and burning need result in little lowering of forest productivity on the strips, whereas broadcast burning practically devastates the strips and temporarily takes an area out of production. Piling the slash on these strips is of course considerably more expensive than burning it as it lies.

[12] An outstanding experiment with this method is that of the Fruit Growers Supply Co. of northern California, in a type of forested country comparable to parts of the Oregon-Washington region under discussion. This company both on national-forest land and on its own lands is cleaning up very thoroughly lanes 100 feet wide which break up the logged area into compartments no larger than 100 acres. It is maintaining a well-equipped, intelligent, and alert protective organization which in the four years that this system has been in effect here has made an excellent record of fire control at reasonable cost.

An essential feature of this method of slash disposal is the intensive protection of the area for 10 or 15 years after cutting or until the acute fire menace from the fresh débris is abated. For each type of country the degree of intensive protection required will vary and it will also be influenced by the proportion of the area that is occupied by burned strips. The width of the strips and the intensity of protection must in any event be sufficient to confine any fires that start to a single block and hold most of them to a much smaller area.

COST OF PARTIAL PILING AND BURNING WITH INTENSIVE PROTECTION

The cost of this method amounts to the expense of piling and burning 20 per cent or so of the slash, plus the cost of protecting the area according to the standards which the owner elects and the conditions require. For average conditions in central and eastern Oregon the piling and burning would amount to about $7 per acre actually piled (if the cut was 15,000 feet per acre), or $1.40 per acre for the entire area. Assuming that protection amounts to about $1.75 per acre, during a 15-year period, the total cost (without discounting future charges) would be in the neighborhood of $3.15 per acre, or 22 cents for each thousand feet cut. In abnormally easy or abnormally difficult country the costs might easily be considerably less or more.

A plan for the application of this method to a hypothetical case is given in some detail on page 45.

EFFECT UPON FOREST GROWTH AND UPON FIRE HAZARD

This method is gaged to give reasonable security against accidental fires without destructive burning and to do this at moderate cost. On perhaps 80 per cent of the area the forest growth benefits from no disposal of slash and no burning, and on the remainder forest conditions are exactly as under the piling and burning method. This method does not remove the slash hazard; it aims to control it. However, it leaves blocks of slash that might make fires that would be hard to fight, should there happen to be a bad combination of conditions or should the intensity of subsequent protective measures not be commensurate with the fireproofing of the strip.

This system has not been in operation long enough on any tract to permit final conclusions as to its effectiveness in controlling accidental fires, but so far the results have been good. The real proof of its success can be had only after a term of years, when the slash hazard is past and the total cost of protecting the area and the fire loss up until that time are known. However, it is such an elastic method that it is simply a matter of widening the fireproofing strip and increasing the protection within the limit of available funds to the point where fire losses will be reduced to an allowable minimum.

SUMMARY OF ADVANTAGES AND DISADVANTAGES OF EACH METHOD

The preceding description of the various slash-disposal methods indicates that hazard reduction is their primary objective and that

the only occasion for burning is to accomplish that purpose. Burning is not beneficial to reproduction, but on the contrary is destructive of at least some of the seedlings, saplings, and small poles. Burning of the material that comprises slash (under 4 inches in diameter) does not help in the control of insects or of forest diseases dangerous to living trees. It does not improve the range. It robs the soil of plant food, removes the ground cover that promotes water retention and lessens erosion, and consequently may affect adversely reforestation and forest production. If the burning is done carelessly and gets out of hand it may be exceedingly destructive to advance reproduction and small reserved trees.

Conversely, this study has developed the conclusion that satisfactory silvicultural results may be attained in Oregon and Washington by letting the slash lie undisposed, or by burning it by methods that confine the fire to a small area. However, the analysis of the fire history of cut-over lands evidences the hazard of slashings and points to the necessity in this region either of complete disposal or, lacking that, a special highly efficient protective organization to keep fire out of slashings during the first few dangerous years.

Current logging areas are found to be particularly subject to fires; there they are from 9 to 59 times as frequent as on old cut-over lands. This shows the need for very intensive protection to prevent fires during logging, regardless of the method of slash disposal on the older areas.

In general, slash disposal should be most intensive on inaccessible areas, in country where the topography is very rough and broken, on south slopes, wherever the slash is heavy, where there is a dense cover of inflammable weeds or bushes, and particularly on areas where there is likelihood of fires originating.

The significant advantages and disadvantages of the seven methods of treating slash already described may be concisely stated as follows:

BROADCAST BURNING

ADVANTAGES

Low cost, usually less than 1 cent per thousand board feet.
Reduces slash fire hazard materially on cut-over lands.
Ease of execution on large scale.

DISADVANTAGES

Great damage to advance growth, 55 to 91 per cent of reproduction and 31 to 100 per cent of reserve trees killed.

Complete destruction of humus material in débris and maximum damage to soil.

Kills without consuming small trees and undergrowth, which remain a fuel for future fires.

No reduction of slash hazard on current logging area.

SPOT BURNING

ADVANTAGES

Low cost, 1 to 3 cents per thousand board feet.
Removes the most dangerous accumulation of slash.

DISADVANTAGES

Relatively large amount of damage to advance growth.
Complete destruction of humus material in débris and maximum damage to soil on about one-third of total area.
No reduction of slash hazard on current logging area.

PILING AND BURNING

ADVANTAGES

Of all the methods described, except swamper burning, which can not be used the year round in this region, it most quickly and effectively eliminates the fire hazard of the slash.
Minor damage to advance growth, ordinarily not over 10 per cent of advance reproduction and rarely over 2 per cent of reserve trees killed.

DISADVANTAGES

Should not be employed unless standard of work is high and then cost averages 45 to 55 cents per thousand board feet.
Does not reduce slash fire hazard on current logging area.
Consumes débris which might otherwise serve to enrich the soil and protect it from erosion.
Danger that investment in careful piling may be nullified by unsuccessful destructive burning.

SWAMPER BURNING

ADVANTAGES

During the portion of the year when it can be employed eliminates slash fire hazard on current logging operation as fast as created.
Very little damage to advance growth, or reserve trees.
Facilitates horse logging.

DISADVANTAGES

High cost, 55 to 60 cents per thousand board feet on an average.
Limited to short period of year because of climatic conditions.
Consumes débris which might otherwise enrich the soil and protect it from erosion.

NO BURNING METHODS

ADVANTAGES

No damage to reproduction or reserve stand through fire.
Maximum benefit to soil; no destruction of humus material.

DISADVANTAGES

No reduction of fire hazard on cut overs.
No reduction of hazard on current logging area.
If lopping, pulling, or piling is practiced, cost is high.

STRIP BURNING WITH INTENSIVE PROTECTION

ADVANTAGES

Low cost, 5 to 7.5 cents per thousand board feet (with moderately intense protection).

Breaks slash area up into small units permitting better protection and reducing probability of large fires.

Presupposes extra fire prevention on the logging operation and adjoining it for a term of years.

Bares by fire but a small percentage of the surface and preserves much of the débris to enrich the soil and protect it from erosion.

DISADVANTAGES

Serious damage to advance growth and reserve trees on the burned strips, removing these areas from production.

Danger of strip fires spreading.

No reduction of slash hazard on current logging area.

Intensive protection through a term of years imperative.

PARTIAL PILING AND BURNING WITH INTENSIVE PROTECTION

ADVANTAGES

Moderate cost, estimated at 22 cents per thousand board feet.

Breaks slash area up into small units, permitting better protection and reducing probability of large fires.

Makes possible fire prevention on the logging operations and adjoining it for a term of years.

Very little damage to advance growth on burned strips.

Bares by fire but a small percentage of the surface and preserves much of the débris to enrich the soil and protect it from erosion.

DISADVANTAGES

No reduction in hazard on current logging area.

Effectiveness in fire prevention dependent upon the efficiency of the protective system throughout a term of years.

The advantages and disadvantages do not everywhere have the same weight. To one owner a certain consideration may be of very much more import than it is to another. And in some localities certain advantages or disadvantages that elsewhere are not pertinent may decide the choice of method. It is therefore quite out of the question to lay down hard and fast rules and say that here this method is always best, or that a certain class of owner should always employ that method.

RECOMMENDATIONS

Flexibility should be the keynote in all slash-disposal plans; blanket rules should be avoided. The method adopted for any particular area should be selected because it fits the character of the timber, the topography, and the fire risk, and will accomplish the purpose for which it is intended at a minimum cost to the owner. The slash-disposal plan should be so flexible that the method may be varied or a combination of methods used, even within a single operation, to fit varying types of timber and hazards.

In deciding upon a slash-disposal plan the principal objectives should be to avoid destruction of the advance young forest growth and to leave the area safe for the new crop to develop, as well as to secure a maximum protection of adjacent stands of virgin timber and the logging operation itself, always endeavoring to get the greatest benefit in proportion to each dollar invested. As Jacobson (*6*) suggests, to make any slash-disposal plan work and tie in with the fire prevention and control plan, the whole-hearted interest and responsibility of the logging superintendent and his organization must be obtained. Slash disposal and fire prevention and control must be planned as the logging progresses. It should be part of the operation and can seldom be separated without higher expense and higher risk.

The slash disposal which necessitates as little handling and as little burning of slash as possible and yet results in a high degree of security from fire during and after logging gives the greatest total of beneficial effects from the point of view of silviculture, fire control, and cost. Such a combination of advantages is perhaps more nearly attained by partial piling and burning with intensive protection than by any other method, but it is not everywhere practicable, nor is it acceptable to all owners. The conditions under which each method is appropriate in the management of pinelands in Oregon and Washington are briefly enumerated in the following paragraphs as concise recommendations for the practicing forester or timberland manager, it being recognized that in a diversified country two or more methods may be employed to advantage on a single operation.

Broadcast burning is not to be recommended for either public or private owner under any conditions, unless the land is to be devoted immediately to a higher use than forest growing, with which the trees would interfere. This method is wholly incompatible with continuous forest production. Neither has the negative method of no burning, implying that the area is given no special protection, any place in Oregon and Washington. The fire hazard is too great to leave large areas without burned fire lines or intensive protection. Such methods as can be recommended involve either great care in the major destruction of the slash, or intensive patrol of areas on which partial protection by slash destruction has been effected.

SPOT BURNING

Spot burning in skillful hands can be a cheap and effective way of moderating the fire hazard without complete destruction of the young growth. It is not recommended for public lands upon which a more expensive and less destructive method is warranted, but it is a makeshift practice for those owners who are not seriously in the business of holding their lands for reforestation and are unwilling to make any considerable expenditure for slash disposal or subsequent fire protection. It is least destructive where the cutting area is isolated or small, the land not steep nor brushy, and the amount of slash not above average. It can never be practiced without some loss in full forest productivity, and falls far short of adequate treatment of logged-off land.

PILING AND BURNING

Piling and burning has commonly been employed until recently to the exclusion of all other methods on public lands in the region under consideration, because it was thought that no other method would give the security against fire that public forests should have. Within recent years the rapid extension of roads into the logging woods, following the universal use of automobiles, has made these cut-over areas much more rapidly accessible to fire-control forces than in the days of saddle-horse transportation. Roads have also made it possible to bring rapidly to a fire such heavy and recently developed equipment as pumps, tank trucks, caterpillars, plows, etc. Moreover, the public is more careful with fire, causative agencies are in better control, and fire-control technic is more highly developed and its forces better organized than a few years ago. On that account there seems to be less occasion to-day for the complete piling and burning of all slash on public or private lands.

The conditions under which complete piling and burning of the slash is recommended within the pine region of Oregon and Washington are three: (1) Operations where the acreage of cut-over land or permanence of the operation would not justify intensive protection through a term of years if the slash were not all burned and when protection by some public or cooperative agency can not be effected; (2) areas of high risk, where man-caused or lightning fires are very likely to start; (3) areas of extra heavy slash, or of steep topography, or of heavy undergrowth where fire lines are not really effective and where no method other than complete disposal will give safety to the new forest. Piling and burning (or swamper burning) should be the universal rule on all areas to be used for recreation and along all highways and permanent railroads and trails, primarily as a fire-preventive measure, and incidentally for æsthetic reasons.

The management of private logged-off lands is on so different a financial basis from that of public lands that, whereas piling and burning may be financially sound for a tract of public land, it may not be so for a private enterprise, and yet in both cases it may be technically desirable. The owner must decide how much he cares to pay for the immunity of his land from fire—some owners are willing to take bigger chances with fire than others.

SWAMPER BURNING

Swamper burning is highly recommended for any type of land where the owner can justify its expense, but its use is limited to the seasons of the year when burning is safe. Perhaps its greatest application is in conjunction with other methods, such as partial piling and burning with intensive protection, where the strips might be swamper-burned as logging proceeds at certain times of the year.

STRIP BURNING WITH INTENSIVE PROTECTION

This method is recommended for private rather than public lands, chiefly because it removes a certain portion of the land from production and does not give the safety from fire that public property should enjoy and can afford. It is recommended to the private

owner of large tracts as a means of obtaining permanent forest productivity at a moderate cost and in these respects it is superior to broadcast burning or spot burning. In a country where relatively narrow isolation strips will be effective, especially in plateau topography, it is particularly satisfactory. It is not to be recommended where the fire risk is especially bad, the slash unusually heavy, the topography steep, or the undergrowth very dense and inflammable.

The proportion of the area in strips and the intensity of the protection are matters of nice judgment if the maximum degree of security is to be obtained for each dollar expended. For an operator who is looking forward to permanent forest production and is willing to employ intensive protection to fireproof the strips more carefully, even at somewhat greater expense, piling and burning (or swamper burning) the slash on the strips may prove to be better business. By that method he will attain more effective fire-retarding lanes, less loss of production on the strips, and greater security to his forest investment.

PARTIAL PILING AND BURNING WITH INTENSIVE PROTECTION

Partial piling and burning gives for this region a favorable combination of good silviculture, acceptable security against accidental fires, and reasonable cost. It is appropriate wherever the area of cut-over land is large enough to justify an intensive protective organization through a term of years, or where small tracts or those upon which the operation is concluded can be protected through a term of years in cooperation with adjoining lands by arrangement with a forest-fire association, the State forester, or the Forest Service. It is not to be recommended where the fire risk is especially bad, where the slash is extra heavy, the topography very rough and broken, or the undergrowth very dense and inflammable. Moreover this procedure should always be applied in a very elastic fashion. The isolation strips may be wide or narrow, close together or far apart, to suit the hazard and the topography; they may cover as little as 10 per cent of the area and as much as 50 per cent. They may be cleaned up very thoroughly of bushes, rotten logs, and low-hanging limbs, or may have only the logging slash itself burned. They may or may not be edged with plowed furrows. The intensive protection may be of any degree of intensity, varying in different parts of the area, and may continue for 10, 15, or 20 years, according to the need.

A SLASH-DISPOSAL PLAN FOR A SPECIFIC AREA

This study indicates that under certain conditions the method of partial slash disposal on strips followed by intensive protection has a place in the management of some of the pinelands of Oregon and Washington. To illustrate further how this method might be applied, how the strips would be located, what fire-prevention provisions are desirable, and what the costs would be, a hypothetical scheme for a specific area is presented. The tract selected for illustration is on the low rolling hills of the Blue Mountains of Oregon, and the stand is practically pure western yellow pine, continuous except for occasional meadows. Let us suppose that there is already

a solid township of cut-over lands and that they are being added to at the rate of 3,000 acres per year, implying a cut of 45,000,000 board feet, or an average cut per acre of 15,000 board feet.

As logging proceeds, the slash is piled and burned for a distance of 75 to 150 feet on each side of all railroad spurs, highways, or secondary roads. Still further to break up the area, the débris on additional strips 100 to 300 feet wide along ridges and creeks is piled and burned. Natural meadows also serve to break up the continuity of the slash areas. During wet or snowy weather, when it can be done safely, the slash is swamper burned on these strips in lieu of piling it after logging. Swamper burning is estimated to cost 55 cents per thousand feet of logs cut, and piling and burning 45 cents, or $8.25 and $6.75 per acre, respectively. Since the isolation strips are on an average about 230 feet wide, it would cost on an average $230 or $188 to burn a mile of strip, depending upon whether the slash was swamper burned or piled and burned.

The accompanying topographic map (fig. 9) of an actual block of six sections in the region from which this hypothetical case is drawn shows a proposed layout of isolation strips. The strips follow no diagrammatic scheme and are not of regular spacing or width, but vary to fit the risks and the character of the slashing. By taking advantage of a number of natural meadows the mileage of fire lanes that must be prepared is considerably lessened. The average size of the blocks of cut-over land (exclusive of the lanes) is 107 acres. In these six sections of about 3,840 acres there are 21¾ miles of strips, and as their average width is 230 feet, the aggregate area of burned slash, including a rather large area about camp, is 645 acres, or 16.8 per cent of the total area protected. Assuming that a quarter of the strips were winter logged and swamper burned and the rest piled and burned, their cost would amount to $1.20 per acre for the total area protected, or 8 cents per thousand feet of logs cut.

The other phase of this method is the intensive protection that must be given for a number of years on account of leaving 83.2 per cent of the slash undisposed. The essentials of protection suitable for an area of this kind are enumerated below—as suggestions, not as a complete fire plan. Several of them are briefed from the existing Forest Service Code for timber-sale area protection. Provisions already in the State law are enumerated for the sake of completeness even though compliance with the State requirements may be assumed regardless of the method of slash treatment employed.

Smoking.—Either the prohibition of or confining of smoking to designated areas should be enforced through the fire season. Such signs as "No Smoking on this Road," together with strict enforcement of smoking regulations, will give results.

Blasting, lunch fires, bonfires, etc.—No unnecessary fires and no blasting should be allowed in the woods during the fire season.

Oil-burning equipment.—Wherever practicable oil-burning equipment should be used in preference to wood burners. This applies to locomotives, skidders, donkeys, and loaders.

Spark arresters.—All oil, wood, or coal burning equipment using artificial draft should be provided with spark arresters which are in perfect repair and in use throughout the fire season.

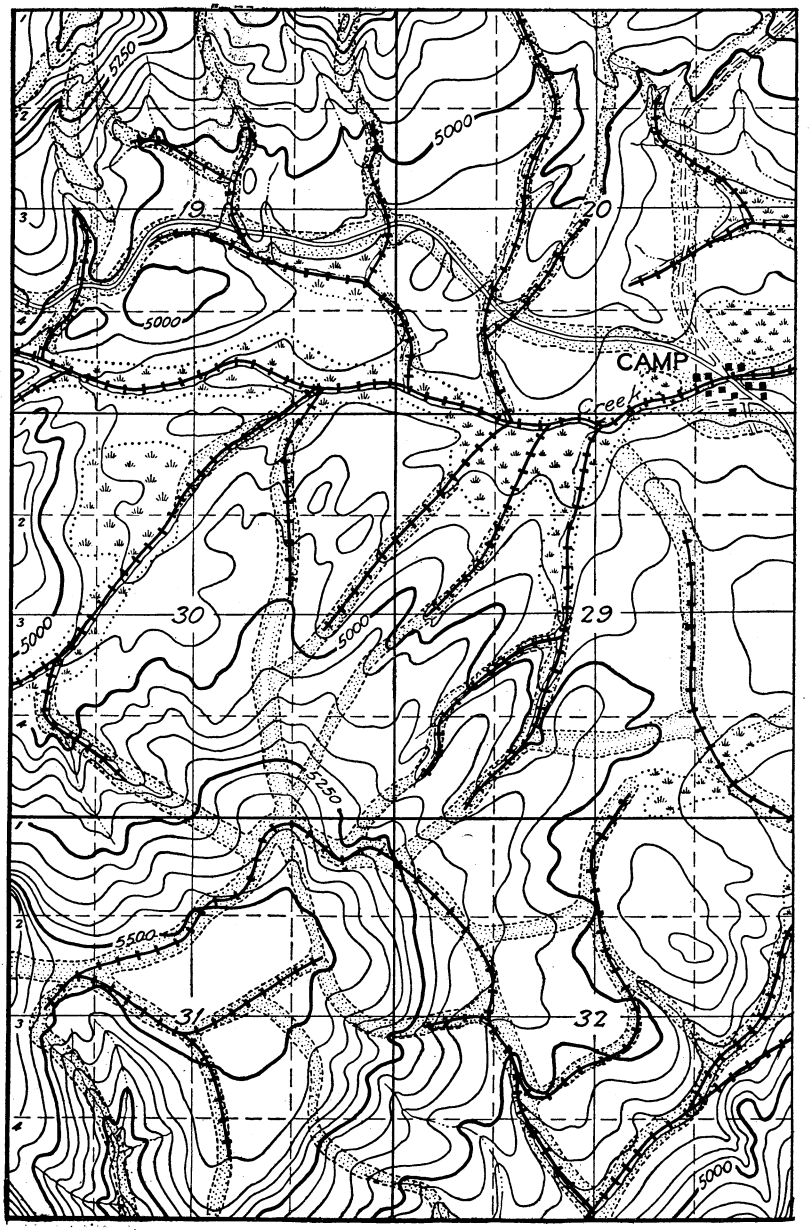

FIGURE 9.—Arrangement of fire lanes on a tract in eastern Oregon where the partial piling and burning method of slash disposal is proposed. These lanes are of variable width, and upon them all the slash is to be piled and burned. Elsewhere it is to be left as it falls but very intensely protected from fire for a term of years. The lanes are constructed along railroads, highways, creeks, and ridges, and connecting the natural meadows to break up the unburned slash into blocks averaging, in this case, 107 acres in size

Designated areas for sanding.—Specific areas should be designated where locomotive flues may be sanded.

Construction of roads.—That the slash area may be accessible by automobile to patrolmen and fire-fighting forces, the principal abandoned railroad grades should be converted into roads to the extent of a mile of road to each section or two, when there are not already favorable automobile roads.

Camp firewarden.—A camp firewarden, responsible for all fire control, should be employed during a long season to devote his entire time to this work. It should be his duty to organize the camps for fire control, enforce all regulations to prevent fire, inspect all tool caches and fire equipment regularly, instruct all employees as to their duties in case of fire, and get suppression forces on every fire quickly.

Lookouts.—To provide for detection, lookouts should be stationed where visibility is good (one lookout to approximately 10,000 acres for the first 5 years after cutting). The following 10 years the number of lookouts can be reduced somewhat every few years in proportion to diminution of the slash fire hazard. Lookouts should be on duty from daylight until dark during the fire season, which ordinarily will be from June 1 to September 30.

Patrolman.—A man with a speeder should constantly patrol the railroad lines; it should be his duty to put out any fires that he may discover, or if the fire is too large, to get in communication with the camp firewarden immediately. Patrol about the active logging or along the highways may also be desirable.

Watchmen.—A watchman should be assigned to each steam skidder or loader at noon and at night.

Firemen.—It is assumed that the company will be operating during the fire season and that there will therefore always be on hand men to fight any fire that may start, and that no special provision for firemen-patrolmen is necessary other than the lookouts, patrolmen, watchmen, and camp firewarden.

Communication.—An efficient telephone system should be maintained to connect lookout points and the patrolmen's stations with the camp firewarden's headquarters and all logging camps. Fire business should have the right of way over all other business.

Maps.—A map of the entire timbered acreage should be posted at the camp firewarden's headquarters. The map should show the annual cutting boundaries, the dates of cutting, and the location of isolation strips, meadows, other firebreaks, water, etc. This will be invaluable in sizing up the fire hazard at a glance. Also it should show the location of all tool caches and other fire-control facilities.

Equipment.—The following fire-fighting equipment should be available for use:

At each camp, in a conspicuous place, a sealed tool box containing shovels, axes, rakes, crosscut saws, back-pack hand force pumps, water bags, or other tools suitable for the region, in sufficient quantity to equip the crew.

With each loader, skidder, and locomotive, a sealed tool box containing 6 shovels, 3 axes, 2 rakes, 1 crosscut saw, 6 pails, 1 back-pack hand force pump, or other equivalent tools appropriate for the region. Also a power pump and not less than 200 feet of hose.

With each caterpillar tractor a chemical fire extinguisher and a shovel.

For each 2,500 acres of old cut-over lands a sealed tool box, containing 3 shovels, 3 axes, 2 rakes, 2 pails, 1 crosscut saw, located in a convenient, accessible place.

One tank car with water pump and hose (for track or road) to every few thousand acres of current logging area.

An autotruck equipped for fire fighting should be available at the headquarters camp.

At each camp a plow or V drag of a type suitable for fire-line construction in the region, with the understanding that logging caterpillars or horses will be available as tractive power in case of fire.

Since current logging areas and older cut-over land must have a certain amount of protection, irrespective of the method of slash disposal, it is not fair to charge all this protective effort to slash treatment. Such items as spark arresters on logging engines and locomotives, fire-fighting tools, tank cars and hose, clearing around camps, watchmen, etc., are incident to any large well-managed operation and should not be considered as a part of the cost of protecting slash areas that if burned completely would not require this extra protection.

The following tabulation gives the estimated cost of applying partial piling and burning with intensive protection to a hypothetical tract in Oregon of the size and yield above indicated. The first group of five items are considered part of the general fire protection plan and therefore not chargeable to slash treatment.

Items of protection and slash disposal	Cost per M feet b. m. of logs cut
No smoking permitted on any part of operation	-------
Prohibition of blasting, lunch fires, etc ; oil-burning equipment; spark arresters; designation of areas for sanding; watchman	-------
Construction of roads on old railroad grades, 1 mile to each thousand acres at $225 per mile for construction and $125 for maintenance during 15 years	$0.0233
Camp firewarden (one-half charged to this extra protection)	.016
Lookout for 15 years, one to every 10,000 acres at first, and for four months each year	.040
Patrolman	.040
Communication	.005
Equipment, map, etc., in excess of usual protection	.020
Cost of intensive protection	.144
Cost of partial slash piling and burning (16.7 per cent of area)	.08
Total cost of this method of slash treatment	.224

This plan is for a certain set of conditions that prevail in one locality and should not be considered appropriate for other regions without modification. Elsewhere the isolation strips may need to be more frequent, more or less roads may be needed, or extra protection be required for a longer or shorter period, or some other type of fire control than those mentioned may be indicated. Where this method of partial piling and burning pine slash followed by intensive protection is appropriate (and that is by no means everywhere in Oregon and Washington) it is thought that it can be carried out

successfully for 22 cents per thousand feet of logs cut, as above itemized.

Such a plan as that outlined has a maximum of advantages and a minimum of disadvantages for those owners who seriously wish to keep their forest lands fully productive of forest crops. There are operators of western yellow pine timber who will not be willing to make so large an investment in slash disposal but who nevertheless want to do more than the bare minimum to save the land from nonproductivity. For such owners the details of this method may be modified to suit their pocketbooks, in the realization, however, that any letting up on the provisions of this system means a sacrifice in security from fire or in forest productivity, or both.

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FIGURE 10.—A small slash pile, 6 feet in diameter and 2.5 feet in height, poorly piled. A small loose pile of this sort must be burned in relatively dry weather because the entire mass of slash becomes wet with a small amount of rain

APPENDIX

TECHNIC OF SLASH PILING

Satisfactory results from piling and burning slash can be had only if close attention is given to proper technic of both operations. The careless or unintelligent execution of either the piling or the burning can readily render the method ineffective, creating an expense without securing the advantages which this type of disposal should give. There are certain important considerations in piling; they are, type of pile, size of pile, location of pile, time of piling, labor, and tools used.

TYPE OF PILE

Compactness is a prime requisite of a good pile, for that quality is necessary to keep the inside dry when the outside is wet and to insure ready and complete combustion. Loose piles fail to shed rain or snow and absorb it instead. (Fig. 10.) To obtain a compact pile the smaller limbs from the upper part of the crown should form its base, creating a mass that is readily ignited. Upon

this are then laid the larger limbs, each being so placed that it will lie closely and keep the pile conical. The top foot or so of the pile should be finished off with material like that which went into the base, as a thatch. (Fig. 11.) The last step is to place a few of the larger limbs about the pile to bind the entire mass together and give assurance of compactness. To get a pile of this composition and compactness implies a pile of large dimensions, perhaps 8 to 10 feet in diameter and 5 or 6 feet in height.

SIZE OF PILE

This study has indicated convincingly that the size of pile is an important factor in successful disposal. The piles must not be so large, and therefore so

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FIGUGE 11.—Good piling pays. Such piles as these can be fired effectively after there has been enough rain to make burning operations relatively safe

infrequent, that the slash has to be carried too far, nor must they be so small that much chopping up of the branches is necessary. The same volume of slash in large piles will occupy less of the forest floor than it would in small piles; for example, the slash from a stand of 20,000 board feet per acre would make approximately 13 piles 9 feet in diameter and 6 feet high, or 42 piles 6 feet in diameter and 4 feet high. The former type of pile would cover half as much ground space as the latter. This in itself is an advantage in favor of large piles where it is an object to keep to a minimum the surface that is scorched.

Not only does the large pile occupy less ground space, but it seems to be possible to burn it with no greater damage if it is properly placed. An analysis of the amount of damage resulting outside of the bounds of the pile indicates that piles 5½ to 6 feet across and 2½ to 3 feet high burned 1.2 per cent of the total area of forest floor outside the bounds of the pile, and that piles 7 to 8 feet across and 4 to 4½ feet high, under comparable conditions, burned 1.0 per cent of the total area outside the pile.

Since it is difficult, where the advance reproduction and reserved trees are abundant, to place the piles so that the flames will not sweep about and do

damage, the question arises whether the reach of flames from large and tall piles will not be more destructive than from small piles. Observation of burning piles indicates that height of pile alone does not augment the radius of destruction, but that the diameter and total mass of burning material control the reach of the flames. Unquestionably the large piles must be placed with more care for near-by reserved trees, but, on the other hand, with many small piles there are many more chances for possible scorching injury.

It is a moot point among slash pilers whether the large pile or the small is more expensive to make. For a large pile the slash has to be carried further, but this is partly offset by having fewer units to build and less chopping up of branches. The crown of an average tree in a stand of 14,000 feet per acre with a volume of 875 board feet would produce about 200 cubic feet of slash and make one pile 9 feet by 5 feet, or four piles 6 feet by 3 feet. This would theoretically necessitate carrying slash a maximum distance of about 20 feet for the big pile or 10 feet for the smaller. However, usually the slash of one tree overlaps that of others, so that the difference in carrying distance to large or small piles is not as real as this theoretical calculation would indicate. A. C. McIntyre found in Arizona that in stands running from 6,000 to 10,000 board feet per acre the small pile is more expensive to build than the large one.

The cost of burning also seems to be less with large piles than with small, there being fewer to ignite, even though there is the same area to walk over. Experience has shown that a large pile which is also compact can stand considerable rain or snow without getting wet inside. Particularly large piles have been burned when covered with as much as a foot of snow. This is a distinct advantage, in that it makes for a longer and safer burning season. The heat from small piles is not sufficient to evaporate the water from the melting snow, and the fire goes out, leaving a skeleton pile which can not be burned with ease at any time.

LOCATION OF PILE

To burn piled slash with the minimum of damage to the forest involves careful location of the piles. Three points particularly require observance; piles should be located (1) away from down logs, snags, or stumps, (2) at a safe distance from reproduction and reserved trees, and (3) in roads or skid trails where practicable. Observance of the first two rules is merely a matter of proper instructions to the pilers and systematic supervision. The placing of piles in roads or skid trails depends upon whether the piling is done before or after logging.

Placing piles at a safe distance from reproduction and living trees is not always strictly possible. Where the stand is dense and uniform, slash would have to be carried a long distance to find safe bare areas. Where possible, however, piles should be kept 15 feet away from trees and 10 feet from reproduction. It is perhaps obvious that more damage will be done to forest production by the killing of one or two seedlings on a spot where they are scarce than by the killing of a clump on a spot of the same size where they are abundant. Slash pilers in their zeal to prevent injury to the more conspicuous seedlings in clumps often will cover up or build near a single seedling far removed from any other reproduction. It is more important to consider how much reproduction will be left than how much will be killed.

Where there is no alternative but to place a pile in the midst of reproduction, the best technic is to leave that patch of slash unpiled, or if this takes too much supervision and the pilers make a pile there anyway, let it go unburned. There is no advantage in going to the expense of piling slash that is not to be burned, and there is no objection to leaving occasional patches of slash unpiled, but there are practical difficulties in getting the pilers to be discriminating in doing selective piling, i. e., leaving a top once in a while that is in a bad place to pile or burn. One solution of this difficulty, which, however, has not been tried in this region, is the "stake method." By this method the foreman of the piling crew sets stakes where piles are to be constructed. This eliminates the possibility of indiscriminate piling by the individual, and it is said that the added cost of supervision is offset by the decrease in the cost of piling.

TIME OF PILING

For efficient handling of slash, piling soon after felling is most desirable; it should keep pace with other parts of the operation. But this is impossible where

there is snow on the ground, and winter-cut slash must therefore await piling until spring. If the slash is allowed to dry out, as it will when not snow-covered, the smaller twigs become brittle and easily broken off, the larger limbs become tough and difficult to chop, and a clean job of disposal is more expensive than with green slash.

A few operators pile before logging, but most of them not until after. With horse logging and to a smaller degree with caterpillar logging, there is some advantage in piling before the logs are taken out; it makes it easier to do the bunching and skidding. However, the logging inevitably tears down some piles and makes extra work. Also some limbs can not be reached until the logs are rolled away. With donkey logging it is quite out of the question to pile until after the skidding is concluded.

One distinct advantage of piling after logging is that it is then possible to place many of the piles in roads and skid trails; these areas are already divested of reproduction and by using them for the slash piles the area denuded by the burning piles is reduced by just that much, a real silvicultural advantage. Some analysis of pile location indicates that slash-piling damage can be reduced 6 to 35 per cent by the placement of piles in logging roads. On 10 plots that were mapped intensively after the areas had been logged and the slash subsequently piled, it was found that 20.4 per cent of the piles were adjacent to logging roads or skid trails, i. e., the center of the pile was within 10 feet of the edge of the road, yet only 1.1 per cent of the piles were in these roads or trails. It appears that with very little extra effort, except for strict supervision of the pilers, a considerable proportion of the piles, perhaps 15 or 20 per cent, could be placed in roads or trails already bare, instead of on the near-by undamaged forest floor.

It has sometimes been considered that prompt piling following logging was wise as a precaution against accidental fires. Although, as has been said, prompt piling aids in handling, evidence indicates that the fire hazard in areas of piled and unburned slash is quite as great as in those of wholly unpiled slash.

LABOR AND TOOLS

Unfortunately slash piling has been looked upon by operator and lumberjack alike as low-grade work; this has resulted in low wages and poor laborers. Under these circumstances where the work is done on a day-labor basis it is liable to be of indifferent quality and expensive in the long run. It has been found in California (*9*), in New Hampshire (*7*), and in Arizona by A. C. McIntyre that slash-disposal costs are materially increased by the employment of low-grade labor. In the Northwest most of the piling is done by contractors, two or more men combining on a unit of area. They are usually rapid workers who, when they have been taught and held to a certain standard of work, do good piling and make good wages. It is important for any operator doing slash piling to use good labor, either on a wage or contract basis, and to maintain as continuous and stable an organization of pilers as possible.

The amount of slash that a piler should handle per day is usually measured by the merchantable board footage of the trees from which it comes. This is variable, because the quantity of slash per thousand feet of logs decreases as the volume of the stand increases, and because there is a variable quantity of broken-down saplings and undergrowth that enters into the slash mass. The efficiency of pilers is affected very much by the topography and the difficulty of finding spots for the piles away from living trees.

From observation and from conversation with pilers, the volume of slash that can be piled per man per day by fairly efficient labor on ground ranging from level to a 20 per cent slope is as follows: For stands under 8,000 feet per acre, the slash from 6,000 to 10,000 feet of logs per day; for stands of 8,000 to 12,000 feet per acre, the slash from 10,000 to 12,000 feet per day; for stands of 12,000 to 15,000 feet per acre, the slash from 12,000 to 16,000 feet per day; for stands of 15,000 to 20,000 feet per acre, the slash from 16,000 to 20,000 feet per day. By referring to Table 1 it can be seen that in each case the cubic-foot volume of slash handled is about the same. This is equivalent to approximately 1 acre of slashing per man per day.

The most efficient organization for piling is a crew of 6 to 10 men working in pairs under the supervision of a foreman. After the men become familiar with the work the foreman can work along with the men. Where two men work together one will do most of the ax work and the other will do the piling.

The essential tools are a sharp swamping ax for each man and a pitchfork for each crew. The latter is invaluable in cleaning up the smaller twigs and the débris, which it is tedious to pick up by hand.

TECHNIC OF BURNING SLASH PILES

If all details of correct piling have been observed the difficulties of burning are reduced to the minimum. But because piling is never 100 per cent perfect and weather conditions can not be controlled, burning is at best a hazardous job. The important phases of the technic of burning are the time of ignition, execution of ignition, organization of crew, tools, and follow-up after burning.

TIME OF BURNING

Spring and fall are the seasons for burning piled slash in this region; the fall is generally considered to be the safer period, and more burning is done then. Spring burning has the advantage of removing the débris before the dry summer, but involves a hazard from hold-over fires. Burning in the spring sometimes fails because the ground becomes dry before the inside of the piles is dry and stays so. In the fall, burning should not be begun at the first light rain, but delayed until the soil is well wetted. Under ideal burning conditions the ground and reproduction are covered with 3 or 4 inches of snow, yet the piles are not wet; this is a rare combination of conditions, for soaking rains usually come in the pine belt before the snows. Advantage must be taken of all favorable weather, spring or fall, when the slash can be burned with reasonable assurance of safety.

Weather conditions at the time of burning largely control the damage to the forest. Loose and small piles will burn only when the weather is comparatively dry, and therefore the firing of such piles often results in excessive damage.

Table 11 records for 16 different plots the damage to the forest in relation to the season and weather conditions.

TABLE 11.—*The relation of season of burning to damage to the forest by piling and burning on the basis of spread of fire outside of bounds of pile*

Plot No.	Area burned outside pile	Month	Weather conditions
	Per cent		
57	4.9	September	Light rains.
58	23.1	do	Light rains, drying.
50	13.3	do	After light rains, drying.
60	8.2	do	Light rains, drying.
99	10.2	do	After light rains, drying.
97	13.4	do	Do.
15	2.5	do	Moderate rains.
20	2.3	October	Light rains, drying.
81	.7	do	After heavy rain.
83	1.6	do	Do.
54	1.5	September	2 inches of snow.
8	1.0	November	Snow.
61	.6	do	After soaking rains.
67	1.4	do	1 inch of snow.
53	.1	March	Snow banked against piles.
46	.9	do	Do.

The danger of early fall burning is conclusively demonstrated by Table 11. In every instance the excessive spread of fire was associated with burning after light September rains. Burning in October and November, after the soil had become saturated by a series of rains, gave good results. The same was true of burning on snow, both in the spring and in the fall. The conclusion is unmistakable that early fall burning should be avoided and that late fall or early spring burning is to be encouraged.

Slash will burn up more completely when it is dry than when wet; this is particularly true of the larger limbs. When surrounding conditions are rather moist, and therefore safe, a fringe of unburned branch stubs and twigs is left around the rim of the pile, but this material does not constitute 5 per cent

of the total volume of slash and is no argument against burning at such a time. Whenever well-built piles will burn there will be a sufficient clean-up to eliminate most of the slash hazard, even without "chunking up."

It is important for the foreman of the burning crew to keep informed of burning conditions, hour by hour throughout the day. After frosty nights it may be too damp to burn even on a south slope until mid morning. Sometimes burning may be dangerous on a south slope yet simultaneously safe on an adjoining north exposure. To utilize fully all the good burning weather, night burning is recommended to supplement the daylight work. Not only does this double the length of the burning period, but it offers the ideal time for good control, when the wind is less apt to blow and the atmosphere humidity is higher.

EXECUTION OF IGNITION

When the weather conditions are ideal, slash burning is simple and the chief thing is to get the piles ignited in the easiest possible way. Usually some finesse is necessary in employing the torch. When there is a wind and the piles tend to burn too fiercely, light them on the leeward side or on top. Or if too much draft is created when a group of adjacent piles are burned or the fire tends to run, ignite every second or every third pile and return later to burn the intervening ones. The increased cost of this method of firing is often justified in the better results that are obtained.

Burning on slopes is quite different from burning on level ground. To overcome the uphill draft start to ignite piles on the top of the slope and work down the hill; this also keeps the men to windward of the smoke.

The torch men should be instructed that it is not obligatory to burn every single pile and that they should skip those that are dangerously close to reproduction or reserved trees. There should be some selectivity in burning, just as there should be in piling.

ORGANIZATION OF CREW

Experience has shown that a crew of four to eight men under the supervision of a foreman is the most effective organization. It is important to get the men to take interest in applying the torch intelligently and to have the maximum number of experienced hands. Each crew should be assigned to a specific tract and work back and forth, each man taking a strip 50 to 75 feet wide, and keeping more or less abreast of his fellows.

On level ground, with large piles, a man will ordinarily burn the slash from 125,000 to 175,000 board feet a day; on slopes of 15 to 35 per cent a man's capacity will be reduced to 100,000 or 125,000 feet.

TOOLS

Torches are indispensable to burning on a large scale. Makeshift methods, such as the use of matches, sprays of dry needles, or pitch wood, are unsatisfactory even on small areas and are expensive in the long run. There are several types of torches in use. Blow torches are desirable only where the slash ignites with difficulty and are not recommended for ordinary use because of their weight, difficulty of keeping in operation, and large consumption of kerosene.

Three types of torches are shown in Figure 12. Type A is used quite extensively on national-forest timber-sale operations in Oregon and Washington. It consists of a 2½ or 3 inch pipe, 16 inches long, provided with a cap on one end and a pipe one-half to five-eighths inch in diameter, which holds the wick, on the other end. The large pipe is the oil chamber and has a capacity of about 1 quart. Several strands of cotton wicking are made to fit snugly in the smaller pipe. One filling of kerosene in the torch will last from four to six hours. The chief objection to this type is its weight of 10 or 12 pounds.

A very satisfactory type of torch (called type B), developed by the Forest Service in Arizona, consists of a 1-inch pipe 4 feet long, drawn down on one end to one-half inch to hold the wick, and provided with a cap on the other end. The capacity of the oil chamber is about a quart. The chief advantage of this torch over the other is that its weight is but 4 or 5 pounds.

Another type (called type C) that has found favor in California is an adaptation of a shop torch, provided with a pipe nozzle and wick, and ferrules into which a stick can be inserted for a handle.

FOLLOW-UP AFTER BURNING

In some cases it has been the practice to have a man follow the burners to "chunk up" the débris after the piles are partially burned. Compact piles

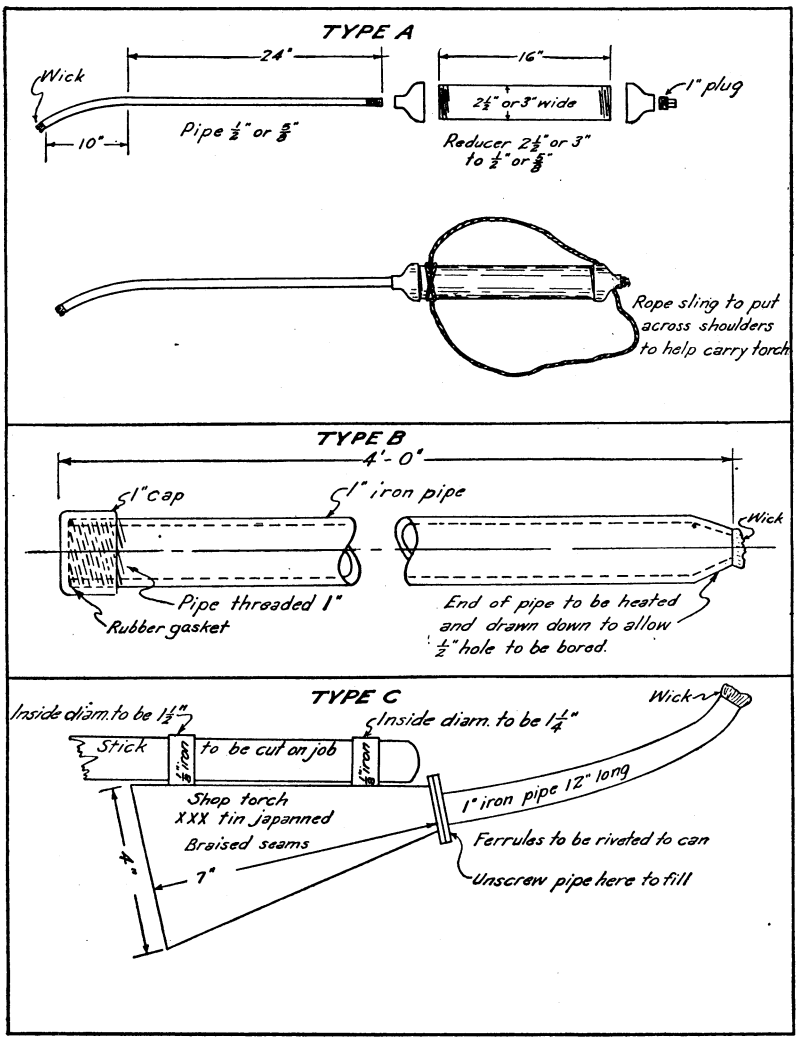

FIGURE 12.—Three types of slash-burning torches used extensively in Washington and Oregon (type A), Arizona (type B), and California (type C)

usually produce enough heat to make a clean burn. Occasionally a ring of débris consisting of the larger branches will remain unburned, but this is really of no consequence. It is very questionable whether the expense of chunking up under any conditions is justified.

Some follow-up of burning is a necessary precaution against the spread of fire, because dry weather close after burning will often cause smoldering logs to burst into flame. Instances are not uncommon where apparently harm-

less fires have developed into real forest fires which did damage until stopped. To prevent such accidents it is always a good procedure to have a man go over the area systematically and either put out the hang-over fires in the logs or dig a trench around them to prevent their spread, unless heavy and continued rains or snows immediately follow the firing of the slash piles.

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