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LOGGING SLASH
A STUDY OF THE PROBLEM IN INLAND EMPIRE FORESTS

by

D. S. Olson and George R. Fahnestock

W. IDAHO

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Roger W. Billings	J. G. Kooch
Royce G. Cox	Hanley A. Morse
A. B. Curtis	V. D. Moss
James C. Evenden	D. S. Olson
J. W. Farrell	L. R. Pugh
William K. Ferrell	Ed. A. Ring
Robert L. Gilbertson	Arthur M. Roberts
E. E. Hubert	Charles A. Wellner
D. S. Jeffers	Lee White

Ernest Wohletz, Chairman

Cover photo: Burning a test plot of logging slash at field laboratory on the Priest River Experimental Forest.

LOGGING SLASH

A COOPERATIVE STUDY
of
THE PROBLEM
in
INLAND EMPIRE FORESTS

D. S. Olson, Research Silviculturist, University of Idaho

George R. Fahnestock, Forester, Fire Research, Intermountain Forest and Range Experiment Station

Forest, Wildlife and Range Experiment Station
University of Idaho
Ernest Wohletz, Director
E. W. Tisdale, Assistant Director

and

Intermountain Forest and Range Experiment Station
United States Department of Agriculture
Forest Service
Ogden, Utah
Reed W. Bailey, Director

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I. INTRODUCTION

This publication has four functions. First, it is a condensed problem analysis. Previous attention to the logging slash problem recorded in committee reports, administrative instructions, and some research literature, provides a history both of the problem itself and of what has been done about it. In recent years, changes in economic conditions, forest practices, logging methods, and forest fire-control techniques have forced reconsideration of the slash problem and have led directly to the current research program. This publication reviews briefly the past history of the slash problem and the conditions that have focussed attention on it again.

In the second place this publication describes the most recent research attack on the logging slash problem in the area whose protection agencies spend more money directly on slash disposal than those of any other area in the United States. The description is concerned more with providing a broad picture of what is being done than with discussing details of research methods. Consideration of slash in the Inland Empire is not new. Over the past 50 years this problem has perhaps received more attention than any other by forest-research workers, forest managers, fire-control men, and committees representing all the forestry interests of the region. The earlier studies were mostly observational; the conclusions drawn from them represented the best judgment of experienced men—educated opinion, in other words, not necessarily fact. The current research program is distinguished from its predecessors by its emphasis on fundamental studies aimed at all phases of the problem.

Thirdly, this publication reports progress on a research program that has been underway for 6 years. Preliminary stages of several projects have been completed. Some results already have been published; others are ready for publication as soon as they can be processed. Also, aided by the thoughts of others outside the research program itself, the authors have arrived at some opinions that go beyond the concrete results attained so far. These opinions are not necessarily superior to those of earlier workers, and they are not represented as such. Nevertheless, they should be of interest because they represent the latest thinking of men who have just spent three to six years studying slash almost exclusively, and who have had access to more fundamental information than their predecessors. Research has not proceeded quite far enough to permit setting up guidelines for meeting specific situations. More definite and applicable results will become available in the near future.

Finally, an attempt is made to forecast the future of slash research and of slash problems. The immediate future of some studies has already been planned; the need for certain other types of work can be readily recognized. Economic trends and changing woods practices will affect the slash problem itself which may require adjustments in future planning of slash research. The lasting value of research now under way and contemplated will depend on how accurately future conditions are foreseen and prepared for.

As the title indicates, this publication deals with a limited area in northern Idaho, eastern Washington, and western Montana. The narrow geographical application reflects a justifiable preoccupation with the truly staggering slash conditions characteristic of the western white pine type, acre for acre the Inland West's most valuable forests, whose distribution is confined essentially to the Inland Empire. Within the same area, however, occur most of the other important forest types of the Inland Northwest. Therefore much of what follows has broader application than the title indicates, and the phrase, "Northern Rocky Mountains," could be used almost interchangeably with "Inland Empire."

II. THE PROBLEM

Indirectly slash is money out of pocket for the man in the street, yet more often than not he doesn't even know the meaning of the word. Let us take a look at this material which causes so much anxiety to so many people while remaining anonymous to most of them.

WHAT IS SLASH?

To grow, a tree must have foliage, and foliage requires branches for its support. When harvested, the crown which has been all important to the living tree becomes a liability. Branches and limby top must be removed from the usable portion of the tree and left in the forest where they become a fire hazard, hinder forestry operations in the woods, and detract from the beauty of the forest. Additional debris accumulates in a normal logging operation from snags, defective trees, right-of-way clearing, and from accidental "push-over" and breakage in felling and skidding operations. Bark and splinters from the manufacture of round and split products in the woods provide additional kindling fuels. All of this is logging slash. It is an inescapable result of timber harvesting that creates a complex problem in the management of forest lands.

Residue from the production or manufacture of any primary product creates a problem until man's ingenuity converts it into a profitable by-product. This principle is well illustrated by the meat packing industry, where, as the saying goes, "Everything but the squeal of the hog is now utilized." The goal of woodsmen has been paraphrased, "Use everything but the sigh in the pines." Until profitable uses are found, large accumulations of unusable residues have a nuisance value and in the case of logging slash may constitute a threat to human life and property.

The debris left after a timber harvest is a heterogeneous mass of very fine to very coarse material—from needles weighing a fraction of a gram to logs weighing tons, and from short branch sticks to 100-foot snags. Utilization of some of this material and treatment of the remainder must recognize the varied components. These may be classified into two general groups: heavy components, having a minimum diameter of 4 inches; and light or fine components, having less than 4 inches diameter. These two classes are distinct not only in appearance but also in their relation to the over-all slash problem.

The coarse material in logging slash—fallen trees, stumps, defective logs, and broken chunks—has good possibilities for utilization in the future and may be expected gradually to pass out of the picture as a problem in the woods. The fine components—principally branches, twigs and foliage—present a different problem. This material is bulky in proportion to the volume of its solid content and consequently expensive to handle. Possibilities of finding commercial uses for it seem remote at present. Unfortunately, these lighter components in slash are much more dangerous as fire hazards than are the heavy components. These flashy fuels are ignited easily, and fire spreads through them rapidly. They serve as kindling fuels to ignite heavier components. In reducing the fire hazard caused by logging slash, the primary aim is to get rid of the kindling fuels which, once ignited, start a chain-like action that often leads to a conflagration.

SLASH AND FOREST LAND MANAGEMENT

Slash exerts some influence, most of it adverse, on nearly all woods practices. Its presence interferes with land use and arouses public indignation. Removal of the slash likewise poses problems related to silvicultural practices and land use, and in addition is expensive. Logging slash is a problem primarily because it creates a fire menace, and only secondarily because of its relationships to other aspects of forest land management.

Fire Hazard

Hot dry summers and frequent severe lightning storms give the northern Rocky Mountains the second highest fire occurrence rate per million acres in the western United States.[3] Once a fire starts, its rate of spread and ease of control depend largely upon the fuel bodies in its path. The fuel type classification system used in this region rates slash in the highest class.[29] Virtually any appreciable body of slash

Figure 1. Debris left after a timber harvest is a heterogeneous mass of very fine to very coarse material.

comprises a combination of fine and coarse fuels in which fires spread rapidly, burn with great intensity and persistence, and are difficult to control. In addition, slash is always associated with some degree of removal of the protective forest cover. As a result, slash dries early, and slash fires are exposed to the action of wind.

While considerable damage may result from burning the logged area, the graver concern is that slash fires will get out of control and run wild, threatening life and property and undoing the work of a lifetime of protecting valuable forest growth. Many disastrous fires in the past that went down in history were due to logging slash: Miramichi, Peshtigo, Hinckley, Bandon, Cloquet, and Tillamook.[15] While many costly slash fires have occurred in this region, the historical conflagration started and burned chiefly in natural fuels. The great Idaho fire of 1910 cost 84 lives, destroyed much private property, and seared 3,000,000 acres of virgin timber. This holocaust was due to a combination of extreme circumstances—many unmanned fires burning (some in slash), a prolonged hot dry spell, and gale winds—a combination not likely to occur again.

The sole purpose of mentioning the 1910 fire is to lay the groundwork for reporting events that followed from which many lessons in fire behavior were learned. The ranks of men who fought the 1910 fire are pretty thin now, but it is not long since terrible fires were being fought in the tangle of debris left by the 1910 fire. That fire raced through the crowns, sometimes going for miles without touching the ground. Trees were killed but not consumed. In a few years the forest of snags began to fall, splintering and piling up like jackstraws. Here were 3,000,000 acres of slash—not logging slash but slash just the same. With no protective covering, fuels became tinder dry in summer, and standing snags drew lightning. Fires "landed a running." Fifty-thousand-acre fires were common. Fire-control organizations were strengthened and fire fighting technique was vastly improved to meet this situation, but it was not until at least 25 years later that the rash of big fires in the old 1910 burn stopped. Undoubtedly, improved fire-control methods helped greatly in stopping these fires, but successful fire control was due principally to a new forest of young growth that eventually came through to shade the ground fuels and ameliorate the microclimate over the expanse of the old burn.

The 1910 burn taught a powerful lesson. In debris, fires started easily and spread rapidly even when burning conditions were not at all critical in green timber. As a fire in old slash gained impetus and generated tremendous heat and convection currents, it ran from the old burn deep into green timber. A composite map of major fires occurring since 1910 clearly shows this cancer-like growth of burned acreage spreading from the debris of one area to another. Logging slash is very similar to the debris in old single burns; therefore, many cutover areas, if not adequately protected, are potential breeding points for big fires. Ignition rate on cutover land is 2.5 times that on old burns.[3]

Because of its high inflammability, slash always has been considered an excessive hazard. Like city fire departments, forest protective agencies intensify protection where it appears possible to meet bad situations; elsewhere they cause the hazard to be condemned and removed. The latter course of action has been the one most extensively employed against slash. The principle is sound; the question is whether the best methods of hazard reduction are being employed.

From the landowner's standpoint, slash disposal is a form of insurance. Fire insurance premiums go down as the effectiveness of the fire department increases. Present day forest "fire departments" are vastly superior in equipment, mobility, and knowledge of fire control principles to those that fought the big fires of the past. This improvement enables today's fire control agencies to deal more effectively with slash fires, but it raises the difficult question of where to draw the line between hazards which must be removed and those against which intensive protection can be successful. As with insurance, the best treatment of the slash hazard is that which results in the best protection for the least money.

Silvicultural Considerations

Slash is indissolubly wedded to silviculture. The silvicultural system used in a given area determines the cutting plan which in turn, controls the volume of slash. What is done about the slash determines to a large degree the future of the stand. Slash becomes part of the problem at the time when two contrasting goals are sought: harvesting the crop, on which economic considerations have their greatest

Figure 2. Many of the disastrous fires of the past that went down in history were due to logging slash. (Half Moon Fire, Montana, 1929)

Figure 3. Present-day forest "fire departments" are superior to those which fought the big fires of the past.

impact; and establishing the new forest, for which biological factors are of greater importance. These two goals are often compromised, and later the slash problem arises. With better understanding of the problems created by slash and how they may be solved, preappraisal of the slash problems that are likely to occur can serve as a governor in compromising harvesting practices with silvicultural aims for the new forest.

Cutting practice.—In the northern Rocky Mountains all species except ponderosa pine are grown almost exclusively in even-aged stands. This means that the bulk of the timber is removed at maturity in heavy cuts. Harvest cutting may be accomplished in one operation or several, with intervals spaced to allow seeding from the remaining trees.

Early light cuttings may be made for such purposes as utilizing weakened trees that are likely to die before the main harvest, improvement thinnings, and for financing and hastening the program of forest road development. These light cuttings remove only a small volume of timber per acre and leave so little slash that disposal is often unnecessary. However, in some forest types it is not economically feasible to harvest a small volume per acre because of high fixed operating costs.

At the other extreme, clear cutting, the maximum amount of slash results. Even so, the disposal problem is relatively simple, however expensive it may be. The quantity of slash is usually so great that some treatment of the area obviously is necessary, while the absence of residual values after such an operation permits the widest leeway in the use of fire and equipment.

Heavy cuts, short of clear cutting, produce the most complicated situations and present the most difficult choice of slash-disposal methods. Usually the quantity of slash is great enough to require disposal as insurance against wildfire and the complicating factors of insects and disease, especially white pine blister rust. The presence of a valuable residual stand further complicates matters. These trees left to reproduce the area and valuable in commercial volume must be protected from damaging effects of disposal methods. Unfortunately, heavy cuts —above 50 per cent—are necessary to satisfactory reproduction in western white pine forests. The only known way of meeting the requirements for reproduction and of avoiding large slash accumulations in the white pine type, is to open the stand by two light cuttings spaced 15 to 20 years apart.

Regeneration.—At the time of harvesting, foresters are primarily concerned with the regeneration of a new forest; consequently the silvicultural systems as expressed by cutting practices are aimed at providing an abundant seed source and favorable environment for the establishment of a new forest crop. Slash left after the harvest from whatever cutting practice, or its method of disposal, may aid or defeat regeneration.

Generally reliance for seed is placed on trees left for that purpose on the cutting area. Tree seeds stored in duff are not a dependable source since they soon lose their viability. Slash has come to be relied on as the seed source for certain species in this region, notably lodgepole pine.[4] Cones of this species are slow in opening and, when retained in the slash left scattered on the ground, continue to release seed for several years.

In forests of the Inland Empire germination has been found to be better on exposed mineral soil than in litter and duff because the seed has closer contact with moisture in mineral soil than it has in the loose, usually dry organic layer. Consequently exposure of mineral soil by logging disturbance and fire is favorable to germination.

Moderate slash left in the woods after logging is no deterrent to seedling establishment, but dense concentrations may impede seedling growth from below and may intercept seed fall from above. Slash disposal methods can be used to prepare more favorable seedbed conditions. Burning away the duff and litter is one means of improving the seedbed; use of bulldozers for bunching slash is another. Not only the teeth on the dozer blade, but also the material pushed before it, serve to cultivate the ground.

Timber stand improvement.—Slash disposal and timber stand improvement commonly go hand in hand after harvest cuttings. The men, equipment, and methods used to dispose of logging slash may be employed simultaneously to destroy undesirable trees and thereby improve the composition and vigor of the stand. Timber stand improvement carried on prior to harvest cuttings may in itself create a slash fire hazard. Thinning, pruning, and weeding, as practiced on the national forests, create slash

Figure 4. Slash has come to be relied on as the seed source for . . . lodgepole pine . . . but dense concentrations left impede seedling growth.

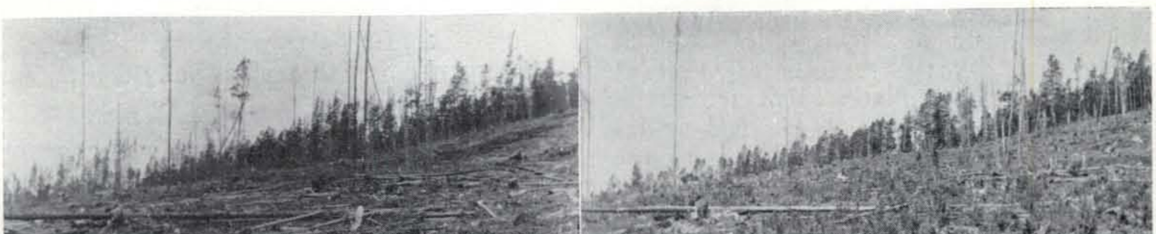


Figure 5. The use of bulldozers for bunching slash also improves seedbed conditions.

for which no money is made available to provide for its disposal. The great McVay Fire in the Black Hills of South Dakota owed its spread chiefly to slash left from thinning ponderosa pine.

Insect and Disease Control

Many decay organisms and insects inhabit slash and play important roles in wood decomposition. In the earlier days of forestry, complete slash disposal (beyond the point necessary for fire hazard reduction) was believed justified as a sanitary measure. More recently authorities have been pretty well agreed that the presence of limby slash does not add appreciably to the danger of insect or disease outbreaks, but a few exceptions are worthy of note.

Bark beetles.—One bark beetle important in this region (*Ips oregoni Eichh.*) may multiply rapidly in ponderosa pine slash and, after exhausting that, may move to living trees.[17] Fallen trees, cull logs, and stumps also present a threat where they occur in quantity, if not disposed of or thoroughly charred. Such material may serve as the breeding ground of enough insects to become a threat to green timber and should be watched for two years to apprehend any serious outbreak of bark beetles. The Douglas-fir and Engelmann spruce beetles in particular prefer fallen timber to standing timber.

Wood rots.—In some places slash contributes to damage by fungi, for certain wood-rotting species fruit more profusely on dead and down material than on living trees. So far as is known, however, in the Inland Empire infection of living trees by fungi from slash is not a serious problem.[5]

White pine blister rust.—Slash is probably unimportant as a breeding place for tree diseases, but its disposal is a vital factor in white pine blister rust control; and experts have warned that without blister rust control young growth western white pine is doomed.

Present control methods consist of eradicating ribes bushes, alternate hosts to the rust. The four important native species of the genus do not thrive in dense shade; consequently their occurrence in virgin forests is minor, and eradication is relatively simple. However, viable ribes seed accumulated through the forest rotation are deeply embedded in the duff. Logging activates germination of the stored seed by admitting sunlight and by disturbing the organic soil mantle. This disturbance favors ribes establishment at about the same rate as it creates slash. As the cut increases, volume of slash becomes greater. Removal of more trees causes more light to be admitted and more soil disturbance. Thus when 50 to 90 per cent of the commercial volume is harvested in one operation in the blister rust protection zone, the forester is faced simultaneously with a big slash disposal job and a big ribes eradication job.

Ribes plants are destroyed mainly by handpulling and by spraying. Neither method can be effective in the presence of any appreciable amount of slash. Not only does the presence of slash make ribes eradication more difficult and expensive, but slash conceals the bushes so that many are likely to be missed; this may largely nullify results of the eradication job. Slash disposal operations themselves further encourage ribes growth. Soil disturbed by slash-piling equipment and scorched around the edges of burned slash piles adds to the area on which new ribes seedlings may be expected.

Light cuts alleviate the ribes control problem as they do the slash problem. Moss[22] found that ribes occurrence can be controlled by partial light cuttings that keep sprouting and suppression in balance through adjustments in canopy density, thus eventually devitalizing the stored seed.

Prescribed broadcast burning, when properly done, can be more effective in suppressing ribes than any other slash-disposal method used where all commercial timber values have been removed from a tract by clear cutting. Then logging slash becomes an asset by providing the fuels necessary for a hot fire that consumes many ribes plants and seeds, and cleans up the area for easy eradication of the remainder. Some dangers are inherent in broadcast burning, particularly for ribes eradication. Slash should be left for 2 or 3 years to provide time for ribes germination and to dry the heavier components of slash in order to get a hard burn that will consume much of the duff. During the first few years after cutting, slash is in its most dangerous state. Thus even in one of its simpler situations, the combined problem of slash disposal and blister rust control has a serious complication.

Figure 6. Slash conceals the ribes bushes so that many are likely to be missed. . . .

Figure 7. Soil . . . scorched around the edges of burned slash piles adds to the area on which new ribes seedlings may be expected.

Figure 8. Heavy accumulations of slash . . . mar the beauty of forest scenery.

Range and Wildlife Management

Presence of slash may reduce the possibilities of use of logged land for domestic livestock grazing. This is particularly important in the more open ponderosa pine and Douglas-fir stands where grazing use is combined with timber growing. Concentrations of slash left after logging not only reduce the area suitable for grazing but result in overgrazing the openings between masses of slash. In some open ponderosa pine areas, owners have willingly paid extra to obtain more thorough removal of slash in order to improve the grazing use of their land.

Presence of large areas of dense slash may exclude game from palatable browse on cut-over land. Hence, wildlife management objectives may indicate that more complete slash disposal be practiced on certain key areas than other considerations would require.

Recreation, Aesthetic Values and Public Relations

Slash left in the woods is unattractive. It is difficult for the public to grasp all the factors related to the presence of this debris. The natural reaction is one of concern over mismanagement of forest lands, apparent waste in harvesting the timber crop, and creation of a fire hazard that the people spend money to abate. More effort should be made to educate the public to a better understanding of some practices that have been found thoroughly sound from a silvicultural standpoint or for economic reasons, such as controlled broadcast burning on some tracts, or leaving slash to decay on others, regardless of outward appearance. For such education to be effective great care must be taken to execute the appropriate slash treatment measures properly. A poor job will nullify a lot of educational effort.

The combination of public disfavor toward logging slash and the potential danger of man-caused fires indicates pretty clearly that slash should be removed from areas frequented by the public, or that such areas should be closed to entry. Heavy accumulations of slash along roads, in stream bottoms, and around recreational developments mar the beauty of forest scenery. In many areas aesthetic considerations indicate that complete slash disposal and post-logging cleanup should be practiced, in excess of work needed to fireproof the area. Closure to entry can be utilized effectively as a fire-prevention tool where the hazard is extreme but may cause unfavorable public reaction.

LEGISLATION

The fact that the presence of slash constitutes a serious fire hazard is widely recognized by state and federal law. Montana[20] and Idaho[12] laws state specifically that slash which results from logging and clearing operations must be treated by an appropriate method and that the operator may either do the job himself or deposit money with the state forester to pay for having it done. In Montana a maximum required expenditure of 75 cents per thousand board feet cut is established; Idaho has no set maximum, but in practice collections rarely exceed $1.00 per thousand. In these two states much of the slash disposal on private lands is accomplished by state crews and crews of timber protective associations that are ultimately responsible to the state forester.

Washington State law[13] requires that a certificate of clearance be obtained from the state forester to the effect that the slash fire hazard has been satisfactorily abated. Since no provision is made for the state forester to collect cooperative funds and do the job, slash disposal is accomplished by the operator. When intensified protection is preferable to disposal, the state forester is empowered to enter into a cooperative agreement with the landowner and collect extra money from him for this extra protection.

Federal law governing administration of the national forests states that as part of the payment for stumpage, purchasers of timber may be required to deposit into a special fund money for abatement of protection from the hazards created by logging.[30] It further provides that collections for this purpose shall be made on the basis of an appraisal of the hazard which will be created by cutting the specific block of timber in question.

Considerable disagreement exists as to whether maximum collections sanctioned by the states are adequate to meet really bad slash situations. The adequacy of even U.S. Forest Service collections is questionable in some cases since there is a hesitancy to collect what might seem to be excessive deductions from stumpage. Fair evaluation of the provisions and application of existing laws must wait for more accurate determination of what constitutes adequate treatment of slash areas.

SLASH AND CHANGING TIMES

The slash problem and attempts to meet it change with time. Industry and government agencies are working together to correct mistakes of the past and improve upon methods of treating slash in keeping with changing woods operations. In the over-all protection plan, logging slash has been viewed as a special menace requiring special treatment. From this viewpoint came the philosophy that it was best to get rid of the hazard for all time by complete slash disposal. If slash is left, a wary eye and intensive protection must be applied for years to come—as with a disease epidemic left to run its natural course.

Until World War II, complete disposal by handpiling and burning was the generally accepted method; compulsory state and federal laws and regulations were built around this concept of slash treatment. After changing methods from horse logging to mechanized operations, handpiling lost much of its effectiveness. High wages following the war made handpiling slash treatment prohibitive in cost, and hand labor has become difficult to hire. Improved fire fighting techniques, availability of heavy equipment, and accessibility of logging areas have raised the question of how much slash disposal is really necessary.

Present Disposal Job

The fast tempo of logging since World War II has greatly expanded the area cut over annually in the Inland Empire and has thereby increased the related slash problems. Approximately 2 billion feet are being cut every year from more than 150,000 acres. Expenditures for slash disposal amount to roughly 2 million dollars a year, or 10 per cent of the stumpage value of the timber harvested annually.

Not only has the slash disposal job gotten bigger; costs have gone up also, just as they have everywhere. Collections per thousand board feet for slash disposal in many cases have not kept pace with increased costs. Consequently, a lag has developed between logging and slash disposal that is causing a growing backlog of untreated cutover acreage. Where this lag exists, it reflects both the inadequacy of slash disposal funds and uncertainty about the most effective way of spending them. Where so much money is involved, the questions naturally arise, Is it being spent wisely in its present uses? and Are there better possibilities in some entirely new approach to abating the hazard of logging slash?

Much slash is being left untreated on areas of light cutting where it seems not to increase the fire hazard unduly. On some tracts of dense slash, partial disposal is practiced by complete removal of debris in compartments or bands to isolate what is left. Also some areas have such great volumes of slash that disposal methods other than broadcast burning would be prohibitive in cost. These are placed under intensive protection until natural decomposition reduces fire hazard to normal. How long this process requires under varying conditions is not known. There is danger that the buildup of logging slash acreage will strain the over-all protection effort which has until recently been organized primarily to meet the threat of fires in natural fuels.

Slash from western redcedar pole-making poses a special problem. Poles usually are made after the sawlog harvest has been completed. The resulting amount of slash is very high in proportion to the commercial volume removed; bark from peeled poles is another slash component added to the already heavy slash accumulation. Addition of pole slash to that from primary logging produces the heaviest concentrations found in the Inland Empire. The risk of fires starting is increased because the pole makers commonly work on top of dry slash left from the sawlog operation. The life of the hazard is prolonged by the practice of leaving poles in the woods to season, thereby pinning down the slash and postponing disposal. Western redcedar slash decomposes more slowly than that of other species of the region. For this reason, Barrows[2] upgrades slash containing 25 per cent or more of western redcedar, one class in fire hazard.

Logging Practices

Modern methods of logging with power saws, trucks, tractors, and jammers are a far cry from those used in horse logging days. Changing methods have affected the slash problem, in some respects beneficially, in others adversely.

Truck roads provide ready access to and within logging areas in event of fire. Hence, the danger of fires developing to large size before they can be manned is lessened. On a typical logging operation in the western white pine type 10 per cent of the area is occupied by logging roads, including right-of-way clearing, and skid trails.[26] Jammer skidding operations require spur roads, paralleling the face of the slopes, at intervals no greater than 500 feet. This means a mile of road for every 60 acres, and no part of the area is logged farther than 250 feet from a road. The network of roads, particularly parallel jammer spurs across slopes, aids in arresting fires and provides lines for backfiring.

On the debit side, clearing for roads and skid trails concentrates the slash on 90 per cent or less of the area. Also, right-of-way clearing adds much nonmerchantable material in excess of the slash from marketable trees. This is often pushed over the lower side of roads under construction and becomes a tangled mass of branchwood, tree trunks, stumps, and dirt. It is not practical to separate and pull out the lighter fuels for piling and burning during safe seasons; and it is dangerous to burn the entire mass at the only time when it will burn—after a long period of dry weather.

Methods of logging do not affect quantity of slash from the harvested trees but do govern slash arrangement. Log length skidding leaves the tops and most of the side branches where the trees are felled. Tree length skidding takes more of the branchwood away from the felling site and leaves it along the skid trails. Felling trees for tractor skidding usually leaves the tops in a different pattern from those felled for jammer skidding.

Logging has always created a certain amount of accidental or extraneous slash in the form of trees knocked over and branches stripped from trees of the residual stand. The use of machinery in modern logging has increased the quantity of extraneous slash a great deal and has created some new disposal problems. Ocular appraisals have indicated that accidental slash can equal or exceed that cut from the harvested trees. No accurate comparison of the amount of extraneous slash that results from different methods of mechanized logging has been made, and ocular appraisals can be misleading. The amount of accidental slash can reflect the care of the operator far more than any difference in logging methods.

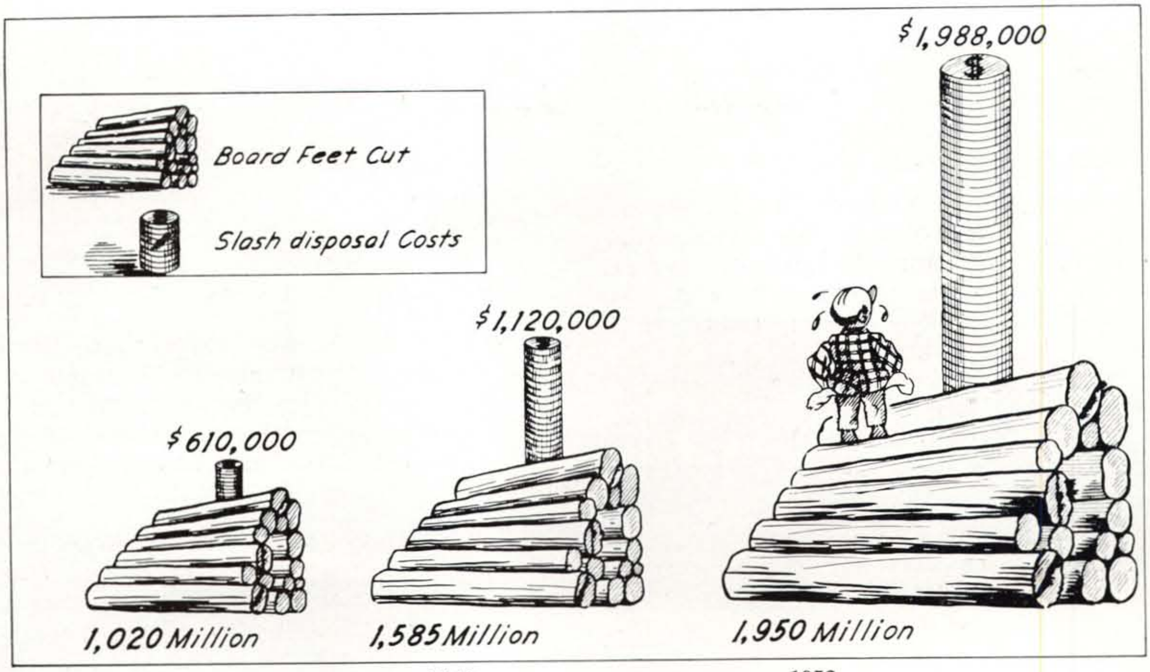
Better Utilization But More Slash: A Paradox

Strange as it may seem, vastly improved utilization in the woods has resulted in considerably more slash per thousand board feet logged. The reason for this is mainly that more unusable material is left on the ground than as upright living trees.

The present high demand for forest products makes it profitable to log defective trees and secondary species. Formerly these were left as a residual stand, useless living trees, which occupied the site to the exclusion of more valuable species. Today under favorable market conditions many trees formerly left standing are being converted to use, principally as lumber and pulp. In the process, the ratio of debris to merchantable volume taken out of the woods has increased for a number of reasons.

1. Defective trees are felled to obtain the usable portions. A 6-log tree may yield only one sound log. The balance is left as slash.
2. More shade tolerant species, with their heavy crowns and high proportion of branchwood to log scale, are being logged.
3. Trees of smaller diameters are being logged, and these have a high ratio of branchwood and tops to log scale.
4. More trees are felled to the acre; this results in a correspondingly greater amount of accidental slash associated with felling and skidding operations.

Some factors that have increased slash volume per thousand board feet of commercial volume taken out of the woods have decreased the amount of money assessed for that work. For example, the slash from a sound mature western white pine yielding a thousand board feet, log scale, will measure a cord. The cost to pile and burn, at present rates, is about $1.85. Since slash disposal assessments are made per thousand board feet log scale, this tree contributes "one unit" toward slash disposal costs. If only one-third of the tree is sound (333 board feet instead of 1,000 board feet) the tree will contribute only one-third of an assessed unit



1945 1949 1953

Figure 9. Approximately 2 billion feet are being cut every year. . . . Expenditures for slash disposal amount to roughly 2 million dollars a year.

Figure 10. High wages following the war made this method of slash treatment prohibitive in cost, and hand labor has become difficult to hire. . . .

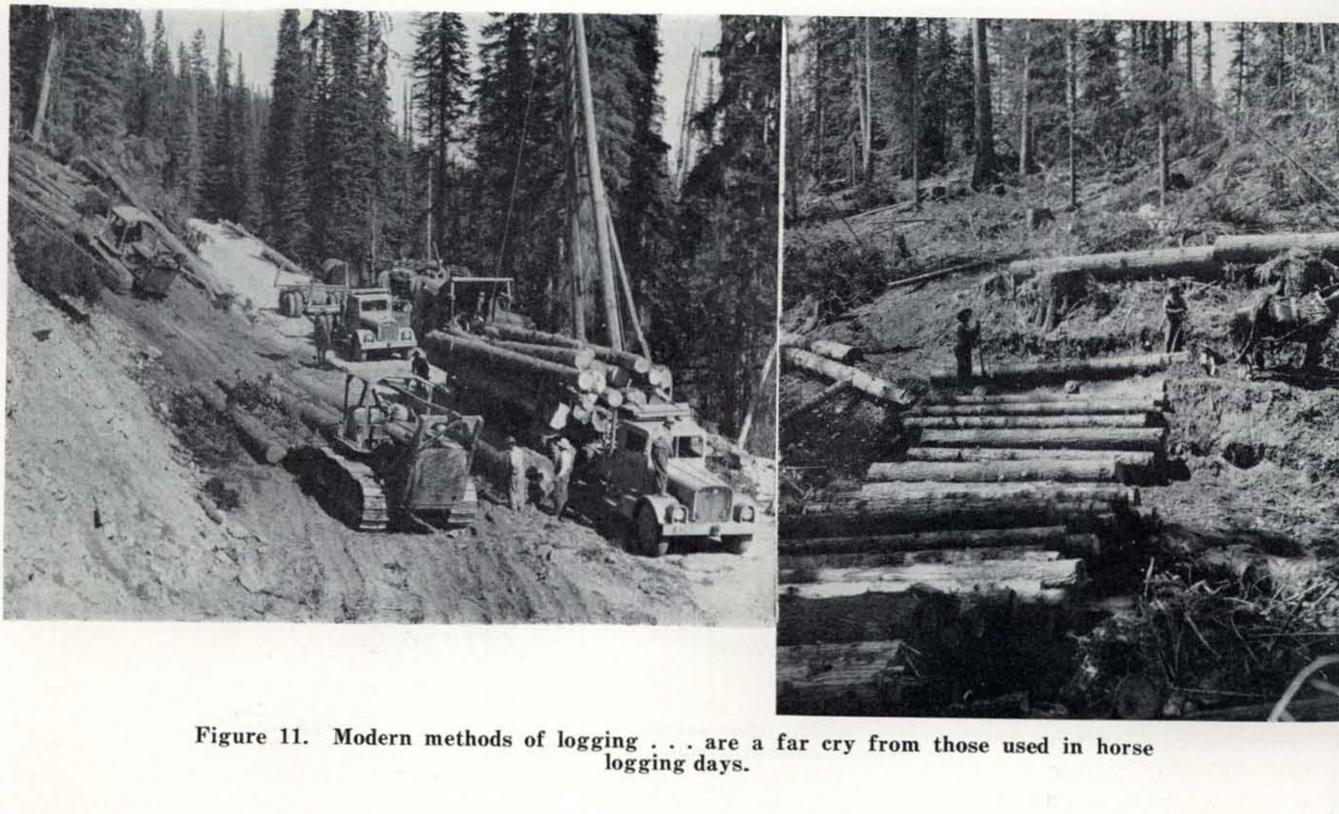


Figure 11. Modern methods of logging . . . are a far cry from those used in horse logging days.

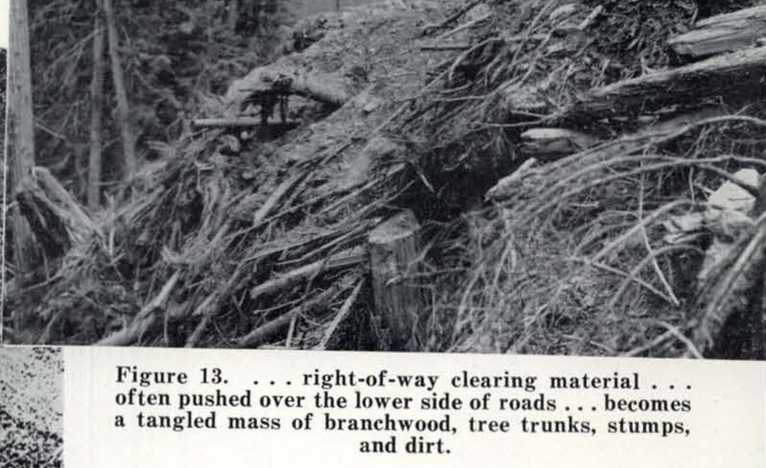


Figure 13. . . . right-of-way clearing material . . . often pushed over the lower side of roads . . . becomes a tangled mass of branchwood, tree trunks, stumps, and dirt.

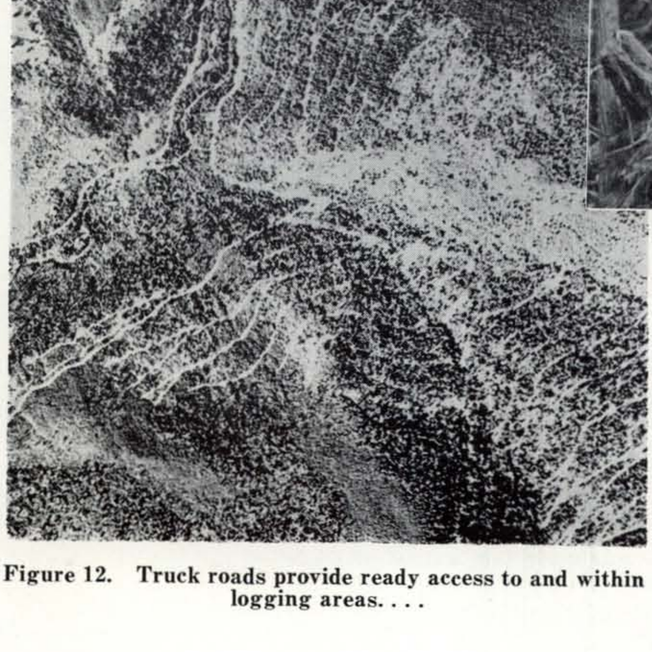


Figure 12. Truck roads provide ready access to and within logging areas. . . .

toward slash disposal; but it will leave more slash than the sound tree—the same amount of branchwood, plus the cull logs. Small trees yield more slash per thousand board feet cut than large trees. For example, cutting white pine in the 14-inch-diameter class creates ten times as much slash per thousand board feet as cutting in the 38-inch class. The net result is that the number of slash dollars, already devalued by increased disposal costs, has not been multiplied to allow for the increased volume of slash per thousand board feet of sound wood volume now harvested.

Uses for Wood Residues

The ideal in slash disposal is complete utilization of all debris remaining after logging. This has been achieved in some countries living in an economy of scarcity. It is unlikely that any such ideal of utilization will be reached in the United States while it is living in an economy of plenty unless ready availability of the material rather than scarcity of the resource is the inducement.

Rapid strides are being made in the Inland Empire in converting wood residues to useful by-products such as paper pulp, hardboard, and "Pres-to-logs," to name a few. Logically, recovery of such residues is planned first at all mill sites where the material is concentrated and to which transportation from the woods has been paid. Much waste from sawmills and planer mills in the Inland Empire is now converted to such uses. When this supply becomes inadequate, salvage operations will be extended to the woods. Already material unsuited for lumber is being brought by the trainload to a large paper mill at Lewiston, Idaho, to meet the growing demand for pulp wood that can no longer be met with sawmill residues. Anticipated expansion of the paper industry in this region will look increasingly to the woods for residues to supply the raw material. As the demand increases, more residues that are now unwanted logging slash, will be removed from the woods.

High cost of handling small material means that the larger components are in first demand. Limby slash has little likelihood of commercial use until the supply of large material has been exhausted. The fine stuff is expensive to handle because of bulk in proportion to solid wood content; the high percentage of bark and foliage at present precludes its use for paper pulp. Since the development of portable wood chippers, interest has been growing in the use of wood chips from branchwood as a soil amender and for livestock bedding.[21] Because of the low value of the product, it appears now that such use would be limited to farms in proximity to the logging area where the hauling distance is only a few miles. Nevertheless, the hope persists that ultimately portable chippers will be employed to combine slash hazard reduction with salvage of a waste product. Salvage can be expedited if the costs of salvage operations are subsidized by slash disposal funds to the extent that such operations diminish the slash problems.

No recent extensive surveys of wood residues after logging have been made in this region. As an indication of what these might be, Anderson,[1] has reported an average loss of 1,117 cubic feet per acre of wood 4 inches in diameter and larger in logging western white pine, 100 cubic feet in pure ponderosa pine, and 250 cubic feet in a mixed ponderosa pine type stand. Current studies show that limby slash from a moderate cut per acre of western white pine and associated species contains 165 cubic feet of wood solids $\frac{1}{4}$ to 3 inches in diameter.

Figure 14. Already material unsuited for lumber is being brought by the trainload to a large pulp mill at Lewiston, Idaho. . . .

Figure 15. . . . the larger components are in first demand.

Figure 16. The fine stuff is expensive to handle and the high percentage of bark and foliage precludes its use for pulp.

III. THE RESEARCH PROGRAM

Despite a half century of serious attention by some of the best minds in forestry, the logging slash problem, like many other important forestry problems, is still unsolved. Two factors have been mainly responsible for the difficulty in keeping up with the situation. First, forestry and wood utilization have been and still are rapidly changing activities in the United States. New demands, new machines, new social and economic forces constantly require the development of new knowledge and new methods. Second, in answer to the cry for answers needed for immediate use, the emphasis has been on applied research. Therefore, in very few types of forestry research has enough fundamental information been accumulated to provide a basis for answering questions as they occur.

The lack of basic knowledge is particularly frustrating where, as in the case of logging slash, the problem involves such varied considerations as fire control, silviculture, soils, pathology, and economics. Past thinking and past research led to practical solutions that never could be considered anything but temporary. One valuable basic concept has been developed, however: that each situation must be analyzed and treated according to its own merits; no single treatment is a panacea.

As a result of present economic and technical developments, the old solutions to the slash problem are at an impasse with conditions now on the ground. Since higher values and higher costs are at stake than ever before in history, research is again being pressed to provide a workable solution. Because of the broad interest and support available at this time, a logging slash research program is in the best position ever not only to solve immediate problems, but also to get at fundamentals.

The present slash research program was initiated in 1948. Through partnership the University of Idaho and the Intermountain Forest and Range Experiment Station are able to accomplish more than either organization could alone. Cooperators supply technical assistance in specialized fields. The advisory committee provides valuable guidance to the program and helps to disseminate results in the most usable form.

OBJECTIVES

The first objective of the present research program is to investigate some of the long-neglected basic facts behind the logging slash problem. This means inquiring into all phases of forestry and related subjects where slash makes itself felt—fire control, silviculture, entomology, pathology, soils, aesthetics, range and wildlife management, wood utilization, and forest influences. In some of these fields work has been done that needs only to be reviewed and interpreted in terms of northern Rocky Mountain conditions. In others, notably fire control, rather extensive controlled experiments are necessary.

The second objective is to provide tools for direct attack on the slash problem as it exists in the woods. The basic facts already mentioned are, of course, tools in themselves; but they are primarily thinking tools, which seldom give the whole answer to any specific situation. They provide general answers to the questions of what, when, where, or why anything should be done, but only occasionally do they tell how, and almost never how much must be done. Therefore research must go further and develop techniques for measuring problem situations and for dealing with them. The current program differs from its predecessors in that it aims to make available reasonably accurate measurement techniques to replace fallible human judgment.

In the third place research has the responsibility to provide a sound basis for the application of methods and techniques. The study of economics provides such a basis. Economic considerations condition the final answers to all of the questions posed in the preceding paragraph. However desirable a given measure may be technically, its adoption depends on whether it is economically feasible. The slash problem is closely tied with the economics of forest protection and management. To solve it, research will have to develop methods that can be applied for what the timberland owner is willing and able to pay.

Finally, research aimed at the slash problem is bound to provide partial answers to some other problems as well. Recognition of this fact makes it possible to so design the current research program that its by-products will be in a form usable in all probable fields of application. This does not mean that logging slash research is trying to be all things to all people, but it does mean that the program will not be blind to opportunities for contributing to related research fields.

WHERE SLASH RESEARCH IS DONE

The logging slash problem must be studied in the field, in the laboratory, and in the library. Research currently in progress covers much area and a multitude of different situations. While laboratory and library studies are necessarily confined to a few locations, field work is carried on wherever expedient in the forests of Idaho, Montana, and northeastern Washington.

Field Studies

Thorough, up-to-date knowledge of forest conditions after logging is essential to full realization and understanding of the problems involved. To obtain this knowledge the research workers annually inspect a variety of logging operations in the Inland Empire's numerous important timber types on private, state, and federal land. Specific field studies are conducted where the desired conditions occur, where labor and facilities are available, and where travel and other expenses can be minimized. As the map shows (figure 17), these activities cover a rather wide geographic area, but the effort is generally concentrated in northern Idaho. Permanent sample plots usually are established on national forest land where they are least subject to disturbance by uninformed persons.

Not all of the specific studies located on the map are subdivisions of the cooperative slash research project, but all those shown are contemporary efforts that contribute significantly to the over-all knowledge of the slash problem. Thus, for example, the study near White Sulphur Springs, Montana, is concerned with the regeneration and management of lodgepole pine; but it has yielded the best information available on the most effective method of slash disposal in the lodgepole pine type to provide for both adequate hazard reduction and prompt regeneration.

Slash Laboratory

One focal point of research activity deserves special mention. To facilitate study of slash inflammability an outdoor laboratory was established in 1952 on the Priest River Experimental Forest. This laboratory covers 5 acres of land that has been cleared of vegetation and fenced; it affords ample space in which to lay out slash for controlled experiments. A special weather station has been set up on this area to provide records needed to accompany certain types of experiments.

The location of the outdoor laboratory is ideal. All nine commercially important species of northern Rocky Mountain trees grow abundantly within a radius of a few miles. Only one mile away the experimental forest headquarters provide living facilities, office space, and an indoor laboratory well equipped to handle the requirements of the slash project. The entire experimental forest is available for such studies as can not be conducted within the 5-acre outdoor laboratory. Since Priest River is in the heart of the northern Idaho logging country, research workers there can easily study situations on the ground in relation to experiments that are in progress.

MATERIAL STUDIED

Experimentation under the present research program concentrates study on material less than 4 inches in diameter. The objective is to find out more about the effect of extensive bodies of fine fuels on fire-control problems and to provide the maximum amount of practical, money-saving information pertinent to slash disposal.

Coarse slash also can be a serious problem but disposal of the fine, kindling fuels from cutover areas satisfactorily reduces the likelihood that the remaining large material will cause trouble. Research on large slash components has consisted chiefly of keeping abreast of the work of others studying wood utilization and forest protection.

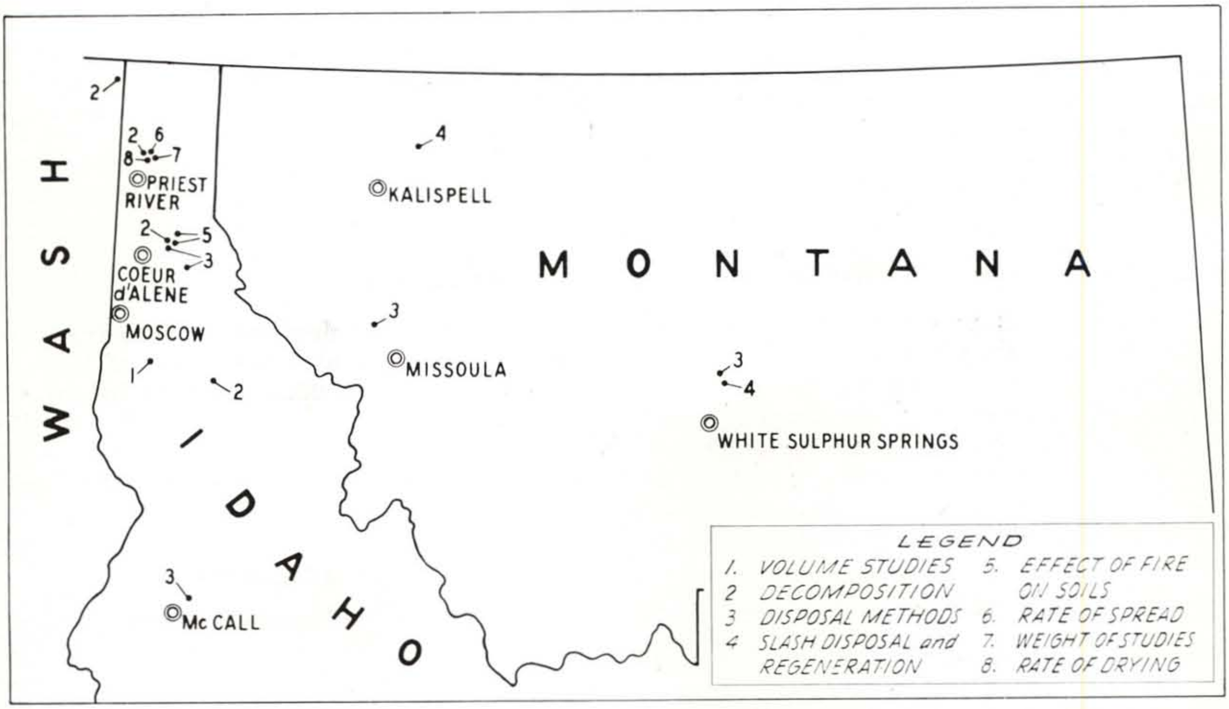


Figure 17. . . . field work is carried on wherever expedient in the forests of Idaho, Montana, and northeastern Washington.

Figure 18. To facilitate the study of slash inflammability an outdoor laboratory was established in 1952 on the Priest River Experimental Forest.

INFLAMMABILITY

Since slash is a problem primarily because of the fire hazard it creates, nearly every phase of the current research program has some tie-in with slash inflammability; and frequent allusion to inflammability occurs throughout the descriptions of the various individual studies. By deduction, many valid conclusions can be drawn concerning relative inflammability without directly measuring it. In the absence of direct measurements, however, reasoned conclusions would go untested and exact quantitative information would never be obtained. Consequently, one major research project is devoted to finding out how various characteristics of slash affect rate of fire spread, heat radiation, and other phenomena of fire behavior.[9 25]

Rate of Spread

The accepted definition of inflammability is "the ease with which fires start and spread." Ease of ignition is rather an academic consideration in the northern Rocky Mountains. Even should man-caused fires be completely prevented—a most unlikely occurrence—there still would be lightning, which starts 65 per cent of all fires at the present time. The rate at which fire spreads, on the other hand, is a very important consideration in planning for fire control, in ordering initial attack, and in determining the probable total size of the fire suppression job. In the study of logging slash inflammability, therefore, attention is focussed primarily on rate of spread.*

Experimental burning of small plots under prescribed conditions is the heart of the rate-of-spread study. Slash to be burned is obtained from healthy, normal-crowned trees that are cut especially for the purpose. Most of the trees used are 10 to 20 inches in d.b.h. and 90 to 100 years old. They are reasonably representative of the timber that make up most of the cut when virgin stands have been exhausted.

All live branches and the tip above the 2-inch diameter point are lopped off and used on the plots. In 1952 a portable chipper was available when the plots were first being established, and the entire experiment was duplicated with chipped slash. Thus, in addition to the study of the factors affecting slash inflammability, a test is being carried on of the effectiveness of chipping as a method of hazard reduction.

Three quantities of slash are burned, corresponding roughly to what would be left after light, medium, and heavy cuts of timber. The quantities are 7.5, 20.0, and 32.5 tons of oven dry slash per acre. The slash for each plot is made up of equal quantities from the top, middle, and bottom thirds of the tree crown so as to prevent abnormal results due to differences in size of material. The slash is thoroughly mixed and is distributed on plots as uniformly as possible.

Slash is placed on plots as soon as it can be cut, weighed, and hauled. It is burned, after drying, during the year it is cut, 1 year after cutting, and 5 years after cutting. Lopped slash is placed on 1/100-acre plots (20.9x20.9 feet); chipped slash on 1/1,000-acre plots (6.6x6.6 feet). Each plot is ignited at the center, and the rate at which the fire spreads outward is measured and recorded. In lopped slash, radial advance is measured by recording the time required for fire to spread outward along four diagonals marked off at 2-foot intervals from the plot center. In chipped slash increase in size is recorded by means of periodic sketches of the fire perimeter in relation to a grid which is laid over the plot. Rate of spread is calculated from these measurements.

Experimental burning is done during settled weather in August at least 2 days after any measurable precipitation and 5 days after rain totalling 0.20 inch or more. Fuel-stick moisture content must be 8 per cent or less, and wind velocity not greater than 2 m. p. h. To meet this last requirement, burning must be done late in the afternoon. During each burning session a running record is kept of wind movement, air temperature, and relative humidity. The slash on each plot is sampled for moisture content just before it is ignited.

Miscellaneous records are kept that may help to interpret rate-of-spread data. Average depth of slash is obtained through four measurements in each plot. Descriptions are written of significant changes in the appearance and gross characteristics of slash as it ages; these are supplemented by annual photographs. Still photographs and time-lapse movies are taken of representative plots as they burn, and notes

* Rate of spread is usually defined as, "The increase in size of a fire expressed in chains of perimeter per hour or some other unit."

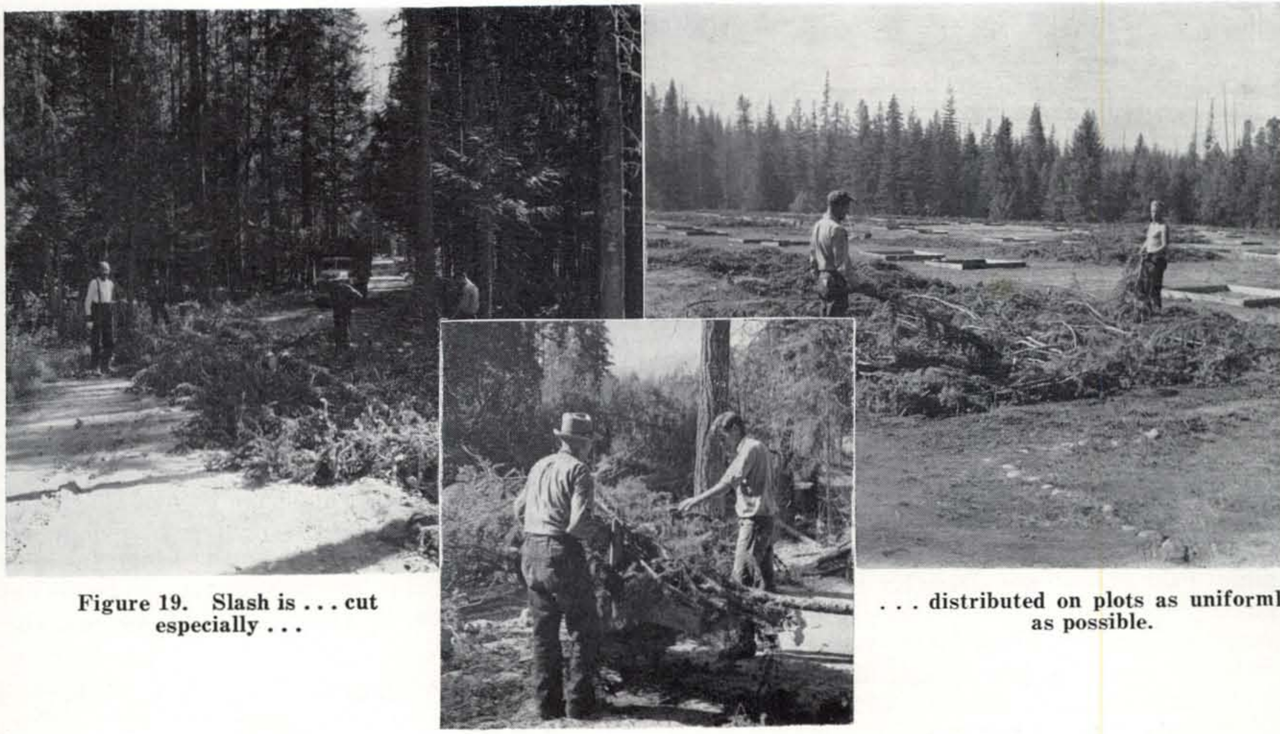


Figure 19. Slash is . . . cut especially . . .

. . . weighed . . .

. . . distributed on plots as uniformly as possible.

Figure 20

Three quantities of slash are burned . . .

. . . 7.5, . . .

20.0, . . .

and 32.5 tons of oven-dry slash per acre.

are made on significant developments. Thus a comprehensive record is built up on the burning of each species, amount, and age of slash.

Since the inception of the burning program in August, 1952, 113 plots of lopped slash and 48 plots of chipped slash have been burned. Rate-of-spread records for lopped slash burned during the year of cutting are complete for all nine commercially important timber species of the northern Rocky Mountains: western white pine, *Pinus monticola* Dougl.; Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco; western redcedar, *Thuja plicata* Donn.; western hemlock, *Tsuga heterophylla* Sarg.; Engelmann spruce, *Picea engelmannii* Parry; ponderosa pine, *Pinus ponderosa* Laws.; lodgepole pine, *Pinus contorta* Dougl.; western larch, *Larix occidentalis* Nutt.; and grand fir, *Abies grandis* (Dougl.) Lindl. One-year-old lopped slash of the first five species listed has also been burned experimentally. Chipped slash of all species except Engelmann spruce has been burned during the year of cutting and one year after cutting.

Effect of Species.—Species is an important factor affecting the inflammability of slash. Experimental burning has shown that the effect of species is least while the slash is fresh, i.e., during the year of cutting. In general fresh slash on a pound-for-pound basis, burned at about the same rate regardless of species; but there were notable exceptions to this pattern. For all practical purposes the experimental fires did not spread at all in the lightest concentrations of western hemlock and Engelmann spruce slash. The main reason was obvious: these two species lost their needles in the process of drying, and the fire was unable to crawl through the sparse layer of needles deposited on the soil surface. A contributing factor was that these two species characteristically have a high proportion of the crown weight concentrated in heavy branches, with the result that fine material is rather widely separated. Rate of spread was consistently higher in fresh western larch slash and lower in ponderosa pine than in the other seven species. The high rate in western larch was obviously due to the presence of the very fine dry needles, the finest of any species. The reason for the low rate in ponderosa pine appeared to result chiefly from the wide spacing of fine fuel components due to the branching habit of the species and to the concentration of much weight in heavy branches. After the slash had aged on the plots for one year, differences among species were more pronounced and extended to all weight classes of the five species tested, viz. western white pine, western redcedar, Douglas-fir, western hemlock, and Engelmann spruce.

It has long been believed that some species of slash are distinctly more hazardous than others because of differences in chemical composition, notably in content of oils, fats, and resins. While this belief may have some merit, experimental burning, combined with measurement and observation of slash, so far has indicated that physical attributes are more important than chemical. Quantity of slash per tree of a given size, branching habit, needle arrangement, and speed with which needles are lost are the species characteristics that have appeared to affect rate of spread significantly.

Effect of Weight.—When slash is burned within the year of cutting, quantity is the prime factor that controls rate of spread. Thus, in general, 32.5 tons per acre of any species burn faster than 20.0 tons of any other species, and 20.0 tons burn faster than 7.5 tons. There are exceptions to this rule, but they do not detract from its importance. Average rates of radial spread in 32.5, 20.0, and 7.5 tons per acre of the current year's slash were found to be 3.0, 1.5, and .75 feet per minute, respectively. As absolute values these figures may not mean much. They are significant chiefly because they show that radial spread increases at the rate of 6 per cent per ton of additional slash.

While they may not accurately represent field conditions, the above rate-of-spread figures are the best basis available for comparing slash with other fuels. Converted to perimeter increase per hour, the standard measure of rate of spread, they become 16, 8, and 4 chains per hour. Adjusted to a burning index of 70—standard for fuel-type ratings—and a slope of 35 per cent—average for U.S. Forest Service Region 1—they are 67, 34, and 17 chains. This means that any fresh slash, when dry, falls in the extreme rate-of-spread class if the weight per acre is more than about 12 tons.

Effect of Age.—In the outdoor laboratory, aging over one winter produced two notable changes in slash of the five species that were given two burning tests. Douglas-fir lost all of its needles, to join Engelmann spruce and western hemlock in this respect; and compaction reduced slash volume about 17 per cent

Figure 21. Each plot is ignited at the center.

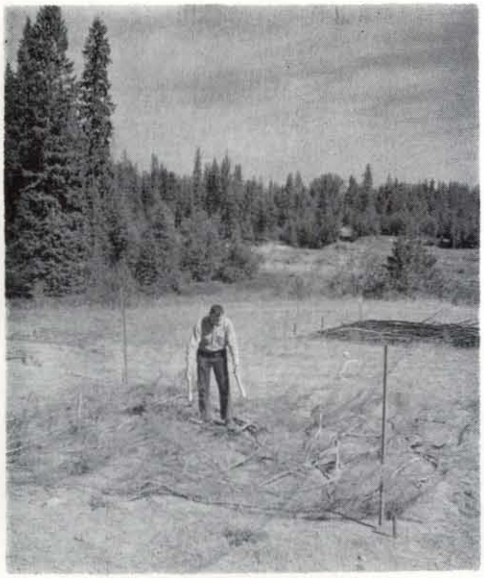
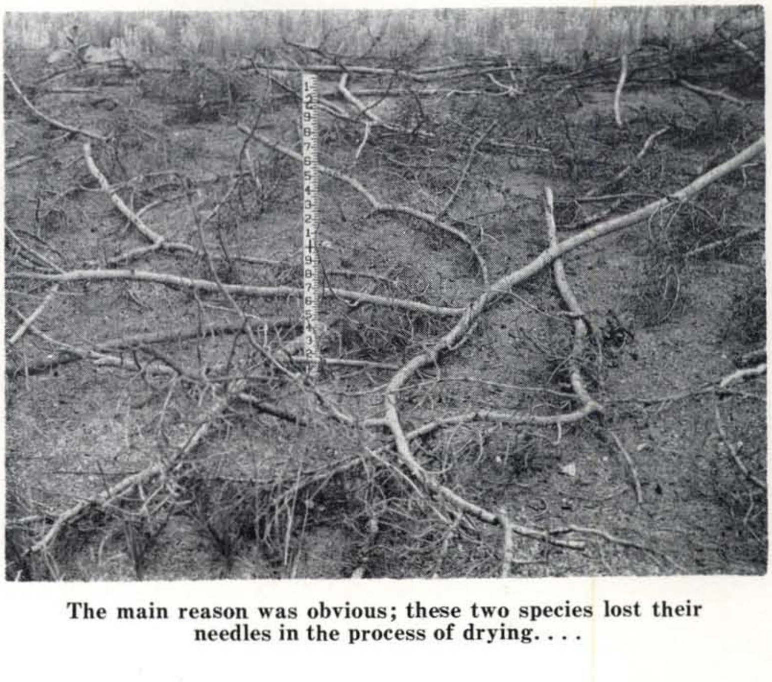


Figure 22. . . . fires did not spread at all in the lightest concentrations of western hemlock and Engelmann spruce slash.



The main reason was obvious; these two species lost their needles in the process of drying. . . .

7.5 tons per acre | 20.0 tons per acre | 32.5 tons per acre

Figure 23. When slash is burned within the year of cutting, quantity is the prime factor that controls rate of spread. (All plots photographed at 3 minutes after ignition.)

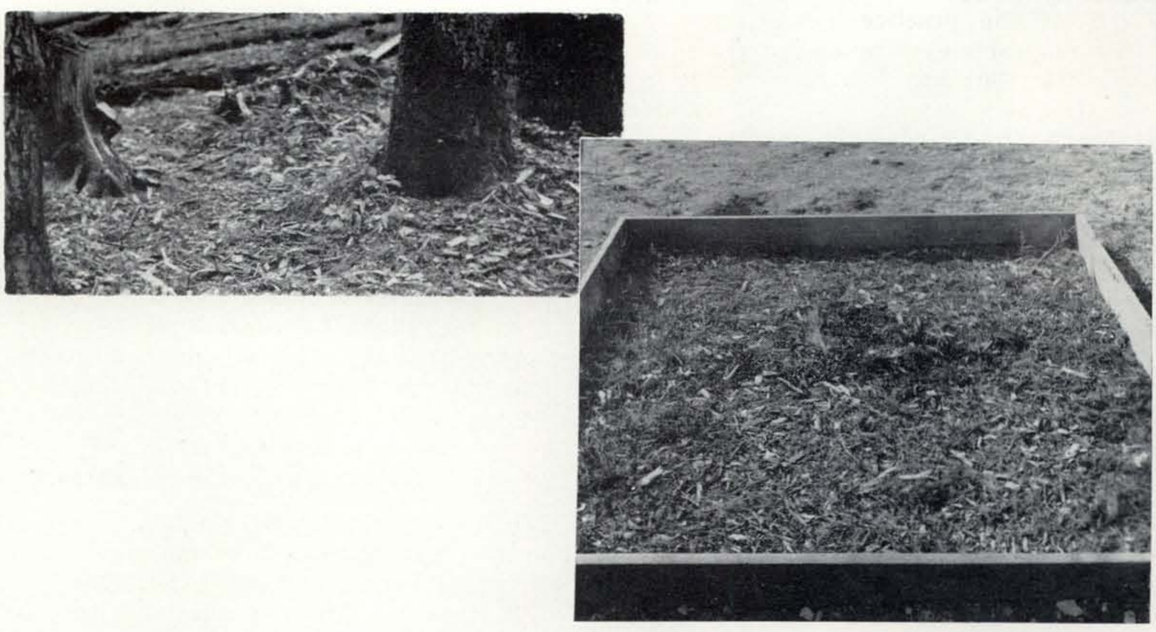


Figure 24. Chipped slash looks much like the duff and litter of the forest floor, and that is how it burned. . . .

on an average in all species. Some loss of needles occurred in western white pine and western redcedar, and some twig breakage and bark fissuring in all species; but these effects of age were relatively insignificant at this stage.

Despite the relatively small apparent changes in all but Douglas-fir slash, aging 1 year reduced rate of fire spread by 32 to 71 per cent in the five species tested. Rearrangement of the finer slash components, notably needles, seemed to be the most important criterion of inflammability changes. The smallest reductions in rate of spread occurred in western white pine and western redcedar slash, which still held foliage and fine twigs in much the same arrangement as during the previous year. Rate of spread declined greatly in Douglas-fir slash, which had lost all of its needles since the original plots were burned. Rate of spread also became considerably slower than the previous year in medium and heavy western hemlock and Engelmann spruce slash, the apparent reason being that the fallen needles had become compacted on the ground over winter to the extent that fire did not crawl through them readily.

Effect of Relative Humidity.[10]—Records of relative humidity, temperature, and wind movement were kept while plots were being burned primarily to maintain a check on the comparability of results; but something more came out of the practice. Burning in late afternoon and early evening avoids undesirable wind velocities but has forced the acceptance of a variation in humidity from a minimum of 23 per cent at the start of the burning session to over 90 per cent at the end. This situation has resulted in a good demonstration of how rising relative humidity affects rate of fire spread in relation to fuel quantity. A 10 per cent rise in humidity caused increases of 11 seconds and 8 seconds, respectively, in the time required for fires to spread 1 foot radially in light and medium slash concentrations (7.5 and 20.0 tons per acre). The lightest concentrations could hardly be burned at all toward the end of the evening. Fires in heavy slash (32.5 tons per acre), however, were not significantly affected by rising humidity within the $1\frac{1}{2}$ to 2 hours during which burning was done. Thus, the experimental burning program has given a graphic demonstration of the fact that nightfall usually brings fire fighters quick help where fuels are sparse and fine, whereas fires burn hot well into the night in heavy fuel concentrations.

Effect of Chipping.—Chipped slash looks much like the duff and litter of the forest floor, and that is how it burned on the plots at Priest River.[8] Fires did not spread consistently in chipped slash except during periods of high temperature, low fuel-moisture content, and low humidity. Even then the fastest spread in chipped slash was only about one-third the rate of spread in the slowest of the lopped slash.

Contrary to experience in burning fresh cut lopped slash, species is more important than quantity in determining rate of fire spread in chipped slash. Chipped pine slash burns fastest because the long needles pass through the chipper virtually intact and form a relatively well-aerated surface on the fuel bed. Chipping short needled species, on the other hand, produces a more compact, duff-like surface that does not support rapid combustion. Results of experimental burning have shown that chipping effectively reduces slash inflammability.

Heat Radiation

Heat radiation is an important factor in fire behavior and in the effects of fire. Intensity of radiation, modified by weather factors and fuel moisture, determines how quickly and at what distance from a fire new fuels are ignited. Radiation intensity is a good indicator of the strength of convectional air currents which a fire can set in motion, hence of the likelihood that spot fires will occur, and the distance they may be from the main fire. Radiated heat is directly responsible for much of the damage that slash fires cause to residual trees.

In the experimental slash burning program, heat radiation is measured on every plot. Results from the first three years of burning are not comparable because three different types of radiometers have had to be used, but some general conclusions can be drawn. As would be expected, intensity of radiation increases as amount of fuel per acre increases. The relationship appears to parallel very closely that which rate of spread bears to fuel weight per acre.

Some species of slash, notably western white and lodgepole pine, burn much more violently than others. The flames are higher and give off large quantities of black smoke. In quiet air these fires exhibit a pulsation effect, featuring low-order explosions of combustible gases

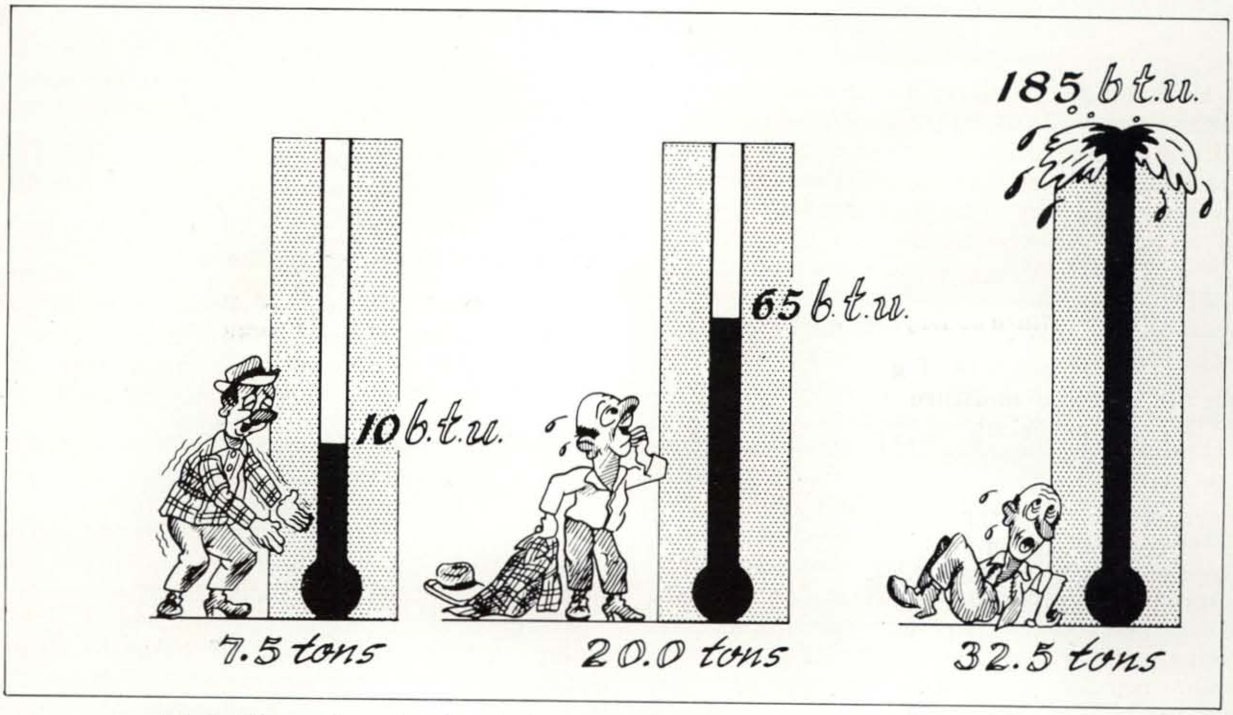
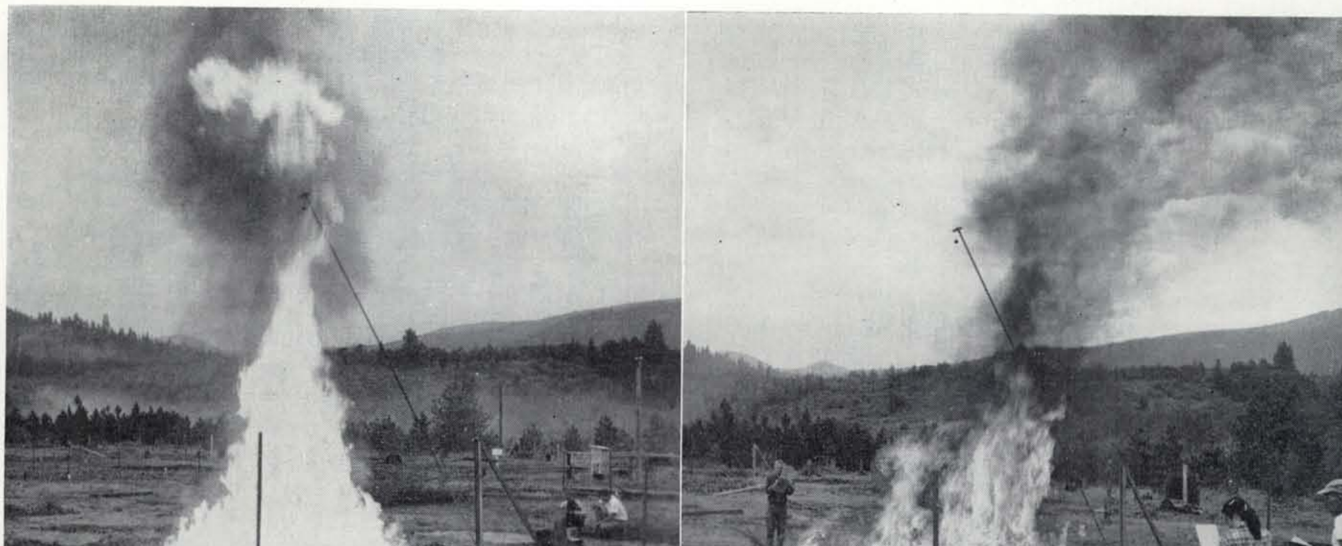


Figure 25. ... intensity of radiation increases as amount of fuel per acre increases.



A B

Figure 26. Some species of slash, notably western white and lodgepole pine burn much more violently than others. A, western white pine; B, western hemlock.

above the main level of the flames. Average maximum radiation from plots of western white and lodgepole pine slash so far has been roughly twice that from any other species. Radiation from western redcedar has been somewhat above that for the remaining six species.

Rate of Drying

The finer components of green logging slash have an average moisture content of around 100 per cent when cut. How soon after cutting does slash become dangerous? Both experience and experimental slash burning results have shown conclusively that slash is most hazardous during the season of cutting, provided it has time to cure. Therefore, to be most effective, slash disposal should be accomplished not only during the year in which the timber is cut, but also before the slash has time to dry. Knowledge of the rate of drying is, then, a prerequisite to the most effective reduction of the fire hazard resulting from logging slash.

A study on the Priest River Experimental Forest in 1953 gave some idea of how soon slash dries to a fully inflammable state. Lopped branches in full sunlight dried to 10 per cent moisture content in 14 days; fully shaded branches reached a minimum of 11 per cent after 25 days. Needles and fine twigs attached to large tops dried much more slowly. Tops exposed to full sun became dangerously dry after about 6 weeks, while those in full shade had dried only to 75 per cent moisture content after 11 weeks, when the experiment was discontinued. Wood in the trunks of these same tops dried to about the fiber saturation point —30 per cent—in 5 to 6 weeks and thereafter underwent no significant change. This was about 10 per cent higher than the moisture content of deadwood of the same size.

The results of the 1953 study of slash moisture content provide some useful guidelines for disposal of the current year's slash. The following suggestions apply primarily to areas where the slash disposal job actually will reduce inflammability or otherwise contribute to easier fire control during the current season.

1. Lopped and broken-off branchwood should be given first attention. On exposed sites it should be cleaned up as soon as possible after logging. In sheltered situations up to 3 weeks of drying weather may be permitted to elapse.
2. Tops cut before July 15 to August 1 and exposed to strong or moderate drying conditions should be treated within 5 to 7 weeks after cutting. Those cut later probably will not become dangerously dry before the end of the fire season.
3. Well-shaded tops in lightly cut stands and on steep north aspects ordinarily need not be treated during the first season.
4. Large slash components, e.g., broken chunks, cull logs, trunks of tops, probably remain too wet to burn well during the entire season of cutting.

Rate of Decomposition

If slash is to be left in the woods and the hazard met by intensive protection of the cutover area, it is important to know how long such protection will be necessary; in other words how fast natural processes of decomposition break down the flashy fuels to alleviate the fire danger. To study slash decomposition a series of permanent sample plots has been established in various locations from the northern tip of Idaho to the Clearwater region representing a fairly wide range in latitude, altitude and site conditions. Each area contains plots of piled slash, lopped and scattered slash, and slash as left by loggers. One installation also includes a plot of chipped slash. In addition, slash decomposition is being studied on old cutting areas where reliable case histories are available.

It is still too early to draw definite conclusions from these studies but the following observations indicate trends:

1. During the first year winter compaction amounts to about 20 per cent for lopped slash and 36 per cent for piled slash.
2. Slash decays most rapidly when brought close to the ground; for this reason lopped slash shows the fastest rate of decomposition.
3. Compaction not only reduces air space and consequently available oxygen for combustion, but also brings the fuels closer to the ground where conditions are most favorable for growth of decay organisms.
4. Branchwood left high above the ground becomes case hardened and, after shedding

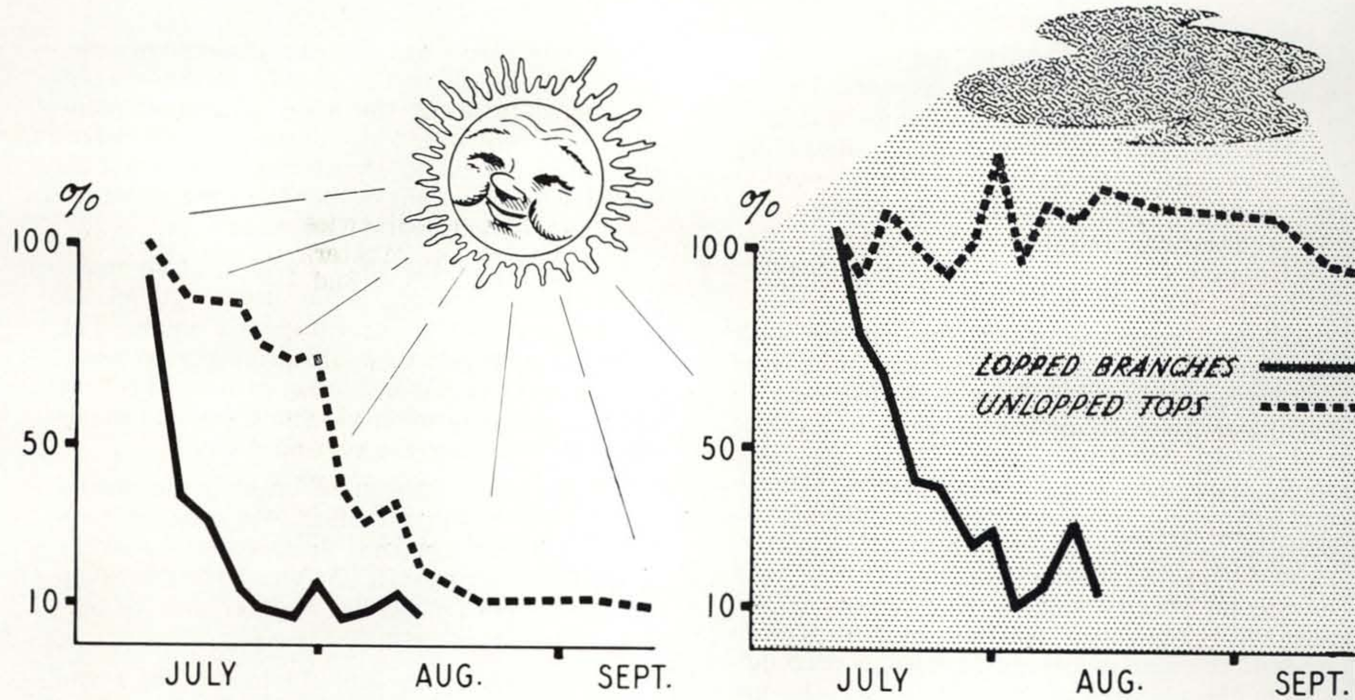


Figure 27. Lopped branches in full sunlight dried to 10 per cent moisture content in 14 days; fully shaded branches . . . after 25 days. Tops exposed to full sun . . . after about 6 weeks; while those in full shade had dried only to 75 per cent moisture content after 11 weeks.

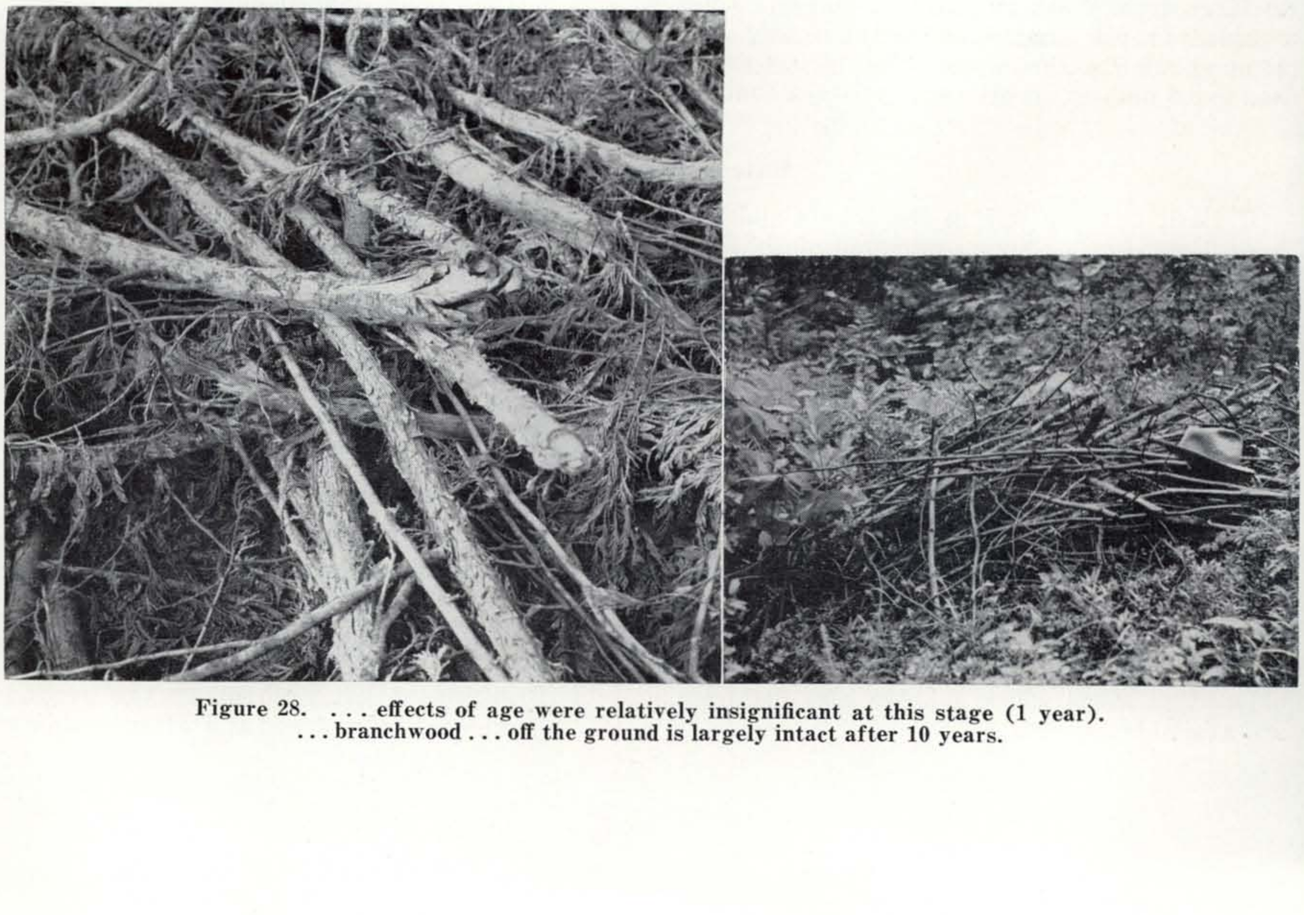


Figure 28. . . . effects of age were relatively insignificant at this stage (1 year). . . . branchwood . . . off the ground is largely intact after 10 years.

the bark, undergoes very little change until by some means the wood is brought close to the ground.

5. By the end of the first year, needle cast is complete for Douglas-fir, western hemlock, western larch and Engelmann spruce, and nearly complete for grand fir. Although a large percentage of pine needles is in place the second year (remaining a high fire hazard), these needles fall off in handling. Western redcedar foliage persists until the fine twigs break down.
6. Disintegration of fine twigs begins in the second year after cutting and is quite pronounced by the third year.
7. Bark begins to loosen significantly the third year.
8. Decay of branchwood is relatively slow. Species having a high percentage of sapwood, like white pine, decay most rapidly; but even so, branchwood of this species, if off the ground, is largely intact after 10 years. Western redcedar is commercially important because it resists decay. This property likewise makes the slash more durable. Western redcedar branchwood has been found little changed 30 years after cutting.

While disintegration of the heavier components of slash is slow, the flashiest fuels—needles, twigs, and bark—disappear in a few years. These components may represent as much as 50 per cent of the volume of solids in limby slash. It has been repeatedly observed, however, that slash can continue to be a very dangerous fuel long after the finest material has disappeared.

QUANTITY AND ARRANGEMENT

Quantity more than any other characteristic of slash governs both inflammability and the size of the disposal job. The accepted practice is to express slash quantity in terms of the volume of timber, board measure, cut on an area. The result is an extremely vague picture of the general slash situation little influenced by either of the important factors, species and tree size. Development of a much more accurate method of measuring slash is prerequisite to satisfactory evaluation of the fire hazard and planning for its abatement. The question is, how to measure a substance that is essentially a mass of odd-shaped solids more or less suspended in air.

Solids, or groups of solids, can be measured in terms of either weight or volume. The slash measurement problem has been attacked from both standpoints. The University of Idaho has concentrated on volume measurements, the Forest Service on weight. The cooperative nature of the research program has resulted in reasonably good correlation between the two methods of slash measurement. To some extent the same trees have been used for the development of both methods. In this way, and through calculation of equivalents, measurements made by either method can be converted into terms of the other. Therefore the potential user may have his choice of methods, and more has been learned about slash quantity and its measurement than if only one method had been investigated.

In the interest of using familiar terminology, volume is the logical point of departure, for foresters are accustomed to measuring their products in terms of volume. "Cords" and "cubic feet" have a familiar sound. Any stated number of "cords per acre" means a series of piles having a known size. Weight, on the other hand, is an unfamiliar concept in connection with the raw products of the forest; it is used almost exclusively as a measure of railroad freight charges and truck load limits. Thus, from the standpoint of utility, as a measure of work to be done terms designating volume may have more meaning than units of weight do for many people. Furthermore, speaking in terms of volume conveys the best possible impression of how unwieldy slash is. Piling a ton of slash is quite a different matter from shoveling a ton of coal.

From the technical point of view, weight is definitely superior to volume. Weight expresses directly and accurately the exact heat content of combustible material. Where the relationship between weight and volume is practically constant, the latter may be used for the sake of convenience, as with liquid fuels. However, in the case of logging slash, the weight-to-volume relationship is extremely variable. Species and age of the timber cut, length of time since cutting, arrangement of slash as a result of logging—these and other considerations govern how much volume a given weight of slash occupies.

It should be apparent by now that neither weight nor volume alone expresses a complete concept of slash quantity. Volume by itself is accurate only at the moment of measurement and for the specific body of slash being measured. Weight by itself is an accurate and consistent measure of fuel quantity but gives no clue either to the rate at which the fuel will burn or to the difficulty of getting rid of it. Combining the two units of measure is more likely to give a basis for understanding a large segment of the logging slash problem.

Volume

How much slash constitutes a serious fire hazard? Obviously one tree felled to the acre does not leave a slash problem, nor do two nor three. Certainly the slash from three trees would make a good bonfire, but the area involved would be relatively small. As more trees are felled, both depth and area of slash increase until ground fuels are connected across the entire acre or the proximity of heavy concentrations creates an equally dangerous situation. Inflammability studies were designed to appraise fire danger in terms of known quantities of fuel. Volume measurements were taken to determine the principal factors that affected quantity of slash fuels, and to some extent their arrangement, in relation to the amount of timber harvested.[23]

Measuring Slash Volume.—As the basis for calculating volume, slash from individual trees was measured, usually from trees felled in normal logging operations over a wide area in the western white pine type. Only the lighter material up to a 4-inch diameter, such as is customarily piled for burning, was included in the measurements. Depth and area measurements were taken of the slash as left by the loggers and again after lopping the top and spreading the branches, as is done in the "lop-and-scatter" treatment when slash is left to natural processes of decomposition. Then the slash was piled in the conventional manner and again measured.

In any of these arrangements the percentage of solids to the entire mass is very small. However, the critical factor in rate of spread is not just the percentage of solids in a given mass of fuels but the arrangement of those fuels within the mass. For example, a 4-foot scantling is a heavy solid occupying little space, and it cannot be ignited with a match. Made into excelsior, it becomes 12 cubic feet of fluffy, highly inflammable material. Needles, twigs, and fine branches are somewhat comparable to the excelsior, and the coarser 2-to-4-inch wood to the scantling.

The depth of unpiled slash represents chiefly arrangement and size of components and is not necessarily a good indicator of the amount of solid material present. Area covered by connected fuels has great significance because it indicates the potential area and perimeter of the fire and hence the chains of fireline needed to control it. The slash from an average mature western white pine tree covers about 500 square feet. In the arrangement left by loggers, the depth varies from 1 inch to 4 feet or more, with large vertical and horizontal blank spaces, or voids, interspersed throughout the mass.

When slash is lopped and spread uniformly, the gross area is not likely to change appreciably; but depth is lessened, and horizontal blank space is reduced. Piling compresses the slash and removes much of the variation in volume caused by large voids in strewn slash. Hence cubic measure of piled slash was used as the standard for computing slash volume. Volume has been expressed in terms of both cubic feet and cords.

Slash Volume and Tree Size.—Crown volume increases with growth of the tree. However, the proportion of crown to tree size and commercial volume decreases. As trees extend upward, new branch development is largely offset by natural pruning. In merchantable sizes the ratio of crown volume to commercial volume decreases very rapidly up to a certain diameter; beyond this it decreases at a constant rate. The breaking point is reached earlier by intolerant species growing in dense stands. It takes six western white pine trees 12 inches in diameter to produce the same scale as one tree measuring 24 inches in diameter, but the latter produces only half as much slash as the six small trees. The same type of relationship exists in every species that grows in this region. The volume of slash per thousand board feet logged is much greater in young stands than in mature stands.

Slash Volume and Species.—The volume of branchwood in young trees grown under similar conditions is much the same for all species associated with the western white pine type. By the time trees are about 40 years old, however, differences in branchwood volume have become apparent. Such intolerant species as western larch and western white pine characteristically have short branches and prune themselves rather rapidly. With the tolerant western redcedar, Engelmann spruce, and western hemlock the lower branches persist and become long and coarse. Thus it is not surprising to find that volume of branchwood is closely related to the scale of shade tolerance among these species.

The wide range in volume of limby slash per tree within the same species and diameter class is due mainly to influences of such factors as site quality, stand density, and crown class. Intolerant trees growing in the open, trees at the fringes of stands, and "wolf" trees may have a ratio of crown to tree size quite comparable to that of tolerant trees. Ponderosa pine, an intolerant tree that commonly grows in open stands, may have as heavy a crown as the tolerant species.

Commercial volume also is affected by species characteristics, particularly taper, so that trees in the same diameter class may yield considerably less scale in one species than in another; and hence, more trees in some species are required to make a thousand board feet than in others. Local volume tables for 16-inch western white pine, Douglas-fir, and western larch of average height give a scale (Scribner) of 370, 260, and 220 board feet respectively, while the more tolerant Engelmann spruce and western redcedar have a scale of 160 and 190 board feet. Combining the factors, crown volume and commercial volume, results in a high ratio of branchwood to board feet among the tolerant species. Engelmann spruce, for example, leaves about four times as much slash as western white pine per thousand board feet logged.

Observation of inflammability tests has indicated that fire may be difficult to control on a bad day even in light density slash—7.5 tons or 30 cords per acre—in connected fuels before needle cast. Fire behavior is most violent in species with characteristically "fluffy" branches such as western white pine, lodgepole, and Douglas-fir. Possibilities of control become progressively less in heavier concentrations of slash and in dangerous topographic situations.

The crux of the whole slash problem lies in heavy concentrations. Fire hazard is extreme, disposal methods other than broadcast burning are ineffective, and costs are exorbitant—upward from $100 per acre. When such conditions exist, the only choice is to broadcast burn the area or to leave it to intensive protection. Thus, the choice is forced to one of two alternatives, neither of which may meet the silvicultural goals of forestry on the tract. The best possibility now apparent of avoiding this dilemma is to prevent heavy concentrations from developing on areas which should not be broadcast burned. Results of the slash volume studies will aid in appraising the slash problem that is likely to result from any planned harvest of any species in the region and any size class.

Slash Volume and Natural Fuels.—Logging slash is additional fuel superimposed upon whatever natural fuels already exist. Consequently in any appraisal of the fire hazard in slash, natural fuels must be taken into account. If the rate-of-spread rating is "medium" before cutting operations, it does not take much slash to bring the rating up to the dangerous "high" classification.

Slash disposal operations assume responsibility only for additional fuel created by logging. When natural fuels contribute substantially to a high hazard rating of the combined fuels, it is questionable whether hand piling and burning the slash alone is a practical means of lowering the fire hazard. However, where bulldozer piling can be done, this method of disposal is highly effective because both slash and natural fuels are scooped into piles for burning.

Calculating Weight of Slash

Weight has been used as the basic measure of slash in determining inflammability. Fire research men in California have found that in each species of tree the dry weight of branches and foliage bore a consistent relationship to stem diameter and length of live crown. Investigation has revealed that the same principle holds good for trees in the northern Rocky Mountains. Through measuring and weighing several hundred trees, a system has been developed for determining crown weights of all nine commercially important species of the northern Rocky Mountains. Although the calculations are somewhat involved and time-consuming, the final product (not yet available) will be a series of tables from which dry weight of crown can be read opposite d.b.h. and crown length.

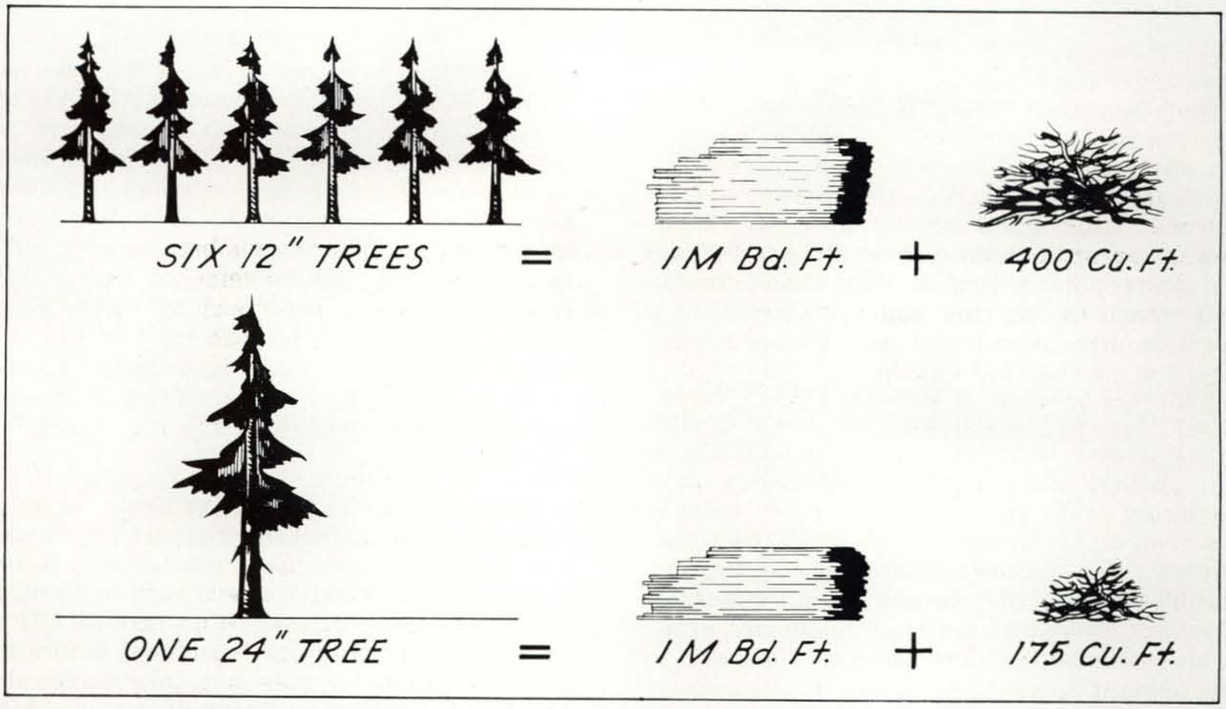


Figure 29. The volume of slash per thousand board feet logged is much greater in young stands than in mature stands.

Tolerant Spruce **Intolerant Larch**
Figure 30. . . . Volume of branchwood is related to shade tolerance.

Ponderosa pine, an intolerant tree which grows in open stands, may have as heavy a crown as tolerant species.

In general crown weight bears the same relationships as crown volume to tree species, size, and form. Dry weight of the living crown is usually greater for tolerant species than for intolerant. Thus western redcedar, western hemlock, Engelmann spruce, and grand fir crowns are much heavier than those of western white pine, lodgepole pine, and western larch trees having the same diameters and crown lengths. Ponderosa pine is the notable exception to the relationship of crown weight and tolerance. This very intolerant tree commonly has a heavy crown; most of its weight, however, is concentrated in big limbs, not in the finer components that contribute most to inflammability.

Research on crown weight and volume has largely answered the troublesome question of why some species of slash have long been rated a more serious fire hazard than others, even though experimental burning results have shown that species has negligible effect on rate of spread in equal amounts of freshly cured slash. The significant point is that the feared species produce several times as much slash per acre as the lightly regarded ones in comparable stands. The intermediate or low hazard rating built up over the years for such large-crowned species as spruce and hemlock depends on the fact that they lose their needles very soon after cutting.

When completed, crown weight tables will be used like timber volume tables. Only through coincidence does the tabulated value closely approximate the weight of any individual tree crown; but the accuracy over any appreciable number of trees, say 1,000 is acceptable. Therefore use of crown weight tables in conjunction with a stand table supplemented by a representative sample of crown length measurements should make possible the advance determination of slash weight per acre, hence potential inflammability, slash disposal needs, and expected size of the disposal job. It is anticipated that in the long run, calculation of slash weight per acre can be simplified through the construction of yield tables based on species, site, and stand characteristics.

Arrangement

The term "arrangement" as applied to slash, has a number of connotations. First, it calls to mind the distribution pattern of slash on the ground. Then, within the slash itself is the proportion of solids and voids as influenced by branching habit, distribution of foliage, and degree of compaction. Finally, there is the surface-area-to-volume ratio, or shape factor, which pertains to the size and shape of slash components and is not really a question of arrangement at all, but can best be considered at the same time for convenience. All of these considerations are important factors affecting inflammability, and through it, the slash disposal job.

Distribution.—The distribution of slash on a logged off area is a function of a complex of factors, chief of which are species, age, size, and condition of the timber, marking practice, method of logging, and volume cut. Three general patterns are commonly recognized: continuous, in which the entire area is covered rather uniformly; patchy, in which the area is spotted with detached bodies of slash; and network, a condition midway between the other two, in which the slash cover is connected but contains large openings. Quantity of slash determines whether it can form a continuous cover or large separate concentrations. Distribution of slash over an area depends chiefly on marking practice and method of logging. If the trees cut are distributed evenly over the area, the slash should be also; where trees are cut in groups, the slash will occur in patches. But felling in windrows and skidding with tractors tend to arrange slash in bands separated by bare ground, while jammer skidding creates concentrations across the slope between roads, regardless of how the trees cut were distributed.

Continuous slash would seem to be the most dangerous arrangement from the standpoint of fire-control, but many experienced firemen contend that in an area of scattered fuel concentrations, such as unburned slash piles, fire spreads faster by spotting and is more resistant to control than it would be if the same amount of fuel were spread out uniformly. This important question of fire behavior needs to be answered definitely. It seems entirely possible that both contentions may be right. Where enough slash is present to form a *deep*, continuous fuel bed, as when stands of mixed western white pine and western redcedar are cut heavily, it is hard to see how patchy concentrations could be as dangerous as a continuous pattern. But where uniform distribution would produce only a thin bed of fuel, then the same amount of slash in piles might make a fire harder to control by building up unapproachable hot spots

Figure 31. Skidding with tractors tends to arrange slash in bands separated by bare ground.

Figure 32. Continuous slash would seem to be the most dangerous, but . . .

. . . slash in piles might cause a fire much harder to control by building up unapproachable hot spots.

and showering the rest of the area with sparks.

Solids and Voids.—A vital factor affecting rate of combustion is the space occupied by fuel per unit of solid volume or weight—fuel density, in other words. Research has progressed far enough to produce some very interesting figures. In western white pine slash, for example, the volume of solids is actually less than 1 per cent of the total space occupied by fresh cut, untreated material. Lopping reduces the over-all volume by about 40 per cent, piling by 93 per cent, and chipping by 98 per cent.[24]

When slash is separated into its component parts, 31 to 64 per cent of the volume and 38 to 66 per cent of the weight are in material 1/4 inch and less in diameter. Needles alone comprise 34 to 51 per cent of the total oven-dry weight. Because of the small number of samples analyzed to date available figures are frequently inconsistent, but general relationships are beginning to take shape. In general, tolerant species have a larger proportion of their total slash weight in needles and small twigs than do intolerant species.

Surface Area and Volume.—The surface-area-to-volume ratio, or shape factor, is a measure of the relative area exposed to air and to radiational heating. A given weight of excelsior burns far more rapidly than the same weight of solid wood because the excelsior has so much more area in proportion to its solid volume. Preliminary calculation has shown that the average pound of Douglas-fir slash has a surface area of approximately 25 square feet. To have the same surface area, a solid cube of Douglas-fir wood would have to be 2.1 feet each way; it would weigh 225 pounds. Foliage is largely responsible for high surface-area-to-volume ratios in slash. Although needles make up only about 35 per cent of the weight of Douglas-fir slash, they account for more than 80 per cent of the surface area.

Actual uses for the calculated values related to arrangement are still somewhat obscure, but their significance is quite apparent. Rearrangement that causes compaction or changes the surface-to-volume ratio alters combustion rate. Thus the reduced inflammability of Douglas-fir slash after aging 1 year reflects the loss of needles, which amounts to (1) compaction of 35 per cent of the fuel weight into much smaller volume and (2) reduction of exposed fuel surface area by nearly 80 per cent. Studies relating to slash arrangement should lead to better understanding of how effective various methods of slash disposal methods are likely to be and how soon natural decomposition can be expected to effect satisfactory fire hazard reduction.

EFFECTS OF FIRE ON SOIL

Whether fire should be used as a means of slash disposal is a matter of great concern to foresters. The effect of fire on site is a basic consideration in choosing a slash disposal method.

Fire is largely responsible for perpetuating the western white pine type. Generally foresters advocate judicious use of fire as a silvicultural tool in western white pine management. Regeneration by either natural or artificial means is more definitely assured on exposed mineral soils than in litter, and in white pine blister rust control zones, ribes eradication is simplified by intense broadcast burns. Consequently controlled broadcast burning, in addition to removing a high slash-fire hazard, may serve as a means of attaining silvicultural aims. In this situation slash becomes an asset by providing a hot fire. However, much speculation persists as to possible adverse effects of fire on run-off, erosion, loss of organic matter, and general site deterioration.

Studies of 14 areas in the western white pine type thus far have shown little cause for concern over the effects of fire on soil.[11] Only two areas showed reduction in infiltration rate due to burning. Erosion was found on only one area after a burn; it appeared to result from very slow revegetation of the area. Chemical analysis showed that total nitrogen and available phosphorus were generally slightly higher on burned than on unburned soils. Soil acidity decreased after burning. Investigations of the organic matter on the forest floor indicated that surface organic matter might regain its initial weight and depth in as short a time as 50 years.

Apparently there are three good reasons why fire has caused no serious alteration of the sites tested:

1. Mosses, lichens, and various herbaceous plants quickly revegetate burns in the western white pine type and greatly di-

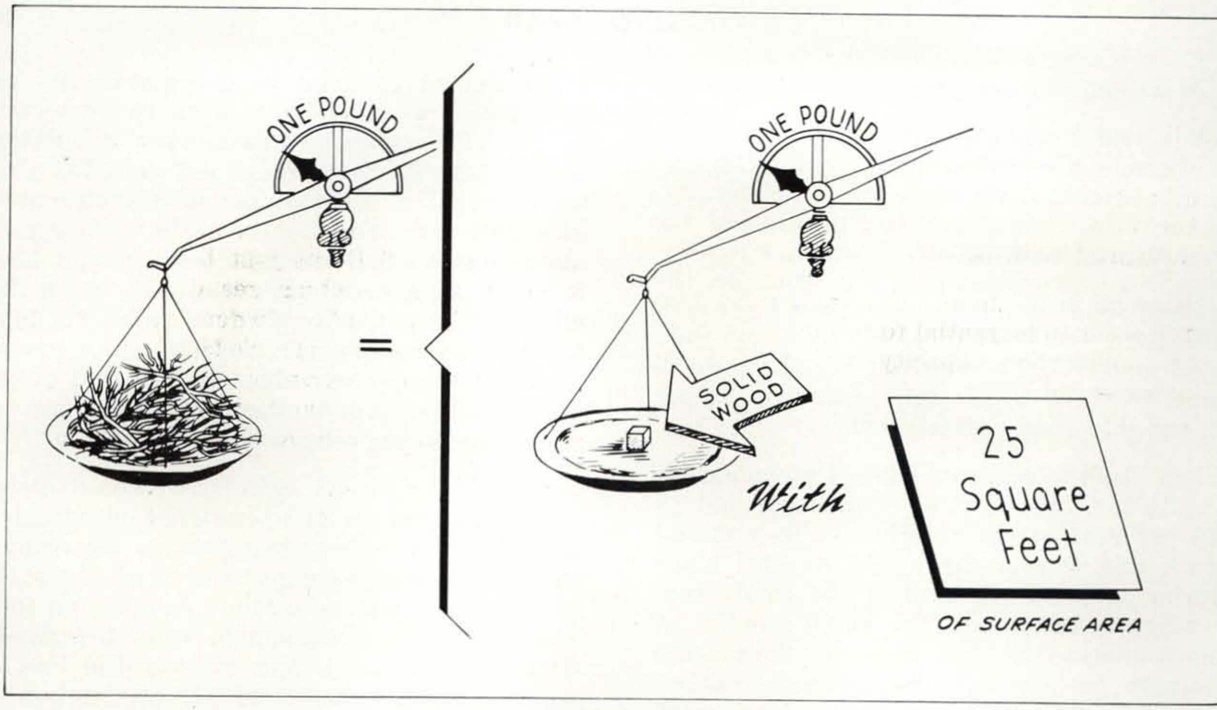


Figure 33. . . . the average pound of Douglas-fir slash has a surface area of approximately 25 square feet.

Figure 34. Lopping reduces the over-all volume by about 40 per cent, piling by 93 per cent, and chipping by 98 per cent.

minish the direct impact of the rain on the soil.

2. These soils have a very high initial infiltration capacity for water; moderate reductions, if they should occur, can be sustained with safety.

3. Rainfall in the Inland Empire usually does not occur in torrential form; consequently, the infiltration capacity is not likely to be exceeded.

Further investigations are under way to check some of the results in more detail. Recently 10 x 10-foot runoff plots have been installed in a large broadcast-burned area and in an adjacent clear-cut but unburned area to determine more accurately the effect of burning on runoff and erosion. In addition, studies are under way to find out just how chemical differences in soil, which result from burning, affect seedling growth. To determine this, seeds and seedlings of the region's leading commercial species have been planted on burned and unburned areas, and their growth and survival are being checked periodically.

Figure 35. Fire is largely responsible for perpetuating the white pine type. . . .

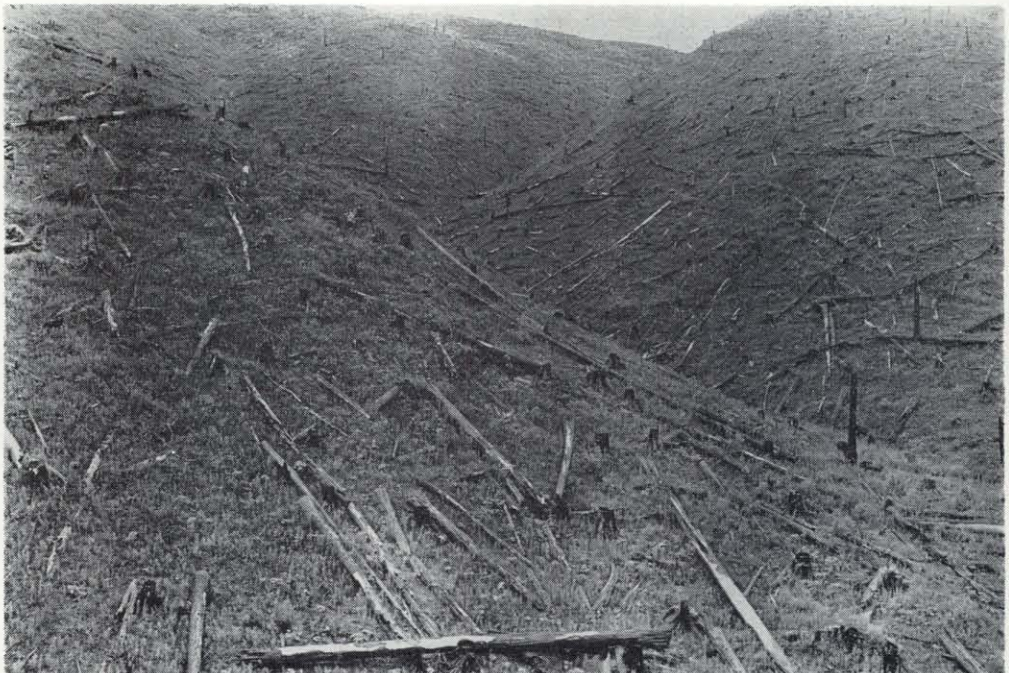


Figure 36. Mosses, lichens, and various herbaceous plants quickly revegetate burns . . . and greatly diminish the direct impact of rain on the soil.

IV. SLASH DISPOSAL

In the northern Rocky Mountains, nature does not reduce the slash fire hazard rapidly enough; so man must help. What has come to be known as slash disposal was one of the first forestry measures to be practiced in the United States. It still is one of the most important. The future of a new timber stand, indeed its very establishment, may depend heavily on how the slash from the old stand has been handled. Unfortunately this fact is all too frequently ignored. Sketchy planning, or none at all, and the assignment of inferior personnel and equipment to slash disposal jobs can greatly reduce the effectiveness of the operation either as a method of fire prevention or as a silvicultural measure.

The common names for slash disposal methods refer to such unique characteristics, as the type of machinery used, and not necessarily to how the final disposal takes place. "Slash treatment" would be a better term than "disposal," for much slash is not actually destroyed or removed from logged areas. The use of fire is implicit in several methods and is so big a subject that it is treated separately.

To date the slash research program has been concerned primarily with obtaining basic information that ultimately can be used in appraising situations and devising the proper means of meeting them. Information on the development and use of slash treatments has come from observation of field practices and review of results obtained by other workers. To a considerable extent comments on and evaluations of slash disposal methods reflect the authors' opinions.

METHODS AND MACHINES

Methods of handling slash have developed more through improvising than by design. Thus, recent advances, chiefly a matter of increasing mechanization, have resulted from adaptation of machinery developed for other uses. Still being used in some situation or other is every method that has proved practicable over the last 50 years.

Handpiling.—On national forests in the Inland Empire, 40 per cent of all slash treated is still piled by hand. Handpiling is slow and expensive, but nobody has found a better way to dispose of moderate to heavy concentrations of slash on steep slopes where a residual stand must be protected. Of all the methods in common use, this one is most dependent for its effectiveness on handling the slash while it is green and pliant. Piling dry brush is prohibititively expensive and reduces the fire hazard less because enough fine material breaks off to form a continuous carpet of flashy fuel between piles.

Bulldozer piling.—Within the last 5 years the bulldozer has taken over 30 per cent of the national forest slash piling job in national forests and probably a comparable percentage on state and private land. Bulldozers are most effective where the volume of slash is large, the residual stand is small, and large stumps are not very numerous. Wet or rocky ground and slopes steeper than 40 per cent rule out effective use of dozers. On favorable bulldozer sites slash piling, seedbed preparation, and destruction of undesirable trees can be accomplished for $10 to $16 per acre, cheaper than hand labor can do the piling job alone. Medium-sized tractors have the greatest all-around utility; but heavier or lighter machines may be desirable, depending on the size and quantity of fuel and on ground condition.[14]

Bulldozers provide the best means yet found to solve some troublesome problems of slash, timber stand improvement, and regeneration. However, studies in other areas have indicated that with some soil types and precipitation patterns, accelerated runoff and erosion occur unless vegetation and litter cover 70 per cent of the soil surface.[27] For adequate soil protection, the percentage must be even greater if soil compacting agencies are active.[28] It stands to reason, therefore, that bulldozer piling of slash can adversely affect watershed values, if total ground cover is reduced too much, and if frequent passage of heavy equipment over the area causes excessive soil compaction. At the same time improper use of equipment causes damage to the underground parts of residual trees. It is important now to determine accurately what effects bulldozer use has on the site in Inland Empire forests.

Lopping.—Disposal of slash by lopping alone is a controversial method. Proponents of lopping point out that bringing slash close to the ground causes it to have a higher moisture content most of the year, to decay more rapidly, and to burn less violently than it would otherwise. Opponents call attention to the fact that lopping can produce concentrations that burn hotter than the same amount of slash still attached to tops. Lopping is inadequate treatment for areas having a large amount of slash per acre and appears to be undesirable where its chief immediate effect is to concentrate the fuel bed or make it more nearly continuous. In areas where there is little enough slash that lopping would be acceptable, perhaps the untreated slash could be tolerated as a calculated risk. The study of slash decomposition is designed to show whether lopping hastens decay sufficiently to warrant use as a method of disposal.

Lopping and scattering costs almost as much as handpiling and burning but does not decrease the fire hazard nearly so much. It is doubtful that scattering improves the results of lopping alone to any appreciable degree. Limited lopping and scattering of slash on skid trails and other denuded areas is an erosion-control measure and should not be confused with slash disposal.

Chipping.—An old objective in slash disposal has been to find some effective method that would not be based on the use of fire. The latest possibility, and one that appears to have great promise, is the portable chipper.[19] Chippers are now commonly used by park, street, and highway departments to reduce brush pruned from trees and cut in roadside cleanup to a form that is not unsightly or that can readily be hauled away. Clearing contractors are using chippers to avoid the problem of trying to burn right-of-way debris during the fire season. Some use of portable chippers is being made on the Pacific coast for disposal of slash after logging.[16] Costs are reported to be similar to those of handpiling. Although promising results have been obtained elsewhere, these machines have not yet been adopted in the Inland Empire.

Rate-of-spread tests at Priest River have shown that chipping satisfactorily reduces inflammability. The chips are readily incorporated into the organic layer of the soil, and they effectively retard erosion when they are spread on skid trails and landings.

Possibilities.—In addition to accepted methods and immediate prospects some more imaginative ideas are always being developed. A few years ago someone suggested using a heavy roller set with cutting blades for breaking up slash and mixing it with the soil. Such a device was tried, but anything that a tractor could pull proved too light to accomplish much.

Currently in use in the South is the Harris Landclearer, a sort of oversized power lawnmower that is towed by a heavy crawler tractor. This machine mangles slash, reproduction, and brush, and mixes everything with the soil. The Landclearer does not appear to be usable in steep country or where much heavy material is on the ground.

There is a persistent idea that some chemical could be sprayed on slash to accelerate decomposition. Investigation of this possibility has been entirely discouraging. Canadian research men are experimenting with inoculation of lodgepole pine slash with decay organisms, but the project is too young to have yielded any results.

Just one thing seems certain: with all the interest that is being shown now, improvement in slash disposal methods is bound to come more rapidly than in the past.

USE OF FIRE

Fire is a potent tool in forestry, but one which can turn on the user and quickly undo the work of years. The most valuable virgin stands of the northern Rocky Mountains depended for their origins on conditions created by wildfire. Now foresters use controlled fire to clean up after logging in the old-growth timber and to recreate conditions favorable to regeneration of valuable tree species. Fire is used in some way on approximately 64 per cent of the area covered by slash disposal operations annually.

Burning piled slash.—By far the commonest use of fire is in the process of burning slash piles. Piling and burning is such an old practice that one expects to find a perfect job being done as a matter of routine. Instead, some slash remains unburned because of poor piling

Figure 37. . . . the bulldozer has taken over 30 per cent of the . . . slash piling job.

Figure 38. The latest possibility . . . is the portable chipper.

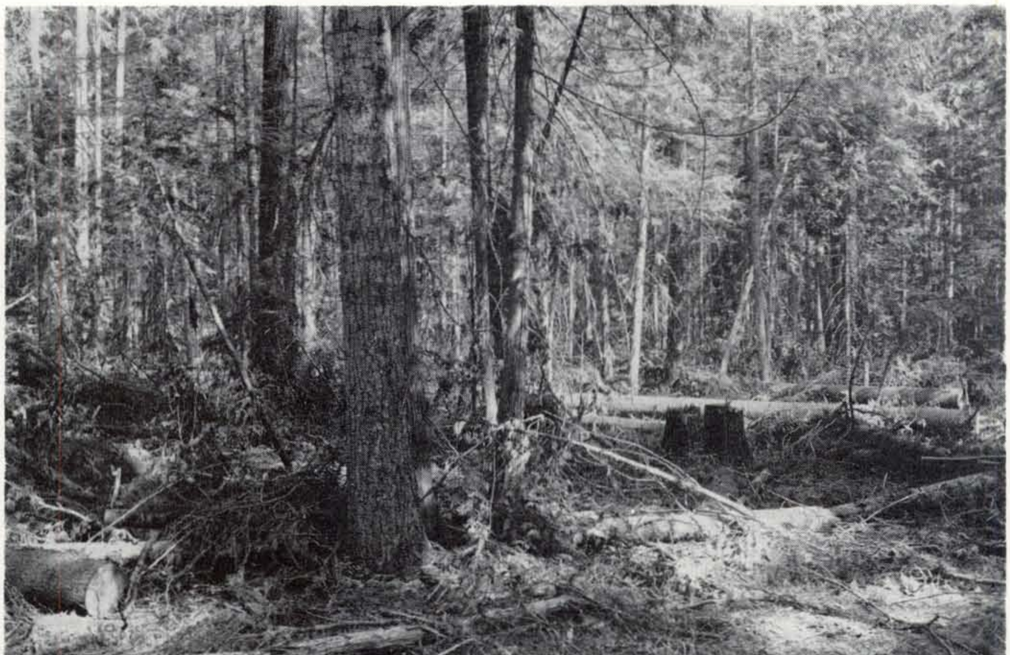


Figure 39. Lopping is inadequate treatment for areas having a large amount of slash per acre.

or poor planning; conversely, some slash pile fires scorch residual trees, consume duff, and kill roots, and sometimes break out of control to cause spectacular and catastrophically expensive wildfires. It seems that too often the burning of piled slash has come to be taken so much for granted, that intelligent planning and skilled execution of the job has been neglected.

The need to do a better job of burning piled slash is primarily an administrative problem. The chief points now requiring attention are planning, training, and supervision. At the same time, research can contribute something. An example is an analysis that showed that roofing slash piles with building paper (or bark), a practice long used by some slashmen, permits burning them more quickly and completely than would be possible otherwise in extremely wet, late fall weather.[6] Although the idea of a slight saving in burning costs is attractive, the main value of roofing is that the piles can be burned during weather so wet that fires can not possibly spread. It must be emphasized that the use of roofs is not a substitute for making good piles. A further test is planned for the roofing of ignition points in dozer-piled slash.

Broadcast burning.—The oldest and still most spectacular use of fire for slash disposal is broadcast burning. This term has fallen into disrepute because many of the early broadcast burns followed too literally the dictionary definition of broadcast, "Cast in all directions," and did far more harm than good. Now "prescribed burning" and "controlled broadcast burning" are favored. No matter what the process is called this use of fire consists of burning relatively large areas of continuous slash that lies pretty much as it fell. As in any other use of fire today, control at all times is implicit.

Strictly as a slash disposal measure, broadcast burning is a last-ditch method for use where no other is practicable. Blowdown areas that have been logged, contain so much heavy material on the ground that piling, even with bulldozers, is almost a physical impossibility. Usually broadcast burning is employed to accomplish something more than just reduction of the fire hazard. Destruction of an undesirable residual stand, seedbed preparation, and control of white pine blister rust are the commonest additional objectives of broadcast burning in the northern Rocky Mountains.

One still encounters the opinion that broadcast burning is a cheap, easy method of meeting situations that otherwise would be completely hopeless. While burning may be the only solution, properly conducting a broadcast burn is neither cheap nor easy. Preparation of some areas involves felling a heavy residual stand of defective, overmature trees at a cost of up to $100 an acre. The burning operation itself is expensive if adequate safeguards are provided against the fire's getting away. Good background knowledge and skillful planning are essential. The job culminates in selection of the right time to burn and intelligent execution of the plan.

Broadcast burning is a highly specialized tool that is used on only 4 per cent of the total area covered by slash disposal operations. Nevertheless, more research is needed than has ever been done. Since Klehm and Davis[6] published the fundamental principles of broadcast burning in 1939, forest managers have used and improved this tool considerably; but research has done very little to help them beyond giving advice. In 1951 a detailed, on-the-site weather study was made with the idea of developing better criteria for determining the right time to burn. More research of this type is needed. Preliminary investigation has shown that pyrotechnic igniters, both fused and remotely detonated types, may be useful. A large-scale field trial is needed to test the feasibility of setting off an entire burn by remote control. Research on techniques of broadcast burning will accomplish at least two results: reduce cost and risk, and provide valuable information on the behavior of fire in relation to fuels and weather.

Spot burning.—Spot burning must be mentioned, if only to condemn the practice for general use. Igniting concentrations of slash as they lie is a halfhearted, uncontrolled use of fire that has produced almost universally unfavorable results. Inevitably, residual trees are scorched by fire that spreads where it should not, while some of the most hazardous slash remains unburned. In addition, this kind of burning always entails the risk of a runaway fire. Spot burning has a legitimate but extremely limited application in cleaning up concentrations of debris around landings and on road rights-of-way, provided the fire cannot spread into the timber. Such situations are essentially controlled broadcast burns on a small scale. Beyond this use the method does more harm than good.

Figure 40. . . . roofing slash piles with building paper permits burning them more quickly and completely than would be possible otherwise in extremely wet, late fall weather.

Figure 41. In 1951 a detailed on-the-site, weather study was made.

Figure 42. ... most spectacular use of fire for slash disposal is broadcast burning.

The future of fire use.—Conversion of decadent stands into vigorous, well-stocked, managed forests requires heavy cutting in nearly all timber types except ponderosa pine. Despite improving utilization, dangerous quantities of fine slash and cull material will be left on many areas during the foreseeable future. Where protection and management objectives indicate that such concentrations should be removed, burning appears to be the only feasible method of disposal. Research still has some decades of work ahead to develop the best techniques of fire use during the transition period.

How extensively fire will be used in managed forests is hard to predict. Foresters frequently express hope that fuller utilization of all species, absence of much defective material, and ability to make frequent, light cuts because of increased demand and accessibility will largely eliminate the functions that fire now performs. On the other hand, one major silvicultural goal is to grow the most valuable species. In the Inland Empire this means, for the most part, the growing of intolerant species that depend on fires for their natural abundance and that probably will be harvested by clearcutting. It is logical to believe that fire will have to be used in some degree to dispose of the great quantity of slash that will result from clearcutting heavy stands of some timber types and to maintain conditions favorable to preferred species. Therefore, it appears that the use of fire has a long future that will require continuing research.

INTENSIVE PROTECTION IN LIEU OF SLASH DISPOSAL

Many persons believe that much of the money now being spent for slash disposal could be used more effectively to protect the cutover area from fire occurrence and to make sure of rapid control should fires start in the slash. This belief is based upon improved techniques in fire detection and control methods, ready accessibility of logged areas, and availability of such heavy equipment as bulldozers and tankers for controlling fires. There is general agreement that complete disposal is unnecessary, and that it is feasible to protect areas of light slash. Disagreement arises over cases where the slash is so heavy that on the one hand the cost of disposal would be excessive and the treatment of questionable effectiveness; and on the other hand, if the slash were left, it would present a serious threat to the overall fire control plan.

Intensified protection may be more expensive than slash disposal. It is not known how long intensive protection will be necessary before the slash has decomposed to the extent that it is no longer dangerous. Western redcedar slash has been found little changed after 30 years. Providing intensive protection to an area over such a long period of years might cost more than burning the slash the first year and getting rid of the hazard. Isolated blocks of heavy slash left for intensive protection are dangerous enough individually; and accumulation of such areas over a 20-year period would be a real threat of a widespread conflagration.

V. A LOOK AT THE FUTURE

The one thing certain in life is change. Changes in the nature of the problem of logging slash are especially assured because they are influenced by what happens in so many other activities. Size, quantity, and arrangement of slash depend on such factors as stand condition, cutting practice, logging methods, and utilization standards. The advent of new machinery and new processes can radically alter slash disposal methods. There is possibility that slash itself may come into demand as a by-product of logging. Clarification of the economics of slash disposal as a fire prevention measure may change the whole attitude toward slash. Only a small portion of what the future holds in store can be foreseen now, and that but dimly. The need for continued research is clear; some of the problems that should receive special attention are recognizable now.

STUDIES NOW IN PROGRESS

The slash research program has many problems yet to be solved. Also, as might be expected, results from the work already done have suggested some supplemental studies that can be undertaken best in connection with those now under way. Completion of the rate-of-spread study will require 2 more seasons of experimental burning separated by 5 years. During the interim, an effort should be made to learn something about how slash distribution affects rate of spread.

Methods of slash measurement developed from study of relatively few trees need to be field tested and prepared for practical application. The ultimate responsibility of research will be to conduct a pilot-plant test and demonstration of measurement techniques in appraising and planning the slash disposal job on a logging chance.

There is a big opportunity for obtaining information of immediate practical value through expansion of the heat radiation study. Measurement of radiation from fires in various slash concentrations, under different weather conditions, and in different topographic situations should show what combinations can be expected to result in undesirable fire spread because of radiation alone. The heat tolerance of northern Rocky Mountain tree species needs to be determined more accurately in conjunction with the measurement of radiation in order to provide guidelines for the placement of slash piles and width of firebreaks that will minimize the likelihood of heat damage to residual trees and of fire spread across established control lines.

The study of how slash burning affects the soil already has provided information about immediate physical and chemical effects; it will be continued to see whether development of the new stand demonstrates any long-range influences. Some broadening of the research program can be expected over the next few years to find out how fire affects watershed values. Now that bulldozer piling covers more ground than slash fires, there is urgent need to expand the study of the effects of slash disposal methods on soils to include the effects of using heavy equipment which lays bare a large percentage of the surface.

Research on slash decomposition is a long-time job. It must be carried to completion in order to provide much-needed basic information on how long after cutting slash constitutes a serious fire hazard that requires special protection.

LOGGING METHODS AND LOGGING SLASH

Koroleff[18] gives new point to consideration of logging methods in relation to slash disposal. He recommends making slash disposal part of the logging operation. The entire tree —top, limbs, and all—would be brought out of the woods to be lopped, bucked, possibly peeled, and loaded at a central point. Slash would be burned progressively or chipped for subsequent use or removal. This system is reported to be in use to some extent in Europe and has been tried on a small scale in eastern Canada. If this system will work anywhere in the western United States, lodgepole pine pulp cuttings and cedar pole operations appear to be the most likely places. One big value of Koroleff's challenge is to focus attention on slash disposal as part of the logging job. It is always best to prevent a problem from arising, insofar as possible, and then deal with what can not be prevented.

In recent years some operators have increased the efficiency of their woods operations by coordinating faller, skidder, and loader into teams whose aim is the most efficient woods-to-truck logging job. A further step would be to include the slash disposal crew, regardless of who runs it, as part of the team, and to tailor logging methods so that they will facilitate the over-all management and protection of the land, not merely to harvest the crop. A first hopeful indication in this direction has been a very recent trend toward better coordination of cedar pole cutting with the saw-log operation.

POSSIBILITIES OF UTILIZING SLASH

Every year in the northern Rocky Mountains logging produces several million tons of cellulose in the form of branchwood and foliage. Thinking about this fine slash mostly takes the form of figuring how to get rid of it cheaply, quickly, and easily. Future research on slash disposal methods must turn from techniques of destruction to possibilities of utilization. The first step toward finding uses for slash is to get it into a form that can be handled readily. Thus far, portable chippers show the greatest promise for this purpose. Chips can be loaded, hauled and measured where lopped slash is almost impossible to handle in any quantity.

Perhaps other methods than chipping will be developed for getting slash into usable form. Slash disposal men and slash researchers are not equipped to carry on specialized investigations of forest products and equipment. However, they can promote such research, keep abreast of developments, and be ready to try out possibilities as they are suggested.

NEED FOR ECONOMIC STUDIES

Payments for slash disposal and for intensified protection in lieu of disposal may be looked upon as insurance premiums. In the fire insurance business, premiums are based on the value of the property and the risk that it will be destroyed or damaged. Where the property is a forest, however, we are poorly equipped to set valuation, to calculate risk, or to appraise damage. With regard to the slash hazard, foresters still are right where the first insurance company was when it opened its doors for the first day of business.

A forest has many values, direct and indirect, tangible and intangible. The easiest to identify and appraise are the value of standing timber and of the land for producing timber. These are direct, tangible values that can be calculated readily in dollars and cents. The effect of the forest on floods and erosion is indirect but tangible. In some places, notably southern California, enough is known about this function of the forest to place a money value on it. As yet this type of knowledge is not available for the northern Rocky Mountains. As a habitat for wildlife and a place for recreation the forest has values which extend over the whole range of directness and tangibility and which have never been satisfactorily appraised anywhere. Damage appraisal does not differ in principle from valuation generally; it is simply the determination of how seriously the original value has been impaired. The only new consideration is the matter of recognizing what constitutes damage.

Land ownership has a powerful influence on valuation and damage appraisal. The nation as a landowner, places a value on every product and function of its forests, regardless of tangibility or distance from the source. The private owner usually holds timberland for one main purpose. In the Inland Empire that purpose is lumber production. Any landowner naturally wants to pay insurance on only the direct value that his property has to him. In the logging slash field, therefore, the question arises, "Should the private owner of timberland be required to pay disposal or protection costs that represent insurance on indirect and intangible values to the general public?" Until values can be appraised more accurately than at present, this will remain an academic question; but it should not be lost sight of.

The concept of risk in fire insurance involves both the probability that damage will occur and the probable magnitude of that damage.

'he latest summary available shows that on he national forests in Montana, northern Idaho, nd northeastern Washington, for the period 931-1939, fire occurrence per million acres was 0 times as great on cutover land as in uncut tands, and area burned was 11 times as great. No over-all comparison of suppression cost and lamages is available. It can be shown, how- ever, that certain individual fires in slash have ost for suppression and damages many times he amount of collections for slash disposal n the timber cut. A new, more detailed study s in the making which will provide an up-to- late comparison of the fire risk on cutover rersus uncut timberland.

Future research must find out the effective- ness of different methods and degrees of slash lisposal and protection. In all the years since orush piling first began, no comprehensive, objective study has been completed to show what reduction of the fire hazard could be expected per dollar expended for slash disposal. In the last analysis, all technical findings concerning inflammability, measurement, and disposal methods become steps in answering two largely economic questions:

1. Is our $2,000,000 bill for slash disposal the right annual premium to pay for insurance against slash fires?

2. Where and how should slash disposal money be spent to buy acceptable protection?

Study of the logging slash problem in the Inland Empire cannot be considered complete until these questions have received satisfactory, practical answers.

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The Clearwater and Potlatch Timber Protective Associations supplied the photographs for figures 3 (lower left), 12, 14, and 34.