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DECAY OF LOGGING SLASH IN THE NORTHEAST

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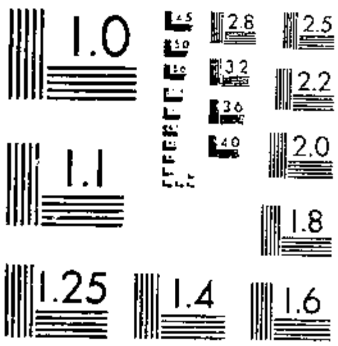

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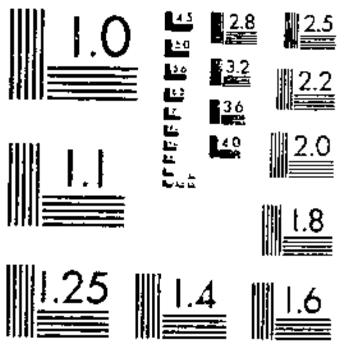

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Decay of Logging Slash in the Northeast[1]

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SUMMARY

Logging slash, the debris left in the forest after cutting operations, is a very dangerous forest-fire hazard. As potential fuel it increases the likelihood of fires, makes them much harder to stop, and increases damage on burned areas. Slash can be disposed of by burning, either broadcast or in piles. Broadcast burning kills advance reproduction and causes site deterioration; burning in piles is expensive; the only practicable alternative is to leave the slash in condition to decay as quickly as possible. The subject of methods of hastening slash decay has had much less study than other phases of fire prevention and control. This bulletin is based on systematic observations on slash decay on experimental plots in different situations in New York and New England, continued through a number of years. It considers the fungi most important in causing decay in this northeastern area, the conditions that favor their activity, and the forest-management practices by which these favorable conditions can be provided.

The average periods required for slash to disintegrate are 15 years for hardwood, 17 years for eastern white pine, and 29 years for red spruce. Under the most favorable conditions for decay, these periods

[1] Submitted for publication April 1944. This study was carried on in cooperation with the Allegheny (formerly Northeastern) Forest Experiment Station and Yale University, New Haven, Conn. The writers wish to acknowledge their cooperation and also that of L. O. Overholts, of the Pennsylvania State College; Dow V. Baxter, of the University of Michigan; A. S. Rhoads and the late James R. Weir, both formerly of the Division of Forest Pathology; H. S. Jackson, of the University of Toronto, Canada; the late L. H. Pennington, of the New York State College of Forestry; and W. H. Snell, of Brown University, for the identification of numerous fungi; M. Westveld, for cooperation and assistance in establishing and maintaining permanent slash plots; and the personnel of the United States Forest Service on the White Mountain National Forest, for granting free access to and assistance in reaching otherwise inaccessible closed areas.

may be shortened by about one-fifth. Unfavorable moisture and temperature conditions retard decay, in some cases by many years. Hundreds of fungi help to disintegrate slash, but about 50 cause the decay of the greater part.

The primary factors controlling the work of the slash-decay fungi are moisture, temperature, and the decay resistance of the wood. Wood decays only when moist, but since fungi need air also they cannot work in wood that is entirely waterlogged. The decay fungi make little or no growth at temperatures below 40° F. and need temperatures of 70° or above for most rapid decay. There are great differences in the inherent resistance of wood to decay; heartwood of the more durable species decays much more slowly than sapwood of any species. Slope, aspect, altitude, and soil type are important in their effect on moisture and temperature but unfortunately cannot be changed to any extent by man. The primary factors, however, may be changed by proper forestry operations.

A short rotation results in less slash per acre and a larger proportion of the fast-decaying sapwood, with consequent early reduction of the slash volume to a relatively safe point. Because broken crown cover maintains more uniform moisture conditions, partial cutting usually favors rapid decay of slash. Clear-cutting, on the other hand, results in high temperatures and unusual dryness and is likely to retard decay.

Scattered slash decays faster than piled or windrowed slash under most conditions. Lopping the slash of conifers and of the more durable hardwoods favors decay, but its high cost must be carefully balanced against its advantages; it is to be avoided on wet sites and for species that waterlog easily. Local conditions will largely dictate the choice of methods of cutting and of slash disposal. In making partial cuttings, care is needed to keep logging injuries to residual trees at a minimum and thus prevent fungus damage by trunk infections.

Independent ratings showed a close correlation between volume of slash and fire danger. Graphs accompanying this bulletin show the reduction of fire danger with increasing age for slash of hardwoods, eastern white pine, and red spruce.

THE PROBLEM OF DISPOSAL OF LOGGING SLASH

Those who harvest forest trees are faced with the problem of the disposal of the resulting logging slash. It has been termed the "garbage" of the woods. Because of its ubiquity in the exploited forest, however, the tendency has been to accept it as a necessary evil, one about which little or nothing can be done in a practical way. In the unregulated forest slash cannot be utilized or disposed of so long as the endeavor is to get as much out of the forest as possible without regard to a future productive stand on the cut-over area. In the Northeast, the huge forest losses caused by the disastrous hurricane of September 21, 1938, are being succeeded by very heavy demands for timber, with a shortage of manpower in the woods and resultant high prices. These conditions cannot fail to cause an even greater than normal disregard for regulation of any sort. The slash problem is assuming more acute proportions than at any previous time in American history. Much of the slash has been and for an indefinite time in the future will be left to disintegrate on the ground. The disintegration is largely due to the action of many organisms, chiefly insects and fungi.

Cooperative investigations with the Bureau of Entomology and Plant Quarantine have been carried on to determine the role of insects and fungi in the disintegration of slash and logs. The conclusions that follow are based upon the results of these experiments.

Blue stain enters the sapwood of bark-covered timber chiefly by means of the burrows of bark and wood-boring beetles. Examination of hundreds of newly established colonies of blue stain showed that beetle burrows were nearly always the centers of origin of the fungus colonies. In some kinds of slash, notably that of eastern white pine (*Pinus strobus* L.), loosening and sloughing of the smooth bark of slash is hastened by the activities of the bark beetles and wood borers. Prompt drying of the decorticated wood distinctly retards decay (*15*).[2] The galleries of wood-boring insects offer an obvious means of entry to the interior of logs and large slash. It has been proved that they facilitate the progress of decay in infested logs (*8*).

Much has been done to prevent and control forest fires, but until recent years almost nothing has been done to determine possible methods of alleviating evils inherent in the various processes of slash accumulation and decay. This investigation is a contribution to the solution of the general problem. The factors controlling decay are so extremely variable and occur in such diverse combinations that it is impossible to consider them in detail. Instead, attempt is made to state general principles governing the manifold conditions encountered in the northeastern forests for guidance locally in applying remedial measures.

PREVIOUS INVESTIGATIONS

A search of forestry literature and conferences with foresters in 1925 indicated that considerable attention had been given to slash as a fire danger, but careful studies of slash decay were few in number and mostly carried on in the West, where conditions and forest species are markedly different from those in the Northeast.

In studying the decay of oak slash in Arkansas, Long (*10*) found that slash lopped and scattered rotted about 1 year sooner than that unlopped. On dry situations there was practically no difference. Slash lopped and piled required 3 to 6 years longer to decay than that unlopped or scattered. Four species of *Stereum* were the main agents in rotting the oak slash. Six years were required to rot oak sapwood, practically all but the very large branches having rotted and fallen in this time. Oak heartwood remains many years after the sapwood is destroyed. Long stated that none of the main slash-rotting fungi were known to produce heart rots in living trees.

Buttrick (*1*) made a regeneration study in northern Michigan where hardwoods with a little white pine had been cut and reworked for distillate wood, leaving relatively small pieces of slash. After 8 years the slash piles had scarcely begun to rot and were a distinct fire danger.

Kittredge and Belyea (*7*), working in the Adirondacks where 75 percent of the trees that had been cut were spruce, found slash evident on all areas that had been cut less than 14 years, and on one area 30 years after cutting.

In a study of slash decay of eastern white pine in New England, Spaulding (*15*), found that under average conditions disintegration took place in about 20 years.

[2] Italic numbers in parentheses refer to Literature Cited, p. 21.

Stumps were not included in the material studied. Swampy or coarse sandy soils delayed decay indefinitely. The factors influencing rate of decay were discussed, with emphasis on heat, since white pine slash appears to be especially responsive to this agency.

In a study of decay of hardwood slash in northern New England with reference to lopping, Spaulding (*14*) called attention especially to the various factors involved. Decay durability for various species, beginning, with the least durable, was given as follows: Aspen, paper birch, basswood, beech, maple, yellow birch, ash, oak, and chestnut. Direction of slope was said to be important in influencing moisture, which in turn controls waterlogging and case-hardening[3] of slash. In general, the southerly slopes are warm and dry; the northerly, cool and moist. Inadvertently, the reverse was said to be the case. The trees were ranked as to readiness of the wood to become waterlogged, beginning with the most readily saturated, as follows: Yellow birch, beech, basswood, maple, aspen, oak, chestnut, and ash. It was concluded that aspen and paper birch rot so quickly that the expense of lopping is not justified; yellow birch is so apt to waterlog that it should rarely be lopped; ash, chestnut, and oak, with little danger from waterlogging and relatively high durability, may well be lopped; and in other species lopping is of questionable value, considering the cost.

Scholtz (*13*), working in northern Michigan and Wisconsin, found that under average conditions slash of northern hardwoods up to 2 inches in diameter almost completely disappeared in 4 to 7 years; similar intermixed slash of white pine and hemlock was a fire danger for 12 to 15 years. He found that larger slash remained a fire danger much longer—basswood for 15 to 18 years, sugar maple and yellow birch for 15 to 17 years. Elm resisted decay longest of the hardwoods, being a fire danger for 20 to 25 years. White pine, hemlock, and white-cedar remained dangerous for 20 years and upward. Wet or dry conditions were found to delay decay as much as 10 years.

Zon and Cunningham (*21*) made a comprehensive study of the regulation of slash disposal in northern Wisconsin, to insure safety from devastating fire. This study dealt with slash of jack pine and of northern hardwoods more or less mixed with hemlock and other northern conifers. The investigators found that by the end of the eighth year branches up to about half an inch in diameter were rotted and broken by the weight of snow. Remnants of the slash piles persisted up to 15 or 16 years, but were well rotted and broken down. Selective cutting created less fire danger than clear-cutting.

Spaulding, Hansbrough, and Westveld[4] made a study of the relationship of decay to the fire danger of slash of red spruce (*Picea rubens* Sarg.) in the White Mountain National Forest, New Hampshire. Considerable effort was made to select a reliable index of its condition. It was finally decided that the percentage of the original slash remaining is the best index for practical use. Comparison of analogous curves showing fire danger and percentage of slash remaining, by age classes, revealed a positive correlation between the two up to about 17 years, after which the danger decreased more rapidly.

INVESTIGATIONAL METHODS

These investigations of slash decay were carried on most intensively in the White Mountain National Forest, but extended from Connecticut to eastern Maine and to western New York. Two methods were used: (1) Extensive reconnaissance, and (2) intensive investigation of limited areas over a period of at least 10 years.

The extensive reconnaissance included slash of all species of trees encountered, of all ages, variously disposed as left by all types of logging or by cutting firewood and pulpwood, on all aspects and slopes, and at elevations ranging from less than 1,000 to more than 4,000 feet, and it covered all kinds of material, from defective logs to the smallest twigs and foliage. Slash of the following species is so generally

[3] "Case-hardening" is used to indicate a very dry and hard condition of the outer wood layers due to early and complete seasoning.

[4] SPAULDING, P., HANSBROUGH, J. R., and WESTVELD, M. FIRE DANGER ON RED SPRUCE SLASHINGS IN NORTHERN NEW HAMPSHIRE AS INFLUENCED BY AGE AND CONDITION OF SLASH. Northeast. Forest Expt. Sta. Tech. Note 28, 3 pp., illus. 1930. [Processed.]

distributed that data could be taken for a wide enough range of conditions to satisfy the requirements of this study.

Red maple (*Acer rubrum* L.).
Sugar maple (*A. saccharum* Marsh.).
Yellow birch (*Betula lutea* Michx.).
Paper birch (*B. papyrifera* Marsh.).
American beech (*Fagus grandifolia* Ehrh.).
White ash (*Fraxinus americana* L.).
Bigtooth aspen (*Populus grandidentata* Michx.).
Quaking aspen (*P. tremuloides* Michx.).
Balsam fir (*Abies balsamea* Mill.).
Red spruce (*Picea rubens* Sarg.).
Eastern white pine (*Pinus strobus* L.).

Considerable data were taken on about as many more species that are too scattered or irregular in distribution to furnish complete series but indicate trends as compared with the above-mentioned species, as follows:

Striped maple (*Acer pensylvanicum* L.).
Sweet birch (*Betula lenta* L.).
Gray birch (*B. populifolia* Marsh.).
Black ash (*Fraxinus nigra* Marsh.).
Butternut (*Juglans cinerea* L.).
Tamarack (*Larix laricina* (Du Roi) K. Koch).
Red pine (*Pinus resinosa* Ait.).
Pitch pine (*P. rigida* Mill.).
Pin cherry (*Prunus pensylvanica* L.).
Black cherry (*P. serotina* Ehrh.).
White oak (*Quercus alba* L.).
Eastern red oak (*Q. borealis* Michx. var. *maxima* Sargent).
Scarlet oak (*Q. coccinea* Muenchh.).
Black oak (*Q. velutina* Lam.).
American linden (*Tilia americana* L.).
Canada hemlock (*Tsuga canadensis* (L.) Carr.).
American elm (*Ulmus americana* L.).

The intensive studies were on four series of plots, some of which have been maintained since 1926. These were established in cooperation with the Northeastern Forest Experiment Station and the White Mountain National Forest on areas where cutting contracts for hardwoods were in operation. This limitation on areas available made it impossible to include all the conditions desired, but this was done as far as feasible. The stands on the plots selected were predominantly mature northern hardwoods with scattered red spruce and balsam fir, and a few hemlocks. About 40 years previously the best spruce had been removed, leaving an overstory hardwood stand. The logging was done as usual in the timber sales of the Forest Service.

Each series of plots had one with the slash lopped and one unlopped as the loggers left it, for a comparison of these two methods of slash disposal in like material under like conditions. On these plots the rotting of slash made under the usual logging conditions was followed for more than 10 years after the felling of the trees. Considerable interference resulted from wind throw of nonmerchantable trees left in the logging and from fallen girdled trees.

Independent ratings were made for each lot of slash examined, for decay of a number of different sizes of slash, for the residual percentage of volume, and for the degree of fire danger.

It must be emphasized that slash is an exceedingly heterogeneous material that does not lend itself to satisfactory, scientifically accurate investigation as usually conducted. Its study in most respects is largely empirical. As an example, for a reasonably small sample of rotted material that will represent the average deteriorated condition of a single slash pile, an ocular estimate must first be made of what is the average condition for that pile, the material in which may vary from an essentially sound to a completely rotted but not disintegrated state. This heterogeneity prevented the working out of slash problems with the scientific accuracy usually to be expected. The difficulty was partly overcome by inspecting large quantities of slash under all conditions possible.

DECAY OF SLASH

The two general types of decay are white rots, which often are soft or somewhat stringy in texture; and brown rots, which are mostly friable and crumble easily to a fine powder. Some rots are intermediate in character, but they are relatively few in number. Hardwood slash is affected mostly by white rots, while coniferous slash often has much brown rot as well as white rot. A survey of the available data shows that the wood of the conifers of North America is attacked by about equal numbers of species of brown rot- and white rot-producing fungi, while on the hardwoods about four-fifths of those fungi cause white rots and only one-fifth cause brown rots.

Average Rate of Decay

Slash decay is largely controlled by local conditions, and these, as well as the progress of the decay, vary greatly. The only feasible way to state the rate of decay is by relative comparisons with averages determined as nearly as possible for use as bases. This was done in these investigations.

Data for the slash of northern hardwoods (beech, birch, and maple) were taken on the four series of plots already mentioned and also on many areas distributed well over the forests of New England and New York. The species of trees included form a very heterogeneous group, but it seemed best to consider them as a single unit in this investigation because of the difficulty of division on the basis of rate of slash decay. The oaks alone present as great variations among themselves as do all the other species. In general, the decay of sapwood of all species is essentially alike, the greatest variations occurring with the heartwood, which usually constitutes a low fire hazard after the sapwood is thoroughly rotted.

The progress of decay under average conditions may be expressed as follows:

PROGRESS IN HARDWOOD SLASH

1 to 2 Years: Some leaves adhere. Beech, ash, and maple twigs and small branches dry out and are largely sound; oak is sap-rotted in shaded and moderately moist situations. Sap rot begins in large slash.

3 to 4 Years: Twigs are falling. Branches to ½ inch in diameter have local rot pockets that cause breakage and falling, especially in birch, oak, and beech. Sap rot is extensive in large slash.

5 to 8 Years: Branches to 1½ inches in diameter have fallen. Large slash has all or most of the sapwood rotted. Heartwood, except oak, is rotting where not waterlogged.

9 to 12 Years: Branches to 3 inches in diameter have fallen. Large slash is punky where not waterlogged. Oak heartwood persists.

13 Years or More: Branches have all fallen. Large slash is falling apart where not waterlogged. Oak heartwood persisting indefinitely.

PROGRESS IN EASTERN WHITE PINE SLASH

1 to 4 Years: Leaves are shed and form a mat among the branches well above the ground. Branches are much decorticated and have pockets of dry rot, by *Lenzites saepiaria*. Large pieces of slash are well sap-rotted by *Polyporus abietinus*.

5 to 6 Years: Twigs begin falling with the branches, which are weakened by pockets of dry rot and begin to break up. Large slash is completely sap-rotted.

7 to 9 Years: The piles flatten, branches break up and fall. Fallen leaves are rotted. Twigs have fallen from the branches.

10 to 12 Years: The piles are sunken by breaking up of smaller branches and rotting of trunks, so that the branches fall from them.

13 to 20 Years: The pieces largely disintegrate. Pieces of small branches remain hard and retain much of their original strength, but break without splintering.

Hemlock slash resembles eastern white pine in its general course of decay, but appears to decay a little more rapidly.

PROGRESS IN RED SPRUCE AND BALSAM FIR SLASH

1 TO 9 YEARS: Twigs are weakened and falling, branches are case-hardened or weakened, but not breaking. Large branches have scattered pockets of rot, and the trunks are well sap-rotted.

10 TO 14 YEARS: Twigs have fallen. Small branches are case-hardened or falling. Large branches are partly sap-rotted, and trunks are mostly completely sap-rotted. Slash piles are sunken or flat.

15 TO 17 YEARS: Small branches up to ½ inch in diameter are weak and falling. Large branches are partly rotted, and trunks are completely sap-rotted to punky.

18 TO 20 YEARS: Small branches have mostly fallen. Large branches are weakened, many falling from the trunk. Trunks are punky or falling apart.

21 YEARS OR MORE: Slash piles are flat on the ground with some pieces of case-hardened, small slash scattered over the top.

ACCELERATED AND RETARDED RATES OF DECAY

Where conditions are especially favorable, the average decay period may be shortened by about one-fifth. Such favorable conditions commonly are found under a moderately broken crown cover.

Decay may be decidedly retarded by waterlogging of large slash or by case-hardening of small slash. Few fungi can attack water-soaked wood, and even these must work on the outer surface, where oxygen is available. The decay period for waterlogged slash may be twice as long as the average, but usually does not exceed this.

Case-hardening usually persists a shorter time than waterlogging, because of the much smaller size of the affected material, which favors ready absorption of precipitation. Since a considerable number of active wood-rotting fungi can thrive on a minimum of water, decay is delayed less by case-hardening than by waterlogging. The serious feature of case-hardening is that it delays decay in the more dangerous fine slash.

FUNGI CAUSING DECAY

A large number of wood- and bark-inhabiting fungi take part in the disintegration of logging slash. The slash of any single species of tree in the Northeast may harbor scores or even hundreds of different fungi, but most of these scavengers of the forest are not fastidious as to the kind of wood they break down, a considerable number attacking that of conifers and hardwoods indiscriminately. Many show a distinct preference for the one or the other, but occasionally cross their invisible barrier to attack the usually avoided woods. Still another group is strictly limited to conifers and another to hardwoods. Small numbers are even limited to single host genera, but such fungi usually cause heart rot in living trees and merely persist alive in infected large slash that happens to lie in such way that a constant moisture supply is maintained.

The formation of fruiting bodies appears to indicate the climax of activities of a wood-decaying fungus. Their location is an approximate index of the place of activity of a slash-rotting fungus and has been used as such in these studies.

The larger part of the known slash-rotting fungi that are important, because of their abundance and their apparent destruction of large quantities of wood, belong to the family Polyporaceae. Numerous members of many other fungus families are important under certain conditions or on certain kinds of wood.

Table 1 gives a list of fungi that appear to be important in disintegrating slash, and shows their occurrence upon the various kinds of wood and the sizes of material usually attacked. Occurrence varies

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somewhat as conditions favor or retard the fungus. Stumps of felled trees usually are not considered to be slash, though they constitute an appreciable part of the wood material left by logging operations. Dead roots remaining undisturbed in the damp soil conduct some moisture to the stump, and evaporation above ground causes movement of water from below until the wood is disintegrated enough to inhibit capillarity. The cut surface of the stump readily absorbs precipitation also. Moisture conditions in stumps favor the growth of fungi, and fruiting bodies develop under these conditions more abundantly than on other forms of slash. The fungi found on stumps are the same as those attacking the larger pieces of severed slash, that is, defective logs, trunks, and larger branches.

TABLE 1.—*Some of the more important fungi found disintegrating slash in the Northeast, with indication of the kinds and sizes of wood commonly attacked*

Important slash fungi	Balsam fir	Eastern white pine	Hemlock	Red and pitch pine	Red spruce	Ash	Aspen	Basswood	Beech	Birch	Cherry	Maple	Oak	Size commonly attacked[1]
														Inches
Aleurodiscus amorphus (Pers.) Rabh.	+													-1
Armillaria mellea Fr	+	+	+	+	+		+			+	+	+	+	3-
Auricularia auricula - judae (Fr.) Schroet.	+	+			+							+	+	1-
Coniophora puteana (Fr.) Karst.	+	+	+	+		+				+		+	+	2-
Corticium galactinum (Fr.) Burt.	+	+	+		+			+		+				2-
Coryne sarcoides (Fr.) Tul.		+	+				+	+	+	+		+	+	6-
Creonectria purpurea Seaver							+		+	+	+	+	+	- ½
Daedalea confragosa Fr.			+			+	+	+	+	+	+	+	+	2-
D. quercina Fr.											+		+	10-
D. unicolor Fr.						+	+	+	+	+	+	+	+	6-
Dasyscypha agassizii (Berk. and Curt.) Sacc.	+	+	+		+									-6
Dermatea molliuscula (Schw.) Cash.										+				-1
Diatrype stigma Fr.						+			+	+	+	+	+	2-
Eutypella angulosa Nits.										+				-2
Exidia glandulosa Fr.							+	+	+	+	+	+	+	-1
E. recisa Fr.						+	+	+		+		+	+	½-2
Fomes applanatus (Fr.) Gill.			+			+	+	+	+	+	+	+	+	12-
F. pini (Fr.) Karst.	+		+		+									8-
F. pinicola (Fr.) Cke.	+	+	+	+	+		+		+	+	+	+		10-
F. roseus (Fr.) Cke.	+		+	+	+		+			+	+	+		10-
F. tsugina (Murr.) Sacc.	+		+	+										10-
Hydnum ochraceum Fr			+	+			+		+	+	+	+	+	2-
Hymenochaete tabacina (Fr.) Lév	+	+	+	+	+	+	+		+	+	+	+	+	1-3
Hypoxylon cohaerens Fr.						+			+	+			+	- ¼
Irpex cinnamomeus Fr.										+			+	2-
Lentinus lepideus Fr.		+	+	+	+									10-
Lenzites betulina Fr.			+			+	+	+	+	+		+	+	12-
L. saepiaria Fr.	+	+	+	+	+		+	+		+	+			1-
L. trabea Fr.	+	+	+	+	+	+	+	+	+	+		+	+	12-
Libertella betulina Desm.									+	+				-1
Minnsia carnea Ell. and Ev. in herb.			+											-⅛
Panus rudis Fr.	+		+					+	+	+	+	+	+	12-
P. stypticus Fr.	+		+		+		+		+	+	+	+	+	1-
Peniophora gigantea (Fr.) Mass.	+	+	+	+										3-
Phlebia cinnabarina Schw.							+	+	+	+	+	+	+	6-
Pholiota adiposa Fr.			+			+	+	+	+	+		+		12-
Polyporus abietinus Fr.	+	+	+	+	+									6-
P. adustus Fr.	+				+	+	+	+	+	+		+	+	6-
P. albellus Pk.						+	+		+	+	+	+	+	2-3
P. anceps Pk.	+	+	+	+	+									12-
P. arcularius Fr.			+				+	+	+	+		+		3-
P. borealis Fr.	+		+		+									12-
P. brumalis Fr.			+				+	+	+	+	+	+	+	1-
P. caesius Fr.	+		+	+	+	+				+		+	+	10-
P. cinnabarinus Fr.	+		+		+		+	+	+	+	+	+	+	5-
P. dichrous Fr.			+		+		+		+	+		+	+	2-
P. gilvus (Schw.) Fr.						+				+	+	+	+	3-
P. glomeratus Pk.									+			+		12-

[1] Dash following a number indicates occurrence on material of diameter indicated and larger. Dash preceding a number indicates occurrence on material up to the indicated diameter.

TABLE 1.—*Some of the more important fungi found disintegrating slash in the Northeast, with indication of the kinds and sizes of wood commonly attacked*—Continued

Important slash fungi	Balsam fir	Eastern white pine	Hemlock	Red and pitch pine	Red spruce	Ash	Aspen	Basswood	Beech	Birch	Cherry	Maple	Oak	Size commonly attacked
														Inches
P. hirsutus Fr.	+	---	+	---	---	+	+	+	+	+	+	+	+	3–
P. pargamenus Fr.	---	---	+	---	---	+	+	+	+	+	+	+	+	6–
P. pubescens Fr.	---	---	---	---	---	+	+	---	+	+	+	+	---	6–
P. radiatus Fr.	---	---	---	---	---	---	---	---	+	+	+	+	---	8–
P. resinosus Fr.	+	---	+	---	+	---	+	+	+	+	+	+	---	12–
P. sulphureus Fr.	---	+	---	---	---	+	---	---	---	+	+	+	+	12–
P. tsugae (Murr.) Overh.	---	---	+	---	---	---	---	---	---	---	---	---	---	12–
P. tulipiferus (Schw.) Overh.	+	+	---	---	---	+	+	---	+	+	+	+	+	–3
P. versicolor Fr.	+	+	+	---	+	+	+	+	+	+	+	+	+	2–
Poria cinerescens (Bres.) Sacc.	---	+	+	+	+	---	---	---	---	+	---	---	+	1–4
P. ferruginosa (Fr.) Karst.	+	---	+	---	+	+	+	+	+	+	+	+	+	1–
P. obliqua (Pers.) Bres.	---	---	---	---	---	---	---	---	---	+	---	---	---	6–
P. prunicola (Murr.) Sacc. and Trott.	---	---	---	---	---	---	---	---	---	+	+	---	---	8–
P. subacida (Pk.) Sacc.	+	+	+	---	+	+	+	---	+	+	+	+	+	10–
P. unita (Pers.) Cke.	---	---	+	---	---	---	---	---	+	---	+	+	+	6–
Schizophyllum commune Fr.	+	+	+	+	+	---	+	+	+	+	+	+	+	[1]
Scoleconectria balsamea (Cke. and Pk.) Seaver	+	---	---	---	---	---	---	---	---	---	---	---	---	–½
S. scolecospora (Bref.) Seaver	---	+	---	+	---	---	---	---	---	---	---	---	---	–1
Stereum fasciatum Fr.	---	---	---	---	---	---	+	+	+	+	---	+	+	3–
S. gausapatum Fr.	---	---	---	---	---	---	---	---	---	---	---	---	+	10–
S. hirsutum Fr.	---	---	---	---	---	---	---	+	+	+	+	+	+	–3
S. murrayi (Berk. and Curt.) Burt.	---	---	---	---	---	+	+	---	+	+	---	+	---	12–
S. purpureum Fr.	---	---	---	---	---	---	+	---	+	+	+	+	+	8–
S. rameale Burt.	---	---	---	---	+	---	---	---	+	+	+	+	+	–1
S. sanguinolentum Fr.	+	+	+	+	+	---	---	---	---	---	---	---	---	6–
Trametes americana Overh.	---	+	+	---	+	---	+	---	---	---	---	---	---	10–
T. heteromorpha (Fr.) Lloyd	+	+	+	+	+	---	---	---	---	---	---	---	---	6–
T. mollis (Sommerf.) Fr.	---	---	---	---	---	+	---	---	+	+	---	+	---	6–
T. sepium Berk.	---	---	+	---	+	---	+	+	+	+	---	+	---	6–
T. serialis Fr.	+	+	---	---	+	---	---	---	---	+	---	---	---	6–
T. subrosea Weir	---	+	---	---	+	---	+	---	---	+	---	---	---	8–
T. variiformis Pk.	+	---	+	---	---	---	+	---	+	+	+	+	---	1–
Trogia crispa Fr.	+	---	+	---	---	---	+	---	+	+	+	+	---	1–
Ustulina vulgaris Tul.	---	---	+	---	---	+	---	+	+	+	+	---	+	12–

[1] All sizes.

Some of the usual so-called heart-rotting fungi of living trees are included in this list. All can persist alive in slash of diseased trees if moisture conditions are favorable, but this so often is not the case that continued decay by them is somewhat infrequent. The following species of these fungi of living trees are important in the slash. *Armillaria mellea* and *Ustulina vulgaris* cause butt rot of living trees and occur in stumps and defective logs left in the woods. *Daedalea unicolor*, *Stereum sanguinolentum*, *Fomes applanatus*, and *F. pini* cause trunk rot in living trees and persist frequently in large pieces of slash; the last persists especially in spruce slash. *Polyporus glomeratus* and *Poria obliqua* regularly cause trunk rot in living trees, producing sterile conks, but form their spore-producing fruiting bodies only on dead trees or logs.[5]

FUNGI DECAYING FINE SLASH

The decay of the fine slash that forms the most extreme fire danger is especially important. It has been found that certain fungi contribute to the reduction of fire danger from small branches and twigs by weakening them and by being asso-

[5] CAMPBELL, W. A., and SPAULDING, P. STAND IMPROVEMENT OF NORTHERN HARDWOODS IN RELATION TO DISEASE IN THE NORTHEAST. Allegheny Forest Expt. Sta. Occas. Paper 5, 25 pp., illus. 1942. [Processed.]

ciated with their early breakage. Special attention is called to some of these fungi. *Minnsia carnea* is so little known that it never has been scientifically described, yet it is plentiful on hemlock twigs and weakens them so that they break at the infected places. *Libertella betulina* is abundant on small branches of the birches and weakens the wood so that it snaps off readily. *Creonectria purpurea* has a similar effect on hardwood twigs, especially of beech. On small hardwood branches *Diatrype stigma*, *Exidia glandulosa* (*10*), *Dermatea molliuscula*, and *Eutypella angulosa* cause breakage and falling of the attacked parts.

The finest twigs of spruce and balsam fir appear not to be rotted so much as weakened by weathering. Fungi are undoubtedly involved, but fruiting bodies give few definite clues to them. Data on the age of slash when twigs begin to drop and small branches to break are given in table 2, together with the chief fungi found attacking and weakening them.

TABLE 2.—*Age of slash of different species when twigs and small branches begin falling, and the more important fungi associated with their fall*

Slash	Age when twigs begin to fall and cause of rot		Age when small branches begin to break and cause of rot	
	Years	Fungus	Years	Fungus
Birch	2	*Libertella betulina*. *Stereum rameale*.	3	*Daedalea confragosa*. *Dermatea molliuscula*. *Diatrype stigma*. *Eutypella angulosa*. *Polyporus albellus*. *P. hirsutus*. *P. radiatus*. *P. tulipiferus*. *Trogia crispa*.
Oak	2	*Stereum rameale*.	5	*Diatrype stigma*. *Exidia glandulosa*. *Irpex cinnamomeus*. *Stereum fasciatum*. *S. hirsutum*. *S. rameale*.
Beech	3	*Creonectria purpurea*. *Hypoxylon cohaerens*	3	*Diatrype stigma*. *Libertella faginea* Desm. *Polyporus hirsutus*. *P. pargamenus*. *P. tulipiferus*.
Sugar maple	1	*Creonectria purpurea*	4	*Lenzites betulina*. *Polyporus hirsutus*. *P. tulipiferus*. *P. versicolor*.
Hemlock	5	*Minnsia carnea*	6	*Lenzites saepiaria*.
White pine	5	*Scoleconectria scolecospora*	6	*Lenzites saepiaria*.
Balsam fir	8	*Scoleconectria balsamea*	10	*Aleurodiscus amorphus*. *Dasyscypha agassizii*. *Lenzites saepiaria*. *Scoleconectria balsamea*
Red spruce	8		10	*Dasyscypha agassizii*. *Lenzites saepiaria*.

The falling of the twigs and small branches results in most of the pieces reaching the ground or lower parts of slash piles where moisture is higher, and the fire danger is consequently much reduced. Disintegration of the fallen infected pieces then proceeds rapidly in spite of the higher moisture.

DANGER OF THE DETERIORATING SLASH TO THE SUCCEEDING FOREST

It is generally recognized that logging slash is seldom a serious hazard to the living trees of the vicinity from the insects living in it or attracted to it. In pine areas there is some danger of development of temporary bark beetle outbreaks, and the Pales weevil (*Hylobius pales* Herbst) may breed in cull logs and stumps and then attack advance reproduction or planted trees. United States Department of Agriculture Circular 411 (*17*) gives a suggestive summary of this subject.

Allowing slash to lie until disintegrated results in the production of many fruiting bodies of the numerous species of fungi that live on fallen deadwood. It would appear that such abundance of infectious material might be dangerous to the succeeding generation of trees and be liable to cause an abnormally high number of infections in the living trees, which finally would be destructive. Fortunately, most of the fungi that fruit most plentifully are limited strictly to deadwood and at most can attack a living tree only in a wound that remains unhealed for a considerable number of years. Even then many of the wood-rotting fungi are likely to become inactive after an infected wound is healed.

A number of the slash fungi may be potentially dangerous, but most of them occur so commonly on large logs and broken or wind-thrown trees that their spores are present throughout the forest, even where little or no cutting has been done for years. Their fruiting bodies on slash somewhat increase a constant normal hazard. The following slash fungi capable of causing heart rot of living trees can be named as common: *Armillaria mellea*, *Daedalea unicolor*, *Fomes applanatus*, *F. igniarius* var. *laevigatus* Fr., *F. pini*, *Pholiota adiposa*, *Pleurotus* spp., *Polyporus borealis*, *P. glomeratus*, *Poria obliqua*, *P. prunicola*, *Stereum fasciatum*, *S. gausapatum*, *S. murrayi*, *S. sanguinolentum*, and *Ustulina vulgaris*. Besides these should be mentioned the canker fungi, *Cytospora chrysosperma* Fr., *Eutypella parasitica* Davidson and Lorenz, *Hypoxylon pruinatum* (Kl.) Cke., *Nectria galligena* Bres., and *Strumella coryneoidea* Sacc. and Wint., which are not listed as slash-rotting fungi but occur on hardwood slash for a few years after cankered trees are felled.

Practically all the slash-rotting fungi can attack living trees only through wounds, and most of them only through large wounds exposing heartwood or large patches of sapwood that dies to a depth of more than 1 inch. Trees must be two decades or more of age to have formed heartwood or to be large enough to have wounds so extensive that infection of exposed dead sapwood may be serious. Where clear-cutting is done, the fruiting of the slash fungi is largely past by the time the new generation of trees can be endangered. In partial cuttings, care should be taken to see that the reserved trees are free from logging injuries, thus keeping danger of infection at a minimum. Bruising the main trunk, knocking off large patches of bark, or breaking off large living branches near the trunk by falling trees may lead to serious decay by the time a second cutting is made. Logging injuries invite attack by decay fungi, and the longer the cutting cycle the more extensive the decay will be. Eastern white pine appears to be especially susceptible to damage by trunk decay entering stubs of broken living branches in the lower crown. Even in this species, however, if reasonable care is taken to avoid such injuries, the slash fungi do not materially increase the usual decay hazard.

FACTORS CONTROLLING DECAY

The factors controlling slash decay can be separated into two groups, (1) the physical factors of the site and (2) the forestal factors of the vegetation clothing the site. The physical factors, being inflexible attributes of the inanimate site, cannot ordinarily be changed by man. The forestal factors, being dependent upon living things, are flexible and can be changed by the forest manager to aid him in accomplishing his aims.

Influence of Physical Factors

Among the most important physical factors in slash decay are moisture, temperature and light, soil, slope, aspect, and altitude.

MOISTURE

Moisture appears to be the most potent factor controlling decay of slash (*14*); in fact, in the Northeast it often obscures or nullifies the effect of most other factors. The moisture of the underlying soil largely regulates that of the air surrounding the slash as well as that of slash lying in direct contact with the soil. It also controls the rate of development of new ground cover and its character and density, all of which influence the decay of the slash that this ground cover surrounds. Slash very readily absorbs moisture from the soil when lying directly upon it. The successful use of small cylinders of wood as forest fuel-moisture measuring devices is based on the fact that wood readily absorbs moisture (*2*). Fine top slash follows the moisture content of the air quite closely, as investigations of fire danger have shown. Moisture and temperature usually are so intimately associated with slash under natural conditions that the effect of one cannot be separated from that of the other. High moisture usually means moderate temperature, while low moisture implies high temperature.

TEMPERATURE AND LIGHT

Temperature is modified considerably by moisture and other factors, including type of soil, slope, aspect, ground cover, and crown cover. To avoid repetition, temperature is discussed under these headings.

Light and the complex of factors intimately associated with it control the activities of many of the fungi that decay slash. Some of these rarely occur except in practically full sunlight, others thrive in broken or intermittent sunlight, while many must have constant shade.

SOIL

The soil influences slash decay through its heat and water relations (*14*, *15*). Sandy soil, which radiates heat readily, is likely to be dry on the surface and cause slash to season quickly, and even to case-harden, so that decay is postponed considerably. On such soils the ground cover is apt to be thin and the fire danger high. In contrast, a clayey soil that retains moisture tenaciously is likely to lead to waterlogging of slash and thus indefinitely delay decay. Ground cover on clay soils is usually heavy and its fire danger low. Slash rots most rapidly on loamy soil types intermediate between these two extremes. On such soils excessive wetness or dryness is rarely encountered, and the ground cover is usually of average density and composition.

SLOPE

The slope of a site partially controls the intensity of heat received from the sun, the volume of precipitation that sinks into the soil, the depth of soil, and to some extent the height of the water table (*14*). Steep slopes are likely to shed most of the precipitation quickly, and the soil is usually thin. The water table is near the surface but is often broken by projecting ledges. As the slope decreases, these extreme conditions give way to deeper soils. Generally, the steeper the slope the greater the environmental variations from the average. Steepness of slope did not affect perceptibly the decay of slash.

ASPECT

The aspect of a slope has a direct influence upon the quantity of heat received from the sun and an indirect effect on other environmental factors. The nearer a slope approaches a right angle to the sun's rays in the hottest part of the day in midsummer, the warmer and drier are the air and the upper layer of the soil. Numerous investigations of this effect have been made with proper instruments and care for scientific accuracy. The general consensus of results has been that the northern aspects are cooler than the southern. According to Warming and Vahl (*19*), in northern latitudes southwest, south, and southeast slopes are warmest, while northeast, north, and northwest slopes are coldest. Hopkins (*6*) expressed the differences in temperature for different aspects in West Virginia with reference to mean temperature as follows: A change in altitude of 400 feet produces a change of 1.1° F. Southern and southwestern aspects equal an addition of 300 feet in elevation of the mean. Northern and northeastern aspects (in coves) equal a decrease in elevation of 300 feet. This would be a difference between the two of 600 feet, or nearly 1.7° mean temperature. Since the red spruce slash was nearly all on distinct slopes and more data were available for the purpose (about 235 areas) than for the other species, an attempt was made to determine with red spruce slash the effect of aspect on decay. With the available data only slightly consistent differences resulting from aspect of slope could be found. It appears that other factors obscured the effect of aspect on slash decay.

ALTITUDE

Decided change in altitude is known to cause perceptible change in environment. Many have studied these changes and contributed data on various factors of environment. Recently, Hopkins (*6*) stated that a change of approximately 400 feet in altitude equals qualitatively a difference of 1° latitude (69 miles) on a level, and produces a mean temperature change of 1.1° F. At higher altitudes the sun's rays have a more powerful effect, as shown by shortening of exposure for photographic films, sunburn, and the need for dark-tinted glasses to protect the eyes. The extremes of day and night temperatures, wind movement, and evaporation are accentuated. In the Northeast, precipitation is likely to increase with elevation; the higher mountains in a group, or isolated peaks rising decidedly above their surroundings, are locally known as "rain makers." The warm season is shortened, snow falling on higher peaks several weeks before it does on the adjacent lowlands and remaining later in spring.

Many studies have been made of the effect of altitude on the ecology of animals and higher plants, but none are known to the writer on the activities of wood-rotting fungi other than their altitudinal range. The present investigations have been limited to commercial cuttings in the mountains of New England and New York, which are not common much higher than 3,000 feet above sea level.

In attempting to determine the effect of elevation on slash decay it was apparent that widely different elevations must be considered if their effect is to be marked enough to present distinct differences in decay. Preliminary field observations indicated that low elevations might be considered as from 500 to 2,750 feet, while elevations above that level might be considered the higher ones. Red spruce and balsam fir grow at all these elevations. Moreover, they have been harvested constantly and extensively, so that much slash of all ages was available for study. These are the only species of which sufficiently abundant slash could be found at the higher elevations.

In 1939 a study was made by Spaulding et al. of the progress of decay of red spruce slash at elevations below 2,750 feet. Since that time considerable additional data have been obtained, especially at elevations above 2,750 feet, so that a comparison now can be made between the two elevation zones. Such a comparison has shown a difference of less than 2 years in the rate of delay of slash as a whole, but curves of the progress of decay of slash larger than 3 inches in diameter show consistent, continuous retardation of 10 years at the higher elevations. This apparent discrepancy may be explained by the fact that decay of large slash was unduly retarded by waterlogging and case-hardening in more numerous cases than at lower altitudes.

Influence of Forestal Factors

RESIDUAL CROWN COVER ON CUT-OVER AREAS

Removal of all or part of the crown cover subjects the slash of the harvested trees more or less severely to abnormal exposure to sunlight and to the resulting high temperatures and low humidity. Slash decays most rapidly under a crown cover so broken that the shadows move across openings in 1 to 2 hours in the hottest part of a midsummer day. Any reduction of the crown cover that does not cause "decadence" in northern hardwoods will be optimum for slash decay, as slash decay is retarded by the same conditions that cause decadence; namely, prolonged exposure to full sunlight in the hottest part of the day in midsummer. Experiments set up to get definite data on this point were accidentally ruined. For this reason, the statement as made rests on scattered observations.

Some ground cover is usually present except under dense pure coniferous stands. When cuttings are made, the ground cover furnishes shade in the openings until a new crown cover is established. Development of the adjacent ground cover and the formation of new crown cover tend to maintain increasingly uniform moisture in the shaded slash.[6] Slash decay thus may be influenced according to the moisture of the site.

[6] See footnote 4, p. 4.

RELATIVE DURABILITY OF DIFFERENT SPECIES OF WOOD

The heartwood of different species of trees varies much in resistance to decay while the sapwood of all species is readily rotted. Because of the great variation in relative quantities of the two, the general rate of decay of a given lot of slash may be much accelerated or retarded. The heartwood of most of the species included in this investigation outlasts the sapwood. The heartwood of some species is much more resistant to decay than is sapwood, especially in large pieces of slash with a heartwood core 10 inches or more in diameter. Resistance to decay in some species is increased by waterlogging of the heartwood. Heartwood slash of the following species was found most durable: Oak, ash, sugar maple, red spruce, white pine, hemlock, beech, and yellow birch. The last three owe their durability largely to their natural tendency to become waterlogged after felling.

AGE OF FELLED TREES

Old age may result in maximum formation of heartwood. Overmature trees may have so thin a layer of sapwood that heartwood extends well out into the small branches. Since the heartwood of most species is more resistant to decay than the sapwood, slash from such trees is of maximum durability and persists far beyond the usual period for the species in younger age classes.

WATERLOGGING AND CASE-HARDENING OF SLASH

Slash frequently is found in two conditions that indefinitely retard the rate of its decay (*14*, *15*); namely, (1) saturation with water and (2) early and complete seasoning. These two conditions, termed waterlogging and case-hardening, are due to excess moisture and excess sunlight, respectively, causes that usually act in opposition to each other. Inherent qualities of the different species of wood greatly influence the occurrence of these conditions in slash.

Saturated wood resists decay indefinitely. The different species of wood vary much in their readiness to absorb water and to become saturated (table 3) (*14*). Waterlogging takes place in 2 to 5 years and usually occurs only in slash 3 inches or more in diameter. The heartwood of some species readily waterlogs while the sapwood does not. The species in the accompanying list grow commonly on sites differing considerably in soil moisture, the factor that largely controls waterlogging of slash. The ratings given are based on comparisons made on sites where the different species grew commonly.

On a wet site waterlogging is to be expected almost regardless of the tree species. On a site of medium moisture, where the soil neither dries out excessively nor remains wet, the species listed in the first column waterlog rarely, those in the second column occasionally, and those in the third column commonly. Yellow birch is almost certain to waterlog, while the other species in the same column are less likely to do so. Waterlogged slash may require a decay period one and one-half to double the usual time, and in exceptional cases, even longer.

TABLE 3.—*Relative liability to waterlogging of slash of some northeastern trees*

Rarely	Occasionally	Commonly
Chestnut	Balsam fir	Aspen
Eastern white pine	Black oak	Basswood
Red spruce	Paper birch	Beech (heartwood)
White ash	Red maple	Hemlock (heartwood)
White oak	Red oak	Yellow birch
	Sugar maple	

Case-hardening is most likely to occur in slash less than 1 inch in diameter. Slash of larger size that becomes case-hardened is so decorticated that the bare wood is exposed to the sun. Small slash of eastern white pine is especially likely to case-harden, pieces ⅛ to ¼ inch in diameter often persisting for more than 20 years. The twigs of red spruce, hemlock, and balsam fir dry so quickly and completely that they commonly resist decay for about 10 years. In the same way, fully exposed twigs of beech, sugar maple, and white ash season quickly and may remain sound for several years. Bigtooth aspen slash sheds its bark in the second year and the decorticated smaller branches case-harden and remain sound several years. Case-hardening occurs especially on dry or exposed sites and is least likely to be favored by the broken canopy resulting from partial cutting. Case-hardening usually delays decay for several years and in exceptional cases may delay it for nearly double the usual decay period.

INFLUENCE OF MANAGEMENT

In any program of forest management, due consideration must be given to the condition of the cut-over area when the harvesting operation is completed. Logging slash, the advance reproduction already on the ground, and the reproduction that is expected to develop shortly are important elements for consideration. The slash is not the least of the three, as it directly exerts a very decisive influence over the other two (*20*).

Season of Cutting

Difference in rate of decay of slash due to different seasons of cutting was not great enough to be detected in these investigations. This may not mean that there is no difference, but probably that none was noted, because other more active variables completely obscured any that might exist.

Methods of Cutting

The residual canopy left by logging is important in the decay of slash left on the ground. Removal of the entire crown cover admits full sunlight, thus raising temperatures at the ground level and drying out the surface layer of soil to an unwonted degree. The slash is fully exposed to the direct rays of the sun as well as to reflected heat of the exposed soil surface until a new ground cover is established. Such drastic exposure dries out the upper and outer layers of slash so that it is seasoned quickly and resists decay. Clear-cutting also tends to leave the slash in masses, which, with the conifers, are likely to pack closely together and become waterlogged beneath (*11*, *16*, *20*), except on unusually dry soils. Slash in full sunlight usually decays more slowly than under partial crown cover.

Partial cutting leaves a broken canopy the shade of which moves hour by hour, so that any given spot is not continuously exposed to full sunlight. Slash on most sites then does not become excessively dry, and conditions favor its decay. Scattered slash under a moderately broken canopy decays more quickly than under any other condition (*10*, *21*). As the masses of slash are seldom continuous, lopping to reduce fire danger seems unnecessary.

As far as the decay of slash is concerned, partial cutting creates more favorable conditions than does clear-cutting. This may be a relatively unimportant matter in hardwoods or in hardwoods with a light intermixture of conifers, as decay of the main body of the slash is relatively rapid in any case. But with stands consisting largely of conifers, it may be worthy of consideration. Where partial cuttings are made with an expected cutting cycle of 15 years or more, care should be taken to avoid logging injury to the reserved trees.

Methods of Slash Disposal

The slash that most concerns the forester consists of foliage, twigs, and smaller branches, since they constitute the acute fire danger, and in coniferous slash may seriously interfere with reproduction following cutting (*20*). Local moisture conditions will largely determine what method of disposal will favor the most rapid decay of the slash. As already shown, the type of cutting will strongly influence the choice of the proper method of slash disposal.

Burning of slash must nearly always be done under careful control for satisfactory results. Controlled burning is expensive but causes slight damage to advance reproduction and reserved trees and little or none to the site. Leaving slash to decay involves the chance of uncontrolled fire, the danger decreasing as fire-prevention measures are intensified and continued. Uncontrolled fire usually burns when damage will be greatest. It may result in a deteriorated site, the death of advance reproduction, and the death of or serious damage to reserved trees. Choice must be made between costly fire-control measures or running high risks of equal or even larger losses in future forest values.

The methods of slash disposal, aside from burning, are piling, leaving in windrows with hauling trails between, scattering over the cutting area, and lopping of branches to get them down on the ground.

PILING

Slash is usually piled where controlled burning is carried on, piling being an integral part of that operation, unless broadcast burning is done. Sometimes piling is resorted to in order to facilitate removal of timber or to free a larger portion of the area for new growth

WINDROWING

Windrowing of slash, especially on hillsides, has been generally practiced. The trees are felled so that the crowns fall on one another and the slash is left in an irregular windrow, while the trunks are free to be hauled away in the open interspaces. This is a general method used in clear-cutting of conifers and of hardwoods in cordwood cuttings. It has serious features, in that accidental fire burns fiercely and is very likely to sweep over the entire cutting area, damaging or killing the advance reproduction; the masses of slash are so dense, even with hardwoods, that satisfactory new reproduction can come in only on part of the area; and where coniferous slash piles lie, reproduction is delayed up to 20 or more years (*20*).

SCATTERING

Where partial cutting is practiced, the slash usually is scattered thinly and more or less regularly over the entire area. Scattered slash under broken canopy usually rots more rapidly than under any other condition. In one instance scattering of the slash was practiced in clear-cutting of red spruce on steep slopes, with a saving of advance reproduction up to a height of about 1 foot. Dense masses of slash accumulated only on the lower side of the hauling trails where construction already had destroyed advance reproduction. With fire excluded, the spruce reproduction in this district 5 to 10 years after cutting was very fine. Where uncontrolled fire burned, spruce disappeared and the sparse hardwood reproduction, largely of weed species, promised little value except as watershed cover. In many mountainous areas of the Northeast, uncontrolled hot fire spells ruin, as the site becomes seriously deteriorated by the burning of the duff and humus, which can be replaced only after a long period of years.

LOPPING

Lopping of slash has been required in the Adirondacks for coniferous slash since 1909. In the White Mountain National Forest lopping of both hardwood and coniferous slash has been required in timber sale contracts for a number of years. At present the dense coniferous slash is burned under careful control.

Investigation of lopping of coniferous slash in New York (*11*, *16*) showed that lopped slash remained damp beneath longer than when unlopped. After the first 2 or 3 years, lopping resulted in less fire danger. The lopped slash decayed sooner than the unlopped.

Lopping is less effective with hardwood slash in getting fine twigs onto the ground than with softwood slash. Hardwood slash is much more openly branched and will not pack closely together unless the branch wood is removed for acid wood, cordwood, or pulpwood; nor will the weight of the foliage increase compactness. Lopping of hardwood slash is costly if properly done, and while it usually brings the heavy, large branches down onto the ground, much fine slash remains off the ground although this decays and falls in 3 or 4 years in any case. The most acute danger is then over, but the larger slash will still burn readily if fire runs over the area in dry fallen leaves and herbaceous ground cover.

The data comparing lopped and unlopped hardwood slash were practically all taken on the plots previously mentioned, since comparable material and conditions were mostly limited to these areas. The results may be briefly stated as follows:

In the first year decay began in the small branches and twigs about equally but with slightly fewer fruiting bodies on the unlopped slash. This was evidently due to quicker drying in the unlopped material. which discouraged fruiting temporarily.

In the second year the weakening of small slash was not perceptibly different, but decay was slower in the lopped large slash. In the meantime waterlogging of lopped yellow birch more than 3 inches in diameter had occurred and inhibited decay.

In the third year waterlogging had reached its maximum. Decay in unwaterlogged slash was advancing about equally, and numerous fruiting bodies of fungi appeared on all sizes of slash.

In the fourth year decay slightly increased in the unlopped as contrasted with the lopped slash This was partly due to the breaking and falling of small branches, which after falling continued disintegration as if they were lopped, and also to the development of new ground cover and canopy, which changed the earlier relatively dry condition to a more moist one. This tended to keep conditions too moist for the decay of slash on the ground but provided optimum conditions for decay off the ground.

In the next few years increasing density of canopy favored decay of slash off the ground, and material up to about 2 inches in diameter decayed and fell to the ground. At the same time fruiting bodies of fungi attacking only larger slash appeared and the lopped and unlopped material that was not waterlogged approached the same degree of decay and continued the same pace subsequently. The main difference between the lopped and unlopped slash was in the relative quantity of waterlogged material. which was considerably larger in the former than the latter. Yellow birch was an important species in most of the plots. When lopped, it waterlogged so promptly that decay could not begin and the watersoaked wood effectively resisted decay for 10 years, when some of the moisture-loving fungi succeeded in getting a foothold. Waterlogging was not limited to yellow birch, however. It took place in heartwood of discarded beech and hemlock logs, especially after the closing of the crown cover.

It has been noted that there is a tendency for lopped and unlopped slash to approach each other in degree of decay after a number of years. This probably is due to the weakening of unlopped parts by decay so that they fall to the ground and afterwards are subject to the same conditions as the lopped material.

In general, lopping is efficient with the conifers and with the more rot-resistant hardwoods. It is to be avoided with those species that waterlog easily, notably yellow birch, and on permanently wet sites. It may be practiced effectively on dry and medium moist sites. It contributes materially to low fire danger by placing inflammable material near the ground, thus keeping fire low, and keeping the slash moist except in the hottest part of summer, when vegetation is green. If well done lopping costs so much that care must be taken to balance correctly the value of the results against the costs. In mixed stands the cost can be reduced by lopping only the species that will give maximum results.

To promote prompt decay of slash and insure a minimum period of high fire danger, a method of slash disposal should be used that will avoid waterlogging and case-hardening—a method based on the moisture of the site and the species of tree supplying the greater part of the slash.

RELATION OF SLASH DECAY AND FIRE DANGER

Decay affects the fire danger of slash by reducing both the quantity of inflammable material and the fuel value of what remains. Both processes go on at the same time.

Reduction in Volume Through Decay

The most obvious effect of decay on slash is the gradual reduction in its volume until it finally disappears. But the degree of reduction is difficult to evaluate or estimate consistently. Nevertheless, it was attempted, along with a number of contributing elements, especially with red spruce and balsam fir slash. Estimates were made of the percentage of the original slash remaining on the ground. By using wide classes and fixing in mind certain conditions of the slash indicative of each class, it was possible to allocate to percentage classes with reasonable definiteness. Consistency was attained by having the estimates made by the same persons checking against each other, disagreements being settled on the spot.

In the field, the following conditions of the slash were taken as indicators of the percentage classes—

100–87.5 percent: Where no slash larger than ⅛ inch in diameter had fallen.
87.4–62.5 percent: Where no slash more than ½ inch in diameter had fallen.
62.4–37.5 percent: Where no material above 3 inches in diameter had fallen.
37.4–12.5 percent: Where no slash less than 3 inches in diameter remained.
12.4–0 percent: Where slash logs were falling apart and were scarcely distinguishable from debris occurring under natural forest conditions.

The curve in figure 1, showing the general progress of reduction in volume of

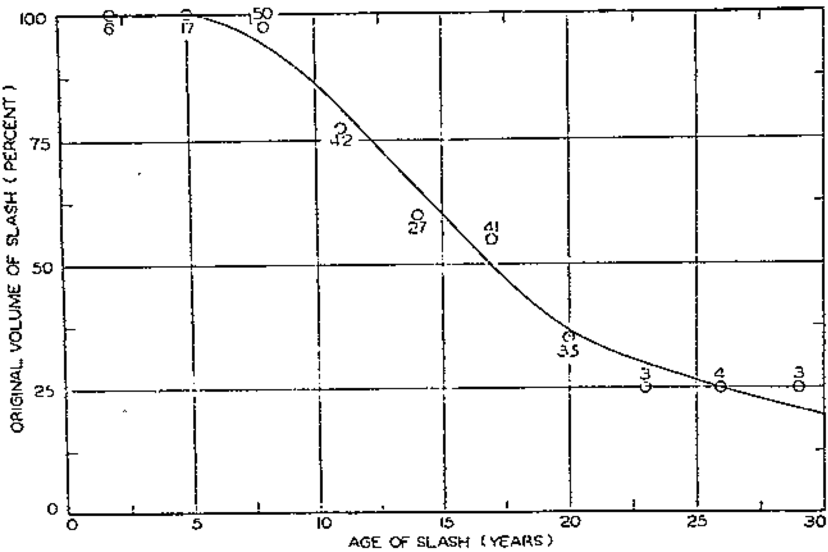

FIGURE 1.—Relation of volume of red spruce slash to its age. Numbers at the points indicate the number of areas on which each point is based.

red spruce slash, was constructed on the basis of arithmetical means. The interpretation is as follows: The volume of slash remains practically unchanged for 6 years, drops to 75 percent at about 12 years, to 50 percent at 17 years, and to 25 percent at 26 years, after which disintegration slows because of the large size of the remnants. These then usually are well scattered and occupy but a small part of the area originally covered by the slash.

While intensive study of reduction of volume of slash by decay has been directed especially to red spruce and balsam fir, long experience shows that slash of all tree species undergoes the same general course of events, but with varying relation to age of slash.

EFFECT OF DECAY ON FUEL VALUE OF SLASH

The fuel value of decaying slash in the forest is affected chiefly by the specific gravity of the wood substance and its water content.

Decay essentially is the consumption of wood by fungi, and its progress is indicated by the decrease in weight per dry unit volume. Using weight per unit of dry wood substance as a basis, the fuel value of wood decreases proportionally to the loss in substance by decay. Decay does not change the fuel value per unit weight of wood substance. Tests show that this is true of both brown and white rots (*3, 5, 9, 12, 18*). Direct tests of air-dry decayed wood have shown a marked decrease in fuel value as rot progresses (*3, 4*).

The moisture content of wood has a direct bearing on its fuel value, since the water content is vaporized and then broken down by high heat. This heat comes from the burning wood materials. The final output of this heat represents the remainder of the fuel value of the dry wood material minus the calories required to dispose of the water. The relative weight of water in well-seasoned wood may be as little as one-fifth or less of the weight of the dry wood mass. Green wood may contain water weighing more than the dry wood substance.

There is considerable variation among the different decays in their effect upon the capacity of rotted wood to absorb and retain moisture. When intermittently wetted, rotted wood absorbs and loses water more readily than sound wood, but throughout the process maintains a higher average moisture content than sound wood. Observations of all kinds of decaying slash show this to be true with slash more than about 1 inch in diameter, which gives up absorbed water only after considerable exposure to sunny weather. On the other hand, the smaller slash dries out promptly in the sun and its water content follows closely the weather conditions.

The inflammability of wood may be increased by decay, especially in its advanced stages. In olden days, dry rotten wood was used as tinder in starting a fire.

As far as fire danger is concerned, the increased inflammability of decaying slash is counterbalanced by the decreased fuel value of its gross volume, so that the fire danger is about the same for equal volumes of sound and rotted material. The principal effect of decay is to diminish the volume of fuel, thus decreasing the fire danger proportionally. This relation appears to be reasonably close with slash under the usual forest conditions. The percentage of original slash remaining would seem to be a practical field guide to the fire danger when environmental danger factors are equal.

Rate of Reduction of Fire Danger by Decay

In the intensive investigation of red spruce slash [7] special attention was given to the fire danger as related to decay at different ages. In the field, an estimate was made of the degree of fire danger under the immediate environmental conditions. The principal consideration was the relation of decay to inflammability of the slash and to rate of spread of fire. No attention was given to resistance to fire control. Five classes of fire danger were recognized, which were characterized as follows:

- Extreme: Slash bulky. Twigs and many leaves still adhering. Slash completely exposed to sun and wind.
- High: Slash somewhat flattened. Twigs fallen. Small branches dried out and frequently case-hardened. Trunks and large branches with early sap-rot. Slash still well exposed to sun and wind.
- Medium: Slash sunken through decay of parts close to the ground. Small branches fallen. Branches up to 2 inches in diameter partially to well rotted. Trunks and large branches well sap-rotted. Most of the slash shaded all or part of the day.
- Low: Slash flat on the ground. All branches fallen. Trunks well rotted but intact. Canopy almost entire and well above ground.
- Safe: Conditions approaching those existing in forests before logging. All branches well decayed. Trunks falling apart.

Curve *a* in figure 2, constructed from the data taken at all elevations, presents the mean fire danger of all the plots in each age class. There is about an even chance that any one individual area may have a danger rating higher or lower than this curve indicates. Surrounding conditions may be such that there is small danger of fire starting, or they may be such as to delay decay and prolong the danger period much beyond the average.

Comparing data for the two elevation zones, 500 to 2,750 and 2,751 to 4,000 feet above sea level, one finds a lag of 1 to 2 years in decrease of initial extreme fire danger in the slash at higher altitudes and a consistent maintenance of that lag to the medium stage, when the differences gradually decreased to the low stage, where they coincided.

Comparing figure 1, showing reduction in volume of red spruce slash as age increases, with figure 2, *a*, showing decrease in fire danger of red spruce slash with increasing age, one immediately notes a marked similarity of the two graphs. There is a very evident relation between slash volume and fire danger. In the preceding discussion of the effect of decay on the fuel value of slash it was concluded that the principal effect of decay is to diminish the volume of fuel, thus decreasing the fire danger proportionally. The close correlation of slash volume

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[7] See footnote 4, p. 4.

and fire danger as indicated by extensive field investigations cannot be accidental. Considering slash apart from its local environment, the volume remaining appears to be a reliable field index of its fire danger. Experience indicates that this is true not only of red spruce slash but also of eastern white pine and hardwood slash.

In general, coniferous slash requires much longer to reach the fire-safety point than does hardwood slash. Notwithstanding considerable variation between the species of hardwoods, it has seemed best to group them as a single unit. This follows because fire danger with them usually is less acute than with the conifers, and relative variations consequently are of lesser importance. Among the conifers it has seemed best to make two groups because of considerable differences and because use of the data is likely to be more detailed than with the hardwoods. Decay of slash of eastern white pine and hemlock runs a similar course. So does that of spruce and balsam fir. Two curves were made to show the decrease of fire danger for eastern white pine (fig. 2, *b*) and for the hardwoods (fig. 2, *c*) in the same manner as for red spruce (fig. 2, *a*). Based on the action of slash under all conditions encountered, the curves present averages for the various ages of slash as accurately as is feasible for such heterogeneous material. Figure 2, *c*, shows

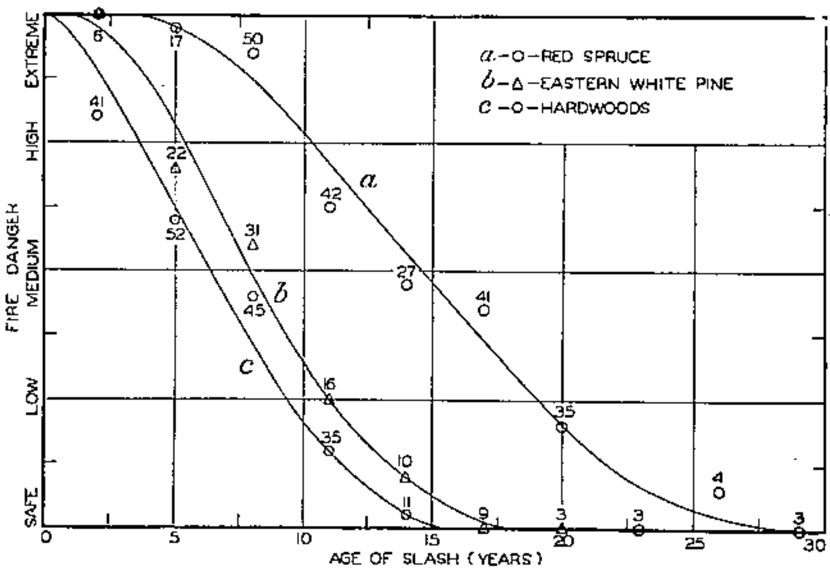

FIGURE 2.—Reduction of fire danger of slash with age: *a*, Red spruce slash; *b*, eastern white pine slash; *c*, hardwood slash. Numbers by the points indicate the number of areas on which each point is based.

that the fire danger for hardwood slash begins to decrease promptly and maintains a rapid uniform rate until a point of low danger is reached, when the rate slows perceptibly.

Casual inspection shows that eastern white pine slash has a decided likeness to hardwood slash in its relatively rapid and uniform rate of decrease of fire danger. This is due to two factors: (1) The type of twig formation of the white pine approaches that of the hardwoods, in that the twigs are long and sparsely spaced, and (2) the branches carrying the twigs are weakened early by pockets of decay and break into pieces 1 to 2 feet long, with an effect similar to lopping. Eastern white pine slash is intermediate between the hardwoods and the finer twigged red spruce in its rate of decay and the corresponding relative fire danger. The branches in the upper or top slash of red spruce and balsam fir are not weakened by pockets of rot and are not broken down nearly so early nor so frequently as are those of eastern white pine. Consequently, the fine twigs of the former generally remain in place until shed from their supporting branches. The fine twigs of red spruce and balsam fir also resist decay and remain strong nearly twice as long as those of eastern white pine. As a result the fire danger of the slash of the two former trees remains very high longer than the slash of eastern white pine.

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