

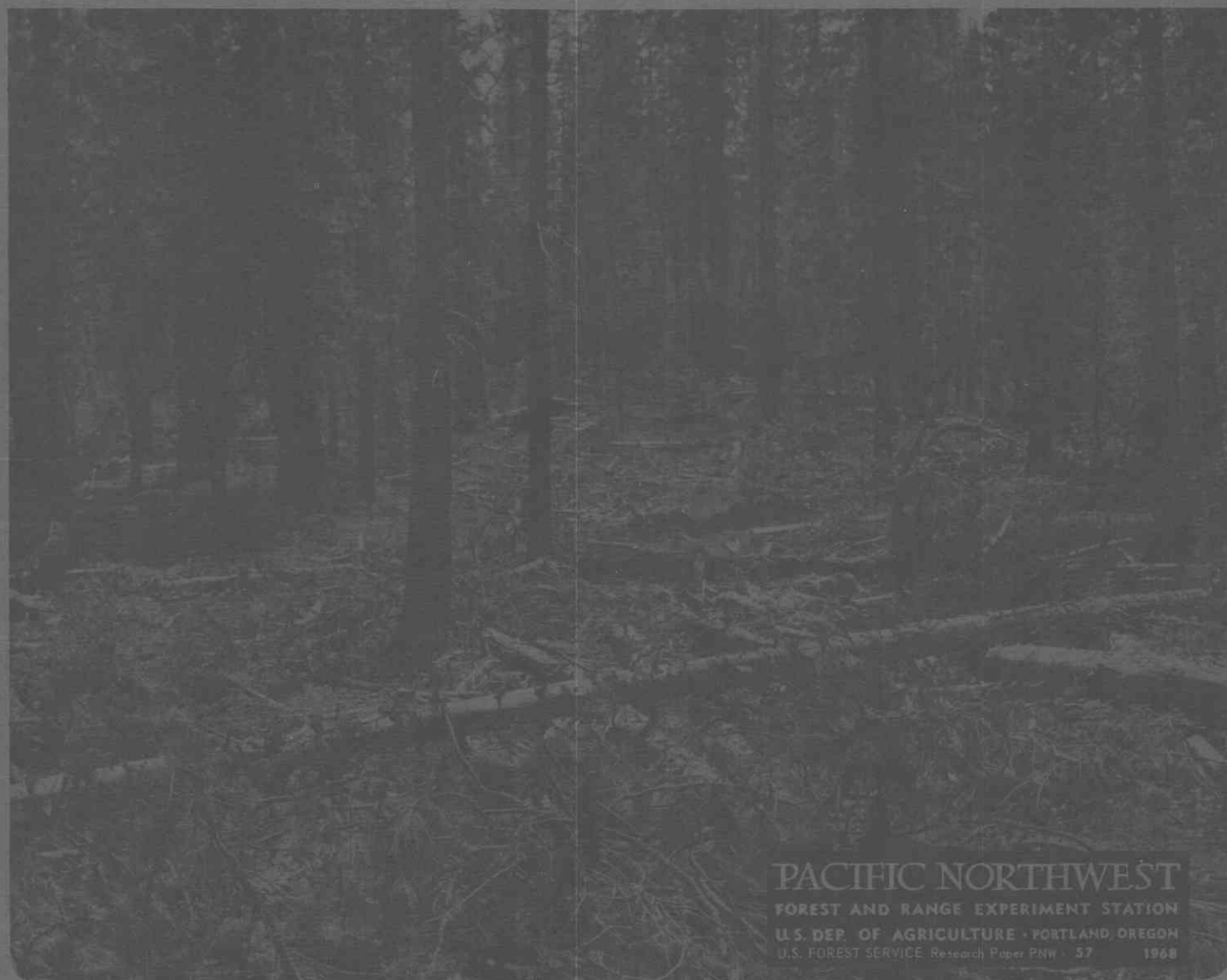
75009/ Dup

Library

MD
WRM
RCH
R₁

FIRE HAZARD FROM PRECOMMERCIAL THINNING OF PONDEROSA PINE

by GEORGE R. FAHNESTOCK



PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U.S. DEP. OF AGRICULTURE • PORTLAND, OREGON
U.S. FOREST SERVICE Research Paper PNW • 37 1968

INTRODUCTION

Precommercial thinning lately has become a major feature in management of ponderosa pine (*Pinus ponderosa* Laws.) on the National Forests in Oregon and Washington. Nearly 47,000 acres were thinned in 1966, up from 9,196 in 1959; and the upward trend appears certain to continue. Current practice is to cut the trees with a powersaw about a foot above the ground and let them lie as they fall. The slash, i.e., the felled trees, becomes a fire hazard as soon as it dries. It also obstructs access, provides a breeding place for certain insect pests (notably engraver beetles, *Ips* sp.), temporarily prevents use of forage by big game and livestock, and is esthetically offensive. On the other hand, thinning greatly increases timber growth and should prevent epidemics of mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Protection by slash may permit forage to become established or recover from overuse. In any case, forage production increases severalfold, and habitat for wildlife is improved significantly. The thinned forest, after the slash deteriorates, is generally easier to protect and esthetically more pleasing than the unthinned.

Are the temporary effects of slash from precommercial thinning serious enough to require countermeasures, the cost of which will reduce the amount of thinning that can be accomplished? One point of view is that the additional fire hazard alone is of sufficient degree and duration to demand abatement in order to prevent loss of the investment in thinning and other values as well. Opposed is the opinion that the hazard, though initially high, is of sufficiently short duration to be tolerated, with appropriate

adjustment in protection measures, so that maximum acreage can be thinned with the funds available. Both points of view have merit, and each probably is completely correct in some areas. The problem of reconciling them is the common one of optimizing allocation of expenditures to obtain maximum net gain in all forest products, tangible and intangible. This publication makes available means for gauging the fire hazard of slash more objectively than has been possible heretofore as a basis for deciding what action is required in specific situations.

Quantity of slash, expressed by ovendry weight per acre, by size class, is probably the best determinant, or indicator, of fire hazard, and certainly is the one on which the best information is available (Fahnestock 1960, Fahnestock and Dieterich 1962, Anderson et al. 1966). Information on quantity also should be useful in assessing the impact of thinning slash on other aspects of resource protection and management. This report draws on available knowledge of slash quantity to provide:

1. A basis for estimating the weight of slash produced by thinning operation.
2. General estimates of the weight of slash to be expected from thinning normal stands of known site and age to various spacings.
3. Inferences regarding flammability and difficulty of fire control for at least 5 years after thinning.
4. Suggestions as to general types of research and operational feedback needed to strengthen the scientific basis for deciding what to do about thinning slash.

QUANTITY OF SLASH

Weights of Individual Trees

The individual tree is the basic unit in computing slash weight per unit of area. In precommercial thinning, the entire tree becomes slash. The three main component parts are crown (foliage, branches, tip), wood (trunk only), and bark. Information on the three components comes from different sources, and continued separation of identities is necessary for interpretation.

Crowns.—Table 1 gives crown weights for ponderosa pine and its common associates up to a 16-inch d.b.h. Few pines larger than 6 inches

are cut in precommercial thinning, but a few of the less valuable species sometimes are. The weights are for living material only and therefore are conservative. The data were adapted from tables developed for the Inland Empire and California (Fahnestock 1960; Chandler 1960). Measurements from 21 ponderosa pines and 13 incense-cedars (*Libocedrus decurrens* Torr.) on the Deschutes National Forest showed that crown weight estimates based on data collected elsewhere for these species could legitimately be used in eastern Oregon; the same was assumed to be true for the other four species.

Table 1.—Individual crown weights of ponderosa pine and its principal associates by d.b.h. class

D.b.h. class (inches)	Ponderosa pine 1/	Incense- cedar 2/	Douglas- fir 1/	Grand fir 1/	Lodgepole pine 1/	Western larch 1/
-----Pounds, oven-dry-----						
1	4	9	3	8	1	1
2	7	19	5	13	2	3
3	15	30	8	20	4	6
4	23	41	15	28	7	10
5	36	53	22	40	13	15
6	48	67	31	52	20	21
7	65	82	42	66	30	27
8	82	98	54	79	42	36
9	103	115	63	95	56	43
10	126	133	84	110	75	55
11	150	152	98	127	96	62
12	178	173	118	145	120	77
13	202	194	131	165	150	89
14	237	216	157	184	178	103
15	—	240	178	205	215	117
16	—	266	205	226	256	134

1/ Adapted from Fahnestock (1960).

2/ Adapted from Chandler (1960).

Boles.—Cubic volume tables are available for ponderosa pine and most of its common associates, the major exception being incense-cedar (Johnson 1955). Some of the tables do not include tree diameters smaller than 6 inches b.h., but reasonable estimates for the smaller sizes can be obtained by extrapolation and comparison with other species. Table 2 is a cubic-foot volume table for ponderosa pine through the range of sizes that are likely to be cut in thinning or dwarfmistletoe control. Values were obtained by entering a standard volume table with heights typical of their respective age-site classes (Meyer 1938). The diameter groupings are those used in available stand tables. The site

and age classes cover the range likely to be thinned in Region 6. Weight of wood is volume times 25, the mean oven-dry weight in pounds of a cubic foot of ponderosa pine (U.S. Forest Service 1955).

Bark.—Ponderosa pine bark volume consistently is about 23.5 percent of peeled wood volume.^{1/} Specific gravity of bark varies widely with growing conditions (Spalt and Reifsnyder 1962). In the absence of a figure for ponderosa pine, the best assumption seems to be that bark density approximates wood density. Therefore, weight of bark is 23.5 percent of the weight of wood in a particular tree bole.

^{1/} Personal communication with F. A. Johnson, Biometrician, Pacific Northwest Forest and Range Experiment Station.

Table 2.—Cubic-foot volume of small ponderosa pines by age class, site index, and d.b.h.

Age class (years)	D.b.h. (inches)					
	1	2-3	4-5	6-7	8-9	10-11
Site index 60: ^{1/}						
20	0.05	0.25	0.95	2.25	—	—
40	.05	.35	1.25	2.90	5.30	9.05
60	.05	.40	1.50	3.30	6.25	10.71
80	.05	.45	1.65	3.30	7.20	12.50
Site index 80: ^{1/}						
20	.05	.25	1.05	2.60	4.65	—
40	.05	.40	1.55	3.40	6.40	10.95
60	.05	.45	1.70	4.00	7.60	13.20
80	.05	.45	1.75	4.25	8.10	14.55
Site index 100: ^{1/}						
20	.05	.35	1.25	2.85	5.20	—
40	.05	.45	1.75	4.10	7.60	13.00
60	.05	.45	1.90	4.50	8.50	15.20
80	—	.45	1.90	4.60	9.05	16.30

^{1/} Approximate equivalents are:
 Site III = site index 85-98
 Site IV = site index 71-84
 Site V = site index 57-70.

Total Weight Per Acre

Two types of total-weight estimates have value for several purposes. Preliminary estimates, based on general characteristics of the stands to be thinned, can be used to determine the need for hazard reduction and/or other extra protection measures over large areas and can form a basis for scheduling thinning operations in patterns that will facilitate fire protection. Working estimates, based on specific measurements in stands scheduled for thinning, can pinpoint the location of hazard so that special protection measures, if needed, can be tailored to specific situations. Both types of estimates are obtained by summing the products of number of trees cut in each d.b.h. class times the respective tree weights; only the sources of

tree numbers differ.

Preliminary estimates.—Normal yield tables (Meyer 1938) for ponderosa pine provide tree numbers for use in preliminary estimates. Prescribed spacing in the thinned stand determines how many crop trees per acre will be left. Number of trees to be cut is determined by subtraction; the best assumption as to size allocation is that the largest trees will be left. Table 3, constructed on this basis, shows estimated weights per acre to be expected when normal stands of pure ponderosa pine of four ages on three sites are thinned to various densities. Several considerations dictate the breakdown into size classes of material:

Table 3.—Tons of slash per acre from thinning normal stands of ponderosa pine to various spacings

Spacing (feet)	Type of material ^{1/}	Site index 60, stand age—				Site index 80, stand age—				Site index 100, stand age—			
		20	40	60	80	20	40	60	80	20	40	60	80
8 by 8	Crowns	9	9	2	—	5	3	—	—	2	<1	—	—
	Bark	1	2	1	—	1	1	—	—	1	<1	—	—
	Trunks ≤ 7 inches	3	8	2	—	4	4	—	—	3	<1	—	—
	Trunks > 7 inches	—	—	—	—	—	—	—	—	—	—	—	—
	Total	13	19	5	—	10	8	—	—	6	1	—	—
10 by 10	Crowns	11	13	6	2	7	7	2	—	4	3	—	—
	Bark	1	3	2	<1	1	2	<1	—	1	1	—	—
	Trunks ≤ 7 inches	3	11	8	2	5	8	2	—	5	5	—	—
	Trunks > 7 inches	—	—	—	—	—	—	—	—	—	—	—	—
	Total	15	27	16	4	13	17	4	—	10	9	—	—
12 by 12	Crowns	11	15	8	4	7	10	5	1	6	7	2	—
	Bark	1	3	3	1	1	3	2	—	2	3	1	—
	Trunks ≤ 7 inches	4	14	12	6	6	13	8	1	8	11	4	—
	Trunks > 7 inches	—	—	—	—	—	—	—	—	—	—	—	—
	Total	16	32	23	11	14	26	15	2	16	21	7	—
14 by 14	Crowns	12	16	10	6	8	12	8	3	7	10	5	1
	Bark	1	3	4	2	2	4	3	1	2	3	2	1
	Trunks ≤ 7 inches	4	15	16	10	7	16	11	6	11	14	6	2
	Trunks > 7 inches	—	—	—	—	—	—	(2)	(<1)	—	(2)	(5)	(1)
	Total	17	34	30	18	17	32	22	10	20	27	13	4
16 by 16	Crowns	12	17	12	9	9	14	10	6	7	12	8	4
	Bark	1	3	4	2	2	4	3	1	3	3	2	1
	Trunks ≤ 7 inches	4	16	18	11	8	18	11	5	12	15	6	2
	Trunks > 7 inches	—	—	—	(3)	—	—	(8)	(7)	—	(8)	(12)	(9)
	Total	17	36	34	22	19	36	24	12	22	30	16	7
18 by 18	Crowns	12	17	13	10	9	15	12	8	8	14	10	7
	Bark	1	4	4	2	2	4	3	1	3	3	2	<1
	Trunks ≤ 7 inches	4	17	20	11	9	20	11	5	13	14	6	2
	Trunks > 7 inches	—	—	—	(6)	—	(<1)	(12)	(13)	—	(13)	(20)	(18)
	Total	17	38	37	23	20	39	26	14	24	31	18	10

^{1/}Crowns, all trees; bark, from trees ≤ 7 inches d.b.h.; trunks ≤ 7 inches d.b.h., wood only; trunks > 7 inches, bark and wood—weights are in parentheses and not included in totals because this material is potentially merchantable.

1. Crowns (foliage and branches) are the fine material that governs rate of fire spread and fire intensity. Crowns of all trees cut become slash.

2. Boles contribute mainly to resistance to control of fires; and in large quantities, mixed with fine material, they also affect rate of spread and fire intensity.

3. Nominally, 6 inches d.b.h. is the maximum size of trees to be cut in precommercial thinning of ponderosa pine, and 7 inches is the minimum size for merchantable pulpwood (U.S. Forest Service 1967). However, occasional trees larger than 6 inches are cut, especially when dwarf-mistletoe control is combined with thinning, when there is no immediate prospect of a market for pine pulpwood, and when 7-inch trees would probably be marketable only if a large volume, mainly in bigger trees, were available. Finally, as a practical matter, the normal yield tables lump 6- and 7-inch trees into a single class, giving no indication of the number of each. Therefore, the break at 7 inches is realistic and convenient for present purposes. Boles larger than a 7-inch d.b.h. are tabulated for the sake of completeness but not included in totals; little of this material would be cut unless it could be sold and removed from the woods.

4. Bark of 7-inch and smaller trees is shown separately; it is the first part of the trunk to become flammable and the part that contributes most to rate of fire spread. Larger trees presumably would be removed with the bark attached; therefore, the combined weights of wood and bark are given.

Stocking differs considerably from normality in most natural stands. The tabulated slash quan-

ties can be multiplied by percent of normal stocking to adjust preliminary estimates for the actual density of stands to be thinned. Errors resulting from such adjustment are likely to be negative for understocked stands and positive for overstocked stands. The fewer trees cut in understocked stands would be larger because of greater growing space. The increase due to average weight of crown and bole would be greater than the loss due to reduction in numbers. The reverse is true for overstocked stands.

Working estimates.—Field tallies of sample plots can provide tree numbers for calculating weights of slash to be expected on specific areas. Such sampling probably need not be done intensively or frequently but should be useful as a training medium and occasional check on ocular estimates. The purposes are to gauge objectively the need for slash disposal or other fire protection measure, assign priorities for treatment, and select the most appropriate methods.

An example from the Deschutes National Forest illustrates the working estimate and provides a comparison of slash weight based on local measurements with weights derived from yield tables. Trees marked for cutting were tallied on twenty-two 1/50-acre plots on four Ranger Districts, selected to represent a wide range of stand characteristics.^{2/} Thinning was to about 14- by 14-foot spacing. The resulting slash weight estimates (table 4) may not be representative of large areas, but they do emphasize the wide range of variation that occurs.

^{2/} The author is indebted to personnel of the Deschutes National Forest for obtaining field tallies.

Table 4.—Slash yields from sample thinning plots on the Deschutes National Forest

Description of stand	Trees cut per acre	Mean d.b.h.	Weight ^{1/}			
			Crown	Wood	Bark	Total
	Number	Inches	----- Tons per acre -----			
Pure ponderosa pine:						
Age 10-20, site III (1 plot)	7,750	1.2	17.5	7.5	1.8	26.8
Age 30-40, site III (1 plot)	3,700	2.7	22.1	26.8	6.3	55.2
Age 30-40, site IV (13 plots):						
Lightest plot	600	3.3	5.2	5.2	1.2	11.6
Heaviest plot	3,800	3.6	37.3	51.9	12.2	101.4
Mean	2,570	—	18.0	20.2	4.7	42.9
Mostly Douglas-fir (1 plot)	4,600	2.7	17.2	21.8	3.3	42.3
Half grand fir (1 plot)	2,250	2.4	13.8	12.2	1.8	27.8
Mostly lodgepole pine (5 plots):						
Lightest plot	450	2.6	.8	2.6	.4	3.8
Heaviest plot	1,950	3.3	5.2	20.2	3.0	28.4
Mean	1,150	—	3.7	8.6	1.3	13.6

^{1/} Does not include wood and bark of trees larger than 7-inch d.b.h., which occurred on 4 plots and averaged 1.4 tons per acre over all 22 plots.

Most of the Deschutes plots in pure ponderosa pine had slash weights slightly greater to much greater than those derived from yield tables for stands of the same age and site. The average for 13 plots in 30-to-40-year-old site IV stands is nearly one-third greater than the comparable value in table 3 for 40-year-old stands of site index 80. Stand density is responsible for the difference; the 13 Deschutes plots averaged more than twice the normal numbers of trees

per acre, and the 10- to 20-year-old site III plot had about four times the normal number. Random or systematic sampling on a large scale almost unquestionably would reduce average weight based on field measurements, since the Deschutes plots represent only the range of stand densities, without reference to area in each density class. The significance of the few measurements made so far is to show the preliminary estimates based on normal yield tables do not exaggerate common field conditions.

FIRE HAZARD: NATURE AND DEGREE

Fuels and weather are the two main components of forest fire hazard; precommercial thinning strongly affects both. The fuel effect consists of suddenly placing tons of fine, small, and medium-sized material near the ground, where conditions are most favorable for ignition and spread of fire. The weather effect consists of exposing the fuels to stronger insolation and air movement as a result of drastically opening up the canopy. The increase in hazard has not been measured directly in young ponderosa pine stands, but a useful first estimate can be made by inference from relevant research findings and experience.

For about 30 years, the fuel component of hazard has been accounted for by means of fuel types defined in terms of expected rate of spread and resistance to control. Rate of spread is "the relative activity of a fire in extending its horizontal dimensions"; resistance to control is "the relative difficulty of constructing and holding a control line as affected by resistance to line construction and by fire behavior" (U.S. Forest Service 1956). "Low," "medium," "high," and "extreme" are the recognized type levels of both hazard components. Values assigned to the various levels are purely relative in the Pacific Northwest scheme: 1, 5, 25, and 125 for rate of spread; 1, 2, 4, and 8 for resistance to control.^{3/} The neighboring Northern Rocky Mountain Region uses absolute values for the levels of hazard, and these are not in the same ratios

as the Pacific Northwest series.^{4/ 5/} However, comparison of fuel-type photographs for the two Regions suggests that, with a little judgment, the two systems can be used interchangeably to characterize fuel types that occur in both Regions. The **extreme** rate-of-spread type for the Pacific Northwest includes the **flash** type that has been added to the original Northern Rocky Mountain series (Barrows 1951).

The existing concept of fuel type includes some influence of general weather, local weather, and microclimate. Ratings are for a specified level of fire danger and take into consideration exposure of the fuel to drying because of topographic aspect and density and height of dominant vegetation. Research during the past 30 years has developed some competent measures of the effects of individual factors on fire behavior separately, so as to evaluate conditions not specifically covered by the fuel-type system.

Rate of Spread

Rate of spread in uncut, young ponderosa pine stands is rated **medium** or **high** in the Northern Rocky Mountains, depending mainly on the amount and compactness of fine fuels—needles and herbage—on and near the ground (fig. 1).^{6/} No rating is available for the Pacific

^{3/} U.S. Forest Service Region 6. Fuel-type mapping—original instructions (with some revisions). File designation F-PLANS-National Fire Planning (1959-Guidelines), 23 pp. (On file at Pacific Northwest Forest and Range Exp. Sta., Seattle, Wash.)

^{4/} Hornby, L. G. Instructions for fuel-type mapping. Developed in cooperation with U.S. Forest Service Region 1, Office of Operation, 28 pp., June 26, 1933. (On file at Pacific Northwest Forest and Range Exp. Sta., Seattle, Wash.)

^{5/} U.S. Forest Service Region 1. Fuel type standards 1936. (On file in Division of Fire Control, Missoula, Mont.)

^{6/} See footnote 5.



Figure 1.—Unthinned young ponderosa pine stands. Upper, U.S. Forest Service Region 1 fuel-type standard, high-low; lower, experimental plot on Pringle Falls Experimental Forest, Oregon, before thinning, that would have the same rating.

Northwest, but stands in the two Regions are quite similar.

Effects of slash. — Experimental burning of small plots of lopped ponderosa pine slash has provided the only objective measurements indicative of probable fire behavior in thinning slash (Fahnestock 1960; Fahnestock and Dieterich 1962). Tonnages of slash in which measured rate of spread would equal **high** and **extreme** levels were found to be as follows:

	<u>Rate of Spread</u>	
	High (Tons)	Extreme (Tons)
Year of cutting	3-12	> 12
1 year after cutting	4-22	> 22
5 years after cutting	> 22	—

These estimates took into account adjustment of the weather factor to midafternoon level and allowance for natural fuel already present. Obviously, from table 3, any intensity of thinning likely to be employed results in at least a **high** rate-of-spread fuel during the year of cutting (i.e., prior to the first winter after cutting) and the next year. (At least 25 percent of the wood in $\leq$ 7-inch-d.b.h. trees is less than 4 inches in diameter, the maximum size accepted in the slash burning experiments).

Dead foliage is the main component of slash that supports high rate of spread. Ponderosa pine slash may retain a noticeable quantity of needles as long as 7 years. Field observation on the Deschutes National Forest indicated substantial needle loss during the 4th year after cutting. Four-year-old slash retained at least 25 percent of its needles, 5-year-old slash only a scattered few. Thus, the rate-of-spread rating for slash from present precommercial thinning would appear to change little during the 1st to 4th years after cutting. Figures 2 and 3 compare available photographs and suggested rate-of-spread ratings for thinning slash with Region 6 standard ratings for slash from commercial cutting.

Loss of needles greatly reduces the influence of slash on rate of spread during the 5th year after cutting. Nevertheless, available indications are that thinning to 14- by 14-foot spacing produces enough slash for a **high** rating in 40-year-old stands with site indexes of 100 or less and also in 60-year-old stands with indexes of 80 or less. Loss of many twigs and smaller branches would be required to further reduce the rating in such heavy concentrations of slash; amount of loss and time involved are not known. Table 5 shows the combinations of age, site index, and thinning intensity that would produce at least a **high** rate-of-spread rating in normal stands after the 1st year.

The results of experimental burning probably underestimate rate of spread in ponderosa pine slash. Spread was somewhat slower than expected from the appearance of the slash. The reason appeared to be relatively high moisture content in the branchwood, which was generally larger in diameter than that of other species. Large material ordinarily would dry better on typical ponderosa pine sites, with rainfall typically close to 20 inches a year, than in the experimental area, with about 30 inches (U.S. Department of Agriculture 1941).

The rate-of-spread ratings based on experimental burning are conservative for the slash created in precommercial thinning because of differences in fuel arrangement. The experimental slash was lopped; it averaged less than 1.4 feet deep when freshly placed on plots, and much of it was in contact with the ground. Thinning slash consists of entire trees, and much of it is supported several feet above the ground. The fine material is more exposed to drying influences than in the experimental plots, and more wind affects a fire, once started. Consequently, thinning slash would support higher rate of spread, pound for pound, both initially and after 5 years, than the experimental slash.

Table 5.—Occurrence of **high** and **extreme** rate-of-spread ratings in normal stands as related to stand characteristics, spacing of "leave" trees, and time since thinning^{1/}

Spacing (feet)	Site index 60, stand age—				Site index 80, stand age—				Site index 100, stand age—			
	20	40	60	80	20	40	60	80	20	40	60	80
1- to 4-year-old slash:												
8 by 8	E	E	H	—	H	H	—	—	H	—	—	—
10 by 10	E	E	E	H	E	E	H	—	H	H	—	—
12 by 12	E	E	E	H	E	E	E	—	E	E	H	—
14 by 14	E	E	E	E	E	E	E	H	E	E	E	H
16 by 16	E	E	E	E	E	E	E	H	E	E	E	H
18 by 18	E	E	E	E	E	E	E	E	E	E	E	H
5-year-old slash:												
8 by 8	—	—	—	—	—	—	—	—	—	—	—	—
10 by 10	—	H	—	—	—	—	—	—	—	—	—	—
12 by 12	—	H	—	—	—	H	—	—	—	—	—	—
14 by 14	—	H	H	—	—	H	H	—	—	H	—	—
16 by 16	—	H	H	—	—	H	H	—	H	H	—	—
18 by 18	—	H	H	H	—	H	H	—	H	H	—	—

^{1/} H= **high**

E= **extreme** (Region 1 standard).



Figure 2.—Precommercial thinning slash at three ages, with suggested fuel ratings. Upper—fresh, extreme-high; middle—3 years old, high-medium (would be high-high in stand as dense as that shown in upper and lower photos); lower—7 years old, high-medium.

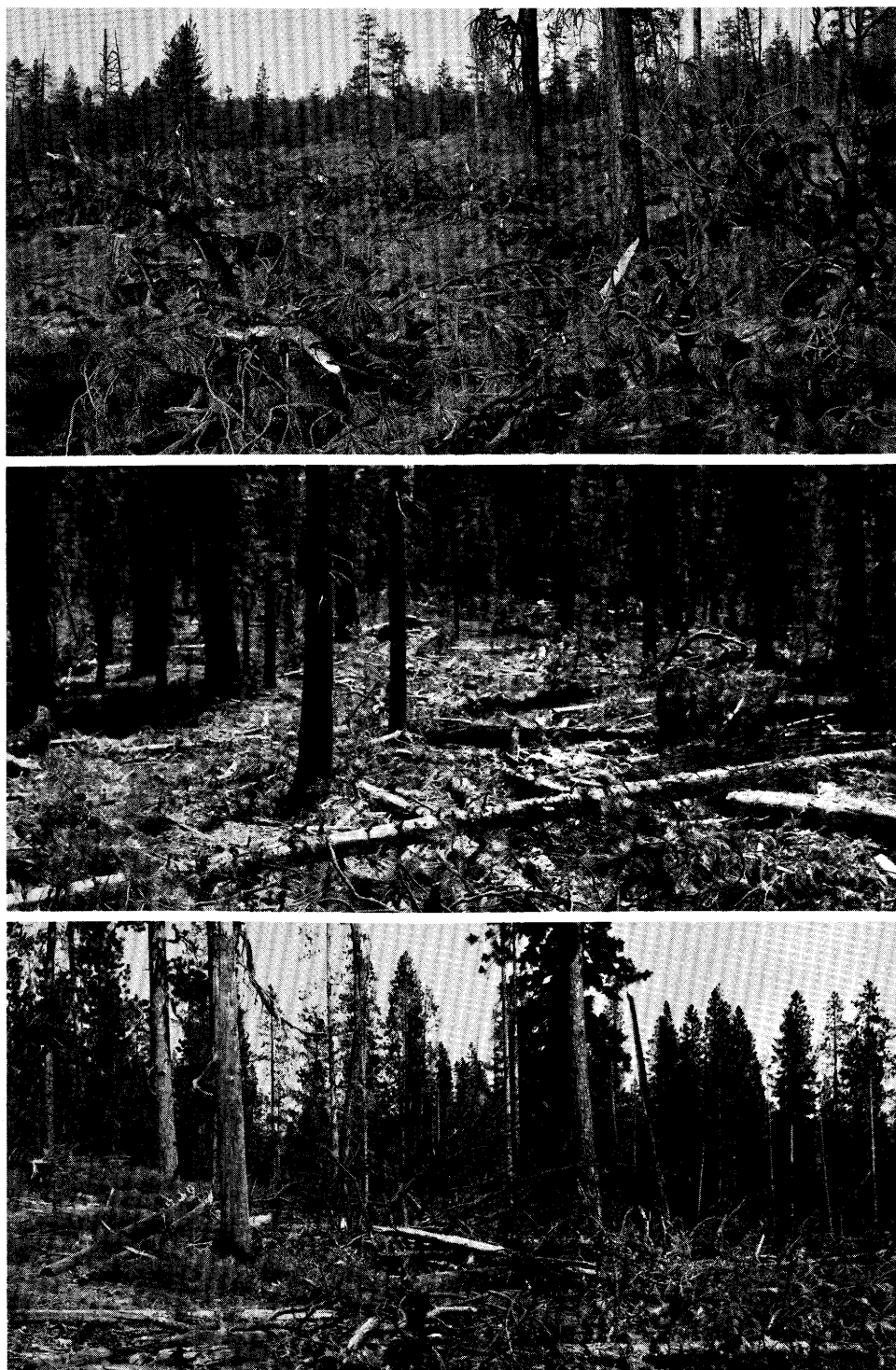


Figure 3.—Some examples of ponderosa pine logging slash in the Pacific Northwest as rated by U.S. Forest Service Region 6 fuel-type standards. Upper—fresh, extreme-medium; middle—1 year old, high-high; lower—7 years old, high-medium.

Effects of weather and climate.—An increase in severity of the weather factors of fire danger accompanies the addition of fuels when stands are thinned. Opening up a stand of trees allows more air movement and stronger insolation. Air and fuel temperatures rise, and, in response, relative humidity and fuel moisture content fall. Lowered fuel moisture content facilitates ignition by small firebrands, an important consideration where human use is heavy. Clearcutting a stand of pole-size ponderosa pine increases potential rate of spread 4.5 times (Fons 1940 Countryman 1956). Inference from measurements in partially cut Douglas-fir stands suggests that cutting 35 percent of the original volume, roughly equivalent to thinning a normal 40-year-old, site IV stand to 13- by 13-foot spacing, raises the general level of fire danger about 50 percent (Morris 1941). Probably the increase in average hours per day and days per year with high fire danger is even more important. Average number of critical fire days increases four times when a mature stand in the western white pine type is cut back to half its original volume (Jemison 1934). The change may be somewhat less, but still should be considerable, in the drier ponderosa pine type.

Composite effect.—There is no way to calculate the true relation of rate of spread to slash weight in thinning slash by adjusting the experimentally determined rates for differences in arrangement and weather. With all factors considered, however, judgment suggests that any fresh slash situation rated **extreme** in table 4 probably would still rate **high** 5 years later. Based on this assumption, the following tabulation indicates the closest spacing that will result in a **high** rating after 5 years when fully stocked stands are thinned:

Stand age	Site index		
	60 (Feet)	80 (Feet)	100 (Feet)
20	12 by 12	14 by 14	12 by 12
40	8 by 8	10 by 10	12 by 12
60	12 by 12	14 by 14	16 by 16
80	14 by 14	18 by 18	18 by 18

Since most stands do not have normal stocking, weight of slash per acre is a more versatile guide than the tabulation. A tentative rule of thumb is that *rate-of-spread rating will remain high for at least 5 years when total weight of slash from trees $\leq$ 7-inch d.b.h. exceeds 15 tons per acre.* The one Region 6 fuel type containing old ponderosa pine slash (7 years) is rated **high**; slash in originally dense stands that have been heavily thinned looks as bad as the fuel-type-standard photograph^{7/} after 5 years (figs. 2 and 3).

Resistance to Control

Resistance-to-control ratings integrate the effects of all factors that obstruct efforts to control fires. Fuels obstruct control efforts by imposing a physical barrier to fireline construction, burning with such intensity as to prevent close enough approach to do effective work, and supporting or contributing to violent fire behavior phenomena such as crowning and spotting. Ponderosa pine thinning slash contributes to resistance to control in all three ways.

Resistance to control is rated **low** by Region 1 in uncut, young ponderosa pine stands. Region 6 has no ratings of uncut stands but gives six examples consisting mainly of slash from commercial logging of ponderosa pine and associated species. Resistance to control is rated **high** for one example each of fresh and 1-year-old slash, **medium** for one example each of fresh, 1-year-old, and 7-year-old, and **low** for one example of 2-year-old. Resistance to line construction as evidenced by quantity of logs on the ground seems to be the main criterion for differentiating. In comparison with the fuel-type photographs, heavy concentrations of precommercial thinning slash appear to contain enough stems to offer **high** resistance to line construction. The stems are much smaller than those that remain after commercial cutting, but they are extremely numerous and interlaced so as to be mutually reinforcing. The original degree of physical resistance should persist until decay significantly weakens the wood.

Fresh, dry slash of any species makes a high-intensity, unapproachable fire. A fire started in dry, fresh slash can become uncontrollable in seconds.^{8/}

^{7/} See footnote 3.

^{8/} Personal observation by the author.

Intensity declines after the needles fall, but it remains much higher than that produced by burning the fuels usually found near the ground in unthinned stands. When burned experimentally, ponderosa pine gave the second highest intensity of the five species of fresh slash recorded. Five years brought a 65-percent reduction, proportionately the least reduction of any species. Potential for spotting approximately parallels intensity; elevated fine fuel, mainly needles, both supplies firebrands and supports the rapid evolution of heat to carry them considerable distances.

Young natural stands of ponderosa pine tend to be somewhat patchy, with intervening open strips and patches that usually contain little fuel other than needle litter. Occurrence of openings that are sufficiently wide and numerous materially reduces resistance to control in thinned stands by making it unnecessary to construct and hold firelines through the slash. Openings of any appreciable width greatly facilitate line construction, but they need to be at least 1/2-chain wide to give much help with line holding, especially if slash is on both sides. The degree to which openings can be used effectively depends also on their orientation with respect to prevailing winds and on policy as to maximum acceptable fire size.

Resistance to control cannot be rated objectively or reliably with knowledge currently available. Total weight of slash per acre may be a helpful criterion in fresh slash; weight of boles, in 5-year-old slash. The sum of the squared or cubed diameters of cut trees could be a useful criterion, perhaps the best for resistance to line construction. The following weight limits are suggested for the **high** resistance-to-control rating until objective determinations can be made:

Condition	Tons of slash per acre	
	Fresh (Total weight)	5-year-old (Boles)
Lines must be built through slash concentrations; openings infrequent or unsuitable	≥ 10	≥ 15
Lines can be built at will	≥ 20	≥ 25

The above guidelines refer only to the effect of the thinning slash itself on resistance to control. Slope, soil characteristics, subordinate vegetation, and preexisting dead fuels could cause lesser quantities of slash to have a **high** rating.

DISCUSSION

This paper consolidates and attempts to interpret available information that contributes to rating ponderosa pine thinning slash as a fire hazard. The tentative conclusion reached is that thinning well-stocked stands to wide spacings (12 feet by 12 feet and wider) commonly produces fuels that rate **high** in rate of spread and resistance to control for at least 5 years after cutting, and that would burn with relatively high intensity.

Drastic thinning is known to be desirable in stagnated ponderosa pine stands (Mowat 1953); diameter growth increases significantly with spacing up to 18 feet by 18 feet, height growth with spacing up to 13 feet by 13 feet (Barrett 1965). Therefore, heavier cuts are likely in the future, leaving fewer stems per acre than the former standard of 350 (Flora 1966) and producing a greater fire hazard than in the past.

Consideration of hazard must go beyond statement of ratings. Some dense young ponderosa pine stands are rated **high** as to rate of spread because of fluffy needles on the ground (fig. 1).^{9/} However, only a small amount of fuel is readily available to burn—probably not more than 2 or 3 tons of fine fuel per acre in most instances, with varying amounts of larger material scattered about. Instantaneous intensity, duration, and total heat output of surface fires are relatively low in both dense and open stands. Consequently, such fires tend to be easy to control and, in thinned or otherwise open stands, to do little damage. Slash in any quantity radically changes the picture. Available fine fuel may

^{9/} See footnote 5.

double or treble,^{10/} and the additional fuel is located off the ground, where it can burn rapidly and completely. Larger fuel components, when dry, prolong combustion and add proportionately to heat output. In fresh slash, the result inevitably is a high-intensity, hard-to-control, damaging fire. Instantaneous intensity declines as fine crown material falls to the ground, but the potential for high total heat output and consequent damage persists for an unknown length of time.

Really severe burning conditions can cause violent fire behavior in dense, young ponderosa pine stands regardless of designated fuel type. When conditions are dry and windy enough that thickets crown out readily, fire intensity in the flareups is bound to be high, and spotting may cause more rapid spread than would occur in slash. Men who vividly remember the spectacular flareups that occur when "dog-hair" thickets burn may conclude that thinned stands, even with slash present, are less hazardous than unthinned stands.^{11/} However, fuel in thinned stands dries more rapidly and becomes drier than in the uncut forest. Exposure to wind results in faster horizontal spread of fire. And fire spreads rapidly in slash even without wind. Consequently, year in and year out, the thinned forest that contains abundant slash up to 5 or more years old should be a considerably greater hazard than the unthinned. It appears significant that many large fires in Western United States have burned almost exclusively in slash. Some of these fires have stopped when they reached uncut timber;^{12/} none has come to attention that started in green timber and stopped when it reached a slash area.

In the long run, precommercial thinning greatly reduces the vulnerability of stands to fire (fig. 4). The crop trees are spaced widely, and crown fires therefore are unlikely to occur. Rate-of-spread rating may remain **high** or go to **extreme** because of increased growth of herbage; but after slash has deteriorated (or has been removed), fires are of short duration and low intensity. Resistance to control is **low**. The difficulty lies in making sure fire does not destroy large areas while slash is present.

^{10/} Material less than one-half inch in diameter constitutes about 40 percent of total crown weight (Unpublished data on file at Pacific Northwest Forest and Range Exp. Sta.).

^{11/} Harmon, W. H., memorandum to H. G. Hopkins, 2470 Silvicultural practices, May 1, 1967.

^{12/} E.g., Merton Creek Fire, St. Joe National Forest, Idaho, ca. 1953; Raft River Fire, Quinault Indian Reservation, Washington, July 1967.

It has been pointed out that the trees cut in precommercial thinning would die anyway over a rotation and would accumulate as fuel.^{13/} However, as a fuel, this gradual accumulation of scattered dead trees never compares with the result of cutting the same trees all at once. In fact, calling attention to the hazard of slowly accumulating and deteriorating fuels only serves to emphasize the much greater hazard of a large volume of fuel created all at once.

The conclusion is inescapable that precommercial thinning to present and prospective standards in ponderosa pine stands of near-normal density seriously increases fire hazard for at least 5 years. The years of extra hazard cannot be averaged against the remaining life of the stand during which hazard is less than it was before thinning. Expectation of better times does not reduce present problems, but it may lead to a false sense of security.

In general, fire occurrence rates and fire losses mount as fuel becomes more hazardous (Barrows 1951). However, such a generalization is not sufficient basis for evaluating the impact of precommercial thinning on the difficulty of fire control.

Information is needed
It is necessary to learn as specifically as possible what changes to expect in fire occurrence rate, fire behavior, cost of control, and damages (as a result of the presence of the slash) *in thinning slash*. Only when this information is in hand can an effective fire control system be designed and optimum division of expenditures be made between thinning and protection. The following brief but intensive investigative program should supply the missing answers:

1. *Analyze fire experience.* Compare fire cause, occurrence rate, final size, suppression cost, and damage on areas of undisposed slash with the same statistics for uncut areas and logged areas on which slash was treated. Use mass statistics and case histories as appropriate.

2. *Measure hazard experimentally.* Develop hypotheses as to rate of spread, resistance to control, and intensity of fires in relation to initial quantity, distribution, and age of slash. Test hypotheses by experimental burning and line building in thinned and unthinned areas. Do experimental burning over a range of fire danger levels, including those high enough that dense reproduction could be expected to crown. Develop relative and, if possible, absolute ratings or measurements of hazard.

^{13/} Harmon, W. H., memorandum to "The Record," 2470 Silvicultural practices (thinning slash analysis), June 21, 1967.



Figure 4.—Naturally open and thinned stands without slash.
Upper—natural pole stand, rated *medium-low* by U.S. Forest Service Region 6 fuel-type standards. Lower—heavily thinned sapling stand after slash disposal, suggested rating *low-low*. (But rate of spread can be anything in such stands, depending on density of grass.)

3. *Inventory the fuel created by precommercial thinning.* "Cruise" slash experimentally before cutting, using the best crown and stem weight information available. Confirm cruise figures and develop adjustment factors by sampling after trees are cut. Measure deterioration by sampling areas thinned 1 to 10 years ago; special photography may be the most efficient method. Map slash distribution in relation to stand characteristics. Calculate areas in the several significant hazard classes.

4. *Determine appropriate action.* Develop alternative combinations of hazard-area dispersal, slash treatment, and fire control operations. Compare as to costs and benefits, taking into account compatibility with all uses of the forest.

The suggested investigations should require not more than 2 years. The cost would be only a small fraction of the cost of either a damaging fire in slash or an unjustified program of slash disposal.

LITERATURE CITED

- Anderson, Hal E., Brackebusch, Arthur P., Mutch, Robert W., and Rothermel, Richard C.
1966. Mechanisms of fire spread research progress report No. 2. Intermountain Forest & Range Exp. Sta. U.S. Forest Serv. Res. Pap. INT-28, 29 pp., illus.
- Barrett, James W.
1965. Spacing and understory vegetation affect growth of ponderosa pine saplings. Pacific Northwest Forest & Range Exp. Sta. U.S. Forest Serv. Res. Note PNW-27, 8 pp., illus.
- Barrows, J. S.
1951. Forest fires in the northern Rocky Mountains. U.S. Forest Serv. Northern Rocky Mountain Forest & Range Exp. Sta. Pap. 28, 251 pp., illus.
- Chandler, Craig C.
1960. Slash weight tables for westside mixed conifers. U.S. Forest Serv. Pacific Southwest Forest & Range Exp. Sta. Tech. Pap. 48, 21 pp.
- Countryman, C. M.
1956. Old-growth conversion also converts fireclimate. U.S. Forest Serv. Fire Control Notes 17(4): 15-19, illus.
- Fahnestock, George R.
1960. Logging slash flammability. U.S. Forest Serv. Intermountain Forest & Range Exp. Sta. Res. Pap. 58, 67 pp., illus.
- and Dieterich, John H.
1962. Logging slash flammability after five years. U.S. Forest Serv. Intermountain Forest & Range Exp. Sta. Res. Pap. 70, 15 pp., illus.
- Flora, Donald F.
1966. Economic guides for a method of precommercial thinning of ponderosa pine in the Northwest. Pacific Northwest Forest & Range Exp. Sta. U.S. Forest Serv. Res. Pap. PNW-31, 10 pp., illus.
- Fons, Wallace L.
1940. Influence of forest cover on wind velocity. J. Forest. 38: 481-486, illus.
- Jemison, G. M.
1934. The significance of the effect of stand density upon the weather beneath the canopy. J. Forest. 32: 446-451.
- Johnson, F. A.
1955. Volume tables for Pacific Northwest trees (a compilation). U.S. Dep. Agr. Handb. 92, 122 tables.
- Meyer, Walter H.
1938. Yield of even-aged stands of ponderosa pine. (Rev. 1961) U.S. Dep. Agr. Tech. Bull. 630, 59 pp., illus.
- Morris, William G.
1941. Fire weather on clear cut, partly cut and virgin timber areas at Westfir, Oregon. The Timberman 42(10): 20-28, illus.
- Mowat, Edwin L.
1953. Thinning ponderosa pine in the Pacific Northwest. U.S. Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Pap. 5, 24 pp., illus.
- Spalt, Karl A., and Reifsnyder, William E.
1962. Bark characteristics and fire resistance: a literature survey. U.S. Forest Serv. Southern Forest Exp. Sta. Occas. Pap. 193, 19 pp., illus.
- U.S. Department of Agriculture.
1941. Climate and man. Yearbook of Agriculture, 1,248 pp., illus.
- U.S. Forest Service.
1955. Wood handbook. Agr. Handb. 72, 528 pp., illus.
- U.S. Forest Service.
1956. Glossary of terms used in forest fire control. Agr. Handb. 104, 24 pp.
- U.S. Forest Service.
1967. Timber stand improvement handbook. Forest Serv. Handb. FSH 2476.1, Region 6 Amendment No. 7, 85 pp., illus.

Fahnestock, George R.

1968. Fire hazard from precommercial thinning of ponderosa pine.
U.S. Forest Serv. Res. Pap. PNW-57, 16 pp., illus. Pacific Northwest
Forest & Range Exp. Sta., Portland, Oregon.

Slash from precommercial thinning of ponderosa pine stands in
the Pacific Northwest can be a high to extreme fire hazard for 5 years
or longer.

Fahnestock, George R.

1968. Fire hazard from precommercial thinning of ponderosa pine.
U.S. Forest Serv. Res. Pap. PNW-57, 16 pp., illus. Pacific Northwest
Forest & Range Exp. Sta., Portland, Oregon.

Slash from precommercial thinning of ponderosa pine stands in
the Pacific Northwest can be a high to extreme fire hazard for 5 years
or longer.

Fahnestock, George R.

1968. Fire hazard from precommercial thinning of ponderosa pine.
U.S. Forest Serv. Res. Pap. PNW-57, 16 pp., illus. Pacific Northwest
Forest & Range Exp. Sta., Portland, Oregon.

Slash from precommercial thinning of ponderosa pine stands in
the Pacific Northwest can be a high to extreme fire hazard for 5 years
or longer.

Fahnestock, George R.

1968. Fire hazard from precommercial thinning of ponderosa pine.
U.S. Forest Serv. Res. Pap. PNW-57, 16 pp., illus. Pacific Northwest
Forest & Range Exp. Sta., Portland, Oregon.

Slash from precommercial thinning of ponderosa pine stands in
the Pacific Northwest can be a high to extreme fire hazard for 5 years
or longer.

Headquarters for the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is in Portland, Oregon. The area of research encompasses Alaska, Washington, and Oregon, with some projects including California, the Western States, or the Nation. Project headquarters are at:

College, Alaska
Juneau, Alaska
Seattle, Washington
Olympia, Washington
Wenatchee, Washington
Portland, Oregon
Bend, Oregon
La Grande, Oregon
Corvallis, Oregon
Roseburg, Oregon

