Not for publication

THREE PRESCRIBED BURNS IN 1-YEAR OLD WHITE SPRUCE SLASH

(Project A-603)

by
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ALBERTA/TERRITORIES REGION
FOREST RESEARCH LABORATORY
CALGARY, ALBERTA
INTERNAL REPORT A-6

FORESTRY BRANCH
DEPARTMENT OF FORESTRY AND RURAL DEVELOPMENT
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TABLE OF CONTENTS

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INTRODUCTION

It is generally recognized that logging slash, by increasing the the concentration of forest fuels, creates a high forest fire hazard. The most severe fire hazard is found on clearcuts where fuels are usually continuous and exposed to the desiccating effects of prevailing weather conditions.

Several hazard reduction methods can be used, including 1) burning, 2) scarifying, 3) piling and 4) windrowing. The need for slash treatment varies from region to region, depending on site, forest cover, method of logging, degree of utilization, and prevailing weather conditions. No two cutovers create the same fire hazard and each should be treated on the basis of a careful appraisal of the variables contributing to the hazard. In Alberta, existing legislation requires that slash be either lopped and scattered, or treated in a manner deemed satisfactory to reduce the hazard to within safe limits. The theory that lopping and scattering of slash brings a greater proportion of the fuels in direct contact with available ground moisture is generally accepted. However, it is possible that fuel quantity, size, arrangement, or condition may have a greater effect on rate of decay than proximity to the ground surface. Or available ground moisture may be the limiting factor controlling the rate of decay.

Results of several fire hazard studies in slash are available (Wright 1939, Williams 1955, Fahnestock 1960, and VanWagner 1965) but no published account comparing the behaviour and effects between lopped and unlopped white slash has been found.

This report presents the results of three 2-acre prescribed burns in 1-year old white spruce slash. The main objectives of the three burns were (1) to compare fire hazard in lopped and unlopped white spruce logging slash, (2) to reduce the fire hazard, and (3) to assess fire effects in terms of fuel consumption.

PREPARATION OF AREA FOR BURNING

Stand Characteristics

Following an inspection of various site and stand conditions in April of 1963, a 6-acre merchantable white spruce stand was selected in cooperation with the Alberta Forest Service as being suitable for burning experiments. An 18.2 per cent timber cruise was carried out by Alberta Forest Service cruisers in October 1963. The stand was clearcut by a local contractor in the summer of 1964, but skidding of logs from the clearcut was not completed until March, 1965. All unmerchantable timber was felled and became part of the slash fuel bed.

Stand characteristics prior to clearcutting are summarized by burning units in Table 1.

Table 1. Stand characteristics

Burning unit	Stems per acre[1]	B.A. per acre	Average d.b.h.
No.	No.	Sq. ft.	Inches
1	212	70	7.4
2	212	70	7.4
3	229	85	7.9

[1] Does not include scattered hardwoods.

Slash Treatment

To assess fire behaviour and effects in lopped and unlopped slash, the following slash treatments were applied (Figure 1):

Unit 1. Partially lopped, with about one-half of the tops lopped and scattered, and the other half left as cut.

Unit 2. Left as cut. It should be noted that a tolerant species such as white spruce usually has a relatively long crown and the lower branches are lopped as part of the logging operation. Figure 2 is representative of fuels on Unit 2.

Unit 3. Lopped and scattered. All branch wood was lopped flush with the stems and scattered evenly throughout the area to increase fuel continuity. Lopping and scattering was completed about 3 months before burning. At the time of burning, no foliage remained attached to lopped branch wood and only about 10 per cent remained on unlopped branch wood.

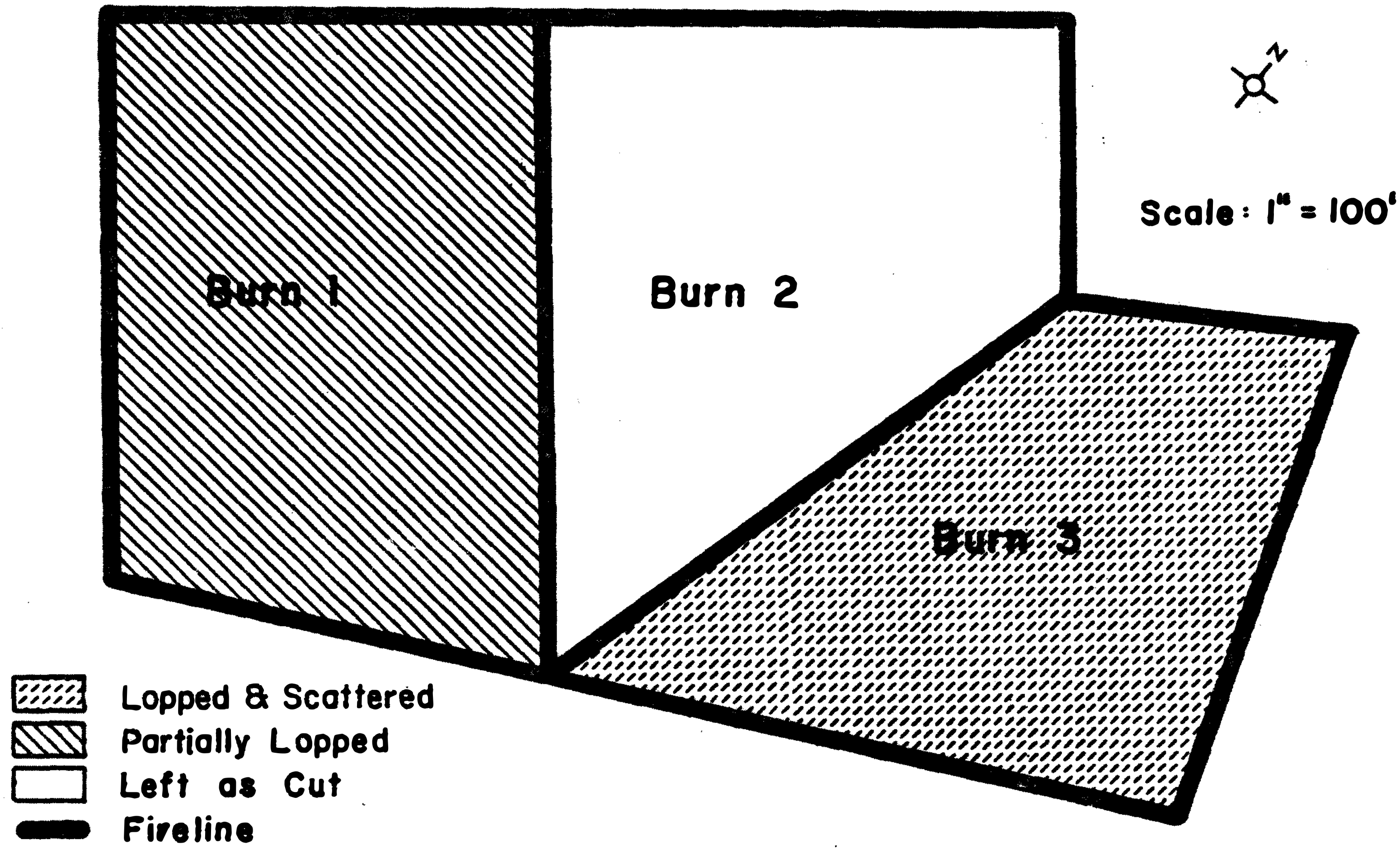

Figure 1 Layout of burning units in white spruce slash

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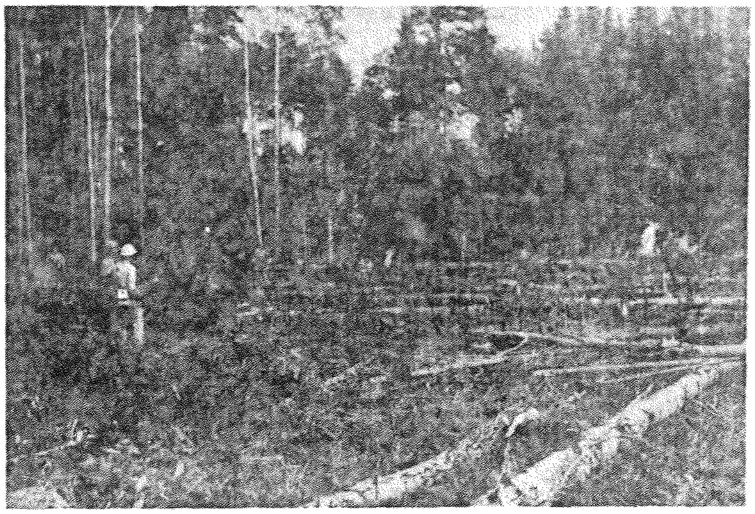

Figure 2. View of slash fuels on a portion of Burning Unit 2.

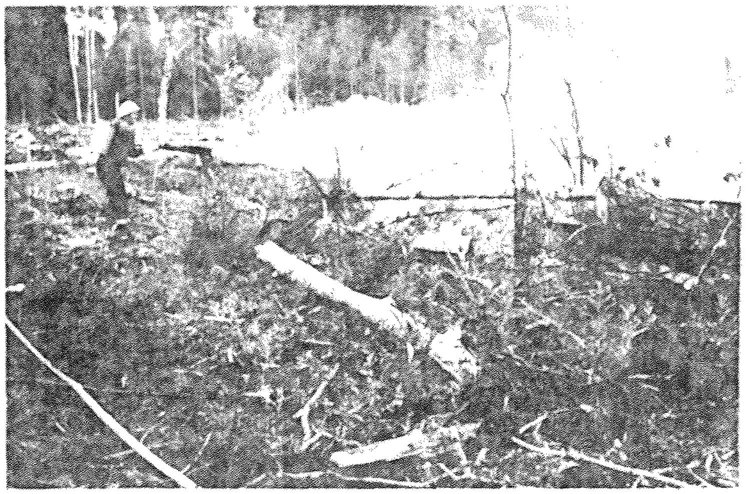

Figure 3. View of flame-thrower being used to ignite fuels on Burning Unit 2. Note the volume of flame.

Fuel Measurement

Stand data were available from the 18.2 per cent timber cruise and supplemented by additional sampling. The distribution of number of stems by diameter class was determined for each burning unit. Cull logs were not a significant fuel on the burning units and no effort was made to assess them in terms of weight and size distribution. A few poplars occurred in Unit 2 but are not included in slash weight determinations.

To aid in determining fuel consumption and fire intensity, eight 1 x 2 metre plots were established randomly in each burning unit and sampled before and after burning. The following information was collected:

1) Average depth of slash in inches.
2) Surface area covered by slash in per cent.
3) Average depth of litter (primarily foliage) in inches.
4) Surface area covered by litter in per cent.
5) Surface area covered by moss in per cent.
6) Average depth of organic material in inches.
7) Average height (inches) and surface area covered by shrubs (per cent).
8) Average height (inches) and surface area covered by herbs (per cent).
9) Average depth of burn in inches.
10) Tally of all fuel pieces intersected by the vertical plane of one 1-metre side of each plot. The fuel pieces were tallied by four size-classes, viz. 1) less than $\frac{1}{2}$", 2) $\frac{1}{2}$ to 2", 3) 2 to 4", and 4) over 4". Mechanical counters and wire frames were used to facilitate the counting procedure.

Depth of the organic layer was measured at the mid-points of the four sides of each plot. To facilitate depth of burn measurement, 6-inch spikes were inserted into the humus at each plot corner, their heads level with the top of the surrounding litter. The length of spike exposed by the fire was measured immediately after burning.

Fuel samples for moisture content determination were collected shortly before ignition. Two samples were taken of lopped and unlopped foliage and three size-classes of slash, viz: (1) less than $\frac{1}{2}$", (2) $\frac{1}{2}$ to 2", and (3) over 2 inches. All fuel samples were oven-dried to constant weight in the field laboratory for 24 to 36 hours at slightly over 212°F. A set of one-half inch moisture indicator sticks was weighed hourly on the day of burning.

Weather Data

A weather station was erected and maintained for 10 days preceeding the burns. Data taken included temperature, relative humidity and rainfall. Wind speed and direction data for the period was available from the Cold Creek Ranger Station, about 15 miles south of the burning site. Weather conditions for the day of burning are given in Table 2.

Firebreaks

The burning site is on level ground and therefore topographical barriers could not be utilized for fire containment. A 10-foot wide fireguard was constructed around the perimeter of the clearcut down to mineral soil. Internal firebreaks were constructed to separate the three burning units. A vegetative firebreak, consisting of poplars and a dense undergrowth of herbs and shrubs, surrounds the clearcut area with the exception of the south side. A firepump was set up by the standby suppression crew from the Whitecourt Forest and fire hose was laid around each burning unit immediately prior to ignition. Some of the vegetation bordering the southern boundary of the clear-cut was wetted during the burning as an added safety precaution.

Burning Plan

On the basis of the objectives, as well as consideration of fuel and weather factors, a burning plan was outlined about three weeks before the burning date as follows:

Proposed burning date: July 28, 1965.

Time of ignition: Unit 1 1:00 p.m.
Unit 2 2:30 p.m.
Unit 3 4:00 p.m.

Precipitation: no heavy rainfall for at least 10 days before burning.

Wind: less than 8 m.p.h.

Relative humidity: between 25 and 50 percent.

Temperature: between 60 and 80°F.

Danger Index: moderate or high.

Drought Index: between 10 and 20.

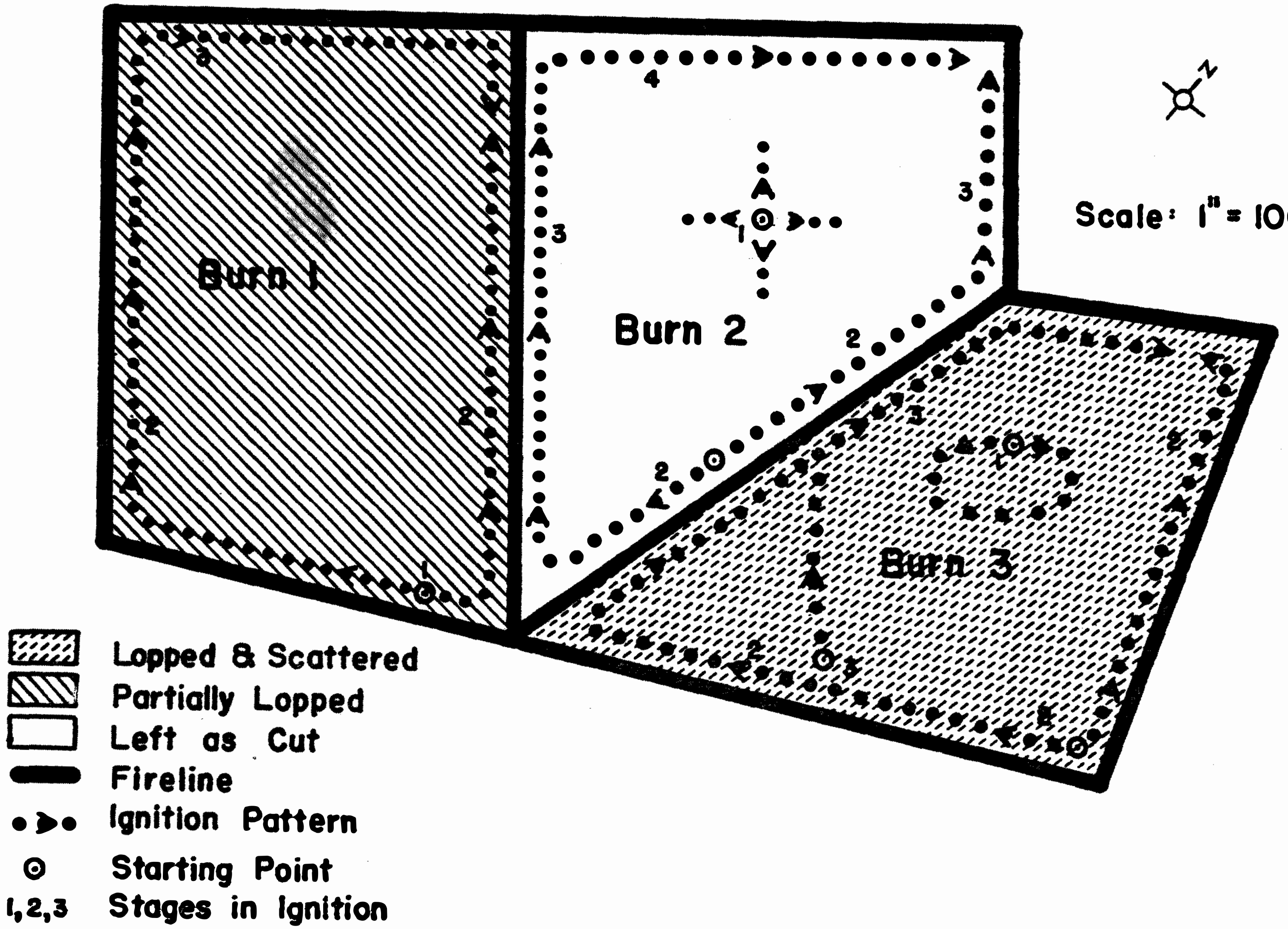

Figure 4. Ignition patterns in hazard reduction burns

Ignition Tools: fusees, drip torches, and a backpack-type flame-thrower (Figure 3).

Ignition pattern: perimeter ignition. The general ignition patterns are given in Figure 4.

ANALYSIS OF DATA

Fuel, weather, and fire behaviour data were analyzed as follows:

1) Fuel weight and size for each burning unit was determined using slash weight -- merchantable cubic foot ratios for white spruce (Kiil 1965). All calculations are based on a 4-inch top diameter. This probably yields a small underestimate of fuel weight as some tops exceeded this limit.
2) Tabulation and summary of weather data, and calculation of fire danger indices. (Table 2).
3) Moisture content was calculated from fuel samples taken on day of burn (Table 3).
4) Proportion of fuels consumed was determined by burning units, fuel types, and size classes. (Table 4).
5) Fire intensity was calculated using a method described by Byram (Davis 1959, p.79). Table 5).

BURNING PROCEDURE

Burn 1:

The first unit was ignited at 1:30 p.m. on July 28, 1965. Two men started lighting in opposite directions along the downwind side of the unit and proceeded upwind along the two sides. The top of the plot was ignited after a continuous fire front had developed along the bottom and two sides of the unit. Lighting was completed in 10 minutes. The fire progressed evenly toward the centre of the burning unit and was over 35 minutes after initial ignition. Average rate of spread of headfire was 4 ft./min.

Burn 2:

The second burn was ignited at 2:40 p.m. An area in the form of a cross was ignited near the centre of the plot and allowed to develop for a few minutes. The entire perimeter was then ignited, starting along the south side of the unit. Lighting was completed in 12 minutes. Owing to the patchy nature of the fuels and several poplar tops scattered throughout the area, some difficulty was experienced in developing a solid fire front. The fire was over in 40 minutes and rate of spread was estimated to be 3 ft./min.

Burn 3:

The plot containing the lopped slash was ignited at 3:30 p.m. Ignition was similar to Burn 2, but instead of a cross, a circle was ignited near the centre of the plot. Ignition was completed in 10 minutes and a continuous fast-spreading fire front developed. The fire was over in 25 minutes and rate of spread was estimated to be 6 ft./min. A general view of the fire on Burn 3 is given in Figure 5.

RESULTS

Weather Conditions and Fuel Moisture

During the ten days preceeding the burns, daily temperatures ranged from 60 to 85°F., and daily minimum relative humidities varied from 30 to 60 per cent. The last heavy rainfall occurred on July 21 when 0.56 inch was recorded. On the day of burning, the Danger Index was 3 (Low), the Slash Hazard Index was 10 (High), and the Drought Index was 5. Weather conditions and moisture indicator stick data on day of burning are given in Table 2.

Table 2. Weather conditions on day of burn

Hour	Temp.	Rel.Hum.	Wind	Wind Direction	Moisture Indicator Sticks	Remarks
	°F	per cent	m.p.h.		per cent	
0900	67	66	4.9	W	19.3	
1100	72	56	3.3	SW	16.3	Winds gusting to 10 m.p.h., skies cloudy.
1300	72	60	3.4	--	14.3	
1430	65	60	5.3	NW	--	Winds gusting to 15 m.p.h., short thunderstorm, trace of rain.
1700	67	66	3.9	W	15.0	

Table 3 gives fuel moisture for lopped and unlopped foliage and branchwood on the day of burning. The lowest moisture content, 9.8 per cent, was recorded for needle litter. Moisture content of herbs and shrubs exceeded 100 per cent. The top one-half inch of moss had a moisture content in excess of 100 per cent while the underlying organic material exceeded 300 per cent.

Table 3. Fuel moisture conditions on day of burn

Slash Treatment	Needles	Twigs less than ½"	Branchwood ½ to 2"	Unmerchantable stem 2 to 4"
		per cent		
lopped	—[2]	11.4	16.2	26.5
left as cut	85.0[3]	13.1	27.2	30.8

1. represents moisture content of surface ½ inch only.
2. no needles remaining on lopped branchwood.
3. represents moisture content of needles still attached to branchwood.

Fuel Consumption

Most of the fine slash fuels (less than ½"), about one-half of the larger slash fuels, practically all of the herbs and shrubs, and the top 1 to 2 inches of litter and humus were consumed by each of the three burns (Table 4). Although statistical probability statements about fuel consumption cannot be made owing to insufficient data, some relationships between slash treatment, fire spread, and fuel consumption are evident.

Following burning, the only physical obstructions remaining were the partially burned unmerchantable stems. Average slash height and cover was reduced considerably making walking relatively easy. Figure 6 illustrates a heavy concentration of charred logs remaining on Burn 1.

Table 4. Fuel Conditions before and after burning

Fuel	Burn 1			Burn 2			Burn 3		
	Before	After	Per Cent Remaining	Before	After	Per Cent Remaining	Before	After	Per Cent Remaining
Slash weight (tons)									
less than ½" dia.	7.5	2.4	32	7.5	0.3	4	8.7	0.3	4
½ to 2")						33			39
2 to 4")	5.4	2.7[1]	50[1]	5.4	2.0	40	5.0	2.2	50
Avg. slash height (ins.)	9.0	5.2	58	8.2	3.2	39	11.8	3.6	30
Slash cover (%)	68	40	58	86	12	14	89	5	6
Minor vegetation									
Shrub cover (%)	1	0	0	5	0	0	16	0	0
Herb cover (%)	14	4	29	12	2	17	8	0	0
Litter and Humus									
Needle litter cover (%)	74	30	41	73	8	11	60	2	3
Surface layer of moss	11	2	18	8	0	0	18	0	0
Depth of humus (inches)	7.8	6.9	88	10.3	8.6	83	10.0	8.4	84

[1] Based on estimate of per cent remaining.

Fuel consumption appears to be dependent primarily on fuel size, continuity, and moisture content. As would be expected, a greater proportion of fine than heavy fuels was consumed. It was estimated that the surface ½ inch of heavy fuels (exceeding 3 inches in diameter) was consumed. All shrubs were eliminated by the burns, but herbacious vegetation was consumed completely on Burn 3 only. More than 89 per cent of the litter and the top ½ inch of moss was consumed on all burns except Burn 1. An average of 0.9, 1.7, and 1.6 inches of the litter and humus was consumed on Burns 1, 2, and 3, respectively.

Fire Intensity

Fire intensity was calculated using the formula:

I = Hwr (Davis, 1959).

where I = fire intensity in Btu per second per foot of fire front.

H = heat yield in Btu per pound of fuel.

w = weight of available fuel in pounds per square foot.

r = rate of spread in feet per second

The first item, H, is taken as 9,000 B.t.u., being the total amount of heat available by burning dry wood completely. In practice this value is affected by moisture content of the fuels and heat losses due to radiation. The heat yield for complete combustion was determined to be about 7,500 Btu. per pound. Another 500 Btu. per pound was subtracted for heat losses due to incomplete combustion. Thus, a net heat yield of 7,000 Btu. per pound was used. (Table 5).

Figure 5. View of the fire on Burning Unit 3. Note the heavy smoke.

Figure 6. View of Burning Unit 1 on day after burn. Note the absence of fine fuels.

Table 5. Fire Intensity Determinations

Burning Unit	Weight of fuel consumed less than ½"	½ to 4"	Total	Fuel Weight	Heat Yield	Rate of Spread	Fire Intensity
No	-----------	tons	-------	lbs./ sq.ft.	Btu./lb.	ft./sec.	Btu. sec./ft.
1	5.1	2.7	7.8	0.36	7,000	0.07	176
2	7.2	3.4	10.6	0.49	7,000	0.05	172
3	8.4	2.8	11.2	0.51	7,000	0.10	351

DISCUSSION

The results of this study in prescribed burning indicate that slash hazard in clear cut areas can be reduced under relatively poor burning conditions. Under conditions of adequate fuels (about 10 tons per acre) and fine fuel moisture content not in excess of about 20 per cent, it is likely that successful hazard reduction burns in one-year-old white spruce slash can be carried out 2 to 3 days after a substantial rainfall.

Information indicates that lopping and scattering favours fire spread in white spruce slash. This is to be expected as lopping favours rate of moisture loss following felling (Kiil 1964) and tends to increase fuel continuity. Using rate of spread as the main criterion for difficulty of control, the results suggest that lopped and scattered one-year-old white spruce slash represents a higher fire hazard than untreated slash of the same age.

Only immediate fire effects, such as fuel consumption and depth of burn, can be assessed at this time. The high surface area-volume ratios and attendant low moisture content of fine fuels facilitates fuel consumption and rate of fire spread. Although depth of burn in lopped and unlopped slash was similar, the data suggest that burning was more uniform where the slash was lopped. At the same time it should be noted that only 12 to 17 per cent of the organic material was consumed by fire, indicating that more than one burn would be needed to expose parts of the mineral soil even under severe burning conditions.

The average rates of spread for the three burns ranged from 3 to 6 feet per minute. These values would probably be considerably higher if the needles had been attached to twigs and branches. Previous studies (Kiil 1964) have shown that white spruce foliage falls off within 3 months after felling, thereby greatly reducing the surface area-volume ratio of the slash fuel bed. Van Wagner (1965) suggests that linear rate of spread in jack pine slash drops by at least one-half after the needles fall. Substantial information is lacking for white spruce slash but approximately the same relationship should hold here as well.

This report covers the initial stages of what is hoped will be a series of prescribed burns in white spruce and lodgepole pine slash to assess and compare the interrelationships between fire weather, fuel consumption, and fire intensity. The main value of the three burns described here was to test several methods and techniques that would conceivably yield an adequate description of the more important fuel, weather, and fire parameters. Accurate and practical methods for describing the fires and fire effects are prerequisites for valid comparisons between two or more burns in terms of success or failure to accomplish burning objectives. The final objective of this series of burning experiments will be to provide quantitative descriptions of fire hazard of lopped and unlopped white spruce and lodgepole pine logging slash at various stages of decay.

SUMMARY

In 1965, three 2-acre prescribed burns were carried out in 1-year-old white spruce slash in west-central Alberta. The primary objectives were (1) to compare fire hazard in lopped and unlopped slash, (2) to reduce the fire hazard and (3) to study fire effects on fuel consumption. The preparation of the site for burning is described. Observations and measurements were made of weather and fuel conditions, including fuel weight and size distribution. The proportion of slash, herbs, shrubs, litter, and humus consumed was determined for each burn. Ignition procedures are described and rate of spread estimated for each burn.

Hazard reduction can be accomplished under relatively poor burning conditions, regardless of slash treatment or humus moisture conditions. Lopping increases the continuity of fuel beds and facilitates the drying of fuels after cutting. Rate of spread appears to be related primarily to fuel size, continuity and moisture content. All three burns were effective in eliminating herbs and shrubs. Depth of burn varied greatly from spot to spot, but the variation was least where fuel continuity was greatest.

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