Canada

Department of Forestry

FOREST RESEARCH BRANCH

British Columbia District

Interim Report

Project B. C. 603

SURFACE AREA OF FINE FUEL COMPONENTS AS A FUNCTION OF WEIGHT

by

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Victoria, B. C.
May, 1963

63-BC-5

SURFACE AREA OF FINE FUEL COMPONENTS AS A FUNCTION OF WEIGHT[1]

(Interim Report - Project B. C. 603)

by

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Abstract

The frequency and weight distributions of fuels in lodgepole pine stands and the relation between weight of fuel and surface area were investigated using 1/10,000-acre circular plots.

A graph to convert the weight of fuel components in centigrams to total surface area in square feet for diameter classes of .1 to .5 inches and from .1 to 1.0 inches is included.

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Introduction

The concept of surface area as a parameter of fire rate-of-spread has been previously suggested. Fahnestock (1) stated that "fuel burns only where it is in contact with the air; the more extensive the contact, the faster and more efficient the combustion." Studies in the Inland Empire by Olson and Fahnestock (2) showed an average pound of Douglas fir slash contained 25 square feet of surface and that needles made up 35 per cent of the weight, but 80 per cent of the surface area.

A direct measure of the surface area of natural fuels is impractical in view of the time involved. For this reason an indirect method using the total weight in grams and number of components was devised to determine total surface area per unit weight of fuel components having diameter limits of from .1 to .5 inches and from .1 to 1.0 inches.

The relation between the weight of a wooden cylinder and its surface area is a simple arithmetic computation. However, if the total surface area of a number of cylindrical fuel components having unequal diameters is to be computed from the total weight of wood, the problem is confounded. Unless the class limits include a relatively small diameter range compared to the diameters being measured, the class midpoint diameter cannot be expected to yield an accurate measure of surface area because of:

(1) the extremely skewed frequency distribution of natural fuel components toward the smaller diameters.

(2) the great disparity in surface area per unit weight of small and large diameter fuel components.

During the summer of 1962 a study was initiated to develop graphs whereby the surface area of fuel components within specific diameter limits might be approximated from their total weight. Of particular interest were ground fuel components under lodgepole pine stands in south central British Columbia near Merritt, B. C.

Method

One hundred and three 1/10,000-acre circular plots (diameter 28") were mechanically spaced in lodgepole pine stands of various ages and heights. Within each plot all dead wood fuel components having a midpoint diameter between .1 inches and 1.5 inches and greater than 2 inches long, were segregated into 1/10-inch diameter classes. The diameter was measured at the midpoint of its length with an open-mouthed diameter gauge. The number and total weight in grams of fuel components in each diameter class were measured. Branched fuels lying within the plot area were broken at each node and treated as individual fuel components. Fuel components extending outside the plot were severed at the plot boundary. Relative humidity at the fuel level was measured with a psychron, and corrections to oven-dry weight made with equilibrium moisture content tables (3).

The age and height of the stand were measured at each of the plots to determine if these stand characteristics influenced the distribution of fine fuels. The distribution of plots in each stand is shown in Figure 1.

Analysis

The absolute and per cent frequency and weight of fuel components within each diameter class were computed for each of the five stands sampled and for the total sample population. The effect of height, age or site on the mean per cent frequency of fuel components in

TABLE I. DISTRIBUTION OF PLOTS BY HEIGHT AND SITE CLASS

Height Class	Site Class		Number of Plots
1. 0-17 feet	Poor	5	12*
0-17 feet	Mod.	7	
2. 18-35 feet	Poor		14
3. 36-50 feet	Poor		33
4. 51-65 feet	Poor		19
5. 51-65 feet	Mod.		25
Total			103

* Both moderate and poor sites grouped in this height class

the three smallest classes were not significant at the 10 per cent level of probability using students "t" test. The percentage of plots on which fuel components within each diameter class occur, shows a strong inverse relation between size of fuel component and frequency of occurrence (Figure 1).

The per cent frequency and weight of fuel components in each diameter class computed from the total population are shown in Figure 2 and Table II. Semi-logarithmic paper was used to enlarge the lower portion of the scale in Figure 2.

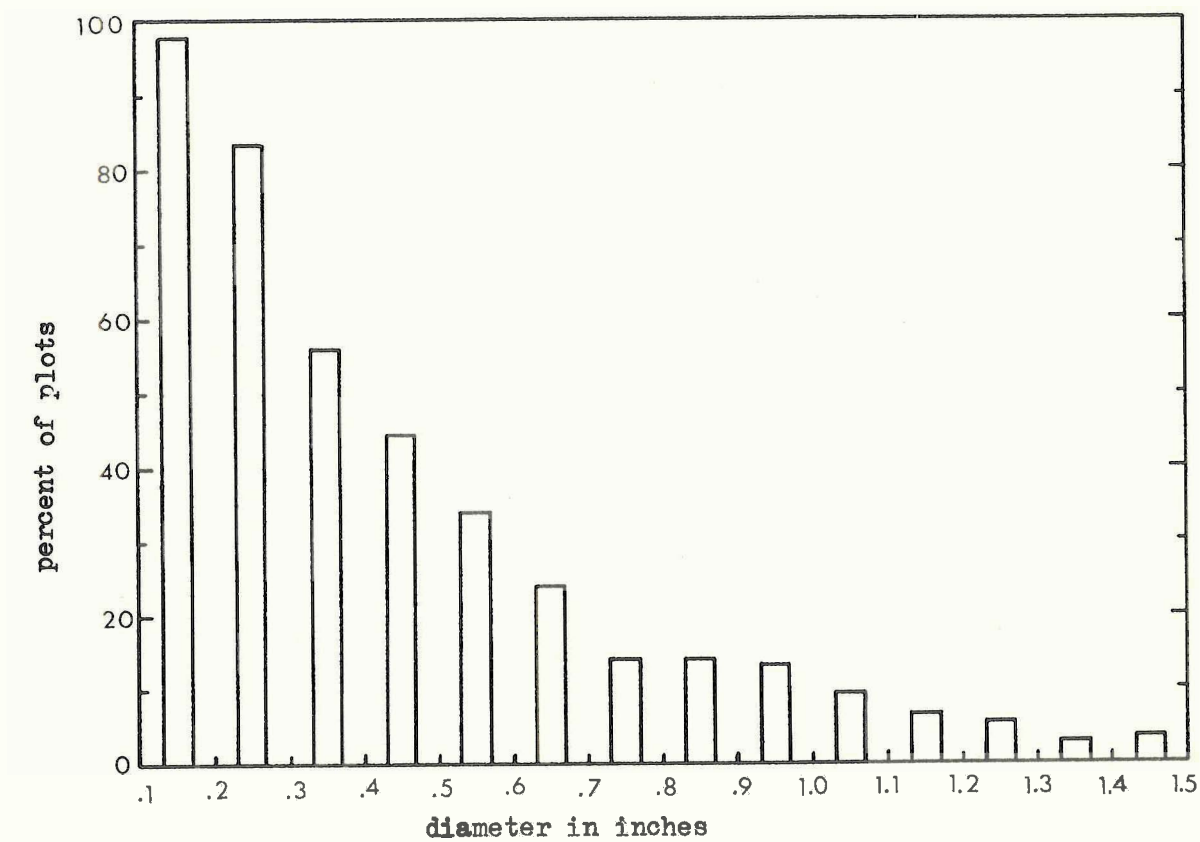

Figure 1 Percent of plots on which fuels within each size class occur, compiled from 103 plots.

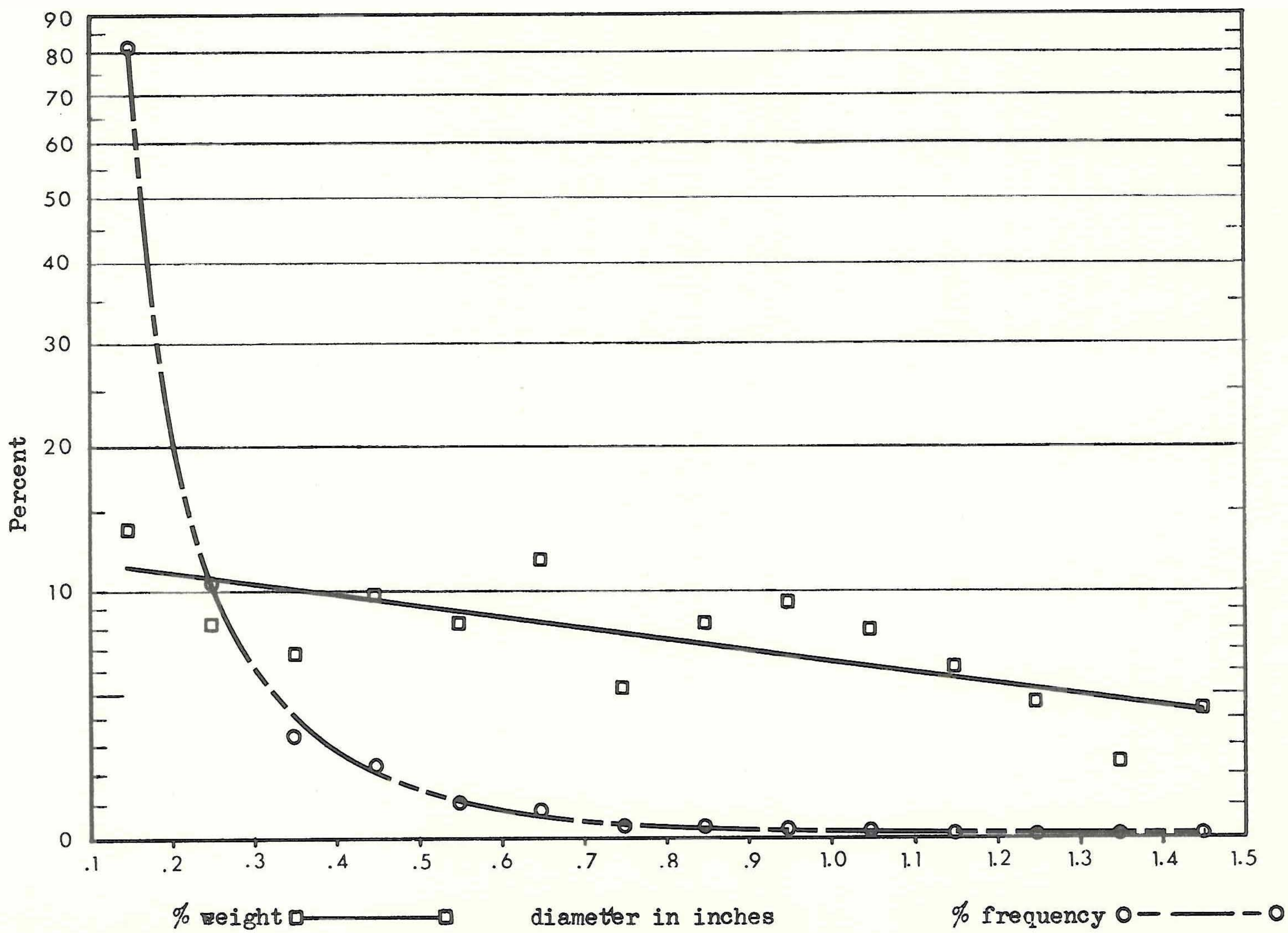

Figure 2 Percentage of total fuel by size classes, compiled from 103 plots.

The skewness illustrated in Figure 1 is emphasized in Figure 2 which considers the number of fuel components within each diameter class. The extreme skewness of the frequency curve indicates that the use of mid-class diameter for computing the surface area of fuel components within definite diameter limits is misleading.

Computation

The weight of the average fuel component in each diameter class was computed by dividing the total weight in each class by the total frequency in that class (Table II). The weight per inch of fuel components is derived from the equation:

$$W \text{ in grams} = \pi\, r^2 l \text{ S.G. } (16.386)$$

where r = radius in inches

l = length in inches; in this case 1 inch

S.G. = specific gravity of lodgepole pine in grams per c.c. = .41(4)

and 16.386 is the number of cubic centimeters in a cubic inch

The weights per inch of fuel components having diameters equal to the class midpoint of the 1/10 inch classes used in this study are shown in Table II. The length in inches of the average fuel component in any class is then computed by dividing the weight of the average fuel component in each class by the computed weight per inch (Table II). Plot size, in all probability, affects all the lengths to a small degree, but especially in the larger diameter classes.

TABLE II. FREQUENCY WEIGHT AND LENGTH OF FUEL COMPONENTS BY EACH DIAMETER CLASS

Diam. Class	.1	.2	.3	.4	.4	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	Total
Abs. Frequency	4112	524	165	117	55	45	18	21	17	11	7	6	3	4	5,060
% Frequency	81.3	10.3	3.3	2.3	1.1	.9	.4	.4	.3	.2	.1	.1	.1	.1	
Abs. Weight (grams)	2922.8	1724.8	1430.1	2082.1	1721.5	2307.6	1096.6	1767.7	2004.1	1676.5	1322.7	982.9	500.3	948.8	21,376.8
% Weight	13.7	8.1	6.7	9.7	8.1	10.8	5.1	8.3	9.4	7.8	6.2	4.6	2.3	4.4	
Weight of average fuel component (grams)	.712	3.29	8.68	17.8	31.3	51.4	61.0	84.1	118	152	189	164	167	237	
Weight per inch from equation 1	.118	.329	.645	1.07	1.48	2.23	2.98	3.82	4.76	5.82	7.00	8.26	9.60	11.1	
Length of average fuel component (inches)	6.03	10.0	13.4	16.6	21.2	22.8	20.5	22.0	24.8	26.2	27.0	19.9	17.4	21.2	

Computation of Surface Area

It has been shown that the frequency distribution of fuel components is extremely skewed toward the smaller diameter classes. This is reason to reject the use of midpoint diameters for computing the surface areas of fuel components within broad size classes. To compute the surface area as a function of weight in terms of the frequency distribution found in this study, two broad size classes were used -- one from .10 to .50 inches, and another from .10 to 1.00 inches. Only the computation for the former is shown in Table III although the same computation may be used to derive the surface area of fuels within any diameter class limits from .1 to 1.5 inches from the data presented here.

If the range of the size classes is changed, so does the frequency distribution shown in Table II. A slightly changed distribution curve is computed, Code B, using the absolute values in each diameter class from Table II, Code A. The change in frequency distribution, although small, favours the small diameter classes (Table III). The computation shown in Table III assumes that 100 fuel components are measured from the average plot. These 100 pieces, using the per cent frequency on Code B, computed from the sample population of Code A and the average weight and length of fuel components from Table II, Code C and E, yield a total weight of 167.0 grams and a surface area of 428.4 square inches or 2.97 square feet. End area was excluded because of the bias introduced by breaking the branched fuel components. If end areas are included, the surface area would be approximately 5.5 square inches larger, the greater share occurring in the smallest class.

TABLE III. COMPUTATION OF TOTAL SURFACE AREA AS A FUNCTION OF WEIGHT IN GRAMS OF FUEL COMPONENTS FROM .10 TO .50 INCHES IN DIAMETER

	Diameter Class	.1+	.2+	.3+	.4+	Totals and Units
Code A.	Absolute frequency	4112	524	165	117	4918
B.	Per cent frequency	83.6	10.7	3.4	2.4	100.1%
C.	Length (from Table II)	6.03	10.0	13.4	16.6	inches
D.	Midpoint diameter	.15	.25	.35	.45	inches
E.	Weight (from Table II)	.712	3.29	8.68	17.8	grams
F.	Total weight (B x E)	59.5	35.2	29.5	42.8	grams
G.	Circumference	.47	.79	1.10	1.41	inches
H.	Average surface area (C x G)	2.84	7.90	14.75	23.20	sq. in.
I.	Total surface area (B x H)	238.0	84.5	50.2	55.7	sq. in.
J.	Total surface area	1.65	.59	.35	.39	sq. ft.

An equivalent weight of fuel is encompassed by a calculated surface area of 318.2 square inches or 2.18 square feet when the midpoint diameter of .30 inches is used. This results in an underestimate of .79 square feet or approximately 26 per cent.

Using the same procedure as outlined in Table III, the surface area of a sample of the same number of pieces having class limits of .1 to 1.0 inches is computed to be 337.5 grams having a surface area of 559.3 square inches or 3.86 square feet.

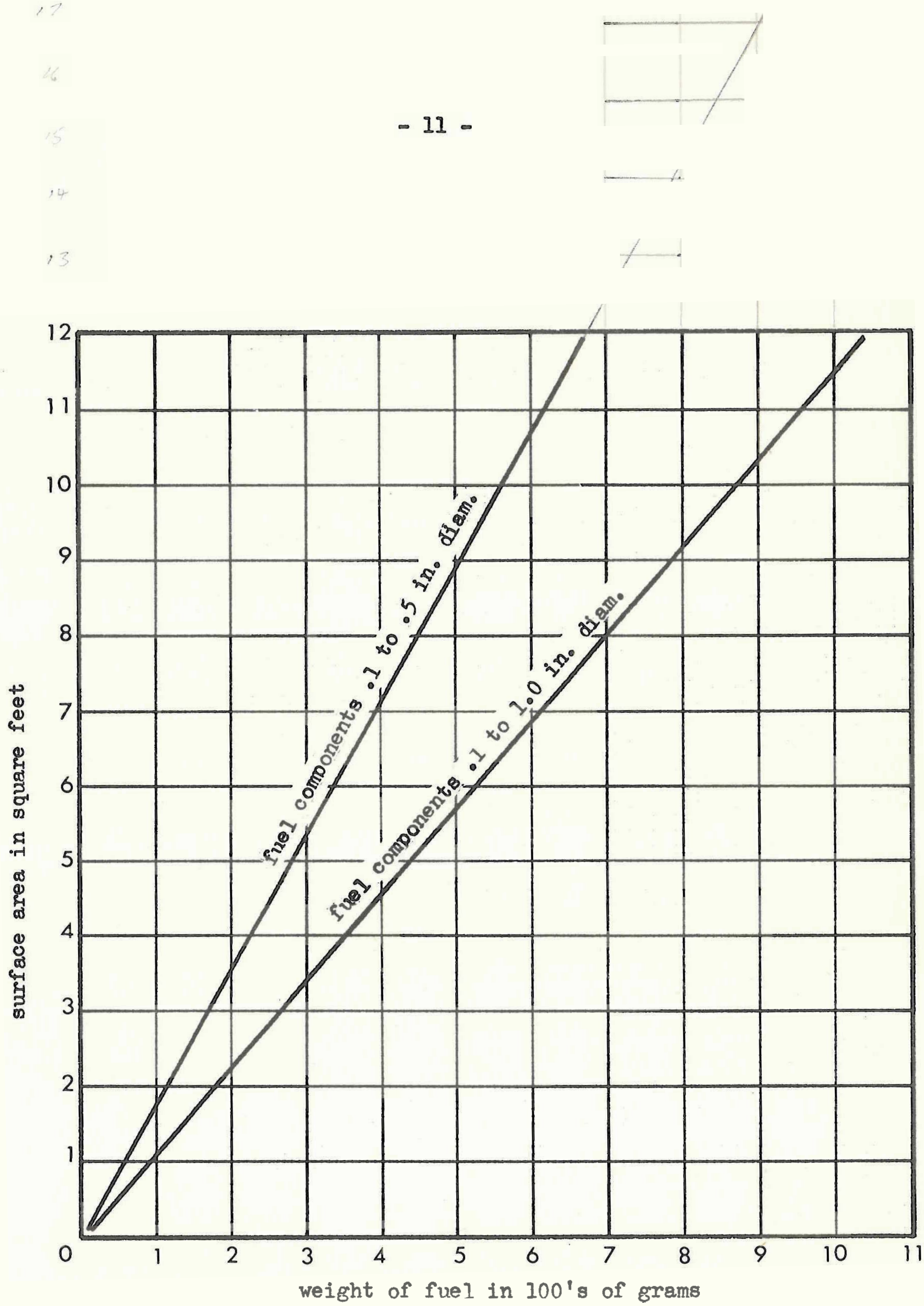

Figure 3 Relation between weight in grams and surface area in square feet of fuel components in two size classes.

In the latter case, if the class midpoint diameter of .55 inches is used to calculate the surface area of an equivalent weight of fuel, only 388.0 square inches or 2.69 square feet of fuel surface is derived, an underestimate of 1.17 square feet or 30 per cent. **Figure 3 shows the surface** area of fuel components sampled within two diameter classes as a function of their weight in hundreds of grams. **The curves shown in Figure 3 should** only be used for lodgepole pine; care should be exercised if plot sizes other than 1/10,000 acre are used.

Conclusions

The results of this paper show that the use of class midpoints for the computation of surface area within broad size classes results in substantial underestimates of the actual surface area, the amount of error being directly proportional to the difference in class limits.

The technique discussed in this paper is of use to fire control personnel involved in fuel research for measuring surface area through the relatively simple measure of weight and the use of the graph shown in Figure 3.

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