Forest Research Branch

SURFACE AREA OF FINE FUEL COMPONENTS

AS A FUNCTION OF WEIGHT

by

S. J. MURARO

Conclusions en français

Abstract

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

A graph is presented from which total surface area in square feet for certain diameter classes of branch litter may be computed using total weight of the fuel in those classes.

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Surface Area of Fine Fuel Components as a Function of Weight[1]

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INTRODUCTION

The concept of surface area as a parameter of fire rate-of-spread has been previously suggested. Fahnestock (1960) 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 (1955) showed that 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.

The relation between the weight of a wooden cylinder of a certain diameter and its surface area can be determined by a simple arithmetical computation. However, if the total surface area of a number of cylindrical fuel compounds having unequal diameters, such as branch litter, is to be computed, the problem is compounded. Since direct measure of the surface area of such natural fuels is impractical in view of the time involved, an indirect method using weight as the basic measurement appeared to be the best alternative.

During the summer of 1962 a study was initiated to develop graphs whereby the surface area of deadwood fuel, within specific diameter limits, might be approximated from its total weight. Of particular interest was branch litter under lodgepole pine (*Pinus contorta*, Dougl. var. latifolia Engelm.) stands in south central British Columbia, near Merritt. Litter smaller than .1 inch in diameter was not considered in this study.

METHOD

One hundred and three 1/10,000-acre circular plots (diameter 28″) were mechanically spaced in five lodgepole pine stands of various ages and heights. Within each plot all branch litter having a midpoint diameter between .1 inch and 1.5 inches and greater than 2 inches long, was separated into 1/10-inch diameter classes. The diameter of each piece was measured at the midpoint of its length with a go no-go gauge. The number and total weight in grams of fuel components in each diameter class were noted. Branched fuels lying within the plot area were broken at each fork and each piece was treated as an individual fuel component. Relative humidity at the fuel level was measured using a psychrometer and the fuel weights measured were reduced to oven-dry weights using equilibrium moisture content tables (Anon. 1951, page 136). This appeared to be in order since sampling was conducted only when the fuel felt dry to the touch; during these periods, differences between fuel moisture content determined from the equilibrium moisture content tables and oven drying were found to be negligible.
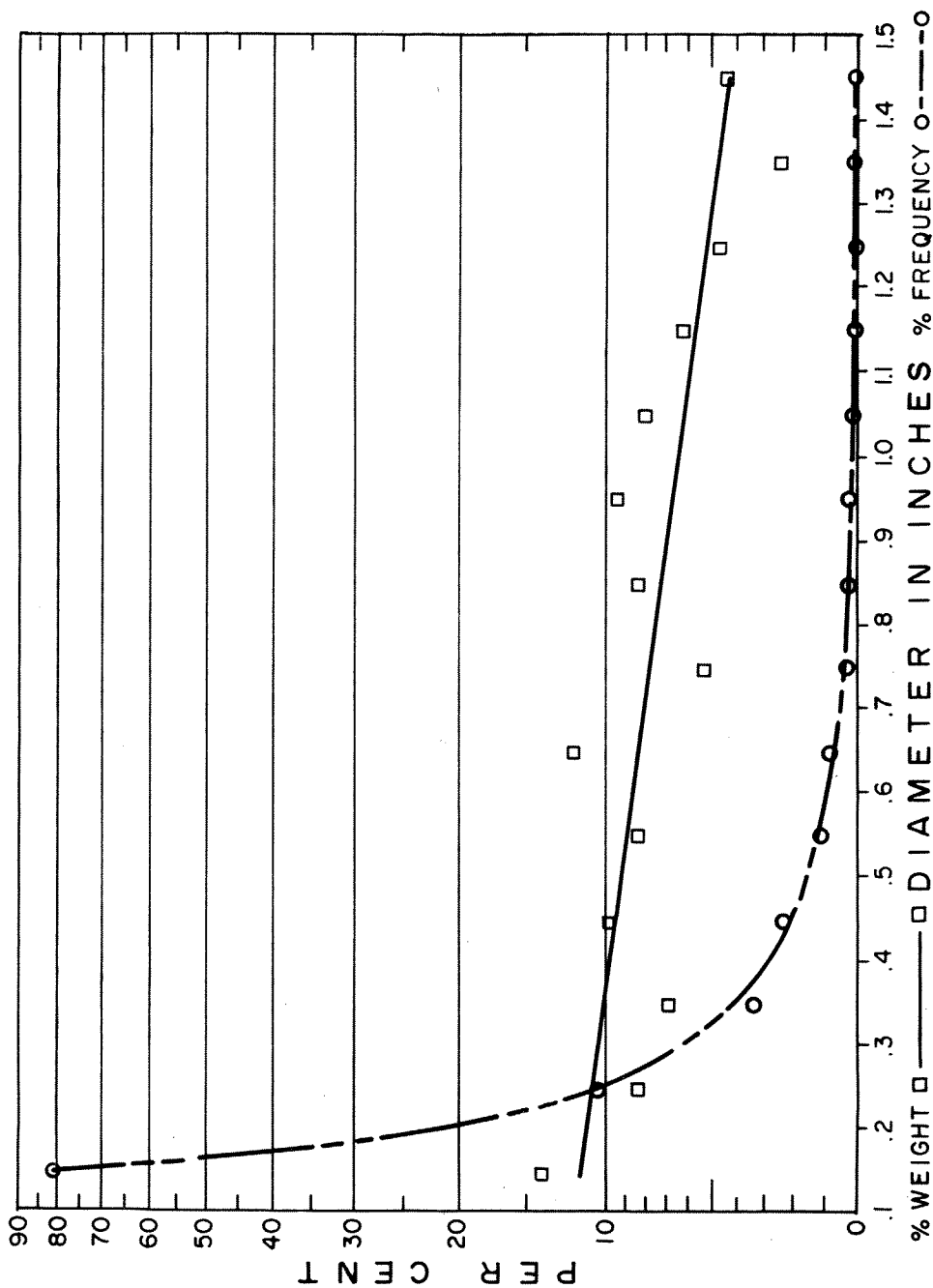
Figure 1. Percentage of total fuel by size classes. Compiled from 103 plots.

The age and height of the stand were measured at each of the plots to provide data for determining if these stand characteristics influenced the distribution of fine fuels. The distribution of plots by height and site classes in each stand is shown in Table 1.

TABLE 1. 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

*Moderate and poor sites were grouped in this height class.

ANALYSIS

The frequency and weight of branch litter within each diameter class were computed for each of the five stands and for the total sample population (Table 2). The frequency distribution (Figure 1) indicates that a modal rather than mean diameter should be used to compute surface area. However, the relatively small variation in *weight* distribution from class to class suggests that the means could be used where weight is concerned. Therefore, in the computation of surface area, the mean diameter of each individual tenth-inch class was used to reduce the effect of the frequency distribution skewness. The frequency distribution of sizes within plots also shows a definite skewness when plotted (Figure 2).

The effect of stand height and site on the frequency of fuel components was tested using Student's "t" test. Results showed that height and site did not have a significant effect, at the 10 per cent level of probability, on the distribution of branch litter in the size range studied.

COMPUTATION OF SURFACE AREA

To circumvent the need to measure the length of each fuel piece for computation of surface area, an average length per diameter class was calculated as follows:

(a) The weight per inch of fuel pieces in each diameter class was derived from equation:

W in grams = (r² LD) 16.386

where r = radius of class midpoint (ins.)

L = length in inches (in this case 1 inch)

D = density in grams per c.c. (lodgepole pine = .41) and 16.386 is the number of c.c.'s in a cu. inch. (Anon. 1951, p. 339).

The resulting weights per inch of fuel pieces having diameters equal to the midpoints of the classes used in this study are shown in Table 2.

(b) The length, in inches, of the average fuel piece in any class was then computed by dividing the weight of the average piece by the computed

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TABLE 2. FREQUENCY WEIGHT AND LENGTH OF FUEL COMPONENTS BY EACH DIAMETER CLASS
(Computed for Class Midpoints)

Diam. Class	.1 +	.2 +	.3 +	.4 +	.5 +	.6 +	.7 +	.8 +	.9 +	1.0 +	1.1 +	1.2 +	1.3 +	1.4 +	Total
Frequency	4,112	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	
Weight (grams)	2,922.8	1,724.8	1,430.1	2,082.1	1,721.5	2,307.6	1,096.6	1,767.7	2,004.1	1,676.5	1,322.7	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	.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	

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weight per inch for the class. Plot size would, in all probability, affect the lengths to a small degree, especially in the larger diameter classes.

Finally, to compute the surface area per size class, the computed length of the average piece was multiplied by the circumference for the mid-diameter of the class and this, in turn, was multiplied by the number of pieces in the class (Table 3).

To demonstrate the development of a graph for computing surface area from weight, two broad size classes were selected as examples—one from .1 to .5 inch and another from .1 to 1.0 inch. Only the computation for the former is shown in Table 3, although the same computation may be used to derive the surface area of fuels within any diameter class limits from .1 inch to 1.5 inches from the data presented in Table 2. Using the frequency values from this table, a new per cent frequency was calculated and is shown in Table 3 as Code B. Then, assuming for simplicity that 100 fuel pieces were taken from a plot, it is shown in Table 3 that these 100 pieces, using the per cent frequency (B) and the average length and weight of fuel pieces from Table 2 (C and E), yield a total weight of 167.0 grams and a surface area of 428.4 square inches, or 2.98 square feet. This will give a surface area per 100 grams of 1.8 square feet litter in the size range of .1 to .5 inch in diameter. Figure 3 depicts this in graphic form and, as such, can then be used to compute the surface area of any weight of litter within the size range.

End area was excluded from the surface area calculations because of the bias introduced in breaking branched pieces. Had end areas (circular basis) been included, the surface area would have been increased by approximately 5.5 square inches or a little more than 1%, the greater increase occurring in the smaller classes.
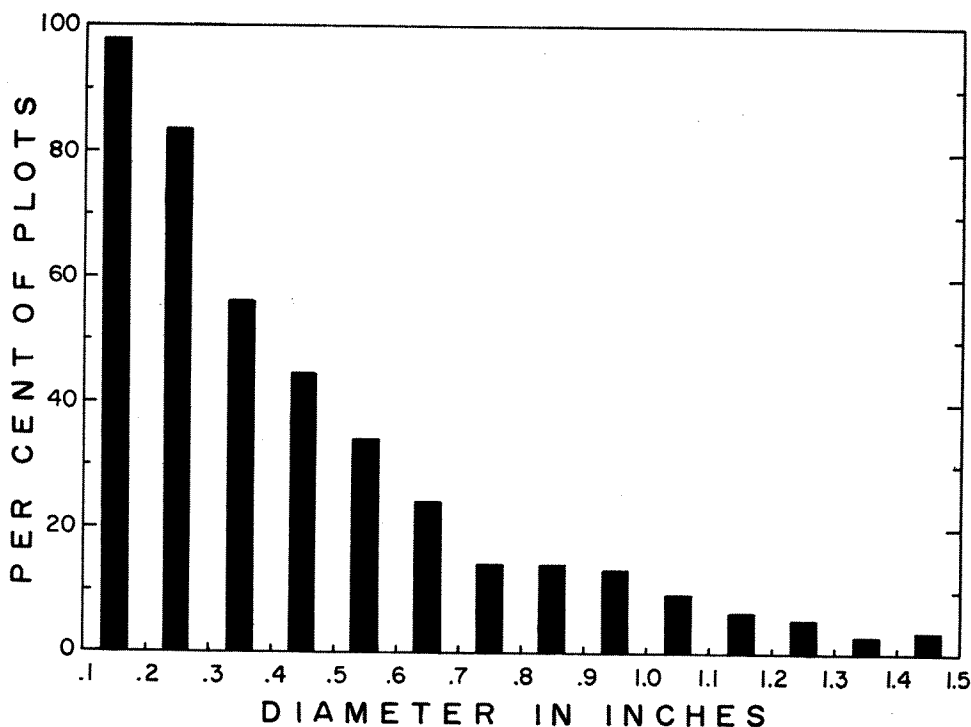

Figure 2. Per cent of plots on which fuels within each size class occur, compiled from 103 plots.

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TABLE 3. COMPUTATION OF TOTAL SURFACE AREA AS A FUNCTION OF WEIGHT
IN GRAMS OF FUEL COMPONENTS FROM .10 TO .50 INCHES IN DIAMETER

Code	Diameter Class	.1+	.2+	.3+	.4+	Totals and Units
A.	Absolute frequency....................	4,112	524	165	117	4,918
B.	Per cent frequency.....................	83.6	10.7	3.4	2.4	100.1%
C.	Length (from Table 2).................	6.03	10.0	13.4	16.6	inches
D.	Midpoint diameter....................	.15	.25	.35	.45	inches
E.	Average Weight (from Table 2)........	.712	3.29	8.68	17.8	grams
F.	Total weight (B × E)..................	59.5	35.2	29.5	42.8	167.0 grams
G.	Circumference........................	.47	.79	1.10	1.41	inches
H.	Average surface area (C × G)..........	2.84	7.90	14.75	23.21	sq. in.
I.	Total surface area (B × H)............	238.0	84.5	50.2	55.7	428.4 sq. in.
J.	Total surface area....................	1.65	.59	.35	.39	2.98 sq. ft.
K.	Surface area per 100 grams............	....	....	....	....	1.8 sq. ft.

To illustrate the bias in surface area that would be introduced had the mid-range diameter been used in the calculation, the surface area was re-computed using the mid-range diameter of .3 inch. Using the same method of computation just described, a surface area of 2.18 square feet is obtained. This is an underestimate of .79 square feet or approximately 26 per cent.

Using the same procedure as shown in Table 3, the weight of a sample of the same number of pieces having class limits of .1 to 1.0 inch is computed to be 337.5 grams, having a surface area of 3.86 square feet or 1.2 square feet per 100 grams, also depicted in Figure 3.

This graph should be used only for lodgepole pine and may not be accurate if used with plot sizes other then 1/10,000 acre.

CONCLUSIONS

Determination of the surface area of the smaller diameter branch litter of forest fuels can be made through the relatively simple process of weighing samples of the fuels in question and applying the weights in graphs such as that developed here (Figure 3).

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 size of the class.

Stand characteristics, height and site, did not have a significant effect, at the 10 per cent level of probability, on the distribution of branch litter in the diameter range .1 to 1.5 inches.

CONCLUSIONS

Il est possible de déterminer la superficie recouverte d'une litière combustible composée de branches mortes de faible diamètre; il suffit tout simplement de peser des échantillons des matières combustibles à l'étude et de porter les poids ainsi relevés sur un graphique dont un exemple est reproduit à la figure 3.

Lorsqu'on emploie les chiffres médians de grandes catégories de diamètre au calcul de la superficie recouverte de litière, on obtient des chiffres inférieurs à la superficie réelle; la marge d'erreur est directement proportionnelle à la grandeur de la catégorie étudiée.

Les caractéristiques du peuplement, son emplacement, ainsi que la hauteur moyenne des arbres, restent sans effet notable, au seuil de probabilité de 10 p. 100, sur la répartition de la litière de branches mortes dont le diamètre est compris dans la marge de 0.1 à 1.5 pouces.
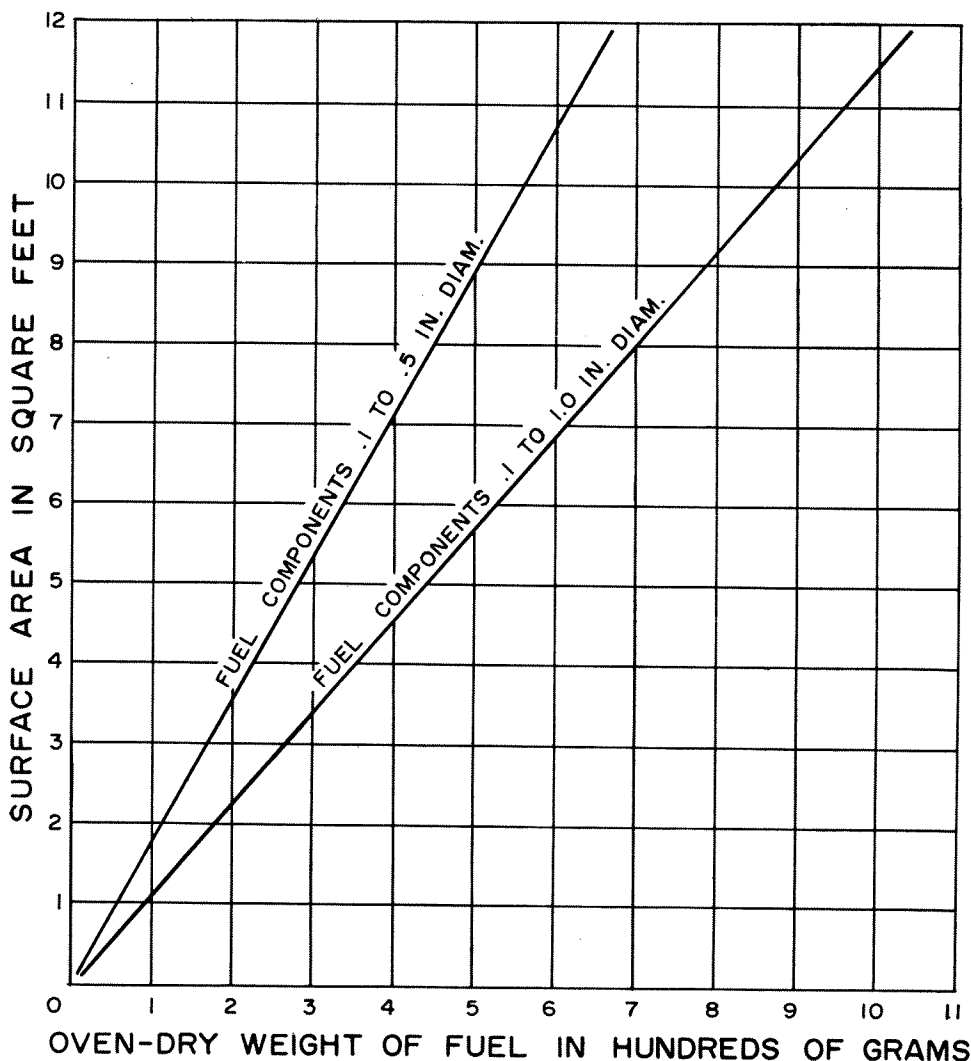

Figure 3. Relation between weight in grams and surface area in square feet of fuel components in two size classes. Surface area – weight ratio of 1.8 square feet and 1.2 square feet per 100 grams for diameters .1 to .5 inch and .1 to 1.0 inch, respectively.

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