English Equivalents

$(9/5\,^{\circ}C) + 32 = {}^{\circ}F$
1 centimeter = 0.39 inch
1 meter = 3.28 feet
1 hectare = 2.47 acres
1 kilometer = 0.62 mile
1 square meter = 10.76 square feet
1 kilogram = 2.20 pounds
1 gram = 0.035 ounce

GPO 988-898

ALASKA • OREGON • WASHINGTON
PNW RESEARCH NOTE
809 NE 6th AVE
Portland, Oregon
97232
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

PNW-333 April 1979

METHOD OF ESTIMATING GROUND FUELS UNDER TWO INCHES IN DIAMETER IN SOUTHWESTERN PONDEROSA PINE STANDS

by

T. W. Eakle[1] and R. F. Wagle[2]

Abstract

Depth and loading of two soil horizons were measured on three areas from the Fort Apache Indian Reservation in Arizona. Regression equations were developed to estimate soil horizon loading (per centimeter squared) from depths (centimeters), (model: $\ln y = 1 + b \ln X$, where y = loading and X = depth). Coefficients of determinations were 0.58 and 0.65 for the 01 and 02 soil horizons, respectively.

KEYWORDS: Fuels (forest fire), residue measurements, soil horizons, litter, ponderosa pine, *Pinus ponderosa*.

Acknowledgments

We wish to thank Ms. Marion Swartz, University of Arizona Computer Center, the White Mountain Apache Tribe, and the Bureau of Indian Affairs staff of the Fort Apache Indian Reservation for their cooperation and the use of their facilities.

This paper resulted from a study on "Fuel Changes in a Ponderosa Pine Type from Prescribed Burning and Wildfire" funded by the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

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[1] Graduate School, University of Arizona, Tucson, Arizona (now with Forest Research Institute, Republic of the Philippines).

[2] University of Arizona, School of Renewable Resources, Tucson, Arizona.

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INTRODUCTION

Due to the immense interest in forest fire control the capability to predict fuel loadings (weight per unit area) has become of utmost importance. Fuel loading is an entity that can be correlated readily with fire behavior and can possibly point the way to predicting fire damage in both prescribed burns and wildfire situations. Probably the best approach for estimating fuel loadings in western forests is that compiled by Brown (1974). We feel that our results can and should be used in conjunction with Brown's inventory method which deals more specifically with down and dead trees and slash. As Brown writes (p. 2), his method "...avoids the time-consuming, costly, and often impractical task of collecting and weighing large quantities of forest debris." It must be mentioned, though, that estimating fuel weight via specific gravity (the basis of Brown's method) is less accurate than actually weighing the fuel.

Our research in prescribed burning necessitated the collection and weighing of moderate sized samples of 01[3] and 02[4] soil horizons. Since these data were costly to collect and regression equations based on them have been useful to us, we have tabulated our results so that others working in ponderosa pine forests can utilize our regression results. These data can be used as an aid for deciding when, where, and how to prescribe burn in ponderosa pine stands.

These data, contained in this report, are directly applicable to southwestern ponderosa pine forests. They deal specifically with stands (populations) located on the Fort Apache Indian Reservation in Arizona. With some additional testing to determine local variation, however, they may be useful over much of the range of the species.

METHODS

Data were collected at three different sites: One in a xeric area and two in relatively mesic areas (as indicated by the understory vegetation). Approximately one-half of the samples came from xeric areas and one-half from the mesic areas.

The 01 and 02 layers in subplots located in the vicinity of permanent plots used for other research purposes were measured for depth, collected, and weighed. The data were collected as follows:

(1) Two or three 1- x 1-ft subplots[5] were located via over-the-shoulder tosses.

(2) Three depths were measured for each subplot of the 01 and 02 layers, and a mean was determined. (See table 1) A sharp, thin spatula was driven by hand into the mineral soil and bent back toward the observer who

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[3] 01 - Organic horizons in which the original form of most vegetative matter is visible to the naked eye. Corresponds to the H layer described in the literature on forest soils (Wilde 1958, Soil Survey Staff 1951 and 1962, Buol et al. 1973).

[4] 02 - Organic horizons in which the original form of most plant or animal matter cannot be recognized by the naked eye. Corresponds to the H layer described in the literature on forest soils (Wilde 1958, Soil Survey Staff 1951 and 1962, Buol et al. 1973).

[5] Two subplots were sampled for each plot in the xeric area where the most permanent plots were located, and three were sampled for each plot in the mesic areas where fewer permanent plots were located. Thus, subplot numbers collected from each area were approximately equal.

Table 1--Descriptive statistics for the 01 and 02 litter layers

	Litter weight			Litter depth		
Litter layer	Mean	Standard deviation	Coefficient of variation	Mean	Standard deviation	Coefficient of variation
	- - - gm/cm^2 - - -		Percent	- - - - - cm - - - - -		Percent
01	0.129	0.067	51.94	1.459	0.800	54.83
02	.259	.234	90.35	.979	1.031	105.31

then measured the vertically exposed 01 and 02 layers. No apparent compaction occurred between layers with this technique.

(3) The 01 and 02 layers were collected from each subplot and placed in separate paper bags and air dried for 2 to 3 weeks. The 02 layer's lower boundary ended where the mineral soil began.

(4) The bags of 01 and 02 layers were then oven dried for 24 hours at 120°C and weighed. The first series of bags were dried for longer periods of time, but no weight changes were noted after 15 additional hours of drying.

A data base consisting of mean depths (in centimeters) and weights (in grams) for 1-ft^2 areas was thus obtained for the 01 and 02 layers (see appendix A). Simple linear regression was used to derive prediction equations for weight per unit areas as a function of depth. The predicted equations are plotted on figure 1 and corresponding values are shown in appendices B and C, without correction for inherent $\log_e$ bias (Baskerville 1972).

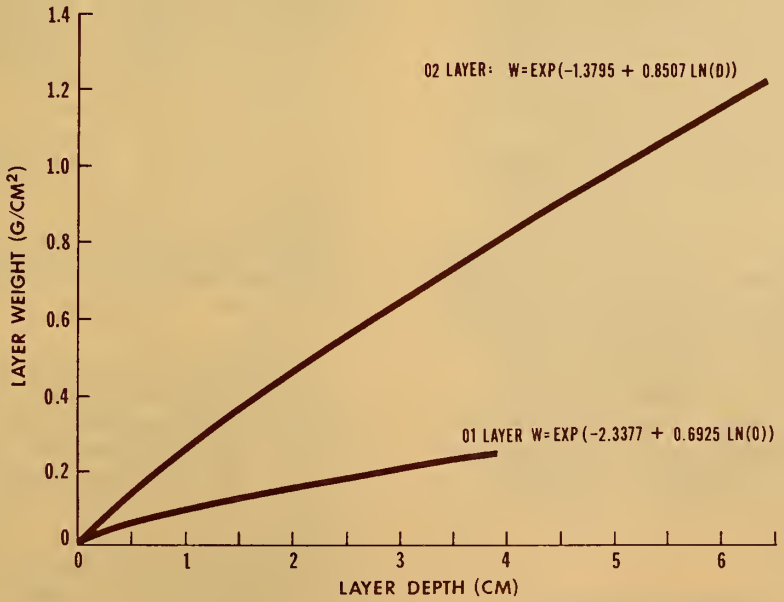

Figure 1.--Weight prediction of the 01 and 02 litter layers, where W=weight and D=depth.

RESULTS AND DISCUSSION

Davis et al. (1968), in a study of ponderosa pine duff on two small 1/4-acre plots, measured duff tonnages per acre of 10.2 tons/acre in one area and 17.6 tons/acre in the second area. Ffolliott et al. (1976) gave an average of 7 tons per acre for the entire forest floor for four small watersheds located on alluvial and sandstone soils (total of 140 acres). This compared to an average of 9.3 tons per acre of ponderosa pine duff in a study made on soils developed from basalt and volcanic cinders (Ffolliott et al. 1968). Ffolliott et al. (1976) stated that "no consistent differences were found in the forest floor characteristics between sandstone and alluvium soils," and that "the means (with 0.95 confidence limits) for depth and weight are comparable with those for forest floors developed on volcanic soils."

Similar relationships for organic material depth and weights occurred between soil types in this study. More material per acre, however, for any given 01 or 02 depth generally occurred in this study. This was to be expected because Ffolliott was measuring only needle fall and duff originating from needles, insofar as possible, in his studies. All duff recognizable as woody or herbaceous in origin was removed from his samples before weighing.[6] In the present study, all dead organic materials up to 2 inches in diameter were included in the samples weighed--although only a few had twigs over 1/4 inch in diameter.

Mean bulk densities (weight per unit volume) were calculated for each soil horizon: 0.129 gm/cc for the 01 layer and .259 gm/cc for the 02 layer. There were no significant differences within and between the sampling areas for the mean bulk densities of the soil surface organic layers. It should be pointed out, however, that bulk densities varied by a factor of 4 at the 1-cm depth in the 01 layer and a factor of 5 at the 1-cm depth in the 02 layer. The same degree of variability occurred in the data shown in Ffolliott et al. (1968, 1976).

As table 2 shows, the regression equations obtained for the 01 and 02 layers are capable of providing modest estimates of their respective loadings ($r^2 = .58$ for 01, and $r^2 = .65$ for 02). Both regression slopes were found to be highly significant. The equations are of the form:

$$\ln \hat{y} = \ln a + b \ln x$$

where: $\hat{y}$ = weight of litter (gms/cm^2)
b = regression coefficient
a = regression coefficient
x = depth of litter layer (cm)

This form has the property of passing through the origin, and the curve has a variable slope, cbx^{b-1}. The slope decreases as depth increases. This mathematical form appears to better fit the field observations than the straight line model. The weight of the 01 layer did not decrease linearly as it decomposed and entered the 02 layer, nor did the weight of the 02 layer decrease linearly as it decomposed to soil.

The coefficients of variability demonstrated how variable the 02 layer is compared to the 01 layer. This observation is not surprising since the 02 layer was more difficult to measure and collect than the 01 layer.

The discrepancy in sample sizes, 219 for the 02 layer versus 240 for the 01 layer (table 2), is

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[6] Personal communication with P. F. Ffolliott.

Table 2--Linear regression results for predicting fuel weights for the 01 and 02 litter layers

Litter layer	Number of observations	Regression coefficients		Standard error	r^2
		In a	b		
01	240	-2.3377	.6925	.3917	.58
02	219	-1.3795	.8507	.5277	.65

caused by the occasional absence of the 02 layer beneath the 01 layer.

As an aid to the forest manager or fire control officer, extensive tables explicating horizon weights are shown in grams per square centimeters and tons/acre in appendices B and C.

In conclusion, this information should provide a more accurate means of predicting fine fuel loading in the ponderosa pine type than any method previously available. It should particularly be of use in conjunction with Brown's method when estimates of total fuel loading are desired. When used in this way, however, Brown's method should be modified to omit measuring materials 2 inches in diameter and smaller.

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APPENDIX A

Explication of data

Layer depths (cm)	Number of observations 01	Number of observations 02
0.1	1	8
.2	5	19
.3	9	21
.4	9	19
.5	11	17
.6	3	9
.7	7	21
.8	13	14
.9	6	9
1.0	24	17
1.1	4	5
1.2	19	13
1.3	8	6
1.4	3	6
1.5	21	7
1.6	6	2
1.7	8	2
1.8	16	1
1.9	9	2
2.0	9	4
2.1	2	0
2.2	9	1
2.3	3	0
2.4	5	1
2.5	9	4
2.6	1	0
2.7	4	0
2.8	2	3
2.9	0	0
3.0	6	0
3.1	0	0
3.2	1	0
3.3	0	0
3.4	2	0
3.5	4	1
3.6	0	0
3.7	0	0
3.8	0	0
3.9	0	1
4.0	1	0
4.5	0	2
5.5	0	2
6.0	0	1
6.5	0	1
Total	240	219

APPENDIX B

Predicted 01 litter weights[1] in both
grams per square centimeter and short tons/acre

Depth (cm)	gm/cm^2	Tons/acre	Depth (cm)	gm/cm^2	Tons/acre
0.1	0.020	0.9	2.1	0.161	7.2
.2	.032	1.4	2.2	.167	7.4
.3	.042	1.9	2.3	.172	7.7
.4	.051	2.3	2.4	.177	7.9
.5	.060	2.7	2.5	.182	8.1
.6	.068	3.0	2.6	.187	8.3
.7	.075	3.4	2.7	.192	8.6
.8	.083	3.7	2.8	.197	8.8
.9	.090	4.0	2.9	.202	9.0
1.0	.097	4.3	3.0	.207	9.2
1.1	.103	4.6	3.1	.211	9.4
1.2	.110	4.9	3.2	.216	9.6
1.3	.116	5.2	3.2	.221	9.8
1.4	.122	5.4	3.4	.225	10.1
1.5	.128	5.7	3.5	.230	10.3
1.6	.134	6.0	3.6	.234	10.5
1.7	.139	6.2	3.7	.239	10.7
1.8	.145	6.5	3.8	.243	10.9
1.9	.151	6.7	3.9	.248	11.1
2.0	.156	7.0	4.0	.252	11.2

[1] Weights are oven dry.

APPENDIX C

Predicted 02 litter weights[1] in both grams per square centimeter and short tons/acre

Depth (cm)	gm/cm^2	Tons/acre	Depth (cm)	gm/cm^2	Ton/acre
0.1	0.035	1.6	3.1	0.659	29.4
.2	.064	2.9	3.2	.677	30.2
.3	.090	4.0	3.3	.695	31.0
.4	.115	5.1	3.4	.713	31.8
.5	.140	6.2	3.5	.731	32.6
.6	.163	7.3	3.6	.748	33.4
.7	.186	8.3	3.7	.766	34.2
.8	.208	9.3	3.8	.784	35.0
.9	.230	10.3	3.9	.801	35.7
1.0	.252	11.2	4.0	.819	36.5
1.1	.273	12.2	4.1	.836	37.3
1.2	.294	13.1	4.2	.853	38.1
1.3	.315	14.0	4.3	.871	38.8
1.4	.335	15.0	4.4	.888	39.6
1.5	.355	15.9	4.5	.905	40.4
1.6	.375	16.7	4.6	.922	41.1
1.7	.395	17.6	4.7	.939	41.9
1.8	.415	18.5	4.8	.956	42.6
1.9	.435	19.4	4.9	.973	43.4
2.0	.454	20.2	5.0	.990	44.2
2.1	.473	21.1	5.1	1.007	44.9
2.2	.492	22.0	5.2	1.023	45.7
2.3	.511	22.8	5.3	1.040	46.4
2.4	.530	23.6	5.4	1.057	47.1
2.5	.549	24.5	5.5	1.073	47.9
2.6	.567	25.3	5.6	1.090	48.6
2.7	.586	26.1	5.7	1.106	49.4
2.8	.604	27.0	5.8	1.123	50.1
2.9	.623	27.8	5.9	1.139	50.8
3.0	.641	28.6	6.0	1.156	51.6
			6.1	1.172	52.3
			6.2	1.189	53.0
			6.3	1.205	53.7
			6.4	1.221	54.5
			6.5	1.237	55.2

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[1] Weights are oven dry.