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and
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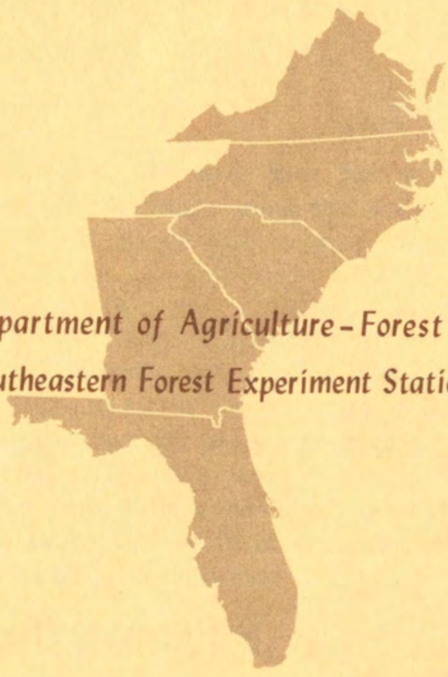

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Predicting Fire Behavior in Palmetto-Gallberry Fuel Complexes

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Abstract.--Rate of spread, fireline intensity, and flame length can be predicted with reasonable accuracy for backfires and low-intensity head fires in the palmetto-gallberry fuel complex of the South. This fuel complex was characterized and variables were adjusted for use in Rothermel's (1972) spread model.

Age of rough, height of understory, percent of area covered by palmetto, basal area of overstory, season of year, moisture content of dead fuels, and midflame windspeed must be known to make predictions. These fire behavior predictions do not apply to high-intensity wildfires where spotting and crowning are occurring.

Keywords: Rate of spread, fireline intensity, flame length, prescribed burning.

Firefighters need to know how fast a fire will spread, how hot it will burn, and what the flame length will be. Prescribed burners need the same information to plan for fireline placement and burnout time, and to keep damage of overstory trees to a minimum. Rate of spread is also needed to estimate smoke production and transport, which are critical factors in smoke management (Southern Forest Fire Laboratory Staff 1976). The mathematical model of fire behavior developed by Rothermel (1972) predicts fire spread and intensity well enough if the fuel is relatively homogeneous. It is difficult to adequately characterize a heterogeneous fuel complex like the palmetto-gallberry type. The purpose of the research described here, therefore, was to characterize the palmetto-gallberry fuel complex and then adjust several variables, such as fuel depth and moisture content of extinction, so that the output of Rothermel's model was representative of measured fire behavior.

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This fuel type is the complex association of saw-palmetto [Serenoa repens (Bartr.) Small] and common gallberry [Ilex glabra (L.) Gray] with many other plants beneath slash pines (Pinus elliottii Engelm.) or mixtures of slash and longleaf pine (P. palustris Mill.). Openings frequently contain small shrubs [Vaccinium spp., Quercus spp., and Kalmiella hirsuta (Walt.) Small] and wiregrass (Aristida spp.). Palmetto and gallberry are two of the most common plants occurring in forest understories on the Lower Coastal Plain of the Southern United States. In this area, live and dead fuels accumulate so rapidly that a wildfire in a 5-year accumulation can seriously damage or kill the pine overstory, even though the pines are fire resistant. To preclude destructive wildfires, burning is often prescribed for hazard reduction.

Throughout the palmetto-gallberry fuel complex, fuel height and fuel loading vary widely. Fuel height may range from 1 to 6 or more feet,[3] while loading may vary from 1 to 25 tons/acre (Bruce 1951; Sackett 1975). This variation makes it impossible to construct a single fuel model that is typical of the type. What is needed, and presented here, is a dynamic fuel model that accounts for site conditions, fuel-accumulation time, and species composition. This model permits reasonably precise prediction of fire behavior, as well as systematic analysis of the consequences of fuel treatments. Rothermel and Philpot (1973) developed a similar model for the chaparral fuel complex.

This paper is divided into two parts for the convenience of the reader. Some may be interested only in the application of the results; others may want details on the methods and procedures used to arrive at this end product. Part I provides the tables and charts needed to predict fire behavior in the palmetto-gallberry fuels; examples are provided to demonstrate the method. Part II gives the details of the research process.

Although the data and methods presented are the best available at this time, certain limitations should be clearly understood. Fire behavior predictions from the Rothermel model are for uniform wind conditions and a continuous, homogeneous fuel layer that is contiguous to the ground. No information on crown fires is presented. Windspeed, wind direction, and characteristics of the fuel layer will vary on actual fires, resulting in possible differences between estimated and actual values. Another major factor, not currently included in the fire behavior model, is the influence of spotting on fire spread and intensity. Spotting is especially important in wildfires. Even so, the predictions given here provide an estimate of fire behavior on prescribed burns and on the initial stages of wildfires. The resulting information can be incorporated in fire planning by the forest fire manager.

PART I: FIELD APPLICATION

The most efficient and accurate way to use the information presented in this paper would be to program all the fuel weight-predicting equations and fuel parameters into a computer-based model of wild land fire behavior like that described by Albini (1976a). Then, not only could all variables be entered on a continuous scale, but additional information on fire growth rate, scorch height, and a number of other factors could be obtained.

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[3] Factors to convert from English units to International System of Units (SI) are listed on page 44.

Since computer terminals are not available at all locations, the results are presented in tables and curves from which reasonably accurate predictions can be made.

DATA NEEDED

Measurements that must be taken in the field have been reduced to a minimum. Those needed to predict fuel characteristics are easily measured. The items needed for predictions are:

1. Age of understory rough (yr)
2. Basal area of overstory (ft^2)
3. Average height of understory (ft)
4. Palmetto coverage (pct)
5. Season of year
6. Midflame windspeed (mi/h).

Average or visual understory height and percent palmetto coverage can be estimated by eye. The simplest method is to locate a number of 100-foot-long transects at different places in the stand. The number of feet of transect covered by palmetto fronds equals the percent palmetto. If transects are not 100 feet long, the percent coverage must be calculated. An estimate of average understory height can also be obtained along these transects. In a very dense understory, the average height is that to the top foliage of the palmetto and gallberry plants. In a scattered or patchy palmetto stand, however, it is necessary to measure heights of low shrubs or grasses that occur in the openings as well as palmetto and gallberry foliage. The average height is between these two measurements and should be weighted by the amount of coverage in each category.

Dead-fuel moisture content can be estimated using the 100-hour timelag tables in the National Fire Danger Rating System (NFDRS) (Deeming and others 1972); such information should be available at the nearest fire danger station. The windspeed needed for predictions is that in the stand that will be burned. Windspeed may be obtained from the danger station and reduced to an appropriate level using tables presented by Cooper (1965).

BACKFIRE BEHAVIOR

Nine pairs of tables predicting fire behavior are presented. In each pair, the one on the left-hand page predicts flame length for backfires or for fires without wind. The one on the right-hand page shows the rate of spread in feet per minute under the same conditions. Your first problem is to determine which pair of tables applies to your conditions. This decision must be based upon the basal area of the tree overstory and the percentage of area covered by palmetto:

Table numbers	Overstory basal area[4]	Palmetto coverage[5]
1, 2	low	sparse
3, 4	low	broken
5, 6	low	continuous
7, 8	medium	sparse
9, 10	medium	broken
11, 12	medium	continuous
13, 14	high	sparse
15, 16	high	broken
17, 18	high	continuous

Once the proper table is selected, it is a simple matter to locate the predicted flame length or spread rate from the age of rough, the dead-fuel moisture content, the height of understory, and the season of year (summer or winter).

WIND ADJUSTMENTS

The values in these tables are for calm conditions or for backfires. With heading fires, adjustments must be made for wind effects. These adjustments can be estimated with the help of tables 19-21 and figures 1 and 2. The proper table to use depends upon overstory density:

Table number	Overstory basal area[6]
19	low
20	medium
21	high

These tables show letter designations for fuel categories. Once the proper letter for your fuel condition has been found, enter figure 1 to determine the effect of wind on rate of spread and figure 2 to determine the effect of wind on flame length. The values found in these figures should be multiplied by the values obtained for backfires in tables 1-18.

FIRE INTENSITY

From flame length, determined in figure 2, fire intensity can be determined. This relationship is illustrated in figure 3, which shows fire intensities in British thermal units per second per foot (Btu/s/ft). This figure also shows

[4] Values of basal area (ft^2) used to generate these tables were: 30 ft^2 for low, 70 ft^2 for medium, and 110 ft^2 for high conditions.

[5] Values of palmetto coverage (percent) used to generate these tables were: 15 percent for sparse, 50 percent for broken, and 85 percent for continuous conditions.

[6] See footnote 4.

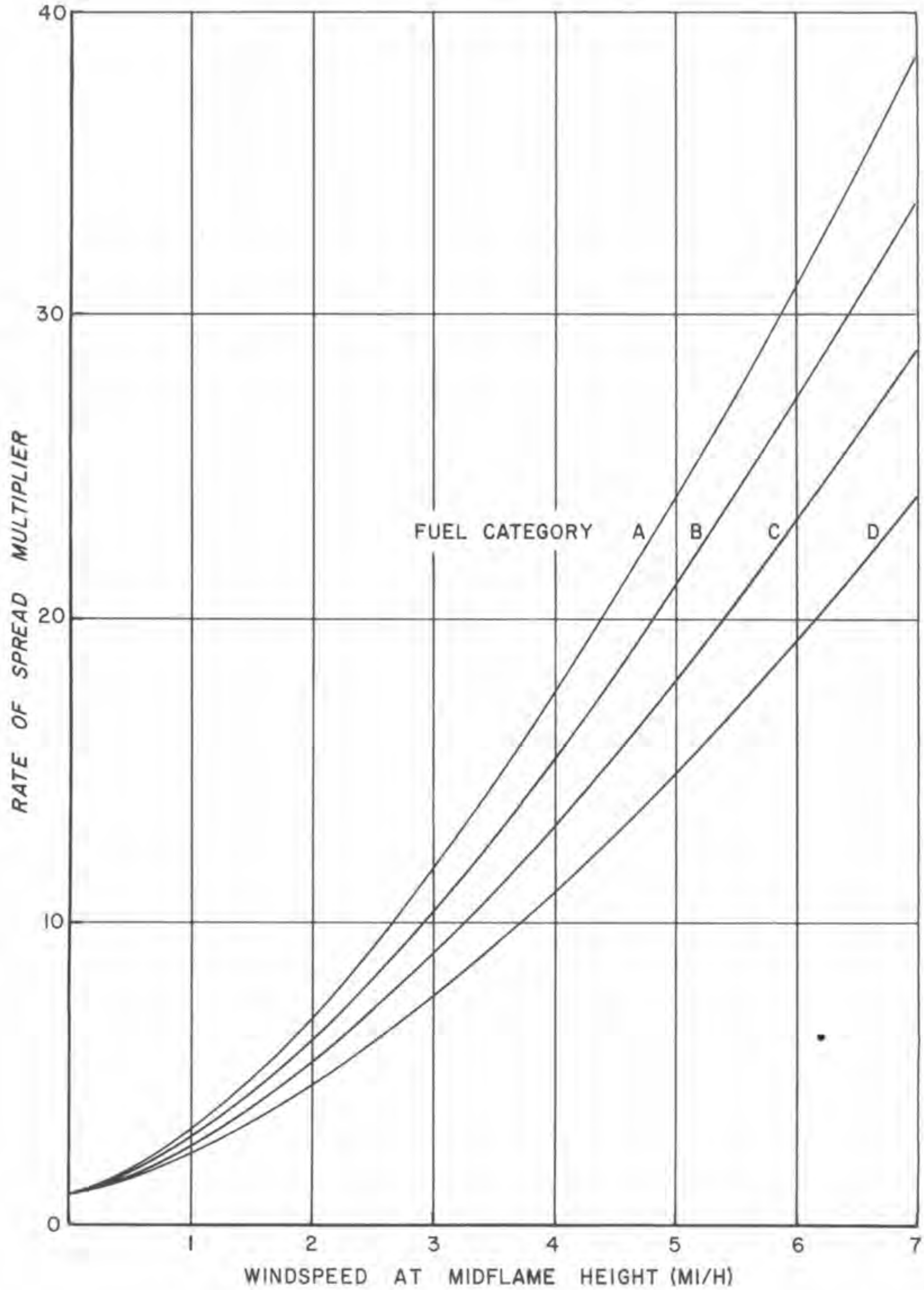

Figure 1. --Rate-of-spread multiplier for head fires.

the intensities at which spotting, loss of control, and crowning often begin. Intensity of prescribed burns is normally below 100 Btu/s/ft. Spotting usually does not occur until intensity reaches 500 Btu/s/ft.

We have worked up some examples to familiarize you with the use of the application tables and figures 1-3. After you have tried these examples, you should have little trouble in making predictions for your own conditions.

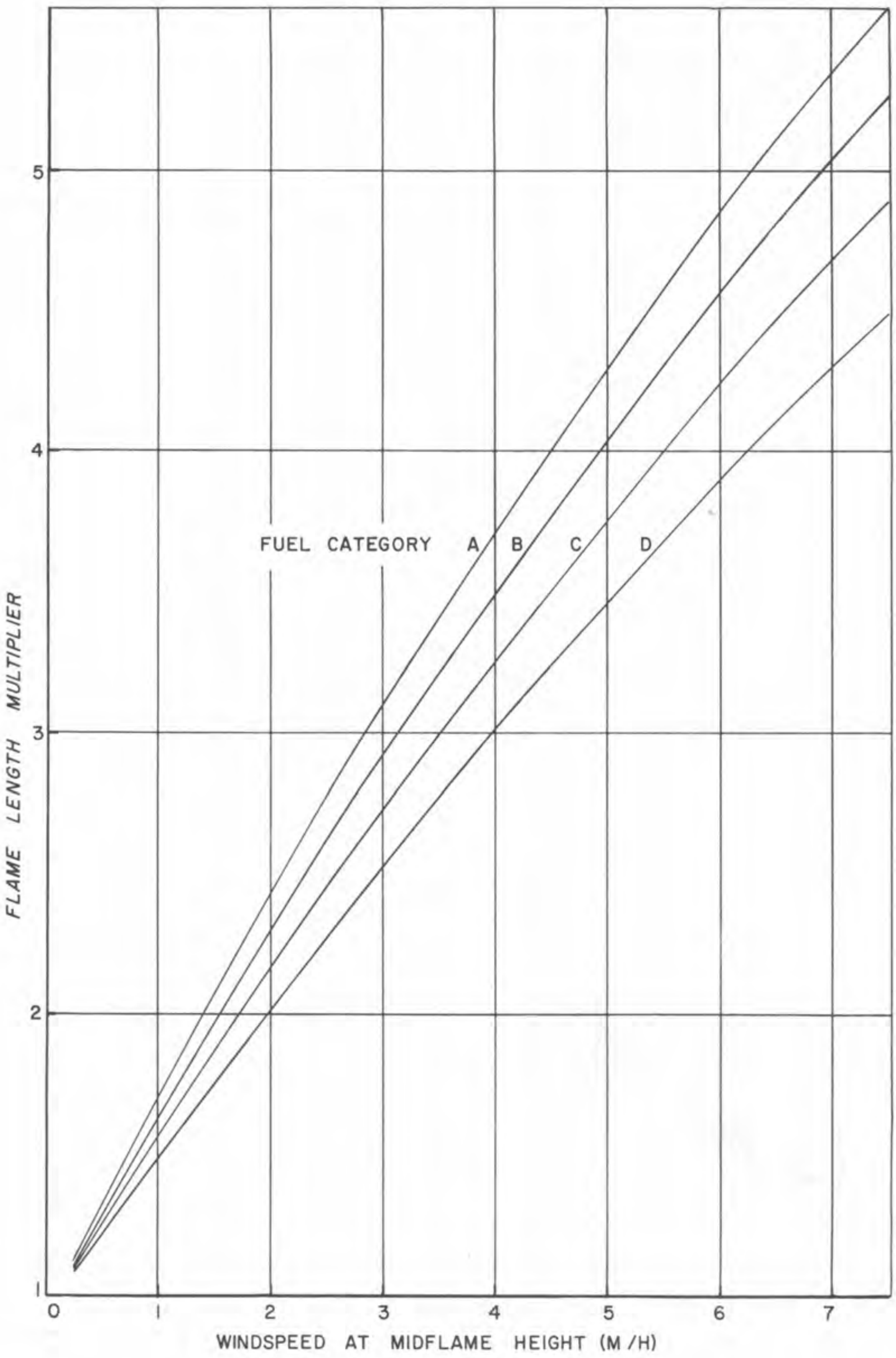

Figure 2. --Flame-length multiplier for head fires.

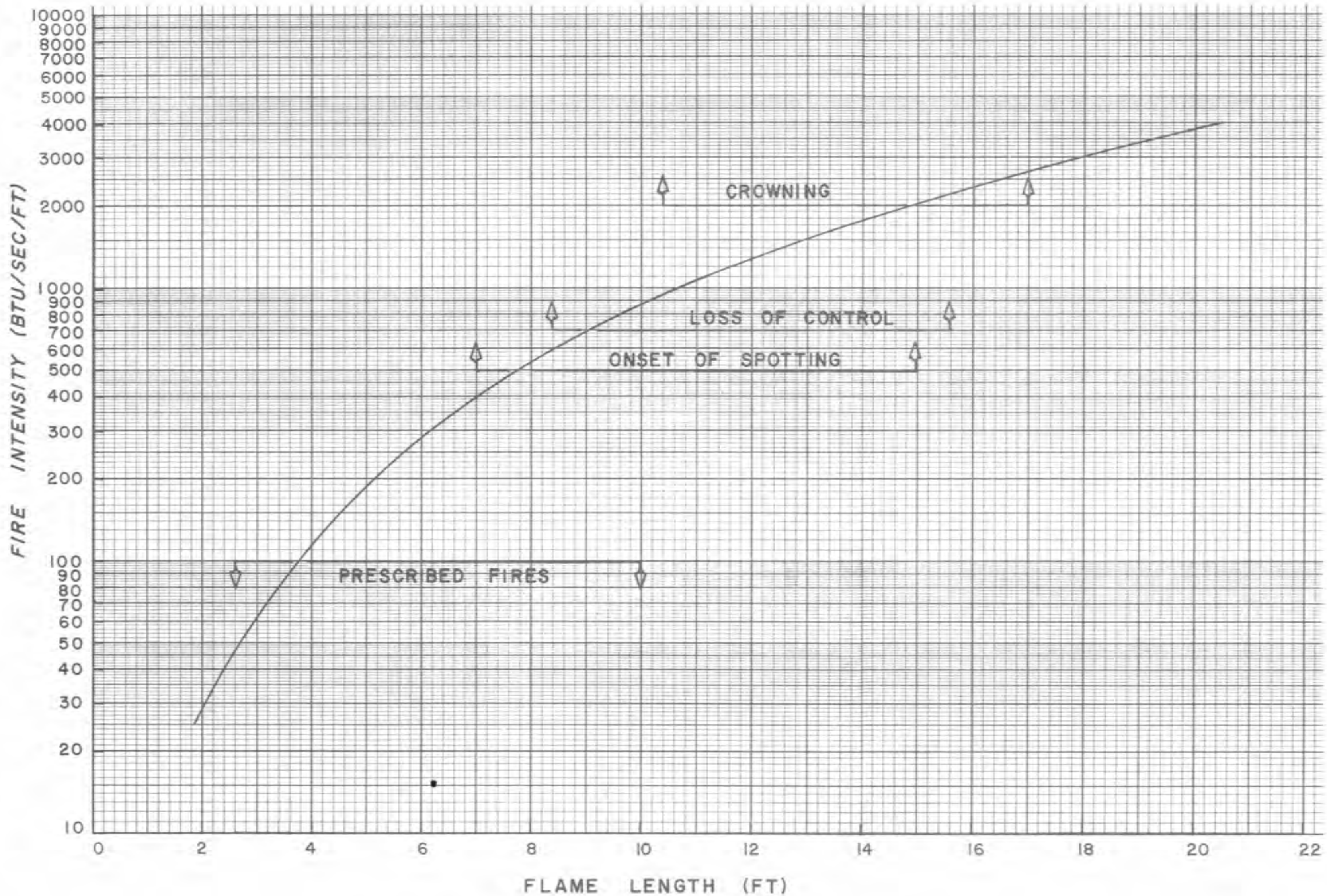

Figure 3. --Relationship between flame length and fire intensity.

Example No. 1

A land manager is planning a prescribed fire in a stand of slash pine that has a 6-year-old palmetto-gallberry understory. The stand conditions have been measured as follows: basal area of 65 ft^2/acre, understory fuel height of $3\frac{1}{2}$ feet, and a coverage of palmetto of 60 percent. Because of the age of rough, he will use a winter backfire; therefore, the wind factors will not be determined for this case. Because this is a planning situation, the values entered in the tables will be rounded to the closest available figures.

The first step is to locate the table that corresponds to basal area of 65 (in this case rounded to 70). After finding this table, the age is located on the left-hand column; tabular age 5 is used because it is closest to the acutal value. Next, find the height of the understory which is shown across the top of the page. The height of $3\frac{1}{2}$ feet falls midway between the values presented in the table. Since rates of spread are very similar for the two heights in question, it makes little difference which column is used. Selecting the column marked "4 feet" and the group of figures under "winter," the rate-of-spread values are seen to range from 0.72 ft/min for moisture contents of 30 percent to a value of 2.4 ft/min for a fuel moisture of 5 percent.

The fuel moisture content at the time of burning would be between these extremes and probably between 10 to 20 percent, resulting in a fairly narrow range in spread rates that need to be considered. Planning the location of interior firelines could be made based on these figures, without knowing the exact moisture content that might occur at the time of burn. An estimate of flame length could also be obtained for this burn by following the same procedures and entering the flame-length tables. Once flame length has been estimated, it would also be possible to estimate fire intensity.

Example No. 2

A fire control officer would like an estimate of initial wildfire behavior during the spring fire season in two different palmetto-gallberry stands. Stand I has recently been burned (2 years ago), is sparsely populated by palmetto, and has an average understory height of 2 feet. Stand II has an old rough (13 years since last disturbance), a fairly dense palmetto cover, and an understory height of 5 feet. It is assumed that the dead-fuel moisture content will be low, about 5 percent, and that the windspeed will be 6 mi/h within the stand. For simplification, assume both stands have the same basal area, 75 ft^2/acre.

Again, the first step is to find the backfire rate-of-spread table with basal area and palmetto values closest to the measured values. Basal area 70 and "sparse" palmetto coverage should be used for Stand I. In this table, find the column for winter and an understory height of 2 feet. Follow down this column to the row for age 2 and a 5 percent moisture content for dead fuel. Rate of spread is found to be 2.8 ft/min. For Stand II, use the table for basal area 70 and "continuous" palmetto coverage. Enter the column for winter and an understory height of 5 feet; go down to age 15 and a moisture content of 5 percent. Estimated rate of spread is 2.9 ft/min.

Now, entering the wind-effect category table for basal area 70, percent palmetto 15 (sparse), height of 2 and age of 2, we find Stand I falls in category B. For Stand II, we also enter the table headed by basal area 70, but the section headed percent palmetto 85 is used. Next, find the age of 15 in the left-hand column and look across until you reach height 5; this gives a category C.

Turning to figure 1, we find a set of curves from which we will obtain our head fire rate of spread multiplier. We enter a windspeed of 6 mi/h and read the value at the intersection with curve B. For Stand I, we get a factor of 27.0. This value is multiplied by the zero-wind rate of spread and gives us a head fire rate of spread of 76 ft/min. Again entering the curve at 6 mi/h windspeed, we find the factor of 23.1 for wind-effect category C. Using this value multiplied by the zero-wind rate of spread, we find the head fire rate of spread in Stand II will be 67 ft/min.

The young understory fuel conditions produce a higher spread rate than the older understory. However, if we enter the flame-length tables following the rate-of-spread procedures, we find a 2.1-foot flame, at zero windspeed, for Stand I and a 3.5-foot flame for Stand II. The wind-effect category does not change, so by entering figure 2 we find the multiplier for flame length. Again entering the graph at 6 mi/h windspeed, we find a factor for curve B of 4.56 and a factor for curve C of 4.24. Multiplying these values times zero-windspeed flame length, we find that the flame length in the young, open stand will be 9.6 feet, while the flame length in the older, heavier fuel will be 14.9 feet. Stand II has a flame $1\frac{1}{2}$ times longer than Stand I. Using figure 3, it is possible to estimate fire intensity. The fire in Stand I would have an intensity of 780 Btu/s/ft, while in Stand II it would be 2,000 Btu/s/ft. Spotting would probably occur on both fires, but crowning would be much more likely in the stand with heavy accumulations of saw palmetto.

As presented in these examples, the fire behavior occurring under different conditions can be assessed. The information is probably most useful in the planning stages, not only for preparing prescribed burn plans, but also to provide presuppression planners a systematic way to note differences that stand age and fuel buildup have on fire behavior factors. Also, if windspeed within the stand and moisture content of the dead fuel are known, real-time estimates of rate of spread could be made.

Table 1.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 30 ft^2/acre (low) and percent palmetto coverage is 15 percent (sparse)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet): 1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet											
1	5	1.2	1.3	1.3	1.4	1.3	1.4	1.3	1.4	1.3	1.5	1.1	1.6
	10	1.0	1.0	1.1	1.1	1.1	1.2	1.1	1.2	.99	1.3	.53	1.1
	15	.88	.92	.97	1.0	1.0	1.1	.98	1.1	.51	1.0	.49	.52
	20	.82	.85	.91	.96	.95	1.0	.53	.97	.49	.52	.47	.50
	30	.65	.67	.69	.77	.48	.51	.43	.46	.40	.42	.38	.41
2	5	1.4	1.5	1.5	1.6	1.5	1.6	1.5	1.6	1.6	1.7	1.6	1.9
	10	1.2	1.2	1.3	1.4	1.3	1.4	1.3	1.4	1.4	1.5	1.1	1.6
	15	1.0	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.0	1.4	.60	1.1
	20	.95	.99	1.1	1.1	1.1	1.2	1.0	1.3	.61	.96	.58	.62
	30	.75	.77	.86	.91	.60	.69	.54	.57	.50	.53	.47	.51
3	5	1.4	1.5	1.6	1.7	1.6	1.7	1.6	1.7	1.7	1.8	1.7	1.9
	10	1.2	1.2	1.3	1.4	1.4	1.5	1.4	1.5	1.4	1.6	1.2	1.7
	15	1.1	1.1	1.2	1.3	1.2	1.3	1.3	1.4	1.1	1.5	.64	1.3
	20	.98	1.0	1.1	1.2	1.2	1.3	1.1	1.3	.65	1.1	.61	.65
	30	.78	.80	.89	.95	.62	.74	.57	.60	.53	.56	.50	.54
4	5	1.4	1.5	1.6	1.7	1.6	1.7	1.6	1.8	1.7	1.8	1.7	2.0
	10	1.2	1.3	1.3	1.4	1.4	1.5	1.4	1.5	1.5	1.6	1.3	1.7
	15	1.1	1.1	1.2	1.3	1.3	1.4	1.3	1.4	1.2	1.5	.65	1.3
	20	.99	1.0	1.1	1.2	1.2	1.3	1.1	1.3	.66	1.1	.62	.67
	30	.79	.82	.88	.97	.63	.68	.58	.61	.54	.57	.51	.55
5	5	1.4	1.5	1.6	1.7	1.6	1.8	1.6	1.8	1.7	1.9	1.7	2.0
	10	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.6	1.5	1.7	1.3	1.7
	15	1.1	1.1	1.2	1.3	1.3	1.4	1.3	1.5	1.2	1.5	.66	1.3
	20	.99	1.0	1.2	1.2	1.2	1.3	1.1	1.4	.66	1.1	.63	.68
	30	.80	.83	.85	.98	.63	.66	.58	.61	.54	.58	.52	.55
8	5	1.4	1.5	1.6	1.7	1.6	1.8	1.7	1.8	1.8	1.9	1.8	2.1
	10	1.2	1.3	1.4	1.5	1.4	1.5	1.5	1.6	1.5	1.7	1.2	1.8
	15	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.1	1.5	.67	1.3
	20	1.0	1.1	1.2	1.2	1.2	1.3	1.0	1.4	.67	1.0	.64	.69
	30	.78	.85	.64	.92	.62	.65	.58	.62	.55	.58	.53	.56
15	5	1.3	1.4	1.5	1.7	1.6	1.8	1.7	1.9	1.8	2.0	1.8	2.2
	10	1.1	1.2	1.3	1.4	1.5	1.6	1.5	1.7	1.5	1.8	1.1	1.8
	15	1.0	1.1	1.2	1.3	1.3	1.4	1.3	1.6	.90	1.6	.67	1.2
	20	.97	1.0	1.2	1.3	1.2	1.4	.69	1.3	.67	.71	.65	.69
	30	.50	.61	.58	.61	.58	.61	.57	.60	.55	.58	.53	.57
25	5	1.1	1.2	1.5	1.6	1.7	1.8	1.8	1.9	1.9	2.1	1.8	2.3
	10	1.0	1.1	1.3	1.4	1.5	1.6	1.6	1.8	1.5	1.9	1.1	1.9
	15	.93	.99	1.2	1.3	1.3	1.5	1.2	1.6	.67	1.6	.66	1.1
	20	.85	.95	1.0	1.2	.89	1.3	.65	1.2	.64	.69	.64	.68
	30	.40	.42	.50	.53	.53	.56	.53	.57	.53	.56	.52	.56

Table 2.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 30 ft^2/acre (low) and percent palmetto coverage is 15 percent (sparse)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet/minute											
1	5	1.5	1.6	1.7	1.9	1.5	1.7	1.2	1.5	1.1	1.4	.75	1.3
	10	1.1	1.2	1.4	1.5	1.2	1.4	1.1	1.3	.79	1.2	.36	.88
	15	.97	1.0	1.2	1.3	1.1	1.3	.89	1.1	.38	.87	.32	.37
	20	.86	.92	1.1	1.2	1.0	1.2	.45	.94	.36	.41	.30	.35
	30	.62	.65	.74	.87	.47	.52	.35	.40	.28	.32	.24	.28
2	5	1.6	1.7	1.9	2.2	1.7	2.0	1.5	1.7	1.3	1.6	1.2	1.5
	10	1.2	1.3	1.5	1.7	1.4	1.6	1.3	1.5	1.1	1.4	.75	1.3
	15	1.0	1.1	1.3	1.5	1.3	1.4	1.1	1.3	.82	1.2	.41	.83
	20	.90	.97	1.2	1.3	1.2	1.3	.94	1.2	.46	.80	.39	.45
	30	.64	.68	.87	.97	.56	.69	.44	.50	.36	.41	.30	.35
3	5	1.5	1.6	1.9	2.1	1.8	2.0	1.5	1.8	1.4	1.7	1.3	1.6
	10	1.2	1.3	1.5	1.7	1.5	1.7	1.3	1.5	1.2	1.4	.88	1.4
	15	.98	1.1	1.3	1.5	1.3	1.5	1.2	1.4	.91	1.3	.43	.97
	20	.87	.95	1.2	1.3	1.2	1.3	1.0	1.3	.48	.93	.41	.47
	30	.63	.67	.86	.97	.57	.72	.46	.52	.38	.43	.32	.37
4	5	1.4	1.6	1.8	2.1	1.7	2.0	1.5	1.8	1.4	1.7	1.3	1.6
	10	1.1	1.2	1.5	1.7	1.4	1.7	1.3	1.5	1.2	1.5	.90	1.4
	15	.94	1.0	1.3	1.4	1.3	1.5	1.2	1.4	.93	1.3	.44	1.0
	20	.84	.92	1.2	1.3	1.2	1.3	.99	1.3	.49	.94	.41	.48
	30	.62	.66	.83	.95	.56	.64	.46	.52	.38	.44	.33	.38
5	5	1.3	1.5	1.8	2.0	1.7	2.0	1.5	1.8	1.4	1.7	1.3	1.6
	10	1.1	1.2	1.4	1.6	1.4	1.6	1.3	1.5	1.2	1.5	.90	1.4
	15	.90	1.0	1.2	1.4	1.3	1.4	1.2	1.4	.91	1.3	.44	1.0
	20	.81	.89	1.1	1.3	1.2	1.3	.96	1.3	.49	.92	.42	.48
	30	.60	.64	.77	.93	.54	.60	.45	.51	.38	.43	.33	.38
8	5	1.2	1.3	1.6	1.9	1.6	1.8	1.5	1.7	1.4	1.7	1.3	1.6
	10	.94	1.1	1.3	1.5	1.3	1.5	1.3	1.5	1.2	1.5	.84	1.4
	15	.81	.91	1.2	1.3	1.2	1.4	1.1	1.4	.82	1.3	.44	.93
	20	.73	.81	1.1	1.2	1.1	1.3	.83	1.2	.48	.79	.41	.48
	30	.53	.61	.52	.81	.50	.55	.43	.49	.37	.43	.33	.38
15	5	.82	.94	1.2	1.4	1.3	1.5	1.3	1.6	1.3	1.6	1.2	1.6
	10	.67	.77	.99	1.1	1.1	1.3	1.2	1.4	1.1	1.4	.72	1.3
	15	.60	.68	.89	1.0	1.0	1.2	.97	1.2	.60	1.2	.41	.80
	20	.55	.62	.82	.94	.85	1.1	.47	1.0	.43	.49	.39	.45
	30	.26	.34	.37	.41	.39	.44	.37	.42	.34	.38	.31	.35
25	5	.52	.61	.84	.98	1.0	1.2	1.1	1.3	1.2	1.4	1.1	1.5
	10	.44	.51	.72	.84	.89	1.0	.96	1.2	.91	1.2	.61	1.2
	15	.40	.46	.65	.77	.78	.95	.73	1.0	.37	1.0	.36	.68
	20	.36	.43	.55	.70	.50	.83	.36	.74	.35	.41	.34	.39
	30	.15	.17	.24	.27	.28	.32	.29	.33	.28	.32	.27	.31

Table 3.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 30 ft^2/acre (low) and palmetto coverage is 50 percent (broken)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	- - -	- - -	- - -	- - -	- - -	- - -	Feet	- - -	- - -	- - -	- - -	- - -
	5	1.2	1.3	1.3	1.4	1.4	1.5	1.4	1.5	1.4	1.6	.91	1.6
	10	1.0	1.1	1.2	1.2	1.2	1.3	1.2	1.4	.83	1.4	.57	1.0
1	15	.92	.98	1.1	1.1	1.1	1.2	.84	1.2	.54	.84	.52	.55
	20	.87	.92	1.0	1.1	.87	1.1	.55	.75	.52	.55	.50	.53
	30	.48	.67	.51	.54	.49	.52	.45	.48	.42	.45	.41	.44
	5	1.4	1.5	1.6	1.7	1.7	1.8	1.7	1.8	1.7	1.9	1.7	2.0
	10	1.2	1.3	1.4	1.5	1.4	1.5	1.5	1.6	1.4	1.7	.98	1.7
2	15	1.1	1.1	1.3	1.3	1.3	1.4	1.3	1.5	.89	1.5	.65	1.0
	20	1.0	1.1	1.2	1.3	1.2	1.4	.86	1.3	.66	.71	.62	.67
	30	.74	.86	.63	.83	.62	.65	.57	.61	.54	.57	.51	.55
	5	1.5	1.6	1.7	1.8	1.8	1.9	1.8	1.9	1.8	2.0	1.8	2.1
	10	1.2	1.3	1.4	1.6	1.5	1.6	1.6	1.7	1.6	1.8	1.3	1.8
3	15	1.1	1.2	1.3	1.4	1.4	1.5	1.4	1.6	1.1	1.6	.70	1.3
	20	1.1	1.1	1.3	1.3	1.3	1.4	1.1	1.4	.71	1.0	.67	.72
	30	.78	.90	.67	.91	.66	.69	.62	.65	.58	.61	.55	.59
	5	1.5	1.6	1.7	1.9	1.8	1.9	1.8	2.0	1.9	2.1	1.9	2.2
	10	1.3	1.4	1.5	1.6	1.6	1.7	1.6	1.8	1.6	1.9	1.4	1.9
4	15	1.1	1.2	1.4	1.4	1.4	1.5	1.5	1.6	1.2	1.7	.73	1.4
	20	1.1	1.1	1.3	1.4	1.4	1.5	1.1	1.5	.73	1.1	.70	.74
	30	.77	.91	.68	.92	.67	.71	.63	.67	.60	.64	.57	.61
	5	1.5	1.6	1.8	1.9	1.8	2.0	1.9	2.0	1.9	2.1	2.0	2.2
	10	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.7	1.9	1.4	2.0
5	15	1.2	1.2	1.4	1.5	1.5	1.6	1.5	1.7	1.3	1.7	.74	1.5
	20	1.1	1.2	1.3	1.4	1.4	1.5	1.2	1.5	.75	1.2	.71	.76
	30	.75	.92	.69	.90	.68	.72	.65	.68	.61	.65	.58	.62
	5	1.5	1.6	1.8	2.0	1.9	2.1	2.0	2.1	2.0	2.2	2.1	2.4
	10	1.3	1.4	1.6	1.7	1.7	1.8	1.7	1.9	1.8	2.0	1.6	2.1
8	15	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.3	1.8	.78	1.6
	20	1.1	1.2	1.4	1.5	1.4	1.6	1.2	1.6	.78	1.3	.75	.80
	30	.61	.89	.70	.75	.70	.73	.67	.71	.64	.68	.61	.65
	5	1.5	1.6	1.8	2.0	2.0	2.1	2.1	2.3	2.2	2.4	2.2	2.5
	10	1.3	1.4	1.6	1.7	1.7	1.9	1.8	2.0	1.9	2.1	1.7	2.2
15	15	1.2	1.3	1.5	1.6	1.6	1.7	1.6	1.9	1.4	1.9	.83	1.8
	20	1.1	1.2	1.4	1.5	1.4	1.6	1.1	1.7	.82	1.3	.79	.85
	30	.57	.60	.68	.72	.70	.74	.69	.73	.67	.71	.65	.70
	5	1.3	1.5	1.8	1.9	2.0	2.2	2.2	2.4	2.3	2.5	2.4	2.7
	10	1.2	1.3	1.6	1.7	1.8	1.9	1.9	2.1	2.0	2.3	1.9	2.4
25	15	1.1	1.2	1.5	1.6	1.6	1.8	1.7	2.0	1.5	2.0	.86	1.9
	20	1.0	1.1	1.3	1.5	1.3	1.7	.92	1.7	.84	1.3	.82	.88
	30	.48	.51	.63	.67	.68	.72	.69	.73	.68	.73	.67	.72

Table 4.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 30 ft^2/acre (low) and palmetto coverage is 50 percent (broken)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet/minute											
1	5	1.1	1.2	1.4	1.6	1.4	1.6	1.3	1.5	1.1	1.4	.63	1.3
	10	.86	.98	1.2	1.3	1.2	1.4	1.0	1.3	.62	1.2	.37	.77
	15	.76	.85	1.0	1.2	1.1	1.3	.71	1.1	.39	.68	.33	.39
	20	.70	.78	.96	1.1	.81	1.1	.44	.65	.36	.42	.32	.37
	30	.35	.52	.45	.50	.42	.47	.34	.39	.29	.33	.25	.29
2	5	1.2	1.4	1.6	1.9	1.7	1.9	1.5	1.8	1.4	1.7	1.2	1.6
	10	.97	1.1	1.4	1.5	1.4	1.6	1.3	1.5	1.1	1.5	.68	1.3
	15	.84	.94	1.2	1.4	1.3	1.5	1.1	1.4	.67	1.2	.43	.74
	20	.77	.85	1.1	1.2	1.1	1.3	.71	1.2	.48	.56	.41	.47
	30	.52	.63	.53	.74	.52	.58	.44	.50	.37	.43	.32	.37
3	5	1.2	1.4	1.7	1.9	1.7	2.0	1.6	1.9	1.5	1.8	1.4	1.7
	10	.97	1.1	1.4	1.6	1.5	1.7	1.4	1.6	1.3	1.6	.89	1.5
	15	.85	.95	1.2	1.4	1.3	1.5	1.2	1.5	.87	1.4	.47	.98
	20	.77	.86	1.1	1.3	1.2	1.4	.87	1.3	.51	.82	.44	.51
	30	.52	.64	.54	.80	.54	.60	.47	.53	.40	.46	.35	.40
4	5	1.2	1.4	1.7	1.9	1.7	2.0	1.6	1.9	1.5	1.8	1.4	1.8
	10	.96	1.1	1.4	1.6	1.5	1.7	1.4	1.6	1.3	1.6	.97	1.5
	15	.83	.94	1.2	1.4	1.3	1.5	1.2	1.5	.93	1.4	.48	1.1
	20	.76	.85	1.1	1.3	1.2	1.4	.92	1.3	.53	.90	.46	.53
	30	.50	.63	.54	.78	.54	.60	.48	.54	.41	.47	.36	.41
5	5	1.2	1.3	1.7	1.9	1.7	2.0	1.7	1.9	1.6	1.9	1.4	1.8
	10	.94	1.1	1.4	1.6	1.5	1.7	1.4	1.7	1.3	1.6	1.0	1.5
	15	.82	.92	1.2	1.4	1.3	1.5	1.3	1.5	.96	1.4	.49	1.1
	20	.75	.83	1.1	1.3	1.2	1.4	.93	1.3	.53	.94	.46	.54
	30	.47	.61	.53	.74	.54	.60	.48	.54	.42	.48	.37	.42
8	5	1.1	1.2	1.6	1.8	1.7	2.0	1.7	1.9	1.6	1.9	1.5	1.9
	10	.88	1.0	1.3	1.5	1.4	1.6	1.4	1.7	1.3	1.6	1.1	1.6
	15	.77	.88	1.2	1.3	1.3	1.5	1.3	1.5	.99	1.5	.51	1.2
	20	.71	.80	1.1	1.2	1.2	1.4	.90	1.3	.54	.98	.48	.55
	30	.35	.55	.50	.57	.52	.58	.47	.54	.42	.48	.38	.43
15	5	.87	1.0	1.3	1.5	1.5	1.8	1.6	1.8	1.6	1.9	1.5	1.9
	10	.72	.83	1.1	1.3	1.3	1.5	1.4	1.6	1.3	1.6	1.1	1.6
	15	.64	.73	.99	1.1	1.2	1.3	1.2	1.4	.95	1.4	.51	1.2
	20	.60	.67	.91	1.1	1.0	1.2	.74	1.2	.52	.93	.48	.55
	30	.27	.30	.41	.45	.45	.50	.44	.50	.41	.47	.38	.44
25	5	.61	.71	1.0	1.2	1.3	1.5	1.4	1.6	1.5	1.7	1.5	1.8
	10	.52	.60	.87	1.0	1.1	1.3	1.2	1.4	1.2	1.5	1.1	1.6
	15	.47	.54	.79	.91	97	1.1	1.0	1.3	.86	1.3	.47	1.2
	20	.43	.50	.70	.84	.77	1.0	.52	1.1	.47	.83	.45	.52
	30	.18	.21	.30	.34	.35	.40	.37	.42	.37	.42	.35	.41

Table 5.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 30 $ft^2/acre$ (low) and palmetto coverage is 85 percent (continuous)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet											
	5	1.3	1.4	1.5	1.7	1.6	1.8	1.7	1.8	1.6	1.9	1.3	1.9
	10	1.1	1.2	1.3	1.4	1.4	1.6	1.4	1.6	1.1	1.6	.67	1.4
1	15	1.1	1.1	1.2	1.3	1.3	1.4	1.0	1.4	.63	1.1	.61	.65
	20	.99	1.1	1.1	1.3	.91	1.3	.65	.90	.61	.65	.58	.62
	30	.50	.53	.57	.59	.56	.59	.53	.56	.50	.53	.48	.51
	5	1.6	1.7	1.9	2.0	2.0	2.1	2.0	2.2	2.1	2.3	2.1	2.4
	10	1.3	1.4	1.6	1.7	1.7	1.8	1.8	1.9	1.8	2.0	1.5	2.1
2	15	1.2	1.3	1.5	1.6	1.6	1.7	1.6	1.8	1.3	1.8	.79	1.5
	20	1.2	1.2	1.4	1.5	1.5	1.6	1.1	1.6	.79	1.2	.75	.81
	30	.62	.88	.71	.75	.72	.76	.68	.72	.65	.69	.62	.66
	5	1.7	1.8	2.0	2.2	2.1	2.3	2.2	2.3	2.2	2.4	2.3	2.5
	10	1.4	1.5	1.7	1.9	1.8	2.0	1.9	2.1	2.0	2.2	1.8	2.3
3	15	1.3	1.4	1.6	1.7	1.7	1.8	1.7	1.9	1.6	2.0	.87	1.9
	20	1.2	1.3	1.5	1.6	1.6	1.7	1.4	1.8	.88	1.6	.84	.89
	30	.68	.99	.78	.93	.79	.83	.75	.80	.72	.76	.68	.73
	5	1.7	1.9	2.1	2.3	2.2	2.4	2.3	2.4	2.3	2.5	2.4	2.6
	10	1.5	1.6	1.8	1.9	1.9	2.1	2.0	2.1	2.1	2.3	2.0	2.4
4	15	1.3	1.4	1.6	1.8	1.8	1.9	1.8	2.0	1.8	2.1	1.2	2.0
	20	1.3	1.3	1.6	1.7	1.7	1.8	1.6	1.9	.93	1.7	.89	.95
	30	.75	1.0	.81	1.0	.83	.87	.80	.84	.76	.81	.73	.77
	5	1.8	1.9	2.2	2.3	2.3	2.5	2.3	2.5	2.4	2.6	2.5	2.7
	10	1.5	1.6	1.9	2.0	2.0	2.1	2.1	2.2	2.1	2.3	2.1	2.4
5	15	1.4	1.5	1.7	1.8	1.8	2.0	1.9	2.1	1.9	2.2	1.4	2.1
	20	1.3	1.4	1.6	1.7	1.7	1.9	1.7	1.9	1.0	1.8	.93	1.2
	30	.78	1.1	.84	1.1	.86	.90	.83	.88	.80	.84	.76	.81
	5	1.9	2.0	2.3	2.5	2.5	2.7	2.5	2.7	2.6	2.8	2.7	2.9
	10	1.6	1.7	2.0	2.1	2.1	2.3	2.2	2.4	2.3	2.5	2.3	2.6
8	15	1.5	1.5	1.8	1.9	2.0	2.1	2.1	2.2	2.1	2.3	1.8	2.4
	20	1.4	1.5	1.7	1.8	1.9	2.0	1.8	2.1	1.4	2.1	1.0	1.6
	30	.79	1.1	.90	1.2	.93	.97	.91	.96	.87	.93	.84	.89
	5	1.9	2.1	2.5	2.7	2.7	2.9	2.8	3.0	2.9	3.1	3.0	3.3
	10	1.6	1.8	2.1	2.3	2.3	2.5	2.5	2.6	2.6	2.8	2.6	2.9
15	15	1.5	1.6	1.9	2.1	2.1	2.3	2.3	2.4	2.3	2.6	2.2	2.7
	20	1.4	1.5	1.8	2.0	2.0	2.2	2.1	2.3	1.8	2.4	1.2	2.1
	30	.75	1.1	.95	1.2	1.0	1.1	1.0	1.1	.99	1.0	.96	1.0
	5	1.7	1.9	2.5	2.7	2.8	3.0	3.0	3.2	3.2	3.4	3.3	3.6
	10	1.5	1.6	2.1	2.3	2.4	2.6	2.6	2.8	2.8	3.0	2.9	3.2
25	15	1.4	1.5	2.0	2.1	2.3	2.4	2.4	2.6	2.6	2.8	2.5	3.0
	20	1.3	1.4	1.9	2.0	2.1	2.3	2.2	2.5	2.1	2.6	1.3	2.5
	30	.67	.87	.93	.98	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.1

Table 6.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 30 ft^2/acre (low) and palmetto coverage is 85 percent (continuous)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	- - -	- - -	- - -	- - -	- - -	Feet/minute	- - -	- - -	- - -	- - -	- - -	- - -
1	5	.96	1.1	1.4	1.6	1.5	1.7	1.4	1.7	1.3	1.6	.92	1.5
	10	.80	.92	1.2	1.4	1.3	1.5	1.2	1.5	.83	1.4	.43	1.1
	15	.72	.81	1.1	1.2	1.1	1.4	.80	1.3	.44	.91	.39	.45
	20	.66	.75	.94	1.1	.75	1.2	.49	.75	.42	.49	.37	.43
	30	.30	.33	.42	.47	.43	.49	.38	.43	.33	.38	.29	.34
2	5	1.1	1.3	1.7	1.9	1.8	2.1	1.7	2.0	1.7	2.0	1.5	1.9
	10	.92	1.1	1.4	1.6	1.5	1.8	1.5	1.8	1.4	1.7	1.1	1.6
	15	.82	.92	1.2	1.4	1.4	1.6	1.3	1.6	.97	1.5	.52	1.2
	20	.75	.84	1.1	1.3	1.2	1.5	.88	1.4	.56	.93	.49	.57
	30	.36	.56	.52	.58	.55	.62	.50	.56	.44	.50	.39	.45
3	5	1.2	1.4	1.8	2.0	1.9	2.2	1.9	2.2	1.8	2.1	1.7	2.1
	10	.96	1.1	1.5	1.7	1.6	1.9	1.6	1.9	1.5	1.8	1.3	1.8
	15	.85	.96	1.3	1.5	1.5	1.7	1.4	1.7	1.2	1.6	.58	1.4
	20	.78	.87	1. 2	1.3	1.3	1.5	1.1	1.5	.62	1.2	.55	.63
	30	.39	.61	.56	.71	.59	.66	.55	.62	.49	.56	.43	.50
4	5	1.2	1.4	1.8	2.1	2.0	2.3	1.9	2.3	1.9	2.2	1.8	2.1
	10	.98	1.1	1.5	1.7	1.7	1.9	1.7	1.9	1.6	1.9	1.4	1.9
	15	.86	.97	1.3	1.5	1.5	1.7	1.5	1.7	1.3	1.7	.80	1.6
	20	.79	.88	1.2	1.4	1.4	1.6	1.2	1.6	.66	1.4	.58	.67
	30	.42	.63	.57	.79	.62	.69	.58	.65	.52	.59	.46	.53
5	5	1.2	1.4	1.8	2.1	2.0	2.4	2.0	2.3	1.9	2.3	1.8	2.2
	10	.98	1.1	1.5	1.7	1.7	2.0	1.7	2.0	1.7	2.0	1.5	1.9
	15	.86	.97	1.3	1.5	1.5	1.7	1.5	1.8	1.4	1.8	.96	1.7
	20	.79	.88	1.2	1.4	1.4	1.6	1.3	1.6	.72	1.5	.61	.85
	30	.43	.63	.58	.82	.63	.70	.59	.67	.54	.61	.48	.55
8	5	1.2	1.4	1.9	2.2	2.1	2.4	2.1	2.4	2.1	2.4	2.0	2.4
	10	.98	1.1	1.5	1.8	1.7	2.0	1.8	2.1	1.8	2.1	1.7	2.1
	15	.86	.97	1.4	1.5	1.6	1.8	1.6	1.9	1.5	1.9	1.2	1.8
	20	.79	.88	1.3	1.4	1.4	1.6	1.4	1.7	.99	1.6	.67	1.2
	30	.41	.63	.59	.84	.65	.72	.63	.70	.58	.66	.52	.60
15	5	1.1	1.2	1.7	2.0	2.0	2.3	2.1	2.5	2.1	2.5	2.1	2.5
	10	.88	1.0	1.4	1.6	1.7	1.9	1.8	2.1	1.9	2.2	1.8	2.2
	15	.78	.88	1.3	1.4	1.5	1.7	1.6	1.9	1.6	2.0	1.5	2.0
	20	.72	.81	1.2	1.3	1.4	1.6	1.4	1.7	1.2	1.8	.73	1.5
	30	.34	.54	.54	.71	.63	.70	.64	.72	.61	.69	.57	.65
25	5	.83	.96	1.4	1.7	1.8	2.1	2.0	2.3	2.1	2.5	2.1	2.5
	10	.69	.79	1.2	1.4	1.5	1.8	1.7	2.0	1.8	2.1	1.9	2.2
	15	.61	.70	1.1	1.2	1.4	1.6	1.5	1.8	1.6	1.9	1.6	2.0
	20	.57	.64	.99	1.1	1.3	1.4	1.4	1.6	1.3	1.7	.76	1.6
	30	.26	.37	.45	.50	.55	.61	.59	.67	.60	.67	.58	.66

Table 7.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 70 ft^2/acre (medium) and palmetto coverage is 15 percent (sparse)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet) 1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet											
1	5	1.6	1.6	1.7	1.8	1.6	1.8	1.6	1.8	1.7	1.8	1.7	1.9
	10	1.3	1.3	1.4	1.5	1.4	1.5	1.4	1.5	1.5	1.6	1.3	1.7
	15	1.1	1.2	1.2	1.3	1.3	1.4	1.3	1.4	1.2	1.5	.66	1.3
	20	1.0	1.1	1.2	1.2	1.2	1.3	1.2	1.3	.67	1.2	.63	.67
	30	.81	.83	.93	.97	.67	.94	.60	.63	.55	.58	.52	.55
2	5	1.8	1.9	2.0	2.1	2.0	2.1	1.9	2.1	2.0	2.1	2.1	2.2
	10	1.5	1.5	1.7	1.7	1.7	1.8	1.7	1.8	1.7	1.9	1.8	2.0
	15	1.3	1.3	1.5	1.5	1.5	1.6	1.5	1.6	1.6	1.7	1.3	1.8
	20	1.2	1.2	1.4	1.4	1.4	1.5	1.5	1.6	1.3	1.6	.79	1.2
	30	.93	.96	1.1	1.1	1.0	1.2	.75	.78	.69	.73	.64	.68
3	5	1.8	1.9	2.1	2.2	2.1	2.2	2.0	2.2	2.1	2.2	2.1	2.3
	10	1.5	1.5	1.7	1.8	1.7	1.9	1.8	1.9	1.8	2.0	1.9	2.1
	15	1.3	1.4	1.5	1.6	1.6	1.7	1.6	1.7	1.7	1.8	1.5	1.9
	20	1.2	1.3	1.4	1.5	1.5	1.6	1.5	1.6	1.4	1.7	.83	1.4
	30	.96	.99	1.1	1.2	1.1	1.3	.78	.82	.72	.76	.68	.72
4	5	1.8	1.9	2.1	2.2	2.1	2.2	2.1	2.2	2.1	2.3	2.2	2.4
	10	1.5	1.6	1.7	1.8	1.8	1.9	1.8	1.9	1.8	2.0	1.9	2.1
	15	1.3	1.4	1.5	1.6	1.6	1.7	1.6	1.8	1.7	1.9	1.5	1.9
	20	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.4	1.7	.84	1.4
	30	.97	1.0	1.2	1.2	1.0	1.3	.79	.83	.73	.78	.69	.73
5	5	1.8	1.9	2.1	2.2	2.1	2.2	2.1	2.2	2.1	2.3	2.2	2.4
	10	1.5	1.6	1.7	1.8	1.8	1.9	1.8	1.9	1.9	2.0	1.9	2.1
	15	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.7	1.9	1.5	1.9
	20	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.4	1.7	.85	1.4
	30	.97	1.0	1.2	1.2	.97	1.3	.79	.83	.74	.78	.70	.74
8	5	1.8	1.9	2.1	2.2	2.1	2.2	2.1	2.3	2.2	2.3	2.2	2.5
	10	1.5	1.6	1.7	1.8	1.8	1.9	1.8	2.0	1.9	2.1	1.9	2.2
	15	1.3	1.4	1.6	1.7	1.6	1.7	1.7	1.8	1.7	1.9	1.4	2.0
	20	1.2	1.3	1.5	1.5	1.5	1.6	1.6	1.7	1.3	1.7	.86	1.3
	30	.98	1.0	1.1	1.2	.83	1.1	.79	.83	.74	.78	.70	.75
15	5	1.6	1.7	1.9	2.1	2.0	2.2	2.1	2.3	2.2	2.4	2.3	2.5
	10	1.4	1.4	1.6	1.8	1.8	1.9	1.9	2.0	2.0	2.1	1.9	2.3
	15	1.2	1.3	1.5	1.6	1.6	1.7	1.7	1.9	1.7	2.0	1.3	2.0
	20	1.2	1.2	1.4	1.5	1.5	1.7	1.5	1.8	.96	1.7	.85	1.1
	30	.81	.97	.76	1.1	.77	.81	.75	.79	.72	.77	.70	.74
25	5	1.3	1.5	1.8	1.9	2.0	2.1	2.1	2.3	2.3	2.4	2.3	2.6
	10	1.2	1.3	1.5	1.7	1.7	1.9	1.9	2.0	2.0	2.2	1.9	2.3
	15	1.1	1.2	1.4	1.5	1.6	1.7	1.7	1.9	1.6	2.0	1.1	2.0
	20	1.0	1.1	1.4	1.5	1.5	1.7	1.3	1.7	.84	1.6	.82	.88
	30	.51	.53	.65	.68	.69	.73	.70	.74	.69	.73	.67	.72

Table 8.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 70 ft^2/acre (medium) and palmetto coverage is 15 percent (sparse)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	- - -	- - -	- - -	- - -	- - -	Feet/minute	- - -	- - -	- - -	- - -	- - -	- - -
1	5	1.9	2.0	2.2	2.5	2.0	2.3	1.6	1.9	1.5	1.7	1.3	1.6
	10	1.4	1.5	1.8	1.9	1.6	1.8	1.4	1.6	1.3	1.5	.96	1.4
	15	1.2	1.2	1.5	1.6	1.4	1.6	1.3	1.4	1.0	1.3	.46	1.1
	20	1.0	1.1	1.3	1.5	1.3	1.5	1.1	1.3	.52	1.0	.43	.50
	30	.73	.76	.99	1.1	.65	.99	.51	.57	.41	.46	.34	.39
2	5	1.9	2.1	2.5	2.8	2.3	2.7	2.0	2.3	1.8	2.1	1.6	1.9
	10	1.5	1.6	1.9	2.1	1.9	2.1	1.7	1.9	1.5	1.8	1.4	1.7
	15	1.2	1.3	1.7	1.8	1.6	1.8	1.5	1.7	1.3	1.6	.98	1.5
	20	1.1	1.1	1.5	1.6	1.5	1.7	1.4	1.6	1.0	1.4	.55	.96
	30	.76	.80	1.1	1.2	.99	1.2	.63	.70	.52	.58	.43	.50
3	5	1.9	2.0	2.5	2.7	2.4	2.7	2.1	2.4	1.8	2.1	1.7	2.0
	10	1.4	1.5	1.9	2.1	1.9	2.2	1.7	2.0	1.6	1.8	1.4	1.8
	15	1.2	1.3	1.6	1.8	1.7	1.9	1.5	1.7	1.4	1.7	1.1	1.6
	20	1.1	1.1	1.5	1.6	1.5	1.7	1.4	1.6	1.1	1.5	.58	1.1
	30	.74	.79	1.1	1.2	1.0	1.2	.65	.72	.54	.61	.46	.52
4	5	1.8	1.9	2.4	2.7	2.3	2.7	2.0	2.4	1.8	2.2	1.7	2.0
	10	1.4	1.5	1.9	2.1	1.9	2.1	1.7	2.0	1.6	1.8	1.5	1.8
	15	1.1	1.2	1.6	1.8	1.6	1.8	1.5	1.7	1.4	1.7	1.1	1.6
	20	1.0	1.1	1.4	1.6	1.5	1.7	1.4	1.6	1.1	1.5	.59	1.1
	30	.72	.77	1.1	1.1	.95	1.2	.65	.72	.54	.61	.46	.53
5	5	1.7	1.8	2.3	2.6	2.3	2.6	2.0	2.4	1.8	2.2	1.7	2.0
	10	1.3	1.4	1.8	2.0	1.8	2.1	1.7	2.0	1.6	1.8	1.5	1.8
	15	1.1	1.2	1.6	1.7	1.6	1.8	1.5	1.7	1.4	1.7	1.1	1.6
	20	.98	1.1	1.4	1.5	1.5	1.6	1.4	1.6	1.1	1.5	.59	1.1
	30	.71	.75	1.0	1.1	.86	1.2	.64	.71	.54	.61	.46	.53
8	5	1.5	1.6	2.1	2.4	2.1	2.4	1.9	2.3	1.8	2.1	1.7	2.0
	10	1.2	1.3	1.7	1.9	1.7	2.0	1.6	1.9	1.6	1.8	1.4	1.8
	15	1.0	1.1	1.4	1.6	1.5	1.7	1.5	1.7	1.4	1.7	1.0	1.6
	20	.89	.98	1.3	1.5	1.4	1.6	1.3	1.6	.99	1.5	.58	1.0
	30	.66	.71	.95	1.1	.68	1.0	.60	.67	.52	.59	.46	.52
15	5	1.0	1.2	1.5	1.8	1.7	2.0	1.7	2.0	1.7	2.0	1.6	2.0
	10	.85	.96	1.3	1.4	1.4	1.6	1.5	1.7	1.4	1.7	1.3	1.7
	15	.74	.83	1.1	1.3	1.3	1.4	1.3	1.5	1.2	1.5	.84	1.5
	20	.67	.75	1.0	1.1	1.2	1.3	1.1	1.4	.65	1.3	.53	.74
	30	.43	.56	.49	.75	.53	.59	.51	.57	.46	.53	.42	.48
25	5	.65	.76	1.1	1.2	1.3	1.5	1.4	1.7	1.5	1.7	1.5	1.8
	10	.55	.63	.90	1.0	1.1	1.3	1.2	1.4	1.3	1.5	1.2	1.6
	15	.49	.56	.81	.93	1.0	1.2	1.1	1.3	1.0	1.4	.60	1.3
	20	.45	.51	.75	.86	.88	1.1	.78	1.2	.48	1.0	.46	.53
	30	.20	.23	.32	.36	.38	.42	.39	.44	.38	.43	.36	.42

Table 9.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 70 ft^2/acre (medium) and palmetto coverage is 50 percent (broken)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet) 1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet											
1	5	1.5	1.6	1.7	1.8	1.7	1.9	1.7	1.9	1.8	2.0	1.8	2.1
	10	1.3	1.3	1.4	1.5	1.5	1.6	1.5	1.7	1.5	1.8	1.2	1.8
	15	1.1	1.2	1.3	1.4	1.4	1.5	1.4	1.5	1.1	1.6	.68	1.2
	20	1.1	1.1	1.2	1.3	1.3	1.4	1.0	1.4	.69	.95	.66	.70
	30	.83	.90	.68	.97	.66	.69	.61	.64	.57	.60	.54	.57
2	5	1.8	1.9	2.0	2.2	2.1	2.2	2.1	2.2	2.1	2.3	2.2	2.4
	10	1.5	1.6	1.7	1.8	1.8	1.9	1.8	2.0	1.9	2.0	1.8	2.2
	15	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.7	1.9	1.2	1.9
	20	1.2	1.3	1.5	1.5	1.5	1.6	1.5	1.7	1.1	1.7	.83	1.0
	30	.99	1.0	1.1	1.2	.82	1.0	.77	.81	.72	.76	.68	.72
3	5	1.8	1.9	2.1	2.3	2.2	2.4	2.2	2.4	2.2	2.4	2.3	2.5
	10	1.5	1.6	1.8	1.9	1.9	2.0	1.9	2.1	2.0	2.1	2.0	2.3
	15	1.4	1.4	1.6	1.7	1.7	1.8	1.8	1.9	1.8	2.0	1.5	2.0
	20	1.3	1.3	1.5	1.6	1.6	1.7	1.6	1.8	1.3	1.8	.89	1.3
	30	1.0	1.1	1.2	1.3	.86	1.1	.82	.86	.77	.81	.73	.77
4	5	1.8	2.0	2.2	2.3	2.2	2.4	2.2	2.4	2.3	2.5	2.4	2.6
	10	1.5	1.6	1.8	2.0	1.9	2.1	2.0	2.1	2.0	2.2	2.0	2.3
	15	1.4	1.5	1.7	1.8	1.7	1.9	1.8	1.9	1.8	2.0	1.6	2.1
	20	1.3	1.4	1.6	1.6	1.7	1.8	1.7	1.8	1.4	1.9	.91	1.4
	30	1.0	1.1	1.2	1.3	.88	1.1	.84	.88	.79	.83	.75	.79
5	5	1.8	2.0	2.2	2.3	2.3	2.4	2.3	2.5	2.3	2.5	2.4	2.6
	10	1.5	1.6	1.8	2.0	1.9	2.1	2.0	2.1	2.1	2.2	2.1	2.4
	15	1.4	1.5	1.7	1.8	1.8	1.9	1.8	2.0	1.9	2.1	1.6	2.1
	20	1.3	1.4	1.6	1.7	1.7	1.8	1.7	1.9	1.4	1.9	.93	1.5
	30	1.0	1.1	1.1	1.3	.89	1.1	.85	.89	.80	.85	.76	.81
8	5	1.8	2.0	2.2	2.4	2.3	2.5	2.4	2.5	2.4	2.6	2.5	2.7
	10	1.6	1.7	1.9	2.0	2.0	2.1	2.1	2.2	2.1	2.3	2.2	2.4
	15	1.4	1.5	1.7	1.8	1.8	1.9	1.9	2.0	1.9	2.1	1.7	2.2
	20	1.3	1.4	1.6	1.7	1.7	1.8	1.8	1.9	1.4	2.0	.96	1.6
	30	1.0	1.1	1.0	1.3	.89	.96	.86	.91	.82	.87	.79	.84
15	5	1.7	1.9	2.2	2.3	2.3	2.5	2.4	2.6	2.5	2.7	2.6	2.9
	10	1.5	1.6	1.9	2.0	2.0	2.2	2.1	2.3	2.2	2.4	2.3	2.6
	15	1.4	1.4	1.7	1.8	1.9	2.0	2.0	2.1	2.0	2.3	1.7	2.3
	20	1.3	1.4	1.6	1.7	1.8	1.9	1.8	2.0	1.3	2.0	1.0	1.6
	30	.69	1.0	.85	1.1	.88	.93	.87	.92	.85	.90	.82	.87
25	5	1.5	1.7	2.1	2.2	2.3	2.5	2.5	2.7	2.6	2.9	2.8	3.0
	10	1.3	1.4	1.8	1.9	2.0	2.2	2.2	2.4	2.3	2.6	2.4	2.7
	15	1.2	1.3	1.7	1.8	1.9	2.0	2.0	2.2	2.0	2.4	1.8	2.4
	20	1.2	1.2	1.6	1.7	1.8	1.9	1.7	2.1	1.2	2.1	1.0	1.6
	30	.58	.60	.77	.81	.83	.88	.85	.90	.84	.89	.83	.88

Table 10.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 70 ft^2/acre (medium) and palmetto coverage is 50 percent (broken)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	- - - - - -	- - - -	- - - -	- - - -	- - - -	Feet/minute	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
1	5	1.3	1.5	1.8	2.1	1.8	2.1	1.6	1.9	1.5	1.8	1.3	1.7
	10	1.1	1.2	1.5	1.7	1.5	1.7	1.4	1.6	1.2	1.6	.82	1.4
	15	.92	1.0	1.3	1.5	1.4	1.5	1.2	1.5	.83	1.3	.46	.91
	20	.84	.92	1.2	1.3	1.2	1.4	.89	1.3	.51	.77	.44	.51
	30	.61	.69	.59	.91	.57	.64	.48	.54	.40	.46	.35	.40
2	5	1.5	1.7	2.1	2.4	2.2	2.5	2.0	2.3	1.8	2.1	1.7	2.0
	10	1.2	1.3	1.7	1.9	1.8	2.0	1.7	1.9	1.6	1.8	1.4	1.8
	15	1.0	1.1	1.5	1.7	1.6	1.8	1.5	1.7	1.3	1.7	.86	1.5
	20	.92	1.0	1.3	1.5	1.5	1.6	1.3	1.6	.81	1.4	.57	.75
	30	.68	.74	.92	1.1	.70	.91	.61	.68	.52	.59	.45	.51
3	5	1.5	1.7	2.1	2.4	2.2	2.6	2.1	2.4	1.9	2.2	1.8	2.1
	10	1.2	1.3	1.7	1.9	1.8	2.1	1.7	2.0	1.6	1.9	1.5	1.9
	15	1.0	1.1	1.5	1.7	1.6	1.8	1.6	1.8	1.4	1.7	1.1	1.6
	20	.92	1.0	1.4	1.5	1.5	1.7	1.4	1.7	1.0	1.5	.61	1.0
	30	.68	.74	.95	1.1	.72	1.0	.64	.71	.55	.62	.48	.55
4	5	1.5	1.6	2.1	2.4	2.2	2.6	2.1	2.4	1.9	2.3	1.8	2.2
	10	1.2	1.3	1.7	1.9	1.8	2.1	1.8	2.0	1.7	2.0	1.5	1.9
	15	1.0	1.1	1.5	1.7	1.6	1.8	1.6	1.8	1.5	1.8	1.1	1.7
	20	.90	.99	1.4	1.5	1.5	1.7	1.4	1.7	1.1	1.6	.63	1.1
	30	.67	.73	.93	1.1	.72	1.0	.65	.72	.56	.63	.49	.56
5	5	1.4	1.6	2.1	2.4	2.2	2.5	2.1	2.4	2.0	2.3	1.9	2.2
	10	1.1	1.3	1.7	1.9	1.8	2.1	1.8	2.0	1.7	2.0	1.6	1.9
	15	.98	1.1	1.5	1.7	1.6	1.8	1.6	1.8	1.5	1.8	1.2	1.7
	20	.88	.98	1.3	1.5	1.5	1.7	1.4	1.7	1.1	1.6	.63	1.1
	30	.66	.73	.90	1.1	.71	.96	.64	.72	.57	.64	.50	.57
8	5	1.3	1.5	2.0	2.3	2.1	2.4	2.1	2.4	2.0	2.3	1.9	2.2
	10	1.1	1.2	1.6	1.8	1.7	2.0	1.7	2.0	1.7	2.0	1.6	1.9
	15	.92	1.0	1.4	1.6	1.6	1.8	1.6	1.8	1.5	1.8	1.2	1.7
	20	.83	.93	1.3	1.4	1.4	1.6	1.4	1.7	1.1	1.6	.64	1.2
	30	.60	.69	.74	1.0	.67	.76	.63	.70	.56	.64	.50	.57
15	5	1.0	1.2	1.6	1.9	1.8	2.1	1.9	2.2	1.9	2.2	1.9	2.2
	10	.86	.98	1.3	1.5	1.5	1.8	1.6	1.9	1.6	1.9	1.6	1.9
	15	.75	.85	1.2	1.3	1.4	1.6	1.5	1.7	1.4	1.7	1.2	1.7
	20	.69	.78	1.1	1.2	1.3	1.5	1.3	1.6	.91	1.5	.63	1.1
	30	.34	.54	.51	.71	.57	.64	.57	.64	.53	.60	.49	.56
25	5	.73	.85	1.2	1.4	1.5	1.8	1.7	1.9	1.7	2.0	1.8	2.1
	10	.61	.70	1.0	1.2	1.3	1.5	1.4	1.7	1.5	1.8	1.5	1.8
	15	.54	.62	.92	1.1	1.2	1.3	1.3	1.5	1.3	1.6	1.1	1.6
	20	.50	.57	.85	.98	1.0	1.2	1.0	1.4	.69	1.4	.57	1.0
	30	.23	.25	.37	.42	.45	.50	.47	.53	.47	.53	.45	.51

Table 11.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 70 ft^2/acre (medium) and palmetto coverage is 85 percent (continuous)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet											
1	5	1.6	1.7	1.9	2.0	1.9	2.1	2.0	2.1	2.0	2.2	2.0	2.3
	10	1.3	1.4	1.6	1.7	1.7	1.8	1.7	1.9	1.7	2.0	1.4	2.0
	15	1.2	1.3	1.5	1.6	1.6	1.7	1.6	1.8	1.2	1.8	.77	1.4
	20	1.2	1.2	1.4	1.5	1.4	1.6	1.1	1.6	.78	1.1	.74	.79
	30	.63	.90	.72	.75	.71	.75	.68	.72	.64	.68	.61	.65
2	5	1.9	2.0	2.2	2.4	2.3	2.5	2.4	2.6	2.4	2.6	2.5	2.7
	10	1.6	1.7	1.9	2.0	2.0	2.2	2.1	2.2	2.2	2.3	2.1	2.4
	15	1.4	1.5	1.7	1.8	1.9	2.0	1.9	2.1	1.9	2.2	1.6	2.2
	20	1.3	1.4	1.6	1.7	1.8	1.9	1.8	2.0	1.3	1.9	.96	1.4
	30	1.0	1.1	.91	1.3	.90	.95	.87	.91	.82	.87	.78	.83
3	5	2.0	2.1	2.4	2.6	2.5	2.7	2.5	2.8	2.6	2.8	2.7	2.9
	10	1.7	1.8	2.0	2.2	2.2	2.3	2.2	2.4	2.3	2.5	2.3	2.6
	15	1.5	1.6	1.8	2.0	2.0	2.1	2.1	2.2	2.1	2.3	1.9	2.4
	20	1.4	1.5	1.7	1.8	1.9	2.0	1.9	2.1	1.7	2.1	1.0	1.8
	30	1.1	1.2	1.1	1.4	.98	1.1	.94	.99	.90	.95	.86	.91
4	5	2.0	2.2	2.5	2.7	2.6	2.8	2.7	2.9	2.7	2.9	2.8	3.0
	10	1.7	1.8	2.1	2.3	2.2	2.4	2.3	2.5	2.4	2.6	2.4	2.7
	15	1.5	1.6	1.9	2.0	2.1	2.2	2.1	2.3	2.2	2.4	2.1	2.5
	20	1.4	1.5	1.8	1.9	2.0	2.1	2.0	2.2	1.8	2.2	1.1	2.0
	30	1.1	1.2	1.2	1.5	1.0	1.3	.99	1.0	.94	1.0	.90	.96
5	5	2.1	2.2	2.5	2.7	2.7	2.9	2.7	2.9	2.8	3.0	2.9	3.1
	10	1.7	1.9	2.2	2.3	2.3	2.5	2.4	2.6	2.5	2.6	2.5	2.8
	15	1.6	1.7	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.5	2.2	2.5
	20	1.5	1.6	1.8	2.0	2.0	2.1	2.1	2.2	1.9	2.3	1.1	2.1
	30	1.1	1.3	1.2	1.5	1.0	1.3	1.0	1.1	.98	1.0	.93	.99
8	5	2.1	2.3	2.7	2.9	2.8	3.1	2.9	3.1	3.0	3.2	3.0	3.3
	10	1.8	1.9	2.3	2.4	2.4	2.6	2.5	2.7	2.6	2.8	2.7	2.9
	15	1.6	1.7	2.1	2.2	2.2	2.4	2.3	2.5	2.4	2.6	2.4	2.7
	20	1.5	1.6	1.9	2.1	2.1	2.2	2.2	2.4	2.1	2.5	1.4	2.4
	30	1.2	1.3	1.3	1.6	1.1	1.4	1.1	1.1	1.1	1.1	1.0	1.1
15	5	2.1	2.3	2.8	3.0	3.0	3.3	3.1	3.4	3.2	3.5	3.3	3.6
	10	1.8	1.9	2.4	2.5	2.6	2.8	2.7	2.9	2.9	3.1	3.0	3.2
	15	1.6	1.7	2.1	2.3	2.4	2.5	2.5	2.7	2.6	2.8	2.7	3.0
	20	1.5	1.6	2.0	2.1	2.3	2.4	2.4	2.6	2.3	2.7	1.9	2.7
	30	1.1	1.3	1.1	1.6	1.2	1.4	1.2	1.2	1.2	1.2	1.1	1.2
25	5	1.9	2.0	2.7	2.9	3.1	3.3	3.3	3.6	3.5	3.7	3.6	3.9
	10	1.6	1.7	2.3	2.5	2.7	2.9	2.9	3.1	3.0	3.3	3.2	3.4
	15	1.5	1.6	2.1	2.3	2.5	2.6	2.7	2.9	2.8	3.0	2.9	3.2
	20	1.4	1.5	2.0	2.1	2.3	2.5	2.5	2.7	2.5	2.9	2.2	2.9
	30	.74	1.1	1.1	1.5	1.2	1.2	1.2	1.3	1.2	1.3	1.2	1.3

Table 12.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 70 ft^2/acre (medium) and palmetto coverage is 85 percent (continuous)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	- - -	- - -	- - -	- - -	- - -	Feet/minute	- - -	- - -	- - -	- - -	- - -	- - -
	5	1.2	1.3	1.7	2.0	1.8	2.1	1.7	2.0	1.6	2.0	1.5	1.9
	10	.95	1.1	1.4	1.6	1.5	1.8	1.5	1.8	1.4	1.7	1.0	1.6
1	15	.84	.95	1.3	1.4	1.4	1.6	1.3	1.6	.93	1.5	.51	1.1
	20	.77	.86	1.2	1.3	1.2	1.5	.85	1.4	.56	.86	.49	.56
	30	.38	.58	.54	.60	.56	.63	.50	.57	.44	.50	.38	.44
	5	1.4	1.5	2.0	2.3	2.2	2.6	2.1	2.5	2.0	2.4	1.9	2.3
	10	1.1	1.2	1.7	1.9	1.8	2.1	1.8	2.1	1.7	2.0	1.6	2.0
2	15	.95	1.1	1.4	1.6	1.6	1.9	1.6	1.9	1.5	1.8	1.1	1.7
	20	.86	.96	1.3	1.5	1.5	1.7	1.4	1.7	.98	1.6	.65	1.1
	30	.60	.72	.67	1.0	.70	.78	.65	.73	.58	.65	.51	.58
	5	1.4	1.6	2.1	2.4	2.3	2.7	2.3	2.6	2.2	2.5	2.1	2.4
	10	1.1	1.3	1.7	2.0	1.9	2.2	1.9	2.2	1.9	2.2	1.8	2.1
3	15	.98	1.1	1.5	1.7	1.7	2.0	1.7	2.0	1.7	2.0	1.4	1.9
	20	.89	.98	1.4	1.5	1.6	1.8	1.6	1.8	1.3	1.8	.71	1.4
	30	.64	.74	.81	1.1	.75	.93	.70	.78	.63	.71	.56	.64
	5	1.4	1.6	2.2	2.5	2.4	2.8	2.3	2.7	2.2	2.6	2.1	2.5
	10	1.1	1.3	1.8	2.0	2.0	2.3	2.0	2.3	1.9	2.2	1.8	2.2
4	15	.98	1.1	1.5	1.7	1.8	2.0	1.8	2.0	1.7	2.0	1.5	2.0
	20	.89	.99	1.4	1.6	1.6	1.8	1.6	1.9	1.4	1.8	.75	1.6
	30	.64	.74	.85	1.1	.77	1.0	.73	.81	.66	.74	.59	.67
	5	1.4	1.6	2.2	2.5	2.4	2.8	2.4	2.8	2.3	2.7	2.2	2.6
	10	1.1	1.3	1.8	2.0	2.0	2.3	2.0	2.3	2.0	2.3	1.9	2.2
5	15	.98	1.1	1.5	1.7	1.8	2.0	1.8	2.1	1.8	2.1	1.6	2.0
	20	.89	.99	1.4	1.6	1.6	1.8	1.7	1.9	1.4	1.9	.78	1.6
	30	.64	.74	.86	1.2	.77	1.1	.74	.83	.68	.76	.61	.69
	5	1.4	1.6	2.2	2.5	2.4	2.8	2.5	2.9	2.4	2.8	2.3	2.7
	10	1.1	1.3	1.8	2.0	2.0	2.3	2.1	2.4	2.0	2.4	2.0	2.3
8	15	.97	1.1	1.5	1.7	1.8	2.0	1.9	2.1	1.8	2.1	1.7	2.1
	20	88	.98	1.4	1.6	1.6	1.9	1.7	2.0	1.6	2.0	.98	1.8
	30	.62	.73	.84	1.2	.78	1.1	.77	.85	.71	.80	.65	.73
	5	1.2	1.4	2.0	2.3	2.3	2.7	2.4	2.8	2.5	2.9	2.4	2.8
	10	.99	1.1	1.6	1.8	1.9	2.2	2.1	2.4	2.1	2.4	2.1	2.5
15	15	.86	.97	1.4	1.6	1.7	1.9	1.8	2.1	1.9	2.2	1.8	2.2
	20	.79	.88	1.3	1.5	1.6	1.8	1.7	2.0	1.6	2.0	1.2	2.0
	30	.50	.65	.63	1.0	.74	.95	.76	.85	.73	.82	.69	.78
	5	.93	1.1	1.6	1.9	2.0	2.4	2.2	2.6	2.4	2.8	2.4	2.8
	10	.76	.87	1.3	1.5	1.7	1.9	1.9	2.2	2.0	2.3	2.1	2.4
25	15	.67	.76	1.2	1.3	1.5	1.7	1.7	2.0	1.8	2.1	1.8	2.2
	20	.62	.69	1.1	1.2	1.4	1.6	1.6	1.8	1.6	1.9	1.3	2.0
	30	.30	.48	.51	.78	.64	.71	.69	.77	.69	.78	.68	.76

Table 13.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 110 ft^2/acre (high) and palmetto coverage is 15 percent (sparse)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet											
1	5	1.9	1.9	2.1	2.2	2.0	2.2	2.0	2.1	2.0	2.1	2.1	2.2
	10	1.5	1.5	1.7	1.8	1.7	1.8	1.7	1.8	1.8	1.9	1.8	2.0
	15	1.3	1.4	1.5	1.6	1.5	1.6	1.6	1.7	1.6	1.8	1.4	1.8
	20	1.2	1.3	1.4	1.5	1.4	1.5	1.5	1.6	1.3	1.6	.80	1.3
	30	.95	.97	1.1	1.1	1.1	1.2	.77	.80	.70	.74	.65	.69
2	5	2.1	2.2	2.4	2.5	2.4	2.6	2.4	2.6	2.4	2.5	2.4	2.6
	10	1.7	1.8	2.0	2.1	2.0	2.2	2.0	2.2	2.1	2.2	2.1	2.3
	15	1.5	1.6	1.8	1.8	1.8	1.9	1.8	2.0	1.9	2.0	1.9	2.2
	20	1.4	1.4	1.6	1.7	1.7	1.8	1.7	1.8	1.8	1.9	1.3	1.9
	30	1.1	1.1	1.3	1.3	1.4	1.4	.95	1.3	.88	.92	.82	.86
3	5	2.2	2.2	2.5	2.6	2.5	2.7	2.5	2.7	2.5	2.7	2.5	2.7
	10	1.8	1.8	2.1	2.2	2.1	2.2	2.1	2.3	2.1	2.3	2.2	2.4
	15	1.6	1.6	1.8	1.9	1.9	2.0	1.9	2.0	2.0	2.1	2.0	2.2
	20	1.4	1.5	1.7	1.8	1.8	1.9	1.8	1.9	1.8	2.0	1.5	2.0
	30	1.1	1.1	1.3	1.4	1.4	1.5	.99	1.4	.92	.97	.86	.91
4	5	2.2	2.2	2.5	2.6	2.6	2.7	2.5	2.7	2.5	2.7	2.6	2.8
	10	1.8	1.8	2.1	2.2	2.1	2.3	2.1	2.3	2.2	2.3	2.3	2.4
	15	1.6	1.6	1.8	1.9	1.9	2.0	1.9	2.1	2.0	2.2	2.0	2.3
	20	1.4	1.5	1.7	1.8	1.8	1.9	1.8	2.0	1.9	2.0	1.5	2.1
	30	1.1	1.2	1.4	1.4	1.4	1.5	1.0	1.4	.93	.98	.87	.92
5	5	2.1	2.2	2.5	2.6	2.5	2.7	2.5	2.7	2.5	2.7	2.6	2.8
	10	1.8	1.8	2.1	2.2	2.1	2.3	2.1	2.3	2.2	2.4	2.3	2.5
	15	1.6	1.6	1.8	1.9	1.9	2.0	2.0	2.1	2.0	2.2	2.1	2.3
	20	1.4	1.5	1.7	1.8	1.8	1.9	1.9	2.0	1.9	2.1	1.5	2.1
	30	1.1	1.2	1.4	1.4	1.4	1.5	1.0	1.4	.93	.98	.88	.93
8	5	2.1	2.2	2.5	2.6	2.5	2.7	2.5	2.7	2.5	2.8	2.6	2.8
	10	1.7	1.8	2.1	2.2	2.1	2.3	2.2	2.3	2.2	2.4	2.3	2.5
	15	1.5	1.6	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.1	2.3
	20	1.4	1.5	1.7	1.8	1.8	1.9	1.9	2.0	1.9	2.1	1.4	2.1
	30	1.1	1.2	1.4	1.4	1.3	1.5	.99	1.1	.93	.98	.88	.93
15	5	1.9	2.0	2.3	2.5	2.4	2.6	2.5	2.7	2.6	2.8	2.7	2.9
	10	1.6	1.7	1.9	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.6
	15	1.4	1.5	1.7	1.9	1.9	2.0	2.0	2.1	2.1	2.3	2.0	2.4
	20	1.3	1.4	1.6	1.7	1.8	1.9	1.9	2.0	1.8	2.1	1.1	2.0
	30	1.1	1.1	1.2	1.4	.96	1.3	.94	.99	.90	.95	.87	.92
25	5	1.6	1.7	2.1	2.2	2.3	2.5	2.4	2.7	2.6	2.8	2.7	2.9
	10	1.3	1.4	1.8	1.9	2.0	2.2	2.2	2.3	2.3	2.5	2.4	2.6
	15	1.2	1.3	1.6	1.8	1.9	2.0	2.0	2.2	2.1	2.3	1.9	2.4
	20	1.2	1.2	1.6	1.7	1.8	1.9	1.8	2.0	1.5	2.1	1.0	1.9
	30	.61	.90	.79	1.0	.85	.90	.86	.91	.85	.90	.83	.88

Table 14.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 110 ft^2/acre (high) and palmetto coverage is 15 percent (sparse)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet) 1 Summer	1 Winter	2 Summer	2 Winter	3 Summer	3 Winter	4 Summer	4 Winter	5 Summer	5 Winter	6 Summer	6 Winter
	Percent	Feet/minute											
1	5	2.1	2.3	2.7	3.0	2.5	2.8	2.1	2.4	1.8	2.1	1.7	2.0
	10	1.6	1.7	2.1	2.3	2.0	2.2	1.7	2.0	1.6	1.8	1.4	1.7
	15	1.3	1.4	1.8	1.9	1.7	1.9	1.5	1.7	1.4	1.6	1.0	1.5
	20	1.2	1.2	1.6	1.7	1.6	1.7	1.4	1.6	1.1	1.5	.57	1.0
	30	.81	.85	1.1	1.2	1.1	1.3	.66	.74	.54	.60	.45	.51
2	5	2.2	2.4	3.0	3.3	2.9	3.3	2.5	2.9	2.2	2.6	2.0	2.4
	10	1.7	1.8	2.3	2.5	2.3	2.6	2.0	2.3	1.9	2.1	1.7	2.0
	15	1.4	1.5	1.9	2.1	2.0	2.2	1.8	2.0	1.7	1.9	1.5	1.8
	20	1.2	1.3	1.7	1.9	1.8	2.0	1.7	1.9	1.5	1.8	.98	1.6
	30	.85	.88	1.2	1.3	1.3	1.5	.82	1.2	.68	.76	.57	.65
3	5	2.2	2.3	3.0	3.3	2.9	3.3	2.6	3.0	2.3	2.7	2.1	2.4
	10	1.6	1.7	2.3	2.5	2.3	2.6	2.1	2.4	1.9	2.2	1.8	2.1
	15	1.4	1.4	1.9	2.1	2.0	2.2	1.9	2.1	1.7	2.0	1.6	1.9
	20	1.2	1.3	1.7	1.9	1.8	2.0	1.7	1.9	1.6	1.8	1.1	1.7
	30	.83	.87	1.2	1.3	1.3	1.5	.84	1.3	.71	.79	.60	.68
4	5	2.1	2.2	2.9	3.2	2.9	3.3	2.6	3.0	2.3	2.7	2.1	2.5
	10	1.6	1.7	2.2	2.4	2.3	2.6	2.1	2.4	1.9	2.2	1.8	2.1
	15	1.3	1.4	1.9	2.1	2.0	2.2	1.9	2.1	1.7	2.0	1.6	1.9
	20	1.2	1.2	1.7	1.8	1.8	2.0	1.7	1.9	1.6	1.8	1.1	1.7
	30	.81	.86	1.2	1.3	1.3	1.5	.84	1.3	.71	.79	.61	.68
5	5	2.0	2.1	2.8	3.1	2.8	3.2	2.5	2.9	2.3	2.7	2.1	2.5
	10	1.5	1.6	2.2	2.4	2.2	2.5	2.1	2.4	1.9	2.2	1.8	2.1
	15	1.3	1.4	1.8	2.0	1.9	2.2	1.8	2.1	1.7	2.0	1.6	1.9
	20	1.1	1.2	1.6	1.8	1.8	1.9	1.7	1.9	1.6	1.8	1.1	1.7
	30	.79	.84	1.2	1.3	1.3	1.4	.82	1.2	.70	.79	.60	.68
8	5	1.7	1.9	2.5	2.8	2.6	2.9	2.4	2.8	2.2	2.6	2.1	2.4
	10	1.4	1.5	2.0	2.2	2.1	2.4	2.0	2.3	1.9	2.2	1.8	2.1
	15	1.2	1.3	1.7	1.9	1.8	2.0	1.8	2.0	1.7	2.0	1.6	1.9
	20	1.0	1.1	1.5	1.7	1.6	1.8	1.6	1.8	1.5	1.8	.98	1.7
	30	.74	.79	1.1	1.2	1.1	1.4	.77	.92	.68	.76	.59	.67
15	5	1.3	1.4	1.9	2.1	2.1	2.4	2.1	2.4	2.0	2.4	2.0	2.3
	10	1.0	1.1	1.5	1.7	1.7	2.0	1.7	2.0	1.7	2.0	1.7	2.0
	15	.87	.97	1.3	1.5	1.5	1.7	1.6	1.8	1.6	1.8	1.4	1.8
	20	.78	.87	1.2	1.3	1.4	1.6	1.4	1.7	1.3	1.7	.69	1.5
	30	.58	.64	.81	.99	.67	.99	.65	.72	.60	.67	.54	.62
25	5	.79	.91	1.3	1.5	1.6	1.8	1.7	2.0	1.7	2.1	1.8	2.1
	10	.65	.74	1.1	1.2	1.3	1.5	1.4	1.7	1.5	1.8	1.5	1.8
	15	.57	.65	.95	1.1	1.2	1.4	1.3	1.5	1.3	1.6	1.2	1.6
	20	.53	.59	.88	1.0	1.1	1.3	1.2	1.4	.95	1.4	.59	1.2
	30	.25	.41	.41	.56	.48	.53	.50	.56	.49	.95	.46	.53

Table 15.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 110 ft^2/acre (high) and palmetto coverage is 50 percent (broken)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	- - -	- - -	- - -	- - -	- - -	- - -	Feet	- - -	- - -	- - -	- - -	- - -
	5	1.8	1.9	2.0	2.2	2.1	2.2	2.1	2.2	2.1	2.3	2.2	2.4
	10	1.5	1.6	1.7	1.8	1.8	1.9	1.8	1.9	1.9	2.0	1.8	2.1
1	15	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.6	1.9	1.1	1.8
	20	1.2	1.3	1.4	1.5	1.5	1.6	1.5	1.7	1.0	1.6	.82	.93
	30	.99	1.0	1.1	1.2	.82	1.0	.77	.81	.71	.76	.67	.72
	5	2.1	2.2	2.4	2.6	2.5	2.7	2.5	2.7	2.5	2.7	2.6	2.8
	10	1.7	1.8	2.0	2.2	2.1	2.3	2.1	2.3	2.2	2.4	2.3	2.5
2	15	1.5	1.6	1.8	1.9	1.9	2.0	2.0	2.1	2.0	2.2	1.9	2.3
	20	1.4	1.5	1.7	1.8	1.8	1.9	1.9	2.0	1.8	2.1	1.0	1.9
	30	1.1	1.2	1.4	1.4	1.2	1.5	.96	1.0	.90	.95	.85	.90
	5	2.1	2.2	2.5	2.7	2.6	2.8	2.6	2.8	2.6	2.8	2.7	2.9
	10	1.8	1.9	2.1	2.2	2.2	2.4	2.2	2.4	2.3	2.5	2.4	2.6
3	15	1.6	1.7	1.9	2.0	2.0	2.1	2.1	2.2	2.1	2.3	2.1	2.4
	20	1.5	1.5	1.8	1.9	1.9	2.0	2.0	2.1	1.9	2.2	1.3	2.1
	30	1.2	1.2	1.4	1.5	1.3	1.6	1.0	1.1	.96	1.0	.90	.96
	5	2.1	2.3	2.6	2.7	2.7	2.9	2.7	2.9	2.7	2.9	2.7	3.0
	10	1.8	1.9	2.1	2.3	2.3	2.4	2.3	2.5	2.3	2.5	2.4	2.6
4	15	1.6	1.7	1.9	2.0	2.0	2.2	2.1	2.2	2.2	2.3	2.2	2.4
	20	1.5	1.6	1.8	1.9	1.9	2.0	2.0	2.1	2.0	2.2	1.4	2.2
	30	1.2	1.2	1.4	1.5	1.3	1.6	1.0	1.1	.98	1.0	.92	.98
	5	2.1	2.3	2.6	2.7	2.7	2.9	2.7	2.9	2.7	2.9	2.8	3.0
	10	1.8	1.9	2.2	2.3	2.3	2.4	2.3	2.5	2.4	2.6	2.5	2.7
5	15	1.6	1.7	1.9	2.1	2.1	2.2	2.1	2.3	2.2	2.4	2.2	2.5
	20	1.5	1.6	1.8	1.9	1.9	2.1	2.0	2.1	2.0	2.2	1.5	2.2
	30	1.2	1.2	1.5	1.5	1.3	1.6	1.0	1.1	.99	1.0	.94	.99
	5	2.1	2.3	2.6	2.8	2.7	2.9	2.7	3.0	2.8	3.0	2.9	3.1
	10	1.8	1.9	2.2	2.3	2.3	2.5	2.4	2.5	2.4	2.6	2.5	2.7
8	15	1.6	1.7	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.3	2.6
	20	1.5	1.6	1.9	2.0	2.0	2.1	2.1	2.2	2.0	2.3	1.5	2.3
	30	1.2	1.3	1.4	1.6	1.1	1.6	1.1	1.1	1.0	1.1	.96	1.0
	5	2.0	2.1	2.5	2.7	2.7	2.9	2.8	3.0	2.9	3.1	3.0	3.2
	10	1.7	1.8	2.1	2.3	2.3	2.5	2.4	2.6	2.5	2.7	2.6	2.9
15	15	1.5	1.6	1.9	2.1	2.1	2.3	2.3	2.4	2.3	2.5	2.3	2.7
	20	1.4	1.5	1.8	1.9	2.0	2.1	2.1	2.3	2.0	2.4	1.4	2.3
	30	1.1	1.2	1.1	1.5	1.1	1.3	1.0	1.1	1.0	1.1	.98	1.0
	5	1.7	1.8	2.3	2.5	2.6	2.9	2.8	3.0	2.9	3.2	3.1	3.3
	10	1.5	1.6	2.0	2.2	2.3	2.5	2.5	2.7	2.6	2.8	2.7	3.0
25	15	1.3	1.4	1.9	2.0	2.1	2.3	2.3	2.5	2.4	2.6	2.4	2.8
	20	1.3	1.3	1.8	1.9	2.0	2.2	2.1	2.3	2.0	2.4	1.2	2.4
	30	.66	.97	.90	1.1	.98	1.0	1.0	1.1	1.0	1.1	.98	1.0

Table 16.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 110 ft^2/acre (high) and palmetto coverage is 50 percent (broken)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet/minute											
1	5	1.6	1.8	2.2	2.5	2.2	2.6	2.0	2.3	1.8	2.1	1.7	2.0
	10	1.3	1.4	1.8	2.0	1.8	2.1	1.7	1.9	1.6	1.8	1.4	1.8
	15	1.1	1.2	1.5	1.7	1.6	1.8	1.5	1.7	1.3	1.7	.82	1.5
	20	.96	1.1	1.4	1.5	1.5	1.7	1.4	1.6	.79	1.4	.57	.70
	30	.71	.77	.98	1.1	.72	.97	.62	.69	.52	.59	.45	.51
2	5	1.8	1.9	2.5	2.8	2.6	3.0	2.4	2.8	2.2	2.6	2.1	2.4
	10	1.4	1.5	2.0	2.2	2.1	2.4	2.0	2.3	1.9	2.2	1.8	2.1
	15	1.2	1.3	1.7	1.9	1.9	2.1	1.8	2.0	1.7	2.0	1.5	1.9
	20	1.0	1.1	1.6	1.7	1.7	1.9	1.7	1.9	1.5	1.8	.74	1.6
	30	.76	.82	1.2	1.3	1.0	1.4	.77	.86	.67	.75	.58	.65
3	5	1.8	1.9	2.6	2.9	2.7	3.1	2.5	2.9	2.3	2.7	2.2	2.5
	10	1.4	1.5	2.0	2.3	2.2	2.5	2.1	2.4	2.0	2.3	1.9	2.2
	15	1.2	1.3	1.7	1.9	1.9	2.2	1.9	2.1	1.8	2.0	1.6	2.0
	20	1.0	1.1	1.6	1.7	1.7	1.9	1.7	1.9	1.6	1.9	.97	1.7
	30	.76	.82	1.2	1.3	1.1	1.4	.81	.89	.71	.79	.61	.70
4	5	1.7	1.9	2.5	2.8	2.7	3.1	2.5	2.9	2.3	2.7	2.2	2.6
	10	1.3	1.5	2.0	2.3	2.2	2.5	2.1	2.4	2.0	2.3	1.9	2.2
	15	1.1	1.3	1.7	1.9	1.9	2.1	1.9	2.1	1.8	2.1	1.6	2.0
	20	1.0	1.1	1.6	1.7	1.7	1.9	1.7	2.0	1.6	1.9	1.0	1.7
	30	.75	.81	1.2	1.3	1.1	1.4	.81	.90	.72	.80	.63	.71
5	5	1.7	1.9	2.5	2.8	2.7	3.0	2.5	2.9	2.4	2.7	2.2	2.6
	10	1.3	1.5	2.0	2.2	2.2	2.5	2.1	2.4	2.0	2.3	1.9	2.2
	15	1.1	1.2	1.7	1.9	1.9	2.1	1.9	2.1	1.8	2.1	1.7	2.0
	20	1.0	1.1	1.5	1.7	1.7	1.9	1.7	2.0	1.6	1.9	1.1	1.8
	30	.74	.80	1.1	1.3	1.0	1.4	.81	.89	.72	.80	.63	.71
8	5	1.5	1.7	2.3	2.7	2.5	2.9	2.5	2.9	2.3	2.7	2.2	2.6
	10	1.2	1.4	1.9	2.1	2.1	2.3	2.1	2.4	2.0	2.3	1.9	2.3
	15	1.0	1.2	1.6	1.8	1.8	2.0	1.8	2.1	1.8	2.1	1.7	2.0
	20	.94	1.0	1.5	1.6	1.7	1.9	1.7	1.9	1.6	1.9	1.1	1.8
	30	.70	.77	1.1	1.2	.82	1.3	.78	.87	.71	.79	.63	.72
15	5	1.2	1.4	1.9	2.2	2.2	2.5	2.2	2.6	2.2	2.6	2.2	2.6
	10	.98	1.1	1.5	1.8	1.8	2.1	1.9	2.2	1.9	2.2	1.9	2.2
	15	.86	.96	1.4	1.5	1.6	1.8	1.7	1.9	1.7	2.0	1.6	2.0
	20	.78	.87	1.2	1.4	1.5	1.7	1.6	1.8	1.4	1.8	.92	1.7
	30	.54	.65	.70	1.0	.70	.94	.70	.78	.66	.74	.61	.69
25	5	.84	.97	1.4	1.6	1.7	2.0	1.9	2.2	2.0	2.3	2.0	2.4
	10	.69	.80	1.2	1.4	1.5	1.7	1.6	1.9	1.7	2.0	1.8	2.1
	15	.61	.70	1.0	1.2	1.3	1.5	1.5	1.7	1.5	1.8	1.5	1.9
	20	.57	.63	.97	1.1	1.2	1.4	1.3	1.6	1.2	1.7	.71	1.6
	30	.27	.42	.45	.61	.54	.60	.57	.64	.57	.64	.55	.62

Table 17.--Predicted flame lengths in palmetto-gallberry fuel type where overstory density is 110 ft^2/acre (high) and palmetto coverage is 85 percent (continuous)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet											
1	5	1.8	1.9	2.2	2.3	2.3	2.4	2.3	2.5	2.3	2.5	2.4	2.6
	10	1.5	1.6	1.8	2.0	1.9	2.1	2.0	2.2	2.1	2.2	2.0	2.3
	15	1.4	1.5	1.7	1.8	1.8	1.9	1.8	2.0	1.8	2.1	1.3	2.0
	20	1.3	1.4	1.6	1.7	1.7	1.8	1.6	1.9	1.0	1.8	.91	1.1
	30	.97	1.1	.86	1.2	.87	.91	.83	.87	.78	.83	.74	.79
2	5	2.1	2.3	2.6	2.8	2.7	2.9	2.8	3.0	2.8	3.0	2.9	3.1
	10	1.8	1.9	2.2	2.3	2.3	2.5	2.4	2.6	2.4	2.6	2.5	2.7
	15	1.6	1.7	2.0	2.1	2.1	2.3	2.2	2.3	2.3	2.4	2.2	2.5
	20	1.5	1.6	1.9	2.0	2.0	2.1	2.1	2.2	2.0	2.3	1.3	2.2
	30	1.2	1.3	1.4	1.6	1.1	1.6	1.0	1.1	1.0	1.1	.95	1.0
3	5	2.2	2.4	2.8	2.9	2.9	3.1	2.9	3.2	3.0	3.2	3.0	3.3
	10	1.9	2.0	2.3	2.5	2.5	2.7	2.5	2.7	2.6	2.8	2.7	2.9
	15	1.7	1.8	2.1	2.2	2.3	2.4	2.3	2.5	2.4	2.6	2.4	2.7
	20	1.6	1.7	2.0	2.1	2.1	2.3	2.2	2.4	2.2	2.4	1.7	2.4
	30	1.3	1.3	1.5	1.7	1.2	1.7	1.1	1.2	1.1	1.1	1.0	1.1
4	5	2.3	2.4	2.8	3.0	3.0	3.2	3.0	3.3	3.1	3.3	3.1	3.4
	10	1.9	2.0	2.4	2.5	2.6	2.7	2.6	2.8	2.7	2.9	2.8	3.0
	15	1.7	1.8	2.2	2.3	2.3	2.5	2.4	2.6	2.5	2.7	2.5	2.8
	20	1.6	1.7	2.0	2.1	2.2	2.3	2.3	2.4	2.3	2.5	1.9	2.5
	30	1.3	1.4	1.6	1.7	1.3	1.8	1.2	1.2	1.1	1.2	1.1	1.1
5	5	2.3	2.4	2.9	3.1	3.1	3.3	3.1	3.4	3.1	3.4	3.2	3.5
	10	1.9	2.1	2.4	2.6	2.6	2.8	2.7	2.9	2.7	3.0	2.8	3.1
	15	1.7	1.8	2.2	2.3	2.4	2.5	2.5	2.6	2.5	2.7	2.6	2.8
	20	1.6	1.7	2.1	2.2	2.2	2.4	2.3	2.5	2.4	2.6	2.0	2.6
	30	1.3	1.4	1.6	1.8	1.3	1.8	1.2	1.3	1.2	1.2	1.1	1.2
8	5	2.3	2.5	3.0	3.2	3.2	3.4	3.3	3.5	3.3	3.6	3.4	3.7
	10	2.0	2.1	2.5	2.7	2.7	2.9	2.8	3.0	2.9	3.1	3.0	3.2
	15	1.8	1.9	2.3	2.4	2.5	2.6	2.6	2.8	2.7	2.9	2.7	3.0
	20	1.7	1.7	2.1	2.3	2.3	2.5	2.5	2.6	2.5	2.7	2.3	2.8
	30	1.3	1.4	1.7	1.8	1.4	1.9	1.3	1.4	1.2	1.3	1.2	1.2
15	5	2.3	2.5	3.1	3.3	3.3	3.6	3.5	3.8	3.6	3.9	3.7	4.0
	10	1.9	2.1	2.6	2.8	2.9	3.1	3.0	3.2	3.1	3.4	3.2	3.5
	15	1.7	1.9	2.3	2.5	2.6	2.8	2.8	3.0	2.9	3.1	3.0	3.2
	20	1.6	1.7	2.2	2.3	2.5	2.6	2.6	2.8	2.7	2.9	2.5	3.0
	30	1.3	1.4	1.6	1.9	1.3	1.9	1.3	1.4	1.3	1.4	1.3	1.4
25	5	2.0	2.2	3.0	3.2	3.4	3.6	3.6	3.9	3.8	4.1	3.9	4.2
	10	1.7	1.8	2.5	2.7	2.9	3.1	3.1	3.4	3.3	3.5	3.4	3.7
	15	1.6	1.7	2.3	2.5	2.7	2.8	2.9	3.1	3.1	3.3	3.2	3.4
	20	1.5	1.6	2.2	2.3	2.5	2.7	2.7	2.9	2.8	3.1	2.7	3.2
	30	1.0	1.2	1.2	1.8	1.3	1.8	1.4	1.4	1.4	1.4	1.4	1.4

Table 18.--Predicted rate of spread in palmetto-gallberry fuel type where overstory density is 110 ft^2/acre (high) and palmetto coverage is 85 percent (continuous)

Age of rough (years)	Dead-fuel moisture	Height of understory (feet)											
		1		2		3		4		5		6	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
	Percent	Feet/minute											
1	5	1.4	1.5	2.0	2.3	2.2	2.5	2.1	2.4	1.9	2.3	1.8	2.2
	10	1.1	1.2	1.6	1.9	1.8	2.1	1.8	2.0	1.7	2.0	1.5	1.9
	15	.95	1.1	1.4	1.6	1.6	1.8	1.6	1.8	1.4	1.8	.92	1.6
	20	.87	.96	1.3	1.5	1.5	1.7	1.4	1.7	.76	1.5	.61	.79
	30	.59	.72	.65	1.0	.69	.76	.63	.70	.55	.62	.48	.55
2	5	1.6	1.8	2.4	2.7	2.6	3.0	2.5	2.9	2.4	2.8	2.3	2.6
	10	1.2	1.4	1.9	2.2	2.1	2.4	2.1	2.4	2.0	2.3	1.9	2.3
	15	1.1	1.2	1.7	1.9	1.9	2.1	1.9	2.2	1.8	2.1	1.6	2.1
	20	.97	1.1	1.5	1.7	1.7	1.9	1.7	2.0	1.6	1.9	.90	1.7
	30	.72	.79	1.1	1.2	.85	1.3	.80	.88	.71	.80	.63	.72
3	5	1.6	1.8	2.5	2.8	2.7	3.2	2.7	3.1	2.5	3.0	2.4	2.8
	10	1.3	1.4	2.0	2.2	2.2	2.6	2.2	2.6	2.2	2.5	2.1	2.4
	15	1.1	1.2	1.7	1.9	2.0	2.2	2.0	2.3	1.9	2.2	1.8	2.2
	20	.99	1.1	1.6	1.7	1.8	2.0	1.8	2.1	1.7	2.1	1.2	1.9
	30	.74	.80	1.1	1.3	.93	1.4	.85	.94	.77	.86	.69	.78
4	5	1.6	1.8	2.5	2.8	2.8	3.2	2.7	3.2	2.6	3.0	2.5	2.9
	10	1.3	1.4	2.0	2.3	2.3	2.6	2.3	2.6	2.2	2.6	2.1	2.5
	15	1.1	1.2	1.7	1.9	2.0	2.3	2.0	2.3	2.0	2.3	1.9	2.3
	20	.99	1.1	1.6	1.7	1.8	2.0	1.9	2.1	1.8	2.1	1.4	2.0
	30	.74	.80	1.1	1.3	.99	1.5	.87	.97	.80	.89	.72	.81
5	5	1.6	1.8	2.5	2.8	2.8	3.2	2.8	3.2	2.7	3.1	2.5	3.0
	10	1.3	1.4	2.0	2.3	2.3	2.6	2.3	2.7	2.3	2.6	2.2	2.5
	15	1.1	1.2	1.7	1.9	2.0	2.3	2.1	2.3	2.0	2.3	1.9	2.3
	20	.98	1.1	1.6	1.7	1.8	2.1	1.9	2.1	1.8	2.2	1.5	2.1
	30	.73	.80	1.1	1.3	1.0	1.5	.89	.98	.82	.91	.74	.83
8	5	1.5	1.7	2.5	2.8	2.8	3.2	2.8	3.3	2.7	3.2	2.6	3.1
	10	1.2	1.4	2.0	2.2	2.3	2.6	2.3	2.7	2.3	2.7	2.3	2.6
	15	1.1	1.2	1.7	1.9	2.0	2.3	2.1	2.4	2.1	2.4	2.0	2.4
	20	.96	1.1	1.6	1.7	1.8	2.1	1.9	2.2	1.9	2.2	1.6	2.2
	30	.71	.79	1.1	1.3	.97	1.5	.90	1.0	.85	.95	.77	.87
15	5	1.3	1.5	2.2	2.5	2.6	3.0	2.8	3.2	2.8	3.2	2.7	3.2
	10	1.1	1.2	1.8	2.0	2.1	2.5	2.3	2.6	2.3	2.7	2.3	2.7
	15	.94	1.1	1.6	1.8	1.9	2.1	2.0	2.3	2.1	2.4	2.1	2.5
	20	.85	.95	1.4	1.6	1.7	1.9	1.9	2.1	1.9	2.2	1.7	2.2
	30	.61	.71	.93	1.2	.84	1.3	.88	.97	.85	.95	.80	.90
25	5	1.0	1.2	1.8	2.1	2.3	2.6	2.5	2.9	2.6	3.1	2.7	3.1
	10	.83	.95	1.5	1.7	1.9	2.1	2.1	2.4	2.2	2.6	2.3	2.6
	15	.73	.82	1.3	1.5	1.7	1.9	1.9	2.1	2.0	2.3	2.1	2.4
	20	.66	.74	1.2	1.3	1.5	1.7	1.7	2.0	1.8	2.1	1.7	2.2
	30	.42	.55	.62	.95	.72	1.1	.78	.87	.79	.89	.77	.87

Table 19.--Wind-effect category for low overstory stand density (basal area = 30 ft^2/acre)

Age of rough (year)	Visual height of understory (feet)					
	1	2	3	4	5	6
Palmetto coverage sparse (15 percent)						
1	B	A	A	A		
2	C	A	A	A	A	
3	C	A	A	A	A	B
5	C	B	A	A	B	B
8		B	B	B	B	B
15			B	B	B	B
25			C	C	C	C
Palmetto coverage broken (50 percent)						
1	C	A	A	A		
2	C	B	A	A	B	
3	C	B	B	B	B	B
5	C	B	B	B	B	B
8		C	B	B	B	B
15			C	B	B	B
25			C	C	C	C
Palmetto coverage continuous (85 percent)						
1	C	B	B	B		
2	D	B	B	B	B	
3	D	C	B	B	B	B
5	D	C	B	B	B	B
8		C	C	B	B	B
15			C	C	C	C
25			D	C	C	C

Table 20.--Wind-effect category for medium overstory stand density (basal area = 70 ft^2/acre)

Age of rough (year)	Visual height of understory (feet)					
	1	2	3	4	5	6
Palmetto coverage sparse (15 percent)						
1	C	A	A	A		
2	C	B	A	A	B	
3	C	B	B	A	B	B
5	C	B	B	B	B	B
8		B	B	B	B	B
15			C	B	B	B
25			C	C	C	C
Palmetto coverage broken (50 percent)						
1	C	B	A	A		
2	C	B	B	B	B	
3	D	B	B	B	B	B
5	D	C	B	B	B	B
8		C	B	B	B	B
15			C	C	C	C
25			D	C	C	C
Palmetto coverage continuous (85 percent)						
1	C	B	B	B		
2	D	C	B	B	B	
3	D	C	B	B	B	B
5	D	C	C	B	B	B
8		C	C	C	B	B
15			C	C	C	C
25			D	D	C	C

Table 21.--Wind-effect category for high overstory stand density (basal area = 110 ft^2/acre)

Age of rough (year)	Visual height of understory (feet)					
	1	2	3	4	5	6
Palmetto coverage sparse (15 percent)						
1	C	B	A	A		
2	C	B	B	B	B	
3	D	B	B	B	B	B
5	D	C	B	B	B	B
8		C	B	B	B	B
15			C	B	B	B
25			C	C	C	C
Palmetto coverage broken (50 percent)						
1	C	B	B	A		
2	D	C	B	B	B	
3	D	C	B	B	B	B
5	D	C	B	B	B	B
8		C	C	B	B	B
15			C	C	C	C
25			D	C	C	C
Palmetto coverage continuous (85 percent)						
1	D	C	B	B		
2	D	C	B	B	B	
3	D	C	C	B	B	B
5	D	C	C	B	B	B
8		D	C	C	C	C
15			C	C	C	C
25			D	D	C	C

PART II: RESEARCH DOCUMENTATION

APPROACH AND PROCEDURES

Rothermel's (1972) rate-of-spread model [with minor revisions (Albini 1976a)] and several other mathematical models of fire behavior and effects are stored permanently at the Lawrence Berkeley Laboratories computer center, University of California, Berkeley. Variables needed for input to the rate-of-spread model include:

1. Loadings by size class of live- and dead-fuel components (dry weight, lb/ft^2)
2. Moisture contents of these components (fraction of dry weight)
3. Surface area/volume ratios (ft^{-1})
4. Heat of combustion (Btu/lb)
5. Mass density (lb/ft^3)
6. Ash fraction (fraction of dry weight)
7. Silica-free ash content (fraction of dry weight)
8. Depth of the fuel bed (ft)
9. Midflame windspeed (ft/min)
10. Slope of the terrain (ft vertical rise/ft horizontal)
11. Moisture content of extinction (fraction of dry weight).

Fuel data were collected for individual species or major groups of similar species (such as miscellaneous shrubs) for use with the Rothermel fire-spread model. Since the model does not accept negative windspeeds (backfires), a windspeed of zero was assumed for backfires. Model predictions were then compared with backfire rates of spread and flame lengths, and adjustments were made in input characteristics until close agreement was reached between predicted and observed spread rates and flame lengths. Once comparable predicted and observed values were obtained, the fuel data were summarized into general categories and size classes so that values for each individual species would not have to be used. These "standard" values were reentered in the spread model to see if predicted and actual rates of spread and flame length still agreed closely.

Fuel Sampling

Limited data for the palmetto-gallberry fuel complex were first entered in the rate-of-spread model in 1970.[7] Values for various species were developed from samples of material collected on plots having different ages of rough (Sackett 1975). In this trial, the Rothermel spread model grossly underestimated rate of spread. Since then, data from many more sample plots have been

[7] Data on file at the Southern Forest Fire Laboratory, Macon, Ga.

collected, and the needed fuel characteristics have been measured more precisely under a wide variety of palmetto-gallberry fuel conditions. Field sampling procedures and general characteristics of the sampled stands were described, and equations to predict the loading by size class for each main fuel category were developed by McNab and others.[8]

Ratios of surface area to volume (S/V) were determined on photomicrographs of cross sections of material that could not be idealized as a flat plate or cylinder. In these cases, a factor was established relating particle size (inches) to S/V (in^2/in^3) as measured on the photomicrographs. For particles with approximate idealized shapes, a factor was assumed (table 22). Then only diameter or thickness was measured at the midpoint of a sample of particles, averaged, and S/V (ft^2/ft^3) calculated as follows:

$$S/V = \frac{F \times 12}{t} \text{ where } F = \text{shape factor and } t = \text{particle size in inches.}$$

Table 22.--Factors used in calculating S/V ratio (ft^{-1}) from measurements of particle thickness or diameter (in), where $S/V = \frac{\text{factor} \times 12}{\text{thickness or diameter}}$

Species, condition, and size class	Factor	Standard deviation
Nonidealized shapes:		
Live slash pine needles (crowns)	3.607	± 0.26
Dead slash pine needles (litter)	4.064	± 0.49
Live and dead palmetto stems 0-¼"	3.758	± 0.20
Live and dead palmetto stems ¼-1"	3.918	± 0.18
Live and dead wiregrass foliage	3.620	± 0.57
Idealized flat plates:		
Live and dead palmetto foliage	2.0	
Live and dead gallberry foliage	2.0	
Live and dead misc. shrub foliage	2.0	
Live and dead herbaceous foliage (forbs and wide-bladed grasses)	2.0	
Idealized cylinders:		
Live and dead gallberry stems	4.0	
Live and dead herbaceous stems (flower stalks)	4.0	
Live and dead misc. shrub stems	4.0	

Particle density was determined by weighing a fuel sample submerged in a tank of water and dividing the sample dry weight by the submerged weight. Total mineral content[9] was obtained in a muffle furnace (Hough 1969). Silica content[9] was determined by acid digestion of the other inorganics, and "effective" mineral content was calculated by subtracting silica content from total mineral content. Heat value[9] was determined in an oxygen bomb calorimeter (Hough 1969).

[8] McNab, W. H., M. B. Edwards, Jr., and W. A. Hough. Estimating weight of fuel components in slash pine/saw-palmetto/gallberry stands. (In preparation for For. Sci.)

[9] Total mineral, silica, and heat content for many fuel samples were measured through work contracted to the Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Ga.

Eleven of the plots having completely documented samples of fuel were burned with prescription backfires. The length of active fireline varied from 650 to 2,500 feet, and the fires burned for 30 to 60 minutes. On plots where burns were observed, windspeeds in the stand were measured during the fire, and moisture contents of the different fuel size classes and types were measured immediately before the fire. Rate of fire spread, flame length, fuel consumption, and smoke production were also estimated as precisely as possible on these burns.

Data Handling

The first step in developing the dynamic fuel model was to establish proper values for the fuel-bed descriptors, which were poorly defined by contemporary measurement techniques. Descriptors included (1) moisture of extinction, (2) fuel-bed depth, and (3) amount of litter layer to include in the fuel model. To establish these parameters, Rothermel's rate-of-spread model was repeatedly applied on the most complete data available--11 test fire plots on which fuel characteristics, spread rate, and flame-length measurements were well documented. The ill-defined quantities were varied systematically over a representative range, and values for these quantities were selected which gave the most faithful predictions of experimental fire behavior. The computations were carried out from the remote-user facility at the Northern Forest Fire Laboratory in Missoula, Montana.

Moisture of extinction.--With this variable, we were guided by laboratory tests (Blackmarr 1972) and by the many years of prescribed burning experience of our staff at the Southern Forest Fire Laboratory. Blackmarr's ignition tests, as well as full-scale test burns, indicated that fire would spread poorly, if at all, in Southern pine needle litter when moisture content of the needles exceeded 45 percent. In a series of test fires in needle litter fuel beds, the model best predicted rate of spread when extinction moisture was entered at 40 percent. If values greater than 40 percent were entered, the predicted spread rate in low-moisture fuels was greater than the observed value; if a lesser value of moisture of extinction was used, the predicted rate of spread was generally less than the observed. This exercise in "variable tuning" emphasized a deficiency in current modeling capability--namely, that the specification of such a sensitive parameter should not remain an "input variable" because there are no simple ways for field personnel to measure or sample this variable. It should be determined by other physical descriptors of the fuel complex. Research is currently in progress at the Northern Forest Fire Laboratory to establish the relevant relationships.

Death of the fuel bed.--This descriptor is deceptively simple for a mixed fuel complex. For nearly uniform natural fuel beds, such as grass fields or continuous brush stands, the depth of the modeled fuel bed is the height of the standing vegetation. Palmetto-gallberry and other mixed fuel associations vary considerably in height on any specific site. The proper value to enter for such beds is the depth of an equivalent fuel bed, loaded with the same average quantities of fuel elements, which would burn with the same rate of spread and intensity as the average for the irregular fuel bed. The relation between this depth and observed average depth of the mixed fuel complex being burned is not necessarily obvious. By a series of systematic trials, it was determined that a value of two-thirds of the visual understory fuel-bed depth gave the most consistent agreement between observed and predicted rate of spread values and flame lengths. In these trials, the moisture of extinction was held at 40 percent. Litter load was varied in these repetitive trials, because height and forest floor loading effects could not be entirely separated. By this process, two-thirds of visual height was chosen as the equivalent fuel-bed depth.

The mathematical model also required the input of only that amount of forest floor fuel (litter and duff) that will be consumed at the head of a spreading fire. This value is much easier to understand than to estimate. What is needed is the quantity of forest floor fuel which is actively involved in the spread of the fire. Experience and laboratory measurements imply that only the litter layer (not the fermentation or humus horizon) is actually consumed at the head of a free-burning fire. This estimate was upheld by repetitive trials of the spread model varying total duff loading in the fuel model. Moisture of extinction was held constant at 40 percent, and the two-thirds factor for fuel-bed depth was used. In this case, the model prediction of flame length was more sensitive to total duff loading than was spread rate. Weight of the litter layer proved the most reasonable approximation for the component of the forest floor involved in the propagation of a fire in this fuel complex and gave acceptable predictions of flame length (fig. 4).

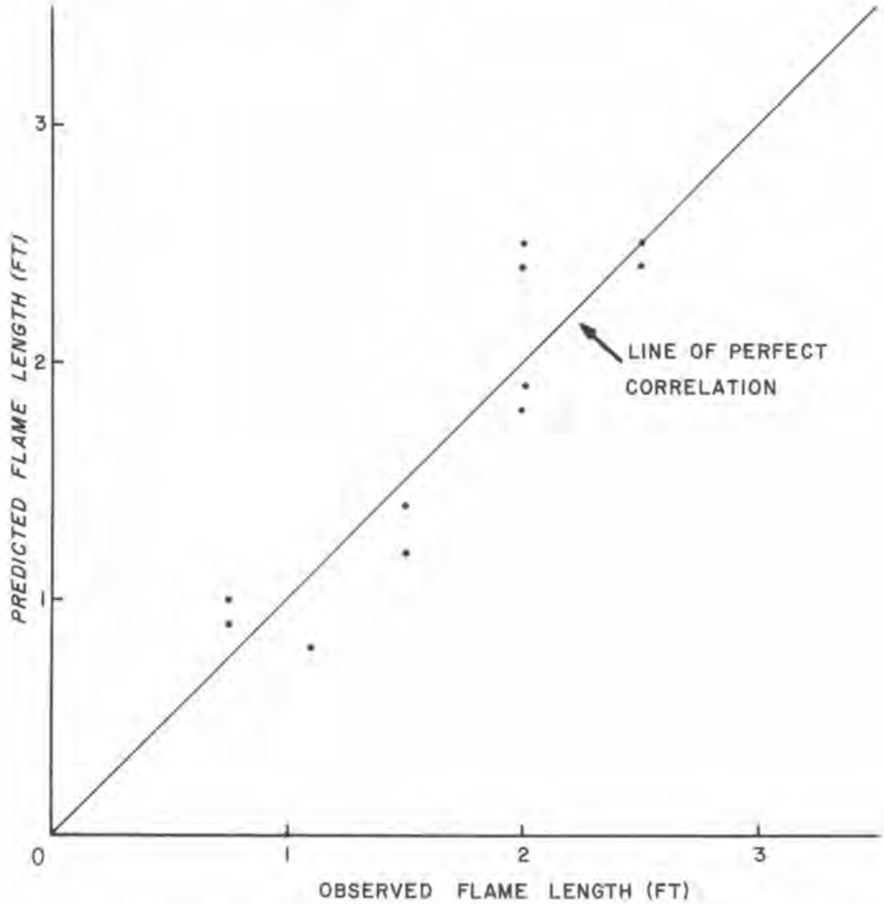

Figure 4.--Observed flame lengths for palmetto-gallberry backfires compared with predictions using weight of litter to represent the component of total forest floor involved in the fire front.

For predicting rates of spread of backfires, a windspeed of zero was entered in the model. There is ample evidence (Beaufait 1965; Hough 1968; Thomas 1971; Van Wagner 1968; Anderson and others 1966) that wind has little effect on the rate of spread of backfires. Figure 5 compares predicted (zero windspeed) and observed rates of spread for the 11 field plots with the most complete data. The dependence upon windspeed of the rate of spread and flame length in the palmetto-gallberry type was derived from the basic spread model, as described in a later section.

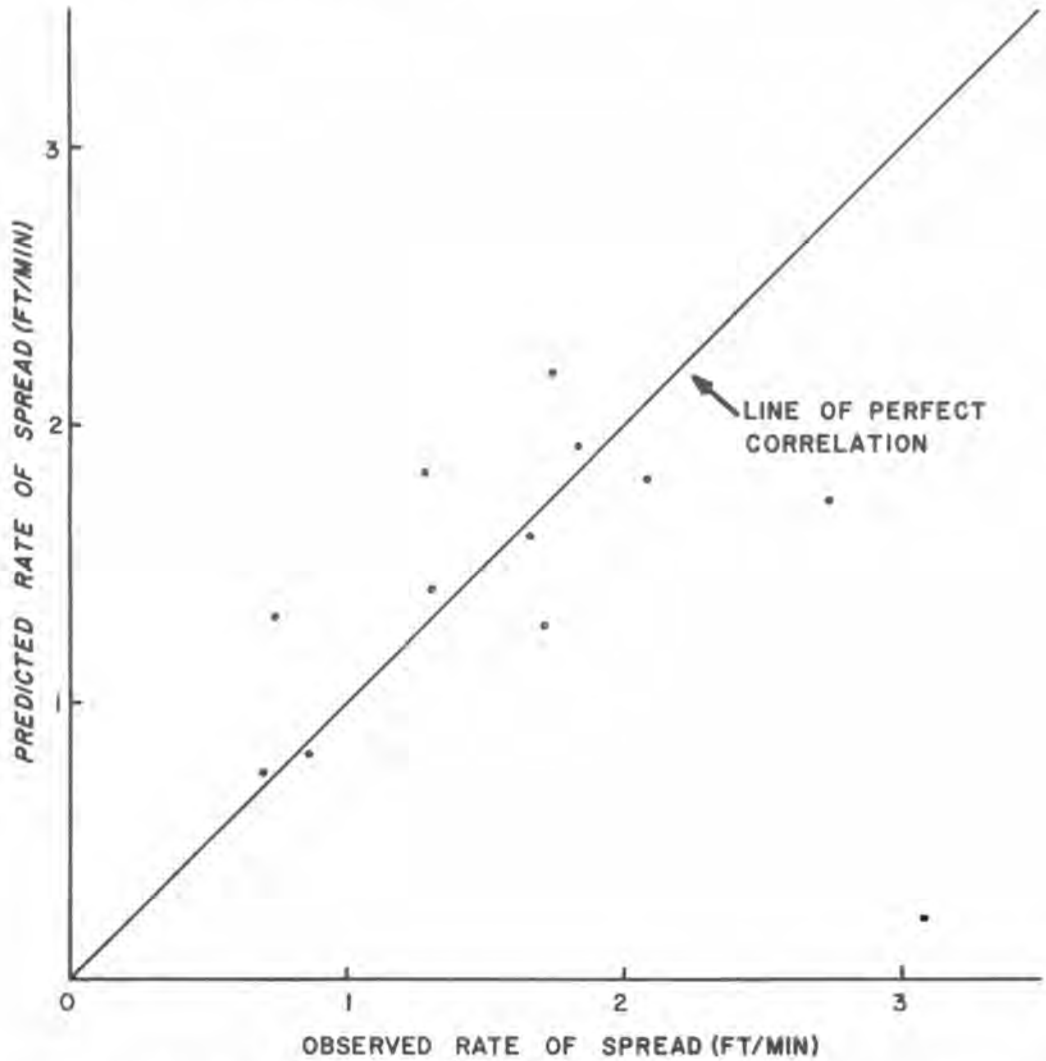

Figure 5.--Observed rate of spread for palmetto-gallberry backfires compared with predictions using model output at zero windspeed.

RESULTS AND DISCUSSION

Fuel Model Development

Averages and standard deviations of fuel descriptors were computed for most species by size class and fuel condition (live or dead). The values (table 23), based on all available laboratory measurements, are presented here to give the reader an idea of variability within and between species. Using these average values as the best estimates for each species, fuel condition, and size class, we then computed the contribution of each species to the plot or stand

Table 23.--Physical and chemical characteristics of the palmetto-gallberry fuel complex by species, fuel condition, and size class

Species or type and condition size class	Low heat value		Particle density		Mineral content		Effective mineral content		Surface area/volume	
	Mean	S.D.[1]	Mean	S.D.[1]	Mean	S.D.[1]	Mean	S.D.[1]	Mean	S.D.[1]
	Btu/lb		lb/ft^3		lb/lb		lb/lb		ft^2/ft^3	
Saw palmetto:										
Live < ¼"[2]	8,122	± 551	50.3	± 1.9	0.047	± 0.005	0.013	± 0.005	--	--
Live foliage	8,100	± 50	50.1	± 3.8	0.034	--	--	--	2,196	± 173
Live stem < ¼"	--	--	53.9	± 3.3	--	--	--	--	409	± 77
Live stem ¼-1"	7,767	± 132	54.7	± 2.5	0.021	± 0.004	0.015	± 0.004	238	± 43
Gallberry:										
Live < ¼"[2]	8,430	± 590	43.8	± 1.6	0.023	± 0.006	0.020	± 0.002	--	--
Live foliage	8,843	± 50	37.4	± 3.5	0.021	--	--	--	2,593	± 414
Live stem < ¼"	--	--	47.0	± 1.6	--	--	--	--	447	± 92
Live stem ¼-1"	8,350	± 219	44.1	± 1.9	0.013	± 0.005	0.010	± 0.004	141	± 34
Mixed shrubs:										
Live < ¼"[2]	8,356	± 277	44.9	± 4.4	0.020	± 0.009	0.016	± 0.003	--	--
Live foliage	8,267	± 75	35.6	--	0.028	--	--	--	2,154	± 469
Live stem < ¼"	--	--	47.2	--	--	--	--	--	833	± 197
Live stem ¼-1"	--	--	42.3	--	--	--	--	--	153	--
Herbaceous:										
Live < ¼"[2]	7,898	± 175	34.7	± 3.8	0.045	± 0.006	0.014	± 0.006	2,881	± 498
Live foliage	7,850	± 50	--	--	0.028	--	--	--	--	--
Saw palmetto:										
Dead < ¼"[2]	8,546	± 298	26.3	± 2.3	0.039	± 0.012	0.008	± 0.010	--	--
Dead foliage	8,408	--	31.6	± 1.0	--	--	--	--	1,994	± 214
Dead stem < ¼"	--	--	27.9	± 2.5	--	--	--	--	263	± 37
Dead stem ¼-1"	--	--	28.4	± 4.5	--	--	--	--	169	± 2
Gallberry:										
Dead stem < ¼"	8,270	--	39.8	± 2.1	0.014	--	0.009	--	404	± 52
Dead stem ¼-1"	--	--	38.4	--	--	--	--	--	136	--
Mixed shrubs:										
Dead < ¼"[2]	8,035	± 441	29.6	± 2.6	0.036	± 0.017	0.010	± 0.020	1,952	± 539
Dead ¼-1"	8,167	± 335	27.4	± 4.3	0.013	± 0.002	0.006	± 0.002	159	± 39
Herbaceous:										
Dead foliage	7,367	± 50	--	--	0.054	--	--	--	1,968	± 121
Slash pine:										
Litter (L&F) < ¼"[2]	8,592	± 138	30.4	± 3.2	0.036	± 0.016	0.012	± 0.016	1,729	± 237
Litter (L) foliage	8,753	± 50	--	--	0.021	--	--	--	1,883	± 229
Litter (F) foliage	8,498	± 55	--	--	0.028	--	--	--	1,900	± 222
Litter ¼-1"	8,393	± 119	27.0	± 4.2	0.018	± 0.008	0.011	± 0.004	107	± 23
Litter 1-3"	8,057	± 242	28.4	± 7.2	0.018	± 0.010	0.008	± 0.012	32	± 15
Litter (H) < ¼"	7,878	± 461	24.5	± 2.2	0.098	± 0.023	0.017	± 0.021	--	--
Longleaf pine:										
Litter (L&F) < ¼"[2]	8,757	± 213	31.7	± 2.2	0.032	± 0.005	0.013	± 0.005	1,851	± 45
Litter ¼-1"	--	--	30.2	± 7.4	--	--	--	--	104	± 22
Litter 1-3"	--	--	32.5	± 7.4	--	--	--	--	19	--
Litter (H) < ¼"	8,031	--	25.0	--	0.082	--	0.013	--	--	--

[1]Standard deviation.
[2]Samples contain foliage and stems < ¼ inch in diameter; all sample sizes are in inches.

value. For example, the fraction of the total live-foliage weight made up of live palmetto foliage was computed. This fraction was used as a weighting factor for each model input variable, allowing us to compute the contribution of live palmetto foliage to the values representing all live foliage occurring on the plot. In this way, plots that had most of the fuel weight in one species had values of particle density, heat value, and the other fuel characteristics closest to that species.

We looked for variation in the weighted average values that might be related to age of rough, which ranged from 1 to 22 years on the fuel sampling plots. Values of the fuel descriptors for each forest stand, by fuel condition and size class, were plotted against age of rough. Other than loading, which is determined separately, the only factor that seemed to be age related was the S/V ratio for the 0- to $\frac{1}{4}$-inch live-fuel class. Other fuel characteristics were unrelated to age of rough. It was decided that the best value for each size class and fuel condition would be the average of all plot values. These values and their standard deviations are presented in table 24.

The greatest differences in S/V ratios were obviously between, rather than within, size classes for different fuel conditions. For this reason, all values were combined to arrive at a single surface area to volume ratio for each of the three size classes being used in the model. Major differences in particle density and silica-free ash were between the live and dead components. Differences in low heat value and total ash content occurred between live and dead fuels and between size classes of fuels, but these differences were not considered significant. In an effort to reduce the number of input values needed for the spread model, representative values were selected for each fuel condition and size class under consideration (table 25). This approach greatly reduces the amount of field work required to get input data for predictions, while reducing precision only slightly.

Table 24.--Physical and chemical characteristics averaged over all plots by major fuel conditions and size classes: palmetto-gallberry fuel complex

Fuel condition and size class	Low heat value		Particle density		Total ash		Silica-free ash		Surface area/volume	
	Mean	S.D.[1]	Mean	S.D.[1]	Mean	S.D.[1]	Mean	S.D.[1]	Mean	S.D.[1]
	Btu/lb		lb/ft^3		- - - - - - lb/lb - - - - - -				ft^2/ft^3	
Aerial fuels:										
Live foliage	8,175	± 92	45.5	± 3.4	0.041	± 0.007	0.015	± 0.007	2,322	± 211
Live 0-¼"	8,302	± 66	49.6	± 1.5	0.032	± .005	0.017	± .006	467	± 98
Live ¼-1"	8,166	± 179	47.4	± 3.2	0.016	± .002	0.012	± .001	166	± 35
Dead foliage	8,299	± 256	30.7	± 1.0	0.038	± .001	0.009	± .002	1,999	± 359
Dead 0-¼"	8,229	± 184	31.9	± 2.7	0.031	± .006	0.010	± .006	322	± 60
Dead ¼-1"	8,167	± 335	27.4	± 4.3	0.013	± .002	0.006	± .002	151	± 37
Surface fuels:										
Dead L layer	8,592	± 138	30.4	± 3.2	0.036	± .016	0.012	± .016	1,806	± 230
Dead 0-¼"	8,229	--	31.9	--	0.031	--	0.010	--	325	± 52
Dead ¼-1"	8,393	± 119	27.0	± 4.2	0.018	± .008	0.011	± .004	107	± 23

[1]Standard deviation.

Table 25.--Physical and chemical values for the palmetto-gallberry complex used as input to the fire behavior model

Fuel condition and size class	Low heat value	Particle density	Total ash	Silica-free ash	Surface area/volume
	Btu/lb	lb/ft^3	- - lb/lb - -		ft^2/ft^3
All live fuels	8,300	46	0.030	0.015	
All dead fuels	8,300	30	0.030	0.010	
All foliage					2,000
All 0-¼" stems					350
All ¼-1" stems					140

Fuel loading by size class was highly correlated with age of rough, height of the understory fuel, percentage of palmetto on the area, and basal area of the overstory timber stand. These characteristics were used to develop predicting equations for each of the needed combinations of fuel condition and size class.[10] These equations (table 26) and the characteristics measured in the forest stand were then used to compute the weight by size class of each fuel component.

Table 26.--Equations used to estimate fuel loading (lb/ft^2 on dry-weight basis) of palmetto-gallberry fuel components used as input to the fire behavior model

Fuel component dry weight	Regression equation
Live foliage	$-0.0036 + 0.00253(AR) + 0.00049\ (PPal) + 0.00282(HT^2)$
Live 0-¼"	$+0.00546 + 0.00092(AR) + 0.00212(HT^2)$
Live ¼-1"	$-0.02128 + 0.00014(AR^2) + 0.00314(HT^2)$
Dead foliage	$+0.00221(AR^{0.51263})\ \exp\ (0.02482\ (PPal))$
Dead 0-¼"	$-0.00121 + 0.00379(\ell n\ AR) + 0.00118(HT^2)$
Dead ¼-1"	$-0.00775 + 0.00021\ (PPal) + 0.00007(AR^2)$
L layer	$(0.03632 + 0.0005336(BA))\ (1 - (0.25)^{AR})$

where:

AR = age of rough, years

PPal = coverage of area by palmetto, percent

HT = height of understory, feet

BA = basal area of overstory, square feet per acre.

Since we wanted to include the effects of changes in live-fuel moisture content on fire behavior, we developed a seasonal curve from biweekly measurements of moisture content of palmetto and gallberry plants. The major seasonal features of this curve were low-fuel moisture content in winter and early spring, followed by a high-moisture content in late spring and summer. We decided to enter only these major differences in the fire behavior model. In this way, live-fuel moisture content values for only two periods of the year had to be used. The live-fuel moisture contents were 130 percent for foliage and 105 percent for stemwood in summer, and 105 percent for foilage and 75 percent for stemwood in winter.

Moisture content of the dead-fuel components also had to be estimated. The original intent was to use the National Fire Danger Rating System (NFDRS)

[10] See footnote 8.

(Deeming and others 1972) 1-hour timelag tables for the L layer and standing dead foliage, and the 10-hour tables for the dead $\frac{1}{4}$- to 1-inch fuels. To reduce the number of moisture content values needed for model input, it was assumed that the forest floor L layer and standing dead foliage were the major carriers of the fire front. The $\frac{1}{4}$- to 1-inch material made up a small part of the total dead-fuel weight and had little influence on spread rate. This size class was assigned the same moisture content value as the other dead fuels.

Actual moisture content of the L layer on field plots ranged from 9 to 33 percent while moisture content predicted by the NFDRS 1-hour tables ranged only from 5 to 11 percent. The 10-hour tables also gave an inadequate range of moisture contents, 6 to 14 percent, for the L layer.

In addition to the 1-hour timelag tables, that proved inadequate, two other methods for estimating dead-fuel moisture content were considered. An empirical relationship between relative humidity, days since rain, and L layer moisture content was reported by Hough (1968), but moisture added by precipitation was not considered. Analysis of the NFDRS components using weather data from the Southeastern United States showed that 100-hour timelag fuel moisture varied from 10 percent (occurring on the 6th day following rain) to 28 percent (immediately after rain).[11] This range is approximately the same as that measured in L layer samples from the field for similar weather conditions. Based on this analysis, we recommend that the NFDRS 100-hour timelag fuel moisture tables be used to estimate dead-fuel moisture content in the palmetto-gallberry model.

Rate of Spread and Flame-Length Estimates

With the relationships outlined, a palmetto-gallberry fuel complex can be completely described by specifying the following:

1. Age of rough (years since last burn)
2. Height of understory (visual height)
3. Percent coverage by palmetto
4. Basal area of overstory stand
5. Summer or winter burn
6. Moisture content of dead fuels.

The first three variables define the standing understory fuel loadings by size class, through predictive relationships. The overstory stand density (basal area) is an indicator of tree biomass and hence of foliar litter production rate. This variable, in conjunction with the age of the rough, permits the computation of litter accumulation (pine needles) on the site. Live-fuel moisture content depends upon whether the burn is in summer or winter. The moisture content of the dead fuels varies widely, depending upon local, recent weather history, and is best estimated using NFDRS 100-hour timelag values.

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[11] Paul, James T. 1973. Analysis of fire danger in southeastern Georgia. Ph.D. diss., Univ. Ga., Athens.

For most areas of the South in which palmetto-gallberry associations are important understory fuels, the terrain is relatively flat. Therefore, the slope was assumed to be zero in the rate of spread model. Windspeed is also an important variable; it is treated separately at the end of the procedure.

Backfire Predictions

To simplify computations, a representative range of values was chosen for each of the variables listed, and the results of the computations at zero windspeed are shown in tables 1-18. The range of variable values was chosen to span the spectrum of conditions normally found:

Age of rough: 1, 2, 3, 4, 5, 8, 15, and 25 years

Height of understory: 1, 2, 3, 4, 5, and 6 feet

Percent covered by palmetto: 15 percent (sparse), 50 percent (broken), and 85 percent (continuous)

Basal area of overstory: 30 (low), 70 (medium), and 110 (high) ft^2/acre

Moisture content of dead fuels: 5, 10, 15, 20, and 30 percent.

Backfire rates of spread were computed with the current version of Rothermel's (1972) model. Flame lengths were computed from Byram's (1959) formula:

$$L = 0.45(I)^{0.46}$$

where

L = flame length in feet

I = Byram's fireline intensity in Btu/s/ft.

Using the "reaction intensity," or rate of heat release per unit area at the fire front, I_R (Btu/ft^2/min), available from Rothermel's model, the rate of spread, R (ft/min), and an estimate of the flame residence time, τ (min), Byram's intensity can be calculated (Albini 1976b):

$$I = (I_R \cdot R \cdot \tau)/60.$$

The residence time was computed from a relationship developed by Anderson (1969), based on the characteristic surface area/volume ratio of the modeled fuel bed where τ (min) = $384/\tilde{\sigma}$ (ft^{-1}).

Head Fire Predictions

According to Rothermel's (1972) model, the principal effect of wind on a free-burning fire is to increase the efficiency of heat transfer from burning fuel to unignited fuel, with accompanying increase in rate of spread but little or no change in reaction intensity. The formula given by Rothermel for the wind-driven rate of spread, R, is:

$$R = (1 + \phi_W)R_o$$

with R_o the rate of spread under no wind, and the "wind factor" ϕ_W a function of fuel-bed packing ratio, β, and the characteristic surface area/volume ratio of the modeled fuel complex, denoted by $\tilde{\sigma}$. Packing ratio is the fraction of the fuel-bed volume which is filled with fuel particles, and $\tilde{\sigma}$ is a weighted average of the surface area/volume ratios of the individual fuel particles. The equation for ϕ_W was developed from laboratory data and is complex but straightforward:

$$\phi_W = AU^B$$

where

U = windspeed, ft/min, at midflame height

$B = 0.02526\ \tilde{\sigma}^{0.54}$

$A = C(\beta_o/\beta)^E$

$C = 7.74 \exp(-\ 0.133\ \tilde{\sigma}^{0.55})$

$E = 0.715 \exp(-\ 0.000359\tilde{\sigma})$

$\beta_o = 3.348/\tilde{\sigma}^{0.8189}$

and $\tilde{\sigma}$ is measured in units of ft^{-1}.

Note that two quantities ($\tilde{\sigma}$ and β) describe the effects of windspeed on head fires. The values of these variables were systematically reviewed for the range of fuel beds considered, with an eye to simplifying this computation. The range of values indeed allows simplification, since

$$1.42 \le B \le 1.52,$$

$$0.351 \le E \le 0.383,$$

$$2.26 \times 10^{-4} \le C\beta_o^{\ E} \le 3.66 \times 10^{-4}.$$

Using midrange values for these parameters, and converting units from ft/min to mi/h for windspeed, we found a formula which approximates the complete expression to within ± 25 percent:

$$\phi_W \doteq 0.2165\ (U(mi/h))^{1.47}/\beta^{0.367}.$$

Thus, by classifying each modeled fuel bed in terms of its packing ratio, β, a set of "categories" could be established, with a representative packing ratio for each. Tables 19-21 were prepared to show in what category each fuel bed falls. Once this category is determined, figures 1 and 2 provide appropriate multiplying factors for adjusting the zero-wind rate of spread and flame length to get the head fire rate of spread and flame length. The use of these tables and graphs was illustrated in the first part of this paper. Figure 6 shows the influence of wind and fuel moisture on predicted head fire rate of spread for typical palmetto-gallberry stand conditions.

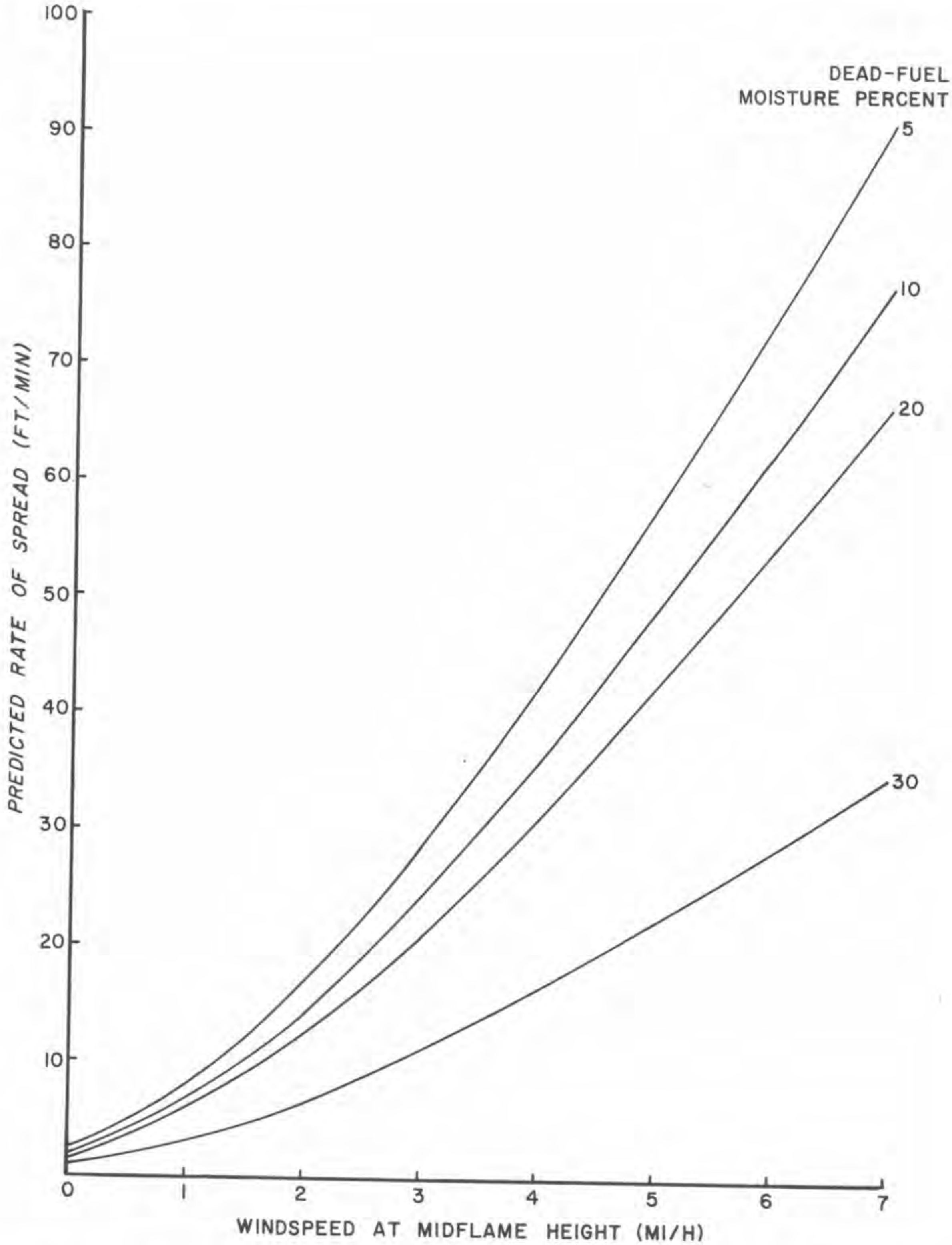

Figure 6.--Influence of wind and fuel moisture content on predicted rate of fire spread in an average palmetto-gallberry association.

Stand conditions: overstory basal area = 70 ft^2/acre, age of rough = 8 yr, understory height = 3 ft, and palmetto coverage = 50 pct

Fire Intensity

The intensity of a free-burning fire, as determined by Byram's (1959) formula, provides a ready measure of the severity of the fire. For hazard-reduction burns in the palmetto-gallberry type, intensities between 20 and 90 Btu/s/ft are satisfactory (Hough 1968). Hodgson (1968) recommends a maximum value of 100 Btu/s/ft for controlled burning, and suggests that at about 600 Btu/s/ft a surface fire may become uncontrollable. Serious spotting has been noted at intensities between 500 and 1,200 (Hodgson 1968; Kiil 1975), and intensities of 2,000 to 3,000 have been associated with crowning (Van Wagner 1968). The maximum height of lethal scorching in coniferous crowns has also been directly related to Byram's intensity (Van Wagner 1973).

In the tables and graphs presented in Part I, we used flame length as a measure of intensity, since this phenomenon is directly observable. But the flame lengths were calculated using Byram's (1959) formula, given earlier. The intensity of a fire can be estimated from its observed or calculated flame length.

Test of Model Output

To provide a general idea of how predicted and actual rates of spread compare, rate-of-spread data (not used to develop model) from past fires in stands of palmetto-gallberry were obtained from the files at the Southern Forest Fire Laboratory. Spread rates were from head and backfires on plots ranging from 0.5 to 2 acres. Variables such as basal area, percent palmetto, and height of the understory were not available for every individual plot. Therefore, the average stand conditions that prevailed in the experimental area were used in several cases. Even though variation in stand conditions was known to occur between individual test plots, the discrepancies were not considered great enough to disqualify the comparisons. For this particular set of data, rates were slightly underestimated (fig. 7). However, most predictions did not differ from observed values by more than ± 8 ft/min for head fires and ±1 ft/min for backfires.

In predicting rate of spread from the original data, it was noted that L layer fuel moisture content was often much higher than that estimated at the nearest fire danger rating station. Also, it was noted that windspeed within the stand was half or less the windspeed measured at the fire danger rating station. For our predictions, we measured windspeed in the stand near the fire, and for best predictions a user should do the same.

If it is inconvenient to measure windspeed, a value can be estimated from the windspeed at the nearest fire danger rating station. The relationship between windspeed at a 20-foot tower in the open and windspeed in a forest stand depends on a number of factors (USDA Forest Service 1970). In slash pine stands it is influenced by basal area and height of the stand (Cooper 1965). The tables presented by Cooper could be used to convert windspeed measured at a nearby danger station into a rough estimate of windspeed within a stand.

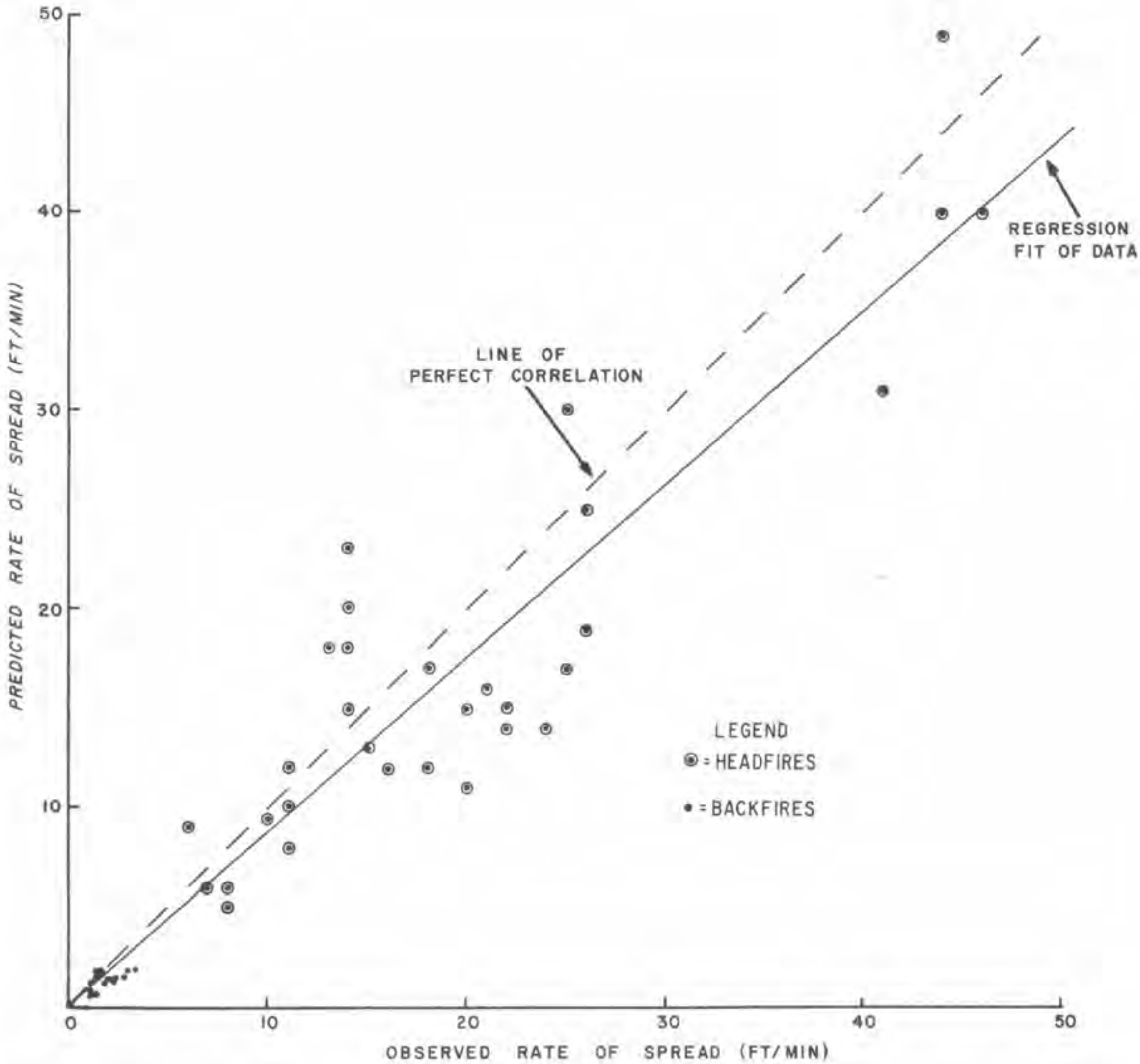

Figure 7.--Relationship between observed and predicted rates of spread for winter fires.

CONCLUSIONS

The material presented in this paper should be useful to forest fire managers. It is especially well suited for prescribed burning, because rate of spread, fire intensity, and flame length can be predicted before the fire is lit. Fire suppression forces can also use the tables and curves to estimate how fast a wildfire will spread in a particular fuel under actual or forecast weather conditions. For instance, the Florida Division of Forestry (1973) published guidelines for forest fire suppression tactics. The section on palmetto-gallberry fuel types indicated that there was not enough information on fire behavior in palmetto-gallberry fuels to be able to specify suppression tactics adequately. We hope that the spread and intensity information provided in this publication will fill this need.

When applying the procedures, the most accurate estimates of rate of spread will result when actual dead-fuel moisture content and midflame windspeed within the stand are measured at the time of burning. If on-site measurements cannot be made, other sources of the needed data must be used and the losses in precision, already discussed, must be accepted.

The user of this information must again be cautioned about the limitations of predictions. The estimated rates of spread do not apply to high-intensity wildfires where spotting and crowning are influencing fire behavior. Spread values are most reliable for backfires and low-intensity head fires, which are typical of prescribed burns and the initial stages of wildfires.

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Throughout this paper, values are in English units because these are still most commonly used in forestry in the United States. Factors for converting from English to metric units are provided below:

To convert from	To	Multiply by
acre	hectare	0.4047
Btu/pound	Joule/gram	2.3244
Btu/second/foot	kilowatt/meter	3.4592
foot	meter	0.3048
foot^2/acre	meter^2/hectare	0.2296
inch	centimeter	2.5400
miles/hour	kilometer/hour	1.6093
pound	kilogram	0.4536
pound/foot^2	kilogram/meter^2	4.8823
pound/foot^3	kilogram/meter^3	16.0185
tons/acre	tonne/hectare	2.2417

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Rate of spread, fireline intensity, and flame length can be predicted with reasonable accuracy for backfires and low-intensity head fires in the palmetto-gallberry fuel complex of the South. Age of rough, height of understory, percent of area covered by palmetto, basal area of overstory, season of year, moisture content of dead fuels, and midflame windspeed must be known to make predictions.

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