BULLETIN No. 77
1969

THE ESTIMATION OF FIRE HAZARD IN WESTERN AUSTRALIA

by
A. B. HATCH

FORESTS DEPARTMENT
PERTH
WESTERN AUSTRALIA

THE ESTIMATION OF FIRE HAZARD IN WESTERN AUSTRALIA

by
A. B. HATCH

W. R. WALLACE
Conservator of Forests

PERTH
1969

THE ESTIMATION OF FIRE HAZARD IN WESTERN AUSTRALIA

by A. B. HATCH

SUMMARY

The fire hazard graphs used in Fire Weather forecasting in Western Australia can be expressed mathematically in two ways; viz. a curved relationship involving a second degree quadratic equation, or as a linear function of the square root of the wood cylinder moisture content.

The three variables, temperature, relative humidity and morning wood cylinder moisture content were closely correlated with fire hazard, and a multiple regression using these variables has proved a valuable method for predicting fire hazard.

INTRODUCTION

The major forest areas of Western Australia experience a typical Mediterranean climate with cool wet winters and hot dry summers. Consequently, the fire season covers a six month period from mid-October to mid-April, and the accurate estimation of fire hazard throughout this period is of fundamental importance to the protection organization of the Forests Department. This applies particularly to the controlled burning programme during the spring and autumn months, and to gang disposition throughout the prohibited burning period from mid-December to mid-March. In addition, with the increased Departmental controlled burning programme, considerable use is being made of forest fire danger tables in planning a controlled burn, and the estimation of fire hazard is the first step in using these tables to calculate the rate of spread of the controlled burn, (Peet, 1965; Harris, 1968).

Fire Hazard Forecasting was introduced into Western Australia by Wallace in 1934, and this valuable work, which is carried out in close co-operation with the Commonwealth Bureau of Meteorology, forms the basis of the Forest Fire Weather System. This work has been discussed in detail by Wallace (1936, 1949) and Wallace and Gloe (1938).

It is important to realize that fire hazard is a measure of fuel inflammability, and as an example of this, Peet (1965), has shown that under normal summer conditions, the moisture content of jarrah leaf litter is closely correlated with the wood cylinder moisture content.

These parameters were related by a linear regression:—

$$Y = 0.020 + 1.134\ X \qquad (1)$$

where Y = moisture content of jarrah leaf litter (%)

and X = moisture content of wood cylinders (%)

THE FIRE HAZARD GRAPH

In the derivation of fire hazard the previous authors related the moisture content of half inch **Pinus radiata** dowels to the fire hazard, and the relationship between these variables is curvilinear in form (Fig. 1).

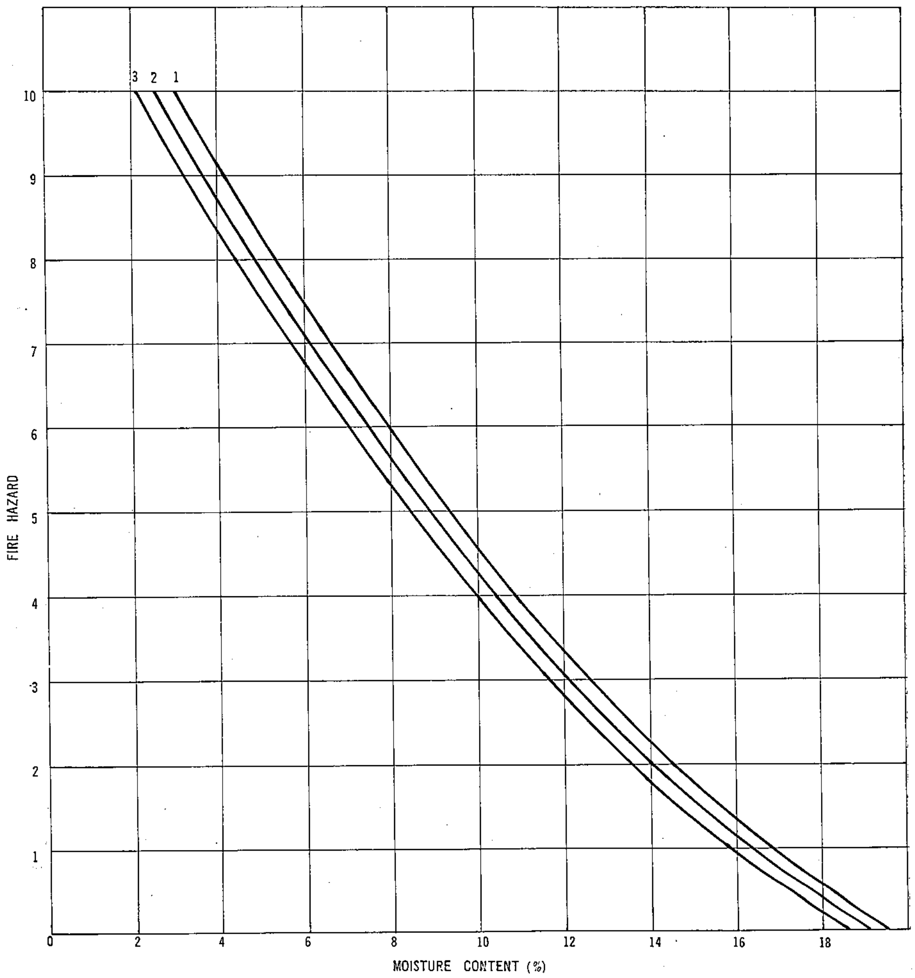

Fig. 1.—Western Australian Fire Hazard Graphs.
Curve 1. For Use on 15th November.
Curve 2. For Use on 15th January.
Curve 3. For Use on 15th March.

As far as can be ascertained there was no early attempt made to derive a mathematical expression to fit the fire hazard graph, and as a first trial a second degree quadratic equation was fitted to the data. For the calculation of the equation the following values were used, (Forests Department, W.A., 1964).

Fire Hazard Y	Wood Cylinder Moisture Content — % X
0	19.4
1	17.0
4	11.0
6	7.9
7	6.5
8	5.3
9	4.1
10	3.2

This data was converted to a square matrix using Y, X and X^2 as the variables, and then inverted using the Bordering Method (Faddeeva, 1959).

From the XY and X^2Y vectors and the inverse matrix the following regression coefficients were obtained:—

$b_1 = -1.0222$

$b_2 = +0.0185$

and the equation for fire hazard becomes:—

$$Y = 12.942 - 1.022X + 0.0185X^2 \quad (2)$$

The Analysis of Variance is shown in Table (1) and this table clearly indicates that the above equation is an extremely good fit of the fire hazard data.

TABLE 1
FIRE HAZARD EQUATION
Analysis of Variance

Source	df	S.S.	M.S.	V.R.	
Regression	2	93.7628	46.8814	2092.92	***
Deviations	5	0.1122	0.0224		
Total	7	93.8750			

R^2 = 0.999
S.D. = 0.1497
S.E.(b1) = 0.05401 t = 18.922 ***
S.E.(b2) = 0.002345 t = 7.889 ***

It was observed by Wallace that wood cylinders showed a gradual loss of oven dry weight during the summer, and to compensate for this weathering effect a nest of fire hazard curves were prepared to simplify the calculations of fire hazard from the moisture content readings. The curves are prepared by reducing the moisture content for the appropriate fire hazard by 0.24 per cent for each month of the fire season. At present, five graphs are used for the months December to April, and the basic fire hazard graph (Equation 2) is applied to November data, with each curve representing the fire hazard moisture content relationship at the middle of the month. The graphs for November, January and March are illustrated in Figure I.

The graphs are very similar algebraically to the original fire hazard graph, and the equations for use during the summer are as follows:—

15th November	$Y = 12.942 - 1.022\,X + 0.0185\,X^2$	(2)
15th December	$Y = 12.699 - 1.013\,X + 0.0185\,X^2$	(3)
15th January	$Y = 12.457 - 1.004\,X + 0.0185\,X^2$	
15th February	$Y = 12.215 - 0.995\,X + 0.0185\,X^2$	
15th March	$Y = 11.980 - 0.986\,X + 0.0185\,X^2$	
15th April	$Y = 11.742 - 0.978\,X + 0.0185\,X^2$	

In a second examination of the data it was observed that the fire hazard graph could be transformed to a series of straight lines by plotting fire hazard against the square root of the wood cylinder moisture content, (Fig. 2).

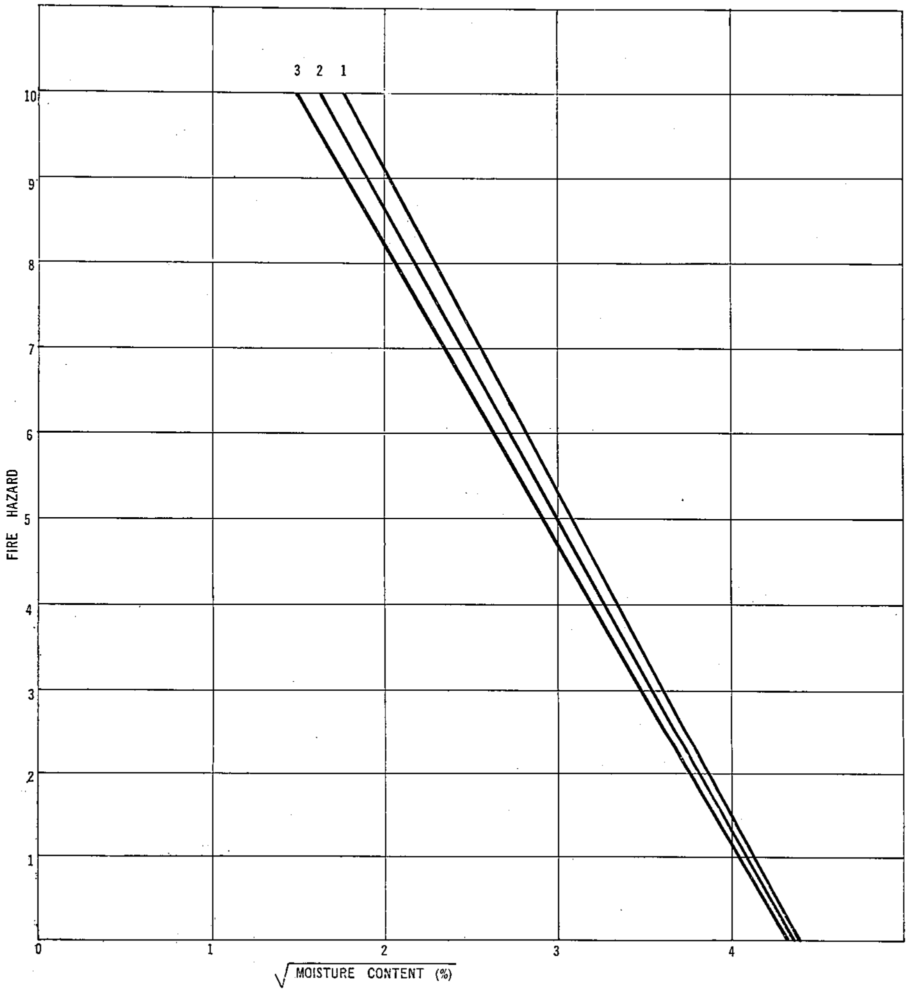

Fig. 2.—Fire Hazard Graphs Calculated from the Square Root of the Wood Cylinder Moisture Content.

Line 1.—For Use on 15th November.
Line 2.—For Use on 15th January.
Line 3.—For Use on 15th March.

The six equations for use during the summer are:—

15th November $Y = 16.770 - 3.823\, X^{\frac{1}{2}}$ (4)

15th December $Y = 16.436 - 3.768\, X^{\frac{1}{2}}$

15th January $Y = 16.103 - 3.712\, X^{\frac{1}{2}}$

15th February $Y = 15.762 - 3.653\, X^{\frac{1}{2}}$

15th March $Y = 15.422 - 3.594\, X^{\frac{1}{2}}$

15th April $Y = 15.067 - 3.530\, X^{\frac{1}{2}}$

The Analysis of Variance of the November and April equations are shown in Table (2), and again it is evident that the square root transformation gives an extremely good fit of the fire hazard data.

TABLE 2

FIRE HAZARD EQUATION

Square Root Transformation

Analysis of Variance

November

Source	df	S.S.	M.S.	V.R.	
Regression	1	92.835	92.835	536.62	***
Deviations	6	1.040	0.173		
Total	7	93.875			

$R^2 = 0\ 989$

S.D. $= 0.4159$

April

Source	df	S.S.	M.S.	V.R.	
Regression	1	93.193	93.193	817.48	***
Deviations	6	0.682	0.114		
Total	7	93.875			

$R^2 = 0.993$

S.D. $= 0.3376$

Due to the properties of the square root transformation the nest of lines given by the calculations are not parallel, but converge towards a point below the X axis.

THE ESTIMATION OF FIRE HAZARD

In an early study of this problem Stoate and Harding (1938) calculated several equations for the objective prediction of fire hazard, but all their calculations were aimed at predicting the wood cylinder moisture content at

1400 hours. However, later observations have shown that this is not generally the minimum moisture content for the day, this factor usually occurring between 1500 and 1600 hours, and the prediction of the maximum fire hazard is the important part of the forecast. In addition, the value calculated from these equations must be referred to the fire hazard graph to determine the actual fire hazard for the day.

Following the work of Stoate and Harding an attempt was made to predict fire hazard directly from meteorological factors and wood cylinder moisture content. The two factors selected were maximum temperature and minimum relative humidity, as both temperature and humidity were considered by Wallace to be two of the most important weather elements influencing fire hazard. In addition, estimates of these two factors have been included in the fire hazard forecasts since 1954.

The data was collected from six fire seasons, viz. 1949-1952 and 1957-1960, summarized data of which were readily available for analysis. After consulting a table of random numbers, samples were selected from the various months of the different fire seasons, rejecting all days on which rain had fallen. It is of interest to note that only two days were rejected on this account. Selection continued until a total of 200 days had been chosen from the data, and the sample distribution is shown in Table 3.

TABLE 3

FIRE HAZARD STUDIES

Distribution of Sample Days

Year	No. of Days							Total
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	
1949	....	....	6	....	....	....	....	6
1950	....	6	7	7	7	7	7	41
1951	....	6	5	7	7	7	1	33
1952	....	....	....	5	5	5	5	20
1957	1	6	5	....	....	....	....	12
1958	1	4	7	7	7	6	1	33
1959	1	7	7	7	7	7	1	37
1960	....	....	....	8	6	4	....	18
Total	3	29	37	41	39	36	15	200

From the meteorological and fire records the fire hazard, maxium temperature, minimum daily relative humidity and 07.30 hours wood cylinder moisture content were recorded, and this data formed the basis of all calculations. The fire hazard frequency distribution for all data is tabulated in Table 4.

TABLE 4
FIRE HAZARD STUDIES
Frequency Distribution of Fire Hazards

Fire Hazard	No. of Days								Total
	1949	1950	1951	1952	1957	1958	1959	1960	
Nil 0–1.0	....	....	....	....	....	....	....	....	0
Low 1.1–4.0	....	4	1	....	....	....	3	....	8
Moderate 4.1–6.0	1	9	10	6	5	6	12	3	52
Average Summer 6.1–7.0	....	8	11	2	3	8	7	5	44
High Summer 7.1–8.0	2	10	8	2	1	8	9	5	45
Severe Summer 8.1–9.0	3	9	2	8	2	6	3	4	37
Dangerous .... 9.1+	....	1	1	2	1	5	3	1	14
Total	6	41	33	20	12	33	37	18	200

In a preliminary examination of the data the relationship between fire hazard and the independent variables were examined as linear regressions. The Analysis of Variance for these equations are shown in Table 5, and the data are plotted graphically in Figures 3 - 5.

TABLE 5
FIRE HAZARD STUDIES
Analysis of Variance

Fire Hazard (Y) and Maximum Temperature (X_1)

$$Y = 0.1525\, X_1 - 5.718 \qquad (5)$$

Source	df	S.S.	M.S.	V.R.	
Regression	1	342.7250	342.7250	561.89	***
Deviations	198	120.7718	0.6100		
Total	199	463.5238			

R^2 = 0.739
S.D. = 0.781
r = 0.860 ***

Fire Hazard (Y) and Minimum Daily Relative Humidity (X_2)

$$Y = 10.213 - 0.09779\, X_2 \qquad (6)$$

Source	df	S.S.	M.S.	V.R.	
Regression	1	281.5462	281.5462	306.33	***
Deviations	198	181.9776	0.9191		
Total	199	463 5238			

R^2 = 0.607
S.D. = 0.959
r = -0.779 ***

Fire Hazard (Y) and 07.30 Hours Wood Cylinder Moisture Content (X_3)

$$Y = 11.034—0.3467 X_3 \qquad (7)$$

Source	df	S.S.	M.S.	V.R.	
Regression	1	258.2428	258.2428	249.08	***
Deviations	193	205 2810	1.0368		
Total	199	463.5238			

R^2 = 0.557
S.D. = 1.018
r =-0.746 ***

These calculations clearly indicate that the three variables studied are closely related (P 0.001) to the fire hazard, but individually they do not give a sufficiently accurate estimate of the fire hazard to be of use for forecasting purposes.

Following this work it was decided to combine the variables in a multiple regression. As a first step the variables temperature and relative humidity were chosen, because these parameters would allow the calculation of fire hazard at centres where wood cylinders are not available.

An information matrix was prepared using these two variables, inverted by the previous method, and the following regression coefficients obtained:—

b_1 = 0.108764
b_2 = —0.045919

and the equation becomes:—

$$Y = 0.1088X_1 —0.04592X_2 —0.5390 \qquad (8)$$

where Y = fire hazard, X_1 = maximum temperature, and X_2 = minimum daily relative humidity.

The Analysis of Variance of this equation is shown in Table 6.

TABLE 6
FIRE HAZARD STUDIES
Analysis of Variance

Source	df	S.S.	M.S.	V.R.	
Regression	2	376 46475	188.23238	425.94	***
Deviations	197	87.05905	0.441924		
Total	199	463.52380			

R^2 = 0.812
S.D. = 0.665
S.E. (b_1) = 0.7424×10^{-2} t = 14.650 ***
S.E. (b_2) = 0.5264×10^{-2} t = 8.724 ***

The multiple regression involving two terms (temperature and relative humidity) has markedly improved the accuracy of the fire hazard estimation in that the standard deviation has been reduced from 0.781 to 0.665, and the

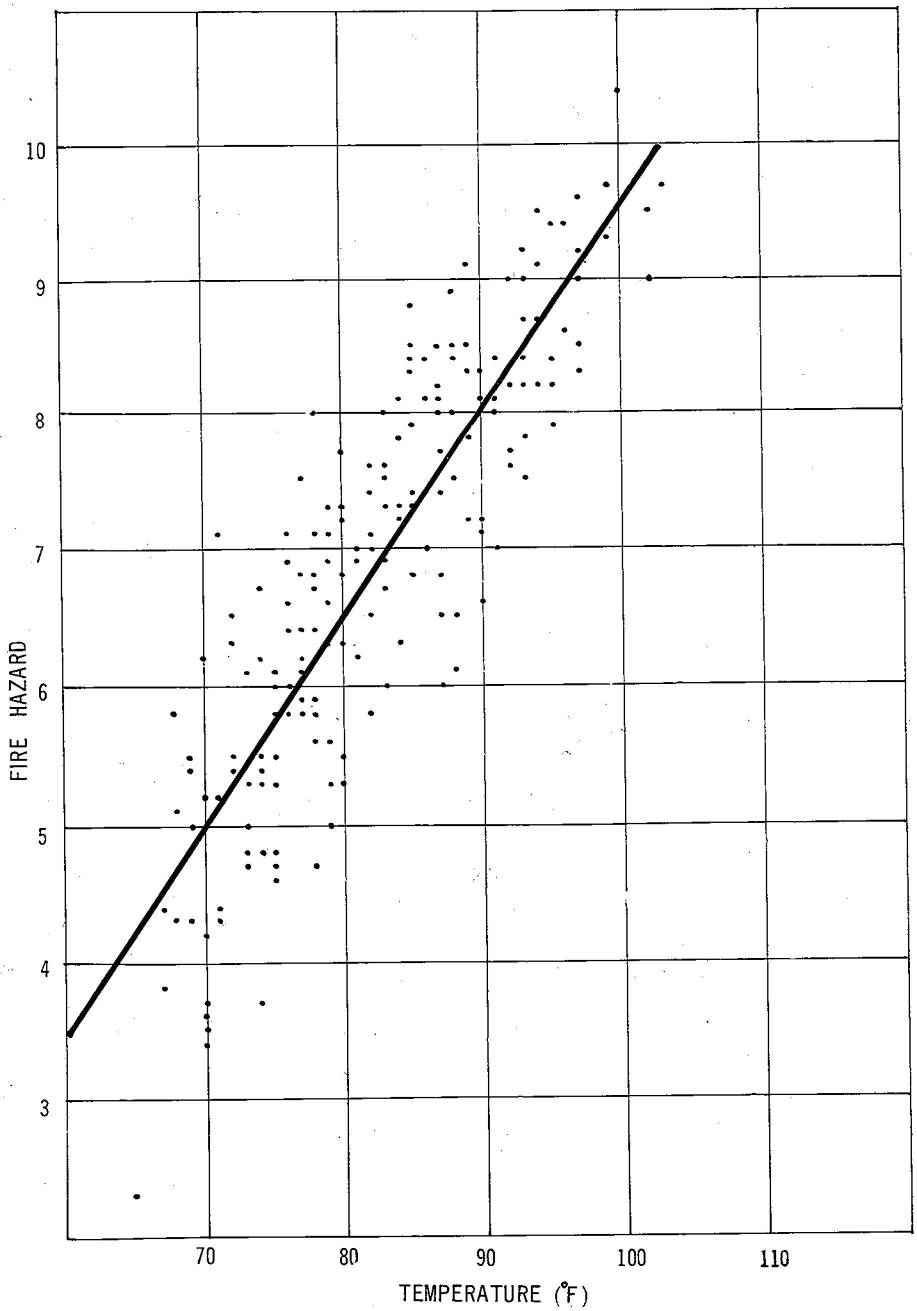

Fig. 3.—Relationship between Fire Hazard and Maximum Temperature.
Y = 0.1525 X — 5.718.

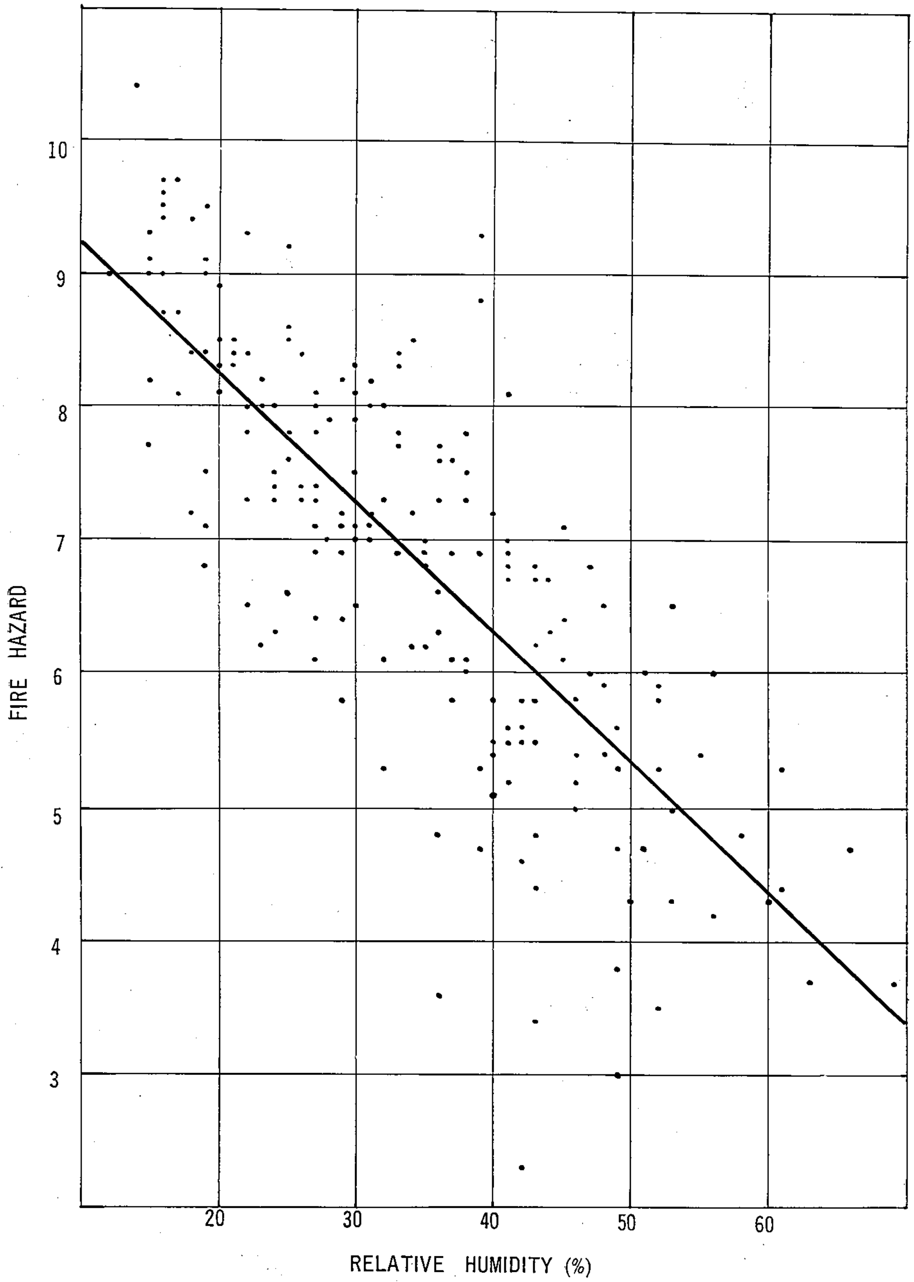

Fig. 4.—Relationship between Fire Hazard and Minimum Daily Relative Humidity.
$Y = 10.213 - 0.09779\ X$.

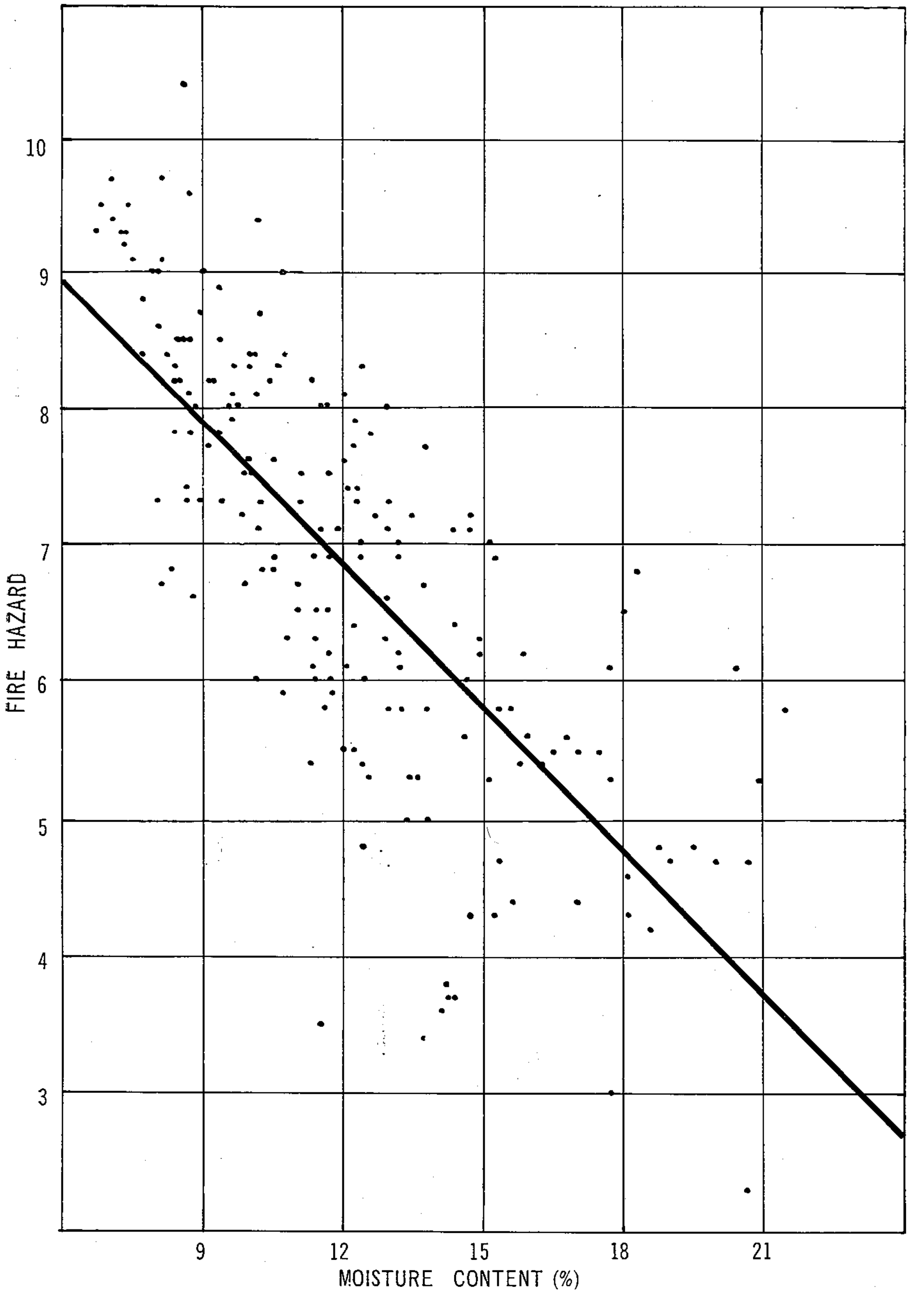

Fig. 5.—Relationship between Fire Hazard and 07.30 Hours Wood Cylinder Moisture Content.
Y = 11.034 — 0.3467 X.

regression equation now accounts for 81 per cent of the variation, as against 74 per cent accounted for by using maximum temperature as a single variable. The fire hazard table, as calculated from Equation (8) is set out in Table (7), and this data has proved very useful in the calculation of basic fire hazard in Western Australia. As well as estimating fire hazard the formula has the added advantage that changes in fire hazard throughout the day are reflected closely by values read off from the appropriate temperature and relative humidity values. These instantaneous values of fire hazard, which can be readily calculated in the field, allow greater flexibility in controlled burning operations.

The equation works particularly well in the dry mid-summer months, but has been shown to have servious disadvantages during spring and early summer months, when sudden rises in temperature can cause a marked over-estimation of the fire hazard. It also breaks down when estimating the fire hazard on the day of a cool change following a prolonged period of hot weather, when the equation seriously underestimates the fire hazard.

Despite these faults the fire hazard estimated by this method has proved very useful in centres where there are no wood cylinders available, and at present the equation is used to determine the basic fire hazard in the Forests Fire Danger Tables used in Western Australia.

The main disadvantages of this method is that it does not include a parameter which would reflect the effect of past weather. The best factor to incorporate this effect is the morning moisture content of the wood cylinders, as this measurement is a complete integration of the past weather conditions.

For the calculation of the equation involving the variables fire hazard (Y), maximum temperature (X_1), minimum relative humidity (X_2), and morning wood cylinder moisture content (X_3), the previous matrix was extended by adding the appropriate values for the morning wood cylinder moisture content. Inversion of this matrix gave the following regression coefficients:—

$b_1 = 0.07773$
$b_2 = —0.04241$
$b_3 = —0.15280$

and the equation relating these variables is:—

$$Y = 3.7404 + 0.07773X_1 - 0.04241X_2 - 0.1528X_3 \qquad (9)$$

The Analysis of Variance of this equation is shown below (Table 8).

TABLE 8
FIRE HAZARD STUDIES
Analysis of Varience

Source	df	S.S.	M.S.	V.R.	
Regression	3	410.36993	136.78998	504.44	***
Deviations	196	53.15387	0.271193		
Total	199	463.52380			

$R^2 = 0.885$
S.D. = 0.5205
S.E. (b_1) = 0.6857×10^{-2} t = 11.336 ***
S.E. (b_2) = 0.4479×10^{-2} t = 9.469 ***
S.E. (b_3) = 1.5300×10^{-2} t = 9.987 ***

TABLE 7

FIRE HAZARD CALCULATED FROM TEMPERATURE AND RELATIVE HUMIDITY

$$Y = 0.1088X_1 - 0.04592X_2 - 0.5390$$

FIRE HAZARD (Y)

Temperature—°F. (X_1)	Relative Humidity—% (X_2) 70	65	60	55	50	45	40	35	30	25	20	15	10	5
60	2.8	3.0	3.2	3.5	3.7	3.9	4.1	4.4	4.6					
62	3.0	3.2	3.4	3.7	3.9	4.1	4.4	4.6	4.8					
64	3.2	3.4	3.7	3.9	4.1	4.3	4.6	4.8	5.0	5.3				
66	3.4	3.6	3.9	4.1	4.3	4.6	4.8	5.0	5.2	5.5				
68	3.6	3.9	4.1	4.3	4.5	4.8	5.0	5.2	5.5	5.7				
70	3.9	4.1	4.3	4.5	4.8	5.0	5.2	5.5	5.7	5.9	6.2			
72	4.1	4.3	4.5	4.8	5.0	5.2	5.4	5.7	5.9	6.1	6.4			
74	4.3	4.5	4.7	5.0	5.2	5.4	5.7	5.9	6.1	6.3	6.6			
76	4.5	4.7	5.0	5.2	5.4	5.6	5.9	6.1	6.3	6.6	6.8	7.0		
78		5.0	5.2	5.4	5.6	5.9	6.1	6.3	6.6	6.8	7.0	7.2		
80		5.2	5.4	5.6	5.9	6.1	6.3	6.5	6.8	7.0	7.2	7.5		
82		5.4	5.6	5.8	6.1	6.3	6.5	6.8	7.0	7.2	7.4	7.7	7.9	
84			5.8	6.1	6.3	6.5	6.7	7.0	7.2	7.4	7.7	7.9	8.1	
86			6.1	6.3	6.5	6.7	7.0	7.2	7.4	7.7	7.9	8.1	8.3	
88			6.3	6.5	6.7	7.0	7.2	7.4	7.6	7.9	8.1	8.3	8.6	8.8
90				6.7	6.9	7.2	7.4	7.6	7.9	8.1	8.3	8.5	8.8	9.0
92				6.9	7.2	7.4	7.6	7.8	8.1	8.3	8.5	8.8	9.0	9.2
94				7.2	7.4	7.6	7.8	8.1	8.3	8.5	8.8	9.0	9.2	9.4
96					7.6	7.8	8.0	8.3	8.5	8.7	9.0	9.2	9.4	9.7
98					7.8	8.0	8.3	8.5	8.7	9.0	9.2	9.4	9.6	9.9
100					8.0	8.3	8.5	8.7	8.9	9.2	9.4	9.6	9.9	10.1
102						8.5	8.7	8.9	9.2	9.4	9.6	9.9	10.1	10.3
104						8.7	8.9	9.1	9.4	9.6	9.8	10.1	10.3	10.5

TABLE 9

FIRE HAZARD CALCULATED FROM TEMPERATURE, RELATIVE HUMIDITY AND 07.30 HOURS WOOD CYLINDER MOISTURE CONTENT

$$Y = 3.7404 + 0.07773\ X_1 - 0.04241\ X_2 - 0.1528\ X_3$$

TABLE A

Temperature—°F. (X_1)	Relative Humidity—% (X_2) 70	65	60	55	50	45	40	35	30	25	20	15	10	5
60	5.4	5.6	5.9	6.1	6.3	6.5	6.7	6.9	7.1					
62	5.6	5.8	6.0	6.2	6.4	6.6	6.9	7.1	7.3					
64	5.7	5.9	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6				
66	5.9	6.1	6.3	6.5	6.7	7.0	7.2	7.4	7.6	7.8				
68	6.0	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.8	8.0				
70	6.2	6.4	6.6	6.8	7.1	7.3	7.5	7.7	7.9	8.1	8.3			
72	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.9	8.1	8.3	8.5			
74	6.5	6.7	6.9	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6			
76	6.7	6.9	7.1	7.3	7.5	7.7	7.9	8.2	8.4	8.6	8.8	9.0		
78		7.0	7.3	7.5	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.2		
80		7.2	7.4	7.6	7.8	8.0	8.3	8.5	8.7	8.9	9.1	9.3		
82		7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.3	9.5	9.7	
84			7.7	7.9	8.1	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.8	
86			7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.4	9.6	9.8	10.0	
88			8.0	8.2	8.5	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.2	10.4
90				8.4	8.6	8.8	9.0	9.3	9.5	9.7	9.9	10.1	10.3	10.5
92				8.6	8.8	9.0	9.2	9.4	9.6	9.8	1·00	10.2	10.5	10.7
94				8.7	8.9	9.1	9.3	9.6	9.8	10.0	10.2	10.4	10.6	10.8
96					9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.6	10.8	11.0
98					9.2	9.4	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1
100					9.4	9.6	9.8	10.0	10.2	10.4	10.7	10.9	11.1	11.3
102						9.8	10.0	10.2	10.4	10.6	10.8	11.0	11.2	11.5
104						9.9	10.1	10.3	10.5	10.8	11.0	11.2	11.4	11.6

TABLE B

M.C.—% X_3		M.C.—% X_3		M.C.—% X_3	
5.0	0.8	16.5	2.5	28.0	4.3
5.5	0.8	17.0	2.6	28.5	4.4
6.0	0.9	17.5	2.7	29.0	4.4
6.5	1.0	18.0	2.8	29.5	4.5
7.0	1.1	18.5	2.8	30.0	4.6
7.5	1.2	19.0	2.9		
8.0	1.2	19.5	3.0		
8.5	1.3	20.0	3.1		
9.0	1.4	20.5	3.1		
9.5	1.4	21.0	3.2		
10.0	1.5	21.5	3.3		
10.5	1.6	22.0	3.4		
11.0	1.7	22.5	3.4		
11.5	1.8	23.0	3.5		
12.0	1.8	23.5	3.6		
12.5	1.9	24.0	3.7		
13.0	2.0	24.5	3.7		
13.5	2.1	25.0	3.8		
14.0	2.1	25.5	3.9		
14.5	2.2	26.0	4.0		
15.0	2.3	26.5	4.0		
15.5	2.4	27.0	4.1		
16.0	2 4	27.5	4·2		

NOTE : To calculate the fire hazard from the above tables.

1. From Table A read off the value corresponding to the temperature and humidity readings.
2. From Table B read off the value corresponding to the 07.30 Hours Wood Cylinder Moisture Content.
3. Subtract (2) from (1) and the net result is the Fire Hazard.

This regression has further improved the accuracy of the fire hazard prediction in that the standard deviation has been reduced from 0.625 to 0.520, and the equation now accounts for 89 per cent of the variation as against 81 per cent when two variables are used. The fire hazard table calculated from Equation (9) is shown in Table 9, and this data forms a very useful aid in Fire Weather Forecasting. This formula also permits the calculation of the fire hazard for any period of the day, using the appropriate temperature and humidity figures in conjunction with the morning wood cylinder moisture content.

The marked advantage gained by using the multiple regression equations is shown in the reduction of standard deviations given by the various formulae, (Table 10).

TABLE 10

FIRE HAZARD STUDIES

The Effect of Different Variables on Regression Variance

Variable	R^2	Variance	S.D.
Temperature .... (T)	0.739	0.6100	0.781
Relative Humidity .... (R.H.)	0.607	0.9191	0.959
Morning Wood Cylinder Moisture Content .... (M.C.)	0.557	1.0368	1.018
T. and R.H.	0.812	0.4419	0.665
T., R.H. and M.C.	0.885	0.2712	0.521

The formula has been found to work equally well in the jarrah, karri and mallet forests of Western Australia. In addition Douglas carried out some preliminary tests on South Australian data with very satisfactory results, (Douglas, pers. comm.).

The major advantage of this equation is that it combines two variables which are good estimates of the present weather, with a third parameter which is probably the most efficient measure available of past weather conditions.

CONCLUSIONS

It is evident from the previous calculations that the form of the fire hazard graph can be expressed as a second degree quadratic equation. In addition, transformation of the data resulted in a linear relationship between fire hazard and the square root of the wood cylinder moisture content. Both graphs are equally suitable for the mathematical expression of this function.

With regard to the estimation of fire hazard, the three variables studied, viz. temperature, relative humidity and morning wood cylinder moisture content, were closely related to the daily fire hazard, but the use of single variables did not give a sufficiently accurate estimate of the fire hazard.

However, the use of these three variables in a multiple regression, resulted in a marked increase in the accuracy of fire hazard estimation, and the final equation, involving the three parameters, has proved the best objective method of forecasting fire hazard yet developed.

The formula has the added advantage that it is applicable to a wide range of forest types.

ACKNOWLEDGMENTS

The author gratefully acknowledges the original suggestion by F. J. Campbell and B. J. Beggs concerning the relationship between fire hazard, temperature and relative humidity. Considerable assistance was also given by C. A. Boundy, of the C.S.I.R.O. Division of Mathematical Statistics, who carried out the calculations involving the three variables.

REFERENCES

Faddeeva, V. N. (1959).—Computational Methods of Linear Algebra. Dover Publications Inc.: New York.

Fisher, R. A. (1954).—Statistical Methods for Research Workers. Oliver and Boyd.: Edinburgh.

Fisher, R. A. and Yates, F. (1963).—Statistical Tables for Biological, Agricultural and Medical Research. Oliver and Boyd.: Edinburgh.

Forests Department, Western Australia (1964).—Foresters Manual (Fire Control). Bull. 58.: Pamphlet No. 7.

Harris, A. C. (1968).—Forest Fire Danger Tables. Forests Dept., Western Australia.

Peet, G. B. (1965).—A Fire Danger Rating and Controlled Burning Guide for the Northern Jarrah (Euc. Marginata Sm.) Forest of Western Australia. Forests Dept., W.A. Bull. 74.

Stoate, T. N. and Harding, J. H. (1940).—Calculated Estimate of Fire Hazard. Aust. For. 5 : 4-12.

Wallace, W. R. (1936).—Forest Fire Weather Research in Western Australia. Aust. For. 1 : 17-24.

Wallace, W. R. (1949).—Forest Fire Weather, Aust. Forestry Conference, 1949.

Wallace, W. R. and Gloe, H. L. (1938).—Forest Fire Weather. Aust. For. 3 : 28-36.

56124/3/69—300 Alex B. Davies, Government Printer, Western Australia.