CURRENT FOREST FIRE DANGER RATING SYSTEM (CFFDRS)

Wang Zheng-fei
(Forest Protection Research Institute, Harbin, China, 150040)

ABSTRACT

Dependent on the burning experiment, a scheme is presented for dealing with the full range of fire danger grade, fire behavior, and fire severity etc. By means of the formula to calculate the Daily Burning Index R.(m/min), derivative equations of the fire behavior can be deduced.

KEY WORDS: Ro, R, I.

INTRODUCTION

Research efforts in forest fire danger over the last few decades have resulted in the development numerical models to represent the danger rating with non dimension's number. It must be early aware that there are still combustion mechanism and dimensional analysis in danger rating system. The "ideal" fire model should be engineering system, comprise derivative equations. The proper order parameter of the engineering system to solve these equations is an important measurement through full sequence.

Dependent on the field burning experiments or in laboratory by collecting the ground surface fuels on the forest floor in stand. A scheme is presented for dealing with the full range of fire danger grade, fire behavior, and fire severity etc. It is based on more hundred burning fires data in Da-Xiaoxingan mountains and Sichuan province of China, plus a theory to describe the physical mechanism for predictions.[1]

By means of the formula as following to calculate the Daily burning Index (D.B.I) Ro. [m/min]

$$Ro = aT + bV + cH - D \qquad (1)$$

where t: day max air temp. ^{o}C, V: noon mean of wind scale, H: 100-lowest RH% every day and a.b.c.D are constants (a=0.03, b=0.05, c=0.01, D=0.3).

table 1 fire danger grades to d.b.i.classes

Fire Danger Grade	1	2	3	4	5
Characters of wildfire	No	Difficult	Medium	Easy	Fierce
D.B.I.Ro(m/min)	0-0.3	0.3-0.5	0.3-0.8	0.8-1.2	>1.2

the r shown in the last column not only expressed full combustibility but also the slowness or rapidity of the fire spread and the critical point may be taken at R0>0.8m/min.

MODEL STRUCTURE

I. Spread Rate

The first problem to be addressed was the surface spread rate because the r is based on the fine fuel moiture content which directly related the

change of daily natural environment adopted daily maximum temperature minimum humidity and wind scale instead to the equation multiple -correlation-regression with r as obtained equation (1) as above.

The fine fuel moisture content whose time lag in practice is only a day or so the computed spread rates would apparently apply in given daily weather regardless ld the further length of time since heavy rain thus the following equation is obtained.

$$R=R_o \cdot K_s \cdot K_\gamma \cdot K_f$$

where R:surface spread rates for that fuel types R_o:D.B.I(m/min),K_s:coefficient of the fuel arrangement(non dimension),K_γ:coefficient of windspeed (non eimedsion),K_f:coefficient of slope degree(non dimension).

When dealing with burning experiment outside or inside the available fuel's weight and its moisture content must be expressed by R.that may be defined as the fuel available energy for combustion with the exception of fuels having components which require a long time to burn out such as logs and heavy limbs these tow energies ordinarily equal according to the D.B.I(Ro)there is no need to measure the fuel moisture content every day accomplished prediction for fire occurrence and fire behavior successfully.

Table 2 Ks Fuels void space and fuel arrangement coefficient

Fuel types	needle litter	fallen leaves	grasses weeds
K_s	0.8	1.2	1.6
	carex forbs	pasture	pinus kor.yunn
	1.8	2.0	1.0

Table 3 K_γ Wind speed coefficient

Wind speed m/s	1	2	3	4	5	6	7	8	9	10	11	12
K_γ	1.2	1.4	1.7	2.0	2.4	2.9	0.3	4.1	5.0	6.0	7.2	8.5

Tble 4 Kf Slope coefficient.

Slopetan	0^o	5^o	10^o	15^o	20^o	25^o	30^o	35^o	40^o	45^o
K_f	1.0	1.2	1.6	2.1	2.9	4.1	6.2	10.1	17.5	34.2

Actually the initial spread as well as the principal direction of spread is determined mostly by the speed and direction of the surface wind and by topography local variations in fuel cover type also affect the spread but their effect are usually less than that of wind and topography they are important however in the rate of fire spread

HI.The Fuel Available for Combustion in A Moving Fire Front

The forest fuels has treated as a combustion system the weight of every layer to the fuel available for combustion on per unit area within the moving fire front and assumed that fire line intensity comes from the two contributions the burning rate and mean burning acceleration and can be expressed by the Linear nomogenous ordinary differential equation This equation is considered as a basic dynamic equation to determine the fuel available W for combustion.

Table 5 Fuel Available W for Combustion Relate to W Surface Fuels and S

Wo(kg/m)	0.5	.0	1.5	.0	2.5	3.0
S 0.3	W(g/m)0.435	0871	.306	1742	.17	.612
0.5	0.492	0986	.479	1972	.46	.957
0.7	0.558	0116	.674	2232	.79	.348
0.9	0.632	1263	.985	2526	.15	.790
1.1	0.715	1430	.145	2860	.57	.290
1.3	0.809	1619	.428	3237	.04	.856

In table 5 the flame belt width may be taken as an intermediate parameter that includes the spread rate (R) and resident time (t),on the fire flame belt For example R=8m/min,take S equal to 1m,when Wo=0.5kg/m2.But w0 only 0.5 kilograms,remaining sum would be replenished by aerial fuels near the fire.

III.Fire intensity

The problem to be addressed was frontal fire intensity.The following equation was used to calculate frontal fire intensity (I) in kw/m (after Byram 1959):

$$I=qWR$$

where q:heat yield of combustion in kj/kg,W:the weight of fuel consumed per unit area (in the active flaming zone) expressed as kg/m2 and R:the spread rate in m/s.In this analysis q value for surface fire be taken in 17000kj/kg.

IV.Flame Length

Fire behavior usually varies with fuels,weather topography and other factors of the local environment Consequently there are no two fire suppression jobs which are exactly alike and how to control a particular fire cannot be detailed in advance Nevertheless,all firefighting is based on while of flame length and is carried out through firing back to extinguish the fire front developed through experience.

An approximate relation between the flame length L_{5} in metter and the fire intensity is given by Byram's scaling law (1966). According to this conception have obtained following equation to determine the flame length measuring method through field experience.

$$L = \alpha \left(\frac{I}{250}\right)^{1/2}$$

where α-1 at grass land or continuous type cover.Equation (5) is expressed by the diagram in Figure 1,in which the flame length is ploted as a function of the frontal fire intensity I.

Frontal Intensity kw/m

Fig Relationship between flame length and fire intensity.

The figure 1 can be used in fire fighting job in field practice,for example flame length .measured 8 meters should understand the fire intensity equals 16000kw/m.

V.Fire Severity

Under some forest fire intensity conditions the forest or trees would be the blaze "Forest Fire Severity Index"(FFSI) as a measure standard and the storing volume amount of stands as the state index of forest ecosystem are suggested to be used.According to the analysis of fire combustion and spreading the follow equation was deduced:

$$P(\%) = \frac{\beta I}{R^{1/2}} \times 100$$

where p(0/0):loss rate of trees :tree species fire resistant coefficient (for Larix gmelini is 0.103×10^{-3}),I:fire intensity,R:rate of spread.Based on this investigation,forest losses will be predicted by fire to resolve the fire effects on the ecology.

VI.Some Estimations For The Spreading Characters

The pattern of initial spread is determined mostly by the surface wind and topography.No wind or in flat terrain,a fire will spread at about the same rate in all directions,so that the initial spread pattern is an approximately circular area with the origin of ignition in the center.If there is a wind which maintains a constant direction,the burned area will assume the shape of an elongated ellipse,with the long axis parallel to the direction of the wind.Often the direction of the wind is not constant but may vary through an angoe of 30 or 40°.In this case,the initial pattern of spread will assmue a fan-shape area.Regardless of circle or ellipse and fan-shape,thier profiles are parabolic curves.

The expression of parabola is $y^2=\alpha x$ or $y=(\alpha x)^{1/2}$,to integrate this equation can be obtained the following formula to calculate the burned area.

$$A(\text{burned area})=2/3oc\cdot bb'$$

where oc :the distance from the orgin of ignition to front and bb':the length of fire front,simplified the shape,anynoe of fire burned area must be involved into the reclangle of oc×bb.All values of the fire spread characters can be calculated in table 6[8].

Table 6 Wind Scale For some Basic Factors and Spread Characters

wind force scale	fun.of tangent*	times (min)	spread rate (m/min)	oc (m)	bb' (m)	a fire area (ha)	perimeter(m)
1-2 tg 25^{0}	0.47	t	R	Rt	0.94Rt	$0.63(Rt)^{2}/10^{4}$	3.1Rt
3-4 tg 20^{0}	0.36	t	R	Rt	0.72Rt	$0.48(Rt)^{2}/10^{4}$	2.9Rt
5-6 tg 15^{0}	0.27	t	R	Rt	0.54Rt	$0.36(Rt)^{2}/10^{4}$	2.6Rt
> 7 tg 10^{0}	0.18	t	R	Rt	0.36Rt	$0.24(Rt)^{2}/10^{4}$	2.4Rt

***Experimental data**