THE GROUND SURFACE DOWN–WIND FIRE SPREAD REGULARITY AND THE FIRE SPREAD MODEL

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ABSTRACT

Some buring testing were carried out on the grassy massland in Da Xing–An–Ling combining with burning control–line in spring and Autumn and under the forest of Populus, Betula, Ourecus, Larix in Xiao Xing–An–ling The wild fire burning testing were also simulated in a laboratory. Based on the observing data collected for three years. The effect factors to the fire spread are the wind, the slope, the atmosphere temperature, the fuel moisture, the fuel loading, and the fuel surface–area–to–volume ratio. their effects and the regularity are analysed by the regression method. As a result, some fire spread models had been found.

Fire spread speed is a linear combination of the factors mentioned above. The mathematical models reveal that the wind speed and the fuel moisture are the most significant factors affecting the fire spread speed; then is the slope, the fuel loading, the fuel surface–area–to–volume, the temprature; the effect of humidity is relatively small.

The flame length is mainly detemined by the fuel loading, the wind, the fuel moisture; then is the temperature, the slope, the fuel surface–area–to–volume ratio.

Key Word: The Ground Surface Fire, Fire spread Speed, Flame Length

INTRODUCTION

Over 80% of former forest fires, the ground surface fire is the most common one. It is important to study the spread regularity of such fires down–wind for the estimation of fire head front speed, fire intensity, fire area and fire–line length. It is also very useful in fire control and prescribed burning.

METHODS OF RESEARCH

1. Burning Testing On The Grassy Massland

The test area was located in Da–Xing–An–Ling forest region. There are a broad and plain gullies

where there are lots of sun herbaceous plant and small bush. These formed a large area grassy massland. Testing were combined with buring control–line in every spring from 1981 to 1983.

We arranged 5 specimen–lands (1m × 1m) randomly on a side of the section of testing area before every testing burning. The fuel samples were gotten from the ground and stoved. The fuel loading and fuel moisture were calculated.

Surveyor's poles were set up by the prescribed intervel (5m or 10m) on the testing area. The time that the fire reached the poles and the fire length were measured. After that, the fire spread speed were calculated. At the same time the wind speed, atmosphere temperature and relative humidity were measured.

2. Burning Testing In The Forest

The test area were located in Xiao–Xing–An–Ling ecology testing station in 1987. The sections of land with same slope and even continuous fuels (2–5m × 20–50m) were selected. Around the section isolation zone were opened up. The way of sampling was the same as that of grass. Then the dry–moisture ratio, fuel loading, fuel moisture, fuel surface–to–volume ratio were calculated.

3. Laboratory Simulation Testing of Burning In The Forest

some fuels of certain weight and thick were put on a special made burning bed (5m × 1m). The inclination of bed was equal to the slope. The way of measurement was the same as that in forest.

THE EFFECT FACTORS OF FIRE SPREAD AND ITS REGULARITY

There are some main factors affecting fire spread, such as wind speed, slope, fuel moisture, fuel loading, fuel surface–area–to–volume ratio and atmosphere temperature.

1. Wind Speed

The wind speed is positively correlative with the fire spread speed. Blown with the wind, the blazes are forward and make the fuel in front of the fire get more radiative heat. At the same time, heat convection is changed into heat advection. Advective hot air can accelorate the fuel heating and drying to burning point.

The relationship between wind speed and flame length is complex. The flame length is positively correlative with the wind speed when the wind speed is low (< 3m / s). As the oxygen can be provided quickly by the wind. The flame length become lower when the wind speed increases (> 3m / s) because the flame are forward inclined.

2. Slope

The affecting of slope to fire spread speed is similar to that of wind speed. Burning on a slope, fire gives more radiative heat to the fuel before it and enhances the advective heating. The fire goes faster on a slope but may not be so accounting in horizontal distance. The horizontal speed will be high if with the wind. Through the experiments we can see, the bigger the slope (< 15), the higher the fire spread speed. The slope helps to increase the flame length because the oxygon provision and fuel heating become easier. That accelorates the burning reaction so the flames are enhanced vertically.

3. Atmosphere Temperature

High atmosphere temperature is favorable to burning. The fire spread speed and flame length are positively correlative with the temperature. When atmosphere temperature increases, so does the fuel temperature and the fuel becomes drier. The last factor plays a more important part in fuel burning.

4. Fuel Moisture

Fuel moisture is negatively correlative with fire spread speed and flame length. As the higher the fuel moisture, the longer the time getting the fuel temperature to burning point and the more heat consumed to dry the fuel so the slower the fire spread. If the fuel moisture reaches a certain level, the heat of the fire is not enough to dry the fuel so that the fuel temperature can not get to its burning point. Therefore, the burning stops and the fire disappears.

5. Fuel Loading

Fuel loading is positively correlative with fire spread speed and flame length. The more the fuel loading, the more heat given out when burning, so the faster the fire spread. At the same time, great amount of combustible gas is produced so that the flames arise highter. In forests the surface fuel have the most significant influence on fire spread speed and flame length.

6. Fuel Surface–Area–To–Volume Ratio

If the fuel is dense, its continuity is good for burning but air supply is insufficient as the intervals in the fuel are small. Otherwise there is not so good continuity in the fuel but a great amount air supply. Based on the facts mentioned above, there exists an optimum value of fuel surface–area–to–volume ratio by which fire burns the most difficult.

FIRE SPREAD MODEL

Prediction models have been made through multi–variable regression with the fire spread data gathered from experiments on grasslands, on ground surface in the forest and in the laboratory.

1. The spread Speed Model of Down–Wind Fire on Grassland

$$R=0.3370+0.066V-0.0052M$$

where R—down–wind fire spread speed (m / min.)

V—wind speed (m / s)

M—fuel moisture (%)

2. The Spread speed Model of Down–Wind Ground Surface Fire In Forest and the Flame length Model

(1). Fire Spread Speed Model

$$R=-3.7052+0.1128P+0.1381T+1.3248V-0.0263Ms$$

where R—the spread speed of down–wind Ground surface fire (m / min)

P—slope (%)

T—atmosphere temperature (℃)

V—wind speed 1.5m above ground surface (m / s)

Ms—surface fuel moisture (%)

(2). Flame Length Model

$$H=-29.092+1.144P+1.741T+12.458V-0.3371Ms+7.806Ws$$

where H—even flame length of down–wind Ground surface fire (cm)

Ws—surface fuel loading (kg / m^2)

3. The Spread Speed Model and the Flame Length Model of down–Wind Ground Surface Fire in Forest by Laboratory Simulation

(1). Fire Spread Speed Model

$$R=0.5904+1.025W-0.0898B+0.1711V$$

where R—the spread speed of laboratory simulation fire (m / min)

W—effective fuel loading (kg / m^2)

B—fuel surface–area–to–volume ratio (kg / m^3)

V—the speed of simulation wind (m / s)

(2). Flame Length Model

$$H=10.977+97.48W-2.959B+1.1018V+1.1633T$$

where H—even flame length (cm)
T—air temperature in laboratory (℃)

CONCLUSION

1. From the models above we can see that the fire spread speed is mainly affected by wind speed and fuel misture. factors as slope, fuel loading, fuel surface–area–to–volume ratio are used when topography and fuel type are changed. Atmosphere temperature although gives some effect. Relative humidity only affects it a little.
2. The flame length is mainly determined by fuel loading, wind speed, fuel moisture; then is the temperatuer, slope, fuel surface–area–to–volume ratio.
3. In the field experiments are dangerous, inefficient and dependent on seasons so more laboratory experiments are suggested though the means have to be improved.

DISCUSSION

In calculation the effective wind speed and the fire spread direction have also to be considered. The effective wind speed is a combination of the effects of wind and slope. It is a function of midflame wind, slope, fuel type. For example, the effective wind speed is a 5km / h for no wind and 60 percent slope and also for a 5 km / h wind and no slope. That is, for this particular example, no wind and a 60 percent slope is effectively as same as 5 km / h wind on the flat. Effective wind speed lets us see the relative effects of wind and slope on prediction. Different fuel types have different effective wind speed.

Wind and slope both have an increasing effect on fire speed in the same direction. In addition, it is possible to obtain prediction for any other direction of speed. Whenever slope and wind are nonzero, wind direction is required. It is favorable to making strategic decision of fire–fighting when taking wind direction (i.e. fire spread direction) into account.

Directions are regarded as degrees clockwise from upslope (when there is a slope). Direction of the wind vector is the direction of the effective wind speed, that is, the direction that the wind is blowing to. If the wind is blowing directly upslope, the direction of the wind vector is regarded as 0; if the wind is blowing directly downslope, 180 is regarded, any value from 0 to 360 can be regarded.

Fire spread direction upslope; wind direction upslope or upward cross–slope, in effect, head fire rate of spread is reinforced by both wind and slope. Fire spread direction downslope; wind direction downslope or downward cross–slope, the slope effect is cancelled but the wind effect remains.

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