Evaluate the effect of observed fuel moisture content on burn-ability of forest in the Tohoku region

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1. INTRODUCTION

Ignition is the initial stage of combustion and is one of the most important processes of fire disaster. As the main fuel source for surface fires, to a certain extent, the in-depth study of the duff layers is the key to the simulation of the subsequent fire development and spreading process, also for the subsequent reduction of the fire risk. And the control of fire danger provides a certain theoretical basis.

The fuel moisture affects the combustibility and is a major factor of the occurrence and development of wildfires, which in turn affects the fire probability, spread speed, and fire behavior (Fang et al., 2006).

In this study, through on-site sampling experiments, the changes in the duff moisture content of four tree species in the Tohoku Region of Japan were observed and analyzed. Considering of the general combustion process of forest combustibles, use formulas to calculate the burn-ability of combustibles. Evaluate and demonstrate the effect of moisture content in the sample on heat required for ignition and fire process.

2. METHODOLOGY

2.1. Field sites and sampling

Aobamori (**fig.1**), located in Sendai City, Miyagi Prefecture, was selected as the observation field. The observation period is from March 18 to April 4 and August 20 to August 28 in 2020.

Fig.1. Map of Aobamori

Four fuel species selected. The four sites are cedar, broadleaf, cypress and pine zone. Three collection points were selected at each site, and the surrounding terrain was taken into consideration. Samples were collected daily on no-rain days, and randomly collect duff sample at each point. In March, mixed sampling of the upper and lower layers of the garbage layer was carried out, and in August, only the upper layer of the garbage layer was collected. Measure soil moisture at the same place. Dry in the laboratory and weigh wet and dry mass.

2.2. H_{rr} for ignition

The spread of fire can be regarded as the process of fuel igniting the unburned area from the burned area during the energy transfer. When the fuel absorb heat and reach the ignition temperature, these fuel will be ignited and the flame front spreads there (Rothermel, 1972).

Consider define H_{rr} with Q_g and Q_i, makes H_{rr} has a physical meaning. It is feasible to be used to evaluate the extreme climate as dryness index. The formula is:

$$H_{rr} = \frac{Q_g}{Q_i} \qquad 1)$$

Where $H_{rr}(\mathrm{m}/min)$ is heat release rate. Q_g $(\mathrm{KJ/m^2/min})$is the heat flux received from the source, represents the rate of heat generated per unit fuel bed. Q_i $(\mathrm{KJ/m^3})$ is the heat required for ignition by the potential fuel, represents the heat required to raise a unit volume of fuel bed to the ignition temperature.

In this study, the value of Q_g quoted the experimental results of Zhang et, al.(1998).

Rothermel put forward in the mathematical model of forest fire spread, the calculation equation of heat required for ignition of unit mass combustibles is:

$$Q_{ig} = C_{pd} \cdot \Delta T_g + M_f (C_{pw} \cdot \Delta T_b + V_b) \qquad 2)$$

Where C_{pd} (kJ·kg^{-1}·°C^{-1}) is the specific heat of fuel, ΔT_g (°C) is the temperature range to ignition, M_f (%) is the fuel moisture content, C_{pw} (kJ·kg^{-1}·°C^{-1}) is the specific heat of water, ΔT_b (°C) is the temperature range to boiling, V_b (kJ·kg^{-1}) is the latent heat of vaporization.

Zhang proposed the following equations base on it.

$$Q_{ig} = C_{pd} \cdot \Delta T_g \left(1 - M_f\right) + M_f \left(C_{pw} \cdot \Delta T_b + k \cdot V_b\right) \qquad 3)$$

Where k is the vaporization coefficient of water vaporization in wood combustible equivalent to pure water, dimensionless. Combine the above two formulas. I will use the following formula to calculate Q_i .

$$Q_i = C_{Pd} \cdot \Delta T_g \left(1 - M_f\right) + M_f (C_{Pw} \cdot \Delta T_b + V_b) \qquad 4)$$

Among them, the values of C_{pd} and T_g are also quoted the experimental results of Zhang. Assume that the room temperature is 15 degrees in spring and 35 degrees in summer. The fuel moisture is the observation data of this

Keywords: Fuel moisture content; Burn- ability; Wildfire; Dryness
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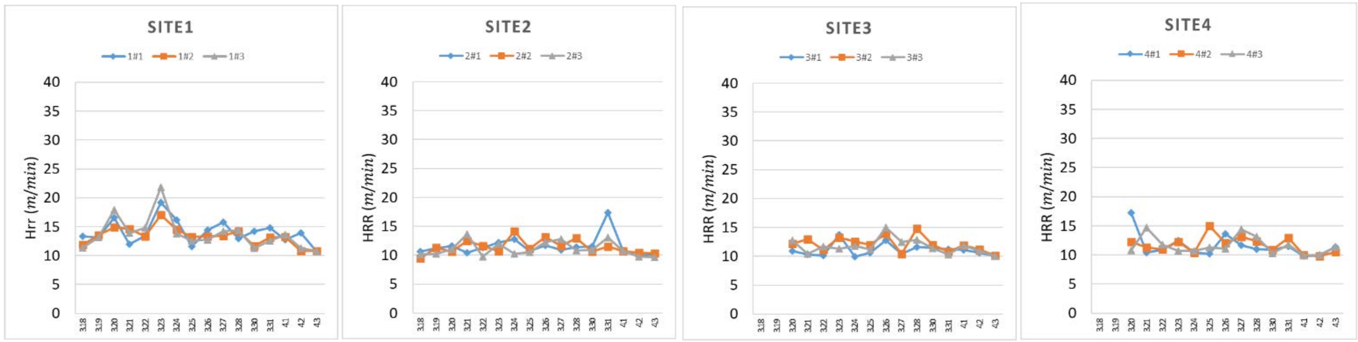
research. The specific heat of water is 4.1868 $kJ^{-1} \cdot kg^{-1} \cdot ℃^{-1}$. The values of T_b and V_b are 100℃ and 2256.6852 kJ/kg.

3. RESULTS AND DISCUSSION

March



August

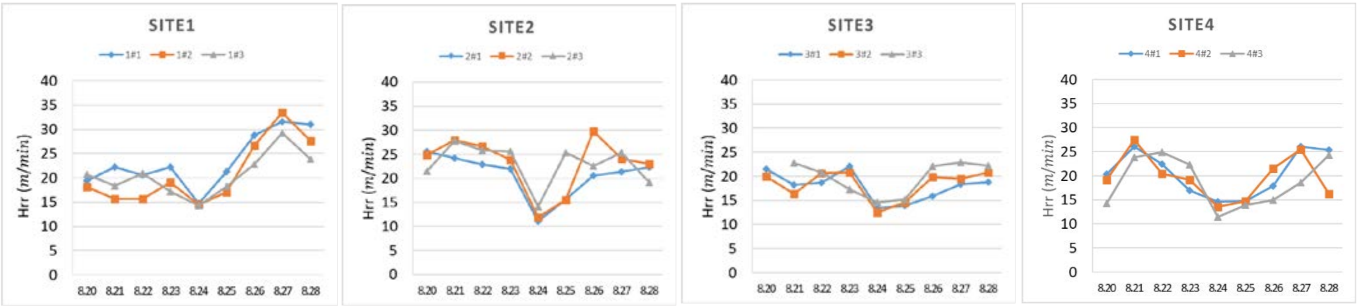


Fig.2. The H_{rr} time series of four sites in March and August

Based on the observation data and experimental results, the value of H_{rr} was calculated by formula. Based on the definition of H_{rr}, the larger value of H_{rr}, the smaller heat required for ignition. In a word, the burning capacity of the fuel is stronger. It can be seen from the **fig.2** that the range of H_{rr} is 10-20 in spring and 10-30 in summer. Due to rain on August 24, H_{rr} dropped significantly. After that, it kept rising continuously when there was no rain. And compared to spring, the increase trend in summer is very significant. This can be explained by the intensity of evaporation, Evaporation intensity is the function of air temperature, so trend is higher in summer. It is worth noting that the upward trend of the four sites is different. We believe that this is due to the difference in characteristics between species, which is the key to the investigation of different species in this research. In addition, since the data from the Sendai City Meteorological Observatory cannot describe the field well, we decided to install the lysimeter and meteorological station.

4. CONCLUSIONS

As a whole, the increase of H_{rr} is very significant after rain, and the growing trend of species is meaningful. It is feasible to evaluate the impact of dryness on the fire severity by analyzing $\mathrm{H_{rr}}$.

In terms of burn-ability, it should be discussed from three aspects: dead, short vegetation, crown. What we observed is only dead fuel, but living plants would prevent fire surface expansion. Due to the high temperature in summer, the moisture evaporation intensity of fuel is higher than that in spring, so the FMC of duff is lower than that in spring, but because there are large amounts of live plants in summer, this has a negative effect on the spread of fire.

In the future, for surface burn-ability, not only the dead fuel, living plants should be considered. We will estimate H_{rr} by using the Fuel moisture model. Analysis evaporation intensity of species to evaluate the burn-ability.

ACKNOWLEDGEMENT

This research was supported by the Ministry of Education, Science, Sports and Culture, Grant-in Aid for Scientific Research(B), 2020-2023 (20H02248, Yoshiya Touge).

REFERENCES

Fang, M. X., et al. Kinetic study on pyrolysis and combustion of wood under different oxygen concentrations by using TG-FTIR analysis, Journal of analytical and applied pyrolysis 77.1 (2006): 22-27.

Rothermel, Richard C. A mathematical model for predicting fire spread in wildland fuels. Vol. 115. Intermountain Forest & Range Experiment Station, Forest Service, US Department of Agriculture, 1972.

Zhang, J. Q., et al. Heat Balance Analysis on Burning Process of Woody Plants, Journal of Northeast Forestry University (1998), 26 (5). 34-38.