พฤติกรรมไฟในป่าเต็งรัง เขตรักษาพันธุ์สัตว์ป่าห้วยขาแข้ง จังหวัดอุทัยธานี

Fire Behavior in Dry Deciduous Dipterocarp Forest at Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province

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บทคัดย่อ

การศึกษาพฤติกรรมไฟในป่าเต็งรัง เขตรักษาพันธุ์สัตว์ป่าห้วยขาแข้ง จังหวัดอุทัยธานี มีวัตถุประสงค์เพื่อศึกษาพฤติกรรมไฟและเพื่อหาความสัมพันธ์ระหว่างพฤติกรรมไฟกับปัจจัยสิ่งแวดล้อมบางประการ ผลการศึกษาจะได้นำไปปรับใช้ในการควบคุม และดับไฟป่าที่เกิดขึ้นในพื้นที่ ในการศึกษาได้วางแปลงตัวอย่างขนาด 200 เมตร x 200 เมตร จำนวน 21 แปลง เพื่อเก็บข้อมูล พฤติกรรมไฟ สมบัติเชื้อเพลิง และปัจจัยด้านอากาศ ผลการศึกษา พบว่า อัตราการลุกลามไฟเฉลี่ย 1.89 เมตร/นาที ความรุนแรงไฟเฉลี่ย 190 กิโลวัตต์/เมตร ความยาวเปลวไฟเฉลี่ย 0.86 เมตร อัตราการลุกลามของไฟมีความสัมพันธ์ไปในทางเดียวกันกับความเร็วลมและความสูงของแหล่งเชื้อเพลิง และมีความสัมพันธ์ไปในทางตรงกันข้ามกับความชื้นของเชื้อเพลิงสด พฤติกรรมไฟมีความรุนแรงในระดับต่ำถึงปานกลาง พนักงานดับไฟป่าสามารถเข้าดับไฟได้โดยตรง ทั้งด้านหัวไฟ ปีกไฟ และหางไฟ แนวควบคุมไฟที่มีความกว้างอย่างน้อย 4 เมตร สามารถควบคุมไฟไว้ได้ ควรมีการเตรียมความพร้อมเมื่อมีไฟเกิดขึ้นและมีลมพัดแรง ข้อแนะนำในการจัดการเชื้อเพลิง ได้แก่ ควรดำเนินการลดความสูงของแหล่งเชื้อเพลิงและรักษาระดับความชื้นของเชื้อเพลิงสดให้สูงอยู่เสมอ

คำสำคัญ: พฤติกรรมไฟ, ปัจจัยแวดล้อมของไฟ, ป่าเต็งรัง

ABSTRACT

The study on fire behavior in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province is aimed to determine fire behavior and to find relationships between the fire behavior and some environmental factors. The results of the study will be applied to fire control and fire suppression in the area. Total twenty one burning plots with 200m x 200m size of each were established in experimental burning site for fire behavior data collection. In addition, fuel properties and fire weather data were collected. The results revealed that averages of rate fire spread, fireline intensity and flame length were 1.89 m min^{-1}, 190 kW m^{-1} and 0.86 m, respectively. Rate of fire spread was related positively to wind velocity and fuel bed depth, but it was related negatively to moisture content of live fuel. Fire behavior was low to moderate fire intensities, that could generally be attacked at the head, flanks and rear fires by firefighters using hand tools. Hand line with at least 4 m wide could hold the fire and it should be at top alert when wind velocity was strong. Reduce the fuel bed depth and maintain high moisture content of live fuel are recommended for fuel management.

Key Words: fire behavior, fire environmental factors, dry deciduous dipterocarp forest

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INTRODUCTION

Forest fire is unclosed and freely spreading combustion which consumes the natural fuels of a forest. i.e., duff, grass, weeds, brush, and tree (Brown and Davis, 1973). Fire behavior is generally defined as the manner in which fuel ignites, flame develops, fire spreads and exhibits other related phenomena such as fire whirls (Countryman, 1964) as determined by the interaction of fuels, weather, and topography (Brown and Davis, 1973). This definition is resemble the National Wildfire Coordinating group as "the manner in which a fire reacts to the influences of fuel, weather and topography". From this definition, the primary factors influencing fire behaviors are fuel, weather and topography. The popular fire behavior descriptors are rate of fire spread, fire intensity and flame length. Rate of fire spread is the speed at which the fire moves across the landscape. It is the primary description of fire behavior and its prediction is crucial to achieve effectiveness in both wildfire control and application of prescribed burning (Mendes – Lopes *et al*., 1998). The fastest rate of spread is the forward rate of spread at the head of the fire. The backward rate of spread is much less, and rate of spread at the fire flanks is intermediate. Fire intensity is the rate of heat energy released during combustion. Flame length is the distance measured from the average flame tip to the base of the flame in the middle of the flame zone (Teie, 1997).

A study of fire behavior in dry deciduous dipterocarp forest (DDF) at Doi Suthep-Pui National Park, Chiang Mai Province. The results were found that rates of fire spread ranged from 0.28 to 6.41 m min^{-1} and fireline intensities ranged from 33.72 to 883.58 kWm^{-1} while, fire behavior in DDF at Kanchanaburi Province during fire season, the average fire spread of head fire was 2.81 m min^{-1}, flank fire and rear fire had the rates of spread of 0.59 and 0.40 m min^{-1}, respectively. The most severe fire occurred in early March when rate of fire spread reached 6.96 m min^{-1} on a 45 % slope (Akaakara, 2000). Sunyaarch (1989) studied fire behavior in DDF at Sakaerat, Nakhon Ratchasima Province and found that fireline intensity, rate of fire spread and flame length from burning in February were 266.03 kWm^{-1}, 2.00 m min^{-1} and 2.58 m, respectively.

Forest fire in Huai Kha Khaeng Wildlife Sanctuary (HKKWS) and Buffer Zone Area (BZA), that located around the eastern border of HKKWS have usually been burnt during dry period. Forest fire always occurs from mid December to late April and the peak fire season is in March. The fire has usually started in DDF located in BZA during the early fire season and spread into mixed deciduous forest later. In addition, extreme drought year the fire would burn in dry evergreen forest at the core area of HKKWS as well. The daily fire or inappropriate fire is an important problem causing damage and decreasing richness and diversity of HKKWS and BZA ecosystem: e.g. decreasing forest health, tree quality, soil fertility and destroying seedling, etc. Consequently, surface run off, failed succession and danger to wildlife are evident. Hence, the study on fire behavior and the relationships between fire behavior and some environmental factors should be conducted in DDF at HKKWS. The results of the study will be applied to fire control and fire suppression particularly in DDF at HKKWS.

MATERIALS AND METHODS

Study Site

HKKWS is located between 14º 56´ and 15º 48´ N latitudes and between 98º 58´ and 99º 28´ E longitudes. Altitudes of the area range from 160 to 1,687 m. The climate is divided into three distinct seasons: summer is from February to April, with the temperature ranging 24-38 ^{0}C. Rainy is from May to October, with the temperature ranging 23-34 ^{0}C. Winter is from November to January, with the temperature ranging 18-20 ^{0}C. The annual rain intensity is about 1,500 mm in HKKWS and between 800-1,200 mm in BZA. The average relative humidity is 55 %. The forest types include DDF, mixed deciduous forest, bamboo forest and evergreen forest. In addition, there are sub-forest types cover the area including rocky forest, pine forest, stream-sand dune vegetation and scrub forest. HKKWS is the large home of wildlife including 68 species of mammals, 355 species of birds, 77 species of reptiles, 29 species of amphibians and 55 species of fresh water fishes (Faculty of Forestry, 2000).

Sample Plot and Data Collection

The total 21 burning plots with 200m x 200m size of each were established in experimental burning site for fire behavior data collection. The data collection was conducted between 10.00 am. and 3.00 pm. from February to March 2007 that was the peak of fire season in HKKWS. A metal post was staked at the center of the burning plot and other metal posts were staked along the 8 cardinal points of the compass, at 10 m intervals. Before fire was ignited in the burning plot fuel properties namely: loading and moisture content were recorded from 5 sampling plots with 1m x 1m size of each, which located in the north, south, east, west and center of the burning plot. Fuels were classified into 2 categories, dead and live. Dead fuel included: litter, twig and dead herb and live fuel included live herb and undergrowth. Loading and moisture content were classified into dead and live categories. Fuel bed depths were measured along the 8 radius lines of the burning plot. Fire was ignited at the center of the burning plot. During burning, the distances of fire spreads were recorded for every 5 minutes at total of 8 directions. Wind velocity, air temperature and relative humidity were also recorded in every 5 minutes as same as fire behavior data. When the fire reached to edge of the burning plot, burning time was recorded, the distances of fire spread on the 8 radius lines of burning plots were marked. Then, the fire was suppressed immediately.

Data Analysis

Rate of fire spread was the distance of flame zone move per a unit of time, that was expressed in meter per minute (m min^{-1}). Fireline intensity and flame length were determined by using Byram's (1959) formula. Moisture content was calculated on a dry weight percentage basis. Fuel Load was determined on dry weight basis, that was expressed in ton per hectare (ton ha^{-1}). Average, minimum, maximum and coefficient of variation were expressed for the results of the study. Pearson's correlation and regression analysis with stepwise method were applied to determine the relationships between fire behaviors and some environmental factors.

RESULTS

Fire behavior

Average rate of head fire spread was 1.89 m min^{-1} with minimum and maximum values of 0.57 and 3.94 m min^{-1}, respectively and coefficient of variation was 52.91 %. Average intensity of head fire was 190 kWm^{-1} with minimum and maximum values of 36 and 372 kWm^{-1}, respectively and coefficient of variation was 52.24 %. Average flame length of head fire was 0.86 m with minimum and maximum values of 0.41 and 1.22 m, respectively and coefficient of variation was 26.74 %.

Average rate of flanks fire spread was 0.66 m min^{-1} with minimum and maximum values of 0.30 and 1.34 m min^{-1}, respectively and coefficient of variation was 48.48 %. Average intensities of flanks fire was 67 kWm^{-1} with minimum and maximum values of 20 and 137 kWm^{-1}, respectively and coefficient of variation was 52.99 %. Average flame length of flanks fire was 0.54 m with minimum and maximum values of 0.32 and 0.77 m, respectively and coefficient of variation was 24.07 %.

Average rate of rear fire spread was 0.42 m min^{-1} with minimum and maximum values of 0.22 and 0.80 m min^{-1}, respectively and coefficient of variation was 33.33 %. Average intensity of rear fire was 43 kWm^{-1} with minimum and maximum values of 14 and 87 kWm^{-1}, respectively and coefficient of variation was 43.56 %. Average flame length of rear fire was 0.44 m with minimum and maximum values of 0.27 and 0.62 m, respectively and coefficient of variation was 20.45 %.

Chaiwatana (2003) studied fire behavior in DDF at HKKWS found that rate of fire spread was 0.95 m min^{-1}, fireline intensity was 227.48 kWm^{-1} and flame length was 1.15 m. Sompoh (1998) also studied fire behavior in DDF at HKKWS and found that fireline intensity was 110.71 kWm^{-1} and flame length was 0.70 m. The results of present study were closely to the results found by Sompho (1998). While, compared with the study of Chaiwatana (2003) rate of head fire spread was higher, but the fireline intensity and flame length were lower due to the amount of available fuel. The fire behaviors of the study were less than in Doi Suthap-Pui National Park due to the differences of topography between northern and central parts.

Environmental Factors

Fuel factors were determined before burning namely: loading, moisture and depth. Average loading of dead fuel was 4.64 ton ha^{-1} with minimum and maximum values of 2.88 and 7.70 ton ha^{-1}, respectively and coefficient of variation was 22.63 %. Average loading of live fuel was 0.73 ton ha^{-1} with minimum and maximum values of 0.27 and 1.71 ton ha^{-1}, respectively and coefficient of variation was 54.79 %. While, Akaakara *et al.* (2004) found only 4 ton ha^{-1} of average fuel loads in DDF at HKKWS. The fuel load measured by Akaakara *et al.* (2004) was composed of litter, twig, grass and undergrowth, while this study added live herb into the fuel loads.

Average moisture content of dead fuel was 12.43 % with minimum and maximum values of 7 and 25 %, respectively and coefficient of variation was 32.42 %. Average moisture content of live fuel was 84.81 % with minimum and maximum values of 43 and 122 %, respectively and coefficient of variation was 24.71 %. Fuel bed depth is sometimes called fuel bed bulk depth. Average fuel bed depth was 12.57 cm with minimum and maximum values of 5 and 25 cm, respectively and coefficient of variation was 52.77 %.

Weather factors were determined during burning namely: temperature, relative humidity and wind velocity. Average weather temperature was 34.43 °C with minimum and maximum values of 27 and 39 °C, respectively and coefficient of variation was 10.82 %. Average relative humidity was 58.19 % with minimum and maximum values of 37 and 75 %, respectively and coefficient of variation was 19.17 %. Average wind velocity was 3.55 km h^{-1} with minimum and maximum values of 1.41 and 5.47 km h^{-1}, respectively and coefficient of variation was 33.82 %.

Forest Fire Research Centre (2006) reported average, minimum and maximum values of temperature from February to March as 26.92, 19.72 and 33.87 °C, respectively, and average relative humidity as 84.57 %. The average temperature of this study was closely to the maximum value in the whole area but the relative humidity was lower due to fire behavior data collection was conducted between 10.00 am and 3.00 pm. while, there were high weather temperature and low relative humidity in the burning site.

The Relationships between Fire Behavior and Environmental Factors

Fire behavior is the manner in which a fire reacts to the influences of fuel, weather and topography. The study was focused only on fuel properties and some weather data due to the limitation of topography factor in the study area. Table 1 showed the results of Pearson's correlation analysis of rate of fire spread, fireline intensity and flame length were related positively to wind velocity and fuel bed depth and they were related negatively to moisture content of live fuel. In addition, fireline intensity and flame length were related positively to loading of live fuel.

Table 1 Correlations between fire behaviors and environmental factors in DDF at HKKWS

	Lod	Lol	Mod	Mol	Hei	Tem	Rh	Win	Ros	I_B	Fl
Lod	1.00										
Lol	0.03	1.00									
Mod	0.10	-0.12	1.00								
Mol	-0.16	-0.05	0.18	1.00							
Hei	0.01	0.51*	-0.32	0.58**	1.00						
Tem	0.35	-0.28	0.08	-0.07	-0.16	1.00					
Rh	0.27	-0.18	0.24	-0.24	0.13	0.53*	1.00				
Win	-0.38	0.43	-0.36	-0.53*	0.61**	-0.34	-0.23	1.00			
Ros	-0.35	0.37	-0.38	-0.59**	0.78**	-0.39	-0.26	0.84**	1.00		
I_B	-0.05	0.56*	-0.39	-0.63**	0.89**	-0.29	-0.12	0.75**	0.91**	1.00	
Fl	-0.01	0.53*	-0.44*	-0.67**	0.86**	-0.32	-0.13	0.76**	0.90**	0.99**	1.00

Abbreviations: Lod=Dead fuel loading, Lol=Live fuel loading, Mod=Moisture content of dead fuel, Mol=Moisture content of live fuel, Hei=Fuel bed depth, Tem=Temperature, Rh=Relative humidity, Ros=Rate of fire spread, I_B=Fireline intensity, Fl=Flame length.
* and ** Correlations (Pearson's correlation coefficients) significant at the 5 and 1 % level of significance, respectively.

Table 2 showed the regression equations with stepwise method for the fire behaviors only wind velocity (Win) and fuel bed depth (Hei) had influent to rate of fire spread (Ros), fireline intensity (I_B) and flame length (Fl).

Table 2 Regression equations of fire behaviors in DDF at HKKWS

Order	Equation	R^2
1	Ros = 0.49 Win + 0.06 Hei	0.80
2	I_B = 9.90 Hei + 27.74 Win	0.84
3	Fl = 0.34 + 0.02 Hei + 0.07 Win	0.81

Akaakara *et al.* (2003) reported forest fire in DDF at HKKWS and found that rate of fire spread related positively to weather temperature. Fireline intensity related positively to loading of undergrowth and weather temperature. Flame length related positively to loading of grass. For instant, Bilgili and Saglam (2003) reported that rate of fire spread of maquis fuels in Turkey was related positively to wind velocity and fuel bed depth.

DISCUSSION

According to the fire control interpretation of Andrew (1980), fire behaviors in DDF at HKKWS were low to moderate fire intensities with rates of head, flanks and rear fire spread were 1.89, 0.66 and 0.42 1.89 m min^{-1}, respectively, fireline intensities of those were 190, 67 and 43 kWm^{-1}, respectively and flame lengths of those were 0.86, 0.54 and 0.44 m, respectively. The behavior of head fire was the highest in the values of rate of spread, fireline intensity and flame length. The next of those were flanks fire and rear fire, respectively. The results should be applied by firefighters for planning of fire suppression and fire break construction. The fire was surface fire, that consumed the fuel on the ground such as fallen leaves, twigs, herbaceous plants, seedlings, saplings etc. thus, the fire behavior was creeping fire with rate of head fire spread between 0.57 and 3.94 m min^{-1} that was not seriously like crown fire. In addition, the wind velocity in dry deciduous forest was not strong, due to the fact that there are dense of tree that were natural wind break.

The fire behaviors were related positively to wind velocity due to wind is served a factor effecting the rate of oxygen supply to the burning fuel. In addition, strong wind tilts the flame closer to the unburned fuel, this is increasing the heat flux to the unburned fuel by increasing effective flame radiation and heat convection. While, the fuel depth affects the bulk density and its always used in describing the compactness of fuel beds. The bulk density of a fuel bed can be used as a measurement of the oxygen availability and distance between particle across which heat must be transferred to ignite additional fuel (Fahnestock, 1960). For instance, the moisture content of live fuel was related negatively to fire behaviors due to the higher of fuel moisture content will prolong the fuel ignition. Any moisture released from the fuels absorbs some heat energy from the fire and then limiting combustion temperature. Loading of live fuel was related positively to fireline intensity and flame length due to fuel loading was used to determine fireline intensity and flame length in Byram's (1959) formula.

Based on the results of study, fire suppression in DDF at HKKWS could generally be attacked at the head, flanks and rear fires by firefighters using hand tools accompanying with backpack pumps. Hand line, at least 4 m wide could hold the fire. It should be at top alert and took machine equipments to support fire control and suppression when wind velocity was strong. Reduce the fuel bed depth and loading of live fuel and maintain high moisture content of live fuel are recommended for fuel management.

CONCLUSION

Fire behavior in DDF at HKKWS was low to moderate fire intensities with rates of head, flanks and rear fire spread were 1.89, 0.66 and 0.42 m min^{-1}, respectively, fireline intensities of those were 190, 67 and 43 kWm^{-1}, respectively and flame lengths of those were 0.86, 0.54 and 0.44 m, respectively. Fuel properties: loadings of dead and live fuels were 4.64 and 0.73 ton ha^{-1},respectively, moisture contents of dead and live fuels were 12.43 and 84.81 %, respectively and fuel depth was 12.57 cm. Rate of fire spread, fireline intensity and flame length were related positively to wind velocity and fuel bed depth and they were related negatively to moisture content of live fuel. In addition, fireline intensity and flame length were related positively to loading of live fuel. Fire behavior was low to moderate fire intensities, that could generally be attacked at the head, flanks and rear fires by firefighters using hand tools. Hand line, at least 4 m wide could hold the fire. Top alert should be made and took machine equipments to support fire control when wind velocity was strong. Reduce the fuel bed depth and loading of live fuel and maintain high moisture content of live fuel are recommended for fuel management.

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