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Fire Behavior in Pelalawan Peatland, Riau Province

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ABSTRACT

During dry season it is easily recognized that smoke will emerge at certain place both in Sumatra and Kalimantan that is in peatland. The worst situation occurred when fire burnt buried log in the logged over area where the fire fighter did not have any experience and knowledge on how to work with fire in peatland. Finally it had been found that one of the reasons why firefighter failed to fight fire in peatland is because they do not have any knowledge and experience on it. In order to know the fire behavior characteristics in different level of peat decomposition for fire management and sustainable management of the land for the community, research done in Pelalawan area, Riau Province, Indonesia, during dry season 2001. Three level of peat decomposition named Sapric, Hemic, and Fibric used. To conduct the research, two 400 m^2 of plot each was established in every level of the peat decomposition. Burning done three weeks following slashing, cutting and drying at different time using circle method. During burning, flame length, rate of the spread of fire, flame temperature and following burning fuel left and the depth of peat destruction were measured. Results of research shown that in sapric site where sapric 2 has fuel load 9 ton ha^{-1} less than sapric 1, fire behavior was significantly different while peat destructed was deepest in sapric 2 with 31.87 cm. In hemic site where hemic 2 has fuel load 12.3 ton ha^{-1} more than hemic 1, fire behavior was significantly different and peat destructed deeper than hemic 1 that was 12.6 cm. In fibric site where fibric 1 has fuel load 3.5 ton ha^{-1} more than fibric 1, fire behavior was significantly different that has no burnt peat found. This results found that the different fuel characteristics (potency, moisture, bed depth, and type) at the same level of peat decomposition will have significantly different fire behavior as it happened also on the depth of peat destruction except fibric. The same condition occurred in the fire behavior at different level of peat decomposition.

Key words: Fire, fuel, peat, sapric, hemic, fibric, Pelalawan.

INTRODUCTION

Transboundary haze pollution due to the smoke from land preparation using fire become a big problem in Indonesia every years especially when the dry season come since last 10 years. It has been found that the smoke of fire rooted from land preparation using fire mostly (60-80%) from an oil palm and industrial forest plantation illegally where rest of it to be believed made by shifting cultivation which unfortunately usually blaming for the smokes occurred (Saharjo, 2000). Zero burning policy had been used as a promising solution for reducing smoke which has an implication to reduce greenhouse gasses, unfortunately it was not work because the smoke increased due to high increasing of land conversion activity done for oil palm and industrial forest plantation hence law enforcement should be strictly applied. For the shifting cultivation they still have a chance to use fire for the land preparation but under controlled which hopefully will reduce greenhouse gas emission during burning. One promising solution is less smoke burning method. This method still uses fire for the land preparation but with fuel management and burning technique that hopefully will reduce the smokes. A previous research done shown the significant result for the secondary forest but not for the peat area that is still looking for the wrights answer.

The choice of strategy in suppressing wildfires and carrying out prescribed burning depends largely on how the fire is expected to behave i.e., its rate of the spread, direction of travel and intensity. The aspects of fire behavior which are prerequisites for the start and spread of fire are flammable fuels, sufficient heat energy to bring fuels to the ignition temperature and adequate of oxygen (Lorimer 1990). How and why fire behave is determined by a number of inter related factors such as fuel, weather, topography and seasonal changes and tome of day (Lorimer 1990).

In order to address this problem of land preparation using fire especially for shifting cultivation (small farmers), it is imperative that a method which still permits its use but with minimum environmental impact must be prescribed. One of the possible solutions is controlled burning during land preparation (Saharjo, 2005; Saharjo and Munoz, 2005). Thus, in order to know more and understand the dynamics of using fire in the land preparation especially for the shifting cultivation, this research was conducted.

MATERIAL AND METHOD

Research site

Research done since August 2001 until July 2002 in peatland the area belong to the community of Pelalawan village, Pelalawan sub-district, Pelalawan district, Riau Province. Research done in the peat area belong to the community closed to area belong to PT. Riau Andalan Pulp and Paper (PT.RAPP). The site was located in 102°00’ E-102°28’ E and 00°10’ N-00°40’ and administratively located in Pelalawan village, Pelalawan sub-district and Pelalawan District, Riau Province. Total peat area in this site was 5362.5 ha.

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Based on vegetation analysis shown that research site was dominated by shrubs and ferns. Another tree vegetation found *Shorea macrophylla, Macaranga pruinosa, Fivus sundaica, Stenochlaena palustris, Parastemon uruphyllus, Baccaurea pendula, Nephrolepis flaccigera* and *Gleichenia linearis.*

Climate in Pelalawan district cannot be separated from Riau province condition, generally the site was tropical climate with annually rainfall range between 2500-3000 mm with daily temperature from 22°C to 31°C. According to data made by Meteorological and Geophysical agency, Ministry of Transportation, annually rainfall in the period between January-December 2001 in the site was 3794.5 mm accompany by 86 rainy days.

Based on survey result and information book about site map and soil for Solok and Pekanbaru 1997 stated that research that was in Pelalawan districts dominated by peat and include in physiographical group of peat dome. About 97.1% of the site was located in 0-8% slope why rest located in the slope of 8-15%. The site also less than 10 cm from the sea level or an average of 2-6 m.

Peat

All site covered by peat consist of three kind of different peat decomposition type namely sapric, hemic and fibric. Fibric was peat type that has low level of decomposition, low humus and resulted in very low nutrition protection capacity. Due to the lack of humic materials hence fibric was a poor media for agricultural activity. Fibric was also a high porosity which hard to protect the water penetration. Hemic was a peat type that has moderate level of decomposition and consists of several humic materials hence in better ability in nutrition protection capacity than fibric. Hemic was a good media for an agricultural activity as long as the peat still has high content of humic materials. Sapric or mature peat was a peat that has high content of humus and also have a very good ability in mineral protecting. Peatland acidity in the site categories was very acid, where pH ranges between 3.0-3.7.

Peat classification for sapric, hemic and fibric conducted through laboratory analysis beside of using peat map made by PT.RAPP. In laboratory analysis, liquid color test in Na-pyrophosphate used to classified peat through a filter paper dipping as height as 1.25 cm into peat that had been watered with Na-pyrophosphate. Color shown through liquid movement and at the end of it then checked with Munsell book in order to know Pyrophosphate Index (PI) that was a *value* number minus *a chrome* number with different meaning : $PI \geq 5$ means fibric, PI = 4 means hemic and $PI \leq 3$ means sapric (USDA, 1975).

Sampling data

To reach the objective, the research conducted in the field and at laboratory scale. Two (2) plots of 400 m^2 (20 m x 20 m) each with different characteristics of peat decomposition was established at hemic, sapric, and at fibric site. To protect from heat penetration during burning then 1-m depth and width canal was established surrounding the plot except in fibric plots.

Before slashing and burning conducted, environmental condition measurement, fuel characterization and peat characterization conducted. Following those activity slashing was conducted where big log (diameter more than 10 cm) send out from the plot. Slashed logs and branching was separated through the plot. During slashed period (drying process) fuel characterization being conducted at different time measurement accompany by environmental condition monitoring such as temperature, relative humidity and wind speed.

Following 3 weeks drying process continued by burning the plot using ring method. During burning, fire behavior (rate of the spread of fire, flame height, flame temperature) monitored through handy camera Sony. Burning was done in the afternoon during 13.00 to 17.00 p.m. using torch made from bamboo filled with gasoline.

Activities conducted before burning

Three sub - plot of 2 m^2 (2 m x 1 m) in all the plot of 400 m^2 at three different peat type (sapric, hemic, and fibric) was established in order to measure fuel characteristics such as fuel moisture, fuel bed depth, and fuel load. Three samples of 100 gram each of materials found in the subplots (litter, leaves, branches, and logs) were taken and used as samples for moisture content measurement. Samples taken put in the oven and dried for 48 hours at 75°C (Clar and Chatten, 1954). Fuel moisture content estimated through dry weight based measurement. Fuel load was estimated through the amount of plants materials both living and dead found in the subplot which were collected, separated and weighed. Fuel bed depth was measured by the average height of the association of living and dead plant materials of various sizes and shapes in the subplots.

Activities conducted during burning

Flame temperature at 0 cm and 1 cm under the peat surface were measured using data logger. The temperature censors (thermocouple) were placed in the subplot at two locations. Burning was conducted through ring method and allowing the fire to propagate naturally. Rate of the spread of fire was measured by the average distance perpendicular to the moving flame front per minute, using a stopwatch and through video camera recording. It was very difficult to measure the average height of the flame directly in the burning condition, and then flame height was calculated through video camera recording.

Activities conducted after burning

Fuel left in the plot was measured by establishing 5 sub-plots 1 m^2 in every plot. These fuels left in the plot was weighted and checked. Soon, following burning, penetration heat depth was measured by digging 5 sub-plot 400 cm^2 each in all the plots until 30 cm depth. Fire intensity was calculated using Byram's equation (Chandler *et al.*, 1983), $FI = 273(h)^{2.17}$, where FI is fire intensity (kW m^{-1}) and h is flame height (m).

Data analysis

A completely random design of variance was used to test for differences among subplots, based on the following model (Steel and Torrie 1981):

$$Ymn = \mu + Tm + Emn$$

Where,

Ymn = fuel and fire behavior parameter at *m* subplot in *n* replication

μ = mean of the treatment population sampled

Tm = treatment (slashing, drying, burning)

Emn = random component

To detect significant difference of fuel and fire behavior parameters among subplots ($p \leq 0.05$), the Duncan test was used (Steel and Torrie, 1981).

RESULTS AND DISCUSSION

Results

Sapric

During burning the rate of the spread of fire in sapric site (Table 1) was vary from 0.47 m minute^{-1} to 0.99 m minute^{-1}, flame length from 1.55 to 2.11 m that resulted in fire intensity that vary from 791.96 kW m^{-1} to 1401.6 kW m^{-1} which reach flame temperature that vary from 800°C to 985° C at the peat surface and 1-cm below the peat surface that vary from 70°C to 90°C. Following burning it had been found that burnt peat depth was different that vary from 18 cm depth with 3% of peat affected to 31.87 cm with 1.75% of peat affected.

Hemic

Flame height during burning in hemic site (Table 1) was vary from 2.9 m to 3.6 m, where rate of the spread of fire was vary from 1.1 m minute^{-1} to 1.9 m minute^{-1} resulted in high flame temperature at the peat surface that vary from 900°C to 1100°C, where 1 cm below the peat surface that vary from 100°C to 130°C. This high flame temperature reflects the high fire intensity resulted that vary from 2949.5 kW m^{-1} to 5050.9 kW m^{-1}. Following burning it had been found that burnt peat depth was vary from 7.16 cm with peat affected was 1.75% to 12.6 cm with peat affected was 3.25%.

Fibric

Flame temperature during burning in fibric site (Table 1) was vary from 3.69 m to 4.12 m, where rate of the spread of fire was vary from 1.47 m minute^{-1} to 3.31 m minute^{-1} which resulted in flame temperature at the peat surface that vary from 875°C to 900°C where 1 cm below the peat surface that vary from 75°C to 90°C. The fire intensity in fibric site was quite high that vary from 5300 kWm^{-1} to 6721 kW^{-1}. Following burning it had been found that no peat burnt.

Discussions

Rate of the spread of fire

Rate of the spread of fire during burning (0.47 to 0.99 m/minute) in sapric site was the lowest (the fastest) compared to hemic (1.1 to 1.9 m/minute) and fibric (1.47 to 3.31 m/minute). A spreading forest fire is a complex combustion processes in which the flaming front is heating and then igniting unburned woody and herbaceous fuels (Johnson, 1992). Lowest rate of the spread of fire indicated that burning process in sapric site was quite slow among others site, as it can be seen through low fire intensity also in sapric where it was range between 791 to 1401.6 kW m^{-1} while in hemic it was 2949.9 to 5050.9 kW m^{-1} and in fibric 5300 to 6721.24 kW m^{-1} and it might be also due to different level of peat decomposed. Higher peat decomposed means that the peat as fuel will be looser or have more chance for heat being transferred downward. Heat produced by combustion of fuels can be transferred to the duff or to the mineral soil surface. The amount of heat transferred downward during the combustion of above ground fuels depend on the fuel present and fire behavior (DeBano *et al.*, 1998).

Flame height

Flame height during burning in sapric site (1.55 to 2.11 m) was the lowest compared to hemic site (2.9 to 3.6 m) and fibric site (3.69 to 4.12 m). Low flame height resulted during burning in sapric believed due to the lower fuel bed depth (82.8 to 96 cm) and characteristics as it mention also by Chandler *et al.*, (1983) that behavior of established fire depends principally on fuel bed depth characteristics. High

Table 1. Weather condition and fire behavior parameters during burning in Sapric, Hemic, and Fibric sites

Parameter	Sapric		Hemic		Fibric	
	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
Weather condition						
Temperature (°C)	38	38	36	39	37	36
Relative humidity (%)	55	50	55	48	53	52
Wind speed (m sec.$^{-1}$)	0.41	1.09	0.41	0.90	1.05	0.67
Fire behavior						
Fuel load (ton ha^{-1})	(119.16±27.17)a	(110.83±27.17)a	(39.5±8.0)a	(51.8±5.7)b	(188.0±6.02)b	(184.5±6.95)a
Fuel bed depth (cm)	(96.0±45.89)b	(82.8±21.33)a	(71.8±4.28)a	(101.6±9.09)b	(97.0±25.26)a	(106.0±13.73)b
Fuel moisture (%)						
* Litter	(6.8±1.1)a	(7.3±0.9)b	(11.92±3.52) a	(12.35±1.87)a	(8.63±1.10)a	(9.19±4.59)a
* Branches	(11.5±2.8)a	(14.3±3.9)b	(21.64±6.65)a	(24.54±7.01)a	(15.60±3.59)b	(12.85±4.85)a
* Peat surface	(81.8±1.5)b	(77.2±1.4)a	(81.8±1.5)b	(77.2±1.4)a	(85.6±1.34)a	(84.75±0.78)a
Flame height (m)	(1.55±0.52)a	(2.11±0.26)b	(2.9±0.3)a	(3.6±0.4)b	(4.12±1.53)a	(3.69±1.8)a
Fire Intensity (kW m^{-1})	(791.96±572.7)a	(1401.61±355.17)b	(1.1±0.2)a	(1.9±0.2)b	(6721.24±5018.34)b	(5300.28±4117.48)a
Rate of the spread of fire (m mnt^{-1})	(0.47±0.15)a	(0.99±0.26)b	(2949.9±547.3)a	(5050.9±1052.4)b	(3.31±1.27)b	(1.47±0.39)a
Flame temp. (°C)						
- 1 cm below ground	70	90	100	130	75	90
- Ground	800	985	900	1100	875	900
Burned fuel%						
Litter	50	80	90	95	95	85
Branches	45	60	50	75	75	55
Log	5	7	(7.16±0.9)a	(12.6±1.3)b	5	5
Burned peat depth (cm)	18	31.87	4.7	13	0	0
Burned peat size (m^2)	12	7	1.75	3.25	0.04	0.04
Burned peat%	3	1.75	0	0		
Slope (%)	0	0	0.04	0.04	0	0
Duration (mnt.)	22.13	21.30	18.0	9.3	15.18	16.30
Burning time	11.22 a.m	13.43 p.m	16.30 p.m	13.05 p.m	12.25 p.m	13.30 p.m

Note: Means are significantly different when standard errors are followed by different letters (p≤0.05).

fuel available in sapric site and also dense (compact) will affect the performance of oxygen during burning, where it was believed as one of the reason why flame height was so slow compared to hemic and fibric site. Fuels densely packed and layered (Wheelan, 1995) do not permit access to oxygen and therefore constrains combustion, beside that compactness (Chandler *et al*., 1983) affects both the air supply to the burning particles and the rate of heat transferred to particles in the a head bed of the flame front.

Fire Intensity

Flame height and fuel available during burning was directly related to the fire intensity, which means that low flame length will have lower fire intensity too. Flame height in sapric site (1.55 to 2.11m) was the lowest among the site, this means that fire intensity in the sapric site (791 to 1401.6 kW m^{-1}) was the lowest also among others site. Fire intensity (Brown and Davis, 1973) is directly proportional to the amount of fuel available for combustion at any given rate of the spread of fire front and higher heat transfer causes the adjacent fuels to be heated and burned, thereby releasing more heat and propagating fire (Johnson, 1992). Low fire intensity as it found in sapric site means that fire in this site was relatively under controlled when it blow-up or it can be managed with less destruction. The site that have higher fire intensity as it found in hemic site (2949.9 to 5050.9 kW m^{-1}) and fibric site (5300.28 to 6721.24 kW m^{-1}) means that fire will be difficult to be controlled and it might be more resources burnt or destroyed.

Flame temperature

Flame temperature was one indicator on how the burnt site could or could not be controlled during burning because it explains also the situation in burning site. High flame temperature as it found in hemic site (900 to 1000°C) was indicator on how worst the damage would occur during burning. Peat with higher level of decomposition will have fuel characteristics more porous than that with lower level of peat decomposition (fibric). This means that the chance of heat transferred through penetration from the heat on surface was higher than peat with low level of peat decomposition. As a result it had been found that the flame temperature during burning at 1 cm below the peat surface was different, sapric (70 to 80°C), hemic (100 to 130°C) and fibric (75 to 90 °C).

Peat destruction

The impact of flame temperature resulted during burning, fire intensity or energy resulted during burning and different level of peat decomposition has a significant impact to the peat itself. Peat destruction due to penetration heat and energy downward depends on how much fuel are present and peat characteristics (Saharjo and Munoz, 2005), especially moisture content because peat destruction could be prevented through high peat moisture content resulting through the water from the canal surrounding burned area Higher level of peat decomposition seems have deeper peat burned as consequences more destruction resulted, sapric site that has the highest of peat decomposition has deeper pet burned (18 to 31.87 cm) compared to hemic site (7.16 to 12.6 cm) and fibric site where no peat burned found.

CONCLUSION

Results of research shown there was a tendency that low level of peat decomposition (fibric) will have lower rate of the spread of fire, higher flame height that directly related to fire intensity which finally resulted in less peat destroyed. This means that fire in the low level of peat decomposition was relatively difficult to be controlled. Among the three site Sapric, hemic, and fibric that burned, it had been found that fire in fibric site will be the most difficult to be controlled when fire blow up and sapric site will be the worst.

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