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Domination and Composition Structure Change at Hemic Peat Natural Regeneration Following Burning; A Case Study in Pelalawan, Riau Province

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ABSTRACT

Biomass burning is the burning of the world's living and dead vegetation, including grasslands, forests and agricultural lands following the harvest for land clearing and land-use change. One of the important information needed following this biomass burning is how long the burnt forest or land can be recovered, and how worst the changing occurred. Repeated burning occurred at the same place trend to clean the vegetation which leads to have the land with lower number and quality of species left. The research objective is to understand the vegetation changing following peat fires in the sapric peat type at the land preparation using belong to the local community located in the Pelalawan district, Riau province, Indonesia during the dry season in the year 2001. Before burning, logging, slashing, drying and burning the site was dominated by *Uncaria glabrata* at seedling stage, *Ficus sundaica* at sapling stage, *Ficus sundaica* at pole stage and *Stenochlaena palustris* at understorey. After logging, slashing and followed by 4 weeks drying then continued by burning with high flame temperature range from 900-1100^{o}C, it had been found that 3-months following burning the site was dominated by *Uncaria glabrata* at seedling stage and *Nephrolepis flaccigera* at understorey while 6-months following burning the site was dominated by *Parastemon uruphyllus* at seedling stage and *Erechites valeriantifolia* at understorey stage.

Key words: peat fires, peat type, flame, natural regeneration, human.

INTRODUCTION

Forest management and land use practices in Sumatra and Kalimantan have evolved very rapidly over the past three decades (Scweithem, 1998). Commercial use of forest resources and forest lands was very limited up to and including the middle decades of this century. This changed dramatically when forestry basic law 1967. Millions of hectares of forest land where awarded as timber concessions in the late 1960s and early 1970s, leading to a timber boom in Sumatra and Kalimantan that changed the landscape of these two islands over a period of two decades. The government policies and procedure for allocating and supervising timber concessions were deeply flawed and riddled with corruption, leading to severe impacts on forest ecosystems, biodiversity and forest dwelling peoples. Poor logging practices resulted in large amounts of waste would left in the forest, greatly elevating fire hazard. Failure by the government and concessionaires to protect logged forests and close old logging roads led to and invasion of the forest by agricultural settlers whose land clearances practices increased the risk of fire.

Logging activities have greatly increased both fire risk and hazards (Mackie, 1984). Access roads opened up the forests to both immigrant and local people for making field (Wirawan, 1993). By opening up the forest canopy, logging activities have greatly stimulated the growth and accumulation of plant biomass near the ground. Additional dead biomass is also provided by deformed logs and branches left behind by loggers. The failure of the rainy season to arrive on time, as was the case in late 1982, prolonged dry season, dried this plant biomass and then helped the fires started by shifting cultivators in September or October to spread wildly unchecked for several months until heavy rain fall in May 1983. As a result, 70% of the burned forest in East Kalimantan occurred in the logged-over forest areas (Wirawan, 1993). When logging companies enter into a new area, they automatically bring with them the fires problem. They are opening up the forests and making them more susceptible to forest fires through road, logging waste, bulldozing through the stands and opening up the canopy and finally bringing in people as the source of fire (Schindler, 1998).

Fire risk is increased dramatically by the conversion of material forests to rubber and oil palm plantations, and by the logging of natural forests, which opens the canopy and dries out the ground cover. Plantations are drier and trees are move every spaced than natural tropical moist forests, thus increasing the opportunities for fire to spread. Evidence also suggests that fires burned mostly easily in secondary forests that had already been disturbed through (frequently illegal) timber operations. Selective logging destroys much of the most undergrowth and the closed canopy that reduces the likelihood and impact of forest fires in natural forests (WWF, 1997).

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MATERIALS AND METHODS

Site and time period

Research was conducted in the period of August 2001 until July 2002 in the peat land area belong to the community of Pelalawan village, Pelalawan sub-district, Pelalawan district, Riau Province.

Peat classification

Peat classification for hemic conducted through laboratory analysis beside of using peat map made by PT. Riau Andalan Pulp and Paper (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: IP $\geq$ 5 means fibric, IP = 4 means hemic and IP $\leq$ 3 means sapric (USDA, 1975).

Vegetation condition

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

Climate

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 between 22-31°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 that accompanied by 86 rainy days.

Geological and geomorphology

Based on survey result and information book about land site map and soil for Solok and Pekanbaru 1997 stated that the research site in Pelalawan districts was dominated by peat and include in physiographical group of peat dome. 97.1% of the site was located in 0-8% slope why rest located in the slope of 8-15%.

Plot establishment

To reach the objective, the research conducted in the field and at laboratory scale. Three (3) plots of 400 m^2 (20 m X 20 m) each is established at hemic site. To protect from heat penetration during burning then 1-m canal was established surrounding the plot. Before slashing and burning conducted vegetation analysis was 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. Following slashing then continued by drying process for 3 three weeks in order to reduce high moisture content of the fuel and less smoke produced during burning. Following 3 weeks drying process was continued by burning the plot using ring method. During burning, fire behavior (rate of the spread of fire, flame length, flame temperature) monitored through handy camera. Burning was done in the afternoon during 13.00-17.00 p.m. using torch made from bamboo filled with gasoline.

Three and six months following burning vegetation analysis conducted in order to know the performance of natural regeneration following burning.

Fire behavior

Activity conducted before burning

Three sub - plot of 2 m^2 (2 m x 1 m) in all the plot of 400 m^2 was established in order to measure fuel characteristics such as fuel moisture, fuel bed depth, and fuel load.

Estimation of fuel moisture. 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 Chaten, 1954). Fuel moisture content estimated through dry weight based measurement.

Estimation of fuel load. Fuel load was estimated through the amount of plants materials both living and dead found in n the subplot which were collected, separated and weighed.

Estimation of fuel bed depth. 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.

Activity conducted during burning

Estimation of flame temperature. Flame temperature at 0 cm and 1 cm under the peat surface were measured using data logger. The temperature censors 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 of fire. 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.

Flame height. It was very difficult to measure the average length of the flame length directly in the burning condition, and then flame height was calculated through video camera recording.

Activity conducted after burning

Fuel left. Fuel left in the plot is measured by establishing 5 sub-plots 1m^2 in every plot. That fuel left in the plot is weighted and checked.

Penetration depth. Soon, following burning, heat penetration depth is measured by digging 5 sub-plot 400 cm^2 each in all the plots until 30 cm depth.

Fire intensity. 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)

Vegetation changing

Activity conducted before burning

Sub-plot establishment. In order to know the vegetation structure and composition changing then 25 m^2 (5 m x 5 m) sub-plot was established in the plot of 400m^2. In these sub-plots, all seedling, sapling, pole and trees and also under growth vegetation was calculated its species and number. Criteria used for seedling, sapling, pole and trees (Kusmana and Istomo, 1995) were as follows: (i) *Seedling* means vegetation that has 1.5-m height. (ii) *Sapling* means vegetation that has 1.5-m height until seedling with 10-cm diameter. (iii) *Pole* means vegetation that has 10-20 cm diameter. (iv) *Trees* means vegetation that has > 20-cm diameter

Data collecting. Before slashing, all seedling, sapling, pole, trees and undergrowth vegetation found in the sub-plot was calculated its species and number. Following slashing was drying for 3-weeks which continued by burning.

Important Value Index (IVI). Vegetation analysis is the way to study species composition and vegetation structure in one ecosystem (Soerianegara and Indrawan, 1998). In the vegetation analysis it was calculating Important Value Index. According to Odum (1971), IVI was numbering density relative (DR), frequency relative (FR) and dominance relative (DR).

IVI = DR + FR + DR

- IVI for trees and pole was: DR + FR + DR
- IV for seedling, sapling and undergrowth vegetation was: DR + FR, where
- Species density (D): Total number of a species/sample unit size x 100%
- Species density relative (DR): Species density/all species density x 100%
- Species frequency (F): Number of plot found for a species/ sample unit size x 100%
- Species frequency relative (FR): Species frequency/ all species frequency x 100%
- Dominancy species (D):
  - o Trees, pole and sapling: Basal area/plot size
  - o Seedling, and under growth vegetation: Canopy covering species size/plot size
  - o Dominance relative (DR): Dominance of a species/all species dominance x 100%

Activity conducted following burning

Data collecting. Following burning in the period of 3 months and 6 months, all seedling, sapling, pole, trees and undergrowth vegetation found in the sub-plot was calculated its species and number.

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 = U + Tm + Emn

Where,

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

U = 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

Before burning

Vegetation analysis result shown that before logging, slashing, drying and burning 15 species of trees from 10 families was found in the hemic site which was dominated by Euphorbiaceae and nine (9) species from 9 families of under storey vegetation.

Important Value Index of seedling was vary from 7.612 (*Alstonia pneumatophora*) to 91.003 (*Uncaria glabrata*), at sapling stage was vary from 4.265 (*Litsea polyantha*) to 72.952 (*Ficus sundaica*), at pole stage was vary from 124.253 (*Baccaurea pendula*) to 175.747 (*Ficus sundaica*) and at under storey vegetation was vary from 19.861 (*Lygodium candens*) to 59.604 (*Stenochlaena palustris*) (Table 1).

Table 1. Important value index of seedling, sapling, pole and understorey before logging, slashing, drying and burning.

No	Botanical name	D (ind/ha)	RD (%)	F	RF (%)	IVI
	Seedling					
1.	*Alstonia pneumatophora*	5	1.730	0.167	5.882	7.612
2.	*Alstonia scholaris*	8	2.768	0.250	8.824	11.592
3.	*Baccaurea pendula*	12	4.152	0.333	11.765	15.917
4.	*Bredelia glauca*	12	4.152	0.417	14.706	18.858
5.	*Ficus sundaica*	4	1.384	0.167	5.882	7.266
6.	*Litsea polyantha*	5	1.730	0.167	5.882	7.612
7.	*Litsea javanica*	7	2.422	0.250	8.824	11.246
8.	*Mangifera indica*	6	2.076	0.167	5.882	7.958
9.	*Parastemon uruphyllus*	18	6.228	0.417	14.706	20.934
10.	*Uncaria glabrata*	212	73.356	0.500	17.647	91.003
		289	100.000	2.833	100.000	200.000
	Sapling					
1.	*Alstonia pneumatophora*	2	2.469	0.083	3.030	5.499
2.	*Alstonia scholaris*	2	2.469	0.083	3.030	5.499
3.	*Baccaurea pendula*	11	13.580	0.417	15.152	28.732
4..	*Bredelia glauca*	5	6.173	0.250	9.091	15.264
5.	*Calophyllum inophyllum*	3	3.704	0.167	6.061	9.764
6.	*Ficus sundaica*	37	45.679	0.750	27.273	72.952
7.	*Litsea polyantha*	1	1.235	0.083	3.030	4.265
8.	*Litsea javanica*	5	6.173	0.250	9.091	15.264
9.	*Mangifera indica*	1	1.235	0.083	3.030	4.265
10.	*Parastemon uruphyllus*	8	9.877	0.333	12.121	21.998
11.	*Shorea macrophylla*	4	4.938	0.167	6.061	10.999
12.	*Syzygium grandis*	2	2.469	0.083	3.030	5.499
		81	100.000	2.750	100.000	200.000
	Pole					
1.	*Baccaurea pendula*	1	33.333	0.083	50.000	124.253
2.	*Ficus sundaica*	2	66.667	0.083	50.000	175.747
		3	100.000	0.167	100.000	300.000
	Understorey					
1.	*Erechites valeriantifolia*	499	8.986	0.583	14.894	23.880
2.	*Lygodium scandens*	394	7.095	0.500	12.766	19.861
3.	*Nephrolepis radicans*	1485	26.742	1.000	25.532	52.274
4.	*Stenochlaena palustris*	1892	34.072	1.000	25.532	59.604
5.	*Trycalsia* sp.	1283	23.105	0.833	21.277	44.381
		5553	100.000	3.917	100.000	200.000

Temperature at the site before burning was vary from 36-39^{O}C, relative humidity vary from 48-55% and wind speed vary from 0.41-1.07 m minute^{-1} in plot 1. Fuel load found in the site in the range between 39.5-51.8 ton ha^{-1}; fuel moisture vary from 10.19-12.35% for dry leaves, 19.4-21.64% for dry branches and 74.2-81.8% for peat surface; while fuel bed depth was vary from 71.8-108.4 cm (Table 2).

Table 2. Weather condition and fire behavior parameters before and during burning.

Parameter	Plot 1	Plot 2	Plot 3
Weather condition			
Temperature (°C)	36	39	38
Relative humidity (%)	55	48	49
Wind speed (m sec^{-1} .)	0.41	0.90	1.07
Fire behavior			
Fuel load (ton ha^{-1})	(39.5±8.0)a	(51.8±5.7)b	(43.7±3.2)a
Fuel bed depth (cm)	(71.8±4.3)a	(101.6±9.1)b	(108.4±3.3)c
Peat depth (cm)	(182.0±2.0)a	(188.3±1.2)a	(187.7±1.5)a
Fuel moisture (%)			
* Leaves	(11.92±3.52)a	(12.35±1.87)a	(10.19±4.72)a
* Branches	(21.64±6.65)a	(24.54±7.01)a	(19.4±5.91)a
* Peat surface	(81.8±1.5)a	(77.2±1.4)a	(74.2±0.2)a
Flame length (m)	(2.9±0.3)a	(3.6±0.4)a	(3.4±0.3)a
Rate.of the spr.(m mnt^{-1})	(1.1±0.2)a	(1.9±0.2)ab	(2.5±0.4)b
Fire int. (kWm^{-1})	(2949.9±547.3)b	(5050.9±1052.4)c	(2552.3±977.2)a
Flame temp. (°C)			
- Ground	900	1100	1000
- 1 cm below ground	100	130	120
Burnt fuel (%)			
* Litter	90	95	98
* Branches	50	75	80
* Depth (cm)	(7.2±0.9)a	(12.6±1.3)b	(6.0±0.8)a
Slope (%)	0	0	0
Plot size (ha)	0.04	0.04	0.04
Duration (mnt.)	18.0	9.3	9.0
Burning time	16.30 p.m	13.05 p.m	14.15 p.m

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

Table 3. Important Value Index of Seedling and Understorey at 3 and 6 months following burning.

No	Species	D (ind/ha)	RD (%)	F	RF (%)	IVI
	Seedling					
	3 months					
1.	*Ficus sundaica*	5	3.030	0.167	8.000	11.030
2.	*Macaranga pruinosa*	14	8.485	0.500	24.000	32.485
3.	*Macaranga triloba*	12	7.273	0.250	12.000	19.273
4.	*Parastemon uruphyllus*	28	16.970	0.417	20.000	36.970
5.	*Shorea macrophylla*	8	4.848	0.333	16.000	20.848
6.	***Uncaria glabrata***	98	59.394	0.417	20.000	79.394
		165	100.000	2.083	100.000	200.000
	6 months					
1.	*Baccaurea pendula*	10	1.266	0.333	8.696	9.961
2.	*Bredelia glauca*	13	1.646	0.417	10.870	12.515
3.	*Ficus sundaica*	20	2.532	0.333	8.696	11.227
4.	*Macaranga pruinosa*	50	6.329	0.583	15.217	21.547
5.	*Macaranga triloba*	21	2.658	0.333	8.696	11.354
6.	*Parastemon uruphyllus*	457	57.848	1.000	26.087	83.935
7.	*Shorea macrophylla*	32	4.051	0.417	10.870	14.920
8.	*Uncaria glabrata*	187	23.671	0.417	10.870	34.540
		790	100.000	3.833	100.000	200.000
	Understorey					
	3 months					
1.	*Cyperus halpan*	97	5.493	0.250	4.412	9.904
2.	*Erechites valeriantifolia*	125	7.078	0.917	16.176	23.255
3.	*Gleichenia linearis*	188	10.646	0.833	14.706	25.351
4.	*Imperata cylindrica*	24	1.359	0.667	11.765	13.124
5.	*Melastoma malabtricum*	75	4.247	0.417	7.353	11.600
6.	*Nephorlepis radicans*	411	23.273	0.833	14.706	37.979
7.	*Stenochalaena palustris*	589	33.352	1.000	17.647	50.999
8.	*Trycalsia* sp.	257	14.553	0.750	13.235	27.788
		1766	100.000	5.667	100.000	200.000
	6 months					
1.	*Cyperus halpan*	124	1.136	0.333	5.195	6.331
2.	*Erechites valeriantnifolia*	2948	27.006	1.000	15.584	42.591
3.	*Gleichenia linearis*	731	6.697	1.000	15.584	22.281
4.	*Imperata cylindrica*	343	3.142	0.833	12.987	16.129
5..	*Melastoma malabtricum*	104	0.953	0.500	7.792	8.745
6.	*Nephorlepis radicans*	2248	20.594	0.833	12.987	33.581
7.	*Stenochalaena palustris*	1820	16.673	1.000	15.584	32.257
8.	*Trycalsia* sp.	2598	23.800	0.917	14.286	38.086
		10916	100.000	6.417	100.000	200.000

After burning

Flame height was vary from 2.9-3.9 m and no significant different each other, rate of the spread of fire vary from 1.1-2.5 m $minute^{-1}$ where it was significant different between plot 2 and 3, resulted flame temperature in the ground that vary from 900-1100°C and flame temperature 1 cm under the ground was vary from 75-90 °C. Fire intensity as one component to understand how fire behaves was varying from 2552-5050.9 kWm^{-1} that significantly different (Table 2).

Important Value Index

Three months following burning Important Value Index of seedling in hemic plot was dominated by *Uncaria glabrata* with IVI was 79.394 and *Parastemon uruphyllus* with IVI was 36.970, while Six months following burning it was dominated by *Parastemon uruphyllus* with IVI was 83.935 followed by *Uncaria glabrata* with IVI was 34.540. Important Value Index for under storey vegetation at three months following burning was dominated by *Stenochlaena palustris* with IVI was 50.999 followed by *Nephrolepis radicans* with IVI was 37.979, while six months following burning it was dominated by *Erechistes valeriantifolia* with IVI was 42.951 followed by *Trycalsia* sp with IVI was 38.086 (Table 3).

High fire intensity resulted during burning that vary from 2552.3-5050.9 kW m^{-1} was an indicator how severe fire in hemic site and it relation to the effect of the materials found both dead and live on the peat surface. Saharjo and Nurhayati (2005) shown that high fire intensity in hemic peat during burning had significant impacts on the changes in chemical and physical properties. As a result of high flame temperature resulted during burning that vary from 900-1100°C in the peat surface have killed the chance of the seed to break the dormancy and germinate due to the temperature was higher than their seed lethal temperature. Secondary succession process begun from seedlings that grew up after fire. Seedlings of secondary species might appear from germination of dormant seeds in the soil (Thompson, 1993); while those of primary species appear from the fruits produced after fire as their seeds are dormant for only short period (Murdoch and Ellis, 1993). Fire can burn seeds and seedling banks depend on the type and intensity. This situation will affect also the performance of the seed stored under the peat surface as it occurred in the plot, as it was also mention by Pierce and Cowling (1991) that recruitment differs after different fire seasons because of fluctuations in the seed bank. Following burning it had been found that the temperature under the peat surface (1-cm) was vary from 100-130°C, beside that burnt peat depth that vary from 6-12.6 cm will affect the growth performance both for species and understorey vegetation. Recruitment of shrubs with soil-stored seeds varies not only with fire intensity but also with fire season (Le Maitre, 1988; Hodgkinson, 1991).The effect of fire depends on the fire regime. A change in the fire regime can change the prospect of the communities (Bond and Wilgen, 1996).

Fire drastically changed the structure and composition of seedling as it can be seen at the three months following burning. The site was dominated by *Uncaria glabrata* with IVI= 79.394 followed by *Macaranga pruinosa* with IVI= 32.485 where before burning the site was dominated by *Uncaria glabrata* with IVI= 91.003 followed by *Parastemon uruphyllus* with IVI= 20.394. During this time only three species previously found before burning left while another 7 species disappeared for a while and 3 new species emerge. At six months following burning another 2 species emerge (the species that found before burning). This fact showed that until six months following burning only 8 species that could adapted with new environment. For many species, the combination of open space, increased availability of resources and temporary reduction in seed predators (enemy-free space) is highly favorable for seedling establishment in the post-fire environment (Bond and Wilgen, 1996).

At under storey vegetation stage it was found that three months following burning their site was dominated by *Stenochlaena palustris* with IVI= 50.999 followed by *Nephrolepis radicans* with IVI= 37.979, compared to the condition before burning seems that following burning the number of species increased to be 8 species than 5 species found before burning. *Cyperus halpan* was a new species of under storey that was not found at before burning stage and dominated the site. Another new species found were *Melastoma malabathricum, Gleichenia linearis* and *Imperata cylindrica*. At six months following burning *Erechites valeriantifolia* dominated the site followed by *Trycalsia* sp.

The data have shown that seedling species in all plot tend to decrease following burning. At three months following burning 70% of the original seedling species found before burning was disappeared for while, even though at six months following burning a few species that found before burning emerge. Vegetation recovery reflects the complex effects of the felling and fire intensities and a logged-over forest seems to be burnt severer than the primary or un-logged forests (Woods, 1989) and also fire drastically affect plant growth, survival and reproduction and can impact the dynamic of seeds and seedlings (Bond and Wilgen, 1996).

The fact shown in seedling species especially following burning regarding the changing of structure and composition was totally different compared to the fact found in understorey vegetation. In understorey vegetation, the total species found at three months following burning tend to increase compared to the total species found before burning, while in seedling species there was tend to decrease. Initial vegetation recovery where is affected strong fires and heavy felling intensity results in higher undergrowth biomass and mean diversity than plant fragment and unfelling site, although there is not strong trends to undergrowth biomass and litter 4 months after fires (Ganzhorn et al., 1990). Post-fire conditions have many advantages for seedlings, space is freed by the burning of established plants, resources increased and seed and seedling predators decline (Bond and Wilgen, 1996).

CONCLUSION

Fire drastically changes the domination and composition structure of the natural regeneration following burning, where it had been found a trend of seedling species to disappeared for a while and replace by new species. At understorey vegetation it was totally different because following burning the number of species found was increased.

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