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SOIL RESPONSES ON PEATLAND FIRE: CASE STUDIES IN JAMBI AND CENTRAL KALIMANTAN

(*Respon Tanah terhadap Kebakaran Lahan Gambut: Studi Kasus di Jambi dan Kalimantan Tengah*)

Lailan Syaufina [1,2 *], Bambang Hero Saharjo [1,2], Ati Dwi Nurhayati [1,2], Erianto Indra Putra [1,2], Wardana [1,2]

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ABSTRACT

Jambi and Central Kalimantan Provinces are among fire-prone provinces that experience fire annually. The provinces have large peatland areas, which are susceptible to fire. The peatland fire cause impacts on peat soil characteristics, including peat physical and chemical properties. The study was conducted in Sinar Wajo Village, Jambi and Kalampangan and Tumbang Nusa villages, Central Kalimantan Provinces. Land clearing activities for agriculture farming mostly caused forest and land fire in both locations. This study compares physical and chemical soil characteristics on burned and unburned peatland areas in Jambi and Central Kalimantan. Samples of peat soil were taken from 0-20 cm depth. Peat soil chemical and physical properties obtained from laboratory analyses were statistically analyzed to compare the properties in burned and unburned areas using JASP. The study resulted in significant differences for Potassium, Sodium, and Calcium, which indicate higher content in the burned plots than the unburned plots.

Key words: Chemical soil properties, land clearing, peatland, physical soil properties

ABSTRAK

Provinsi Jambi dan Kalimantan Tengah merupakan daerah rawan kebakaran, yang selalu mengalami kebakaran setiap tahun. Kedua provinsi memiliki lahan gambut yang luas yang rentan terhadap kebakaran. Kebakaran hutan dan lahan gambut memberikan dampak pada sifat tanah gambut, termasuk sifat fisika dan sifat kimia. Penelitian ini dilakukan di Desa Sinar Wajo, Jambi, Desa Kalampangan dan Tumbang Nusa, Kalimantan Tengah. Kebakaran hutan dan lahan di lokasi penelitian pada umumnya disebabkan oleh kegiatan penyaiapan lahan untuk pertanian. Penelitian ini bertujuan untuk membandingkan sifat fisika tanah dan sifat kimia tanah pada lahan gambut terbakar dan tidak terbakar di Jambi dan Kalimantan Tengah. Sampel tanah gambut diambil pada kedalam 0-20 cm. Hasil analisis laboratorium sampel tanah diolah secara statistik dengan menggunakan JASP untuk membandingkan sifata tanah terbakar dan tidak terbakar. Hasil penelitian menunjukkan bahwa terdapat perbedaan yang signifikan untuk Kalium, Natrium, dan Kalsium.

Kata kunci: Lahan gambut, penyiapan lahan, sifat fisika tanah, sifat kimia tanah,

[1] Department of Silviculture, Faculty of Forestry and Environment, IPB University, Jl. Ulin, Kampus IPB, Darmaga, Bogor, Jawa Barat 16680 Indonesia. Tel.62-0251-8621677, Fax.62-0251-8621256
[2] RFMRC, Faculty of Forestry and Environment, IPB University, Jl. Ulin, Kampus IPB, Darmaga, Bogor, Jawa Barat 16680 Indonesia. Tel.62-0251-8621677, Fax.62-0251-8621256
* Corresponding author's:
e-mail: lailans@apps.ipb.ac.id.

INTRODUCTION

Jambi Province and Central Kalimantan Province are among Indonesia's most fire-prone provinces with large peatland areas. There are 621,090 ha and 2,659,231 ha peatland areas in Jambi and Central Kalimantan, respectively (BBSDLP 2011). The peatlands play an important role in balancing the ecosystem and environment, including biodiversity, hydrological function, carbon stock and sequestration, and livelihood contributing to Sustainable Development Goals (Page et al. 2011, Harrison 2013, Ishihara et al. 2017, MoEF 2019). Despite the important functions, the peatlands are very susceptible to fire, contributing to transboundary haze pollution.

Jambi and Central Kalimantan experience forest and land fire annually as fire-prone areas. All fire in peatland is caused by human factors, purposely or by negligence. Land clearing activities seem to be the main cause of the fire. Land preparation for agriculture farming, plantation, settlements and other purposes use fire as the cheapest and the fastest tool to clear the land. It leads to deforestation. Carlson et al (2012) reported that fire has contributed to the main causes of deforestation in the period of 1989–2008 (93%) and net carbon emission (69%). There is a strong correlation between land-use change or land cover with fire occurrence in Sumatera dan Kalimantan (Adrianto 2020, Miettinen and Liew 2005).

Peat soil is originated from the decomposition of organic materials, including trees, shrubs, seedlings grasses growing on land, which influenced by water dynamics produce accumulation and decomposition materials. The peat has high carbon content and unique characteristics, including irreversible drying. Peat soil has physical characteristics of low bulk density, high porosity, low capacity, and chemical properties of low pH, low nutrients, high carbon-nitrogen ratio, and high cation exchange capacity.

Heat produced by forest and land fire influences peat soil properties in different magnitudes, driven by several factors, including fire intensity, fire severity (Syaufina and Ainuddin 2011), the origin of soil properties, and post-fire precipitation (DeBano et al. 1998). The fire may destroy soil properties.

This study compares physical and chemical soil characteristics on burned and unburned peatland areas in Jambi and Central Kalimantan.

METHOD

Research Location and Time

This research was conducted in Sinar Wajo Village, Jambi Province, Kalampangan and Tumbang Nusa villages, Central Kalimantan Province (Figure 1.) for a 1 (one) month.

Research Tools and Materials

The materials used in this study were soil samples 0-20 cm deep in burned and unburned areas. The equipment used are peat borer, soil ring, balance, oven, distance measuring tape/ruler. To study the fire condition, unstructured interviews with community and firefighters working in the study area were also conducted.

Data Collection and Research Procedure

The soil samples for physical soil properties were taken using soil rings in undisturbed sites both in burned and unburned plots randomly. Meanwhile, the soil samples for chemical properties were randomly taken using peat borer for 0-20 cm deep in both burned and unburned plots. The laboratory analyzed the soil samples for physical and chemical soil properties using the standardized soil analyses procedures. To estimate fire severity in the field, this study used peat fire severity classification of Artsybashev described in Fire Severity Assessment Methods (Syaufina 2017). Burned peat depths were measured using a tape/ruler.

Data Analyses

Peat soil characteristics data obtained from the laboratory were analyzed using Independent-t-test and Descriptive analyses by JASP. Dependent variables are:

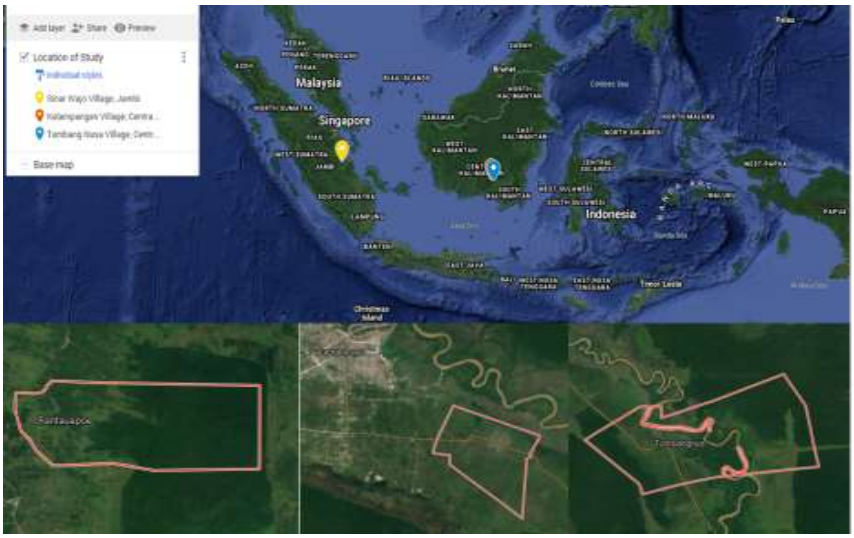

Figure 1 Location of the Study

physical soil properties, including Bulk Density, Porosity, and Permeability; and chemical soil properties, including: N-Total, P, K, Na, Ca, Mg, C-organic, and pH (H_2O). The t-test was conducted to compare the soil properties in burned and unburned plots, with Hypotheses as follows:

H_0: Soil properties in burned area = Soil properties in an unburned area
H_1: Soil properties in burned area ≠ Soil properties in an unburned area

RESULTS AND DISCUSSIONS

Burned area condition

Sinar Wajo Village, Jambi

Sinar Wajo village is located in Tanjung Jabung Timur Regency, Jambi Province, as peatland dominated area. Starting from 1997, the village suffered from forest and peat fires nearly every year. Our respondent stated that there was no fire in their village before 1997. The village suffered from the flood in 1996. The most severe fire experienced by the village occurred in 1997, 2012 and 2015.

Around 700 ha was burned in 2015, and 500 ha of them has been converted to plantation. The fire has delayed oil palm harvesting periods from twice a month to five months remain unfruited. Before the fire, the villagers could harvest areca nut for every 20 days. However, fire has caused fruitless for more than ten months. Forest and peatland fire has burned the areca nut and oil palm plantation and lowered the plant productivity in the unburned area, resulting to a significat decrease of their income.

The study location experienced a huge peat fire has burnt more than 10 ha area surrounding the village in July 2017. The fire was suppressed by the BNPB helicopterusing the water bomb sent and direct suppression using water pumps and nozzles. The fire has extinguished after 48 hours by the suppression team, including Manggala Agni, BNPB, MPA (community fire brigade) and local people. Limited access to the burned area may become one of the obstacles for fire suppression here. Most of the burnt area was a logged-over area covered by shrubs and ferns. The remained and unfinished lodges surrounding the area and some areca nut seedlings left in the polybags may indicate that the fire was deliberately on purpose for land clearing activities. All three fire types of ground fire, surface fire, and crown fire were found in the study area. However, surface fire seems to be dominated the area as land clearing activities caused dry surface fuel accumulation. Based on the measurement of burned depth, the fire severity in the study area is classified as low fire severity as the burned depth is around 10 cm deep.

Figure 2 Burned peatland condition in Jambi

Kalampangan Village

Kalampangan Village located in Sebangau Regency, Palangka Raya City, Central Kalimantan Province as peatland dominated area. The majority of the people here are Javanese transmigrant from Central and East Java. As a farmer, they cultivate vegetables such as mustard greens, cucumbers, kale, corn, and onions. Most of the farmers used fire to prepare the land for cultivation and it seems that they do not understand the risk of using fire in preparing the land. They understand that the peat lacks of nutrient, so they believe that ash from fires can be used to fertilize the peat soil. Land clearing was practiced, including slashing the grass, ferns, shrubs, and other woody materials, piling the slashed materials, and burn them. They know how to burn safely without disturbing the surrounding area.

Huge fires in 2015 have severely impacted the villagers as they suffered from smoke and thick haze, causing respiratory diseases and lack of visibility during the fire. All of the farmers protected their land from being fired during the fire episode in 2015.

However, we found best practices on managing the peat without fire for cultivation from one of the villagers in Kalampangan. Instead of using ash from the fire, he chooses to add compost, fertilizer, manure, and limestone to the peat to increase its nutrient content. The result is remarkable; he can get the optimal growth of crops and forest trees while protecting the peat in his area from subsidence. Among forest trees in his area are jelutung, gaharu, rambutan and jackfruit. He cultivates chili, corn, and cassava between the forest trees stand.

Tumbang Nusa Village

Tumbang Nusa Village is located in Jabiren District Pulang Pisau Regency, Central Kalimantan, as peatland dominated area. All of the people in the village are the indigenous people from Dayak Tribe and most of them are fishermen. Most of the people stated that the peat is not suitable for cultivation, thus only a few of them use their land to plant the crops and woody trees such as jelutung and pineapples.

Due to the severe impact of a huge fire episode in 2015 when most people suffered from lack of visibility and respiration problems, people in Tumbang Nusa refused to use fire for land clearing and land preparation. The fire's origin in 2015 fire episode did not come from the village as they didn't use any fire from land clearing, but it came from the fire outside the village that spread wildly to the village.

Most of the villagers has understand the risk of using fire in opening and preparing the land, thus they don't use any fire for land preparation. Here they add compost and

limestone to add the nutrient content of the peat. However, they still believe that the main factor of severe peat fires in 2015 was due to the cigarette.

Tumbang Nusa also has the MPA (fire brigade) like the other village. Recently, the MPA in coordination with BRG (Peatland Restoration Agency) established some dipwells as a source of water during dry seasons. The dipwells is established each 100 m distance. The dipwells will also be used as a water source for peat fire suppression in the future.

Soil responses on fire

Bulk density is the most important characteristics of peat (Andriesse 1988). It is influenced by humification, peat type and hydrological factors. High humification correlates with high bulk density, which lowers as the wetness increases. Values of bulk density range from 0.05 gr/cm^3 in very fibric, undecomposed materials to less than 0.5 gr/cm^3 in well-decomposed materials (Andriesse 1988).

Bulk Density (BD) analyses show a slight increasing value after the fire. It ranged from 0.15 to 0.12 g/cm^3 with an average of 0.22 g/cm^3 in unburned plots and from 0.12 to 0.34 g/cm^3 with an average of 0.50 g/cm^3 burned plots (**Table 1**, **Figure 2**.). The heating process during a fire may increase soil temperature and destroy surface soil structure, soil pore space, increase *bulk density* (Murtinah et al. 2017), and decrease soil water level and moisture content. It leads to an increase in bulk density (Ratnaningsih and Prasetyaningsih 2017). Besides, ash produced by the burning process may fill soil pores that can increase bulk density.

Soil porosity ranged from 4.49-91.49% in the burned plots with an average of 5.45%. It ranged from 73.76-89.55% in the unburned plots with an average of 83.76%. The large variation in water retention between peat materials is a function of porosity, pore size distribution (Sanches and Logan 1992) and hydraulic conductivity (Andriesse 1988). Coarse fibric materials have large pores, whereas the most-decomposed sapric material has relatively small pores. Water is increasingly held as the degree of decomposition increases.

Similar to Bulk Density, soil permeability has a slight difference between those in burned and unburned plots. It ranged from 25.15-75.55 cm/hr in the burned plots with an average of 48.32 cm/hr and between 24.78-73.25 cm/hr

Table 1 Descriptives of Physical and Chemical Peat Soil Properties

		Valid	Missing	Mean	Std. Deviation	Minimum	Maximum
Bulk Density	Burned	9	0	0.204	0.064	0.120	0.340
	Unburned	9	0	0.229	0.095	0.150	0.370
Porosity	Burned	9	0	85.451	4.489	76.050	91.490
	Unburned	9	0	83.757	6.749	73.760	89.550
Permeability	Burned	9	0	48.318	19.298	25.150	75.550
	Unburned	9	0	48.391	17.288	24.780	73.250
N-Total	Burned	9	0	0.838	0.284	0.610	1.390
	Unburned	9	0	0.847	0.174	0.580	1.160
P	Burned	9	0	539.833	1155.206	94.340	3613.210
	Unburned	9	0	189.728	65.606	103.770	292.450
K	Burned	9	0	1824.418	4780.758	98.770	14567.900
	Unburned	9	0	215.363	73.845	123.460	345.680
Na	Burned	9	0	314.130	574.311	74.070	1839.510
	Unburned	9	0	123.457	28.285	86.420	160.490
Ca	Burned	9	0	3039.689	6854.701	437.800	21308.400
	Unburned	9	0	670.489	234.170	323.000	1036.100
Mg	Burned	9	0	467.611	285.949	227.900	1141.600
	Unburned	9	0	402.867	124.881	231.100	617.200
Corg%	Burned	9	0	52.593	8.363	31.010	56.860
	Unburned	9	0	55.517	1.544	51.970	56.800
PH H2O	Burned	9	0	3.804	1.068	3.230	6.620
	Unburned	9	0	3.292	0.366	2.550	3.680

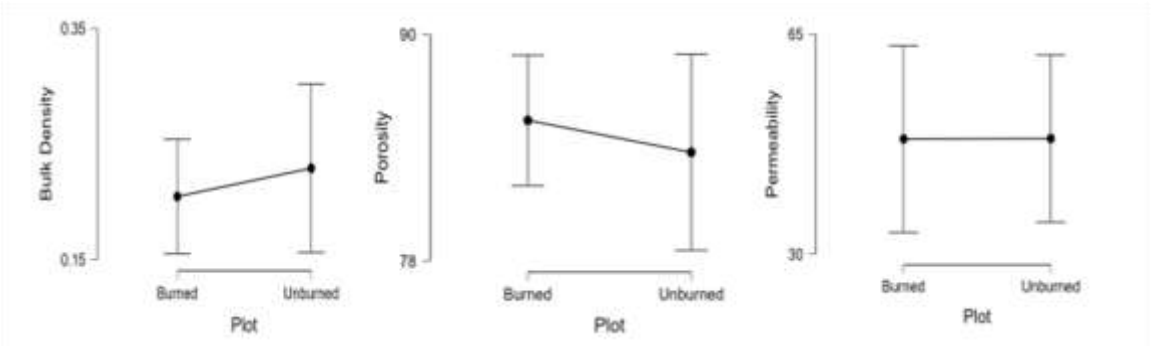

Figure 2 Physical peat soil properties in burned and unburned plots

in the unburned plots with an average of 83.76 cm/hr. All physical characteristics have no significant difference between burned and unburned areas (Table 2).

For chemical characteristics, only K, Na, Ca has significant differences (**Table 2**., **Figure 3.**). K content ranged from 98.77-14,567.90 ppm with an average of 1,824.42 ppm in the burned plots and from 123.46-345.68 ppm with an average of 215.36 ppm in the unburned plots. Na content ranged from 74.07-1,839.51 ppm in the burned plots with an average of 314.13 ppm and from 86.42-160.49 ppm in the unburned plots with an average of 123.46 ppm. Ca content ranged from 437.80-21,308.40 ppm in the burned plots with an average of 3,039.69 ppm and from 323-1,036.10 ppm in the unburned plots with an average of 670.49 ppm. Mg content ranged from 227.9-1,141.60 ppm in the burned plots with an average of 467.61ppm and from 231.10-617.20 ppm in the unburned

Table 2 Independent T-Test for physical and chemical peat soil properties in burned and unburned plots

	t	df	p	
Bulk Density	-0.640	16	0.531	
Porosity	0.627	16	0.539	
Permeability	-0.008	16	0.993	
N-Total	-0.080	16	0.937	
P	0.908	16	0.377	
K	1.010	16	0.328	[a]
Na	0.995	16	0.335	[a]
Ca	1.036	16	0.315	[a]
Mg	0.622	16	0.542	
Corg%	-1.031	16	0.318	
PH H2O	1.361	16	0.192	

Note. Student's t-test.
[a] Levene's test is significant ($p < .05$), suggesting a violation of the equal variance assumption

Table 3 Independent T-Test of peat soil properties based on locations

	t	df	p	
Bulk Density	-0.554	16	0.587	
Porosity	0.582	16	0.569	
Permeability	-2.546	16	0.022	
N-Total	-0.205	16	0.840	
P	-1.641	16	0.120	[a]
K	-1.476	16	0.159	[a]
Na	-1.709	16	0.107	[a]
Ca	-1.550	16	0.141	[a]
Mg	-1.754	16	0.099	
Corg%	2.302	16	0.035	[a]
pH H_2O	-1.128	16	0.276	[a]

Note. Student's t-test.
[a] Levene's test is significant ($p < .05$), suggesting a violation of the equal variance assumption

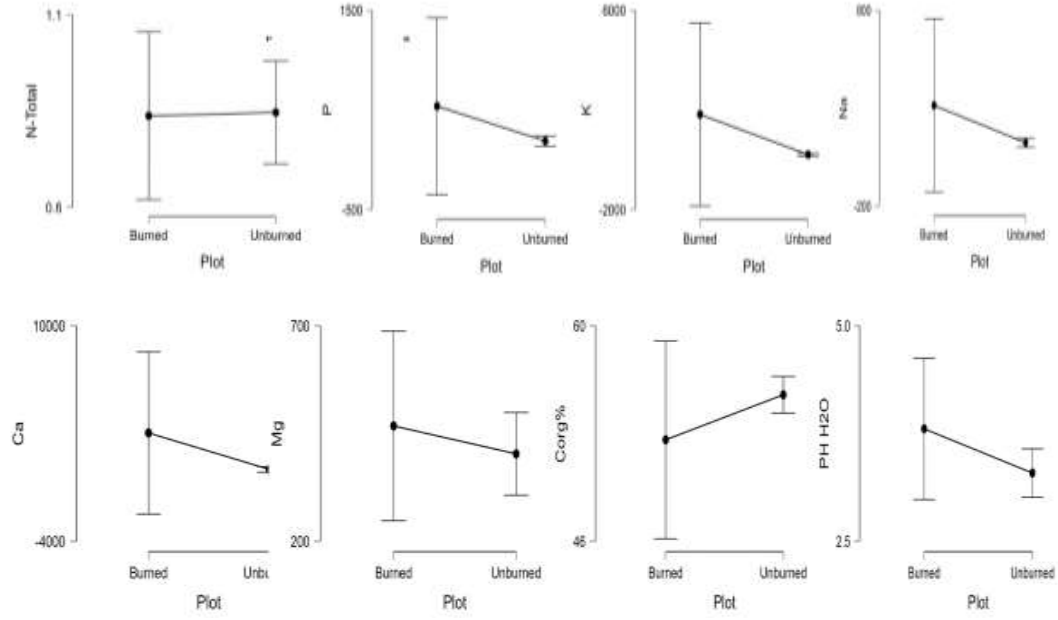

Figure 3 Chemical peat soil properties in burned and unburned plots

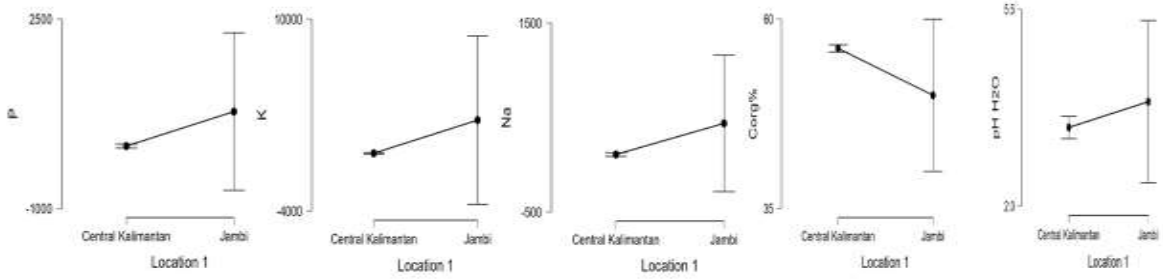

Figure 4 Chemical peat soil properties in Central Kalimantan and Jambi

plots with an average of 402.867 ppm. Corganic content ranged from 31.01-56.86 % in the burned plots with an average of 52.59% and from 51.97-56.80% in the unburned plots with an average of 55.51 ppm. pH value ranged from 3.23-6.62 in the burned plots with an average of 55.51 and from 2.55-3.68 in the unburned plots with an average of 3.29 (**Table 1.**).

The increase of macro cations is due to cations supply from the ash produced by burning, deposited to soil, and soil surface materials decomposition (Sanchez 1992). The accumulation of ashes in forest-peat-fires impacted area instantly increased pH, organic matter, humic acid content, hydrophobicity, available-N, and available-K (Agus et al. 2019). The residual ash from fires proved to be rich in metallic nutrients such as Ca, Mg, K, and Na (Wasis et al. 2019). The burning process may alter soil properties both physical and chemical soil properties (Syaufina and Abi Hamzah 2021).

Some of the peat characteristics seem to have significantly different between those in Jambi and Central Kalimantan, particularly for chemical peat properties of P, K, Na, C-org, and pH. Most of the soil properties show a higher Jambi content than those in Central Kalimantan, except for the C-organic content. Both locations have acidic soil properties with a mean pH value ranging from 3.39 (Central Kalimantan) to 3.85 (Jambi).

CONCLUSIONS

Forest and land fire affected peat soil properties both in the peatland of Jambi and that of Central Kalimantan. The study found significant differences in chemical peat soil properties of Potassium, Sodium, and Calcium, which are higher in the burned plots than the unburned plots. Whereas insignificant differences were found in the physical peat properties of bulk density, porosity and other chemical peat properties of N, P, Mg, C-org, and pH. Significant differences were also found for chemical peat soil properties in the Jambi and Central Kalimantan provinces of P, K, Na, C-org, and pH.

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