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Changes in some soil chemical properties in peatland after two years of fire in Kubu Raya, West Kalimantan

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Abstract*. The peatland fire that occurred in 2018 is located in Kubu Raya Regency, West Kalimantan. The initial study based on samples collected in the fire period reported that there were some changes in chemical properties leading to peatland damages. The study aimed to evaluate the effect of land fires on changes in some soil chemical properties after two years of fires. Soil samples of fired and unfired peatland were subjected to soil analyses. Soil analyses covered soil pH, organic carbon (C), phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and bulk density (BD). The results showed that after two years of peatland fires did not affect the changes in peat soil pH, organic C, P, Ca, Mg, K, Cu, Zn, Mn and BD. One plot of fired peatland showed that the weight of fresh frond and leaf area of oil palm grown on it was not statistically different from those of unfired peatland. The results suggested some chemical properties return to the previous equilibrium due to the high buffering capacity of peat soil.*

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INTRODUCTION

Indonesia has a peatland area of 13,4 million hectares, most of which is spread across the islands of Sumatra, Kalimantan, and Papua (Ritung *et al.* 2019). The existence of peatlands can provide benefits in reducing global warming because storing carbon in the soil and vegetation on it absorbs carbon dioxide (CO_2) gas (Uddin *et al.* 2019). In addition, peatlands serve as water storage with a large capacity so as to prevent the occurrence of floods in the rainy season and become a source of water in the dry season. But in the last period it is known that there has been frequent peat damage due to fires. Peatland fires are considered to damage peatlands both physically, chemically, and biologically. Therefore, peatland management must become a priority to prevent peatland fires (Nurhayati *et al.* 2021). Although in some degrees, peat fires increased the concentration of nutrients in soil solution and soil pH of peat soils (Beest *et al.* 2019; Sulaeman *et al.* 2021).

Peatland fires cause a lot of losses because they result in the loss of vegetation and organism living on peatlands, increased CO_2 emissions, and also air pollution due to ash particles in the atmosphere (Wasis *et al.* 2018, 2019; Larasati *et al.* 2019). Therefore, a detailed analysis of the impact of peat fires is important to continue to be studied. Of the many things associated with peat fires, changes in the physicochemical properties of peat soil after fires become a measured parameter to find out how much damage is due to peatland fires.

There is a question of whether the change in the physicochemical properties of peat soil comes from the addition of burned peat ash or from the ash of vegetation that grows on it. Furthermore, how the ability of peat soil to buffer the changes in physicochemical properties that occur due to the addition of ash. In general, changes in physicochemical properties measured after peatland fires are soil pH, soil organic C level, and soil bulk density.

Peatlands on the island of Kalimantan are spread in several provinces, including West Kalimantan Province so this province is one of the provinces prone to peatland fires. Peatland fires in West Kalimantan province are known to have occurred frequently and spread in several locations. This study used peatland fires that occurred in 2018 in Kubu Raya Regency West Kalimantan as a study case. Precisely the location was situated around Kubu Raya Regency. Peatland fires at that site are reported to have resulted in an increase in soil pH, reduced concentrations of organic C, and a drastic increase in soil bulk density. The study, therefore, aimed to evaluate how the physicochemical properties of peat soils after two years of fires and to evaluate the burned peat soil in supporting the growth of oil palm cultivated by local farmers.

METHODS

Location and Research Period

This research was conducted by collecting the peat soil samples at the burned and unburned points in the location around Kubu Raya Regency, West Kalimantan Province. The sampling point of burned and unburned peat soil is presented in Figure 1. Peat soil samples of burned peat soil were collected at points KR 1A, KR 3A, KR 4A, and KR 5A. Peat soil samples of unburned peat soil were collected at points KR 1B, KR 2B, KR 3B, KR 4B, and KR 5B. All peat soil samples of fired and unfired peat soil were collected at a depth of 0-30 cm. The duration of the research from soil sample collection to soil analyses was from September 10 to September 30, 2020. The soil analyses were conducted in Integrated Chemistry Laboratory of IPB University and in the Department of Soil Science and Land Resource Laboratory, Faculty of Agriculture, IPB University.

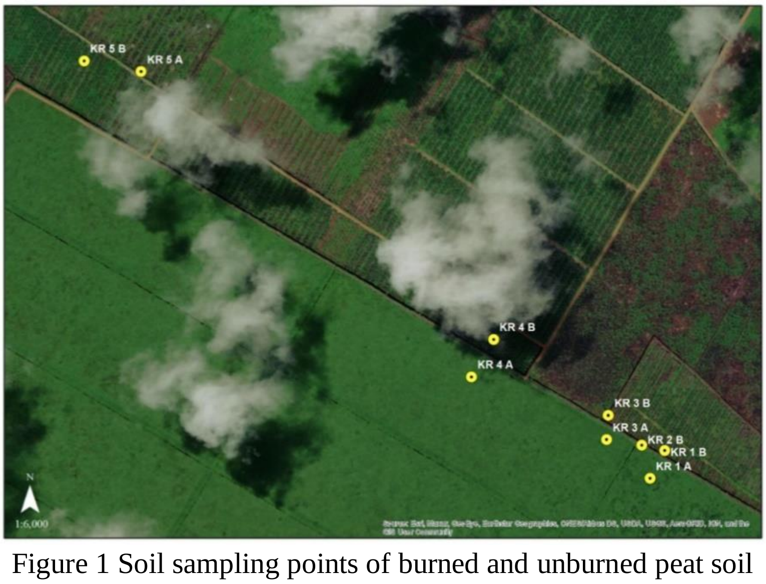

Figure 1 Soil sampling points of burned and unburned peat soil

Data Collection

Sampling of peat soil was conducted at determined points. The coordinate points and land descriptions are presented in Table 1. Photographs of peat soil sampling points are presented in Figure 2. Disturbed soil samples for chemical analyses were collected by boring peat soil at a depth of 0-30 cm, and undisturbed soil samples to measure the soil bulk density (BD) was conducted by using cube-shaped kubiena with a size of 10 cm x 10 cm x 10 cm at a depth 0-30 cm.

Land Type	**Photos**
KR 1 A	
KR 1 B	
KR 2 B	
KR 3 A	
KR 3 B	
KR 4 A	
KR 4 B	
KR 5 A	
KR 5 B	

Figure 2 Photos of soil sampling locations

Soil pH was determined using pH meter, organic carbon (C) was determined with the loss on ignition method where soil sample was heated in a muffle furnace at 550 ^oC for four hours, and organic C was calculated gravimetrically. Available P was determined using Bray 1 method (Bray and Kurtz 1945). Exchangeable calcium (Ca), exchangeable magnesium (Mg), exchangeable potassium (K), and exchangeable sodium (Na) were determined by extracting soil samples using 1,00 mol L^{-1} ammonium acetate pH 7,00 and the content of Ca, and Mg was determined by atomic absorption spectrophotometer (AAS) while the content of K and Na were determined by flame photometer. Iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) total was digested using concentrated nitric acid and perchloric acid, and the content of Fe, Mn, Cu, and Zn were determined by AAS. Soil BD was determined by dividing oven-dry weight soil with the volume of kubiena.

Growth of oil palm was evaluated in KR 5A as burned peatland and KR 5B as unburned peatland. The number 3 frond of oil palm was weighted, and the data were called the fresh weight of frond in kg. Lengt of frond, number of leaf, length of leaf, width of leaf were measured as supporting data to calculate the leaf area. Leaf area was calculated using the formula as follows: leaf area (m^2) = (length of leaf (cm) x width of leaf (mm) x number of leaf)/100.000.

Table 1 Coordinates and field description of collected soil samples points

Land Type	Latitude	Longitude	Vegetation	Description
KR 1 A	S 00°13’13,76”	E 109°18’13,6”	Shrubs	Burned
KR 1 B	S 00°13’11,78”	E 109°18’14,59”	Oil palm	Unburned
KR 2 B	S 00°13’11,45”	E 109°18’12,9”	Oil palm	Unburned
KR 3 A	S 00°13’10,96”	E 109°18’10,25”	Shrubs	Burned
KR 3 B	S 00°13’08,82”	E 109°18’10,54”	Oil palm	Unburned
KR 4 A	S 00°13’05,92”	E 109°18’00,01”	Shrubs	Burned
KR 4 B	S 00°13’03,72”	E 109°18’01,70”	Oil palm	Unburned
KR 5 A	S 00°12’43,59”	E 109°17’35,68”	Oil palm dan shrubs	Burned
KR 5B	S 00°12’42,52”	E 109°17’31,90”	Oil palm	Unburned

Data Analysis

Data from the soil analysis obtained is then processed using Microsoft Office Excell 2019. Furthermore, analyses of variance (ANOVA) were carried out using the Minitab 19 program to find out the effect after two years of peatland fires on changes in pH, organic C, Bray 1-P, exchangeable Ca, exchangeable Mg, exchangeable K, exchangeable Na, Fe total, Mn total, Cu total, Mn total, soil BD, the fresh weight of frond of oil palm and leaf area of oil palm. If ANOVA resulted in significantly different than the mean value difference test was carried out using the Tukey test at the alpha level <0,05. If ANOVA was not significantly different, then the mean value difference test was not carried out.

RESULTS AND DISCUSSION

The results of the changes in physicochemical properties after two years of fire are presented in Table 2. The physicochemical properties of burned peat soil were represented by KR 1A, KR 3A, KR 4A, and KR 5A. As for unburned peat soils were represented by KR 1B, KR 2B, KR 3B, KR 4B, and KR 5B. Table 3 shows the mean values of the physicochemical properties of burned and burned peat soil. Analyses of variance showed that physicochemical properties between burned peat soil and unburned peat soil were not significantly different statistically. The mean values of each physicochemical property are presented in Table 3. The values of soil pH between burned and unburned peat soil were very close. This was very different from previous reports that there has been a change in soil pH close to the value of 6.

Even after 2 years of fires, the pH value of burned peatlands was slightly lower than that of unburned ones (Table 3). The level of peat soil acidity is closely related to the content of organic acids, humic acid, and fulvic acid (Miller and Donahue 1990). Organic C, after two years of fire, was not different between burned and unburned peat soil. Organic C levels reportedly dropped quite sharply after the fire. However, the results of the organic C analysis after two years of fire showed that there was not any decrease in organic C levels. Peat depth data (Table 4) shows that the depth of peat soil between burned and burned peat soil were relatively same. This was contrary to some previous studies reporting that peatland fires have led to reduced soil organic C concentrations and decreased peat depth (Wasis *et al.* 2019; Sulaeman *et al.* 2021).

Table 2 Physicochemical properties of unburned and burned peat soil

Land type	pH	Organic C	Bray 1-P	Ca	Mg	K	Na	Fe	Mn	Cu	Zn	BD
		%	mgkg^{-1}	cmol (+) kg^{-1}				mgkg^{-1}				gcm^{-3}
Burned												
KR 1A 0-30 cm	4,27	57,9	27,8	1,73	0,44	0,13	0,12	995	13,3	4,45	4,83	0,13
KR 3A 0-30 cm	4,19	57,9	53,7	1,15	0,46	0,25	0,20	1.532	11,9	5,01	5,26	0,15
KR 4A 0-30 cm	4,09	57,9	36,0	1,18	0,35	0,13	0,19	2.195	16,7	3,87	5,17	0,16
KR 5A 0-30 cm	4,17	57,7	40,1	0,88	0,28	0,07	0,16	2.325	20,1	3,88	6,51	0,15
Unburned												
KR 1B 0-30 cm	4,17	57,9	39,2	0,92	0,11	0,07	0,04	995	13,3	4,45	4,83	0,32
KR 2B 0-30 cm	4,36	57,5	25,2	2,88	0,42	0,12	0,07	2.028	27,4	6,25	8,31	0,38
KR 3B 0-30 cm	4,07	57,7	43,6	0,53	0,12	0,14	0,05	1.800	6,54	4,80	6,58	0,19
KR 4B 0-30 cm	4,12	57,9	51,8	0,92	0,28	0,14	0,18	2.325	20,1	3,88	6,81	0,14
KR 5B 0-30 cm	4,26	58,0	38,2	0,50	0,43	0,07	0,20	1.629	12,2	2,67	4,31	0,16

Table 3 The mean values of physicochemical properties of unburned and burned peat soil

Land type	pH	Organic C	Bray 1 P	Ca	Mg	K	Na	Fe	Mn	Cu	Zn	BD
		%	mgkg^{-1}	cmol (+) kg^{-1}				mgkg^{-1}				gcm^{-3}
Burned	4,18	57,8	39,4	1,24	0,38	0,15	0,17	1.762	15,5	4,30	5,44	0,15
Unburned	4,20	57,8	39,6	1,15	0,27	0,11	0,11	1.755	15,9	4,41	6,17	0,24

Note: The result of ANOVA showed that the soil properties of burned and unburned peat soil were not different

Table 4 The depth of burned and unburned peat soil

Land Type	Latitude	Longitude	Status	Depth (cm)
KR 1 A	S 00°13’13,76”	E 109°18’13,61’’	Burned	400
KR 3 A	S 00°13’10,96”	E 109°18’10,25”	Burned	400
KR 4 A	S 00°13’05,92”	E 109°18’00,01”	Burned	450
KR 4 B	S 00°13’03,72”	E 109°18’01,70”	Unburned	395

Bray 1 P values as available P for the plant, between burned and unburned peat soil, were not significantly different statistically. The values of Ca, Mg, K, and Na as basic cations of burned peat soil were not significantly different from those of unburned peat soil. The mean values of Ca, Mg, K, and Na were relatively higher than those of unburned peat soil, suggesting there was an addition of ashes from burned organic materials. This result was the same as what Sulaeman *et al.* (2021) reported. As for the case of Kubu Raya, West Kalimantan, this might not be from bottom peat materials but from burned vegetation growing on peat soil.

The mean values of micronutrient Fe, Mn, Cu, and Zn of burned peat soil were not significantly different from those of unburned peat soil. As for bulk density, abbreviated BD, the BD of burned peat soil was not significantly different from those of unburned peat soil. The BD value of burned peat soil was lower than that of unburned peat soil. This is contrary to what was reported by Wasis *et al.* (2019) who reported that peat fires had increased the value of BD peat soil.

ANOVA resulted in that the leaf area and fresh weight of the frond were not statistically different. The mean values of the leaf area and fresh weight of the frond are presented in Table 5. Table 5 shows that mean values of the leaf area and fresh weight of the frond of oil palm growing in burned peat soil (KR5A) and in unburned peat soil (KR 5B) were not different. The mean values of leaf area and fresh weight of frond of oil palm grown in unburned peat soil were relatively higher than that of burned peat soil. This was because of better oil palm management in unburned peat soil than in burned peat soil. KR 5B, as unburned peat soil, was owned by an oil palm company, while KR 5A, as burned peat soil, belongs to the village people. The result showed that after two years of fire, peat soil in Kubu Raya could support the growth of oil palm. These results suggested that the drastic changes in some physicochemical properties immediately after the fire could be caused by the addition of ash from vegetation grown on peat soil. The high buffering capacity of peat soil returns the physicochemical changes to the previous equilibrium.

Table 5 The growth of oil palm grown in burned and unburned peat soil

Land type	**Status**	**Vegetation**	**Year of planting**	**Repetition**	**Lengt of frond (cm)**	**Number of leaf**	**Length of leaf (cm)**	**Width of leaf (mm)**	**Leaf area (m^2)**	**Mean of leaf area (m^2)**	**Fresh weight of frond (kg)**	**Mean of fresh weight of**
KR 5A	Burned	Shrubs and oil palm	2014	1	391	155	78,0	45,0	6,00	4,90	3,60	2,77
				2	432	119	75,0	40,0	3,90		2,60	
				3	336	124	74,5	35,0	3,60		2,10	
KR 5B	Unburned	Oli palm	2014	1	451	151	84,5	44,0	6,20	6,10	4,00	3,37
				2	397	132	85,0	45,0	5,60		2,20	
				3	440	148	81,0	50,0	6,60		3,90	

Note: Anova was done for leaf area and fresh weight of frond as growth indicators

CONCLUSION

Changes in physicochemical properties of the soil after peat fires that occurred in Kubu Raya West Kalimantan were not significantly different between burned and unburned peat soils. The burned peat soil could support the growth of oil palm, suggesting that peat soil had the ability to buffer rapid changes and possibly also changes in the physicochemical properties of peat soils immediately after fire came from the ash of burning vegetation that has grown on peat soil.

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