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Abstract
Peatland fires occur every year in the South Kalimantan Province Indonesia, particularly affecting soil characteristics. The purposes of this study are to analyse the physical aspects of soil (colour and soil texture) caused by fires and to investigate the chemical characteristics of soil (pH, Fe^{2+}, P_2O_5, and K_2O). This study used measurements in the field based on a map of peatland fires in the region and laboratory results. There were 24 samples in this study; they were taken in October 2018, which was about a month after the fire, and in January 2019, which was about four months after the burning. The samples were analysed regarding the soil colour, texture, pH, Fe^{2+}, P_2O_5, and K_2O. The results of the study indicated that the characteristics of the soil on burned land in October 2018 had higher pH, P_2O_5, and K_2O levels than in January 2019. Fires occurred in soil brought changes to the soil physical and chemical properties. The added combustion ash affected the physical and chemical properties of the land, such as soil colour, texture, pH, P_2O_5, K_2O, and Fe^{2+}.

Keywords
Peatland, land burning, soil characteristics

Introduction

Land fires in Indonesia are regional and global disasters. They do not only bring impacts to Indonesia but gas emission from the combustion also affect neighbouring countries (Nugroho, 2017). Fires in Indonesia occur not only on dry land but also on wetlands (Cahyono et al., 2015; Rauf, 2016). In wetlands, they often burn on deep organic soils that accumulate in this ecosystem. Fires can occur on high-frequency wetlands that will increase in the future (Brown et al., 2015; Watts & Kobziar, 2013), one of which is on peatland.

Peatlands in Indonesia are estimated at 20.6 million hectares or around 10.8% of Indonesia's land area. Peatland fire in Indonesia regularly occurs in the dry season. The dry season is compounded by the number of dry days within the dry season or the El Niño, and the drainage system of peatland (Novitasari et al., 2019; Nugroho, 2017). In the reaction of peatland burning, the Indonesian government has propelled an activity to reestablish more than 2 million ha of peatland between presently and 2020 for Kalimantan, Sumatra, and Papua Islands (Hansson & Dargusch, 2017).

Kalimantan peatland area reaches 5.7 ha, or 27.8% of the island (Wahyunto & Suparto, 2004) and this area becomes the main location of Reducing Emissions from Deforestation and forest Degradation (REDD+) which is a project of sustainable management of forests and enhancement of forest carbon stocks in developing countries (Rajiani & Pypłacz, 2018). Peatland in South Kalimantan is always burned every year (Arisanty et al., 2019; Vetrita & Cochrane, 2020). The area burned in South Kalimantan Province has increased in the last 3 years. The burned area reached 2,331.96 Ha in 2016; 8,290.34 Ha in 2017 and raised to 98,637.99 Ha in 2018. Most of the peatlands in South Kalimantan Indonesia are at risk of experiencing fires. In January 1st to September 14th, 2018, 552 land fires were causing the area to burn up to thousands of hectares. The most burned land area occurred in Banjarbaru, which reached 467.03 hectares and mostly located on peatland (Kumparan, 2018).

Peatlands in South Kalimantan are classified as thin and medium peat soils (Wahyunto & Suparto, 2004). Fires every year occurred on peatlands increasingly cause degraded soil conditions in South Kalimantan. Research on the impact of peat fires on the physical and chemical characteristics of soils in Indonesia is still limited, especially in South Kalimantan, although fires continue to occur every year in the South Kalimantan region.

Literature Review

Burned Peatland

Peatlands are lands rich in organic material with organic C > 18% and a minimum thickness of 50 cm. Natural materials on peat soil are formed from undecayed plant remnants and are often found in swampy areas or poorly drained basins. Peat soils are generally formed in water-saturated and nutrient-poor conditions (Agus et al., 2019; Xu et al., 2018). They consist of at least 30% of dead organic matter's dry mass. Peatlands can have vegetation and no peat on its surface (Joosten, 2009). In general, the minimum thickness of peat in a bog is 30 cm (Joosten et al., 2012).

Peatlands play critical economic and ecological roles (Saputra, 2019) and are crucial for the life of human culture (Xu et al., 2018). Human interference in peatland management causes damage. Problems occurring in peatlands are fire, deforestation, land subsidence (Saputra, 2019), and agricultural land clearing (Frolking et al., 2011). The inventory of peatland potential is still shallow due to the problematic interpretation of satellite imagery and the low data obtained through field measurements (Joosten, 2009). It is crucial to conserve peatland ecosystems since they have essential functions, which are the preservation of water resources, flood suppression, prevention of seawater intrusion, supporting various life/biodiversity, and climate control as it is one of the carbon supplies (Wahyunto & Suparto, 2004; Wiri et al., 2017).

Human is the highest factor in causing the damage (Prayoto et al., 2017; Tacconi, 2003); for instance, community's lack of the attention to peatlands, forest conversion on a peatland such as land clearing and plantations with inappropriate trenching and peatland fires (Prayoto et al., 2017). However, drying as a result of climate alter and human action brings down the water table in peatlands and increments the recurrence and degree of peat fires (Turetsky et al., 2015).

Cultivated peatlands are more vulnerable to fires than conserved ones (Prayoto et al., 2017). The vulnerability is best characterised as a total degree of human welfare that integrates a natural, social, financial and political introduction to a run of potential hurtful annoyances (Blistanova et al., 2016). Burning peatlands is considered the easiest way to clear them; the community also deems it can increase soil fertility (Wiri et al., 2017; Zulkifli & Kamarubayana, 2017). Fires on peatlands are more difficult to extinguish than the others. Areas with extensive and deep peatland will take years to ensure that the fires have been completely extinguished (Jones, 2005). The dynamics of peat fires are caused by the exploitation of large-scale agricultural and plantation activities. These activities are followed by forest clearing and peatland drainage so that it made the peatland dry; if accompanied by a long dry season, everything can increase the danger level of fires (Page, 2016). Conversion of secondary forests by cutting down and burning organic matter that converted into available nutrients will increase the pH of the soil at the surface of the soil. However, these nutrients are easily dissolved by high rainfall. Land becomes degraded over a long period of time and flammable during the dry season (Agus et al., 2020). To make it worst, burned peat forests need 27 to 47 years to recover, depending on the environment in which the vegetation grows (Marlier et al., 2019).

Effect of fire for soil characteristics

Combustion of peatlands can cause damage to peat soil. The soil physical nature determines the land quality because land with excellent physical properties will provide good environmental quality (Susandi et al., 2015). The peat characteristics affected by open-fire have undergone extreme changes (Könönen et al., 2015). Peat soil burned has decreased water content, water binding power, porosity, and permeability while Bulk Density (BD) and Particle Density (PD) has increased, compared to non-burning peat soil. Fire decreases total carbon (TC), total nitrogen (TN), and organic phosphorus (P_o), but fire increases inorganic phosphorus (P_i) and total calcium (TCa) (Smith et al., 2001). The microbial abundance and phosphatase movement within the burned soils substantially diminished compared to those of the unburned soil (Sazawa et al., 2018).

Peat fires also affect soil temperature, structure, and ability to absorb water. Damage to the structure and reduced pore will cause increased soil fill weight — fires' open' the soil due to loss of litter, understorey, and canopy. The open ground will increase temperature, evaporation rate, loss of organic matter and decreased water content available (Lubis, 2016). In areas with low topography, peatland fires can change the volume, height, and water storage in wetlands after fires (Watts & Kobziar, 2013).

Based on background, the purposes of this research are (1) to analyse the physical characteristics of soil (colour and soil texture) caused by fires in Banjarbaru, Indonesia (2) to investigate the chemical characteristics of soil (pH, dissolved Fe^{2+}, P_2O_5, and K_2O) caused by fires.

Materials and Methods

This research was conducted in Banjarbaru, South Kalimantan Province, Indonesia. The city of Banjarbaru is geographically located between 3 ° 25'40 "-3 ° 28 '37" LS and 114 ° 41'22 "-114 ° 54'25" BT (BPS, 2018). Soil samples were measured based on the location of peatland fires in Banjarbaru, obtained from the data of Sipongi hotspot points (SiPongi, 2018). There were 24 samples in total: 12 samples in October 2018 and 12 samples in January 2019 taken in the same location; they were taken based on fire occurrence on peatland in Banjarbaru, Indonesia. The sampling map is shown in Figure 1. The fires occurred around September 2018 in the research area. The samples were taken in October 2018, which was about one month after the fire; and in January 2019, which was about 4 months after the fire. One month after the fire, the land was still dry because the burning vegetation had not grown back. In January 2019, the land was wet and inundated because it was the rainy season, and the vegetation began to grow again. The land cover at the research location was shrubs. The location of research in the field can be seen in Figure 1 and Figure 2.

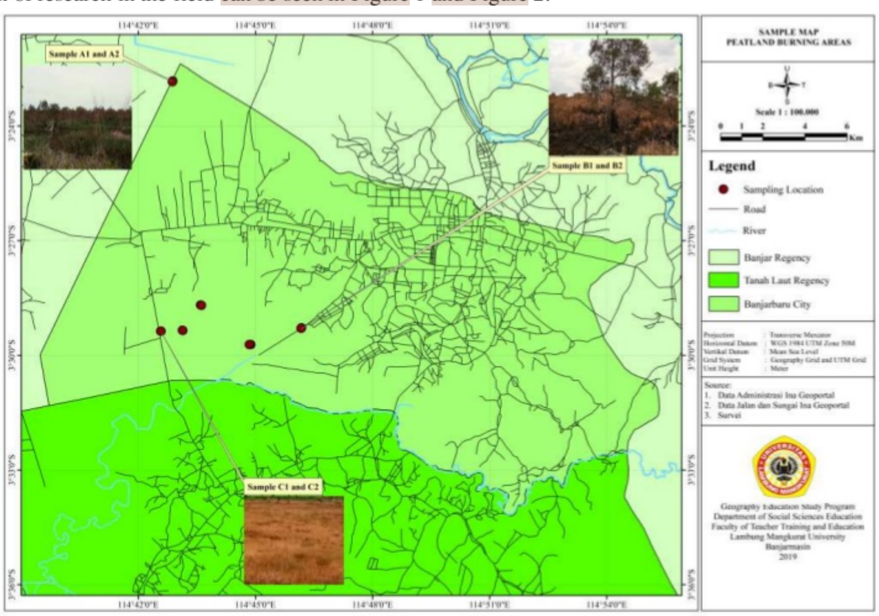

Fig. 1. Research location

The sampling utilised a peat soil drill. The drilling depth was 1 meter. The fire has an impact on peat depth. The peat in the research area included shallow/thin peat types with an average thickness of about 50-100 cm and medium peat with a diameter of 100-200 cm based on the map of peat in Kalimantan (Wahyunto & Suparto, 2004). In location, peat only has the depth about 10 cm-15 cm because of peat degradation due to fire. The extent of peat burned has a relationship with the fire recurrence (Wijedasa, 2016).

The samples were analysed regarding colour, pH, texture, dissolved Fe^{2+}, P_2O_5, and K_2O. Soil colour and pH were identified directly in the field. The soil colour was identified using Munsell's soil book; the soil pH was determined using Soil pH meter. The dissolved Fe^{2+}, P_2O_5, and K_2O were identified through laboratory tests.

Fig. 2. Research location (a) One month after the fire (October 2018); and (b) Four months after the fire (January 2019)

Results

Physical Characteristics of Soil in Burned Peatland

Soil Color

The colour characteristics of the soil at one month after the fire and 4 months after the fire are presented in Table 1.

Tab. 1. The colour of soil on burned land

Samples No.	X	Y	Soil colour 1 month after the fire		Soil colour 4 months after the fire	
A1	244795.8	9627240	7.5 YR 3/1	Very Dark Grey	7.5 YR3/2	Dark Brown
A2	244786.0	9627210	7.5 YR 3/2	Dark Brown	7.5 YR3/2	Dark Brown
B1	245542.4	9613998	7.5 YR 3/2	Dark Brown	7.5 YR3/2	Dark Brown
B2	245551.7	9613996	7.5 YR3/2	Dark Brown	7.5 YR3/2	Dark Brown
C1	246582.6	9614035	7.5 YR3/2	Dark Brown	7.5 YR 3/2	Dark Brown
C2	246573.0	9614040	7.5 YR3/2	Dark Brown	7.5 YR3/2	Dark Brown
D1	247435.5	9615259	7.5 YR3/2	Dark Brown	7.5 YR3/2	Dark Brown
D2	247466.1	9615244	7.5 YR3/1	Very Dark Grey	7.5 YR3/2	Dark Brown
E1	252218.8	9614169	7.5 YR3/2	Dark Brown	7.5 YR3/2	Dark Brown
E2	252203.1	9614150	7.5 YR3/2	Dark Brown	7.5 YR3/2	Dark Brown
F1	249811.4	9613362	7.5 YR3/1	Very Dark Grey	7.5 YR3/2	Dark Brown
F2	249750.6	9613357	7.5 YR3/1	Very Dark Grey	7.5 YR3/2	Dark Brown

The fire caused the colour to be very dark grey in within one month after the land burning. Moreover, fire locations at points A1, D2, F1, and F2 had very dark grey soil colours; the mixture of combustion ash resulted in the grey colour of the soil within a month after the fire.

Nevertheless, change in colour did not occur on all soils at the research site. Some research locations, such as points A2, B1, B2, C1, C2, D1, E1, and E2, did not experience changes in soil colour between 1-month post-fire and 4-months post-fire. There was additional rainwater inundating the land in 4 months after the fire at the locations A1, D2, F1, and F2 washing residual combustion ash on the ground, which caused the soil to become dark brown.

Soil texture

The soil texture characteristics at one month after the fire and 4 months after the fire can be seen in Table 2.

Tab. 2. The soil texture on burned land

Samples No.	X	Y	Soil Texture 1 month after the burning				Soil Texture 4 months after the burning			
			Sand (%)	Silt (%)	Clay (%)	Texture	Sand (%)	Silt (%)	Clay (%)	Texture
A1	244795.8	9627240	1.3	49.05	49.65	Silty Clay	1.74	52.62	45.64	Silty Clay
A2	244786.0	9627210	5.53	49.68	44.79	Silty Clay	1.27	13.71	85.02	Clay
B1	245542.4	9613998	0.40	62.94	36.62	Silty Clay Loam	0.92	51.25	47.83	Silty Clay
B2	245551.7	9613996	0.23	63.68	36.10	Silty Clay Loam	2.17	59.03	38.80	Silty Clay
C1	246582.6	9614035	0.15	55.11	44.74	Silty Clay	1.05	56.21	42.74	Silty Clay
C2	246573.0	9614040	3.03	53.86	43.11	Silty Clay	0.95	55.20	43.85	Silty Clay
D1	247435.5	9615259	0.01	57.32	42.67	Silty Clay	25.97	39.39	34.64	Clay Loam
D2	247466.1	9615244	10.78	54.88	34.34	Silty Clay Loam	27.77	41.03	31.19	Clay Loam
E1	252218.8	9614169	30.47	37.30	32.23	Clay Loam	19.57	33.63	46.80	Clay
E2	252203.1	9614150	36.49	36.07	27.44	Clay Loam	21.34	29.25	49.42	Clay
F1	249811.4	9613362	7.01	57.36	35.63	Silty Clay Loam	2.80	56.85	40.35	Silty Clay
F2	249750.6	9613357	2.98	59.03	37.98	Silty Clay Loam	3.64	56.69	39.67	Silty Clay

The soil texture was dominated by excellent size material such as silt and clay. At one month after the fire, the silt content dominated the surface compared to sand and clay. Minimum of sand content at 1 month was 0.01, while the maximum of sand content at 1 month was 36.49. Besides, minimum of silt content at 1 month was 36.07, while the maximum of silt content at 1 month was 63.68. Further, the minimum of clay content at 1 month was 27.44, while the maximum of clay content at 1 month was 49.65. Range of sand at 1 month was 36.48. Range of silt was 27.61. Range of clay was 22.21. In the other hand, the mean of sand was 9.1733 with the standard deviation were 12.18556 and variance was 148.488. Mean of silt was 53.0233, with the standard deviation were 8.81815 and variance was 77.760 and mean of clay was 38.7750 with the standard deviation were 6.30513 and variance was 39.755.

The material content at 4 months was dominated by clay. Minimum of sand at 4 months was 0.92, while the maximum of sand was 27.77. Minimum of silt was 13.71, while the maximum of silt was 59.03. Minimum of clay was 31.19, while the maximum of clay was 85.02. Range of sand, silt and clay contents were 26.85, 45.32, and 53.83. Means of sand, silt and clay contents were 9.0992, 45.4050, and 45.4958. Standard deviations of sand, silt and clay contents were 10.96999, 14.14991, and 13.56061. Variances of sand, silt and clay contents were 120.341, 200.220, and 183.890. Descriptive statistics of sand, silt and clay contents were presented in Table 3.

Tab. 3. Descriptive statistics of sand, silt, and clay contents

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
1month_Sand	12	36.48	.01	36.49	9.1733	3.51767	12.18556	148.488
1 month_Silt	12	27.61	36.07	63.68	53.0233	2.54558	8.81815	77.760
1 month_Clay	12	22.21	27.44	49.65	38.7750	1.82013	6.30513	39.755
4 months Sand	12	26.85	.92	27.77	9.0992	3.16676	10.96999	120.341
4 months Silt	12	45.32	13.71	59.03	45.4050	4.08473	14.14991	200.220
4 months Clay	12	53.83	31.19	85.02	45.4958	3.91461	13.56061	183.890
Valid N (listwise)	12							

The silt content was also higher in one month after the fire, compared to 4 months after. The clay content was also higher in 4 months than one month. The soil texture in one month after the fire was dominated by silty clay and silty clay loam, while the soil texture in 4 months after the fire was silty clay and clay loam. The fire created new ash on the ground so that the silt content in one month after the fire was higher than 4 months after. The rainwater in 4 months after the fire washed the residual combustion ash on the ground causing the soil texture to be dominated by silty clay.

Chemical Characteristics of Soil in Peatland

pH

The pH at one month after the fire and 4 months after the fire are displayed in Table 4.

Tab. 4. The characteristics of pH on burned land

Samples No.	X	Y	pH 1 month after the fire	pH 4 months after the fire
A1	244795.8	9627240	6	4
A2	244786.0	9627210	4	4
B1	245542.4	9613998	4	4
B2	245551.7	9613996	5	4
C1	246582.6	9614035	5	4
C2	246573.0	9614040	5	4
D1	247435.5	9615259	5	4
D2	247466.1	9615244	3	4
E1	252218.8	9614169	5	4
E2	252203.1	9614150	4	4
F1	249811.4	9613362	6	4
F2	249750.6	9613357	5	4

The soil pH a month after the fire ranged from 3-6, while the soil pH 4 months after the fire was 4. Mean of pH a month after the fire is pH 4 month is 4. The standard deviation of 1 month is 0.866, while the standard deviation of 4 months is 0. The average pH condition decreased. The peatland was dry in one month after the fire and was flooded after 4 months due to additional water from the rain and from canals around the peatland. Descriptive statistic of pH is presented in Table 5.

Tab. 5. Descriptive statistics of pH

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
1 month	12	3	3	6	4.75	.250	.866	.750
4 months	12	0	4	4	4.00	.000	.000	.000
Valid N (listwise)	12							

Fires added minerals from ash or charcoal to the soil, increasing the pH level of the soil within a month after the fire. Alkaline oxides from the ash remaining combustion added at the time of the fire increased the pH levels. The pH level decreased along with the inundation of peatlands during the rainy season. The dissolution of residual combustion ash in stagnant soil caused the pH levels to drop.

Fe Dissolved (Fe^{2+})

The characteristics of Fe^{2+} at one month after a fire and after 4 months of fire are presented in Table 6.

The level of Fe^{2+} in one month of fire was lower than 4 months after, except at points A1, A2, E1, and E2. The highest Fe^{2+} at one month after the fire was 268.78 ppm, while the lowest was 18.18 ppm. Range of Fe^{2+} was 250.60 and the mean of Fe^{2+} at one month was 94.2592. Standard deviation at one month was 77.92506.

Tab. 6. Fe^{2+} in burned land

Samples No.	X	Y	Fe^{2+} 1 month after the fire (ppm)	Fe^{2+} 4 months after the fire (ppm)
A1	244795.8	9627240	125.53	30.39
A2	244786.0	9627210	268.78	105.36
B1	245542.4	9613998	71.67	150.11
B2	245551.7	9613996	77.87	2200.74
C1	246582.6	9614035	57.30	265.45
C2	246573.0	9614040	48.82	305.89
D1	247435.5	9615259	18.18	332.53
D2	247466.1	9615244	76.89	344.78
E1	252218.8	9614169	88.68	30.39
E2	252203.1	9614150	227.75	105.36
F1	249811.4	9613362	43.30	150.11
F2	249750.6	9613357	26.34	2200.74

Furthermore, the highest Fe^{2+} at 4 months after the fire was 2200.74 ppm, while the lowest was 30.39 ppm. The Fe monthly concentration was lost due to the combustion process. After 4 months of the fire, rainwater inundated the peatland and caused a reduction condition increasing $Fe^{2+.}$ Range of Fe^{2+} was 2170.35, and the mean of Fe^{2+} at 4 months was 518.4875, with the standard deviation at 4 months of 793.33348. Descriptive statistics of Fe^{2+} was presented in Table 7.

Tab. 7. Descriptive statistics of Fe^{2+}

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
1 month	12	250.60	18.18	268.78	94.2592	22.49503	77.92506	6072.315
4 months	12	2170.35	30.39	2200.74	518.4875	229.01565	793.33348	629378.007
Valid N (listwise)	12							

P_2O_5 Content

The characteristics of P_2O_5 levels at one month after the fire and after 4 months of fire can be seen in Table 8.

Tab. 8. P_2O_5 levels in burned land

Samples No.	X	Y	P_2O_5 1 month after the fire (mg/100 g)	P_2O_5 4 months after the fire (mg/100 g)
A1	244795.8	9627240	14.50	2.89
A2	244786.0	9627210	10.56	1.70
B1	245542.4	9613998	14.61	2.03
B2	245551.7	9613996	4.88	2.31
C1	246582.6	9614035	4.45	2.40
C2	246573.0	9614040	56.94	2.88
D1	247435.5	9615259	2.99	3.19
D2	247466.1	9615244	15.38	1.71
E1	252218.8	9614169	26.11	3.27
E2	252203.1	9614150	12.70	2.47
F1	249811.4	9613362	10.79	7.33
F2	249750.6	9613357	9.92	1.99

P_2O_5 concentrations were higher one month after the fire and then decreased at 4 months after the fire. The highest P_2O_5 level at one month after the fire was 56.94 mg/100 g, while the lowest was 2.99 mg/100 g. The highest P_2O_5 level at 4 months after the fire was 7.33 mg/100 g; while the lowest was 1.70 mg/100 g. Range of P_2O_5 at 1 month was 53.95, while the range of P_2O_5 at 4 months was 5.63. Mean of P_2O_5 at 1 month was 15.3192, while the mean of P_2O_5 at 4 months was 2.8475. Standard deviation at 1 month was 14.48576, while standard deviation at 4 months was 1.50868. Variance value at 1 month was 209.837, while variance at 4 months was 2.276. Descriptive statistics of P_2O_5 was presented in Table 9.

Tab. 9. Descriptive statistics of P_2O_5 levels

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
1 month	12	53.95	2.99	56.94	15.3192	4.18168	14.48576	209.837
4 months	12	5.63	1.70	7.33	2.8475	.43552	1.50868	2.276
Valid N (listwise)	12							

P_2O_5 levels increased at one month after the fire due to the burning of organic matter and mineralisation caused by high temperatures. At 4 months after the fire, P_2O_5 levels decreased; this was resulted from the rainwater on peatland, causing loss of P_2O_5 levels in the soil since it dissolved in water inundating the peatlands.

K_2O Content

Characteristics of K_2O levels at one month after the fire and 4 months after the fire are displayed in Table 10.

Tab. 10. K_2O levels in burned land

Samples No.	X	Y	K_2O 1 month after the fire (mg/100 g)	K_2O 4 months after the fire (mg/100 g)
A1	244795.8	9627240	9.37	8.40
A2	244786.0	9627210	8.95	4.81
B1	245542.4	9613998	8.01	6.97
B2	245551.7	9613996	7.66	6.87
C1	246582.6	9614035	8.46	10.67
C2	246573.0	9614040	8.05	9.67
D1	247435.5	9615259	7.25	5.96
D2	247466.1	9615244	7.82	5.28
E1	252218.8	9614169	7.85	6.52
E2	252203.1	9614150	7.87	3.18
F1	249811.4	9613362	7.51	3.29
F2	249750.6	9613357	7.68	2.56

K_2O levels were almost the same as P_2O_5 levels. One month after the fire, K_2O levels were higher than 4 months after. The highest K_2O level one month after the fire was 9.37 mg/100 g, while the lowest was 7.25 mg/100 g. The highest K_2O level at 4 months after the fire was 10.67 mg/100 g, and the lowest was 2.56 mg/100 g. Range of K_2O level at 1 month was 2.12, and the range of K_2O level at 4 months was 8.11. Mean of K_2O level at 1 month was 8.0400, while the mean of K_2O level at 4 months was 6.1817. The standard deviation at 1 month was 0.60804, while standard deviation at 4 months was 2.55265. Variance at 1 month was 0.370. Variance at 4 months was 6.516. K_2O levels were higher at one month after a fire due to the burning of organic matter and mineralisation caused by high temperatures. At 4 months after the fire, K_2O levels decreased at almost all samples except at C1 and C2. The cause of decreased K_2O was rainwater inundating peatlands. The flooded peatlands washed K elements in the soil and dissolved them in water. Descriptive statistics of K_2O levels were presented in Table 11.

Tab. 11. Descriptive statistics of K_2O levels

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
1 month	12	2.12	7.25	9.37	8.0400	.17553	.60804	.370
4 months	12	8.11	2.56	10.67	6.1817	.73689	2.55265	6.516
Valid N (listwise)	12							

Discussion

Fire causes an increase in pH, P_2O_5, and K_2O levels; it also brought changes in soil colour, texture, and decreased Fe^{2+}. The residual combustion ash on the soil increased the silt, pH, of P_2O_5, and K_2O levels. Characteristic peat soil in October 2018 was soil colour was very dark grey-dark brown, the soil texture was silty clay and silty clay loam, the pH level was 3-6. Fe^{2+} was 18.18-268.78 ppm. Mean of Fe^{2+} was 94.2592 ppm. P_2O_5 content was 2.99-56.94 mg/100 g. P_2O_5 mean was 15.3192 mg/100 g. K_2O content was 7.25-9.37 mg/100 g. Mean of K_2O content was 8.0400 mg/100 g.

The pH, P_2O_5, and K_2O levels decreased along with rainwater on the peatland due to the loss of residual combustion ash on it. Fe^{2+} increased with the addition of rainwater on the peatland. The reduction reaction increased Fe^{2+}. In January 2019, characteristics of peat soil were the soil colour was dark brown, the soil texture was silty clay and clay loam, and the pH level was 4-7. The concentration of Fe^{2+} was 30.39-2200.74 ppm. Fe^{2+} mean was 518.4875 ppm. P_2O_5 content was 1.70-7.33 mg/100 g. Mean of P_2O_5 was 2.8475 mg/100 g. K_2O content was 2.56-10.67 mg/100 g. Mean of K_2O_5 was 6.1817 mg/100 g.

The soil in peatland is a land easily subjected to change and damage. Fires cause changes to the soil's nature. Changes in soil properties can be physical, chemical, and biological. Fires on organic soil can increase some nutrients, such as the P elements. Fires can increase pH levels, P levels, and K levels. The fire effects were limited to Fe and related to pH and organic content (Norouzi & Ramezanpour, 2013). Characteristic of soils was found that pH levels, soil fertility, and P were dissolved (Tata et al., 2018). The land fire was an increase in pH, P and K levels in the soil (Ekinci, 2006; Wasis et al., 2019). Ca also experienced a significant increase after land fires (Wasis et al., 2019). P levels increased 6 times in burned soils compared to unburned soils, especially at the surface of the soil (Sulwiński et al., 2017). Organic phosphorus (Po) decreases, but inorganic phosphorus (Pi) increases after the land fire (Wang et al., 2015).

Fires can indeed add P_2O_5 and K_2O to the soil, but they are only temporary. $P_2O_5$and K_2O will be lost due to the rainwater inundated. The damage produced by combustion is more considerable. The accumulation of ashes in wooded area peat fires impacted place right away improved pH, organic matter, humic acid content, hydrophobicity, available-N and available-K. However, their availabilities had solely been briefed as they were without difficulty diminished and washed way, which results in long-term degradation (Agus et al., 2019). Fires burning over these landscapes moreover expend surface peat, uncovering more seasoned peat strata (Sinclair et al., 2020). The impact of peat fires is not only on the ground but also affects up to 30-50 cm deep (Yustiawati et al., 2016). The fire also causes a decrease in peat soil thickness of 10-15 cm (Wasis et al., 2019). In the research location, we found the peat depth only about 10-15 cm due to land fire every year. This condition is characteristic of land degradation.

The land fire also has damaged peatland organism. Peatland fires cause 100% mortality of flora and fauna of the soil. Total microorganisms, total fungi, and soil respiration have decreased due to land fires (Wasis et al., 2019). Species are showed more significant damage at higher temperatures, with harm taking place at once after heat exposure (Noble et al., 2019). Wetland fires influence aquatic animal and plant neighbourhood structure, at least for brief intervals post-fire (Venne et al., 2016). In research, we found that warm temperature after the fire and no organism in soil, and this is the loses of land fire.

Conclusions

Fires occurred in peat soil in Banjarbaru, South Kalimantan, Indonesia brought changes to the soil physical and chemical properties, but the effect of fire is only temporary. This research recommends no land burning to prepare agriculture land, although the land burning increases pH, P_2O_5 and K_2O, due to the land fire has the highest effect on land degradation. The next research should be expanded to the other peatland in Indonesia and more of soil properties to understand the more impact of fire for peatland properties.

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