

Physical and Chemical Peatsoil Properties Assessment in Kampar Peninsular Region, Sumatera, Indonesia

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Abstract: *Forests and peat fires prior to agriculture use has become a perennial problem in Indonesia, especially in the last 20 years during the dry season. Most of that smoke originates from human activity - land use and land cover change (LULCC) i.e. illegal forests and peat land, slash and burn method during cultivation or plantation agriculture development, etc. In order to understand how big the burning impact to peat soil parameters change in those three different conditions i.e. before burning (naturally), seven days after burning and ninety days after burning in same site location, accordingly we conducted a study. This research was conducted in Teluk Meranti District, Kampar Peninsular Region, Sumatera, Indonesia. The study was carried out in January till December 2014. The research result showed that same physical and chemical parameters had changed significantly following burning compared to natural condition.*

Keywords: Physical, Chemical, Peat soils, Peat fire

1. Introduction

Fire has been increasingly recognized as one of the major threats to the remaining peat swamp forests in Indonesia. Due to the inherent characteristics of the peat soil, disturbed peat swamp forests are highly susceptible to fire especially during a prolonged dry season. Like any other wetland, the bio-physical and geochemical processes as well as the functioning of peat swamp forests are very much controlled by its hydrological regimes [23,18].

Peat fires in the wet tropics are of threat to health of millions people and through the emission of carbon to the atmosphere a significant contribution to the greenhouse effect [35,29]. The impact of peat fires through a haze over thousands of kilometers is not a new phenomenon. The problem of haze became widespread in the smoke-haze pollution and un-natural disasters in Indonesia [1] even throughout in Southeast Asia [16, 22]).

Peat fires have been reported in areas where there had been land clearing or over illegal logging due to human activities[32,10,21]. Peat soil has been reported to burn over large areas in the upper 30 cm. Topsoil. This is because the top layer of drained peat is normally dried and is an extremely good burning material. Once ignited, it spreads easily and the fire is extremely difficult to put out [15].

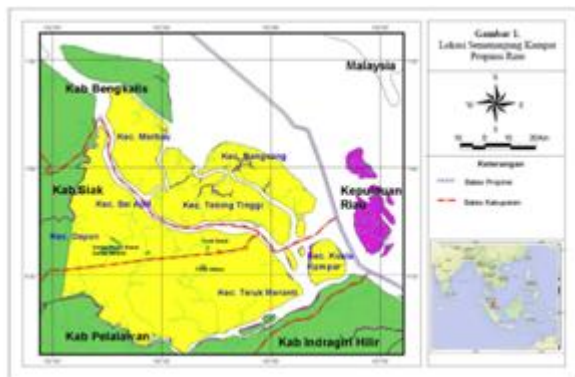
Most of the fires in peat areas are classified as ground fire. This type of fire occurs in subsurface organic fuels such as duff layers under forest stands, arctic tundra and organic soils of bogs, swamp and peat [8]. Peat fire is dominated by shouldering combustion under the soil surface, penetrating into deeper horizons of the soil, burning out funnel shaped

pits and then spreads in a horizontal manner [4]. A study conducted by [2] shows that fire caused considerable changes in the vegetation composition and structure of the burned forest. It also changed the chemical and physical characteristics of the peat soil [19,20].

In addition, the burning will impact to environment, social, cultural and economic, especially for local community[39,24], otherwise it will change to physics and chemistry peat soil parameters[12,9,25,3]. The destruction of forests and swamp peat ecosystem will contribute to climate change as a result of the increase in greenhouse gas emissions that are released into the air while burning [15,17].

The experiment was carried out on a farmer's peat swamp forest near the village of Teluk Meranti, one of the local districts in Pelalawan Regency, Riau Province, and Sumatera Island, Indonesia (Figure 1). This area that has been accused of forests and peat fires are categorized as the vulnerable area[30]. Besides that, approximately 92.02 percent of total area with 4,239.44 sq. km as peat swamp forests in the region and it is treated as peat swamp forest hydrology conservation area in Sumatera, Indonesia[6].

Teluk Meranti located also as part of Semenanjung Kampar Peninsular region that famous as rest of one the key areas of biodiversity peat swamp forest [11] and bird life area conservation in Sumatera Island[5]. In addition, the main function of this area as stabilizing of micro and macro climate change, carbon sequestration protection and hydrological catchment area for fresh water source that released during dry session[6].



2. Material and Method

2.1. Research Time and Place

The study was carried out between January 2014 and December 2014 on peatlands in the area belonging to the local government of Teluk Meranti District, Pelalawan Regency, and Riau Province, Indonesia. The site is located between 0°41'30"N–0°03'30"S and 103°12'54"E–102°12'54"W.

Figure 1. Location study in Teluk Meranti District as part of Kampar Peninsular Region in Sumatera Island Indonesia(modified after [30]).

Majority, the climate in area study is almost similar to other area climate conditions in the rest of Riau Province. Generally, the site has a tropical climate with annual rainfall ranging between 1,949 mm/yr and 2,951 mm/yr with total day rain ranging between 151 day/yr and 181 day/yr, 9 month/yr wet and 2-3 month/yr dry. The average daily temperature is 27° C with minimum 22°C and maximum 31°C[7].

Peat bogs occupy hollows sounding Kampar River; can be very deep peat (more than 6.5 m), the flow of water from acidic peat swamp forests and colored black or reddish. The peat soil classification based on field assessment categorized as fibric and hemic decomposition types as shown in Table 1.

Table 1: Sampling point location, total peat depth, peat color and decomposition level

Sampling number	Total Peat depth	Peat color	Peat Decomposition
#1	8 m	0-10 cm (10YR 2/1)	Fibric
		10-50 cm (10YR 2/2)	Hemic
#2	6.5 m	0-10 cm (10YR 2/2)	Fibric
		10-50 cm (10YR 3/2)	Hemic
#3	7 m	0-10 cm (10YR 2/1)	Fibric
		10-50 cm (10YR 3/1)	Hemic

Based on laboratory analysis shows the peat soil physical properties on the site study is very acidic, with pH ranging between 3.72 and 4.09 in natural condition. According to previously studied by Saharjo (1999) where peat of the fibric type has a low level of decomposition and a low percentage of humus, which results in very low nutrition protection capacity. Because of the lack of humid materials, fibric peat is a poor medium for agricultural activity. Fibric peat also has a high porosity. Peat of the hemic type has a

moderate level of decomposition and consists of several humic materials—hence its better ability in nutrition protection than fibric peat. Hemic peat is a good medium for agricultural activity as long as it still has a high content of humic materials.

2.2. Data Sampling

To aim the objective so the research was conducted in the field and in the laboratory. Based on the site assessments, three sampling points were observed with labelled as natural condition (Snc₁, Snc₂, Snc₃), seven day following burning (Ssdb₁, Ssdb₂, Ssdb₃), and ninety day following burning (Sndb₁, Sndb₂, Sndb₃) were chosen to represent research sites. Random peat samples were taken in the plot with total depth 0–25cm. The peat soils were collected using copper ring cylinder 10 cm in diameter to allow the samples to retain their natural characteristics in laboratory analysis. Each sampling point was taken by divided into five intervals i.e. 0-5 cm, 5-10 cm, 10-15 cm and 15-25 cm and then later we had composited to calculate the average value.

2.3. Research Material

The properties of peat soil analyzed for physical and chemical. The physical properties were identified including bulk density, porosity, water content and permeability. The chemical properties including soil pH (H₂O), available organic-C, ash content, total nitrogen, phosphorus, magnesium, exchangeable cations calcium, sodium, base saturation, and cation exchange capacity. These peat soil physical and chemical properties were analyzed at the laboratory of Soil Science, Faculty of Agriculture, Riau University, Pekanbaru, Indonesia.

2.4. Data Analysis

The physical and chemical peat soils properties were analyzed through *in-situ* and *ex-situ* analysis. Laboratory analysis was carried out according to [37] methods as shown in Table 2.

Table 2: Physical and chemical peat soil parameters measured and analytical methods

Parameters	Methods	Unit
<i>Physical parameters</i>		
Bulk density	Gravimetric	g/cm ³
Particle density	Gravimetric	g/cm ³
Water content	Gravimetric	% vol.
Porosity	Calculation	%
Permeability	Lambe	cm/hr
<i>Chemical parameters</i>		
Soil pH (H ₂ O)	pH Meter	
Cation exchange capacity	N NH ₄ OA _c pH7	me/100g
Natrium	Kjeidahl	%
Available phosphorus	HCL 25%	ppm
Potassium	HCL 25%	me/100g
Exchangeable cations calcium	N NH ₄ OA _c pH7	mg/g
Sodium	N NH ₄ OA _c pH7	mg/g
Magnesium	N NH ₄ OA _c pH7	mg/g
Base saturation	Kjeidahl	%
Ash content	Dry ash	%
Organic-C	Dry ash	%

At the first step, we were calculated the average value of individual parameters. Then continue with one-way analysis of variance (ANOVA) test for variables from measurements were used to compare the differences of those three conditions. To help data calculation and analysis so we had used SPSS™ software version 17.

3. Result and Discussions

3.1. Result

The summary both of physical and chemical peat soil characteristic analysis before and after burning were summarized in Table 3.

Effect of fire to physical properties

Apparently, bulk density and particle density were increased ($p \leq 0.05$) for seven days post-burning compared to that of natural condition. In contrary, porosity decreased significantly. While water content and permeability trend to decrease even though statistically was not significant.

Ninety days post-burning compared to that of natural condition where water content was increased significantly. In contrary, bulk density was decreased significantly while particle density and permeability trend to decrease even though statistically was not significant.

Ninety compared to seven days post-burning where porosity and water content were increased significantly ($p < 0.05$). In contrary, bulk density decreased significantly then followed by permeability decreased even though statistically was not significant while particle density was not changed.

Effect fire to chemical properties

Apparently, pH, potassium, exchange cations calcium, sodium and natrium increased significantly followed by cation exchange capacity and ash content increased also but statistically were not significant post-burning compared to that of natural condition. In contrary, natrium decreased significantly while phosphorous, organic-c, magnesium and base saturation decreased but statistically was not significant.

Ninety post-burning compared to that of natural condition where pH increased significantly then followed by organic-c, ash content, phosphorous, cation exchange capacity increased also but statistically not significant. The exchange cation calcium decreased significantly while potassium, magnesium and base saturation decreased also but statistically was not significant while the natrium was not changed.

Ninety days post-burning compared to that of seven days post-burning where ash content, natrium, available phosphorous and cation exchange capacity increased but statistically was not significant. In contrary, the exchangeable cation calcium and sodium decreased significantly then followed by organic-c, potassium and base saturation but statistically was not significant while the pH was not changed.

3.2. Discussion

Peat destruction by fire affects the soil physical and chemical properties. The effect of fire on the chemical and physical properties of peat soil varies significantly depending on the type of soil, its moisture content, the intensity and duration of the fire, and the timing and intensity of post fire precipitation [9]. Soil properties may also change in response to heat and increased exposure [28].

Table 3: Mean values, standard deviations and mean comparison test of nutrient mass fraction measured of the physical and chemical peat soil parameters before and after burning

Parameters	Before burning (Natural conditions)	After burning	
		Seven days	Ninety days
<i>Physical properties</i>			
Bulk density (g/cc)	0.17±0.15	0.20±0.02 ^a	0.16±0.01 ^c
Particle density (g/cc)	1.06±0.01	1.09±0.02 ^a	1.06±0.01 ^c
Porosity (%)	83.74±1.18	81.39±1.87 ^a	84.31±1.28 ^{b,c}
Water holding capacity (%)	223.90±70.00	144.93±79.70	929.07±120.61 ^{b,c}
Permeability (cm/hr)	40.08±23.06	35.61±12.75	29.62±19.41
<i>Chemical properties</i>			
pH	3.88±0.11	4.16±0.28 ^a	4.16±0.29 ^b
Organic-c (%)	45.58±2.64	45.68±3.99	44.71±5.30
Ash content (%)	8.82±5.29	8.61±7.99	10.57±10.60
Natrium (%)	0.69±0.23	0.52±0.12 ^a	0.69±0.08
Phosphorous (ppm)	15.41±9.31	39.29±43.22	39.51±41.16
Potassium (me/100g)	0.15±0.06	0.47±0.41 ^a	0.02±0.01 ^c
Exchangeable cation calcium (me/100g)	0.36±0.15	0.56±0.20 ^a	0.07±0.02 ^{b,c}
Sodium (me/100g)	0.02±0.01	0.05±0.00 ^a	0.02±0.00 ^c
Magnesium (me/100g)	0.11±0.00	0.10±0.03	0.08±0.05
Cation exchange capacity (me/100g)	81.78±7.22	81.82±7.62	83.34±7.04
Base saturation (%)	7.75±24.01	1.47±0.52	0.22±0.01

Significant at $p \leq 0.05$ with legend (a) seven days post-burning compare to that of natural condition, (b) ninety days post-burning compared to that of natural condition, and (c) ninety days post-burning compared to that of seven days post-burning.

Changes in soil chemical properties will also affect the soil physical properties because the mean effect of heating was destruction of the structure in the surface layer. The soil of the burnt area is no longer protected from the beating action of raindrops and it becomes dispersed and compact so that finally soil permeability will decrease [13], as was found in all burnt sites in this study. Besides destroying the litter layer, heat also destroyed insects and other micro-organisms that channel the soil, resulting in reduction of soil porosity [32], as was found also in the sites burnt for this study.

The decrease of calcium, magnesium, potassium, and sodium following burning may have been caused by leaching and runoff as a result of vegetation destruction [36,34], while the increase in nutrients resulted from the presence of ash [14,32]. Losses of nutrients following burning are likely the result of leaching and surface runoff caused by rain several weeks after burning. Losses of organic matter and nutrients can continue long after a fire event through erosion, leaching, and volatilization. The presence or absence of duff, humus, and other unincorporated organic materials on the forest floor and the amounts consumed are of key importance in determining how the soil is affected [8], and [31] has shown that even if there were changes in soil chemical properties following burning in the cultivation area, they did not improve soil fertility.

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These facts show that using fire for land preparation, especially in peat areas, i.e. shifting cultivators or agriculture development recently by companies, will eventually degrade the peatsoil parameters then later will finally minimize peatsoil sustainability. Furthermore the impact of burning of peat depends on the level of peat decomposition. Burnt peat, as mentioned above, will never return to the original state because peat depth decreases every time a fire is used for land preparation[32].

The situation becomes dangerous when biomass (as fuel) use is not selective and no special treatment is used during burning. As long as fire is used, whether by shifting cultivators or, recently, by companies, the future of peat is uncertain. It is predicted that if fire is continued to be used in peat areas without any treatment to prevent peat destruction, then in a few short years peat will be totally lost, as has occurred in South Sumatra where 3 m deep peat has vanished in 20 years' time[33,26,27].

However, as land attributes are complicated in their composition and distribution, predicting the impact of spatial variability on the behavior or response of systems to most management strategies has been challenging. There is

a mismatch between the wealth of knowledge available on peatlands and the sustainability of management options utilized to conserve these non-renewable resources.

Peatlands display tremendous spatial variability in critical physical and chemical properties. These properties have a major role in determining the quality of such systems. The subject matter is even more complicated when these properties are evaluated in terms of their inherent resilience to anthropogenically-induced changes. Designing risk - management strategies or even attempting to rehabilitate such systems requires examining these properties from the resilience stand point.

Diminished output of response curves to resilience-based systems is apparent. The loss in terms of profitability cannot be argued. However, with the impact of spatial variability taken for granted, the gain in terms of preserving the original properties and maintaining the land quality in a truly sustainable manner is evident. It is therefore imperative that management strategies consider the impact of spatial variability to maintain stewardship over these non-renewable natural resources.

Peat areas are sensitive ecosystem. Peat catches fire easily if it is dried because of its organic nature. In its natural condition peat is not expected to catch fire as the water table reaches the ground surface and/or the peat deposit is completely saturated. Peat forests in an undrained peat basin are not expected to catch fire. Therefore to prevent the onset of fire in peat forests the peat basin should be managed in a manner that will minimize the drainage of the land and keep the deposit continuously wet and at a high water table level.

The data reported in this paper indicate that regular use of fire for land preparation in peatland, without any treatment to prevent peat destruction, will decrease the quality of peat and finally result in the total disappearance of peat forever.

Although burning increases the amount of nutrients in the soil, which temporarily enhances growth performance, it also has negative effects. As has been reported for several parts of Indonesia, peatlands being burned repeatedly for land preparation will significantly reduce in depth. This negative consequence is especially important for cultivators that depend on cultivation on peatlands for a large part of their income. This paper provides facts on the relation between regular peat burning for land preparation and the status of burnt peatlands in the near future, especially in human activity - land use and land cover change that caused to peat fire.

4. Conclusion

The slash and burn method during cultivation or plantation agriculture development etc. will impact an increase or decrease of some of physics properties seven days following burning, but it will decline again ninety days or later. Following burning also has been tremendous increase the chemical properties in seven days, but decrease again in ninety days or after.

There is an urgent need for a more concerted action in TelukMeranti District to minimize or stop the continuous loss and degradation of peatlands, as a result of increasing unsustainable exploitation or development activities which are leading to degradation and increased susceptibility to forest fires.

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