Jurnal Manajemen Hutan Tropika, *32*(2), 163–173, April 2026
EISSN: 2089-2063
DOI: 10.7226/jtfm.32.2.177

Scientific Article
ISSN: 2087-0469

Factors Influencing the Physical Characteristics of Peats in West Kalimantan's Forests and Oil Palm Plantations

Muhammad Nuriman[1*], Ari Krisnohadi[1], Rossie Wiedya Nusantara[1], Bambang Widiarso[1], Tri Tiana Ahmadi Putri[2]

[1]Department of Soil Science, Universitas Tanjungpura, Pontianak, West Kalimantan, Indonesia 78124
[2]CV Sky Agro Energy, Pontianak, West Kalimantan, Indonesia 78114

Received January 31, 2025/Accepted November 12, 2025

Abstract

Peatlands in West Kalimantan play a vital role in regulating water and supporting land productivity, yet they are highly sensitive to changes in hydrological conditions and land use. Peatland areas widely practice drainage and cultivation, which can alter the physical properties of peat and have long-term implications for ecosystem stability and land management. However, how land use and groundwater conditions influence peat physical characteristics across different hydrological settings remains insufficiently understood. This study examined peat physical properties across contrasting hydrological units representing cultivated peatlands and peat swamp forests. Bulk density, water content, and porosity were evaluated in relation to groundwater level, peat thickness, sampling depth, soil suborder, and land use. The results indicate that groundwater conditions and land use are the primary controls of peat physical properties. Peat soils under shallow groundwater conditions consistently exhibited higher water content and porosity, with values exceeding 80%, whereas cultivated peatlands showed lower water retention and porosity compared to forested peatlands. Peat thickness, soil suborder, and sampling depth further influenced the vertical and spatial variability of peat characteristics. Differences were observed both between hydrological units and across soil layers, reflecting pronounced spatial heterogeneity associated with site-specific management. Overall, these findings demonstrate that peat physical properties vary systematically across hydrological units and soil layers, highlighting the importance of hydrology-based and site-specific management strategies to maintain peatland stability and support sustainable land management.

Keywords: *peatland, water table, peat depth, land use, sustainable management*

**Correspondence author, email*: *muhammad.nuriman@faperta.untan.ac.id*

Introduction

The province of West Kalimantan, Indonesia, encompasses a vast peatland area of approximately 1,547,876 ha, which is distributed across tidal, transitional, and inland peatlands (Anda et al., 2021). The characteristics of peat in these areas are influenced by various factors, including the source of organic matter and environmental conditions during its formation (Parfenova et al., 2016; Masganti et al., 2017; Liu et al., 2023). Additionally, external factors such as land cultivation, drainage, and fertilization can also impact the properties of peat (Nursyamsi et al., 2016; Gramlich et al., 2018; Anshari et al., 2021).

Sustainable management of peatlands is crucial to minimize degradation and maintain their ecological function (Astiani et al., 2017; Uda et al., 2017; Jurasinski et al., 2020). One aspect of peatland management is water management, which has a significant impact on both agricultural productivity and ecological function (Nursyamsi et al., 2016; Monteverde et al., 2022; McCalmont et al., 2023). Canals in peatlands can alter soil aeration conditions, impacting peat physical properties such as bulk density, moisture content, and porosity (Dohong et al., 2018; Sinclair et al., 2020).

The Indonesian Government has established peat hydrological units (PHU) to protect and manage peat ecosystems (Republik Indonesia, 2016). PHUs are peatlands with cultivation and protection functions, aimed at ensuring sustainable use of peatlands while minimizing environmental damage and maintaining their ecological function. The determination of peat cultivation and protection functions is based on the thickness of the peat, which is classified as less than or more than 3 m (Kementerian Lingkungan Hidup dan Kehutanan, 2017).

The objective of this research is to investigate the physical properties of peat under different influencing factors, including the impact of water management, land cultivation, and other external factors. This study will contribute to the development of sustainable peatland management practices that balance agricultural productivity and ecological conservation.

Methods

Site description This research was conducted in the province of West Kalimantan, specifically in three PHUs. The research sites are shown in Figure 1. The first location, PHU 1, is

Jurnal Manajemen Hutan Tropika, *32*(2), 163−173, April 2026
EISSN: 2089-2063
DOI: 10.7226/jtfm.32.2.177

ISSN: 2087-0469

situated in the Pawan River-Tolak River Peat Hydrological Area, which is located in Ketapang Regency. The land in this area is primarily used for oil palm cultivation. The second location, PHU 2, is located in the Sungai Kapuas-Sungai Ayak Peat Hydrological Area. The peatland in this area is also used for oil palm cultivation in Sekadau District. Field investigations were conducted in PHU 1 and PHU 2 in 2019, PHU and Sungai Terentang-Sungai Kapuas (PHU 3) and Kubu Raya District in 2022. The land use in PHU 3 is riparian forest.

Both PHU 1 and PHU 2 are drained peatlands for oil palm plantations, while PHU 3 is covered by undrained forest land. The National Digital Elevation Model shows that the two oil palm locations have a similar land elevation of 19 m above sea level in Ketapang District and 21 m above sea level in Sekadau District. In contrast, the peatland with forest land cover is at 4 m above sea level (Badan Informasi Geospasial, 2024).

Climate conditions Analysis of the humidity and reference evapotranspiration (ETo) data from the last 10 years (2012–2022) reveals significant differences (p-value < 0.05) among the three study sites, while the annual rainfall data does not show any significant difference (p-value > 0.05) (Badan Meteorologi, Klimatologi, dan Geofisika, 2023). PHU 1 receives average annual rainfall of 2,980 mm, with average humidity of 83%, and average reference evapotranspiration (ETo) of 3.62 mm day^{-1}. In contrast, PHU 2 receives significantly more annual rainfall of 3,767 mm on average with higher average humidity of 85.64% and slightly lower ETo of 3.32 mm day^{-1}. Similarly, PHU 3 experiences a high annual rainfall of 3,202 mm with an average humidity of

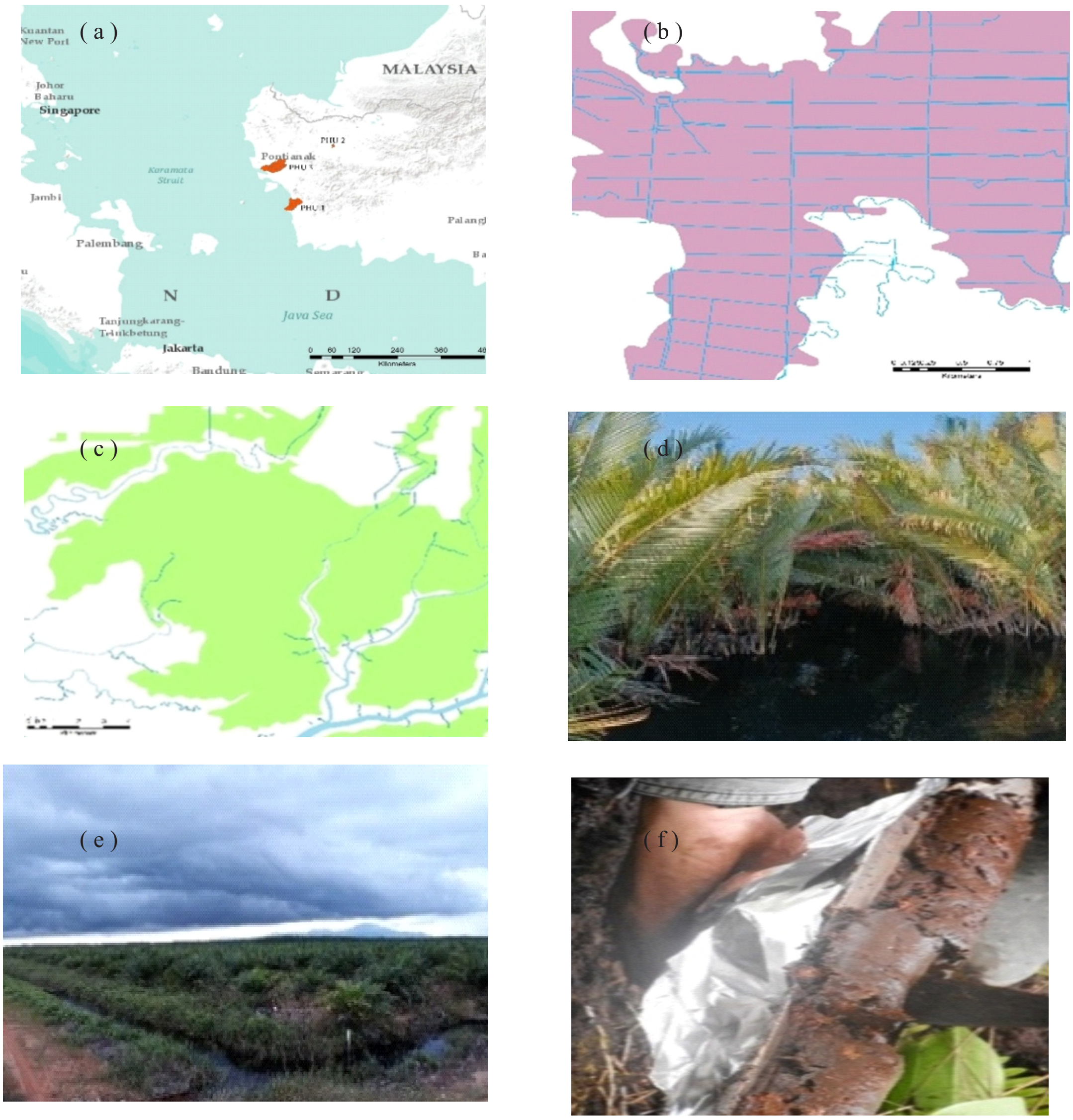


Figure 1 Peatlands in West Kalimantan were sampled for this study. Three peat hydrological units (PHU) in West Kalimantan that were surveyed (a); Oil palm land cover (pink) with canal density (blue line) (b); Peat swamp secondary forest land cover (green) with river density (blue line) (c); Photo of canal in oil palm plantation (d); Photo of river in secondary peat swamp forest (e); Photo of peat sampling using a peat auger transferred to aluminum foil (f).

Jurnal Manajemen Hutan Tropika, *32*(2), 163−173, April 2026
EISSN: 2089-2063
DOI: 10.7226/jtfm.32.2.177

ISSN: 2087-0469

84.86% and a reference evapotranspiration (ETo) of 3.48 mm day^{-1}. These values demonstrate clear climate differences among the three locations.

The sampling process Sampling was conducted at 89 observation points, resulting in a total of 178 samples. The observed layer was divided into two depths of 0–50 cm and 50–100 cm. The sampling process was carried out using a peat auger from Eijkelkamp, a reliable and high-quality tool for soil sampling (Royal Eijkelkamp, 2025). Samples taken from the peat drill were weighed in the field using a CHQ pocket scale 200 g 0.01 g, then were wrapped in aluminum foil and transferred for further analysis in the laboratory located in the Soil Physics and Conservation Laboratory, Tanjungpura University.

Analysis of bulk density, water content and porosity Three key physical parameters, namely bulk density, water content, and porosity, were measured in the laboratory. These parameters are fundamental to understanding the physical behavior and hydrological characteristics of peat soils, as highlighted in the Regulation of the Minister of Environment and Forestry Number 10/2019 regarding the determination, designation, and management of peat dome peaks within PHUs (Kementerian Lingkungan Hidup dan Kehutanan, 2019).

The bulk density was calculated using Equation *[1]*.

$$\text{Bulk density (g cm}^{-3}\text{)} = \frac{\text{(Weight of the dry soil)}}{\text{(Volume of the soil sample)}} \qquad [1]$$

We measured the soil volume using the water-displacement method (Robert et al., 2019). The water content was calculated using Equation *[2]*.

$$\text{Water content (\%)} = \text{((Weight of the wet soil – Weight of the dry soil)/Volume of the soil sample)} \times 100 \qquad [2]$$

Furthermore, the porosity was calculated using Equation *[3]*

$$\text{Porosity (\%)} = 1 - \left(\frac{\text{Bulk density}}{\text{Particle density}}\right) \times 100 \qquad [3]$$

The particle density was measured using pycnometer in the laboratory.

Identified factors *Peat hydrological units* PHU is a peat ecosystem situated between two rivers, between a river and the sea, and/or in a swamp (Kementerian Lingkungan Hidup dan Kehutanan, 2019). The investigated PHUs are part of the national PHU (Kementerian Lingkungan Hidup dan Kehutanan, 2017). Following are the number of observation plots in each PHU: 1) PHU Pawan River-Tolak River (PHU 1), 21 plots; 2) PHU Kapuas River-Ayak River (PHU 2), 27 plots; and 3) PHU Terentang River-Kapuas River (PHU 3), 41 plots.

Water table depth Water table measurements were taken temporally with a long measuring tape in the drilled hole from the ground surface to groundwater. The water table depth is categorized into two groups based on Government Regulation Number 57/2016 (Republik Indonesia, 2016), which are 1) Less than 40 cm from the ground surface, indicating a relatively high water table depth; 2) More than 40 cm from the ground surface, indicating a relatively low water table depth.

Peat depth Peat is organic material formed naturally from incompletely decomposed plant remains and accumulates in swamps when its depth is 50 cm or more (Subardja et al., 2016). Government Regulation Number 57/2016 designates peat depths for specific uses, with depths less than 300 cm being suitable for cultivation and depths greater than 300 cm being protected (Republik Indonesia, 2016). Based on this regulation, this study categorizes peat depths into two different categories: less than 300 cm and greater than 300 cm.

Peat depth was measured using the Eijkelkamp peat drill up to a mineral layer (substratum) beneath. The measurement was carried out in stages, every 50 cm up to the mineral layer.

Soil suborder In the USDA soil classification hierarchy, suborder is the second level after order. At this level, there are five types of histosols: folists, wassists, fibrists, hemists, and saprists (Soil Survey Staff, 2022). The research site has two suborders, which are fibrists and hemists. Fibrists are peat or organic soils with a dominant degree of fibric weathering in the organic soil control cross-section, while hemists are peat soils with a dominant hemic weathering in the organic soil control cross-section.

Sampling depth interval This sampling interval allows for the illustration of peat characteristics at various depths. Information obtained from the top 50 cm of soil gives an estimate of its physical properties, while data from 50-100 cm deep can reveal the physical properties of deeper peat layers. Peat samples were obtained from the following layers: 1) From the soil surface to a depth of 50 cm, referred to as the topsoil layer; 2) From a depth of 50 cm to a depth of 100 cm, referred to as the subsoil layer.

Land use Based on the Indonesian National Standard (SNI) 7645:2010 for land cover classification (Badan Standardisasi Nasional, 2010), the three sites have the following land uses: 1) PHU 1 is an oil palm plantation in Ketapang Regency; 2) PHU 2 is an oil palm plantation in Sekadau Regency; and 3) PHU 3 is a secondary peat swamp forest in Kubu Raya Regency.

Statistical analysis Statistical analysis was performed using Real Statistics, obtained from http://www.real-statistics.com. To determine whether there were differences in each factor, analysis of variance and the t-test were used. If the significance level was < 0.05, the Tukey test was conducted to identify the differences between each factor. For abnormal data, the Games-Howell test was used. The data underwent descriptive analysis and normality analysis using the Shapiro-Wilk test, followed by ANOVA analysis and t-tests on the variables of content weight, moisture content, and porosity of peat soil against the factors of location (PHU), depth of water table, depth of peat, soil suborder, peat, sample depth interval, and land use.

Results

The physical properties of the peat soils in the three PHUs differed significantly in terms of water content and porosity. However, the bulk density of the peat soils did not differ significantly between the sites. These results indicate that the location of the peat physical properties monitoring can cause differences in physical properties.

Land cover at the study sites had a major impact on the physical properties of the peat soil. Although there was no significant difference in bulk density, the moisture content and porosity varied significantly between the different land covers.

Peat thickness is also a crucial factor that affects the physical properties of peat soil. There are significant differences in bulk density and water content for peat thicknesses of less than 300 cm and more than 300 cm. Furthermore, the physical properties of peat soil are also affected by differences in peat suborders, namely hemists and fibrists. Differences in bulk density and porosity in peat soil are evident.

Variations in water table depth and soil sampling depth contribute to these differences. To fully understand the potential and challenges of peat soil management in this area, it is critical to look at the physical properties of peat and the factors influencing them. The overall analysis results are shown in Table 1.

Analysis of the interaction between PHU and peat thickness shows a diverse pattern. Although bulk density does not show a statistically significant interaction (p-value > 0.05), both moisture content and porosity show significant differences between PHUs in both peat thickness classes (p-value < 0.05). For thin peat layers (< 300 cm), moisture content and porosity varied greatly between the three PHUs, reflecting differences in local hydrological conditions and decomposition rates. Importantly, for deep peat layers (> 300 cm), moisture content and porosity also differed significantly between PHUs, indicating that the physical properties of deep peat remain influenced by local site conditions in this study area. These findings confirm that spatial heterogeneity persists even in deeper peat layers and are consistent with site-specific hydrological patterns and previous disturbance history (Hikmatullah & Sukarman, 2014). See Table 2 for group means and significance notation.

The correlation analysis results (Table 3) revealed a significant negative correlation between water content and porosity of the peat soil at the surface (0–50 cm depth), with Pearson correlation coefficients of -0.795 and -0.566, respectively. Bulk density showed a positive correlation with a coefficient of 0.432. These findings indicate that as soil depth increases, water content and porosity decrease, while bulk density increases. However, this relationship did not occur in the 50–100 cm depth range, where the p-values were greater than 0.01 and the Pearson correlation coefficients were 0.221, 0.194 and 0.084 for water content, porosity, and bulk density, respectively.

Discussion

Variation of physical properties in water table depth The water table depth significantly influences the bulk density, moisture content, and porosity of peat soil. A water table depth of less than 40 cm has significantly different physical properties than a water table depth of more than 40 cm. A water table depth of less than 40 cm has a significantly lower bulk density than a water table depth of more than 40 cm.

The lowering of the water table causes the peat soil to have an oxidative layer that is rich in oxygen (aerobic). The depth of the water table or the thickness of the oxidative layer recommended by Government Regulation Number 57/2016 is less than 40 cm (Republik Indonesia, 2016). This is supported by previous research (Putra & Hayasaka, 2011), which identified a water table depth of 40 cm as critical for preventing peat soil from experiencing fires. The water content and porosity at a water table depth of less than 40 cm are significantly greater than at a water table depth of deeper than 40 cm, and the water table depth class of greater than 40 cm tends to show uniform values with minimal differences among various PHUs.

Syaufina (2008) stated that the factors influencing peat fires are peat water content and the depth of the water table. Furthermore, Syaufina et al. (2004) assert that the incidence of fires is also affected by land cover, which will influence the local climate, as evidenced by the peat swamp ecosystem.

A relevant case study is the research conducted by Ginting et al. (2016) on peatland in Sumatra, Indonesia. Their research found that the optimal water table depth for the growth of oil palm plants and prevention of fires and CO_2 emissions exceeding the IPCC permissible threshold is within the range of 40–70 cm. Peat water content becomes critically at risk of burning when the moisture content reaches the hydrophobic point, which is less than 30–48% (Winarna et al., 2016).

A study conducted by Marwanto et al. (2018) on peatlands in West Kalimantan, Indonesia, found that the use of oil palm and secondary forests resulted in a significant decrease in water table depth during the 2015 El Niño event, which occurred from September to November of that year. Specifically, the water table depth decreased by more than 150 cm, leading to the occurrence of forest fire. This is noteworthy because the normal water table depth in this region is typically between 30 and 50 cm. Therefore, it is essential to examine the depth of groundwater in more detail, considering specific land uses, to effectively manage peatlands.

Considering the results and analyses presented in the existing literature, it can be posited that the implementation of peatland conservation practices must take into account the influence of water table depth, as regulated by Government Regulation Number 57/2016 on the physical characteristics of peatlands in plantations (Republik Indonesia, 2016). This requires the development of tailored irrigation and drainage systems that align with the unique properties of peatlands. The water table depth significantly impacts the physical properties of peat and the incidence of fires. Therefore, it is crucial to develop conservation practices that consider this influence.

Variation of physical properties in land use The water content and porosity of peat soils in oil palm plantations were reported to be lower compared to secondary wetland forests, while the bulk density in oil palm plantations was higher.

Jurnal Manajemen Hutan Tropika, *32*(2), 163−173, April 2026
EISSN: 2089-2063
DOI: 10.7226/jtfm.32.2.177

ISSN: 2087-0469

Table 1 Bulk density, water content, and porosity were measured for each of the following factors: PHU, groundwater depth, peat depth, sub order, sampling depth, and land use

Variable	Factors	Total data (N)	Mean	St. dev	Shapiro-Wilk test (Normality) *p*-value	ANOVA *p*-value	t-test *p*-value
Bulk density (g cm^{-3})	PHU 1	42	0.13 a	0.04	0.77	0.36	-
	PHU 2	54	0.13 a	0.04	0.10		
	PHU 3	82	0.12 a	0.03	0.19		
	SWL < 40 cm	126	0.12 a	0.03	0.16	-	0.00
	SWL > 40 cm	52	0.14 b	0.04	0.41		
	PD < 300 cm	110	0.13 a	0.03	0.10	-	0.01
	PD > 300 cm	68	0.11 b	0.04	0.11		
	Hemists	125	0.13 a	0.03	0.49	-	0.00
	Fibrists	52	0.10 b	0.03	0.01		
	SD 0–50 cm	89	0.14 a	0.03	0.11	-	0.00
	SD 50–100 cm	89	0.11 b	0.03	0.02		
	Oil palm	96	0.13 a	0.04	0.23	-	0.17
	Forest	82	0.12 a	0.03	0.19		
Water content (% vol)	PHU 1	42	82.67 b	7.42	0.10	0.00	-
	PHU 2	54	79.52 a	9.92	0.06		
	PHU 3	82	87.59 c	3.44	0.21		
	SWL < 40 cm	126	86.02 a	5.46	0.00	-	0.00
	SWL > 40 cm	52	79.03 b	10.01	0.06		
	PD < 300 cm	110	85.15 a	7.28	0.00	-	0.01
	PD > 300 cm	68	82.09 b	8.17	0.01		
	Hemists	125	83.55 a	7.89	0.00	-	0.30
	Fibrists	52	84.90 a	7.46	0.00		
	SD 0–50 cm	89	80.66 a	8.76	0.00	-	0.00
	SD 50–100 cm	89	87.30 b	4.70	0.00		
	Oil palm	96	80.90 a	9.01	0.00	-	0.00
	Forest	82	87.59 b	3.44	0.21		
Porosity (%)	PHU 1	42	89.90 a	1.93	0.18	0.00	-
	PHU 2	54	88.99 a	2.67	0.11		
	PHU 3	82	91.20 b	2.28	0.12		
	SWL < 40 cm	126	90.83 a	2.15	0.27	-	0.00
	SWL > 40 cm	52	88.75 b	2.71	0.40		
	PD < 300 cm	110	90.22 a	2.53	0.11	-	0.97
	PD > 300 cm	68	90.23 a	2.49	0.15		
	Hemists	125	89.70 a	2.40	0.08	-	0.00
	Fibrists	52	91.42 b	2.35	0.00		
	SD 0–50 cm	89	89.18 a	2.45	0.01	-	0.00
	SD 50–100 cm	89	91.27 b	2.11	0.60		
	Oil palm	96	89.39 a	0.01	0.01	-	0.00
	Forest	82	91.20 b	0.12	0.12		

Note: SWL = soil water level; PD = peat depth; SD = sampling depth. The statistical significance of the data is denoted by *p*-values, where *p*-value < 0.01 indicates a very significant difference, *p*-value < 0.05 indicates a significant difference, and *p*-value > 0.05 indicates no significant difference. Mean values with different notations (a, b) indicate significant differences in t-test and ANOVA with Tukey on normal data, and Games-Howell on abnormal data.

This aligns with the findings of Tonks et al. (2017), who reported that the water content in peatlands used for forests was significantly higher at 82.3%, compared to oil palm plantations at 56.56%. Similarly, Firdaus et al. (2010) found that the bulk density of peat soils in forests was significantly lower than in oil palm plantations, with values of 0.11 g cm^{-3} compared to 0.17 g cm^{-3} in oil palm plantations, while porosity in forests at 91.5% is higher than in oil palm at 86.4%.

However, it is important to note that the results of Junedi

Table 2 Interaction between PHU and peat thickness

PHU	Peat depth (cm)	Bulk density (g cm^{-3})	Water content (%)	Porosity (%)
PHU 1	< 300	0.14	84.97 b	90.09 ab
PHU 2	< 300	0.13	79.33 a	88.86 a
PHU 3	< 300	0.12	87.91 b	90.88 b
PHU 1	> 300	0.12	81.25 a	89.79 a
PHU 2	> 300	0.12	79.74 a	89.13 a
PHU 3	> 300	0.10	86.41 b	92.31 b

Note: Interaction was significant for water content and porosity (p-value < 0.05), but not for bulk density (p-value > 0.05). Different superscript letters indicate significant differences at p-value < 0.05.

Table 3 Pearson correlation between water table and water content, bulk density and porosity across all PHUs

PHU	Variable	Water content		Bulk density		Porosity	
		SD 0–50 cm	SD 50–100 cm	SD 0–50 cm	SD 50–100 cm	SD 0–50 cm	SD 50–100 cm
PHU 1	SWL (n = 21)	0.526*	0.379	-0.247	0.152	0.148	-0.240
PHU 2	SWL (n = 27)	0.527**	0.218	-0.622**	-0.492**	0.570**	0.434*
PHU 3	SWL (n = 41)	0.325*	0.047	0.207	0.143	-0.240	-0.167
All PHU	SWL (n = 89)	0.795**	0.221	-0.427**	0.086	0.566**	0.193

Note: *Significant correlation at 0.05 level; **Very significant correlation at 0.01 level n is the number of data tested; SWL = soil water level; SD = sampling depth

et al. (2017) and Dhandapani et al. (2023) suggest that the bulk density of peat soils in oil palm plantations is significantly higher compared to that in secondary wetland forests. This increase in bulk density is often associated with peat degradation, which can lead to a decrease in soil porosity and an increase in soil density, negatively affecting plant growth and ecosystem health (Liu et al., 2020; Wang et al., 2021).

Despite these findings, the present study found that the bulk density in oil palm plantations was not significantly different from that in forests. However, it demonstrated that the water content and porosity of peat soils are of concern for peat soil degradation. These factors can reduce the ability of peat soils to store water, thereby increasing the risk of flooding and drought. Consequently, the key parameters for land degradation based on land cover are water content and porosity.

Variation of physical properties in sampling depth The physical properties of peat soil are significantly influenced by various sampling depth intervals, particularly in relation to bulk density, moisture content, and porosity. According to Kunarso et al. (2022), the bulk density of forest and perennial vegetation at a depth of 0–40 cm was 0.17 g cm^{-3} and 0.24 g cm^{-3}, exhibiting a decline to 0.11 g cm^{-3} and 0.23 g cm^{-3} at a depth of 40–80 cm. Bulk density tended to be higher in drained peatlands than in forest sites. Notably, there are significant in the bulk density, water content, and porosity at a depth of 0–50 cm among the different PHUs (Figure 2). However, there was no significant differences in bulk density and water content observed at depths of 50–100 cm between PHUs.

The physical properties of peat soils are contingent upon the sampling depth, exhibiting a reduction in bulk density and an increase in moisture content and porosity at greater depths. The discrepancies in physical attributes between PHUs are more evident in the upper soil layer (0–50 cm), where there are notable differences compared to the lower soil layer (50–100 cm). These observations carry significant implications for the stewardship and preservation of peatland resources, particularly concerning indicators of land degradation based on the variations in properties between the 0–50 cm and 50–100 cm peat layers.

Variation of physical properties in peat depth The peat thickness significantly affects its physical properties, particularly bulk density and water content. This study's findings align with previous research, which indicated that shallow peat tends to have a higher bulk density compared to deep peat. However, water content varies, with previous research indicating that deeper peat has a higher water content than shallow peat.

Based on this, the physical properties of peat soil need to consider the thickness of the peat; this understanding is in line with government regulations related to peatland management based on peat thickness classes of less than 3 m and more than 3 m. Land management is determined by the function of peat ecosystems, namely the cultivation function for peat with a thickness of less than 3 m and the protection function for peat with a thickness of more than 3 m (Republik Indonesia, 2016). The focus of these regulations is not only on the greater water content and porosity of protected peat but also on the substantial volume of water that can be stored or safeguarded within the peat ecosystem.

Jurnal Manajemen Hutan Tropika, *32*(2), 163−173, April 2026
EISSN: 2089-2063
DOI: 10.7226/jtfm.32.2.177

ISSN: 2087-0469

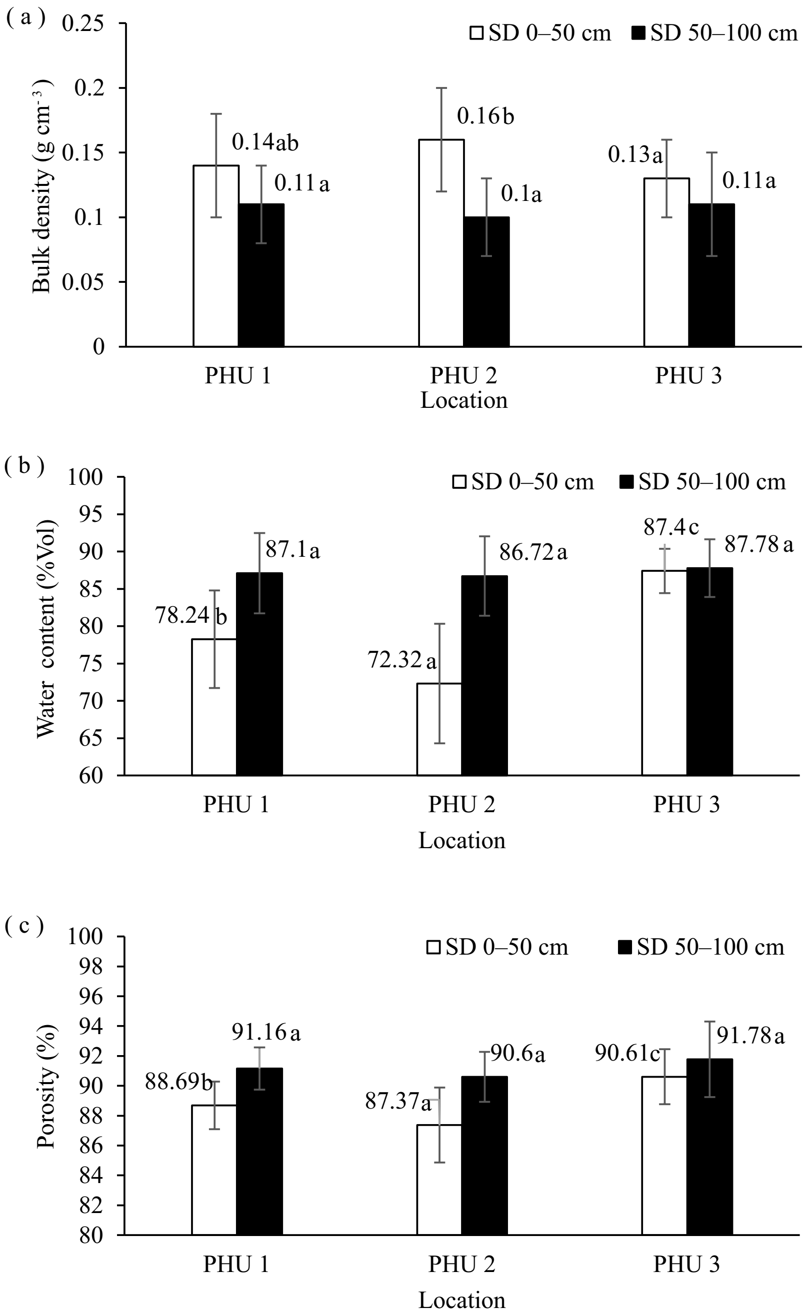


Figure 2 Comparison of bulk density (a), water content (b), and porosity (c) of peat soil at sampling depth at each location (SD = sampling depth; Mean values with different notations (a, b) indicate significant differences between SDs at each location).

Variation of physical properties in sub-ordo This study reveals significant differences in the physical properties of bulk density and porosity between the two suborders, fibrists and hemists. According to the Soil Survey Staff (2022), fibrists have a lower bulk density compared to hemists, while the porosity of fibrists is larger than that of hemists. These findings are consistent with previous research by Osman (2018) and Arabia et al. (2020). Although the porosity values obtained in this study differ relatively from previous studies. In this study, the porosity of hemists reached 93%, while the porosity of fibrists soil reached 91.42%. This is significant because hemists' porosity is higher than fibrists', which is the opposite of previous studies.

The differences in porosity values between this study and previous studies could be due to a number of factors, including differences in sampling locations, soil preparation methods, and measurement techniques. In addition, the results of this study highlight the importance of considering the unique characteristics of each peat soil suborder in land management strategies. The lower bulk density and higher

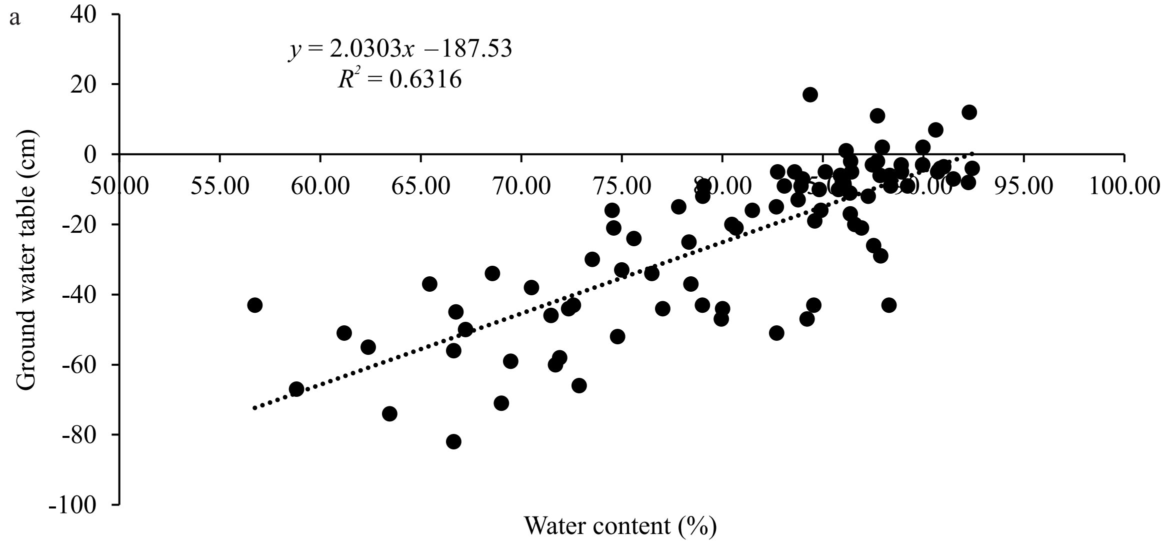
Jurnal Manajemen Hutan Tropika, *32*(2), 163−173, April 2026
EISSN: 2089-2063
DOI: 10.7226/jtfm.32.2.177

ISSN: 2087-0469

porosity of fibrists indicate that they have a higher water-holding capacity and are more prone to waterlogging. This implies that land management strategies for fibrists should prioritize water conservation, while hemists focus on water management. For example, in areas that have already been canalized, canal blocking should be implemented; for fibrists, this means canal blocking without overflow, whereas for hemists, it involves canal blocking with overflow (Dohong et al., 2018).

Relationship between groundwater table and physical properties of peat The correlation analysis shows a strong relationship between groundwater depth and soil water content only in the upper peat layer (0–50 cm). As shown in Figure 3a, deeper groundwater levels are associated with lower soil water content, with an R^2 of 63.16%. This indicates that the water table strongly influences near-surface moisture conditions. In contrast, no meaningful relationship was observed at the 50–100 cm depth (Figure 3b). Soil water content in the deeper layer remains relatively stable regardless of fluctuations in groundwater depth, suggesting that this layer is less sensitive to short-term hydrological variation.

These findings are consistent with previous studies (Adhi et al., 2020; Ma et al., 2022; Nasution et al., 2023), which reported that groundwater dynamics are primarily controlled by moisture conditions in the upper peat layer. Both our study and these previous works confirm that soil water content in the 0–50 cm layer plays a dominant role in regulating groundwater depth, whereas the 50–100 cm layer shows



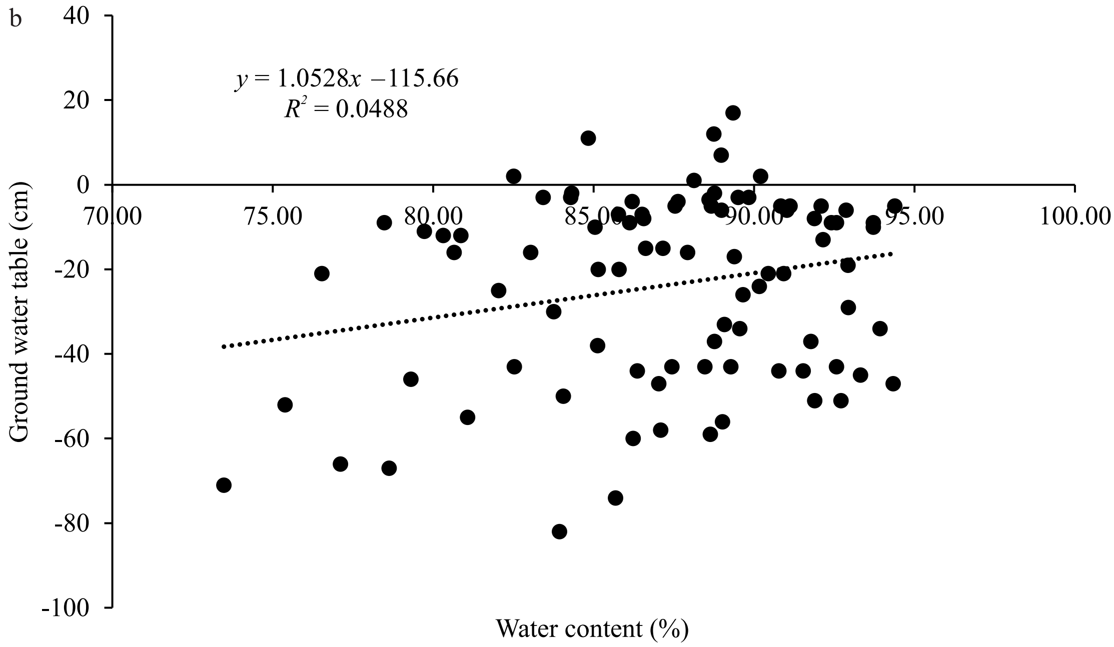


Figure 3 Illustrates the relationship between water content at a sample depth of 0–50 cm (a) and 50–100 cm (b) in relation to the groundwater table.

minimal influence. Therefore, peatland management should prioritize monitoring and maintaining water content in the upper 0–50 cm peat layer, as this zone plays the most critical role in sustaining peat hydrological stability and preventing degradation.

Conclusion

This study highlights that variations in the physical properties of peat soils are significantly affected by water table depths, land use, sampling depth, peat thickness, and soil suborders. These findings demonstrate the crucial role of these factors in shaping peatland ecosystems, with direct implications for both agricultural productivity and environmental conservation. Effective peatland management and conservation strategies must integrate these factors to mitigate risks of fire, land degradation, and hydrological imbalance, particularly in vulnerable tropical peatlands. Furthermore, this research underscores the need for customized, site-specific water and land-use management approaches to ensure the long-term sustainability of peat ecosystems. By providing insights into the relationship between physical soil properties and management practices, these findings offer a scientific foundation for developing sustainable cultivation and conservation frameworks on tropical peatlands.

Acknowledgment

We thank Gusti Randa, Slamet, Leo, Reza, Putri J, and Fahrul R for their assistance in the field and laboratory. The funding and activities of this research were supported by CV Sky Agro Energy.

References

Adhi, Y. A., Anwar, S., Tarigan, S. D., & Sahari, B. (2020). Relationship between groundwater level and water content in oil palm plantation on drained peatland in Siak, Riau Province, Indonesia. *Pertanika Journal of Tropical Agricultural Science*, *43*(3), 415–427.

Anda, M., Ritung, S., Suryani, E., Hikmat, M., Yatno, E., Mulyani, A., & Subandiono, R. E. (2021). Revisiting tropical peatlands in Indonesia: Semi-detailed mapping, extent and depth distribution assessment. *Geoderma*, *402*, Article 115235. https://doi.org/10.1016/j.geoderma.2021.115235

Anshari, G. Z., Gusmayanti, E., & Novita, N. (2021). The use of subsidence to estimate carbon loss from deforested and drained tropical peatlands in Indonesia. *Forests*, *12*(6), Article 732. https://doi.org/10.3390/f12060732

Arabia, T., Basri, H., Zainabun., & Mukhtaruddin. (2020). Physical and chemical characteristics in peat lands of Aceh Jaya District, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *499*, Article 012004. https://doi.org/10.1088/1755-1315/499/1/012004

Astiani, D., Burhanuddin, B., Curran, L. M., Mujiman, M., & Salim, R. (2017). Effects of drainage ditches on water table level, soil conditions and tree growth of degraded peatland forests in West Kalimantan. *Indonesian Journal of Forestry Research*, *4*(1), 15–25. https://doi.org/10.20886/ijfr.2017.4.1.15-25

Badan Standardisasi Nasional. (2010). *Standar Nasional Indonesia 7645:2010 Klasifikasi penutup lahan*. Jakarta: Badan Standardisasi Nasional

Badan Informasi Geospasial. (2024). *Map of West Kalimantan Province*. BIG. Retrieved from https://inaland.big.go.id/map

Badan Meteorologi, Klimatologi, dan Geofisika. (2023). *Rainfall data*. BMKG. Retrived from https://dataonline.bmkg.go.id/data-harian

Dhandapani, S., Evers, S., Boyd, D., Evans, C. D., Page, S., Parish, F., & Sjogersten, S. (2023). Assessment of differences in peat physico-chemical properties, surface subsidence and GHG emissions between the major land-uses of Selangor peatlands. *Catena*, *230*, Article 107255. https://doi.org/10.1016/j.catena.2023.107255

Dohong, A., Abdul Aziz, A., & Dargusch, P. (2018). A review of techniques for effective tropical peatland restoration. *Wetlands*, *38*, 275–292. https://doi.org/10.1007/s13157-018-1017-6

Firdaus, M. S., Gandaseca, S., Ahmed, O. H., & Majid, N. M. A. (2010). Effect of converting secondary tropical peat swamp forest into oil palm plantation on selected peat soil physical properties. *American Journal of Environmental Sciences*, *6*(4), 402–405. https://doi.org/10.3844/ajessp.2010.402.405

Ginting, E. N., Darlan, N. H., & Winarna. (2016). Effective water management for oil palm in peatland: For peat conservation and yield optimization. In *15th international peat congress* (pp. 497–501). Kuching, Malaysia.

Gramlich, A., Stoll, S., Stamm, C., Walter, T., & Prasuhn, V. (2018). Effects of artificial land drainage on hydrology, nutrient and pesticide fluxes from agricultural fields–A review. *Agriculture, Ecosystems & Environment*, *266*, 84–99. https://doi.org/10.1016/j.agee.2018.04.005

Hikmatullah, H., & Sukarman, S. (2014). Physical properties of peat soil in relation to its thickness in Jambi Province, Indonesia. *Journal of Tropical Soils*, *19*(3), 147–154. https://doi.org/10.5400/jts.2014.v19i3.131-141

Junedi, H., Armanto, M. E., Bernas, S. M., & Imanudin, M. S. (2017). Changes to some physical properties due to conversion of secondary forest of peat into oil palm plantation. *Sriwijaya Journal of Environment*, *2*(3), 76–80. https://doi.org/10.22135/sje.2017.2.3.76-80

Jurasinski, G., Ahmad, S., Anadon-Rosell, A., Berendt, J., Beyer, F., Bill, R., Blume-Werry, G., Couwenberg, J., Günther, A., Joosten, H., , Koebsch, F., Köhn, D., Koldrack, N., Kreyling, J., Leinweber, P., Lennartz, B., Liu, H., Michaelis, D., Mrotzek, A., ..., & Wrage-Mönnig, N. (2020). From understanding to sustainable use of peatlands: The WETSCAPES approach. *Soil Systems*, *4*(1), Article 14. https://doi.org/10.3390/soilsystems4010014

Kementerian Lingkungan Hidup dan Kehutanan. (2017). *Keputusan Menteri Lingkungan Hidup dan Kehutanan Nomo 219 Tahun 2017 tentang Penetapan Peta Kesahutan Hidrologis Gambut Nasional*. Kementerian Lingkungan Hidup. http://pkgppkl.menlhk.go.id/v0/kepmen-no-129-tahun-2017-penetapan-peta-kesatuan-hidrologis-gambut-nasional/

Kementerian Lingkungan Hidup dan Kehutanan. (2017). *Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor 10 Tahun 2019 tentang Tata Cara Inventarisasi dan Penetapan Fungsi Ekosistem Gambut.* Peraturan.go.id. https://peraturan.go.id/id/permen-lhk-no-p-14-menlhk-setjen-kum-1-2-2017-tahun-2017

Kementerian Lingkungan Hidup dan Kehutanan. (2019). *Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor 14 Tahun 2017 tentang Penentuan, Penetapan, dan Pengelolaan Puncak Kubah Gambut berbasis Kesatuan Hidrologis Gambut*. Peraturan.go.id. https://peraturan.go.id/id/permen-lhk-no-p-10-menlhk-setjen-kum-1-3-2019-tahun-2019

Kunarso, A., Bonner, M. T., Blanch, E. W., Grover, S. (2022). Differences in tropical peat soil physical and chemical properties under different land uses: A systematic review and meta-analysis. *Journal of Soil Science and Plant Nutrition*, *22*(4), 4063–4083. https://doi.org/10.1007/s42729-022-01008-2

Liu, H., Price, J., Rezanezhad, F., & Lennartz, B. (2020). Centennial-scale shifts in hydrophysical properties of peat induced by drainage. *Water Resources Research*, *56*(10), Article e2020WR027538. https://doi.org/10.1029/2020WR027538

Liu, Y., Li, Z., Wang, D., Li, X., Zheng, X., Liu, H., Liu, J., & Li, Z. (2023).The Genetic Characteristics of Intermittency and Continuity in Peat Formation and Accumulation Processes. *Ore Geology Reviews*, 161,105650. https://doi.org/10.1016/j.oregeorev.2023.105650

Ma, L., Zhu, G., Chen, B., Zhang, K., Niu, S., Wang, J., Ciais, P., & Zuo, H. (2022). A globally robust relationship between water table decline, subsidence rate, and carbon release from peatlands. *Communications Earth & Environment*, *3*(1), Article 254. https://doi.org/10.1038/s43247-022-00590-8

Marwanto, S., Watanabe, T., Iskandar, W., Sabiham, S., & Funakawa, S. (2018). Effects of seasonal rainfall and water table movement on the soil solution composition of tropical peatland. *Soil Science and Plant Nutrition*, 64(3), 386–395. https://doi.org/10.1080/00380768.2018.1436940

Masganti, M., Anwar, K., & Susanti, M. A. (2017). Potensi dan pemanfaatan lahan gambut dangkal untuk pertanian. *Jurnal Sumberdaya Lahan*, *11*(1), 43–52. https://doi.org/10.21082/jsdl.v11n1.2017.43-52

McCalmont, J., Kho, L. K., Teh, Y. A., Chocholek, M., Rumpang, E., Rowland, L., Basri, M. H. A., & Hill, T. (2023). Oil palm (*Elaeis guineensis*) plantation on tropical peatland in South East Asia: Photosynthetic response to soil drainage level for mitigation of soil carbon emissions. *Science of the Total Environment*, *858*, Article 159356. https://doi.org/10.1016/j.scitotenv.2022.159356

Monteverde, S., Healy, M. G., O'leary, D., Daly, E., & Callery, O. (2022). Management and rehabilitation of peatlands: The role of water chemistry, hydrology, policy, and emerging monitoring methods to ensure informed decision making. *Ecological Informatics*, *69*, Article 101638. https://doi.org/10.1016/j.ecoinf.2022

Nasution, H., Yusfaneti, Y., & Saat, A. (2023). The relationship between peat water content to physical properties of peat at various ages of oil palm plant and year products in Mekar Jaya Village. *Attractive: Innovative Education Journal*, *5*(1), 437–446 https://doi.org/10.51278/aj.v5i1.720

Nursyamsi, D., Noor, M., & Maftu'ah, E. (2016). Peatland management for sustainable agriculture. In M. Osaki, & N. Tsuji (Eds.), *Tropical peatland ecosystems* (pp. 493–511). Springer, Tokyo. https://doi.org/10.1007/978-4-431-55681-7_34

Osman, K. T. (2018). Peat soils. In K. T. Osman (Ed.), *Management of soil problems* (pp. 145–183). Springer, Cham. https://doi.org/10.1007/978-3-319-75527-4_7

Parfenova, L. N., Selyanina, S. B., Trufanova, M. V., Bogolitsyn, K. G., Orlov, A. S., Volkova, N. N., & Sokolova, T. V. (2016). Influence of climatic and hydrological factors on structure and composition of peat from northern wetland territories with low anthropogenic impact. *Science of the Total Environment*, *551*, 108–115. https://doi.org/10.1016/j.scitotenv.2016.01.204

Putra, E. I., & Hayasaka, H. (2011). The effect of the precipitation pattern of the dry season on peat fire occurrence in the Mega Rice Project area, Central Kalimantan, Indonesia. *Tropics*, *19*(4), 145–156. https://doi.org/10.3759/tropics.19.145

Republik Indonesia. (2016). *Peraturan Pemerintah Republik Indonesia Nomor 57 Tahun 2016 tentang*

Perubahan Atas Peraturan Pemerintah Nomor 71 Tahun 2014 tentang Perlindungan dan Pengelolaan Ekosistem Gambut. Peraturan.go.id. https://peraturan.go.id/id/pp-no-57-tahun-2016

Robert, U. W., Etuk, S. E., & Agbasi, O. E. (2019). Bulk volume determination by modified water displacement method. *Iraqi Journal of Science*, *60*(8), 1704–1710. https://doi.org/10.24996/ijs.2019.60.8.7

Royal Eijkelkamp. (2026). Peat sampler-Operating instructions. Retrieved from https://www.royaleijkelkamp.com/products/augers-samplers/soil-augers-samplers/profile-samplers/peat-sampler-set/

Sinclair, A. L., Graham, L. L., Putra, E. I., Saharjo, B. H., Applegate, G., Grover, S. P., & Cochrane, M. A. (2020). Effects of distance from canal and degradation history on peat bulk density in a degraded tropical peatland. *Science of the Total Environment*, *699*, Article 134199. https://doi.org/10.1016/j.scitotenv.2019.134199

Soil Survey Staff. (2022). *Keys to soil taxonomy* (13th ed.). USDA Natural Resources Conservation Service.

Subardja, D. S., Ritung, S., Anda, M., Sukarman, E. S., & Subandiono, R. E. (2014). *Klasifikasi tanah nasional*. Bogor: Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian.

Syaufina. L., Nuruddin, A. A., Basharuddin, J., See, L. F., & Yusof, M. R. M. (2004). The effects of climatic variations on peat swamp forest conditions and fire behaviour. *Jurnal Manajemen Hutan Tropika*, *10*(2), 1–14.

Syaufina, L. (2008). *Kebakaran hutan dan lahan di Indonesia: Perilaku api, penyebab, dan dampak kebakaran*. Bayumedia Pub.

Tonks, A. J., Aplin, P., Beriro, D. J., Cooper, H., Evers, S., Vane, C. H., & Sjögersten, S. (2017). Impacts of conversion of tropical peat swamp forest to oil palm plantation on peat organic chemistry, physical properties and carbon stocks. *Geoderma*, *289*, 36-45. https://doi.org/10.1016/j.geoderma.2016.11.018

Uda, S. K., Hein, L., & Sumarga, E. (2017). Towards sustainable management of Indonesian tropical peatlands. *Wetlands Ecology and Management*, *25*, 683–701. https://doi.org/10.1007/s11273-017-9544-0

Wang, M., Liu, H., & Lennartz, B. (2021). Small-scale spatial variability of hydro-physical properties of natural and degraded peat soils. *Geoderma*, *399*, Article 115123. https://doi.org/10.1016/j.geoderma.2021.115123

Winarna, Murtilaksono, K., Sabiham, S., Sutandi, A., & Sutarta, E.S. (2016). Hydrophobicity of tropical peat soil from an oil palm plantation in North Sumatra. *Journal of Agronomi*, *15*(3), 114–121. https://doi.org/10.3923/ja.2016.114.121