BUKTI KORESPONDENSI RESPONDENSI DAN SUBSTANSI ISI

ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul	:	Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir South Sumatra, Indonesia
Jurnal	:	JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT-(SCOPUS Q3)
Penulis	:	Bakri, Momon Sodik Imanudin, A Napoleon, As'ad Syazili, Muh Bambang Prayitno, A. Hermawan, Khoiriyah, Rujito A Suwignyo, Eunho Choi, Hyunyoung Yang.
Kontribusi	:	Penulis Pertama dan Korespondensi

No.	Perihal	Tanggal
01	Submission	5 April 2025
02	New notification	29 April 2025
03	Peer Review	29 April 2025
04	Editor decision: accepted	14 Mei 2025
05	Proofing	15 Mei 2025
06	Final Paper	16 Mei 2025

[JDMLM] Submission Acknowledgement

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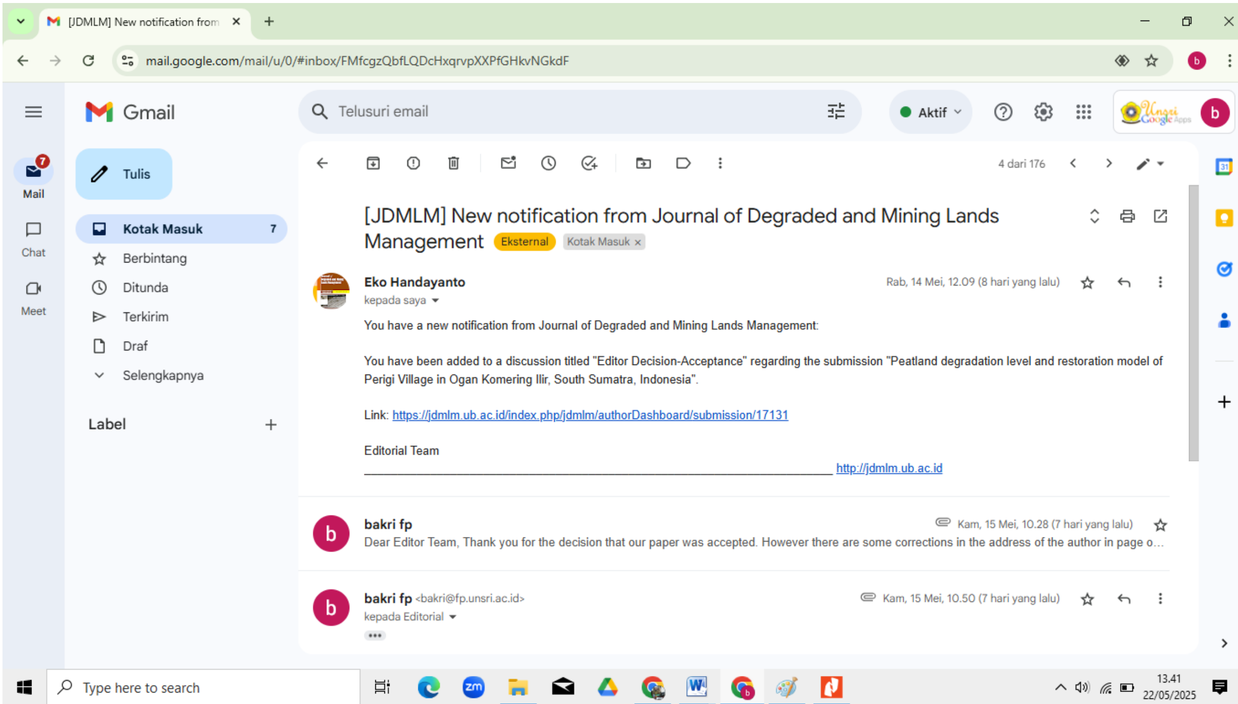

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Dear Authors

[Bakri, Momon Sodik Imanudin, A Napoleon, As'ad Syazili, Muh Bambang Prayitno, Khoiriyah, Z, Rujito A Suwignyo, Eunho Choi, Hyunyoung Yang]

Your manuscript entitled "**Peatland Degradation Level And Restoration Model of Perigi Village in Ogan Kemering Ilir South Sumatra Indonesia**" has been reviewed by the Journal of Degraded and Mining Lands Management reviewers. Your manuscript needs revisions based on the reviewer's comments (attached). A substantial amount of work is necessary to raise this current manuscript to the standard of a research article published in this journal.

If you want to revise your manuscript, please make sure you have followed the reviewer's comments before submitting/uploading the revised version.

All the best

Eko Handayanto

JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 12, Number 0 (……… 2025):0000-0000, doi:10.15243/jdmlm.2025.120.0000
ISSN: 2339-076X (p); 2502-2458 (e),www.jdmlm.ub.ac.id

Research Article

REVISIONS REQUIRED

Please see comments/corrections inserted in related sections

This manuscript was carelessly prepared, and the English is vague and confusing. The authors should have sought help from English proofreaders before submitting this manuscript.

This manuscript presents the results of a problem-identification study, not the results of problem-solving research as directed by the scope of this journal.

The methods presented in the Materials and Methods section are trivial (not presented in detail) and are only techniques/procedures of soil sampling and laboratory analysis, not research methods designed to solve problems related to the management of degraded land.

To fit within the scope of this journal, the authors are requested to include the results of a study on the use of the characterized LRC humic acid for managing degraded and mining lands, for example, a simple pot experiment designed to improve the fertility of degraded peat soils.

HN (& editor)

Peatland ~~Degradation~~ degradation ~~Level~~ level ~~And~~ and ~~Restoration~~ restoration ~~Model~~ model of Perigi Village in Ogan Kemering Ilir South Sumatra, Indonesia

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Article history:
Received ……………..
Revised ……………..
Accepted ……………

Keywords:
adaptive agriculture
drainage
land degradation
peat land

Abstract

The use of peatlands for plantations and industrial tree plantations is increasingly widespread and causes land damage due to excessive drainage ~~during~~. Meanwhile, adaptive agricultural efforts have not yet been found appropriate~~ly~~ so that the peat environment is maintained. This study ~~aims~~ aimed to ~~determine the~~ assess~~ment~~ ~~of~~ peatland degradation in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency. Data analysis ~~uses~~ used a descriptive method which ~~is~~ was then continued with an evaluation of the determination of the level of land damage with standard criteria for land damage in wetlands based on PERMENLH No. 20 (2008). ~~Based on the~~ The results of observations, field measurements, and laboratory analysis showed~~, it~~ shows that the three lands experienced damage with a moderate damage status (R.II). The parameters that limit and contribute to the land damage score to a moderate damage status are shallow groundwater depth, redox, and soil pH that exceeds the threshold value that has been set. Adaptive

JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 12, Number 0 (……… 2025):0000-0000, doi:10.15243/jdmlm.2025.120.0000
ISSN: 2339-076X (p); 2502-2458 (e),www.jdmlm.ub.ac.id

technology must accommodate local knowledge and can increase income. Sustainable land management by monding soil has great potential to be applied in peat land agriculture. Industrial crop such as Arabica coffee was cultivated in the field and show good growth perfomance.

Comment [lr1]: How could you recommend this if you did not do research on this matter.

To cite this article: Bakri, A., Imanudin, M.S.,~~Bakri, A~~. Napoleon, A., Syazili., A., ~~M.~~ Prayinto, M.B., Khoiriyah. Z., Suwignyo, R.A., Khoiriyah., Choi, E.~~,~~ and Yang H.~~, T~~. 2025. Peatland ~~Degradation~~ degradation ~~Level~~ level ~~And~~ and ~~Restoration~~ restoration ~~Model~~ model of Perigi Village in Ogan Kemering Ilir, South Sumatra, Indonesia. Journal of Degraded and Mining Lands Management12(0):0000-0000,doi:10.15243/jdmlm.2025.120.0000.

Introduction

Indonesia has the largest tropical peat area in the world, with an area of 13.43 million hectares spread across three large islands, namely Sumatra 5.8 million hectares, Kalimantan 4.5 million hectares, and Papua 3 million hectares (BRGM, 2024). Peatlands in Indonesia face a number of serious challenges. Land conversion activities for agriculture and plantations, as well as fires that occur especially during the dry season, have threatened the existence of these peatlands (Lestari *et al.*, 2024). This conversion and fires not only reduce the area of peatlands but also contribute to significant green-house ~~emiision~~ emissions (Uda *et al.*, 2019; Butterbach-Bahl *et al.*,2024). In 2015, ~~reported that~~ forest and land fires in Indonesia covering 2.6 million ha weare predicted to have released around 1.74 Gt CO2-eq (Word Bank, 2016; Suharjo and Novita, 2022).

The problem of peatland fires that occur every year~~, -~~ is that the conversion of functions to oil palm plantations results in a decrease in the function of peatlands (Imanudin *et al.*, 2018; Haryanto *et al.*, 2023). This has an impact on carbon emissions that contribute to global climate warming. In addition, inappropriate use of peatlands can also cause peatland degradation. About 43% of peatlands in Central Kalimantan have experienced degradation (Agus *et al.*, 2014). Degraded peatlands have experienced a decrease in their function in supporting the ecosystem. On the other hand, 119.7 million tons of carbon emissions are produced from peatland fires in Sumatra and Kalimantan each year (Miettinen *et al.*, 2017). ~~It was recorded that from~~ From 2001 to 2015, there had been land and forest fires reaching 1.7 million ha (Ramdhan, 2018); There was also a fire in 2019 that burned an area of 1.6 millions of hectares (Cifor, 2019),~~.~~ ~~And~~ and 1,1 million hectares in 2023 (Ministry of Environment and Forestry, 2023).

Based on data from the Ministry of Environment and Forestry in 2022, the condition of the peat ecosystem shows that 15.85 million hectares (65.45%) are in a state of minor damage, 3.08 million hectares (12.74%) are moderately damaged, 1.05 million hectares (4.35%) are severely damaged, and 206,935 million hectares (0.85%) are in a state of very severe damage. Degraded land not only becomes unproductive~~,~~ but can also be a source of various disasters such as drought, floods, landslides, and fires (Bowen *et al.*, 2024). These disasters have the potential to accelerate global warming. The negative impacts of degraded land are ~~not only felt in the surrounding area,~~f elt not only in the surrounding area, but can also spread far and affect wider areas (Wahyunto, 2014).

Peatland degradation occurs due to errors resulting from human activities, especially in land management. Incorrect water management is the main cause of peatland degradation (Masganti *et al.*, 2014; Sakuntaladewi *et al.*, 2024). In addition, degradation is also caused by fires and mining activities. Degradation causes a decrease in peat multifunction, such as productivity and environmental carrying capacity (Loisel, J., Gallego-Sala, 2022) Peatland productivity is highly dependent on human management and actions. Several researchers reported that peatland productivity decreased due to the degradation of soil fertility, physical properties, and soil biology (Maftuah *et al.*, 2014; Yuwati et al.,~~m~~ 2022; Deng *et al.*, 2025). The fertility of degraded peatland is lower. Likewise with its physical and biological properties. Therefore, in order to be used as agricultural land, it is also necessary to improve soil fertility in addition to improving water management (Wang *et al.*, 2023; Jaya *et al.*, 2024).

To assess the sustainability of peatland use, the government issued PP No. 71 of 2014 which was updated with PP No. 57 of 2016 concerning the protection and management of peat ecosystems. This regulation places more emphasis on the protection of peat ecosystems, as stated in Article 23 paragraph (2) of PP 57/2016 which states that peat ecosystems with a protective function are declared damaged if there is artificial drainage. Paragraph (3) states that peat ecosystems with a cultivation function are declared damaged if the groundwater level is > 0.4 m. In addition, the government also issued PP No. 150 of 2000 concerning the control of land damage for biomass production. This regulation aims to ensure that land used for biomass production does not experience damage that can reduce its productivity and sustainability.

In this regard, data and information on the distribution and characteristics of degraded land are very important to know accurately~~,~~ to understand and assess the level of damage that has occurred~~,~~ so that it can prevent further damage to land and the environment. This information is also very useful in formulating sustainable management strategies to restore the function of peat ecosystems so that development planning does not cause a decline in the quality of land and environmental resources.

Materials and Methods

This research was conducted in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency, South Sumatra, Indonesia (Figure 1~~), ~~). Laboratory analysis was conducted in~~–~~ soil fertility and Environmental Laboratory of the Palembang City Environmental and Land Service which started from October 2024 until January 2025.

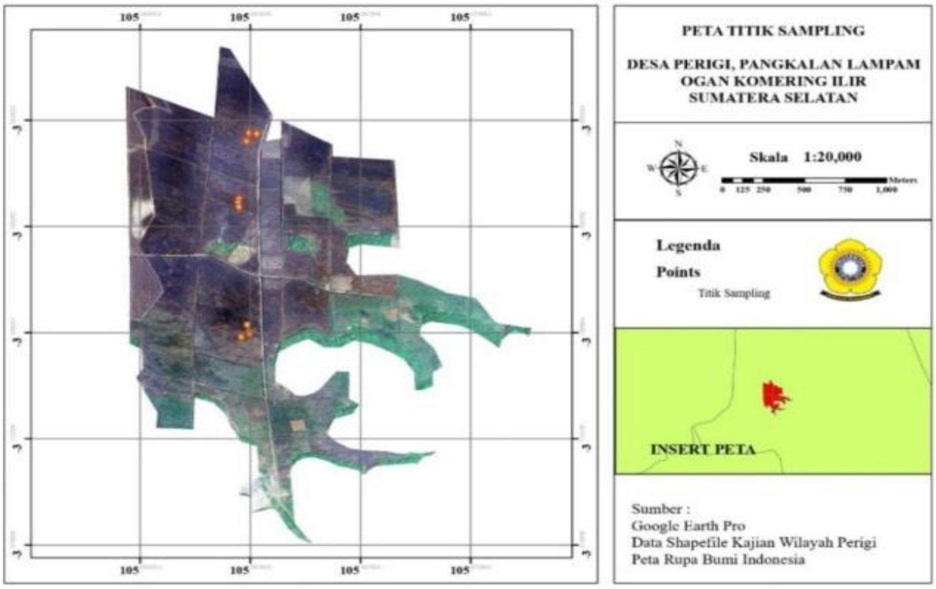

Figure 1. Samping soil map → The maps, coordinates, and legends are blurry. All legends must be written in English

~~The tools used in this research activity are as follows: 1). Stationery, 2). Peat Drill, 3). Global Positioning System (GPS), 4). Rubber Bracelet, 5). Camera, 6). Mattress, 7). Munsell Soil Color, 8). Meter, 9). Base Map of Research Location, 9). Sample Plastic. The materials used in this research activity are as follows: 1). Chemical Materials for Laboratory Analysis, 2). Soil Samples.~~

Determination of sampling locations was determined using the stratified random sampling method **→ ~~,~~ by what strata? → describe in a bit more detailed about the sampling methods, and the process of soil samples prior to laboratotatory analysis.**

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Observations and soil sampling were carried out on burnt peatlands, with each land as many as 3 location points with 2 replications. Data analysis used a descriptive method, which was then continued with an evaluation of determining the level of soil damage with standard criteria for soil damage in wetlands based on Government Regulation of the Republic of Indonesia No. 150 of 2000.

The variables observed in this study were: 1) Peat Maturity; 2) Soil Color; 3) Pond Height; 4) Pyrite Layer Depth; 5) Shallow Groundwater Depth; 6) Redox; 7) pH; 8) Electrical Conductivity; 9) Microbial Content. **→ methods (including references) used to observe the variables should be clearly described.**

The data analysis for determining the status of land damage begins with identification based on the main parameters above, followed by an evaluation. This evaluation aims to determine whether or not ~~a~~ land is damaged according to the standard criteria for land damage in wetlands based on Government Regulation of the Republic of Indonesia No. 150 of 2000, as shown in ~~table~~ Table 2.

~~Tabel~~ Table 2. Standard criteria for assessing peatland/wetland damage

No	Parameter	Critical Threshold – (references?)
1.	Depth of pyrite layer from ~~ground~~ soil surface (cm)	< 25 cm with pH < 2,5
2.	Water table depth (cm)	> 25
3.	Redox for soil containing pyrite (mV) ~~Redoks for soil containing pyrite (mV)~~	> -100
4.	~~Redoks~~ Redox for peat soil (mv)	> 200
5.	~~Ph~~ pH (H_20) 1:2,5	< 4,0 ; > 7,0
6.	Ele~~i~~ctrical Conductivity (dS/m)	> 4,0
7.	Microbial population (cfu/g tanah)	<10^2 cfu/g soil

The standard assessment of land degradation is carried out by calculating the results of the relative frequency of damaged land from each variable and given a score. The total land damage score is used to determine the status of land damage (Table 3).

Table 3. Land Degradation Score Based on Relative Frequency

FRTR (%)	Score	Accumulated Score Value	Land degradation level (references???)
0-10	0	0	No ~~damaged~~ amage
11-25	1	1-8	Light ~~demage~~ damage
26-50	2	9-14	Medium ~~demage~~ damage
51-75	3	15-20	Heavy ~~demage~~ damage
76-100	4	21-24	Very heavy ~~demage~~damage

Source: Government Regulation of the Republic of Indonesia No. 150 of 2009

Results

The physical characteristics of peat soil observed included ~~parameters of~~ waterlogging height, peat maturity, color, and groundwater depth (T~~t~~able 4). The observed chemical properties of peat soil included soil pH, carbon content, potassium, nitrogen and phosphorus, which can be seen in Table 4.The level of peat maturity is divided into three types, namely fibric, hemic and sapric. The soil color obtained on shallow peat, medium peat, and deep peat are 10YR 2/1 (Black). Peat color is one of the indicators of peat maturity. In November, the height of the puddles is in the range of 11-28 cm from the ground surface. Howerver in September (dry season), the groundwater level drops 70-80 cm below the surface.

Tabel 4. ~~Results of~~ Soil Physical ~~Properties~~ Characteristics

Sampling point	Soil depth (cm)	Peat maturity class	~~Munsel soil~~ Soil Colo~~u~~r	Water Table Depth (cm)	Puddle height (cm)
D3 (deep peat)	0-30	~~Saprik~~Sapric	10 yr 2/1	-49	11
	30-60	~~Saprik~~Sapric	10 yr 2/1	-49	11
S2 (medium peat)	0-30	~~Saprik~~Sapric	10 yr 2/1	-48	15
	30-60	~~Saprik~~Sapric	10 yr 2/1	-48	15
P1 (shallow peat depth)	0-30	~~Hemik~~Hemic	10 yr 2/1	-53	28
	30-60	~~Hemik~~Hemic	10 yr 2/1	-53	28

~~Table 5, showed the~~ The results of the analysis of soil samples presented in Table 5 ~~in the laboratory~~ showed ~~ed~~ that the soil N content ranged ~~between~~ from 0.39% ~~–~~ to 0.81% (low), phosphorus content in each peat land is in the range of 42,195 – 51,765 ppm (very high). The potassium (K-dd) content in each peat land is in the range of 0.13 – 0.19 me/100g (very low). ~~And~~ The cation exchange capacity (CEC) content in each peat land is in the range of 20 – 22.5 me/100g (moderate).

Table 5. Soil Chemical ~~Properties~~ Characteristics → decimals are separated with 'periods' not 'commas'

Sampling point	Soil depth (cm)	pH		~~C~~ Organic C	~~N~~ Total N	Available P- ~~Availability~~	Exchangeable K- ~~dd~~	CEC
		H_2O	~~KCL~~ KCl	%		(ppm)	me/100g	
D3 (deep)	0-30	3,52	3,18	17,80	0,81	42,195	0,13	22,5
	30-60	3,49	3,05	18,96	0,53	46,545	0,13	22,5
S2 (medium)	0-30	3,44	3,31	17,02	0,56	50,315	0,19	22,5
	30-60	3,70	3,25	20,12	0,60	49,3	0,19	20
P1 (shallow)	0-30	3,50	3,26	18,18	0,39	51,765	0,19	20
	30-60	3,27	3,20	20,12	0,78	45,965	0,19	20

~~Tabel~~ Table 6. Land degradation identification of shallow seat lands

No	Parameter	Threshold	Mean value		Criteria status (references???)
			0-30 cm	30-60 cm	
1.	Depth of pyrite layer from ~~ground~~ soil surface (cm)	<25 cm with pH < 2,5	>120	>120	Under limit
2.	Water table depth (cm)	>25 cm	53 (dry) -11 (puddle)	53 (dry) -11 (puddle)	~~Excedds~~ Exceeds limit
3.	~~Redoks~~ Redox for soil containing pyrite (mV)	>-100	-	-	Under limit
4.	~~Redoks~~ Redox for peat soil (mv)	>200	390	414	~~Excedds~~ Exceeds limit
5.	Ph (H_20) 1:2,5	<4.~~,~~0 ; >7,0	3,5	3.~~,~~5	~~Excedds~~ Exceeds limit
6.	~~Elictrical~~ Electrical Conductivity (dS/m)	>4.~~,~~0	0.~~,~~397	0.~~,~~312	Under limit
7.	Microbial population (cfu/g of soil)	<10^2 cfu/g soil	2.~~,~~6.10^5	3.10^4	Under limit

Table7.Land Degradation~~uin~~ identification of ~~medium~~ medium peat layers

No	Parameter	Threshold	Mean value		Criteria status (references???)
			0-30 cm	30-60 cm	
1.	Depth of pyrite layer from ~~ground~~ soil surface (cm)	<25 cm with pH < 2,5	50	50	Under limit
2.	Water table depth (cm)	>25 cm	48 (in dray) -15 (in wet)	48 (In dray) -15 (In Wet)	Excedds limit
3.	~~Redoks~~ Redox for soil containing pyrite (mV)	>-100	399	414	Excedds limit
4.	~~Redoks~~ Redox for peat soil (mv)	>200	-	-	Under limit
5.	pH (H_20) 1:2,5	<4,0 ; >7,0	3,44	3,70	~~Excedds~~ Exceeds limit
6.	~~Elictrical~~ Electrical Conductivity (dS/m)	>4,0	0,726	0,377	Under limit
7.	Microbial population(~~cfu~~ CFU/g ~~tanah~~ soil)	<10^2 ~~cfu~~ CFU/g soil	2,1.10^4	1,4.10^4	Under limit

Table 8. Land degradation ~~Identifikasi~~ Identification of deep peat soil layers

No	Parameter	Threshold	Mean value		Criteria status
			0-30 cm	30-60 cm	
1.	Depth of pyrite layer from ~~ground~~ soil surface (cm)	<25 cm with pH < 2,5	60	60	Under limit
2.	Water table depth (cm)	>25 cm	46 (In dry) -28 (In wet)	46 (In dry) -28 (In wet)	~~Exceedds~~ Exceeds limit
3.	~~Redoks~~ Redox for soil containing pyrite (mV)	>-100	436	401	Exceedds limit
4.	~~Redoks~~ Redox for peat soil (mv)	>200	-	-	Under limit
5.	Ph ($H_2$0) 1:2,5	<4,0 ; >7,0	3,52	3,49	~~Exceedds~~ Exceeds limit
6.	Ele~~i~~ctrical Conductivity (dS/m)	>4,0	1,59	0,530	Under limit
7.	Microbial population (~~cfu~~CFU/g ~~tanah~~ soil)	<10^2 ~~cfu~~CFU/g soil	3.10^4	$1,3.10^4$	Under limit

Discussion

The depth of the pyrite layer from the peat soil surface for the three lands (Table 5-7) is below the threshold/critical, namely <25 cm. The average depth of pyrite in deep peatlands, medium peatlands and shallow peatlands is 60 cm, 50 cm, and 0 cm, respectively (no visible pyrite layer). The deepest pyrite depth is in deep peatlands. This is related to the depth of the peat soil. The deeper the peat soil, the deeper the pyrite layer in the mineral soil layer. In flooded conditions (anaerobic) pyrite will not be dangerous, but if it is drained excessively and pyrite is oxidized, sulfuric acid and iron compounds will be formed, which are harmful to plants.

The depth of shallow groundwater in deep peatlands, medium peatlands, and shallow peatlands is above the threshold/critical level of >25 cm, which are 46 cm, 48 cm, and 53 cm, respectively (Table 4). Low groundwater levels can indicate peat damage. Changes in the peat ecosystem from natural peat to agricultural land have an impact on the decline in groundwater levels due to the process of logging, slashing, burning vegetation, making drainage, and land preparation.

The redox value in shallow peatlands, medium peatlands and deep peatlands is above the threshold/critical, which is > 200 mV. In shallow peatlands, the redox value is at 390 mV and 414 mV~~,~~; in medium peatlands, it is at 399 mV and 414 Mv, and in deep peatlands, it is at 436 mV and 401 mV. Based on the criteria for soil redox conditions, the four lands above are included in soils with a perfect oxidation atmosphere. Peatlands with an Eh value > 200 mV, peat can be oxidized or degraded. According to Saragih *et al.*, (2014) that if peat is oxidized, the peat will become dry and peat subsidence will occur. This condition affects the damage to peat soil.

According to Liu (1985, in Syekhfani, 2014), Eh will have an oxidative status if it has a value of >400 mV, while low reduction status occurs in soil with an Eh value between 400-200 mV, moderate reduction status ranges from 00-(-100) mV, and reduction status occurs in soil with an Eh value <(-100) mV. Based on this classification, deep peat land has an oxidation status, medium peat land with a depth of 0-30 cm has a low reduction status, a depth of 30-60 cm has an oxidation status, and shallow peat land with a depth of 0-30 cm has a low reduction status, a depth of 30-60 cm has an oxidation status. Thus, from the results above it can be concluded that the three lands with a depth of 30-60 cm all have an oxidation status or the soil has degraded.

Table8. Status of Gradation soil ~~redoks~~ redox

Redoks Status	Range Eh (mV)
~~Ocidation~~Oxidation	>400
~~Loe~~ Low reduction	400-200
Moderate reduction	00-(-100)
High? reduction	<(-100)

Source: Liu, 1985 in Syekhfani, 2014. → do not use secondary citations, use primary citations only

Soil reaction (pH) for the three lands above the threshold/critical, namely pH <4.0; >7.0. The average soil pH on deep peat land, medium peat land and shallow peat land with a depth of 0-30 cm and 30-60 cm are respectively 3.52, 3.49, 3.44, 3, 70 and 3.5 cm. Based on the data above, ~~it shows that~~ the pH of peat soil is not good. This is in accordance with the characteristics of peat which is known as less fertile soil, characterized by low pH (acidic) (SDLP Research and Development, 2014).

The DHL value of peat soil for the three lands is below the threshold/critical, namely > 4.0 dS/cm. DHL on shallow peat land with a depth of 0-30 cm and 30-60 cm is 0.39 and 0.31, respectively~~,~~; on medium peat land with a depth of 0-30 cm and 30-60 cm is 0.72 and 0.37, respectively, and on deep peat land with a depth of 0-30 cm and 30-60 cm is 1.59 and 0.53 respectively. According to Pamungkas and Irianto (2015), in tidal wetlands, including peatlands, the presence of groundwater depth affects the content of relatively concentrated salt ions in groundwater. However, DHL on the three lands is included in the good range.

The number of peat soil microbes for the three lands was below the threshold/critical, namely <102 cfu/g of soil. The number of microbes in shallow peatlands with depths of 0-30 cm and 30-60 cm were 2.6,105 cfu/g and 3.104 cfu/g, respectively, in medium peatlands with depths of 0-30 cm and 30-60 cm were 2.1,104 cfu/g and 1.4,104 cfu/g, respectively, and in deep peatlands with depths of 0-30 cm and 30-60 cm were 3.104 cfu/g and 1.3,104 cfu/g. The measurement results showed that the number of peat soil microbes in all lands was included in good status. The presence of total microbes can also describe the quality of the soil. The higher ~~the~~ total number of microbes indicates that the chemical and physical atmosphere in the soil is very supportive of soil microbial activity (Abdulkarim *et al.*, 2015).Fauziah and Ibrahim (2020) added that the bacterial population in peatlands was found to be higher in the upper soil layer (0-30) cm. And also at the sapric maturity level, it has the highest population.

According to the Regulation of the Minister of Environment Number 7 of 2006, if one of the critical parameter thresholds is exceeded, the land is said to be damaged. Based on these provisions, it can be concluded that land damage has occurred in the three peatlands in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency, with the number of damaged parameters in succession on shallow, medium, and deep peatlands having 3 parameters, namely shallow groundwater depth, redox, and pH which are the main causes of land damage (Table 6-8) .

Parameters that exceed the critical threshold and become limiting factors are shallow groundwater depth, redox, and soil pH. The low shallow groundwater depth in the three areas can indicate peat damage. Peat ecosystems with cultivation functions are declared damaged if the groundwater depth is more than 0.4 meters. In addition, a decrease in the depth of the groundwater level due to the creation of drainage that is too deep and wide can cause the peat to dry out and increase the risk of peatland fires (Nusantara *et al.*, 2023).

The low redox value of the soil in the three peatlands, namely the Eh value (redox potential) of more than 200 mV, has an impact on the peat being oxidized and degraded. Oxidized peat will become dry and cause the peat surface to decrease, which can damage the peat soil. Dry peatlands are also very susceptible to fire. According to the research results of Wawan and Hermanto, 2017, peatland fires can cause the soil redox value to decrease. Redox changes occur due to changes in elements and chemical reactions in the soil due to fires. In addition, the decrease in groundwater levels results in an increase in the DHL value so that it can trigger poisoning of certain elements in plants (Harun *et al.*, 2020).

Each of the lands also has a low pH value or is above the threshold for land damage. Peat soil generally has a low pH, ranging from 3.0 to 5.0. This is due to the high content of organic acids, such as humic acid and fulvic acid, the result of the decomposition of organic matter (Mulyani and Zahrah, 2022). However, the low pH of this soil affects the availability of nutrients for plants. In acidic peat soil, macronutrients such as calcium (Ca), nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) are not available in sufficient quantities. Conversely, micronutrients such as aluminum (Al), iron (Fe), and manganese (Mn) increase to reach toxic levels for plants. In peat soil, the cation exchange capacity (CEC) is high but the percentage of bases is very low, making it difficult to absorb nutrients, especially bases. In addition, soil that is too acidic can inhibit the development of certain microorganisms that are important for soil fertility. Therefore, providing ameliorative materials such as manure and biochar is important in land restoration efforts.

Adaptation of Mounding Technology for Industrial Crops (Libarica Coffee)

Crop adaptation model without changing the groundwater level is by using the Mounding technique (soil mounding). The height of the mound must be above the high tide level. So far, the maximum water level is at 60-70 cm. From this water height, a safety factor of 30 cm can be added. So that the height of the mound of land (mounding) is 100 cm from the ground surface.

Figure 8 shows farmers making mounding for coffee cultivation. Liberica coffee plants are coffee plants for wetlands that have been successfully developed in Riau province. The introduction of coffee plants is intended to make farmers more interested in utilizing the land. Coffee is an industrial plant that has a clear market and relatively stable prices. Reported by Media Indonesia (2018), liberica coffee cultivation has been successfully cultivated in Keduburapat Village, Rangsang Pesisir District, Meranti Islands Regency, Riau. For a 1 hectare planting area, it can produce 1-5 tons of coffee. And in one coffee tree can reach 20 kg. From these conditions, it is very important to conduct large-scale trials of Liberica coffee.

Figure 9. Mounding technology for coffee cultivation on peat land of Perigi Indonesia.--> the legends of the right photo are too small and unreadable. The legends must be in English

The problem of soil acidity and low nutrients in peat soil requires coffee plants to be given amelioration materials and fertilization. Samson and Mahmudi's (2024) research showed that the use of dolomite lime and shrimp waste liquid fertilizer can increase the growth and yield of peanuts on peat soil. A dose of 6 tons ha-1 of dolomite lime and 400 mL L-1 of shrimp waste liquid fertilizer effectively increased root volume. The provision of liquid fertilizer from waste will also increase the growth of soil microbes.Added research by Ferry et al (2020) giving lime in combination with manure and liquid fertilizer can increase the growth of Liberica coffee. The optimum dose is dolomite lime 2.5 tons/ha, manure 10 tons/ha and liquid fertilizer 0.5 liters/tree Kartika et al (2022) added that the application of 10 g of mycorrhizal biofertilizer per plant and 50% inorganic fertilizer is the best combination in increasing the growth of liberica coffee on peatlands. The recommended 100% dose value is 20 g of Urea/plant, 25 g of SP36/plant, 15 g of KCl/plant, and 10 g of Kisserit/plant. Can be reduced to 50 if combined with the use of microbial liquid fertilizer. Fertilizer application is given twice a year, at the beginning and end of the rainy season.

Planting industrial crop such as Liberica Coffe~~-~~ that have the potential to generate new income can encourage farmers to more utilize the land. This condition can automatically protect the land from fires.

Conclusion

Based on the results of observations, field measurements and laboratory analysis, it shows that the three lands experienced damage with a moderate degradation status (R.II). The land damage that occurred was caused by natural factors, namely land conditions in low fertility conditions and human activity factors that caused a decrease in land quality. The parameters that limit and contribute to the land damage score to a moderate degradation status are shallow groundwater depth, redox, and soil pH that exceeds the predetermined threshold value.

Acknowledgments

The research was funded by collaboration research ~~-~~between the National Institute of Forest Science (NIFoS) Republic of Korea and Sriwijaya University Indonesia. The authors would like to acknowledge Deasy. M. Irfan support, and Sumantri and Agus Prihanto for the field assistance during the field survey

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JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 12, Number 4 (July 2025):8117-8126, doi:10.15243/jdmlm.2025.124.8117
ISSN: 2339-076X (p); 2502-2458 (e), www.jdmlm.ub.ac.id

Research Article

Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir, South Sumatra, Indonesia

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Abstract

The use of peatlands for plantations and industrial tree plantations is increasingly widespread and causes land degradation due to excessive drainage. Meanwhile, adaptive agricultural efforts are not yet appropriate for maintaining the peatland environment. This study aimed to assess peatland degradation in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency. Data obtained were analyzed using a descriptive method, followed by an evaluation of the determination of the level of land degradation with standard criteria for land degradation in wetlands based on the Regulation of the Indonesian Minister of Environment No. 20, 2008. The observations, field measurements, and laboratory analysis showed that the three lands experienced moderate degradation. The parameters that limit and contribute to the land degradation score to a moderately degraded status are shallow groundwater depth, redox, and soil pH that exceeded the threshold value. Adaptive technology must accommodate local knowledge and can increase farmer income.

Article history:
Received 5 April 2025
Revised 9 May 2025
Accepted 16 May 2025

Keywords:
adaptive agriculture
drainage
land degradation
peat land

To cite this article: Bakri, Imanudin, M.S., Napoleon, A., Syazili, A., Prayinto, M.B., Hermawan, A., Khoiriyah. Z., Suwignyo, R.A., Choi, E. and Yang, H. 2025. Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir, South Sumatra, Indonesia. Journal of Degraded and Mining Lands Management 12(4):8117-8126, doi:10.15243/jdmlm.2025.124.8117.

Introduction

Indonesia has the most significant tropical peat area in the world, with an area of 13.43 million hectares spread across three large islands, namely Sumatra, 5.8 million hectares, Kalimantan, 4.5 million hectares, and Papua, 3 million hectares (Directorate of Forest and Land Fire Control, Directorate General of Climate Change Control, 2020). Peatlands in Indonesia face some serious challenges. Land conversion activities for agriculture and plantations, as well as fires that occur primarily during the dry season, have threatened the existence of these peatlands (Lestari et al., 2024). This conversion and fires reduce the area of peatlands and contribute to significant greenhouse emissions (Uda et al., 2019; Butterbach-Bahl et al., 2024). In 2015, forest and land fires in Indonesia covering 2.6 million ha were predicted to have released around 1.74 Gt CO_2-eq (Grosvenor et al., 2024; Syaufina et al., 2024). The problem of peatland fires that occur every year is that the conversion of peatlands to oil palm plantations results in a decrease in the function of peatlands (Imanudin et al., 2018; Haryanto et al., 2023). This has an impact on carbon emissions that contribute to global climate warming. In addition, inappropriate use of peatlands can also cause peatland degradation. About 43% of peatlands in Central Kalimantan have experienced degradation (Yuwati et al., 2021). Degraded peatlands have experienced a decrease in their function in supporting the ecosystem. On the other hand, 119.7 million tons of carbon emissions are produced from peatland fires in Sumatra and Kalimantan each year (Miettinen et al., 2017). From 2001 to 2015, land and forest fires reached 1.7 million ha (Ramdhan, 2018). A fire in 2019 burned 1.6 million hectares (CIFOR, 2019), and 1.1 million hectares in 2023 (Directorate of Forest and Land Fire Control, Directorate General of Climate Change Control, 2020).

According to data from the Ministry of Environment and Forestry in 2022, the condition of the peat ecosystem shows that 15.85 million hectares (65.45%) are in the status of slightly degraded, 3.08 million hectares (12.74%) are moderately degraded, 1.05 million hectares (4.35%) are severely degraded, and 206,935 million hectares (0.85%) are in the status of very severely degraded. Degraded land not only becomes unproductive but can also be a source of various disasters such as drought, floods, landslides, and fires (Bowen et al., 2024). These disasters have the potential to accelerate global warming.

The negative impacts of degraded land are felt not only in the surrounding area but can also spread far and affect more expansive areas (Imanudin et al., 2019; Jaya et al., 2024). Environmentally, these fires can result in biodiversity loss, land degradation, and large amounts of greenhouse gas emissions, all contributing to global climate change (Doelman et al., 2023).

Peatland degradation occurs due to human error, especially in land management. Incorrect water management is the leading cause of peatland degradation (Masganti et al., 2015; Sakuntaladewi et al., 2024). In addition, degradation is also caused by fires and mining activities. Degradation causes a decrease in peat multifunction, such as productivity and environmental carrying capacity (Loisel and Gallego-Sala, 2022). Peatland productivity is highly dependent on human management and actions. Several researchers reported that peatland productivity decreased due to the degradation of soil fertility, physical properties, and soil biology (Imanudin et al., 2018; Yuwati et al., 2021; Deng et al., 2025). The fertility of degraded peatlands is lower, as are their physical and biological properties. Therefore, to be used as agricultural land, it is also necessary to improve soil fertility in addition to improving water management (Wang et al., 2023; Jaya et al., 2024).

To assess the sustainability of peatland use, the government issued Government Regulation No. 71 of 2014, updated with Government Regulation No. 57 of 2016 concerning the protection and management of peat ecosystems. This regulation emphasizes the security of peat ecosystems, as stated in Article 23 paragraph 2 of Government Regulation No. 57 of 2016, which states that peat ecosystems with a protective function are declared degraded if there is artificial drainage. Paragraph 3 states that peat ecosystems with a cultivation function are considered degraded if groundwater is >0.4 m. In addition, the government also issued Government Regulation No. 150 of 2000 concerning the control of land degradation for biomass production. This regulation aims to ensure that land used for biomass production does not experience degradation that can reduce its productivity and sustainability.

In this regard, data and information on the distribution and characteristics of degraded land are critical to accurately understand and assess the level of degradation that has occurred, so that it can prevent further degradation to land and the environment. This information is also very useful in formulating sustainable management strategies to restore the function of peat ecosystems so that development planning does not cause a decline in the quality of land and environmental resources.

Materials and Methods

This research was conducted in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency, South Sumatra, Indonesia (Figure 1). Laboratory analysis was conducted in the Soil Fertility and Environmental Laboratory of the Palembang City Environmental and Land Service, which started from October 2024 until January 2025.

The research area is 10 ha on burnt peatland land, and a drainage network system has been developed. The sampling method was based on purposive sampling. Soil sample was taken based on peat depth level, namely shallow, medium, and profound depth classes. Soil samples were taken at two layers, namely 0-30 cm and 30-60 cm. Observations and soil sampling were conducted on burnt peatlands, with each land having as many as 3 location points with two replications.

Data analysis used a descriptive method, followed by an evaluation to determine the level of soil degradation with standard criteria for soil degradation in wetlands according to Government Regulation No. 150 of 2000. The variables observed in this study were: 1) peat maturity, 2) soil color, 3) pond height, 4) pyrite layer depth, 5) shallow groundwater depth, 6) redox, 7) pH, 8) electrical conductivity, and 9) microbial content. The observed subjects and measurement methods are presented in Table 1.

The data analysis for determining land degradation status begins with identification based on the main parameters above, followed by an evaluation. This evaluation aims to determine whether or not land is degraded according to the standard criteria for land degradation in wetlands based on Government Regulation No. 150 of 2000 (Table 2).

The standard assessment of land degradation was carried out by calculating the results of the relative frequency of degraded land from each variable and assigning a score. The total land degradation score was used to determine land degradation status (Table 3).

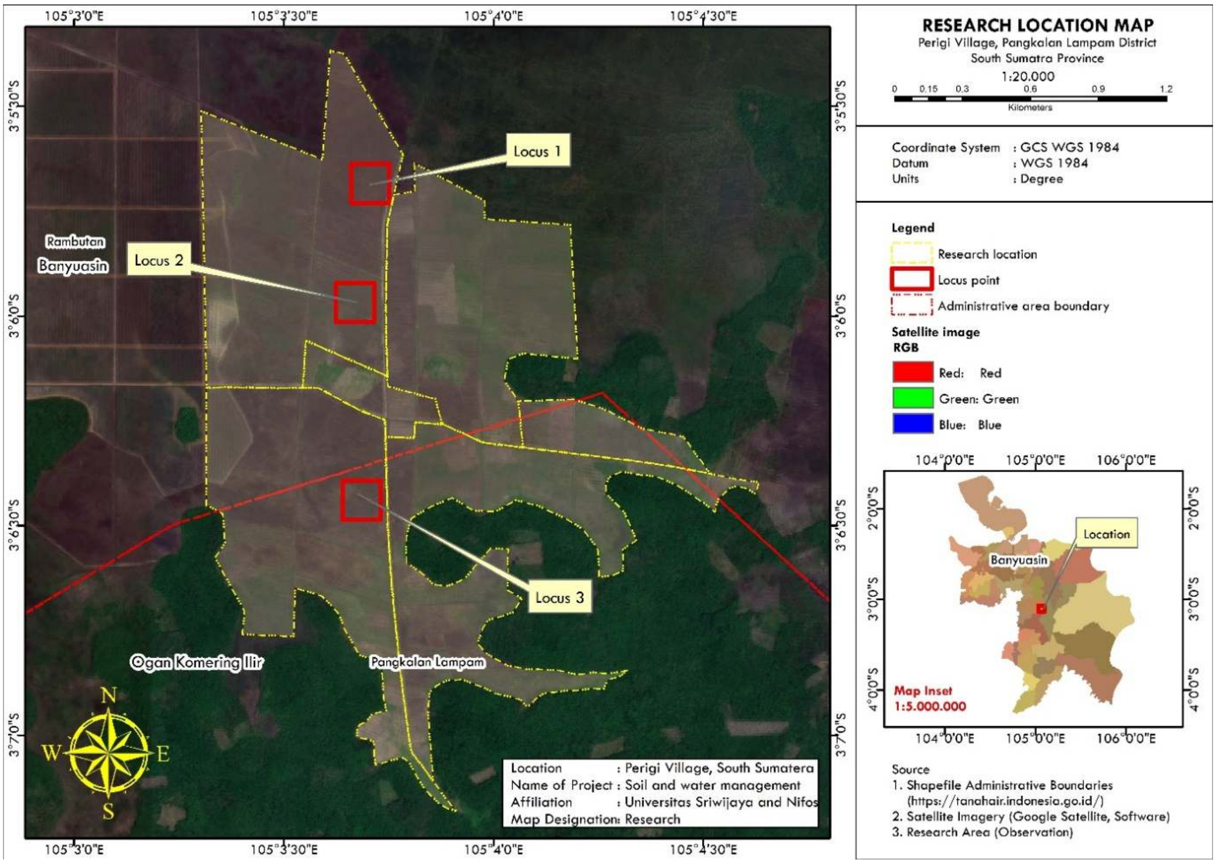

Figure 1. Sampling soil map in the study area of the Perigi peatland.

Table 1. The measurement methods of the parameters observed in this study.

Parameters	Measurement Methods
Depth of pyrite layer from the soil surface (cm)	Measured directly in the field, the distance of the pyrite layer from the ground surface was measured. The soil sample was given a hydrogen peroxide solution (H_2O_2). Foamy soil indicates a layer of pyrite (Maulidi et al., 2023).
Water table depth (cm)	Drilling was carried out, and the vertical distance between the ground surface and the water table was measured (Imanudin et al., 2024).
Redox for soil containing pyrite (mV)	Measured using a redox electrode connected to a multimeter or pH meter. Redox electrodes usually consist of a working electrode (usually platinum) and a reference electrode (usually Ag/AgCl or calomel). The potential difference between these two electrodes is measured as the redox potential (Boonman et al., 2024).
Redox for peat soil (mv)	Measured using a redox electrode connected to a multimeter or pH meter. Redox electrodes usually consist of a working electrode (usually platinum) and a reference electrode (usually Ag/AgCl or calomel). The potential difference between these two electrodes is measured as the redox potential (Boonman et al., 2024).
pH (H_2O) 1:2,5	pH measurements were carried out using a pH meter (Apori et al., 2023).
Electrical conductivity (dS/m)	Measured using a conductivity meter (EC meter) and probe (Nanda et al., 2025).
Microbial population (CFU/g soil)	Counting the number of colonies is the counting plate method. The plates selected and counted are petri plates containing between 30 and 300 colonies (Giyanto and Nurmansyah, 2021).

Table 2. Standard criteria for assessing peatland/wetland degradation.

Parameter	Critical Threshold*)
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5
Water table depth (cm)	>25
Redox for soil containing pyrite (mV)	>100
Redox for peat soil (mv)	>200
pH (H_2O) 1:2.5	<4.0; >7.0
Electrical conductivity (dS/m)	>4.0
Microbial population (CFU/g soil)	<10^2 CFU/g soil

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

Table 3. Land degradation score based on the relative frequency of degraded land.

RFDL (%)	Score	Accumulated Score Value	Land degradation level
0-10	0	0	Not degraded
11-25	1	1-8	Slightly degraded
26-50	2	9-14	Moderately degraded
51-75	3	15-20	Severely degraded
76-100	4	21-24	Very severely degraded

Notes: RFDL = Relative Frequency of Degraded Land (Krisnayanti et al., 2023, and Government Regulation of the Republic of Indonesia No. 150, 2000).

Results and Discussion

The physical characteristics of peat soil observed included waterlogging height, peat maturity, color, and groundwater depth (Table 4). The observed chemical properties of peat soil, including soil pH, carbon content, potassium, nitrogen, and phosphorus, are presented in Table 4. The level of peat maturity is divided into three types: fibric, hemic, and sapric. The soil color obtained on shallow, medium, and deep peat is 10YR 2/1 (black). Peat color is one of the indicators of peat maturity. In November, the height of the puddles is in the range of 11-28 cm from the ground surface. However, in September (dry season), the groundwater level drops 70-80 cm below the surface.

Astiani et al. (2018) reported that peatlands began to experience a decline in quality (there was an impact) when the groundwater level decreased from a depth of 0.5-1.0 m. This condition has caused an increase in CO_2 emissions. In the field, the decline in groundwater levels occurs more quickly before the dry season if no control of the water level in the constructed channels is carried out. In an effort to control water loss in the channel, it is recommended that a canal blockage be built. Research by Urzainki et al. (2023) proved that the construction of canal blocking is effective in raising groundwater levels and can reduce carbon emissions. It is estimated that the operation of canal blocks prevented the emission of 1.07 Mg ha^{-1} CO_2 in the dry year and 1.17 Mg ha^{-1} CO_2 in the wet year.

The analysis results of soil samples in Table 5 show that the soil N content ranged from 0.39% to 0.81% (low), and phosphorus content in each peatland is 42.19-51.76 ppm (very high). The potassium (exchangeable K) content in each peatland ranges from 0.13-0.19 me/100 g (very low). The cation exchange capacity (CEC) content in each peatland ranged from 20 to 22.5 me/100 g (moderate).

The depth of the pyrite layer from the peat soil surface for the three lands (Tables 6, 7, and 8) is below the threshold/critical, namely <25 cm. The average depth of pyrite in deep peatlands, medium peatlands, and shallow peatlands is 60 cm, 50 cm, and 0 cm, respectively (no visible pyrite layer). The most profound pyrite depth is in deep peatlands. This is related to the depth of the peat soil. The deeper the peat soil, the deeper the pyrite layer in the mineral soil layer. In flooded conditions (anaerobic), pyrite will not be dangerous. However, if it is drained excessively and pyrite is oxidized, sulfuric acid and iron compounds will be formed, which harm plants.

Table 4. Soil physical characteristics.

Sampling point	Soil depth (cm)	Peat maturity class	Soil Color	Water Table Depth (cm)	Puddle height (cm)
D3	0-30	Sapric	10 yr 2/1	-49	11
(deep peat)	30-60	Sapric	10 yr 2/1	-49	11
S2	0-30	Sapric	10 yr 2/1	-48	15
(medium peat)	30-60	Sapric	10 yr 2/1	-48	15
P1	0-30	Hemic	10 yr 2/1	-53	28
(shallow peat depth)	30-60	Hemic	10 yr 2/1	-53	28

Table 5. Soil chemical characteristics of peat soil in Perigi.

Sampling point	Soil depth (cm)	pH H_2O	pH KCl	Organic C (%)	Total N (%)	Available P (ppm)	Exch. K (me/100 g)	CEC me/100 g)
D3	0-30	3.52	3.18	17.80	0.81	42.19	0.13	22.50
(deep)	30-60	3.49	3.05	18.96	0.53	46.54	0.13	22.50
S2	0-30	3.44	3.31	17.02	0.56	50.31	0.19	22.50
(medium)	30-60	3.70	3.25	20.12	0.60	49.30	0.19	20.00
P1	0-30	3.50	3.26	18.18	0.39	51.76	0.19	20.00
(shallow)	30-60	3.27	3.20	20.12	0.78	45.96	0.19	20.00

Note: Exch. K = exchangeable K.

Table 6. Land degradation identification of shallow peatlands.

Parameter	Critical Threshold *)	Mean Value		Critical Status
		0-30 cm	30-60 cm	
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5	>120	>120	below the limit
Water table depth (cm)	>25 cm	53 (dry) -11 (puddle)	53 (dry) -11 (puddle)	exceed the limit
Redox for soil containing pyrite (mV)	>-100	-	-	below the limit
Redox for peat soil (mv)	>200	390	414	exceeds the limit
pH (H_2O) 1:2.5	<4.0 ; >7.0	3.5	3.5	exceeds the limit
Electrical conductivity (dS/m)	>4.0	0.397	0.312	below the limit
Microbial population (CFU/g of soil)	$<10^2$ CFU/g soil	2.6×10^5	3×0^4	below the limit

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

Table 7. Land degradation identification of medium peat layers.

Parameter	Critical Threshold *)	Mean Value		Critical Status
		0-30 cm	30-60 cm	
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5	50	50	below the limit
Water table depth (cm)	>25 cm	48 (dry) -15 (wet)	48 (dry) -15 (wet)	exceeds the limit
Redox for soil containing pyrite (mV)	>-100	399	414	exceeds the limit
Redox for peat soil (mv)	>200	-	-	below the limit
pH (H2O) 1:2.5	<4.0 ; >7.0	3.44	3.70	exceeds the limit
Electrical conductivity (dS/m)	>4.0	0.726	0.377	below the limit
Microbial population (CFU/g soil)	<102 CFU/g soil	2.1×104	1.4×104	below the limit

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

Table 8. Land degradation identification of deep peat soil layers

Parameter	Critical Threshold *)	Mean Value		Critical Status
		0-30 cm	30-60 cm	
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5	60	60	below the limit
Water table depth (cm)	>25 cm	46 (dry) -28 (wet)	46 (dry) -28 (wet)	exceeds the limit
Redox for soil containing pyrite (mV)	>-100	436	401	exceeds the limit
Redox for peat soil (mv)	>200	-	-	below the limit
pH (H_2O) 1:2.5	<4.0 ; >7.0	3.52	3.49	exceeds the limit
Electrical conductivity (dS/m)	>4.0	1.59	0.530	below the limit
Microbial population (CFU/g soil)	<102 CFU/g soil	3×104	1.3×104	below the limit

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

The shallow groundwater depth in deep peatlands, medium peatlands, and shallow peatlands is above the threshold/critical level of >25 cm, which are 46 cm, 48 cm, and 53 cm, respectively (Table 4). Low groundwater levels can indicate peat degradation. Changes in the peat ecosystem from natural peat to agricultural land have an impact on the decline in groundwater levels due to the process of logging, slashing, burning vegetation, making drainage, and land preparation.

The redox value in shallow peatlands, medium peatlands, and deep peatlands is above the threshold/critical, which is >200 mV. In shallow peatlands, the redox value is at 390 mV and 414 mV; in medium peatlands, it is at 399 mV and 414 mV, and in deep peatlands, it is at 436 mV and 401 mV. Based on the criteria for soil redox conditions, the four lands above are included in soils with a perfect oxidation atmosphere. Peatlands with an Eh value >200 mV can be oxidized or degraded. According to Imanudin et al. (2018), if peat is oxidized, the peat will become dry, and peat subsidence will occur. This condition causes the degradation of peat soil.

According to Koskinen et al. (2024), Eh will have an oxidative status if it has a value of >400 mV, while low reduction status occurs in soil with an Eh value between 400-200 mV, moderate reduction status ranges from 00-(-100) mV, and reduction status occurs in soil with an Eh value <-100 mV (Table 9). Based on this classification, deep peat land has an oxidation status, medium peat land with a depth of 0-30 cm has a low reduction status, a depth of 30-60 cm has an oxidation status, and shallow peat land with a depth of 0-30 cm has a low reduction status, a depth of 30-60 cm has an oxidation status. Thus, from the results above, it can be concluded that the three lands with a depth of 30-60 cm all have an oxidation status, or the soil has degraded.

Table 9. Status of soil redox

Redox Status	Eh range (mV)
Oxidation	>400
Low reduction	400-200
Moderate reduction	0-(-100)
Reduction	<-100

Source: Mattila (2024).

Soil pH for the three lands above the threshold/critical, namely pH <4.0; >7.0. The average soil pH on deep peatland, medium peatland, and shallow peatland with a depth of 0-30 cm and 30-60 cm is respectively 3.52, 3.49, 3.44, 3.70, and 3.5 cm. Based on the data above, the pH of peat soil is not suitable. This follows the characteristics of peat, which is known as less fertile soil, characterized by low pH (acidic). Peatlands are marginal lands for agriculture and plantations because of their low soil fertility, due to the characteristics of very acidic soil (pH <7), low macronutrient content (K, Ca, Mg, N, and P), and low micronutrient content (Cu, Zn, Mn, and B). With these conditions, it is necessary to organize and process peatlands properly so that they can be used as planting land (Manalu et al., 2024)

The EC value of peat soil for the three lands is below the threshold/critical, namely >4.0 dS/cm. EC value on shallow peat land with a depth of 0-30 cm and 30-60 cm is 0.39 and 0.31, respectively; on medium peat land with a depth of 0-30 cm and 30-60 cm is 0.72 and 0.37, respectively, and on deep peat land with a depth of 0-30 cm and 30-60 cm is 1.59 and 0.53 respectively. According to Imanudin et al (2024), in tidal wetlands, including peatlands, groundwater depth affects the content of relatively concentrated salt ions in groundwater. However, EC on the three lands is included in the good range.

The number of peat soil microbes for the three lands was below the threshold/critical, namely <10^2 CFU/g of soil. The number of microbes in shallow peatlands with depths of 0-30 cm and 30-60 cm were 2.6×10^5 CFU/g and 3×10^4 CFU/g, respectively, in medium peatlands with depths of 0-30 cm and 30-60 cm were 2.1×10^4 CFU/g and 1.4×10^4 CFU/g, and in deep peatlands with depths of 0-30 cm and 30-60 cm were 3×10^4 CFU/g and 1.3×10^4 CFU/g. The measurement results showed that the number of peat soil microbes in all lands was included in good status. The presence of total microbes can also describe the quality of the soil. The higher number of microbes indicates that the chemical and physical atmosphere in the soil is very supportive of soil microbial activity (Abdulkarim et al., 2017). Fauziah and Ibrahim (2020) reported that the peatland bacterial population was higher in the upper soil layer of 0-30 cm. Also, at the sapric maturity level, it has the highest population.

According to the Regulation of the Indonesian Minister of Environment No. 7 of 2006, if one of the critical parameters is over the thresholds, the land is considered degraded. Based on these provisions, it can be concluded that land degradation has occurred in the three peatlands in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency, with the number of degradation parameters in succession on shallow, medium, and deep peatlands having three parameters, namely shallow groundwater depth, redox, and pH which are the leading causes of land degradation (Tables 6, 7 and 8).

Parameters over the critical threshold and become limiting factors are shallow groundwater depth, redox, and soil pH. The low shallow groundwater depth in the three areas can indicate peat degradation. Peat ecosystems with cultivation functions are declared degraded if the groundwater depth exceeds 0.4 m. In addition, a decrease in the depth of the groundwater level due to the creation of too deep and wide drainage can cause the peat to dry out and increase the risk of peatland fires (Nusantara et al., 2023). The low redox value of the soil in the three peatlands, namely the Eh value (redox potential) of more than 200 mV, impacts the peat being oxidized and degraded. Oxidized peat will dry and cause the peat surface to decrease, damaging the peat soil. Dry peatlands are also very susceptible to fire. According to the research results of Hermanto and Wawan (2017), peatland fires can cause the soil redox value to decrease. Redox changes occur due to changes in elements and chemical reactions in the soil due to fires. In addition, the decrease in groundwater levels increases the DHL value, which can trigger poisoning of certain elements in plants (Harun et al., 2020).

Each land has a low pH value or is over the threshold for land degradation. Peat soil generally has a low pH, ranging from 3.0 to 5.0. This is due to the high content of organic acids, such as humic acid and fulvic acid, which decompose organic matter (Mulyani and Zahrah, 2022). However, the low pH of this soil affects the availability of nutrients for plants. In acidic peat soil, macronutrients such as calcium (Ca), nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) are not available in sufficient quantities. Conversely, micronutrients such as aluminum (Al), iron (Fe), and manganese (Mn) increase to reach toxic levels for plants. In peat soil, the cation exchange capacity (CEC) is high, but the percentage of bases is very low, making it difficult to absorb nutrients, especially bases. In addition, soil that is too acidic can inhibit the development of certain microorganisms essential for soil fertility. Therefore, providing ameliorative materials such as manure and biochar is vital in land restoration efforts.

Adaptation of mounding technology for industrial crops (Liberica coffee)

Crop adaptation model without changing the groundwater level is achieved using the mounding technique (soil mounding). The height of the mound must be above the high tide level. So far, the maximum water level is at 60-70 cm. From this water height, a safety factor of 30 cm can be added so that the mound of land (mounding) height is 100 cm from the ground surface. Figure 2 shows farmers making mounds for coffee cultivation. Liberica coffee plants are coffee plants for wetlands that have been successfully developed in Riau province. The introduction of coffee plants is intended to make farmers more interested in utilizing the land. Coffee is an industrial plant with a definite market and relatively stable prices. Martono et al. (2020) reported that Liberica coffee has been successfully cultivated in Keduburapat Village, Rangsang Pesisir District, Meranti Islands Regency, Riau. For a 1 ha of planting area, it can produce 1-5 t of coffee. In one coffee tree, it can reach 20 kg. Based on these conditions, conducting large-scale trials of Liberica coffee is very important.

Figure 2. Mounding technology for coffee cultivation on peat land of Perigi Indonesia.

The problem of soil acidity and low nutrients in peat soil requires coffee plants to be given amelioration materials and fertilization. Samson and Mahmudi (2024) reported that using dolomite lime and shrimp waste liquid fertilizer can increase the growth and yield of peanuts on peat soil. A 6 t/ha dose of dolomite lime and 400 mL/L of shrimp waste liquid fertilizer effectively increased root volume. The provision of liquid fertilizer from waste will also increase the growth of soil microbes. According to Ferry et al. (2021), giving lime in combination with manure and liquid fertilizer can increase the growth of Liberica coffee. The optimum dose is dolomite lime 2.5 t/ha, manure 10 t/ha, and liquid fertilizer 0.5 L/tree. Kartika et al (2022) added that applying 10 g of mycorrhizal biofertilizer per plant and 50% inorganic fertilizer is the best combination in increasing the growth of Liberica coffee on peatlands. The recommended 100% dose value is 20 g of Urea/plant, 25 g of SP36/plant, 15 g of KCl/plant, and 10 g of Kisserit/plant. The inorganic fertilizer dose can be reduced to 50% if combined with microbial liquid fertilizer. Fertilizer application is given twice a year, at the beginning and end of the rainy season. Planting an industrial crop such as Liberica coffee that has the potential to generate new income can encourage farmers to utilize the land more. This condition can automatically protect the land from fires. Jaya et al. (2024) reported that efforts to improve peatland degradation are being made by implementing agroforestry technology. The combination of annual and food crops greatly helps farmers to increase their income. Some plant combinations are "sengon" (*Paraserianthes falcataria*) plants with pineapple plants, or rubber with pineapple

Conclusion

Based on the results of observations, field measurements, and laboratory analysis, the three lands experienced moderate degradation status. The land degradation that occurred was caused by natural factors, namely low fertility conditions and human activity factors that caused a decrease in land quality. The parameters that limit and contribute to the land degradation score to a moderate degradation status are shallow groundwater depth, redox, and soil pH that exceed the predetermined threshold value.

Acknowledgments

This study was funded by collaborative research between the National Institute of Forest Science (NIFoS), the Republic of Korea, and Sriwijaya University, Indonesia. The authors would like to acknowledge Deasy M. Irfan, Sumantri, and Agus Prihanto for their field assistance during the field survey.

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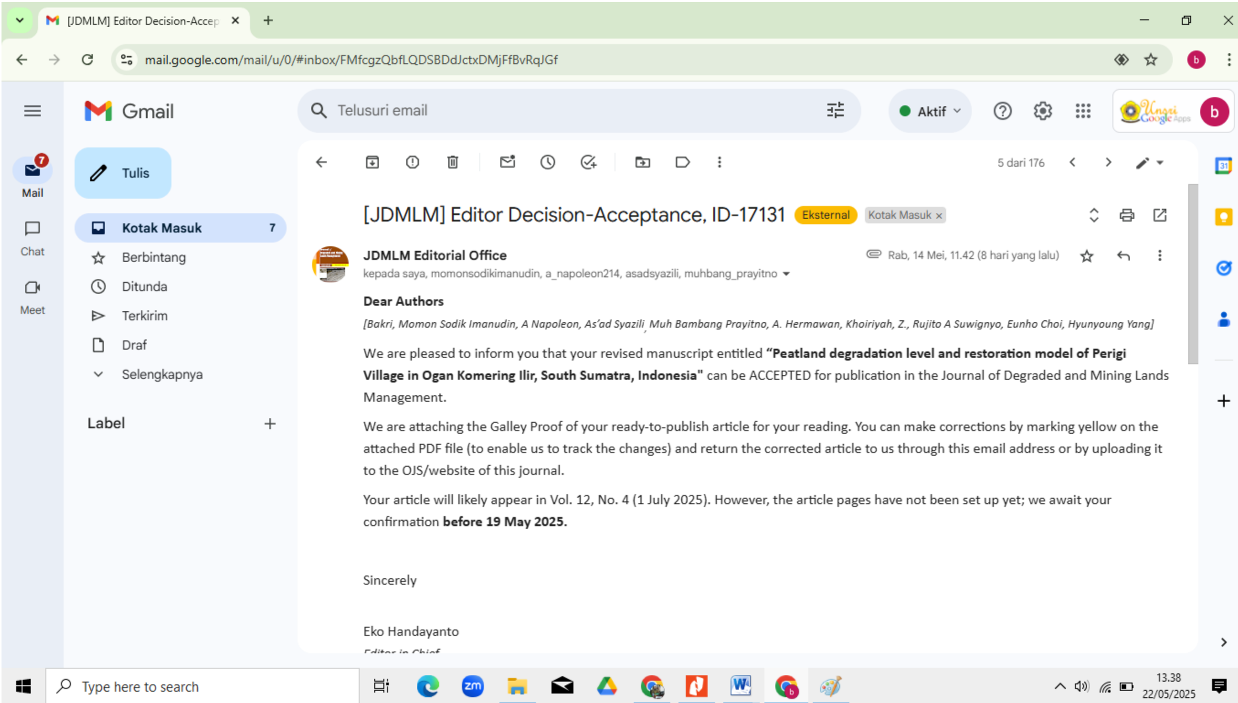
Editor Decision



[JDMLM] Editor Decision-Acceptance, ID-17131

JDMLM Editorial Office

kepada saya, momonsodikimanudin, a_napoleon214, asadsyazili, muhbang_prayitno

Rab, 14 Mei, 11.42 (8 hari yang lalu)

Dear Authors

[Bakri, Momon Sodik Imanudin, A Napoleon, As'ad Syazili, Muh Bambang Prayitno, A. Hermawan, Khoiriyah, Z., Rujito A Suwignyo, Eunho Choi, Hyunyoung Yang]

We are pleased to inform you that your revised manuscript entitled **"Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir, South Sumatra, Indonesia"** can be ACCEPTED for publication in the Journal of Degraded and Mining Lands Management.

We are attaching the Galley Proof of your ready-to-publish article for your reading. You can make corrections by marking yellow on the attached PDF file (to enable us to track the changes) and return the corrected article to us through this email address or by uploading it to the OJS/website of this journal.

Your article will likely appear in Vol. 12, No. 4 (1 July 2025). However, the article pages have not been set up yet; we await your confirmation **before 19 May 2025.**

Sincerely

Eko Handayanto

JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
p-ISSN: 2339-076X, e-ISSN: 2502-2458, http://www.jdmlm.ub.ac.id
Research Centre for the Management of Degraded and Mining Lands
and Soil Department, Faculty of Agriculture, Brawijaya University
Jl. Veteran, Malang 65145, Indonesia, Ph+62341553623; email: editor.jdmlm@ub.ac.id

Date: 16 May 2025

LETTER OF ACCEPTANCE

Article No: 17131

To,

Bakri[1], Momon Sodik Imanudin[1], A Napoleon[1], As'ad Syazili[1], Muh Bambang Prayitno[1], A. Hermawan[1], Khoiriyah, Z.[1], Rujito A Suwignyo[2], Eunho Choi[3], Hyunyoung Yang[3]

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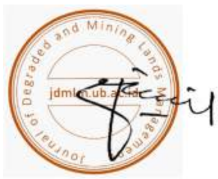
[3] National Institute of Forest Science, Global Forestry Division, Future Forest Strategy Department, Seoul 02455, Republic of Korea

Dear Authors,

We are pleased to inform you that your article entitled **"Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir, South Sumatra, Indonesia"** has been **accepted** for publication in the Journal of Degraded and Mining Lands Management (p-ISSN: 2339-076X, e-ISSN: 2502-2458). The article will likely come in Vol. 12. No. 4 (1 July 2025).

Sincerely yours



Prof Eko Handayanto PhD
Editor in Chief

Scopus coverage years: from 2019 to 2025, Scopus CiteScore 2023 = 1.5,
SNIP 2023 = 0.393, SJR 2024 = 0.277, H-index = 11

Pembayaran

JDMLM Editorial Office

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Sab, 17 Mei, 18.33 (5 hari yang lalu)

Dear Authors

We would like to inform you that the APC payment of **Rp. 3,565,000** has been received by the JDMLM Editorial Office. The APC is used to maintain CrossRef memberships and DOI, DOAJ-dnts, reviewer incentives, and editorial staff allowances. The receipt of payment is attached.

The status of your article is now IN PRESS. Please visit https://jdmlm.ub.ac.id/index.php/jdmlm/issue/view/52; the DOI will not be active until 1 July 2025.

Thank you for supporting Journal of Degraded and Mining Lands Management.

Sincerely yours

Ach Riyanto

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No	DESCRIPTION	PRICE	TOTAL
1	Article Processing Charge for an article entitled **"Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir, South Sumatra, Indonesia"** Payment date: 17 May 2025	3,565,000 IDR	3,565,000
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Thank You

JDMLM Editorial Office

Prof Eko Handayanto PhD

JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 12, Number 4 (July 2025):8117-8126, doi:10.15243/jdmlm.2025.124.8117
ISSN: 2339-076X (p); 2502-2458 (e), www.jdmlm.ub.ac.id

Research Article

Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir, South Sumatra, Indonesia

Bakri[1*], Momon Sodik Imanudin[1], A Napoleon[1], As'ad Syazili[1], Muh Bambang Prayitno[1], A. Hermawan[1], Khoiriyah, Z.[1], Rujito A Suwignyo[2], Eunho Choi[3], Hyunyoung Yang[3]

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Article history:
Received 5 April 2025
Revised 9 May 2025
Accepted 16 May 2025

Keywords:
adaptive agriculture
drainage
land degradation
peat land

Abstract

The use of peatlands for plantations and industrial tree plantations is increasingly widespread and causes land degradation due to excessive drainage. Meanwhile, adaptive agricultural efforts are not yet appropriate for maintaining the peatland environment. This study aimed to assess peatland degradation in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency. Data obtained were analyzed using a descriptive method, followed by an evaluation of the determination of the level of land degradation with standard criteria for land degradation in wetlands based on the Regulation of the Indonesian Minister of Environment No. 20, 2008. The observations, field measurements, and laboratory analysis showed that the three lands experienced moderate degradation. The parameters that limit and contribute to the land degradation score to a moderately degraded status are shallow groundwater depth, redox, and soil pH that exceeded the threshold value. Adaptive technology must accommodate local knowledge and can increase farmer income.

To cite this article: Bakri, Imanudin, M.S., Napoleon, A., Syazili, A., Prayinto, M.B., Hermawan, A., Khoiriyah. Z., Suwignyo, R.A., Choi, E. and Yang, H. 2025. Peatland degradation level and restoration model of Perigi Village in Ogan Komering Ilir, South Sumatra, Indonesia. Journal of Degraded and Mining Lands Management 12(4):8117-8126, doi:10.15243/jdmlm.2025.124.8117.

Introduction

Indonesia has the most significant tropical peat area in the world, with an area of 13.43 million hectares spread across three large islands, namely Sumatra, 5.8 million hectares, Kalimantan, 4.5 million hectares, and Papua, 3 million hectares (Directorate of Forest and Land Fire Control, Directorate General of Climate Change Control, 2020). Peatlands in Indonesia face some serious challenges. Land conversion activities for agriculture and plantations, as well as fires that occur primarily during the dry season, have threatened the existence of these peatlands (Lestari et al., 2024). This conversion and fires reduce the area of peatlands and contribute to significant greenhouse emissions (Uda et al., 2019; Butterbach-Bahl et al., 2024). In 2015, forest and land fires in Indonesia covering 2.6 million ha were predicted to have released around 1.74 Gt CO_2-eq (Grosvenor et al., 2024; Syaufina et al., 2024). The problem of peatland fires that occur every year is that the conversion of peatlands to oil palm plantations results in a decrease in the function of peatlands (Imanudin et al., 2018; Haryanto et al., 2023). This has an impact on carbon emissions that contribute to global climate warming. In addition, inappropriate use of peatlands can also cause peatland degradation. About 43% of peatlands in Central Kalimantan have experienced degradation (Yuwati et al., 2021). Degraded peatlands have experienced a decrease in their function in supporting the ecosystem. On the other hand, 119.7 million tons of carbon emissions are produced from peatland fires in Sumatra and Kalimantan each year (Miettinen et al., 2017). From 2001 to 2015, land and forest fires reached 1.7 million hectares (Ramdhan, 2018). A fire in 2019 burned 1.6 million hectares (CIFOR, 2019), and 1.1 million hectares in 2023 (Directorate of Forest and Land Fire Control, Directorate General of Climate Change Control, 2020).

According to data from the Ministry of Environment and Forestry in 2022, the condition of the peat ecosystem shows that 15.85 million hectares (65.45%) are in the status of slightly degraded, 3.08 million hectares (12.74%) are moderately degraded, 1.05 million hectares (4.35%) are severely degraded, and 206,935 million hectares (0.85%) are in the status of very severely degraded. Degraded land not only becomes unproductive but can also be a source of various disasters such as drought, floods, landslides, and fires (Bowen et al., 2024). These disasters have the potential to accelerate global warming.

The negative impacts of degraded land are felt not only in the surrounding area but can also spread far and affect more expansive areas (Imanudin et al., 2019; Jaya et al., 2024). Environmentally, these fires can result in biodiversity loss, land degradation, and large amounts of greenhouse gas emissions, all contributing to global climate change (Doelman et al., 2023).

Peatland degradation occurs due to human error, especially in land management. Incorrect water management is the leading cause of peatland degradation (Masganti et al., 2015; Sakuntaladewi et al., 2024). In addition, degradation is also caused by fires and mining activities. Degradation causes a decrease in peat multifunction, such as productivity and environmental carrying capacity (Loisel and Gallego-Sala, 2022). Peatland productivity is highly dependent on human management and actions. Several researchers reported that peatland productivity decreased due to the degradation of soil fertility, physical properties, and soil biology (Imanudin et al., 2018; Yuwati et al., 2021; Deng et al., 2025). The fertility of degraded peatlands is lower, as are their physical and biological properties. Therefore, to be used as agricultural land, it is also necessary to improve soil fertility in addition to improving water management (Wang et al., 2023; Jaya et al., 2024).

To assess the sustainability of peatland use, the government issued Government Regulation No. 71 of 2014, updated with Government Regulation No. 57 of 2016 concerning the protection and management of peat ecosystems. This regulation emphasizes the security of peat ecosystems, as stated in Article 23 paragraph 2 of Government Regulation No. 57 of 2016, which states that peat ecosystems with a protective function are declared degraded if there is artificial drainage. Paragraph 3 states that peat ecosystems with a cultivation function are considered degraded if groundwater is >0.4 m. In addition, the government also issued Government Regulation No. 150 of 2000 concerning the control of land degradation for biomass production. This regulation aims to ensure that land used for biomass production does not experience degradation that can reduce its productivity and sustainability.

In this regard, data and information on the distribution and characteristics of degraded land are critical to accurately understand and assess the level of degradation that has occurred, so that it can prevent further degradation to land and the environment. This information is also very useful in formulating sustainable management strategies to restore the function of peat ecosystems so that development planning does not cause a decline in the quality of land and environmental resources.

Materials and Methods

This research was conducted in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency, South Sumatra, Indonesia (Figure 1). Laboratory analysis was conducted in the Soil Fertility and Environmental Laboratory of the Palembang City Environmental and Land Service, which started from October 2024 until January 2025.

The research area is 10 ha on burnt peatland land, and a drainage network system has been developed. The sampling method was based on purposive sampling. Soil sample was taken based on peat depth level, namely shallow, medium, and profound depth classes. Soil samples were taken at two layers, namely 0-30 cm and 30-60 cm. Observations and soil sampling were conducted on burnt peatlands, with each land having as many as 3 location points with two replications.

Data analysis used a descriptive method, followed by an evaluation to determine the level of soil degradation with standard criteria for soil degradation in wetlands according to Government Regulation No. 150 of 2000. The variables observed in this study were: 1) peat maturity, 2) soil color, 3) pond height, 4) pyrite layer depth, 5) shallow groundwater depth, 6) redox, 7) pH, 8) electrical conductivity, and 9) microbial content. The observed subjects and measurement methods are presented in Table 1.

The data analysis for determining land degradation status begins with identification based on the main parameters above, followed by an evaluation. This evaluation aims to determine whether or not land is degraded according to the standard criteria for land degradation in wetlands based on Government Regulation No. 150 of 2000 (Table 2).

The standard assessment of land degradation was carried out by calculating the results of the relative frequency of degraded land from each variable and assigning a score. The total land degradation score was used to determine land degradation status (Table 3).

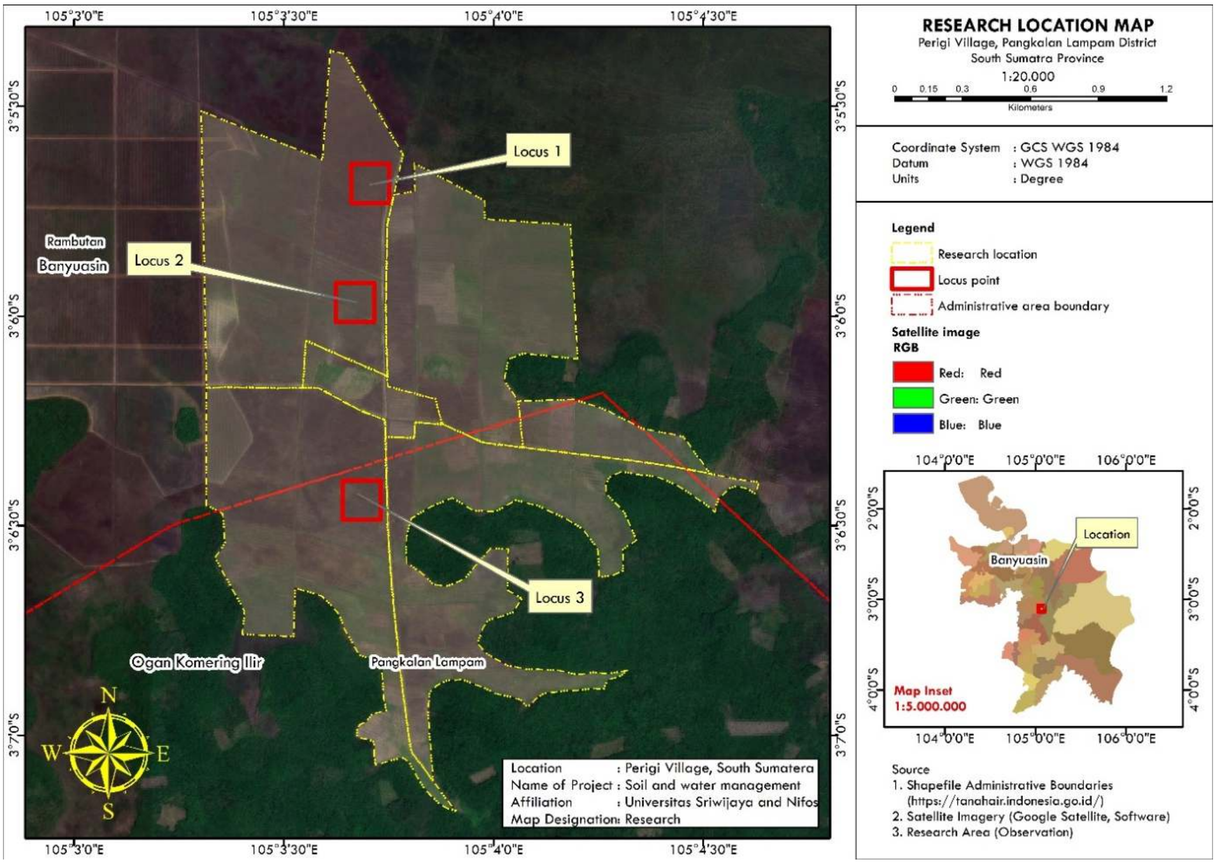

Figure 1. Sampling soil map in the study area of the Perigi peatland.

Table 1. The measurement methods of the parameters observed in this study.

Parameters	Measurement Methods
Depth of pyrite layer from the soil surface (cm)	Measured directly in the field, the distance of the pyrite layer from the ground surface was measured. The soil sample was given a hydrogen peroxide solution (H_2O_2). Foamy soil indicates a layer of pyrite (Maulidi et al., 2023).
Water table depth (cm)	Drilling was carried out, and the vertical distance between the ground surface and the water table was measured (Imanudin et al., 2024).
Redox for soil containing pyrite (mV)	Measured using a redox electrode connected to a multimeter or pH meter. Redox electrodes usually consist of a working electrode (usually platinum) and a reference electrode (usually Ag/AgCl or calomel). The potential difference between these two electrodes is measured as the redox potential (Boonman et al., 2024).
Redox for peat soil (mv)	Measured using a redox electrode connected to a multimeter or pH meter. Redox electrodes usually consist of a working electrode (usually platinum) and a reference electrode (usually Ag/AgCl or calomel). The potential difference between these two electrodes is measured as the redox potential (Boonman et al., 2024).
pH (H_2O) 1:2,5	pH measurements were carried out using a pH meter (Apori et al., 2023).
Electrical conductivity (dS/m)	Measured using a conductivity meter (EC meter) and probe (Nanda et al., 2025).
Microbial population (CFU/g soil)	Counting the number of colonies is the counting plate method. The plates selected and counted are petri plates containing between 30 and 300 colonies (Giyanto and Nurmansyah, 2021).

Table 2. Standard criteria for assessing peatland/wetland degradation.

Parameter	Critical Threshold*)
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5
Water table depth (cm)	>25
Redox for soil containing pyrite (mV)	>100
Redox for peat soil (mv)	>200
pH (H_2O) 1:2.5	<4.0; >7.0
Electrical conductivity (dS/m)	>4.0
Microbial population (CFU/g soil)	$<10^2$ CFU/g soil

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

Table 3. Land degradation score based on the relative frequency of degraded land.

RFDL (%)	Score	Accumulated Score Value	Land degradation level
0-10	0	0	Not degraded
11-25	1	1-8	Slightly degraded
26-50	2	9-14	Moderately degraded
51-75	3	15-20	Severely degraded
76-100	4	21-24	Very severely degraded

Notes: RFDL = Relative Frequency of Degraded Land (Krisnayanti et al., 2023, and Government Regulation of the Republic of Indonesia No. 150, 2000).

Results and Discussion

The physical characteristics of peat soil observed included waterlogging height, peat maturity, color, and groundwater depth (Table 4). The observed chemical properties of peat soil, including soil pH, carbon content, potassium, nitrogen, and phosphorus, are presented in Table 4. The level of peat maturity is divided into three types: fibric, hemic, and sapric. The soil color obtained on shallow, medium, and deep peat is 10YR 2/1 (black). Peat color is one of the indicators of peat maturity. In November, the height of the puddles is in the range of 11-28 cm from the ground surface. However, in September (dry season), the groundwater level drops 70-80 cm below the surface.

Astiani et al. (2018) reported that peatlands began to experience a decline in quality (there was an impact) when the groundwater level decreased from a depth of 0.5-1.0 m. This condition has caused an increase in CO_2 emissions. In the field, the decline in groundwater levels occurs more quickly before the dry season if no control of the water level in the constructed channels is carried out. In an effort to control water loss in the channel, it is recommended that a canal blockage be built. Research by Urzainki et al. (2023) proved that the construction of canal blocking is effective in raising groundwater levels and can reduce carbon emissions. It is estimated that the operation of canal blocks prevented the emission of 1.07 Mg ha^{-1} CO_2 in the dry year and 1.17 Mg ha^{-1} CO_2 in the wet year.

The analysis results of soil samples in Table 5 show that the soil N content ranged from 0.39% to 0.81% (low), and phosphorus content in each peatland is 42.19-51.76 ppm (very high). The potassium (exchangeable K) content in each peatland ranges from 0.13-0.19 me/100 g (very low). The cation exchange capacity (CEC) content in each peatland ranged from 20 to 22.5 me/100 g (moderate).

The depth of the pyrite layer from the peat soil surface for the three lands (Tables 6, 7, and 8) is below the threshold/critical, namely <25 cm. The average depth of pyrite in deep peatlands, medium peatlands, and shallow peatlands is 60 cm, 50 cm, and 0 cm, respectively (no visible pyrite layer). The most profound pyrite depth is in deep peatlands. This is related to the depth of the peat soil. The deeper the peat soil, the deeper the pyrite layer in the mineral soil layer. In flooded conditions (anaerobic), pyrite will not be dangerous. However, if it is drained excessively and pyrite is oxidized, sulfuric acid and iron compounds will be formed, which harm plants.

Table 4. Soil physical characteristics.

Sampling point	Soil depth (cm)	Peat maturity class	Soil Color	Water Table Depth (cm)	Puddle height (cm)
D3	0-30	Sapric	10 yr 2/1	-49	11
(deep peat)	30-60	Sapric	10 yr 2/1	-49	11
S2	0-30	Sapric	10 yr 2/1	-48	15
(medium peat)	30-60	Sapric	10 yr 2/1	-48	15
P1	0-30	Hemic	10 yr 2/1	-53	28
(shallow peat depth)	30-60	Hemic	10 yr 2/1	-53	28

Table 5. Soil chemical characteristics of peat soil in Perigi.

Sampling point	Soil depth (cm)	pH H_2O	pH KCl	Organic C (%)	Total N (%)	Available P (ppm)	Exch. K (me/100 g)	CEC me/100 g)
D3	0-30	3.52	3.18	17.80	0.81	42.19	0.13	22.50
(deep)	30-60	3.49	3.05	18.96	0.53	46.54	0.13	22.50
S2	0-30	3.44	3.31	17.02	0.56	50.31	0.19	22.50
(medium)	30-60	3.70	3.25	20.12	0.60	49.30	0.19	20.00
P1	0-30	3.50	3.26	18.18	0.39	51.76	0.19	20.00
(shallow)	30-60	3.27	3.20	20.12	0.78	45.96	0.19	20.00

Note: Exch. K = exchangeable K.

Table 6. Land degradation identification of shallow peatlands.

Parameter	Critical Threshold *)	Mean Value		Critical Status
		0-30 cm	**30-60 cm**	
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5	>120	>120	below the limit
Water table depth (cm)	>25 cm	53 (dry) -11 (puddle)	53 (dry) -11 (puddle)	exceed the limit
Redox for soil containing pyrite (mV)	>-100	-	-	below the limit
Redox for peat soil (mv)	>200	390	414	exceeds the limit
pH (H_2O) 1:2.5	<4.0 ; >7.0	3.5	3.5	exceeds the limit
Electrical conductivity (dS/m)	>4.0	0.397	0.312	below the limit
Microbial population (CFU/g of soil)	$<10^2$ CFU/g soil	2.6×10^5	3×0^4	below the limit

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

Table 7. Land degradation identification of medium peat layers.

Parameter	Critical Threshold *)	Mean Value		Critical Status
		0-30 cm	30-60 cm	
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5	50	50	below the limit
Water table depth (cm)	>25 cm	48 (dry) -15 (wet)	48 (dry) -15 (wet)	exceeds the limit
Redox for soil containing pyrite (mV)	>-100	399	414	exceeds the limit
Redox for peat soil (mv)	>200	-	-	below the limit
pH (H2O) 1:2.5	<4.0 ; >7.0	3.44	3.70	exceeds the limit
Electrical conductivity (dS/m)	>4.0	0.726	0.377	below the limit
Microbial population (CFU/g soil)	<102 CFU/g soil	2.1×104	1.4×104	below the limit

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

Table 8. Land degradation identification of deep peat soil layers

Parameter	Critical Threshold *)	Mean Value		Critical Status
		0-30 cm	**30-60 cm**	
Depth of pyrite layer from the soil surface (cm)	<25 cm with pH <2.5	60	60	below the limit
Water table depth (cm)	>25 cm	46 (dry) -28 (wet)	46 (dry) -28 (wet)	exceeds the limit
Redox for soil containing pyrite (mV)	>-100	436	401	exceeds the limit
Redox for peat soil (mv)	>200	-	-	below the limit
pH (H_2O) 1:2.5	<4.0 ; >7.0	3.52	3.49	exceeds the limit
Electrical conductivity (dS/m)	>4.0	1.59	0.530	below the limit
Microbial population (CFU/g soil)	<102 CFU/g soil	3×104	1.3×104	below the limit

*) Regulation of the Indonesian Minister of Environment No. 20 (2008).

The shallow groundwater depth in deep peatlands, medium peatlands, and shallow peatlands is above the threshold/critical level of >25 cm, which are 46 cm, 48 cm, and 53 cm, respectively (Table 4). Low groundwater levels can indicate peat degradation. Changes in the peat ecosystem from natural peat to agricultural land have an impact on the decline in groundwater levels due to the process of logging, slashing, burning vegetation, making drainage, and land preparation.

The redox value in shallow peatlands, medium peatlands, and deep peatlands is above the threshold/critical, which is >200 mV. In shallow peatlands, the redox value is at 390 mV and 414 mV; in medium peatlands, it is at 399 mV and 414 mV, and in deep peatlands, it is at 436 mV and 401 mV. Based on the criteria for soil redox conditions, the four lands above are included in soils with a perfect oxidation atmosphere. Peatlands with an Eh value >200 mV can be oxidized or degraded. According to Imanudin et al. (2018), if peat is oxidized, the peat will become dry, and peat subsidence will occur. This condition causes the degradation of peat soil.

According to Koskinen et al. (2024), Eh will have an oxidative status if it has a value of >400 mV, while low reduction status occurs in soil with an Eh value between 400-200 mV, moderate reduction status ranges from 00-(-100) mV, and reduction status occurs in soil with an Eh value <-100 mV (Table 9). Based on this classification, deep peat land has an oxidation status, medium peat land with a depth of 0-30 cm has a low reduction status, a depth of 30-60 cm has an oxidation status, and shallow peat land with a depth of 0-30 cm has a low reduction status, a depth of 30-60 cm has an oxidation status. Thus, from the results above, it can be concluded that the three lands with a depth of 30-60 cm all have an oxidation status, or the soil has degraded.

Table 9. Status of soil redox

Redox Status	Eh range (mV)
Oxidation	>400
Low reduction	400-200
Moderate reduction	0-(-100)
Reduction	<-100

Source: Mattila (2024).

Soil pH for the three lands above the threshold/critical, namely pH <4.0; >7.0. The average soil pH on deep peatland, medium peatland, and shallow peatland with a depth of 0-30 cm and 30-60 cm is respectively 3.52, 3.49, 3.44, 3.70, and 3.5 cm. Based on the data above, the pH of peat soil is not suitable. This follows the characteristics of peat, which is known as less fertile soil, characterized by low pH (acidic). Peatlands are marginal lands for agriculture and plantations because of their low soil fertility, due to the characteristics of very acidic soil (pH <7), low macronutrient content (K, Ca, Mg, N, and P), and low micronutrient content (Cu, Zn, Mn, and B). With these conditions, it is necessary to organize and process peatlands properly so that they can be used as planting land (Manalu et al., 2024)

The EC value of peat soil for the three lands is below the threshold/critical, namely >4.0 dS/cm. EC value on shallow peat land with a depth of 0-30 cm and 30-60 cm is 0.39 and 0.31, respectively; on medium peat land with a depth of 0-30 cm and 30-60 cm is 0.72 and 0.37, respectively, and on deep peat land with a depth of 0-30 cm and 30-60 cm is 1.59 and 0.53 respectively. According to Imanudin et al (2024), in tidal wetlands, including peatlands, groundwater depth affects the content of relatively concentrated salt ions in groundwater. However, EC on the three lands is included in the good range.

The number of peat soil microbes for the three lands was below the threshold/critical, namely <10^2 CFU/g of soil. The number of microbes in shallow peatlands with depths of 0-30 cm and 30-60 cm were 2.6×10^5 CFU/g and 3×10^4 CFU/g, respectively, in medium peatlands with depths of 0-30 cm and 30-60 cm were 2.1×10^4 CFU/g and 1.4×10^4 CFU/g, and in deep peatlands with depths of 0-30 cm and 30-60 cm were 3×10^4 CFU/g and 1.3×10^4 CFU/g. The measurement results showed that the number of peat soil microbes in all lands was included in good status. The presence of total microbes can also describe the quality of the soil. The higher number of microbes indicates that the chemical and physical atmosphere in the soil is very supportive of soil microbial activity (Abdulkarim et al., 2017). Fauziah and Ibrahim (2020) reported that the peatland bacterial population was higher in the upper soil layer of 0-30 cm. Also, at the sapric maturity level, it has the highest population.

According to the Regulation of the Indonesian Minister of Environment No. 7 of 2006, if one of the critical parameters is over the thresholds, the land is considered degraded. Based on these provisions, it can be concluded that land degradation has occurred in the three peatlands in Perigi Village, Pangkalan Lampam District, Ogan Komering Ilir Regency, with the number of degradation parameters in succession on shallow, medium, and deep peatlands having three parameters, namely shallow groundwater depth, redox, and pH which are the leading causes of land degradation (Tables 6, 7 and 8).

Parameters over the critical threshold and become limiting factors are shallow groundwater depth, redox, and soil pH. The low shallow groundwater depth in the three areas can indicate peat degradation. Peat ecosystems with cultivation functions are declared degraded if the groundwater depth exceeds 0.4 m. In addition, a decrease in the depth of the groundwater level due to the creation of too deep and wide drainage can cause the peat to dry out and increase the risk of peatland fires (Nusantara et al., 2023). The low redox value of the soil in the three peatlands, namely the Eh value (redox potential) of more than 200 mV, impacts the peat being oxidized and degraded. Oxidized peat will dry and cause the peat surface to decrease, damaging the peat soil. Dry peatlands are also very susceptible to fire. According to the research results of Hermanto and Wawan (2017), peatland fires can cause the soil redox value to decrease. Redox changes occur due to changes in elements and chemical reactions in the soil due to fires. In addition, the decrease in groundwater levels increases the DHL value, which can trigger poisoning of certain elements in plants (Harun et al., 2020).

Each land has a low pH value or is over the threshold for land degradation. Peat soil generally has a low pH, ranging from 3.0 to 5.0. This is due to the high content of organic acids, such as humic acid and fulvic acid, which decompose organic matter (Mulyani and Zahrah, 2022). However, the low pH of this soil affects the availability of nutrients for plants. In acidic peat soil, macronutrients such as calcium (Ca), nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) are not available in sufficient quantities. Conversely, micronutrients such as aluminum (Al), iron (Fe), and manganese (Mn) increase to reach toxic levels for plants. In peat soil, the cation exchange capacity (CEC) is high, but the percentage of bases is very low, making it difficult to absorb nutrients, especially bases. In addition, soil that is too acidic can inhibit the development of certain microorganisms essential for soil fertility. Therefore, providing ameliorative materials such as manure and biochar is vital in land restoration efforts.

Adaptation of mounding technology for industrial crops (Liberica coffee)

Crop adaptation model without changing the groundwater level is achieved using the mounding technique (soil mounding). The height of the mound must be above the high tide level. So far, the maximum water level is at 60-70 cm. From this water height, a safety factor of 30 cm can be added so that the mound of land (mounding) height is 100 cm from the ground surface. Figure 2 shows farmers making mounds for coffee cultivation. Liberica coffee plants are coffee plants for wetlands that have been successfully developed in Riau province. The introduction of coffee plants is intended to make farmers more interested in utilizing the land. Coffee is an industrial plant with a definite market and relatively stable prices. Martono et al. (2020) reported that Liberica coffee has been successfully cultivated in Keduburapat Village, Rangsang Pesisir District, Meranti Islands Regency, Riau. For a 1 ha of planting area, it can produce 1-5 t of coffee. In one coffee tree, it can reach 20 kg. Based on these conditions, conducting large-scale trials of Liberica coffee is very important.

Figure 2. Mounding technology for coffee cultivation on peat land of Perigi Indonesia.

The problem of soil acidity and low nutrients in peat soil requires coffee plants to be given amelioration materials and fertilization. Samson and Mahmudi (2024) reported that using dolomite lime and shrimp waste liquid fertilizer can increase the growth and yield of peanuts on peat soil. A 6 t/ha dose of dolomite lime and 400 mL/L of shrimp waste liquid fertilizer effectively increased root volume. The provision of liquid fertilizer from waste will also increase the growth of soil microbes. According to Ferry et al. (2021), giving lime in combination with manure and liquid fertilizer can increase the growth of Liberica coffee. The optimum dose is dolomite lime 2.5 t/ha, manure 10 t/ha, and liquid fertilizer 0.5 L/tree. Kartika et al (2022) added that applying 10 g of mycorrhizal biofertilizer per plant and 50% inorganic fertilizer is the best combination in increasing the growth of Liberica coffee on peatlands. The recommended 100% dose value is 20 g of Urea/plant, 25 g of SP36/plant, 15 g of KCl/plant, and 10 g of Kisserit/plant. The inorganic fertilizer dose can be reduced to 50% if combined with microbial liquid fertilizer. Fertilizer application is given twice a year, at the beginning and end of the rainy season. Planting an industrial crop such as Liberica coffee that has the potential to generate new income can encourage farmers to utilize the land more. This condition can automatically protect the land from fires. Jaya et al. (2024) reported that efforts to improve peatland degradation are being made by implementing agroforestry technology. The combination of annual and food crops greatly helps farmers to increase their income. Some plant combinations are "sengon" (*Paraserianthes falcataria*) plants with pineapple plants, or rubber with pineapple

Conclusion

Based on the results of observations, field measurements, and laboratory analysis, the three lands experienced moderate degradation status. The land degradation that occurred was caused by natural factors, namely low fertility conditions and human activity factors that caused a decrease in land quality. The parameters that limit and contribute to the land degradation score to a moderate degradation status are shallow groundwater depth, redox, and soil pH that exceed the predetermined threshold value.

Acknowledgments

This study was funded by collaborative research between the National Institute of Forest Science (NIFoS), the Republic of Korea, and Sriwijaya University, Indonesia. The authors would like to acknowledge Deasy M. Irfan, Sumantri, and Agus Prihanto for their field assistance during the field survey.

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ISSN: 2339-076X (Print)

ISSN: 2502-2458 (Online)

DOI: 10.15243/jdmlm

Distribution: Open Access

Frequency: Published in **January**, **April**, **July**, and **October**

Published by: IRC-MEDMIND and Soil Department, Faculty of Agriculture, Brawijaya University, Jalan Veteran No 1, Malang 65145, East Java, Indonesia

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