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Elucidating indigenous farmers' avoidance of deep peatlands for food crop farming in South Sumatra province, Indonesia

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Abstract

Most peatlands in Indonesia have been drained for plantation industries (Oil palm, Acacia) and agricultural purposes in a broad sense. Theoretically, peatlands are extremely sensitive to hydrological changes. The research aimed to elucidate the fact that indigenous farmers avoid deep peatlands for food crop farming. This qualitative and quantitative research has been conducted from 2020 to 2023 in South Sumatra province. It used a field survey method and the data were collected by using a purposive sampling method. There are two main reasons farmers to avoid deep peatlands for cultivating food crops, namely instinctive and latent challenges. The first ones are temporary and technical, so farmers are able to overcome these challenges with a scientific and technological approach. Latent ones are very difficult or impossible to repair and tend to cause the destruction and extinction of peatlands. The government should stop granting concession permits and make deep and very deep peatlands into conservation areas, because of their impact on the environment. Approaches are recommended for sustainable peatland management, namely decentralisation, conservative, protective, and optimal approaches.

Key words: farmers, income, instinctive challenges, latent challenges, rice production, suitability.

Introduction

Peatlands are receiving serious attention as the issue of global climate change and global warming becomes stronger (Zuhdi 2019). They are natural ecosystems of high value because they have biodiversity, regulate the climate, and are a source of livelihood for millions of residents around the location (Zuhdi et al. 2019, Zhang et al. 2022). Damage to peatlands due to human activities such as agricultural expansion and drainage construction, peat mining, together with extreme climate manifestations have contributed to the degradation of around 65 million ha of peatlands in the world (Armanto et al. 2023a; 2023b). The emissions resulting from this damage are very significant and reach around 3 Gt CO_2 per year, or around 5 % of the global carbon balance (Junedi 2017, Holidi 2019). The problem of clearing peatlands, excessive drainage, and frequent fires are the main factors contributing to Greenhouse Gas Emissions, such as CO_2, methane (CH_4), and nitrogen oxide (N_2O), which will become a time bomb for the sustainability of our life (Armanto et al. 2022).

Peatlands in South Sumatra are about 1.01 million ha and mostly found in the Eastern Part (Armanto 2019a, 2019b; Holidi et al. 2019). About 44 % of those peatlands are located in non-forest areas, 42 % in production forests (He et al. 2023), oil palm and acacia plantations, and the rest (14 %) found in protected forests (wildlife reserves and national parks). At present time most peatlands have been drained for oil palm plantation (Armanto and Wildayana 2022, 2023), oil palm and acacia plantations and agricultural purposes in a broad sense (Alikhani et al. 2021).

The peatlands cultivation has changed groundwater levels, namely groundwater depletion, drainage systems, swamp forest logging and land clearing by burning (Wildayana and Armanto 2018a, 2018b). Farmers cultivating food crop farming (especially rice) in peatlands always pay serious attention to the depth of peatlands because in very deep ones (Yan et al. 2023), besides it is difficult and less fertile to cultivate rice, so it produced low rice yield and low income of farmers (Byg et al. 2023, Wildayana and Armanto 2018c, 2018d, 2021). Furthermore, this research is important because it provides information about indigenous farmers avoid deep peatlands for food crop farming (Wildayana et al. 2019, 2018).

This research aims to understand indigenous knowledge why farmers avoid the deep peatlands. It focuses on explaining scientifically why deep peatlands are avoided by indigenous farmers while the government gives concession permission to private companies such as oil palm and acacia plantations.

Materials and Methods

Research location

The research was carried out from 2020 to 2023 and was conducted in South Sumatra province, Indonesia which is geographically located between 1–4° South latitude and 102–106° East longitude (Fig. 1).

According to the Decree of the Ministry of Environment and Forestry of Indonesia Republic, Nr. SK.129/MENLHK/SETJEN/PKL.0/2/2017 concerning Determination of the PHU Map, total area of observed PHU was 995,756 ha (PMRA 2022). General descriptions of observed PHU are given in Table 1.

Table 1. General descriptions of observed peatland hydrological units.

Parameters	Merang-Ngirawan	Saleh-Sugihan	Sugihan-Lumpur	Burnai-Sibumbung
Area, ha	82,021	190,230	636,828	86,679
Burnt area 2019, ha	8513	29,167	39,786	10,134
Restoration types	Canal blocking and livelihood revitalisation	Canal blocking	DPG and canal backfilling	3-R and DPG
Targeted restoration area, ha	Muara Medak, 33,104	All villages in PHU, 4766	All villages in PHU, 228,378	All villages in PHU, 39,445

Note: DPG – Peat care village program; 3-R – rewetting; revegetation and revitalisation. Source: Field and laboratory data analysis (2023).

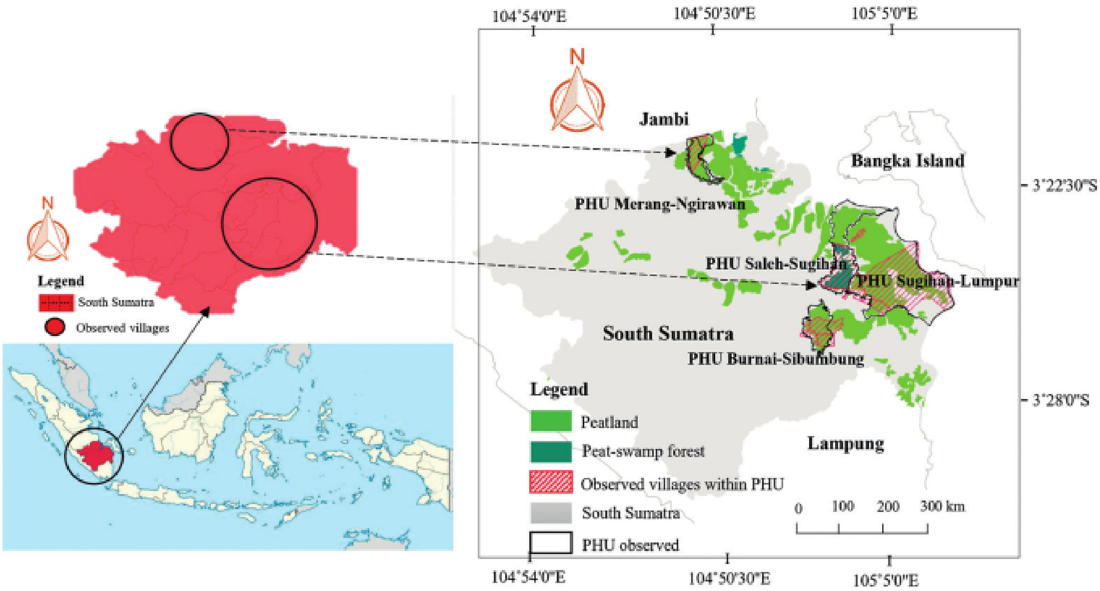

Fig. 1. Research location in South Sumatra province, Indonesia.
Note: PHU is Peat Hydrological Unit.

Study population

The number of respondents interviewed was 525 households (15 % of the total population of 3500 households of peatlands), and 2–3 villages were selected for each PHU, so the number of selected villages was 12. Data of respondents were collected by using a purposive random sampling method, questionnaires, and snowball sampling techniques (Table 2).

Informant criteria

The interview scopes were on questions about elucidating indigenous farmers avoid deep peatlands for food crop farming. Data and information were taken also from related stakeholders, namely government, concession owners, NGOs as

Table 2. General descriptions of selected respondents.

Plots and size	Districts (villages)	Population (household)	Sample (respondent)
Merang-Ngirawan (82,021 ha)	Musi Banyuasin (Merang-kepayang, Muara medak)	770	116
Saleh-Sugihan (190,230 ha)	Banyuasin (Banyu biru, Simpang heran)	910	137
Sugihan-Lumpur (636,828 ha)	OKI (Simpang tiga sakti, Riding)	945	142
Burnai-Sibumbung (86,679 ha)	OKI (Kedaton, Menang raya)	875	131
Total		3500	525

Source: Field and laboratory data analysis (2023).

well as indigenous farmers.

Research instrument

This research is a combination of qualitative and quantitative methods. This research used a field survey method and the data were collected by using a purposive sampling method. Composite soil samples were taken purposively at depths of 5–20 cm and 30–50 cm, then analysed in the laboratory for bulk density and organic C. The complete research objects and parameters as well as measurement methods are summarised in Table 3.

Data analysis

All data collected were processed on the basis of measured parameters and analysed, tabulated, elaborated descriptively, and then analysed statistically by using SPSS program version 21. The land suitability method was carried out following the Ministry of Agriculture Regulation concerning Guidelines for Land Suitability for Agricultural Commodities No. 79/Permentan/OT.140/8/2013. The pace at which the depth of peatlands varies year over year is the basis for the data projections for 2050 (PMRA 2022). The results for projections for 2050 were derived from the data.

Rice production and income of farmers was calculated at the MDG price of IDR 4500 kg^{-1}. The Indonesian Rupiah (IDR) exchange rate is: 1 IDR = $6.0842 \cdot 10^{-5}$ € and 1 € = 16,436 IDR (average for November 2023). Revenue was obtained from multiplying rice production by the selling price, while the average income of farmers is the difference between revenue and production costs. Rice production was measured using Square method 5×5 m and income of farmers was calculated using farm analyses with formula (1).

$$I = TR - TC, \tag{1}$$

where: I is income, IDR million·ha^{-1}·yr^{-1}; TR is total revenue, IDR million·ha^{-1}·yr^{-1}; TC is total cost, IDR million·ha^{-1}·yr^{-1}.

Table 3. Research object, parameter and methods of measurements.

Object	Parameters	Methods	Total samples
Farmers	Legality and ownership, %	Questionnaire	525
	Age, year	Questionnaire	525
Peatlands	Plot area of farmers, ha	Questionnaire	525
	Peat maturity (scale)	Squeeze method	80
	Bulk density, g·cm^{-3}	Ring sample	э
	Organic C, %	Walkey and Black	40
	Area percentage, %	Questionnaire	525
	Peat depths, m	Boring	80
	Soil acidity, pH value	pH meter	80
	Soil fertility (scale)	Certainty factor method	40
	Inundation depth, m	piezometer	40
	Aluminium and iron, ppm	Spectrophotometer	80
Rice	Production, t MDG·ha^{-1}·yr^{-1}	Square method 5×5 m	16

Note: MDG is milled dry grain.

Results and Discussion

Characteristics of farmers' activities

Plot area of farmers (generally > 84 %) had plots on average < 5 ha, only a small number of farmers had > 5 ha, meaning most farmers only fulfilled their own family needs (subsistence farming). Distance describes how far the plots are from the main road to the district capital, the average is 36 km away from the main road. It is relatively close, making easier for rural communities to transport. Roads play a very important role in facilitating village development; alleviating poverty through increasing production and prices of agricultural products; and reducing agricultural input costs. Therefore, the expansion of rice fields increased markedly in areas close to markets and roads, but the road construction can cause degradation of the peatlands.

Legality and ownership (explaining the plot locations), it turns out that > 95 % of the rice fields were located in PHU area. This was not in accordance with the spatial plan because all PHU areas may not be converted into agricultural and plantation areas. Ownership explains how rice fields owners get plots, around 61 % of rice fields plot ownership was obtained through market buying and selling transactions.

Age of the plot owners at the conversion time was around 40 years with an average length of education of 12 years (Senior High School). They have been involved in trading (average 26 years); or domiciled as a civil servant (25 years), and commercial plantations (35 years). It is noteworthy that very few subsistence farmers were doing rice field farming (only 13 years).

Expansion of rice fields began in the 1980s. This expansion has brought many changes to the physical landscape or ecosystem and created rural socio-economic changes. The changes started with the transmigration program, but over time, farmers expanded rice fields and faced various intrinsic challenges and latent challenges of peatlands, so farmers avoided deep peatlands for food crop farming (rice fields).

Our interviewed results explained that in the end they realised peatlands were not suitable for rice fields, so that in the 1960s native farmers became less motivated to farm on them. However, starting in the 2000s, large companies operating in the plantation industries expanded the area of oil palm plantations to > 10,000 ha. Finally, the government formed a foundation of the Nucleus Estate System (NES), where the plantation industries are responsible for processing and distributing Fresh Fruit Bunches (FFB). Farmers act as plasma under the supervision of the plantation industries and do not manage their oil palm directly. Instead, farmers are coordinated in a production organisation called Village Unit Cooperative (VUC) that functions as a partially integrated management system. As a result, in the field, there is often a communication gap between the parties involved and FFB financial transparency, and one of the main challenges is the lack of technical assistance received by plasma farmers. Differences of opinion between the two parties sometimes drag on and last for 20 years. Finally, farmers have difficulties in replanting of their oil palm trees.

Since plantation industries have entered PHU sites, farmers have been encouraged to own peatlands even though they were aware that these peatlands are not suitable for rice fields due to latent challenges. The goal of farmers is to control the peatlands and oil palm after knowing the economic potential of FFB. Farmers gained knowledge from experience as workers in the plantation industries or as part of core partnerships between companies and farmers. Hence, they were trying to sell their peatlands although their peatlands are located in conservation areas (depths of peatlands more than 3 m).

Characteristics of peatlands

Results determining peatland suitability for agriculture – peatland maturity, bulk density (BD), carbon content and peatland depths, are presented in Table 4.

BD values varied between 0.11–0.29 $g \cdot cm^{-3}$ depending on weathering level. The more mature of peatlands is observed, the BD values will increase. Fibric maturity has average BD lower than 0.11 $g \cdot cm^{-3}$, but hemic and sapric maturity has average BD values more than 0.20 $g \cdot cm^{-3}$ because of the influence of compaction. The average BD of fibric is significantly different from the average BD of hemic and sapric. Increase BD is due to compaction and increased peatlands degradation.

The carbon contained in peatland is known as organic C content in peatlands of 43–54 %. It is closely related to peatlands maturity. With the increasing maturity, organic C content decreases and is significantly different between organic C in fibric, compared to organic C in hemic and sapric. It diversity ranges from 54.27 ±2.24 % for fibric; about 49.32 ±3.78 % for hemic, around 43.78 ±8.76 % for sapric and significantly different among the values.

Table 4 shows that the highest peat maturity is hemic (close to 50 %), followed by sapric maturity and the lowest is fibric maturity, 36.26 % and 17.86 % respectively. The large area of hemic maturity is caused by land clearing, drainage and repeated fires, so that the peatlands become well decomposed.

It is explained in Figure 2 that from 1990 to 2050, very deep and deep peatlands show a downward trend, because of massive forest and land fires, intensive drainage and illegal logging systems getting out of control. On the contrary, shallow peatland shows an upward trend, started with the lowest percentage in the beginning of the year and will become the highest in the year 2050, which is around 5 % and 60 % of each. Furthermore, although the peatlands medium also shows a downward trend, it is predicted that in 2050 it will remain just slightly below 40 %, about 10 % higher than in 2020.

Very deep peatlands (> 3 m) with a fibric to hemic maturity were found in dome area and are largely avoided by farmers for food crop farming because they are less fertile and have no agricultural potency and recommended as for a conser-

Table 4. Distribution and characteristics of peatlands maturity.

Peat maturity	BD, $g \cdot cm^{-3}$	Organic C, %	Area, %
Fibric	0.11 ±0.12[a]	54.27 ±2.24[a]	17.86
Hemic	0.21 ±0.17[b]	49.32 ±3.78[b]	45.88
Sapric	0.29 ±0.28[c]	43.78 ±8.76[c]	36.26
Total			100.00

Note: BD is bulk density. Means in one column and followed by the same lower case are not significantly different at the 5% test level.

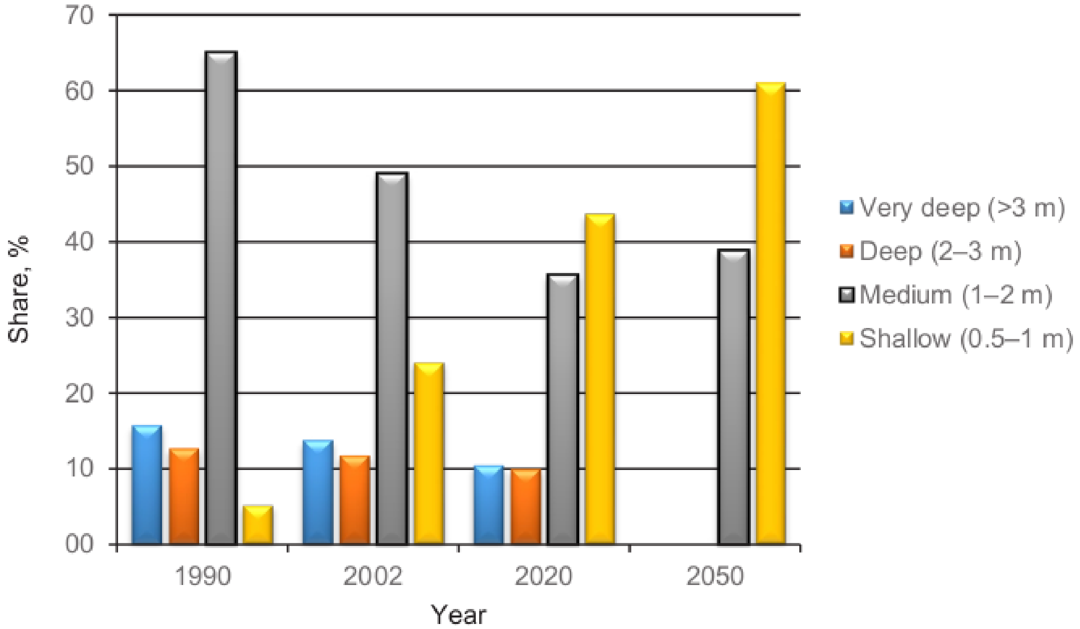

Fig. 2. Estimated depths of peatlands in the research area 1990–2050.
Source: It was interpreted from Landsat images (1990, 2002, 2020) and the field survey (2023). It was estimated on the basis of PMRA (2022) and the field survey (2023).

vation area. In general, these peatlands have a very inhibited drainage, rapid permeability, and has a very deep cross-section of the soil.

Deep peatlands (2–3 m) have experienced the fate of almost the same as very deep peatlands. It is estimated that deep peatlands would disappear in 2050 because the Government has permitted large private companies to cultivate Oil palm and Acacia. The peatlands become objects of forest and land fires, intensive drainage and illegal logging systems that are going increasingly uncontrolled. Deep peatlands with fibric to hemic maturity were commonly found in dome areas.

Medium peatlands (1–2 m) with hemic to sapric maturity were commonly found on the sides or edges of the peatlands dome. These peatlands generally have potential for food crop farming. Indigenous farmers have cultivated food crops, vegetables, and fruits in these peatlands.

Shallow peatlands (0.5–1 m) continued to increase from year to year remarkably compared to other peatlands. In 1990 the peatlands had an area of around 5.27 %, and its increase occurred due to excessive peatlands clearing by logging, drainage, and fires. In 2002, the extent was 24.24 % and around 43.77 % in 2020 and estimated to expand to 61.07 % in 2050.

Suitability of peatlands for food crop farming

Instinctive challenges of peatlands are predominantly temporary, technical or economic, so they are easier to overcome with science and technology approaches. Various instinctive challenges were identified, namely release of toxic metals, eutrophication of surface water, disruption of hydrological balance, waterlogging, drought, local fisheries, release of organic pollutants, changes in salt and freshwater systems, changes in groundwater supply, and air pollution. Especially for food crop farming (rice fields), instinctive challenges can be overcome with land suitability methods.

Peatlands can be classified into four land capability classes, namely class S1 (very suitable), S2 (suitable), S3 (marginally suitable), and N (not suitable) according to the Ministry of Agriculture Regulation concerning Guidelines for Land Suitability for Agricultural Commodities No. 79/Permentan/OT.140/8/2013. Figure 3 illustrates the potential of peatlands for food crop farming. Data on food crop farming in peatlands indicates a 63 % less potential, which is notably significantly different from a high potential of only 1 %. Then, it shows that low potential and medium potential, declared 20 % and 16 % respectively.

There is a relationship between land suitability class and rice cultivation production. This relationship is expressed in the form of a description as follows:

1) High potential if land suitability for rice cultivation was in the range of 75 % classified as suitable and < 25 % as marginally suitable. Rice production ranges from 8–10 t MDG·ha^{-1}·year^{-1}.

2) Medium potential if land suitability for rice cultivation consisted of 25–50 % classified as suitable and 50–75 % as marginally suitable. Rice production ranges from 5–7 t MDG·ha^{-1}·year^{-1}.

3) Low potential if land suitability for rice cultivation was indicated as 50–75 % classified as marginally suitable and 25–50 % as unsuitable). Rice production ranges from 2–4 t MDG·ha^{-1}·year^{-1}.

4) Less potential if land suitability class for rice cultivation showed > 75 % classified as permanently not suitable and < 25 % as marginally suitable. Rice production ranges from less than 1 t MDG·ha^{-1}·year^{-1}.

The results presented in Figure 3 show, that 63 % of the research area belonged to less potential, meaning there is no opportunity for rice cultivation because there are a lot of latent challenges and very difficult to reclaim or require high costs and rice production is not optimal. Limiting factors of peatland suitability for rice cultivation are given in Table 5. It was relevant with work of Armanto et al. (2013).

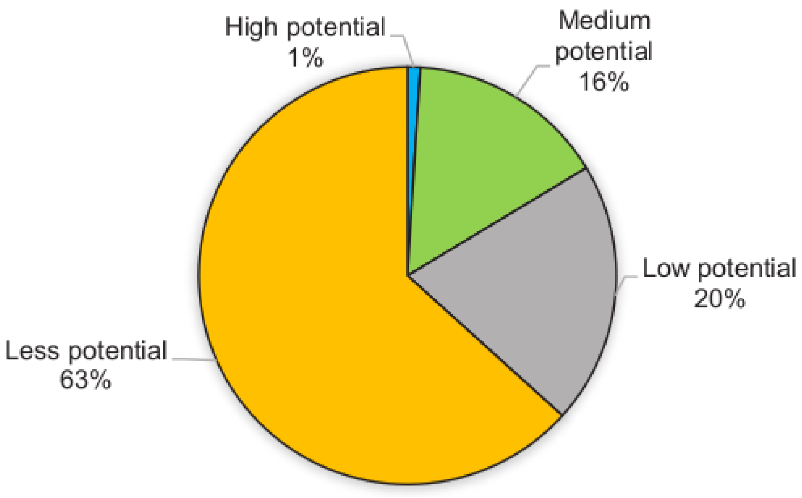

Fig. 3. Potency of peatlands for rice cultivation.

Source: Land suitability is based on topographic maps of South Sumatra (scale 1:50,000), Landsat imaginary analyses (2022), soil maps, field observations and laboratory analyses (2023).

Suitability class N means that the land shows dominant la-

Table 5. Limiting factors of peatland suitability for rice cultivation.

Class	Subclass*	Limiting factors
N	N	Latent limiting factors
S3	S3-anfx	Soil acidity, soil fertility, stagnant water, Al, Fe toxicity
S2	S2-nfx	Soil fertility, stagnant water and Al, Fe toxicity
S2	S2-anfx	Soil acidity, soil fertility, stagnant water and Al, Fe toxicity

Note: * a – very high soil acidity and difficult to be managed; n – very low to low soil fertility; f – flood, frequency and duration, flood water depth and water flow should be considered in order to determine this limitation; x – salinity, high salt content which limits crop growth. Source: Results of field observation, laboratory and image analyses (2023).

tent limiting factors. Land suitabilityS3 indicates that there are factors limiting plant growth, including soil acidity, soil fertility, stagnant water, Al, Fe toxicity. Land suitability class 2 indicating there are limiting factors including soil fertility, stagnant water and Al, Fe toxicity.

The results of field and laboratory analysis showed that even though peatlands provide low suitability for rice cultivation, there are still few opportunities to increase actual suitability to potential suitability based on agricultural science and technology by providing soil ameliorant materials and other actions needed (Table 6). For example, the actual land suitability class (S3-anfx) can be increased to potential land suitability (S2-af) by providing actions including lime, macro- and microfertilizers, water blocking leading to peatlands, not burning biomass, not leaching Na and H elements, and keeping peatlands always wet. However, the actual land suitability of S3-nfx and S3-nx can change to potential land suitability of S3-fx and S3-x only by changing the limiting factors but cannot change the land suitability class order, because the factors determining the land suitability class order are very dominant.

Rice production and income of farmers

Rice was developed by indigenous farmers for their own food (subsistence farming) because it is relatively easy to cultivate and its price was stable compared to other food crops and are capable of providing rice production ranging from 2.50–6.50 t MDG $ha^{-1}\cdot year^{-1}$. The average rice production cost was IDR 5.5 million $ha^{-1}\cdot year^{-1}$.

Table 7 shows differences in rice production and income of farmers based on peat depth. The deeper the peatlands

Table 6. Efforts to increase land capability for rice cultivation.

Actual*	Potential	Efforts to increase actual suitability to potential suitability
S3-anfx	S2-af	Lime, macro- and microfertilizers, water blocking leading to peatlands, not burning biomass, not leaching Na and H elements, and keeping peatlands always wet
S2-anfx	S2-af	
S3-nfx	S3-fx	
S3-nx	S3-x	

Note: * a – very acidic and difficult to be managed; n – very low to low fertility; f – flood, frequency, duration, flood depth and water flow should be considered in order to determine this limitation; x – salinity, high salt content. Source: Results of field observation, laboratory and image analyses (2023).

Table 7. Rice productivity and income of farmers in peatlands.

Peat depths	Average rice production, t MDG·ha^{-1}·year^{-1}	Income of farmers, IDR million·ha^{-1}·year^{-1}
Very deep	< 2.12 ±0.15[a]	3.49 ±0.24[a]
Deep	3.20 ±0.26[b]	8.88 ±0.31[b]
Medium	4.10 ±0.24[c]	12.79 ±0.34[c]
Shallow	4.45 ±0.20[d]	19.10 ±0.32[d]

Note: Values in the same column and indicated by the same superscript are not significantly different at the test level of 5%; MDG is milled dry grain.

were identified, the lower rice production was because the more limiting factors for rice growth were found, such as low soil fertility; unregulated water conditions; less able to support rice growth; pest and disease attacks; lack of soil nutrients; technical difficulties in the rice cultivation due to access difficulty to very deep and deep peatlands.

Rice production and income of farmers were significantly different for each peatland depth. Income of farmers was obtained from the t-test, so it was concluded that H0 was rejected, meaning there were differences in income among them based on different peatland depths. Peatlands with shallow depths could provide the highest rice production and income of farmers (around 4.45 t MDG·ha^{-1}·year^{-1} and IDR 19.10 million·ha^{-1}·year^{1}) and were significantly different from very deep, deep and medium peatlands.

Latent challenges and land uses of peatlands

All coercive actions against peatlands have triggered the presence of latent challenges in peatlands, for example biodiversity loss (habitat, genetics, genes) especially for native flora and fauna; loss of production functions (peat, water, crop cultivation); and loss of social and environmental functions. Latent challenges are generally hidden and lie beneath what we perceive as obvious, deep, long-standing, and ongoing, but they still emerge in a variety of ways. They are very difficult or impossible to reclaim and tend to lead to the destruction and disappearance of peatlands.

Latent challenges were only possible done by strong investors, plantation industries and large speculators who were capable of converting peatlands to oil palm and acacia plantations on a large scale. Farmers were unable to face this latent challenge because it was repeated, global, and had huge impacts on the environment. Even if it continues to grow and is less attended, it is possible that peatlands will disappear in 2050 as represented in Figure 2. It illustrates that the area of deep peatlands is decreasing from year to year, on the other hand, the area of shallow peatlands is becoming more and more widespread over time. This indicates that deep peatlands will be destroyed and disappeared.

Conclusions

Peatlands fall into land suitability classes of N (permanently not suitable) and S3 (marginally suitable), if peatlands are forced for rice cultivation, then rice cultivation cannot be carried out optimally. There are two main reasons farmers avoid deep peatlands for cultivating food crops, namely instinctive challenges and latent challenges.

Instinctive challenges are dominantly temporary, technical or economic, non-repetitive, local, and have less impact on the environment, so that they are easier to overcome with a scientific and technological approach and farmers are able to face these instinctive challenges. Efforts needed to overcome the instinctive challenges, namely installing water blocking to irrigate peatlands (rewetting), liming, not burning peatlands, and fertilizing. Based on their potential, there are four potential groups of peatlands, namely high potential; medium potential; low potential; and less potential.

Latent challenges are very difficult or impossible to repair and tend to lead to the destruction and extinction of peatlands. Latent challenges are only possible for strong investors, plantation industries and large speculators capable of converting peatlands to oil palm and acacia plantations on a large scale. The government should stop granting business permits (concessions) and make deep and very deep peat lands for conservation areas, not reserved for large private companies for Oil palm and Acacia plantations because of their environmental impact, especially due to the logging process, over drainage and land clearing by burning is global, regional and local. Four approaches are recommended for sustainable peatland management, namely decentralisation approach; conservative approach; protective approach, and optimal approach.

It is suggested to the Government to carry out coordination at any level involving stakeholders, government and indigenous farmers in carrying out peatlands restoration. Peatlands are not permitted to be opened for any purpose without having adequate technology and knowledge regarding the two characteristics of peatlands, namely instinctive challenges and latent challenges. Apart from that, it is necessary to involve indigenous farmers in the use of peatlands.

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