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Land Swap Option for Sustainable Production of Oil Palm Plantations in Kalimantan, Indonesia

Reza Ariesca [1,2], Andi Adriana We Tenri Sau [3], Wahyu Catur Adinugroho [4], Arief Ameir Rahman Setiawan [1,4], Tofael Ahamed [5] and Ryozo Noguchi [6,*]

1 Graduate School of Science and Technology, University of Tsukuba, Tsukuba 305-8577, Japan
2 Coordinating Ministry for Economic Affairs, Jakarta 10710, Indonesia
3 Ministry of Environment and Forestry, Jakarta 10270, Indonesia
4 National Research and Innovation Agency, Jakarta 10710, Indonesia
5 Faculty of Life and Environmental Science, University of Tsukuba, Tsukuba 305-8577, Japan
6 Laboratory of Agricultural Systems Engineering, Division of Environmental Science and Technology, Graduate School of Agriculture, Kyoto University, Kyoto 606-8501, Japan
* Correspondence: noguchi.ryozo.8j@kyoto-u.ac.jp

Abstract: Indonesia is the largest producer of palm oil; it is essential to manage its palm oil industry in a sustainable manner through swapping the oil palm plantation in peatland to mineral soil to reduce the greenhouse gas emissions. This study employed the latest spatial data using the ArcGIS software to analyze the potential area for the land swap option and to calculate the potential reduction in greenhouse gas emissions in Kalimantan, Indonesia. There are 1.08 million ha of oil palm in peatland, while 0.64 million ha of the area in mineral soil under the convertible production forest have the potential for land swapping. Via the land-swap option, emission reductions of 65.43% (from 979.05 $MtCO_2eq$ to 336.64 $MtCO_2eq$) for the calculation period of 25 years and up to 61.19% (from 2147.81 $MtCO_2eq$ to 833.67 $MtCO_2eq$) for that of 50 years is possible compared to the initial condition. The land swap will also increase the production of fresh fruit bunch (FFB) by 17.16% per year because the productivity of FFB in mineral soil is higher than that of the peatland. Considering that land swaps are costly, policymakers and stakeholders must collaborate to execute the land-swap option for the sustainability of Indonesian palm oil.

Keywords: climate change; emission reduction; land swap; peatland; productivity; SDGs

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1. Introduction

The projected global demand for vegetable oils by 2031 is approximately 249 Mt [1], while in 2050 this demand is projected to reach 310 Mt, comprising their use for products such as edible vegetable oil and biodiesel [2]. Moreover, the global demand for palm oil grows by 7% per year, while the demand for other vegetable oils grows by 4% per year [3]. Indonesia contributed approximately 50% of global palm oil production in 2017, and combined with Malaysia, both countries represent over 80% of the global production of palm oil [2,4]. The total area of oil palm plantations in Indonesia and Malaysia in 2019 was 16.3 million ha and 5.74 million ha, respectively [5,6]. Despite its contribution to fulfilling the global demand for vegetable oils, raising awareness for sustainability has sparked a discussion on the palm oil industry. Studies have shown that the CO_2 emissions from oil palm plantations in the peatlands are among the largest proportions of greenhouse gas emission [3]. Several other studies revealed that the peat swamp forest in Kalimantan has degraded, which is caused by logging, conversion to large-scale agriculture and/or industrial plantation, artificial drainage canals, fires, poverty, and traditional farming practices, climate change, and land use policy [7]. Furthermore, a study also stated that approximately 20.8% of oil palm plantations in Indonesia are in peatlands [3], and large-scale agriculture, such as oil palm in a peatland in Central Kalimantan, will potentially release 93–217 mega tCO_2 eq over the next 25 years [8]. Malaysia, as the second largest producer of oil palm, might encounter similar issue on the management of oil palm in peatland. A study has shown that oil the palm plantation in a peatland in Sarawak, Malaysia has grown rapidly from 197,323 ha in 1990 to 657,273 ha in 2018 [9].

Oil palm plantations will continue growing until they reach the maximum available land [3]. Another study showed that the maximum amount of suitable land to be cultivated for oil palm in Indonesia is approximately 44.7 million ha [5]. A study conducted in 2012 showed that approximately 4.5 million ha of area in West Kalimantan has potential for oil palm [10].

In an effort to improve peat governance in Indonesia, the Government of Indonesia enacted several regulations in 2016, one of which is Law Number 57 [11]. According to that regulation, there are two types of peatland functions: cultivation and protection. Peatland with a depth greater than 3 m is assigned for protection, while peatlands that are less than 3 m in depth are allowed for cultivation [11]. The Government of Indonesia also enacted the Indonesian Sustainable Palm Oil (ISPO) certification in 2011 as a mandatory scheme for the palm oil industry to ensure that the oil palm products from Indonesia are managed in a sustainable manner [12].

Peat is a type of organic soil that consist of partly decomposed vegetation and is formed over centuries in waterlogged conditions [13]. The term 'peatland' refers to the peat soil and the wetland habitats growing on the surface. Emissions from drained peatlands are estimated at 1.9 Gt of CO_2eq annually [14], while mineral soil is the world's most cultivated land and may contain traces of up to 30% of organic matter [15]. Peatlands have a critical role in climate change mitigation and adaptation. Peatlands cover only approximately 3–5% of the earth's surface but are home to more than 30% of the carbon stored in soil worldwide [13].

Swapping oil palm plantations in peatlands into mineral soils is essential in reducing the emission while maintaining productivity. A study suggested that the land swapping of oil palm plantations in peatland into mineral soil supports the sustainability of the palm oil industry [3]. There is also another study that carried out a small-scale pilot project for land swaps in Kapuas Hulu, West Kalimantan [10]. This study revealed that land swapping potentially helps Indonesian bargaining power in meeting market demand while utilizing the palm oil industry in a sustainable manner. However, there has not been any study that reveals the availability and distribution of potential areas for land swapping and their impact on the potential emission level.

The purposes of this study were to analyze the availability of potential areas for the land swapping of oil palm plantations in peatland with mineral soil using the latest data of oil palm plantation and peatland coverage to investigate its potential emissions and the strategy of implementing land swaps in Kalimantan, Indonesia. The findings from this study will show the potential area for land swaps located in the mineral soil in Kalimantan, Indonesia. The results of the study will also give an overview of the option to reduce greenhouse gas emissions from oil palm plantations in peatlands without disregarding their productivity and purposes in fulfilling the global demand for vegetable oils. In the long run, the on-ground implementation of this study of land swap will reduce emissions and contribute to Indonesia's target of achieving sustainable development goals by 2030, especially for climate action, since it will help accomplish the Indonesia Nationally Determined Contribution (NDC) and meet the recent Forestry and Other Land Use (FOLU) Net Sink 2030 targets.

2. Materials and Methods

2.1. Study Area

This study focused on Kalimantan, the second largest island in Indonesia, which consists of five provinces: West Kalimantan, Central Kalimantan, South Kalimantan, East Kalimantan, and North Kalimantan, as shown in Figure 1. Kalimantan is located between latitude 4°24′ N and 4°10′ S and longitude 108°30′–119°00′ E. The equator crosses this area, giving the island a tropical climate with a relatively constant temperature of approximately 25–35 °C throughout the year in the lowlands. In general, the soil in Kalimantan consists of red-yellow podzolic, podzols, organosol, laterite, regosol, alluvial, lithosols, and latosols [16–18]. Meanwhile, the characteristics of the peatland in Kalimantan are its mean thickness of around 4–6 m, its bulk density is approximately 0.08–0.64 g cm^{-3}, and its carbon concentration of 23.80–62.00% [19].

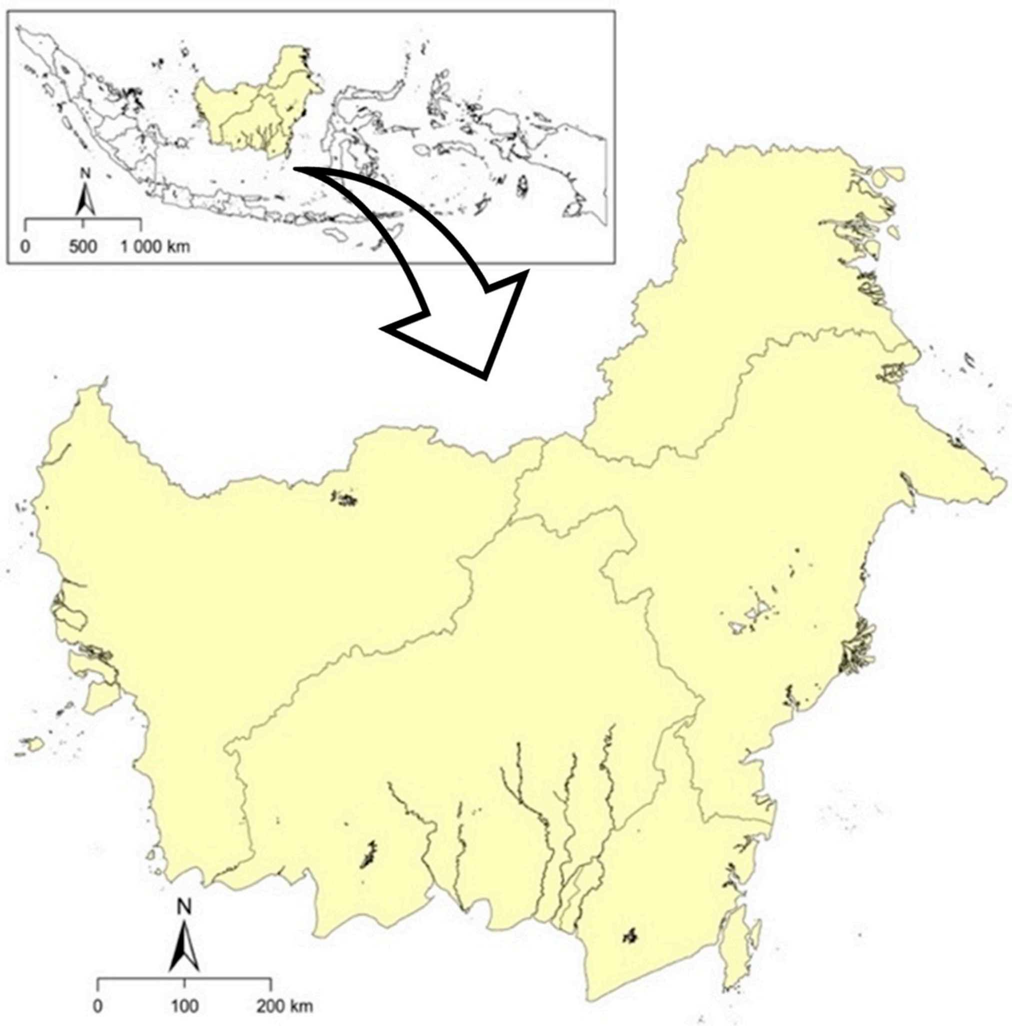

Figure 1. Study area in Kalimantan, Indonesia.

2.2. Work Procedure

There were four stages conducted in this study. The first stage was the data collection in which all the required data were collected from various sources. The second stage was data processing. In this stage, the digital data were analyzed using the ArcGIS software version 10.8.1 to obtain the area of oil palm plantation in peatland and the potential area for oil palm in mineral soil. The third stage was calculating potential carbon stock and potential emissions from the existing oil palm plantation in peatland, restoration in peatland, mineral soil, and oil palm in mineral soil. The FFB productivity was also calculated for both oil palm plantation in peatland and mineral soil. Finally, the last stage was calculating the land swap cost, which consisted of the restoration cost and replanting cost. The overall work procedure of this study is presented in Figure 2.

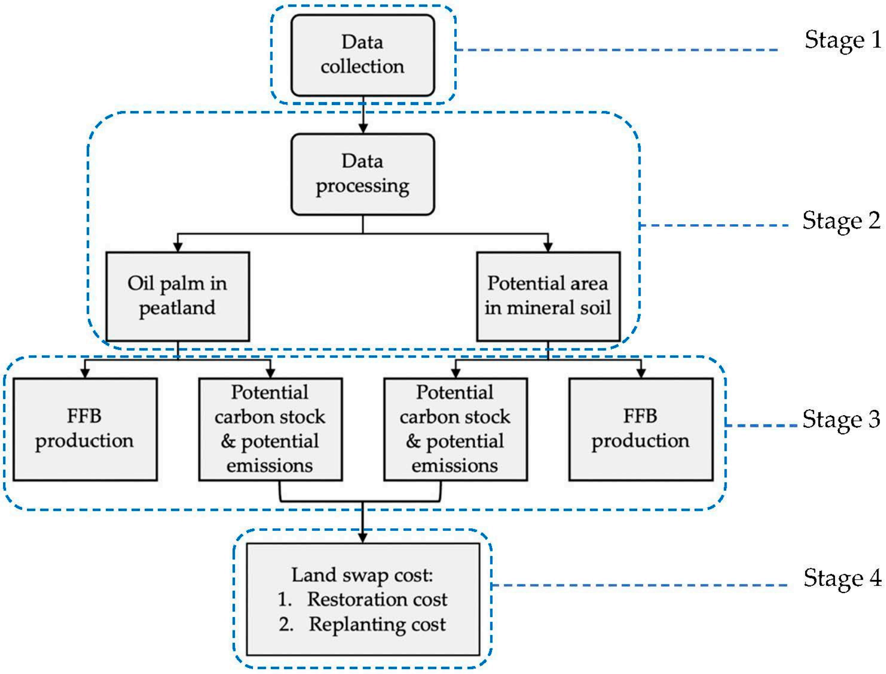

Figure 2. Work procedure of the study.

2.2.1. Data Collection

Table 1 shows the type and source of data of oil palm plantations, forest, and peatland that were used in this study, which were collected from various institutions in Indonesia. To analyze the potential area for swapping the oil palm plantations in the peatland with mineral soil, the data used are the latest spatial data of oil palm plantations acquired from the Coordinating Ministry for Economic Affairs (CMEA), Republic of Indonesia, according to the Minister of Agriculture (MoA), the Republic of Indonesia Decree in 2019. Data on peatland, forest land cover, forest concession, and other related data were obtained from the Ministry of Environment and Forestry (MoEF), Republic of Indonesia. The data of Indonesian Sustainable Palm Oil (ISPO)-certified companies were used to generate the average FFB productivity in mineral soil and peatland.

Table 1. Type and source of data of oil palm plantations, forests, and peatland.

Required Data	Source	Type of Data	Year
Oil palm plantation	Coordinating Ministry for Economic Affairs, the Republic of Indonesia	Digital file	2019
Indonesian administration border Indonesian forest area Indonesian peatland cover Indonesian conservation area Indonesian forest utilization Indonesian non-forest utilization (mining, transmigration, settlement, etc.)	Ministry of Environment and Forestry, the Republic of Indonesia	Digital file	2017, 2019, 2020, 2022
Time series data of oil palm	Statistics Indonesia, the Republic of Indonesia	Tabular and Digital file	Time series data since 1990
ISPO-certified documents	National certification agency	Report	2021

2.2.2. Data Processing

The digital data of oil palm plantations were acquired from the Coordinating Ministry for Economic Affairs (CMEA), Republic of Indonesia; data of peatland, forest land cover and forest concession and related data from the Ministry of Environment and Forestry (MoEF), Republic of Indonesia, were spatially analyzed to obtain the current condition of Indonesian oil palm plantation distribution using the ArcGIS software version 10.8.1. The work was conducted in two steps. The first step was to overlay the oil palm plantations, forest area, and peatland to obtain data on which plantations are in peatland and mineral soil. The second step was to classify the oil palm plantations in peatland into two categories: cultivation and protection functions.

The potential areas for the land swapping in mineral soil were acquired by analyzing related digital data via weighted overlay using the ArcGIS software version 10.8.1. There are four criteria used to obtain the potential area for land swapping. First, the area must be in the convertible production forest (Hutan Produksi Konversi/HPK); second, it must be clean and clear of the forest and non-forest utilization; third, it must be in mineral soil; and fourth, the land cover and land use are not primary forest, plantations, settlements, agriculture, mining, and water bodies. According to Indonesian Government Regulation Number 23 in 2021, HPK is a forest area that can be spatially reserved for non-forestry utilization. The utilization activities that are allowed for HPK include transmigration, settlements, agriculture, plantation, industry, national strategic infrastructure, national economic recovery, food estate and energy, and land subject to agrarian reform [20].

2.2.3. Calculation of Potential Carbon Stock and Potential Emissions

The calculation of potential carbon stock and potential emissions was performed using two options. Both options use a 25-year life span according to the optimum life cycle of oil palm plantations. The first option entails the existing conditions, which are oil palm plantations in peatland, and the second option includes peatland restoration and land-swap activities in mineral soil for 25 and 50 years.

The potential emission was measured by calculating the aboveground biomass and belowground biomass for the current oil palm plantations in peatland and the option of executing the land swapping. The aboveground biomass and belowground biomass values for oil palm were obtained from the modified study published in 2005 [21]. The value of biomass (aboveground and belowground biomass) for the potential area in mineral soil was obtained from the Indonesian National Carbon Accounting System (INCAS), published by the Ministry of Environment and Forestry (MoEF), Republic of Indonesia, and multiplied by the coefficient value of 0.5 to obtain the value of the biomass carbon stock, as stated in its document [22]. The carbon stock from the restoration in peatland uses the value for the broadleaf species in tropical moist/wet forests [23]. Moreover, carbon stock values equivalent to the carbon dioxide values in the atmosphere were obtained by multiplying the carbon stocks by a factor ($-44/12$). In addition, the global warming potential values for gases other than CO_2 were obtained from the study published by the Green House Gas Protocol [24].

Furthermore, the emissions from peat decomposition were estimated using the value from the 2013 Supplement to the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories: Wetlands [25], while the emissions factor for rewetting activities in the peatland was obtained from a study conducted by Wilson et al. in 2016 [26].

Potential Emission for the Existing Condition in Peatland

The value from Syahrinudin [21], Greenhouse Gas Protocol [24], and total area of existing oil palm plantations in peatland were applied to measure the potential emissions from oil palm plantations in peatland, as described in the following formula.

$$NER_{op\ peat} = A \times \left[\left\{ C_{op} \times \left(-\frac{44}{12} \right) \right\} + \sum_{i=1}^{n=4} \left(EF_{peat} \right)_i \times GWP_i \right] \times p \quad (1)$$

where $NER_{op\ peat}$ represents the net emission/removal of oil palm plantations in the existing condition in peatland (tCO_2eq), A is the total area of oil palm plantations in peatland (ha), C_{op} is carbon stock of oil palm plantations (tC/ha) [21], $\left(EF_{peat} \right)_i$ is the emission factor of CO_2(1), CH_4(2), N_2O(3), and DOC(4)/degradable organic carbon (tCO_2/ha/yr), GWP_i is the global warming potential of CO_2(1), CH_4(2), N_2O(3), and DOC(4), and p is the calculation period (year). The emission factors in the drained organic soil of CO_2, CH_4, N_2O, and DOC use the values published in the IPCC document [25], which are 11, 0, 1.2, and 0.82, respectively. The global warming potential (GWP) for CO_2(1), CH_4(2), N_2O(3), and DOC(4) is obtained using the values from Wilson et al. [24], which are 40.33, 0, 0.32, and 3.01, respectively.

To measure the potential carbon stock from biomass in the potential area in mineral soil, we use Formula (2), as follows:

$$C_{mineral} = \sum_{i=1}^{n=8} (A_m)_i \times C_i \quad (2)$$

where $C_{mineral}$ represents the total carbon stock from biomass in mineral soil (tC), $(A_m)_i$ is the area for each land cover in mineral soil (ha), and C_i is the carbon stock value for each land cover in mineral soil (tC/ha). In this study, the value of C_i refers to the Indonesian National Carbon Accounting System (INCAS) [22], which categorized the biomass for each region. The C_i values for the Kalimantan region based on its land covers are: (1) Swamp shrubs (30); (2) Secondary dryland forest (162.48); (3) Secondary mangrove forest (101.57); (4) Secondary swamp forest (136.21); (5) Dryland agriculture (10); (6) Dryland agriculture mixed with shrubs (30); (7) Shrubs (30); and (8) Open land (2.5) [22].

Potential Emission for the Land Swap Option

The potential emissions for the land swap option were derived from three sources: oil palm in mineral soil, oil palm in peatland, and peatland restoration, as described by the formulas below:

$$NER_{landswap} = NER_{op\ mineral} + NER_{peat\ ls} \quad (3)$$

where $NER_{landswap}$ represents net emission/removal for the land swap option (tCO_2eq), $NER_{op\ mineral}$ is net emission/removal from mineral soil (tCO_2eq), $NER_{peat\ ls}$ is net emission/removal from peatland after land swap (tCO_2eq). $NER_{op\ mineral}$ (tCO_2eq) is the sum of $C_{mineral}$ and carbon stock of oil palm in mineral soil according to the equation below:

$$NER_{op\ mineral=}C_{mineral} + \left\{ \left(A_m \times C_{op} \right) \times -\frac{44}{12} \right\} \quad (4)$$

where $A_m \times$ is the total potential area in mineral soil (ha) and C_{op} is the carbon stock from oil palm plantation (tC/ha).

The net emission/removal from peatland after the land swap ($NER_{peat\ ls}$, tCO_2eq) is the sum of net emission/removal from oil palm in peatland after the land swap ($NER_{op\ peat\ ls}$, tCO_2eq) and net emission/removal from peatland restoration ($NER_{peat\ rest}$, tCO_2eq).

$$NER_{peat\ ls} = NER_{op\ peat\ ls} + NER_{peat\ rest} \quad (5)$$

The formula for $NER_{op\ peat\ ls}$ (tCO_2eq) is similar to Formula (1), with the exception that the area was changed to the total of oil palm plantations in peatland after the land swap ($A_{op\ peat\ ls}$, ha), as shown in the Formula (6).

$$NER_{op\ peat\ ls} = A_{op\ peat\ ls} \times \left[\left\{ C_{op} \times \left(-\frac{44}{12} \right) + \sum_{i=1}^{n=4} (EF_{peat})_i \times GWP_i \right\} \right] \times p \quad (6)$$

The formula for $NER_{peat\ rest}$ is also similar to Formula (1), but the carbon stock value for broadleaf (C_{rest}, tC/ha) was applied [23]. The area also changed to the total area for peatland restoration ($A_{peat\ rest}$, ha), and the emission factors changed to the value for rewetted organic soil, as shown in Formula (7).

$$NER_{peat\ rest} = A_{peat\ rest} \times \left[\left\{ C_{rest} \times \left(-\frac{44}{12} \right) + \sum_{i=1}^{n=4} (EF_{wet})_i \times GWP_i \right\} \right] \times p \quad (7)$$

The emission factors in rewetted organic soil for CO_2, CH_4, N_2O, and DOC use the values from study [26], which are 0, 2.77, 0.44., and 2.09, respectively.

2.2.4. Land Swap Cost

The cost needed for land swapping is gathered from the literature and government regulations. The cost calculated in this study is the cost for the restoration of ex-oil palm in peatland and for replanting the oil palm plantation in mineral soil. There were two values from the literature to calculate the cost of for restoration: hydrological restoration and revegetation [27,28], while the cost for replanting referred to the standard issued by the Ministry of Agriculture, Republic of Indonesia in 2020 [29].

$$F_{total} = \left\{ A_{peat\ rest} \times \left(F_{hyd} + F_{veg} \right) \right\} + \{ A_m \times (P_0 + P_1 + P_2 + P_3) \} \quad (8)$$

where F_{total} represents the total cost (million USD), $A_{peat\ rest}$ is the total area for peatland restoration (ha), F_{hyd} is the hydrological cost (2000 USD/ha), F_{veg} is the revegetation cost (853 USD/ha), A_m is the total potential area in mineral soil (ha), P_0 is the cost of land clearing and replanting of oil palm in mineral soil (USD/ha), and P_1, P_2, P_3 represent the average cost of maintenance, years 1, 2, and 3, respectively, in mineral soil (USD/ha) [29].

3. Results

3.1. Current Condition of Oil Palm Plantation in Indonesia

Indonesian oil palm plantation in 2019 covered approximately 16.3 million ha that were distributed in 26 provinces, as shown in Figure 3. Oil palm plantations involve three main actors: private companies with a share of 55%, state-owned companies with 4%, and smallholder farmers with 41% [27]. The main producers of oil palm are in Sumatra and Kalimantan, with a total area of 15.53 million ha; the remainder are distributed on other islands of Indonesia (Java, Sulawesi, Papua, etc.).

Figure 4 shows the distribution of oil palm plantations in Kalimantan, which is approximately 5.66 million ha, with 4.58 million ha in mineral soil and 1.08 million ha in peatland. Furthermore, Figure 5 shows that the oil palm plantations in peatland are divided into two categories: those planted in the cultivation function (0.66 million ha) and those planted in the protection function (0.42 million ha).

Figure 6 shows the land utilization in Kalimantan, Indonesia. In addition to oil palm plantations, other concessions exist in the surroundings, such as natural forest concessions, which accounted for 10.42 million ha, plantation concessions of approximately 5.22 million ha, and restoration concessions of approximately 0.31 million ha.

Figure 3. Indonesian oil palm plantations cover approximately 16.3 million ha.

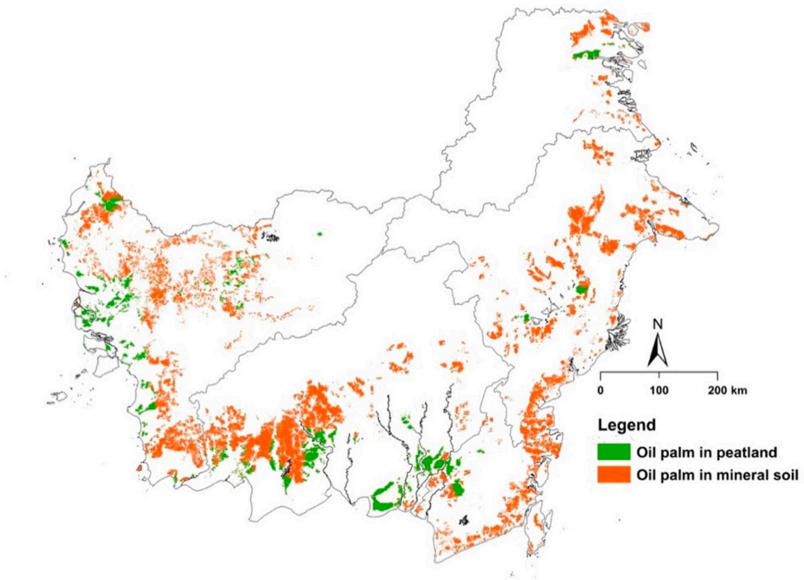

Figure 4. The total area of oil palm plantations in Kalimantan, Indonesia is 5.66 million ha; 4.58 million ha in mineral soil and 1.08 million ha in peatland.

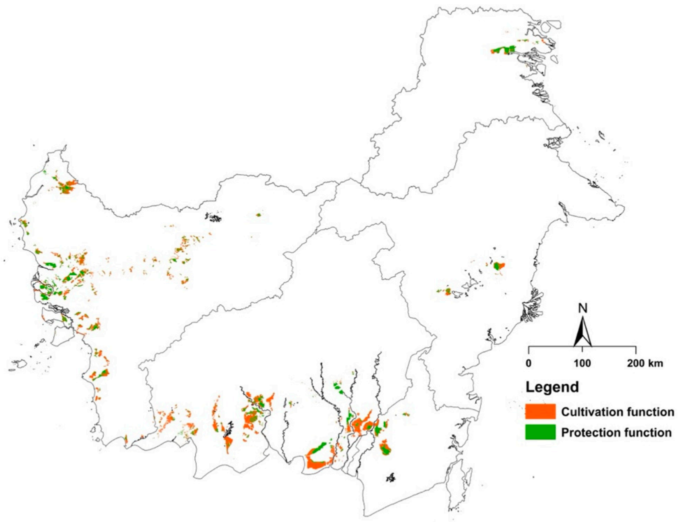

Figure 5. Oil palm plantations in peatland under cultivation function (0.66 million ha) and under protection function (0.42 million ha) in Kalimantan, Indonesia.

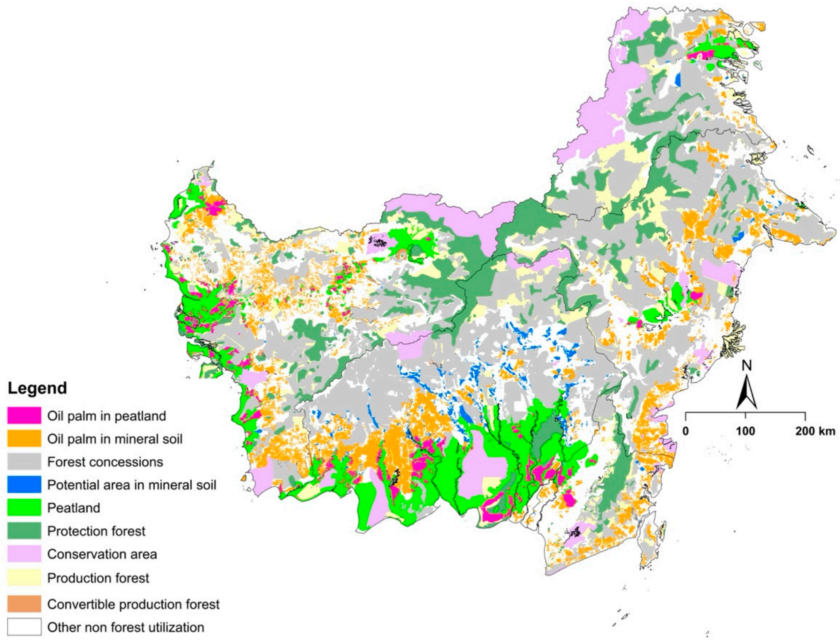

Figure 6. Land utilization in Kalimantan, Indonesia.

3.2. Potential Area for Land Swapping

The convertible production forest (HPK) is chosen as one of the parameters for identifying the potential area for oil palm plantation due to the Government of Indonesia's (GoI) regulation, which allows HPK to be converted for non-forest utilization, such as oil palm plantation [20]. An analysis shows that mineral soil is available under the HPK of approximately 0.64 million ha (Figure 7), mostly concentrated in the Central Kalimantan Province (0.42 million ha). The potential area for land swapping consists of eight types of land cover: secondary dryland forest, secondary mangrove forest, secondary swamp forest, dryland agriculture, dryland agriculture mixed with shrubs, shrubs, swamp shrubs, and open land, as shown in Table 2.

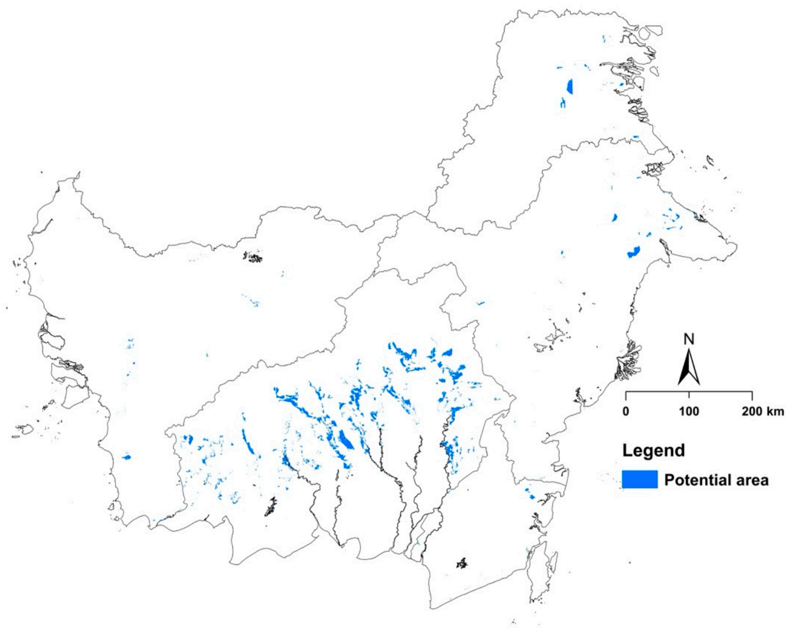

Figure 7. The potential area for oil palm plantations in mineral soil (0.64 million ha) in Kalimantan, Indonesia.

Table 2. Land cover for the potential area in convertible production forest (hutan produksi konversi/HPK) in Kalimantan.

Land Cover in 2020	Area (ha)
Swamp shrubs	85,961.31
Secondary dryland forest	178,422.90
Secondary mangrove forest	2015.05
Secondary swamp forest	60,126.76
Dryland agriculture	8748.74
Dryland agriculture mixed with shrubs	180,038.77
Shrubs	114,710.59
Open land	11,750.77
TOTAL	641,774.89

Figure 8 shows how the land swapping of oil palm plantations in peatland to mineral soil will be conducted. Oil palm plantations will be replanted in mineral soil at approximately 0.64 million ha, while the previous oil palm plantation area in peatland (0.64 million ha) will be restored using the broadleaf species. The remaining oil palm plantations in peatland (0.44 million ha) will be sustainably managed.

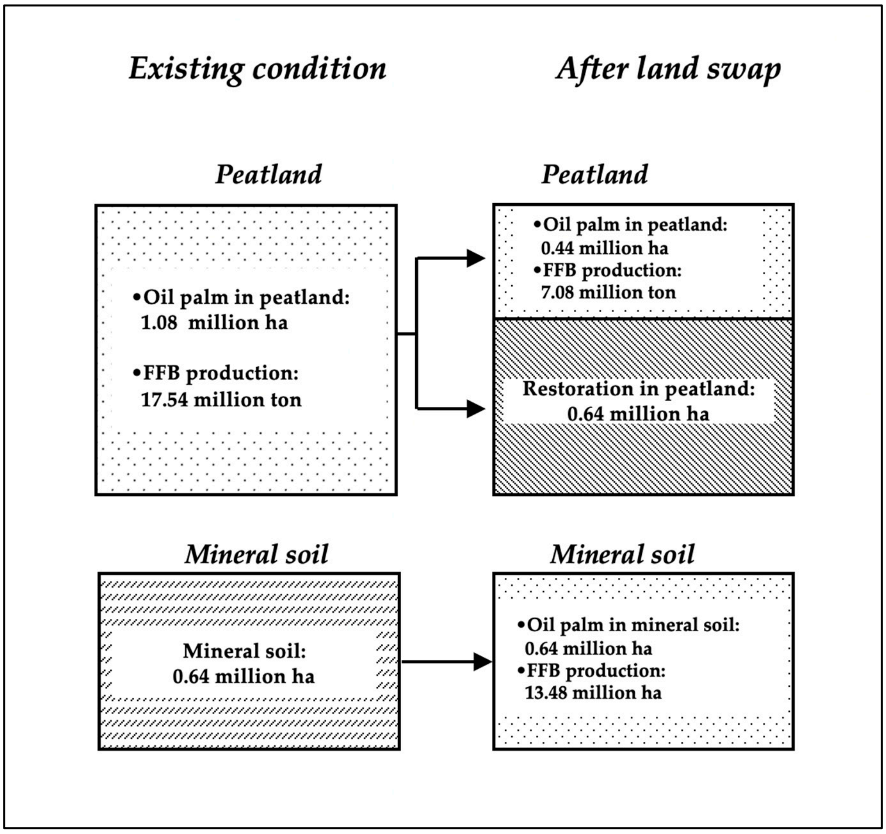

Figure 8. Illustration of land swap from peatland to mineral soil.

Table 3 shows the carbon stock and potential net emission from the potential area for land swaps in mineral soil. The calculation is performed for 25 years (a one-cycle life span of oil palm plantations) and 50 years (two cycles of oil palm plantations). The existing condition is if oil palm plantations continue to be cultivated in the peatland, while the option of 25 and 50 years is if the land swap option is executed in a 0.64 million ha area in mineral soil. Both options include the potential amount of carbon stock from biomass, which will produce emissions once the biomass is lost. In terms of soil emissions, four gasses were measured in this study, namely CO_2, CH_4, N_2O, and DOC. Peatland has the highest soil emissions in both options, while the soil emissions from mineral soils are considered zero [25]. According to Table 3, in 25 years, the existing condition (oil palm plantation in peatland) has the potential to store carbon at approximately 54.58 MtC, while in the land swap option for 25 years and 50 years, the remaining oil palm plantation in peatland, peatland restoration, and oil palm plantations in mineral soil have the potential to store carbon at approximately 109.44 MtC and 126.22 MtC, respectively. In terms of soil emissions, the soil emissions from peatland for the existing conditions are 1173.97 $MtCO_2eq$. For the land swap options, the soil emissions in 25 years and 50 years are 558.55 $MtCO_2eq$ and 1117.10 $MtCO_2eq$, respectively, while the soil emission from mineral soil is considered zero [25,30]. Thus, the potential net emission from the current practice is 973.84 $MtCO_2eq$, while in the land swap option, the total potential net emissions for 25 years and 50 years are 336.64 $MtCO_2eq$ and 883.67 $MtCO_2eq$, respectively. By swapping the oil palm plantation in peatland to mineral soil, there will be a 65.43% potential emission reduction for the 25 years option and a 61.19% potential emission reduction for the 50 years option.

Table 3. Carbon stock and potential emissions in the potential area for land swapping in Kalimantan, Indonesia.

Parameter	Land Utilization	Existing Condition (Year)		Land Swap (Year)	
		0–25	0–50	0–25	0–50
Average carbon stock (MtC)	Oil palm in peatland	54.58	54.58	22.28	22.28
	Restoration in peatland			54.76	71.54
	Mineral soil	48.92	48.92		
	Oil palm in mineral soil			32.40	32.40
Subtotal (MtC)		103.50	103.50	109.44	126.22
Potential carbon emissions from biomass ($MtCO_2$)	Oil palm in peatland	(200.13)	(200.13)	(81.69)	(81.69)
	Restoration in peatland			(200.79)	(262.31)
	Mineral soil			179.37	179.37
	Oil palm in mineral soil			(118.80)	(118.80)
Subtotal ($MtCO_2$)		(200.13)	(200.13)	(221.91)	(283.43)
Potential carbon emissions from soil ($MtCO_2eq$)	Oil palm in peatland	1173.97	2347.94	473.51	947.02
	Restoration in peatland			85.04	170.08
	Mineral soil				
	Oil palm in mineral soil				
Subtotal ($MtCO_2eq$)		1173.97	2347.94	558.55	1117.10
Total potential emissions ($MtCO_2eq$)		973.84	2147.81	336.64	833.67

Figure 9 shows the potential carbon stock of the existing condition and the land swap option of oil palm in peatland to mineral soil. The graph shows the option of the land swap for two cycles: 25 years and 50 years. The maximum carbon stock for the oil palm plantations in peatland for 25 years is 83.95 MtC, with an average carbon stock of 54.68 MtC. In the land swap option, the maximum carbon stock for the remaining oil palm plantations in peatland and oil palm plantations in mineral soil is 34.20 MtC and 49.75 MtC, respectively, with an average carbon stock of 22.28 MtC and 32.40 MtC, respectively. The maximum carbon stock for peatland restoration for the 25 years option is equivalent to that of the 50 years option, which is 138 MtC, with the average carbon stock for 25 years and 50 years being 42.58 MtC and 71.17 MtC, respectively.

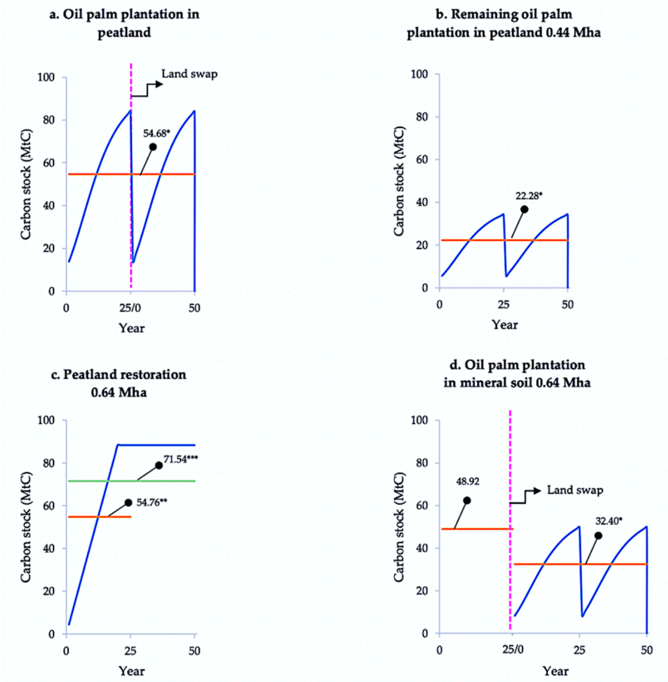

Figure 9. Potential carbon stock of existing conditions and land swapping. * Average for 0–25 years or 0–50 years; ** Average for 0–25 years; *** Average for 0–50 years.

3.3. Cost for Land Swap

The cost calculated in this study is divided into two categories: the restoration cost and replanting cost [27]. The restoration cost is the cost needed to restore the 0.64 million ha area of peatland that was previously planted with oil palm plantation into broadleaf species, while the replanting cost is the cost to plant oil palm plantation in mineral soil, which amounted to 0.64 million ha. The cost for restoration in peatland is divided into two types: hydrological restoration cost and revegetation cost. The hydrological restoration cost unit refers to Hansson and Dargusch [27], i.e., 2000 USD/ha, and the revegetation cost unit refers to Muhayah and Asysyifa [28], i.e., approximately 12,117,883 Indonesian Rupiah (IDR)/ha which is equals to 853 USD/ha (the calculation uses the exchange rate of USD 1 = IDR 14,500). Therefore, the cost for restoration amounted to 2853 USD/ha, which means that the total cost for restoration of the ex-oil palm plantation in peatland for the area of 0.64 million ha is approximately USD 1826 million (Table 4).

Table 4. Hydrological restoration and revegetation costs in peatland.

Parameter	Value
Area (a)	0.64 million ha
Canal width of 4–10 m (c)	2000 USD/ha
Revegetation (R)	853 USD/ha
TOTAL (a*(c + R))	USD 1826 million

The unit cost for replanting used in this study refers to the average cost needed for oil palm replanting in mineral soil, according to the regulation issued by the Director

General of Crops, Ministry of Agriculture, Republic of Indonesia in 2020. According to the guidance, it is assumed that after the plantation reaches three years of age [29], it will produce a fresh fruit bunch (FFB) to be harvested. The calculation uses the exchange rate of USD 1 = IDR 14,500. The total cost of planting and maintaining oil palm in mineral soil in Kalimantan until the plantation reaches three years of age is USD 2352 million (Table 5), which means that the total cost of a land swap in this study is approximately USD 4178 million.

Table 5. Cost for replanting oil palm in mineral soil.

Activities	Cost (Million USD)
Land clearing and replanting	1043
Maintenance Year 1	425
Maintenance Year 2	518
Maintenance Year 3	366
Total	2352

4. Discussion

4.1. Land Swap Option

The total oil palm plantation in peatland in Kalimantan accounted for 1.08 million ha, while the available potential area for land swapping in mineral soil was 0.64 million ha. This result contrasts with the study focused on Kalimantan Island [31], which stated that the available land for oil palm production in Indonesia is 18.2 million ha. This study focused on convertible production forest (HPK) as the potential area for land swapping in mineral soil, which is attributed to the Indonesian regulation that allows such forest functions to be converted for non-forest utilization, one of which is for oil palm plantations [20]. The amount of potential area in HPK as a result of this study is insufficient for swapping the whole oil palm plantation in the peatland with mineral soil in Kalimantan. Therefore, there is a shortage of area in mineral soil around 0.44 million ha. However, further analysis shows that among the 1.08 million ha of oil palm in peatland, 0.42 million ha are located under the protection function and the rest are under the cultivation function (0.66 million ha). The option of swapping the oil palm plantation in peatland with mineral soil should be prioritized for the plantation on the protection function first, followed by those planted on the cultivation function.

Swapping the oil palm plantation in peatland to mineral soil will increase the productivity of fresh fruit bunch (FFB). Sampling gathered from the Indonesian Sustainable Palm Oil (ISPO) report shows that the FFB productivity for oil palm in peatland and mineral soil is 16.3 t/ha and 21 t/ha, respectively. According to this study, the production of FFB will increase by 17.16% compared to the current practice, which is planted in peatland. Oil palm contributes to the economic development of Indonesia. Implementing the land swap option will help the country's target on achieving SDG by 2030, especially Goal Number 8, Decent Work and Economic Growth. The export value of crude palm oil (CPO) and other CPO in 2021 is approximately USD 26.76 million [32]. The increase in FFB will not only boost the export volume that will generate more foreign exchange, but it will also raise farmers' income. In the future, to ensure sustainable agriculture production, it is crucial to take economic sustainability into account [33].

To execute the land swap, land clearing will occur for the option of 25 years for both peatland and mineral soil. To restore peatland and to plant the oil palm in mineral soil, all vegetation in the area must be cleared, which will result in carbon removal from the biomass that is equal to 116.31 $MtCO_2eq$ from the oil palm biomass in peatland and 179.38 $MtCO_2eq$ from the biomass in mineral soil. Such emissions only happen once the land is cleared. Once the mineral soil is planted with oil palm, there will be no carbon removal from the biomass or the soil. Khasanah et al. [30] assumed that C_{stock} in mineral soils neither increases nor decreases due to oil palm cultivation; in addition, the IPCC also considers the emission from mineral soil to be zero [25]. Therefore, in this study, the source of emission in mineral soil originated from the biomass itself once it was eliminated. If one continues calculating for the second, third, and n-cycles of oil palm plantations, the largest potential net emission in mineral soil will occur during the first cycle. The potential net emission from the second and third cycles is considered zero since there is no land use change, so the carbon emission and removal are balanced.

The restoration in peatland explains approximately 0.64 million ha oil palm plantations in peatland that are moved to mineral soil. That area will be restored by planting broadleaf species to regain its initial condition. It is important to perform a restoration over peatland, which was previously utilized for agriculture. According to one study [34], the degradation cycle in Borneo Island is alarming since there were unmanaged secondary growth areas and peatland exploitation without further development. Such exploitation increased carbon dioxide (CO_2). Another study [7] suggested that the restoration of degraded peatland is needed to address the degraded peatland issue and its associated impact, especially in the Southeast Asian region.

Numerous potential net emissions from peatland show the importance of peat swamp forests as the largest carbon pool of soil organic carbon [35]. In 2018, the Government of Indonesia imposed a moratorium on the expansion of oil palm plantations countrywide for 3 years [36]. Another study [35] revealed that to avoid peatland degradation, the policy should be implemented permanently rather than as a short period of moratorium. This study that covers an area of 1.08 million ha reveals that swapping oil palm plantation in peatland to mineral soil will potentially reduce emissions for 25 years and 50 years by approximately 637.20 $MtCO_2eq$ and 1314.14 $MtCO_2eq$, respectively. Therefore, the land swap option will contribute to the reduction in emissions in Indonesia in agriculture, forestry, and other land use (AFOLU) sectors. Oil palm in peatland is one contributor of emissions in AFOLU sectors [8]. Indonesia and Malaysia as the two largest oil-palm-producing countries, might encounter similar situation over their peatland due to the expansion of oil palm plantation. The Government of Malaysia decided to limit the oil palm plantation in their country by up to 6.5 million ha in 2023 to prevent further deforestation and conversion of peatland into oil palm plantations, as well as to reduce CO2 emissions [9]. For a better management of oil palm in peatland, this land swap option with some adjustment will potentially be adopted by the Malaysian government.

The land swap option in this study, which consists of peatland restoration activity, will contribute to the Government of Indonesia's commitment to reduce emissions nationwide by 31.89% unconditionally and 43.20% conditionally by 2030 [37]. The result of this study will also support the Government of Indonesia's achievement on SDG 13 (climate action) and SDG 15 (life on land), since the potential of emission reduction positively contributes to the climate change mitigation and adaption, and the improvement of peatland and degraded land, which in return will improve the quality life on land.

4.2. Land Swap Cost

Based on the calculation, the total cost for land swapping for an area of 0.64 million ha is USD 4178 million. That amount is considerably large regarding the restoration of the peatland ecosystem due to the high cost of restoring the hydrological function. However, there will be a trade-off over the high cost for land swap and the economic benefit, such as the increase in FFB's productivity and environment-related aspects, such as reduction in emissions, as well as the potential profit from the carbon trading.

Furthermore, the Peatland and Mangrove Restoration Agency, Republic of Indonesia, currently allocated a peatland restoration budget of 12,000,000 IDR (828 USD)/ha. This amount is consistent with a study [28] that stated that the revegetation cost for peatland in South Kalimantan is approximately 853 USD/ha. However, the budget allocated by the Government of Indonesia and Muhayah and Asysyifa [28] does not consider the hydrological restoration cost. The hydrological cost was measured as part of peatland restoration to reduce the spread of fires to mitigate CO_2 emissions [30]. Therefore, this study included the hydrological restoration cost for peatland restoration since the area that will be restored is the ex-oil palm plantation, which will be prone to fire once its vegetation is cleared

Considering the current practice of peatland restoration implemented by the Indonesian government, the option of restoring the hydrological function can be executed. The potential income from the carbon trade scheme could be considered one of the prospective sources of funds for the land swap. The Government of Indonesia enacted a carbon tax regulation of 30,000 IDR/tCO_2eq, which equals to 2.1 USD/tCO_2eq using the exchange rate of USD 1 = IDR 14,500 [28]. In the current practice, such a tax will be imposed on the energy sector and will be followed by other sectors. There is another possibility as a source of land swap funding. The Indonesian government implemented an oil palm replanting program for smallholder farmers (Program Peremajaan Sawit Rakyat/PSR) in 2017. With this program, a smallholder farmer can obtain funding from the government in the amount of 30,000,000 IDR/ha (2069 USD/ha) [38]. Since its implementation, the program was able to cover approximately 0.24 million ha to be replanted.

The Government of Indonesia has enacted a carbon tax scheme for the energy sector. The carbon tax in current practice, imposed by the Government of Indonesia, is around 2.1 USD/tCO_2eq [28], whilst the median price for carbon in the Asian region is approximately 28 USD/tCO_2 [39]. This policy creates opportunities to generate income from carbon trade that is potentially implemented in the peatland restoration area as one of the sources for land swap funds. This is also supported by the enactment of the new Indonesian Government Regulation Number 98 Year 2021 on Carbon Economic Value to support NDC's targets and GHG emission control [40]. In addition, considering the minimum current carbon tax price (2.1 USD/tCO_2eq) [41] in Indonesia, the option to restore the peatland would potentially benefit the Indonesian government by minimum USD 92,284 for 25 years and 190,323 USD for 50 years. While using the average carbon price in the Asian region (28 USD/tCO_2eq) [39], the potential benefit for 25 years and 50 years could reach USD 1.23 million and USD 2.54 million, respectively.

4.3. Land Swap Strategy

Spatial analysis shows that the potential area for land swapping in mineral soil is approximately 0.64 million ha, which is insufficient to move the whole oil palm in peatland in Kalimantan since the total oil palm plantations reached 1.08 million ha. In addition, the result also shows that the oil palm plantation in peatland under the protection function is approximately 0.42 million ha. Therefore, land swapping will be prioritized for plantations under the protection function and followed by the remaining plantations under the cultivation function. Ideally, land swapping is executed after the oil palm plantation reaches its optimum life cycle of 25 years and/or once the plantations are no longer productive.

There are several aspects that need to be considered in implementing land swaps, such as the transportation network, location of palm oil mills, access to the market, and environmental impact. The land swap option might cause soil degradation [42]; therefore, the execution of land swap must apply good agricultural practices to minimize the environmental impact. In addition, to ensure the sustainability of the palm oil industry, the Indonesian Government enacted the Indonesian Sustainable Palm Oil (ISPO) since 2011, with the latest revision in 2020 [12]. ISPO is a certification scheme that is mandatory for all oil palm business entities in Indonesia. It regulates three aspects of sustainability: economic, social, and environmental. By implementing ISPO, the negative impact of oil palm utilization, such as land degradation, could be minimized because it was managed sustainably.

Indonesian Government policy interventions at all levels are crucial to execute land swap. According to Law Number 11 Year 2020 on job creation [43], the central government has the authority to control and monitor the peatland management and impose the moratorium of oil palm plantation in peatland. The local government has the authority to control and monitor the peatland management on non-forest areas (Areal Penggunaan Lain/APL). The local government also contributes to the facilitation of the replanting program and provides technical recommendations on new plantations based on the prevailing laws. Challenges will occur in executing the land swap, be it from the company and the farmers themselves or among the stakeholders. Therefore, multistakeholder approaches need to be conducted to gain awareness and support for implementing land swapping for better oil palm management in Indonesia.

5. Conclusions

According to the analysis, the potential area for land swapping in the mineral soil is approximately 0.64 million ha, which is not sufficient to swap the oil palm plantations in peatland in Kalimantan. On the other hand, swapping the oil palm in peatland with mineral soil can be an option to mitigate greenhouse gas emissions from the palm oil industry. The result shows that the land swap option will potentially reduce emissions over 25 years by 65.43%, while over 50 years, it will potentially reduce emissions by 61.19% from the initial condition and increase the productivity of FFB by 17.16% per year. Initially, the emission reductions from the land swap option are equal in benefit for the Indonesian government, which could save minimum USD 92,284 in 25 years and USD 190,323 in 50 years. When using the median carbon price in the Asian region, the potential benefit for 25 years and 50 years could reach USD 1.23 million and USD 2.54 million, respectively.

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Abbreviations

AFOLU	Agriculture forestry and other land use
C	Carbon
CMEA	Coordinating ministry for economic affairs
CO_2eq	Carbon dioxide equivalent
CPO	Crude palm oil
DOC	Degradable organic carbon
FFB	Fresh fruit bunch
FOLU	Forestry and other land use
GoI	Government of Indonesia
g	gram
GWP	Global warming potential
ha	Hectare
HPK	Hutan produksi konversi/Convertible production forest
IDR	Indonesia rupiah
INCAS	Indonesian national carbon accounting system

IPCC	Intergovernmental panel on climate change
ISPO	Indonesian sustainable palm oil
M	Million
MoA	Ministry of Agriculture
MoEF	Ministry of Environment and Forestry
NDC	Nationally determined contribution
SDG	Sustainable development goals
t	Tonne
USD	United states dollar

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