JURNAL ILMU LINGKUNGAN
Volume 23 Issue 5 (2025) : 1404-1411 ISSN 1829-8907

Economic Valuation of Peatland Carbon Sequestration in the Revegetation Area of the Kebun Plasma Nutfah, Kedaton Village, Kayuagung District, South Sumatra Province

Olce Veronica[1], Eka Intan Kumala Putri[1], Dea Amanda[1], and Nuva[1]

[1]Department of Resource and Environmental Economics, Faculty of Economics and Management, IPB University, Bogor, Indonesia; e-mail: olceveronica@apps.ipb.ac.id

ABSTRAK

Lahan gambut di Indonesia saat ini mengalami deforestasi dan degradasi yang disebabkan oleh kebakaran lahan gambut. Kebijakan restorasi gambut yang telah diberlakukan bertujuan untuk menanggulangi kebakaran lahan gambut sekaligus mencegah terjadinya kebakaran lahan gambut berulang. Restorasi lahan gambut diperlukan karena kebakaran lahan gambut menyumbang emisi yang besar ke lingkungan yang berdampak terhadap perubahan iklim. Kebun Plasma Nutfah yang berlokasi di Kabupaten Ogan Komering Ilir, Provinsi Sumatera Selatan merupakan salah satu pilot project restorasi gambut berkas kebakaran. Kebun Plasma Nutfah merupakan lahan gambut yang terbakar berulang pada tahun 1997 dan 2006 saat musim kemarau. Kebun Plasma Nutfah telah dilakukan penanaman kembali dengan menggunakan komoditas yang adaptif terhadap kondisi lahan gambut. Studi ini bertujuan untuk melakukan monetisasi serapan karbon di Kebun Plasma Nutfah dan mendefinisikannya sebagai nilai ekonomi menggunakan tingkat ketelitian Tier 2. Perhitungan nilai ekonomi serapan karbon dilakukan pada *carbon pool* atas permukaan dan bawah permukaan lahan gambut di Kebun Plasma Nutfah seluas 10 hektar. Hasil penelitian ini menunjukkan bahwa Kebun Plasma Nutfah memiliki serapan karbon sebesar 121.606.27 ton, dan nilai ekonomi serapan karbon sebesar Rp 48.216.885.174. Semakin besar diameter pohon, maka semakin besar kemampuan pohon dalam menyerap CO_2, dan semakin dalam gambut, maka semakin besar cadangan karbon yang terkandung. Lahan gambut berfungsi sebagai penyimpan karbon, namun juga berpotensi menjadi bahan bakar ketika musim kemarau sehingga menghasilkan emisi yang besar ketika terjadi kebakaran. Kondisi Kebun Plasma Nutfah saat ini membutuhkan pengelolaan kolaboratif untuk melestarikan Kebun Plasma Nutfah dan mencegah terjadinya kegiatan yang dapat menyebabkan terjadinya kerusakan lahan gambut di Kebun Plasma Nutfah.

***Kata kunci*:** Degradasi, Gambut, Kebakaran gambut, Restorasi, Serapan karbon

ABSTRACT

Peatlands in Indonesia are currently experiencing deforestation and degradation caused by peatland fires. The Peatland restoration policy that has been established aims to tackle Peatland fires while preventing them from recurring. Peatland restoration is necessary because peatland fires contribute large emissions to the environment, impacting climate change. Kebun Plasma Nutfah located in Ogan Komering Ilir District, South Sumatra Province is one of the pilot projects to restore burnt peat swamp forests. Kebun Plasma Nutfah is a peat swamp forest that burned repeatedly in 1997 and 2006 during the dry season. Kebun Plasma Nutfah was then revegetated with commodities that are adaptive to peatlands. This study aimed to monetize Kebun Plasma Nutfah's carbon sequestration and define it as the economic value of peat swamp forest with a Tier 2 accuracy. The calculation of the economic value of carbon sequestration was carried out on above-ground and below-ground carbon pools in the 10-hectare peatland in Kebun Plasma Nutfah. The results of this study show that Kebun Plasma Nutfah has a carbon sequestration of 121.606,27 tons, with an economic value of carbon sequestration of Rp 48.216.885.174. The larger the diameter of the tree, the greater the CO_2 that the tree can absorb, and the deeper the peat, the higher the carbon stock. Peatland is indeed a carbon stock, but it has the potential to become fuel during the dry season, resulting in large emissions when fires occur. The current condition of the Kebun Plasma Nutfah requires collaborative management to preserve the Kebun Plasma Nutfah and prevent activities that can cause damage to peatlands in Kebun Plasma Nutfah.

***Keywords*:** Burnt peatland, Carbon sequestration, Degradation, Peatland, Restoration

Citation: Veronica, O., Putri, E. I. K., Amanda, D., Nuva. (2025). Economic Valuation of Peatland Carbon Sequestration in Kebun plasma Nutfah, Kedaton Village, Kayuagung District, South Sumatra Province. Jurnal Ilmu Lingkungan, 23(5), 1404-1411, doi:10.14710/jil.23.5.1404-1411

1. INTRODUCTION

Peat is an organic material formed naturally from incompletely decomposed plant remains with a thickness of up to 50 cm and accumulates in swamps (Ministry of Environment and Forestry, 2017). The incomplete decomposition process of plant remains makes peat able to store large amounts of carbon (Murdiyarso *et al.* 2017). Globally, peatlands can store around 329-525 GtC or 15-35% of total terrestrial carbon. About 445 GtC or 86% of the peatland carbon is found in temperate regions (Mickler *et al.* 2017; Leifeld & Menichetti 2018) such as Canada and Russia, while the other 14% is in the tropics, which is about 70 Gt, and Indonesia contributes 46 Gt to the carbon stock of tropical peatlands (Murdiyarso *et al.* 2017).

Indonesia contains the world's largest tropical peatland area (Page *et al.* 2011; Uda *et al.* 2020) but with a significant number-about 3,74 million hectares or 25,1% has been degraded (Wahyunto & Dariah 2014), mainly due to deforestation and recurrent fires (Leng *et al.* 2019; Sanjaya *et al.* 2023). These fires emit large amounts of greenhouse gases, contributing to climate change (Nara *et al.* 2017; Setyawati & Suwarsono 2018). While intact peatlands act as major carbon sinks, degradation causes long-term CO_2 emissions unless restoration is implemented (Page *et al.* 2011; Jauhianien *et al.* 2016).

Climate change has become a global issue, largely driven by rising greenhouse gas (GHG) emissions. One major source of these emissions is forest and land fires, particularly in peatland areas, which account for about 54% of Indonesia's total GHG emissions (Yuningsih *et al.* 2018). Indonesia's climate change mitigation efforts focus on two key sectors, the forestry sector as a source of carbon sequestration and the energy sector to reduce GHG emissions from energy generation, transportation, industry, cities, and peatlands (Irawan & Purwanto 2020). Efforts to enhance carbon sequestration include sustainable forest management, prevention of deforestation and forest degradation, tackling illegal logging, prevention of forest and land fires, and forest and land restoration (Siagian *et al.* 2024).

The peat restoration policy has been in place since 2017 intending to tackle peatland fires as well as preventing fires from occurring in the following year. One of the peat restoration techniques is revegetation (replanting). Revegetation is an effort to restore land cover in peat ecosystems by planting native peat species or species that are adaptive to peatlands (Peraturan Menteri Lingkungan Hidup dan Kehutanan, 2017). The restoration of degraded peatlands must consider the peat ecosystem covering diverse endemic tree species (Page & Waldes 2008). Especially revegetation needs to increase land cover which can increase carbon sequestration.

In this area, the peatland burnt repeatedly during the dry season in 1997 and 2006. The natural succession that formed 4 years after the fire, consisted only of ferns and swamp grass, no succession of trees. At the end of 2010, the revegetation of the burned forest by planting a native peatland tree species started. The species planted included Jelutung Rawa (*Dyera lowii*), Ramin (*Gonystylus bancamus*), Punak (*Tetramerista glabra*), Meranti (*Shorea belangeran*), and along with several other local tree varieties. The canopy closure increased from 0% before planting to 50-70% after planting and an increase in carbon sequestration by planted tree species (BP2LHK Palembang 2017).

The estimation of the economic worth of carbon is anticipated to give a general overview of the financial gains that connected parties will make if they maintain their forest stands as part of their efforts to lower the level of carbon emission on Earth (Amru *et al.* 2023). Additionally, it is anticipated that determining the economic worth of carbon is a way to prepare for possible and will make it easier to conduct transactions in carbon trading (Suwarna *et al.* 2012; Amru *et al.* 2023).

This paper presents the economic value of carbon sequestration in the revegetation of burned peatland forest in Kebun Plasma Nutfah, Ogan Komering Ilir District, South Sumatra Province. In this study, the economic value of carbon sequestration in the revegetated area of Kebun Plasma Nutfah only calculated four commodities, namely Jelutung Rawa (*Dyera lowii*), Ramin (*Gonystylus bancamus*), Punak (*Tetramerista glabra*), Meranti (*Shorea belangeran*). The calculation of the economic value of carbon sequestration was carried out using Tier 2 accuracy levels.

2. METHODOLOGY

2.1. Research Location and Time

The study was conducted between February and May 2024. The research location was Kebun Plasma Nutfah in Kedaton Village, Kayuagung District, South Sumatra Province, in coordinate -3.396291, 104.857893. Kebun Plasma Nutfah is a peatland that has been revegetated after a fire as a result of a collaboration between the Environment and Forestry Research and Development Agency of Palembang and The International Tropical Timber Organization (ITTO) in 2010 until 2023.

2.2. Data Collection Method

Information data was gathered from the booklet "The Demonstration Plot of Ex-Fire Peat Swamp Forest Restoration" which was published by the Environment and Forestry Research and Development Agency of Palembang.

2.3. Data Analysis Method

The estimation of the economic value of carbon sequestration in Kebun Plasma Nutfah was carried out with a Tier 2 level of accuracy. Tier 2 uses data obtained from previous research at the national level without taking data directly from the field by researchers.

The carbon price in this study refers to the Singapore carbon price in 2024 stated in the World

Bank Group State and Trends of Carbon Pricing (2023) which is SGD25/ton C, while the exchange rate used in this study is Rp 15,860.

1) Biomass

The estimation of biomass was carried out on the above-ground carbon pool and below-ground carbon pool. The equation used to estimate above-ground biomass is as follows (Murdiyarso *et al.* 2004).

$$AGB = \sum_{i=1}^{4} BJ_i \times 0{,}19 \times Di_i^{2,37} \times JP_i \quad (1)$$

Description:

AGB	: Above Ground Biomass (kg)		
BJ_i	: Wood specific gravity (g/cc)		
	1.	Jelutung Rawa	: 0,36 g/cc
	2.	Ramin	: 0,84 g/cc
	3.	Punak	: 0,80 g/cc
	4.	Meranti	: 0,86 g/cc
D_i	: Diameter (cm)		
JPi	: Number of trees		
	1.	Jelutung Rawa	:2375 trees
	2.	Ramin	: 475 trees
	3.	Punak	: 475 trees
	4.	Meranti	:1425 trees

2) Carbon Stock

The estimation of carbon stock in above-ground and below-ground carbon pools uses different approaches. The estimation of the aboveground carbon stock is done by converting the AGB content using a conversion factor, where the carbon fraction uses the following common values used at the global level (Murdiyarso *et al.* 2004).

$$AGCS = 0{,}5 \times AGB \quad (2)$$

Description:

AGCS : Above-ground carbon stock (kg)
0,5 : Carbon fraction (conversion factor)
AGB : Above-ground biomass (kg)

The calculation of below-ground carbon stock requires data on peat soil content and the percentage of C-Organic content based on the maturity level of the peat soil. Peatlands in Kebun Plasma Nutfah have a hemic maturity level, so the values of peat soil content and C-Organic content used are 0.1716 tons/m^3 and 48%. The formula for below-ground carbon stock is as follows (Wahyunto *et al.* 2003; Murdiyarso *et al.* 2004).

$$BGCS = W \times A \times D \times \%C - organik \quad (3)$$

Description:

BGCS : Below-ground carbon stock (kg)
W : Bulk density (0,1716 ton/m^3)
A : Peat area (m^2)
D : Depth of peat (m)
%C-organic : C-organic percentage (48%)

3) Economic Value of Carbon Sequestration

The estimation of the economic value of carbon sequestration in the above and below-ground carbon pool uses different approaches. For the above-ground carbon pool, the conversion of carbon stock into CO_2 sequestration is carried out, while for the below-ground carbon pool, the calculation of carbon uptake is carried out and then continued by converting carbon uptake to CO_2 sequestration. After each carbon pool is obtained the uptake value of CO_2it can be converted to monetary value to obtain the economic value of carbon sequestration in peatlands. The equation used is as follows (Hardjana 2010).

$$ACO_2 = AGCS \times 3{,}67 \quad (4)$$

Description:

$AC0_2$: Above-ground carbon sequestration (ton)
$AGCS$: Carbon stock atas permukaan (ton)
3,67 : Conversion factor

To estimate the economic value of below-ground carbon sequestration, carbon uptake was first calculated from the potential carbon sequestration of peat soils in Southeast Asian tropical rainforest of 65 % (Warren *et al.* 2017), where the percentage will be used in the carbon uptake determination equation (Legawa 2021).

$$CU = 65\% \times BGCS \quad (5)$$

Description:

CU : Carbon uptake (ton)
BGCS : Below-ground carbon stock (ton)

After calculating the carbon uptake, the conversion of carbon uptake of $C0_2$ was carried out using the following equation (Legawa 2021).

$$BCO_2 = \frac{MRCO_2}{ARC} \times CU \quad (6)$$

Description:

B$C0_2$: Below-ground carbon sequestration (ton)
MR$C0_2$: Conversion factor (44)
ARC : Conversion factor (12)
CU : Carbon uptake (ton)

After obtaining carbon uptake in each carbon pool above and below ground, the estimated value of carbon uptake is obtained using the following equation (Simbolon *et al.* 2015).

$$EC = CO_2 \times CP \times NT \quad (7)$$

Description:

EC : Economic value of carbon (Rp)
$C0_2$: $C0_2$ sequestration (ton)
CP : Carbon price (SGD 25/tonC)
NT : Exchange rate (IDR 15.860/SGD)

3. RESULTS AND DISCUSSION

The first step in estimating carbon stock and the economic value of carbon sequestration using Tier 2 is to collect data from the components of the estimation calculation. For peatlands with land cover, the identification of tree species, the number of trees, and the diameter of each tree species are needed to estimate the above-ground biomass (AGB), which will be used to obtain the above-ground carbon stock using a conversion factor. Tree diameter can be determined by multiplying the annual diameter increment with the age of the tree, while the number of trees can be determined by using the spacing and percentage of live trees. The peatland in Kebun Plasma Nutfah has tree cover with the dominant tree species Jelutung Rawa (*Dyera lowii*), Ramin (*Gonystylus bancanus*), Punak (*Tetramerista glabra*), and Meranti (*Shorea belangeran*). To estimate the biomass content of trees, tree diameter and number of trees are required. The tree diameter and number of trees in Kebun Plasma Nutfah used in this study are represented in Table 1.

Table 1. Trees Diameter and Number of Trees in Kebun Plasma Nutfah

No	Tree species	Diameter increment (cm/tahun)	Tree diameter (cm)	Number of trees
1	Jelutung Rawa	2,83	39,62	2375
2	Ramin	1,36	19,04	475
3	Punak	1,36	19,04	475
4	Meranti	2,36	33,04	1425

Source: Environment and Forestry Research and Development Agency of Palembang (2017)

The number of trees standing in Kebun Plasma Nutfah is known by the planting distance used, which is 5×4 meters, assuming 500 stems/hectare and the percentage of live trees is 95%. In Kebun Plasma Nutfah, each tree species is planted in a different area. Jelutung Rawa was planted on 5 hectares, Ramin 1 hectare, Punak 1 hectare, and Meranti 3 hectares (BP2LHK Palembang 2017).

The estimated economic value of carbon sequestration refers to the Singapore carbon price in 2024 in the World Bank Group State and Trends of Carbon Pricing (2023) which is SGD25/ton C, while the exchange rate used in this study is IDR 15.860.

3.1. Estimating the Economic Value of Above-Ground Carbon Sequestrations in Kebun Plasma Nutfah

Estimating the economic value of carbon sequestration on the above ground of Kebun Plasma Nutfah requires the estimation of AGB and carbon stock. AGB estimation requires data on tree species, tree diameter, and number of trees. The calculation steps for estimating the AGB of Kebun Plasma Nutfah are presented in Table 2.

Based on Table 2, it can be seen that the total biomass contained in each tree has different biomass values. The amount of biomass value of a tree is influenced by different stand conditions such as tree age, stand composition and structure, tree height, and tree diameter (Qirom *et al.* 2019; Sitaniapessy & Papilaya 2019). The size of tree dimensions affects the biomass and carbon storage potential and $C0_2$ uptake of vegetation compared to vegetation density (Qirom *et al.* 2019).

The estimation results of AGB in Kebun Plasma Nutfah indicate that Jelutung Rawa (*Dyera lowii)* possesses the highest total biomass potential among the tree species assessed. It is because Jelutung Rawa was planted in the largest area, so the number of trees is greater than other trees. The potential biomass of Jelutung Rawa from this study was smaller than the results of the study by Indriani *et al.* (2015) in the peat swamp forest of the Giam Siak, which showed that the biomass of Jelutung Rawa planted in the Biosfer Giam Siak Kecil-Bukit Batu was 499.015 kg/ha. While the AGB found in Jelutung Rawa in this study was 198.978 kg/ha. This may occur when there is a difference in tree diameter. The larger the diameter of the tree, the greater the $C0_2$ that can be absorbed by the tree, so that the biomass stored will be greater (Dharmawan & Siregar 2008).

Additionally, among all species studied, Meranti (*Shorea belangeran*) exhibited the highest AGB per hectare, it was 309.079,75 kg/ha. It happens because of the bulk density and the diameter of Meranti is the largest than other species. AGB of Meranti (*Shorea belangeran*) in Kebun Plasma Nutfah was larger than Meranti Batu (*Shorea uliginosa*) in Biosfer Giam Siak Kecil-Bukit Batu study by Indriani *et al.* (2015). The type of Merati in Kebun Plasma Nutfah has a carbon stock of 309.079 kg/ha, while Meranti Batu in Biosfer Giak Siak Kecil-Bukit Batu has 88.867 kg/ha.

After obtaining the AGB, the calculation for the estimation of carbon stock on the above ground can be done by multiplying the AGB by the conversion factor. The estimated carbon stock content on the above-ground Kebun Plasma Nutfah is presented in Table 3. Based on Table 3, the largest potential carbon stock in Kebun Plasma Nutfah was found in Jelutung Rawa (*Dyera lowii*), while the largest carbon stock per hectare was found in Meranti (*Shorea belangeran*) 154.539,877 kg/ha.

Table 2. Estimation of above-ground biomass in Kebun Plasma Nutfah

No	Tree species	Bulk density (g/cc) (BJ)	Diameter (cm) (D)	Number of trees (JP)	$AGB\ (kg) = \sum_{i=1}^{4} BJ_i \times 0{,}19 \times D_i^{2{,}37} \times JP_i$
1	Jelutung Rawa	0,36	39,62	2375	994.894,46
2	Ramin	0,84	19,04	475	81.759,30
3	Punak	0,80	19,04	475	77.866,00
4	Meranti	0,86	33,04	1425	927.239,25
		Total			2.801.759,01

Data processing result (2024)

Table 3. Estimation of Above-Ground Carbon Stock in Kebun Plasma Nutfah

Tree species	AGB (kg)	Above-ground carbon stock (kg/ha)	$Total\ AGCS\ (kg) = 0,5 \times AGB$
Jelutung Rawa	994.894,46	99.489,446	497.447,23
Ramin	81.759,30	40.879,65	40.879,65
Punak	77.866,00	38.933,00	38.933,00
Meranti	927.239,25	154.539,877	463.619,63
Total			1.040.879,50

Data processing result (2024)

After obtaining the results of the estimation of carbon stock on the above ground, it can be continued with the conversion to $C0_2$ sequestration by using the conversion factor for carbon stock on the above ground presented in Table 4.

Table 4. Estimation of above-ground $C0_2$ sequestration in Kebun Plasma Nutfah

Tree species	AGCS (kg)	$AC0_2(kg) = AGCS \times 3,67$
Jelutung Rawa	497.447,23	1.825.631,33
Ramin	40.879,65	150.028,31
Punak	38.933,00	142.884,11
Meranti	463.619,63	1.701.484,03
Total		3.820.027,78

Data processing result (2024)

The $C0_2$ sequestration in the revegetation area of the Kebun Plasma Nutfah was found to be approximately 3.820.027,78 kg. This number shows the potential of vegetation in the Kebun Plasma Nutfah to absorb $C0_2$ from the atmosphere. Ecologically, the presence of vegetation with high carbon sequestration capacity helps reduce $C0_2$ concentrations in the atmosphere (Leifeld and Menichetti 2018), stabilize the local climate, and supports the function of peat ecosystems in maintaining global balance (Junaedi *et al.* 2022).

After obtaining the $C0_2$ sequestration, then the value of carbon sequestration is converted to monetary value by referring to the Singapore carbon price in 2024 in the World Bank Group State and Trends of Carbon Pricing (2023) which is SGD25/ton C, while the exchange rate used in this study is IDR 15.860. Referring to the carbon price, the economic value of carbon sequestration of each tree species in presented in Table 5.

Table 5. Estimation of the Economic Value of Carbon Sequestration on the Above-Ground in Kebun Plasma Nutfah

Tree species	$AC0_2$ (ton)	$EC\ (Rp) = AC0_2 \times CP \times NT$
Jelutung Rawa	1.825,63	723.862.823
Ramin	150.03	59,486.225
Punak	142.88	56.653.548
Meranti	1.701,48	674.638.417
Total		1.514.641.014

Data processing result (2024)

Based on the calculations presented in Table 5, the total estimated economic value of carbon sequestration above-ground reaches IDR 1.514.641.014. This value represents the estimated economic benefits generated from the ability of vegetation in the Kebun Plasma Nutfah revegetation area to sequester carbon. Thus, these results demonstrate the significant economic value of peatland ecosystem services derived from carbon sequestration by vegetation in the area.

3.2. Estimating the Economic Value of Below-Ground Carbon Sequestrations in Kebun Plasma Nutfah

Estimating the economic value of above-ground carbon sequestration is done by estimating the below-ground carbon stock first. The below-ground carbon stock of peatlands is influenced by the thickness of the peat, the content weight of the peat soil, and the %C-organic content which depends on the maturity level of the peat. The area of peatland where the economic value of carbon sequestration is calculated in Kebun Plasma Nutfah is 10 hectares. Peatland in Kebun Plasma Nutfah has a maturity level of Hemic peat, which is half-rotted peat and some of the parent material is still recognizable. The estimation of below-ground carbon stock was obtained by multiplying the peat soil content weight, land area, peat thickness, and %C-organic. The peat soil and %C-organic were determined based on the maturity level of the peat, where the maturity level of the peat in Kebun plasma Nutfah is Hemic, so the peat soil content is 0.1716 g/cc the %C-organic is 48% (Wahyunto *et al.* 2003). The estimation of subsurface carbon stock in Kebun Plasma is presented in Table 6 below.

Table 6. Estimation of the Below-Ground Carbon Stock in Kebun Plasma Nutfah

Bulk density (ton/m^3) (W)	Land area (m^2) (A)	Depth of peat (m) (H)	%C-organic (%) (C)	$BGCS\ (ton) = W \times A \times D \times \%Corganic$
0,1716	100.000	6	48	49.420,8

Data processing result (2024)

The below-ground carbon stock is a measure of the soil's ability to bind $C0_2$ from the air (Buwono *et al.* 2022). Table 6 shows that the below-ground carbon stock is greater than the above-ground carbon stock (see Table 3). Peat soils store enormous amounts of carbon (Yu 2012). The deeper the peat, the higher the carbon stock (Hamzah *et al.* 2019). This is because below-ground soil, plant roots, and other dead organic matter are also carbon stores besides the soil itself. These estimation results are in line with research conducted by Sutaryo (2009) and Graham *et al.* (2022) that the peat soils store larger carbon stocks than above-ground peatlands. This below-ground peatland is indeed a carbon stock, but it has the potential to become fuel during the dry season, which can lead to widespread fires in forests and peatlands (Hamzah *et al.* 2019).

To estimate the below-ground $C0_2$ sequestration, it is necessary to calculate the carbon uptake first, where carbon sequestration in peat soils in tropical rainforests in Southeast Asia is 65% (Warren *et al.* 2017) so that this percentage is used as a conversion factor in the equation to obtain carbon uptake in peatlands (Legawa 2021). After calculating the carbon uptake, the conversion to $C0_2$ sequestration was continued. The calculation of below-ground carbon uptake and $C0_2$ sequestration is presented in Table 7.

Table 7. Estimation of the Below-Ground Carbon Sequestration in Kebun Plasma Nutfah

Carbon uptake (ton)	Carbon sequestration (ton)	Economic value of carbon sequestration (Rp)
$CU = 65\% \times BGCS$	$BCO_2 = \frac{MRCO_2}{ARC} \times CU$	$EC\ (Rp) = CO_2 \times CP \times NT$
32.123,52	117.786,24	46.702.244.160

Data processing result (2024)

Based on the calculations presented in Table 7, the total estimated economic value of carbon sequestration below-ground reaches IDR 46.702.244.160. This significant economic value indicates that the below-ground peat component contributes significantly to the total carbon sequestration of peat ecosystems. Previous studies have revealed that the subsurface of peatlands plays an important role in maintaining global carbon balance (Wright *et al.* 2011). This value also represents the potential economic benefits that can be generated if carbon sequestration is monetized through carbon trading schemes or other schemes.

Table 8. The result of the Total Estimation of the Economic Value of Carbon Sequestration in Kebun Plasma Nutfah

The estimated component	Kebun Plasma Nutfah
Carbon sequestration (ton)	121.606,27
Economic value of carbon sequestration (Rp)	48.216.885.174

Data processing result (2024)

For policymakers managing forest areas, an overview of the economic value of a forest area is intended to serve as a reference to terms for making decisions in managing and maintaining owned forest areas (Ulya *et al.* 2015; Kadir 2021; Amru *et al.* 2023) because knowing the economic valuation value of a forest area can direct the behavior of individuals, communities, and organizations (Kadir 2021).

The value of carbon sequestration in Kebun Plasma Nutfah is inseparable from the influence of the presence of vegetation. Vegetation is the source of carbon in terrestrial systems. Vegetation also acts as $C0_2$ sequestration from the atmosphere and stores it in biomass. Above-ground carbon storage, necromass storage, litter storage, below-ground carbon storage, and soil C-organic storage depend on Carbon inputs into and out of the terrestrial system, namely vegetation (Firyadi *et al.* 2018).

3.3. Carbon Management Efforts in Kebun Plasma Nutfah

To reduce carbon emissions and preserve the role of peatlands as major carbon sinks, hydrological restoration and revegetation are essential strategies. The current condition of the Kebun Plasma Nutfah is the result of revegetation which has succeeded in restoring land cover and restoring the function of carbon sequestration in peatlands. However, around the Kebun Plasma Nutfah area there are large canals built by the owner of the Plantation Permit (Izin Usaha Perkebunan-IUP). Based on field visits, it appears that the peatlands of the Kebun Plasma Nutfah are not flooded throughout the year, as is the natural condition of peatlands. Despite this, the revegetation has proven effective in reducing fire risk. Historically, Kebun Plasma Nutfah did not experience any fires during the major fire events in South Sumatra in 2015 and 2019 and has remained fire-free up to the present.

However, rewetting peatlands is necessary because moistened peat will retain its moisture so that it will not burn easily when there is a source of fire. Maintaining a water table of no less than 40 cm will also prevent the peatlands from oxidizing so that the carbon in the peat soil will not be released into the atmosphere. For now, monitoring is needed to keep the peat soil moist. Even though the canals were not built to drain water from the peat in the Kebun plasma Nutfah, they are still affected. Drained peat soils undergo oxidation, raising the risk of severe wildfires, both of which contribute to higher $C0_2$ emissions (Pindilli *et al.* 2018).

Collaborative management is needed to preserve the Kebun Plasma Nutfah. The tentative structure proposed as an effort to create a collaborative institution in the management of the Kebun Plasma Nutfah is illustrated in Figure 1.

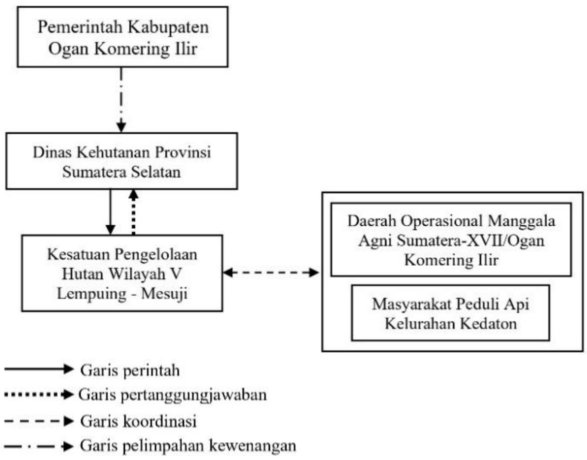

Figure 1. Tentative Structure for Collaborative Management of the Kebun Plasma Nutfah

Government of Ogan Komering Ilir District delegated management authority to the South Sumatra Provincial Forestry Service. At the field level, the South Sumatra Provincial Forestry Service instructed the Integrated Forest Management Unit V Lempuing-Mesuji/Kesatuan Pengelolaan Hutan (KPH) Wilayah V Lempuing Mesuji to manage, maintain, and supervise the Kebun Plasma Nutfah. Thus, the KPH is responsible to the South Sumatra Provincial Forestry Service. In its implementation, the

KPH coordinates with the Manggala Agni OKI, and Kedaton Village Fire Awareness Community/Masyarakat Peduli Api (MPA) Kelurahan Kedaton.

4. CONCLUSIONS

The biomass potential in Kebun Plasma Nutfah is 2.914,46 tons, the total carbon stock is 50.461,68 tons, with a total carbon sequestration potential of 121.606,27 tons, so the economic value of carbon sequestration is IDR 48.216.885,174. The results of the assessment of the economic value of carbon sequestration in Kebun Plasma Nutfah show that the area has a fairly high carbon economic value. This shows that if in its natural condition, the peatland area in Kebun Plasma Nutfah provides environmental services of high economic value in the form of carbon sequestration which is valued monetarily. Preserving the peat ecosystem in Kebun Plasma Nutfah will maintain the benefits of carbon economic value and prevent environmental disasters that occur as a result of damage to the Kebun Plasma Nutfah such as forest and land fires.

REFERENCES

Agus, F., Subiksa, I.G.M. 2008. Lahan Gambut: Potensi untuk Pertanian dan Aspek Lingkungan. Bogor. Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF).

Amru, K., Damanik, M., Ura', R. Najib, N.N., Rahmila, Y.I. 2023. Potential Absorption and Economic Carbon Valuation of Teak (Tectona Grandis) at Hasanuddin University City Forest for Supporting Emission Reduction in Makassar City. Journal of Natural Resources and Environmental Management. Vol. 13. Hal 481-491. Doi:10.29244/jpsl.13.3.481-491.

Badan Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan Palembang. 2017. The Demonstration Plot of Ex-Fire Peat Swamp Forest Restoration.

Buwono, S., Harjanti, D.T., Anasi, P.T., Wiyono, H., Apriliyana, M.I. 2022. Carbon Stock Analysis in Peat Soil at Rasau Jaya Tiga Village. Social, Humanities, and Education Studies (SHEs): Conference Series, Vol. 5. Page 186-192.

Dharmawan, I.W.S., Siregar, C.A. 2008. Soil Carbon and Carbon Estimation of Avicennia Marina (Forsk.) Vierh. Stand at Ciasem Purwakarta. Jurnal Penelitian Hutan dan Konservasi Alam, Vol. 5. Page 317-328, Doi:10.20886/jphka.2008.5.4.317-328.

Firyadi, F., Widiatmaka, W., Iswati, A., Ardiansyah, M., Mulyanto, B. 2018. Carbon Balance, Emissions and Sequestration of CO2 Historically due to Land Use Changes in Banyuasin Regency, South Sumatera. Journal of Natural Resources and Environmental Management, Vol. 8. Page 317-328. Doi:10.20886/jphka.2008.5.4.317-328.

Graham, L.L.B., Applegate, G.B., Thomas, A., Ryan, K.C., Saharjo, B.H., Cochrane, M.A.A. 2022. Field Study of Tropical Peat Fire Behaviour and Associated Carbon Emissions. Fire, Vol. 5. Page 1-20. Doi:10.3390/fire5030062.

Hamzah, H., Napitupulu, R.R.P., Muryunika, R. 2019. Kontribusi Cadangan Karbon Tanah dan Tumbuhan Bawah pada Ekosistem Gambut Bekas Terbakar sebagai Karbon Tersimpan di Lahan Tropika. Jurnal Silva Tropika, Vol. 3. Page 108-117. Doi: 10.22437/jsilvtrop.v3i1.6407.

Hardjana, A.K. 2010. Potensi Biomassa dan Karbon pada Hutan Tanaman Acacia mangium di HTI PT. Surya Hutani Jaya, Kalimantan Timur. Jurnal Penelitian Sosial dan Ekonomi Kehutanan, Vol. 7 No. 4. Page 237-249. Doi:10.20886/jsek.2010.7.4.237-249.

Indriani, D., Gunawan, H., Sofiyanti, N. 2015. Survival Rate dan Total Akumulasi Biomassa Permukaan dari Lima Jenis Pohon yang Digunakan dalam Eksperimen Restorasi pada Lahan Gambut Bekas Kebakaran di Area Transisi Cagar Biosfer Giam Siak Kecil-Bukit Batu Desa Tanjung Leban Bengkalis Riau. Jurnal Online Mahasiswa FMIPA Universitas Riau, Vol. 2. Page 170-175.

Irawan, U.; Purwanto, E 2020. Pengukuran dan Pendugaan Cadangan Karbon pada Ekosistem Hutan Gambut dan Mineral, Studi Kasus di Hutan Rawa Gambut Pematang Gadung dan Hutan Lindung Sungai Lesan, Kalimantan. Yayasan Tropenbos Indonesia: Bogor.

Jauhiainen, J., Page, S.E., Vasander, H. 2016. Greenhouse Gas Dynamics in Degraded and Restored Tropical Peatlands. Mires Peat, Vol. 17. Page 1–12. Doi:10.19189/MaP.2016.OMB.229.

Junaedi, A.; Hidayat, N.; Rizal, M.; Munthe, E. 2022. Serapan Karbondioksida vegetasi Hutan Rawa Gambut Berdasarkan Tingkat Pertumbuhan. Jurnal Hutan Tropika. 17(2):237–245. https://e-journal.upr.ac.id/index.php/JHT.

Kadir, M.I. 2021. The Economical Value of Carbon Jompie Botanical Garden Parepare. Gorontalo Journal of Forestry Research, Vol. 4. Page 126–139, Doi:10.32662/gjfr.v4i2.1779.

Ministry of Environment and Forestry. 2017. Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia. Nomor P.16/MENLHK/SETJEN/KUM.1/2/2017 tentang Pedoman Teknis Pemulihan Fungsi Ekosistem Gambut.

Legawa, A.T. 2021. Potensi Serapan Karbon Tanaman Meranti (Shorea sp.) pada Variasi Tingkatan Muka Air Tanah di Media Tanah Gambut. Yogyakarta (ID).

Leifeld, J.; Menichetti, L. 2018. The Underappreciated Potential of Peatlands in Global Climate Change Mitigation Strategies. Nature Communications, Vol. 9. Doi:10.1038/s41467-018-03406-6.

Leng, L.Y.; Ahmed, O.H.; Jalloh, M.B. 2019. Brief Review on Climate Change and Tropical Peatlands. Geosciences Frontiers, Vol. 10, 373–380, Doi:10.1016/j.gsf.2017.12.018.

Mickler, R.A.; Welch, D.P.; Bailey, A.D. 2017. Carbon Emissions during Wildland Fire on A North American Temperate Peatland. Fire Ecology, Vol. 13. Page 34–58. Doi:10.4996/fireecology1301034.

Murdiyarso, D.; Hergoualc'h, K.; Basuki, I.; Sasmito, S.; Hanggara, B. 2017. Cadagan Karbon di Lahan Gambut. World Agroforestry Centre: Bogor.

Murdiyarso, D.; Rosalina, U.; Hairiah, K.; Muslihat, L.; Suryadiputra, I.N.N.; Jaya, A. 2004. Petunjuk Lapangan: Pendugaan Cadangan Karbon di Lahan Gambut. Wetlands International-Indonesia Programme. Bogor (ID).

Nara, H.; Tanimoto, H.; Tohjima, Y.; Mukai, H.; Nojiri, Y.; Machida, T. 2017. Emission Factors of CO2, CO and CH4 from Sumatran Peatland Fires in 2013 Based on Shipboard Measurements. Tellus B: Chemical and Physical Meteorology, Vol. 69. Page 1–14. Doi:10.1080/16000889.2017.1399047.

Page, S.E.; Rieley, J.O.; Banks, C.J. 2011. Global and Regional Importance of The Tropical Peatland Carbon Pool. Global Change Biology, Vol. 17. Page 798–818. Doi:10.1111/j.1365-2486.2010.02279.x.

Page, S.E.; Waldes, N. Unlocking the Natural Resource Functions of Tropical Peatlands: Understanding the Nature and Diversity of Peat Swamp Forest Vegetation as a Foundation for Vegetation Restoration Studies. In: Wosten, J.H.M.; Rieley, J.O.; Page, S.E. (eds) Restoration of Tropical Peatlands. Alterra - Wageningen University and Research Centre and the EU INCO -RESTORPEAT Partnership: 30-39.

Peraturan Pemerintah. 2016. Peraturan Pemerintah Nomor 57 Tahun 2016 tentang Perubahan atas Peraturan Pemerintah Nomor 71 Tahun 2014 tentang Perlindungan dan Pengelolaan Ekosistem Gambut.

Pindilli, E.; Sleeter, R.; Hogan, D. 2018. Estimating the Societal Benefits of Carbon Dioxide Sequestration Through Peatland Restoration. Ecological Economics, Vol. 154. Page 145–155. Doi:10.1016/j.ecolecon.2018.08.002.

Qirom, MA.; Halwany, W.; Ramanadi D, R.; Tampubolon, AP. 2019. The Study on Biophysical Peatland Landscape in Sebangau National Park: Case in Mangkok Resort. Jurnal Ilmu Pertanian Indonesia, Vol. 24. Page 188-200. Doi:10.18343/jipi.24.3.188.

Sanjaya, H.; Kurniawan, A.; Ickwantoro, I.; Marlina, D. 2023. Prediksi Jumlah Kejadian Titik Panas Pada Lahan Gambut di Indonesia Menggunakan Prophet. INFOTECH Journal, Vol. 9. Page 354–360.

Setyawati, W.; Suwarsono. 2018. Carbon Emission from Peat Fire in 2015. IOP Conference Series: Earth and Environmental Science, Vol. 166. Doi:10.1088/1755-1315/166/1/012041.

Siagian, K.; Karuniasa, M.; Mizuno, K. 2024. The Estimation of Economic Valuation on Carbon Sequestration of Agroforestry Land System. Journal of Natural Resources and Environmental Management, Vol. 14. Page 231–240. Doi:10.29244/jpsl.14.2.231.

Simbolon, D.Y.P.; Afifuddin, Y.; Latifah, S. 2015. Valuasi Ekonomi Hutan Tele di Kabupaten Samosir. Peromena Forestry Science Journal, Vol. 4 No. 3. Page 86-94.

Sitaniapessy, P.; Papilaya, P.M. 2019. Analisis Tingkat Penyimpanan Senyawa Karbon (C-Stock) Pada Vegetasi Hutan Mangrove Berdasarkan Perbedaan Substrat Di Pulau Saparua Kabupaten Maluku Tengah. Biopendix: Jurnal Biologi, Pendidikan, dan Terapan, Vol. 5. Page 8–12. Doi:10.30598.

Sutaryo, D. 2009. Perhitungan Biomassa: Sebuah Pengantar untuk Studi Karbon dan Perdagangan Karbon. Wetlands International Indonesia Programme. Bogor (ID).

Suwarna, U.; Elias; Darusman, D.; Istomo. 2012. Estimation of Total Carbon Stocks in Soil and Vegetation of Tropical Peat Forest in Indonesia. Jurnal Manajemen Hutan Tropika, Vol. 18. Page 118–128. Doi:10.7226/jtfm.18.2.118.

Uda, S.K.; Schouten, G.; Hein, L. 2020. The Institutional Fit of Peatland Governance in Indonesia. Land Use Policy. Doi:10.1016/j.landusepol.2018.03.031.

Ulya, N.A.; Warsito, S.P.; Andayani, W. 2015. Economic Value of Carbon of Merang Kepayang Peat Swamp Forest, South Sumatera Province. Jurnal Manusia dan Lingkungan, Vol. 22. Page 52–58.

Wahyunto; Dariah, A. 2014. Degradasi Lahan di Indonesia: Kondisi Existing, Karakteristik, dan Penyeragaman Definisi Mendukung Gerakan Menuju Satu Peta. Jurnal Sumberdaya Lahan, Vol. 8. Page 81–93. Doi: 10.2018/jsdl.v8i2.6470.

Wahyunto; Ritung, S.; Subagjo, H. 2003. Map of Area of Peatland Distribution and Carbon Content in Sumatera. In Wetlands International – Indonesia Programme & Wildlife Habitat Canada (WHC). pp. 1–15 ISBN 9799589932.

Warren, M.; Hergoualc'h, K.; Kauffman, J.B.; Murdiyarso, D.; Kolka, R. 2017. An Appraisal of Indonesia's Immense Peat Carbon Stock Using National Peatland Maps: Uncertainties and Potential Losses from Conversion. Carbon Balance Management, Vol. 12. Doi:10.1186/s13021-017-0080-2.

Wilson, D.; Blain, D.; Couwenber, J.; Evans, C.; Murdiyarso, D.; Page, S.; Renou-Wilson, F.; Rieley, J.; Strack, M.; Tuittila, E.S. 2016. Greenhouse Gas Emission Factors Associated with Rewetting of Organic Soils. Mires Peat, Vol. 17. Page 1–28. Doi:10.19189/MaP.2016.OMB.222.

World Bank Group. State and Trends of Carbon Pricing 2023. 2023. Doi: 10.1596/978-1-4648-2006-9.

Wright, EL.; Black, CR.; Cheesman, AW.; Drage, T.; Large, D.; Turner, BL.; Sjögersten, S. 2011. Contribution of subsurface peat to CO2 and CH4 fluxes in a neotropical peatland. Glob Chang Biol. 17(9):2867–2881. doi:10.1111/j.1365-2486.2011.02448.x.

Yu, Z.C. 2012. Northern Peatland Carbon Stocks and Dynamics: A Review. Biogeosciences, Vol. 9. Page 4071–4085. Doi:10.5194/bg-9-4071-2012.

Yuningsih, L.; Yulianty, T.; Harbi, J. 2018. Analisis Vegetasi Pada Lahan Hutan Gambut Bekas Terbakar di Kabupaten Ogan Komering Ilir Provinsi Sumatera Selatan Indonesia. Sylva, Vol. 7. Page 58–67.