



Study on Potential Carbon in Pocut Meurah Intan Forest Park, Aceh Province

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Received : May 09, 2023

Received in revised from: May 30 2023

Accepted : May 31, 2023

Online : August 04, 2023

Abstract – The existence of forest park areas plays an essential role as carbon sequestration can reduce the concentration of greenhouse gases in the atmosphere. Analysis of carbon potential is essential in determining the amount of available carbon potential. This study aims to analyze the carbon potential in the forest park area Pocut Meurah Intan Forest Park. The study used a descriptive method with the sampling technique of the path system. Data analysis and calculation of carbon potential using allometric equations to calculate the total biomass. Spatial analysis using Arc.GIS 10.4 software and the carbon content analysis was carried out using the ashing method. The results showed that the potential carbon stock of Pocut Meurah Intan Forest Park was 640,282 tons. The carbon potential is the carbon stored above the ground in the form of carbon from above-ground biomass (trees, poles, saplings, undergrowth) and organic matter (necromass and litter). The highest carbon potential was found in the secondary dryland forest land cover with a total of 555,204 tons or 167.6 tons ha⁻¹, followed by shrubs of 78,949 tons or 33.3 tons ha⁻¹, and the lowest potential carbon stock was found in the open field of 303 tons or 2.8 tons ha⁻¹. The increase in land cover in secondary dryland forests causes increased carbon storage. The low potential for carbon stocks is due to land clearing and a small number of stands, resulting in a decrease in potential carbon stocks

Keywords: carbon, potential carbon, carbon stock, land use, forest management

Introduction

The increasing rate of forest degradation in Indonesia is a contributing factor to increasing global climate change. Indonesia's forest destruction rate increased to 1.87 million ha from 2000–2005 (Wilki *et al.*, 2007). The forest areas can absorb CO₂ in photosynthesis, are stored as organic matter, and almost part of forest biomass consists of carbon (Brown, 1997). Deforestation causes the increase of greenhouse gases in the atmosphere. Increased forest destruction will reduce the ability of forests to store carbon.

The Pocut Meurah Intan Aceh Forest Park is located in the areas of two regencies, namely Aceh Besar and Pidie Regency with a total area of 6,215 ha. Pocut Meurah Intan Forest Park is a nature conservation area to preserve natural or artificial plants and animals, for research purposes, to support cultivation, culture, tourism, and recreation. According to (Djufri, 2003), Pocut Meurah Intan Forest Park is very useful in suppressing carbon in the atmosphere due to the high carbon stored in the biomass of the land cover. The potential carbon stored in the Pocut Meurah Intan Forest Park need to be estimated to find the contribution to reducing greenhouse gas emissions. This effort can be done by analyzing the carbon potential stored in land cover of the Pocut Meurah Intan Forest Park. (Situmorang, Sugianto and Darusman, 2016; Muslih *et al.*, 2022) added that the estimation of carbon potential based on land cover data supports the estimation of carbon stored in forests. Furthermore (Ramadhan, Basri and Harun, 2014), explained that the dominant trees with large diameter influence the high carbon potential in a land cover class. Measuring biomass in forest areas is needed to obtain the carbon's potential value.

The Pocut Meurah Intan Forest Park's capacity to reduce carbon emissions is determined by its land cover. Dense vegetation cover can absorb higher carbon because it has a higher volume of biomass. It is possible to

calculate potential carbon stored in various land cover classes as part of carbon budget analysis (Lasco, 2002; Situmorang, Sugianto and Darusman, 2016). Data on carbon potential stored in various land cover classes is essential for the basis of sustainable forest management of Pocut Meurah Intan Forest Park. Thus, Pocut Meurah Intan Forest Park as a carbon storage area will be further improved in the future. This study analyzes the potential of carbon stored in various land cover classes in Pocut Meurah Intan Forest Park. This study provides information regarding the carbon potential stored in Pocut Meurah Intan Forest Park for supporting the local government regarding the direction of forest management in the future.

Materials and Methods

The research area is located in Pocut Meurah Intan Forest Park. The Pocut Meurah Intan Forest Park area covers of 6,215 ha, and is geographically located with coordinates of 05°25'15"- 05°26'30"N and 95°45'25"E. The location included two regencies including Aceh Besar and Pidie.

The materials and tools used are the 2018 land cover map, for carbon measurement using a tree diameter gauge (phi band), height meter (Laser distance), meter, scale, tape, raffia rope, camera, stapler, stationery and tally sheet.

The area of each land cover is determined based on the 2018 land cover map of Pocut Meurah Intan Forest Park (KLHK, 2018). The area of each land cover and its classification was calculated by spatial analysis using ArcGIS 10.1 using field data acquisition. Landsat imagery is used as the main source of remote sensing imagery. Land cover classification is based on SNI 7645:2010 (Nasional, 2010). Measurement of carbon potential stored in each land cover is carried out by measuring the biomass of each land cover. The type of land cover (land cover) is determined from the interpretation of satellite imagery. Furthermore, the calculation of carbon potential based on GIS by multiplying carbon stock data on each land cover with land cover area data (Tosiani *et al.*, 2017).

In order to obtain biomass data on various land covers, samples were collected on plots of 20x20 m with three replications. In the 20 x 20 m plot, for the calculation of plant biomass at the tree level by measuring the diameter of the tree stands (diameter at breast height/dbh) above 20 cm. A 10x10 m subplot for the calculation of plant biomass at the pole level (10-19 cm diameter). A 5 x 5 m subplot for the calculation of the sapling level (2–9 cm in diameter) and a 2 x 2 m subplot for the biomass calculation for the seedling level (diameter below 2 cm with a height of 1.5 m) (Nasional, 2011).

Measurement of carbon potential in the field using destructive (direct) and non-destructive (indirect) methods. Analysis of potential carbon data on above-ground plants (trees, poles and saplings) using non-destructive methods through allometric equations (Table 1). The carbon data on understory and litter using the destructive method. For carbon analysis from both methods, a 300 g of biomass samples were collected for analysis of carbon content in the laboratory.

Table 1. Allometric equation for tree biomass estimation

Tree type	Biomass (kg tree ⁻¹)	Sources
Branched tree	DW = 0,11 ρ D ^{2.62}	Ketterings (2001)
Unbranched tree	DW = π ρ H D ² / 40	Hairiah <i>et al.</i> (1999)
Necromass	DW = (π/ 40) ρ H D ²	Hairiah (2002)
Banana	DW = 0,030 D ^{2.13}	Arifin (2001); Van Noordwijk (2002)
Pine	DW = 0,0417 D ^{2.6576}	Waterloo (1995)

DW = dry weight (kg tree⁻¹), H = plant height (cm), ρ = wood density (Mg m⁻³, kg dm⁻³ or g cm⁻³), D = diameter (cm) at breast height (1.3 m), B_j (ρ) of wood averaged 0.7 g cm⁻³ and B_j (ρ) dead wood about 0.4 g cm⁻³, = constant phi (22/7 or 3.14). Sources; (Rahayu, 2007) in Measurement of Stored Carbon in Various Land Uses.

The calculation of the amount of carbon using the formula according to (Nasional, 2011):

$$Cb = B \times \% C \text{ organic} \quad (1)$$

C_b = Total carbon (kg);

B = biomass (kg);

% C organic = percentage of carbon obtained from laboratory analysis

To determine the biomass of understory and litter, used the formula according to (Nasional, 2011). :

$$Total\ DW = \frac{DW\ Subsample(g)}{FW\ Subsample(g)} \times Total\ fresh\ weight\ (g) \quad (2)$$

DW = dry weight, FW = fresh weight, (g) = gram.

Measurement of the dry biomass of dead tree biomass (necromass) using geometric methods, namely measuring diameter, tree height, the volume of dead trees, density and calculating the necromass organic matter. The measurements were in the main plots with data collected from each plot (Nasional, 2011). To calculate the necromass biomass is according to the formula:

$$DW = \left(\frac{\pi}{40}\right) \times \rho \times H \times D^2 \quad (3)$$

DW = dry weight,

π = 22/7 or 3.14

ρ = 0.4 (dry density of necromass),

H = height / length of dead tree,

D = diameter of dead tree

Calculating total plant carbon is done by multiplying the total amount of plant biomass with a percentage value of 0.47 carbon content or using the percent carbon value obtained from the laboratory analysis (Nasional, 2011). The calculation of carbon stock in the plot uses the following equation:

$$C_{plot} = (C_{Tag} + C_{Tb} + C_{Necromass} + C_{Litter} \quad (4)$$

C_{Plot} = total carbon in plot (ton ha⁻¹)

C_{Tag} = total above-ground carbon (ton ha⁻¹)

C_{Tb} = total understorey carbon (ton ha⁻¹)

$C_{Necromass}$ = total necromass carbon (ton ha⁻¹)

C_{Litter} = total litter carbon (ton ha⁻¹)

Results

Land Cover

The land cover of Pocut Meurah Intan Forest Park is classified into seven cover classes, including; 2 classes of forest cover and five classes of non-forest, with a total area of 6,215 ha. The land cover area of the Pocut Meurah Intan Forest Park in 2018 is in Table 2.

Table 2. Land cover area in Pocut Meurah Intan Forest Park

No	Land covers	Areas (ha)	Percentage (%)
1	Secondary dryland forests	3,313	53.30
2	Plantation forests	42	0.68
3	Shrub	2,372	38.16
4	Savanna	266	4.28
5	Shrub-mixed dryland farm	35	0.56
6	Settlement	81	1.30
7	Open field	107	1.72
Total		6,215	100.00

Biomass potential

In this study, carbon measurements were carried out by measuring above-ground biomass. The results of the study showed that the total biomass obtained was 1,359,816 tons. The total amount of land cover biomass is detailed shown in Table 3.

Table 3. The total biomass of each land cover in Pocut Meurah Intan Forest Park

No	Land cover	Biomass potential (ton ha ⁻¹)	Areas (ha)	Total biomass (ton)
1	Secondary dryland forests	356.18	3,313	1,179,869
2	Plantation forests	164.86	42	6,950
3	Shrub	70.45	2,372	167,109
4	Savanna	8.28	266	2,202
5	Shrub-mixed dryland farm	65.15	35	2,279
6	Settlement	9.93	81	806
7	Open field	5.64	107	601
Total			6,215	1,359,816

Potential carbon stock

The result of the study shows that the total potential carbon stock stored in Pocut Meurah Intan Forest Park Pocut Meurah Intan is 640,282 tons. The potential total carbon is in the form of carbon from above-ground biomass and organic matter (necromass and litter). The total carbon potential in each land cover in Pocut Meurah Intan Forest Park is presented in Table 4.

Table 4. Total carbon potential in Pocut Meurah Intan Forest Park

No	Land Cover	Tree (ton ha ⁻¹)	Poles (ton ha ⁻¹)	Saplings (ton ha ⁻¹)	Undergrowth (ton ha ⁻¹)	Necromass (ton ha ⁻¹)	Litter (ton ha ⁻¹)	Total (ton ha ⁻¹)	Total areas (ha)	Total carbon (ton)
1	Secondary dryland forests	152.9	8.4	3.9	0.7	0.5	1.1	167.6	3,313	555,204
2	Plantation forests	66.0	3.7	2.3	0.7	3.1	1.9	77.7	42	3,277
3	Shrub	18.3	8.2	2.2	0.5	3.1	1.0	33.3	2,372	78,949
4	Savanna	0	0.0	1.7	1.1	0.0	1.3	4.1	266	1,099
5	Shrub-mixed dryland farm	10.8	4.6	13.0	0.4	1.2	0.6	30.7	35	1,075
6	Settlement	3.1	0.0	0.1	0.5	0.0	0.9	4.6	81	376
7	Open field	1.2	0.0	0.0	0.5	0.0	1.1	2.8	107	303
Total									6,215	640,282

The highest total carbon potential stored in the secondary dryland forest land cover class was 555,204 tons or 167.6 tons ha⁻¹, followed by shrubs at 78,949 tons or 33.3 tons ha⁻¹ and the lowest was found in the open field class at 303 tons or 2.8 tons ha⁻¹ of carbon.

Discussion

The largest land cover area of Pocut Meurah Intan Forest Park is secondary dryland forest covering an area of 3,313 ha or 53.30%, and the smallest is Shrub-mixed dryland farm class covering an area of 35 ha or 0.56% of the total Pocut Meurah Intan Forest Park areas. The area of land cover Pocut Meurah Intan Forest Park in the class of shrubs, savanna/grass, dry land agriculture mixed with shrubs, settlements, and open land. This indicates the occurrence of illegal logging, encroachment for gardening and the emergence of settlements in the Pocut Meurah Intan Forest Park areas. (Maulana, Basri and Sugianto, 2018) stated that there was a decrease in forest area of 238.71 ha in Pocut Meurah Intan Forest Park. While Samsul *et al.* (2018) stated that the intensity of the activities of residents around Pocut Meurah Intan Forest Park resulted in changes in the landscape due to land clearing, logging, gardening, and forest burning. Open field occurs due to residents not being used for gardening. It also increases reforestation through natural succession.

The total biomass potential in Pocut Meurah Intan Forest Park Pocut Meurah Intan shows that the highest biomass potential is in the secondary dryland forest land cover with a total biomass of 1,179,869 tons. Meanwhile, the lowest biomass potential is in the open land of 601 tons. The low potential of biomass stored in open land is due to the small amount of vegetation resulting in low biomass potential. The high potential for biomass in secondary dryland forest land cover is due to the broadest land cover compared to other cover classes of 3,313 ha and the number of tree populations (diameter 20 cm) is still relatively high, in good condition and has not

been disturbed. (Tosiani *et al.*, 2017) stated that in general, the biomass of tree parts was correlated with the diameter and total height of the tree so that increasing the diameter of the stand had an impact on increasing the biomass in each part of the tree.

The highest biomass potential was found in the secondary dryland forest land cover of 356.18 tons ha⁻¹. This is not significantly distinguishable compared with the study by Fauzi *et al.* (2011) that the amount of biomass in the secondary dryland forest Gayo Lues district of 310.03 tons ha⁻¹. Plantation forest land cover is much lower than secondary dryland forest at 164.86 tons ha⁻¹. The amount of biomass in forest plantations is lower due to disturbances to the pine stand population, especially forest fires and tree felling by the community for farming which causes the potential for biomass to decrease and is a direct indication of its ability to store carbon.

The biomass stored in the shrub land cover is 167,109 tons or 70.45 tons ha⁻¹ with an area of 2,372 ha. The potential for biomass in shrubs has large biomass storage after secondary dryland forest. The sample groups of trees and bushes dominated each plot with the highest amount of biomass in trees of 92,156 tons or 38.9 tons ha⁻¹ and the lowest on undergrowth of 2,405 tons or 1.0 tons ha⁻¹. According to Fauzi *et al.* (2011) stated that the amount of carbon in the shrub class in the Gayo Lues district was 20 tons ha⁻¹ or biomass 42.6 tons ha⁻¹. The lowest biomass potential is found in the open field class of 601.30 tons or 5.64 tons ha⁻¹ from an area of 107 ha. Only a few trees, such as teak and pine, were found in the open field area. Most of the open land area is former logging and forest fires that are not used optimally, leaving open land, which has an impact on decreasing biomass potential.

The high carbon potential in the secondary dryland forest land cover is partly due to the very large area and the relatively large volume of trunk diameter and tree height that has not been disturbed. The potential for stored carbon in the open land class is the lowest. This was due to the very small number of tree-level stands. (Rahayu, 2007) stated that the type of vegetation influences the carbon potential. The land cover with a higher wood density value impacts higher biomass than land with a low wood density value.

(Tosiani, 2015) stated that the carbon content in secondary dryland forest of 169.7 tons ha⁻¹ was not much different from the amount of carbon based on field measurements of 167.6 tons ha⁻¹. The largest amount of carbon stock was found in the sample group of trees of 506.632 tons or 152.9 tons ha⁻¹ and the lowest carbon stock was found in the necromass sample group of 1.705 tons or 0.5 tons ha⁻¹. (Rahayu, 2007) added that the largest proportion of carbon storage on land is large trees. (Ramadhan, Basri and Harun, 2014) stated that an increase in the number of trees in the sample group will affect the total stem diameter value, significantly increasing stored carbon stocks.

The potential for the carbon stored in the plantation forest class is 3,277 tons or 77.7 tons ha⁻¹. The plantation forest in Pocut Meurah Intan Forest Park is dominated by the Pine (*Pinus merkusii*) and its value is comparable to the pine forest land cover class in Pocut Meurah Intan Forest Park with the research of (Ramadhan, Basri and Harun, 2014) with a total stored carbon stock of 78.9 tons ha⁻¹. (Gintings, 1997) added 74.6 tons ha⁻¹ of carbon from the *Pinus merkusii* plantation forest in East Java. (Tosiani, 2015) added that the carbon stock in plantation forests is 76.70 tons ha⁻¹.

The shrub class has a high potential for carbon stocks after secondary dryland forest of 78.949 tons or 33.3 tons ha⁻¹. The high carbon potential in the shrub land cover class is due to the area of 2,372 ha, which increases the overall carbon stock potential. The amount of carbon potential in the shrub class is not much different from the previous researchers at 23.8 tons ha⁻¹. Meanwhile (Tosiani, 2015) obtained the carbon potential value of shrubs of 30 tons ha⁻¹.

In the savanna/grass land cover, the carbon stored was 1,099 tons or 4.1 tons ha⁻¹ with an area of 266 ha. This lower carbon stock is due to the absence of potential carbon in the trees, poles, and necromass samples. The potential carbon value is not much different from the statement (Tosiani, 2015) that the carbon content based on land cover class in the savanna/grass class is 4.00 tons ha⁻¹. (Grace *et al.*, 2006) suggested that due to the very high rate of fire prone to occur in the savanna, about 20% of the biomass burned and the large amount of carbon that had been stored was released quickly back into the atmosphere so that the savanna only stored carbon in relatively small amount compared to other land cover classes. The dry land mixed bush farming land cover is not much different from the savanna class, which is thought to store 1,075 tons of carbon stock or 30.7 tons ha⁻¹ with an area of 35 ha. (Tosiani, 2015) stated that the carbon potential of dryland mixed bush farming class is 30 tons ha⁻¹.

The lowest carbon values are in open land and settlements. The open land class has a low carbon potential of 292.18 tons or 2.7 tons ha⁻¹, while the residential class is 376 tons or 4.6 tons ha⁻¹. (Tosiani, 2015) explained that the carbon content based on land cover class in settlements was not much different by 4 tons ha⁻¹ and open land class by 2.5 tons ha⁻¹.

Conclusion

Pocut Meurah Intan Forest Park has an area of 6,215 ha with the dominant land cover class is secondary dryland forest covering an area of 3,313 ha and the lowest on shrub-mixed dryland farm covering an area of 35 ha. The highest carbon potential stored is in secondary dryland forests of 555.204 tons or 167.6 tons ha⁻¹, followed by shrubs of 78.949 tons or 33.3 tons ha⁻¹ and the lowest is in open field of 303 tons or 2.8 tons ha⁻¹. The high carbon potential in the secondary dryland forest class is partly due to covered the largest area and the relatively large volume of trunk diameter and tree height that has not been disturbed.

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