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The Economic Value of Carbon Stocks in PT Hutan Mulya Central Kalimantan

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Abstract

This study aims to determine how much carbon stock is stored in logged-over areas by comparing carbon stock in virgin forests. Calculate potential biomass, carbon, carbon dioxide uptake, and economic value of CO_2eq uptake in the Logged area of PT Hutan Mulya using purposive sampling data collection techniques for each plot and non-destructive methods through allometric equations. The highest carbon stock potential is in the tree-level diameter class and the location with the highest carbon stock is in the virgin forest area. Meanwhile, the logged area based on the company's establishment from 2011–2022 covering an area of 14,583 ha has a carbon stock potential of 772,537 tons C to the carbon dioxide storage value of 2,835,210.57 tons CO_2eq. Based on the assumed price of USD 4.5, the potential economic value of carbon obtained by the government through carbon sales tax is IDR 85,056,317,100. The net profit obtained by the company is IDR 109,494,570,499.42. In contrast, the potential net economic value of the carbon business project scenario results in a combined logged area and virgin forest area of IDR 160,960,838,842.31 for the company and IDR 125,035,753,500 for the government.

Keywords: biomass, carbon stock, diameter, economic value, production forest

1. Introduction

One of the factors causing forest degradation is harvesting activities, which are carried out by Forest Product Utilization Companies (PBPH). Unsustainable forest harvesting activities by PBPH can be a major contributing factor to forest degradation [1]. Putri and Wulandari [2] explain that carbon reserves of dipterocarp natural forest stands in the PBPH area of PT Sarpatim, Central Kalimantan with above ground biomass (AGB) carbon content of 204.92 tons C ha^{-1}, which that an increase in the amount of biomass is followed by an increase in the amount of carbon storage in Hardiansyah et al. [3] which calculated the potential economic value of carbon in the TPTII area using a carbon price assumption of USD 5 as the selling value of carbon. This is because there is no new regulation regarding the economic value of carbon as stated in Presidential Regulation Number 98 of 2021 [4].

This research is new and interesting because it was conducted in PBPH forests where the research location is an ex-felling area which is assumed to have drastically reduced carbon stocks. The calculations were carried out up to the potential economic value of carbon with reference to carbon prices according to the new carbon market issued by the government through the carbon exchange index. This study aims to determine the potential carbon stock and the economic value stored AGB in each diameter class of the growth stage in Logged of Areal and expected to be an essential reference for PBPH companies that will start a carbon credit scheme project to facilitate the calculation of carbon stock estimates.

2. Materials and Methods

2.1. Research Location and Time

Tree diameter data collection and documentation will be carried out in the standing forest area (LoA: Logged Over Area) Block 2016, and Block 2022 PT Hutan Mulya Central Kalimantan Province, Field research will be carried out for approximately one month.

2.2. Data Collection

This study uses quantitative methods with primary data collection through survey methods in the LoA area, namely block 2016 and block 2022 and the Virgin Forest area as control data, as many as five randomly cut plots with data collection techniques by purposive sampling for each plot. This study used a modified ICRAF plot design by Lestari and Dewi [5], each plot has two plots with a plot area of 20 x 100 m for a stand diameter of 30 cm up. Within the plot, there is another plot with a size of 5 x 40 m for stands with a diameter of 5–30 cm, so that the total plots in this study are 30 plots from the Logging Block and Virgin Forest. However, the data was grouped based on the growth level of the diameter class consisting of sapling level (5–9.9 cm), pole level (10–19 cm) and tree level (20 cm and above) to make it easier to determine which growth level has the highest carbon potential. Tree measurements were made on the circumference (trunk circle) at chest height (± 120 cm).

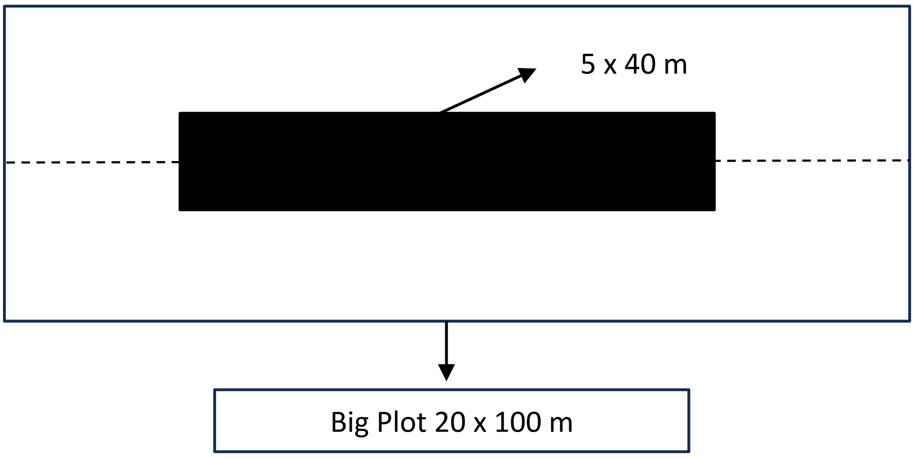

Figure 1. Desain plot ICRAF [5].

2.3. Data Analysis

Data analysis in this study is quantitative methods through a statistical data processing approach to calculate stand fragility values, carbon potential and potential economic value of carbon stocks. Standard methods can be explained briefly and cited as necessary, while new methods or techniques must be explained in detail. If there are several mathematical equations, they need to be numbered sequentially.

2.3.1. Stand density

Before calculating the allometric equation, first, calculate the stand density with the following formula:

$$\text{Stand density} = \frac{\text{Number of individuals of a species}}{\text{Total sample plot area (ha)}} \quad (1)$$

2.3.2. Biomass (B)

Calculation of carbon biomass through allometric equations using Microsoft Office Excel application. Primary data from the field will be used to determine the value of biomass stored in trees. The equation formula to determine standing biomass uses the several allometric formulas, namely Ketterings et al. [6], Chave et al. [7], Brown [8], Hardiansyah [9] and Anggraeni [10] allometric equation for mixed dryland forest types in Central Kalimantan cited by Anitha et al. [11] which can be seen in (Table 1).

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Table 1. Allometric equation model

Rainfall (mm year^{-1})	Allometric equation model	Coefficient of determination (R^2)	Source	Location
< 1500	B = ρ * EXP(–0.667 + 1.784 * LN(D) + 0.207 * (LN(D)^2 – 0.0281*(LN(D)^3)	0.97	Chave [7]	Indonesian, Cambodia, Brazil, Malaysia, Papua New Guinea, etc
1500–4000	B = 0.118 $D^2$2.53	0.90	Brown [8]	Dipterocarpaceae Forest of Asia, America Latin
1500–4000	B = 0.11 ρ* ($D^2$2.62)	0.90	Ketterings et al. [6]	Indonesian, Jambi, Mix Forest
1500–4000	B = 0,18 ρ* ($D^2$2.50)	0.96	Hardiansyah [9]	Indonesian, West Kalimantan's, Central Kalimantan's
1500–4000	B = 0.2137 $D^2$2.445 ρ^2 0.763	0.98	Anggraeni [10]	Central Kalimantan's, Mix Virgin Forest

B: Biomass (kg); D: Diameter (cm); ρ: Wood density

2.3.3. Carbon (C)

Potential reserves of elemental carbon (C) of live stands in Asian/broadleaf forests have a percentage of 47% [12]. The estimated amount of elemental carbon (C) can be calculated by multiplying the biomass by the % of standing carbon elements. The formula for calculating carbon content is as follows:

$$\text{Biomass (Ton ha}^{-1}) = \text{Biomass (kg)} \times (10.000/20/100\ \mathrm{m}^2) \quad (2)$$

$$\text{Carbon (Ton)} = \text{Biomass (ton/ ha)} \times 47\ \% \quad (3)$$

$$\text{Carbon Total (Tons)} = C1 + C2 + C3 + ... + C \quad (4)$$

2.3.4. Carbon dioxide uptake (CO_2eq)

Based on the statement in Noor et al. [13] that the potential carbon dioxide uptake (CO_2eq) emission is calculated through the formula as follows:

$$\mathrm{CO_2eq} = \text{Cn} \times 3.67 \quad (5)$$

where CO_2eq is carbon dioxide uptake (ton ha^{-1}); Cn is carbon content per unit area (ton ha^{-1}); and 3.67 is equivalent number or conversion of carbon element C to CO_2eq.

2.3.5. Carbon economic value

In this study, the price of USD 1 as a reference in calculating the economic value is equivalent to IDR 15,248.79, based on the average exchange rate of USD to IDR in the last 1 year period (November 2022 – October 2023) with a reference carbon price according to the price on the Indonesian Carbon Exchange in 2023 which is USD 4.5. The economic value of carbon is obtained by multiplying the prevailing carbon price by the absorption value of (CO_2eq) that has been obtained in the forestry sector [14]. The formula is as follows:

$$\text{NEK} = \text{HJC} \times \mathrm{CO_2eq} \times \text{LoA total area} \quad (6)$$

where NEK is Economic value (IDR ha^{-1}) with USD 1 equivalent to IDR 15,248.79 (Average, 2022/2023); HJC is carbon price (IDR = USD 4.5 = IDR 254,157.66 per ton); USD 4.5 = IDR 254,157.66 by the Indonesian Carbon Exchange in 2023; CO_2eq = CO_2 Uptake (Ton ha^{-1}).

3. Result

3.1. Stand Density

A total of 72 plant species were found, with 651 individuals from sapling, pole and tree growth levels from the 30 plots observed. Based on the growth level of the diameter class, the density in the virgin forest is dominated by the pole level (10–19), while the standing area of Block 2016 and Block 2022 is dominated by the sapling level, namely the diameter class (5–9.9 cm) (Table 2). The density value of the Logged Over Area is lower than the density value in the virgin forest because it has been logged at the tree level. This is due to the inverse relationship between diameter and density. The higher the density value of a tree stands in an area, the smaller the increase in tree diameter and vice versa. The larger the tree diameter, the smaller the tree population [15].

Table 2. Diameter class density stand growth stage

Growth stage (Cm)	Stand density (N ha^{-1})		
	Virgin Forest*	Block 2016 (LoA)**	Block 2022 (LoA)**
Sapling (5–9.9 cm)	520	530	580
Pole (10–19 cm)	730	70	20
Trees (20 cm up)	203	128	75
TOTAL (tons ha^{-1})	1,453	728	675
Average	484.33	242.67	225.00

Virgin Forest*: Protected area; LoA** : Logged Over Areal/Forestation

3.2. Potential AGB Stands

Calculating potential biomass with allometric models in tropical forests will be more accurate if variables such as diameter, tree height, and wood density are used [16]. The results showed some differences in biomass potential in each area. Potential of standing AGB in logged areas and virgin forests are grouped by growth stage and average five carbon biomass allometric models (Table 3).

Table 3 shows that the tree level in both virgin forest and LoA area has the highest biomass value among other growth level diameter classes. The potential biomass value at the sapling level in the LoA area, namely RKT 2022, is higher (8.57 tons ha^{-1}) than RKT 2016 (7.18 tons ha^{-1}), while the largest total potential biomass value is in the virgin forest area (255.83 tons ha^{-1}). The smallest potential biomass is in RKT 2022 (98.18 tons ha^{-1}). While in Junaedi's research (2007) conducted at PT Sari Bumi Kusuma, the potential for primary forest biomass from tree stands was 377.00 tons ha^{-1}, pole level 51.57 tons ha^{-1}, and saplings 29.14 tons ha^{-1} which was more significant than the potential biomass at the trees level and sapling level in virgin forest. In this case, it can be interpreted that the high potential biomass in the virgin forest of PT Hutan Mulya is due to the large biomass of tree and pole stands, in accordance with the statement of Wassihun et al. that forest stand density has a significant effect on AGB at a significance level of 1% [17].

Table 3. Biomass potential of AGB stands based on growth stage

Growth stage	Area type (Ton ha^{-1})			Average quantity (Ton ha^{-1})
	Virgin forest*	RKT 2016 (LoA)**	RKT 2022 (LoA)**	
Trees (20 cm up)	172.36	106.85	87.83	122.35
Pole (10–19 cm)	74.13	13.22	1.78	47.28
Sapling (5–9.9 cm)	9.33	7.18	8.57	8.36
TOTAL (ton ha^{-1})	255.83	127.25	98.18	177.98

Virgin Forest* : Protected area and LoA** : Logged Over Areal/Forestation

3.3. Carbon Stock Potential AGB Stand

The results of the calculation of carbon stock potential show that each plot has a different carbon value even though the area and number of plots are the same. This is due to differences in density which affects the number of stands found and differences in diameter size because each growth level (saplings, poles, trees) has a different diameter size limit and a different measuring plot area, as seen in Table 4.

Table 4 shows that the carbon potential in the virgin forest is higher than in the LoA area, which is 120.24 tons C ha^{-1}. However, when viewed based on the diameter class of the growth level, virgin forest area and LoA area, the potential carbon stock is equally dominated by the tree level. In the National FREL research by Hardiansyah et al. [3], although the carbon potential of virgin forest is smaller, it only has a small difference in carbon numbers, namely 6.37 tons C ha^{-1}, while the secondary area has almost 50% difference from the carbon potential according to National FREL due to harvesting activities for a diameter of 50 cm up

Table 4. Carbon stock potential of AGB stands by growth stage

Growth stage	Area type (Ton ha^{-1})			Average quantity (Tons ha^{-1})
	Virgin forest*	RKT 2016 (LoA)**	RKT 2022 (LoA)**	
Trees (20 cm up)	81.01	50.22	41.28	57.50
Pole (10–19 cm)	34.84	6.21	0.83	22.22
Sapling (5–9.9 cm)	4.38	3.37	4.03	3.93
TOTAL (tons ha^{-1})	120,24	59.81	46.14	83.65

Virgin Forest* : Protected area and LoA** : Logged Over Areal/Forestation

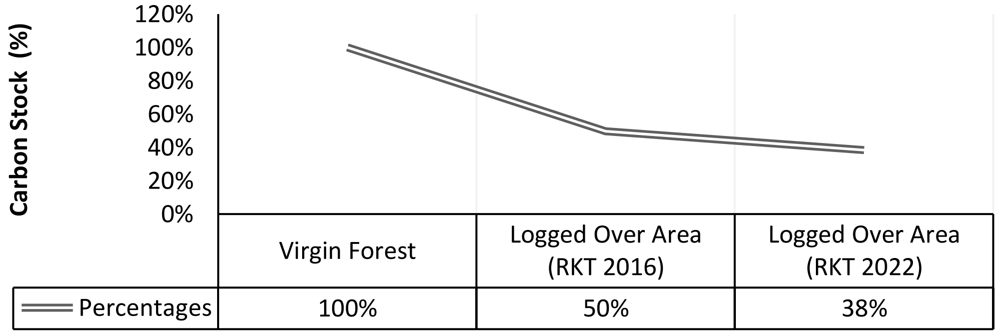

Figure 2. Potential standing carbon stocks in virgin forest areas and decreasing in logged areas.

Based on Figure 2, the percentage of carbon stock potential of AGB shows an increase in carbon storage in the RKT 2022 standing area to RKT 2016 of 13.67 tons C ha^{-1} by about 12%. Meanwhile, the decrease in carbon potential is around 50–62%. According to Kasianus et al. [18], the IPCC divides carbon classes into two categories: the good category class with carbon storage of > 138 tons ha^{-1} and the poor category class with carbon storage of < 138 tons C ha^{-1}.

When compared with the results of the above research, it can be said that the results of the study on the potential value of carbon in the Virgin forest area (120.24 tons C ha^{-1}), RKT 2016 (59.81 tons C ha^{-1}) and RKT 2022 (46.14 tons C ha^{-1}) with an average of 52.97 tons ha^{-1} in the LoA area are still said to be less good because the average value of carbon is less than 138 tons C ha^{-1}. While a significant decline is seen in the 2022 RKT, where the average carbon potential is only 46.14 tons C ha^{-1} (38%), the estimated level of potential carbon loss is around 74.09 tons C ha^{-1} (62%). Increasing the carbon potential of the area needs to be done through replanting with various types of plants.

3.4. Carbon Dioxide Uptake (CO_2eq)

The carbon dioxide uptake calculation shows that the virgin forest area has a greater uptake value than the standing area (LoA). The size of this absorption rate is related to the size of the stands found in each observation plot. The potential uptake of CO_2 can be based on the observation plot can be seen in Table 5.

Table 5. Carbon dioxide uptake CO_2eq of stands by growth stage

Growth stage	Area type (Ton ha^{-1})			Average quantity (Tons ha^{-1})
	Virgin forest*	RKT 2016 (LoA)**	RKT 2022 (LoA)**	
Trees (20 cm up)	297.31	184.31	151.50	211.04
Pole (10–19 cm)	127.87	22.81	3.06	81.54
Sapling (5–9.9 cm)	16.09	12.38	14.78	14.42
Total (tons ha^{-1})	441.27	219.49	169.35	307.00

Virgin Forest*: Protected area and LoA**: Logged Over Areal/Forestation

Luhulima et al. [19] stated that forests have an essential role in absorbing and emitting carbon in the forest. The process of carbon stored in plants is referred to as carbon sequestration, while the amount of carbon stored in plants depends on the type and nature of the plant. Table 5 illustrates that the highest CO_2eq sequestration is in virgin forest areas with an average sequestration value of 441.27 CO_2eq tons ha^{-1}. Meanwhile, in the area of live stands/LoA, the highest uptake value was found in the 2016 RKT, which amounted to 219.49 tons ha^{-1}.

3.5. Comparison of Biomass Values by Allometric Model Type

The results of the allometric test through five allometric models vary based on the highest biomass value, namely Brown [8]. These results have a different order from the results of the West Kalimantan Sub-National FREL test [3]. Figure 3 shows the results.

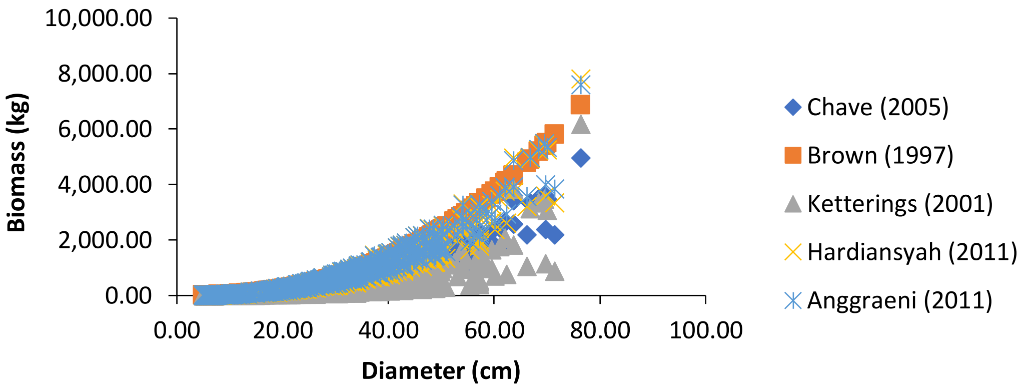

Figure 3. Biomass calculation chart based on the allometric model shows that the Brown allometric model has the highest results compared to the results of other allometric.

The first position that has the highest biomass in the West Kalimantan Sub-National FREL is the same as the results of this study, namely from the Brown [8] model test, while the next results are occupied by the Ketterings et al. [6], Hardiansyah [9], and Chave et al. [7] models. Meanwhile, this study shows that Ketterings et al. [6] is the allometric model with the lowest biomass value among other models. This explains that in addition to differences in the allometric models used, significant variations are caused by parameters and floristic composition differences.

3.6. Economic Value of Carbon Stocks AGB

Three carbon economic benefits can be generated from virgin forest, LoA, and a combination of virgin forest and LoA. The calculation of the economic value of carbon uses a reference to the carbon price in the NDC (*Nationally Determined Contribution*) document, which is a reference to the United States dollar (USD) and based on the average price of the Indonesian Carbon Exchange in 2023, which is USD 4.5. Table 6 shows that the highest potential economic value of carbon is found in the Virgin Forest area (IDR 302,800,346.83 ha^{-1}), followed by the 2016 RKT/LoA area (IDR 150,612,721.63 ha^{-1}) and 2022 RKT/LoA (IDR 116,206,022.94 ha^{-1}). This economic value results from multiplying the carbon price (USD) by the stored value of CO_2eq (tons ha^{-1}), where every USD 1 = IDR 15,248.79.

Table 6. The average economic value of carbon stock

Location	Storage potential CO_2eq (ton ha^{-1})	Carbon economic value potential (Ha)	
		IDR 4.5	IDR 15,248.79
Virgin forest*	441.27	1,985.73	30,280,034.68
RKT 2016**(LoA)	219.49	987.70	15,061,272.16
RKT 2022** (LoA)	169.35	762.07	11,620,602.29

Virgin Forest*: Protected area and LoA** : Logged Over Areal/Forestation

The potential economic value of carbon in Table 7 shows that during the company's establishment from 2011 to 2022, there were 14,583 ha of LoA. If it is assumed that the selling price of carbon is USD 4.5, the total potential economic value obtained from the sale of carbon in the LoA sector is USD 12,758,447.6, equivalent to IDR 194,550,887,599.42 (194 billion 550 million).

Table 7. The average economic value of carbon stocks in the area

No.	Year activity	LoA** Area (Ha)	Average carbon potential (Ton ha^{-1})	Carbon dioxide storage potential (CO_2eq)	Carbon economic value potential	
					USD 4.5	IDR 15,248.79
1	2022	1,586	52.98	308,348.35	1,387,567.56	21,158,726,443.99
2	2021	1,609	52.98	312,819.98	1,407,689.92	21,465,568,000.24
3	2020	1,183	52.98	229,997.54	1,034,988.92	15,782,328,741.01
4	2019	1,409	52.98	273,936.21	1,232,712.92	18,797,380,554.59
5	2018	1,243	52.98	241,662.67	1,087,482.02	16,582,784,974.70
6	2017	1,090	52.98	211,916.58	953,624.62	14,541,621,578.78
7	2016	1,100	52.98	213,860.77	962,373.47	14,675,030,951.06
8	2015	928	52.98	180,420.72	811,893.25	12,380,389,747.81
9	2014	1,078	52.98	209,583.56	943,126.00	14,381,530,332.04
10	2013	1,150	52.98	223,581.72	1,006,117.71	15,342,077,812.48
11	2012	1,009	52.98	196,168.65	882,758.93	13,461,005,663.29
12	2011	1,198	52.98	232,913.82	1,048,112.19	15,982,442,799.43
Total		14,583		2,835,210.57	USD 12,758,447.6	IDR 194,550,887,599.42
Average		1,215		236,268	USD 1,063,203.96	IDR 16,212,573.96

Virgin Forest*: Protected area and LoA**: Logged Over Areal/Forestation

Based on Permen LHK No. 21 [20] Article 35, it is said that in the carbon trading mechanism, there will also be tax levied on the carbon according to Article 3 Paragraph 2 Letter C, which is levied in the form of central, regional and customs taxes by the state following legislation and NDC achievement targets at a rate of IDR 30 kg^{-1} (CO_2eq ha^{-1}) [21]. In the NDC policy stipulated in Presidential Regulation Number 98 Paragraph (1) Letter b [4], the potential net carbon economic value generated based on the LoA of 14,583 ha is IDR 194,550,887,599.42 – IDR 85,056,317,100 = IDR 109,494,570,499.42 (109 billion 494 million). The value of IDR 85,056,317,100 (2,835,210.57 tons CO_2eq x 1,000 kg x IDR 30) is the amount of tax imposed by the government in carbon trading.

Table 8. The average economic value of carbon stocks in PT Hutan Mulya protected area

No.	Protected area/Virgin forest*	Total LoA** (Ha)	Average carbon potential (Ton ha^{-1})	Carbon dioxide storage potential (CO_2eq tons ha^{-1})	Carbon economic value potential	
					USD 4.5	IDR 15,248.79
1	River border	587	120.24	259,027.92	1,165,625.62	17,774,380,358.97
2	Germplasm area	332	120.24	146,503.01	659,263.55	10,052,971,514.78
3	In situ conservation area	2,101	120.24	927,116.95	4,172,026.29	63,618,352,869.14
Total		3,020		1,332,647.88	USD 5,996,915.48	IDR 91,445,704,742.89

Virgin Forest*: Protected area and LoA**: Logged Over Areal/Forestation

Table 8 shows the calculation of the economic value of carbon in the virgin forest sector with an area of 3,020 ha obtained through the price of USD 4.5. USD 5,996,915.48 is equivalent to IDR 91,445,704,742.89, so the potential value of the net carbon economy after being subject to the carbon tax is IDR 91,445,704,742.89 – IDR 39,979,436,400 = IDR 51,466,268,343 (51 billion 466 million).

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4. Discussion

Stand density is influenced by differences in tree diameter size, stand age and logging area age. The difference in potential stand biomass in virgin forest and LoA locations is because RKT 2022 is a new post-felling area that is still 2 years old, and regeneration of sapling level to pole level is still not visible as in the RKT 2016 area, so the sapling level is dominant in RKT 2022 like statement of Hikmatyar et al. [16] that the largest tree carbon stocks are found in areas with the highest number of trees. Meanwhile, in the TPTI standing area, namely RKT 2016 and RKT 2022, there is a difference in the amount of potential biomass because tree biomass will increase as the felling age increases.

The low carbon potential of trees in LoA due to the average diameter of trees that tend to be < 30 cm in PT Hutan Mulya affects the difference in the value of carbon is large with carbon in primary forests. This is evidenced by the highest potential biomass value in the virgin forest area of PT Hutan Mulya by the red Meranti species which dominates this area with a total stand of 45 individuals ha^{-1} and an average diameter of 29.42 cm. Variations in carbon storage in land cover areas can be influenced by stand growth or tree age which affects tree diameter, forest type, climate and the accuracy of vegetation analysis methods, Irfan et al. [22] also said that the larger the diameter of stands in an area, the greater the potential carbon produced and vice versa. According to Erly et al. [23], calculating the total forest carbon stock is based on the content of biomass and organic matter in five carbon pools, as follows: Aboveground biomass (70%) and belowground biomass (20%).

Suppose the scenario project managed in the carbon business uses LoA and virgin forest areas to get the maximum economic value of carbon. In that case, the calculation is only by adding up the economic value of carbon in the LoA area with virgin forest areas IDR 285,996,592,342.31 (285 billion 996 million), then reduce the combined economic value with the total tax rate imposed, namely IDR 285,996,592,342.31 – IDR 125,035,753,500 = IDR 160,960,838,842.31 (160 billion 960 million). This carbon economic value is the value of benefits that can be provided by the world community for the quality of some ecosystems in the PT Hutan Mulya LoA area as a forest area that is still able to function as a sink for CO_2eq emissions, even though it has experienced logging in forest harvesting activities.

Based on research by Hardiansyah [9], it is said that the economic potential of carbon within 50 years in areas without logging can provide economic benefits of IDR 6.83 million ha^{-1} with the assumption of using a carbon price of USD 5 per ton C, while in selective logging areas in planting lanes and selective logging lanes it is IDR 6.12 million ha^{-1} with transaction costs of IDR 558,000 ha^{-1} $year^{-2}$. If the economic value of carbon is compared with the economic value of timber based on financial analysis alone, then the highest economic value comes from timber because the results show that in the virgin forest area and LoA 2016 and LoA 2022 with a total area of 3 ha from the level of trees, poles and saplings, the weight of logs reaches 891.91 m^3 with the economic value of timber per m^3 is IDR 2,500,000 (IDR 2 million 500). So that the total income from logs is IDR 2,229,790,883 (IDR 2 billion 229) per 3 ha, while the income from the economic value of carbon of the three areas is smaller at IDR 56,961,909.13 (IDR 56 million 961) per 3 ha. But even so, in terms of ecology, the economic value of carbon will increase over time and will provide greater benefits, while the economic value of timber will decrease over time because the potential of stands in the forest is decreasing and the quality of the forest ecosystem is also decreasing due to timber harvesting activities in the production area.

The project scenario presented in this research can be a solution for the company's business in the forestry sector, because according to Ekins Paul and Dimitri Zenghelis, the energy transition to a low-carbon economy is one of the realizations of efforts in investing, which is not only profitable in terms of business economics, but also in terms of ecology, which is based on the sustainability of environmental ecosystems [24].

Quoted from Saragih et al. [25], that forest services in carbon sequestration and storage to reduce CO2 in the air reached 77.9%, while the direct benefits of forest processing in the form of wood products were only 4.1%. This proves that although the utilization of production forests for commercial timber provides the highest economic value financially, the value of timber is only 4.1% compared to other benefits. The alternative conservation strategy of establishing production forests managed by the private sector (PBPH) is the right choice. Still, it must be balanced with optimizing forest utilization through the economic value of direct or indirect benefits. The addition of carbon sequestration productivity can be one of the bases for compensating forest managers, including companies with the TPTI silviculture system, in realizing sustainable forest development and avoiding further deforestation.

5. Conclusions

The results showed that the tree-level diameter class in virgin forest areas dominated the potential carbon stock. The average value of the calculation of five types of allometric shows that the Brown (1997) allometric model has the highest results compared to other allometric models. In 2011–2022, LoA had an area of 14,583 ha with a potential carbon stock of 772,532 tons C, equivalent to a carbon dioxide sequestration value of 2,835,210.57 tons CO_2eq. Based on the calculation of the potential economic value of carbon in the LoA area, it can be concluded that the profit obtained by the government through carbon sales tax is IDR 85,056,317,100 (85 billion 56 million). In contrast, the net profit obtained by the company is IDR 109,494,570,499.42 (109 billion 494 million). This study illustrates that maintaining vegetation in production forest areas through rehabilitation does not reduce the value of timber production and increases economic value by selling carbon stocks. Of course, it can still preserve the ecological functions of the forest to remain sustainable.

Author Contributions

AF: Conceptualization, Methodology, Survey, Entry Data, Writing - Editing; **GH**: Review & Editing, Supervision; **AY**: Review & Editing, Supervision.

Conflicts of interest

There are no conflicts to declare.

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