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Carbon stocks potential and economic value valuation of carbon stocks in Ebony stand

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***Abstract**. One of the important activities to achieve the implementation of REDD+ activities is the measurement and reporting of carbon stocks. Information on the potential for carbon stocks in a plant stand or forest area can provide an overview for related parties of the potential carbon stocks and the added value that will be obtained if it maintains and develops a certain plant species to support the reduction of greenhouse gas emissions. This study aims to determine the potential of biomass, carbon stocks, and economic valuation of the carbon stocks potential of several Ebony stand contained in the Kawanua Arboretum BP2LHK Manado. The types of Ebony stand that were the object of this study was* Dyospiros celebica, Dyospiros rumphii, *and* Dyospiros ebenum. *Determination of biomass potential and carbon stocks using the allometric equation. The economic valuations of each potential carbon stocks of Ebony stand are obtained based on the selling value of carbon set by the World Bank Group. Based on the results of the study, it is known that the carbon stocks potential of each Ebony stand, namely* Diospyros rumphii, *is 74.246 tons/ha, followed by the potential carbon storage in the Diospyros celebica stand of 67.768 tons/ha and* Diospyros ebenum *of 64.977 tons/ha, while the economic valuation value of the highest carbon storage potential is found in the* Diospyros rumphii *stand of USD 148.492 followed by* Diospyros celebica *is USD 135.536, and* Diospyros ebenum *is USD 129.954.*

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INTRODUCTION

The issue of global warming continues to be a concern for the international world, this is due to the impact of global warming that we can feel directly. The General Directorate of Climate Change Control of the Ministry of Environment and Forestry (KLHK 2021) stated that global warming has a direct impact on human health, food security, ecosystems, and so on. One of the main causes of global warming is the increase in Greenhouse Gas (GHG) emissions. The greenhouse gas effect occurs due to the presence of greenhouse gases that trap the heat of solar radiation that is reflected into space by the earth's surface. GHG can be caused or sourced from nature or from human activities (anthropogenic) (Purwanta 2017). Greenhouse Gas is a term that is often used for gases that have a greenhouse effect, such as chlorofluorocarbons (CFCs), carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), ozone (O_3), and water vapor (H_2O) (Suprihatin *et al.* 2012), where CO_2 is one of the elements of greenhouse gases with the largest percentage.

Efforts to overcome global warming due to the effects of GHG are still being carried out at the international level, one of which is by suppressing the release of greenhouse gases through the REDD+ mechanism (*Reducing Emission from Derofestation and Forest Degradation*). REDD+ is a mechanism by which developed countries provide incentive funds to developing countries that have large forests and are able to maintain to reduce greenhouse gas emissions (IPCC 2009). This is because, theoretically, plants or trees in the forest serve as a place for carbon deposition (Putri and Wulandari 2015).

Indonesia, as a developing country with extensive forests and a very high level of biodiversity, is expected to be able to utilize and play an important role in the REDD+ mechanism by conserving its forests and reducing the rate of deforestation during the level of carbon sequestration. One of the important elements of achieving REDD+ activities is the measurement and reporting activities on carbon stocks (Masripatin *et al.* 2010). Measurement activities are carried out to find out how much absorption and carbon stock is contained in an individual stand and in a forest area. Information on the absorption capacity and carbon stock in a stand and area is expected to support related parties in making policies to reduce the release of GHG. Information on carbon absorption in individual stands and forest area is also expected to provide an overview for related parties of the potential added value that can be obtained if it maintains and develops a certain plant species to support the reduction of greenhouse gas emissions.

One of the plant species that exists found in Indonesia and is endemic to several regions in Indonesia is the Eboni plant. Ebony is a plant that comes from the *Diospyros* family and the Ebenaceae tribe. Alrasyid (2002) stated that approximately 100 of the total number of *Diospyros* species in the world are in Indonesia. Of the entire *Diospyros* family in Indonesia, not all are Ebony plants. The term Ebony is an international trade term for a species derived from the *Diospyros* family that has a high selling value (Riswan 2002). Of the 100 species of *Diospyros* in Indonesia, there are only 7 species that are declared as Ebony plants, namely, *Diospyros pilotanthera, Dyospiros lolin, Diospyros macrophylla, Dyospiros ebenum, Diospyros celebica, Diospyros ferea and Dyospiros rumphii.* The characteristics of ebony wood are very favored by the international market, making Ebony wood one of the woods with high economic value which causes large exploitation of magnitude and results in the presence of Ebony plants in natural forests, especially Sulawesi forests, to be very critical (Kinho 2013). The existence of Ebony plants that are increasingly rare in natural forests makes the information obtained about Ebony plants very limited, one of which is information about the carbon absorption of Ebony plants.

Kawanua Arboretum is a research forest of the Manado Environmental and Forestry Research and Development Center (BP2LHK Manado), which has a collection of 13 types of *Diospyros* plants, of which 5 are Ebony plants. *Diospyros* in the Arboretum Kawanua are planted in the form of a plot. The Ebony plant distribution owned by the Kawanua Arboretum is the most complete collection of Ebony plants in Indonesia. This study aims to determine the potential of biomass, carbon stocks, and economic valuation of the carbon stocks potential of several Ebony stand contained in the Kawanua Arboretum BP2LHK Manado. The Ebony stand that were the object of this study were *Diospyros cellebica, Diospyros rumphii and Diospyros ebenum.* Until now, information about the potential for carbon stocks and the economic valuation of the carbon stocks potential of Ebony stand is still very limited, so the research team assessed the need to conduct this research. The results of this research activity are expected to be new information and may be the only information about the potential carbon stocks of Ebony plants when developed as plantation forests and also how the economic value of potential carbon reserves in Ebony plantation forests is. This is due to the presence of the very rare Ebony plant. The Kawanua Arboretum is the only location that collects the most complete Ebony stand developed in the form of plantation forests.

METHOD

Research Location and Time

This study was conducted on Ebony stand (*D. cellebica*, *D. rumphii*, *D. ebenum*) which are in the Arboretum of Kawanua. Kawanua Arboretum is a research forest owned by Balai Research and Development of Environment and Forestry (BP2LHK) located in the city of Manado, North Sulawesi province. The arboretum is located at coordinates N:01033.727' E:1240 54,21'. The total area of the entire arboretum is about 5 Ha (Halawane 2016), with an Ebony plantation forest stand of 5200 m^2/0,52 Ha. The Kawanua Arboretum Ebony plant began to be developed in 2012 as an ex-situ conservation effort and research media. The location of Ebony plant plot is located at an altitude of 70 meters above sea level with temperatures ranging from 29 - 34 ^oC, humidity levels of 40 - 70%, and an average monthly rainfall of 270 mm, flat to undulating topography (Halawane 2016). This research was carried out for two months, namely between April and May 2022. The location of the study can be seen in Figure 1.

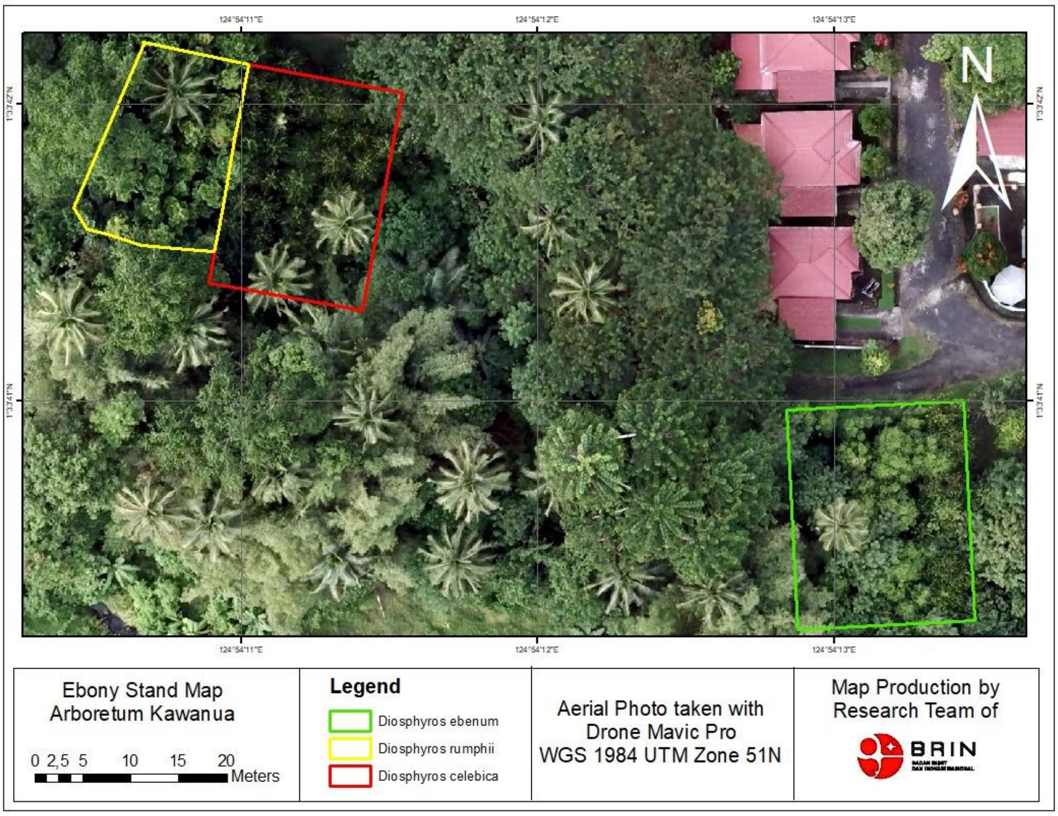

Figure 1 Location map of Ebony stand

Research Tools and Materials

The tools used in this study include the Global Positioning System (GPS) for location tagging, DSLR cameras for documentation, measuring meters, raffia ropes, office stationery for data recording, which includes field books and pencils to record measurement results, color paint as a marker for trees that have been taken data. The material used in this study was an Ebony stand (*Diospyros celebica*, *Diospyros rumphii* and *Diospyros ebenum*) where each type of Eboni Stand was 10 years old and, in a plot measuring 400 m^2 with the number of individuals each 50 so that the total Ebony stand used in this study amounted to 150 individu. In addition, the study also uses data information, including rainfall from the BMKG (Meteorology, Climatology and Geophysics Agency).

Data Collection Methods

The data collection method in this study used a *Non-Destructive* Method. The use of non-destructive methods in this study is because the object of study is an ex-situ conservation area of Ebony Plants, where the Non-Destructive Method is considered appropriate for use. This is because in obtaining data, it is only measuring the circumference of the tree without any effort on the object of study. The non-destructive method is also often used in the type of stand that has been found to be allometrically close to that of a stand. The disadvantage of the non-destructive method, when compared to the destructive method, is that the non-destructive method is not appropriate when used in tree stands that have a specific branching pattern that requires a destructive method to determine its allometric formula (Hairiah *et al.* 2011). The data collected included the diameter of the Ebony and the specific gravity of the Ebony plant species. The diameter of the Ebony plant is obtained by a survey of each individual ebony plant (*D. cellebica, D. rumphii, D. ebenum*). The data measured are in the form of the circumference of each individual ebony plant.

The circumference of each individual is measured 1,3 meters above ground level (Hairiah *et al.* 2011) which is then converted into a diameter value. The diameter value obtained is further used in Allometric analysis to obtain Ebony stand' biomass potential and carbon stocks' potential. Data on the specific gravity of the Ebony plant in this study was obtained from https://www.wood-database.com/. The Ebony stands and data retrieval process can be seen in Figure 2

Figure 2 Ebony stand and measurements of Ebony stand diameters

Data Analysis Methods

Biomass Potential and Carbon Stocks Ebony stand

Determination of biomass potential in this study using an allometric equation approach developed by Chave *et al.* (2005). The allometric equation is the result of the development of potential biomass analysis in species for which the allometric equation has not been specifically discovered. The use of allometric in this study also considers that the equations are arranged based on the most important predictors in estimating biomass in a stand, namely the diameter and specific gravity of wood. Arifanti *et al.* (2014) stated that the calculation of potential biomass estimates using the allometric equations of Chave *et al.* (2005) showed results that were closest to the results of geometric calculations and had been tested in various types of forests. The use of allometric also considers the data factors needed in the analysis can be obtained through *non-destructive* methods, considering that the object of study is a plantation forest developed as *ex-situ* conservation. Hairiah *et al.* (2011) stated that using allometrics to estimate biomass potential is one way to reduce tree destruction. The data required on this allometric equation include the diameter of the tree, rainfall data, and the specific gravity of each species of ebony plant. Lubis *et al.* (2013) state that rainfall data is an important component in estimating biomass in a stand. Therefore, the allometric equation used considers rainfall data. Based on the BMKG report, the rainfall of this study location was carried out into the dry rain class, which is < 1.500 mm/year. The allometric equations of Chave *et al.* (2005) for the location of the dry rain class are as follows:

$$(AGB)_{est} = \pi * \exp(-0{,}667 + 1{,}784 \ln(D) + 0{,}207\ (\ln(D))^2 - 0{,}0281\ (\ln(D))^3)$$

AGB : Biomass of above-ground trees (kg/trees)
D : DBH, Diameter of the trunk at chest level
Π : Specific gravity of wood (g/cm^3)

The analysis then proceeded to calculate carbon stocks using the biomass content approach developed by the (IPCC 2009). The analysis can be seen in the following equation:

$$C = 0{,}5\ x\ W$$

C : Carbon Stocks (tC)
0,5 : Coefficient of carbon content in plants
W : Biomass (Kg)

Valuation of The Economic Value of Potential Carbon Reserves

After knowing the amount of carbon stocks in each Ebony stand, the analysis continued to calculate the economic valuation of the potential carbon reserves in each Ebony stand. The economic valuation of each potential carbon stock of Ebony stand is obtained using the formula:

Carbon Economy Valuation = ΣC (tons) of Ebony stand x Selling Value of Carbon

The selling value of carbon in the international market is obtained from data released by the World Bank (2021).

RESULTS AND DISCUSSION

Biomass Potential and Carbon Storage of Ebony stand

The value of biomass in a plant can be interpreted as the amount of organic matter stored in a plant. Hairiah *et al.* (2011) stated that through the process of photosynthesis in plants, there is a process of absorption of CO_2 in the air, and then the CO_2 absorbed is then distributed to all parts of the plant, therefore by measuring the value of biomass in a plant, it can describe a large amount of CO_2 value that has been successfully absorbed by a plant. The results of the analysis of estimation and biomass potential of the three types of Ebony plants in this study can be seen in Table 1.

Table 1 The results of the analysis of total biomass potential

No	Species	Number of individuals	Age (years)	Number of diameter classes (cm)		Specific gravity (gr/cm^3)	Biomass potential estimation (kg/400 m^2)	Biomass potential (kg/ha)
				5-10	11-15			
1	*Diospyros celebica*	50	10	15	35	1,12	5.421,47	135.536,64
2	*Diospyros rumphii*	50	10	8	42	1,10	5.939,64	148.492,33
3	*Diospyros ebenum*	50	10	17	33	0,92	5.198,22	129.955,51

Based on the data presented in Table 1, it shows that the highest biomass estimation value of ebony stand is in the *Diospyros rumphii* stand, which is 5.939,64 kg per 400 m^2 with a potential biomass value of 148.492,33 kg/ha, followed by the estimated biomass value of the *Diospyros celebica* stand, which is 5.421,47 kg per 400 m^2 with a potential biomass value of 135.536,64 kg/ha, while the lowest biomass estimation value is in the stand *Diospyros ebenum* is 5.198,22 kg per 400 m^2 with a potential biomass value of 129.955,51 kg/ha.

After obtaining data on the potential of biomass in each ebony analysis stand in this study, it was then continued to analyze the carbon stocks contained in each ebony stand. The carbon stock potential was analyzed using formulations that have been conveyed in previous research methods. The results of the analysis of the potential carbon stocks in this study are presented in Table 2.

Table 2 Total carbon stocks analysis results

No	Species	Biomass Estimation (ton/400 m^2)	Biomass Potential (tons/ha)	Estimated Carbon Stocks (tons/ 400 m^2)	Carbon Stocks Potential (tons/ha)
1	*Diospyros celebica*	5,42	135,54	2,71	67,77
2	*Diospyros rumphii*	5,94	148,49	2,97	74,25
3	*Diospyros ebenum*	5,20	129,95	2,60	64,98

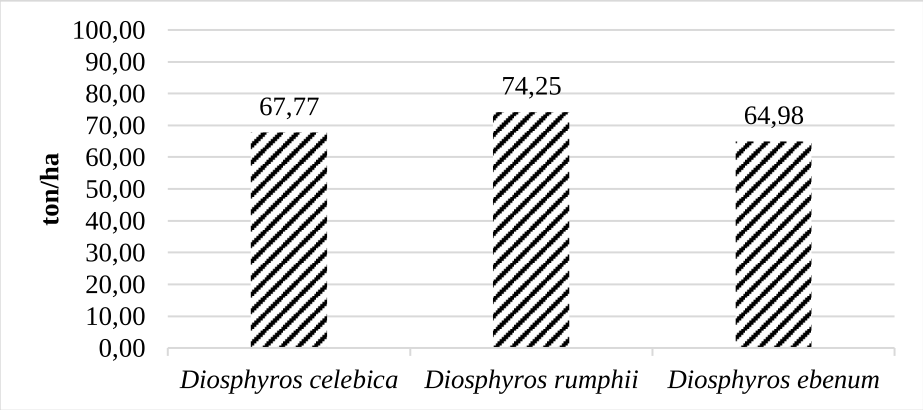

Figure 3 Potential carbon stocks contained in each ebony stand

Based on the data presented in Table 2 and also Figure 3, it can be seen that the highest estimated value of carbon deposits is in the *Diospyros rumphii* stand, which is 2,97 tons/400 m^2 with a potential carbon storage of 74,25 tons/ha, followed by the estimated value of carbon stocks of *the Diospyros celebica* stand which is 2.710 tons/400 m^2 with a potential value of carbon stocks of 67,77 tons/ha, while the estimated value of the lowest carbon stocks is at the stand of *Diospyros ebenum* 2,60 tons/400 m^2 with a potential value of carbon stocks of 64,98 tons/ha. Based on these results, it can be concluded that the potential value of carbon stocks will be proportional to the potential value of the biomass stand, the higher the potential value of biomass, the value of the potential carbon stocks will also be higher this is in line with (Istomo and Farida (2017) statement that in the end, the biomass potential in a stand will affect the carbon stocks of the stand.

Table 2 and Figure 3 show that there are differences in the potential for carbon stocks in each Ebony stand, where the highest carbon stocks potential is found in *the Diospyros rumphii* stand, and the lowest is found in the *Diospyros ebenum* stand. The amount of carbon stock value in a stand can be influenced by several factors, namely the density, age, dimensions, and specific gravity of the wood (Samsoedin *et al.* 2016). Based on the data presented in Table 1, it shows that there is no difference between the age and also the density of the stands of each ebony stand, where each ebony stand at the time this study was carried out was the same as the age of 10 years, as well as the density of the Ebony stand where each Ebony stand was planted on the same land area of 400 m^2 with the same number of individuals also namely 50. Based on the variable data used in Allometrics, researchers concluded that the factors that cause differences in biomass potential and carbon deposits in each Ebony stand are caused differences in diameter and the specific gravity value of each ebony stand.

Based on the data presented in Table 2, the results of diameter measurements are divided into 2 diameter classes, namely diameter classes 5 - 10 cm and 11 - 15 cm. It can be seen that the individual stands of *Diospyros rumphii* are dominated by the diameter class of 11 - 15 cm, where the number of individuals of *Diospyros rumphii* which is in the diameter class of 11 - 15 cm is more than *Diospyros celebica* and also *Diospyros ebenum*. In addition to the difference in the diameter of each stand, the difference in data variables that determine the difference in biomass potential and also carbon stocks is found in the specific gravity value, where the specific gravity of the *Diospyros rumphii* species is known to be quite high and almost the same as the specific gravity of *Diospyros celebica* and higher than *Diospyros Ebenum* as the lowest carbon storage potential value.

The difference in data variables causes differences in biomass potential and carbon stocks in this study in accordance with several carbon stocks studies that have been carried out that the diameter value and specific gravity affect the magnitude of biomass potential and carbon stocks in a stand. Fauziah *et al.* (2021) in his research stated that the determining factor for the magnitude of biomass potential and carbon stocks in a stand is not only determined by the age and the number of stands in an area, the difference in biomass potential and carbon stocks is also greatly influenced by the size of the diameter of a stand. Hardjana (2009) in his research, stated that there is a relationship between the diameter of the amount of biomass and the carbon stocks of a stand, where the larger the diameter of a stand, the value of the potential biomass and the carbon stocks will also be higher.

Specific gravity is an important factor determining the amount of potential value of biomass and carbon stocks in a stand, this is because specific gravity is a description of the arrangement of organic matter contained in a plant. The higher the specific gravity of a plant species, the higher the value of organic matter contained in the species, and vice versa, the lower the specific gravity value of a plant species, the content of organic matter owned is also low, where the difference in organic matter content contained in a species will also affect the stored carbon content (Tuah *et al.* 2017). Maulana (2010) also stated that the factor that directly affects the carbon deposits of a stand is specific gravity.

One of the important activities in responding to the issue of carbon trading is the inventory of Indonesia's carbon absorption capacity in a broad unit to then be utilized in various international negotiations (Farmen *et al.* 2014). The results of this study provide an overview of the potential carbon stocks of Plant species owned by Indonesia, namely the Ebony plant. The results of this study are expected to be utilized by the government in international negotiations aimed at reducing greenhouse gas emissions. In addition, the results of this study are also expected to be an illustration to various policymakers and the community in maintaining the Ebony plant species as a plantation forest. This is because the Ebony plant has considerable potential in carbon sequestration and storage, where the greater the carbon stocks of a stand, the greater the incentives received as part of carbon trading will also be greater. In addition, maintaining tree stands is one way to reduce global warming and climate change, where trees will absorb and store one of the largest greenhouse gas elements, namely CO_2 (Rahmawaty *et al.* 2017). The greater carbon stocks of a stand indicate that the stand has great potential to reduce global warming and also climate change due to the effects of greenhouse gases.

Based on the results of this research activity, it shows that the Ebony plant has a considerable carbon stock potential. When compared with some of the results of previous studies on plantation forests. The research conducted by (Purwanto *et al.* 2012) in Mahogany plantation forests (diameter 10-23 cm) showed an average potential carbon stock of 23.119 tons /ha, where the carbon stocks were still smaller when compared to the average carbon stock potential of ebony stand in this study, which ranged from 64,97 - 74,26 tons/ha. Research on the potential for carbon stocks was also carried out by (Yuniati and Kurniawan

2011) on teak plantation forests in Kupang Regency, where the results showed that the average potential carbon stoks of teak plants in diameter (5 - 30 cm) were 63,23 tons/ha, this value was also still below the average value of potential reserves shown by the results of this study, namely 64,97 - 74,26 tons/ha.

Economic Value Valuation of Potential Carbon Reserves of Ebony Crops

The valuation of economic value of the carbon stocks potential of a plant species is one of the important aspects for the public and policymakers to know. The valuation of the economic value of a plant species carbon stocks can be an illustration of how much economic benefits will be obtained from certain species if developed into plantation forests and when carbon trading is carried out. An economic valuation can be interpreted as the value of goods and services that can be traded, thus providing income (Betani *et al.* 2016).

Carbon trading has been widely discussed recently linked to efforts to build a safer environment from air pollution as well as efforts to anticipate global climate change (Cifor 2003). The mechanism that the international world has agreed on to reduce air pollution and anticipate global climate change is REDD+. The REDD+ mechanism is a new concept that is implemented in forest conservation activities with economic incentives for the amount of carbon that can be maintained in line with the sustainability of a forest area or peatland (Wicaksono and Yurista 2013).

The World Bank Group estimates that in 2030 the price of carbon in the international market will reach at least USD 50 – 100/ton C, this price is an effective price in carbon trading to reduce greenhouse gas emissions globally, but the *World Bank Group* states that the average price of carbon worldwide is only USD 2 /ton C. Carbon prices in each country itself are determined by local conditions in each country such as policies regarding handling climate and also technological advances. Based on the average price of carbon around the world, the valuation of the economic value of potential carbon stocks in this study can be seen in the following Table 3.

Table 3 Economic value valuation of potential carbon stocks

No	Species	Carbon stocks potential (tons/ha)	Economic value valuation of carbon stocks (USD)	Economic value valuation of carbon stocks potential (IDR= Rp 14.358/ USD)
1	*Diospyros celebica*	67,77	135,54	1.946.025
2	*Diospyros rumphii*	74,25	148,49	2.132.048
3	*Diospyros ebenum*	64,98	129,95	1.865.879

Table 3 shows that the economic valuation value of the highest potential carbon reserves of Ebony stand is at *the Diospyros rumphii* stand of USD 135,54 (IDR 1.946.025), followed by *Diospyros celebica* worth USD 148,49 (IDR 2.132.048) and *Diospyros ebenum* with an economic valuation value of USD 129,95 (IDR 1.865.879). The economic valuation value is a calculation using the potential carbon deposits per hectare of each ebony stand with the equation according to the *World Bank Group,* which states that the average value of carbon trading worldwide is currently USD 2/tonC.

The economic value of potential carbon stocks in the Ebony stand used in this study can still continue to increase in line with the increase in the selling value of carbon that the World Bank Grou has estimated, namely USD 50 – 100/ton C in 2030. The increase in the economic value of carbon reserves is also predicted to continue to increase in line with the increase in factors determining the amount of carbon stocks mentioned earlier, such as the age and diameter of ebony stand, considering that the research object used at the time of the study was still at the age of 10 years. Kinho *et al.* (2020) stated that the maximum potential diameter in each ebony stand could reach: 100 cm for *Diospyros celebica,* 40 - 60 cm for *Diospyros rumphii,* and 20 - 30 cm for *Diospyros ebenum,* when compared to the average tree diameter at the time this study was carried out is still far from the maximum potential diameter of the Ebony stand.

CONCLUSIONS

The highest carbon stock potential is found in the stands of *Diospyros rumphii* at 74,25 tons/ha, followed by the potential for carbon deposits in *Diospyros celebica* stands at 67,77 tons/ha and *Diospyros ebenum* of 64,98 tons/ha. Meanwhile, the economic valuation of the highest carbon stocks potential is found in the *Diospyros rumphii* stand, which is USD 148,49, equivalent to IDR 2.132.048, followed by *Diospyros celebica* of USD 135,54, equivalent to IDR 1.946.025, then the valuation value of potential carbon stocks of *Diospyros ebenum,* which is USD 129,95 or equivalent to IDR 1.865.879.

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