The potential of biomass and carbon storage of *avicennia alba* in the mangrove rehabilitation area of Kedaburapat village, Kepulauan Meranti district

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Abstract. This research was conducted from May – August 2023 in the rehabilitation mangrove area of Kedaburapat Village, Rangsang Pesisir Sub-District, Kepulauan Meranti Regency, Riau Province. This study aims to determine the average of tree diameter, potential biomass and carbon storage of each tree and the relationship between potential biomass and carbon storage with the diameter of the *Avicennia alba* rehabilitation mangrove trees in Kedaburapat Village. The method used in this study is a survey method and determination of sampling points by purposive sampling. The potential biomass and carbon storage of each tree were calculated using the allometric method. The relationship between average tree diameter and potential biomass and carbon storage was analyzed using simple linear regression. The average diameter at breast height (DBH) of *A. alba* per tree ranged from 2.81 – 4.03 cm, the average biomass per tree was 7.39 – 12.80 kg, the average carbon storage per tree was 3.47 – 5.00 kg C and tree carbon total per ha was 32.62 – 43.95 ton C/ha. The potential of biomass and carbon storage of each tree has a relatively strong positive relationship with the average tree diameter, with a correlation coefficient (r) of 0.9921. The quality of the waters measured in this study were temperatures ranging from 28-30°C, salinity 25-28‰, and pH 7.5-7.9. Environmental parameters indicate that the condition of the rehabilitation mangrove area in Kedaburapat Village is still good and can support the life of mangrove vegetation.

1 Introduction

Global warming is one of the most discussed issues at this time, namely the process of increasing the average temperature of the atmosphere, sea and earth's land. According to experts, global warming has caused many things that have a negative impact on survival such as rising sea levels, increasing the intensity of extreme weather phenomena, and changing the amount and pattern of precipitation. Other consequences of global warming are affecting agricultural production, loss of glaciers, and extinction of various types of animals. Global

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warming is related to the increasing levels of greenhouse gases in the atmosphere, such as methane (NH_4) and CO_2 gases. One of the efforts made to reduce the presence of greenhouse gases, especially CO_2 gas is to increase the forest area. Especially for coastal areas that are expected to absorb CO_2 are mangrove forests. The existence of mangrove forests in coastal areas is believed to be one of the efforts to reduce CO2 gas content from the atmosphere.

One of the efforts to reduce carbon emissions is by reforestation. Plants can absorb carbon in the air through photosynthesis, thereby minimizing the impact of carbon emissions Mangrove forests have a very important function like other forests, namely as carbon sinks and stores (C). Mangrove forests play a role in efforts to mitigate the consequences of global warming because mangroves can function as carbon (C) stores[1]. Rachmawati et al.[2] stated mangrove ecosystems have important ecological functions for coastal areas. In addition, the ecological function of mangroves is to absorb and store carbon in efforts to mitigate global warming.

Carbon storage of an ecosystem will be related to the type and size of mangrove trees. Based on this, the potential of biomass and carbon storage by the rehabilitated mangroves is very interesting to study, so that the contribution of the rehabilitated mangroves to global warming can be informed. The mangrove forest in Kedaburapat Village, Meranti Islands Regency, Riau Province is partly the result of rehabilitation or planting of *Avicennia alba* species with different planting time, namely 2017, 2018 and 2019. The existing mangrove ecosystem has become a habitat for various biota, increases fertility and can store carbon. Based on this, the purpose of this study was to measure tree diameter, potential biomass, potential carbon storage on average per tree and the relationship between tree diameter and potential biomass and carbon storage in *A. alba* rehabilitation with different planting periods in Kedaburapat Village, Kepulauan Meranti District, Riau Province.

2 Material and Methods

2.1. Time and place

This research was conducted in May - July 2023 in the mangrove ecosystem as a result of rehabilitation in Kedaburapat Village, Rangsang Pesisir District, Meranti Islands Regency, Riau Province (Figure 1). Biomass and carbon storage calculations were carried out at the Marine Chemistry Laboratory, Department of Marine Science, Faculty of Fisheries and Marine Science University of Riau.

Fig. 1. Map of research locations

2.2. Material and Tools

Materials and tools used to collect data on tree diameter, potential biomass and carbon storage in *A. alba* in the field included raffia rope for making transects and plots, tape measurers, and tools for measuring water quality (thermometers, refractometers, pH meters).

2.3. Research methods

The method used in this research is a survey method. To collect data, direct observations, measurements and sampling were carried out in the field, then continued with data analysis.

2.4. Determination of Research Stations

Sampling stations were determined using a purposive sampling technique, namely sampling was carried out on the basis of certain considerations [3]. In this study the research location were divided into 3 stations with different mangrove *A. alba* planting periods, namely Station 1 with a planting period of 2017 (six years), Station 2 with a planting period of 2018 (five years) and Station 3 with a planting period of 2019 (four year). Each station is divided into 3 zones, namely: Zone 1 (lower zone), zone 2 (middle zone), and zone 3 (upper zone)

2.5. Research Procedure

2.5.1. Water Quality Measurement

Parameters of water quality in the mangrove ecosystem that were measured in this study were temperature, salinity, and degree of acidity (pH). Measurements were made at high tide with three replications.

2.5.2. Biomass Potency of Avicennia alba

Calculation of *A. alba* mangrove biomass in this study used the Allometric equation method which is a non-destructive method. Allometrics is defined as a study of a relationship between the growth and size of one part of an organism and the growth or size of the whole organism. In the study of forest or tree biomass, allometric equations are used to determine the relationship between tree size (diameter) and overall (dry) weight of trees [4]. In this study, the data collected was tree diameter by measuring tree rings. Biomass potential in *A. alba* is calculated using the following equation referring to[5]:

$$\text{AGB: Wtop} = 0{,}308\ \text{DBH}^{2{,}11} \quad \text{and} \quad \text{BGB : WR} = 1{,}28\ \text{DBH}^{1{,}17}$$

Note:
Wtop : Above Biomass (kg); WR : Bottom biomass (kg). DBH: tree diameter

measured at breasth height.

2.5.3. Avicennia alba Carbon Storage Potential

Calculation of carbon potential in each *A. alba* mangrove tree is calculated using a formula that refers to INS[6], namely:

$$Cb = B \times \%C\ Organic$$

Note:

Cb = Biomass carbon stock (kg).
B = Total Biomass (kg).
%C= The percentage value of carbon storage is 0.47.

Calculation of carbon stock per hectare for biomass can use a formula that refers to INS[6], namely:

$$Cbh = \frac{Cx}{1000} x \frac{10000}{Lplot}$$

Note:

Cbh : Carbon stock per hectare of biomass expressed in ton/ha.
Cx : The carbon stock in each carbon pool in each plot is expressed in kilograms (kg)
$Lplot$: The plot area of each carbon pool is expressed in m^2.

2.6. Data Analysis

Data obtained from measurements in the field were processed using Microsoft Excel to obtain the average diameter, potential biomass and carbon stock of each tree. The relationship between tree diameter and potential biomass and carbon storage in each *A. alba* tree was calculated using a simple linear regression test. Furthermore, the results of the analysis are discussed descriptively.

3 Result and Discussion

3.1. General Conditions of Research Locations

Kedaburapat Village is directly facing the Malacca Strait so the coast of this village has a very high threat of erosion. To overcome the threat of erosion on the coast of Kedaburapat Village, a breakwater (bronjong stone) construction has been built which is approximately 230 m from the current coastline starting in 2014 and is still being added to it. This breakwater is 8 meters wide at the bottom and 2.5 meters at the top.

Mangrove *A. alba* planting activities in Kedaburapat Village have started since 2014, but the planting was only successful after planting in 2017, 2018 and 2019 with a planting distance of 1 meter, namely after the breakwater was installed and a mud bed was formed. The existence of a breakwater not only provides the benefit of protecting the beach from waves but also functions as a place for fishing boats to rest on the bridge pillars made by Kedaburapat Village officials. The bridge, which was built approximately 230 m long, is accompanied by huts, and has also become a tourist attraction for the community.

3.2. Water Quality Parameters

The results of water quality measurements around the rehabilitation mangroves are used as supporting data to determine changes in parameters at each station which can be seen in Table 1.

Table 1. Average Water Quality Measurements around the Kedaburapat rehabilitation mangroves

No.	Parameter	Unit	Station		
			1	**2**	**3**
1.	Salinity	‰	25	27	28
2.	pH	-	7,5	7,6	7,9
3.	Suhu	°C	28	29	30

Based on Table 1, it can be seen that the average water quality parameters at each station are relatively similar. The data showed that the average water quality parameters in the waters of Kedaburapat Village, salinity ranged from 25-28‰, water temperature 28-30 °C and water pH 7.5-7.9. The salinity value obtained in the mangrove rehabilitation environment at Kedaburapat is a good value for mangrove life. According to Wantasen[7] mangrove vegetation grows well in estuary areas with a salinity of 10-30‰. The temperature at the study site ranges from 28-30°C, including conditions that are still good and suitable for aquatic life[8].

3.3. Avicennia alba Tree Diameter

Diameter of the rehabilitated *A.alba* tree in Kedaburapat Village at each station based on the planting period can be seen in Table 2.

Table 2. Average Diameter at Breast Height (DBH) of *A. alba* at each station

Station	Plot	Tree diameter average of *A. alba*
	1	3.89
1	2	3.56
	3	4.64
	Average	**4.03**
	1	3.00
2	2	3.71
	3	3.72
	Average	**3.48**
	1	2.34
3	2	3.00
	3	3.10
	Average	**2.81**

In Table 2, it can be seen that the average tree diameter is higher at Station 1 in the 2017 planting period (6 years), namely 4.03 kg and the lowest is at Station 3 with the 2019 planting period (4 years), which is 2.81 kg corresponds to the growing season plant or age of *A. alba*. The diameter of the tree is higher at station 1 due to its longer life. This is in accordance with what was stated by Darwati et al. [9] that diameter can be affected by the intensity of light received, age and number of leaves which are related to the process of photosynthesis. In addition, he also added that mangroves with older ages provide quite a lot of litter production for soil fertility. Furthermore, Kadarsah and Choesin [10] stated that planting age is known to have an effect and shows a tendency towards certain patterns of vegetation structure parameters (height, density, DBH, and biomass) and litter fall production.

3.4. Avicennia alba Biomass Potential

The results of the calculation of the average potential biomass of each *A.alba* tree in the mangroves resulting from the rehabilitation of Kedaburapat Village can be seen in Table 3

Table 3. The average potential of *A. alba* tree biomass at each station

Station	Plot	Biomass Potential of *A. alba* per tree (kg)
	1	11.98
1	2	10.35
	3	16.07
	Average	**12.80**
	1	8.17
2	2	11.29
	3	11.47
	Average	**10.31**
	1	5.59
3	2	8.07
	3	8.49
	Average	**7.39**

In Table 3 it can be seen that the average biomass potential in *A. alba* is highest at Station 1 which has the highest age and tree diameter (12.80 kg) and the lowest is at Station 3 with the lowest tree age and diameter (7.39 kg). This shows that the potential of biomass is closely related to the size of the tree diameter. Rachmawati et al.[2] stated that the mangrove biomass content is influenced by the density, diameter, type, and wood density of mangroves. Ahmed et al.[11] stated that the difference in the value of biomass at each station was thought to be due to differences in the age of mangrove planting.

The value of biomass increases as the diameter of the tree trunk increases[12]. The larger the tree diameter, the higher the biomass. Furthermore, Haruna [13] added that the larger the diameter of a tree, the greater the biomass contained in the tree, so that more CO_2 is absorbed. Carbon storage describes how much a tree stores carbon. The size of the carbon storage in a vegetation depends on the amount of biomass contained in the tree, soil fertility and the absorption capacity of the vegetation[14].

3.5. A. alba Carbon Storage Potential of A. alba

The results of calculating the average carbon storage for each *A. alba* tree and the total at each station with different planting periods or ages in the Kedaburapat rehabilitation center can be seen in Table 4.

Table 4. The average carbon storage potential for each *A. alba* tree and the total at each station

Station	Plot	Potential of *A. alba* Carbon storage per tree (Kg C)	Potential of *A. alba* total Carbon storage (ton C/ha)
	1	5.63	33.21
1	2	4.87	26.28
	3	7.55	47.57
	Average	**5.00**	**35.69**
	1	3.84	37.62
2	2	5.31	42.45
	3	5.39	51.77
	Average	**4.85**	**43.95**
	1	2.63	24.71
3	2	3.79	36.43
	3	3.99	36.71
	Average	**3.47**	**32.62**

In Table 4 it can be seen that the highest average potential for carbon storage in each *A. alba* tree is at Station 1 (5.00 Kg C), followed by Station 2 (4.85 Kg C) and Station 3 (3.47 Kg C). Furthermore, the total carbon average of *A. alba* at each station was highest at Station 2 (43.95 tons/ha), followed by Station 1 (35.69 tons C/ha and Station 3 (32.62 tons C/ha). The highest carbon storage potential was found in *A. alba* which has the highest average age or diameter and high tree density. According to Purnomo [15] that trunk diameter, tree density, and soil type affect the value of biomass which will indirectly affect the value of a tree's carbon stores. The higher the value of the biomass of a stand, the higher the carbon storage. Biomass and carbon stored are influenced by soil physicochemical parameters, tree diameter and density. The higher the value of soil physicochemical parameters obtained, the higher the value of biomass and stored carbon produced. According to Uthbah et al. [16] the amount of carbon in the form of biomass is influenced by soil type, tree species diversity, tree age, and litter production. The age of mangrove trees affects the carbon value because the age of a mangrove stand will be directly proportional to its biomass content [17]. Increasing tree age is directly proportional to increasing diameter, the older the plant, the greater the stand biomass content [18].

Shaduw et al.[19] stated that the biomass content in a forest was highly dependent on the results obtained during photosynthesis, as well as the age and history of the stand. Each species has a different contribution to the total biomass and carbon stock at each location.

Carbon storage in *A. alba* resulting from rehabilitation was still relatively low compared to that obtained Hariah and Rahayu [20] in the Pandansari ecotourism mangrove area, namely biomass of 2.7 ton/ha and carbon value of 1.35 ton/Ha in *A. alba*. However, this is thought to be due to his older age..

3.6. Correlation between A. alba tree diameter with its potential biomass and carbon storage

The results of the analysis of the relationship between the average diameter of *A. alba* mangrove trees and the average potential biomass per tree obtained the equation Y = -5.4655 + 4.543x and the relationship between the average tree diameter and the average carbon storage per tree obtained the equation Y = -2.5691+2.1353x with a correlation coefficient (r) value of both of them of 0.9921 (Figure 2).

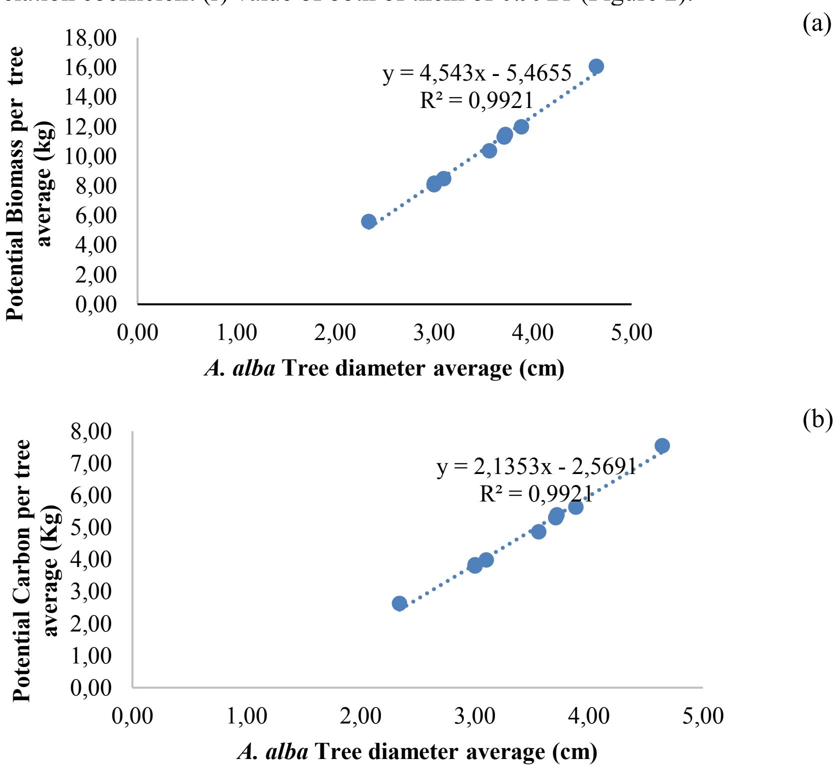

Fig. 2. Relationship between *A. alba* tree diameter and potential biomass (a) and potential carbon storage per tree (b)

The average diameter of *A. alba* trees increases with age. The potential for biomass and carbon storage is higher in *A. alba* which has a longer lifespan with a higher tree diameter. The diameter of the A. alba tree has a very close relationship with the biomass potential and carbon storage potential in the tree. This is in accordance with what was stated by Hariah and Rahayu [20] that the size of the trunk diameter is directly proportional to the value of the biomass, the higher the DBH (Diameter at Breast Hight), the older the tree and the more carbon stock it has.

Mardliyah et al.[21] revealed that the height of the stand has an effect on the biomass value which increases along with the growth of the stand (diameter and height) which will produce a large biomass value and stored carbon. However, Andiani et al.[22] obtained a relatively weak relationship with tree diameter.

4 Conclusion

The average diameter of *A. alba* trees increases with age. The potential for biomass and carbon storage is higher in *A. alba* which is older and has a larger tree diameter. The diameter of the *A. alba* tree has a very close relationship with the biomass potential and carbon storage potential of the tree.

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