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Estimation of Mangrove Carbon Stocks at Muara Badak Waters, Kutai Kartanegara

Fatimah, Muhammad Sumiran Paputungan, and Dewi Embong Bulan(✉)

Marine Science Study Program, Faculty of Fisheries and Marine Science, Mulawarman University, Samarinda, Indonesia
dewi.embong@fpik.unmul.ac.id

Abstract. The most important ecological function of the mangrove ecosystem is to absorb and store carbon in efforts to mitigate global warming. This study aims to determine the density of mangrove species and analyze the amount of carbon stock in mangrove area at the Muara Badak Kutai Kartanegara, East Kalimantan. This research was conducted in July 2022 at two sampling stations using the line transect method. The results showed that the average mangrove density at Station I was 1,100 ind/ha and at Station II was 1,133 ind/ha, indicating that the two stations were in moderate/good condition. The estimated carbon stock of mangrove at Station I has an average carbon of 1.789 tons/ha and at Station II has an average carbon of 2.169 tons/ha. The correlation between mangrove density and mangrove carbon stock showed a close relationship with the R value is 0.9278.

Keywords: Mangrove · carbon stock · mangrove density · Muara Badak

1 Introduction

Global warming is a global issue marked by an increase in the temperature of the earth's surface and the emission of greenhouse gases. Increases in temperature on the surface of the Earth can cause ice to melt at the South Pole and the Pole North, which in turn raises sea levels and disrupts the ecological balance [1]. The utilization of the concept of blue carbon as a means of mitigating the effects of global warming is one of the many approaches that have been proposed. Within this framework, ecosystems such as seagrass ecosystems, mangrove ecosystems, and brackish swamp areas all play an important part in the process of absorbing and storing carbon [2].

Donato et al. (2012) found that mangroves have the capacity to store carbon at a rate that is three times higher than that of terrestrial tropical forests and other marine ecosystems [3]. Carbon storage in mangroves is linked to the process known as "sequestration," which refers to the removal of carbon from the atmosphere and its subsequent storage in plant tissues (roots, stems, and leaves). This carbon is later converted into biomass [4]. The capacity of mangroves to store carbon is affected by the types of trees present, the number of trees present, and a variety of other environmental factors.

The total mangrove area in Indonesia is 3,112,989 hectares, which accounts for 22.6% of the total mangrove area on the planet [5]. Since 2005, however, the mangrove forests

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of Indonesia have suffered a loss of about 1% of their area each year. One of these is the mangrove forest area that is located in the Kutai Kartanegara Regency. It is estimated that there are 100,000 hectares of mangrove forests in the Mahakam Delta region of Kutai Kartanegara, and according to a report published by the Regional Research and Development Agency of Kutai Kartanegara in 2018, this region has experienced a total degradation or damage level of 47.8%. There is a good chance that the primary reason mangrove forests went extinct was because of the transformation of 57,912 hectares of mangrove forest into ponds. This was one of the most common uses of mangrove land [6]. If mangrove forests are cut down, it will almost certainly lead to the disappearance of important ecological functions in coastal areas. As part of their role in maintaining the health of the ecosystem, mangroves take in and store carbon as part of the fight against global warming [7].

Several studies have been conducted in East Kalimantan to estimate mangrove carbon stocks. In a study conducted in East Kalimantan by Dharmawan et al. (2020), carbon stocks were estimated to be 265.67 tons-C/ha in Paser Regency, North Penajam Paser Regency, East Kutai Regency, Berau Regency, and Kutai Kartanegara Regency [8]. Pangempang Bay is one of the areas in Kutai Kartanegara Regency with a lot of mangroves. The diversity of mangroves in Pangempang Bay is classified as medium, ranging from 1.58% to 1.38%, which is suspected due to the thickness of the mangrove forest, which is the green belt of the mangrove forest area [9]. However, there has never been any research on carbon stocks in mangroves in the Pangempang Bay area, Muara Badak, therefore this research is essential to determine carbon absorption and carbon stocks in mangrove at the Muara Badak, Kutai Kartanegara Regency.

2 Methods

2.1 Research Location

The study was carried out in July 2022 in Pangempang Bay, Muara Badak District, Kutai Kartanegara, East Kalimantan, with two sampling locations, Station I on the shore facing the sea and Station II on the estuaria side facing the river (**Fig. 1**).

2.2 Sampling Plot and Data Collection

Purposive sampling was used in the research area. A 10x10 m^2 quadratic transect was established to identify sites with sufficient mangrove cover on the landward, middleward, and seaward sides. Along each transect, mangroves were counted and identified. Basic vegetation metrics such as (a) diameter at breast height (DBH) in cm, (b) basal area in meter, and (c) density were measured for each identified species.

2.3 Mangrove Density Calculation

The mangrove density was calculated using the formula as follows and the standard criteria for density and mangrove cover was accorded to The Minister of the Environment's Decree No. 201 of 2004 [10].

$$d = ni/A \times 10.000 \tag{1}$$

where,

d = Density (Ind/m^2)
ni = Total number of individuals of the i-th species
A = Total area of sample observation (m^2)

2.4 Biomass and Carbon Stock Analysis

The biomass of mangroves was calculated using a disruptive sampling procedure that involved harvesting numerous mangroves in the transect region. The total dry weight of mangrove samples (trunks, roots, leaves, and branches) was calculated. Following that, biomass data from mangrove samples were evaluated to determine the value of carbon content in various regions. The allometric model that was developed by Komiyama et al. (2005) utilized in order to determine the value of the biomass [11]. According to IPCC (2006), the carbon concentration in organic matter was around 50%, hence the estimated amount of carbon stored was calculated as follows:

$$\text{Cb} = \text{B} \times \%\,\text{C Organic} \tag{2}$$

where,

Cb = Carbon content of biomass (kg)
B = Total biomass (kg)
% C organic = Percentage value of carbon content, 0.47

Obtaining the value of carbon absorption in mangrove litter necessitates several calculations, including determining the dry weight of the litter. The value of carbon content in mangrove litter is calculated as follows [12]:

$$\text{Dry weight} = \frac{gbk}{m^2/day} \tag{3}$$

where,

Gbk = gram dry weight
m^2/day = meters squared per day

To find out the value of carbon uptake R_(CO_2) in mangrove litter, it can be calculated using the equation according to Chen et al. (2016) [13]. The following is the mangrove litter absorption formula:

$$\text{R\_(CO}_2\text{)} = \text{NPP} \times \text{C\_mangrove} \times 44\big/12 \tag{4}$$

where,

R_(CO_2) = Absorbance CO_2 (g CO_2 m^{-2} yr^{-1})
NPP = Net Primary Productivity (1/3 of litter productivity)
C_mangrove = Percentage of litter carbon of 47%
44/12 = conversion of elemental C to CO_2

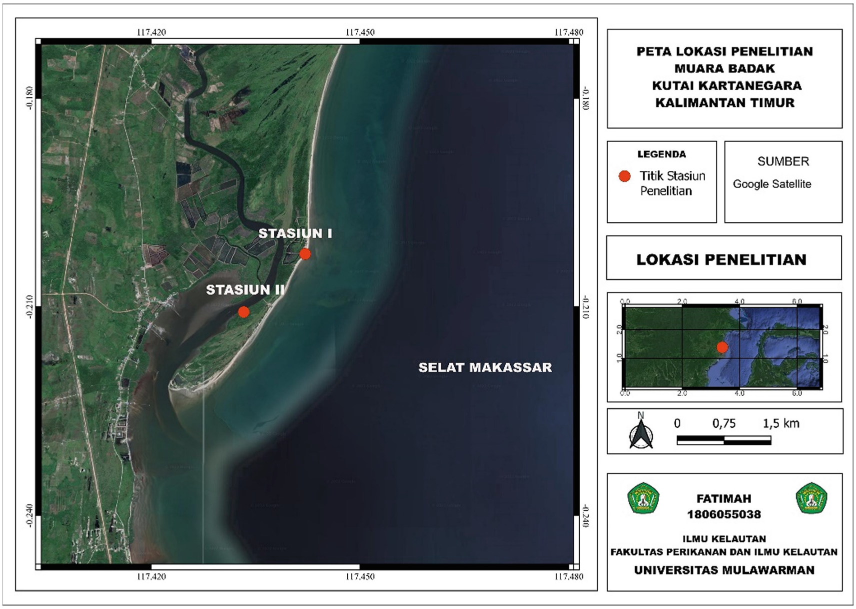

Fig. 1. The sampling location

3 Results and Discussion

3.1 Mangrove Density and Biomass

The identification of mangroves was accomplished by first observing particular characteristics of the plant's roots, flowers, leaves, and stems, and then comparing these observations with information contained in identification books [14, 15]. According to the findings, there were four different species of mangroves present on the island. These species included *Rhizophora mucronata*, *Rhizophora apiculata*, *Avicennia marina* and *Sonneratia alba.* Based on the distribution of mangroves at the two sites, it was determined that at station I only *Rhizophora apiculata* have been found, while at station II, three species were found. The increase in the number of plant species is considered to be one of the most important indicators of the ecosystem's health in the wetland area [16]. When it comes to mangroves, the distribution of these trees is determined by a physical parameter such as salinity and the competition they face from other types of vegetation [17].

The density of mangrove species in a community is measured using mangrove density [18]. Mangrove density can indicate the number of stands surrounding it. The density values at Stations I and II are shown in Table 1. The condition of the mangroves was rated as moderate based on their density at Stations I and II. The average density value at Station I was 1,100 ind/ha, and the average density value at Station II was 1,133 ind/ha. In accordance with Decree No. 2004 issued by the Minister of the Environment In 2001, the density fell into the category of "medium," which indicates that the mangrove forest was in an overall satisfactory condition at that time. Because of the distinct differences

Table 1. Density of Mangrove

Code	Plot	Mangrove Species	Density (ind/ha)	Category
Station I	I II III	*Rhizophora apiculata* *Rhizophora apiculata* *Rhizophora apiculate*	1200 1300 800	Moderate Moderate Seldom
Average			**1.100**	**Moderate**
Station II	I II III	*Rhizophora mucronata* *Avicennia marina* *Rhizophora mucronata* *Sonneratia alba* *Sonneratia alba* *Rhizophora mucronate*	1600 100 700 100 200 700	Very solid Seldom Seldom Seldom Seldom Seldom
Average			**1.133**	**Moderate**

between the two areas, the population density at Station II is significantly higher than that of Station I. Station I is situated in a coastal region that is also popular with tourists and experiences a high level of overall anthropogenic activity. The low density value in a mangrove area is caused by changes in the function of mangrove land used for settlements or tourism, cultivation, and anthropogenic influences that cause mangroves to experience damage and pressure [19]. This results in the mangroves having a lower population. Because of this, the mangrove ecosystem becomes stressed and suffers a population decline.

The *Rhizophora apiculata* mangroves are the predominant vegetation along the coast where station I can be found. Different types of *Rhizophora apiculata* can be discovered in sandy and muddy substrates. These mangroves can be found anywhere from the coast to inland areas [20]. Mangrove species *Sonneratia alba, Rhizophora mucronata*, and *Avicennia marina* were discovered at Station II. Station II can be found in an area of the estuary that has a propensity to be closed and in an area that has a relatively thick layer of muddy substrate. *Rhizophora mucronata* will be able to thrive on a diverse range of mud substrates [21].

At Station I, the average amount of biomass was 385.58 tons/ha, while at Station II, the average amount of biomass was 467.48 tons/ha (Table 2). It can be seen in Fig. 2 that Station II has a diameter that is greater than 25 cm. This indicates that the high value of the biomass that the mangrove stands contain is influenced by the diameter of the mangrove stands. Trees with diameters greater than 25 cm were discovered at Station I. This finding was confirmed by Mardliyah et al. (2019), who found that tree diameter has a relationship with biomass and that tree growth will affect the value of biomass [22]. At Station I, tree diameters greater than 25 cm were discovered.

3.2 The Carbon Adsorption at Mangrove Litter

According to the findings of this research, the station with the highest litter carbon uptake was Station II, which had an average value of 1.78 g CO_2-eq/m2/day, while the station

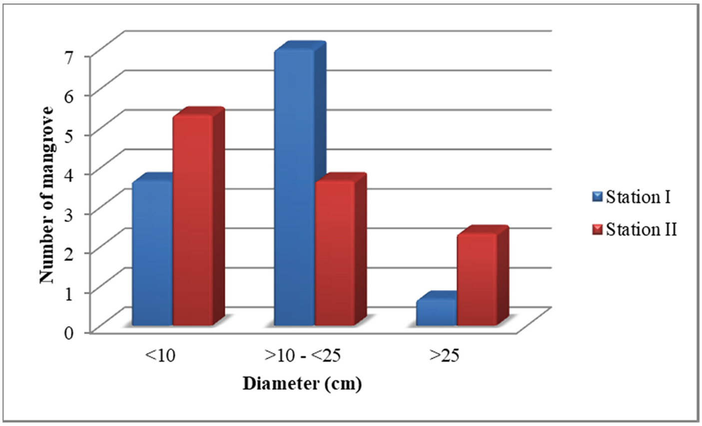

Fig. 2. Diameter of mangrove

Table 2. Mangrove Biomass at the Research Location

Code	Plot	Total Biomassa (ton/ha)
Station I	I II III	651,36 235,28 270,123
Average		**385,58**
Station II	I II III	911,36 394,22 96,48
Average		**467,48**

with the lowest mangrove litter carbon uptake had an average of 0.33 g CO_2-eq/m2/day (Fig. 3). The high rate of carbon uptake in mangrove litter is influenced by the high rate of litter production, the density of mangroves, the species of mangroves, and the weather, all of which can affect the carbon uptake in mangrove litter [23].

Through the process of photosynthesis, trees are able to take in carbon dioxide from the atmosphere, transform it into organic carbon, and finally store it as biomass in their stems, leaves, roots, branches, and twigs [24]. The majority of the litter that is produced is from fallen leaves. This is because the thin leaves are of an irregular shape and size, which makes it more difficult for them to succeed. If there is a high production of mangrove leaves, the capacity for carbon absorption and storage will be significantly improved [25].

3.3 Carbon Stock Estimation in Mangroves

The results of the research on the estimation of carbon stocks in mangrove stands in the Muara Badak District were obtained by measuring the stem diameter at each station. At

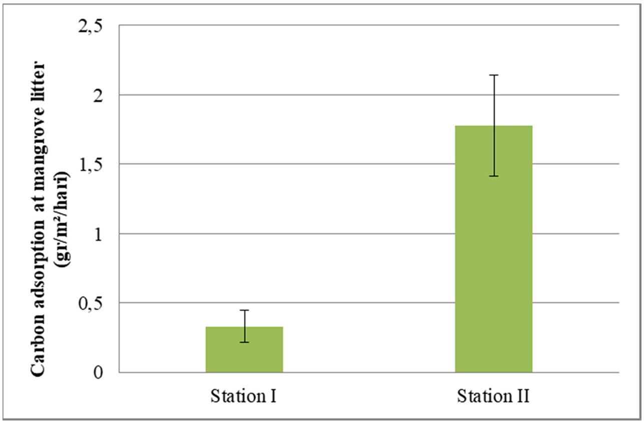

Fig. 3. Carbon absorption at Stations I and II

one station, three plots were measuring 100 m^2, so these measurements were used to determine the size of the station. Figure 4 presents the carbon stock information.

Station II had the highest carbon stock measurement results, with an average of 216,911 tons C/ha, whereas Station I had a carbon stock value of 178,912 tons C/ha. This difference was due to the fact that Station II measured carbon stock more precisely. The high value of mangrove biomass contributes to Station II's high carbon stock, which in turn is influenced by the high value of mangrove biomass (Table 2). Irsadi et al. (2017) found that the amount of stored carbon is directly proportional to the amount of biomass, meaning that the higher the carbon content, the higher the biomass value [26]. This was demonstrated by the fact that the biomass value increased as the carbon content increased. Additionally, the location of the research can have an effect on the total amount of carbon stock. Since Station II is situated in an estuary that has fertile soil, it has a significant amount of carbon stock. According to Nedhisa and Tjahjaningrum (2019), estuaries are

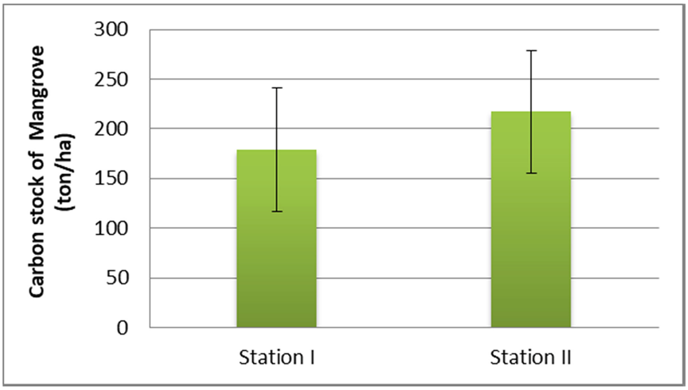

Fig. 4. Carbon stock at Stations I and II

places that increase the fertility of the soil because they receive a supply of organic particles and nutrients from the tides [27].

An average carbon estimate of 233,055 tons C/ha was found in the mangrove region that is part of the natural tourism industry in Youtefa Bay [28]. This result is higher than the carbon stock in this study because the tree biomass content in Youtefa Bay nature tourism is more significant, specifically 505,601 tons/ha. The amount of carbon stock in mangroves can be influenced by a number of factors, one of which is the biomass content of the mangrove trees. Rahmattin et al. (2020) conducted research in the mangrove region on the coast of Surabaya, East Java, and found that there was an average carbon stock of approximately 16.33 tons C/ha [29]. The state of the mangroves in the coastal area of Surabaya has deteriorated significantly over the years, which may explain why the results of this study showed a greater capacity for carbon storage than those obtained in the previous study from that region. The average value of mangrove carbon stocks was also obtained in the study that was conducted by Rahmat et al. (2022) in the village of Pasar Banggi Rembang [30]. The value that was obtained was 193.47 tons C/ha, which was not too dissimilar from the carbon stocks that were found in this study. *Rhyzophora stylose* is the type of mangrove that is found in Pasar Banggi Rembang Village, and it is the type of mangrove that has the highest significant carbon stock value. However, it is possible that there are other types of mangroves. Although *Rhizophora mucronate* was the most prevalent species in this study. Using a linear regression test, the relationship between mangrove density and mangrove carbon stock showed a strong correlation equal to $R^2 = 0.928$. The biomass and carbon stock are proportionally greater when the density value is higher [31, 32].

4 Conclusion

The density of mangroves at Station I was measured at 1,100 individuals per hectare. The mangrove litter had an average carbon uptake rate of 0.33 g CO_2-eq/m^2/day, and the area was able to store an average carbon stock of 178.91 tons per hectare. Additionally, the density of mangroves is 1,133 ind/ha at Station II, allowing for an average daily carbon uptake of 1.78 g CO_2-eq/m^2, and an average stockpile of 216.99 metric tons per hectare.

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