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Species diversity and estimation of carbon stock in abandoned shrimp pond of mangrove ecosystem in East Kalimantan

R Diana[1*], P Matius[1], Syahrinudin[1], Karyati[1], M Hendra[2] and R Melsitiara[2]

[1]Laboratory of Ecology and Conservation of Tropical Forest Biodiversity, Faculty of Forestry, Mulawarman University, Jl. Penajam, Samarinda, 75123 Indonesia
[2]Faculty of Science, Mulawarman University, Jl. Barong Tongkok Samarinda, 75123 Indonesia

*Email: ritadiana@fahutan.unmul.ac.id

Abstract. The mangrove forest ecosystem plays an absorbent and carbon sink to reduce CO2 levels in the atmosphere, including in degraded mangrove areas. This research was conducted precisely on abandoned shrimp ponds in mangrove areas in the Mahakam Delta. Four different locations are locating on Sepatin ponds, ponds, ponds, and ponds Bayur headland. The purpose of this study was to estimate the above-ground carbon stock in abandoned shrimp ponds. Carbon stock measurement methods create a 125 m transect and quadrant divided into six plots at each location. These measurements were conducted on living vegetation and dead wood from felling vegetation. Measurement of above-ground biomass was done by measuring the tree diameter at breast height (1.3 m) on each tree diameter> 5 cm in radius quadrant plot 7 m. Vegetation has a diameter <5 cm categorized in seedling criteria and measured 30 cm from the ground within the quadrant plot radius of 2 m. The vegetation diversity experienced a succession calculated using the diversity index by calculating the dominance index, diversity index, and similarity index of vegetation. While the calculation of above-ground biomass accumulation using allometric equations according to the species. The results showed that vegetation analysis in the fourth study sites obtained a high dominance index value at each location. The study is inversely proportional to the value of diversity and similarity index. The highest total carbon stock at Tanjung Nipah location was 11.599 Mg C. Ha^{-1}, followed by Sepatin 6.248 Mg C. Ha^{-1}, Benati Dalam 3.579 Mg C. Ha^{-1}, and lowest carbon stock at Bayur location 1.460 Mg C. Ha^{-1}.

1. Introduction

Mangrove forests are essential in some ecological types of coastal areas because they protect the region from coastal abrasion, prevent seawater intrusion, and act as a buffer against sedimentation from the mainland to the sea. The mangrove ecosystem is essential for climate change mitigation. In the Indo-Pacific zone, mangrove forests that are still intact will store five times more carbon [1] than other forest types, with about 1.023 tonnes of carbon or equal to 3,750 tonnes of carbon dioxide per hectare (approximately 60% of which is in mud) [1, 2]. Mangrove forests are also under threat today due to exploitation and management practices that are less concerned with long-term sustainability. The demands of growth emphasize economic goals with a focus on physical infrastructure development.

Converting mangrove forests to expand shrimp ponds is one of the contributing factors to the destruction of the mangrove forest ecosystem and coastal ecosystems' degradation. The Mahakam Delta is an ideal location for mangrove development. However, Mahakam Delta has changed dramatically as a result of the overuse of its ecosystem [3, 4]. Delta Mahakam's capacity to mitigate natural hazards in coastal areas is harm resulting from land-use change and resource extraction. The transition from a mangrove field to a pond has several consequences, including erosion (coastal abrasion). The mangrove ecosystem's role as a reducer and protector against waves and strong winds, loss of habitat, and the search for eating food for different forms of fish, shrimp, and marine biota are all affected the destruction of the mangrove ecosystem. The shift in land use has a significant effect on the mangrove's critical

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position as a carbon sink and absorber, with the role of mangrove habitats as CO2 absorbers and reservoirs now contributing to CO2 emissions [5] [6].

The ecology of the mangrove forest is complex, diverse, and fragile [7]. It is dynamic because the mangrove forest will grow and evolve continuously and have succession as its natural growth patterns change [8]. This environment is both caring and challenging to repair if it destroys. Most mangrove species thrive in muddy soils, especially in areas where mud accumulates [8] [9]. Since mangroves in Delta Mahakam have been converting to pond land, their storage capacity has been reducing, and their role has changed to contribute to CO_2 emissions [3]. Green House Gas (GHG) emissions, especially CO_2, can be reduced to reduce GHG enhancement in the atmosphere. One of them is lowering CO_2 emissions by calculating the number of Biomass and carbon stocks, which are essential for reducing emissions and the degradation of forest functions [6]. Another is lowering CO_2 emissions by knowing stock carbon in a region aimed at the GHG absorbent by calculating the number of Biomass and carbon stocks, which are essential components for reducing emissions and the degradation of forest functions.

In the Mahakam Delta, many ponds are abandoned. Many dams broke down due to a significant flood event at the end of 2009 and were never re-activated because repairing the damaged pond costs a significant amount of money. As time passes, this stagnant pond's state will gradually restore the mangrove feature where the former pond land has a succession. Besides knowing the mangrove ecosystem's ability to accumulate carbon, the study will assess the diversity of species and mangrove vegetation in abandoned shrimp ponds.

2. Materials and Methods

2.1. Study area

This study has been conducting in Mahakam Delta in East Kalimantan, which geographically located between 117°15’ and 117°40’ East longitude and 0°19’ and 0°55’ South altitude. The location of vegetation sample plots is also present in the following map (Figure 1).

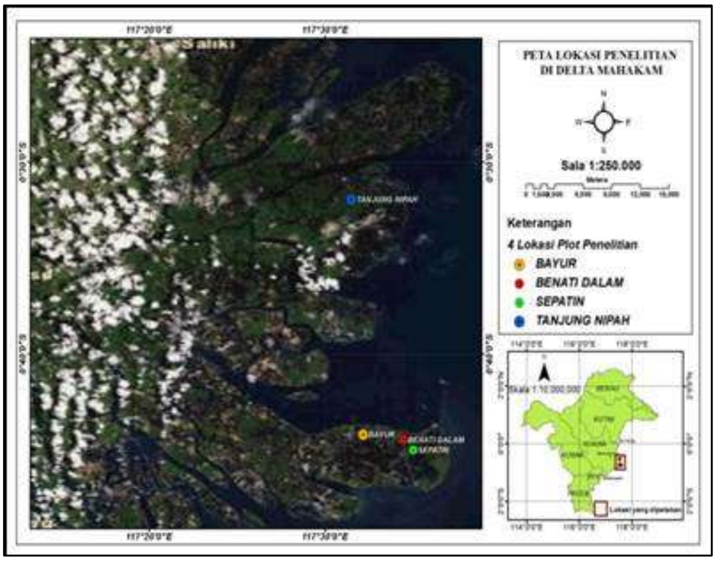

Figure 1. Research area in Mahakam Delta in East Kalimantan

2.2. Sampling

This study determined the species diversity and carbon stock have been constructed in 4 (four) different areas in 5 years abandoned shrimp pond. The vegetation sample plots were purposively plotted in a different location and distributed as shown in Figure 1. The research area location of sample plot one located in Sepatin village at the coordinates 00˚45.009' South latitude and 117˚35,029' East longitude. The second plot located in Benati Dalam at the coordinates of 00˚44.469' South latitude and 117˚34,458' East longitude. The third plot located in Tanjung Nipah in the coordinates 00˚31.953' South latitude and 117˚31.514' East longitude and the fourth plot located in the Bayur in the village of Sepatin at the coordinates 00˚44,204' South latitude and 117˚32.180' East longitude.

2.3. Vegetation data collection

Each sampling site has four separate location transects, each measuring 125 meters and running roughly parallel to the shoreline. We created six subplots (one for every 25 meters forward distance) within each transect, each containing multiple quadrants for different rising phases, as shown in the diagram below. The sample plot is set up by making a transect along the 125 m at each sampling location, according to [10] with quadrant plots every 25 m, for just a total of six quadrant plots on the 125 m Transect. Each transect is drawing using a rope on each quadrant with a radius of 12 m. To create a hexagonal sub-plot that shaped four quadrants, namely quadrants A, B, C, and D.

The living and dead trees that were still standing upright generated two separate samples. In contrast, the fallen tree collected the third sample. The first step is to assess live plants, which include seedlings and trees. A seedling is a less than 1.37 meters tall plant, and sampling takes 2 meters in the plot circle. In a circular map, they measured the diameter of living and dead trees that still stood with a radius of 7 m and the condition of trees diameter >5 cm. Diameter Breast High (dbh) measurements are taken at a fixed height of 1.3 m from the ground, while seedling diameter measurements are taking at the height of 30 cm from the ground. The fallen tree's measurement or branches in the quadrant is the second element (A, B, C, and D). The plot sampling installation is describing in the figure 2.

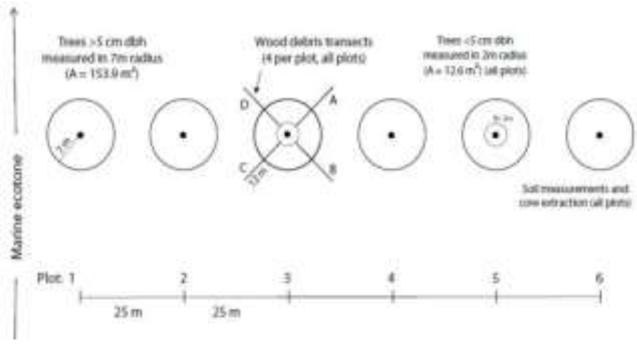

Figure 2. Transect, sub plot and quadrant layout

2.4. Data analysis

The data was analyzed using standard quantitative plant ecology indicators such as species abundance, diversity, dominance, and evenness. The following equation is used to calculate species diversity based on the distribution patterns among different species.

$$H' = -\sum_{i=1}^{S} (pi \text{ x} \ln(pi))$$

where:

H': Species diversity index
S: Number of species in the population
pi: Ratio between the no of species i (ni) compared with the number of individual species count
Criteria species diversity (SD)
High: > 3, Medium: 2 – 3, low: 0-2

$$C = \sum_{i=1}^{S} pi^2$$

where:
C = Species richness index
S = Species count
ni = Species I individual count
N = Total individual in total n
Pi = ni/N = the proportion of species i

Species distribution is defined as whether individual trees are distributed evenly into species on site, defined as follows.

$$e = \frac{H'}{\ln(S)}$$

where:
e = Eveness index
H' = Diversity index
s = species count

2.5. Biomass and carbon stocks calculation
The biomass and carbon stocks of seedlings were calculated using the allometric equation to determine the biomass of the seedlings depending on the vegetation species and diameter. Allometric equations, such as that in table 1, are used to estimate seedling biomass, and indeed the density value of species is determined using the database value at db.worldagroforestry.org/wd. The carbon stock is calculated by multiplying the amount of biomass by the carbon fraction. The carbon fraction of each species calculates the value of carbon fraction, and if the carbon fraction is uncertain, the IPCC's default carbon fraction of 0.47 is used.

Table 1. The allometric equation for estimating seedlings biomass

Spesies	Biomass	Diameter (cm)
Avicennia alba	B = (114.6x-38.65) x ρ	0.3 – 1.2
Avicennia marina	B = (216.6x-79.15) x ρ	0.3 – 1.2
Rizophora apiculata	B = (159.33x-63.9) x ρ	0.3 – 1.2

2.5.1. Calculation of biomass and carbon stock. The calculation of tree biomass is done using the allometric equation corresponding to the vegetation species and its diameter. The stock carbon calculation procedure are the same as in seedling (Table 2)

Table 2. The allometric equation for estimating tree biomass

Spesies	Biomass	Diameter (cm)	Reference
Avicennia alba	B = 0.2901 x D^2.2605	5.0-16.0	[1]
Avicennia marina	B = 0.1848 x (D)^2.3524	5.0-25.8	[1]
Rhizophora mucronata	B = 0.251 x 0.701 x(D)^2.46	5.0-6.1	[17]
Rhizophora apiculata	B = 0.9789 (D)^2.6848	6.1-9.8	[18]
Sonneratia alba	B = 0.251 x 0.475 x (D)^2.46	6.9	[17]

2.5.2. Calculation of biomass and carbon stock on dead wood. The ratio of biomass to dead wood is calculated using the formula in [10] by calculating the volume of the tree first by using the formula:

$$\text{Volume (m3/Ha)} \frac{(d1^2 + d2^2 + d3^2 + \cdots . dn^2)\ x}{8\ x\ L}$$

where:
d1, d2, dN = Diameter of dead wood
L = Transek length based on diameter class
(Grades 5 m, 3 m and 2 m)

Then the obtained volume value is multiplied by the deadwood species' weight based on the class of diameter (Table 3). It can be obtained the value of tree biomass and converted into hectares to value biomass with units Kg Ha^{-1}.

$$\text{Biomass (Kg Ha}^{-1}) = V \times WD$$

where: V = Volume and WD = wood density

Tabel 3. Species weight dead wood rebah based on its diameter class

Diameter	Wood density ($g.cm^{-3}$)
>7.5 cm	0.622
>7.5 cm	0.528
2.5-7.5 cm	0.584
<2.5 cm	0.554

3. Result and Discussion

3.1. Species diversity

The mangrove ecosystem of abandoned ponds has a relatively low diversity of type [10]. The dominant index values in each of the four locations follow a similar trend toward the value of 1, indicating that each location has a dominant type. The dominance of species in the area influences the importance of this similarity index. Bayur's research location has a high dominance index ranking. It is stated that a location has only one species, or that one species has the most individuals, or that one species dominates the location. Since the dominance index is inversely proportional to the diversity index value, the biodiversity index will be small when the dominant index is high.

Figure 3 shows that the diversity index will be lower at each research location with a high dominance index. If the dominancy index exceeds 0, practically no one is dominating, and the diversity index is high. As the dominance index hits one, one species is in control, and the diversity index has a low value. The index is a uniformity approaching a value of 0, indicating a dominance pattern in the ecosystem, with the dominance index being inversely proportional to diversity and similarity. Diversity and similarity, on the other hand, have a positive relationship. In all of the site's research areas, the value diversity index is low category because of an abandoned pond that has not stabilized in the area. The majority of habitats with high diversity indexes are making up of several organisms and their abundance. In contrast, if a population is composed of just a few species, and only a few species are dominant, the ecosystem's diversity would be reduced. In general, mangrove ecosystems have a low index value of diversity when compared to other ecosystems [5][11]. Furthermore, in an ecosystem that has been disturbed by land clearing for ponds and is recovering naturally, the increased value of diversity indicates the ecosystem's stability [18]. Therefore, the mangrove ecosystem's high diversity makes it less vulnerable to environmental influences [8] [9][12].

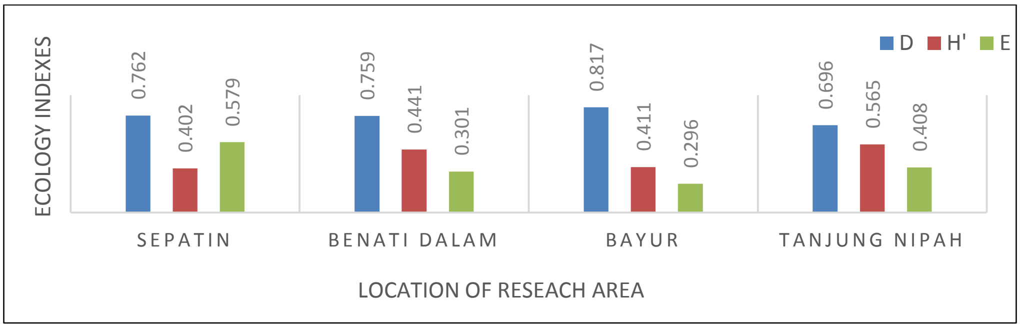

Figure 3. Species diversity (H'), dominancy (D) and evenness index (E)

3.2. Carbon stock seedling at four research locations

The amount of carbon stored in plants is equal to half the amount of biomass. The more biomass a plant has, the more efficient its carbon content is (the more extensive the carbon stock). The three species included in the seedling group at all four sampling sites are *Avicennia alba*, *Avicennia marina*, and *Rhizophora apiculata*. Figure 4 below shows a sequence of stock carbon levels from highest to lowest on Tanjung Nipah's site, followed by Benati Dalam, Sepatin, and Bayur. Tanjung Nipah has the highest carbon content of 5.894 Mg C Ha^{-1} of any place. The data was collected for a total of 18 individuals, each with a diameter of 2.0 cm on average. It has a species *Rhizophora apiculata* with a diameter greater than the species *Rhizophora apiculata* in another location at this location. Furthermore, as compared to the seedling species in the four locations, *Rhizophora apiculata* has the highest value of species, 0.8814 g/cm^3, while *Avicennia Alba* has 0.6987 g/cm^3 and *Avicennia marina* has 0.7316 g/cm^3. As a result, this is one of the factors that contribute to Tanjung Nipah's high stock carbon value.

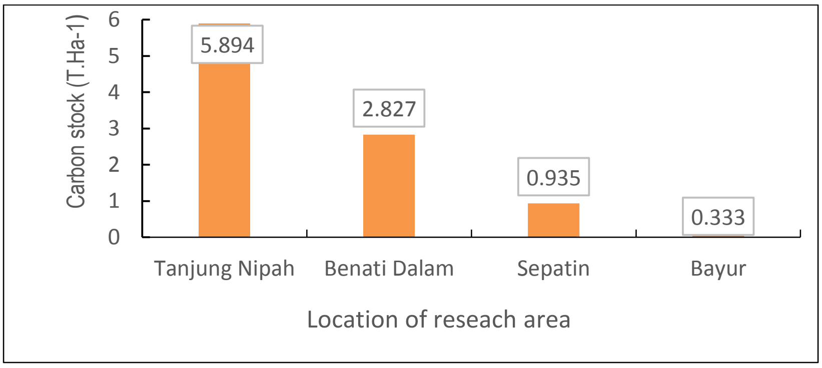

Figure 4. Carbon stock seedling in four location

The highest stock carbon after Tanjung Nipah is Benati Dalam, with a stock carbon value of 2.827 Mg C Ha^{-1}. With a total of 35 individuals and an average diameter of 0.8 cm, this area is dominated by the *Avicennia alba* and *Avicennia marina* species, with a more significant number of other locations. The species *Avicennia alba* occupies the location of Sepatin, which has a stock carbon value of 0.935 Mg C Ha^{-1}. With five individuals, this location has the second-largest average diameter after Tanjung Nipah, which is 1.6 cm. Bayur has the lowest stock carbon value of 0.333. There are only five individuals in total, each with an average diameter of 0.7 cm. *Rhizophora apiculata* is represented by four individuals, while one individual represents the *Avicennia marina*. According to [13] [14], regeneration of seedlings in mangrove forests in abandoned ponds tends to occur only in one or 2 types. Therefore the location with small number of seedling causes a small amount carbon stock.

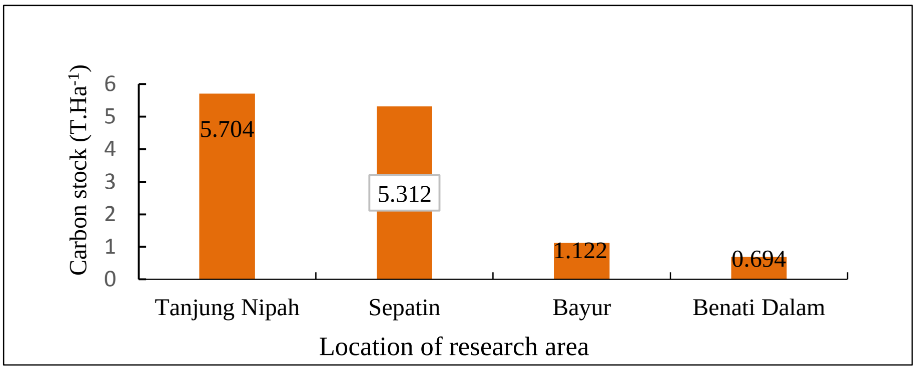

Figure 5. Carbon stock tree in four location

Carbon is stored in any part of the tree, including the roots, branches, leaves, and fruits [8]. However, this study's stock carbon calculation is limited to the section's above-ground (ground surface) area. *Avicennia alba*, *Avicennia marina*, *Rhizophora mucronata*, *Rhizophora apiculata,* and *Sonneratia alba* were grown at each of the four research sites. Tanjung Nipah's position is shown to have the highest stock carbon value, followed by Sepatin, Bayur, and last Benati (Figure 5). The research area in Tanjung Nipah has the highest stock carbon value of 5.704 Mg C Ha^{-1}. The result of data analysis reveals that *Rhizophora apiculata* has the biggest a sizeable average diameter of 7.0 cm. This species only be found in Tanjung Nipah and is not found in other research locations. *Avicennia Alba*, *Avicennia Marina*, *Rhizophora apiculata*, *and Sonneratia alba* and this species have the highest value of species weight among the tree species in these four locations. Then, the Sepatin site has a stock carbon value of 5.312 Mg C Ha-1 and is dominated by Avicennia Alba. Then there are the Avicennia marina species, which has 118 individuals, which is more than the other locations. Following that, Avicennia Alba dominates the Bayur site, which has a stock carbon value of 1.122 Mg C Ha^{-1} and is followed by *Avicennia Marina*, which has 49 individuals. The location of Benati Dalam has the lowest carbon value of 0.694. There are only 15 individuals of the tree in this research field. There are nine *Rhizophora apiculata* individuals and six *Avicennia marina* individuals. The maximum diameter size for the Avicennia marina is 6.9 cm, even though this species has the smallest number of individuals compared to the other places.

3.3 Carbon stock of necro-mass

Stock carbon is also found in undecomposed wooden dead. In this study, the carbon stock measurements were in the dead tree's wood in the plot and analyzed based on the diameter. Carbon stock of deadwood at four consecutive locations from the highest to the lowest is on the location of Benati in then followed Bayur, Sepatin and Last is Tanjung Nipah (Figure 6). According to [1] [2] [8] the effects of tides on mangrove forests cause the quantity of carbon stock in the necro-mass in the mangrove forest is lower than in the forest on dry land.

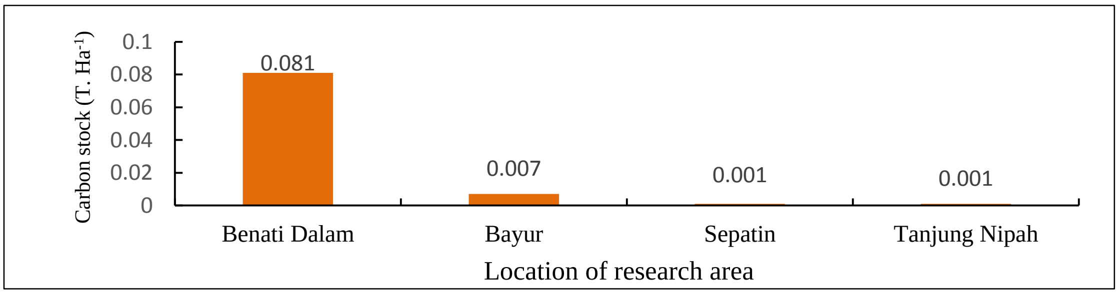

Figure 6. Carbon stock of necromass

The value of the stock carbon for the highest necromass at Benati Dalam is 0.081 Mg C Ha-1. This location collected data on a necromass with a wide diameter of 6.8 cm. The size of diameter is affected by necro-mass biomass [9], and the most significant value is the average diameter of the necro-mass. Following that is the location of Bayur, which has a stock carbon value of 0.007 Mg C Ha^{-1} and with the number of individuals of 61 individuals, but the average diameter is just 0.6 cm. Following that is the position of Sepatin, which has a carbon stock value of 0.0011 Mg C Ha^{-1}, with an average diameter of 0.7 cm. However, only 18 individuals were obtained at this location. The smallest value of carbon stock is in Tanjung Nipah, namely 0.001 Mg C Ha^{-1}. There are only four plants found in this location; even though the trees have a large diameter of 2.6 cm, the value of carbon stock is small compared to other locations. The location with the lowest carbon stock value but not too much carbon stock value is Sepatin. Tanjung Nipah only has four plants, but the average diameter for the necro-mass is 2.6 cm.

3.4. Total stock above-ground carbon stock

Figure 7 shows the expected carbon stock obtained from data analysis in four research locations: Sepatin, Benati Dalam, Bayur, and Tanjung Nipah by summing the stock carbon in seedlings, trees, and necromass in each location.

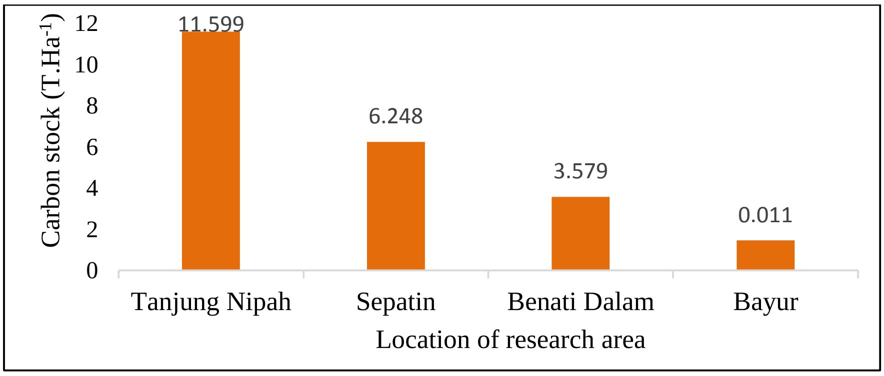

Figure 7. Total above-ground carbon stock

Tanjung Nipah has the highest carbon stock value of 11.599 Mg C Ha^{-1}, as seen in the figure 7 above. Tanjung Nipah's carbon accumulation deposited carbon stocks for seedlings, and the tree wood is the largest compared to other locations. Then follows the location of Sepatin, which has a stock carbon value of 6.248 Mg C Ha-1 due to its location in the tree with the highest stock carbon. Furthermore, the highest stock of carbon is found in the Benati site's seedlings, which has a stock carbon value of 3.579 Mg C Ha^{-1}. In Bayur, the value carbon stock of necromass and litterfall is 1.460 Mg C Ha^{-1}. This value is limited compared to other abandoned shrimp ponds because the area has a low stock carbon value, with both the seedling and necromass becoming the effect of the lowest of carbon stocks. The figure 7 shows Tanjung Nipah has the highest carbon stock value compared to the other three areas. Tanjung Nipah has the highest value of carbon stock due to natural vegetation regeneration, and the location has a higher density of seedlings than other areas. Natural regeneration will increase the accumulation of carbon stocks in an ecosystem that is experiencing disruptions, such as in abandoned ponds [15] [16] [17]. Many species have a high absorption rate when it comes to storing carbon, in this study *Rhizophora apiculata* has many individual plants compared to other locations. The greater the plant's diameter size, the greater the stock value or the species' ability to accumulate carbon.

4. Conclusion

There are deficient diversity species in a 6-year-old abandoned shrimp pond, with a rate of 0.475, a dominance index of 0.768, and an evenness index of 0.579. Carbon stock accumulation continues to be low, with the highest value being 11.599 Mg C Ha^{-1} at Tanjung Nipah, followed by Sepatin at 6.248 Mg C Ha^{-1}, Benati at 3.579 Mg C Ha^{-1}, and Bayur at 1.460 Mg C Ha^{-1}.

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