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Blue Carbon Stock Estimation Of Mangrove Ecosystem In Tanjung Pemancingan, Kotabaru Regency, South Kalimantan

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Abstract:
Background*: Mangrove ecosystems are crucial in global climate change mitigation efforts. One form of environmental service provided by mangroves is as a carbon sink (blue carbon) which is effective in reducing the concentration of carbon dioxide gas (CO2) in nature. This study aims to determine the estimated stock of blue carbon in the mangrove ecosystem in Tanjung Pemancingan, Kotabaru Regency, South Kalimantan.*
Materials and Methods*: Determination of data collection stations was carried out by purposive sampling, considering the level of tree density and mangrove zonation based on SPOT-7 image analysis. The allometric equation is used to calculate the above-ground biomass (AGB), below-ground biomass (BGB), and litter components with tree diameter at breast height (DBH), wood density, and mangrove area as variables. The calculation of blue carbon stock is 47% of total biomass.*
Results*: The results showed that the mangrove area of 21.07 hectares in Tanjung Pemancingan has a total carbon stock of 9,104.773 tons.*
Key Word*: Blue Carbon Stock; Mangrove Ecosystem; Climate Change; Tanjung Pemancingan*

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I. Introduction

Mangrove ecosystems are forests that develop in coastal areas with an essential substrate in mud and calm waters and are protected from waves. Their existence is influenced by tidal activity. Mangrove forests grow adjacent to the land at the highest tide range, so this ecosystem is a transitional area whose existence is, of course, also influenced by factors from land and sea.

As a transitional land and sea ecosystem, mangroves hold many functions and roles covering bioecological, physical, and chemical aspects. One of the functions of the mangrove ecosystem in the chemical aspect is carbon reserves. Mangrove ecosystems can store more carbon than tropical forests. Furthermore, the Ministry of Environment and Forestry (2020) states that this mangrove ecosystem can store 800 - 1,200 tons C /ha or 4-5 times the land forest. This ecosystem is also referred to as blue carbon. Carbon storage by mangrove ecosystems effectively reduces levels of carbon dioxide (CO_2) in the atmosphere, which affects climate change and global warming.

Carbon storage in mangrove ecosystems, commonly known as carbon sinks in mangrove ecosystems, is contained in 4 main components. These components are above-ground biomass, below-ground biomass, litter, and soil organic content such as a bottom substrate or sediment (Hairiah et al., 2011). The determining factors for the amount of carbon stock in mangroves include mangrove species, tree trunk diameter, tree height, and wood density. In addition, the determining factor for the amount of carbon stock in mangrove ecosystems is vegetation density. The density of mangrove vegetation is directly proportional to the amount of carbon stock. The higher the vegetation, the higher the carbon stock, and vice versa (Imiliyana et al., 2012).

An exotic landscape characterizes Tanjung Pemancingan Kotabaru, and its coastal area has a mangrove ecosystem on the west and east to the mouth of the Sekukup River. On the west side, most of the mangroves grow in the former pond area. In comparison, the mangroves on the east side face directly to the Makassar Strait. The existence of mangroves in Tanjung Pemancingan has excellent potential as a store of carbon stocks.

This study aims to analyze the carbon stock stored in the above-ground biomass (AGB), below-ground biomass (BGB), and litter components and to calculate the total carbon stock of the mangrove ecosystem in the Tanjung Pemancingan area, Kotabaru Regency, South Kalimantan Province.

II. Materials And Methods

Data collection activities were carried out in November 2021. The location of this activity is around the port operation area and coal terminal of PT. Arutmin Indonesia NPLCT. The research area covers the mangrove area west of Sekukup Bay and the mangrove area bordering the northern area of RT 2 of Sarang Tiung Village. Map of data collection locations can be seen in Figure 1.

The tools and materials used in this study included roller meters, sewing tape measure, GPS (Global Positioning System), sample bags, raffia, identification slides, stationery, cellphones, ovens, digital scales, measuring cups, laptops, Microsoft Office, ArcGIS Pro 2.8.4, SAGA GIS and SPOT-7 Image 2020.

Data Acquisition

1. Sampling Location Determination

Determining the sampling location was carried out using the purposive sampling method referring to the work map that had been made. This method is a method of determining the location based on the representativeness of the mangrove area. In addition, this method also considers the dominance, density, and zoning of mangroves at the study site (Ariani et al., 2012). Determining the sampling location also considers the vegetation density level resulting from previous image analysis based on the Normalized Difference Vegetation Index (NDVI). The number of stations used in this study amounted to 14, representing high-density, medium-density, and low-density levels.

2. Tree Diameter Measurement

Tree diameter measurements were based on the method listed in Indonesia National Standard (SNI) 7724 of 2011.

3. Wood Sampling

Wood sampling is done to determine the density of the wood. Wood samples were taken from each tree species. Wood sampling was carried out with 3 (three) repetitions for each species of mangrove tree.

Data Analysis

1. Wood Density Measurement

Measuring the density of wood is carried out by weighing the wet weight of the wood samples taken. After weighing the wet weight, the wood samples were placed in the oven at 100 ° C for ±48 hours. Furthermore, the sample that has been put in the oven is weighed for dry weight. The following formula can calculate the density of wood:

$$\mathbf{Density}\left(\mathbf{g/cm^3}\right) = \frac{\mathbf{Dry\ Weight\ (g)}}{\mathbf{volume\ (cm^3)}}$$

2. Biomass Measurement

Calculating above-ground and below-ground biomass use the formula from Komiyama et al. (2005), while the biomass in the litter uses the calculation from Hairiah et al. (2011).

a. **Above ground biomass**

$$\mathbf{AGB = 0.251\ \rho\ D^{2.46}}$$

b. **Below ground biomass**

$$\mathbf{BGB = 0.199\ \rho^{0.899}\ D^{2.46}}$$

c. **Litter**

$$Bo = \frac{Bks \times Bbt}{Bbs}$$

Figure 1. Data Collection Locations

Description:

AGB : Above-ground biomass content (kg)
BGB : Below-ground biomass (kg)
ρ : Density of wood (g/cm3)
D : Diameter of trees at breast height (cm)
Bo : Weight of organic matter (kg)
Bks : Sample dry weight (kg)
Bbt : Total wet weight (kg)
Bbs : Sample wet weight (kg)

3. Carbon Stock Measurement
The formula for calculating carbon from biomass is as follows:

$$C_b = B \times \text{organic } \%C$$

Description:
C_b : Carbon content of biomass
B : Total biomass (kg)
%C Organic: 47%

4. Carbon Stock per Hectare
Calculation of carbon stock per hectare can use the equation from SNI 7724:2011 as follows:

$$C_n = \frac{C_x}{1000} \times \frac{10000}{l_{plot}}$$

Description:
Cn : Carbon content per hectare (ton/ha)
C_x : Carbon content in each plot (kg)
l_{plots} : Plot area (m^2)

The tools and materials used in this study include a roller meter, sewing meter, GPS (Global Positioning System), sample bag, hypsometer, rope, identification slides, stationery, cellphone, oven, digital scale, measuring cup, laptop, Microsoft Office, ArcGIS 10.5, SAGA GIS and Sentinel 2Aimagery 2020 acquisition.

Data collection in the research field is done by collecting3features. The first feature is to measure the tree height using a *haga* hypsometer. The second feature is to measure the diameter of the tree at breast height (DBH) using a sewing meter. The measurement of tree diameter is based on the method by Indonesia National Standard 7724:2011. Wood sampling is the last feature collected in the research field. Using the harvest sampling method, wood samples were taken by doing 3 repetitions from each species of mangroves.

Data Analysis
1.Mangrove Community Structure
a. Species Density (Di)

$$Di = \frac{ni}{A}$$

Description:
Di : Species density
ni :Number of mangroves per species
A : Total area of sampling stations (m^2)

b. Relative Species Density (RDi)

$$RDi = \frac{ni}{\Sigma n} \times 100\%$$

Description:
RDi : Relative Species density
ni :Number of mangroves per species
Σn :Total number of mangrove trees in sampling stations

c. Species Frequency (Fi)

$$Fi = \frac{Pi}{\Sigma P}$$

Description:
Fi : Species frequency
Pi :Number of plots where mangrove species are found
ΣP : Total number of observations plots per sampling station

d. Relative Species Frequency (RFi)

$$\mathbf{RFi = \frac{Fi}{\Sigma P} \times 100\%}$$

Description:
RFi : Relative species frequency
Fi :Species frequency
ΣP : Total number of observations plots per sampling station

e. Species Coverage (Ci)

$$\mathbf{Ci = \frac{\Sigma BA}{A} BA = \frac{\pi DBH^2}{4}}$$

Description:
Ci : Species coverage(m^2)
BA : tree surface area(m^2)
DBH : trees diameter at breast height (cm^2)
A :Total area of sampling stations (m^2)

f. Relative Species Coverage (RCi)

$$\mathbf{RCi = \frac{Ci}{\Sigma C} \times 100\%}$$

Description:
RCi : Relative species coverage
Ci : Species coverage (m^2)
ΣC : Total area of all species (m^2)

g. Important Value Index (IVI)
IVI = RDi + RFi + RCi
Description:
IVI : Importance Value Index
RDi : Relative Species density
RFi : Relative species frequency
RCi : Relative species coverage

2. Normalized Difference Vegetation Index (NDVI)

The image used in determining the mangrove coverage levels is the Sentinel 2A Image acquired in January 2020. The image was then analyzed using the Normalized Difference Vegetation Index (NDVI) to determine the mangrove density category. NDVI algorithm is as follows:

$$\mathbf{NDVI = \frac{(NIR\text{-}R)}{(NIR+R)}}$$

Description:
NDVI : Normalized Difference Vegetation Index
NIR : Near Infra-Red
R : Red

The results of NDVI were then reclassified into 3 coverage levels (high, medium, and low) based on the formula from Setiawan, et al (2013) as follows:

$$\mathbf{KL = \frac{xt - xr}{k}}$$

Description:
KL : Interval levels
xt : highest value
xr : lowest value
k : desired number of levels (3 levels)

3. Mangrove Density
Mangrove density is calculated using the formula below:

MD = IND / TA

Description:
MD : Mangrove Density (Ind/m^2)

IND : Individuals (number of mangrove trees)
TA : Total area per sampling station (m^2)

The results of mangrove density analysis are then used to describe the mangrove condition based on the Minister of Environment Decree No. 201 of 2004.

4. Mangrove Height

The height of mangrove trees is calculated using the following formula:

$$\mathbf{t = b - a}$$

Description:
t : tree height (cm)
b : the scale reading that appears when measuring the tip of the tree
a : the scale reading that appears when measuring the base of the tree

5. Trees' Volume

The volume of mangrove trees is calculated using the following formula:

$$\mathbf{V = 1/4\pi.d^2.t.f}$$

Description:
V : Mangrove trees volume (cm^3)
π : 3,14
d : Diameter at breast height (cm)
t : tree height (cm)
f : tree shape figure (0,6)

6. Wood Density Measurement

The density of wood is measured by weighing the wet weight of the wood sample that has been taken. After weighing the wet weight, the wood sample was then placed in an oven at 100 ^oC for ± 48 hours. The dry weight of the sample that has been put in the oven is then weighed. The density of wood can be calculated by the formula:

$$\textbf{Wood density (g/cm}^3\textbf{)} = \frac{\textbf{dry weight (g)}}{\textbf{volume (cm}^3\textbf{)}}$$

7. Biomass

The formula to calculate mangrove biomass is as follows:

$$\mathbf{B = V \times Wood\ Density}$$

Description:
B : Biomass (kg)
V : Volume pohon (m^3)
Wood Density : Mangrove wood density (convert the units in the previous calculation to units of kg/m^3)

8. Carbon Stock

The formula for calculating carbon from biomass is as follows:

$$\mathbf{C_b = B \times \%C}$$

Description:
C_b : Carbon content of biomass (kg)
B : Biomass (kg)
%C : 47%

9. Carbon Stock per Hectare

Calculation of carbon stock per hectare can use the equation from SNI 7724:2011 as follows:

$$C_n = \frac{C_x}{1000} \times \frac{10000}{A_{plot}}$$

Description:
C_n : Carbon Stock per Hectare (ton/ha)
C_x : Carbon stock per observation plot (kg)
A_{plot} : Total area of observation plot (m^2)

III. Result

1. Above-Ground Carbon Stock Estimation

Above-ground biomass (AGB) is all living material above the ground. This part of the biomass includes stems, stumps, branches, bark, seeds, and leaves from vegetation, both from tree strata and understorey strata on the forest floor (Anshary, 2021). The content of carbon stocks above the ground of the mangrove ecosystem at data collection stations can be seen in Table 1.

Table 1. Above-ground carbon stock

Station	Species	Number of Trees	Average diameter (cm)	AGB (ton/ha)	C_b (ton C/ha)
1	*Avicennia officinalis*	13	7,72	12.38	5,82
	Avicennia rumphiana	72	8.75	102.98	48,40
	Total	**85**	**8.59**	**115.35**	**54,22**
2	*Avicennia officinalis*	26	11.97	114.68	53.90
	Avicennia marina	5	10,19	10.94	5,14
	Avicennia rumphiana	11	11.75	34,92	16,41
	Rhizophora apiculata	2	22.55	190.30	89.44
	Total	**47**	**12.85**	**350.84**	**164.90**
3	*Avicennia rumphiana*	7	8.05	6,80	3,20
	Rhizophora apiculata	20	21,62	1060.58	498,47
	Total	**27**	**18,11**	**1067,39**	**501.67**
4	*Avicennia officinalis*	1	36,31	35,68	16,77
	Avicennia rumphiana	10	14.84	63.75	29.96
	Rhizophora apiculata	6	18,26	137,63	64,69
	Xylocarpus granatum	5	30,83	130,10	61,15
	Total	**22**	**20,38**	**367,17**	**172.57**
5	*Avicennia officinalis*	9	6,65	5.53	2.60
	Avicennia rumphiana	29	7,74	29.03	13.64
	Rhizophora apiculata	5	10.25	17,34	8,15
	Xylocarpus granatum	1	7,32	0.70	0.33
	Total	**44**	**7.80**	**52,60**	**24,72**
6	*Avicennia officinalis*	18	12,14	68,17	32.04
	Bruguiera gymnorhiza	10	7,20	9,83	4.62
	Rhizophora apiculata	32	8.58	59.99	28,19
	Xylocarpus granatum	1	5,41	0.33	0.16
	Total	**61**	**9.35**	**138,32**	**65.01**
7	*Avicennia marina*	3	21.02	32,10	15.09
	Rhizophora apiculata	49	12.87	270,27	127.03
	Total	**52**	**13,34**	**302.37**	**142,11**
8	*Avicennia marina*	3	18.37	22.95	10.79
	Rhizophora apiculata	37	19,18	480.85	226.00
	Total	**40**	**19,12**	**503,80**	**236.79**
9	*Avicennia rumphiana*	11	11.67	56.97	26,77
	Rhizophora apiculata	16	18,17	287,64	135,19
	Total	**27**	**15,52**	**344.61**	**1 61.96**
10	*Avicennia rumphiana*	4	22,13	62,76	29.50
	Rhizophora apiculata	32	13.78	214,15	100.65
	Sonneratia alba	1	52.55	55,31	26.00
	Total	**37**	**15,73**	**332,23**	**156,15**
11	*Sonneratia alba*	19	42,51	887.98	417.35
	Total	**19**	**42,51**	**887.98**	**417.35**
12	*Sonneratia alba*	21	40,37	1111.70	522.50
	Total	**21**	**40,37**	**1111.70**	**522.50**
13	*Sonneratia alba*	16	48.45	1411.66	663,48
	Total	**16**	**48.45**	**1411.66**	**663,48**
14	*Rhizophora apiculata*	1	5,41	0.45	0.21
	Sonneratia alba	16	49,52	1413.69	664,43
	Total	**17**	**46.93**	**1414,14**	**664.65**

Based on the data in the table above, it is known that the carbon stocks in the Tanjung Pemancingan mangrove ecosystem show mixed results. Estimation of above-ground carbon stock at Station 5 shows a relatively low value of 24.72 tons C/ha. Meanwhile, the above-ground carbon stock stored at Station 14 is the highest of all data collection stations, with a total of 664.65 tons C/ha. In addition, general mangroves located at Stations 11 to 14 have higher ground carbon stocks than those at other stations.

Several factors cause significant differences in the amount of carbon stock in mangrove ecosystems. The first factor is the size the diameter of the different tree trunks. The calculation of carbon stock is strongly influenced by the size of the tree trunk diameter. If the tree trunk's diameter gets bigger, the potential carbon stock in the tree is also getting more significant. The second factor is the characteristics of the mangrove species. Each tree species has its characteristics; for example, Sonneratia alba has a trunk diameter that tends to be larger, thus enabling this type to store higher carbon stocks. Rhizophora apiculata has a higher density than other types, and the density (wood density) is one of the components required for carbon stock calculations.

The mangroves found at Stations 11 to 14 are dominated by Sonneratia alba mangroves with an average diameter of more than 40 cm. This causes the amount of carbon stock in that zone to be very high compared to mangroves in other zones, which have different vegetation types and an average diameter of smaller tree trunks. This is in accordance with Anshary et al. (2022) statement that the amount of carbon stock above the ground of mangroves in a location is influenced by several factors such as diameter, type of mangrove, and density. Komiyama et al. (2005) also stated that wood density is essential for calculating biomass using the allometric method.

2. Below-Ground Carbon Stock Estimation

Below-ground biomass (BGB) is all the biomass from the living root system of plants. This understanding of the root system is valid until a specific diameter is determined. This is done because plant roots with smaller diameters tend to be difficult to distinguish from soil organic matter and litter (Anshary, 2021). The amount of below-ground carbon stocks in mangrove ecosystems at data collection stations can be seen in Table 2.

Table 2. Below-ground carbon stocks

Station	Species	Number of Trees	Average diameter (cm)	BGB (ton/ha)	C_b (ton C/ha)
1	*Avicennia officinalis*	13	7,72	10,21	4.80
	Avicennia rumphiana	72	8.75	85,27	40.08
	Total	**85**	**8.59**	**95.48**	**44.88**
2	*Avicennia officinalis*	26	11.97	94.67	44.50
	Avicennia marina	5	10,19	9.06	4,26
	Avicennia rumphiana	11	11.75	28.90	13.58
	Rhizophora apiculata	2	22.55	153,37	72.09
	Total	**47**	**12.85**	**286.00**	**134,42**
3	*Avicennia rumphiana*	7	8.05	5,63	2.65
	Rhizophora apiculata	20	21,62	854.78	401.75
	Total	**27**	**18,11**	**860.41**	**404.39**
4	*Avicennia officinalis*	1	36,31	29,69	13.95
	Avicennia rumphiana	10	14.84	52,79	24,81
	Rhizophora apiculata	6	18,26	110.93	52,14
	Xylocarpus granatum	5	30,83	108.25	50.88
	Total	**22**	**20,38**	**301.66**	**141.78**
5	*Avicennia officinalis*	9	6,65	4.57	2,15
	Avicennia rumphiana	29	7,74	24.04	11.30
	Rhizophora apiculata	5	10.25	13.97	6,57
	Xylocarpus granatum	1	7,32	0.58	0.27
	Total	**44**	**7.80**	**43,16**	**20,28**
6	*Avicennia officinalis*	18	12,14	56,72	26,66
	Bruguiera gymnorhiza	10	7,20	8.01	3.77
	Rhizophora apiculata	32	8.58	48.35	22,72
	Xylocarpus granatum	1	5,41	0.28	0.13
	Total	**61**	**9.35**	**113,36**	**53,28**
7	*Avicennia marina*	3	21.02	26.58	12.49
	Rhizophora apiculata	49	12.87	217.82	102.38
	Total	**52**	**13,34**	**244,41**	**114.87**
8	*Avicennia marina*	3	18.37	19.01	8.93
	Rhizophora apiculata	37	19,18	387.54	182,14
	Total	**40**	**19,12**	**406.55**	**191.08**
9	*Avicennia rumphiana*	11	11.67	47,17	22,17
	Rhizophora apiculata	16	18,17	231.82	108.96
	Total	**27**	**15,52**	**279.00** _ _	**131,13**
10	*Avicennia rumphiana*	4	22,13	51.97	24,43
	Rhizophora apiculata	32	13.78	172.60	81,12
	Sonneratia alba	1	52.55	48,27	22.69
	Total	**37**	**15,73**	**272.84**	**128,23**
11	*Sonneratia alba*	19	42,51	774.86	364,19
	Total	**19**	**42,51**	**774.86**	**364,19**
12	*Sonneratia alba*	21	40,37	970.08	455.94
	Total	**21**	**40,37**	**970.08**	**455.94**
13	*Sonneratia alba*	16	48.45	1231.83	578.96
	Total	**16**	**48.45**	**1231.83**	**578.96**

Station	Species	Number of Trees	Average diameter (cm)	BGB (ton/ha)	C_b (ton C/ha)
14	*Rhizophora apiculata*	1	5,41	0.37	0.17
	Sonneratia alba	16	49,52	1233.60	579.79
	Total	**17**	**46.93**	**1233.97**	**579.96**

Table 2 shows that the carbon stock in the below-ground component has the same trend as that in the above-ground component. Mangrove, which contains the least below-ground carbon stock, is at Station 5 with 20.28 tons C/ha. While Station 14 is the location with the highest below-ground carbon stock content, amounting to 579.96 tons C/ha. In general, the mangrove zone in the eastern part has a higher carbon stock content when compared to mangroves in other zones.

Factors that affect the below-ground carbon stocks are tree trunk diameter, tree species, and wood density. Calculating above-ground and below-ground carbon stocks uses the same components, namely tree trunk diameter, and wood density, but uses different constants. Komiyama et al. (2005) stated that below-ground biomass has a very similar amount to above-ground biomass, in which biomass is the main element in calculating carbon stock. This is due to the robust mangrove root system and growing in muddy substrates. Even so, the lower carbon stock component comes from the deposition of carbon stock absorbed from the top after going through photosynthesis.

3. Litter Carbon Stock Estimation

Litter is the part of the plant that has fallen in the form of leaves and branches lying on the ground (Hairiah et al., 2011). Litter has an essential role in the mangrove ecosystem. In addition to being soil organic matter, litter can also store biomass as small particles to be used as nutrients. The value of litter biomass and carbon stock at data collection stations can be seen in Table 3 below:

Table 3. Litter carbon stock

Station	Biomass (ton/ha)	Litter Carbon Stock (ton C/ha)
1	1.10	0.52
2	0.94	0.44
3	0.61	0.28
4	0.79	0.37
5	1.35	0.63
6	0.77	0.36
7	0.89	0.42
8	0.62	0.29
9	0.96	0.45
10	1.01	0.47
11	1.17	0.55
12	1.26	0.59
13	0.66	0.31
14	0.47	0.22

Based on the estimation of litter carbon stocks, the litter carbon stocks obtained at data collection stations have varied values. Station 5 has a biomass of 1.35 tons/ha and the highest litter carbon stock with an amount of 0.63 tons C/ha. Meanwhile, the lowest litter carbon stock was found at Station 14, with 0.22 tons C/ha.

The total dry weight of litter can be interpreted as the value of biomass so that the biomass content is influenced by several factors closely related to the loss of litter mass after going through the drying process. Litter has the lowest carbon stock content when compared to other components. Wanatorei (2013) stated that leaves have a high-water content, so the biomass content is low. Another factor that affects the amount of biomass in the litter is canopy cover. Windusari (2012) states that the amount of litter increases with increasing tree age and the level of canopy coverage in mangrove ecosystems.

4. Total Carbon Stock

The carbon stock of all components consisting of the above-ground, below-ground, and litter is accumulated to determine the content of carbon stocks that mangrove ecosystems can store. The total carbon stock in the mangrove ecosystem in the Tanjung Pemancingan area can be seen in Figure 2.

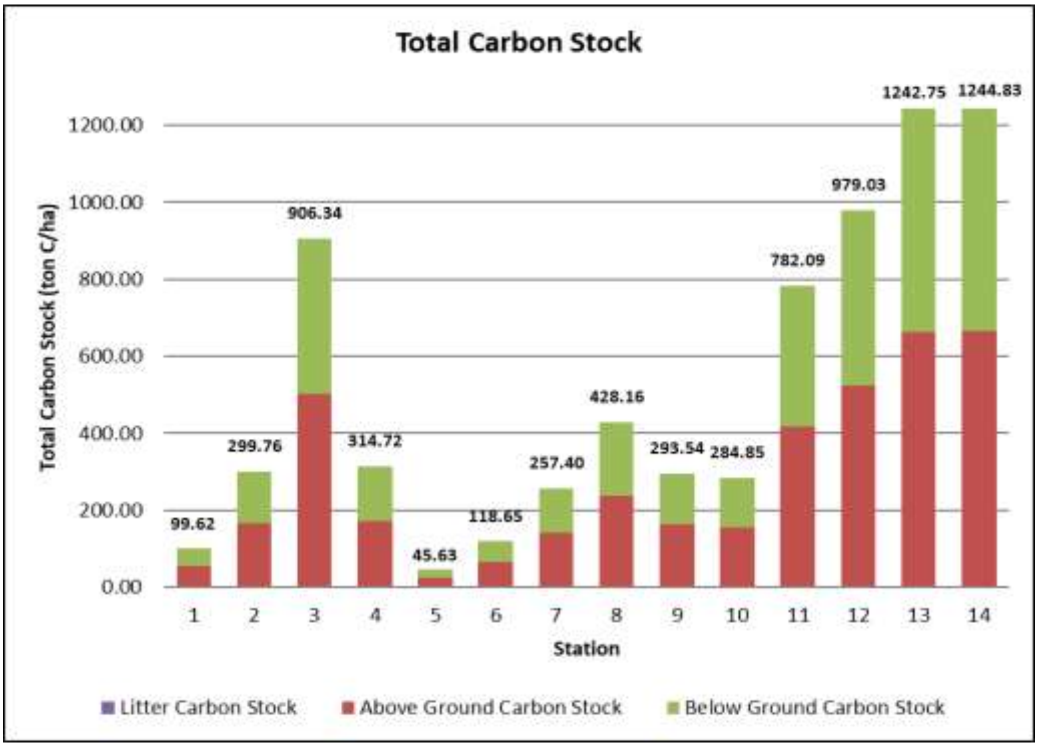

Figure 2. The total carbon stock of the mangrove ecosystem at each station

Based on the bar graph in Figure 2, it can be seen that the total carbon stock has the same trend as the above-ground and below-ground carbon stocks. The highest total carbon stock was found at Station 14, with 1244.83 tons C/ha, followed by Station 13, with a total carbon stock of 1242.75 tons C/ha. Meanwhile, the lowest total carbon stock was found at Station 5, with a value of 45.63 tons C/ha. In general, it can be seen that mangroves in the eastern zone have higher total carbon stocks than mangroves in other zones.

The total value of carbon stock obtained is because the above-ground part is the component with the highest carbon stock, followed by below-ground carbon stock. Carbon stocks in litter do not significantly affect the total carbon stock as a whole. However, according to research from Hidayanto et al. (2004), this component has a significant role, namely as the main constituent of organic matter in the soil in mangrove ecosystems.

Based on the bar graph in Figure 2, it can be seen that the total carbon stock has the same trend as the above-ground and below-ground carbon stocks. The highest total carbon stock was found at Station 14, with 1244.83 tons C/ha, followed by Station 13, with a total carbon stock of 1242.75 tons C/ha. Meanwhile, the lowest total carbon stock was found at Station 5, with a value of 45.63 tons C/ha. In general, it can be seen that mangroves in the eastern zone have higher total carbon stocks than mangroves in other zones.

The total value of carbon stock obtained is because the above-ground part is the component with the highest carbon stock, followed by below-ground carbon stock. Carbon stocks in litter do not significantly affect the total carbon stock as a whole. However, according to research from Hidayanto et al. (2004), this component has a significant role, namely as the main constituent of organic matter in the soil in mangrove ecosystems.

The estimated total carbon stock in all mangrove areas spread over three zones representing various levels of tree density of various species of mangroves in Tanjung Pemancingan can be seen in Table 4.

Table 7. Mangrove Biomass Estimation

Mangrove Zone	Station	Carbon stock (ton/Ha)	Mangrove Zone Area (Ha)	Estimated Total carbon stock
Zone 1	1	99.62	12.111	4,035.555
	2	299.76		
	3	906.34		
	4	314.72		
	5	45.63		
Z1 Average Carbon Stock (Ha)		**333.214**		
Zone 2	6	118.65	5.660	1565.103
	7	257.4		
	8	428.16		
	9	293.54		
	10	284.85		
Z2 Average Carbon Stock (Ha)		**276.52**		

Mangrove Zone	Station	Carbon stock (ton/Ha)	Mangrove Zone Area (Ha)	Estimated Total carbon stock
Zone 3	11	782.09	3.299	3,504.115
	12	979.03		
	13	1242.75		
	14	1244.83		
Z3 Average Carbon Stock (Ha)		**1062.175**		
TP-NPLCT Mangrove Carbon Stock Estimation			**21.07**	**9,104.773**

Table 4 shows that the total estimated mangrove carbon stock in Tanjung Pemancingan (TP) is 9,104.773 tons C in an area of 21.07 ha. The estimated total value of mangrove carbon stock correlates with the total biomass, which is influenced by tree species, density level, tree diameter, height, and the mangrove area.

IV. Conclusion

The total estimated mangrove carbon stock in the study area at Tanjung Pemancingan is 9,104.773 tons C in an area of 21.07 ha. The total value of mangrove carbon stock correlates with the total biomass, which is influenced by tree species, wood density, density level, diameter size, and area of mangrove area.

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