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Blue Carbon Stock Estimation on Various Levels of Mangrove Coverage in Bunati Village, Tanah Bumbu Regency

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Abstract:
Background:*The mangrove is a coastal ecosystem that lived in muddy substrates with calm water and its existence is affected by sea tidal activity. As a transitional ecosystem between land and sea, mangroves have many functions, one of which is to store blue carbon stock to reduce the impact of global warming.Numerous factors determine the carbon stock value including mangrove coverage. One of the locations that have a mangrove ecosystem is Bunati village in Tanah Bumbu Regency, South Kalimantan Province. However, there is no research on blue carbon stock estimation in this location. Based on this problem, the authors believe that research is needed regarding blue carbon stock at a different coverage level of the mangrove ecosystem in Bunati Village, Tanah BumbuRegency. The objectives of this research are to estimate blue carbon stock on various levels of mangrove coverage in Bunati Village, Tanah BumbuRegency and to estimate total blue carbon stock in Bunati Village, Tanah BumbuRegency based on NDVI analysis and blue carbon stock estimation.*
Materials and Methods:*This research uses a purposive sampling method based on coverage level from the results of Sentinel 2A 2020 imagery with Normalize Difference Vegetation Index (NDVI) analysis. The calculation of biomass is using trees volume and the estimation of blue carbon stock is 47% of total biomass.*
Results: *The result shows that mangrove with high-level coverage has blue carbon stock of 32,367.03 tons C. Mangrove with medium-level coverage has blue carbon stock of 939.69 tons C. Mangrove with low-level coverage has blue carbon stock of 41.03 tons C/ha.*
Key Word: *Mangrove; Biomass; Blue Carbon Stock; Carbon Sink; Bunati.*

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I. Introduction

Mangrove is an ecosystem that grows in a coastal area with a muddy substrate, and calm water, and its existence is affected by tidal activities. As a transition ecosystem, mangrove has many functions and roles for the surrounding environment, one of which is as a carbon sink(Sondak, 2015). Mangrove ecosystem can absorb more carbon compared to other types of land forests such as boreal forests and tropical rain forests, so the mangrove ecosystem is also called the blue carbon ecosystem.Thecarbon sink is very advantageous to shrink carbon dioxide (CO_2) concentration in the atmosphere which causes climate change and global warming.

Carbon sink in mangrove ecosystem can be found in 4 main components. Those components namely: aboveground biomass (e.g., trunks, branches, and leaves), belowground biomass (e.g., roots), litter, and organic soil(Hairiah, et al., 2011). Above-ground biomass is the most important component and has a bigger amount of carbon sink in comparison to below-ground biomass and litter. In addition, above-ground biomass binds other components and disables them from re-emitting the sequestrated carbon (Gibbs, Brown, Niles, & Foley, 2007). The number of blue carbon stocks in those components is determined by several factors.

Factors that determine the amount of blue 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 the mangrove ecosystem is the density of vegetation. The density of mangrove vegetation is directly proportional to the amount of carbon stock. The denser the vegetation, the higher the carbon stock, and vice versa(Imiliyana, Muryono, & Purnobasuki, 2012).

The amount of carbon stored in the mangrove ecosystem is closely related to the amount of biomass in the mangrove ecosystem. The amount of biomass can be calculated by measuring diameter, height, and wood density. After obtaining the biomass of the entire mangrove ecosystem, the determination of carbon stock is carried out using the conversion rate, which is 47% of the total biomass (Indonesian National Standard, 2011). The sampling method used to determine the sample is purposive sampling and harvest sampling. Whereasthe method to determine the level of mangrove coverage is using the Normalized Different Vegetation Index (NDVI)(Padillah, 2016).

Tanah Bumbu Regency is one of the regencies in South Kalimantan which has a mangrove ecosystem area (Tanah Bumbu Regional Regulation, 2016). One location that has a mangrove ecosystem in Tanah Bumbu Regency is Bunati Village. The mangrove ecosystem on the coast of Bunati is located along the Bunati River with an area of about 20 ha (Bunati Village Regulation, 2020). An ecosystem with a large area has great potential to become a carbon sink ecosystem. However, research on the estimation of blue carbon stocks in mangrove ecosystems on the Bunati coast has never been done before. Therefore, it is necessary to conduct research on blue carbon stocks at various mangrove density levels to determine the difference in the amount of carbon stock stored at each coverage level and to calculate the total blue carbon stock in the mangrove ecosystem of Bunati Village, Tanah Bumbu Regency.

II. MaterialsAnd Methods

This research was carried out from April – November 2020. The timeline includes the preparation stage, data collection, data analysis, and report writing. Data collection was held in Bunati Village, AngsanaSub-district, Tanah Bumbu Regency, South Kalimantan Province, Indonesia.

The data used in this research are primary and secondary. Primary data were obtained through data collectionin Bunati Village. There are 6 sampling stations in the research area, each station has 3 observation plots. The determination of the sampling stations is done by using the purposive sampling method referring to the work map that has been made (Figure 1). The determination of the sampling location was carried out by taking into account the canopy density as a result of the NDVI analysis. The number of stations used in this study was 6 stations, each representing the level of canopy density. The observation plot used is a plot measuring 10 x 10 m. Secondary data that was used in this research is Sentinel 2A imagery downloaded from the USGS website.

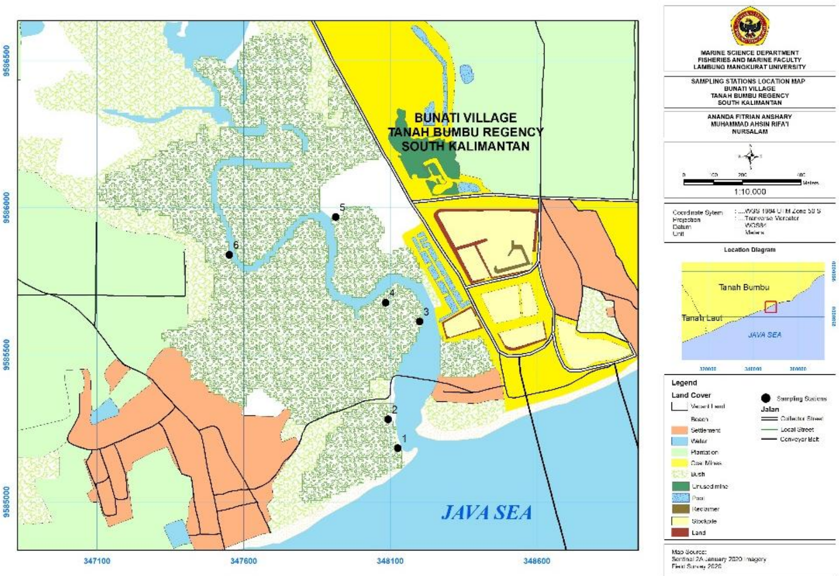

Figure 1. Sampling Stations Location Map

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)

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

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

c. Species Frequency (Fi)

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

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:

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

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:

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

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:

$$\textbf{MD = IND / TA}$$

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:

$$\textbf{t = b – a}$$

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:

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

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 ^{o}C 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:

$$\textbf{B = V x Wood Density}$$

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. General Condtion

Mangrove condition in Bunati village can be assessed with Minister of Environment Decree No. 201 of 2004criteria as in Table 1. The assessment is based on the mangrove's number of trees per area.

Table 1. Mangrove Condition in Bunati Village

Station	Density (trees/ha)	Category	Criteria
1	333	Sparse	Poor
2	467	Sparse	Poor
3	1,367	Moderate	Good
4	1,633	Very Dense	Good
5	300	Sparse	Poor
6	1,033	Moderate	Good

2. Compositions of Mangrove

The compositions of the Mangrove in Bunati Village can be seen in Table 2.

Table 2. Composition of Mangrove in Bunati Village

No	Species	Station					
		1	2	3	4	5	6
1	*R. mucronata*	✓		✓	✓	✓	✓
2	*R. apiculata*		✓		✓	✓	✓
3	*B. gymnorhiza*			✓	✓	✓	✓
4	*C. tagal*	✓					

The structure of the mangrove ecosystem can be known based on the calculation of the Important Value Index (IVI). In general, *Rhizophora mucronata* mangrove is the species that has the highest IVI in the mangrove ecosystem in Bunati Village. Based on the statement from (Supriharyono, 2000)the IVI value of each type of mangrove is very dependent on the conditions of mangrove growth. Mangroves to grow well, require several supporting factors. One of the main supporting factors in the growth of mangroves is the availability of nutrients or organic matter. The INP of the mangrove ecosystem in Bunati Village can be seen in Figure 2 below:

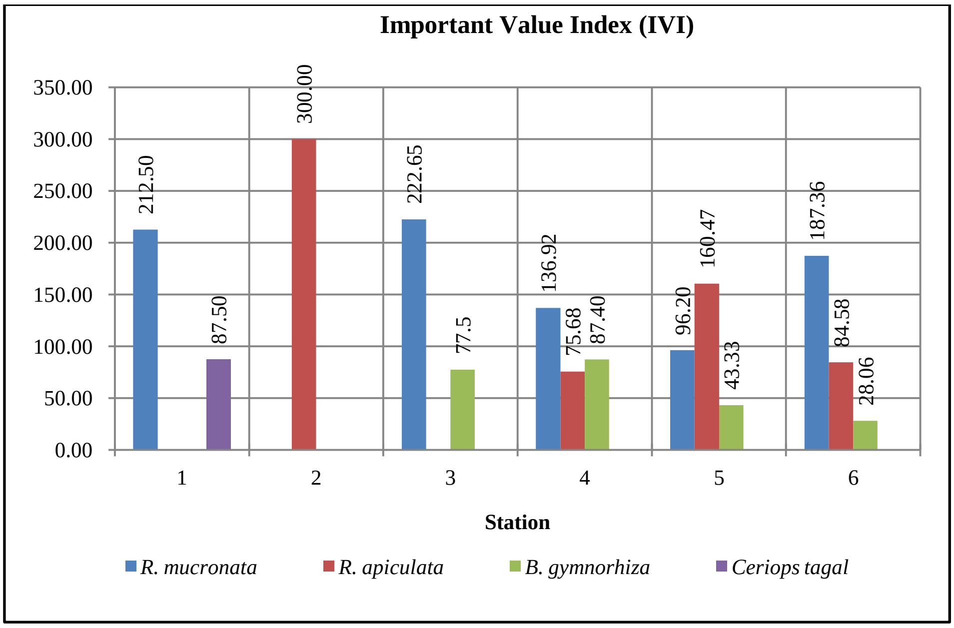

Figure 2. Important Value Index

3. Mangrove Canopy Coverage Levels

Based on the results of the NDVI analysis using Sentinel 2A imagery, the canopy coverage levels in the mangrove ecosystem of Bunati Village can be seen in Table 3 below:

Table 3. Mangrove Canopy Coverage Levels

No	Canopy Coverage Levels	Class Interval	Area (ha)	Area (%)
1	Low	0.08 – 0.312	1.23	1.51
2	Medium	0.312 – 0.546	7.12	8.87
3	High	0.546 – 0.78	72.82	89.61

The NDVI value at each station was taken from all observation plots and then searched for the distribution of the NDVI value based on the minimum and maximum values. After determining the minimum and maximum values, then determine the median value at each sampling station. Based on research from(Mayuftia, Hartoko, & Hendrarto, 2013), the median value is used to describe the relationship between blue carbon stock and NDVI. The median NDVI value at each station can be seen in Table 4 below:

Table 4. NDVI Value in Sampling Stations

Station	NDVI Range Value	NDVI Median Value	Canopy Coverage Levels
1	0.273 – 0.49	0.299	Low
2	0.363 – 0.503	0.462	Medium
3	0.64 – 0.692	0.675	High
4	0.508 – 0.748	0.702	High
5	0.149 – 0.301	0.268	Low
6	0.463 – 0.524	0.504	Medium

5. Trees Volume

This study uses data on height, diameter, and density to calculate tree volume. The volume of trees at each sampling station can be seen in Table 5 below:

Table 5. Trees Volume in Each Sampling Station

Station	Species	Volume (m^3/ha)
1	*R.mucronata*	41.33
	C. tagal	17.00
	Total	**58.33**
2	*R. apiculata*	42.33
	Total	**42.33**
3	*R.mucronata*	356.00
	B. gymnorhiza	46.33
	Total	**402.33**
4	*R.mucronata*	386.33
	R. apiculata	251.00
	B. gymnorhiza	100.67

Station	Species	Volume (m^3/ha)
	Total	**738.00**
5	*R.mucronata*	12.33
	R. apiculata	9.67
	B. gymnorhiza	6.00
	Total	**28.00**
6	*R.mucronata*	142.00
	R. apiculata	139.00
	B. gymnorhiza	10.00
	Total	**291.00**

Factors that affect the amount of volume are the level of density, height and diameter of the tree trunk. Based on Table 5. it can be seen that the size of the tree volume at Stations 1, 3, 4, 5 and 6 is directly proportional to the density level. However, this is different at Station 2 where Station 2 has a higher density than Station 1, but has a lower tree volume. This factor is because Station 2 has a smaller diameter and a lower average tree height compared to Station 1. The volume at Station 4 is the highest with a tree volume of 738 m^3/ha while the lowest tree volume is at Station 5 with a volume of28 m^3/ha. The results of these calculations are in accordance with the results of research from(Bismark, Subiandono, & Heriyanto, 2008) which shows that tree volume is influenced by the density level, tree trunk diameter, and tree height.

The volume obtained is then added up according to the canopy density level (Table 4) where each canopy density level is represented by 2 sampling stations. Mangroves with high density have a volume of 1140.33 m^3/ha. Mangroves with medium density have a volume of 333.33 m^3/ha and mangroves with low or sparse density have a volume of 86.33 m^3/ha.

6. Wood Density

Another variable that will determine the amount of biomass in a mangrove species is the wood density of each mangrove. Wood density was obtained from an average of 3 repetitions. The results of the analysis of the calculation of the density of wood can be seen in Table 6 below:

Table 6. Mangrove Wood Density

No	Species	Density (g/ml)
1	*R. mucronata*	0.84
2	*R.apiculata*	0.85
3	*B.gymnorhiza*	0.74
4	*Ceriopstagal*	0.78

7. Biomass Estimation

Biomass estimation can be done after knowing the tree volume and wood density at each sampling station. Biomass estimation of the Bunati Village Mangrove Ecosystem can be seen in Table 7 below:

Table 7. Mangrove Biomass Estimation

Station	Species	Biomass (ton/ha)
1	*R.mucronata*	34.72
	C. tagal	13.26
	Total	**47.98**
2	*R. apiculata*	35.98
	Total	**35.98**
3	*R.mucronata*	299.04
	B. gymnorhiza	34.29
	Total	**333.33**
4	*R.mucronata*	324.52
	R. apiculata	213.35
	B. gymnorhiza	74.49
	Total	**612.36**
5	*R.mucronata*	10.36

Station	Species	Biomass (ton/ha)
	R. apiculata	8.22
	B. gymnorhiza	4.44
	Total	**23.02**
6	*R.mucronata*	119.28
	R. apiculata	118.15
	B. gymnorhiza	7.40
	Total	**244.83**
	Grand Total (ton/ha)	**1297.50**

Based on the calculation results, it is known that the location with the highest biomass is at Station 4 with a total biomass of 612.36 tons/ha. Biomass at Station 3 is 333.33 tons/ha, Station 6 is 244.83 tons/ha, Station 1 is 47.98 tons/ha, Station 2 is 35.98 tons/ha and the smallest is at Station 5 with biomass 23.02 tons/ha

The estimated biomass at each station as in Table 7 is then added up according to the canopy density level where each density level is represented by 2 sampling stations. The estimation of biomass at the canopy coverage levels can be seen in Figure 3 below:

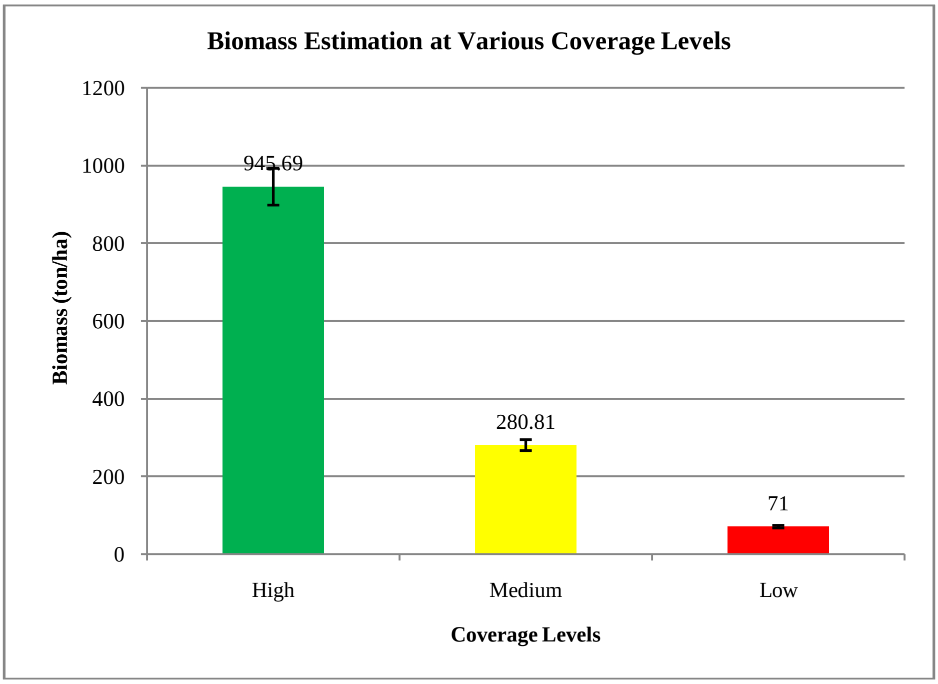

Figure 3. Biomass Estimation at Various Coverage Levels

8. Blue Carbon Stock Estimation

Biomass data that has been processed using tree volume and wood density can then be used to estimate the blue carbon stock of the mangrove ecosystem in Bunati Village. Calculation of carbon stock follows the rules of Indonesian National Standard (SNI) 7724:2011 that 47% of biomass is carbon. Further estimation of blue carbon stock can be seen in Table 8 below:

Table 8. Blue Carbon Stock Estimation

Station	Species	Blue Carbon Stock (ton C/ha)
1	*R.mucronata*	16.32
	C. tagal	6.23
	Total	**22.55**
2	*R. apiculata*	16.91
	Total	**16.91**
3	*R.mucronata*	140.55

Station	Species	Blue Carbon Stock (ton C/ha)
	B. gymnorhiza	16.11
	Total	**156.66**
4	*R.mucronata*	152.52
	R. apiculata	100.27
	B. gymnorhiza	35.01
	Total	**287.81**
5	*R.mucronata*	4.87
	R. apiculata	3.86
	B. gymnorhiza	2.09
	Total	**10.82**
6	*R.mucronata*	56.06
	R. apiculata	55.53
	B. gymnorhiza	3.48
	Total	**115.07**

The estimated blue carbon stock at each sampling station is then added up according to the canopy density level to determine the carbon stock at the canopy density level. Each density level is represented by 2 sampling stations. The graph showing the estimated blue carbon stock at each canopy density level can be seen in Figure 4 below:

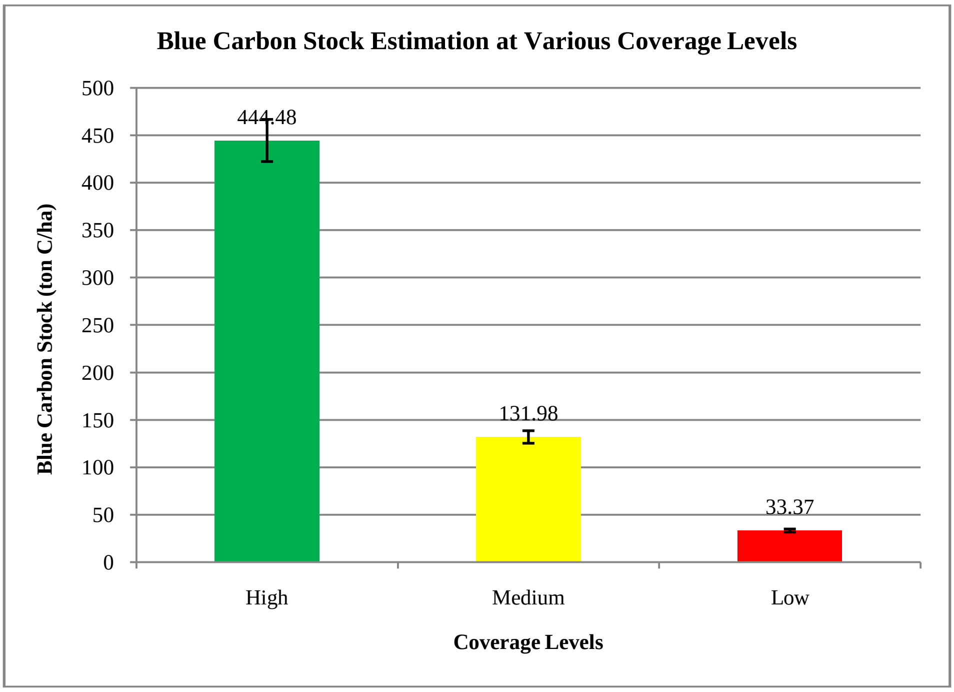

Figure 4. Blue Carbon Stock Estimation at Various Coverage Levels

Based on the graph in Figure 4, the estimated carbon stock at the mangrove with high level coverage is 444.48 tons C/ha. Mangroves with medium density have blue carbon stocks of 131.98 tons C/ha and mangroves with lowc overage level have 33.37 tons C/ha of blue carbon stocks. This shows that the higher the canopy coverage level, the higher the amount of carbon stock will be. This is supported by the results of research conducted by (Karmila, Jauhari, & Kanti, 2020). The study showed that a higher canopy density had a higher carbon stock value.

9. Total Mangrove Blue Carbon Stock in Bunati Village

Based on the carbon calculation data that has been done, then the data can be used to calculate the total blue carbon stored in the mangroves in Bunati Village. The results of the calculation of the total blue carbon stored in mangroves in Bunati Village can be seen in Table 11below:

Table 11. Total Mangrove Blue Carbon Stock in Bunati Village

Coverage Levels	Carbon Stock (ton C/ha)	Area (ha)	Blue Carbon Stock Total (ton C)
High	444.48	72.82	32,367.03
Medium	131.98	7.12	939.69
Low	33.37	1.23	41.03
	Grand Total	**81.17**	**33,347.76**

IV. Conclusion

The total blue carbon stock of the mangroves in Bunati Village is 33,347.76 tons C. The highest carbon stock is found in mangroves with a high coverage level of 32,367.03 tons C. Mangroves which are included in the medium category have carbon stocks of 939.69 tons C and mangroves with sparse or low coverage have a carbon stock of 41.03 tons C.

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