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Estimation of Carbon Storage in Necromass in the Mangrove Area of Kayu Ara Permai Village, Siak Regency

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ABSTRACT

This research was conducted in March 2025 at the Mangrove Area of Kayu Ara Permai Village, Sungai Apit Subdistrict, Siak Regency. The study aimed to estimate the organic matter and carbon stocks of necromass and to determine the relationship between the number of necromass and its carbon stock. The method used was a survey, with purposive sampling, at three research stations. Measurements of organic matter and carbon stock of necromass were carried out using the volume method. The results showed that mangrove density ranged from 2,377.78 to 3,088.89 ind/ha, necromass organic matter ranged from 0.9676 to 2.1520 tons/ha, and necromass carbon stock ranged from 0.4548 to 1.0114 tons/ha. Based on the results of this study, there was a very weak positive correlation between necromass amount and its carbon stock, with a correlation coefficient (r) of 0.188.

Keywords: Mangrove, Necromas, Organic Matter, Carbon Stock.

1. INTRODUCTION

Global warming is one of the world's current problems, characterized by climate change that threatens coastal ecosystems. The main cause of global warming is the increase in greenhouse gas emissions such as carbon dioxide (CO_2) and methane (CH_4) produced by the industrial sector, transportation activities, and agricultural and livestock activities (Rahman et al., 2017). One mitigation effort to reduce atmospheric carbon dioxide concentrations is the concept of blue carbon, which involves three major ecosystems that act as carbon sinks in their networks and sediments: seagrass ecosystems, salt marshes, and mangroves.

One of the ecosystems that plays a significant role in blue carbon is the mangrove forest. Mangrove forests are coastal ecosystems that play an important role in carbon storage in tropical regions. Mangrove forests can store more than three times the average carbon per hectare compared to terrestrial tropical forests (Danoto et al., 2012). Carbon storage in mangrove ecosystems occurs in several main components: aboveground biomass, belowground biomass, and necromass (dead organic material, including coarse woody debris and litter).

Necromass is the mass of dead tree parts, both standing (dead trees) and fallen on the ground (dead wood) (SNI 7724, 2019). Necromass in mangrove ecosystems has great potential for carbon storage. This is because necromass can persist for long periods in mangrove sediments, which are often anaerobic and inhibit the decomposition of organic material.

The Mangrove Area of the Historic River in Kayu Ara Permai Village, Sungai Apit District, Siak Regency, represents one of the well-preserved mangrove ecosystems. This area not only serves as an ecotourism site but also plays an important role in maritime transportation routes, settlements, and local ports (Siwolo et al., 2024).

Due to limited information on estimating carbon storage in necromass in the mangrove ecosystem of Kayu Ara Permai Village, Siak Regency, the author is interested in conducting a study titled "Estimation of carbon storage in necromass in the Mangrove Area of Kayu Ara Permai Village, Siak Regency."

2. RESEARCH METHOD

Time and Place

This research was conducted in March 2025 in Kayu Ara Permai Village, Sungai Apit District, Siak Regency (Figure 1).

Method

The method used in this study was a

survey. The survey method is employed to collect data obtained directly from field research at the data collection site (Shinta et al., 2022). Necromass directed the field, and the samples were taken. The measured water quality parameters included temperature, salinity, and pH, which were recorded directly at the study site.

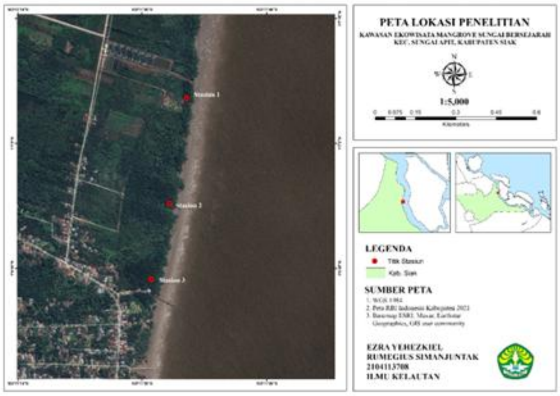

Figure 1. Location research

Procedures

The selection of research stations was conducted using a purposive sampling method. The study site is located in the Mangrove Area of the Historic River, Kayu Ara Permai Village, Sungai Apit District, Siak Regency. The research area consists of three stations: Station 1 is near shrimp pond activities; Station 2 is within the Mangrove Sungai Bersejarah (MSB) ecotourism area; and Station 3 is near residential areas. Mangrove density data were collected using the transect plot method. At each station, three transect lines were established, extending from the seaward direction toward the land, each approximately 50 meters in length. Each transect line contained three plots (quadrats) measuring 10×10 m² for tree category observations (Heriyanto & Amin, 2013). Within each plot, mangrove species were identified, and the number of individual trees was counted.

Data Analysis

The determination of mangrove density conditions was based on the Decree of the Minister of Environment No. 201 of 2004 concerning the Standard Criteria and Guidelines for Determining Mangrove Degradation. Mangrove density was calculated using the formula established by the SNI (2011) as follows:

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

Explanation:

K = Density of a species (individuals/m^2)
ni = number of individuals
A = Total plot area (m^2)

Measurement of organic matter in necromass from dead trees and dead wood using the volume method. Carbon measurement in necromass was carried out on dead mangroves, both on mangroves that were still standing (dead trees) and on mangroves that had fallen to the ground (dead wood). For dead trees, measure the diameter at breast height (DBH) and the total height of the dead tree. The volume of dead trees can be calculated using the equation (SNI 7724, 2019), namely:

$$Vpm = \frac{1}{4}\,\pi\,(dbh / 100) \times t \times f$$

Explanation:

Vpm : the volume of dead trees (m^3)
Dbh : The diameter at breast height of dead trees is 1.3 (m)
t : the total height of dead trees (m)
f : A form factor of 0.6 can be used.

To determine the organic matter content of dead trees, the calculation was performed using the following equation (SNI 7724, 2019):

$$Bopm = Vpm \times BJpm$$

Explanation:

Bopm : the organic material of dead trees (kg)
Vpm : the volume of dead trees (m^3)
BJpm : The specific gravity of dead trees (kg/m^3).

For fallen dead wood, the diameters at both the base and the tip were measured, along with the total length of the wood. The volume of dead wood was calculated using the following equation (SNI 7724, 2019):

$$Vkm = 0{,}25\,\pi\,\left(\frac{dp+du}{2\times 100}\right)^2 \times P$$

Explanation:

Vkm : the volume of dead wood (m^3)
dp : the diameter of the base of dead wood (cm)
du : the diameter of the tip of dead wood (cm)
p : the length of dead wood (m)
π : 22/7 or 3.14

To determine the organic matter content, the calculation was carried out using the following equation (SNI 7724, 2019):

$$Bokm = Vkm \times BJkm$$

Explanation:

Bokm	:	dead wood organic material (kg)
Vkm	:	dead wood volume (m^3)
BJkm	:	dead wood density (kg/m^3).

The specific gravity of mangroves is calculated using the equation (Kusuma et al., 2023):

$$Bjpm = \frac{BK}{VS}$$

Explanation:

BJpm	:	Specific gravity of mangrove (g/cm^3)
BK	:	Sample weight (g)
VS	:	Sample volume 10 cm (cm^3)

The specific gravity of mangroves is calculated using the equation (Kusuma et al., 2023):

$$Ckm = Bokm \times \%\ C\ organik$$

$$Cpm = Bopm \times \%\ C\ organik$$

Explanation:

Cpm	:	carbon content of dead trees (kg)
Ckm	:	carbon content of dead wood (kg)
Bopm	:	total organic matter of dead trees (kg)
Bokm	:	total organic matter of dead wood (kg)
% C	:	percentage of carbon content, equal to 0.47

The relationship between the amount of necromass and its carbon stocks is determined using simple linear regression. The strength of the relationship can be determined by the correlation coefficient, which can be divided into five categories (Anwar, 2009). If r = 0.00–0.199, the relationship is very weak; r = 0.20–0.399, the relationship is weak; r = 0.40–0.599 indicates a moderate relationship; r = 0.60–0.799 indicates a strong relationship; and r = 0.80–1.00 indicates a very strong relationship.

3. RESULT AND DISCUSSION

Water Quality Parameters

The results of water quality parameter measurements at the study site showed an average temperature of 28.3°C, a salinity of 28 ‰, and a pH of 8.1. These average water quality values support the growth and sustainability of mangrove ecosystems, as they align with the seawater quality standards for mangroves stated in the Decree of the Minister of Environment No. 51 of 2004, which specifies that suitable conditions for mangroves include a temperature range of 28–32 °C, pH between 7–8.5, and salinity up to 34 ‰. The measurement results are presented in Table 1.

Table 1. Water Quality

Parameter	Station 1	Station 2	Station 3	average
Temperature (°C)	29	27	29	28,3
Salinity (‰)	28,5	26,5	29	28
pH	8,1	8	8,2	8,1

Mangrove Density

The mangrove vegetation at the three research stations comprised 10 species. The types of mangroves found at the three stations were: *Rhizophora apiculata, Xylocarpus granatum, Bruguiera gymnorrhiza, B.sexangula, Lumnitzera littorea, Heritiera littoralis, Excoecaria agallocha, Sonneratia alba, Avicennia alba, and Scyphiphora hydrophyllacea*. The results of the mangrove density calculations at each station are shown in Table 2.

Table 2. Mangrove Density Categories in the Mangrove Area of Kayu Ara Permai Village

Station	Mangrove Density (ind/ha)	criteria	condition
1	3088,89	Good condition	Very dense
2	2377,78	Good condition	Very dense
3	2788,88	Good condition	Very dense

Based on the standard criteria for mangrove degradation established by the Ministry of Environment (KLH, 2004), the mangrove forest condition at each station exhibited similar characteristics. The mangrove forests at Stations 1, 2, and 3 were classified as being in good condition with a very dense structure.

Organic Matter of Mangrove Necromass

Based on the research conducted in the mangrove area of Kayu Ara Permai Village, the results of mangrove necromass organic matter are presented in Table 3.

Table 3. Organic Matter of Mangrove Nekromass

Station	Necromass organic matter (tons/ha)
1	0,9676
2	2,1520
3	1,9585
average	1,6927

The results of organic matter calculations in mangrove necromass across the three research stations showed that the total necromass organic matter ranged from 0.9676 to 2.1520 tons/ha. The highest necromass organic matter was recorded at Station 2, with a value of 2.1520 tons/ha, while the lowest was observed at Station 1, with a value of 0.9676 tons/ha.

The difference in the amount of necromass between stations is likely influenced by several factors, including tidal fluctuations, the size of dead wood and dead trees, and the relatively small amount of dead wood present. This is in line with the statement by Tsani et al. (2022) that, in general, mangrove forests can produce dead organic biomass or not, depending on tidal fluctuations that carry necromass from the water body to other areas. Research by Alviana et al. (2023) found that necromass has the lowest average carbon stock among the three carbon pools. This is because the average necromass diameter is relatively small. In addition to being influenced by diameter, necromass is also influenced by its height and length.

Carbon Stock of Mangrove Necromass

Based on the research conducted in the mangrove area of Kayu Ara Permai Village, the results of mangrove necromass carbon stock are presented in Table 4.

Table 4. Carbon Stock of Mangrove Necromass

Station	Carbon Stock (tons/ha)
1	0,4548
2	1,0114
3	0,9205
average	0,7956

The results of the mangrove organic matter calculations across the three research stations showed that total necromass ranged from 0.4548 to 1.0114 tons/ha. The highest necromass organic matter was recorded at Station 2, with a value of 1.0114 tons/ha, while the lowest was observed at Station 1, with a value of 0.4548 tons/ha. Based on this study's results, the average carbon stock in the mangrove forest of Kayu Ara Permai Village was 0.7955 tons/ha. The total carbon stock in this area is higher than the necromass carbon stock reported in the mangrove forest of Sumbernadi Village, South Lampung District, Lampung Regency, which ranged from 0.009 to 0.036 tons/ha (Kusuma et al., 2024).

The differences in carbon stock may be attributed to variations in the number and diameter of dead trees or woody debris at each station. This is consistent with the statement of Alviana et al. (2023), who noted that stem diameter size is a key factor influencing biomass and carbon stock values; the larger the tree diameter, the greater its biomass and carbon storage capacity. The carbon stored in necromass represents the residual carbon retained within the tree trunk before the tree's death. This stored carbon originates from the remnants of photosynthetic processes that occurred during the tree's life (Kusuma et al., 2022).

Table 5. Number of Necromass (ind/ha) and Carbon Stock (ton/ha)

Station	Number of necromas (ind/ha)	Carbon stock (ton/ha)
1	366,67	0,4548
2	477,78	1,0114
3	355,56	0,9205

The analysis of the relationship between the number of necromass and necromass carbon stock shows that the correlation between them is very weak, as indicated by a correlation coefficient (r) of 0.188 and an R^2 value explaining only 3.5% of the variation in necromass organic matter, while other factors influence the remaining 96.5%. This study indicates that the amount of necromass cannot be used as a primary indicator for estimating mangrove necromass carbon stock. This finding is consistent with the results of Alviana et al. (2023) in the mangrove ecosystem of Pengudang Village, which found that dead wood's contribution to total carbon stock is among the smallest due to its limited size and distribution.

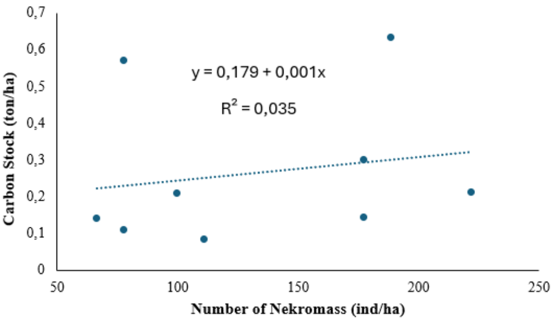

Figure 2. The Relationship Between the Number of Necromass and Mangrove Carbon Stock

In addition, environmental factors such as stand age, vegetation density, tidal patterns, decomposer fauna activity, and substrate type greatly influence the accumulation of organic necromass. Agustin et al. (2011) stated that necromass accumulation is affected by the rate of ecological succession and the biophysical conditions of the mangrove area, not merely by the number of necromasses present. The larger and older the necromass, the greater its potential contribution to the carbon stock that remains in the system for a longer period. However, if most of the necromass found consists of small branches or decayed trunks, its contribution to the total necromass biomass will be very low.

4. CONCLUSION

Based on the research conducted, the following conclusions were obtained: The composition of mangrove vegetation at the tree level indicates that the estimated organic matter necromass ranges from 0.9676 to 2.1520 tons/ha. Sequentially, the necromass organic matter at stations 1, 2, and 3 is 0.9676, 2.1520, and 1.9585 tons/ha, respectively. The estimated necromass carbon stock ranges from 0.4548 to 1.0114 tons/ha, with necromass carbon stocks at stations 1, 2, and 3 being 0.4548, 1.0114, and 0.9205 tons/ha, respectively. The relationship between the number of necromass and the necromass carbon stock shows a positive but very weak correlation (r = 0.188).

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