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ESTIMATION OF CARBON RESERVES IN SEDIMENTS IN THE MANGROVE ECOSYSTEM OF BUKIT BATU VILLAGE, BENGKALIS REGENCY, RIAU

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ABSTRACT

This research was carried out in December 2021. Sampling and water quality measurements were carried out in the Bukit Batu Muara River, Bengkalis Regency, Riau Province. Sample analysis was continued at the Marine Chemistry Laboratory, Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau. The purpose of this study was to determine the estimation of carbon stocks in sediments, the comparison of carbon stocks between transects, and the relationship between density and carbon stocks in the Muara Sungai Bukit Batu mangrove area, Bengkalis Regency, Riau Province. The method used in this study is a survey method. Parameters measured included mangrove density (Ind/Ha), organic matter content, and carbon stock in sediments. In addition, water quality was also measured in the form of temperature, salinity, and degree of acidity. Analysis of carbon stock using the loss on ignition method. The result of average density of mangroves throughout the transect is 3733.33 (Ind/Ha). The lowest carbon stock value in sediments is in transect 2 with medium mangrove density with a value of 29.26 tons/ha, while the highest carbon stock value is in transect 3 with high-density mangrove areas with a value of 36.15 tons/ha. The results of a simple linear regression to determine the relationship between mangrove density and carbon stock show a coefficient of determination $R^2 = 0.023$, which means that 2.3% of total carbon stock is affected by density, while 97.7% is influenced by other factors. The value of $R = 0.152$, which means that the relationship between density and carbon stock in the Bukit Batu river estuary area, Bengkalis Regency, is low.

Keywords: Carbon, Mangrove ecosystem, Sediment of mangrove.

1. INTRODUCTION

Global warming is a hot topic of conversation among the world community. This is inseparable from the impacts caused by global climate change, rising sea levels, and an extreme increase in the earth's temperature. The main factor causing global warming is the increasing concentration of greenhouse gases in the atmosphere, one of which is carbon dioxide (CO_2). The concentrations of these gases on a global scale are cumulatively directly affected by human activities, although these gases also occur naturally[1]. Plants play a role in reducing gas emissions such as CO_2 by absorbing it in the process of photosynthesis and converting it into organic carbon compounds. One of the ecosystems absorbing greenhouse gas emissions is the mangrove forest. Mangrove forests can be found along the coastline in tropical and subtropical regions. Mangrove ecosystems play an important role in mitigating global warming by reducing CO_2 concentrations[2].

The coastal area is covered with a variety of different mangrove species. Mangroves can be identified based on the morphological characteristics of each constituent part, such as roots, stems,

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leaves, flowers, and fruit. Currently, mangroves are experiencing pressures such as deforestation and changes in land use. This will cause considerable damage to mangrove forests. So that it will affect the amount of carbon absorption that will be absorbed by mangroves.

The damage and reduction in the area of mangrove ecosystems are related to the absorption and storage of carbon to reduce CO_2 levels in the air. Mangrove plants will convert CO_2 in the air through the process of photosynthesis which is then distributed to other plant organs, such as stems, leaves, roots, fruit, and others[3]. Mangrove forest is a coastal ecosystem that can absorb CO_2 and has various other potential benefits, both for the environment and humans. The role of mangroves concerning Blue Carbon is emphasized as an effort by mangroves to utilize CO_2 for photosynthesis and store it in biomass and sediment stocks to mitigate climate change. This is reinforced by the statement of Donato et al.[4], who found that mangroves are one of the forests with the highest carbon stores in the tropics and are very high compared to the average carbon stores in various other forest types in the world, thus the existence of mangrove forests in coastal areas is believed to be one of the efforts to reduce carbon gas (CO_2) content. from the atmosphere.

The contribution of mangrove ecosystems to absorb carbon in coastal areas is not only through carbon storage in the form of biomass from the mangrove vegetation itself but also that which is buried in sediments. Murray et al.[5] stated that mangrove sediments have a higher ability to store carbon compared to carbon storage in the mangrove trees themselves. Added by Murdiyarso et al.[6] that the highest carbon storage in mangrove ecosystems is found in the sediment section.

One of the areas that still have mangrove areas in Riau Province is Bukit Batu District in Siak Regency. Existing mangrove ecosystems are increasingly being threatened by human activities such as logging, pollution, and conversion. There is no information regarding the carbon content of sediments in this mangrove ecosystem. In connection with that, this research is very necessary. For this reason, the purpose of this study was to analyze carbon stocks in mangrove sediments in Bukit Batu Village, Bengkalis Regency, Riau Province

2. RESEARCH METHOD

Time and Place

This research was carried out from November to December 2021. Sampling was carried out in the mangrove ecosystem area in Bukit Batu Village, Bengkalis Regency, Riau Province (Figure 1). Sample analysis was carried out at the Marine Chemistry Laboratory, Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau.

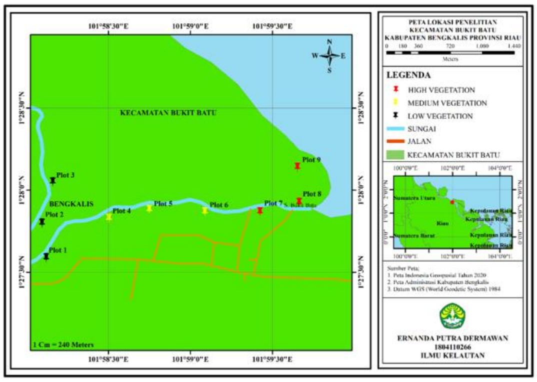

Figure 1. Map of research locations

Methods

The method used in this research is the survey method. Data collection was carried out through measurements and direct sampling in the field. The samples obtained were followed by analysis in the laboratory. The data obtained is then processed and discussed descriptively regarding the relevant literature.

Procedure

Water Quality Parameters

Water quality parameters are measured in situ at high tide during water inundation in many mangrove ecosystems. Measurements were made on each plot of each station. Measurement of environmental quality parameters in this study included: temperature, salinity, and pH.

Mangrove Species and Density

Mangrove density data collection using the quadrant plot transect method or sample plots (transect plot). The sampling transect was set at one station which was considered representative of the mangrove forest area in Bukit Batu Village. At the station, 3 transect lines were drawn from the direction of the waters to the land along ± 50 meters. Each transect consists of three plots or quadrant plots of 10 m x 10 m, each transect is approximate ± 100 meters apart. These locations were chosen because each transect location has a different density. Mangrove species were identified referring to Noor et al.[7] to obtain mangrove density values, species determination, and density calculations for each mangrove species were carried out in 9 plots according to Bengen[8]. Data on mangrove trees with a trunk diameter of ≥ 4 cm were calculated. Then the circumference of the tree trunk was measured at the height of an adult's chest (±1.3 m) using a cloth tape measure. The distance between one plot to the next is about 20 meters.

Furthermore, mangrove density is calculated using the following formula:

$$\textbf{Density (D) (ind/ha)} = \frac{\textit{number of individuals of a species}}{\textit{sample area}} \times 10.000$$

Sediment sampling

The data needed to analyze and obtain organic carbon stocks in the soil are the depth of the soil sample, the sample interval is taken, and the density of the soil (density). To find out this, the stages of work that need to be carried out are as follows: a) Before taking samples, organic waste and live leaves (if any) are cleaned from the soil surface; b) Then do coring by inserting the corer into the ground vertically at a predetermined point until the depth reaches the base of the corer. The core is rotated to cut the fine roots in the soil. Then the corer is pulled slowly from the ground while continuing to rotate it to maintain that the sediment samples taken are complete; c) The samples that have been obtained are split horizontally, and divided based on 5 depths (5 samples), namely 0-20 cm, 20-40 cm, 40-60 cm, 0-80 cm, and 80-100 cm. d) The samples obtained are then put into sample plastic bags and labeled on each bag to facilitate identification and analysis in the laboratory; e) The sample is stored in an ice box so that it can last until it is time to be analyzed in the laboratory.

Analisis Sampel di Laboratorium

Sediment samples obtained from the field were then analyzed in the laboratory using the Loss on Ignition (LOI) method referring to the Indonesian National Standard; Howard et al.[9-10]. The stages of the analysis are: a) the sediment sample obtained is placed in a container that has been prepared and labeled. Then the samples were dried in an oven at 80˚C for 48 hours. b) After the sample is dry, it is then crushed or mashed using a mortar so that the condition of each sample becomes homogeneous. Then each sample that has been mashed is placed back into the sample cup; c) The sample is then taken with a small spoon and weighed as much as 10 g (W0) and placed in the prepared cup. Then it is burned at 550˚C for 3 hours. After that, the sample is cooled in a desiccator and weighed again and the results are recorded.

Data processing calculated according to Howard et al.[10] is the depth of sediment samples, soil density, carbon density, carbon estimation, and the percentage of organic carbon in sediments. Organic matter (OM) is calculated using the equation:

$$\%OM = \frac{(Wo-Wt)}{Wo} x\ 100$$

Information:

%OM = Percentage of sediment organic matter lost in the combustion process

W0 = Dry weight before burning (g)

Wt = Final weight after burning (g)

The conversion of the percentage of organic matter to the percentage of carbon is calculated using the equation:

$$\%C = (\ 0,\ 580\ x\ \%\ OM)$$

Information:

%C = The carbon content of organic sedimentary materials

%OM = Percentage of sediment organic matter

0,58 = Constant for converting % organic matter to % organic C

The determination of Bulk Density (density of soil) is calculated using the formula:

$$BD = m\ (massa)/V\ (volume)$$

Information:

BD = Bulk Density (g/cm^3)

The density of carbon in soil is estimated by the equation:

$$\text{Soil C Density} = (\%C\ x\ BD)$$

Information:

%C = The carbon content of organic sedimentary material

BD = Bulk density (g/cm^3)

Total carbon content:

$$\text{Soil C} = (BD\ x\ SDI\ x\ \%C)$$

Information:

Soil C (MgC/ha) = Estimation of Carbon Stores

BD = Bulk density (g/cm^3)

SDI = Sample Depth Intervals (cm)

Data Analysis

Data obtained from measurements in the field and analysis results in the laboratory were then processed using Microsoft Excel to obtain estimates of carbon stocks in sediments. A simple linear regression test was used to determine the relationship between mangrove density and estimated carbon stocks in sediments. Furthermore, the results of the analysis are discussed descriptively.

3. RESULT AND DISCUSSION

Water Quality

Water quality can affect mangrove ecosystems and the living conditions of biota in coastal areas. Poor water quality as long as it can be minimized by mangrove ecosystems will turn into good water. Parameters that need to be observed in the management of mangrove ecosystems are temperature, salinity, and pH. In addition, each research location is geographically located in estuary waters which are influenced by tides. Water quality parameter values can be seen in Table 1.

The water temperature measured in the waters of Bukit Batu Village is around 28-30^{o}C. The pH value at the study site ranged from 5-6 – 6.2. In estuarine waters in Bukit Batu Village with this pH, mangroves can live and develop properly. Salinity at the study site ranged from 7 – 10.66 ppt. All parameters measured, including temperature, pH, and salinity, are still at a good threshold for mangrove survival according to quality standards for marine biota[11].

Mangrove Species and Density

The results showed that there were 10 types of mangrove species found in the Bukit Batu mangrove ecosystem, including true and follow-up mangroves. The most common true mangrove species found in the study area were *Rhizophora apiculata* and *Sonneratia alba*, while the few mangrove species found were *Xylocarpus granatum, Bruguiera gymnorrhiza, Ceriops Tagal*. The density of mangroves on all transects ranged from 2200 – 5700 ind/ha (Table 2).

Based on the Decree of the Minister of Environment No. 201 of 2004 regarding the standard for damage to mangrove forests, if the mangrove density is > 1500 ind/ha then the mangrove forest is classified as dense cover. Therefore, the density of mangroves at the study site is classified as dense. The mangrove tree category at the study site in each plot has a different level of density, and the distribution of mangrove species at the study site is uneven.

Table 1. The average value of water quality parameters in the mangrove ecosystem of Bukit Batu Village

No	Sampling Point	Salinity (ppt)	pH	Temperature (^oC)
1	Transect 1	9.00	5.60	29.33
2	Transect 2	7.66	5.93	29.33
3	Transect 3	10.66	6.20	28.00
	Average	9.10	5.91	28.88

Table 2. The density of mangrove tree group vegetation (ind/ha) in the Bukit Batu mangrove ecosystem

Species	Transect 1			Transect 2			Transect 3		
	Plot			Plot			Plot		
	1	2	3	1	2	3	1	2	3
R. apiculata	2100	1800	1800	1800	1000	1800	2800	2500	2900
A.marina	400	0	0	0	0	0	0	0	0
S. caseolaris	0	0	0	1700	0	0	0	0	0
L. racemosa	0	0	0	400	0	0	0	0	0
X. granatum	0	0	200	500	0	400	600	2300	0
B.gymnorrhiza	0	500	0	0	0	0	2300	0	0
A.alba	0	400	100	0	0	0	0	0	0
R. mucronata	0	0	0	0	1700	1100	0	0	1700
M. citrifolia	0	0	100	0	0	0	0	0	0
C.tagal	0	0	0	0	0	500	0	0	0
Total	2500	2700	2200	3600	3300	4200	5700	4800	4600

The density of mangroves at the study site on all transects is classified as dense, which can be divided into 3 categories, namely mangroves with low density on transect 1, medium density on transect 2, and high density on transect 3. The same. Mangrove density is influenced by different characteristics in the three research areas, where most of the research areas are mangrove forest areas that are far from human settlements so forest utilization that occurs in these areas is minimal. Mangrove density is most commonly found in mangrove ecosystem areas that have mud substrate.

The species found in all sampling plots were *R. apiculata*. This species is also the species with the highest density. Efriyeldi et al.[12] found that the population growth of *R. apiculata* was more clustered and the competition between individuals was very high. The density of mangroves in the mangrove ecosystem of Bukit Batu Village is higher than that obtained by Dewi et al.[13] in Kayu Ara Permai Village, Sungai Apit District, Siak Regency, with an average of 2166 ind/ha and Efriyeldi et al.[14] in Bunsur Village, Sungai Apit District, namely 1281 ind/ha. This is thought to be due to the better preservation of the ecosystem in this location from disturbance by the community not to cut down indiscriminately. According to Akram & Hasnidar[15] the causes of mangrove damage in the Bira Village, Makassar City are due to the logging of mangrove trees for fuel, infrastructure development, and beach abrasion.

Organic Materials in Sediments

The percentage value of organic carbon is obtained from the results of ashing to obtain organic matter content and is converted into organic carbon. The value of sediment organic matter at each transect can be seen in Table 3.

In Table 3 it can be seen that the average value of sediment organic matter based on transects in the mangrove ecosystem in Bukit Batu Village, Bengkalis Regency is in the range of 16.70 – 22.18%, with an average of 20.04%.

Table 3. Average organic matter content in sediments

Plot	Transect 1	Transect 2	Transect 3
1	22.45	19.34	18.27
2	19.97	15.97	20.71
3	24.12	147.9	24.75
Average	22.18	16.70	21.24

Table 4. Average inter-transect sediment carbon stock (tons/ha) in the mangrove ecosystem of Bukit Batu Village

Plot	Transect 1	Transect 2	Transect 3
1	30.82	31.68	30.63
2	31.44	28.26	38.45
3	36.09	27.83	39.36
Average	32.78	29.26	36.15

The value of the organic matter in each transect and plot at each point is different. The lowest organic matter value in sediments was found in transect 2 with medium mangrove density with a value of 16.70%. The highest organic matter value is found in transect 1 with low mangrove density, which is 22.18%. For a comparison of the organic average, it can be seen in Figure 2.

Carbon stocks in sediments can be influenced by the content of organic matter, the type of substrate, and the location of the research station. Stations that are close to the coastline have the smallest value compared to other stations far from the coast[16]. The organic matter content of sediments is also influenced by other factors, as suggested by Widiatmaka[17], that soil organic matter, including sediment, is very sensitive to climate, topography, soil and plant management, as well as other anthropogenic conditions.

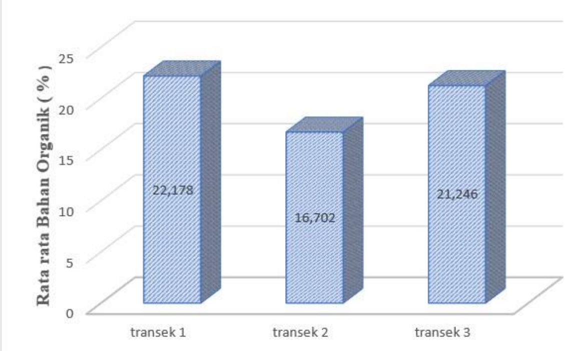

Figure 2. Sediment organic matter content on each transect

Carbon Stocks in Sediments

The results of the calculation of sediment carbon stock according to plots and transects in the mangrove ecosystem of Bukit Batu Village, Bengkalis Regency can be seen in Table 4.

In Table 4 above it can be seen that the lowest carbon stock value in sediments is in transect 2 with medium mangrove density which is 29.26 tons/ha. The highest carbon stock value was in transect 3 with high-density mangrove areas with a value of 36.15 tonnes/ha, with an average of 32.73 tonnes/ha at the study site. The distribution of the average value of carbon content at each location is different. This can be influenced by soil density conditions and mangrove canopy cover at each location. According to Hickmah et al.[18] organic carbon storage is determined by bulk density, organic matter content, and sample depth. To see more details the comparison of sediment carbon stock values at each transect can be seen in Figure 3.

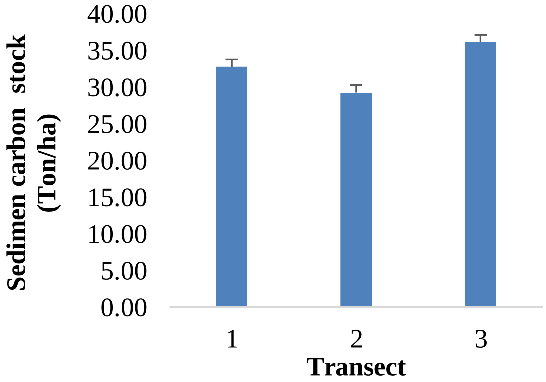

Figure 3. Sedimentary carbon stock values at each transect in the mangrove ecosystem of Bukit Batu Village

Carbon storage in the mangrove ecosystem of Bukit Batu Village is lower than that obtained by Hickmah et al.[18] in the Karimunjawa mangrove ecosystem, namely vertically near the river flow of 172.72 tons/ha, while far from the river flow is 76.17 tons/ha. Overall, the average yield of total carbon between plots in sediments has values that are not much different. The results obtained are quite small compared to the results of Mahasani et al.[19] in the mangrove forest of the Ngurah Rai Grand Forest Park, Bali, which ranged from 830.46 tonnes/ha to 2161.68 tonnes/ha and the results of Syukri et al.[20] ranged from 530.9 tonnes/ha to 1963.9 tonnes/ha Ha. The difference in the value of the total carbon content of mangrove sediments is due to the different conditions of mangrove cover at each location, the types of mangroves that grow at each location, and also the characteristic structure of the soil sediments at each location[21]. The low carbon content in mangrove sediments can be caused by various human activities, and changes in land use for ponds have the potential to disrupt mangrove ecosystems as carbon stores[22].

Marbun et al.[23] stated that mangrove forests can store large amounts of carbon, both in biomass and sediment. Furthermore, Mahasani et al.[19] stated that various factors affect carbon storage in the soil, including environmental factors such as land use and soil physicochemical factors such as temperature, pH, pores, texture, bulk density, and others. The above statement was added by Hickmah et al.[18] that organic carbon storage is also affected by sediment pH, particle size, and type.

Relationship between Mangrove Density and Carbon Stock in Sediments

The results of a simple linear regression analysis using the Microsoft Excel application show that the relationship between carbon stocks and mangrove density shows a low relationship with a value of R = 0.152. The results of the analysis of the relationship between density and the amount of carbon stock show that the coefficient of determination $R^2 = 0.023$, which means that 2.3% of the total carbon stock is affected by density, while 97.7% is influenced by other factors. The results can be seen in Figure 4.

The results obtained in this study are different from those stated by Syukri et al.[20] that the high value of mangrove canopy cover is directly proportional to the sediment biomass content. The higher the biomass content, the more carbon content in the sediment will also increase. The SNI[9] states that the amount of carbon stock is directly proportional to the density of mangroves. This means that the denser the mangroves, the greater the carbon stock. Lestariningsih et al.[16] stated that the estimation of carbon stocks in the substrate is thought to be more influenced by organic matter and research location.

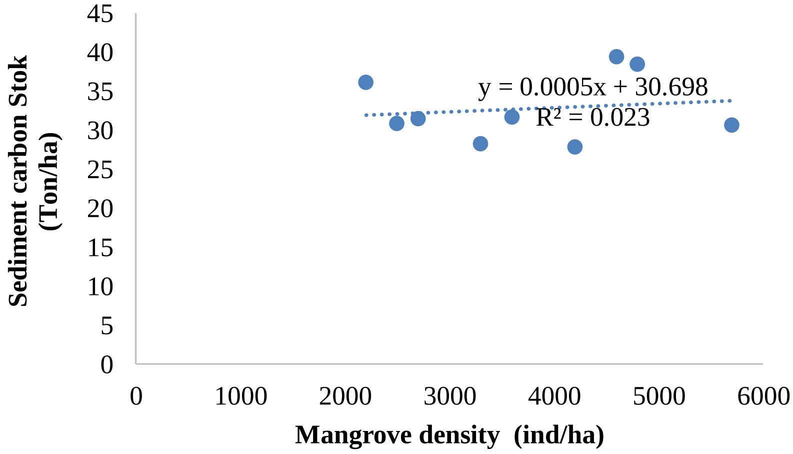

Figure 4. Relationship between mangrove density and carbon stock

4. CONCLUSION

The average yield of carbon stock estimation in all plots is 32.73 tonnes/ha. Comparison of carbon stocks between transects shows that the highest amount of carbon occurs in transects with high mangrove density followed by low transects and transects of medium mangrove density to transects with the lowest carbon stocks. The results of linear regression to determine the relationship between mangrove density and carbon stock in mangroves show a weak relationship with an R-value = 0.152.

Carbon storage in sediments in this study has a weak relationship with density, for this reason, the researchers suggest examining what other factors cause this low relationship

REFERENCES

1. Massugito M, Nedi S, Amin B. Analysis of carbon reserves in the mangrove forest ecosystem of Kuala Indragiri Riau Province. *Jurnal Online Mahasiswa Fakultas Perikanan dan Ilmu Kelautan Universitas Riau*, 2015; *2*(2): 1-9.
2. Sondak CFA. Estimation of potential absorption of blue carbon by North Sulawesi's mangrove forests. *Journal of Asean Studies on Maritime Issues*, 2015; 1(1): 24-29.
3. Fitria A, Dwiyanoto G. Mangrove ecosystem and mitigation global warming. *Jurnal Ekologi, Masyarakat & Sains. ECOTAS*, 2021; 2(1): 29-34.
4. Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M. Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, 2011; 4(5): 293-297.
5. Murray BC, Pendleton L, Jenkins WA, Sifleet S. *Green payments for blue carbon: economic incentives for protecting threatened coastal habitats*. Nicholas Institute Report, 2011.
6. Murdiyarso D, Purbopuspito J, Kauffman JB, Warren MW, Sasmito SD, Donato DC, Manuri S, Krisnawati H, Taberima S, Kurnianto S. The potential of Indonesian mangrove forests for global climate change mitigation. *Nat Geosci.*, 2015; 5:1089-1092.
7. Noor YR, Khazali M, Suryadiputra INN. *Panduan pengenalan mangrove di Indonesia*. PHKA/WI-IP, Bogor, 2006. (*In Indonesia*)
8. Bengen DG. *Pedoman teknis pengenalan dan pengelolaan ekosistem mangrove*. Pusat Kajian Sumberdaya Pesisir dan Lautan IPB. Bogor, Indonesia, 2002. (*In Indonesia*)

9. [SNI] Standar Nasional Indonesia. *Pengukuran dan perhitungan cadangan karbon-pengukuran lapangan untuk penaksiran cadangan karbon hutan*. Jakarta. Badan Standarisasi Nasional, 2011. (*In Indonesia*)
10. Howard J, Hyot S, Isensee K, Pidgeon E, Telszewski M. *Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses*. Conservation International, Intergovernmental Oceanographic Commission of UNESCO, International Union for Conservation of Nature. Arlington, Virginia, USA, 2014.
11. Keputusan Menteri Negara Lingkungan Hidup Nomor 51 Tahun 2004. Tentang baku mutu air laut. Kementerian Negara Lingkungan Hidup, Jakarta, 2004 (*In Indoenesia*)
12. Efriyeldi, Ahmadryadi, Amin B. Morphometric conditions of *Rhizophora apiculata* in area with different anthropogenic activities in the east coast of Indragiri Hilir, Sumatra. *Asian Journal of Environment, History, and Heritage*, 2018; 2(1): 113-121.
13. Dewi D, Efriyeldi E, Amin B. Estimation of carbon reserved in mangrove forest of Sungai Apit District, Siak Regency, Riau Province. *Asian Journal of Aquatic Sciences,* 2021; 4(3): 197-207.
14. Efriyeldi E, Mulyadi A, Samiaji J. Condition of mangrove ecosystems in Sungai Apit Siak District based on standard damage criteria and quality indicators mangrove environment. IOP Conf. Series: Earth and Environmental Science, 2020; 430. doi:10.1088/1755-1315/430/1/012013
15. Akram AM, Hasnidar. Identification of mangrove ecosystem damage in Bira Village Makassar City. *Journal of Indonesian Tropical Fisheries*, 2022; 5(1): 1 – 11.
16. Lestariningsih WA, Soenardjo N, Pribadi R. Estimation of carbon stocks in mangrove areas in Timbulsloko Village, Demak, Central Java. *Buletin Oseanografi Marina*, 2018; 7(2): 121-130
17. Widiatmaka. The urgency of maintaining carbon in the soil in the framework of climate change mitigation and adaptation. *Prosiding International Seminar of Adaptation and Mitigation on Climate Change. Padang 11 Maret*, 2013
18. Hickmah N, Maslukah L, Wulandari SY, Sugianto DN, Wirasatriya A. Study of organic carbon stock in sediments in the Karimunjawa Mangrove Vegetation Area. *Indonesian Journal of Oceanography (IJOCE),* 2021; 3(4): 88 - 95
19. Mahasani IGAI, Widagti N, Karang WGA. Estimation of the percentage of organic carbon in ex-pond mangrove forests, Perancak, Jembrana Bali. *Journal of Marine and Aquatic Science*, 2015; 1: 14-18.
20. Syukri M, Mashoreng S, Werorilangi S, Isyrini R, Rastina R, Faizal A, Gosalam S. Kajian Stok Karbon Mangrove di Bebanga Kabupaten Mamuju Sulawesi Barat. *Prosiding Simposium Nasional V Kelautan dan Perikanan V Unhas 5 Mei 2018. (In Indonesia).*
21. Suryono S, Soenardjo N, Wibowo E, Ario R, Rozy EF. Estimation of biomass and carbon content in Perancak Mangrove Forest, Jembrana Regency, Bali Province. *Buletin Oseanografi Marina*, 2018; 7(1):1-8.
22. Sulistyorini IS, Edwin M, Imanuddin I. Estimation of organic soil carbon stock in mangroves in Teluk Kaba and Muara Teluk Pandan Kutai National Park. *Agrifor: Jurnal Ilmu Pertanian dan Kehutanan*, 2020; 19(2): 293-302.
23. Marbun A, Antonius PR, Joshian NW, Schaduw, Paruntu CP, Angmalisang PA, Manoppo VEN. Analysis of carbon stock in mangrove sediments in Baturapa Village, Lolak District, Bolaang Mongondow Regency. *Jurnal Pesisir dan Laut Tropis,* 2020; 8 (1): 20-30