ECOLOGICAL FUNCTIONS OF MANGROVE BASED ON CARBONDIOXIDE ABILITIES AND CARBON STORAGE AT CENGKRONG BEACH, TRENGGALEK REGENCY

Abdulkadir Rahardjanto[1]*, Ulpa Riski Kumala Sari[2], Lud Waluyo[3], Husamah[4]
[1,2,3,4]Faculty of Teacher Training and Education, Universtas Muhammadiyah Malang, Jl. Raya Tlogomas 246 Malang 65144. East Java, Indonesia
*Corresponding author, e-mail: abdkadir@umm.ac.id

ABSTRACT

The decline in the ecological function of mangroves is due to the reduced area of mangroves in Cengkrong Beach, Trenggalek Regency due to deforestation, to improve environmental quality, the researcher wants to examine the ecological function of mangroves in carbon absorption and carbon storage. The purpose of this study was to analyze the ecological function of mangroves based on the ability to absorb carbon dioxide and to analyze the carbon storage capacity of mangrove forest stands at Cengkrong Beach, Trenggalek Regency. This type of research is descriptive quantitative. The population in this study were all types of mangrove trees and litter in the research plot. Research on tree diameter, tree species and number, wet weight of litter was carried out randomly using simple random sampling. The data analysis technique was correlation test using SPSS 21. The results found 8 types of mangroves, namely *Avicennia marina, Bruguiera gymnorrizha, Ceriops decandra, Ceriops tagal, Rhizophora apiculata, Rhizophora mucronata, Sonneratia alba*, and *Sonneratia caseolaris.* Carbon sequestration in Cengkrong, Trenggalek Regency has a total average of 33.963.42 tons/ha per year, equivalent to standing biomass of 20.136.6 tons/ha. The carbon storage capacity of trees is 9.262.9 tons C/ha, while the carbon storage capacity of litter is 225.48 tons C/ha.

Keywords: Carbondioxide Abilities, Carbon Storage, Ecological Functions, Mangrove

INTRODUCTION

Global warming is one of the environmental issues that must receive special attention. The result is an increase in the average temperature of the earth due to the effect of greenhouse gases, so that it can cause global climate change (Abouelfadl, 2012; Bharath & Turner, 2009; Cavicchioli et al., 2019; Cianconi et al., 2020; Ebi & Hess, 2020). This has become a problem for the community, including in Indonesia. Global warming occurs due to the accumulation of greenhouse gases such as carbon dioxide (CO_2) 50%, chloroflourocarbon (CFC) 25%, methane gas (CH_4) 10%, and the rest are other gases (Rahmah et al., 2015). The biggest contributor to global warming is carbon dioxide gas. The concentration of carbondioxide gas in the pre-industrial period was around 278 ppm, while in 2005 it was 379 ppm and continues to increase annually. CO_2 concentration from 2004 to 2010 increased from 373 ppm to 383 ppm (Ali et al., 2022; Balat & Öz, 2007; Olivier et al., 2017; Simmons et al., 2013). Reducing greenhouse gases can be done by increasing CO_2 absorption through forest vegetation, one of which is mangroves (Dinilhuda et al., 2020; Iksan et al., 2019; Sumarmi et al., 2021).

Indonesia is a country with the largest mangrove forest area in the world. This type of forest grows on coastal ecosystems and is affected by tidal conditions (Mughofar et al., 2018). Mangroves are crucial to maintaining the ecological functions in coastal areas,

especially in C storage which can reduce global warming mitigation (Rachmawati et al., 2014).. Soils in mangroves contain large amounts of organic matter and have the highest carbon storage in the tropics (Kusumaningtyas et al., 2019; Palacios Peñaranda et al., 2019; Wiarta et al., 2019).

The mangrove ecosystem is able to absorb CO_2 through the process of photosynthesis and convert it into carbohydrates, which will then be distributed throughout the plant body (T. Heriyanto et al., 2020; Hikmatyar et al., 2015). The results of the photosynthesis process reduced by respiration will accumulate in the form of carbon biomass (Hairiah et al., 2011). By measuring carbon in the body of dead plants (necromass), it will indirectly determine the amount of CO_2 that is not released into the air through combustion (Hairiah et al., 2011). The carbon stock stored in mangrove ecosystems is more than twice that of terrestrial and tropical forests. Litter decomposition in aquatic plants is not so large in releasing carbon into the air, so that the release of emissions in mangrove forests is smaller than in land forests which is almost 50%(Hairiah et al., 2011). Indonesia's mangrove ecosystem is able to absorb carbon in the air as much as 67.7 Mt per year. The amount of carbon content is influenced by the ability of plants to absorb CO_2 from the environment through the sequestration process (Rachmawati et al., 2014).

Mangrove forest in Cengkrong, Trenggalek Regency is a mangrove vegetation found around the Cengkrong beach which has an area of 87 hectares (Mughofar et al., 2018; Susilo et al., 2015). In 2003-2005 the mangrove forest in Cengkrong was severely damaged, about 50% of its area. One of the causes of the damage is land conversion and massive deforestation. Around the year 2005-2008, mangroves experienced natural improvement and reached an area of almost 80%(Susilo et al., 2015). Based on an interview by the head of the Community Monitoring Group, large-scale logging occurred because the community did not understand the importance of mangrove forests for the life of other biota and the economic crisis occurred. As a form of improving environmental quality, research on the ecological function of mangroves in storing carbon in mangrove stands is considered important because it can help determine the amount of CO_2 absorbed by mangrove plants, given the lack of data and references regarding carbon stocks in mangrove ecosystems, especially in Trenggalek Regency. In addition, the community will better understand the ecological benefits of mangroves as carbon sinks so that mangrove conservation efforts in order to reduce the potential impact of global warming can be paid more attention.

Based on this, the objectives of the research are as follows: (1) Analyzing the ecological function of mangrove forests based on the ability to absorb CO2 in Cengkrong, Trenggalek Regency; and (2) to analyze the carbon storage capacity of mangrove forest stands in Cengkrong, Trenggalek Regency. Research on carbon sequestration in mangrove forests, will obtain data on carbon stocks in the mangrove forest of Cengkrong, Trenggalek Regency and is expected to provide information about the potential of carbon stored in mangrove forest vegetation. The results of this study can be used as a reference or reference in making policies regarding the management, planning and protection of mangrove forests in order to achieve sustainable forest management as well as greenhouse gas emissions. It is also hoped that this research can provide an overview, reference material or reference for further researchers regarding the carbon stock in the mangrove forest of Cengkrong beach, Watulimo District, Trenggalek Regency.

METHOD
Place and Time of Research

The research was carried out March-April 2018 at Cengkrong beach, Trenggalek Regency. The study was conducted in the Cengkrong mangrove forest, Karanggandu Village, Watulimo District, Trenggalek Regency (Figure 1). The coordinates of each station, namely Station I: S8°17'52.0" E111°42'23.0", Station II: S8°17'49.3" E111°42'24.1", Station III: S8°17'47.9" E111°42'22.9", and Station IV: S8°17'50.8" E111°42'19.0". Sample analysis was conducted at the Forestry Laboratory of the Universitas Muhammadiyah Malang.
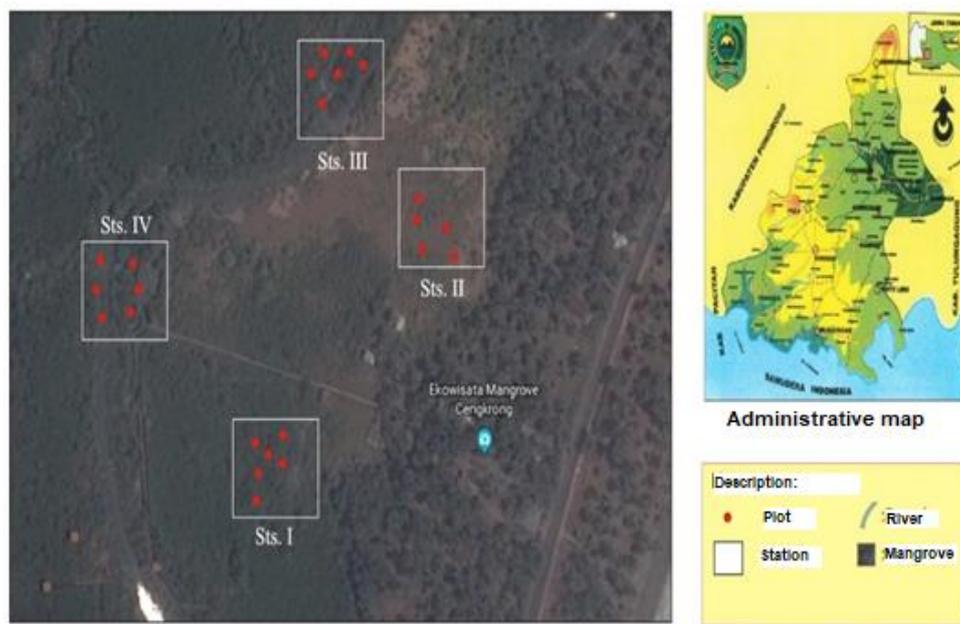

Figure 1. Map of Research Location

Population and Sample

The population is all mangrove trees and non-woody litter in the Cengkrong Mangrove Forest, Karanggandu Village, Watulimo District, Trenggalek Regency. The samples of this research were mangrove trees and non-woody litter in the Cengkrong Mangrove forest research plot, Karangandu Village, Watulimo District, Trenggalek Regency.

Total sampling is the species of mangroves in the Cengkrong Mangrove forest research plot, Karanggandu Village, Watulimo District, Trenggalek Regency. Calculation of sample size or number of samples, using the formula (t-1) (r-1) 15. t is the number of treatment groups and r is the number of each treatment group. The study used 6 plots with 4 stations.

At the initial observation, the beach substrate was muddy, so that the population members were homogeneous. So the samples of trees and litter were taken randomly using simple random sampling. Sampling was carried out at the time of maximum low tide.

Research Variable

The research variables were mangrove tree biomass and litter in the Cengkrong Mangrove forest research plot, Karanggandu Village, Watulimo District, Trenggalek Regency. To avoid misperceptions in the study, there are operational definitions of variables as follows: (1) CO_2 absorption in the Cengkrong Mangrove

Forest, Karanggandu Village, Watulimo District, Trenggalek Regency is the amount of mangrove plant biomass that can describe carbon uptake in vegetation, and (2) The storage capacity of carbon in the Cengkrong Mangrove Forest, Karanggandu Village, Watulimo District, Trenggalek Regency can describe the CO2 that is not released into the air through combustion.

Tools and Materials

The tools needed in this research are as follows: Cos Phi Meter , GPS, scissors, roller meter, ruler, analytical scale, soil tester, soil thermometer (Weksker), label paper, stationery, wooden stake, oven, jumbo raffia rope, crackle bag, Steples, Lenovo A700 Hp Camera, and Litter trap. Materials or objects in the study are all types of mangrove trees with a minimum diameter of 2 cm and litter under mangrove stands.

Activity Steps

The steps in research using non-destructive methods are as follows: (1) In this study, 4 stations were made with an area of 2.5 hectares. At each station 6 observation plots were taken randomly, so that 24 observation plots were obtained. (2) In observing tree-level stands, plots with a size of 10 x 10 m are made, poles with a plot size of 5 x 5 m, and a sub-plot for taking litter with a size of 0.5 x 0.5 m is made, as shown in Figure 2. (3) In a plot with a size of 10 x 10 m, tree data collection at the polishing level (10 cm dbh 20 cm), on a 5 x 5 m plot, tree data collection at the sapling level (2 cm dbh 10 cm) measured at a height of 1.3 m above ground level for normal trees. (4) In the 0.5 x 0.5 m sub-plot, litter biomass data was collected in each observation plot. (5) Weigh the wet and then record the results. (6) Put 100 g of sub-sample in an oven at 800 C for 48 hours. (7) Weigh the dry weight of the sample, then record the results.
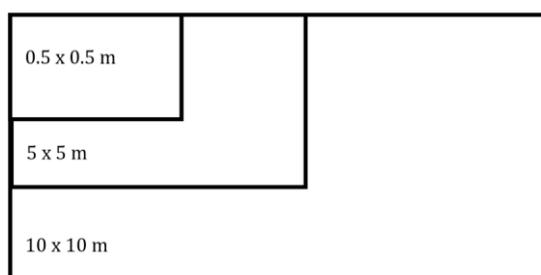

Figure 2. Multilevel observation plot (Hairiah et al., 2011)

Method of collecting data

The method of data collection is by observing the Cengkrong Mangrove Forest, Trenggalek Regency by observing the tree diameter (dbh), tree species, and the number of trees contained in the observation form.

Data analysis

Analysis of data in research, quantitative data is presented in the presentation of data in the form of numbers, averages and percentages. Tree and litter biomass data, carbon stock and carbon sequestration are presented in the form of graphs and tables and analyzed using Microsoft Excel 2013. Meanwhile, data on species density, relative density, frequency, relative frequency and important value index will be presented in tabular form. The relationship between biomass, carbon storage, and carbon dioxide uptake will be tested using a correlation test and analyzed using SPSS

21. Qualitative data is the result of data analysis which will be described using descriptive-inductive in the discussion regarding the ecological function of mangroves seen from forest carbon uptake data. Mangroves and carbon storage.

Measurement of Carbon Stock in Stands and Litter
a) Biomass Analysis

Determination of biomass using allometric equations for each species of mangrove is presented in Table 1 and Table 2.

Table 1. Allometric Equations on Mangrove Types

Species	Equality	Reference(s)
Avicennia marina	$B = 0,1848D^{2.3624}$	(Dharmawan & Siregar, 2008)
B. gymnorhiza	$B = 0,0754D^{2.505\rho}$	(Kauffman & Donato, 2012)
Ceriops tagal	$B = 0,188495D^{2.3379}$	(Clough & Scott, 1989)
R. apiculata	$B = 0,048D^{2.614}$	(Balitbang Kehutanan, 2013)
R. mucronata	$B = 0,128D^{2.6}$	(Fromard et al., 1998)
Sonneratia alba	$B = 0,3841\rho D^{2.101}$	(Kauffman & Donato, 2012)
S. caseolaris	$B = 0,251\rho D^{2.46}$	(Komiyama et al., 2005)

where B: Biomass (kg), D: Diameter (cm), and ρ: Density of Wood (g/cm2).

Table 2. Wood Specific Gravity (refer to Komiyama et al., 2005)

Species	Wood Specific Gravity (ρ)
Sonneratia alba	0.078
Sonneratia caseolaris	0.340

b) Carbon Stock Analysis

The concentration of carbon contained in organic matter is 46%, so it is estimated that the amount of carbon stored is by multiplying 0.46 by the biomass as in Formula 6 (Metz et al., 2005):

Cb = B x 0.46 (6)

where Cb: Carbon stock (kg) and Biomass: Biomass (kg).

c) Carbondioxide Absorption Analysis (CO₂)

Conversion of carbon stock to total CO_2 uptake can use the ratio of the relative atomic mass of C (12) to the delative molecule of CO_2 (44), which is formulated in Equation 7 (Metz et al., 2005):

$$WCO2 \frac{Mr.CO2}{Ar.C} x\ Cn$$ (7)

where WCO2: CO2 Absorption (kg), Mr: Molecular Relative, and Cn: Carbon Stock (kg).

d) Litter Biomass Content

The measurement of the litter biomass was carried out by weighing the sample at a constant dry weight. The total dry weight is determined using the Formula 8 (Hairiah et al., 2011).

$$Total\ BK = \frac{BK\ sub\ sample\ (gr)}{BB\ sub\ sample\ (gr)} x\ total\ of BB\ sample\ (gr)$$ (8)

where BK: Dry Weight and BB: Wet Weight.

RESULTS AND DISCUSSION

Data on the number and species of mangroves found at each station in Cengkrong, Trenggalek Regency are presented in Table 3.

Table 3. Data on the Number of Mangrove Species Found on Cengrong Beach

Mangrove Stand Type	Station			
	I	II	III	IV
Avicennia marina (Forssk.) Vierth.	0	0	76	80
Bruguiera gymnorrizha (L.)Lamk.	9	67	0	0
Ceriops decandra (Griff.)	0	0	9	2
Ceriops tagal (Perr.)	16	27	85	108
Rhizophora apiculata (BI.)	78	33	19	74
Rhizophora mucronata Lmk.	64	37	24	25
Sonneratia alba J.E Smith	28	28	68	59
Sonneratia caseolaris (L) Engl	3	11	0	0
Total	198	203	281	384

Based on the results of research conducted on the measurement of stem diameter on mangrove species per station at Cengkrong Beach, Trenggalek Regency, the results obtained are as listed in Table 4, Table 5, Table 6, and Table 7.

Table 4. Measuring Data on Average Tree Diameter at Station 1

No	Species	Diameter (cm)			
		P1	P2	P3	R
1	*Bruguiera gymnorizha* (L.) Lamk.	24.52	24.53	24.53	24.52
2	*Ceriops tagal* (Perr.)	51.91	51.92	51.92	51.91
3	*Rhizophora apiculata* (Bl.)	163.32	163.40	163.43	163.38
4	*Rhizophora mucronata* Lmk.	174.51	174.55	174.58	174.55
5	*Sonneratia alba* J.E Smith	78.10	78.12	78.14	78.12
6	*Sonneratia casolaris* (L) Engl	4.14	4.14	4.14	4.14

Table 5. Measuring Data on Average Tree Diameter at Station 2

No	Species	Diameter (cm)			
		P1	P2	P3	R
1	*Bruguiera gymnorizha* (L.) Lamk.	187.16	187.18	187.21	187.18
2	*Ceriops tagal* (Perr.)	78.63	78.73	78.74	78.70
3	*Rhizophora apiculata* (Bl.)	72.94	72.98	72.97	72.96
4	*Rhizophora mucronata* Lmk.	75.82	75.93	75.92	75.89
5	*Sonneratia alba* J.E Smith	52.83	52.84	52.84	52.84
6	*Sonneratia casolaris* (L) Engl	20.41	20.42	20.42	20.42

Table 6. Measuring Data on Average Tree Diameter at Station 3

No	Species	Diameter (cm)			
		P1	P2	P3	R
1	*Avicennia marina* (Forssk.) Vierh.	326.17	326.54	326.57	326.43
2	*Ceriops decandra* (Griff.)	26.11	26.11	26.12	26.11
3	*Ceriops tagal* (Perr.)	296.63	296.85	297.23	296.90
4	*Rhizophora apiculata* (Bl.)	59.00	59.02	59.02	59.01
5	*Rhizophora mucronata* Lmk.	88.33	88.37	88.37	88.36
6	*Sonneratia alba* J.E Smith	391.19	391.49	391.50	391.39

Table 7. Measuring Data on Average Tree Diameter at Station 4

No	Species	Diameter (cm)			
		P1	P2	P3	R
1	*Avicennia marina* (Forssk.) Vierh.	396.31	396.42	396.46	396.39
2	*Ceriops decandra* (Griff.)	3.82	4.04	4.04	3.97
3	*Ceriops tagal* (Perr.)	405.61	405.65	405.74	405.66
4	*Rhizophora apiculata* (Bl.)	283.02	281.79	281.84	282.22
5	*Rhizophora mucronata* Lmk.	78.97	78.98	78.98	78.98
6	*Sonneratia alba* J.E Smith	316.36	316.49	316.49	316.45

Data presentation of the results of research conducted on stem diameter measurements will obtain data on biomass, carbon stock and carbon dioxide absorption at mangrove species per station at Cengkrong Beach, Trenggalek Regency, the results are as listed in Table 8.

Table 8. Mangrove Carbondioxide Uptake Data in Cengkrong Beach, Trenggalek Regency

Carbondioxide Uptake Data					
Description	Station 1	Station 2	Station 3	Station 4	Total Average
Biomassa (ton/ha)	1,449.27	7,153.87	29,460.45	42,48.61	20,136.6
Carbon Stock (ton/ha)	666.67	3,290.78	13,551.81	19,542.100	9,262.9
CO_2 Absorption (ton/ha)	2,444.43	12,066.2	49,689.96	71,653.100	33,963.42
Litter Carbon Stock (ton/ha)	109.30	150.70	344.61	417.31	255.48

The next data is presented in the form of litter biomass measurements from wet weight and dry weight calculated based on time (days, months, and years), as listed in Table 9.

Table 9. Forest Floor Litter Biomass at Each Station

Station	Average Day		Average Total BK		
	BB	BK	Day	Month	Year
1	10.17	6.51	0.66	19.8	237.7
2	12.29	7.38	0.91	27.3	327.6
3	20.09	10.36	2.081	62.43	749.16
4	31.4	8.01	2.52	75.6	907.2

The results of the analysis of the types of mangroves found at each station differ in terms of the number of each species and the total number of individuals per station. From the four stations found 8 types of mangroves, namely *Avicennia marina* (Forssk.) Vierth., *Bruguiera gymnorrizha* (L.) Lamk., *Ceriops tagal* (Perr.), *Ceriops decandra* (Griff.), *Sonneratia alba* J.E Smith, *Sonneratia caseolarosis* (L) Engl, *Rhizophsora mucronata* Lmk., and *Rhizophora apiculata* (BI.). Station IV ranks first, there are 384 individuals from 6 types of mangroves, namely *Avicennia marina* (Forssk.) Vierth., *Sonneratia alba* J.E Smith, *Rhizophsora mucronata* Lmk., *Rhizophora apiculata* (BI.), *Ceriops tagal* (Perr.), and *Ceriops decandra* (Griff.). While station I has a low density, which is found 198 individuals from 6 different types of mangroves, namely *Bruguiera gymnorrizha* (L.) Lamk., *Ceriops tagal* (Perr.), *Sonneratia alba* J.E

Smith, *Sonneratia caseolarosis* (L) Engl*, Rhizophora mucronata* Lmk., and *Rhizophora apiculata* (BI.)

Based on the data obtained from the research on tree biomass in Cengkrong beach, Trenggalek Regency, it will be presented in a bar chart in Figure 3 for tree biomass per week, Figure 4 for tree biomass per month, and Figure 5 for biomass per year.
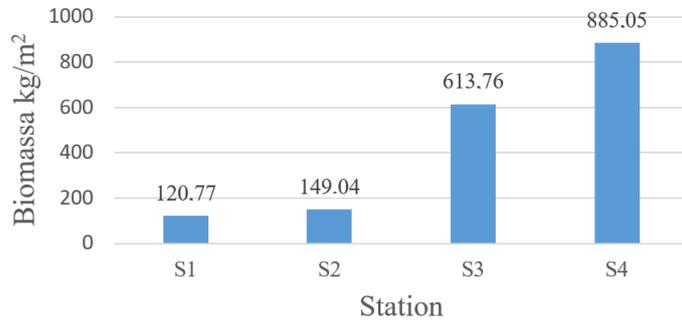

Figure 3. Diagram of Total Average Biomass of Mangrove Stands at Each Station
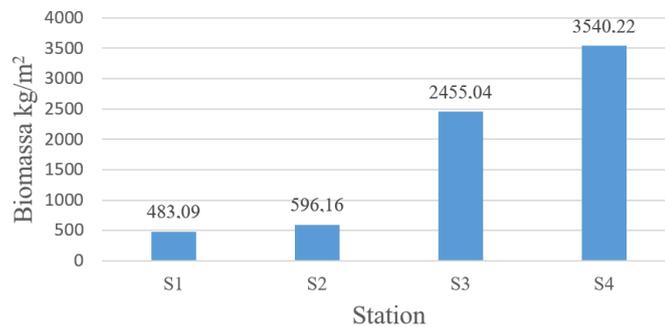

Figure 4. Diagram of Total Average Biomass of Mangrove Stands at Each Station

The results of the research conducted in Cengkrong, Trenggalek Regency using 4 different stations, the average biomass values obtained are different, it can be seen from Figure 3, Figure 4, and Figure 5. Tree biomass at each station was measured. to describe the level of productivity of mangrove forests in the study area. The average total biomass was obtained from tree diameter measurements with a distance of 2 weeks for 6 weeks, so that 3 replications were obtained.
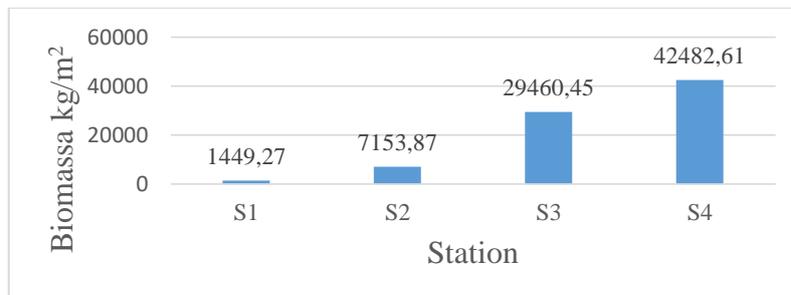

Figure 5. Diagram of Total Average Biomass of Mangrove Stands at Each Station

The diagram states that the highest average total biomass per week is at station IV of 885.05 kg/m². and the lowest average weekly biomass at station I was 120.77 kg/m2. The total mean is obtained from the average total biomass in all plots

in one station which is measured for 2 weeks divided by 2 so that the total average biomass per week is obtained. The highest average biomass per month will also follow the average total biomass per week, namely at station IV, where the total biomass per month is 3540.22 kg/m^2. Likewise, the highest average total biomass per year was at station IV 42,842.61 kg/ha.

The data from research on biomass, carbon storage and carbon dioxide uptake in stands will be presented based on Table 10. The diagram shows that biomass, carbon storage, and carbon dioxide uptake are interrelated.

Table 10. Biomass Correlation Test, Carbon Stock and Carbondioxide Uptake

		Biomassa	**Carbon_Stock**	**Absorption_CO$_2$**
Biomassa	Pearson Correlation	1	1.000**	1.000**
	Sig. (2-tailed)		.000	.000
	N	4	4	4
Carbon _Stock	Pearson Correlation	1.000**	1	1.000**
	Sig. (2-tailed)	.000		.000
	N	4	4	4
Absorption_CO$_2$	Pearson Correlation	1.000**	1.000**	1
	Sig. (2-tailed)	.000	.000	
	N	4	4	4

**. Correlation is significant at the 0.01 level (2-tailed).

Analysis of the presentation of data on research results proves that the carbon storage capacity of trees is related to the average total biomass and carbon dioxide uptake. This can be seen in Table 10, presenting data from the correlation test. The results of the correlation test show that the probability value for both biomass and carbon stock, biomass with carbon uptake, and carbon stock or carbon storage with CO_2 uptake is 0.00. Where 0.00> 0.005 so the interpretation is that there is a relationship between biomass and carbon stock, biomass with CO_2 uptake and carbon stock with CO_2 absorption. The highest carbon storage capacity of trees per year is at station IV of 19,542.61 tons/ha, and the lowest is at station I of 666.67 tons/ha. This is comparable to carbon dioxide absorption where the highest yield of carbon dioxide absorption is at station IV 71,653.100 tons/ha, and the lowest at station I is 2444.43 tons/ha.
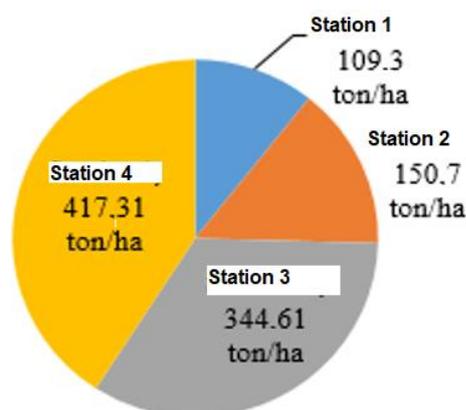

Figure 6. Carbon Saving Power Diagram (Carbon Stock) Litter

The analysis of the results showed that the carbon storage capacity of litter in the mangrove forest in Cengkrong, Trenggalek Regency at each station can be seen based on the diagram above. The highest carbon storage capacity at station IV was 417.31 tons/ha, and the lowest at station I was 109.3 tons/ha. Each station has a different average total carbon storage capacity in litter, this is obtained from the conversion of the average total dry weight of litter. So that the total dry weight of litter obtained at each station can be analyzed based on Figure 7.
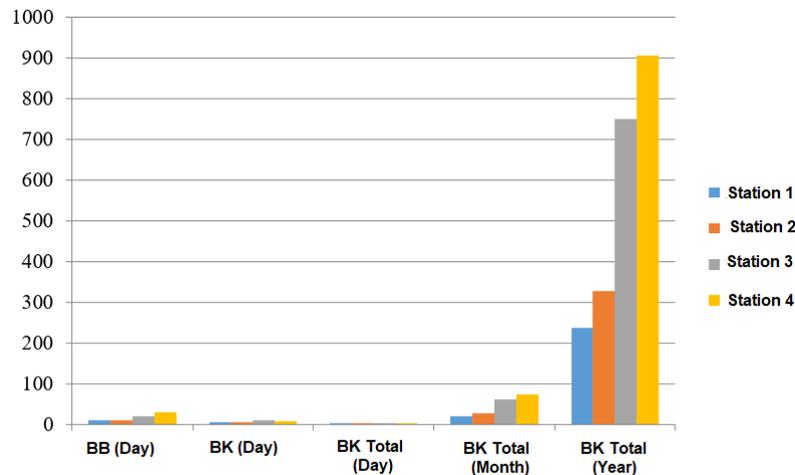

Figure 7. Forest Floor Litter Biomass Diagram at Each Station

The total average dry weight was obtained for 6 weeks, so to find out the average dry weight per day divided by 42 days. This will result in the highest total dry weight per day at station IV of 2.52 kg/m2. and the lowest at station I is 0.66 kg/m2. As for the assumption of the average monthly and yearly litter biomass, the largest amount found at station IV is 75.6 kg/m2 per month and 907.2 kg/ton per year. Analysis of litter biomass measurement data from wet weight and dry weight calculated based on time (days, months, and years).

Table 11. Species Density, Relative Density, Species Frequency, Relative Frequency and Important Value Index of Mangrove Vegetation at Station I

No	Mangrove species	Station 1				
		Di	Rdi (%)	F	Rfi (%)	IV
1	*Bruguiera gymnorrizha*	0.015	4.55	0.083	8.70	13.24
2	*Ceriops tagal*	0.027	8.08	0.125	13.05	21.13
3	*Rhizophora apiculata*	0.13	39.4	0.208	21.74	61.13
4	*Rhizophora mucronata*	0.107	32.32	0.25	26.087	58.4
5	*Sonneratia alba*	0.047	14.14	0.208	21.74	35.88
6	*Sonneratia caseolaris*	0.005	1.52	0.083	8.70	10.21
	Total	**0.33**	**100**	**0.958**	**100**	**200**

Analysis of the relative density of mangroves in the Pantai Cengkrong area, Watulimo District, Trenggalek Regency, it can be seen that the highest relative density level of the 4 stations is *R. apiculata* (BI.) 39.4% at station I, station II is dominated by *B. gymnorrizha* (L.) Lamk, which is 33.05%, station III *C. tagal* (Perr.) 30.25% and

station IV is dominated by *C. tagal* (Perr.), 31.04%. As for the relative density of species from the four stations the highest was *R. apiculata* found at station I, and for the lowest relative density was *C. decandra* (Griff.), which was 0.58% at station IV.

Table 12. Species Density, Relative Density, Species Frequency, Relative Frequency and Important Value Index of Mangrove Vegetation at Station II

No	Mangrove species	Station 2				
		Di	Rdi (%)	F	Rfi (%)	IV
1	*Bruguiera gymnorrizha*	0.112	33.005	0.25	27.27	60,28
2	*Ceriops tagal*	0.045	13.30	0.125	13.64	26.94
3	*Rhizophora apiculata*	0.055	16.26	0.125	13.64	29.90
4	*Rhizophora mucronata*	0.062	18.23	0,17	18.18	36.41
5	*Sonneratia alba*	0.047	13.79	0,17	18.18	31.98
6	*Sonneratia caseolaris*	0.018	5.42	0.083	9.10	14.51
	Total	**0.338**	**100**	**0.917**	**100**	**200**

Table 13. Species Density, Relative Density, Species Frequency, Relative Frequency and Important Value Index of Mangrove Vegetation at Station III

No	Mangrove Species	Station 3				
		Di	Rdi(%)	F	Rfi (%)	IV
1	*Avicennia marina*	0.127	27.05	0.25	18.75	45.80
2	*Ceriops decandra*	0.015	3.203	0.125	9.38	12.58
3	*Ceriops tagal*	0.142	30,25	0.25	18.75	48.100
4	*Rhizophora apiculata*	0.032	6.76	0.21	15.63	22.39
5	*Rhizophora mucronata*	0.04	8.54	0.25	18.75	27.30
6	*Sonneratia alba*	0.113	24.2	0.25	18.75	42.95
	Total	**0.47**	**100**	**1.33**	**100**	**200**

Table 14. Species Density, Relative Density, Species Frequency, Relative Frequency and Important Value Index of Mangrove Vegetation at Station IV

No	Mangrove Species	Station 4				
		Di	Rdi(%)	F	Rfi (%)	IV
1	*Avicennia marina*	0.133	22.99	0.25	18.75	41.74
2	*Ceriops decandra*	0.003	0,58	0.125	9.38	9.95
3	*Ceriops tagal*	0.18	31.04	0.25	18.75	49.78
4	*Rhizophora apiculata*	0.123	21.26	0.208	15.63	36.89
5	*Rhizophora mucronata*	0.042	7.184	0.25	18.75	25.93
6	*Sonneratia alba*	0.098	16.95	0.25	18.75	35.70
	Total	**0.58**	**100**	**1.33**	**100**	**200**

The results of the analysis of the relative frequency of mangroves found in Cengkrong, Trenggalek Regency at four different stations, the highest at station I was *Rhizophora mucronata* Lmk. 26.09%, Station II *Bruguiera gymnorrizha* (L.) Lamk. 27.27%. Stations III and IV on average have almost the same relative frequency wherein the highest relative frequency is *Avicennia marina* (Forssk.) Vierth, C. tagal (Perr.), *Rhizophora mucronata* Lmk. and, *Sonneratia alba* J.E Smith with a score of

18.75%. This is in accordance with station IV. Meanwhile, the lowest relative frequencies were *B. gymnorrizha* (L.) Lamk and *S. casolaris* (L) Engl, which was 8.70 % at station 1.

The results of the analysis of the significance index at the four highest stations for station I *Rhizophora apiculata* (BI.) 61.13%, station II *Bruguiera gymnorrizha* (L.) Lamk. 60.28%, station III *Ceriops tagal* (Perr.) 48.100%, station IV *Ceriops tagal* (Perr.) 49.78%. At the four stations the highest index is *Rhizophora apiculata* (BI.) 61.13%, which is at station I. Meanwhile, the lowest important value index from the four stations is *Ceriops decandra* (Griff) 9.95% which occupies station IV. This can be seen from the graph above.

The next process is the dark reaction which begins with CO_2 which is fixed into 3 phosphoglycerate (PGA) molecules with the help of the rubisco enzyme. 3 phosphoglycerate (PGA) molecules will be reduced to 1,3-bisphosphoglycerate (PGAP) molecules using ATP. The next process is the conversion of 1.3-bisphosphoglycerate (PGAP) into phosphoglyceraldehyde (PGAL) using NADPH, then PGAL will be reduced to glucose ($C_6H_{12}O_6$) as the end result of the reduction process. The formation of glucose (6 carbon sugar) will require 2 cycles, so the next process is the regeneration of phosphoglyceraldehyde (PGAL) into Ribulose biphosphate (RuBP) (Evans, 2013; Janssen et al., 2014). Thus the measurement of the amount of carbon stored in the plant body (biomass) will describe the amount of CO_2 absorbed by plants. While the measurement of C stored in the dead soil (necromass) will describe the amount of CO_2 that is not released into the air through combustion (Faradilla et al., 2020; Lanya et al., 2016).

Biomass is the amount of organic matter produced by an organism per unit area in an ecosystem. Measurement of tree biomass in this study was carried out using a non-destructive method consisting of measuring tree diameter. As for the litter biomass, harvesting is done by installing a litter trap in a stand. This serves to prevent the litter from being carried away by the tide. Allometric equations are used to estimate biomass in a tree stand, where a vegetation is 40-50% composed of carbon (Altanzagas et al., 2019; Laskar et al., 2020).

The lowest average total stem biomass was found at station I, which is about 120.77kg/m2 per week. while for the monthly average by multiplying the average total biomass per week by 4 and to find out the average total per year, multiplying the average total biomass per month by 12. At station I, the total average is low, because the mangroves found at station I are dominated by small diameter trees. Biomass measurements were carried out on stem organs. Trees are measured at a height of 1.3 meters above ground level. Measurement is done by knowing the circumference of a tree by converting it into diameter. Meanwhile, the highest average total biomass was at station IV. It can be seen that at station IV is dominated by trees that are old so they have a large diameter.

In general, the biomass of each part of the tree is the largest sample obtained from trees that have a large diameter (Niapele, 2013). This is in line with the process of plant growth, where plants with older trees will have a large number of leaves. Leaves are part of the plant which is the site of photosynthesis, so it can also affect the size of the biomass. Meanwhile, according to Lusiana et al (2020) The biomass of a land use system is influenced by the type of vegetation. A land use system consisting of trees with species that have a high density value, the biomass will be higher when compared to land that has species with the lowest density value.

The biomass of the mangrove forest floor is one indicator of the amount of supply of organic matter which is a food chain in a mangrove aquatic ecosystem. The largest total production is leaf litter which is accommodated in litter traps that are installed in each observation plot at each station. There are 6 observation plots at each station. Litter collection was carried out every 2 weeks for 6 weeks. So to obtain the total dry weight of biomass for 6 weeks divided by 42 days, we will get the average litter biomass per day for the total dry weight.

Leaf litter has a shorter biological period, which is easier to fall than other litter components such as twigs, flowers, and fruit. In addition, the leaves tend to be easily aborted by wind and rain, because the leaves have a low mass. The higher the density, the higher the litter production, and vice versa. In addition to the density level, the rate of litter production is also influenced by the type of mangrove and the age of the mangrove. The research conducted did not distinguish between litter production based on different types of mangroves. At station IV, the highest average total dry weight per year is 907.2 kg/ton, where station IV is an area with high vegetation density and is close to the estuary. Meanwhile, for station I, the density is relatively low (Mchenga & Ali, 2017; Mohamed et al., 2016; Randa et al., 2020). This is in line with the opinion Hasibuan et al (2021), where the higher the tree density, the higher the litter production, and vice versa. In addition to tree density is also influenced by the type of mangrove and its age.

In this study, the biomass content of the litter was lower than that of the stand. This is due to the litter taken at the research site only on leaf fall. Leaves have a low biomass content because they store more water content. This is in accordance with the opinion Maylani et al (2020) and Xiong and Nadal (2020), which states that leaves have a high water content because they are photosynthetic units which generally have many cell cavities filled with water. Other opinions are also conveyed Harrison et al (2020) and Xu et al (2016), the leaves are composed of stomata cavity, so the structure is less dense and heavy. The amount of water from the environment will be absorbed by the leaves so that the cavities in the leaves are filled with water.

The results of the research conducted are in line with Evans (2013) it can seen from the distribution of biomass that occurs in each component of the tree will describe how much the distribution of the results of tree photosynthesis is stored in the plant body. The process of photosynthesis occurs in the leaves, but the largest distribution of photosynthetic products used by plants for growth is the stem. The stem is composed of wood constituent substances such as hemicellulose, lignin, and cellulose. According to Ramage et al (2017), stems are composed of 40-50% cellulose, where cellulose is a long chain sugar molecule composed of carbon, so the higher the cellulose, the higher the carbon content. Substances that make up wood will make the stem more composed of wood components compared to water, so that the biomass weight of the stem will be greater than other organs.

The biomass content in mangrove stands illustrates the ability of mangroves to absorb carbon dioxide in the atmosphere and can determine the storage capacity of carbon in mangrove forests. Based on the analysis results, the total carbon biomass estimation in mangrove stands is 20,136.6 tons/ha (equivalent to 9,262.9 tons C/ha or 33,963.42 tons CO_2/ha). The biomass value is influenced by the size of the tree diameter. The size of the tree diameter is influenced by the storage of biomass from the conversion of CO_2 which is absorbed by plants through the process of photosynthesis. This agrees with Imiliyana et al (2012) which states that the greater the potential of stand biomass is due to the older age of the stand. So that growth

occurs in the cambium cells in a radial direction, forming new cells that affect the increase in the size of the stem diameter. Meanwhile, according to Niapele (2013), The stem organ has the highest biomass, because the largest proportion of photosynthetic results is stored in the stem.

The mangrove vegetation at station IV has the highest ability to absorb CO_2 because the area has a high vegetation density and is supported by many stands with large diameters. While at station I, the density of mangrove vegetation is low and the stem diameter of the stands is small. As long as the tree or stand is alive, the process of absorbing CO_2 from the atmosphere continues. Tree felling activities or the natural death of trees will stop the CO_2 absorption process.

Data on the total carbon stock or carbon storage capacity in the mangrove forest of Cengkrong Beach, Trenggalek Regency is 9,262.9 tons C/ha. At station IV, it is very influential on the total value of carbon storage at Cengkrong Beach, Trenggalek Regency, because at station IV the value of carbon storage is the highest compared to other stations. The carbon content in mangrove stands can determine how much plants bind CO_2 in the atmosphere. Some of the carbon will be used as energy in plant physiological processes and some will enter the plant structure and become part of the plant. The amount of carbon stock in the stand was obtained based on the amount of biomass. This is in line with Iksan et al (2019) and Rudianto et al (2019) that part of the total biomass of the stand is the amount of carbon stored by the stand as carbon stock. So any factors that affect biomass will affect carbon stocks. It can be seen that the highest amount of biomass is at station IV which will then be followed by the highest amount of carbon storage at that station, and vice versa the lowest amount of biomass is at station I and will be followed by the lowest amount of carbon stock at that station.

The amount of carbon stock in plants can describe the amount of CO_2 in the atmosphere that is absorbed by plants. CO_2 sequestration has a relationship with carbon stocks (N. M. Heriyanto & Subiandono, 2012). The ability of mangroves to absorb CO2 is directly proportional to the carbon stock contained in the vegetation. This is in line with the opinion Prentice (2018) the number of C atoms in CO_2 is directly proportional to the number of C atoms bonded to the sugar. Mangrove vegetation in absorbing the highest CO_2 at station IV is 71,653,100 tons CO_2/ha equivalent to a carbon stock of 19,542,100 tons C/ha, while at station I it has a low capacity of 2,444.43 tons CO_2/ha equivalent to 666.67 tons C. /Ha. The total CO_2 absorption in the Cengkrong mangrove forest is 33,963.42 tons CO_2/ha, equivalent to a total carbon stock of 666.67 tons C/ha.

The mangrove vegetation found at the 4 research stations consisted of 8 species, namely: *Avicennia marina* (Forssk.) Vierth, *Bruguiera gymnorrizha* (L.) Lamk, *Ceriops decandra* (Griff), *Ceriops tagal* (Perr.), *Rhizophora apiculata* (BI.), *Rhizophora mucronata* Lmk., *Sonneratia alba* J.E Smith, and *Sonneratia caseolaris* (L) Engl. Each station has a distribution of the number and types that will describe the density of a vegetation. The results of observations regarding species density, relative density, species frequency, relative frequency, and important value index of mangroves in the mangrove ecotourism area in Cengkrong, Watulimo District, Trenggalek Regency, showed different values at each observation station. The highest vegetation density was found at station IV of 0.58. This is due to the location of station IV being near the river mouth, and having an older tree age of 9-12 years than station I which has a tree age of 4-9 years.

The highest relative density of the four stations was *R. apiculata* at station I, which was 39.4%. Meanwhile, the lowest relative density was *C. decandra* (Griff.), which was 0.58% at station IV. The high relative density of R. apiculata was caused by *Rhizophora* sp. have tolerance to environmental conditions such as substrate, tides, salinity and nutrient supply, which spread and can grow in various places (Usman et al., 2013).

Species frequency is one of the parameters used to express the proportion between the number of samples containing a particular species and the total number of samples. The frequency is influenced by the number of plots where mangrove species are found. The more the number of squares found, the higher the frequency of the presence of mangrove species will be (Indriyanto, 2006). The relative frequency of mangroves found in the ecotourism area of Cengkrong Beach, Trenggalek Regency, of the four highest stations, namely *R. apiculata* (BI.), 27.3% was found at station II. While the lowest relative frequency was *B. gymnorrizha* (L.) Lamk and *S. casolaris* (L) Engl, which was 8.70 % at station I. The large number of *R. apiculata* species was due to the condition of the substrate at the sandy mud sampling site.

The important value index of mangrove species at each location is 200, this shows the role of each large mangrove species in the mangrove ecotourism area of Cengkrong Beach and the influence on the growth of mangroves in a community. Mangrove exploitation, stable water conditions and suitable habitat are factors that can affect the important value index. One of the supporting factors for mangrove growth is the availability of nutrients and organic matter (Alongi, 2018; Frederika et al., 2021). Jadi semakin tinggi kepadatan, maka semakin banyak produksi seresah. Sehingga meningkatnya produksi seresah yang dihasilkan akan memungkinkan kondisi lingkungan subur. According to Tolangara et al (2019), important value index is obtained based on the determination of various parameters, namely the relative density of species and relative frequency of species.

The important value index of each different location has a different value. The occurrence of competition in each species in obtaining nutrients and sunlight as its physiological material, will cause differences in the important value index of mangrove vegetation. According to Parmadi et al (2016), the type of substrate and tides are also factors that cause differences in the density of vegetation. The important value index obtained from the four stations is the highest, namely *Rhizophora apiculata* (BI.) 61.13%, which is found at station I. Meanwhile, the lowest important value index from the four stations is *Ceriops decandra* (Griff) 9.95% at station IV.

Plants can live well because they are in accordance with the habitat where they grow. Habitat will affect plant growth. In a habitat, the suitability of plant species with the environment is very influential. This agrees with Sallata (2013), namely the existence of plants related to abiotic factors where they grow which will affect their physiological and morphological functions. Abiotic factors that affect plant growth, namely light, temperature, humidity, salinity, and soil pH.

CONCLUSIONS

Based on the results of the research, the following conclusions can be drawn: (1) Carbon dioxide absorption in Cengkrong, Trenggalek Regency has a total average of 33,963.42 tons/ha per year, equivalent to standing biomass of 20,136.6 tons/ha. (2) The annual carbon storage capacity has a total average of 4 stations 9,262.9 tons C/ha. Meanwhile, the carbon storage capacity in litter is 255.48 tons C/ha from a total

average of 4 stations. Carbon dioxide uptake in mangrove stands based on correlation test was related to total biomass in stands and carbon stock. So that any factor that affects the reduction of carbon stock will also affect the absorption of carbon dioxide.

ACKNOWLEDGEMENTS

REFERENCES

Abouelfadl, S. (2012). Global Warming – Causes, Effects and Solution'S Trials. *JES. Journal of Engineering Sciences*, *40*(4), 1233–1254. https://doi.org/10.21608/jesaun.2012.114490

Ali, M., Jha, N. K., Pal, N., Keshavarz, A., Hoteit, H., & Sarmadivaleh, M. (2022). Recent Advances in Carbon Dioxide Geological Storage, Experimental Procedures, Influencing Parameters, and Future Outlook. *Earth-Science Reviews*, *225*, 103895. https://doi.org/https://doi.org/10.1016/j.earscirev.2021.103895

Alongi, D. M. (2018). Impact of Global Change on Nutrient Dynamics in Mangrove Forests. *Forests*, *9*(10), 1–13. https://doi.org/10.3390/f9100596

Altanzagas, B., Luo, Y., Altansukh, B., Dorjsuren, C., Fang, J., & Hu, H. (2019). Allometric Equations for Estimating the Above-Ground Biomass of Five Forest Tree Species in Khangai, Mongolia. *Forest*, *10*(661), 1–17.

Balat, H., & Öz, C. (2007). Technical and Economic Aspects of Carbon Capture and Storage – A Review. *Energy Exploration & Exploitation*, *25*(5), 357–392. http://www.jstor.org/stable/26160771

Balitbang Kehutanan. (2013). *Pedoman Penggunaan Model Alometrik untuk Pendugaan Biomassa dan Stok Karbon Hutan di Indonesia*. Pusat Penelitian dan Pengembangan Konservasi dan Rehabilitasi, Badan Penelitian dan Pengembangan Kehutanan – Kementerian Kehutanan.

Bharath, A. K., & Turner, R. J. (2009). Impact of climate change on skin cancer. *Journal of the Royal Society of Medicine*, *102*(6), 215–218. https://doi.org/10.1258/jrsm.2009.080261

Cavicchioli, R., Ripple, W. J., Timmis, K. N., Azam, F., Bakken, L. R., Baylis, M., Behrenfeld, M. J., Boetius, A., Boyd, P. W., Classen, A. T., Crowther, T. W., Danovaro, R., Foreman, C. M., Huisman, J., Hutchins, D. A., Jansson, J. K., Karl, D. M., Koskella, B., Mark Welch, D. B., … Webster, N. S. (2019). Scientists' warning to humanity: microorganisms and climate change. *Nature Reviews Microbiology*, *17*(9), 569–586. https://doi.org/10.1038/s41579-019-0222-5

Cianconi, P., Betrò, S., & Janiri, L. (2020). The Impact of Climate Change on Mental Health: A Systematic Descriptive Review. *Frontiers in Psychiatry*, *11*(March), 1–15. https://doi.org/10.3389/fpsyt.2020.00074

Clough, B. F., & Scott, K. (1989). Allometric relationships for estimating above-ground biomass in six mangrove species. *Forest Ecology and Management*, *27*(2), 117–127. https://doi.org/https://doi.org/10.1016/0378-1127(89)90034-0

Dharmawan, I. W. S., & Siregar, C. A. (2008). Karbon Tanah dan Pendugaan Karbon Tegakan Avicennia marina (Forsk.) Vierh. di Ciasem, Purwakarta. *Penelitian Hutan Dan Konservasi Alam*, *V*(No.4), 317–328.

Dinilhuda, A., Akbar, A. A., Jumiati, & Herawati, H. (2020). Potentials of Mangrove Ecosystem as Storage of Carbon for Global Warming Mitigation. *Biodiversitas*,

21(11), 5353–5362. https://doi.org/10.13057/biodiv/d211141

Ebi, K. L., & Hess, J. J. (2020). Health Risks Due to Climate Change: Inequity in Causes and Consequences. *Health Affairs*, *39*(12), 2056–2062. https://doi.org/10.1377/hlthaff.2020.01125

Evans, J. R. (2013). Improving Photosynthesis. *Plant Physiology*, *162*(4), 1780–1793. https://doi.org/10.1104/pp.113.219006

Faradilla, L., Mustari, K., Asrul, L., & Kaimuddin. (2020). Carbon Stock Analysis of Some Cocoa Planting syStems in Climate Change Mitigation Efforts in East Luwu Regency. *IOP Conference Series: Earth and Environmental Science*, *486*(1). https://doi.org/10.1088/1755-1315/486/1/012083

Frederika, Y. C., Ihsan, Y. N., & Riyantini, I. (2021). Nutrient Profile and Mangrove Vegetation Composition in. *Jurnal Ilmu Kelautan*, *7*(1), 42–51.

Fromard, F., Puig, H., Mougin, E., Marty, G., Betoulle, J. L., & Cadamuro, L. (1998). Structure, above-ground biomass and dynamics of mangrove ecosystems: new data from French Guiana. *Oecologia*, *115*(1), 39–53. https://doi.org/10.1007/s004420050489

Hairiah, K., Ekadinata, A., Sari, R. R., & Rahayu, S. (2011). *Pengukuran Cadangan Karbon*. World Agroforestry Centre.

Harrison, E. L., Arce Cubas, L., Gray, J. E., & Hepworth, C. (2020). The Influence of Stomatal Morphology and Distribution on Photosynthetic Gas Exchange. *Plant Journal*, *101*(4), 768–779. https://doi.org/10.1111/tpj.14560

Hasibuan, I. M., Amelia, R., Bimantara, Y., Susetya, I. E., Susilowati, A., & Basyuni, M. (2021). Vegetation and Macrozoobenthos Diversity in The Percut Sei Tuan Mangrove Forest, North Sumatra, Indonesia. *Biodiversitas*, *22*(12), 5600–5608. https://doi.org/10.13057/biodiv/d221245

Heriyanto, N. M., & Subiandono, E. (2012). Composition and Structure, Biomass, and Potential of Carbon Content In Mangrove Forest At National Park Alas Purwo. *Jurnal Penelitian Hutan Dan Konservasi Alam*, *9*(1), 23–32.

Heriyanto, T., Amin, B., Rahimah, I., & Ariani, F. (2020). Analysis of Biomass and Carbon Stock on Mangrove Forest Ecosystem in Sandy Coastal Area of Kawal Village Bintan Regency. *Jurnal Manajemen Riset Dan Teknologi*, *2*(1), 31–41.

Hikmatyar, M. F., Ishak, T. M., Pamungkas, A. P., Soffie, S., & Rijaludin, A. (2015). Estimasi Karbon Tersimpan pada Tegakan Pohon di Hutan Pantai Pulau Kotok Besar, Bagian Barat, Kepulauan Seribu. *Al-Kauniyah Jurnal Biologi*, *8*(1), 40–45. https://doi.org/10.15408/kauniyah.v8i1.2704

Iksan, M., Al Zarliani, W. O. D., Nare, L., Hafidhawati, S., & Baena, F. (2019). Biomass and Carbon Uptake of Mangrove Forests Pohorua Village, Muna Regency. *OPEN ACCESS Journal of Applied Biology*, *3*(2), 57–64.

Imiliyana, A., Muryono, M., & Purnobasuki, H. (2012). Estimasi stok karbon pada tegakan pohon. In *Institut Sepuluh November*. Institut Teknologi Sepuluh Nopember.

Indriyanto, I. (2006). *Ekologi Hutan*. Bumi Aksara. https://opac.perpusnas.go.id/DetailOpac.aspx?id=662740

Janssen, P. J. D., Lambreva, M. D., Plumeré, N., Bartolucci, C., Antonacci, A., Buonasera, K., Frese, R. N., Scognamiglio, V., & Rea, G. (2014). Photosynthesis at The Forefront of a Sustainable Life. *Frontiers in Chemistry*, *2*(June), 1–22. https://doi.org/10.3389/fchem.2014.00036

Kauffman, J. B., & Donato, D. C. (2012). *Protocols for The Measurement, Monitoring and Reporting of Structure, Biomass and Carbon Stocks in Mangrove Forests*. Center for

International Forestry Research.

Komiyama, A., Poungparn, S., & Kato, S. (2005). Common allometric equations for estimating the tree weight of mangroves. *Journal of Tropical Ecology*, *21*(4), 471–477. https://doi.org/DOI: 10.1017/S0266467405002476

Kusumaningtyas, M. A., Hutahaean, A. A., Fischer, H. W., Pérez-Mayo, M., Ransby, D., & Jennerjahn, T. C. (2019). Variability in the Organic Carbon Stocks, Sources, and Accumulation Rates of Indonesian Mangrove Ecosystems. *Estuarine, Coastal and Shelf Science*, *218*, 310–323. https://doi.org/https://doi.org/10.1016/j.ecss.2018.12.007

Lanya, I., Merit, I. N., & Antara, I. M. (2016). Original Research Article Carbon Stock Due to The Intensity of The Use of Forest Areas in Forest Management Unit of West Bali. *International Journal of Bioscience and Biotechology*, *4*(1), 49–58.

Laskar, S. Y., Sileshi, G. W., Nath, A. J., & Das, A. K. (2020). Allometric models for above and below-ground biomass of wild Musa stands in tropical semi evergreen forests. *Global Ecology and Conservation*, *24*, e01208. https://doi.org/https://doi.org/10.1016/j.gecco.2020.e01208

Lusiana, B., Noordwijk, M. van, & Rahayu, S. (2020). *Cadangan karbon di Kabupaten Nunukan, Kalimantan Timur: Monitoring secara spasial dan pemodelan*. proyek pengelolaan sumberdaya alam untuk penyimpanan karbon (FORMACS).

Maylani, E. D., Yuniati, R., & Wardhana, W. (2020). The Effect of Leaf Surface Character on The Ability of Water hyaciNth, Eichhornia crassipes (Mart.) Solms. To transpire water. *IOP Conference Series: Materials Science and Engineering*, *902*(1). https://doi.org/10.1088/1757-899X/902/1/012070

Mchenga, I. S. S., & Ali, A. I. (2017). Mangrove Litter Production and Seasonality of Dominant Species in Zanzibar, Tanzania. *Journal of East African Natural History*, *106*(1), 5–18. https://doi.org/10.2982/028.106.0103

Metz, B., Davidson, O., de Coninck, H., Loos, M., & Meyer, L. (2005). IPCC Special Report on Carbon Dioxide Capture and Storage. In *Advances in Chemical Engineering* (Vol. 58). Cambridge University Press. https://doi.org/10.1016/bs.ache.2021.10.005

Mohamed, M. O. S., Mangion, P., Mwangi, S., Kairo, J. G., Dahdouh-Guebas, F., & Koedam, N. (2016). *Are Peri-Urban Mangroves Vulnerable? An Assessment Through Litter Fall Studies*. 39–51. https://doi.org/10.1007/978-3-319-25370-1_3

Mughofar, A., Masykuri, M., & Setyono, P. (2018). Zonasi dan Komposisi Vegetasi Hutan Mangrove Pantai Cengkrong Desa Karanggandu Kabupaten Trenggalek Provinsi Jawa Timur. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (Journal of Natural Resources and Environmental Management)*, *8*(1), 77–85. https://doi.org/10.29244/jpsl.8.1.77-85

Niapele, S. (2013). Estimasi Biomassa dan Karbon Tegakan Dipterocarpa Pada Ekosistem Hutan Primer dan LOA (Log Over Area) di PT. Sari Bumi Kusuma (SBK) Kalimantan Tengah. *Agrikan: Jurnal Agribisnis Perikanan*, *6*(1), 29. https://doi.org/10.29239/j.agrikan.6.1.29-36

Olivier, J. G. J. G. J., Schure, K. M. M., & Peters, J. A. H. W. A. H. W. (2017). *Trends in Global CO2 and Total Greenhouse Gas Emissions: 2017 report* (Issue December). https://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2017-trends-in-global-co2-and-total-greenhouse-gas-emissons-2017-report_2674.pdf

Palacios Peñaranda, M. L., Cantera Kintz, J. R., & Peña Salamanca, E. J. (2019). Carbon stocks in mangrove forests of the Colombian Pacific. *Estuarine, Coastal and Shelf*

Science, *227*, 106299. https://doi.org/https://doi.org/10.1016/j.ecss.2019.106299

Parmadi, E. H. J., Dewiyanti, I., & Karina, S. (2016). Indeks Nilai Penting Vegetasi Mangrove Di Kawasan Kuala Idi , Kabupaten Aceh Timur. *Jurnal Ilmiah Mahasiswa Kelautan Dan Perikanan Unsyiah*, *1*(1), 82–95.

Prentice, I. C. (2018). *The Carbon Cycle and Atmospheric Carbon Dioxide*. IPCC.

Rachmawati, D., Setyobudiandi, I., & Hilmi, E. (2014). Potensi Estimasi Karbon Tersimpan pada Vegetasi Mangorove di Wilayah Pesisir Muara Gembong Kabupaten Bekasi. *Jurnal Omni-Akuatika*, *XIII (19)*(November 2014), 85–91.

Rahmah, F., Basri, H., Konservasi, J., Lahan, S., Unsyiah, P., & Unsyiah, F. P. (2015). Potensi Karbon Tersimpan Pada Lahan Mangrove dan Tambak di Kawasan Pesisir Kota Banda Aceh. *Jurnal Manajemen Sumberdaya Lahan*, *4*(1), 527–534.

Ramage, M. H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D. U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., Dupree, P., Linden, P. F., & Scherman, O. (2017). The wood from the trees: The use of timber in construction. *Renewable and Sustainable Energy Reviews*, *68*, 333–359. https://doi.org/https://doi.org/10.1016/j.rser.2016.09.107

Randa, G., Lestari, F., & Kurniawan, D. (2020). Produksi dan Dekomposisi Serasah Mangrove di Muara Sungai Jang Kecamatan. *Samakia : Jurnal Ilmu Perikanan*, *11*(1), 34–43. http://samakia.ibrahimy.ac.id/index.php/JSAP

Rudianto, Putra, A. A., & Utama Dewi, C. S. (2019). Analysis of the Ability of Mangrove Sequestration and Carbon Stock in Pejarakan Village, Buleleng Regency, Bali. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, *11*(3), 511–526. https://doi.org/10.29244/jitkt.v11i3.24049

Sallata, M. K. (2013). Pinus (Pinusmerkusii Jungh et de Vriese) dan keberadaannya di Kabupaten Tana Toraja, Sulawesi Selatan. *Info Teknis EBONI*, *10*(2), 85–98.

Simmons, C. T., Mysak, L. A., & Matthews, H. D. (2013). Investigation of The Natural Carbon Cycle Since 6000 BC using an Intermediate Complexity Model: The Role of Southern Ocean Ventilation and Marine Ice Shelves. *Atmosphere - Ocean*, *51*(2), 187–212. https://doi.org/10.1080/07055900.2013.773880

Sumarmi, S., Purwanto, P., & Bachri, S. (2021). Spatial Analysis of Mangrove Forest Management to Reduce Air Temperature and CO2 Emissions. *Sustainability (Switzerland)*, *13*(14). https://doi.org/10.3390/su13148090

Susilo, E., Purwanti, P., & Lestariadi, R. A. (2015). *Pemanfaatan Sumberdaya Mangrove Di Pancer Cengkrong Dan Damas, Pantai Prigi, Trenggalek*. *5*(2), 19–25.

Tolangara, A., Ahmad, H., & Liline, S. (2019). The Composition and Important Value Index of Trees for Wildlife Feed in Bacan Island, South Halmahera. *IOP Conference Series: Earth and Environmental Science*, *276*(1), 0–6. https://doi.org/10.1088/1755-1315/276/1/012037

Usman, L., Syamsuddin, & Hamzah, S. N. (2013). Analisis Vegetasi Mangrove di Pulau Dudepo Kecamatan Anggrek, Kabupaten Gorontalo Utara. *Jurnal Ilmiah Perikanan Dan Kelautan*, *1*(1), 11–17. http://ejurnal.ung.ac.id/index.php/nike/article/view/1211

Wiarta, R., Indrayani, Y., Mulia, F., & Astiani, D. (2019). Carbon Sequestration by Young Rhizophora apiculata plants in Kubu Raya District, West Kalimantan, Indonesia. *Biodiversitas*, *20*(2), 311–315. https://doi.org/10.13057/biodiv/d200202

Xiong, D., & Nadal, M. (2020). Linking Water reLations and Hydraulics with Photosynthesis. *Plant Journal*, *101*(4), 800–815.

https://doi.org/10.1111/tpj.14595

Xu, Z., Jiang, Y., Jia, B., & Zhou, G. (2016). Elevated-CO2 Response of Stomata and its Dependence on Environmental Factors. *Frontiers in Plant Science*, *7*(MAY2016), 1–15. https://doi.org/10.3389/fpls.2016.00657