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Estimation of Biomass and Carbon Content in Mangroves Area of Kartomulyo Beach, Pati Regency, Central Java, Indonesia

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Abstract— Mangrove ecosystem is one of the ecosystems that plays an important role to reduce carbon in the air and store it from the air in the form of biomass at the body parts of mangrove plants including stems. Research on the estimation of carbon stocks is very much needed to support the improvement of the world's climate, because currently the world is experiencing a global crisis called climate change, both of which can support the life of land and sea biota. The objectives of this research were: 1) to Assess the mangrove population, 2) to Assess environmental parameters in mangrove areas, 3) to Assess the carbon stock in the Kertomulyo Beach area, and the method used was purposive sampling method and observation, carried out at three stations with various conditions of the mangrove ecosystem. Each research station is divided into 6 research plots. The value of mangrove biomass was calculated using the above ground allometric formula to estimate carbon stocks. Water quality measurements are carried out directly in the field according to the Indonesian National Standard (SNI). It is known that there are three species of mangroves consisting of 192 individuals for *Avicennia alba*, 259 individuals for *Avicennia marina* and 248 individuals for *Rhizopora mucronata*. The average density of all mangrove species from these three stations is 280 individuals/ha. The highest frequency, closure and INP were *Avicennia marina* at the three stations. The environmental parameters measured were temperature in the range of 29-30°C, pH at 7.9-8 ppm and salinity at 22-23 ($^0/_{00}$) for each observation station.The estimated total CO_2 carbon at three stations covering an area of approximately 4.3 hectares is 5.36 tons C/ha for Average Carbon Storage/ha, 16.07 ton C/ha for Total Carbon. Mangrove carbon stock at each station on Kartomulyo beach was 2.27 C/ton at station 1, 2.32 C/ton at station 2 and 2.80 C/ton at station 3.

KEYWORDS: Biomass, Carbon sequestration capability, Carbon stocks, Carbon storage, Climate change, Mangrove ecosystem, Water quality.

1. Introduction

The terms of climate change and global warming are often confused, inaccurate and interchangeably, but there is difference in it (Chophel, 2021)[1]. Climate change can be defined as changes in the atmosphere layers, such as temperature, precipitation, and other climate variables. Global warming is one of the consequences of climate change, related to the rise in the average temperature near the Earth's surface (Al-Maliki et al., 2022)[2]. Climate change is an implication of global warming (R. M. Santos & Bakhshooddeh)[3]. Further, Chopel (2021)[1] clearly puts it in the context when he quotes Lorenz, "Climate is what you expect; weather is what you get.".

Many severe and possibly permanent changes in our planet's ecological and geological systems are consequences of climate change (R. M. B. Santos et al., 2015)([4]). The impacts of climate change include: melting ice at the South Pole, shifting seasons, and rising sea level (Priestley et al., 2021)[5]. House gas glass, such as carbon dioxide (CO_2) and methane (CH_4) are the main causes the occurrence of global warming ((Kweku et al., 2018)[6]. The high CO_2 gas in the atmosphere can be minimized due to the earth's ability to store natural carbon in the form of forest-based coastal ecosystems mangrove.

Based on the National Mangrove Map officially released by the Ministry of Environment and Forestry in 2021, it is known that the total area of Indonesia's mangroves is 3,364,076 Ha (Djamaluddin & Djabar, 2022)[7]. Mangrove ecosystems in Indonesia have almost 75% of the total mangroves in Southeast Asia or about 27% of the total mangroves in the world and the mangrove ecosystem has the highest diversity in the world (Hariyanto et al., 2019)[8].

Pati Regency has a total area of 150,368 Km^2 and it has a coastline of ± 60 Km. from Dukuhseti District on the north side to Batangan District on the east side. The coastline of Pati Regency has 15.98 km of coastal/mangrove vegetation and 34.16 km of non-mangrove coastline. The area of mangrove forest in Pati Regency has decreased from 348.18 ha in 2014 to 138.5 ha in 2017. The community structure of the people in Pati district is as fish farmers and fishermen. They are people who depend on the beach and the sea for their lives. The beach and the sea are the lifeblood of the community, so the quality of the coastal environment must be preserved. Quality decrease of coastal environment is indicated by mangrove damage. Mangrove forest is part of the coastal ecosystem of Pati Regency which provides productive natural resources.

They are both as a source of income, food, building material and source of nutrients for the biota that live in it such as a place to live, feeding ground, nurseries ground and spawn ground, climate regulation, carbon storage as well as recreation or tourism areas (Suratman, 2021)[9].

Mangroves are natural resources that play an important role in maintaining the balance between terrestrial and aquatic ecosystems (Nugroho et al., 2020)[10]. Mangrove ecosystem is an area that functions as a bridge between land and sea (Suratman, 2021)[9]. It has functions as ecological stability or balance of ecosystems, nutrient sources, as nursery areas, feeding ground areas, and spawning ground, and mangrove ecosystems can also contribute to controll the pace of global climate change and ecological dynamics of an ecosystem positively (Saru et al., 2020)[11] . One of the ecosystem services provided by mangroves in relation to combating global climate change is to absorb and store large amounts of blue carbon from the atmosphere and oceans so that its role is now recognized in tackling climate change (Britain, 2016)[12]. Mangrove vegetation carries out the process of photosynthesis by absorbing carbon dioxide from the atmosphere (Maulidia et al., 2022)[13] which is then converted into organic carbon in the form of biomass (Iksan et al., 2019)[14]. Most of the biomass in mangrove vegetation is in the form of carbon. The carbon value contained in mangrove vegetation is the potential carbon stored from mangroves. One way to determine the value of stored carbon owned by mangrove vegetation is by estimating (Twilley et al., 1992)[15].

The decrease in the number of mangrove forests due to human or other activities has an impact on carbon absorption, carbon storage and the amount of capture fisheries and aquaculture production (Rudianto et al., 2020)[16] . The decline of mangrove forests in the world by 30-50% for the last half century is due to coastal development, expansion of ponds and tree cutting (Donato et al., 2011)[17]**.** Meanwhile, the mangrove ecosystem continues to shrink by up to 54% in mangrove forest areas due to conversion for various purposes in Indonesia every year for a period of 17 years (1982-1999) (Qadarisma et al., 2021)[18]**.** The above conditions trigger awareness to make alternative efforts in overcoming the problem of global warming. These efforts are carried out, among others, through forest rehabilitation activities. According to Cahyaningrum & Hartoko, (2014)[19], these efforts need to be supported by activities to obtain data and information on the level, status, and trends of periodic changes in greenhouse gas emissions from various emission sources and their absorbers, including carbon stock (carbon storage).

2. MATERIAL AND METHOD

The research was carried out on March 2 to May 15, 2020, located in three mangrove areas which are considered to represent the condition of mangroves at Kertomulyo Beach, Pati Regency Central Java Province. The first location is located near the pond area, the second location is located near the river mouth, and the last location is located in the location of ecotourism activities. Sample analysis carried out in situ or directly at the observation site, namely identification of mangrove species, measurement of tree circumference, and measurement of water quality (temperature, salinity, and pH).

2.1. Determination of Sampling Plot

The plot used in this observation is a circular plot with a diameter of 14 m, with a distance between plots of 20 m. According to Kauffman and Donato (2012)[20] plot size is 14 (r = 7 m, A = 153.9 m) in diameter for measuring trees with diameter > 5 cm.

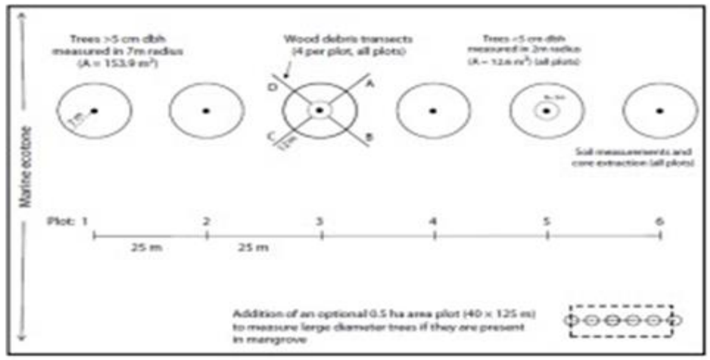

Figure 1. Line transects and circle plots (Kauffman, 2012) [20]

2.2. Mangrove Data Collection

Determination of stations for mangrove transect data collection based on regional representation. The transect line is drawn from the closest point with the sea to the mainland along the 125 m. Zero point (0 m) is at least 15 m from the shoreline. The distance of each circle plot is 25 m started at the zero point. The transect center point is located at the 0, 25, 50, 75, 100 and 125 meters.

Measurement of DBH (Diameter at Breast Height) or measurement of the tree trunk link of mangrove was carried out on each plot with the following settings:

1. Trees > 5 cm in diameter are measured in a radius of 7 meters.
2. Trees < 5 cm in diameter are measured in a radius of 2 meters.
3. DBH measurements were carried out at living trees (environmental conditions around)

2.3 Mangrove Vegetation Analysis

2.3.1. Species Density (Di)

Species density (Di) is the number of stands of the i species in a unit area. Determination of species density through the formula of (Dharmawan, I.W.E., Suyarso, I.U. Yaya 2020)[21]

$$Di=di/A$$

Information :
Di : Species density
di : Species density–i (stand/100m^2)
D : Number of species-i

2.3.2. Species Relative Density (RDi)

Relative density (RDi) is the number of comparisons between the numbers of species stands of the 1st species with the total stands of all species. Determination of Relative Density (RDi) using the formula of (Dharmawan, I.W.E., Suyarso, I.U. Yaya 2020)[21].

$$RDi = Di / D \times 100\%$$

Information :
RDi : Relative density of –i type (%)
Di : Density of species i
D : Total density

2.3.3. Species Frequency (Fi)

Species frequency (Fi) is the probability of finding an i-th species in all sample plots compared to the total number of sample plots made. For calculating the frequency of species (Fi) used the formula of (Dharmawan, I.W.E., Suyarso, I.U. Yaya 2020)[21]

$$Fi = qi / q_{total}$$

Information :
Rfi : Relative frequency of –i species (%)
qi : Number of plots found species –i
q_{total} : Total number of plots created

2.3.4. Species Relative Frequency (RFi)

Relative frequency (RFi) is the ratio between the i-th type frequency and the total frequency of all species. To calculate the relative frequency use the formula of (Dharmawan, I.W.E., Suyarso, I.U. Yaya 2020)[21]

$$RFi = Fi / F \times 100\%$$

Information :
Rfi : Relative frequency of –i species (%)
Fi : Frequency of species i
F : Total frequency

2.3.5. Closure of Species (Ci)

Species closure (Ci) is the area of the i-th species of closure in a certain unit area. To calculate species closure using formula of (Dharmawan, I.W.E., Suyarso, I.U. Yaya 2020)[21]

$$Ci = BAi / A$$

Information :
Ci : Closure of Species
BAi : Species closure -i
A : Total area of sampling area (m^2)

2.3.6. Relative Closure of Species

Relative closure (RCi) is the comparison between the i-th species closure and total area of closure for all species. To calculate RCi, we use formula of (Dharmawan, I.W.E., Suyarso, I.U. Yaya 2020)[21]

$$RCi = Ci / C \times 100\%$$

Information :
RCi : Relative Closure of –i type (%)
Ci : Closure of species i
C : Total closure for all species

2.3.7. Important Value Index (IVI)

The Important Value Index (IVI) is an index of importance that can be used to express the level of Evenness or level of dominance of vegetation species in the community or mangrove ecosystem (Qadarisma et al., 2021)[18]. The IVI value is obtained from the accumulated values of the sum of the values of relative density (RDi), relative dominance (RCi), relative frequency (RFi) of each mangrove species (Kusmana & Azizah, 2022)[22]. To calculate RCi, we use formula (Dharmawan, I.W.E., Suyarso, I.U. Yaya 2020)[21]

$$IVI = RDi + RCi + RFi$$

Information :
RDi : Relative density of –i type (%)
Rci : Relative Closure of –i type (%)
RFi : Relative frequency of –i type (%)

2.3.8. Carbon Stock Analysis

Candri et al., (2020)[23] stated that the carbon stock was estimated from the biomass, by following the rule 46% of biomass is carbon. So the estimated amount stored carbon is by multiplying 0.46 by biomass. After calculating the carbon stock in kilograms, the carbon stock is converted to tons. According to Purwiyanto & Agustriani (2018)[24] conversion of carbon stock into units of tons per hectare. Counting carbon from biomass using the following formula:

$$C = B \times \%C$$

Information :
C : Carbon content of the biomass, expressed in (kg);
B : Total biomass, expressed in (kg);
%C : the percentage value of carbon content, is 0.46%([NSA] National Standards Agency, 2011)[25]

3. Result and Discussion

3.1. Mangrove Composition

Based on the results of observations of the species of mangroves in the coastal area of Kertomulyo Beach, there are 3 mangrove species found with a total of 699 individuals. The complete data is presented in Table 1.

Table 1. Species of mangroves at Kertomulyo Beach

No	Species	Quantity (individual)
1	*Avicennia alba*	192
2	*Avicennia marina*	259
3	*Rhizopora mucronata*	248
	Total	**699**

There are 3 species of mangroves found at the research site, namely *Avicennia alba*, *Avicennia marina* and *Rhizopora mucronata*. and the *Avicennia marina* was the highest species individuals found. The number is around 259 individuals. The above condition is because the *Avicennia marina* is a pioneer mangrove species at the protected beach location in the research area and the optimum salinity for growth of *Avicennia marina* varies from 10 to 90 % seawater (salinity 35 ppt.) at the part of the tidal-affected riverbank along the shoreline. These findings are in accordance with the opinion of Triest et al., (2021)[26] which states that *Avicenia marina* is a pioneer species in mangrove swamp habitat in protected coastal locations, and it grows in low salinity at parts along riverbanks that are influenced by tides and along the coastline (Herison et al., 2014)[27], and *Avicenia marina* is a species of mangrove that can grow and dominate as well as develop well at salinities close to fresh up to 90% (Nguyen et al., 2015)[28].

3.2. Mangrove Vegetation Analysis

Mangrove forest vegetation in Indonesia has the highest species diversity in the world. 202 species were recorded, consisting of 89 tree species, 5 palm species, 19 liana species, 44 epiphytic species, 21 cycads (Ilman et al., 2011)[29]. However, there are only approximately 47 specific plant species of mangrove forests and there is one important/dominant true plant belonging to the 4 families Rhizophoraceae (Rhizophora, Bruguera, and Ceriops), Sonneratiaceae (Sonneratia), Avicenniaceae (Avicennia) and Meliaceae (Xylocarpus) in the mangrove forest. Vegetation analysis serves is to determine how large the distribution of various species in an area through direct observation (Solikhatun et al., 2020)[30].

In this research, it can be explained that only two species of *Avicennia* sp. found in the research area, namely *Avicennia marina* and *Avicennia alba* and one species of *Rhizopora* sp. namely *Rhizopora mucronata*. *Avicennia alba* found at the research site was identified as having respiratory roots that grew upwards and the bark was dark brown in color. The leaves are green on top and lighter green on the bottom. The shape of the leaves is elliptical and the tip is tapered and the fruit is green with a conical shape. These findings are in accordance with the results of research from (Yunus et al., 2020)[31].

Avicennia marina found at the research site had green leaves on the upper surface and yellowish green on the underside, some of which were white on the underside. It was found growing and developing at each observation station at salinity of 30 - 34 ppt and temperatures of 28 - 31 °C with clayey substrate.The leaves are oval/a tapered tip. Yunus et al., (2020)[31] also stated the same thing as the findings above. *Avicennia marina* in the local language is known as *api-api* which is one of the species of plants that are spread throughout Indonesia and are abundantly available and provide various benefits. In addition, api-api leaves have long been used in traditional medicine for the treatment of skin diseases, rheumatism, smallpox, boils and animal feed on farms. Huang et al., (2016) [32] stated at his research that Avicennia marina is the most abundant and common mangrove species and has been used as a traditional medicine for skin diseases, rheumatism, ulcers, and smallpox. The last one was *Rhizopora mucronata* which was found at the research site. This species has a dark gray color with rough bark. It has elliptical leaves with pointed ends. The fruit of *Rhizopora mucronata* is elliptical and it has one brown seed and a taproot shape. In general, *Rhizopora mucronata* grows in groups, its habitat is in tidal rivers and in river mouths. Optimal growth of *Rhizopora mucronata* occurs in waterlogged areas and in humus-rich soils. The ecology of *Rhizopora mucronata* is the same as *Rhizopora apiculata* but it is more tolerant of harder and sandy substrates. The above conditions are in accordance with the results of research from (Yunus et al., 2020) [31].

3.3. Mangrove Density

The results of the analysis showed that the highest density was *Rhizopora mucronata* found at station 1 with a density value of 350 individuals/ha. This indicates that the *Rhizopora mucronata* species has the ability and suitability to grow and develop properly. This is because *Rhizopora mucronata* is a species that was intentionally planted in the rehabilitation of mangrove areas at station 1. This finding is reinforced by Gunawan's (2017) [33] statement that *Rhizopora* spp are mangrove vegetation that is often used for rehabilitation and the chances of success are quite high. The high density of *Rhizopora mucronata* is also related to its high reproductive ability because *Rhizopora mucronata* has a large, elongated propagule shape, and can be spread by currents widely, and has more food reserves so that the chance of survival is higher (Robert et al., 2015) [34].

The highest density at stations 2 and 3 was *Avicennia marina*, which was 292 individuals/ha for station 2 and 321 individuals/ha for station 3. This condition was due to the uniform distribution of *Avicennia marina* seeds in the front zone which contained a slightly soft muddy substrate that supported its growth. It's in line with Vitri Lestari et al., (2020) [35] stated that *Avicennia marina* is one of the mangrove species in the major category. This shows that *Avicennia marina* is always present in the mangrove ecosystem and *Avicennia marina* is also tolerant of high salinity and has the ability to grow in various habitats in tidal areas. The average density of all mangrove species from these three stations is 280 individuals/ha.

The amount of mangrove density can determine the amount of mangrove damage which is regulated in the Minister of Environment Decree No. 201 of 2004 concerning the standard criteria for mangrove damage. The criteria are damaged if the number of trees is <1000 trees/ha, the criteria are moderate if the number is 1000-1500 trees/ha and the criteria are very dense having a number of >1500 trees/ha.

The low density of mangrove vegetation on Kertomulyo Beach below <1000 trees/ha indicates that the mangrove vegetation community is in a disturbed or damaged condition (Decree., 2004)[36]. Kertomulyo Beach is thought to be a location for mangrove rehabilitation. This assumption is due to the large number of mangrove plants in the category of young plants which can be seen from the diameter of the existing trees. The density of mangrove trees is also influenced by the intensity of light entering the mangrove forest base. The above conditions are in accordance with the results of research by Poedjirahajoe et al., (2017)[37] which stated that the intensity of the incoming light then affects the environmental temperature and the survival of algae and phytoplankton in the mangrove ecosystem. The more the mangrove density, the higher the mangrove carbon content or the mangrove density

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is directly proportional to the mangrove carbon content (Martuti et al., 2017)[38].

3.4. Mangrove Closure

The values of species closure were closely related to the circumference of the tree trunk. The highest closure value at the three stations with an average closure value of 48.53% was occupied by *Avicennia marina* species at the three stations. This is because *Avicennia marina* species are able to compete for more nutrients than other species. The stem volume of *Avicennia marina* is quite large and widespread, causing the *Avicennia marina* species has a higher level of mastery of one species or closure than other species.

The closure of mangrove species is different for each species in an area, if the size of the trunk is getting bigger it will expand its closure. This is in accordance with the opinion of Majesty et al., (2019)[39] stated that the closure of this species is due to its ability to grow in various substrate conditions, which indicates that it is suitable for the rehabilitation of mangrove areas species, and Statemen of Serosero, Abubakar and Hasan (2020)[40] stated that the condition was closely related to the tree diameters, where if the tree diameters were large, it would have a higher closing value.

3.5. Species Frequency

Based on the data at the research site, it is known that the highest frequency at the three stations is *Avicennia marina* with an average frequency of 39.57%. This is due to the uniform distribution of *Avicennia marina* seeds in each zone and the ability of *Avicennia marina* seeds to survive in the environment is better than the ability of other mangrove species. The abiity is supported by environmental factors such as substrate, water salinity and water temperature compared to other mangrove species.

The species of *Rhizopora mucronata* has the second large frequency due to differences in environmental physical and chemical factors in each zone that support the growth of this species of mangrove. This condition is caused by the spread of *Rhizophora* sp which is influenced by the tides of sea water in which helps the spread of floating seeds to various places and the seeds are rooted at the ends and can anchor themselves to the mud at low tide, then grow upright. This is in line with the results of a research of Nugroho et al., (2020)[10] stated that environmental factors of mangrove forests include water temperature, water salinity, water pH, soil salinity, soil pH and soil texture play an important role in mangrove growth.

3.6. Important Value Index (IVI)

The Important Value Index (IVI) calculations performed from the data obtained are presented in Table 2:

Tabel 2. The IVI of Kertomulyo beach mangroves

Important Value Index (%)			
Species	Station 1	Station 2	Station 3
Avicennia alba	85,23	101,47	91,73
Avicennia marina	122,67	118,76	134,11
Rhizopora mucronata	92,11	79,77	74,15

Based on the IVI comparison table for the three stations, it shows that there are differences in the important value index at each station for each species. The difference in this important value index is influenced by the condition of the mangrove ecosystem at each station. The Importance Value Index level on a scale of 0-300 shows the representativeness of the mangrove species, the more the species dominates the greater the IVI value of a species. Mangrove species have a highest IVI, they have a very large role in the mangrove ecosystem in their habitat, and vice versa if the IVI of a species is small, then its presence does not have too much influence on the ecosystem. The above finding is reinforced by the statement of Saputro et al., (2021)[41] stated that the IVI is affected by the biotic and abiotic factors and the most dominant species has the largest value index.

3.7. Dominance Index (C), Diversity Index (H'), and Uniformity or Evenness Index (e)

The results of data analysis show that the Dominance Index (C), Diversity Index (H'), and Evenness Index (E) of mangroves in the mangrove area of Kertomulyo Beach, Kertomulyo Village, Trangkil District, Pati Regency are presented as in Figure 2.

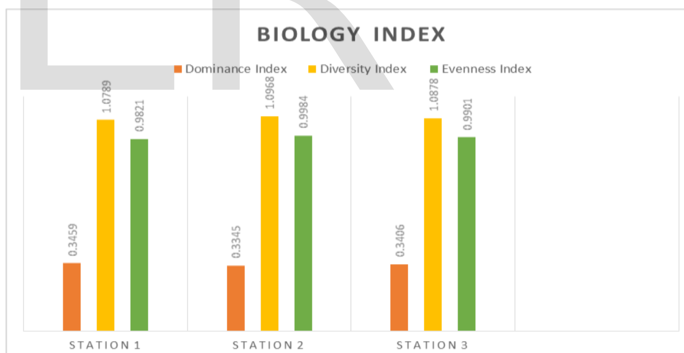

Figure 2. Kertomulyo beach mangrove biological index recapitulation.

3.7.1. Dominance Index (C)

The dominance index (C) describes the pattern of concentration and distribution of species dominance in the stand. The highest dominance index value is 1 (one). This indicates that a stand is controlled by a species or there is a concentration of dominance in a species. The value of the dominance index (C) is getting smaller, the more the species of dominance pattern is spreading (Nuraina et al., 2018)[42]. The results of data analysis obtained a dominance index (C) of mangroves in the mangrove area of Kertomulyo Beach, Kertomulyo Village, Trangkil District, Pati Regency as presented in Figure 2.

The dominance index value at each research station ranged from 0.3345 - 0.3459. Based on Odum (1993)[43], the three criteria stations had a moderate dominance value indicated by the presence of a dominant species, namely *Rhizopora mucronata* at station 1 which had a dominance value of 0.1555 and *Avicennia marina* at stations 2 and 3 with dominance values of 0.1262 and 0.1565, respectively, or having the number of individuals more than half of the total individuals at each station.

3.7.2. Diversity Index (H')

The Species Diversity Index (H) is used to determine the level of species diversity in a forest stand which can also be a measure in assessing the succession process that runs in the forest community (Asadi & Pambudi, 2020) [44]. Based on Figure 12, the diversity index value (H') ranges from 1.0789-1.0968. Based on Odum's (1993) [43] criteria, this value is included in the medium category (1<H'<3). Diversity in the moderate category indicates that the mangrove community is in a balanced condition, with sufficient productivity with ecological pressures.

The diversity value of a community is influenced by the number of species and the number of individuals in the community. The species diversity of a community will be high if the community consists of many species and no species dominates. Khairul (2020) [45] added that low diversity indicates that the ecosystem is under pressure or environmental conditions have decreased. The decline in diversity growth is due to environmental pressures that are always changing over time.

3.7.3. Evenness (E)

The species Evenness Index (E) serves to determine the even distribution of individuals between species in a habitat. The species Evenness index value ranges from 0-1, if E = 1 then all species are plentiful. Based on Figure 2, the uniformity index value (E) ranges from 0.9821 to 0.9984. This value is high because it is close to 1 so that all species have the same or even Evenness at each station. Based on Odum (1993) [43] criteria, high Evenness indicates that the mangrove species found at each research station tends to be evenly distributed, meaning that no particular species dominates a station. If the value of the evenness index is small, then the evenness of mangrove species in the community is less, it means that the number of individuals for each species is not the same, so there is a tendency to be dominated by certain species. The species Evenness index value is useful as a guide for the community in the future in enriching vegetation species in mangrove forest areas.

3.8. Environmental Parameters

Observations of environmental parameters were carried out to determine environmental parameters that affect the waters in the mangrove forest area to support mangrove vegetation life (Baderan et al., 2018)[46]. The environmental parameters measured were temperature, salinity, and degree of acidity. Environmental parameters that affect the life of mangrove vegetation on the coast of Kertomulyo Beach are shown in the Table 2.

Table 2. Results of Measurement of Physical-Chemical Parameters in Mangrove Areas on the Kertomulyo Coast.

Parameter	Station 1	Station 2	Station 3
Temperature (^{0}C)	30	29	29
pH (ppm)	7,9	8	8
Salinity ($^0/_{00}$)	23	22	23

Based on table 2, it can be seen that the temperature of each research location ranged from 29 - 30°C. This value range is still within the tolerance limit of mangroves. The temperature range at each observation station is in accordance with the conditions of the mangrove habitat. Mangroves are typical tropical coastal plants that can grow at temperatures of 19-40°C, while the fluctuation tolerance is not more than 10°C. This is in accordance with the statement of Niagara et al., (2021)[47]. Furthermore Aksomkoae (1993)[48] reinforced by his opinion stated that the high and low temperatures in mangrove habitats are caused by the intensity of sunlight received by water bodies, the volume of stagnant water in mangrove habitats, and weather conditions.

The results of salinity measurements at each research station obtained data in the range of 22 - 23$^0/_{00}$, while the tolerance limit for mangrove growth ranges from 11 - 25$^0/_{00}$ (Niagara et al., 2021)[47]. This condition is very supportive for plant growth and development because the composition of the mud substrate is more than the sand substrate composition. The data above shows that the nutritional needs of plants are optimally fulfilled because mangrove plants are generally found living in coastal areas with high seawater salinity.

The pH value at each research station was obtained in the range of 7.9 - 8. The value of the pH range is still at the tolerance limit for mangrove growth. Mangrove can live at a pH ranging from 5.0 to 8.5 in general (Prihadi et al., 2018)[49]. The pH value of water is one of the factors that can affect water productivity, where waters with a pH of 6.5 - 7.5 are productive waters, waters with a pH of 7.5 - 8.5 are waters that have very high productivity, and waters with a pH greater than 8.5 are categorized as unproductive waters. It is lin line with opinion of Das (2019)[50] stated that pH between 7 to 8.5 is ideal for biological productivity.

In this research, the pH at each station was still following the quality standards in the Minister of Environment Decree No. 51 year 2004 (Minister & Environment, 2004)[36]. The results of measurements of environmental quality, which include temperature, salinity, and pH of mangrove on Kertomulyo Beach (Table 2), indicate that these locations are suitable habitats for mangrove growth.

3.9. Mangrove Biomass at Kertomulyo Beach

Calculation of the biomass value of mangrove vegetation at the research site shows different biomass values, as shown in Figure 3

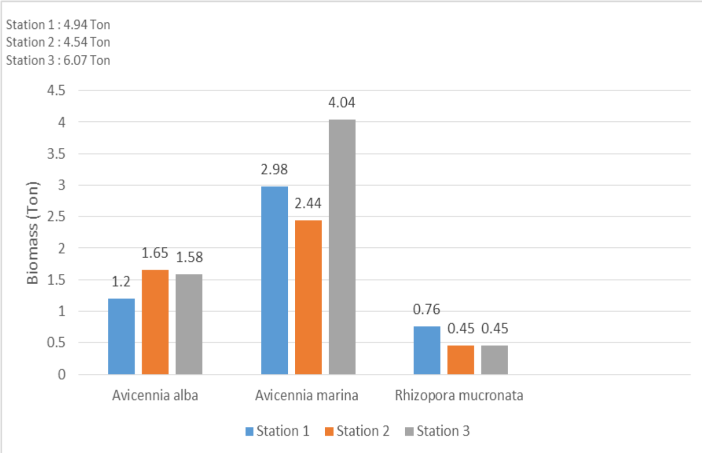

Figure 3. Biomass content of each species at Kertomulyo Beach

The results from figure 2 showed that the highest biomass value was found at station 3 of 6.07 tons/ha and *Avicennia marina* species at the three stations had the highest biomass value of the three species. This difference was caused by the tree diameter (DBH) of *Avicennia marina* which was larger than *Rhizopora mucronata*. *Avicennia marina* had some individuals with a diameter of more than 30 cm in the measurement plot. The presence of trees which have diameter > 30 cm in a land type contributes significantly to the total carbon stock in tree biomass. The more trees that make up a land with a diameter of > 30 cm, the higher carbon stock that will be in the land. This finding is in accordance with the journal report from Mildrexler et al. (2020)[51] stated that large trees play a major role in the accumulated carbon stock of these forests.

3.10. Mangrove Carbon Stock Deposits at Kertomulyo Beach

The total value of carbon stock storage based on the results of the analysis that has been carried out at stations 1, 2 and 3 for each station is presented in Figure 4.

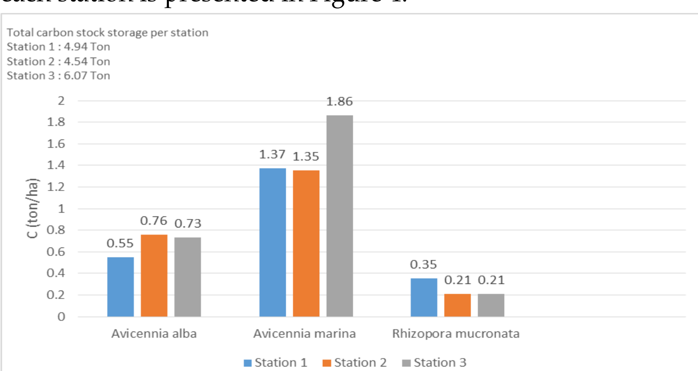

Figure 4. Carbon stock storage per station

Based on Figure 3, it can be explained that the total value of carbon stock storage for each station is 2.27 C/ton for first station, 2.32 C/ton for the second station and 2.80 C/ton for third station 3. The highest carbon was found at station 3. The difference in stored carbon stock was due to the difference in diameter between stands. It means that the larger the diameter of the existing trees on a land, the weight of the tree biomass on the land will be greater. The large weight of biomass will affect the amount of carbon stock in a land. Individual stands that have a diameter more than 30 cm (> 30 cm) are the largest carbon stocks in a land. The above findings are in accordance with the opinion of (Sianturi & Masiyah, 2018)[52]

3.11. Equivalent Stock C to CO_2

After the carbon content value is obtained, then the calculation of the stock C to CO_2 is calculated based on the location of the research station. The results of the calculation can be seen in Table 3.

Table 3. Equivalent stock C to CO_2

Location	Total Carbon (C) (tonnes/ha)	Equivalent Stock C to CO2 (tons/ha)
Station 1	2,27	8,32
Station 2	2,32	8,51
Station 3	2,80	10,27

The table above shows that the carbon content of station 1 is 2.27 tons/ha. It is equivalent to 8.32 tons CO^2/ha. Carbon content at station 2 is 2.32 tons/ha. It is equivalent to 8.51 tons of CO^2/ha and The carbon content at station 3 is 2.80 tons/ha. That is equivalent to 10.27 tons of CO^2/ha. The highest CO^2 absorption value is found at station 3. The high CO^2 absorption value by vegetation in the mangrove area illustrates the ability of mangrove vegetation to fix CO^2 which is then stored in the form of carbon stocks in tree stands.
The results obtained from the research conducted are the differences in the value of CO^2/ha at each station. This could be due to differences in the number of trees, tree species, and distribution of diameter classes. these differences affect the amount of CO2 absorption produced. The large amount of carbon bound in a plant can describe how much the plant's ability to bind CO2 gas from the atmosphere. The statement above is in accordance with what was stated by (Maizaldi et al., 2019) [53] in the results of his research.

4. Conclusions and Recommendations

4.1. Conclusion

Based on the results of the research, it can be concluded that

1. There are three species of mangrove found, namely *Avicennia alba* was 192 individuals, *Avicennia marina* was 259 individuals and *Rhizopora mucronata* was 248 individuals. The average density of all mangrove species from these three stations is 280 individuals/ha. It indicates the low vegetation density (<1000 trees/ha). It means that the mangrove vegetation community is in a disturbed or damaged condition. The highest frequency, closure and IVI were *Avicennia marina* at the three stations. The dominance index value at each research station ranged from 0.3345-0.3459 (medium), the diversity index value (H') ranged from 1.0789-1.0968 (medium (1<H'<3)) and the index value evenness (E) ranged from 0.9821 to 0.9984 (high).
2. The range of temperature, pH and salinity at each observation station is in accordance with the conditions of the mangrove habitat so that it supports plant growth and

development.
3. Biomass, Carbon Content and Equivalent Stock of C to CO_2 from observations in the mangrove area of Kertomulyo Beach which has the highest value is at station 3.

4.2. Recommendation

1. It is very necessary to disseminate information to the public about the importance of maintaining mangrove forests as carbon storage plants especially in the mangrove area of Kertomulyo Beach.
2. It is needed to further research to determine the carbon contained in undergrowth, dead wood, and soil organic matter. This follow-up research is to obtain complete information about the stored carbon in Kertomulyo Beach

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