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Species diversity and composition, and above-ground carbon of mangrove vegetation in Jor Bay, East Lombok, Indonesia

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Abstract. *Zulhalifah, Syukur A, Santoso D, Karnan. 2021. Species diversity and composition, and above-ground carbon of mangrove vegetation in Jor Bay, East Lombok, Indonesia. Biodiversitas 22: 2066-2071.* Mangroves play a very important role to mitigate global warming. This study aimed to assess the species diversity and composition as well as the above-ground biomass and carbon content of mangroves in Jor Bay (*Teluk Jor*), Lombok Island, Indonesia. A purposive sampling method was implemented using transects and square plots as data collection techniques. The data was analyzed to reveal the frequency, density, dominance, above-ground biomass, and carbon content. The results of this study found seven mangrove species, namely *Avicennia marina, Ceriops tagal, Rhizophora apiculata, Rhizophora stylosa, Sonneratia alba, Sonneratia caseolaris*, and *Lumnitzera racemosa*. In general, *Sonneratia alba* was the most important species in terms of frequency, density, and dominance followed by *Rhizophora apiculata*. In total, mangrove vegetation in Jor Bay stored 697.45 ton C/ha, or equivalent to carbon monoxide uptake of 2559.63 CO^2/ ha. In accordance with species composition, *Sonneratia alba* had the largest contribution to total carbon content with 453.76 tons C/ha), followed by *Rhizophora apiculata* with 74.47 tons C/ha. These findings suggest that mangrove vegetation in Jor Bay stored large amount of carbon in the form of above-ground biomass, implying the importance to preserve this area for carbon conservation.

Keywords: Conservation, content of carbon, mangrove species, mangroves

INTRODUCTION

Carbon emissions have been a major concern worldwide since their rapid increase in the atmosphere which triggers global warming (Florides et al., 2009; Hansen et al. 2013; Shakun et al. 2021). Global warming is the condition of warmer climate of the earth compared to the historical condition due to the accumulation of greenhouse gases, such as CO_2 (around 50%), chlorofluorocarbon (CFC, 25%), methane gas (10%), and other gases (Anderson et al. 2016; Kweku et al. 2017). Nonetheless, the impacts of global warming could be reduced through organic carbon sequestered from photosynthesis and stored in woody biomass, such as mangrove forest tree stands (Estrada et al. 2014; Santos et al. 2017; Virgulino-Júnior et al. 2020).

Mangrove forests are among ecosystems with the richest in carbon content globally (Alongi 2012), with most of the carbon stored underground (Kristensen et al. 2008; Mcleod et al. 2011). Several studies have presented the carbon cycle in mangrove forests and the primary production of synthesis, biomass, litter production, decomposition, carbon emissions, and other variables from them (Bouillon et al. 2008; Breithaupt et al. 2012). Mangroves can store more carbon than terrestrial forests (Alemaheyu et al. 2014; Banuwa et al. 2019; Iksan et al. 2019). Each mangrove species has a different capacity for storing carbon (Donato et al. 2011).

While mangrove forests have a crucial role in mitigating climate change, the existing management and utilization are not necessarily resembling the efforts to preserve their persistence (Iksan et al. 2019). For example, in Indonesia, the rate of degradation and loss of mangrove forests is high, almost 50-60%, which is caused by anthropogenic activities, such as logging, settlements, mining, salt ponds, fisheries, and other industrial projects (Malik et al. 2015; Murdiyarso et al.2015; Ilman et al.2016; Malik et al. 2017). These problems have caused the management of mangroves for the conservation of coastal areas to become very complicated.

One parameter commonly used to assess the success in mangrove management and conservation is the diversity of fauna associated with mangrove species (Idrus et al. 2019a). An example from ecological aspect highlights the presence of mangroves that have vital function in the connectivity of the diversity of fish species associated with seagrass (Syukur et al. 2021). In some cases, the management and conservation of mangrove ecosystems would involve reforestation programs to ensure that the mangroves are in good condition and grow continuously, such as in Pasar Banggi, Rembang District, Indonesia (Saputro et al. 2019).

In other instances, the success of mangrove revegetation can be seen from social aspect through how local communities obtain livelihoods from the mangrove ecosystem (Idrus et al. 2019a). While some indicators have been explored to assess the sustainability of mangrove

conservation as mentioned above, another indicator that can be used is carbon content in mangrove species.

Studies on carbon content in mangrove species have been rarely conducted, moreover in a lesser-known region such as in Lesser Sunda Islands, including Lombok, Indonesia. Thus, this study aimed to assess the species diversity and composition as well as the above-ground biomass and carbon content of mangroves in Jor Bay (*Teluk Jor*), Lombok Island. The results of this study can be a source of information for the management in the area, especially as an ecological monitoring tool to support mangrove conservation programs.

MATERIALS AND METHODS

Study area and period

The study was conducted in Jor Bay (*Teluk Jor*), East Lombok District, Lombok Island, Indonesia (Figure 1). Jor Bay is located in the southeastern part of Lombok Island. This research was conducted for five months, from January to May 2020. The study location has an area of 61.52 ha (Idrus et al. 2019b), which is a buffer zone of the Mandalika Special Economic Zone on the southern coast of Lombok Island.

Data collection and analysis

Data was collected using transect method. Five locations were selected to establish a line transect with length of 100 m perpendicular to the coastline (Figure 1). In each transect three sample plots (squares) were made so that a total of fifteen plots were made. Plot sizes differed for mangroves for tree, sapling, and seedling categories. Plot size 10 x 10 m for trees (height> 1.5 m), 5 x 5 m for saplings (height> 1.5 m), and 2 x 2 m for seedlings (height ≤ 1.5 m) (Figure 2) with 10 m spacing between squares. In each plot, all mangrove species were recorded and identified along with the number of trees, saplings, and seedlings. The circumference of the tree trunk was measured at 1.3 m from the ground. The data was then analyzed to calculate the frequency, density and area of cover (dominance). An analysis of carbon content was then carried out by calculating the volume and biomass.

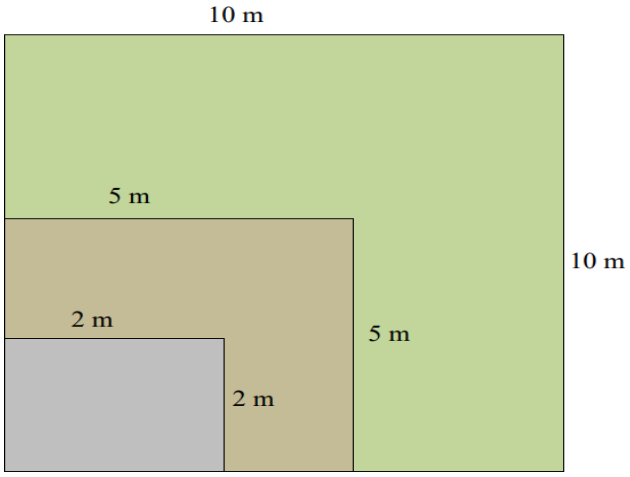

Figure 2. Mangrove plots

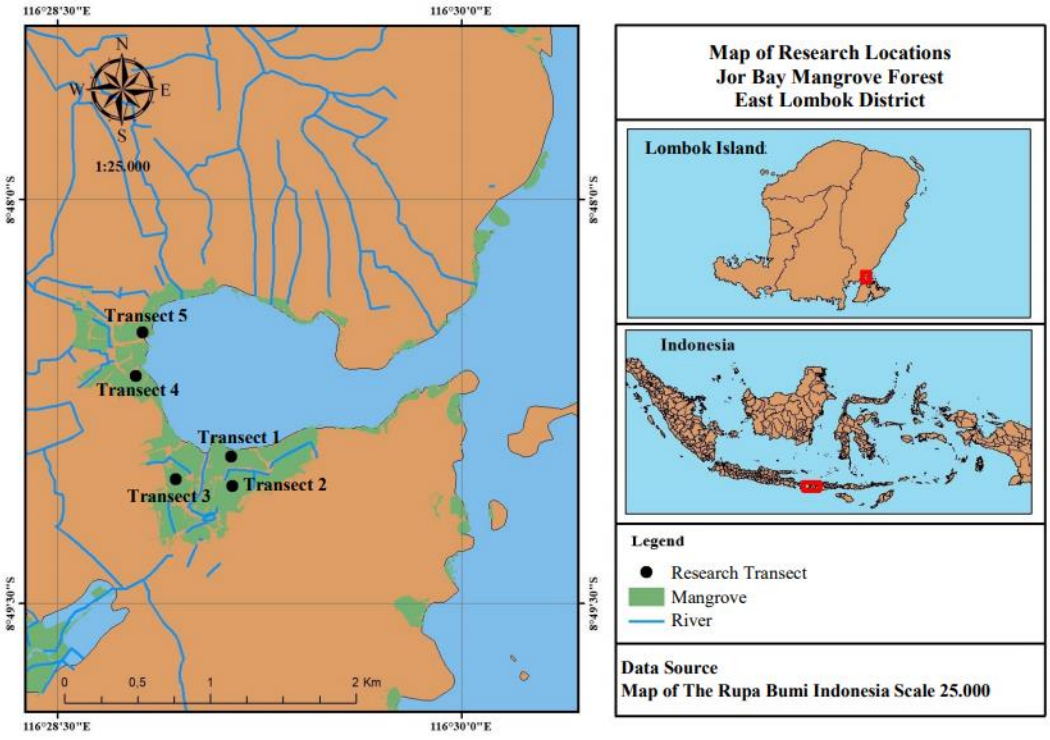

Figure 1. Map of the study sites in Jor Bay, Lombok Island, Indonesia which consisted of five transects

Frequency

Frequency is the intensity of finding a species in a community or ecosystem. For the purposes of plant community analysis, the Relative Frequency of a species (FR-i) was used and calculated using the following formula (Alongi, 2012):

$$FR - i = \frac{\text{Number of Plots Where a Species is Found}}{\text{Sum of All Sample Plots}}$$

Density

Density is the number of individuals per unit area or unit volume. The density of the species can be calculated as K-i and the relative density of each species to the total density can be calculated as KR-i. The formula for calculating Relative Density of a species is as follow:

$$KR - i = \frac{\text{Species Density}}{\text{Density of All Species}} \text{ x } 100\%$$

Coverage area

The coverage area is the proportion between the area covered by plant species and the total habitat area. Relative species closure is the ratio between the area of type i cover and the total area covered for all species. The formula is as follows:

$$CR - i = \frac{\text{Species Closure}}{\text{Cover of All Species}} \text{ x } 100\%$$

The potential carbon content of mangrove species was determined using non-destructive sampling method prescribed by the IPCC (IPCC 2003). The volume of mangrove was first calculated to produce biomass value, which was then converted into carbon content. The volume was calculated using the following formula:

$V = 1/4.\ \Pi.d^2.t.f$

Where:
V : volume of trees (m^3)
Π : constant (3,14)
d : diameter at breast height
t : total height (m)
f : tree shape number (0,6)

Then the biomass was calculated as follow:

Biomass = V x wood density

Where: the wood density of *Rhizophora* = 0.92; *Bruguiera* = 0.91; *Avicennia* = 0.74; *Sonneratia* dan *Xylocarpus* = 0.74; *Ceriops* = 0.85; *Lumnitzera* = 0.88; (Alongi, 2012).

Then the carbon content was calculated following IPCC (2003):

Carbon content = biomass x 50%

The calculation of carbon dioxide (CO_2) absorption used the formula:

CO_2 = Mr.CO/Ar. C x carbon content

Where:
CO_2 : Carbondioxia uptake
Mr : Relative molecule
Ar : Relative atom

RESULTS AND DISCUSSION

Composition of mangrove species

The results of the study found seven natural mangrove species apart from the mangrove vegetation species, namely *Avicennia marina*, *Ceriops tagal*, *Lumnitzera racemosa*, *Rhizophora apiculata*, *Rhizophora stylosa*, *Sonneratia alba* and *Sonneratia caseolaris* (Table 1). The most dominant mangrove species was *Sonneratia alba*, as this species prefers muddy habitats and areas of high salinity to achieve optimal growth (Idrus et al. 2019a). *Lumnitzera racemosa* less dominated since this species has low adaptability in the location. Hence, it can be assumed that environmental conditions have a direct effect on the growth and development of mangrove vegetation. Among all transects, Transect III had the highest abundance of mangrove species which is due to the location having a muddy substrate.

Table 1. The composition and abundance of mangrove species in Jor Bay, Lombok, Indonesia

Species	Transect I	Transect II	Transect III	Transect IV	Transect V	Total individuals
Avicennia marina	-	10	10	-	4	24
Ceriops tagal	-	-	17	-	17	34
Lumnitzera racemosa	-	-	10	-	-	10
Rhizophora apiculata	10	95	-	2	11	118
Rhizophora stylosa	22	-	13	-	-	35
Sonneratia alba	39	10	116	45	22	232
Sonneratia caseolaris	-	-	22	-	-	22

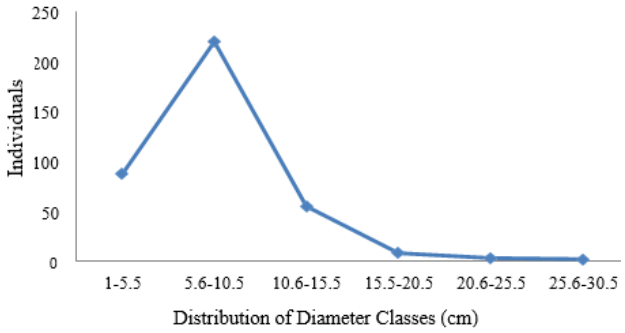

Figure 3. Number of mangrove individuals across diameter classes

Table 2. Relative Frequency (FR), Relative Density (KR) and Relative Dominance (DR) of trees of mangrove species in Jor Bay, Lombok, Indonesia

Species	FR (%)	KR (%)	DR (%)
Avicennia marina	5.26	2.38	3.31
Ceriops tagal	5.26	2.38	1.90
Rhizophora apiculata	10.53	5.95	1.50
Rhizophora stylosa	5.26	2.38	1.86
Sonneratia alba	68.42	83.33	87.51
Sonneratia caseolaris	5.26	3.57	3.93
Total	100	100	100

Table 3. Relative Frequency (FR), Relative Density (KR) and Relative Dominance (DR) of saplings of mangrove species in Jor Bay, Lombok, Indonesia

Species	FR (%)	KR (%)	DR (%)
Avicennia marina	6.90	4.20	7.16
Ceriops tagal	6.90	8.74	5.41
Lumnitzera racemosa	3.45	3.50	1.02
Rhizophora apiculata	27.59	26.57	25.76
Rhizophora stylosa	10.35	3.50	3.56
Sonneratia alba	41.38	46.85	48.34
Sonneratia caseolaris	3.45	6.64	8.76
Total	100	100	100

Table 4. Relative Frequency (FR), Relative Density (KR), and Relative Dominance (DR) of seedlings of mangrove species in Jor Bay, Lombok, Indonesia

Species	FR (%)	KR (%)
Avicennia marina	5.56	10.00
Ceriops tagal	5.56	2.00
Rhizophora apiculata	27.78	37.00
Rhizophora stylosa	22.22	23.00
Sonneratia alba	38.89	28.00
Total	100	100

Diameter distribution

The density of mangroves varied across diameter classes (Figure 2). Mangrove with diameter class of 5.6-10.5 cm had the highest density with 220 individuals, followed by the class of 1-5.5 cm with 80 individuals. While classes of 20.6-25.5 cm, and 25.6-30.5 cm had only three individuals. The mangrove density graph forms an inverted but imperfect J curve. The high and low number of individuals at specific diameter classes illustrates that the forest experienced structural changes. These changes affect the sustainability of the subsequent regeneration of forest stands. The 5.6-10.5 cm diameter class was mostly found in Jor Bay due to tree felling activities where people generally used mangrove wood excessively, or this can be due to uprooted by the wind (Din et al. 2008; Osti et al. 2009). Other destructive activities included the conversion of mangrove land into ponds and illegal logging in the area.

Other studies in the Regional Marine Protected Area in Gili Sulat, East Lombok showed that mangrove vegetation structure resembles an inverted J curve where the seedling had the highest number of individuals while the trees had the lowest (Setiawan and Mursidin 2018). Similarly, mangrove stands on Tanakeke Island, South Sulawesi showed that the number of trees decreases with the curve resembled an inverted J; these characteristics indicate that the forest is balanced (Suwardi et al. 2013). The availability of stands in community-managed forests will form a very high inverted J curve to guarantee the future (Ontorael et al. 2012).

The relative frequency, relative density, and relative dominance of tree categories for each mangrove species are different (Table 2). *Sonneratia alba* had the highest relative frequency (68.42%), followed by the *Rhizophora apiculata* (10.53%), while the four other types were the lowest (5.26%). Similarly, the highest relative density value was seen in *Sonneratia alba* (83.33%), followed by the *Rhizophora apiculata* (5.95%), and the lowest was three other species (2.38%). Again, the *Sonneratia alba* had the highest relative dominance of tree (87.51%), followed by *Sonneratia caseolaris* (3.93%), and the lowest was the *Rhizophora apiculata* (1.50%) (Table 2).

The highest value of relative frequency in the sapling category was *Sonneratia alba* (41.38%), followed by *Rhizophora apiculata* (27.59%), and the lowest were two other species (3.45%) (Table 3). Similarly, the highest relative density was *Sonneratia alba* (46.85%), followed by the *Rhizophora apiculata* (26.57%), and the lowest were other two species (3.50%). Again, *Sonneratia alba* had the highest value of relative dominance (48.34%), and *Rhizophora apiculata* (25,76%) ranked second, and *Lumnitzera racemosa* (1.02%) was the lowest.

The high relative frequency and relative density of *Sonneratia alba* at tree and sapling levels are due to the higher adaptability to environmental factors which support the optimal growth of this species compared to other species. The highest relative dominance of this species is also caused by their ability to obtain more nutrients to ensure that the stem volume is large enough and the canopy is wide, resulting in its dominance over other types; additionally, it also prefers muddy substrates and tolerates high salt level (Ardiansyah et al. 2012; Nurdin et al. 2015; Urrego et al. 2014).

Table 5. Volume, biomass, carbon content and CO_2 uptake of mangrove vegetation in Jor Bay, Lombok, Indonesia

Species	Volume (m^3/ha)	Biomass (ton/ha)	Carbon content (ton C/ha)	Absorption CO_2 (ton CO_2 /ha)
Avicennia marina	2.45	36.72	18.36	67.38
Ceriops tagal	5.64	93.58	46.79	171.72
Lumnitzera racemosa	0.68	15.99	8.00	29.35
Rhizophora apiculata	7.52	148.92	74.47	273.30
Rhizophora stylosa	2.75	58.80	29.40	107.90
Sonneratia alba	66.49	907.52	453.76	1665.30
Sonneratia caseolaris	7.51	127.26	66.67	244.68
Total	93.04	1388.79	697.45	2559.63

At sapling level, *Sonneratia alba* had the highest relative frequency (38.89%), followed by *Rhizophora apiculata* (27.78%) (Table 4). However, the highest relative density was *Rhizophora apiculata* (37%), while *Sonneratia alba* ranked second. The highest relative density of the seedling category of *Sonneratia alba* is likely due to environmental factors that support the distribution of the seed compared to others. On the other hand, the highest relative frequency of *Rhizophora apiculata* at seedling category is because they can survive better in the environment during the juvenile stage than other species (Abino et al. 2014; Mitra et al. 2011).

Biomass and carbon content

The results of the analysis of volume, biomass, carbon content and carbon dioxide uptake are presented in Table 5. *Sonneratia alba* had the highest volume (66.49 m^3/ha) and *Lumnitzera racemosa* was the lowest (0.68 m^3/ha). Similarly, *Sonneratia alba* had the highest biomass value (907.52 m^3/ha), followed by *Rhizophora apiculata* (148.92 m^3/ha), and *Lumnitzera racemosa* being the lowest (15.99 m^3/ha). *Sonneratia alba* had the highest biomass (907.52 ton/ha) and carbon content due to its large trunk diameter and tree height. So that the greater the tree biomass, the greater the carbon absorbed. Thus, the total carbon content in aboveground vegetation in Teluk Jor is 697.45 ton C/ha (equivalent to 2559.63 CO_2/ ha).

Biomass and carbon content in Teluk Jor is higher than those in Bahowo, Bunaken District with biomass of 433.69 ton/ha (equivalent to 748.07 ton of CO_2/ha) (Bachmid et al. 2018) and in Kubu Raya, West Kalimantan with biomass of 438.79 ton/ha (805.68 ton of CO_2/ha) (Prakoso et al. 2017).

Sonneratia alba had the highest tree density value than other trees and, thus, had the highest potential carbon stock. The higher the mangrove density, the greater the carbon content, where the stand density, stand composition and structure, and the quality of the mangrove growth sites affect the increase in biomass and carbon content of mangrove trees. Mangroves' ability to store carbon can reduce the rise in carbon emissions in nature (Alongi, 2020; Dinilhuda et al. 2018; Turner et al.2009;). Mangroves per hectare can store four times as much carbon as other tropical forests worldwide. The mangrove vegetation in Teluk Jor can absorb carbon dioxide of 2559.63 CO_2/ha, equivalent to the carbon dioxide emissions produced by the transportation of 241.46 ton CO_2/ha (Iqbal et al. 2017). Mangrove forests can mitigate climate change by absorbing CO_2 from the atmosphere and oceans at a much higher rate than terrestrial forests (Mcleod et al. 2011). Therefore, mangrove forests are one of the natural resources that must be preserved to reduce the impact of climate change.

In conclusion, mangrove forest resources have made important contributions to the environment. One of them is as a carbon sink. The mangroves in Jor Bay consisted of seven species (*Sonneratia alba*, *Sonneratia caseolaris*, *Rhizophora stylosa*, *Rhizophora apiculata*, *Ceriops tagal*, *Avicennia marina*, and *Lumnitzera racemosa*). *Sonneratia alba* was the most significant species in the studied area, followed by the *Rhizophora apiculata*. The analysis of biomass and carbon content suggests that the mangrove vegetation in Jor Bay has potential capacity in absorbing carbon dioxide.

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