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Vegetation structure, biomass, and carbon of Mangrove Forests in Ambon Bay, Maluku, Indonesia

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Abstract. *Mangrove forests serve a substantial part in coastal areas as high-carbon-storage woody vegetation ecosystems that grow on muddy and anaerobic soils. This study determined the species composition and estimated the biomass production and storage of carbon in Ambon Bay mangrove forests. Vegetation surveys for species composition were conducted using the square plot technique by making standard observation plots for density, frequency, dominance, and important value index data analysis. We used Allometric equations and the Loss-on-ignition method to calculate the biomass and soil carbon. Vegetation surveys revealed eight species of tree-habitus mangroves, and* Sonneratia alba *was a mono-dominant species with an important value index of more than 100%. The study revealed the highest average potential of biomass and carbon in Passo Village with AGB 280.47±168.94 Mg ha^{-1}, BGB 83.06±55.1 Mg ha^{-1}, and sediment carbon 320.03±106.97 Mg C ha^{-1}. The carbon stock of the mangrove forest in Ambon Bay was estimated at 400.67±166.25 Mg C ha^{-1}. We conclude that mangrove forest carbon stores in Ambon Bay had relatively high values. Passo Village has the largest carbon store compared to other locations in the Ambon Bay mangrove forest.*

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INTRODUCTION

Mangrove forests are woody ecosystems with a high carbon content found in intertidal areas. Mangrove growth is influenced by salinity and muddy habitats and occurs under anaerobic conditions due to tides, resulting in mangroves having a unique biomass allocation pattern. A large amount of mangrove carbon fixed can accumulate and be stored over a long term (Lovelock and Duarte 2019; Bindu et al. 2020). Mangrove ecosystems absorb and preserve enormous amounts of organic carbon in their biomass and sediment (Kusumaningtyas et al. 2019). In addition to potentially high carbon sequestration, mangroves also provide timber, non-timber forest products (NTFPs), and support fishery commodities for both direct benefits. They also provide indirect benefits such as water filters, disaster protection (including tsunamis, storms, erosion barriers, and rising sea levels), and other benefits such as breeding grounds, spawning, nesting, and nourishment for marine fauna (Barbier et al. 2016). Mangrove forests are also crucial in mitigating climate change. They are one of the most carbon-rich ecosystems, with four times tropical forests' productivity and sequestration levels (Alongi 2014; Hamilton and Lovette 2015; Giri et al. 2021).

Mangrove forests mitigate the effects of atmospheric CO_2 concentrations by acquiring and storing C stocks in the carbon pool ecosystem, such as above-ground biomass (AGB), below-ground biomass (BGB), necromass, and soil carbon (Taju and Marelign 2022). Approximately 45–50% of mangrove plant dry matter consists of carbon (Hiraishi et al. 2014). Moreover, information on forest carbon potential is needed to maintain forest sustainability in an area (Ulqodry et al. 2020). Several methods for determining forest biomass and carbon have been developed, including the use of allometric equations. Over several decades, allometric equations for mangrove species have been developed to estimate biomass and growth using the relationship between biomass and diameter at breast height (DBH) (Komiyama et al. 2005). Indonesia has approximately 3.4 million ha of mangrove forests, with Maluku Province has mangrove potential ranked in the top five provinces with the broadest mangrove crown density class (174,565 ha). However, the most extensive abrasion, reaching 1,425 ha, threatens its existence (KLHK 2021).

Maluku Province is an archipelago consisting of large and small islands, with mangrove forests growing along the coastline, bays, lagoons, and estuaries. In particular, the Ambon Bay mangrove forest is estimated to have an area of ±52 ha, with a damage rate of 10–15% (The government of Ambon City 2003 in Madiama et al. 2016). Landsat-7 ETM satellite imagery data analysis in 2006 revealed that the area of mangrove forests on the coast of Ambon Bay had decreased to 34 ha (Suyadi 2017). Rotua (2013) also shows that mangrove forests in Ambon Bay have decreased at a rate of 2.98 ha/year due to land conversion and other land use. High potential abrasion and anthropogenic disturbances have caused a continuous decline in the mangrove forests in the Ambon Bay area. Investigating vegetation structure classification, diversity, distribution pattern, and regeneration status is essential for improving sustainable ecological management and conservation of mangrove ecosystems.

METHOD

Study Area

This research was conducted from November 2021 to January 2022 in four villages in Ambon Bay, Maluku, Indonesia: Waiheru, Nania, Negeri Lama, and Passo Villages (Figure 1) are mangrove growing areas. Based on satellite image analysis, these four villages have different mangrove areas. Location 1, Waiheru Village, has a mangrove area of ±18 ha-^{1}, Location 2, Nania Village has a mangrove area of ±3 ha-^{1}, Location 3, Negeri Lama Village has a mangrove area of ±2 ha-^{1}, and Location 4, Passo Village has a mangrove area of ±23. ha-^{1}.

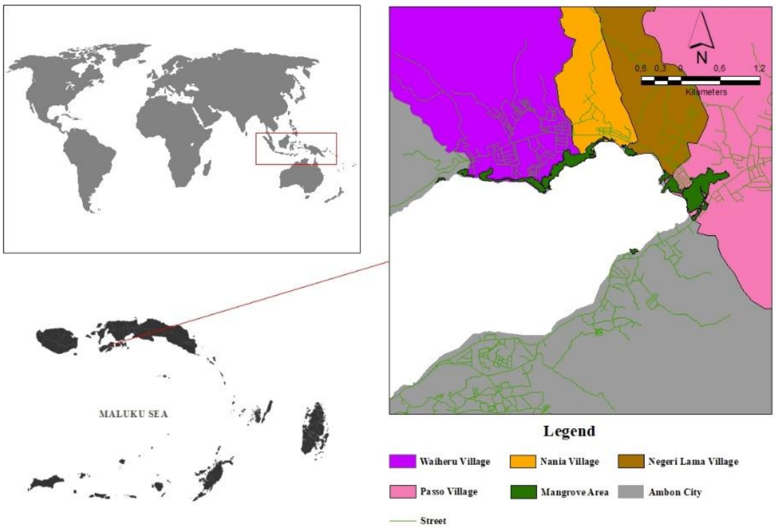

Figure 1 Research location

Sampling Design

Data were collected using a purposive sampling technique. A total of 49 square plot surveys were conducted at four locations. Vegetation structure was analyzed with the following criteria: (a) seedlings (height < 1.5 m) were taken from a 2 × 2 m square plot, (b) saplings (> 1.5 height and < 10 cm in diameter) were taken from a 10 × 10 m square plot, and (c) trees (DBH ≥ 10 cm) were taken from a 20 × 20 m square plot (Figure 2). This study used an allometric method to estimate the mangrove forest biomass. The data collected included species name, number of individual species, and tree DBH. Soil sampling was performed at 0–30 cm depth in each observation plot.

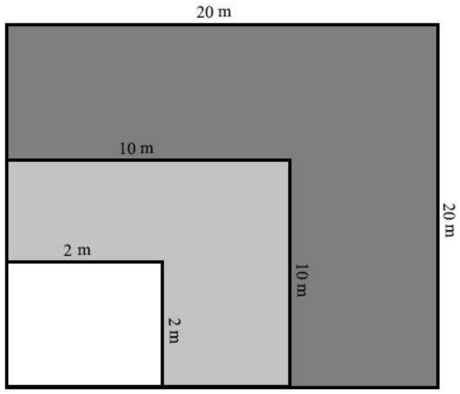

Figure 2 vegetation survey sample plot

Data Analysis

Vegetation Structure, Diversity Index, Species Richness, and Evenness Index

The ecological indicators of density, dominance, and relative frequency were calculated to determine the vegetation information in each village. The importance value index indicates the dominance of the species (Opuni-Frimpong et al. 2021). Density (D), frequency (F), basal area (BA), and importance value index (IVI) were calculated using the following formula:

$$\text{D (ind ha}^{-1}\text{)} = \frac{Number\ of\ individuals\ of\ a\ species\ (ind)}{Sample\ plot\ area\ (ha)}$$

$$\text{RD} = \frac{Density\ of\ a\ species}{Density\ of\ all\ species} x100$$

$$\text{F} = \frac{Number\ of\ plots\ found}{Total\ number\ of\ plots}$$

$$\text{RF} = \frac{Frequency\ of\ a\ species}{Frequenci\ of\ all\ species} x100$$

$$\text{BA (m}^{2}\text{ ha}^{-1}\text{)} = \frac{Basal\ area\ of\ a\ species}{Sample\ plot\ area\ (ha)}$$

$$\text{RBA (\%)} = \frac{Basal\ area\ of\ a\ species}{Basal\ area\ of\ all\ species} x100$$

IVI (%) = RD + RF (seedling growth stage)

IVI (%) = RD + RF + RBA (tree and sapling growth stage)

Vegetation diversity (H') was calculated using the Shannon-Wiener index (Shannon and Weaver 1949), species richness (R1) was calculated using the Margalef index (Magurran 1988), and species evenness (E) was calculated using the Pielou evenness index (Pielou 1966). The following formula calculates the three indices used:

$$H' = -\sum_{i=1}^{s} \frac{ni}{n} \ln(\frac{ni}{N})$$

Where: H' is low (< 1); H' is moderate (1 < H' ≤ 3); and H' is high (> 3)

$$R1 = \frac{(S-1)}{\ln(N)}$$

: R1' is low (< 3.5); R1 is moderate (3.5–5.0); and R1 is high (> 5.0)

$$E = \frac{H\prime}{S}$$

Where: E is low (0–0.30); E is moderate (0.31–0.60); and E is high (0.61–1.0)

Estimation of Biomass and Carbon

Allometric equations are non-destructive methods for estimating total or partial individual tree weight based on observable tree characteristics such as tree height and DBH (Komiyama et al. 2005). Soil carbon was analyzed using the loss-on-ignition (LOI) method of Ben-Dor and Banin (1989). According to the IPCC equation (2008), carbon is estimated from biomass, which states that 47% of biomass is carbon. The allometric equations used to estimate the stand biomass are listed in Table 1.

Table 1 Mangrove allometric equation

No	Species	Allometric equations	References
Above Ground Biomass (AGB)			
1	*Aegiceras corniculatum*	$B = 0.168*\rho*D^{2.47}$	Clough and Scott (1989)
2	*Avicennia officinalis*	$B = 0.168*\rho*D^{2.47}$	Clough and Scott (1989)
3	*Bruguiera cylindrica*	$B = 0.251*\rho*D^{2.46}$	Komiyama et al. (2005)
4	*Rhizophora apiculate*	$B = 0.235*D^{2.42}$	Ong et al. (2004)
5	*Rhizophora mucronate*	$B = 0.168*\rho*D^{2.47}$	Clough and Scott (1989)
6	*Rhizophora stylosa*	$B = 0.105*D^{2.68}$	Clough and Scott (1989)
7	*Sonneratia alba*	$B = 0.251*\rho*D^{2.46}$	Komiyama et al. (2005)
8	*Xylocarpus moluccensis*	$B = 0.168*\rho*D^{2.47}$	Clough and Scott (1989)
9	General Equation	$B = 0.168*\rho*D^{2.47}$	Clough and Scott (1989)
Below Ground Biomass (BGB)			
1	General Equation	$B = 0.199*\rho^{0.899}*D^{2.22}$	Komiyama et al. (2005)

ρ = wood density (g cm^{-2}); B = biomass (kg m^{-2}); DBH = diameter at breast height (cm)

RESULTS

Vegetation Composition and Structure

The vegetation composition recorded in four villages in Ambon Bay (Waiheru, Nania, Negeri Lama and Passo) revealed 5 mangrove families, namely Acanthaceae, Lythraceae, Meliaceae, Primulaceae, and Rhizophoraceae (Table 2). At the research location in Waiheru Village, 8 species of mangroves were found such as *A. corniculatum, A. officinalis, B.cylindrica, R. apiculata, R. mucronata, R. stylosa, S. alba,* and *X. moluccensis*. In Nania Village, 5 species were found: *A. corniculatum, B. cylindrica, R. mucronata, S. alba,* and *Xylocarpus moluccensis*. Four species were found in Negeri Lama Village, 4 species were found: *A. corniculatum, B. cylindrica, R. mucronate,* and *S. alba.* Whereas, in Passo Village, 6 species were found: *A. corniculatum, B. cylindrica, R. apiculata, R. mucronata, S. alba,* and *X. moluccensis*.

The result showed Negeri Lama Village had the highest density of seedlings (21,250 ind ha^{-1}), while Waiheru Village had the lowest density (11,125 ind ha^{-1}), where the seedlings of *R. mucronata* and *S. alba* were found to be the dominant species (IVI 33.52–89.01%). The highest sapling density was found in Waiheru Village (280 ind ha^{-1}), while the lowest sapling density was found in Nania Village (60 ind ha^{-1}), where *B. cylindrica* saplings were dominant (IVI 114.31–158.12%). The highest tree density was found in Passo Village (576.25 ind ha^{-1}), and the lowest density was found in Nania Village (455 ind ha^{-1}), where *S. alba* and *R. mucronata* were found to be the dominant species (IVI 38.30–227.28%).

Table 2 Density, frequency, basal area, and IVI of mangrove species at the study site

Loc	**Species**	**Seedling**			**Sapling**				**Tree**			
		D ind ha^{-1}	**F**	**IVI %**	**D ind ha^{-1}**	**F**	**BA m^2 h^{-1}**	**IVI %**	**D ind ha^{-1}**	**F**	**BA m^2 h^{-1}**	**IVI %**
Waiheru	*A. corniculatum*	125	0.05	5.47	20	0.2	0.03	28.26	2.50	0.10	0.03	4.21
	A. officinalis	125	0.05	5.47					6.25	0.10	0.14	5.60
	B. cylindrica	2,375	0.20	38.74	140	0.4	0.40	130.71	26.25	0.50	0.42	25.33
	R. apiculata	125	0.40	5.47	10	0.1	0.01	13.56	18.75	0.25	0.32	14.46
	R. mucronata	3,000	0.05	61.75	40	0.3	0.13	51.76	186.25	0.60	4.50	84.40
	R. stylosa								1.25	0.05	0.01	2.09
	S. alba	5,375	0.40	83.10	55	0.2	0.14	53.90	147.50	0.90	11.62	121.25
	X. moluccensis				15	0.1	0.06	21.80	90.00	0.40	2.51	46.44
	Total	11,125	1.15	200	280	1.2	0.78	300	478.75	2.9	19.55	300
Nania	*A. corniculatum*	4,000	0.40	59.34								
	B. cylindrica	500	0.20	18.13	20	0.2	0.11	144.31				
	R. mucronata	6,000	0.60	89.01	40	0.2	0.07	155.69	255	0.6	5.44	118.78
	S. alba	2,500	0.20	33.52					135	0.8	15.07	149.56
	X. moluccensis								65	0.2	1.05	31.67
	Total	13,000	1.4	200	60	0.4	0.18	300	455	1.6	21.56	300
Negeri lama	*A. corniculatum*				50	0.3	0.15	64.59				
	B. cylindrica	10,000	0.25	67.06	100	0.5	0.54	158.12	18.75	0.50	0.32	34.42
	R. mucronata	5,625	0.5	66.47	25	0.3	0.04	37.47	81.25	0.25	1.21	38.30
	S. alba	5,625	0.5	66.47	25	0.3	0.06	39.82	450	1.00	11.54	227.28
	Total	21,250	1.25	200	200	1.3	0.79	300	550	1.75	13.07	300
Passo	*A. corniculatum*	2,000	0.10	19.91	40	0.3	0.08	65.95				
	B. cylindrica	5,125	0.25	50.43	70	0.3	0.28	129.29	42.5	0.60	0.60	22.69
	R. apiculata								1.25	0.01	0.01	2.44
	R. mucronata	4,125	0.50	69.05	15	0.1	0.04	26.60	232.5	5.62	5.62	92.08
	S. alba	8,000	0.20	60.61	5	0.1	0.01	10.58	282.5	19.58	19.58	164.46
	X. moluccensis				30	0.3	0.12	67.58	17.5	0.59	0.59	18.33
	Total	19,250	1.05	200	160	1	0.53	300	576.25	26.41	26.41	300

loc: location, D: density, F: frequency, BA: basal area, IVI: important value index

Diversity, Richness and Evenness of Mangrove Species

The species diversity, richness, and evenness of the mangrove forests the mangrove forests in four villages in Ambon Bay (Waiheru, Nania, Negeri Lama and Passo) are presented in Table 3. Diversity for all mangrove growth stages in the four villages showed low to moderate species diversity (0.63–1.35), while species richness showed low species richness (0.45–1.44). Moreover, the species' evenness showed moderate to high (0.51–0.60 and 0.63–0.96).

Table 3 Diversity, richness and evenness of mangrove species in mangrove forests in Ambon Bay, Maluku

GS	**Location**											
	Waiheru site			**Nania site**			**Negeri lama site**			**Passo site**		
	H’	**R1**	**E**	**H’**	**R1**	**E**	**H’**	**R1**	**E**	**H’**	**R1**	**E**
Seedling	1.18	1.11	0.66	1.16	0.92	0.83	1.05	0.57	0.96	1.28	0.60	0.92
Sapling	1.4	1.24	0.78	0.63	0.91	0.91	1.21	1.44	0.87	1.35	1.15	0.83
Tree	1.4	1.18	0.67	0.96	0.44	0.87	0.56	0.45	0.51	1.02	0.48	0.63

Note: GS: Growth stage, H': species diversity index, R1: species richness index, E: species evenness index

Tree Biomass

The highest tree biomass was found in Passo sites with AGB (280.47±168.94 Mg ha^{-1}) and BGB (83.06 ±55.1 Mg ha^{-1}) (Figure 3). *Sonneratia alba* (80%) contributed the most to AGB and BGB at the Passo sites. In contrast, the lowest tree biomass was found in Negeri Lama Village in AGB (79.27±23.11 Mg ha^{-1}) and BGB (36.02±8.91 Mg ha^{-1}). *Sonneratia alba* (88%) also contributed the most to the AGB and BGB at the Negeri lama site.

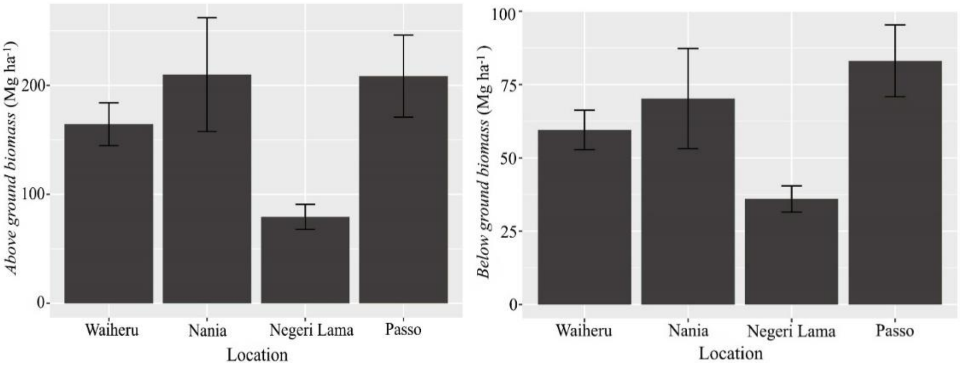

Figure 3 AGB and BGB of mangroves in the Ambon Bay mangrove forest, Maluku

Soil Carbon

The soil carbon rates in the four villages are shown in Figure 4. The bulk density (BD) value in the four villages were 0.27 g cm^3 in Waiheru Village, 0.22 g cm^3 in Nania Village, 0.29 g cm^3 in Negeri Lama Village, and in Passo Village 0.26 g cm^3. The greatest amount of soil carbon in the four villages was found in Passo Village (320.03±106.97 Mg C ha^{-1}), while the lowest was found in Negeri Lama Village (226.49±92.40 Mg C ha^{-1}).

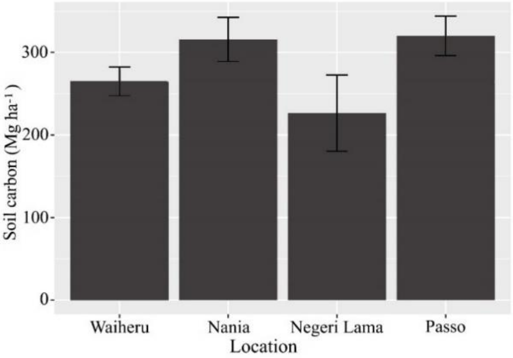

Figure 4 Soil carbon in the Ambon Bay mangrove forest, Maluku

Carbon Stock

Carbon stocks were calculated by following the equation from IPCC (2008), which states that 47% of biomass is carbon, carbon from aboveground biomass (AGC), and carbon from below-ground biomass (BGC). Furthermore, the results of the soil carbon (SOC) analysis were summed with carbon from biomass to determine the overall carbon stock of the study site. The highest average carbon stocks of mangrove forests showed in Figure 5, were found in Passo Village of AGC (97.98±79.40 Mg ha^{-1}), BGC (39.04±25.85 Mg C ha^{-1}), and SOC (320.03±106.98 Mg C ha^{-1}). In contrast, the lowest average carbon was found in Nania Village of AGC (37.25±10.86 Mg ha^{-1}), BGC (16.93±4.18 Mg C ha^{-1}), and SOC (226.49±92.40 Mg C ha^{-1}). In addition, SOC had the highest percentage of carbon storage (70–80%).

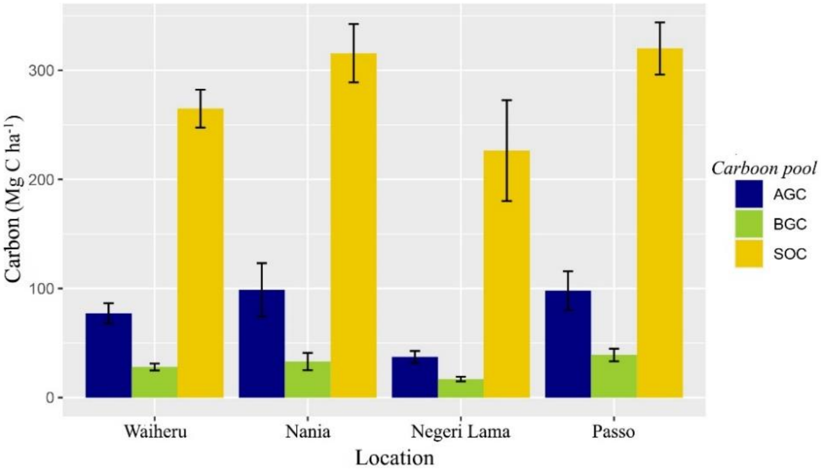

Figure 5 Total carbon in the mangrove forest of Ambon Bay, Maluku

DISCUSSION

The diversity of mangrove species in Ambon Bay, Maluku, was categorized as low, accounting for only 8% of the total mangrove trees in Indonesia. Kusmana (2009) reported 89 species of mangrove trees in Indonesia. *S. alba* was a mono-dominant tree species with the highest density, frequency, dominance, and importance index. *S. alba* is a mangrove pioneer species in the Indo-Pacific, spreading throughout the seashore of various mangrove ecosystems (Jenoh et al. 2016). *S. alba* is also a species with a high tolerance to salt that can grow in the seaward zone compared to other species (Hasegawa et al. 2014). Furthermore, compared to other species in several mangrove ecosystems, *S. alba* showed a comparatively large basal area (Mullet et al. 2014; Natividad et al. 2015).

The abundance of seedlings can be influenced by seed dispersal and the quality of microsites, such as soil fertility, which may promote regeneration through the germination of numerous tree seeds (Khumbongmayum et al. 2006). Seedlings found at the study site had a higher density than saplings and trees, which showed good potential regeneration, with a total of seedlings (11,125–21,250 ind ha^{-1}), saplings (60–280 ind ha^{-1}), and trees (455–570 ind ha^{-1}). Seedling density of 5,000–10,000 ind ha^{-1} have good mangrove forest regeneration potential (Rasquinha and Mirshra 2021). In general, the growth rate of seedlings has a higher density (> 1,000 ind ha^{-1}) than that of saplings and trees; tree densities decline with increasing forest age (Goessens et al. 2014; Azman et al. 2021).

The result showed *Sonneratia alba* (IVI > 100%) was known to have the highest dominance in the four villages compared to other species because it has a large diameter and is also influenced by the age of the plant. *Sonneratia alba* is the dominant monospecies in mangroves in Ambon Bay, Maluku. Mangrove species with a high IVI can illustrate the existence of species that are more stable in maintaining their growth or have the ability to adapt and tolerate environmental conditions (Dendang and Handayani 2015).

The diversity index is broadly divided into two types: the evenness index or species dominance, which describes how individuals are distributed among various species, and species richness, which indicates how many species are found (Kaper and Rousseau 2019). The results showed that species diversity, richness, and evenness in mangrove forests in Waiheru Village, Nania Village, Negeri Lama Village, and Passo Village were classified as moderate to low (Table 3). The biomass potential and carbon sequestration of mangrove forests are affected by species variety, richness, and evenness (MacKenzie et al. 2016; Motlagh et al. 2020; Rasquinha and Mishra 2021).

Sonneratia alba was found to make a very high contribution to biomass production in the four villages. This species is known to have a specific gravity of wood (0.53 g cm^{-2}), which is smaller than *Rhizophora mucronata* (0.70 g cm^{-2}) and *Bruguiera cylindrica* (0.74 g cm^{-2}) (Komiyama et al. 2005). This species was found to have a larger diameter (10–115.9 cm) and is the only type of mangrove that can grow at a DBH of more than 50 cm. A larger diameter is strongly suspected to be one of the main factors for the high biomass of this type. Changes in species composition due to natural or anthropogenic disturbances can considerably impact forest carbon stocks (Rao et al. 2021). Furthermore, an increase in biomass productivity can occur because of selection, in which the dominant species is selected because of natural disturbances and contributes to the highest productivity in the community (Cheng et al. 2018; Zuppinger-Dingley et al. 2014).

It is known that biomass productivity is significantly affected by diversity depending on species composition and environmental factors (Fichtner et al. 2018; Li et al. 2019). In addition, species richness in a community is in line with increased biomass, which can be affected by the niche effect, in which species have certain niches that allow them to use resources more efficiently, thereby increasing biomass production (Turnbull et al. 2013). Tree biomass is affected by specific gravity, diameter, wood density, and ecological variables such as soil fertility and salinity (Kusmana and Watanabe 1992; Virgulino-Júnior et al. 2020). Trees with a large diameter and canopy will produce large biomass and affect the increase in litter productivity and organic matter in sediments, thereby creating an optimal habitat for increasing mangrove biomass, subsequently increases mangrove carbon (Wang et al. 2019). The standard range of above-soil biomass values in the tropics is 8.7 Mg ha^{-1} to 384 Mg ha^{-1} (Hiraishi et al. 2014).

Soil carbon (SOC) in Negeri lama, Nania, Waiheru, and Passo sites was classified as having high SOC content (226 Mg ha^{-1}, 256 Mg ha^{-1}, 298 Mg ha^{-1} and 320 Mg ha^{-1}). The SOC value may be higher at 0–1 m, considering that SOC research is limited to a depth of 30 cm. According to Siringoringo (2014), significant changes in soil carbon storage occur at 0–30 cm depth. The average soil carbon value in global mangrove forests at a depth of 1 m is estimated to be 237 Mg C ha^{-1} (Ouyang and Lee 2020). Measurement of bulk density (BD) is important to estimate SOC, research data in various regions conducted on 4,800 land measurements have an average value of BD (0.68 g cm^{3}) and (0.62 g cm^{3}) (Sanderman 2017), this indicates lower BD at the study site (0.22–0.29 g cm^{3}). SOC differences can be influenced by biomass productivity, and a productive tree encourages the accumulation of organic matter through litter production, which can increase SOC stocks by developing pneumatophores and stable roots aggregates (Lange et al. 2015). In addition, litter, necromass, and organic matter sources also greatly affect SOC in mangrove forests. According to Rey et al. (2011), plant residues of decomposition produced 1.69 Mg C ha^{-1} of mangrove SOC. This amount was greater than tropical forests, which only contributed 0.49 Mg C ha^{-1} for SOC.

Carbon storage from biomass comprises 21% of the total carbon stock in mangrove forests (Howard et al. 2014). In this study, AGC and BGC contributed to more than 21% of the total carbon content. Underground carbon sources provide for more than half of the total carbon store and sometimes reach 90% of the total carbon stock of mangrove ecosystems (Donato et al. 2011). Carbon from the SOC at the study site had the highest contribution (> 80%). Carbon from tree stands and soil in the four villages shows the importance of mangrove forest areas in climate change mitigation. The ability of mangroves to store carbon can reduce natural carbon emissions (Alongi 2020; Dinilhuda et al. 2018).

Table 4 demonstrates the total carbon storage in mangrove forests around the world. Mangrove forests in Ambon Bay, Maluku, showed a relatively high carbon content (406.21±175.22 Mg C ha^{-1}). This amount exceeded the average global mangrove carbon (386 Mg C ha^{-1}). The causes of differences in mangrove forest carbon stocks in various regions include differences in stand age, tree composition, species diversity, and geographical environment (Schile et al. 2017; Liu et al. 2018). The ability of mangrove ecosystems to reduce and store carbon is highly dependent on biophysical variables and geomorphic conditions (Rovai et al. 2018).

Table 4 Carbon stocks of mangrove forests in several areas

Location	**AGC (Mg ha^{-1})**	**BGC (Mg ha^{-1})**	**Soil C (Mg ha^{-1})**	**C Total (Mg ha^{-1})**	**Reference**
Ambon Bay Indonesia	84.64±61.09	32.10±20.44	289.45±93.78	406.21±175.22	This study
Tiwoho, Indonesia	182.20±41.10	70.80 ±17.90	509.50±70.60	762.60±128.30	Cameron et al. (2019)
Bintan, Indonesia	260.58±41.01	108.78±20.86		369.36±61.87	Camacho et al. (2011)
North Hainan, China	66±39	28±10	147±116	242±153	Bai et al. (2021)
North Sumatra, Indonesia	92.26±22.65	30.08±6.82	127.49±33.21	249.83±62.68	Hanggara et al. (2021)
West coast of the Gulf, Thailand	135.85±104.36	56.38±42.39	52.29±25.87	311.34±150.58	Swangjang and Panishkan (2021)
Kerala, India	40.11±7.97	18.45±3.11	81.26±10.16	139.82±10.67	Harishma et al. (2020)
Word mangrove				386 (55 – 1,376)	Hiraishi et al. (2014)

CONCLUSION

Analysis of the mangrove vegetation observed at four sites in Ambon Bay (Waiheru, Nania, Negeri lama, and Passo) resulted in a total enumeration of eight species belonging to five mangrove families: Acanthaceae, Lythraceae, Meliaceae, Primulaceae, and Rhizophoraceae. The amount of biomass and total carbon storage in the mangrove forests in Ambon Bay was quite high. The total biomass ranged from 18.08 Mg ha^{-1} to 1054.47 Mg ha^{-1}, and the total carbon ranged from 146.25 Mg C ha^{-1} to 1027.75 Mg C ha^{-1} for the highest, moreover the soil sediment ranges from (70–80%). The highest amount of biomass and carbon stocks were in the mangrove forest of Passo Village AGB (208.47±168.94 Mg ha^{-1}), BGB (83.06±55.01 Mg ha^{-1}), AGC (97.98±79.40 Mg C ha^{-1}), BGC (39.04±25.85 Mg C ha^{-1}), and SOC (320.03±106.98 Mg C ha^{-1}). In contrast, the lowest biomass and carbon storage were found in Negeri Lama Site, AGB (79.27±23.11 Mg ha^{-1}), BGB (36.02±8.91 Mg ha^{-1}), AGC (37.26±10.86 Mg C ha^{-1}), BGC (16.93±4.18 Mg C ha^{-1}), and SOC (229.49±92.40 Mg C ha^{-1}).

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