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Estimation of aboveground carbon stock based on mangrove zones in Ijo River Estuary, Ayah Village, Kebumen, Indonesia

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Abstract. *Ningtyas SRA, Mu'ali AYF, Putri DNAR, Silaningtyas NW, Tsabita FA, Aprianto MK, Sari SP, Fauziyyah MD, Nugraheni RS, Juniati SD, Isa MN, Nofitasari H, Sutarno, Sugiyarto, Indrawan M, Yap CK, Budiharta S, Setyawan AD. 2023. Estimation of aboveground carbon stock based on mangrove zones in Ijo River Estuary, Ayah Village, Kebumen, Indonesia. Indo Pac J Ocean Life 7: 148-155.* The increasing concentration of greenhouse gases, including carbon dioxide in the atmosphere is the driver of global warming which triggers climate change. One strategy to mitigate climate change is reducing carbon emissions and increasing the carbon stock. Mangrove forest is recognized as the largest carbon sink on the Earth, therefore, the conservation and restoration of mangrove forest are increasingly promoted as an effective way to tackle climate change. While many studies assess the carbon stock of mangrove forests, a context-specific assessment is needed to enrich the existing studies in this field. This study aimed to investigate the aboveground carbon stored in vegetation occurring in three mangrove zones (i.e., seaward, middle and landward zones) in Ijo River Estuary, Ayah Village, Kebumen, Central Java, Indonesia. Purposive sampling on each mangrove zone was conducted with vegetation data at tree and pole stages collected using nested plot methods. Aboveground biomass was calculated using an allometric equation while carbon stock was estimated using the method of the National Standardization Agency. In total, there were 11 mangrove species in the observation plots, consisting of seven true mangrove species and four mangrove associates. The seaward zone had five species and an amount of aboveground biomass (29324.07 MgB/ha), while the middle zone consisted of five species and had biomass of 52776.62 MgB/ha, and the landward zone was composed of five species and had biomass of 6428.74 MgB/ha. The carbon stock in the seaward, middle and landward zones were 43.06, 197.42 and 186.00 MgC/ha, respectively. In total, the Ayah Mangrove Forest contained aboveground biomass of 88529.43 MgB/ha, equal to 1143.31 MgC/ha carbon stock. The findings of this study reiterate the importance of conserving mangrove forests as an effective way to reduce carbon emissions which are the major cause of global warming.

Keywords: Carbon-stock, climate change, mitigation, Kebumen, zonation mangrove

INTRODUCTION

Climate change is caused mainly by anthropogenic activities, either directly or indirectly, leading to variabilities in climate and atmospheric composition in a relatively short period compared to historical changes during the Earth's epoch. Climate change has negatively impacted various life systems on the Earth, making it one of the global most important issues in recent decades (Gerard et al. 2020). One of the drivers of climate change is global warming (DITJEN PPI MENKLHK 2017). Global warming can be defined as the increase of the average temperatures at atmospheric, ocean, and terrestrial levels. It happens because the sun's radiation is not reflected in the atmosphere. Instead, it is trapped in the Earth due to the high concentration of greenhouse gases, such as methane and carbon dioxide. Therefore it is often called the greenhouse effect. The drastic increase in the concentration of greenhouse gases will lead to hotter temperatures on the Earth which can drive various climate phenomena such as storms, extreme rain, and prolonged drought, which eventually trigger disasters such as floods, landslides, forest fires, drought, water and food crises, etcetera (Triana 2018). Among the greenhouse gases, carbon dioxide is considered the most significant contributor to the warmer climate due to its greatest concentration in the atmosphere caused by the increased emission in the Anthropocene era (Manabe 2019). While there are several strategies to reduce carbon dioxide emissions, one strategy that has low cost is through carbon sequestration stored in plant biomass.

Among various vegetation types, mangroves are the most significant carbon sink, which has a high potential contribution to climate change mitigation.

Mangroves grow in areas between terrestrial and coastal zones (Mulyana et al. 2021). This vegetation type is affected by intertidal sea waves, high saline water, and soil. Therefore mangroves are commonly found on coastlines and estuaries. Mangrove forest is a transitional ecosystem between terrestrial and coastal areas and only occurs in tropical and subtropical regions. Prominent species usually indicate this ecosystem with specific morphological characteristics, such as thick leaves and knee roots (Sarker et al. 2021).

The mangrove ecosystem plays essential roles in the physical, ecological, and socio-economic aspects (Pattimahu et al. 2020). From a physical perspective, the presence of mangrove forests serves as protectors from waves, winds and storms, abrasion, and tsunamis. In terms of ecological aspects, it acts as the habitat of high diversity of flora and fauna and neutralizes coastal pollution. From a socio-economic view, the mangrove ecosystem provides sources of livelihood for the surrounding communities from various goods (e.g., timber, firewood, fish) and is developed for ecotourism. With increasing concerns about climate change, many recent studies revealed that the mangrove ecosystem sequesters and stores a significant amount of carbon in the vegetation and the soils effectively compared to other ecosystems (Pham et al. 2019). It is estimated that mangrove ecosystems globally contribute to storing 10% of total carbon on the Earth (Dinilhuda et al. 2020). Mangrove trees can store carbon an average of 6-8 Mg CO_2 e/ha, which is higher than any terrestrial tropical forests (Harishma et al. 2020). Nonetheless, mangrove species' capacity to sequester and store carbon differs (Purnomo 2020). The carbon sequestration by mangrove plants mainly occurs in the leaves, branches, stems, roots, and soils. The total carbon storage of a mangrove ecosystem is positively correlated with the extent and condition of the mangrove forest, meaning the higher the extent and the better condition of the mangrove forest, the greater the carbon stock in a unit area, and vice versa (Hong et al. 2017).

While many studies assess the carbon stock of mangrove forests, a context-specific assessment is needed to enrich the existing studies in this field. One mangrove forest which is little known regarding its carbon stock potential is in Ayah Village, Ayah Sub-district, Kebumen District, Central Java Province, Indonesia. The mangrove forest in this village is located at the mouth of the Bodo River, which flows toward the Indian Ocean. The mangrove forest is already developed as an ecotourism object in the Kebumen region, with facilities including gazebos, boats, photo spots, food stalls, parking areas, toilets, and prayer rooms. Various faunas are found in the Ayah Mangrove Forest, including fishes, crustaceans, birds, and mollusks. However, the flora includes *Rhizophora mucronata*, *Sonneratia caseolaris*, *Avicennia marina*, *Rhizophora apiculata*, *Acanthus ebracteatus*, *Acrostichum aureum*, *Bruguiera gymnorrhiza* and *Nypa fruticans* (Halizah and Puspitasari 2017). This study aimed to investigate the aboveground carbon stored in vegetation occurring in three mangrove zones (i.e., seaward, middle and landward zones) in Ayah Village, Kebumen, Central Java, Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted in the mangrove forest in Ayah Village, Ayah Sub-district, Kebumen District, Central Java Province, Indonesia (Figure 1). The study area has geographical coordinates of 7°43'09.5"S and 109°23'32.9"E. The mangrove forest is located at the mouth of Ijo River, close to Logending Beach, a popular tourist spot in the region.

Figure 1. Map of study location at mangrove forest in Ayah Village, Ayah Sub-district, Kebumen District, Central Java, Indonesia

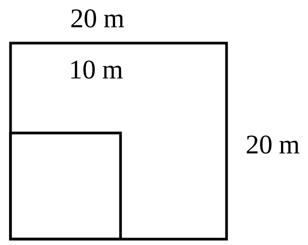

Figure 2. Plot illustration

Data collection procedure

Data collection was conducted in November 2022. Vegetation sampling used nested plots by establishing observation plots, each plot measuring 20×20 m to collect data for the tree stage and 10×10 m for the pole stage (Figure 2). The tree stage is defined as a woody plant with Diameter Breast Height (DBH) >20 cm, while poles are young trees with DBH 10-20 cm. Ayah Mangrove Forest has three zones, namely seaward, middle and landward. Within each zone, there were observation plots. The species name was identified at each plot, and the DBH and plant height were measured. The species name was determined based on the information from the local community and cross-checked with relevant literature.

Data analysis

Data on the diversity and zonation of mangrove plants were analyzed descriptively. Aboveground biomass was calculated using an allometric equation as presented in Table 1, and carbon stock was estimated following National Standardization Agency (2011) as follows:

$$C_n = \frac{C_x}{1.000} \, x \, \frac{10.000}{l_{sub-plot}}$$

Where: Cn= carbon stock per hectare (MgC/ha), Cx= carbon per subplot (Kg), *Isub-plot*= extent of subplot (m²)

RESULTS AND DISCUSSION

Ayah Mangrove Forest can be considered multifunctional mangrove-based ecotourism (Pratama and Wibawanto 2019). The area of the Ayah Mangrove Forest is organized based on species which is used as an educational tool for visitors. The mangrove density is high, with mangrove classification arranged by planting year. The oldest mangrove plant was planted in 1995 and is still present nowadays. The research results documented 11 species belonging to 8 families across the observation plots. Among them, seven species were true mangroves: *N. fruticans, Avicennia alba, A. marina, Sonneratia alba, Xylocarpus granatum, R. apiculata*, and *R. mucronata*, which belong to 5 families, namely Arecaceae, Acanthaceae, Lythraceae, Meliaceae, and Rhizoporaceae. The other 4 species were mangrove associates: *Cocos nucifera, Acacia mangium, Barringtonia asiatica*, and *Hibiscus tiliaceus* from 4 families (Arecaceae, Fabaceae, Lecythidaceae, and Malvaceae) (Figures 3 and 4).

The number of species in this study is higher than that in Jakarta Bay, Indonesia, which consisted of 3 families with 6 species, namely *S. alba*, *A. alba*, *Rhizophora stylosa*, *A. marina*, *R. apiculata* and *R. mucronata* (Slamet et al. 2020). However, the richness is lower than the mangrove forest in Segara Anakan, Cilacap, Indonesia with 24 species, consisting of ten species of a true mangrove, i.e., *A. marina*, *S. caseolaris*, *S. alba*, *B. gymnorrhiza*, *Aegiceras corniculatum*, *R. mucronata*, *R. apiculata*, *N. fruticans*, *Ceriops tagal*, *Heritiera littoralis* belonged to six families (Acanthaceae, Sonneraticeae, Rhizophoraceae, Myrsinaceae, Arecaceae, dan Strecaliaceae), while the other 14 species were non-mangrove (Widyastuti et al. 2018).

Figure 3. The condition of mangrove vegetation in Ayah, Kebumen, Central Java, Indonesia

Table 1. Allometric equations used to calculate aboveground biomass of each mangrove species

Species	Equation	References
True mangroves		
Avicennia alba	$AGB = 0.079211xD^{2.470895}$	Tue et al. (2014)
Avicennia marina	$AGB = 0.185x(D^{2.352})$	Dharmawan and Siregar (2008)
Nypa fruticans	$AGB=0.222x(D^{2.7048})$	Rahman et al. (2020)
Rhizopora apiculata	$AGB=10^{(-1.315+2.614*LOG(D))}$	Amira (2008)
Rhizopora mucronata	$AGB =0.045x(D)^{2.868}$	Gevana and Im (2016)
Sonneratia alba	$AGB = 0.258 \text{ x } D^{2.287}$	Kusmana et al. (2018)
Xylocarpus granatum	logAGB =-0,763 + 2,23 logD	Tarlan (2008)
Mangrove associates		
Acacia mangium	$AGB = 0.199 \, D^{2.148}$	Siregar and Heriyanto (2010)
Cocos nucifera	AGB= 4.5+7.7+H (kg/tree)	Hairiah et al. (2010)
Hibiscus tiliaceus	$AGB = 0.168 \text{ x } \rho \text{ x } D^{2.47}$	Chave et al. (2005)
Barringtonia asiatica	$0.0661xD^{2.591}$	Ketterings et al. (2021)

Note: D: Diameter at breast height, H: height and ρ: wood density (Word Agroforestry Center 2022)

A **B** **C**

Figure 4. Mangrove species at three different zones in Ayah Mangrove Forest: A. *Rhizophora mucronata* in the seaward zone; B. *R. mucronata* in the middle zone; C. *R. mucronata* in the landward zone

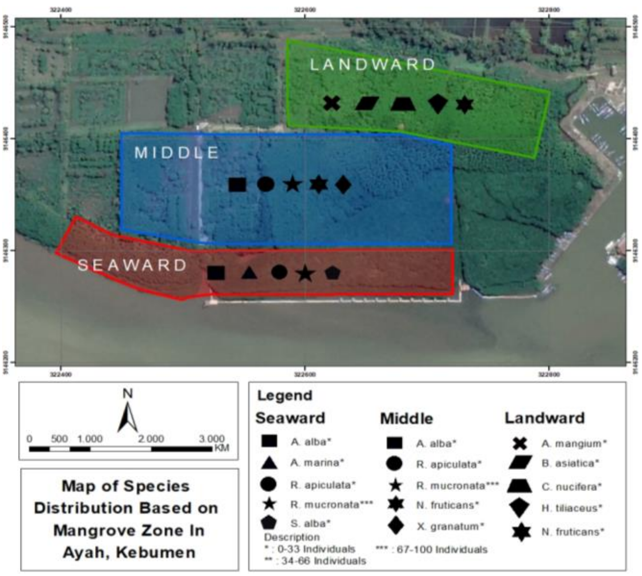

Figure 5. Map of mangrove zonation and the composing species in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

The Important Value Index (IVI) is commonly used to show the dominance of species within a vegetation community (Yuliana et al. 2019). In Segara Anakan, Cilacap, the species with the highest IVI was *A. marina* (Widyastuti et al. 2018), while in the Ayah Mangrove Forest, the most important species was *Rhizophora* sp. This species has a high adaptation ability in various environmental conditions. It is easy to regenerate naturally as the falling propagules will plant themselves in the soil with the shoots facing upwards. Besides naturally regenerating, the presence of *Rhizophora* sp. in the Ayah Mangrove Forest was also from planting conducted by the management. The second most dominant species in the Ayah Mangrove Forest was *Avicennia* sp. which grows naturally as well as being planted under mangrove rehabilitation programs conducted in Bantul District, Yogyakarta, Indonesia (Purwaningrum, 2020), Tugu Sub-district, Semarang, Indonesia (Martuti 2013), and Subang, West Java, Indonesia (Siringoringo et al. 2018).

Zonation in the mangrove ecosystem is formed due to the different abilities of mangrove species to respond to environmental conditions (Mughofar et al. 2018). Generally, the mangrove ecosystem can be classified into three zones based on water level and intertidal condition: seaward, middle, and landward (Sunarni et al. 2019). The Seaward zone is located closest to the sea, while the landward zone is located closest to the land, and in between the two zones, there is the middle zone (Figure 5).

In the seaward zone of the Ayah Mangrove Forest, all plant species documented were true mangrove consisting of five species (i.e., *A. alba*, *A. marina*, *R. apiculata*, *R. mucronata*, *S. alba*) with the dominance of *R. apiculata* and *R. mucronata*. The dominance of species from the general of *Rhizophora* is due to the high adaptability to a wide range of salinity, temperature, pH, tidal waves, and organic matter (Rosalina Rombe 2021). The seaward zone has a high salinity level with substrates suitable as the habitat of *R. apiculata* (Dharmawan et al. 2016).

The middle zone is the transition zone between the seaward and landward zones. In this zone, there were five true mangrove species, namely *A. alba*, *R. apiculata*, *R. mucronata*, *X. granatum,* and *N. fruticans*. In the middle zone, there were a significant number of *R. mucronata*, but a species not found in the seaward zone was documented in the middle zone, i.e., *N. fruticans.* In this zone, *Rhizophora sp.* was found in the intertidal area with sandy substrates (Syah, 2020). The *N. fruticans* in the middle zone are likely caused by the significant number of seeds produced from this species (Eddy et al. 2019).

The landward zone is commonly used as an area for rehabilitation programs using species from the Rhizophoraceae family (Pimple et al. 2022). The vegetation community in this zone is a transition of true mangroves into terrestrial plants (Luo et al. 2022). Plant species in the seaward zone are often found in sandy beach ecosystems, such as *B. asiatica*, *Pandanus tectorius*, and *Terminalia catappa* (Sumanto 2020). The seaward zone in the Ayah Mangrove Forest is composed of four species, i.e., *C. nucifera*, *H. tiliaceus*, *B. asiatica*, *A. mangium,* and *N. fruticans*. The three species other than *N. fruticans* are categorized as mangrove associates. In this zone, there was also a plant collection garden and nurseries.

Aboveground biomass

In Ayah Mangrove Forest, there were five species at the tree stage and ten species at the pole stage. The total aboveground biomass of the vegetation in the mangrove forest was 88529.43 MgB/ha, composed by 50298.78 MgB/ha of aboveground biomass at the tree stage and 38230.65 MgB/ha at the pole stage (Table 2). At the tree stage, species with the highest aboveground biomass was *R. mucronata* with 32787.33 MgB/ha, while the lowest was *C. nucifera* with 72.14 MgB/ha. At the pole stage, species with the highest amount of aboveground biomass was *R. mucronata* with 25550.12 MgB/ha, while the lowest was *H. tiliaceus* with 54.70 MgB/ha. Aboveground biomass was calculated using DBH as a predictor in which the larger the DBH, the greater the amount of aboveground biomass. In addition, the total biomass in a unit area is affected by the number of individuals (density), implying that the more density of mangrove plants, the greater the amount of aboveground biomass. Biomass also has positive correlation with carbon stock, thus a mangrove with high biomass will have a great carbon storage (Irsadi et al. 2017).

The seaward zone had the greatest amount of aboveground biomass with 29324.07 MgB/ha (Table 3). In this zone, there were five species (i.e., *A. alba, A. marina, R. apiculata, R. mucronata,* and *S. alba*) with the largest AGB was contributed by *R. mucronata.* The middle zone had AGB of 52776.62 Mg/ha which was contributed by *A. alba, R. apiculata, R. mucronata, N. fruticans, and X. granatum* with *N. fruticans* had the largest share with 15576.87 MgB/ha. The lowest amount of AGB was found in landward zone with only 6428.87 MgB/ha with the presence of mangrove associates (*C. nucifera, H. tiliaceus, B. asiatica* and *A. mangium*) and true mangrove *N. fruticans*. In this zone, *N. fruticans* had the largest share of ABG with 5689.65 MgB/ha.

Carbon stock

The results of analysis of carbon stock in Ayah Mangrove Forest is presented in Table 4 which shows the minimum, maximum, average and total carbon stock across the plots. Based on Table 3, carbon stock differed among species. In term of minimum value, species with the highest amount of carbon stock was *X. granatum* with 265.45 MgC/ha while the lowest was *R. apiculata* with 2.57 MgC/ha. In term of maximum value, *C. nucifera* had the highest carbon stock with 351.6 MgC/ha and *H. tiliaceus* had the lowest carbon stock with 5.25 MgC/ha. Therefore, it can be inferred from Table 4 that overall *C. nucifera* had the highest carbon stock with 351.6 MgC/h while *R. apiculata* had the lowest with 2.57 MgC/ha.

We found that total carbon stock differed among mangrove zones. In the seaward zones, the total carbon stock was 43.06 MgC/ha which was contributed by five true mangrove species, i.e., *A. alba* (4.75 MgC/ha), *A. marina* (5.75 MgC/ha), *R. apiculata* (6.28 MgC/ha), *R. mucronata* (15.20 MgC/ha), and *S. alba* (11.07 MgC/ha) (Table 5). In the middle zone, the total carbon stock was 197.42 MgC/ha, accumulated from five true mangrove species, namely *A. alba* (3.51 MgC/ha), *N. fruticans* (45.76 MgC/ha), *R. apiculata* (8.57 MgC/ha), *R. mucronata* (14.82 MgC/ha) and *X. granatum* (124.76 MgC/ha). The landward zone had total carbon stock of 186.00 MgC/ha which was contributed by *A. mangium* (5.35 MgC/ha), *B. asiatica* (5.42 MgC/ha), *C. nucifera* (6.87 MgC/ha), *H. tiliaceus* (134.94 MgC/ha) and *N. fruticans* (33.43 MgC/ha).

In term of total carbon stock, the highest was *N. fruticans* with 611.93 MgC/ha followed by *X. granatum* with 265.45 MgC/ha while the lowest was *H. tiliaceus* with 4.44 MgC/ha followed *N. fruticans* with 11.38 MgC/ha. The biomass and carbon stock differed among species which is affected by the different ability of each species in sequestering carbon inferred from DBH, wood density and height (Mahmood et al. 2020). Carbon sequestration can be defined as the capacity of a plant to capture and store carbon for a long period in its body parts (Schmidt et al. 2019).

Table 2. Aboveground biomass of each species at tree and pole stages in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Spesies	**Biomassa (MgB/ha)**		**Total**
	Trees	**Poles**	**(MgB/ha)**
Nypa fruticans	15576.87	5689.65	21266.52
Rhizophora mucronata	32787.33	25550.12	58337.45
Rhizophora apiculata	1459.00	1869.92	3328.92
Avicennia marina	-	489.66	489.66
Xylocarpus granatum	-	2654.51	2654.51
Avicennia alba	298.91	707.49	1006.4
Sonneratia alba	-	706.88	706.88
Cocos nucifera	72.14	278.50	350.64
Barringtonia asiatica	-	115.40	115.40
Hibiscus tiliaceus	104.53	54.70	159.23
Acacia mangium	-	113.82	113.82
Total	50298.78	38230.65	88529.43

Table 3. Aboveground biomass in each zone in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Zone	**Species**	**Biomass (MgB/ha)**
Seaward	*Avicennia alba*	707.49
	Avicennia marina	489.66
	Rhizophora apiculata	1869.92
	Rhizophora mucronata	25550.12
	Sonneratia alba	706.88
	Total	**29324.07**
Middle	*Avicennia alba*	298.91
	Nypa fruticans	15576.87
	Rhizophora apiculata	1459.00
	Rhizophora mucronata	32787.33
	Xylocarpus granatum	2654.51
	Total	**52776.62**
Landward	*Acacia mangium*	113.82
	Barringtonia asiatica	115.40
	Cocos nucifera	350.64
	Hibiscus tiliaceus	159.23
	Nypa fruticans	5689.65
	Total	**6428.74**

Table 4. The minimum, maximum, average and total carbon stock of each species in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Species	Total plots	Carbon stock (MgC/ha)			
		Min	Max	Average	Total
Rhizophora mucronata	109	13.07	39.09	0.7	76.33
Nypa fruticans	12	5.86	80.25	527.05	611.93
Xylocarpus granatum	1	-	-	-	265.45
Avicennia marina	4	4.35	7.35	19.77	79.1
Avicennia alba	8	9.74	16.83	11.56	18.09
Rhizophora apiculata	16	2.57	18.23	3.18	31.84
Sonneratia alba	3	6.23	8.33	6.45	19.35
Barringtonia asiatica	1	-	-	-	11.54
Cocos nucifera	4	12.73	351.6	13.14	13.86
Hibiscus tiliaceus	3	3.57	5.25	2.47	4.44
Acacia mangium	1	-	-	-	11.38
Total					1.143.31

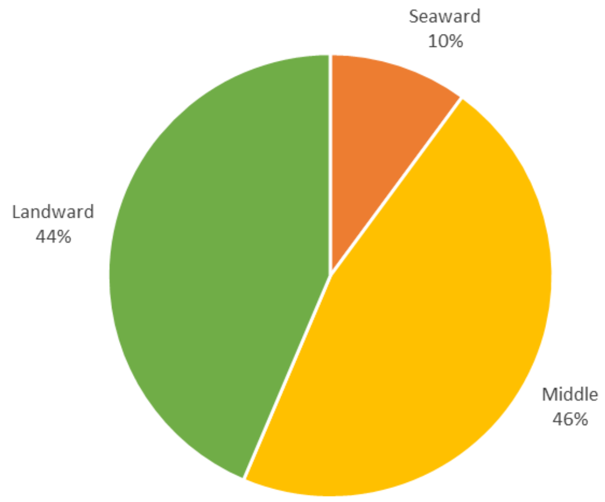

Figure 6. Proportion of total carbon stock of each zone in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Table 5. Carbon stock in each zone in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Zone	Species	Carbon Stock (MgC/ha)
Seaward	*Avicennia alba*	4.75
	Avicennia marina	5.75
	Rhizophora apiculata	6.28
	Rhizophora mucronata	15.20
	Sonneratia alba	11.07
	Total	**43.06**
Middle	*Avicennia alba*	3.51
	Nypa fruticans	45.76
	Rhizophora apiculata	8.57
	Rhizophora mucronata	14.82
	Xylocarpus granatum	124.76
	Total	**197.42**
Landward	*Acacia mangium*	5.35
	Barringtonia asiatica	5.42
	Cocos nucifera	6.87
	Hibiscus tiliaceus	134.94
	Nypa fruticans	33.43
	Total	**186.00**

As a mangrove forest, the carbon contained in the aboveground vegetation in Ayah beach can be categorized as blue carbon. This term refers to all carbon stored in coastal and marine ecosystems in which many studies showed that these ecosystems could absorb carbon greater than terrestrial ecosystems, including forests. Ecosystems producing blue carbon include mangroves, tidal swamps, seagrass, coral reefs, etc. In mangrove forests, carbon is not only stored in the vegetation but also stored in the soil sediment (Krauss et al. 2014). When combined, the carbon stored in mangrove vegetation and soil makes this ecosystem the largest carbon sink on Earth (Hamilton and Friess 2018).

There were four mangrove species which occurred in more than one zone, yet the similar species might have different carbon stock among different zones. Such species included *A. alba*, *R. apiculata*, and *R. mucronata* which occurred on the seaward and middle zones, and *N. fruticans* which occurred on the middle and landward zone. Such a difference is likely caused by the number of individuals of each species, number of plots, DBH and environmental conditions of the habitat where the plant grows.

The middle zone had the highest carbon stock compared to other zones which contributed to 46% of total carbon stock in all zones (Figure 6). The *X. granatum* with carbon stock of 124.76 MgC/ha make the total carbon stock in the middle zone was higher than the other zones. The landward zone shared 44% of total carbon of all zones with *H. tiliaceus* as the species with the largest contribution of carbon stock in this zone with 134.94 MgC/ha. The high number of individuals of each species and the size of the DBH in the seaward zone was one factor that cause the high carbon stock in this zone.

The seaward zone had the lowest total carbon stock compared to other zones with only a proportion of 10% of total carbon across all zones. On the other hand, *R. mucronata* had the largest carbon stock in this zone, with 15.20 MgC/ha. The low carbon stock in the landward zone is likely caused by the very low presence of mangrove species compared to other zones. In conclusion, the Ayah Mangrove Forest can provide ecosystem services in the form of carbon stock. The total aboveground biomass in the Ayah Mangrove Forest was 88529.43 MgB/ha, equal to

1143.31 MgC/ha carbon stock. The great amount of carbon stored in the Ayah Mangrove Forest implies the potential of the forest to contribute to climate change mitigation. The findings of this study reiterate the importance of conserving mangrove forests as an effective way to reduce carbon emissions which are the major cause of global warming. In addition, expanding the extent of mangrove forests through rehabilitating degraded mangrove forests and better managing existing mangrove forests would enhance the mangrove ecosystem's capacity for sequestering and storing carbon.

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