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Species composition, stand characteristics, aboveground biomass, and carbon stock of mangroves in Panabo Mangrove Park, Philippines

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Abstract. *Alimbon JA, Manseguiao MRS. 2021. Species composition, stand characteristics, aboveground biomass, and carbon stock of mangroves in Panabo Mangrove Park, Philippines. Biodiversitas 22: 3130-3137.* Mangrove ecosystems have been recognized for their roles in climate change mitigation through their carbon sequestration capacity. However, information on the ecology and carbon stock of mangroves is limited. Thus, this study assessed the species composition, stand characteristics, aboveground biomass, and carbon stock of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines. Data for vegetation analysis and biodiversity assessment were collected using transect line plots method. Meanwhile, aboveground biomass estimation was conducted using nondestructive method. Twenty plots with size of 10 m x 10 m each were established to account for the stand characteristics and aboveground biomass of mangroves. Species composition data identified five species from four families. *Avicennia marina* was the most important species with an importance value of 153.33%. Stand structure analysis revealed a basal area of 14.65 m^2 ha^{-1} and a mean density of 11835 stems ha^{-1}. Biodiversity indices indicated very low species diversity (H' = 1.027), low species richness (R = 0.5148) and less even distribution of species (J = 0.6383). Using allometric equation, the aboveground biomass was 77.45 Mg ha^{-1} with an estimated stored carbon of 37.18 Mg ha^{-1} and sequestration potential of 136.44 Mg CO_2ha^{-1}. These baseline data demonstrate that the area can store and sequester potential amounts of carbon and carbon dioxide, respectively, despite the low diversity.

Keywords: *Avicennia marina*, biomass, carbon stock, diversity, Philippine mangroves

INTRODUCTION

Mangroves are community of trees, shrubs, trunkless palms, and ground fern that are morphologically adapted to tidal ecosystems (Duke 2011). The mangrove ecosystem is recognized for the goods and services it provides to other organisms and the biosphere in general (Alongi 2012). Hence, it is regarded as an "ecologically and economically important forest of the tropics" (Alongi 2014). It serves as a habitat and nursery ground for crabs, fishes, and shrimps and a buffer of coastal communities against typhoons and tsunami (Wagner et al. 2004; Melana et al. 2005; FAO 2007; Duke 2011; Camacho et al. 2020). It provides food and livelihood for nearby residents (Satyanarayana et al. 2012; Sawairnathan and Halimoon 2017; Gevaña et al. 2019) and plays as sink of carbon (Gevaña et al. 2019; Dinilhuda et al. 2020).

Worldwide, the number of mangrove species is still uncertain but ranges from 50 to 70 species (FAO 2007). The Philippines, a tropical archipelagic country in Southeast Asia which is considered as the most mangrove diverse region in the world (Spalding et al. 2010), has a mangrove area of 247,362 hectares [as of 2003] and has relatively high diversity with 35 true mangrove species making it rank fourth worldwide (FAO 2007). However, the extent of mangrove areas in the country has declined for the past century (Buitre et al. 2019) due to natural disturbances as well as anthropogenic activities (Garcia et al. 2014) such as overexploitation and conversion (Primavera 2004).

Numerous assessments on mangrove biodiversity in the Philippines were already done. However, only few studies in the country (e.g., Gevaña and Pampolina 2009; Camacho et al. 2011; Castillo and Breva 2012; Abino et al. 2014a, b; Barcelete et al. 2016; Bigsang et al. 2016; Venturillo 2016; Gevaña et al. 2017; Sharma et al. 2017; Dimalen and Rojo 2019) assessed the carbon stock and carbon dioxide sequestration potential of mangrove ecosystems. The scarcity of information on carbon stock and sequestration capacity of established mangrove stands in the country exists (Castillo and Breva 2012). Knowledge of this aspect of mangrove ecology is vital to climate change mitigation strategies (Murdiyarso et al. 2015) and decision-making processes (Kamruzzaman et al. 2018).

Moreover, no information on biomass, carbon stock, and sequestration capacity of mangroves in Davao Gulf has been published. Among the areas facing Davao Gulf is Panabo City that hosts a 73-hectare Panabo Mangrove Park (City Government of Panabo 2019). Thus, this study assessed the species composition and stand characteristics and estimated the aboveground biomass and carbon stock of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines. The results of this study are expected to provide baseline information on these aspects of mangrove ecology in this site. Hence, it can be used as reference for better management of the park and for future studies which aim to investigate the dynamics of mangroves.

MATERIALS AND METHODS

Study area

This study was carried out in Panabo Mangrove Park (7°16'20.579" N, 125°40'50.984" E), Panabo City, Davao del Norte. This site was selected as a sampling area due to accessibility and safety considerations (Castillo and Breva 2012; Abino et al. 2014a, b). The mangrove area is managed by the Local Government Unit - Panabo City thru the City Environment and Natural Resources and the Bureau of Fisheries and Aquatic Resources. The area receives tidal inundation regularly and has a muddy soil type with a depth of as much as 1.00 meter. Settlements of approximately more than 100 households within the 500-m radius from the mangrove park were noted. Ongoing construction of a boardwalk and docking area was also observed during the conduct of the study.

Data collection

In April 2019, fieldwork was done. It utilized the transect line plots method to quantitatively describe species composition, stand structure, and biomass of mangroves (English et al. 1997). Five transects were established perpendicular to the shore. Four 10 m x 10 m plots were established to each side of the transect line with a 30-meter distance between them based on stand characteristics. Establishment of replicate plots to the side of the transect line provides an increased likelihood of capturing the variation in mangrove forest stands. To delimit the plots, fiberglass tape, bamboo stakes, and nylon/rope were utilized. A total of 20 plots were established, yielding a total sampled area of 2,000 m^2. Inside each plot, a complete inventory of all trees with diameter at breast height (DBH) of at least four centimeters inside the quadrat was done (Canizares and Seronay 2016) following the procedure presented by Howard et al. (2014). For speedy measurement of the DBH of the individual tree, measuring tape and a marked bamboo pole were used. DBH trees that are fairly straight or leaning were measured parallel to its trunk. For a tree that is forked at or below 130 cm, DBH was measured just below the fork, but if the fork is close to the ground, it was considered as two trees. For stilt-rooted *Rhizophora* species, DBH was measured 130 cm above the highest stilt root. Mangrove saplings and seedlings were only accounted for biodiversity assessment but not for carbon stock estimation since their DBH are less than four centimeters (Canizares and Seronay 2016).

Identification of species

All species found in each plot were identified using the Field Guide to the Philippine Mangroves of Primavera (2009). This identification guide was also used in several studies (Barcelete et al. 2016; Pototan et al. 2017). Field Guide to Mangrove Identification and Community Structure Analysis by Lebata-Ramos (2013) was also used. Using both field guides facilitated a better understanding of morphological features of mangroves and easier taxon identification.

Figure 1. Location of Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines (Google Earth, 2021)

Data analysis

Data were analyzed to describe mangrove stand in terms of density (stems ha^{-1}), basal area (m^2 ha^{-1}), relative density, relative frequency, and relative dominance. The importance value of each mangrove species was also determined. They were calculated using the formulas presented by English et al. (1997), and these are as follows.

Basal area per tree (cm^2) = πDBH^2 /4

Stand basal area (m^2 ha^{-1}) = sum of basal areas/area of the plot

Density (stems ha^{-1}) = (no. of living stems in a plot x 10,000)/area of the plot

Relative density = (density of a species/total density of all species) x 100

Relative frequency = (frequency of a species/total frequency of all species) x 100

Relative density = (total basal area of a species/total basal area of all species) x 100

Importance value = relative density + relative frequency + relative dominance

For diversity analysis, species diversity, richness, and evenness were determined using Shannon-Weiner, Margalef's and Pielou's indices, respectively as presented by Magurran (2004). The formulas are as follows.

Shannon-Weiner Index

$$H' = -\sum[\left(\frac{ni}{N}\right) ln \left(\frac{ni}{N}\right)]$$

Where:
H' : Shannon-Weiner index
N : total individuals of the population sampled
ln : the natural logarithm
n_i : total number of individuals belonging to *i* species

Margalef's Index

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

Where:
R : Margalef's index
S : total number of species
ln(N): natural logarithm of the total number of individuals

Pielou's Evenness Index

$$J = \frac{H'}{H'max}$$

Where:
J :Pielou's evenness index
H' :Shannon-Weiner index
H'max:diversity observed to a maximum diversity

The aboveground biomass of mangroves was determined using an allometric equation developed by Komiyama et al. (2005). The equation is:

AGB = 0.251 p D$^{2.46}$

Where:
AGB : aboveground biomass
p : wood density
D : diameter at breast height.

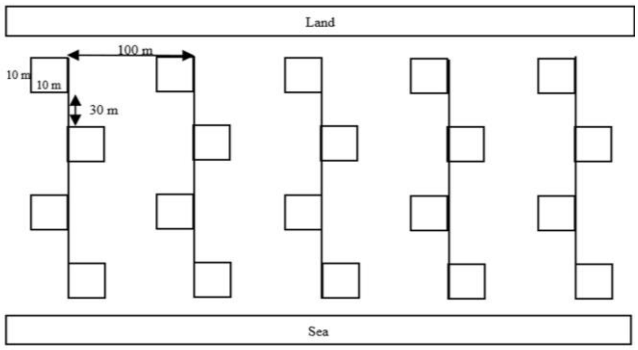

Figure 2. The field survey design using transect line plots method

Species-specific wood density values for common mangroves presented by Howard et al. (2014) were adapted. To estimate carbon stock, the aboveground biomass value is multiplied by a factor of 0.48 (Kauffman and Donato 2012; Howard et al. 2014; Alavaisha and Mangora 2016). Carbon dioxide sequestration potential estimation was done by multiplying the carbon stock value by a factor of 3.67 (Howard et al. 2014).

To determine the relationship between the importance value index and aboveground biomass of mangrove species, Spearman's rank correlation was used. This was calculated using Paleontological Statistics (PAST) software (Hammer et al. 2001).

RESULTS AND DISCUSSION

Species composition

A total of 2367 mangrove individuals from all sampling plots were identified in the Panabo Mangrove Park belonging to five different species of the registered 16 species in Panabo City (Pototan et al. 2017). The species identified were *Aegiceras corniculatum, Avicennia marina, Rhizophora apiculata, R. mucronata* and *Sonneratia alba.* These species are under four genera of four families as classified by Primavera (2009) and Duke (2011). All identified species in the study site, though with decreasing population trend based on the most recent assessment, are of Least Concern conservation status according to International Union for Conservation of Nature Red List of Threatened Species Version 2021 - 1 (IUCN 2021). None of these species is listed in the National List of Threatened Philippine Plants and their Categories (see DENR Administrative Nos. 2007-01 and 2017-11). The species composition of the study site is summarized in Table 1.

Compared with the different mangrove communities around Davao Gulf, this record of five species showed a lower diversity than Banaybanay, Davao Oriental with 33 species (Pototan et al. 2021), Sta. Cruz, Davao del Sur with 17 species (Cardillo and Novero 2018), Hagonoy, Davao del Sur with 12 species (Jumawan et al. 2015), and Tagum City and Carmen, Davao del Norte with 11 and 12 species, respectively (Pototan et al. 2017).

Stand characteristics

Table 2 showed the characteristics of all mangrove species identified in the sampling site. As reflected, *S. alba*, which individual registered the largest DBH of 24.29 cm, accounted for the largest stand basal area (G) of 8.74 m² ha⁻¹ and the greatest mean DBH of 8.46 cm. In terms of stand basal area, *A. marina* (8.62 m² ha⁻¹) came next, then *R. mucronata* (2.02 m² ha⁻¹) and *R. apiculata* (0.28 m² ha⁻¹), respectively. However, for mean DBH, *R. mucronata* (7.76 cm) ranked second. This was then followed by *A. marina* (7.22 cm) and *R. apiculata* (5.90 cm), respectively. Though *A. marina* had the highest stem density, its basal area was behind *S. alba* only for its trees have relatively small trunks (Lozano and Bueno 2015), as evidenced in their respective DBH ranges and mean DBH. This result of *S. alba* species with the largest basal area can be attributed to large DBH of the accounted individuals (Cintron and Novelli 1984) even if it did not occur in all plots and not the densest species. Besides, this species has been documented to have a relatively large basal area compared to other species in several mangrove ecosystems in the country, such as Olango Island Wildlife Sanctuary (Lozano and Bueno 2015) and Sarangani Province (Mullet et al. 2014; Natividad et al., 2015). Globally, the basal areas of *S. alba* and *A. marina* are relatively higher, but the other species' basal areas are lower than the mangroves in Kerala, India (Sreelekshmi et al. 2018). This study recorded no DBH and basal area measurements for *A. corniculatum* since, during fieldwork, all individuals of this species found inside the sampling plots had DBH less than the minimum requirement to be accounted for. Measurement was only limited to those mangrove individuals with DBH, an important component to determine an individual's basal area, of 4.00 cm or more.

Further, vegetation analysis revealed that *A. marina*, being found in all plots, was the most frequent species with a relative frequency of 28.17%. This occurrence can be attributed to its ability to survive in diverse mangrove habitats and tolerate a wide range of environmental conditions such as salinity and tidal inundation (Tomlinson 1986; Duke 2011). It also registered the highest stem density of 7855 stems ha⁻¹ and a relative density of 66.37%.

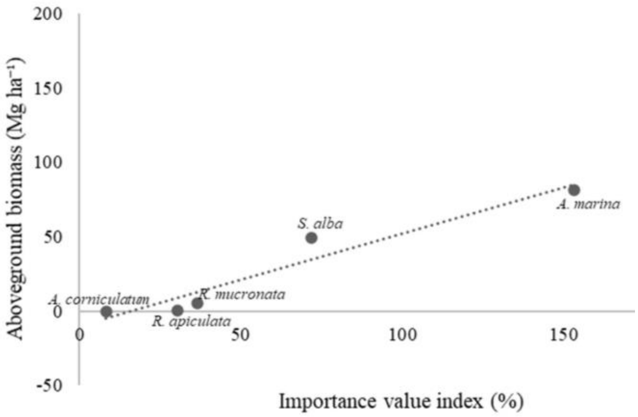

Figure 3. Relationship between important value index and aboveground biomass of mangrove species in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Table 1. Mangrove species identified in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Species	Family	Conservation Status	Total number of sampled individuals
Aegiceras corniculatum (L.) Blanco	Myrsinaceae	Least Concern	27
Avicennia marina (Forsk.) Vierh	Avicenniaceae	Least Concern	1571
Rhizophora apiculata Blume	Rhizophoraceae	Least Concern	143
Rhizophora mucronata Lamk	Rhizophoraceae	Least Concern	296
Sonneratia alba J. Smith	Sonneratiaceae	Least Concern	330
Total			2367

Table 2. Characteristics of different mangrove species in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Rank	Species	DBH Range (cm)	Mean DBH (cm)	Stand basal area (m² ha⁻¹)	Mean density (stems ha⁻¹)	Relative frequency (%)	Relative density (%)	Relative dominance (%)	Importance Value (%)
1	*Avicennia marina*	4.77 - 18.46	7.22 ± 0.13	8.62 ± 1.62	7855 ± 925	28.17	66.37	58.79	153.33
2	*Sonneratia alba*	4.84 - 24.29	8.46 ± 0.30	8.74 ± 1.16	1650 ± 444	19.72	13.94	38.17	71.83
3	*Rhizophora mucronata*	5.09 - 12.06	7.76 ± 0.52	2.02 ± 0.90	1480 ± 1126	21.13	12.51	2.76	36.40
4	*Rhizophora apiculata*	5.03 - 7.58	5.90 ± 0.84	0.28 ± 0.08	715 ± 141	23.94	6.04	0.29	30.27
5	*Aegiceras corniculatum*	-	-	-	135 ± 79	7.04	1.14	0.00	8.18

Note: Data on mean DBH, stand basal area, and mean density are presented in mean±standard error. The mark - means no data available during study period since the identified individuals had DBH of less than 4.00 cm

Furthermore, it was found to be dominating the area with a relative dominance of 58.79%. Even if it did not post the highest mean basal area among all species, it was still the most dominant due to its considerably high density (Kauffman and Bhomia 2017). With these, *A. marina* was the most important species with an importance value index (IVI) of 153.33%. Moreover, *S. alba* ranked second with an importance value of 71.83%, followed by *R. mucronata* with 36.40%, then *R. apiculata* with 30.27%. *A. corniculatum* is considered to be the least important species with an importance value of 8.18%. This account implies that *A. marina* is the most acclimatized (Pototan et al. 2017) and has the greatest biomass contribution (Pototan et al. 2021) in the area. Further, this study revealed a positive correlation between the IVI and aboveground biomass of mangrove species (Figure 3) which means that species with higher IVI have greater aboveground biomass accumulation. Truly, the most important species, *A. marina*, had the most contribution to the stand aboveground biomass with 81.57 Mg ha^{-1} (see Table 5). This finding affirmed the result of Matatula et al. (2021) which reported that a significant correlation exists between species importance value index and aboveground biomass.

Table 3 showed the stand characteristics of Panabo Mangrove Park. Structural analysis recorded a mean DBH of 7.67 cm, a stand basal area of 14.65 m^2 ha^{-1}, and a mean density of 11835 stems ha^{-1}. Compared with other mangrove communities in the Philippines, its mean DBH measurement is relatively higher than those measurements in Calatagan Mangrove Forest Conservation Park, Batangas (Cudiamat and Rodriguez 2017), several plantations stand in Banacon Island, Bohol (Camacho et al. 2011; Gevaña et al. 2017) and afforested mangrove stands in Laguindingan, Misamis Oriental (Sharma et al. 2017). However, it is lower than those in San Juan, Batangas (Gevaña et al. 2008), Bahile Village, Palawan (Abino et al. 2014b), and Pinabacdao, Samar (Abino et al. 2014a). Also, its stand basal area is relatively higher than the basal areas of 3- and 9-year-old afforested stands in Laguindingan, Misamis Oriental (Sharma et al. 2017), Olango Island Wildlife Sanctuary, Cebu (Lozano and Bueno 2015), and Calatagan Mangrove Forest Conservation Park, Batangas (Cudiamat and Rodriguez 2017). However, it is lower than the 21-year-old mangrove stands in Laguindingan, Misamis Oriental (Sharma et al. 2017) and surveyed zones along Puerto Princesa Bay, Palawan (Dangan-Galon et al. 2016). Furthermore, its mean stem density is relatively lower than the young stands in Banacon Island, Bohol (Gevaña et al. 2017) but higher than the inventories reported by Dangan-Galon et al. (2016) in Puerto Princesa Bay, Palawan, Lozano and Bueno (2015) in Olango Island Wildlife Sanctuary, Cebu, and Sharma et al. (2017) in afforested mangrove stands in Laguindingan, Misamis Oriental.

Diversity analysis

As shown in Table 4, the study site had low species diversity (H' = 1.0273). This could be due to harsh environmental conditions that threaten the growth and development of varied mangrove species in coastal habitats (Duke 2011). Another possible reason for the low diversity level is the planting of pre-selected species during reforestation (Picardal et al. 2011). Newly planted *Rhizophora* species in the area were observed during fieldwork. On the other hand, a less even distribution of species (J = 0.6383) was also noted. This result is primarily due to the abundance of *A. marina* that dominates the site. In terms of species richness, the area registered an overall index value of 0.5148, which is deemed to be low given that there were only five species identified in all sampling plots.

Aboveground biomass and carbon stock estimation

Biomass measurement is a prerequisite for carbon stock estimation so is the latter for the calculation of carbon dioxide sequestration potential (Intergovernmental Panel on Climate Change 2013; Howard et al. 2014). As shown in Table 5, the mean aboveground living biomass (AGB) of mangroves in Panabo Mangrove Park was 77.45 Mg ha^{-1}, equivalent to an aboveground living carbon (AGC) stock of 37.18 Mg ha^{-1}. This record means that the study site can sequester at least 136.44 Mg CO_2 ha^{-1}. Notably, the accounted aboveground living biomass of the study site can only be attributed to four species, namely (in order of contribution): *A. marina, S. alba, R. mucronata,* and *R. apiculata.* Of the four species, the *A. marina*, being the most important species, had the greatest contribution due to its highest stem density (Abino et al. 2014b). This species was also documented in Catmon, San Juan, Batangas, the Philippines as the greatest contributor to stand above-ground biomass and stored carbon (Gevaña et al. 2008).

Table 3. Characteristics of mangrove stand in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Stand characteristics	Unit	Mean value
Diameter at breast height	cm	7.67
Stand basal area	m^2 ha^{-1}	14.65
Density	trees ha^{-1}	11835

Table 4. Biodiversity indices of mangrove stand in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Biodiversity indices	Value
Shannon-Weiner Index	1.0273
Pielou's Index	0.6383
Margalef's Index	0.5148

Table 5. Estimated aboveground living biomass, carbon stock, and carbon dioxide sequestration potential of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Species	Aboveground living biomass (mg ha^{-1})	Carbon stock (mg ha^{-1})	CO_2 sequestr. potential (mg ha^{-1})
Avicennia marina	46.30	22.23	81.57
Sonneratia alba	27.98	13.43	49.29
Rhizophora mucronata	2.89	1.39	5.10
Rhizophora apiculata	0.28	0.13	0.49
Total	77.45	37.18	136.44

IPCC (2013) provided a range of default values for aboveground biomass of mangroves in tropical wet areas. The range is 8.7 to 384 Mg ha^{-1}. Also, Howard et al. (2014) presented that carbon stock is estimated to be 55 to 1376 Mg ha^{-1} with an average of 386 Mg ha^{-1} and an average carbon dioxide equivalent of 1415 Mg ha^{-1}. With this, it can be noted that the estimated biomass of the study site was within the range of default values. However, carbon stock and carbon dioxide equivalent were lower than the estimated averages for this study considered only the aboveground living component of the mangroves. Also, given that about 21% of stored carbon in the mangrove ecosystem can be attributed to aboveground living biomass (Howard et al. 2014), the area can store as much as 177.05 Mg C ha^{-1}. In addition, the sampled area can potentially sequester as much as 649.77 Mg CO_2 ha^{-1}.

To date, limited studies are available on biomass, carbon stock, and carbon dioxide sequestration potential of mangroves in the Philippines. The mean values generated in this study were relatively higher than those of *Rhizophora* stand in Verde Passage, San Juan, Batangas (Gevaña and Pampolina 2009), *Rhizophora*-dominated large plot in Poctol, San Juan, Batangas (Gevaña et al. 2008), *Avicennia*-dominated small plots in Catmon, San Juan, Batangas (Gevaña et al. 2008) and 3- and 9-year-old afforested stands in Laguindingan, Misamis Oriental (Sharma et al. 2017). Also, this account was even higher than that of a 22-year-old reforested stand in Aklan (Castillo and Breva 2012). On the other hand, it can be noted that these values were relatively lower than those of Sarangani Province (Barcelete et al. 2016; Bigsang et al. 2016), Cotabato City (Dimalen and Rojo 2019), 21-year-old afforested stand in Laguindingan, Misamis Oriental (Sharma et al. 2017), plantation and natural stands in Banacon Island, Bohol (Camacho et al. 2011; Gevaña et al. 2017), natural and reforested stands in Samar (Castillo and Breva 2012; Abino et al. 2014a) and natural and reforested stands in Palawan (Castillo and Breva 2012; Abino et al. 2014; Venturillo 2016).

Globally, the estimated biomass and stored carbon of Panabo Mangrove Park were relatively higher than those of the oligohaline zone of Dhangmari area, Sundarbans, Bangladesh (Kamruzzaman et al. 2018), *A. marina*-dominated zone along Yinglou Bay, South China (Wang et al. 2014), Pulau Semakau, Singapore (Friess et al. 2016), open-canopy mangroves in Mahajamba Bay, Madagascar (Jones et al. 2015), Piraque-Acu River, Brazil (da Motta Portillo et al. 2017), restored mangrove sites in Muisne, Esmeraldas Province, Ecuador (DelVecchia et al. 2014) and the Pacific Coast and Bay Islands in Honduras (Bhomia et al. 2016). However, these estimates were not as high as those in neighboring Asian countries such as Vietnam (Nam et al. 2016), Malaysia (Hossain 2014; Ismail et al. 2015; Suhaili et al. 2020), Indonesia (Murdiyarso et al. 2015; Alongi et al. 2016; Asadi et al. 2018; Widyastuti et al. 2018), India (Kathiresan et al. 2013; Hebbalalu et al. 2014; Sahu et al. 2016) and *H. fomes*-dominated vegetation in Sundarbans, Bangladesh (Rahman et al. 2015). Further, this account was even lower than the records in East Coast, Florida (Doughty et al. 2016) and several African countries such as Liberia (Tang et al. 2016; Kauffman and Bhomia 2017), Mozambique (Sitoe et al. 2014; Trettin et al. 2016), Tanzania (Alavaisha and Mangora 2016), Cameroon (Tang et al. 2016) and Gabon (Kauffman and Bhomia 2017).

Differences in measurements of biomass, carbon stock, and carbon dioxide sequestration potential among areas around the globe can be due to different environmental factors (e.g., temperature, precipitation, tidal inundation, river flows, nutrient cycling and availability, salinity) and even morphological characteristics (e.g., size) that affect productivity and rate of respiration of mangrove ecosystems (Alongi 2012). Several studies (Jones et al. 2015; Alavaisha and Mangora 2016; Kauffman and Bhomia 2017) have also attributed these differences to environmental variability.

In conclusion, even if the site has very low species diversity, low species richness, and less even distribution of species, its ability to store and sequester carbon and carbon dioxide, respectively, cannot be undermined. Thus, conservation and protection efforts should be continued, especially that the area has become a local ecotourism destination. Periodic monitoring of this aspect of mangrove ecology and estimation of carbon in other pools are recommended as this information is equally helpful in mangrove conservation and management.

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