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STAND STRUCTURE, SPECIES COMPOSITION AND CARBON ACCUMULATION IN THE POLYHALINE ZONE OF THE SUNDARBANS MANGROVE FOREST, BANGLADESH.

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Mangrove stand structure may have direct impact on the conditions and functioning of mangrove ecosystems, and it can modify the distribution and richness of fauna in these habitats. The mangrove ecosystem throughout the polyhaline zone of Sundarbans Mangrove Forest (SMF) was chosen for research on stand structure, biomass accumulation, and carbon storage. Field data were collected from seven sample plots measuring an area of 700 m^2. Species diversity, diameter class distribution vs. biomass carbon, and species-specific contributions to total biomass carbon were examined. *Excoecaria agallocha* has maintained its dominance (42.4%, relative density) of the stand. The mean above and below-ground biomass carbon stock of the mangrove community was 197.1 and 173.2 Mg ha^{-1} yr^{-1}, respectively. *Avicennia officinalis* accounted for only 16.7% individually, contributing over 45% to the total biomass carbon while *Xylocarpus mekongensis* was the second-highest contributor. The majority of the tree's diameter were around 10–5 cm, but their share of the total above-ground biomass carbon is only 12%. In comparison, a significant amount of biomass carbon is contributed by tree species with a diameter of 35 to 40 cm, which account for only 3.9% of all trees, but account for 17.8% of the total above-ground biomass carbon. Mangrove communities growing in the polyhaline zone of the SMF have significant species diversity and considerable carbon stock. These findings should be incorporated in future decision-making processes for the area and contribute to a better understanding of the SMF's function in reducing the effects of global warming.

Keywords: Polyhaline zone, stand structure, above and below-ground biomass, species composition, carbon stock

INTRODUCTION

Mangrove forests, found mostly in tropical and subtropical regions, are unique coastal ecosystems known for their dynamic nature and covering a small percentage of global forests (Friess 2019). These ecosystems provide essential services including provisioning services such as fish, fuelwood, and materials and regulating services such as coastal protection, flood prevention, and water quality (Brander et al. 2012). Mangroves also acts as a buffer against siltation, which helps safeguard offshore coral reefs and, in turn, influences the reefs' productivity (Zaiton et al. 2019). Beyond these essential services, mangroves emerge as noteworthy contributors to carbon sequestration efforts, thereby aiding in climate change mitigation. When contrasted with other vegetative ecosystems, mangroves exhibit an impressive capacity to amass up to five times more carbon per hectare than tropical evergreen rainforests (Friess 2019). Depending on local factors related to forest structure and biophysical characteristics, mangrove ecosystems' capacity to store carbon differs across geographical locations (Boone & Bhomia 2017, Jones et al. 2014). Plant growth, and more critically hydrological and geomorphic features, are required for carbon sequestration. For instance, more carbon is stored in tropical mangrove ecosystems (895–890 t C ha^{-1}) than in subtropical or temperate forests (547–566 t C ha^{-1}) (Sanders et al. 2016). Mangrove ecosystems are essential for global carbon cycle management because of the great capacity of mangroves to trap carbon (Alongi 2014). In addition, mangrove ecosystem's carbon stock varies according to species (Sajib et al. 2014), vegetation type (Adame et al. 2013, Cerón-Bretón et al. 2011,Mitra et al. 2011), and salinity (Adame et al. 2013).

In addition, mangrove forests are among the world›s most productive ecosystems, in addition to being unique wetland ecosystems in intertidal coastal regions of the tropics and subtropics (Lugo & Snedaker 1975, Nagarajan et al. 2008). Biomass and productivity in various mangrove forests throughout the world have been studied (Day et al. 1996, Komiyama et al. 2000, Putz & Chan 1986, Saintilan 1997), primarily to help inform ecosystem management and evaluate carbon stocks in mangrove communities (Kauffman et al. 2011, Liu et al. 2014, Sitoe et al. 2014, Wang et al. 2013). Carbon accumulation patterns and their relation to species dominance (richness) and individual tree size are controlled by the age and size distribution of trees in stands, as well as the history of stand growth in the area (Kamruzzaman et al. 2018).

The Sundarbans, which span 6017 km^2 in Bangladesh and 4000 km^2 in India, are the world's biggest tract of mangrove forest. It is a RAMSAR site with three animal refuges that were given UNESCO's World Heritage designation in 1997. Due to its environmental benefits and biodiversity, the forest is extremely important for conservation both domestically and internationally (Mukrimaa et al. 2016, Iftekhar & Saenger 2008). There are three ecological zones in Sundarbans Mangrove Forest (SMF), namely freshwater (oligohaline), moderately saline (mesohaline), and saltwater (polyhaline) zones that distinguish the Sundarbans mangrove forest (Chaffey et al.1985).

Sequestering carbon in mangrove forests (Khan et al. 2007,Bouillon et al. 2008), organic carbon dynamics (Machiwa & Hallberg 2002), biomass and net primary productivity (Kamruzzaman et al. 2017) have been studied. Few previous research also has explored the stand structure, biomass, and carbon storage of Bangladesh's Sundarbans Mangrove Forest (SMF) with its biodiversity and role as a carbon sink among other tropical forest ecosystems (Ahmed et al. 2011, Iftekhar & Saenger 2008, Rahman et al. 2015) and no previous research has looked at the particular species› contribution to the overall storage of carbon of the mangrove communities in this area. This current study intends to measure the structural properties of mangroves in the polyhaline zone of Bangladesh›s Sundarbans Mangrove Forest (SMF) to estimate their participation in the SMF's total carbon stocks.

MATERIALS AND METHODS

Study area

The research took place in March 2023, in Munshiganj area under Burigoalini range of Sundarbans Mangrove Forest. The study area is situated between longitudes 89° 00' – 89° 19' E and latitudes 21°36' – 22° 24' N (Figure 1). This region is frequently inundated by tidal flooding. There is a variation of approximately 1600 mm in the west to 2000 mm in the east in the region with 80% probability of annual precipitation. Winter lasts from October to February, and the rainy season lasts from June to September. February to December sees the lowest temperatures (12–25 °C), while March to June sees the highest temperatures (26–34 °C). From 70 to 80% is the range of the annual relative humidity (Rahman & Asaduzzaman 2010).

Methods

Sampling and tree measurement

The study managed to establish seven plots (10 m × 10 m) that covered 700 m^2 area in the polyhaline zone of Sundarbans Mangrove Forest. Due to plot destruction by river erosion and storm damage, all of the plots were considered to be approximately 200 m from the shore line. All of the woody plants (trees taller than 0.10 meters) in the research plot were numbered and identified. Carbon storage in mangrove stands is primarily determined by its structural features, specifically its height (H) and diameter at breast height (DBH). Therefore, the H and DBH of every tree in the research plots were measured and assigned a number.

Forest structure

Eight mangrove species were found growing at the study site. Those are *Excoecaria agallocha* L. (Euphorbiaceae); *Avicennia officinalis* L. (Avicenniaceae); *Xylocarpus mekongensis* J. Koening (Maliaceae); *Aegiceras corniculatum*

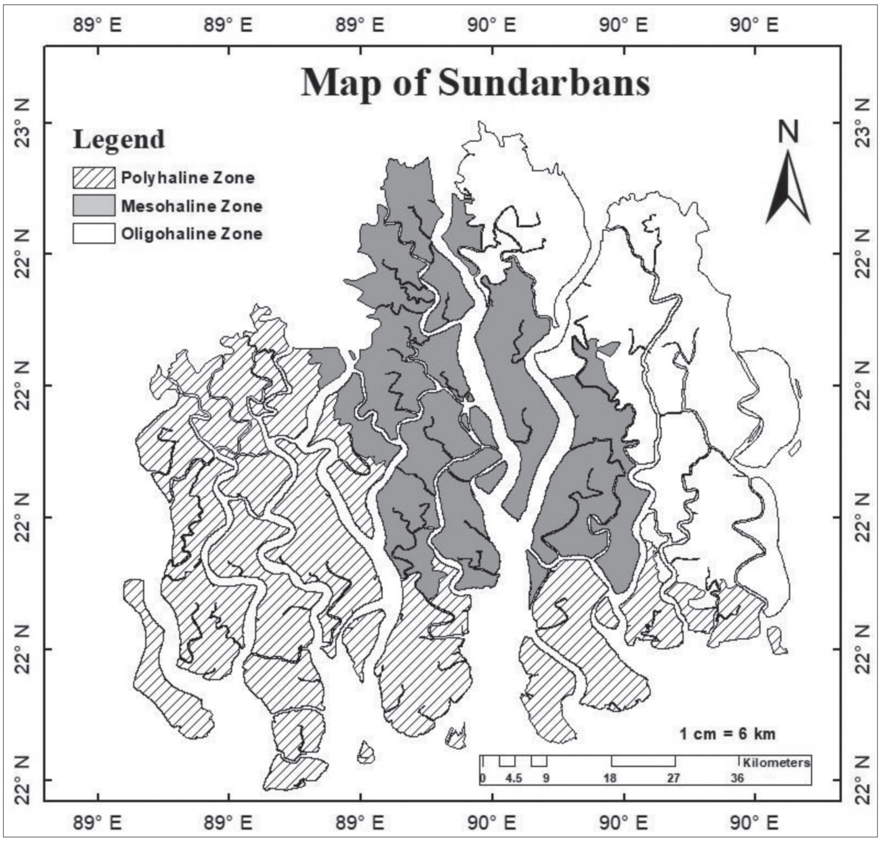

Figure 1 Map of different salinity zones of the Sundarbans mangrove forest (SMF), Bangladesh (▨ study area)

L. Blanco (*Primulaceae*); *Heritiera fomes* Buch-Ham. (Maliaceae); *Ceriops decandra* Griff. (Rhizophoraceae); *Sonneratia apetala* Buch-Hum. (*Lythraceae*) and *Bruguiera gymnorrhiza* L. (Rhizophoraceae).

Data analysis

Stand structure analysis

The data on trees, saplings, and seedlings, as well as the number of individuals within each species and their stem diameters, are used to analyse the mangrove stand structure analysis. Standardised methodology developed by Cintron & Schaeffer-Novelli (1984) was used to calculate structural indices such as the Importance Value Index (IVI). The formula employed was IVI = Relative Frequency + Relative Density + Relative Dominance. In accordance with the methodology outlined by Pool et al. (1977), the Complexity Index (I_c) was determined using the formula I_c= number of species × density × basal area × mean height × 10^{-5}.

Biomass and carbon estimation

Above-ground biomass estimation using allometric equation

The semi-destructive sampling data was applied to develop the species-specific allometric models, where AGB (kg $tree^{-1}$) was displayed alongside DBH and total height (H) (Mahmood et al. 2019). The most suitable model was chosen based on the criteria of having the smallest residual standard error (RSE) and the highest coefficient of determination (R^2), following the methodology outlined by Picard et al. (2012).

However, there is no developed allometric equation for estimating above-groundbiomass in all species. Therefore, we employ the general allometric equation of the other investigated mangrove species found in this study in those situations (Chave et al. 2009).

$$AGB = 0.0509 \times \rho \times D^2 \times H$$

where AGB = above-ground biomass, ρ = wood

Species	Model, ln (AGB) = a + b	a*	b	Adj. R^2	RSE
Excoecaria agallocha	ln (a) + b ln ($DBH^2 \times H$)	-2.5721	0.8623	0.9903	0.1539
Avicennia sp.	ln (a) + b ln (DBH)	-1.5554	2.2069	0.9781	0.2287
Xylocarpus sp.	ln (a) + b ln (DBH)	-1.9174	2.3100	0.9720	0.1989
Heritiera fomes	ln (a) + b ln (DBH)	-1.9944	2.4603	0.9931	0.1434
Sonneratia apetala	ln (a) + b ln ($DBH^2 \times H$)	-2.8869	0.9170	0.9938	0.1633
Bruguiera sp.	ln (a) + b ln (DBH)	-1.4473	2.2870	0.9845	0.1926

a* = stands for the value of ln (a)

density, D = DBH & H= height (Chave et al. 2005). The wood density data were obtained from Global Wood Density Database.

Below-ground biomass estimation using allometric equation

Using common allometric relationships between dbh and biomass, the below-ground biomass of mangrove tree species was estimated (Komiyama et al. 2005)

$$BGB = 0.199 \times \rho^{0.899} \times D^{2.22}$$

where BGB = Below-ground biomass, ρ = Wood density and D = DBH. The same allometric equation was used to estimate the biomass of each species of tree.

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Conversion of above-ground and below-ground biomass to AGBC & BGBC

In order to determine the carbon content of each individual tree, the estimated above-ground and below-ground biomass was further multiplied by 0.47 (Gifford 2000).

Statistical analysis

The Microsoft Excel 2019 software was used for all statistical analyses. KaleidaGraph v 4.1 software (Synergy software, USA) was used to draw the figures.

RESULTS

Stand structure

The mangrove plant species and their structural composition along the polyhaline zone of Sundarbans Mangrove Forest are presented in Table 1. The study area had eight true mangrove species classified into six families. Among all the studied species, *E. agallocha* had the highest importance index value (Iv = 90.1). The closest species in terms of importance value index was *A. officinalis* with an Iv value of 71.8. The Iv value for the rest of the species including *H. fomes, X. mekongensis, C. decandra, A. corniculatam, S. apetala,* and *B. gymnorrhiza* was 27.3, 42.5, 28.5, 28.6, 7.92, and 3.27, respectively. Based on the Iv value, *E. agallocha* was the major species in the mangrove community along the polyhaline zone of Sundarbans. In the studied area, *E. agallocha* had a specific density of 1585.7 ha^{-1} and a relative dominance of 29.6%, respectively.

Table 2 lists the mangrove community's structural characteristics. The complexity index (Ic) of the mangrove community ranged from 19.6 to 168.1. The highest complexity index (Ic) values (151.7, 165.4, and 168.1) were found in Plots 2, 3, and 5, respectively, in the study area. When compared to the other plots, these had a higher species diversity, a larger basal area, and a higher density of trees. Conversely, because of smaller basal area and fewer species, Plot 1 had the lowest Ic value at 19.6.

Table 1 Structural composition of mangrove communities within the polyhaline zone of Sundarbans, Bangladesh

Species	Specific density (n ha^{-1})	Basal area (m^2 ha^{-1})	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value (Iv)
H. fomes	371.4	26.7	9.9	13.9	3.7	27.3
A. officinalis	685.7	281.5	18.3	16.7	38.5	71.8
X. mekongensis	314.3	112.2	8.4	19.4	15.3	42.5
E. agallocha	1585.7	216.4	42.4	19.4	29.6	90.1
C. decandra	371.4	2.07	9.9	13.9	0.28	28.5
A. corniculatum	385.7	55.1	10.3	11.1	7.5	28.6
S. apetala	14.3	36.4	0.38	2.78	5.0	7.92
B. gymnorrhiza	14.3	0.82	0.38	2.78	0.11	3.27

Table 2 Stand structure of mangrove communities within the polyhaline zone of Sundarbans, Bangladesh

Plot no.	No of species	Density	Total basal area	Mean *H* (m)	Mean DBH (cm)	Complexity index
1	5	2400	46.1	3.5 ± 0.19	14.3 ± 1.29	19.6
2	5	4600	163.7	4.4 ± 0.24	17.9 ± 1.69	165.4
3	5	5200	157.5	4.1 ± 0.42	16.4 ± 1.49	168.1
4	4	2800	91.5	4.0 ± 0.23	18.5 ± 1.61	40.6
5	6	4400	162.1	3.5 ± 0.20	18.9 ± 1.59	151.7
6	4	3600	56.2	3.3 ± 0.15	13.3 ± 0.78	26.5
7	5	3200	88.5	3.5 ± 0.17	17.2 ± 1.34	49.9
Mean		3742.9 ± 358.5	109.4 ± 17.9	3.8 ± 0.14	16.6 ± 0.74	88.8 ± 24.2

Biomass and carbon accumulation

The average above-ground biomass of the mangrove stands was 419.4 ± 77.02 Mg ha^{-1}, with a range spanning from 104.7 Mg ha^{-1} (Plot 6) to 642.3 Mg ha^{-1} (Plot 5). Similarly, the mean below-ground biomass reached 368.6 ± 64.2 Mg ha^{-1}, varying from 150.7 Mg ha^{-1} (Plot 6) to 560 Mg ha^{-1} (Plot 2), respectively (Table 3). These above-ground, below-ground, and total biomass values were converted into mean total AGBC, BGBC, and mean TBC stocks of 197.1 ± 36.2, 173.2 ± 30.2, and 370.4 ± 66.1 Mg ha^{-1}, respectively (Table 4).

The study area representing the polyhaline zone of the Sundarbans is characterised as a mixed forest stand, as illustrated in Figure 2, which displays the typical distribution of mangrove tree species across diameter classes in the study area. Figure 2 indicates that approximately 45.1% of all individuals have diameters ranging from 10.10 to 15.00 cm. The second-highest diameter class, encompassing diameters between 15.10 and 20.00 cm, comprises nearly 17.6% of the total tree population in the area. Within the studied mangrove region, *S. apetala* emerged as the largest tree, standing at 9.7 m tall and with a DBH of 68.1 cm, followed by *A. officinalis* at 64.7 cm DBH and 8.3 m in height.

In order to investigate the role of different species in carbon sequestration, we conducted an analysis of the carbon content attributed to each species, as presented in Figure 3a. The population density per hectare for each species is illustrated in Figure 3b. Through the species-specific carbon storage analysis including both above-ground and below-ground biomass carbon, we noticed the sequence as *A, officinalis*

Table 3 Biomass accumulation (Mg ha^{-1}) in mangrove communities within the polyhaline zone of Sundarbans, Bangladesh

Plot no.	Above-ground biomass (Mg ha^{-1})	Below-ground biomass (Mg ha^{-1})	Total biomass (Mg ha^{-1})
1	199.7	152	351.7
2	617.8	560	1177.8
3	634.6	553.3	1187.9
4	406	307.4	713.4
5	642.3	542.9	1185.2
6	104.7	150.7	255.4
7	330.9	313.7	644.6
Mean	419.4 ± 77.02	368.6 ± 64.2	788 ± 140.7

Table 4 Biomass carbon accumulation (Mg ha^{-1}) in mangrove communities within the polyhaline zone of Sundarbans, Bangladesh

Plot no	Above-ground biomass carbon (Mg ha^{-1})	Below-ground biomass carbon (Mg ha^{-1})	Total biomass carbon (Mg ha^{-1})
1	93.9	71.4	165.3
2	290.4	263.2	553.6
3	298.2	260	558.3
4	190.8	144.5	335.3
5	301.9	255.2	557
6	49.2	70.8	120
7	155.5	147.4	303
Mean	197.1 ± 36.2	173.2 ± 30.2	370.4 ± 66.1

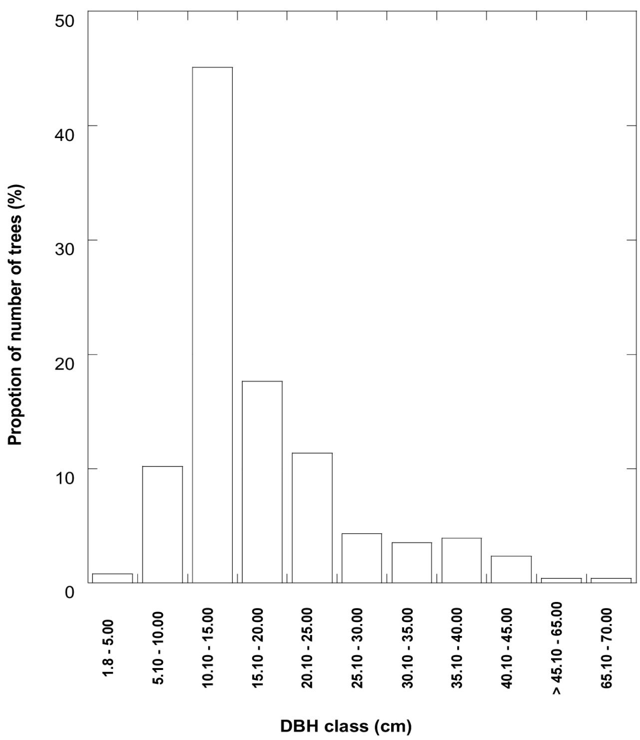
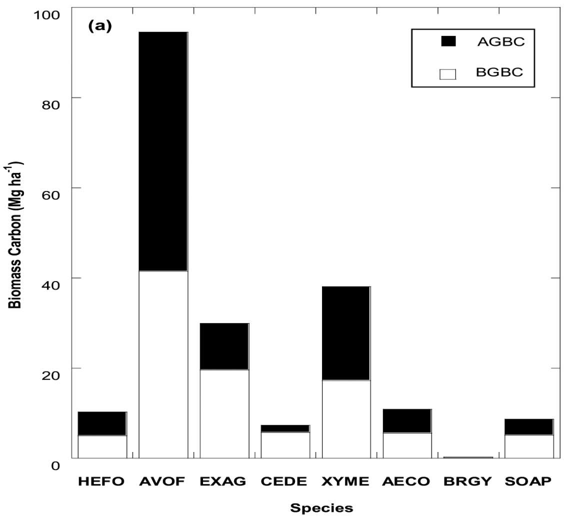


Figure 2 Stem diameter distribution of trees in the mangrove communities within the polyhaline zone of Sundarbans, Bangladesh



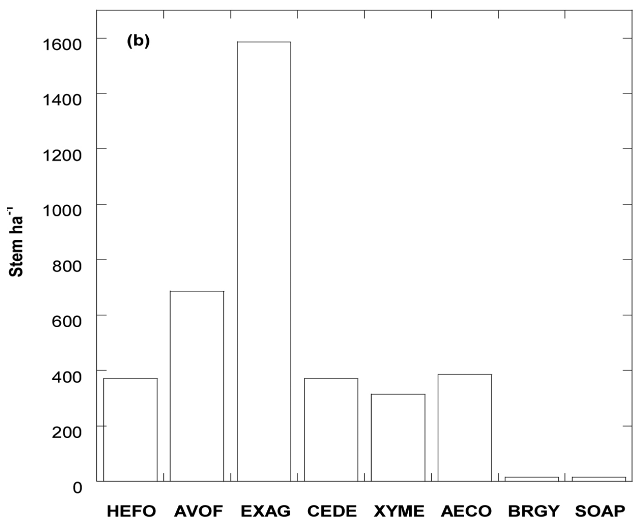


Figure 3 **(a)** Contribution of each species to the biomass carbon per hectare in the study area;
Figure 3 **(b)** Number of individuals contributing to their respective shares of the study area's species-specific carbon stocking

> *X. mekongensis* > *E. agallocha* > *A. corniculatam* > *H. fomes* > *S. apetala* > *C. decandra* > *B. gymnorrhiza* (Figure 3a).

The diameter class distribution of various mangrove species in the study area is used to assess the above-ground and below-ground carbon pools, as shown in Figure 4. In the study area, the majority of the trees diameter found in 10–15 cm, but their share of the total above-ground biomass carbon was only 12%. In comparison, a significant amount of biomass carbon is contributed by tree species with a diameter range of 35 to 40 cm, which account for only 3.9% of all trees, but account for 17.8% of the total above-ground biomass carbon (Figure 4a).

While the majority of the forest's trees are species with diameter ranging between 10 and 15 cm, but they only account for 16% of the totalbelow-ground biomass carbon. However, only a small proportion of trees, specifically those with a diameter of 35 to 40 centimeters to provide roughly the same amount of biomass carbon (15.9%)of all biomass carbon found below-ground (Figure 4b).

DISCUSSION

Forest structure and composition

The intricate relationship between the structure and composition of mangrove species significantly impacts the ecological processes in mangrove forests, depicting a complex web of relationships that govern the distribution and abundance of fauna inhabiting these unique ecosystems (Soares 1999, Cavalcanti et al. 2009). Hence, a comprehensive understanding of mangrove vegetation structure and species composition is necessary for effective ecosystem management and conservation strategies. Our investigation of forest composition in the polyhaline zone of the Sundarbans found eight major mangrove species with DBH exceeding 10 cm. Particularly, all species identified within this study area were classified under 6 distinct families, underscoring the diverse botanical richness present in this unique ecosystem. Among these species, it was observed that *E. agallocha* exhibited dominance with an Importance Value Index (Iv = 90.1), followed closely by *A, officinalis* at (Iv = 71.8).

Within our study area, the average stand density measured 3742.9 ha^{-1}, with a peak stand density reaching 5200 ha^{-1} at Plot number 3. These values surpassed those documented by Kamruzzaman et al. (2018) for the oligohaline region of the forest, where the mean stand density stood at 2629 ha^{-1} and even the most densely populated area, Dhangmari, recorded a stand density of 4800 ha^{-1}. Despite the high salinity characteristic of the polyhaline zone in Sundarbans, the average DBH of trees (16.6 cm) also exceeded that reported for the oligohaline

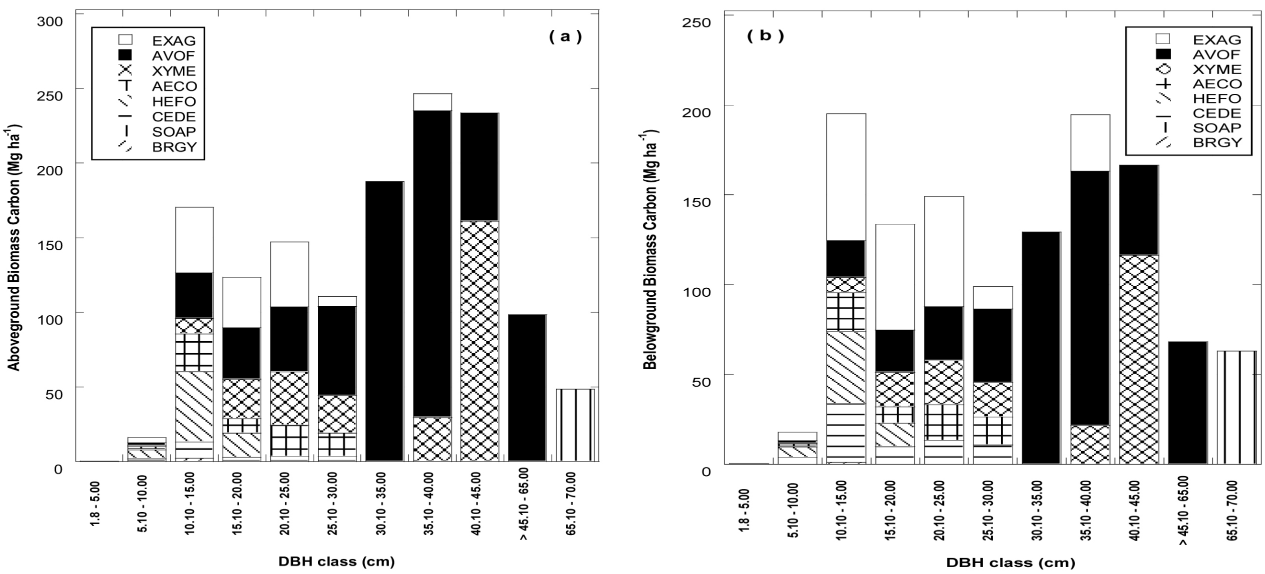


Figure 4 **(a)** Above-ground carbon pool in the study area in relation to the diameter class of various mangrove species

Figure 4 **(b)** Below-ground carbon pool in the study area in relation to the diameter class of various mangrove species

zone (8.7 cm). Hence, it could be indicative that the polyhaline zone has more mature trees compared to the oligohaline zone as well as the study area is less disturbed and free from illegal extraction or harvesting (Erwin 2005). This statement becomes more evident when considering the total basal area calculated for the polyhaline zone (109.4 m^2 ha^{-1}), significantly exceeding that of the oligohaline zone in Sundarbans (22.0 m^2 ha^{-1}). The *E. agallocha - X. mekongensis* dominated community in the study area exhibits the highest total basal area of 163.7 m^2 ha^{-1}, while the *A. officinalis-A. corniculatam* community has the smallest basal area at 46.1 m^2 ha^{-1}. As reported by Kamruzzaman et al. (2018), the *H. fomes-X. mekongensis-A. officinalis* community in the oligohaline zone had the largest total basal area of 34.2 m2 ha^{-1}, whereas the *E. agallocha-H. fomes* community had the smallest at 5.1 m2 ha^{-1} in Karamjol and Dhangmari areas of the oligohaline zone, respectively. Such variations in the basal area between polyhaline and oligohaline zones can be attributed to factors like altitude, species composition, tree age, disturbance levels, and succession stages within stands (Sahu et al. 2016). However, when considering mean height, the polyhaline zone recorded a lower value of 3.8 m compared to the reported value of 8.9 m for the oligohaline zone (Kamruzzaman et al. 2018). This difference may be caused due to higher stand density in the polyhaline zone acting as a limiting factor for plant growth by intensifying competition for resources (Volin et al. 2005, Li et al. 2014).

The stem density and species quantity within our study area exhibited a consistent decline as DBH class of tree species increased, with the exception of young individuals falling within the 10–15 cm DBH class (Figure 2). This pattern was also observed in the oligohaline zone as reported by Kamruzzaman et al. (2018). Analysis of tree distribution across various DBH intervals revealed dominance of small trees in the study area, with a notably limited presence of large trees but a considerable number of medium-sized individuals. This observation suggests that species with smaller DBH values primarily utilize available resources. Furthermore, the distribution pattern by DBH size class indicated a decrease in individual numbers from lower to higher classes, suggesting a growing forest.

Excoecaria agallocha, as the dominant species in the study area, exhibited the highest relative frequency and relative density, which can be attributed to its ability to thrive in challenging environments with high salinity levels. This is further supported by a recent phenological study on *E. agallocha* (Mariam & Alamgir 2022), which revealed consistent germination and survival rates across all three salinity zones. Despite this, the Importance Value (Iv) of *E. agallocha* (90.1) was notably lower compared to the dominant species *H. fomes* (Iv 106.1) identified in the oligohaline zone. Now, in terms of the complexity index, the polyhaline zone showed a significantly larger value (88.8) compared to the value (18.8) found in the oligohaline zone (Kamruzzaman et al. 2018). This disparity suggests that the stand structure in the polyhaline zone is more complex than that in the oligohaline zone, possibly due to highly scattered seed dispersal and succession influenced by through increased sedimentation and nutrient cycling resulting from frequent inundation in near coastal areas as opposed to inland regions like the oligohaline zone (Singh et al. 2005, Aziz & Paul 2015).

Biomass and carbon stock

The mean above-ground biomass of our studied stands was 419.4 ± 77.02 Mg ha^{-1}, with a range spanning from 104.7 Mg ha^{-1} (Plot 6) to 642.3 Mg ha^{-1} (Plot 5). This result was much higher compared to, the estimated aboveground biomass (AGB) in Kuala Sepetang (South) Forest Reserve, Malaysia, which ranged from 33.65 to 437.46 Mg ha^{-1}, with a mean value of 133.97 Mg ha^{-1} (Muhd-Ekhzarizal et al. 2018). The arrangement of mangrove vegetation influences the distribution and correlation of carbon stock within mangrove ecosystems, primarily through factors such as sediment build-up, changes in biomass, and biogeochemical properties (Stephenson et al. 2014). Subsequent to this observation, notable variations were noticed in the accumulation of above-ground and below-ground biomass carbon among the study sites. For instance, study Plot 6 exhibited the lowest levels of above-ground and below-ground carbon stock at 49.2 Mg ha^{-1} and 70.8 Mg ha^{-1} respectively, whereas study Plot 5 displayed the highest above-ground carbon stock and study Plot 2 had the highest below-ground carbon stock. Now, it can also be stated that vegetation in Plot 2 allocated a greater proportion of biomass to below-ground structures, as evidenced by the substantial result of 560 Mg ha^{-1} below-ground biomass in Plot 2 (Table 3).

The present experiments also showed variation in biomass and carbon stock in the polyhaline zone compared to the oligohaline zone of the Sundarbans as well as other mangrove forests in the world. The total biomass carbon in our study area was 370.4 Mg ha^{-1}, which is three times higher compared to the total biomass carbon (117.98 Mg ha^{-1}) estimated in the oligohaline zone of the Sundarbans (Kamruzzaman et al. 2018). Furthermore, the total carbon stock (370.4 Mg C ha^{-1}) in our study area was remarkably higher than the estimated carbon stock values (89.74 Mg C ha^{-1}) in the Sulaman Lake Forest Mangroved, Sabah, Malaysia (Besar et al. 2020), 216.17 Mg ha^{-1} in the Republic of Yap, Micronesia (Kauffman et al. 2011), 212 Mg ha^{-1} in the Sumatra, Sulawesi, Java, Kalimantan, Papua and Bali, Indonesia (Alongi et al. 2016), 61.29 Mg ha^{-1} in the Peninsular Malaysia, Malaysia (Hong et al. 2017), 254.6 Mg ha^{-1} in the Cotabato City Mangrove Forest, Philippines (Dimalen & Rojo 2019).These significant carbon stock disparities point out the importance of Sundarbans Mangrove Forest in global carbon reduction compared to other mangrove vegetations in the world.

The identification of species with greater carbon sequestration potential relies significantly on understanding their species-specific contribution to biomass carbon. This study represents the first investigation conducted in the polyhaline zone of the SMF in Bangladesh, where the species-specific contribution to carbon accumulation were measured. Within the study plot, about 80% mangrove species were having diameters below 30 cm, but their impact on above-ground biomass (AGB) and below-ground biomass (BGB) carbon accumulation was relatively limited, constituting only 41% of AGB carbon mass and 48% of BGB carbon mass, respectively. In contrast, individuals with diameters ranging from 30 to 70 cm, although comprising only 10.6% of the total population, made substantial contributions to AGB and BGB carbon accumulation, accounting for 58.9% and 51%, respectively. Regarding species-specific contribution, *A. officinalis* exhibited lower species richness compared to *E. agallocha* but played a crucial role in carbon storage. *E. agallocha* demonstrated the highest specific density, followed by *A. officinalis* and *X. mekongensis*; however, concerning carbon storage capacity, *A. officinalis* emerged as the most influential followed by *X. mekongensis*. Consequently, it can be inferred that tree-level carbon storage in the examined mangrove stands cannot be solely elucidated by species richness alone. This statement is also consistent with the findings of Ahmed & Kamruzzaman (2021), which indicate that larger-sized trees and stands with lower density have a greater capacity for carbon sequestration compared to smaller-sized trees and denser stands.

The findings of our study suggest a positive correlation between basal area and carbon stock in mangrove forests, with increased basal area corresponding to higher carbon stocks. This relationship holds true for both aboveground biomass carbon (AGBC) and belowground biomass carbon (BGBC) individually. These conclusions align with previous studies, such as the work of Tamooh et al. (2008) on a Kenyan mangrove forest, which similarly found that higher basal areas were associated with increased BGBC stocks. Likewise, studies by Kamruzzaman et al. (2017) and Ahmed et al. (2022) conducted in the Sundarbans mangrove forest in Bangladesh also observed a significant increment in carbon stock with increasing basal area. Overall, the current highlights the differential carbon sequestration potential between the polyhaline and oligohaline zones of the Sundarbans in Bangladesh, indicating that the former possesses a greater capacity for carbon storage. Specifically, our findings underscore the importance of targeted management strategies for species like *X. mekongensis* and *A. officinalis* to enhance carbon sequestration in this region. Besides, the increased dominance of species like Gewa (*E. agallocha*), which has comparatively lower carbon sequestration potential, necessitates more concentrated planning and management to facilitate the growth and richness of other potentially more valuable species in terms of both ecological and economic values.

CONCLUSION

The research on stand structure and carbon storage in the polyhaline zone of Sundarbans Mangrove Forest in Bangladesh gives important insights into the complex link between mangrove ecosystems and carbon sequestration. The findings emphasise the necessity of knowing this ecosystem's structural properties for effective conservation and climate change mitigation efforts. With its distinctive polyhaline zone, the Sundarbans serve an important role in carbon storage, contributing to worldwide efforts to prevent climate change. It is feasible to conclude that the biomass and carbon accumulation of mangrove species change depending on the species and size class. Carbon storage is not affected by species dominance rather it is influenced by basal area. The potential yield of carbon storage inside the polyhaline zone of SMF should be evaluated by estimating current carbon stocks directly. This study adds to our understanding of mangrove ecology and underlines the importance of long-term management techniques to Mangrove the Sundarbans critical role in carbon storage and general ecosystem health.

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