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Tree-biomass-carbon estimation in the coastal afforestation sites of Chittagong, Bangladesh

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Abstract

Global climate is changing relentlessly due to anthropogenic greenhouse gas emissions into the atmosphere. Its impacts are globally visible now. Bangladesh is the worst-affected country in the world due to this climate change. Coastal afforestation, among several forestry options, is critical to climate change mitigation and adaptation. This study estimated the tree biomass growth and its carbon in the Kattoli and Parki beach under the Chittagong coastal forest division. The study estimated that the total biomass density of *Acacia auriculiformis, Acacia nilotica, Avicennia officinalis, Casuarina equisetifolia, Samanea saman, Sonneratia apetala* and *Terminalia arjuna* were 131.57±6.77, 116.96±6.41, 350.64±7.99, 296.47±9.46, 119.27±7.45, 154.86±4.78 and 117.11±9.68 tha^{-1}, respectively, with the mean annual increment of 65.79±3.38, 58.48±3.20, 15.25±0.35, 33.15±1.60, 59.63±3.73, 6.45±0.11 and 58.55±4.84 $tha^{-1}yr^{-1}$, respectively. Furthermore, the total biomass-carbon of each species was also estimated, which were 65.79±3.38, 58.48±3.2, 175.32±3.10, 148.23±4.73, 59.63±3.73, 77.43±2.39 and 58.55±4.84 $tCha^{-1}$ for the respective species, respectively, with the mean annual increment of 32.89±1.69, 29.24±1.60, 7.62±0.17, 16.57±0.80, 29.82±1.86, 3.23±0.10, 29.28±2.42 $tCha^{-1}yr^{-1}$, respectively. All the findings of the study indicate that afforestation with both mangrove and non-mangrove species along with the coastal belts in Chittagong has the potential to mitigate climate change. The results can be useful for climate change mitigation practitioners, researchers, and policymakers on a native and broad scale.

Keywords: Tree species; Coastal plantation; Carbon sequestration; Aboveground biomass; Belowground biomass.

Introduction, scope and main objectives

Climate change is a severe global phenomenon due to the increasing concentration of CO_2, which is a prominent cause of global warming. Burning of fossil fuels and deforestation/degradation are imposing this (Karl and Trenberth 2003). The coastal regions cover 19 districts out of 64 districts in Bangladesh. The whole coast forms 710 km long coastline along the Bay of Bengal (Sarwar 2005). The coastal zone covers 47,201 km^2 land area, which is 32% of the total landmass of the country (Islam 2004). The area forms the lowest landmass and is part of the delta of the extended Himalayan drainage ecosystem (Siddiqi 2001). However, global climate change is one of the greatest threats to human lives and properties in coastal regions of Bangladesh.

The coastal afforestation program started in 1965-66 with the objectives of building shelterbelts and providing some other tangible benefits in the coastal areas of Bangladesh (Siddiqi 2001). Presently, Bangladesh has a unique afforestation program on the newly accreted lands of the Bay of Bengal. There has been planning that all new accretions in the Bay will be afforested to ensure their stabilization and further accumulations (Iftekhar and Islam 2004). During the last four decades, the Bangladesh Forest Department has successfully implemented massive plantation programs. It has already established 172,000 ha of mangrove plantations scattered over coastal areas and off-shore islands (Hossain 2014). The dominant mangrove tree species planted on the coasts are Keora *Sonneratia apetala* (Keora), *Avicennia officinalis* (Baen), *Bruguira gymnorhiza* (Kankra), *Nypa fruticans* (Golpata) and *Excoecaria agallocha* (Gewa) (Chaudhuri and Choudhury 1994). Mangrove forests serve to conserve and stabilize newly accreted land and develop a suitable environment for the biodiversity (Papry 2014; Siddiqi 2001).

The embankments along the coastal belts of Bangladesh are under threat due to sea-level rise and cyclonic storm surges. To reduce the impact of climate change, it needs to develop sustainable forest management along the coastal belt of Bangladesh. It has been estimated that the tree tissues store 307 $tCha^{-1}$ atmospheric carbon in the forests of Bangladesh generally, indicating that per hectare forest cover can demand particular payment for carbon sequestration and this capital can develop the forestry sector in multipurpose aspects (Miah 2001).

Trees are essential carbon sink and biomass sources, including timber, fuelwood, food, and fodder. About 70–90% of total forest biomass is from the aboveground portion, where most of it is in trees (Cairns et al. 1997). There are importantly six-carbon pools in the forests, i.e., aboveground trees, aboveground non-tree, belowground roots, litter, deadwood, and soil organic matter (Dixon et al.

1994). Among them, the aboveground and belowground biomass of the trees is ecologically significant (Pan et al. 2011). Different studies were for measuring carbon in different forest pools of the earth (Sahu et al. 2016; Dar and Sundarapandian 2015; Jepsen 2006; Hossain 2014; Fukuda et al. 2003; Nam et al. 2016; Chen et al. 2003; Carswell et al. 2009; Chiti et al. 2010; Wei et al. 2014; Bhomia et al. 2016; DeGryze et al. 2004; Brown 2002; Sitoe et al. 2014; Shin et al. 2007; Kauffman et al. 2011). Among them, the tree biomass-carbon estimation got huge attention.

Coastal afforestation can play a vital role in climate change mitigation by stabilizing carbon content in the atmosphere through mangrove and non-mangrove trees. It can play an important role in reducing the damages and protect human lives by acting as a protective shelterbelt during cyclones and storm surges (Nandy and Ahammad 2012). Many studies were for estimating mangrove and non-mangrove tree carbon (Adame et al. 2013; Ahmed and Iqbal 2011; Ajonina et al. 2014; Donato et al. 2011; Fromard et al. 1998; Guerra-Santos et al. 2014; Hossain et al. 2016; Hossain et al. 2012; Jones et al. 2014; Kauffman et al. 2011; Khan et al. 2007; Murdiyarso et al. 2009; Rahman et al. 2014; Ren et al. 2010; Sherman et al. 2003; Sitoe et al. 2014). However, the study of biomass and carbon estimation in the coastal afforestation sites in Bangladesh is insufficient. The coastal afforestation in both Kattoli and Parki beach is vital for its socio-economic and climate change issues. However, there is no significant research work in Katttoli and Parki beach on estimating the concentration of tree biomass carbon. The study conducted its attempts to estimate the biomass growth and the carbon of trees planted through the coastal belt in Kattoli and Parki beach. The study's findings will contribute to the coastal afforestation practitioners and climate change mitigation policymakers in Bangladesh.

Methodology/approach

The geographic scope of the study was in the coastal afforestation sites of Chittagong under the Chittagong Coastal forest division. The specific sites were in the Kattoli forest beat and Parki beach of Anowara Upazila. The study conducted its attempts from August 2016 to September 2016. It performed a forest inventory in the shelterbelt plantation of 23-year-old *Casuarina equisetifolia* stands in the Parki beach and 24-year-old along with 2-year-old plantations of Kattoli forest beat. There was a species-wise distribution of the diameter (dbh) class, as well as the total height class of the trees. The measurement only considered frequently planted tree species based on the abundance of the tree species, including both mangrove and non-mangrove species. To understand the carbon sequestration of the tree species, the study measured the aboveground and belowground biomass of the trees. This paper is a part of the research project, as described in the acknowledgment. Some basic facts mentioned in this paper can be similar in other documents under the same project also.

Description of the study area

The studied areas were at Kattoli forest beat under Pahartali Thana in Chittagong city and Parki beach under Anwara Upazila in Chittagong District. The coastal plantation in the Kattoli forest beat and Parki beach are under the Chittagong coastal forest division. Sitakunda Thana on the north, Double mooring and Bandar thana on the south, Panchlaish and Double mooring on the east, and the Bay of Bengal on the west bind Pahartali thana. According to the population census 2011, the total population of Pahartali Thana is 190,637 in 13.3 km^2. Males constituted 51.7% and females 48.3% with a population density of 14323 km^{-2}. The average literacy rate of people is 65.8% (BBS 2012).

Bird-eye view of Kattoli study area indicating the waypoints of 42 permanent plots and whole covered area by connecting the border waypoints (Figure 1).

a b

Figure 1: Demarcated (a) Kattoli and (b) Parki beach study area connecting the boundary waypoints showing the waypoints of the permanent plots under the Chittagong coastal forest division.

On the north by Patiya and Karnafuli Thana, on the east by Chandanaish Upazila, on the south by Banshkhali Upazila, on the west by Port Thana, and the Bay of Bengal bind Anowara Upazilla with an area of 164 km^2 (BBS 2012). According to the population census 2011, the total population of Anowara Upazila is 2,59,022, comprising 48.9% males and 51.1% females, with a population density of 1578 km^{-2}. The literacy rate of people is 52% (BBS 2012).

Bird-eye view of Parki beach study area under Anowara Upazila indicating the waypoints of 16 permanent plots and the whole covered area by connecting the border waypoints (Figure 1).

Sampling and data collection

The study examined 58 sample square plots for vegetation study taken 42 from Kattoli forest beat and 16 from Parki beach plantation area. It selected the plots by stratified random sampling technique. The size of each plot was 10×10 m^2.

The centers of the plots were determined by a GPS as the global coordinates (latitude and longitude). The plots ranged from latitude N22.19132° to N22.9652° and longitude E91.7512° to E91.81523°.

The seven frequently planted tree species were *Acacia auriculiformis, Acacia nilotica, Avicennia officinalis, Casuarina equisetifolia, Samanea saman, Sonneratia apetala, Terminalia arjuna*. Among them, *A. officinalis* and *S. apetala* are the mangrove tree species, and the rests are non-mangrove tree species. The study considered only these frequently planted tree species.

Collection of primary data

A structured data sheet recorded information on diameter at breast height (dbh) at 1.3 m and the total height of trees. It only considered the tree dbh measured 5 cm and above for biomass and carbon study. To measure dbh, it used slide calipers and measuring tapes, and to estimate total height, it used Shunto Clinometer. The stand age of *S. apetala* and *A. officinalis* and mound plantation in Kattoli beat were 24, 23 and 2 years, respectively. The *C. equisetifolia* shelterbelt in Parki beach was 23 years of age.

Data analysis

The study classified the tree data into six diameters at breast height (dbh) and six height classes. In all values of dbh, five cut-points made six dbh classes based on equal percentile, as class 1 ≤8.28 cm, class 2 among 8.29 to 13.05 cm, class 3 among 13.06 to 18.14 cm, class 4 among 18.15 to 21.33 cm, class 5 among 21.34 to 23.87 cm and class 6 among 23.88+ cm. Likewise, six height classes were class 1: ≤6.10 m, class 2: 6.11 to 7.80 m, class 3: 7.81 to 8.90 m, class 4: 8.91 to 11.20 m, class 5: 11.21 to 16.50 m and class 6: 16.51+ m.

The study applied the allometric regression equation for estimating the aboveground and belowground biomass in the trees. It estimated carbon using the standard biomass-carbon conversion factor.

Species-specific allometric equations were not available for this study during the study period. For this reason, it used a general allometric equation only. It estimated the aboveground biomass density (ABD) of trees using the allometric model described by Pearson et al. (2005):

Biomass, kg/tree = exp (-2.289+2.649**ln*dbh-0.021**ln*dbh^2), where *ln* is the natural logarithm.

The following allometric equation estimated the belowground biomass density (BBD) described by Pearson et al. (2005).

BBD, kg/tree = exp(-1.0587+0.8836**ln*ABD) where *ln* is the natural logarithm.

Finally, the biomass was converted to carbon stock using the factor 0.5 for estimating both aboveground carbon density (ACD) and belowground carbon density (BCD) (Pearson et al. 2005). It calculated the Mean Annual Increment (MAI) of both biomass and carbon. To do it, the study divided the biomass and carbon by the age of the stands of the particular tree species.

Results

1. Structural distribution of planted tree species on the coastal area

The dbh class ≤8.28 cm and 8.29 to 13.05 cm were dominant in the height class ≤6.10 m of the tree species *Acacia auriculiformis* (Akashmoni), having percentages of 90.5 and 88.9, respectively (Table 1). For *Acacia nilotica* (Babla), 95% of the dbh class ≤8.28 cm was dominant in the ≤6.10 m height class. For *Avicennia officinalis* (Baen), the dbh class 23.88+ cm was dominant in the height class 8.91 to 11.20 m having the percentage 62. For *Casuarina equisetifolia* (Jhau), the dbh class 23.88+ cm was dominant in the height class 16.51+ m having the percentages of 95. For *Samanea saman* (Raintree), both dbh classes ≤8.28 cm and 8.29 to 13.05 cm were dominant in the height class ≤6.10 m having the percentages 91 and 100, respectively. For *Sonneratia apetala* (Keora), all the individuals of the dbh class 21.34 to 23.87 cm were dominant in the 8.91 to 11.20 m height class. For *Terminalia arjuna* (Arjun), all the individuals of dbh classes ≤8.28 cm and 8.29 to 13.05 cm were dominant in the height class ≤6.10 m.

The highest dbh was in the *A. Officinalis* 22.56±0.36 cm, while the lowest was in the *T. arjuna* 6.28±0.31. The highest height was in the *C. equisetifolia* 13.67±0.33 m while the lowest was in the *T. arjuna* 3.28±0.26 m.

Table 1: Height and diameter at breast height (dbh) class distribution of coastal planted tree species in Kattoli and Parki beach under the Chittagong coastal forest division.

Scientific name of the tree species	dbh class (cm)	Height class (m) (%)						
		≤ 6.10	6.11 - 7.80	7.81 - 8.90	8.91 - 11.20	11.21 - 16.50	16.51+	Total
Acacia auriculiformis	≤ 8.28	90.5	9.5					100.0
	8.29 - 13.05	88.9	11.1					100.0
	13.06 - 18.14							
	18.15 - 21.33							
	21.34 - 23.87							
	23.88+							
Acacia nilotica	≤ 8.28	95.0	5.0					100.0
	8.29 - 13.05							
	13.06 - 18.14							
	18.15 - 21.33							
	21.34 - 23.87							
	23.88+							
Avicennia officinalis	≤ 8.28							
	8.29 - 13.05							
	13.06 - 18.14	20.0	60.0	20.0				100.0
	18.15 - 21.33		53.8	43.6	2.6			100.0
	21.34 - 23.87		11.5	46.2	42.3			100.0
	23.88+			11.9	61.9	26.2		100.0
Casuarina equisetifolia	≤ 8.28	11.1	77.8	11.1				100.0
	8.29 - 13.05	4.3	44.3	41.4	7.1	2.9		100.0
	13.06 - 18.14		16.7	11.1	11.1	61.1		100.0
	18.15 - 21.33		2.5	2.5		85.0	10.0	100.0
	21.34 - 23.87				2.9	26.5	70.6	100.0
	23.88+				3.4	1.7	94.8	100.0
Samanea saman	≤ 8.28	90.9	9.1					100.0
	8.29 - 13.05	100.0						100.0
	13.06 - 18.14							
	18.15 - 21.33							
	21.34 - 23.87							
	23.88+							
Sonneratia apetala	≤ 8.28							

Scientific name of the tree species	dbh class (cm)	Height class (m) (%)						
		≤ 6.10	6.11 - 7.80	7.81 - 8.90	8.91 - 11.20	11.21 - 16.50	16.51+	Total
	8.29 - 13.05	16.7	50.0	16.7	16.7			100.0
	13.06 - 18.14		9.4	15.1	58.5	17.0		100.0
	18.15 - 21.33				30.0	70.0		100.0
	21.34 - 23.87				100.0			100.0
	23.88+							
Terminalia arjuna	≤ 8.28	100.0						100.0
	8.29 - 13.05	100.0						100.0
	13.06 - 18.14							
	18.15 - 21.33							
	21.34 - 23.87							
	23.88+							

2. The biomass growth of trees and its carbon contents in the coastal afforestation

Considering all the tree species, aboveground biomass, belowground biomass, and total biomass density were 211.87±15.57 tha^{-1}, 39.20±2.42 $tha^{-1,}$ and 251.06±17.98 tha^{-1}, respectively (Figure 2). Among these species, *A. officinalis* provided the highest aboveground, belowground, and total biomass density, which was 298.57±6.9 tha^{-1}, 52.07±1.09 tha^{-1}, 350.64±7.99 tha^{-1}, respectively (Table 2).

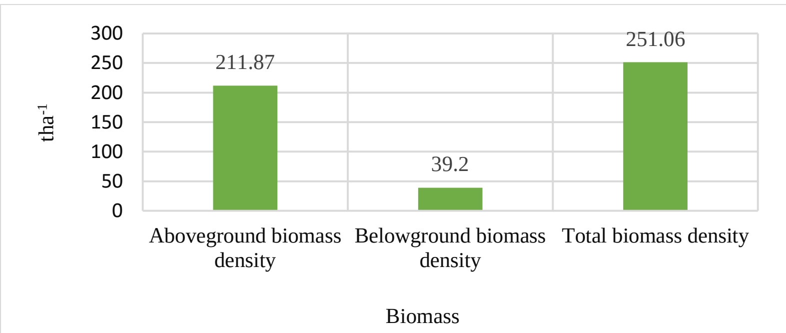

Figure 2. Aboveground biomass, belowground biomass and total biomass density in the coastal afforestation sites of Kattoli and Parki beach under the Chittagong coastal forest division.

The estimated above-ground biomass density of *C. equisetifolia, S. apetala, A. auriculiformis, S. saman, A. nilotica,* and *T. arjuna* were 250.6±8.21 tha^{-1}, 129.70±4.06 tha^{-1}, 106.84±5.59 tha^{-1}, 96.57±6.12 tha^{-1}, 94.87±5.27 $tha^{-1,}$ and 94.73±7.93 tha^{-1}, respectively. The belowground biomass density of the tree species were 45.78±1.25 tha^{-1}, 25.16±0.73 tha^{-1}, 24.31±1.19 tha^{-1}, 22.15±1.30 tha^{-1}, 21.78±1.11 $tha^{-1,}$ and 21.80±1.68 tha^{-1}, respectively (Table 2).

Table 2. Tree biomass growth and its carbon in the coastal afforestation sites of Kattoli and Parki beach under the Chittagong coastal forest division.

Scientific name of the tree species	Total ABD (tha^{-1})	Total BBD (tha^{-1})	Total biomass (tha^{-1})	Total biomass carbon ($tCha^{-1}$)
Acacia auriculiformis	106.84±5.59	24.31±1.19	131.57±6.77	65.79±3.38
Acacia nilotica	94.87±5.27	21.78±1.11	116.96±6.41	58.48±3.2
Avicennia officinalis	298.57±6.9	52.07±1.09	350.64±7.99	175.32±3.10
Casuarina equisetifolia	250.6±8.21	45.78±1.25	296.47±9.46	148.23±4.73
Samanea saman	96.57±6.12	22.15±1.30	119.27±7.45	59.63±3.73
Sonneratia apetala	129.70±4.06	25.16±0.73	154.86±4.78	77.43±2.39
Terminalia arjuna	94.73±7.93	21.80±1.68	117.11±9.68	58.55±4.84

Notes: ABD means Aboveground Biomass Density; BBD means Belowground Biomass Density.

For the total biomass density, the estimated values for the respective species were 296.47±9.46 tha^{-1}, 154.86±4.78 tha^{-1}, 131.57±6.77 tha^{-1}, 119.27±7.45 tha^{-1}, 116.96±6.41 $tha^{-1,}$ and 117.11±9.68 tha^{-1}, respectively (Table 2).

3. Mean Annual Increment (MAI) in biomass and carbon

Considering all the tree species, MAI in biomass was 30.11±3.28 $tha^{-1}yr^{-1,}$ and its carbon was 15.05±1.64 $tCha^{-1}yr^{-1}$ (Figure 3). Among the tree species, *A. auriculiformis* had the highest MAI of the total biomass and its carbon having 65.79±3.38 $tha^{-1}yr^{-1}$ and 32.89±1.69 $tCha^{-1}yr^{-1}$, respectively (Table 3). The other three species of mound plantation in Kattoli forest beat also showed higher MAI in biomass and carbon. The MAI of the total biomass and its carbon of *S. saman* was 59.63±3.73 $tha^{-1}yr^{-1}$ and 29.82±1.86 $tCha^{-1}yr^{-1}$, respectively, followed by *T. arjuna* having 58.55±4.84 $tha^{-1}yr^{-1}$ and 29.28±2.42 $tCha^{-1}yr^{-1}$, respectively and *A. nilotica* having 58.48±3.20 $tha^{-1}yr^{-1}$ and 29.24±1.60 $tCha^{-1}yr^{-1}$, respectively.

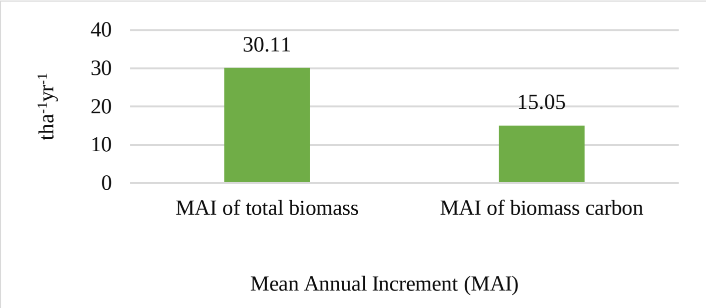

Figure 3. Mean Annual Increment (MAI) in biomass and carbon in the coastal afforestation sites of Kattoli and Parki beach under the Chittagong coastal forest division.

Table 3. Mean Annual Increment (MAI) in biomass and its carbon in the coastal afforestation sites of Kattoli and Parki beach under the Chittagong coastal forest division.

Scientific name of the tree species	MAI of the total biomass ($tha^{-1}yr^{-1}$)	MAI of the total biomass carbon ($tCha^{-1}yr^{-1}$)
Acacia auriculiformis	65.79±3.38	32.89±1.69
Acacia nilotica	58.48±3.20	29.24±1.60
Avicennia officinalis	15.25±0.35	7.62±0.17
Casuarina equisetifolia	33.15±1.60	16.57±0.80
Samania saman	59.63±3.73	29.82±1.86
Sonneratia apetala	6.45±0.11	3.23±0.10
Terminalia arjuna	58.55±4.84	29.28±2.42

Discussion

Among the stands of seven tree species, the 2-year old mound plantations of *A. auriculiformis, A. nilotica, S. saman,* and *T. arjuna* were the younger stands with lower dbh and height class (Table 1). There was an innovative plantation technique involved with the non-mangrove tree species. That was planting each individual in the mound[1]. Miah et al. (2011) reported *A. auriculiformis* in 4-year-old stand having a dbh and height of 9.39 cm and 7.22 m, which showed similarity with the present study. Generally, on favorable sites, *A. nilotica* has the dbh and height range of 60 cm, and 2.5 to 25 m (Sharma et al. 1996) seems similar to the present study.

[1] The present study introduces the plantation of the non-mangrove tree species in the mounds as a 'mound plantation'.

Haque et al. (2000) mentioned that diameter growth showed a more extensive range "for the same age of all the species except *A. officinalis* at different sites". The general trend about diameter and height of the species was, as the tree age increased the diameter, the height increment dropped down gradually for all the species except *C. decandra*. *S. apetala* showed diameter growth ranging from 10.3 cm to 26.5 cm at Bogachottor beat in Sitakunda range and Domkhali beat of Mirsharai range (Haque et al. 2000). Uddin and Hossain (2013) mentioned that 27-year-old *S. apetala* attained dbh and height growth of 21 cm and 16.5 m in Ochkhali beat and 24.5 cm and 18.5 m in Dalchar beat of Nolchira range of Hatiya Island, Bangladesh. It coincides with the present study.

A. officinalis of 20 to 29-year-old plantations attained a dbh and height range of 13.0 to 21.5 cm and 7.4 to 10.2 m in three beats of Mirsharai coastal forest, respectively (Uddin and Hossain 2013). It represents a vast difference with the present study of 24-year-old plantation having dbh and height class of *A. officinalis* between 23.88+ cm and 8.91 to 11.90 m, respectively, which is in agreement with Haque et al. (2000), who found the dbh of *S. apetala* 9.52 cm at 16- year age and 14.97 cm at 15- year age. It occurred due to variation in density of the species within the same age as well as due to differences in site condition.

According to Miah and Raihan (2017), the average dbh and height of 16-year-old *Casuarina* plantation at Cox's Bazar was 19.6 cm and 19.2 m which supports (dbh class 18.15 to 21.33 cm and height class 11.21 to 1.50 m) the present study.

As the mean dbh was the highest in *A. officinalis* followed by *C. equisetifolia* and *S. apetala,* the aboveground, belowground and total biomass density were also the highest in *A. officinalis* plantation followed by *C. equisetifolia* and *S. apetala.* The aboveground, belowground and total biomass density were found comparatively lower in *A. auriculiformis, S. saman, A. nilotica,* and *T. arjuna* because of the lower mean dbh of the species. China shows the total carbon storage at 4, 5, 8, and 10-year *S. apetala* plantation, which were 47.9, 71.7, 95.9, and 108.1 $tCha^{-1}$, respectively (Ren et al. 2010). Within the mangrove forest in south-east Mexico, the above-ground biomass was higher in *Conocarpus erectus* having 253.18±32.17 tha^{-1}, lower in *Avicennia germinans* having 161.93±12.63 tha^{-1}, and moderate in *Rhizophora mangle* and *Laguncularia racemose* having 181.70±16.58 tha^{-1} and 206.07±19.12 tha^{-1}, respectively (Guerra-Santos et al. 2014).

The mean aboveground living biomass of mangroves in the Mgeni estuary of South Africa was 94.49±7.83 tha^{-1} (Steinke et al. 1995). Another study about the Sundarbans presents that the estimated total aboveground and belowground biomass of *Ceriops decandra* was 33.49 and 14.36 tha^{-}

^{1}, respectively (Hossain et al. 2012). From the above discussion, it can state that the concentration of aboveground biomass density, belowground biomass density, and total biomass density of the three species in the study area represent in a reasonable stock level.

As the total biomass density was also the highest in *A. officinalis* plantation followed by *C. equisetifolia* and *S. apetala,* the total biomass carbon was also the highest, 175.32±3.10 $tCha^{-1}$ in *A. officinalis* plantation followed by *C. equisetifolia,* 148.23±4.73 $tCha^{-1}$ and *S. apetala* 77.43±2.39 $tCha^{-1}$ (Table 2). The total biomass-carbon of *A. auriculiformis, S. saman, T. arjuna,* and *A. nilotica* were 65.79±3.38 $tCha^{-1}$, 59.63±3.73 $tCha^{-1}$, 58.55±4.84 $tCha^{-1,}$ and 58.48±3.2 $tCha^{-1}$, respectively. In another study, it finds that the forests of Bangladesh can sequestrate 92 $tCha^{-1}$ on average (Shin et al. 2007). Another study in Japan reports that the total biomass-carbon stock in Manko Wetland, Okinawa Island, was 62 $tCha^{-1}$ (Khan et al. 2007). Hence, it can say that the quantity of total biomass-carbon in Kattoli and Parki beach is of a reasonable level of stock. The higher concentration of biomass-carbon in the *A. officinalis*, *C. equisetifolia* and *S. apetala* stands is due to the higher ages of the stands than that of the mound plantation in Kattoli beach. The *C. equisetifolia* stands in Parki beach was of 23 years old, and *S. apetala* and *A. officinalis* stands in Kattoli were of 24 years old. Whereas, the mound plantation with non-mangrove species was only 2 years old.

In the case of the Sundarbans, the mean carbon density was 256.7 ± 17 $tCha^{-1}$ (Ahmed and Iqbal 2011). *Heritiera fomes* (Sundri) was the most dominating forest type storing more ecosystem carbon of 360.1±22.71 $tCha^{-1}$ than any other types in the Sundarbans (Rahman et al. 2017). The ecosystem carbon stock of Can Gio Mangrove Biospheres Reserve and Kien Vang Protection forests were 889±111 $tCha^{-1}$ and 844±58 $tCha^{-1}$, respectively in Vietnam (Nam et al. 2016). The mean ecosystem carbon across the three Indonesian mangrove forests was 993.3 $tCha^{-1}$ (Murdiyarso et al. 2009). The excessively higher concentration of carbon at the ecosystem base in Vietnam and Indonesia is due to the especially higher accumulation of organic carbon in the forest soils and higher biomass growth in the forests (Kauffman et al. 2011). As ecosystem carbon includes carbon of all the pools of the forests, it is higher than both biomass-carbon and soil-carbon separately (Kauffman et al. 2011).

A study of China shows the accumulated average annual rate of total carbon storage at 4, 5, 8, and 10-year *S. apetala* plantation, which were 5.0, 7.9, 8.7, and 8.4 $tCha^{-1}yr^{-1}$, respectively (Ren et al. 2010). Another study of Dominican Republic reveals that the mean biomass increment of 23 plots in a 4700-ha mangrove forest was 9.7±1.0 $tha^{-1}yr^{-1}$ (Sherman et al. 2003). Mean annual increment shows the growth rate of the tree species. The present study shows an immensely fast growth of the non-mangrove tree species in the mound plantation. As it was very early age of only 2 years, it is difficult to conclude anything on this growth performance. A future and real measurement of this non-mangrove species planted in the saline soil can verify the real performance.

Conclusions/ wider implications of findings

The results show a promising carbon sequestration rate in the selective forest areas under the Chittagong coastal forest division. The higher carbon stock per hectare and Mean Annual Increment (MAI) of frequently planted tree species in the coastal belt show this potential. Among the seven species, *A. officinalis* had the highest total biomass carbon, which was 175.32±3.10 $tCha^{-1}$, with a lower MAI of 7.62±0.17 $tCha^{-1}yr^{-1}$. The growth of the non-mangrove trees in the coastal belt (mound plantation) also shows a high potential of carbon sequestration. *A. auriculiformis* had the highest MAI of the total biomass-carbon, which was 32.89±1.69 $tCha^{-1}yr^{-1}$. However, this study recommends a future verification of the growth performance of the mound plantation. The other sites of the afforestation along the Chittagong coast thus show a probability of having higher biomass growth and carbon sequestration. However, this higher carbon sequestration rate of the coastal plantation reflects a potential applicant to international carbon trading like A/R CDM. This study can contribute to climate change mitigation practitioners in Bangladesh.

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