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# Carbon sequestration capacity of four mangrove forest tree species in the coastal regions of Bhola, Bangladesh

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**Abstract**

Sundarbans is the largest mangrove forest in the world and provides many basic components to the modern ages. The main objective of the present study was to estimate carbon sequestration capacity of four mangrove forest tree species in the coastal regions of Bhola. The study was conducted on the basis of field data and nondestructive method was used for determination of biomass and carbon. The highest mean DBH was recorded for *Excoecaria agallocha*(9.74cm) followed by*Xylocarpus mekongensis*(7.78cm),*Aegiceras corniculatum*(6.55cm) and*Heritiera fomes*(5.40cm) respectively. The highest mean height was recorded for*Excoecaria agallocha*(8.39m) followed by *Xylocarpus mekongensis*(7.28m),*Aegiceras corniculatum*(6.84 cm) and*Heritiera fomes*(5.84cm) respectively. The highest survival percentage was found in*Excoecaria agallocha*followed by*Aegiceras corniculatum*>*Xylocarpus mekongensis*>and*Heritiera fomesrespectively*. Maximum carbon was found in*Excoecaria agallocha*(11.75tha$^{-1}$) followed by*Xylocarpus mekongensis*(8.34 tha$^{-1}$)*Heritiera fomes*(3.92tha$^{-1}$) and *Aegiceras corniculatum*(3.11tha$^{-1}$).The variable results were found in different mangrove forest species and their values were greatly influenced by different parameters.The present suggested that coastal should be plated on the basis of their higher survival and more growth capable species.

**Keywords:** Mangrove, biomass, carbon, storage, sequestration

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## 1. Introduction

Sundarbans is the single largest mangrove forest in the world.The Sundarbans mangrove forest covers an area of about 10,000 km$^2$, of which forests in Bangladesh extends over 6,017 km$^2$and West Bengal extends over 4,260 km$^2$.The most abundant tree species are *Heritiera fomes* and *Excoecaria agallocha*. Besides the sundri, other tree species in the forest include *Xylocarpus mekongensis* and *Aegiceras corniculatum* are also the most important mangrove forests tree.The Sundarbans are under threat from both natural and human-made causes. In 2007, the landfall of Cyclone Sidr damaged around 40% of the Sundarbans. The forest is also suffering from increased salinity due to rising sea levels due to climate change and reduced freshwater supply.Maximum plantation on the coastal regions are planted as monospecific. Inrecent year in some of the older plantations,particularly in Patuakhali and Bhola civil districts,sundri, gewa, passur and kankra have been plantedafter thinning. Nipa has also been planted successfullyin this part of the coastal regions. There are eleven coastal districts in Bangladesh such Cox's Bazar, Chattogram, Feni, Noakhali, Laximpur, Bhola, Borguna, Patuakhali, etc. Among them, Main Sundarbans is situated inBagerhat, Khulna and Satkhira andSundarbans features are also found in other districts.Sundarbans is the biggestmangrove forests in the world and is very essential for Bangladesh in economically and ecologically. Besides,mangrove forest acts as shelterbelt and protects from the natural calamities during the adverse conditions(Siddiqi, 2001). Only mangrove forest provides about 41% revenue of the total forest resources and produces 45% of the total timber and fuelwood in Bangladesh (Canonizado and Hossain 1998). Approximately600,000 people earn their livelihood, directly or indirectly from this forest (MOEF 1993).

Sundarbans is rich in biodiversity than other mangroves forest in the world and provides habitats of 45%, 42%, 46% and 36% mammals, birds, reptiles and amphibians respectively (Chaffey and Sandom, 1985). Globally also conservation of the mangroves of Bangladesh is very important as the forest alone supports about 41% of all mangrove species in the world and many globally endangered species. In fact observing the protective role played by the Sundarbans against the massive cyclone of 1960 that hit very hard in the central part of the coast the country initiated its coastal afforestation program. The coastal plantation programs are the

most effective in the whole area of Bangladesh. Successfully plantation programs are established inthousands of hectare land and the total coastal regions are covered by green belts. Plantation programs are increased day by day in the new accreted char land at geometrical rate. But the contribution of carbon sequestration capacity of mangrovespecies are still unknown due to lack of information and sufficient data.So it is the urgent need to estimate the biomass and carbon stock of four mangrove forest tree species for the carbon trading facilities. On this background, the objective of the present study was to find out the contribution of carbon sequestration of four mangrove forest tree species on the basis of different ages in the coastal areas of Bhola.

## 2. Materials and Method

### The study areas

The study area lies at $20^0$.20' to $20^0$.50' N latitudes and $91^0$.54' to $92^0$.28' E longitudes. It is located at Cox's Bazar Sadar, Inani and Teknaf Ranges of Chittagong Coastal Forest Division. The total study area was 415ha under three Ranges and seven Beats. The land surface of the area is flat to gentle slope and sandy in nature. The whole study area was under coastal area and south east parts of Bangladesh. All regions of the area were saline zone and inundated by saline water. The elevation of the study area ranged between 1meter and 4 meter mean sea level.

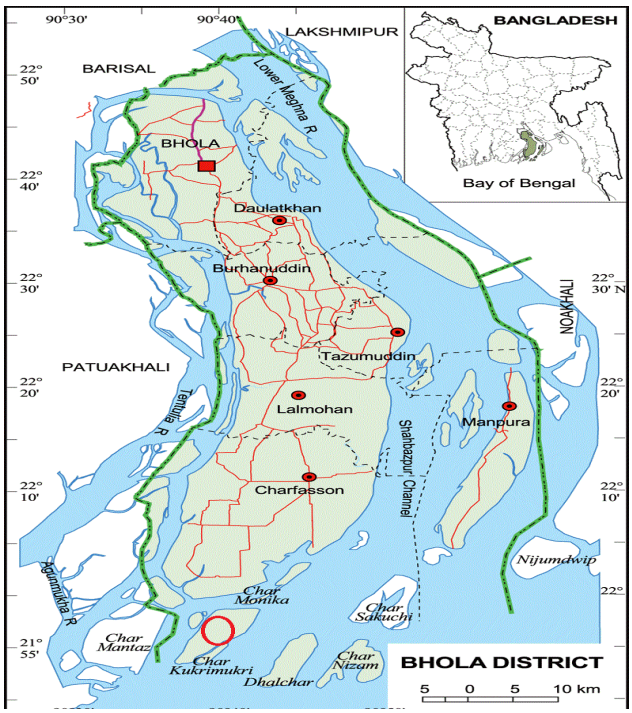


**Figure 1.** Map of the study area in Char Kukri-Mukri Island, Charfashion Upazila, Bhola District, Bangladesh (Source: Google image)

### Climatic condition

The climate is tropical in nature. The climate is pleasant and balanced. Winter begins in the middle of November and lasts until the end of February. The summer comes from March and continues up to the end of May. The rainy season starts in June and continues up to October. About 85% of rainfall occurs during this season. The main rainfall starts in the middle of June and continues up to the middle of July and an average 3000 mm rainfall occurs during this time. From October to February the weather is mild with low rainfall. The minimum and maximum mean temperature vary from16.80° to 28.20° C in December and May respectively (Cox's Bazar Weather Station, 2019**)**. The humidity in the whole area is high throughout the year. In June, the highest humidity is 91%, while the minimum humidity is 70% in February (Rahman, 2009).

### Selection of plots

The study was conducted on the basis of the field data collection, observation and laboratory analysis during January 2020 to December 2020. Plots of the present study were selected using Global Positioning Systems

(GPS). A systematic sampling method was used for the selection of each plot with the help of global positioning system which is recognized all over the world (Pearson *et al.*, 2007). For the convenience of the study, a total of 627 plots were selected from the whole study area and each plot was 100 m apart from each other. Although the minimum sampling intensity (number of plots per hectare) required for such studies was suggested to be 1 % by Rana *et al.* (2012).

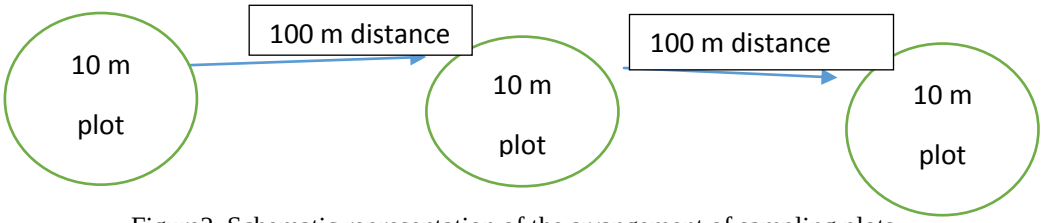


Figure2. Schematic representation of the arrangement of sampling plots.

**Growth and biomass measurement of tree**

After laying out of the plots, the number of trees in each plot were counted and recorded. The trees were measured for height and diameter at breast height (DBH). Each tree was marked and numbered to prevent double counting. A diameter tape was used to measure the DBH (1.30 m above from the ground level) of all the trees in each plot. Height of the trees having DBH equal or greater than 5 cm was measured with a Hega-altimeter. Trees on the border was included in a plot if > 50 % of their basal area fell within the plots and excluded if < 50 % of their basal area fell outside the plot. Trees overhanging to the plots were excluded, but with their trunk inside of the sampling plots, and branches out were included. Care was taken to ensure that the diameter tape is put around the stem exactly at the point of measurement.

**Estimation of tree biomass**

A non-destructive method was used to measure the aboveground biomass of an individual tree. The model of Brown *et al*. (1989) was used to determine the aboveground biomass (AGB) of each tree from its height and DBH values. This method is taken to be one of the most suitable methods for biomass estimation in tropical forests (Alves *et al*., 1997; Brown, 1997; Schroeder *et al.*, 1997).
The model for aboveground biomass is as follows.
$AGB=\exp.\{-2.4090+0.9522\ln(D^2HS)\}$

Where,
AGB is the aboveground biomass (kg), H is the height of the trees (m),
D is the diameter at breast height (cm), S is the wood density (kg /$m^3$) for specific species.
Wood density values of the species of the present study were obtained from Sattar *et al*. (1999).
Aboveground biomass per plot and per hectare were calculated by the following formulas:
AGB per plot = Summation of the AGB values of all the trees in a plot.

$$\text{AGB per hectare} = \frac{\text{Sum of AGB values of all the plots}}{\text{Total area of all the plots}} \times 10{,}000$$

BGB was considered to be 20 % of the aboveground biomass as suggested by Mac Dicken (1997). The formula is given below:
BGB= AGB× (15 / 100)
The aboveground and belowground biomass was added to get the total biomass of a tree.

**Carbon stock in trees**
The carbon stock of a tree was estimated by assuming that biomass contained 50 % carbon (Brown *et al.*, 1989). Carbon stocks per plots and per hectare were also calculated.

$$\text{Carbon stock per hectare} = \frac{\text{Sum of biomass of all the plots}}{\text{Area of a track, } m^2 \times \text{total number of plots}} \times 10{,}000 \times 0.50$$

**Data analysis**
All data were analyzed with computer software IBM SPSS ver. 21 to conduct Analysis of variance(ANVA) and Duncan Multiple Range Test (DMRT) in order to the significant ($p \leq 0.05$) variations among different parameters.

## 3. Results and Discussion.

Diameter at breast height, height and survival percentage were measured for estimating the total biomass and carbon storage of four mangrove forest trees species (Table1). The present study revealed that the highest diameter at breast height, height and survival percentage of *Heritiera fomes* were 6.01cm, 7.51m and 55% respectively. The mean annual diameter increment varied from 0.28 to 0.33 cm and height increment from 0.29 to 0.36 m and survival percentage from 41 to 55% in 16 to 21 years old plantation areas.The highest diameter at breast height, height and survival percentage of *Excoecaria agallocha* were 10.32cm, 11.16m and 72% respectively. The mean annual diameter increment varied from 0.49 to 0.55 cm and height increment from 0.46 to 0.55 m and survival percentage from 59 to 72 % in 16 to 21 years old plantation areas.The highest diameter at breast height, height and survival percentage of *Xylocarpus mekongensis*were 8.43cm, 8.16m and 50% respectively. The mean annual diameter increment varied from 0.40 to 0.46 cm and height increment from 0.39 to 0.41 m and survival percentage from 38 to 50% in 16 to 21 years old plantation areas. The highest diameter at breast height, height and survival percentage of *Aegiceras corniculatum* were 7.03cm, 7.11m and 67% respectively. The mean annual diameter increment varied from 0.33 to 0.38 cm and height increment from 0.32 to 0.39 m and survival percentage from 55% to 67% in 16 to 21 years old plantation areas.

The significant variations were found in different species on the basis of different parameters. Latif *et al*. (1992) found the mean diameter increment ranged from 0.06-.15 cm for *Heritiera fomes*, 0.04-0.19 cm for *Excoecaria agallocha* in the Sundarbans. Siddiqi and Khan (1990) reported that the height and diameter increment varied between 0.27-0.70 m and 0.50- 0.90 cm for 11-14 years old *Excoecaria agallocha plantation* in the coastal belt. The annual height increment in this genus varied from 0.23-0.38 m for the plantation of age 10-13 years (Siddiqi and Khan, 1996). A study was conducted (Siddiqi *et al.*, 1992) in the coastal region of Sundarbans. The found that more than 90% survival for *Excoecaria agallocha*and *Heritiera fomes*at different coastal belt. Siddiqi and Khan (1996) reported growth performance of 4 years old stands from the same experiment and they found higher survival for*Excoecaria agallocha* (97%) followed by *Heritiera fomes* (92%), *Phoenixpaludosa* (92%) and *Aegiceras corniculatum* (68%).

Siddiqi (2001 and 2002) prepared a report on the basis of survival, height and diameter of 11 mangrove species at the age of 8 years at Char Kukri Mukri and mentioned that higher survival for *Nypafruticans*(97.30%) followed by *Excoecaria agallocha*(90.30%), *Heritiera fomes*(84.70%), *Phoenix paludosa*(84.70%), *Bruguiera sexangula* (61.30%) *and Xylocarpus mekongensis* (58.30%).

**Table 1.** Ages of four mangrove species diameter at breast height (DBH), height (H), survival (%) mean annual diameter increment (MADI) and mean annual height increment (MAHI)

| Species | Ages (yrs.) | DBH (cm) | Height (m) | Survival (%) | MADI (cm) | MAHI (m) |
|---|---|---|---|---|---|---|
| *Heritiera fomes* | 21 | 6.01 | 7.51 | 41 | 0.29± | 0.36± |
| | 18 | 5.82 | 5.91 | 46 | 0.32 | 0.33 |
| | 17 | 5.32 | 5.32 | 50 | 0.32 | 0.32 |
| | 16 | 4.44 | 4.6 | 55 | 0.28 | 0.29 |
| | **Mean** | **5.40** | **5.84** | **48** | **0.31** | **0.32** |
| *Excoecaria agallocha* | 21 | 10.32 | 11.16 | 59 | 0.49 | 0.53 |
| | 18 | 10.10 | 8.27 | 64 | 0.55 | 0.46 |
| | 17 | 9.01 | 8.16 | 53 | 0.53 | 0.48 |
| | 16 | 8.43 | 5.97 | 72 | 0.53 | 0.37 |
| | **Mean** | **9.74** | **8.39** | **62** | **0.53** | **0.46** |
| *Xylocarpus mekongensis* | 21 | 8.43 | 8.16 | 48 | 0.40 | 0.39 |
| | 18 | 7.93 | 7.42 | 42 | 0.44 | 0.41 |
| | 17 | 7.84 | 7.02 | 38 | 0.46 | 0.41 |
| | 16 | 6.92 | 6.53 | 50 | 0.43 | 0.41 |
| | Mean | **7.78** | **7.28** | **55** | **0.43** | **0.41** |
| *Aegiceras corniculatum* | 21 | 7.03 | 7.11 | 62 | 0.33 | 0.34 |
| | 18 | 6.67 | 5.67 | 55 | 0.36 | 0.32 |
| | 17 | 6.44 | 5.43 | 58 | 0.37 | 0.32 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 16 | 6.04 | 5.13 | 67 | 0.38 | 0.32 |
| | Mean | **6.55** | **6.84** | **60** | **0.36** | **0.33** |

In the present study, the highest mean DBH was recorded for *Excoecaria agallocha*(9.74cm) followed by*Xylocarpus mekongensis*(7.78cm),*Aegiceras corniculatum*(6.55cm) and*Heritiera fomes*(5.40cm) respectively(Table 1).The highest mean height was recorded for*Excoecaria agallocha*(8.39m) followed by *Xylocarpus mekongensis*(7.28m),*Aegiceras corniculatum*(6.55cm) and*Heritiera fomes*(6.84m) respectively(Table 1). Siddiqi (2001;2002) recorded the highest height for *Excoecaria agallocha*(9.23m), followed by*Heritiera fomes*(5.33m) and *Phoenix paludosa* (2.93m) in 8 years old plantation. The maximum DBH value was found in*Excoecaria agallocha*(7.33cm), followed by*Heritiera fomes*(3.13cm) and *Phoenix paludosa* (5.06cm) in 8 years old plantation.The variable results were found in the study areas due to the cause of anthropogenic activities in the coastal forest areas.

In the present study, the highest biomass was recorded for *Excoecaria agallocha*(15.16 kg/tree) followed by*Xylocarpus mekongensis*(12.13 kg/ tree),*Heritiera fomes*(6.54kg/tree) and*Aegiceras corniculatum*(4.14kg/ tree) respectively (Table 2). The highest mean carbon was recorded for*Excoecaria agallocha*(11.75 t $ha^{-1}$) followed by *Xylocarpus mekongensis*8.34 $tha^{-1}$),*Aegiceras corniculatum*(3.11 t $ha^{-1}$) and*Heritiera fomes*(3.92t $ha^{-1}$) respectively (Table 2).

**Table 2.** Aboveground biomass (AGB), belowground biomass (BGB), total biomass (TB) and total carbon (TC) per tree

| Species | Age (yrs.) | AGB (kg) | BGB (kg) | TB (kg) | TC (kg) | Total carbon ( t $ha^{-1}$) |
|---|---|---|---|---|---|---|
| *Heritiera fomes* | 21 | 15.30 | 3.05 | 18.35 | 9.17 | 3.92 |
| | 18 | 11.4 | 2.29 | 13.72 | 6.86 | |
| | 17 | 8.72 | 1.74 | 10.46 | 5.23 | |
| | 16 | 8.20 | 1.64 | 9.84 | 4.92 | |
| | **Mean** | **10.91** | **2.18** | **13.09** | **6.54** | |
| *Excoecaria agallocha* | 21 | 37.90 | 7.57 | 45.44 | 22.70 | 11.75 |
| | 18 | 27.30 | 5.46 | 32.79 | 16.40 | |
| | 17 | 21.70 | 4.34 | 26.05 | 13.02 | |
| | 16 | 14.20 | 2.84 | 17.04 | 8.52 | |
| | **Mean** | **25.28** | **5.05** | **30.33** | **15.16** | |
| *Xylocarpus mekongensis* | 21 | 25.90 | 5.18 | 31.07 | 15.56 | 8.34 |
| | 18 | 21.10 | 4.21 | 25.26 | 12.63 | |
| | 17 | 19.50 | 3.91 | 23.45 | 11.70 | |
| | 16 | 14.40 | 2.88 | 17.26 | 8.63 | |
| | **Mean** | **20.23** | **4.05** | **24.26** | **12.13** | |
| *Aegiceras corniculatum* | 21 | 12.60 | 2.51 | 15.09 | 7.54 | 3.11 |
| | 18 | 9.170 | 1.83 | 11 | 5.50 | |
| | 17 | 8.23 | 1.65 | 9.877 | 4.94 | |
| | 16 | 6.90 | 1.38 | 8.281 | 4.14 | |
| | **Mean** | **6.90** | **1.38** | **8.28** | **4.14** | |

Biomass and carbon were estimated of four different mangrove forest species. The total biomass carbon was found out on the basis of their aboveground biomass and belowground biomass. In this case, total organic carbon was estimated on the basis of each tree and per hectare. The variations were found in different mangrove forest species due to variations in DBH, height and survival percentages.

## 4. Conclusion

*Heritiera fomes* is the most important and dominant mangrove tree species and other species also play a vital role in the Sundarbans. The present study focused that the growth rate of *Heritiera fomes* was less than other species such as *Excoecaria agallocha*, *Xylocarpus mekongensis*and *Aegiceras corniculatum.* Growth is the essential parameter for survival and it is found in the present study. The coastal areas are planted for saving of human and natural resources. In this case, more growth capable trees should be planted in the whole coastal areas of Bangladesh

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