Bangladesh J. Bot. **50**(2): 365-371, 2021 (June)

ROLE OF FOREST TREE SPECIES IN THE CARBON STORAGE OF THE KAPTAI NATIONAL PARK, BANGLADESH

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Keywords: Protected forest, Hilly region, Forest tree species, Allometric equations, Carbon stock

Abstract

The study was conducted to estimate the biomass and carbon stock in the dominant tree species of the Kaptai National Park of Bangladesh. A total of 77 tracks and 308 plots were selected and all trees in each plot were measured to estimate the biomass following allometric equations. There were planted stand of *Acacia auriculiformis, Dipterocarpus turbinatus, Gmelina arborea, Lagerstroemia speciosa, Swietenia macrophylla* and *Tectona grandis*. Biomass and carbon stocks of these corresponding tree species were 35.03, 73.86, 23.52, 30.16, 44.49, and 42.67 mg/ha. The highest carbon stock per tree was in *D. turbinatus* (372.19 kg C/tree), followed by *S. macrophylla* (226.49 kg C/tree), *T. grandis* (215.06 kg C/tree), *A. auriculiformis* (176.56 kg C/tree), *L. speciosa* (151.19 kg C/tree) and *G. arborea* (118.54 kg C/tree), respectively. The findings of the study will be helpful for the estimation of carbon stocks in the forests of Bangladesh.

Introduction

Forests play an important role in regional and global carbon cycles. They can be both sources and sinks of carbon depending on management, exploitation and disturbances. When they are managed well they can sequester or conserve significant quantities of carbon on the land (Sharma *et al.* 2011). Thus, there is a need to accurately determine the amount of carbon stored in different forest ecosystems (Nizami 2010). Plants in the forests capture carbon dioxide from the atmosphere and store it in the form of fixed biomass. Among them, trees play a major role in forest carbon storage and act as the principal sink of carbon (Karthick and Pragasan 2014) because they are long lived, and their wood is also long lasting. However, deforestation and other degradation processes can lead to conversion of these sinks into sources of carbon dioxide. For several decades, the forests of Bangladesh have suffered severely from human interferences including over-cropping, burning, hill cutting, habitat destruction, indiscriminate and illegal logging, etc. It was reported that there had been rapid forest deterioration and deforestation in most parts of the tropics over the last decade, with South-East Asia incurring the highest loss (Hansen *et al.* 2013). Therefore, degradation of forest at the scale that occurred in Kaptai National Park and its surrounding areas has certainly caused attrition of tree biomass and carbon stocks. In this context the present work was carried out to determine the present stocks of tree biomass and carbon of different dominant forest tree species in the Kaptai National Park, Rangamati, situated in the south-eastern region of Bangladesh.

Materials and Methods

The Kaptai National Park was established in 1999 in Rangamati Hill Tracts District and lies between 22°27´ to 22°32´ N latitudes and 92°30´ to 92°16´ E longitudes. It encompasses an area of 5464 hectares within two forest ranges, namely Kaptai Range and Karnaphuly Range under the

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DOI: https://doi.org/10.3329/bjb.v50i2.54094

management of Rangamati Hill Tracts South Forest Division (Fig. 1). Many scientists reported that there are about 412 species of plants in these forests (Rahman *et al.* 2013). It was also reported that the dominant tree species in these forests included *Dipterocarpus turbinatus* Gaertn, *Protium serratum* (Wall. *ex* Coelbr.) Engl., *Terminalia bellirica* (Gaertn.) Roxb., *Trewianudi flora* L., *Aphanamixis polystachya* (Wall.) R. Parker and *Lagerstroemia speciosa* L. etc. (Asadozzaman *et al.* 2016). About 90% land of the area was hilly; settlers occupy 4% area, and 6% land was arable (Khisa 1997).

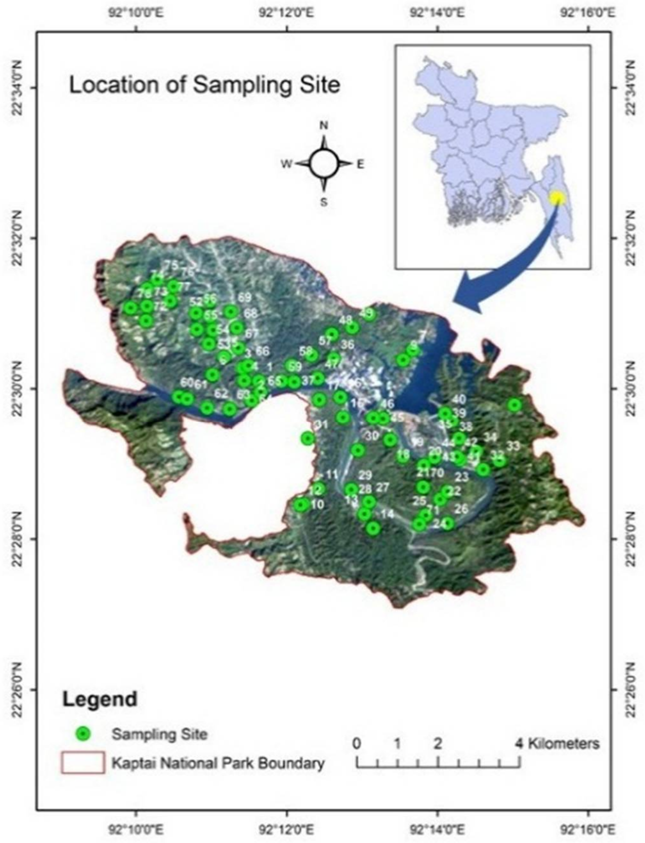

Fig. 1. Map showing the location of the study area in Kaptai National Park, Bangladesh.

The mean annual temperature and rainfall were 20.50^{0}C and 2531 mm, respectively. The mean annual humidity was around 80% (Meteorological Station, Kaptai Power Development Board Records of 2016).

Biomass and carbon stocks of trees were estimated by allometric equations (non-destructive) method and the data are analysed in the Bangladesh Forest Research Institute. Seventy seven tracks or reference points, each being 500 m apart from the other, and all tracks were selected over the total park area using the Global Positioning System (GPS). Four circular plots of 10 m radius (314 m^2 area) were demarked in north-south and east-west directions at a distance of 100 m from the center of each track (Fig. 2).

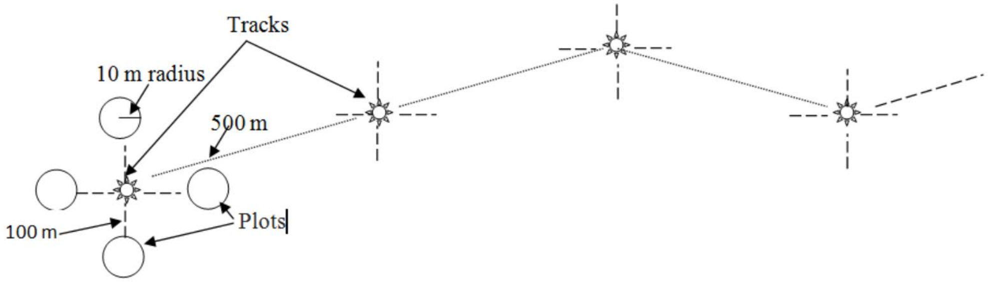

Fig. 2. Schematic representation of the arrangement of sampling tracks and plots.

Thus, there were 308 (4 × 77) sampling plots and sampling was done between January 2014 and December 2016. The number of trees species and the number of individuals of tree species in each plot were recorded. Diameter at breast height (DBH; 1.3 m above the ground level) and height (H) of each tree were measured by Hega- altimeters. Aboveground biomass (it include main stem, branches and leaves), below ground biomass and total biomass and carbon storage for each tree were estimated using the allometric equations (Alves *at al.* 1997, Brown 1997, Schroeder *et al.* 1997). The equations are shown below:

$$AGB = \exp.\{-2.4090 + 0.9522 \ln (D^2HS)\}$$

where, AGB is the aboveground biomass (kg), H is the height of the trees (m), D is the diameter at breast height (cm) and S is the specific gravity of timber (Mg m^{-3}). There were six timbers species in the study and their specific gravities (S) were 0.57, 0.59, 0.75, 0.65, 0.42 and 0.71 Mg m^{-3} in *L. speciosa*, *Tectona grandis*, *Swietenia macrophylla*, *Acacia auriculiformis*, *Gmelina arborea and Dipterocarpus turbinatus*, respectively (Sattar *et al.* 1999). Belowground biomass (BGB) was calculated considering 15% of the aboveground biomass (Mac Dicken 1997).

$$BGB= (AGB \times 15/100)$$

$$TCS= (AGB+BGB) \times 0.50$$

The above and below ground biomasses were added to get the total biomass of a tree. The total carbon stock (TCS) is calculated taking 50% of the total biomass as carbon (Brown *et al.*1989). Biomass and carbon per tree values were multiplied by the number of trees per circular plot and then values were converted to hectare to obtain biomass and carbon stock per hectare. ANOVA and DMRT for carbon stock per tree was performed by using SPSS 20 version.

Results and Discussion

The per tree biomass and carbon stock values of *A. auriculiformis*, *D. turbinatus*, *G. arborea*, *L. speciosa*, *S. macrophylla* and *T. grandis* of different ages are presented in Table 1. In all the tree species, biomass and carbon values increased with age but, however, similarly aged (12 years) *A. auriculiformis* trees produced much higher biomass(497.97 kg/tree) than *L. speciosa* (202.61 kg/tree).

*A. auriculiformis*is a fast growing exotic and *L. speciosa* is a slow growing indigenous hardwood species. *A. auriculiformis and G. arborea* trees were younger and produced smaller trees with lower values of biomass and carbon than the others. On the other hand, similarly aged *D. turbinatus*, *L. speciosa* and *S. macrophylla* produced higher biomass and carbon than *T. grandis.* Here, belowground biomass was calculated from the values of aboveground biomass. So, the trend of variation in total biomass and carbon with ages of tree species and among tree species followed that of the aboveground biomass. The variation in aboveground biomass among tree species was significant at $p < 0.001$ (F-value for 24.56 at degree of freedom of 5).

Table 1. Biomass and carbon stock of forest tree species varying in age in Kaptai National Park.

Forest tree species	Age (Yrs.)	AGB (kg/tree)*	BGB (kg/tree)	Total biomass (kg/tree)	Carbon stocks (kg/tree)
Acacia auriculiformis	5	164.63 ± 6.11	24.69 ± 0.11	189.32 ± 3.41	94.66
	8	256.85 ± 3.29	38.53 ± 0.19	295.38 ± 4.89	147.69
	12	497.97 ± 9.31	74.69 ± 1.11	572.67 ± 5.61	286.33
Dipterocarpus turbinatus	15	591.85 ± 10.39	88.78 ± 1.15	680.63 ± 5.97	340.31
	20	722.30 ± 11.41	108.35 ± 1.81	830.65 ± 6.89	415.33
	25	971.84 ± 12.69	145.78 ± 1.93	1117.62 ± 7.91	558.81
Gmelina Arborea	5	159.63 ± 2.18	23.94 ± 0.31	183.57 ± 1.71	91.79
	7	225.59 ± 2.48	33.84 ± 0.39	259.43 ± 2.31	129.71
	10	397.58 ± 3.21	59.64 ± 0.65	457.22 ± 3.39	228.61
Lagerstroemia. Speciosa	12	202.61 ± 5.37	30.39 ± 0.94	233.00 ± 2.72	116.50
	16	378.15 ± 7.31	56.72 ± 0.97	434.87 ± 3.61	217.43
	18	466.31 ± 5.79	69.95 ± 0.99	536.26 ± 4.85	268.13
Swietenia macrophylla	10	270.29 ± 4.11	40.54 ± 0.81	310.83 ± 2.97	155.42
	16	397.74 ± 5.68	59.66 ± 0.63	457.40 ± 3.67	228.70
Tectona Grandis	15	222.91 ± 5.17	33.44 ± 0.46	256.35 ± 2.11	128.18
	20	307.52 ± 5.29	45.53 ± 0.51	353.05 ± 2.11	176.82
	25	410.12 ± 5.97	61.52 ± 0.71	471.64 ± 3.49	235.82
	30	562.27 ± 5.35	84.34 ± 0.73	646.61 ± 5.31	323.31

AGB = aboveground biomass, BGB = Belowground biomass, *F-values for the variation in aboveground biomass among tree species=24.56 at degree of freedom of 5, significantly at $p < 0.001$; Belowground biomass was calculated on the basis of aboveground biomass; total carbon was calculated from the total biomass. So F- value were the same for all these parameters.

Average biomass values of the present study (above ground, below ground) are presented in Table 2. Aboveground biomass (AGB) per tree was the highest in *D. turbinatus* (647.29 kg per tree) and the lowest in *G. arborea* (206.15 kg per tree). Biomass was calculated on the basis of height, diameter at breast height (DBH) and specific wood gravity (S) of trees. Belowground biomass (BGB) followed the trend of aboveground biomass (AGB) and the maximum value was found in *D. turbinatus* (97.09 kg per tree) and the minimum value in *G. arborea* (30.92 kg/tree). The total tree biomass followed the order *D. turbinatus* > *S. macrophylla* > *T. grandis* > *A. auriculiformis* > *L. speciosa* > *G. arborea,* respectively. The maximum and the minimum values were 744.38 kg/tree (*D. turbinatus*) and 237.07 kg/tree (*G. arborea*), respectively (Table 2). Duncan's multiple range test values showed that aboveground, belowground and total tree biomass of *D. turbinatus* differed significantly from the other tree species. On the other hand, *L. speciosa* and *S. Macrophylla* were similar but statistically different from the others. Similarly, *A. auriculiformis*, *S. macrophylla* and *T. grandis* did not differ significantly among themselves but differed significantly from others. However, wide variations in the biomass potential of a tree species may occur due to differences in provenances, stand density, tree age, site characteristics and management etc. The ranges of total aboveground biomass were 9.38 - 306.01 kg/tree for *G. arborea* and 7.25 - 314.61 kg/tree for *S. macrophylla* in the Philippines (Kawahara *et al.* 1981). It was also observed that total aboveground biomass of *A. auriculiformis* and *G. arborea* was in the range of only 15.71-49.08 kg/tree and 9.18–68.58 kg/tree in the Philippines (Buante 1997). Aboveground tree biomass was found to range from 21.32 Mg/ha (*G. arborea*) to 66.94 mg/ha (*D. turbinatus*), and belowground biomass varied from 2.20 to 6.92 mg/ha in the present study (Table 2).

Table 2. Average aboveground, belowground and total biomass per tree and per hectare.

Tree species	AGB/tree (kg)*	BGB/tree (kg)	TB/tree (kg)	AGB/ha (Mg)*	BGB/ha (Mg)	TB/ha (Mg)
A. auriculiformis	306.48b	45.97b	353.13b	31.75b	3.28b	35.03b
D. turbinatus	647.29a	97.09a	744.38a	66.94a	6.92a	73.86a
G. arborea	206.15C	30.92c	237.07c	21.32c	2.20c	23.52c
L. Speciosa	264.28c	39.64c	303.93c	27.33c	2.83c	30.16c
S. macrophylla	393.90b	59.09b	452.99b	40.37b	4.12b	44.49b
T. grandis	374.01b	56.10b	430.11b	38.68b	3.99b	42.67b
Mean	365.45	54.81	420.25	37.73	3.89	41.62

TB = total biomass, *Figures followed by the same letter in a column do not differ significantly at $p < 0.001$ from each other according to DMRT.

The mean aboveground, belowground and total biomass values per hectare were 37.73, 3.89 mg, respectively. Almost double aboveground biomass of *D. turbinatus* (81.42 mg/ha) in Tankawati (Padua Range, Chittagong South Forest Division, Bangladesh) natural forests around this area was reported by Ullah and Al-Amin (2012). The average aboveground biomass of tropical deciduous and mixed deciduous forests were 31.8 mg/ha and 20.7 mg/ha, respectively in Central India (Salunkhe *et al.* 2016). The aboveground biomass varied between 124.56 and 254.99 mg/ha where the stand density ranged from 128 to 168 trees per hectare in Manipur, Northeast India (Thokchom and Yadava 2017). Wide variations in above ground biomass among the tropical forests were also observed due to disturbances, along with regional differences in stem size distribution, soil fertility and topography (Salunkhe *et al.* 2016).

Table 3 shows the average values of carbon stock in individual tress of the six dominant species along with the average values per hectare. The maximum (323.64 kg/tree) and the minimum (103.08 kg/tree) aboveground carbon (AGC) stocks per tree were estimated in *D. turbinatus* and *G. arborea*, respectively (Table 3). The same species also had, respectively the highest (48.55 kg) and the lowest (15.46 kg) belowground carbon (BGC) stock per tree. On a unit area basis, above ground, below ground and total carbon stocks were in the range of 10.66 to 33.47 mg/ha (*G. arborea* and *D. turbinatus*, respectively) and 1.10 to 3.46 mg/ ha. The minimum and the maximum values were always found in *G. arborea* and *D. turbinatus*, respectively. The level of significance of variation in carbon stocks followed the same trend of biomass.

Table 3. Carbon stocks per tree and per hectare.

Tree species	AGC/tree (kg)	BGC/tree (kg)	TC/tree (kg)	AGC/ha (Mg)	BGC/ha (Mg)	TC/ha (Mg)
A. auriculiformis	153.53b*	23.03b*	176.56b*	15.88b*	1.64b*	17.52b*
D. turbinatus	323.64a	48.55a	372.19a	33.47a	3.46a	36.93a
G. arborea	103.08c	15.462c	118.54c	10.66c	1.10c	11.76c
L. speciosa	132.14c	19.82c	151.96c	13.67c	1.42c	15.09c
S. macrophylla	196.95b	29.54b	226.49b	20.37b	2.11b	22.48b
T. grandis	187.01b	28.05b	215.06b	19.34b	1.99b	21.33b
Mean	182.73	27.43	210.16	18.90	1.38	20.28

AGC=Aboveground carbon, BGC=belowground biomass, TC=total carbon. *Figures followed by the same letter in a column do not differ significantly at $p < 0.001$ from each other according to DRTM. The variance ratio (F=12.459; degree of freedom (df) = 5) was significantly at $p < 0.001$.

Carbon stocks were 60.09 and 121.43 mg/ha in the forests of Manipur, Northeast India, respectively (Thokchom and Yadava 2017). The carbon stocks of four typical dry deciduous forests of Central India were estimated at 25 - 54 mg/ha in mixed non-teak forest, 13 - 42 mg/ha in dry mixed non-teak forest, 33 - 53 mg/ha in teak-dominated forest and 16 - 24 mg/ha in dry teak forest (Salunkhe *et al*. 2016). The mean carbon stock of trees in the natural forests of Bangladesh was reported to be 110.94 mg/ha (Ullah and Al-Amin 2012). In the present study area, *Dipterocarpus turbinatu s*trees were large and old growing, and hence it had sequester the maximum carbon. On the other hand, although *Tectona grandis* trees were the highest in number, they were smaller in size; they could produce an intermediate value per unit area. *Dipterocarpus turbinatus* had the highest increment rates (43.90 kg/tree in biomass and 21.95 kg/tree in carbon stock) followed by *Acacia auriculiformis* (40.93 kg/tree in biomass and 20.45 kg/tree in carbon stock) and *G. arborea* (39.85 kg/tree in biomass and 19.92 kg/tree in carbon stock). *Tectona grandis* had the least values of biomass and carbon stock (18.76 kg/tree in biomass and 9.38 kg/tree in carbon) but those were not significantly different from *L. speciosa* (21.20 in biomass and 10.60 kg/tree in carbon stock). Here in the present study, *A. auriculiformis* and *G. arborea* are fast growing and are popular in plantation forestry, especially on degraded soils because of their capabilities of growing fast even on poorly fertile soils. Although they can fix carbon at a rapid rate, their wood is usually short lasting. As forest degradation might have brought about depletion of carbon in all the pools, immediate reforestation could improve the carbon sequestration potentials of the forest of Kaptai National Park in Bangladesh.

Acknowledgements

The authors are grateful to the Divisional Officers of Bangladesh Forest Research Institute (BFRI) for their permission during the entire period of this research work. Special thanks are due to Prof. Dr. Nazmul Alam, Professor, Department of Botany, Jahangirnagar University, Savar, Dhaka for his support and encouragements.

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(Manuscript received on 9 March, 2020; revised on 30 October, 2020)