Estimation of biomass carbon stock at three plantation sites in Sher-e-Bangla Agricultural University campus

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Abstract: Urban forests play an important role in mitigating hazards evolved due to climate change. The study was conducted at three plantation sites in Sher-e-Bangla Agricultural University Campus (SAU) aiming at exploring floristic composition, stand characteristics and biomass carbon stocks. Both purposive (Woodlot and homegarden) and systematic sampling method were followed. A total of 35 genera and 38 tree species that were belonged to 25 families were recorded in SAU campus. Among the three plantation areas, homegaraden was found rich in species composition followed by woodlot and roadside. *Mangifera indica* was found dominant species in SAU (IVI = 17.25 %). Stem density and Mean DBH varied significantly among the three plantation systems ($p < 0.05$), while basal area and biomass carbon (Above - and below ground) exhibited with insignificant difference ($P > 0.05$). The average biomass carbon stocks for roadside, homegardens and woodlot were 159.18 ± 36 $Mgha^{-1}$, 169.37 ± 34 $Mgha^{-1}$ and 206.19 ± 42 $Mgha^{-1}$, respectively. When three plantation systems considered as whole, the mean biomass carbon, basal area, stem density, mean DBH were 174.24 ± 21 $Mgha^{-1}$, 34.16 ± 3.51 m^2ha^{-1}, 1096.87 ± 121.10 tree ha^{-1}, 19.83 ± 1.63 cm, respectively. This study reveals that the urban institutional forest is rich in terms of plant species and carbon stocks and similar work should be extended to other urban green space in order to know the overall carbon stocks in Dhaka City.

Key words: Carbon dioxide, climate change, biomass carbon stocks, basal area, stem density, mean DBH.

Introduction

Biodiversity conservation and global climate change are the two burning issues those got an immense attention to scientific community and policy makers in the recent decades (IPCC, 2013). Increasing level of atmospheric CO_2 due to burning of fossil fuels, cement production and deforestation, are the main drivers of this climate change. A recent prediction reveals that if the rising trend of CO_2 is continue in this manner it would elevate the atmospheric temperature by 2-4.2 °C by the year of 2050 (IPCC, 2013). It will ultimately induce to melt out of the polar ice which would increase the sea level rise by 5 m and consequently, the coastal region will adversely be affected by saline water particularly in developing countries like Bangladesh (Rahman *et al.,* 2014). Also, the livelihoods pattern will be changed that would cause people to migrate towards urban areas (IPCC, 2013). The urban areas has also exhibited with warmer climate than the peri-urban areas due to high level of fossil fuel combustion and elevated proportion of imperious surface (Liu and Li, 2012). Alongside of these ecosystem services, urban green space is playing an important role in sequestering atmospheric carbon dioxide through photosynthesis. However, in the context of global carbon research, a lot of works have conducted in natural forest, afforested and reforested ecosystems outside the urban areas (Liu and Li, 2012). However, some recent studies both in developed and developing countries reveals that urban green spaces are rich in biodiversity and also, can store a considerable carbon in above- and belowground (Nowak *et al*., 2013).

In Bangladesh, the every district town and the seven divisional towns are rich in biodiversity where the urban forest are designated as roadside plantation, woodlot, homestead, parks, and institutional plantation. However, the quantification of carbon stocks in these diverse urban forests is yet to be done. Therefore, the present study was undertaken in Sher-e-Bangla Agricultural University Campus as a model of urban institutional forest carbon assessment in Bangladesh where three types of Urban Forests are studied (e.g., Roadside plantation, Woodlot and Homegarden).

Materials and Methods

Sher-e-Bangla Agricultural University (SAU), situated in Dhaka city which spreads over an area of 86.92 acres (35.2 ha). It is situated between 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level. The average summer minimum to maximum temperature varies 25°C to 32°C.The wettest month for Dhaka is July with an average rainfall of 367.9 mm while the driest month is December with 8.9 mm precipitation.

A total of 32 sample plots of 10x10 m^2 size were selected (0.01ha), each were laid out in all the three plantation sites. Both purposive (Woodlot,and homegarden) and systematic sampling method (roadside) were followed. Ten (10) plots were laid out along the roadside, 15 from homegarden and 7 from woodlot at three plantation sites. To measure the floristic composition of species in study area the basal area, relative density, relative dominance, relative frequency and Importance Value Index (IVI) were calculated (Moore and Chapman, 1986 and Shukla and Chandel, 1980). The total carbon stock of the tree was therefore measured by non-destructive method using equations involving the DBH (diameter at breast height, height for palm species) and wood density. The girth of each individual was converted to tree diameter, dividing the girth by π (3.1416) due to lack of DBH tape. The total biomass was measured in terms of above ground biomass (AGB), below ground biomass (BGB) of each tree species. The AGB was measured based on the allometric equation develop for tropical trees that can be used for wide graphical and diameter range (Chave *et al*., 2005). The BGB was measured based on regression model developed by Cairns *et al.*, (1997). The palms AGB was measured based on the equation proposed by Brown *et al.*, (2001). The specific density of the trees for AGB calculation was taken from Global wood density database standard average value of tree species (Patwardhan *et. al.,* 2003), FAO's list of wood densities for tree species from tropical Asia (Zanne *et al.,* 2009). After estimating the biomass from allometric relationship it will be multiplied by 0.5 as wood contains half percent of carbon of it total biomass.

Results and Discussion

Stand structure: Tree characteristics like mean DBH, stem density and basal area at 32 sample plots of three plantation sites with their mean values and standard error were collectively presented in Table 1. The mean DBH (cm), Stem density (tree ha^{-1}) and Basal area (m^2 ha^{-1}) of homegarden were 14.17 ± 1.46 (range: 6.05-23.11), 1426.67 ± 155.06 (range: 600-2600) and 35.21 ± 5.87 (range: 7.79-82.78), respectively. On the other hand the mean DBH (cm), stem density (tree ha^{-1}) and basal area (m^2 ha^{-1}) of Roadside were 27.68 ± 3.08, (range: 15.37-42.34), 480.00 ± 61.10 (range: 200-800) and 33.80 ± 7.08 (range: 5.77-69), respectively. Again the Mean DBH (cm), Stem density (tree ha^{-1}) and Basal area (m^2 ha^{-1}) of Woodlot were 20.76 ± 2.34 (range: 13.75-30), 1271.43 ± 289.26 (range: 600-2300) and 38.28 ± 2.83 (range: 27.72-48.83), respectively. The mean DBH (cm), stem density (tree ha^{-1})and basal area (m^2 ha^{-1}) of three plantation sites (homegarden, roadside and woodlot) were 19.83 ± 1.63 (range: 6.05-42.34), 1096.88 ± 121.11 (range: 200-2600) and 34.16 ± 3.51(range: 5.76-82.78), respectively (Table 1). In ANOVA test there was no significant difference ($p > 0.05$) was found in Above-and below ground biomass carbon and basal area while stem density and mean DBH showed significant differences ($p < 0.05$) between and within the group of three plantation sites in 32 sample plots.

Table 1. Mean DBH, stem density and basal area at three plantation sites in SAU Campus

Species Parameter	Plantation sites			Average
	Homegarden	Roadside	Wood lot	
Mean DBH (cm)	14.17	27.68	20.76	19.83
Stem density(tree ha^{-1})	1426.67	480.00	1271.43	1096.88
Basal area(m^2 ha^{-1})	35.21	33.80	38.28	34.16

The study showed that the average stem density (1096.88 tree ha^{-1}) was higher than recorded stem density (705 tree ha^{-1}) from Taiwanese highway plantation (Wang, 2011) but lower than the mean stem density (4528 stem ha^{-1}) in roadside plantation found in Bangladesh. The findings of very high density in three plantation sites compared to other study due to maintaining a closer tree spacing in roadside and woodlot while in homegarden, this site contained diverse tree species (juvenile and adult) due to different multipurpose uses. On the other hand the average basal area (34.16 m^2 ha^{-1}) of present study was higher than basal area (16.88 m^2 ha^{-1}) in Chunati Wildlife Sanctuary, Cox's Bazar (Rahman and Hossain, 2003) and 27.07 m^2 ha^{-1} in Dudpukuria-Dhopachori Wildlife Sanctuaries of Chittagong South Forest Division (Hossain *et al.,* 2013) but lower than the basal area (53.5 m^2 ha^{-1}) in Chittagong Hill Tracts (South) Forest Division (Nath *et al.,* 1998). The cause behind the non significance difference ($p > 0.05$) in above-and below ground biomass carbon and basal area could be due to the difference in replication at three plantation sites.

Species composition: A total of 351 individuals belonging to 38 tree species in 35 genera and 25 families were recorded from the selected total of 32 plots at three plantation sites (roadside, woodlot and homegarden) in Sher-e-Bangla agricultural university campus. Among the three plantation sites higher species composition was found in homegarden which belonged to 34 species in 31 genera and 24 families followed by roadside vegetation which comprised of 4 species in 4 genera and 4 families, while a total of 7 species belonged to 8 genera and 6 families were recorded from woodlot area. Of the 38 tree species, *Polyalthia longifolia, Swietenia macrophylla* and *Mangifera indica* were most important tree species at roadside, woodlot and homegarden, respectively in terms of importance value index. As a whole, *Mangifera indica* was the most dominant tree species at three plantation sites in Sher-e-Bangla agricultural university campus (Table 2, 3 & 4). Meliaceae was the most dominant family accounted for 23% of all the recorded species and 21% of the total estimated biomass carbon at three plantation sites in SAU campus. The families with least biomass carbon estimated were Piperaceae, Ebenaceae, Punicaceae and Oleaceae (accounted only one individual tree each).

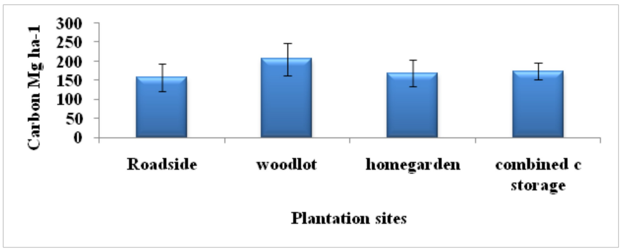

Fig. 1. Av. carbon stock of different plantation sites in SAU Campus

Tree biomass carbon content: The recorded average biomass carbon stock of the three plantation sites were 174.24 ± 21 Mg C ha^{-1} (Fig. 1). An average biomass carbon stock of the roadside, woodlot and homegarden were 159.18 ± 36 Mg C ha^{-1}, 206.19 ± 42 Mg C ha^{-1} and 169.37 ± 34 Mg C ha^{-1}, respectively (Fig. 1).The carbon stock and carbon contribution (%) of species in respect of no. of trees, mean DBH (cm), basal area m^2 ha^{-1} and IVI (%) of roadside, woodlot and homegarden are shown in Table 2, 3 and 4, respectively. The highest carbon stock and carbon contributing species in roadside, woodlot and homegarden were *Swietenia macrophylla* comprised (68.26 Mg C ha^{-1}, 43.17%), *Swietenia macrophylla* (66.43 Mg C ha^{-1}, 32.22%) and *Mangifera indica* 34.35 (58.18 Mg C ha^{-1}, 34.35%), respectively (Fig. 2).

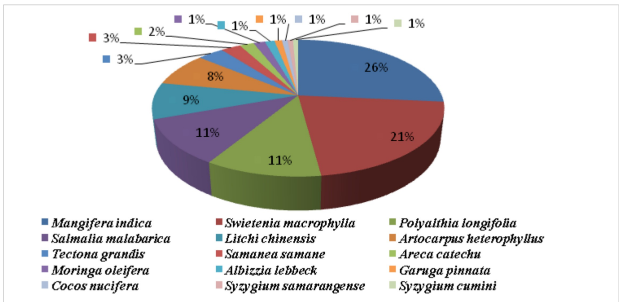

Figure 2. Percent carbon contribution by fifteen species from total of thirty eight species

In a study it was reported that a significant positive correlation found between mean DBH and carbon stock as well as between basal area and total woody C have also showed a high correlation of biomass with diameter at breast height (Mani and Parthasarathy, 2007).Similar research was carried out at Gujarat University campus, Ahmedabad where the total carbon stock in the trees of

Gujarat University campus was found to be 661.30 Mg C ha^{-1} (Rathore and Jasrai, 2013).The mean biomass carbon (174 Mg ha^{-1}) of the present study was higher than mean biomass carbon (65-158 Mg ha^{-1}) in Bangladesh (Gibbs *et al.,* 2007) but lower than the mean biomass carbon 192.80 Mg ha^{-1} in roadside plantation, (Rahman *et al.,* 2015). In another study it was found that biomass tree organic carbon was 110.94 Mg C ha^{-1} in a purely natural forest where no plantation were ever held, which shows less than the University plantation (Ullah and Al-Amin, 2012). The current study is in accordance with the findings of Nowak and Crane, 2002, the individual urban trees on an average contain approximately four times more C than individual trees in forest stands. The another causes for being higher carbon stock of the present study area is due to differences in basal area, wood density, age structure, species composition, storage potential, stage of development and site characteristics between urban and natural stands.

Table 2. Structural attributes with biomass carbon in roadside area

Sl.No.	Scientific Name	No. of Trees	Mean DBH	BA m^2 ha^{-1}	IVI (%)	% Carbon	C (Mg ha^{-1})
1	*Polyalthia longifolia*	26	23.91	12.63	43.94	35.50	56.13
2	*Swietenia macrophylla*	16	32.98	15.06	27.10	43.17	68.26
3	*Mangifera indica*	2	59.36	5.54	17.99	20.48	32.28
4	*Roystonea regia*	1	42.33	1.41	10.97	0.85	1.34
	Total		159.18				

Table 3. Structural attributes with biomass carbon in woodlot area (mixed plantation)

Sl.	Scientific Name	No. of Trees	BA m^2 ha^{-1}	Mean DBH	IVI (%)	% Carbon	C (Mg ha^{-1})
1	*Swietenia macrophylla*	62	17.94	15.38	51.31	32.22	66.43
2	*Litchi chinensis*	6	6.4	30.00	10.98	30.70	63.30
3	*Mangifera indica*	6	5.79	27.68	10.43	15.49	31.93
4	*Tectona grandis*	8	4.32	21.60	9.14	12.79	26.37
5	*Samanea samane*	1	2.28	45.10	5.44	5.56	11.46
6	*Carpinus caroliniana*	4	0.93	14.14	5.35	1.72	3.55
7	*Azadirachta indica*	1	0.34	17.38	3.71	0.79	1.62
8	*Albizzia lebbeck*	1	0.28	15.79	3.65	0.74	1.53
	Total		206.19				

Table 4. Structural attributes with biomass carbon in homegaden area [(top 10 species,(34)]

Sl No.	Scientific Name	No. of Trees	BAm^2 ha^{-1}	Mean DBH	IVI (%)	% Carbon	C (Mg ha^{-1})
1	*Mangifera indica*	50	10.92	16.63	22.46	34.35	58.18
2	*Artocarpus heterophyllus*	36	6.61	17.14	16.20	16.91	28.64
3	*Salmalia malabarica*	4	6.55	50.29	7.82	22.69	38.42
4	*Moringa oleifera*	9	2.17	19.37	5.13	3.25	5.50
5	*Garuga pinnata*	10	0.82	11.27	5.00	2.08	3.52
6	*Psidium guajava*	17	0.47	6.48	4.76	0.85	1.45
7	*Syzygium samarangense*	10	0.58	10.00	3.44	1.48	2.51
8	*Annona reticulata*	7	0.44	9.95	3.17	0.88	1.49
9	*Citrus grandis*	6	0.24	8.12	2.83	0.45	0.76
10	*Zizyphus jujuba*	9	0.40	8.56	2.78	1.01	1.71
		1	0.01	3.18	0.49	0.01	0.01
Total (With remaining sp. Value)		169.37					

Species wise carbon composition: Among 38 tree species, only 15 species were considered as the most significant in terms of total carbon storage. It was observed from the study that these 15 species was accumulated 96% of the total biomass carbon and the rest 23 species contributed only 4% to store carbon in the study area. Out of 15 species, *Mangifera indica* accumulated the highest percentage of carbon (26%), followed by *swietenia macrophylla, Polyalthia longifolia, Salmalia malabarica, Litchi chinensis, Artocarpus heterophyllus* and *Tectona grandis* with carbon storage percentage of 21, 11, 11, 9, 8 and 3, respectively (Fig. 2). The maximum value of IVI for *Mangifera indica* might be due to high fruit demand.

Family composition and family carbon composition: A total 25 families were recorded at the three plantation sites in Sher-e-Bangla Agricultural University campus. Among 25 families only 10 most important families are shown in Fig. 3. From the perspective of carbon composition, Anacardiaceae family occupied the highest carbon from the others and it was approximately 25% but their species composition under this family was lower i.e. only 16.80%. On the other hand, Meliaceae encompasses the highest number of species composition that was almost 23% but their contribution on carbon composition was lower i.e., 21%.

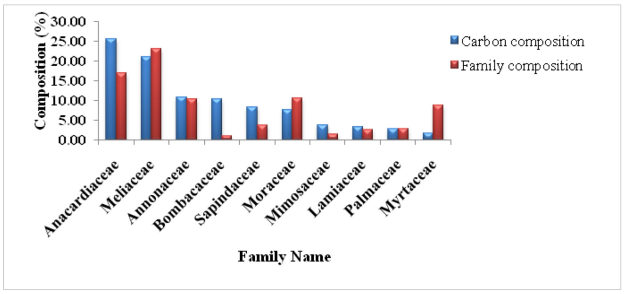

Fig. 3. Carbon composition in respect to family in the plantation sites.

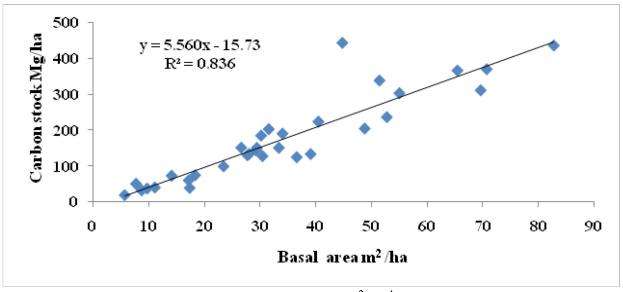

Fig. 4. Relationship between basal area m^{2}ha^{-1} and total carbon stock Mg ha^{-1}

Relationship between stand structure and carbon stocks: Correlation analysis was used to determine the relationship between basal area and carbon stock. It was found that the relationship between basal area ($m^2 ha^{-1}$) and total carbon was significant ($p < 0.01$). The following figure indicates that the value of r was 0.914 and R^2 is 0.836 (Fig. 4). The result indicates that tree carbon content increase with the increase in basal area. So, sites with higher basal area tend to store more carbon. The present study followed the relationship of basal area and carbon stock. In woodlot plantation site, the average carbon stock (206.19 Mg C ha^{-1}) value was higher than the carbon stock of roadside (159.18 Mg C ha^{-1}) and homegarden (169.37 Mg C ha^{-1}) due to higher basal area in woodlot (38.28 m^2 ha^{-1}) compared to roadside (33.80 m^2 ha^{-1}) and homegarden (35.21 m^2 ha^{-1}) basal area (Fig. 1 & Table 1).

In SAU campus, the total carbon stock of roadside, woodlot and homegarden for 7810 m^2, 19512 m^2 and 25327.75 m^2 area were 124.31 Mg C, 150.66 Mg C and 428.50 Mg C, respectively . So, in woodlot plantation sites there is an ample scope to increase the carbon stock by extending the woodlot area through plantation activity. On the other hand, more plantations in the existing area can also enriched the level of carbon stock at roadside and homegarden in Sher-e-Bangla Agricultural University.

As a sustainable land management option in an urban institutional area, Sher-e-Bangla Agricultural University campus can serves as a model because of carbon stock at three plantation sites (roadside, woodlot and homegarden) act as a tools for making policies in future plantation protocol in this university as well as other institutional areas. The summery that can be drawn from this findings is that, as an institutional plantation sites (roadside, woodlot and homegarden) in urban area, Sher-e-Bangla Agricultural university campus can store a significant amount of biomass carbon (174.24 Mg C ha^{-1}) as well as contributing in greening the campus area (Fig. 1). As a result, besides carbon sequestration "green" campus could potentially attract better staff and students with sound healthy enviornment which also provides supportive role for biodiversity conservation in urban area.

The results of the present study prove that plantations acting as store house of carbon by stocking C in their tissues, thereby lowering the levels of atmospheric greenhouse gases as stated by Brown *et al*., 1989. The future study will be helpful, moreover, to obtain a clear picture about the change in tree biomass as well as in change in carbon stock, biodiversity conservation and carbon sequestration rate which will contribute in the planning sustainable land management issues.

From the result of this study, it can be concluded that management of existing vegetation, and increasing in vegetation cover at the studied area, are likely to be more effective strategies for retaining carbon in the landscape and potentially increasing carbon sequestration. Present study will facilitate to get more complete understanding of the organic carbon sequestration potential of different types of plantations in urban institutional areas.

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