Measurement of Sequestered Standing Carbon Stock in Major Agroforestry Tree Species

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ABSTRACT

In the present investigation, the aboveground and belowground carbon sequestration potential of agroforestry tree species from seven sectors of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) campus was measured as a proxy of carbon fixation of agroforestry trees in Bangladesh. This campus occupies the area of 75.55 ha. Carbon emission has been increasing day by day due to anthropogenic activities and contributing to global climate change. Biomass production in different forms, i.e., aboveground biomass (AGB), belowground biomass (BGB), total biomass (TB), plays an essential role in carbon sequestration in trees. We estimated these biomasses by the nondestructive method to calculate the aboveground carbon (AGC), belowground carbon (BGC), total carbon (TC), and total CO_2 of the study area. We found that the standing aboveground biomass and belowground biomass of agroforestry trees were 29.97 tha^{-1} and 7.79 tha^{-1} respectively, while the total standing biomass of agroforestry trees in 75.55 ha area was 37.76 tha^{-1}. In the case of carbon, we observed that the total carbon sequestration and total carbon dioxide intake of agroforestry trees were 18.88 tha^{-1} and 69.29 tons CO_2, respectively, in the study area. The highest carbon dioxide sequestration was observed in sector 6 (25%), and the lowest was observed in sector 3 (5%). The findings of carbon sequestration obtained from this study will be helpful for policymakers to take necessary steps against the adverse effect of global warming through carbon emission.

Keywords: *Carbon sequestration, Agroforestry tree species, Biomass.*

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Highlights of this paper

- Agroforestry tree species are getting popular in urban and man-made forest plantations in Gazipur and elsewhere in Bangladesh.
- The present study showed the carbon sequestration status in BSMRAU campus (around 19 tha^{-1}) in different agroforestry tree species, which will be helpful for creating awareness about environmental pollution among people.

1. INTRODUCTION

Carbon dioxide (CO_2) emission has increased by 18% with an alarming rate in the environment by reaching to the highest level after 1750 [1]. In recent decades (2009-2010) CO_2 level increased per year by 2.3ppb which was 1.5ppb in 1990-2000 and 2ppb in 2001-2009 [2]. Climate change as well as global warming were occurred as a results of CO_2 emission, discussed in Kyoto protocol at Japan (1997) [3]. Kyoto protocol especially addressed the increasing carbon emissions around the world, which is now a major global issue [4, 5].

Greenhouse gas emissions can be reduced by controlling emissions primarily, and by storing carbon. Carbon sequestration in growing forests and other land use systems is known to be a cost-effective option for global warming and climatic change mitigation. Sequestration is the method of carbon dioxide reduction in the atmosphere with the aim of reducing world climate change. Trees i.e. biomass production play an important role in the reduction of CO_2 from atmosphere by carbon sequestration. Active absorption of CO_2 from the atmosphere by the photosynthetic process helps to store biomass in different plant parts and ultimately increases the carbon sequestration [4, 6]. Carbon stocks are composed of aboveground and belowground biomass with living and dead plants, and wood products, litter, and soil organic matter etc. are the major carbon pools in any ecosystem [7-9].

In the sub-urban area of Gazipur District (Bangladesh), multiple industries releases CO_2 in the atmosphere, which causes air pollution in the environment. In this district, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and Bhawal National Park act as a carbon pool with lot of agroforestry tree species. Agroforestry is a popular land management system in many countries, where forest resources are depleted. According to the state of world forest [10] Bangladesh is among the 15 countries, where both forest and agricultural land are decreasing. Agroforestry act as a tool for clean development mechanism to reverse land degradation and increase the carbon sequestration. Agroforestry species can be utilized as a source of wood and forest product demand, which can reduce the burden of natural forest. So, the improvement of urban green spaces with agroforestry trees is one of the possible ways to mitigate the adverse effects of urbanization in an ecological manner, making cities more beautiful and calm to live in [11]. Several ecosystem services are provided from trees including removal of atmospheric pollutants, biodiversity conservation, oxygen regeneration, reduction of noise pollution, microclimate regulation, mitigation of urban heat, prevention of soil erosion, groundwater recharge, and carbon sequestration [2]. Trees are important sinks for atmospheric carbon i.e. CO_2 where 50% of tree standing biomass is carbon. Importance of green spaces for carbon sequestration is already accepted and well documented. But hardly any attempts have been made to study the potential of trees in carbon sequestration from sub-urban areas of Gazipur district. At the same time quantitative information on the agroforestry tree species is needed to know the contribution of agroforestry in carbon sequestration. So, this study intended to clarify the carbon sequestration by different agroforestry tree species in BSMRAU campus of Gazipur district.

2. MATERIALS AND METHODS

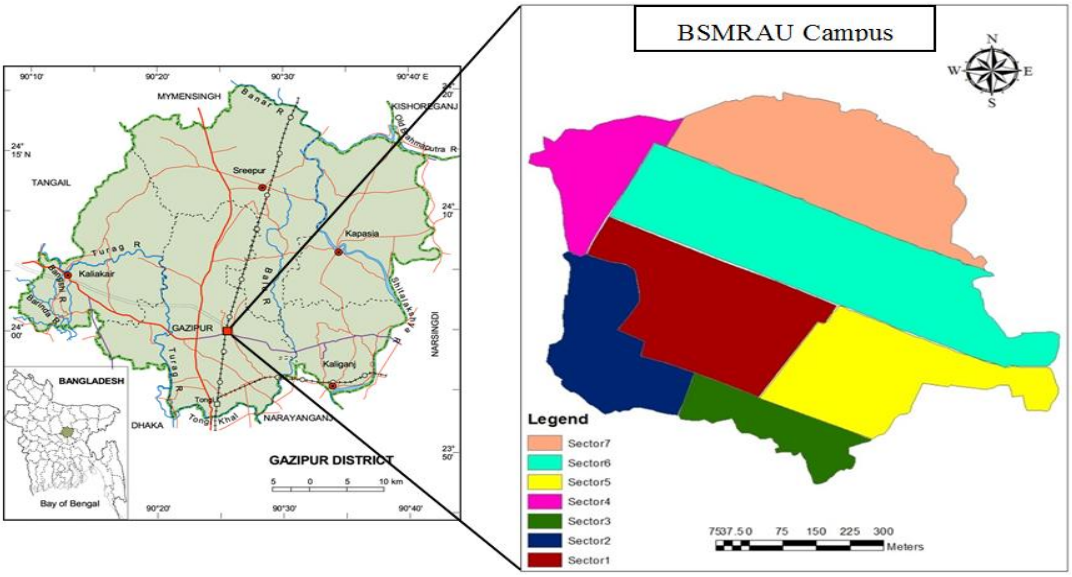

Figure-1. Map indicates the location of study area.

Table-1. Representative agroforestry tree species in BSMRAU campus.

Sl. No.	Common/ local name	Scientific Name	Sl. No.	Common/ local name	Scientific Name
1	Shimul	Bombax ceiba	39	Bajna	Zanthoxylum rhetsa
2	Kalo koroi	Albizia lebbeck	40	Minjiri	Senna siamea
3	Gamar	Gmelina arborea	41	Kath badam	Terminalia catappa
4	Jujube	Ziziphus mauritiana	42	Plum	Prunus domestica
5	Mast tree	Polyalthia longifolia	43	Agar	Aquilaria malaccensis
6	Mehogony	Swietenia macrophylla	44	Bilimbi	Averrhoa bilimbi
7	Bohera	Terminalia bellirica	45	Sissoo	Dalbergia sissoo
8	Haritaki	Terminalia chebula	46	Teak	Tectona grandis
9	Velvet apple	Diospyros discolour	47	Jamrul	Syzygium samarangense
10	Jackfruit	Artocarpus heterophyllus	48	Banyan	Ficus benghalensis
11	Bakul	Mimusops elengi	49	Palmyra palm	Borassus flabellifer
12	Arjun	Terminalia arjuna	50	Custard apple	Annona squamosa
13	Coconut	Cocos nucifera	51	Plum rose	Syzygium jambos
14	Mango	Mangifera indica	52	Guchichapa	Plumeria sp
15	Neem	Azadirachta indica	53	Sharifa	Annona reticulata
16	Gora neem	Melia azedarach	54	Rendi koroi	Samanea saman
17	Nishinda	Vitex negundo	55	Christmas tree	Araucaria heterophylla
18	Kharajora	Litsea monopetala	56	Kanchan	Bauhinia variegata
19	Jiga	Garua pinnata	57	Litchi	Litchi chinensis
20	Kodom	Anthocephalus chinensis	58	Betel nut	Areca catechu
21	Drumstick	Moringa oleifera	59	Mahua	Mahua longifolia
22	Carambola	Averrhoa carambola	60	Rubber plant	Hevea brasiliensis
23	Wood apple	Aegle marmelos	61	Royal Palm tree	Roystonea regia
24	Black berry	Syzygium cuminii	62	Eucalyptus	Eucalyptus camaldulensis
25	Raj koroi	Albizia richardiana	63	Indigofera	Indigofera sp
26	Guava	Psidium guajava	64	Bok ful	Sesbania grandiflora
27	Pomelo	Citrus grandis	65	Tamarind	Tamarindus indica
28	Acacia	Acacia auriculiformis	66	Ipil ipil	Leucaena leucocephala
29	White koroi	Albizia procera	67	Gliricidia	Gliricidia sepium
30	Olive	Olea europaea	68	Catechu	Acacia catechu
31	Indian bay leaf	Cinnamomum tamala	69	White acacia	Faidherbia albida
32	Hog plum	Spondias mangifera	70	Calliandra	Calliandra tweedii
33	Chalta	Dillenia indica	71	Trichandra	Leucaena trichandra
34	Date	Phoenix sylvestris	72	Jarul	Lagerstroemia speciosa
35	Orboroi	Phyllanthus acidus	73	Royal poinciana	Delonix regia
36	Telsur	Hopea odorata	74	Aonla	Phyllanthus emblica
37	Sal	Shorea robusta	75	Mangium	Acacia mangium
38	Datoi	Grewia nervosa			

2.1. Study Area

The study conducted in Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. BSMRAU is located at the latitude 24°09" N and longitude 90°25" E. The average day temperature ranges from 86.9°F to 67.7°F. The study area is similar to the Bhawal National Park in term of soil properties and topography. The average annual rainfall in Gazipur city and adjoining area is 2036 mm [12]. The total 187 acres (75.55 ha) area of BSMRAU campus was selected for the carbon sequestration study which divided into seven sectors Figure 1. Representative tree species were selected for sampling from each sector of the study area Table 1.

2.2. Biophysical Measurements

The height and diameter at breast height (DBH) are two important biophysical measurements for each tree sample. The height of the tree species was measured by Hypsometer instrument. The tree diameter at breast height (DBH) was measured by using diameter measure tape as well as alloy tree calipers.

2.3. Estimation of Aboveground Biomass (AGB)

All living biomass above the soil considered as aboveground biomass (AGB). The aboveground biomass (AGB) was calculated by multiplying the volume of biomass and wood density of tree species [13].

The calculated volume was based on diameter and height of trees, whereas the wood density value for the tree species obtained from web site (www.worldagroforestry.org).

$$\text{Above ground biomass, AGB (g)} = \text{Volume of biomass (cm}^3) \times \text{Wood density (g/cm}^3)$$

Finally, the biomass of all tree species from all sectors (t) were calculated for total area (tha^{-1}).

2.4. Estimation of Belowground Biomass (BGB)

The biomass of living roots excluding fine roots having <2mm diameter are considered as belowground biomass (BGB) [14]. The belowground biomass (BGB) was calculated by multiplying aboveground biomass taking 0.26 as the root to shoot ratio [13, 15].

$$\text{Belowground biomass, BGB (tha}^{-1}) = 0.26 \times \text{Aboveground biomass, AGB (tha}^{-1})$$

The carbon sequestration is multiplied by factor of 3.67 to get the carbon dioxide (CO_2) because 1 ton carbon is equal to 3.67 tons of CO_2 [16].

2.5. Data Analysis

The graphical presentation and calculations of data were implemented by the Excel software (version 2016) and the mapping of BSMRAU campus was created using ArcGIS 10 software (Environmental Systems Research Institute, Redlands, California, USA). GIS is widely used in land use land cover (LULC) monitoring in Bangladesh and elsewhere in the world [17, 18].

3. RESULTS AND DISCUSSION

The aboveground and belowground biomass in selected tree species were estimated by calculating carbon percentage and by measuring the tree height, DBH and wood density. The standing biomass stalks in agroforestry trees of seven sectors in BSMRAU campus were shown in Table 2. The highest aboveground, belowground and total biomass were observed in the trees species of sector 6 (7.49 tha^{-1}, 1.95 tha^{-1} and 9.44 tha^{-1}) followed by sector 7 (7.11 tha^{-1}, 1.85 tha^{-1}, 8.96 tha^{-1}), sector 1 (4.76 tha^{-1}, 1.24 tha^{-1}, 6.00 tha^{-1}), sector 5 (4.19 tha^{-1}, 1.09 tha^{-1}, 5.28 tha^{-1}), sector 2 (2.80 tha^{-1}, 0.73 tha^{-1}, 3.53 tha^{-1}), and sector 4 (2.14 tha^{-1}, 0.56 tha^{-1}, 2.70 tha^{-1}). The lowest was observed in sector 3 (1.48 tha^{-1}, 0.38 tha^{-1}, 1.86 tha^{-1}). In total, the aboveground and belowground biomass of agroforestry trees were 29.97 tha^{-1}, 7.79 tha^{-1}, respectively, while total biomass of agroforestry trees in 75.55 ha area was 37.76 tha^{-1}. Generally, the carbon concentration of different tree parts assumed to be 50% of the dry weight [14, 19, 20] as the carbon content in any woody biomass of forest is around 50% of dry matter [14, 19, 21, 22].

Table-2. The sector wise total biomass and sequestered carbon of agroforestry trees in BSMRAU campus.

Sectors	Area in ha	AGB tha^{-1}	BGB tha^{-1}	TB tha^{-1}	AGC tha^{-1}	BGC tha^{-1}	TC tha^{-1}	tCO_2
1	12.01	4.76	1.24	6.00	2.38	0.62	3.00	11.01
2	7.06	2.80	0.73	3.53	1.40	0.36	1.76	6.47
3	3.74	1.48	0.38	1.86	0.74	0.19	0.93	3.42
4	5.40	2.14	0.56	2.70	1.07	0.28	1.35	4.95
5	10.55	4.19	1.09	5.28	2.10	0.54	2.64	9.69
6	18.88	7.49	1.95	9.44	3.75	0.97	4.72	17.32
7	17.91	7.11	1.85	8.96	3.56	0.92	4.48	16.44
Total	75.55	29.97	7.79	37.76	14.99	3.90	18.88	69.29

Note: AGB, Aboveground Biomass; BGB, Belowground Biomass; TB, Total Biomass; AGC, Aboveground Carbon; BGC, Belowground Carbon; TC, Total Carbon; tCO_2, Ton CO_2.

The sequestered carbon stalks in agroforestry trees of BSMRAU campus are also given in Table 2. Similar to the biomass, the highest carbon content was sequestered as aboveground, belowground and total carbon in sector 6 (3.75 tha^{-1}, 0.97 tha^{-1}, 4.72 tha^{-1}), followed by sector 7 (3.56 tha^{-1}, 0.92 tha^{-1}, 4.48 tha^{-1}), sector 1 (2.38 tha^{-1}, 0.62 tha^{-1}, 3.00 tha^{-1}), sector 5 (2.10 tha^{-1}, 0.54 tha^{-1}, 2.64 tha^{-1}), sector 2 (1.40 tha^{-1}, 0.36 tha^{-1}, 1.76 tha^{-1}), and sector 4 (1.07 tha^{-1}, 0.28 tha^{-1}, 1.35 tha^{-1}). The lowest was found in sector 3 (0.74 tha^{-1}, 0.19 tha^{-1}, 0.93 tha^{-1}).

The total sequestered carbon stalk in aboveground and belowground biomass of agroforestry tree species were 14.99 tha^{-1} and 3.90 tha^{-1} respectively, while total sequestered carbon of agroforestry trees in 75.55 hectares area was 18.88 tha^{-1}. In BSMRAU campus, the total carbon dioxide intake by agroforestry trees was 69.29 tons CO_2.

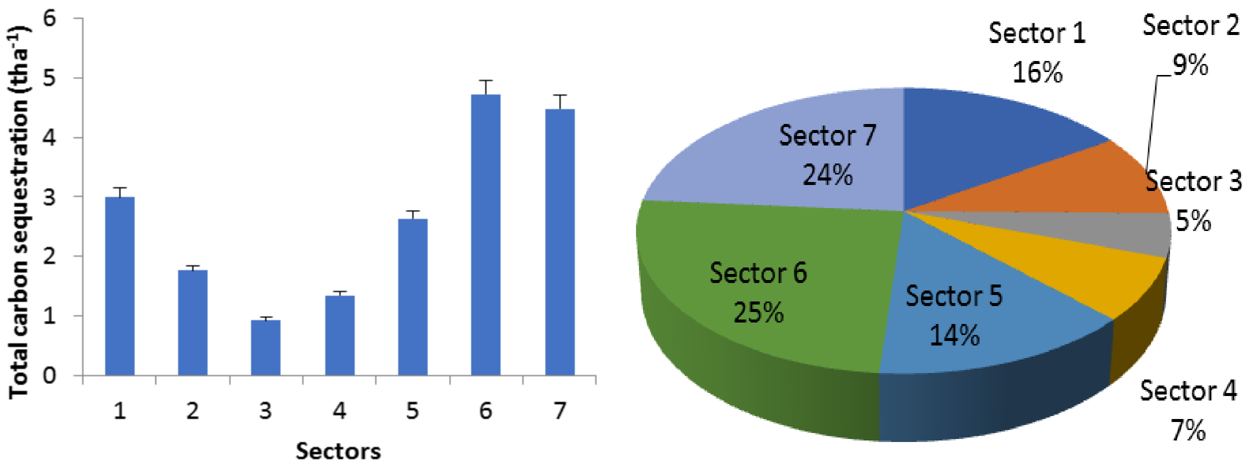

Figure-2. Cumulative total carbon sequestered ($tCha^{-1}$) and sequestered CO_2 of agroforestry tree species from seven sectors of BSMRAU campus.

Figure 2 showed cumulative percentage of carbon dioxide intake (tCO_2) in agroforestry trees in seven sectors of BSMRAU campus. The highest carbon dioxide sequestration was observed in sector 6 (25%) followed by sector 7 (24%), sector 1 (16%), sector 5 (14%), sector 2 (9%), sector 4 (7%) and lowest was observed in sector 3 (5%). The Gazipur district is densely populated area with a lot of commercial activities and developing as a prominent suburban area near Dhaka capital. In most places of Gazipur district, the natural vegetation is being replaced by the concrete industries and housing sectors. The vegetation of BSMRAU campus remain undisturbed in this situation for a long time which strongly helps in carbon sequestration. Moreover, growing more trees would be the only viable solution to maintain carbon sequestration balance in the study area.

4. CONCLUSION

The BSMRAU campus stored 37.76 tha^{-1} total standing biomass in different agroforestry tree species which cumulatively intake 69.29 tons CO_2 and helps in establishing a green campus with carbon sequestration, microclimatic modification etc. The highest carbon sequestration was observed in sector 6 and 7 due to wide range of agroforestry tree species coverage.

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