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Measurement of above-ground carbon stocks of roadside agroforestry plantation at Sadar upazila of Mymensingh district in Bangladesh

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ABSTRACT

In this research, floristic composition and above-ground carbon stocks of all woody species in roadside plantations under Sadar Upazila of Mymensingh District were studied. A total of 280 sample plots of 2 m×10 m size was selected following systematic random sampling in a zigzag manner on both sides along the roadside plantation were measured. The result showed that a total of 29 species of 14 families were recorded where the most common species are *Acacia auriculiformis*, *Swietenia sp,* and *Artocarpus heterophyllus*. It was found that *Albizia saman*, *Albizia lebbeck* and *Swietenia sp* comprises 71% of total aboveground carbon of which *Albizia saman* occupies the highest (50%) amount among the tree species in the study area. Similarly, *Swietenia sp* in the case of tree seedlings, *Cocos nucifera* in case of palm species and *Acacia auriculiformis* deadwood species occupy the highest amount of above-ground carbon (68, 48 and 73%) respectively in the study area. The study revealed that the total carbon stock measured in the roadside plantation were 2554.27 Mg/ha where tree occupies the highest (2078.44 Mg/ha) amount of carbon stock and the lowest (2.85 Mg/ha) in seedlings/saplings in the study area. The results indicate that two attributes such as tree basal area and stand density/ha are strongly related to above-ground carbon stocks, but stand mean height is weakly related. Therefore, the study recommends that the above-ground carbon stocks would increase with the increase of planting trees having greater DBH, basal area and stand density in the roadside areas.

Introduction

The two important current issues are global warming and biodiversity loss among the world scientists and policymakers which caused mainly by the burning of fossil fuel and deforestation during the last few decades (IPCC, 2013). The last century finished with an increase in global temperature by 0.74°C and the atmospheric CO_2 concentration of 379 ppm which would be doubled by 2050 if the current rate of increase continues and will lead to the global temperature rise of up to 2-4°C (IPCC, 2013). A projection by IPCC (2013) revealed that by the end of the 21st century the global sea level will rise by 28-98 cm due to the melting of polar ice, which would badly alter low-lying coastal countries like Bangladesh, Maldives, the Netherlands existence and livelihoods pattern.

Forest retention, associated with afforestation and reforestation programs through agroforestry, tropical, in particular, can play a vital role in mitigating global climate change and has a potential role as a carbon sequestration strategy because of carbon storage potential of its multiple plant species which can be significant sinks of atmospheric carbon due to their fast growth and high productivity (Montagnini and Nair, 2004). By including trees in agricultural production systems, such as agroforest, community forests, village woodlots and roadside plantation under participatory management, could hold carbon and contribute to climate change mitigation (Rahman *et al.,* 2015). For representing a carbon sequestration potential of 1.9 Pg of carbon over 50 years at a rate of 94 $Mgha^{-1}$ in management landscapes, the global coverage of agroforest is 1023 million ha (Nair *et al.*, 2009). Participatory forest management project in the forms of agroforest, village woodlots, and road and highway plantations has been practiced in Bangladesh since 1976s. According to Jashimuddin and Inoue (2012), 48,420 ha of roadside plantations, 30,666 ha of woodlots and 8778 ha of agroforestry plantations have been raised during the last 30 years as the outcomes of these PMF projects in Bangladesh for the poor people especially landless, land-poor and rural women of the surrounding rural communities, are targeted as participants in the roadside plantations program. However, commonly practiced roadside plantation under participatory forest management in Bangladesh has its potential contribution to livelihood supplementation and carbon sequestration, but it has so far received no research attention in estimating carbon sequestration particularly. Now a days, tree density-based allometric model that is becoming popular for estimation of species-level tree

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biomass carbon by using diameter at breast height (dbh) (Pandey *et al.*, 2014; Rahman *et al.*, 2014). However, for swift calculation of biomass carbon, a basal area based allometric model could be another significant option as both basal area and biomass carbon have a strong relation to dbh (Torres and Lovett, 2012; Rahman *et al.*, 2014). The study has made great contributions in estimating ecosystem-level aboveground carbon stocks using tree biomass (Torres and Lovett, 2012; Rahman *et al.*, 2014). Therefore, considering the above-mentioned facts, the study has aimed to estimate the above-ground carbon stocks of roadside plantation at Sadar Upazila of Mymensingh district in Bangladesh.

Materials and Methods

Study area

The study was carried out at Sadar Upazila of Mymensingh District which is located in 24° 38′ to 24° 54′ north latitudes and 90°11′ to 90°30′ east longitudes (Fig. 1). The area of Sadar Upazila is 388.45 km^2 (Wikipedia, 2019). In the study site, a moderate climate present with average temperature and rainfall of 25.3°C and 2249 mm along with clayey texture soil which contains a large quantity of iron and aluminum and highly aggregated.

Road network of the study area

In Mymensingh District, there is 285.83 km National Highway, 569.62 km Regional Highway and 1777.21 km District road (RHD, 2019). While Mymensingh Sadar Upazila has 1138 km roads consists of 166 km metalled, 4 km semi-metalled and 968 km unmetalled roads (BBS, 2013). In this study, metalled and semi-metalled roads as a total of 170 km were considered as study sites for sampling.

The vegetation of the study area

The roads and highways in Sadar Upazila have been planted with various types of vegetation on both sides under social forestry program of the Mymensingh Forest Division. Several tree species such as Akashmoni (*Acacia auriculiformis*), Raintree (*Albizia saman*), Mahogoni (*Swietenia sp*), Kalokoroi (*Albizia lebbeck*), Sadakoroi (*Albizia procera*), Sissoo (*Dalbergia sissoo*), Pithraj (*Aphanamixis polystachya*) and Goraneem (*Melia azedarach*), etc. palms, shrubs have been planted along the roadside in the study area.

Sampling design

Considering 170 km of roads as sampling area a total number of 510 plots of size 2m×10m were selected following systematic sampling in a zigzag manner on both sides of the road which apart from 500 m of each plot (Fig. 2). Nearly half of the total plots were unconsidered for sampling due to the absence of vegetation. The rest 280 plots were selected randomly and then above-ground biomass such as a live tree, non-tree vegetation (tree seedlings/saplings, shrubs, palms) and deadwood selected as carbon pools for estimating carbon stocks (Table 1).

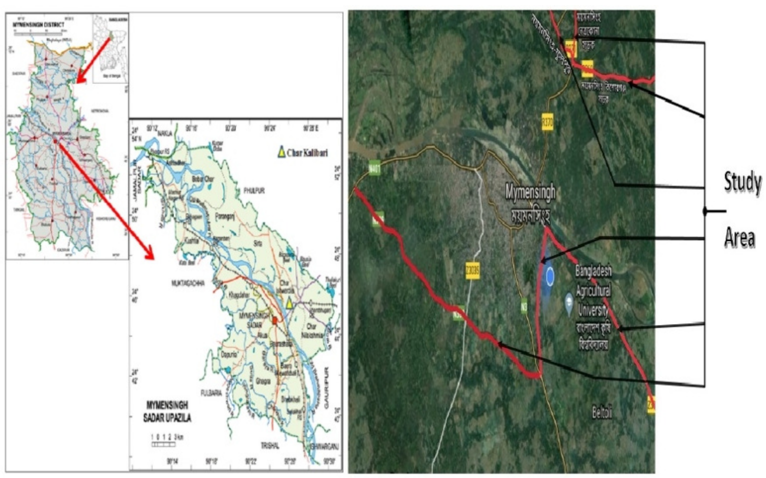

Fig. 1. Map of Mymensingh Sadar upazila road network showing study sites (source: Google map)

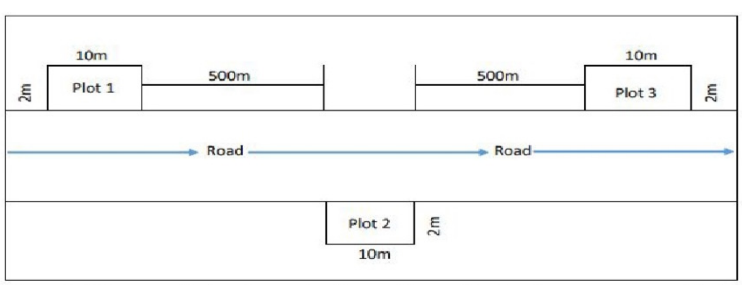

Fig. 2. Diagram of the zigzag plot layout for model development along with the roadside plantation in the study area (Rahman *et al.*, 2015)

Carbon stocks of roadside plantation

Table 1. Key carbon pools in the study area and their definition

Above-ground C pool	Definition
Live trees	An above-ground live tree, the minimum diameter is ≥5 cm in dbh.
Non-tree vegetation	Tree seedling/sapling, the diameter is • 5 cm in dbh. Shrubs, Palms
Deadwood	Standing and down deadwood of trees, shrubs, palms, seedlings/saplings if intact.

Vegetation and carbon measurement parameters

Within each plot, the vegetation parameters such as the name of species, number of species, diameter at beast height (dbh) (cm) (≥5 cm) of tree and deadwood, height of species (m) of a tree, shrubs, palms, seedlings/saplings and deadwood were recorded. The height of tree species and standing deadwood was measured with a Suunto Clinometer. In the case of tree seedlings/saplings, palms, shrubs and down deadwood species measuring pole was used for height measurement. Wood density of tree and deadwood species was collected from the list of wood densities for tree species from tropical America, Africa and Asia (http://www.fao.org/3/w4095e/w4095e0c.htm).

Analysis of vegetation parameters

The vegetation parameters were analyzed according to Moristia (1959) for basal area, Yadav *et al*. (1987) for relative density, relative dominance and relative frequency and Holdridge *et al*. (1971) for important value index (IVI) of all tree species in the study area.

Above and below-ground biomass estimation

In this study, the above-ground biomass of tree and deadwood species was calculated according to the following allometric equation (Chave *et al.*, 2005).

$$AGB = \rho \times \exp(-1.499 + 2.148 \times \ln(DBH) + 0.207 \times (\ln(DBH))^2 - 0.0281 \times (\ln(DBH))^3)$$

Here, AGB= Above-ground biomass; ρ= Wood density (gcm^{-3}); DBH= Diameter at breast height (cm); ln= Natural logarithm; 1.499, 2.148, 0.207 and 0.0281 are constant.

The following allometric equation was used to calculate above-ground biomass of different shrubs, palms and tree seedlings/saplings species (Pearson *et al*., 2005).

$$AGB = 6.666 + 12.826 \times ht^{0.5} \times \ln(ht)$$

Here, AGB= Above-ground biomass, ln= Natural logarithm, ht= Height (m), 6.666 and 12.826 are constant

To estimate the below-ground biomass, the regression model developed by Cairns *et al.* (1997) which is based on knowledge of above-ground biomass was employed.

$$BGB = \exp(-1.0587 + 0.8836 \times \ln AGB)$$

Here, BGB= Below-ground biomass, ln= Natural logarithm, AGB= Above-ground biomass, -1.0587 and 0.8836 are constant.

Total biomass= Sum of all above-ground and below-ground biomass

Estimation of carbon stocks

To quantify carbon stocks from the total biomass estimates a conversion factor of 0.5 as suggested by the IPCC (2007) was used.

Carbon (Mg)= Total biomass × 0.5

Total carbon stock (Mg/ha)= Sum of all above-ground and below-ground carbon pools

Statistical analysis

Data were accomplished by organizing and recording into the excel sheet and different tables and relationship graphs were done in Microsoft Office Excel.

Results and Discussion

Vegetation composition of roadside plantation

From the results, a total of 23 live tree species under 12 families, 5 seedlings tree species under 4 families, 2 deadwood species under 2 families, 4 palm plants species under 1 family of total plant species have been recorded from 280 sample plots which comprise 84.62%, 3.14%, 5.24% and 7% of total plant population of roadside plantation in the study area (Table 2). Considering identified plant species *Acacia auriculiformis, Swietenia macrophylla, Artocarpus heterophyllus* were the three most dominant live tree species, *Streblus asper* and *Swietenia sp* were the dominated tree seedling species, *Acacia auriculiformis* and *Tamarindus indica* were two deadwood species and *Cocos nucifera* was the highest number of palm species in the study area (Table 2). Rahman *et al*. (2015) recorded that the 36 species belongs to 17 families of which some legume species were dominated in the roadside plantations from five southwestern districts of Bangladesh.

Stand density of roadside plantation

The minimum stand density (0 tree/ha) and the maximum stand density (4000 tree/ha) with an average stand density (2053 tree/ha) were recorded in roadside plantations in the study area (Table 3). The stand density (2053 tree/ha) in our study was much higher than recorded from other Asian countries. For example, 705 tree/ha were recorded from Taiwanese highway plantations (Wang, 2011) and 279 trees/ha from urban roadside forests in Shenyang, China (Liu and Li, 2012). Compared with some natural and restored forest systems in Bangladesh, our result for stand density was higher than 381 trees/ha in Chittagong Hill Tracts (South) Forest Division (Nath *et al.,* 1998) and 459 trees/ha in Chunati Wildlife Sanctuary, Cox's Bazar (Rahman and Hossain, 2003). Rahman *et al.* (2015) stated that the average stand density of range 3000–7950 tree/ha was recorded from roadside plantations across five southwestern districts of Bangladesh which were supportive to the study results.

Table 2. A list of woody perennials found in roadside plantations in the study area

Common name	Scientific name	Family	Number of species
Trees			
Akashmoni	*Acacia auriculiformis*	Mimosaceae	96
Mahogony	*Swietenia sp*	Meliaceae	34
Kanthal	*Artocarpus heterophyllus*	Moraceae	25
Aam	*Mangifera indica*	Anacardiaceae	11
Babla	*Acacia nilotica*	Mimosaceae	8
Sada koroi	*Albizia procera*	Mimosaceae	7
Sissoo	*Dalbergia sissoo*	Papilionaceae	6
Raintree	*Albizia saman*	Mimosaceae	6
Goraneem	*Melia azedarach*	Meliaceae	6
Arjun	*Terminalia arjuna*	Combretaceae	6
Jam	*Syzygium cumini*	Myrtaceae	6
Debdaru	*Polyalthia longifolia*	Annonaceae	4
Kalokoroi	*Albizia lebbeck*	Mimosaceae	4
Bel	*Aegle marmelos*	Rutaceae	3
Tentul	*Tamarindus indica*	Papilionaceae	3
Pitraj	*Aphanamixis polystachya*	Meliaceae	3
Chatim	*Alstonia scholaris*	Apocynaceae	3
Sesrakoroi	*Albizia chinensis*	Mimosaceae	3
Segun	*Tectona grandis*	Verbenaceae	3
Eucalyptus	*Eucalyptus sp*	Myrtaceae	2
Gamar	*Gmelina arborea*	Verbenaceae	1
Kadam	*Anthocephalus chinensis*	Rubiaceae	1
Katbadam	*Terminalia catappa*	Combretaceae	1
Tree seedlings/saplings			
Mahogony	*Swietenia sp*	Meliaceae	3
Shaora	*Streblus asper*	Moraceae	3
Akashmoni	*Acacia auriculiformis*	Mimosaceae	1
Sada koroi	*Albizia procera*	Mimosaceae	1
Kanchan	*Bauhinia sp*	Caesalpinaceae	1
Palm			
Narikel	*Cocos nucifera*	Palmae	8
Tal	*Borassus flabellifer*	Palmae	6
Khejur	*Phonix sylvestris*	Palmae	3
Supari	*Areca catechu*	Palmae	3
Deadwood			
Akashmoni	*Acacia auriculiformis*	Mimosaceae	14
Tentul	*Tamarindus indica*	Papilionaceae	1

Table 3. Descriptive statistics of stand characteristics in roadside plantations in the study area

Stand characteristics	Plot No.	Minimum	Maximum	Mean	Std. error
Stand density (tree/ha)	280	0	4000	2052.63	256.19
Tree basal area (m^2/ha)	280	0.03	21.85	1.85	0.93
Tree DBH (cm)	280	10.93	176.50	38.80	7.19
Tree height (m)	280	3.5	26.02	12.21	1.31

Tree basal area

The results showed that the average tree basal area was 1.85 m^2/ha while the maximum tree basal area was 21.84 m^2/ha and the minimum tree basal area was 0.03 m^2/ha in the roadside plantation of the study area (Table 3). Rahman *et al.* (2015) reported that the average tree basal area of range 20.7-95.3 m^2/ha was recorded from roadside plantations across five southwestern districts of Bangladesh which was supportive of the present study results.

Tree DBH and height

The results showed that the average DBH of a tree was 38.80 cm while the maximum DBH of a tree was 176.50 cm and the minimum DBH was 10.93 cm (Table 3). The maximum height of the tree was 26.01 m and the minimum height of the tree was 3.5 m while the average height was 12.21m (Table 3). The biggest tree in diameter encountered was an *Albizia saman* with a DBH of 176.50 cm, with a height of 26.02 m and another tallest tree was a *Tectona grandis* with a height of 24.77 m with a DBH of 57.93 cm. While the smallest tree in diameter recorded was an *Albizia procera* with a DBH of 10.93 cm with a height of 3.6 m (Table 3). Nagendra and Gopal (2010) reported that the average DBH of the tree across all street side plantations in Bangalore was 39 cm and the average height was 9.7 m. The biggest tree in diameter encountered was a *Ficus bengalensis* with a DBH of 232 cm, although with a height of just 15 m while the tallest tree was a Eucalyptus species with a height of 25 m but a DBH of only 55 cm which is more or less similar to the present study findings.

Relative density (RD%), relative frequency (RF%), relative dominance (RDo%) and Important value index (IVI%) of tree species in roadside plantation

Table 4 revealed that *Acacia auriculiformis* showed the maximum (39.02 and 24.55%) RD and RF followed by *Swietenia sp* (13.82 and 13.64%), *Artocarpus heterophyllous* (10.16 and 7.27%), *Mangifera indica* (4.47 and 6.36%) and *Acacia nilotica* (3.15 and 4.55%), respectively (Table 4). While *Albizia saman* showed the highest (44.24%) RDo followed by *Acacia auriculiformis* (15.28%), *Swietenia sp* (11.78%), *Albizia lebbeck* (6.94%) and *Mangifera indica* (4.05%), respectively (Table 4). This was because of most of the large DBH trees belonging to *Albizia saman* and very few numbers of large DBH trees belonging to *Acacia auriculiformis*. In roadside plantation, it was observed that *Acacia auriculiformis* showed the maximum (26.28%) IVI followed by *Albizia saman* (16.77%), *Swietenia sp* (13.08%), *Artocarpus heterophyllous* (6.61%) and *Mangifera indica* (4.96%), respectively in the study area (Table 4). Rahman *et al*. (2015) stated that *Albizia saman*, *Dalbergia sissoo*, *Acacia nilotica* and *Leucaena leucocephala* had more or less similar contribution to RD, RF and IVI in roadside plantations across five southwestern districts of Bangladesh which was supportive to the study result. Islam (2013) observed that *Polyalthia longifolia* showed the maximum IVI (43.94%) followed by *Swietenia macrophylla* (27.105%), *Mangifera indica* (17.99%), and *Roystonea regia* (10.97%) respectively in roadside plantation at Sher-e-Bangla Agricultural University campus, Dhaka.

Carbon stocks of roadside plantation

Above-ground carbon contents for tree species

The results showed that *Albizia saman* occupies the highest (40104.6 Mg/ha) amount of above-ground biomass as well as carbon (20052.32 Mg/ha) while *Aphanamixis polystachya* tree occupies the lowest (28.804 Mg/ha) amount of above-ground biomass as well as carbon (14.402 Mg/ha) in the study area (Table 5 and Fig. 3). *Albizia saman*, *Albizia lebbeck*, *Swietenia sp*, *Acacia auriculiformis* and *Syzygium cumini* are the five most dominant trees which contribute 50%, 11%, 10%, 9%, and 6% respectively in term of above-ground carbon (Table 5 and Fig. 3). The above-ground biomass and carbon content in our study was much higher than recorded from other study in Asia. For example, 1114 Mg above-ground biomass and 656 Mg total carbon was recorded from *Acacia auriculiformis* tree species in the Pondicherry University campus plantations, India (Sundarapandian *et al.*, 2014).

Table 4. Relative density (RD), relative frequency (RF), relative dominance (RDo) and important value index (IVI) of trees in roadside plantations in the study area

Sl. No.	Scientific name	RD (%)	RF (%)	RDo (%)	IVI (%)
1	*Acacia auriculiformis*	39.02	24.55	15.28	26.28
2	*Albizia saman*	2.44	3.64	44.24	16.77
3	*Swietenia sp*	13.82	13.64	11.78	13.08
4	*Artocarpus heterophyllus*	10.16	7.27	2.40	6.61
5	*Mangifera indica*	4.47	6.36	4.05	4.96
6	*Albizia lebbeck*	1.62	2.72	6.94	3.76
7	*Syzygium cumini*	2.43	4.54	3.17	3.39
8	*Acacia nilotica*	3.25	4.55	1.53	3.11
9	*Dalbergia sissoo*	2.44	4.55	1.62	2.87
10	*Terminalia arjuna*	2.43	2.72	0.99	2.05
11	*Melia azedarach*	2.44	2.73	0.72	1.96
12	*Tectona grandis*	1.21	1.82	2.38	1.81
13	*Polyalthia longifolia*	1.63	2.73	0.61	1.65
14	*Albizia procera*	2.85	1.82	0.19	1.62
15	*Albizia chinensis*	1.22	2.72	0.72	1.56
16	*Tamarindus indica*	1.22	1.82	1.62	1.55
17	*Aegle marmelos*	1.22	1.82	0.23	1.09
18	*Alstonia scholaris*	1.21	2.73	0.19	1.30
19	*Aphanamixis polystachya*	1.21	1.81	0.09	1.04
20	*Eucalyptus citriodora*	0.81	0.91	0.26	0.66
21	*Terminalia catappa*	0.41	0.91	0.64	0.65
22	*Anthocephalus chinensis*	0.41	0.91	0.21	0.51
23	*Gmelina arborea*	0.41	0.91	0.13	0.48

Above-ground carbon contents

The results revealed that *Swietenia sp* seedling occupies the highest (16.22 Mg/ha) above-ground biomass as well as carbon (8.11 Mg/ha) while *Streblus asper* occupies the lowest (1.11 Mg/ha) biomass and carbon (0.55 Mg/ha) in the study area (Table 5). Among the 4 species of palm, *Cocos nucifera* occupied the highest (77.32 Mg/ha) amount of above-ground biomass and carbon (38.66 Mg/ha) followed by *Areca catechu* where above-ground biomass (AGB) amount is 37.11 Mg/ha and above-ground carbon amount is 18.56 Mg/ha (Table 5). In case of deadwood, *Acacia auriculiformis* tree occupies the highest amount of biomass (1095.36 Mg/ha) and carbon (547.68 Mg/ha) while *Tamarindus indica* tree occupies the lowest amount of biomass (399.87 Mg/ha) and carbon (199.94 Mg/ha) in the roadside plantations in the study area (Table 5).

Table 5. Aboveground biomass (AGB) and aboveground carbon (AGC) content of trees in roadside plantations in the study area

Sl. No.	Scientific name	AGB (Mg/ha)	AGC (Mg/ha)	AGC stock (%)
1	*Albizia saman*	40104.6	20052.32	50.34
2	*Albizia lebbeck*	8410.09	4205.05	10.56
3	*Swietenia sp*	7566.39	3783.19	9.50
4	*Acacia auriculiformis*	7379.42	3689.71	9.26
5	*Syzygium cumini*	5131.29	2565.65	6.44
6	*Mangifera indica*	3034.16	1517.08	3.81
7	*Tectona grandis*	1490.42	745.21	1.87
8	*Acacia nilotica*	1288.99	644.49	1.62
9	*Dalbergia sissoo*	1077.57	538.78	1.35
10	*Artocarpus heterophyllus*	1047.92	523.96	1.32
11	*Tamarindus indica*	845.52	422.76	1.06
12	*Terminalia arjuna*	477.295	238.65	0.60
13	*Albizia chinensis*	383.78	191.89	0.48
14	*Terminalia catappa*	358.304	179.15	0.45
15	*Melia azedarach*	323.17	161.59	0.41
16	*Polyalthia longifolia*	316.39	158.196	0.40
17	*Eucalyptus citriodora*	116.397	58.199	0.15
18	*Aegle marmelos*	107.04	53.52	0.13
19	*Anthocephalus chinensis*	61.65	30.82	0.08
20	*Albizia procera*	45.53	22.76	0.06
21	*Alstonia scholaris*	42.35	21.18	0.05
22	*Gmelina arborea*	36.39	18.19	0.05
23	*Aphanamixis polystachya*	28.804	14.402	0.04

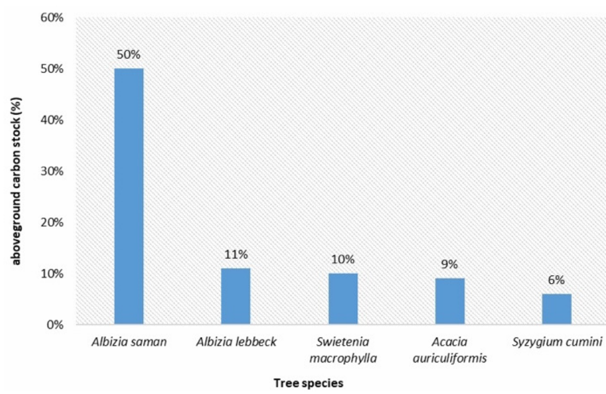

Fig. 3. Aboveground carbon stock (%) of the five most dominant species

Below-ground carbon contents of roadside plantation

The results showed that among the vegetation, tree occupies the highest (692.82 Mg/ha) below-ground biomass as well as carbon (346.41 Mg/ha) while tree seedlings/saplings occupy the lowest (0.95 Mg/ha) below-ground biomass as well as carbon (0.47 Mg/ha) along with the total below-ground carbon (425.71 Mg/ha) (Table 6). Gurashi and Hassan (2018) reported that mean carbon stock, above and below-ground biomass and CO_2 emissions in the inventory period of 2006 and 2016 were 67.4, 31.68 ton/ha and 116.16 GC/ha respectively in AbuGeili Forest, Sudan which was supportive to this study result.

Total carbon stocks of roadside plantation

The tree occupied the highest content (2078.44 Mg/ha) which accounts for 81% of carbon stocks while the tree seedlings/saplings occupied the lowest content (2.85 Mg/ha) which accounts for 0.11% of carbon stocks with total carbon stock of 2554.27 Mg/ha in roadside plantation in the study area (Table 7).

The total carbon content (2554 Mg/ha) of present study was higher than the reported range (65-158 Mg/ha) of tree biomass carbon for Bangladesh (Gibbs *et al.,* 2007), 111.46 Mg/ha in Hill Forest of Bangladesh (Ullah and Al-Amin, 2012), 192.80 Mg/ha in roadside plantation of Bangladesh (Rahman *et al.,* 2015). We thus estimated a much higher amount of carbon in roadside plantations compared to other studies from tropical and subtropical regions. This may be due to the higher percentage of large trees which have the maximum dbh and basal area in our study.

Stand characteristics and carbon contents

Tree height (r= 0.61 and R^2= 0.37) was moderately related to above-ground carbon stock but the relationship was significant (p-value is less than 0.05) (Fig. 4). It was found that basal area/ha (r= 0.99 and R^2= 0.99) and stand density/ha (r= 0.93 and R^2= 0.87) had a very strong relationship with total above-ground carbon and the relationship was significant (p-value· 0.05) (Fig. 5 and 6). Two attributes that are strongly related but stand height were weakly related to total above-ground carbon stock. This was because more basal area, canopy cover and stand density/ha indicate more amount of biomass and more biomass indicates more carbon stock. But with the similar height of different plots having a wide variation in the number of trees. So, mean tree height is weakly related to above-ground carbon stock. According to Kuyah *et al.* (2012) DBH (R^2= 0.99) is very strongly related to above-ground biomass. Henry *et al.* (2009) have shown tree volume is very strongly related to total above-ground biomass.

Table 6. AGB and AGC content of seedlings/saplings, palm and deadwood species in roadside plantations

Sl. No.	Scientific name	AGB (Mg/ha)	AGC (Mg/ha)	AGC stock (%)
Seedling/saplings				
1	*Swietenia sp*	16.22	8.11	68.20
2	*Bauhinia sp*	3.65	1.83	15.36
3	*Acacia auriculiformis*	1.65	0.82	6.93
4	*Albizia procera*	1.14	0.57	4.81
5	*Streblus asper*	1.11	0.55	4.66
Palm				
6	*Cocos nucifera*	77.32	38.66	47.51
7	*Areca catechu*	37.11	18.56	22.80
8	*Borassus flabellifer*	36.14	18.07	22.21
9	*Phonix sylvestris*	12.17	6.08	7.48
Deadwood				
10	*Acacia auriculiformis*	1095.36	547.68	73.26
11	*Tamarindus indica*	399.87	199.94	26.74

Table 7. Total above and below-ground carbon stocks of woody perennials in roadside plantations in the study area

Woody perennials	AGB (Mg/ha)	AGC (Mg/ha)	BGB (Mg/ha)	BGC (Mg/ha)	C Stock (AGC+BGC) (Mg/ha)	C stock (%)
Live tree	3464.07	1732.03	692.82	346.41	2078.44	81.37
Seedling/Sapling	4.75	2.38	0.95	0.47	2.85	0.11
Palm	40.68	20.34	8.14	4.07	24.41	0.96
Deadwood	747.61	373.81	149.52	74.76	448.57	17.56
Total	4257.12	2128.56	851.42	425.71	2554.27	100

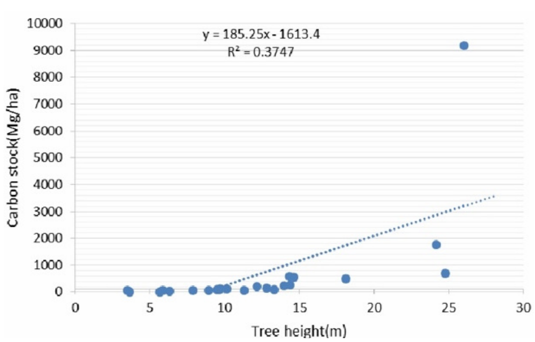

Fig. 4. Relationship between tree height and aboveground carbon stock

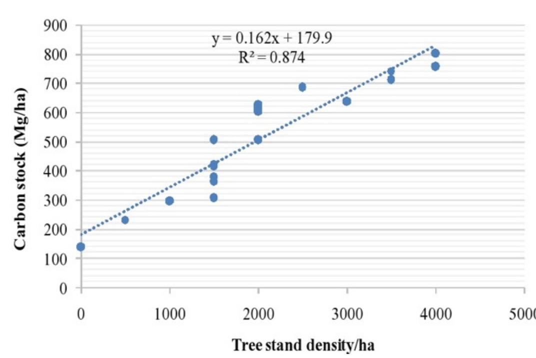

Fig. 5. Relationship between basal area and aboveground carbon stock

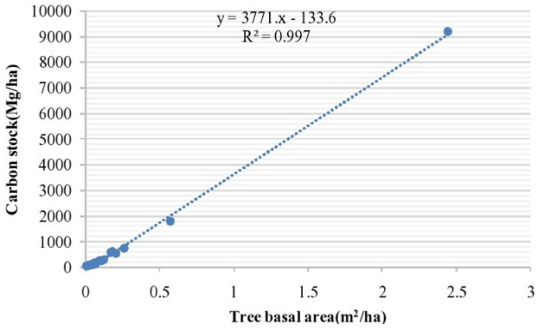

Fig. 6. Relationship between stand density/ha and total aboveground carbon stock

Conclusion

The study revealed that the vegetation structure, species richness, density and recruitment of trees in the roadside of Mymensingh are richer even the other natural forests of Bangladesh. The carbon stock of roadside plantation is quite satisfactory and substantial. The results indicate that two attributes such as basal area and stand density of trees are strongly related to above-ground carbon stocks, but the average height of tree is weakly related. Therefore, the study recommends that the amount of above-ground carbon stocks would increase with the increase of planting trees having greater DBH, basal area and stand density in the roadside areas. Moreover, it can be suggested that by increasing more plantations in the roadside and its surrounding areas that could be on a trajectory towards carbon sequestration in addressing the long-lasting environmental issues in Bangladesh respectively.

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