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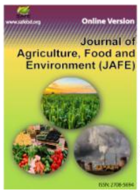

Original Article

Tree species diversity and carbon stock measurement: a study in charland homesteads in Sirajganj district of Bangladesh

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A B S T R A C T

Homesteads are considered as a potential sources of carbon (C) stock which mitigate the adverse effect of climate under the changing environment. Therefore, a study was conducted to find out the tree species diversity and carbon stock of the existing homesteads situated in the Kazipur upazilla of Sirajganj district, Bangladesh. Four villages were selected randomly from the selected upazila, namely Shaldah, Fuljor, Natuarpara and Panagari. A total of 64 homesteads were selected randomly from the four villages as sample of the study. From the study, a total of 18 individual tree species under 14 families were recorded where tree diversity ranged from 0 to 1.85 with average value of 1.06. Carbon stock was quantified as 50% of the tree biomass and out of 64 homesteads the average tree carbon stock was found 16.54 Mg ha^{-1}. The study revealed that homestead has the great potentiality to store substantial amount of atmospheric carbon and conservation of tree species diversity.

Introduction

Global climate change adversely effect on global environment including national economies, people living, productivity faster than before. Change in weather patterns and rising of sea levels are becoming more extreme in history. At the present age both animals and plants are suffering from a global climate change, which is a cause of decrease of biodiversity and increasing greenhouse gases (GHGs), specially carbon dioxide (CO_2). Homestead argofoerstry system is very important in increasing carbon stock due to more than one layer of tree species and contributing farmer's daily needs. Homesteads are ensuring families with much needed income (Michon and Mary, 1994) and are considered to be one of the major contributors of rural livelihoods (Regmi *et al.*, 2004). People living in these charlands depend on agriculture and their homesteads for their livelihood (Chowdhury, 1998). Also, these homesteads provide them a stable climate by storing CO_2 through multilayer tree species.

The marginal and poor people are living in chars for centuries and homesteads are their main source to fulfil nutritional security. But the dangerous effect of flood force them to move another place to build up homestead. As for they are reluctant to develop their homesteads. But still homesteads would play a great role to feed them and improve their livelihood while decreasing atmospheric carbon, extreme temperature and climatic events. It would be possible if they develop their homesteads in a proper way with sufficient plantation.

On this consideration it is necessary to conduct research in charland homesteads for the people's awareness regarding the necessity of establishing homesteads for mitigating climate change and improving their livelihood. This study was taken to fulfil the objectives to estimate tree species diversity and carbon storage (both tree and soil C) in selected areas and to establish a relationship between tree diversity and carbon storage in the study area.

Materials and Methods

The study was carried out in the Kazipur upazilla whichis consist of 12 local government unit − 'unions'. Out of 12 unions, 2 unions namely Natuarpara and Monsurnagar were randomly selected. Natuarpara unions have 13 villages and Monsurnagar unions has 11 villages. Shaldah and Fuljor villages of Monsurnagar union; and Natuarpara and Panagari of Natuarpara union were randomly selected. In the Monsurnagar union of Kazipur upazilla Natuarpara and Pnanagari villages of Natuarpara union were selected. Out of 712 farm families, 15%, viz. 178 household were selected by random sampling method. Then finally 64 representative farm families were taken for questionnaire survey, carbon stocks quantification and tree diversity assessment.

The survey was done in 64 household owners with the help of a set questionnaire. All the data were collected directly from the sampled area as field data and farmer's personal contact as household biophysical data (distance in kilometre from the households to the nearest market and urban centre) and demographical data (household age, head age, education, family size). Other data like households' socioeconomic condition and agricultural land possession, earning from home garden, annual income from agricultural land were also collected and the data, based on land size was recorded in decimal and finally converted into hectare.

The biodiversity of which is focused on tree diversity was estimated by using Shannon-Wiener Diversity Index (SWDI). Every homestead was considered as quadrat plot and tree diversity was quantified within the plot by setting an index based on their number and frequency.

Allometric equations related to DBH of trees was used to measure tree biomass (Pearson *et al*., 2007). After measuring the biomass, it's multiplied by wood carbon content (50%) (Chave *et al*., 2005).

Carbon (Mg) = 50 % of tree biomass × wood carbon content.

The Soil Organic Carbon (SOC) was determined by the potassium dichromate ($K_2Cr_2O_7$) volumetric-external heating method (Bao, 2005).

MS excel 2013 and SPSS-23 software were considered for analysing field data. Above- ground biomass carbon was calculated using international standard common tree allometric combined with local tables of wood density. To study the relationship among diversity and carbon stock, regression analysis was used.

Results and Discussion

Tree Species diversity in homesteads

Species diversity at various home gardens was quantified by the Shannon-Wiener Diversity Index and a significant difference was found among 64 homesteads.

Table 1. Tree diversity at various homesteads.

Homestead size	Mean trees ha^{-1}	Recorded trees		SWDI*	
		Total	Mean	Mean	Range
Small (23)	32	13	15.91	0.82±0.09	0−1.66
Medium (17)	25	14	14.53	1.08±0.09	0−1.54
Large (24)	14	17	22.74	1.16±0.1	0−1.85

*SWDI= Shannon-Winner Diversity Index

Tree diversity was presented in Table 1 and the Shannon-Winner Diversity Index (SWDI) showed a range between 0 to 1.85 for diversity value within the homesteads. This SWDI index revealed that large homesteads (n = 24) had higher average value 1.16 ± 0.1 and small homestead (n = 23) had the least (0.82±0.09) where medium homestead (n = 17) had a moderate mean value of tree diversity (1.08 ± 0.09). The result could be compared as large than medium and small. It was clear that large homesteads had 17 various species where the mean trees species per hectare of small homesteads were 13 trees ha^{-1}, the medium homestead had 14 different species where average trees species per hectare of large homesteads were 14 trees ha^{-1} and small homestead had 32 various tree species where the average trees of medium homesteads were 25 tree ha^{-1} (Table 1). This variation was due to plant composition and species richness, soil characteristics, climate, topography, and homesteads size. Management of tree diversity is the vital issue for biodiversity conservation around the world mostly the country like Bangladesh because it has the potentiality for maintaining a sound and healthy environment and regulating a balanced ecosystem function. Our results of SWI were not higher than that the home gardens in three villages of Sri Lankan (SWDI: 2.13; n = 59), (SWDI: 1.87; n = 30) and (SWDI: 1.99; n = 59) respectively (APN, 2012) and one from Thailand (1.9-2.7) (Gajaseni *et al.,* 1999) but higher than three villages in western Kenya (SWI: 1.55–1.77, 0.74 and 0.86) respectively (Senanayake *et al.,* 2009) (Henry *et al.,* 2009). Tree density is directly influence on carbon sequestration (Roshetko *et al.,* 2017). The tree density of the sampled areas is lesser than Rangpur district's homesteads (385.3 to 1629.5) $hectare^{-1}$ and (11-77 trees home $garden^{-1}$) [Jaman *et al*., 2014].

Species occurrence at different homesteads

A variety of species under different families were found at different homesteads. The study explored 18 tree species under 14 families. Their local name, botanical name family, their total number, % of occurrence, and in which purpose they are used are shown in Table 2.

Table 2. Tree species identified in sixty-four homesteads in Kazipur upazilla of Siragjanj district.

Sl No	Scientific Name	Local Name	Family	Primary use	Total No	% of Total No
1	*Eucalyptus camaldulensis*	Eucalyptus	Myrtaceae	Tm, fl	372	45.10
2	*Mangifara indica*	Aam	Anacardiaceae	Fr, fl ,wd	52	7.01
3	*Sigium guajava*	Guava	Myrtaceae	Fr, fl	46	6.49
4	*Bombax ceiba*	Simul	Malvacea	Co, wd, fl	26	2.84
5	*Moringa oleifera*	Dramstick	Moringaceae	Vg, fl	70	8.47
6	*Melia azedarach*	Beads Tree	Meliaceae	Tm, md	73	9.15
7	*Citrus maximae*	Jambura	Rutaceae	Fr	6	0.60
8	*Swietenia mahogani*	Mehoguni	Moringacae	Wd	8	1.09
9	*Ziziphus jujube*	Ber	Rahmnaceae	Fr, fl	27	3.39
10	*Artocarpus heterophyllus*	Khanthal	Moraceae	Fr, tm, vg, md, dy	31	3.66
11	*Erythina orientalis*	Mander	Fabaceae	Fr, wd	7	0.88
12	*Olea europaea*	Jolpai	Oliaceae	Fr, ol, fl	6	0.85
13	*Tarninalia arjuna*	Arjun	Combretaceae	Wd,Md,Ol,Fr	2	0.19

Sl No	Scientific Name	Local Name	Family	Primary use	Total No	% of Total No
14	*Syzygium cuminis*	Jam	Myrtaceae	Fr, fl, wd	43	5.81
15	*Tamarindus indica*	Tentul	leguminoseae	Fr, tm	4	0.06
16	*Leucaena leucocephala*	Ipil-ipil	Fabaceae	Fl, Tm	38	4.81
17	*Annona sqamosa*	Ata	Anonaceae	Fr	5	0.60
18	*Litchi sinensis*	Lichus	Sapindaceae	Fr, Wd	5	0.24

Here, Tm = timber, Fl = flower, Fr = fruit, Wd = wood. Co = cotton, Vg = vegetable, Md = medicine, Dy = dye, Ol = oil

Table 3. Percent of occurrence of five major species present in study areas.

Sl No	Species	Scientific name	Percent of occurrence
1	Eucalyptus	*Eucalyptus camaldulensis*	45.10
2	Bead Tree	*Melia azedarach*	9.15
3	Drumstick	*Moringa oleifera*	8.47
4	Guava	*Psidium guajava*	6.49
5	Jam	*Syzygium cumuni*	5.81

There were five major trees observed in the homesteads namely, Eucalyptus which is 45.10 % of total trees followed by Bead Tree (9.15%), Drumstick (8.47%), Guava (6.49%) and Ipil-ipil (5.81%) (Table 3). Species composition is highly depending on density of trees. Our observed tree species in sampled areas was lesser than homesteads of Chittagong, Potuakhali, Tangail and Ishurdi (76, 57, 52 and 34) (Mohhammed *et al.*, 2005; Sarker *et al.*, 2014) and greater than that of Bhola, Borguna, Patuakhali, Rajshahi and Rangpur district (31, 30, 20, 28 and 21) (Miah *et al.*, 2013; Abedin *et al.*, 1990). Also, 33.33% fruit and 28.57% timber species were found in homesteads of Habigonj district and 10 fruits and 6 timbers in Mymenshing district (Mannan *et al.*, 2014; Zico *et al*., 2011).

Tree density at various homesteads in Kazipur upazilla of Sirajganj district

The Stem density was measured and a variation was found among the homesteads (Table 4). It represented a range of tree density from 82.54 to 1002. Among the three category of homesteads, the small homestead (0.01-0.03 ha) had greater tree density (11759.87 tree ha^{-1}) with average of 488.87 ± 51.43 and large homestead (>.05 ha) had the lowest tree density value (5464.08 tree ha^{-1}) with average of 234.65 ± 21.34 where medium homesteads (0.03 ha) had medium tree density value (6232.23 tree ha^{-1}) with average of 367.42 ± 39.95. This result may be arranged in order of small than medium and large in case of density.

Table 4. Tree density of various homesteads in Kazipur upazilla of Sirajganj district.

Homestead catagories	LTDV per hectare	HTDV per hectare	Total tree density (ha^{-1})	Mean
Small (24)	251	1002	11759.87	488.87 ±5.43
Medium (17)	120	703	6232.23	367.42 ± 39.95
Large (23)	82.54	412.12	5464.08	234.65 ± 21.34

Here, LTDV= Lower Tree Density Value, HTSV= Higher Tree Density Value

Average basal area (m^2 ha^{-1}) and mean DBH (cm) of different homestead

Data based on average no. of trees, average BA and DBH were calculated from total sampled homesteads in Kazipur upazilla of Sirajganj district. Table 5 showed that large homesteads had greater basal area (4.47 m^2 ha^{-1}) than medium (4.61 m^2 ha^{-1}) and large homestead (5.21 m^2 ha).

Table 5. Average basal area (m^2 ha^{-1}) and DBH (cm) of various homesteads in Kazipur upazilla of Sirajganj district.

Parameters	Homesteads		
	Small	Medium	Large
Average basal area (m^2 ha^{-1})	4.47(0.66)	4.61(0.89)	5.21(0.61)
Mean DBH (cm)	8.99(.32)	10.87(.81)	14.59(0.43)

In the case of DBH, large homesteads showed higher value of 14.59 cm and small homesteads had the lowest value of 8.99 cm whereas medium homesteads had a moderate average DBH of 10.87 cm. These variations were due to various species age cycles and their frequencies which depend on soil, climate, and length of the homestead.

Carbon storage in different homesteads in Sirajganj district

Global climate is changing at a faster rate, as a result of an increasing rate of atmospheric carbon dioxide. But trees play a great role in mitigating climate change by sequestering a huge amount of CO_2 where homesteads can influence to mitigating climate change by its multistore trees and other plant species.

Tree carbon stock at various homesteads in Sirajganj district

Tree carbon stock at various homestead was measured and significant differences were found. Among total homesteads average above and below ground carbon stock was ranges from 1.63 Mg C ha^{-1} to 57.75 Mg ha^{-1}. Large homestead had the greater carbon stock (21.01 ± 2.56 Mg ha^{-1}) and lowest carbon stock (14.66 ± 3.10 Mg ha^{-1}) in the small homesteads and moderate carbon stocks (16.82 ± 4.23 Mg ha^{-1}) in medium homesteads (Table 6). Average standing carbon stocks in Kerala (16.0 to 36.0 Mg ha^{-1}), Kandy (90.0 Mg C ha^{-1}) and Matale (104.0 Mg C ha^{-1}) (Kumar et al., 2011; Dissanayake *et al*. 2009; Dissanayake *et al*., 2009). Homesteads in Eliya of Sri Lanka and Nepal had 77 Mg C ha^{-1} and 240 Mg ha^{-1} carbon stock respectively (Premakanta *et al*., 2009; Rana *et al*., 2011). Homesteads of Indonesia contained 82.0 to 211.0 Mg C ha^{-1} carbon stocks (Kessler *et al*. 2012).

Table 6. Tree Carbon storage in different homesteads in Kazipur upazilla of Sirajganj district.

Homestead category	Number of homestead	Range Mg C ha^{-1}		Mean
		Highest	Lowest	
Small	23	45.52	1.63	14.66 ± 3.10
Medium	17	57.75	3.38	16.82 ± 4.23
Large	24	48.56	6.52	21.01 ± 2.56

Relation between DBH and carbon stock

The regression relation between the mean DBH (cm) and carbon storage was estimated at various homesteads and presented in Figure 1. A relationship was estimated as; y = 2.354x - 9.718 (R^2 = 0.285) where R^2 was positive, r = 0.054 which indicates that the relationship was very weak but significant (5% level of significance) between DBH and carbon stock. The equation also stated that carbon stocks increased at the rate of 2.354 Mg ha^{-1} per unit change of mean DBH (cm). The study states that the higher the average DBH higher will be the carbon content. A similar result was found by Jaman (2014) in homesteads of Rangpur.

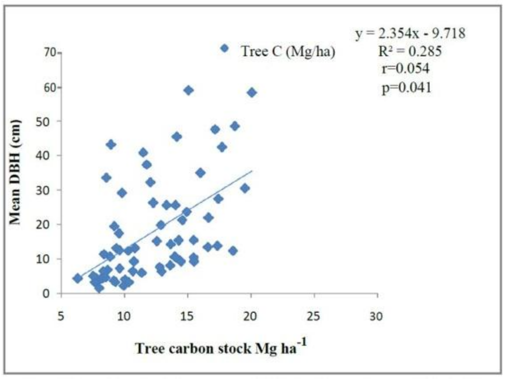

Figure 1. The relationship between mean DBH and carbon stock (Mg ha^{-1}) in homesteads of Kazipur upazilla of Sirajganj district.

Relation between tree diversity and tree carbon

The regression relationship was explored by an equation; y = 12.22x + 5.132 (R^2 = 0.154) and showed in the Figure 2, where R^2 was positive, r= 0.041. It indicated a weak and significant correlation between diversity and carbon stock. The equation states that carbon stock increased at a rate of 12.22 Mg ha^{-1} per unit change in tree diversity.

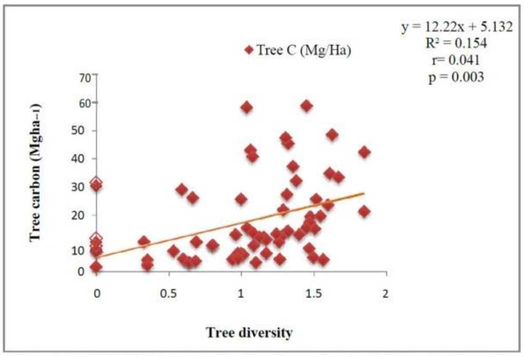

Figure 2. The relationship between tree diversity and tree carbon (Mg ha^{-1}) at different homesteads in Kazipur upazilla of Sirajganj district.

Soil Organic Carbon (SOC) at different homesteads

SOC were collected from three layers i.e., 0−10 cm, 10−20 cm and 20−30cm. It varies between 2.51 Mg ha^{-1} to 23.64 Mg ha^{-1} at 0−10 cm depth and it varies between 3.29 Mg ha^{-1} to 22.53 Mg ha^{-1} at 10−20 cm depth and 3.21−18.34 Mg ha^{-1} at 20-30 cm depth of the homesteads under study. 0-10 cm depth soil had the higher SOC value of 14.23 ± 1.09 and lowest mean value of 12.67± 1.18 Mg ha^{-1} in small homesteads where the medium homesteads had a medium average value of 13.46 ± 1.41 Mg ha^{-1}. In 10−20 cm depth large homesteads had the greater average value of SOC (11.81 ± 0.92 Mg ha^{-1}) followed by small homesteads (8.45 ± 0.58 Mg ha^{-1}) and medium of homesteads (9.49 ± 0.88 Mg ha^{-1}). In case 20-30cm depth large homestead had the mean value of (7.87± 0.54 Mg ha^{-1}), small homesteads (6.78± 0.58 Mg ha^{-1}) and medium homesteads (7.12 ± 0.56 Mg ha^{-1}) (Table 7).

Table 7. SOC at different homesteads in Kazipur upazilla of Sirajganj district.

Homestead Category	Depth(cm)	Range SOC (Mg ha^{-1}) Highest	Lowest	Mean
Small (24)	0-10	12.32	2.51	12.67± 1.18
	10-20	21.53	4.26	8.45 ± 0.28
	20-30	18.34	3.21	6.18±0.58
Medium (17)	0-10	23.64	4.62	13.46 ± 1.41
	10-20	12.54	3.68	9.49 ± 0.288
	20-30	11.58	3.43	7.12±0.56
Large (23)	0-10	22.26	4.17	14.23 ± 1.29
	10-20	15.50	3.22	11.81 ± 0.92
	20-30	11.32	3.78	7.87±0.54

Saha *et al*. (2009) stated that average SOC in two different layers (5-10 and 20-25 cm) was 49.24 Mg ha^{-1} with the range was from 2.95 to 70.19 Mg ha^{-1} which was lesser than Kerala's home garden (101.5 to 123.4 Mg ha^{-1}), coastal land area of Ireland (383 Mg ha-1) [Xu *et al*., 2011] but greater than Iranian homesteads (0.49 to 16.64 Mg ha-1) (Zeraatpishe *et al.*, 2012) and Brazilian savanna soils (22.98 Mg ha-1) (Juliana *et al.*, 2014). SOC content within 1 m soil depth under moist deciduous forests in the district of Kerala were 176.6 Mg ha^{-1} that is much greater than the present homestead SOC because forests characterized by high rates of litter fall, very low soil disturbance and high plant species diversity (Saha *et al.*, 2008)

Relation between tree diversity and Soil Organic Carbon

Tree diversity and soil organic carbon (Mg ha^{-1}) relation was estimated by an equation; y = 2.841x + 21.46 (R^2 = 0.019) and shown in the Figure 3, where R^2 value is positive, r = 0.139 and it showed that there is a very weak and non-significant relation between tree diversity and SOC. The equation showed that an increase in the SOC at a rate of 2.841 Mg ha^{-1} per unit change in tree diversity. Jaman *et al*., 2014 found a positive relationship between tree diversity and soil carbon stocks (Mg ha^{-1}) in his study.

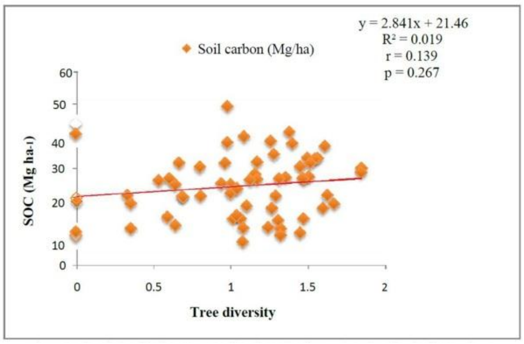

Figure 3. The regression relation between tree diversity and SOC at different homesteads in Kazipur upazilla of Sirajganj district.

Conclusion

Carbon stocks among the three homesteads categories represent that large homesteads had highest carbon stocks (44.6 Mg ha^{-1}) than medium (39.3 Mg ha^{-1}) and small homestead (36.5 Mg ha^{-1}). Largest tree carbon content was found (24.83 Mg ha^{-1}) in large homestead and the lowest (20.94 Mg ha^{-1}) was found in small homestead where the medium of homesteads had a moderate value of tree carbon (Mg ha^{-1}). SOC has measured and found that highest SOC (23.64 Mg ha^{-1}) in large homesteads followed by small homesteads. Positive relationship between species diversity and carbon stock indicates that higher the tree diversity, higher the carbon stock as well.

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