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RESEARCH ARTICLE

TREE SPECIES DIVERSITY AND CARBON STOCK IN CHARLAND HOMEGARDENS OF BANGLADESH

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ABSTRACT

Four Bangladeshi villages were chosen at random to represent a total of 64 home gardens.The study's objective was to evaluate the variety of tree species and the carbon store in the tree biomass on Char Island, both above and below groun. The Shannon Wiener index was used to evaluate the variety of tree species, and allometric equations were used to estimate the carbon stock, with the assumption that the stock represented 50% of the carbon in the tree biomass. The findings indicated that home garden ecosystems could store an average of 18.00 Mg of carbon per hectare, ranging from 1.66 Mg of carbon per hectare to 58.93 Mg per hectare and tree species diversity ranged from 0 to 1.84 with a mean value of 1.05 where most abundant was *Eucalyptus camaldulensis* (44.21%) which stored the most C (33.62Mg ha^{-1}) followed by *Moringa oleifera* (29.37 Mg ha^{-1}) in tree biomass. The study provides a evidence of tree diversity and carbon storage in char island.

KEYWORDS

Carbon stock, Tree diversity, homegarden

1. INTRODUCTION

A home garden, according to a study, is a sophisticated and sustainable land use system that integrates a range of agricultural products, meets household requirements, creates employment opportunities, and generates money (Weerahewa et al., 2012). It can also be a source of carbon sequestration, a strategy for preventing climate change. The additional carbon that can be stored in the environment of trees is known as C sequestration (Bernouxet al., 2006). According to a study, tropical agro-forestry systems have the ability to sequester 95 t CO2 ha-1, ranging from 12 to 228 tCO2 ha-1 (Albrecht and Serigne., 2003). Depending on its characteristics, management strategies, land uses, and geography, complex agro-ecosystems can exhibit significant variation in C sequestration and biodiversity (Montagnini and Nair, 2004). While a home garden, as a scope of agro-ecosystems with a great range of plant species, living forms, and production activities, may offer higher levels of productivity and more stable C stocks, carbon sequestration is also a strategy for mitigating climate change (Houghton et al., 1993; Yachi and Loreau, 1999).

However, in Bangladesh the situation on Char Island is very different. The term "char island" refers to any accumulation in a river course or estuary that is surrounded by the waters of an ocean, sea, lake, or stream (Chowdhury, 1988). At the current study, biodiversity and carbon stock were measured in a homestead on Char Island in North-Western Bangladesh, which

may be important for carbon stock. These Char islands' residents rely on agriculture and their backyard gardens for a living. Additionally, by storing CO2 through a variety of multilayer tree species, these home gardens give them a steady environment. According to research by Roshetko and Purnomosidhi, the average above-ground carbon stocks in Lumpung home gardens in Indonesia were assessed to be 56.5 Mg C/ha after taking into account species, classes, rotation durations, and time (Roshetko and Purnomosidhi, 1998). A well-established home garden can also provide 29% lumber, 32.26% fuel, 38.71% medicinal plants, and 45% fruit and food (Roy et al., 2013).

Similar to this, Bangladesh's char island home gardens can be used as a source of biodiversity preservation and carbon storage to lessen climate change. More consideration must be given to adaptation strategies that local land users might adopt with the effective cooperation of stakeholders and policymakers in order to address future issues of biodiversity conservation and the negative consequences of climate change (Murthy et al., 2013). In light of this, research into the home gardens on Char Island was important to educate the public about the value of a well-established home garden in enhancing plant diversity and creating a more favorable climate. As a result, the study's attention was drawn to tree diversification and storage carbon.

2. METHOD AND MATERIALS

2.1 Location and Study Area

In Kurigram district, four villages within two upazillas (administrative units) participated in the study. The Kurigram district is situated in

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Bangladesh's northern region. The district has a total size of 2255.29 sq km and is situated between latitudes 20°03' and 26°03' N and longitudes 89°27' and 89°32' E. The four villages that were under study are Dagarkuti, Kolakata, Borovita, and Charuapara. These include the communities of Borovita and Charuapara in Chilmary upazilla, and Dagarkuti and Kolakata in Ulipur upazilla.The area of Ulipur Upazilla is 504.19 square kilometers, and it is situated between latitudes 25°33' and 25°49' north and 89°29' and 89°51' east. Chilmary Upazilla is situated at 25.5667°N and 89.6917°E.

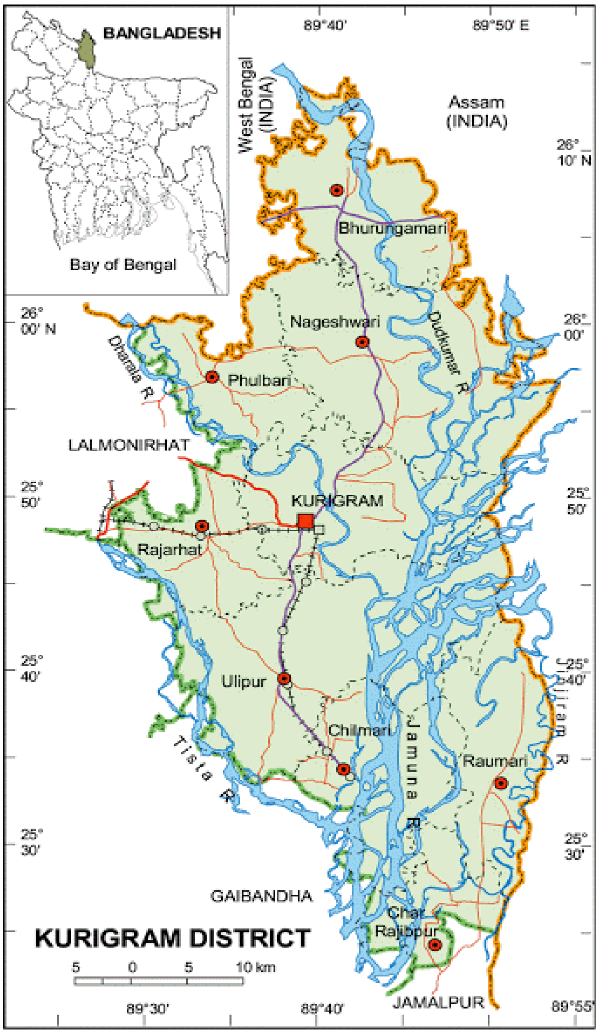

Plate 1: Kurigram district

Kurigram experiences tropical dry and wet weather. In general, the climate is characterized by monsoons, high temperatures, high levels of humidity, and significant rainfall. Early in April, the hot season starts, and it lasts through July. The lowest and maximum mean temperatures for the months of January, February, March, and April were between 7 and 16 °C and 32 and 36 °C, respectively (BBS, 2012). The district's average annual rainfall is approximately 1587 mm, with the greatest rainfall recorded during the monsoon months being 1378.6 mm (BMD, 2014). Alluvial soil makes up 80% of the soil in the study area, with bare soil accounting for the remaining 20% (SRDI., 2014).

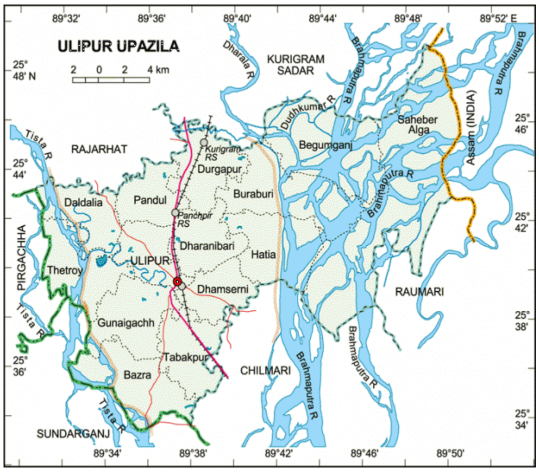

Plate 2: Ulipurupazillaplate

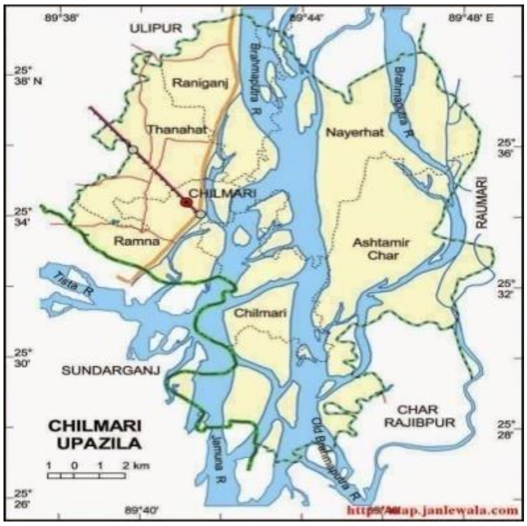

Plate 3: Chilmariupazilla

2.2 Sampling Technique

Ulipur and Chilmari were two of the nine upazillas (administrative units) of Kurigram that were randomly chosen. There are 14 unions (administrative unit) in Ulipur and 6 in Chilmari Upazilla, respectively. Hatia and Buraburi were randomly chosen from among the 14 unions in Ulipur, and Ranigang and Nayarhat were chosen from among the 6 unions in Chilmari Upazilla. One village named Dagarkuti and one village named Kolakata from the Htia and Buraburi union were arbitrarily chosen to be in Ulipur upazilla.Two villages, Borovita in the Ranigang union and Charuapara in the Nayarhat union, were arbitrarily chosen from the Chilmari upazilla. A sample of 15% out of 712 farm families, was taken (Jaman et al., 2016). By using the stratified random sample method, 178 households were chosen (table 1) Finally, 64 representative farm families were chosen from homegardens rich in various species to participate in questionnaire surveys, carbon stock measurements, and tree diversity assessments. The formula of garden Yamane was employed to determine the ultimate home (Yamane, 1967).

Table 1: Distribution of Population and Sample Size in Four Selected Village

Upazilla	Union	Village	No. of total households	No. of households primary selected selected (N)	ultimate number of households chosen for data gathering (n)
Ulipur	Hatia	Dagarkuti	247	62	22
	Buraburi	Kolakata	135	60	12
Chilmary	Ranigang	Borovita	260	65	24
	Nayarhat	Churoapara	70	17	6
Total			712	178	64

2.3 Survey of Backyard Plots

First, the home gardens were separated into three categories for comparison purposes: tiny (0.01-0.03 ha), medium (0.03-0.05 ha), and large (> 0.05 ha). There were 23, 17, and 24 home gardens in each of the three categories (Jaman et al., 2016). The breast height (1.37 m) of each perennial tree was taken into consideration when selecting it, and each tree's local name and botanical name were documented down to the species level. Using a measuring tape, the DBH of each chosen species was calculated. The biomass of the trees was determined for each kind of tree using an allometric equation developed (Chave et al., 2005). Using the global wood density database and the FAO list of wood densities for tree species from Tropical Asia, the wood density for the species under study was determined (Zanne et al., 2009). Climbers were not chosen for this study because the study plots lacked palm trees and because it was difficult to tell stems apart.

2.4 Estimation of Biodiversity

Using the Shannon Wiener Diversity Index, biodiversity with an emphasis on tree diversity was estimated (SWI). Each of the homesteads served as a sample plot, and the variety of the tree species was quantified therein by creating an index based on their frequency and number. The Shannon-Wiener diversity index (SWI), which is effective for evaluating the diversity of tree species, was employed in this study. The Shannon-Wiener diversity index exhibits the maximum diversity when all species are equally plentiful relative to the fraction of species abundance in the population; when the sample only contains one species, it displays the least diversity, or 0 diversity. The species (i) to species total ratio (Pi) was calculated, and the same ratio's natural logarithm was multiplied (Ln Pi). The total across all species is multiplied by -1 to arrive at the final value (Shannon et al., 1963)

$\mathbf{H} = \sum_{i=1}^{n} \mathrm{P}i \ \mathrm{Ln}\ \mathrm{P}i$

Where, Σ= Summation.

pi = The percentage of the entire sample of that species. Total number of distinct species *i* , divided by total no. of plant species discovered in a sample community.

H = Shannon index

n = No. of species

2.5 Allometric Equation for Above and Below Ground Biomass:

2.5.1 Tree Biomass

Tree biomass equations relate to diameter at breast height (dbh) and differ depending on the species. This is due to the fact that trees in comparable functional groups can have significantly diverse growth forms in various geographic locations (Pearson et al., 2007). Allometric equations for tropical trees were developed (Chave et al., 2005). These equations can be used for a wide range of morphological and diameter circumstances.

2.5.2 Above-Ground Biomass

The following equation has been used to calculate above-ground biomass:

AGB = $\rho\times \exp(-1.499+2.148\times\ln(\mathrm{DBH}) + 0.207\times(\ln(\mathrm{DBH}))^2 - 0.028(\ln(\mathrm{DBH}))^3)$ (Chave *et al.*, 2005)

ρ = Wood density (g cm^{-3}): - 1.499, 2.148……………………………….0.207 and 0.0281= Constant.

2.5.3 Below Ground Biomass

The model equation created by Cairns et al., 1997, which is based on information of above ground biomass, was used to determine the below ground biomass and carbon. It is the most practical and economical way to calculate root biomass.

BGB = exp (-1.0587 + 0.8836 x ln AGB)

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

2.5.4 Conversion of Biomass to Carbon

Using an allometric relationship to estimate biomass, it was then multiplied by the wood carbon content's (50%) value. Nearly all tropical forest carbon measuring experiments make the assumption that all tissues, including wood, leaves, and roots, contain 50% carbon on a dry mass basis.

Carbon (Mg) = Biomass estimated by allometric equation × Wood carbon content % = Biomass estimated by allometric equation × 0.5. (Chave et al., 2005).

2.6 Analysis of Data

Using MS Excel 2007 and SPSS-23, field data that were gathered through questionnaire surveys were processed and analyzed. Using international standard common tree allometries and regional tables of wood density by tree species, above-ground biomass carbon was calculated. Regression analyses were applied in order to examine the association between various variables.

3. Results and Discussion

3.1 Tree Diversity at Various Homegardens in Kurigram District

A substantial difference was discovered across 64 home gardens in the research area when tree diversity in various home gardens was assessed using the Shannon-Winner diversity index. Table 2 displayed the diversity of trees, and the Shannon-Winner diversity index indicated that the home gardens' diversity value ranged from 0 to 1.84. This diversity index revealed that large homegarden (n = 23) had the highest mean value of 1.17 ± 0.1 and small homegarden (n = 24) had lowest mean value of 0.86 ± 0.09 where medium homegarden (n = 17) had moderate mean value of tree diversity (1.12 ± 0.09). Large > medium > small is the order of the results. The average number of tree species per hectare in large home gardens was 13 with 17 different types, in medium home gardens it was 24 with 15 different types, in small home gardens it was 33 with 14 different types (table 2). According to the study, differences in species composition and richness, soil properties, climate, topography, and garden size account for the variation.

Table 2: Tree Diversity at Various Homegardens in Kurigrm District

Homegarden size	Mean number of tree species per hectare	Species recorded in homegardens		Shannon-Winner Index (SWI)	
		Total	Mean	Mean ± SE	Range
Small (24)	33	14	16.21	0.86 ± 0.09	0-1.66
Medium (17)	24	15	14.93	1.12 ± 0.09	0-1.54
Large (23)	13	17	21.76	1.17 ± 0.1	0-1.84

Drescher and Karyono carried out similar research and discovered that Shannon-Wiener diversity indices in tropical home gardens varied widely, ranging from 0.93 in rural Zambia, which was lower than the study's mean value, to almost 3.0 in West Java, Indonesia, which was higher than the present result (Drescher, 1998; Karyono, 1990). A group researchers conducted a study that was comparable to the current study but had the opposite outcome (Jaman et al., 2016). The small size home garden had the highest mean tree diversity (1.66 ±0.05), followed by medium (1.65 ±0.05) and large (1.6 ± 0.06) home gardens, with a range of 1 to 2.2 and a mean value of 1.64 0.03.

3.2 Tree Species and Their Presence in Various Backyard Gardens

There were five major species found in the homegardens namely, Eucalyptus which is 44.21 % of total number of species followed by neem (9.5%), shojna (8.40%), payara (7.06%) and ipil-ipil (5.72%) (Table 3). According to a survey conducted in Bangladesh's hoar homestead, the percentage of fruit species included coconut (80.67%), mango (79.33%), guava (63.67%), and papaya (51.67%) (Mannan et al., 2013).

Table 3: Presence of Five Major Species Present in Study Areas

Sl. No.	Species name	Scientific name	% of occurrence
1.	Eucalyptus	*Eucalyptus camaldulensis*	44.21
2.	Neem	*Meliaazedarach*	9.25
3.	Shojna	*Moringaoleifera*	8.40
4.	Peyara	*Psidiumguajava*	7.06
5.	Ipil-ipil	*Leucaenaleucocephala*	5.72

3.3 Tree Carbon Stock at Various Home Gardens in Kurigram District

Significant differences were discovered when the carbon stock at different homes was measured. The average tree carbon stock (both above and below ground) was determined to be 18.00 Mg ha-1 among 64 home gardens, with values ranging from 1.66 Mg C ha-1 to 58.93 Mg ha-1. Among the home gardens large home gardens (> 0.05 ha) had the highest carbon stock (20.55 ± 2.66 Mg ha^{-1}) with a number of 23 and lowest carbon stock

(15.68 ± 3.00 Mg ha^{-1}) was found in small home gardens (0.02 > 0.03 ha) with a number of 24 while medium carbon stock (17.82 ± 4.20 Mg ha^{-1}) was found in medium home gardens with a number of 17 (table 4). As the large home garden had the highest tree ha^{-1} carbon content was higher in large home garden.

Similar research was conducted in central Kerala, India, by Kumar, where average standing carbon stocks of home gardens ranged from 16 to 36 Mg ha-1per unit area, with small home gardens having higher standing carbon stocks than large and medium home gardens due to species richness and tree density (Kumar, 2011). The average carbon stock (AGB C stock + BGB C stock) was 53.53 Mg ha-1; n=64; ranging from 6.25 to 193.83 Mg ha-1; and tiny home gardens had a higher amount of carbon (69.15 Mg ha^{-1}) than medium-sized (47.96 Mg ha^{-1}) and large-sized (39.93 Mg ha^{-1}) home gardens. The size of the home gardens, species mix, soil qualities, management practices, and financial circumstances of the homestead owner all affect the carbon stock inside the home gardens in the Kurigram district.

Table 4: Tree Carbon Stocks at Various Home Gardens in Kurigram District

Category of Home Garden	Number of home garden	Carbon stock range Mg/Ha		Mean ± SE
		Highest	Lowest	
Small	24	45.52	1.66	15.68 ± 3.00
Medium	17	58.93	3.38	17.82 ± 4.20
Large	23	48.56	6.52	20.55 ± 2.66

3.3.1 Above and Below Ground Carbon (AGC and BGC) Stock in Different Home Gardens

According to measurements of above- and below-ground carbon stocks large home gardens had highest quantity of above ground (17.28 Mg ha^{-1}) and below ground (3.27 Mg ha^{-1}) carbon and small home gardens had the lowest amount of above ground C (12.66 Mg $ha^{-1)}$ but medium amount below ground C (3.02 Mg ha^{-1}) where medium home gardens had a moderate amount of above ground C (14.19 Mg ha^{-1}) but the lowest amount of below ground C (2.9 Mg ha^{-1}) (Figure 1). Smaller homesites (<0.4 ha) had more soil carbon per unit area (119.3 Mg ha^{-1}) than bigger ones [0.4 ha] with C stock of 108.2 (Mg ha-1) because they had more trees and plant types (Subhrajit et al., 2009).

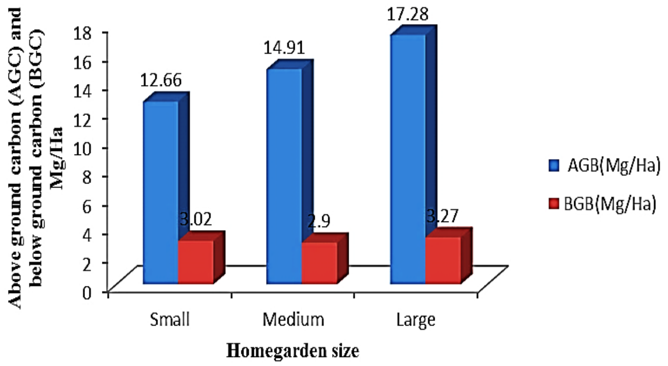

Figure 1: Above and below ground carbon stocks (Mg ha-1) at varioushomegarden in Kurigram district

3.3.2 Major Tree Species and Their Carbon Content at Various Homegardens

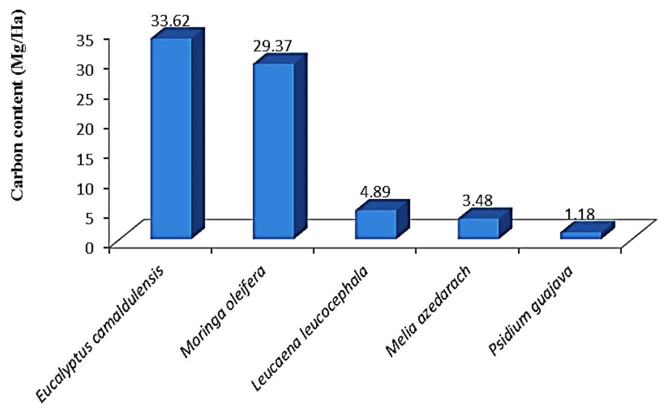

Figure 2: Five major tree species and their C content (Mg)

According to the study, Eucalyptus camaldulensis stored the most carbon (33.62Mg ha-1), followed by Moringao leifera (29.37Mg Mg ha-1), Leucaena leucocephala (4.89 Mg ha-1), Melia azedarach (3.48 Mg ha-1), and Psidium guajava (1.18 Mg ha-1) (Figure: 2). According to the results of the current study, Eucalyptus trees were the most prevalent (44.21% occurance; Table 4), and as a result, they contain the most carbon. According to a similar study conducted betel nuts were the most prevalent species (453 no.), with 15.59 Mg of carbon, followed by mango (362 no., 26.7 Mg), jackfruit (178 no., 29.71 Mg), Mahagani (146 nos., 17.24 Mg), Gora neem (128 nos., 5.65 Mg) and Eucalyptus (98 nos., 6.4 Mg) at various homegarden (Jaman et al., 2016).

3.4 The Relationship Between Tree Diversity and Tree Carbon (Mg Ha- 1).

A linear association between tree diversity and biomass carbon (Mg ha-1) was investigated using the equation y = 12.22x + 5.132 (R2 = 0.154), which is depicted in Figure 3 and has a positive R2 value, r=0.041, and a significance level of $p < 0.05$ (figure 3). It showed that there was a very slight but statistically significant association between tree diversity and tree carbon (5% threshold of significance). According to the calculation, the amount of carbon in the atmosphere grew at a rate of 12.22 Mg ha-1 for every unit change in tree diversity. A group researchers conducted a similar investigation, and, in his research, he discovered a favorable relationship between tree diversity and tree carbon supply (Jaman et al., 2016). Another study by indicates that increased structural diversity raises aboveground carbon in Canadian forests (Weifeng et al., 2011).

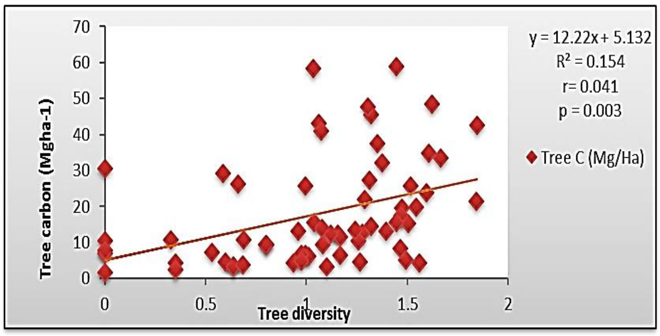

Figure 3: The relationship between tree diversity and tree carbon (Mg ha^{-1}) at various homegardens in Kurigram

4. Conclusion

Due to carbon dioxide emissions, deforestation, and over-exploitation by humans, two pressing challenges in today's globe are climate change and biodiversity destruction. However, the current study demonstrated that because of their multifaceted functions, home gardens had a potential role in mitigation and adaptation to climate change. The study displayed an overall picture of the homesteads on Bangladesh's North-Western Char Island in terms of plant diversity and carbon stock, showing how these variables differed depending on the size of the home gardens and their vegetational traits. According to the study, household gardens in Charlatan have the potential to play a part in biodiversity preservation as well as climate change adaptation and mitigation. Due to the unfavorable climatic conditions, the residents of Char Island are unable to improve their home gardens, which forces them to relocate. However, people can make improvements to their home gardens, which are a significant source of plant diversity and a carbon store.

Author's Contribution

BI planed, conduct experiments, gathered and analysed data. IJN, BK , MSI and DNN helped in writing, editing and revising the manuscript. DMFH helped in supervising the experiment. All the authors read and approve the final manuscript.

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Competing Interest

All authors accept and declare that there is no conflict of interest either financially or otherwise.

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