MEASUREMENT OF BIODIVERSITY AND CARBON STOCK IN NORTH-WESTERN CHAR ISLAND HOMEGARDENS OF BANGLADESH

A THESIS

BY

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AGROFORESTRY AND ENVIRONMENTAL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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This is to certify that thesis entitled, "MEASUREMENT OF BIODIVERSITY AND CARBON STOCK IN NORTH-WESTERN CHAR ISLAND HOMEGARDENS OF BANGLADESH" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in ***Agroforesty and Environmental*** *Science embodies the result of a piece of bona fide research work carried out by* ***Benazir Iqbal ,*** *Registration No.* ***08-03121*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2015
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DEDICATED

TO

THOSE PARENTS WHO SUPPORT THEIR GENERATIONS THROUGH THIK AND THIN

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ABSTRACT

The study was conducted in Ulipur and Chilmari upazillas of Kurigram district. Four villages were selected randomly from the selected upazilas, namely Dagarkuti, Kotakata, Borovita and Charuapara. A total of 64 homegardens were selected randomly from these villages as sample of the study and data were collected on the basis of tree diversity, carbon stock and farmer's livelihood. A total of 821 trees were sampled and 18 different tree species under 14 families were identified and recorded. The Shannon Wiener index was used to evaluate the tree diversity per homegarden and it ranged from 0 to 1.84 with a mean value of 1.05. Allometric equations were used for carbon estimation where C stock was assumed as 50% of the tree biomass carbon. Among 64 homegardens average tree carbon stock was calculated 18.00 Mg ha^{-1} and average SOC was found 24.56 Mg ha^{-1}. Among the homegardens large homegardens contain the highest amount of carbon (tree C + soil C stock) (46.43 Mg ha^{-1}) compared to medium (40.75 Mg ha^{-1}) and small (37.99 Mg ha^{-1}) homegardens. Among the char island farmers of Kurigram district 98.83% of large farmer had 31.8% income from their homegarden where medium (82.35%) and small (54.16%) farmers had 17.56 % and 15.26% income, respectively. The study provide a strong statement that homegarden has a potential role in carbon storage, conservation of species diversity and improving livelihood of farmers. However specific homegarden management plan and motivation activities should be increased to develop homegardens.

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LIST OF ABBREVIATION AND ACRONYMS

AGC	:	Above ground carbon
AGB	:	Above-ground biomass
A/R	:	Aforestation and Reforestation
AEZ	:	Agro-Ecological Zone
AFS	:	Agroforestry system
et al.	:	And others
µ	:	Average
BGC	:	Below ground carbon
BGB	:	Below-ground biomass
DW	:	Biomass dry weight
BFW	:	Biomass fresh weight
C	:	Carbon
CO_2	:	Carbon dioxide
Cm	:	Centimeter
CERU	:	Certified emission reduction units
CDM	:	Clean development mechanism
CFM	:	Collaborative forest management
^0C	:	Degree Celsius
FAO	:	Food and agriculture organization
e.g.	:	For example
GIS	:	Geographic Information System
Gt	:	Giga ton
GBH	:	Girth breast height
GPS	:	Global Positioning System
GHG	:	Green house gas
Ha	:	Hectare
IVI	:	Importance Value Index

LIST OF ABBREVIATION AND ACRONYMS (cont'd)

IPCC	:	Intergovernmental Panel on Climate Change
Mg	:	Mega gram = 10^6 gram
NFM	:	National forest management
O_2	:	Oxygen
%	:	Percent
REDD	:	Reducing Emissions from Deforestation and Forest Degradation
SOC	:	Soil organic carbon
m^2	:	Square meter
DBH	:	Stem diameter at breast height (over bark)
T	:	Ton
UNFCC	:	United Nations Framework Convention on Climate Change
ρ	:	Wood specific gravity (g/cm^3)
tk	:	Taka

INTRODUCTION

Humanity of the present age is suffering from a global challenge of climate change, which is a result of loss of biodiversity and increasing greenhouse gases (GHGs), mainly carbon dioxide (CO_2). Deforestation and forest degradation, particularly in tropical regions, are significant contributors to biodiversity loss and climate change (Strassburg *et al.,* 2009). It is estimated that deforestation and forest degradation contributed 12–20% of global greenhouse gas emissions over the last 20 years mainly in the tropics (Saatchi *et al.,* 2011). There is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities (IPCC, 2001). Also deforestation contributes about 5.9 Gt. CO_2 annually over the world (IPCC, 2007). This changing climate can impact not only environment but also socio-economic condition of human causing a change in global economy. So biodiversity and its relationship with the carbon cycle has become an important consideration in international efforts to mitigate the loss of climate change, through reducing the conversion of natural ecosystems (Midgley *et al.*, 2010). The United Nations program for Reducing Emissions from Deforestation and Forest Degradation (UN–REDD) is focused on maintaining carbon storage within tropical forests in developing countries (Gibbs *et al.,* 2007). Recently many technologies and land use management practices have been developed in many countries to overcome this critical challenge. Homegarden argofoerstry system is one of them which has potential in biodiversity conservation, increasing carbon stock due to multilayer tree species and contributing farmer's daily needs. Homegardens are providing families with much needed income (krol, 1992., Michon and Mary.,1994) and are considered to be one of the major contributors of rural livelihoods (Shrestha *et al.*, 2002; Regmi *et al*., 2004). The provisioning role of agroforestry and homegardens to maintain species diversity may also facilitate more stable and longer term stability of carbon stocks as well as diversification of homegarden derived products (Yachi and Loreau

1999; Brookfield et al. 2002; Henry et al., 2009). But the scenario of char island homesteades are quite different. ‘Char island’ a tract of land surrounded by the waters of an ocean, sea, lake, or stream; it usually means any accretion in a river course or estuary (Chowdhury, 1988). Rivers and island water bodies consist of 6.7% of the total land of Bangladesh (Ahmed, 2001) and Char islands are prone to adverse climatic condition due to high temperature, high rainfall at rainy season with a scouring effect of flood. The marginal and poor people are living in chars for centuries and homegardens are their main source to meet up nutritional security. But the scouring effect of flood force them to move other place to build up homestead. As a result they are reluctant to develop their homegardens. But still homegardens would play a potential role to feed them and improve their livelihood while reducing atmospheric carbon, extreme temperature and climatic events. It would be possible if they develop their homegardens in a proper way with sufficient plantation.

Present study was taken for measuring biodiversity and carbon stock in char island homestead gardens in North-Western Bangladesh which has significant relation with the liveihood of the farmers of these areas. The study was conducted in the char land of two upazillas namely Ulipur and Chilmari in Kurigram district. People living in these Char islands depend on agriculture and their homegardens for their livelihood. Also these homegardens provide them a stable climate by storing CO_2 through multilayer tree species. From a study Roshetko and Purnomosidhi (1998) reported that considering the species, classes and rotation lengths and time average above ground carbon stocks estimated to be 56.5 Mg C/ha in Lumpung homegarden in Indonesia and a study in Southeastern Nigeria reported that tree crops and livestock produced in home gardens accounted for more than 60% of household income (Okigbo, 1990). Also an established homegarden can contribute to 45% fruit and food, 38.71% medicinal plants, 32.26% firewood and 29% timber (Roy, *et al.*, 2013). Similarly char island homegardens in Bangladesh can be utilized as a source of biodiversity conservation and storage of carbon along with a source of family income. To meet future challenges of biodiversity conservation, to ensure food security and adverse effects of climate change, mitigation and adaptation practices that can be used by local land users through effective support by stakeholders and policymakers needs further attention (Murthy *et al.*, 2013). On this consideration it was necessary to conduct research in char island homegardens to make the people aware of the impotence of establishing homegarden for mitigating climate change and improving their livelihood. Therefore the study was focused on tree diversity, carbon stock and farmer's livelihood to fulfill the following objectives.

OBJECTIVES:

1. To measure tree diversity of the selected area and to estimate carbon storage (tree C and soil C) in selected area; and
2. To establish a relationship between plant diversity and carbon stock with farmers livelihood

CHAPTER II

REVIEW OF LITERATURE

2 .1 An overview of tree diversity and species richness in homegarden

Gautam *et al.* (2004) reported that in the wetter parts of the middle hill areas of Nepal (e.g. Illam), more than 75% of home gardens had 21 to 50 diverse species per household, whereas the drier part had 11-40 species per household.

Mattsson *et al.* (2015) conducted an study on Quantification of carbon stock and tree diversity of homegardens in a dry zone area of Moneragala district, Sri Lanka and reported that 70 different tree and plant species were identified from 55 genera and 30 families and in total 4,278 trees were measured. The most common species found was Bead Tree (*Azadirechta indica* A. Juss., *n* = 1014) accounting for 24% of all trees measured followed by Cashenut (*Anacardium occidentale* L., *n* = 509, 12%) and Coconut (*Cocos nucifera* L., *n* = 362, 8%). Tree diversity described by the SW I showed a variation between 0.76–3.01 with a mean value of 2.05 ± 0.07 where small sized homegardens had the highest mean diversity of trees followed by medium and large homegardens.

Buchmann (2009) reported from a study of homegarden in Cuba that there were 25 homegardens in Central Cuba containing 182 plant species.

Roy *et al.* (2013) conducted a study to assess the status, plant diversity, traditional uses, spatial arrangement and importance of homestead garden for biodiversity conservation of the urban and rural households in Kishoreganj Sadar of northern Bangladesh. Their study reported that 62 plant species belonging to 36 families including 5 threatened species were identified. The majority of the species were used as fruit and food (45%) followed by medicinal plants (38.71%), firewood

(32.26%), and timber (29%). Farmers perceived importance of homestea for fruit and food (85%) followed by building materials (78.75%), subsistence family income (73.75%), and source of firewood (68.75%).

Watson and Eyzaguirre (2002) stated that Homegardens contain a wide spectrum of plant species, some of which are landraces, rare or threatened species and specific cultivars selected for a set of desirable traits.

Hayat and Kudus (2010) reported that a total of 3414 individual trees representing 120 species, 81 genera and 31 families were recorded. Species with highest relative abundance were *Swintonia sp.* (0.12), *Garcinia eugnifolia* (0.09) and *Syzygium sp.* (0.05). Species diversity was high with Simpson's index of diversity with a value of 0.96, while Shannon-Weiner index was 5.42 and Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness were 0.264, 0.378, and 0.419, respectively. Results indicated that species richness and species diversity were high, but evenness was low in this logged-over coastal forest in Malaysia.

Mannan *et al.* (2013) reported that plant biodiversity in the haor homesteads of Bangladesh contain eighty four useful plant species among them 33.33% fruits, 28.57% timber, 22.62% summer vegetables and 15.48% were winter vegetable. Number of fruits species were found highest (28 spp) followed by the timber (24 spp), summer vegetables (19 spp) and winter vegetables (13 spp). Coconut, Mahagani, brinjal and bottle gourd were found most prevalent in their respective category. Inter species diversity was highest (0.799) in the fruit species and lowest in summer vegetable.

Bardhan *et al.* (2012) had conducted an study in Bangladesh and reported that a total of nine locations were selected for this research which comprised of five AF

(Agroforestry) sites and four NFs (National forest). Shannon–Weiner Diversity Index (H) was similar for homegarden AF (3.50) and NF (2.99), with no statistical difference between them.

Kumar (2011) and Pushpakumara *et al. (*2012) reported that the large variability of AGB carbon among homegardens are primarily a result of tree density which is highest in small homegardens (small: 80 trees ha^{-1}), followed by medium (23 trees ha^{-1}) and larger units (15 trees ha^{-1}).

Kabir & Webb (2008) reported that the high floristic diversity was a reflection of the potential of homegardens to serve as repositories of genetic diversity in south-western Bangladesh. They also stated that species richness varied greatly and ranged from 17 to 69 plant species per homegarden with a mean value of 44 ± 1.09.

Ahmed *et al*. (2004) reported from several studies in the homesteads of Gazipur district, central Bangladesh that species diversity in a homestead garden can range from less than five to more than 100.

Henry *et al*. (2009) reported that a total of 49 tree species were identified in the two locations of Vihiga and 56 in the two of Siaya in highlands of western Kenya. Tree biodiversity as measured with the Shannon index (H) was significantly ($P < 0.05$) higher in Siaya (H = 0.62) than in Vihiga (H = 0.50). Values of the Shannon index (H), used to evaluate biodiversity which ranged from 0.01-0.03 in woodlots, from 0.4–0.6 in food crop plots and from 1.3–1.6 in homegardens. *Eucalyptus saligna* was the most frequent tree species found as individual trees (20%).

Senanayake *et al.* (2009) reported that the mean Shannon Wiener Index (SWI) of 2.05 is lower than the SWI found by APN (2012) in the homegardens of the

Keeriyagaswewa village (SWI: 2.13; n = 59) located in the Sri Lankan dry zone but higher than in Siwalakulama village (SWI: 1.77; n = 30; intermediate zone) and Pethiyagoda village (SWI: 1.99; n = 59, wet zone) and in the Meegahakiula area (SWI: 1.55 to 1.77) in intermediate zone.

Saha *et al.* (2009) reported that the estimated SWI, which was found in their study was higher than the mean SWI found in homegardens from two villages in West Bengal, India and six villages in Dhaka Division, Bangladesh (APN, 2012), but lower than in Kerala homegardens in India.

Drescher (1998) and Karyono (1990) reported that mean Shannon-Wiener diversity indices in tropical homegardens have been reported to vary broadly from 0.93 in rural Zambia to almost 3.0 in West Java, Indonesia.

Saikia *et al.* (2012) reported that homegardens of Upper Assam, northeastern India are diverse and species-rich. They made a survey on 80 homegardens in 17 villages of Golaghat and Jorhat districts of Upper Assam. Structure, diversity and plant uses were analyzed. Altogether, 294 plant species representing 217 genera and 92 families were encountered. Of these, 260 species were economically important and were categorized into seven used categories.

Fernandez & Nair (1986) reported that species distribution in the homegardens is determined by environmental factors and dietary habits as well as the socio-economic and market demands.

Babu *et al.* (1982) and Michon *et al.* (1983) Stated that species diversity of the tropical homegardens is generally believed to be very high.

Saikia (2012) reported that a high variability in density of plant species was noticed in different homegarden categories and tree density was highest in the small (4,574 individuals ha^{-1}) followed by medium (4,046 individuals ha^{-1}) and large-sized (3,448 individuals ha^{-1}) homegardens. Similarly, frequency of species occurrence increased with decreasing homegarden size. On the other hand, basal area of the tree species was highest in medium (3.51 m^2 ha^{-1}) followed by large- (3.22 m^2 ha^{-1}) and small-sized (1.78 m^2 ha^{-1}) homegardens. Medium-sized homegardens, were also more species rich (236 spp.) than large-sized (total 232 spp.) and small-sized (total 210 spp.) ones. Number of species per homegarden was variable (17 to 69 with a mean of 44 ± 1.09) but, the difference was not significant in different homegarden categories.

Mattsson *et al.* (2015) reported from an study on quantification of carbon stock and tree diversity of homegardens in a dry zone area of Moneragala district, Sri Lanka stated that in total 4,278 trees were sampled and 70 tree species identified and recorded. The Shannon Wiener index were used to evaluate diversity per homegarden and ranged from 0.76 to 3.01 with a mean value of 2.05 ± 0.07.

2.2 Homegarden as a potential source of tree carbon stock

Mattsson *et al.* (2015) reported that a mean above-ground biomass stock was 13 Mega grams per hectare (Mg C ha^{-1}) with a large range among homegardens (1 to 56 Mg C ha^{-1}, n = 45). The variation was due to a variation of tree diversity and composition between individual homegardens among 45 dry zone homegardens in the dry south-eastern part of Moneragala district of Sri Lanka. Mean above-ground carbon stock per unit area was higher in small homegardens (0.2 ha, 26 Mg C ha^{-1}, n = 11) and statistically different compared to medium (0.4–0.8 ha, 9 Mg C ha^{-1}, n = 27) and large (1.0–1.2 ha, 8 Mg C ha^{-1}, n = 7) homegardens.

Mattsson *et al.* (2013) stated from a comparative analyses in the dry zone environments in Sri Lanka that the estimated carbon stock (Hambantota and Anuradapura district) was ranging from 10 to 55 Mg C ha^{-1} (mean 35 Mg C ha^{-1}). For comparison they found that carbon stock was ranging between 48 to 145 Mg C ha^{-1} with a mean value of 87 Mg C ha^{-1} in Kandyan homegardens in the wet zone in Sri Lanka.

Henry *et al.* (2009) reported that trees represented the most important C pool in aboveground biomass, contributing to 81% and 55% of total aboveground farm C in Vihiga and Siaya, respectively in Kenya, followed by hedgerows (13 and 39%, respectively) and permanent crop stands (5 and 6%, respectively). The homegardens represented the second C pool in importance, with 25 and 33% of C stocks in Vihiga and Siaya, respectively. An average farm would store 6.5 - 0.1 Mg C farm ha^{-1} in Vihiga and 12.4 -0.1 Mg C farm ha^{-1} in Siaya. At both sites, the C sequestration potential in perennial above ground biomass was estimated at 16 Mg C ha^{-1}.

Palm *et al.* (1999) reported that the estimated time-averaged above ground C stock of *Imperata* grasslands/agricultural fallows 2.2 Mg C ha^{-1} in the humid tropics in Kenya.

Mandal *et al.* (2013) reported on Comparison of C Stock among Collaborative Forests in Nepal. They stated that total carbon stock in collaborative forests varied from site to site. It was found that the highest quantity of carbon stock was 274.66 *t* ha^{-1} in Gadhanta-Bardibas CFM (Collaborative Forests management) while it was lowest about 197.10 *t* ha^{-1} in Banke-Maraha CFM.

Liu *et al.* (2014) reported that the study was aimed to estimate the carbon stocks of above- and below-ground biomass in Lesio-louna forest of Congo. The total carbon stocks in all the biomass was 3395.365 t C for AGB, which is 3.395365×10^{-6} Gt C and 909.689934 t C for BGB, which was 9.09689934×10^{-7} Gt C. In this forest, the carbon stock was more important in AGB compared to BGB with respectively 3395.365 t C against 909.689934 t C.

Mattsson *et al.* (2013) reported that the above ground biomass carbon stocks in dry zone homegardens (n = 8) ranging from 10 to 55 Mg C ha^{-1} with a mean value of 35 Mg C ha^{-1}, whereas carbon stocks in wet zone homegardens (n = 4) range from 48 to 145 Mg C ha^{-1} with a mean value of 87 Mg C ha^{-1}.

Roshetko *et al*. (2002) conducted an study on carbon stocks in Indonesian homegarden system and reported that an estimates from Javanese and Sumatran homegardens tree carbon stock varies from 35 to 59 Mg C ha^{-1}.

Jensen (1993) studied on Soil conditions, vegetation structure and biomass of a Javanese homegarden and reported that a mature (>35-year old) agroforests had a carbon stock of 101 Mg C ha^{-1} which is similar to 9-year old Sumatran agroforests 14 Mg C ha^{-1}.

Kumar (2011) found that Kerala homegardens in India had AGB carbon stocks ranging from 16 to 36 Mg ha^{-1}.

Dissanayake *et al.* (2009) stated that the AGB carbon stock in homegardens in Kandy, Sri Lanka was 90 Mg C ha^{-1} and Matale was 104 Mg C ha^{-1}.

Montagnini and Nair (2004) and Henry et al.(2009) reported that the differences in carbon stock was a result of differences in tree diversity, management practices, homegarden age, site characteristics and composition.

IPCC (2007) reported that worldwide, the average amount of C stored in the above ground compartments of agroforestry systems was estimated to a range between 40 and 150 t C ha^{-1}.

Albrecht *et al.* (2013) estimated a potential C sequestration in tropical agro-forestry systems of 95 t C ha^{-1} (varying widely between 12 and 228 t C ha^{-1}).

Montagnini and Nair (2004) reported that Variability in C sequestration and biodiversity can be high within complex agroecosystems, depending on factors such as vegetation age, structure, management practices, land uses and landscape.

Bora (2013) conducted an study in ten tropical forests of Cachar district, India to estimate AGB, carbon stocks and their relationship with density, basal area and diversity indices. The AGB was ranged from 32.47 Mg ha^{-1} to 261.64 Mg ha^{-1} and C-stocks ranged from 16.24 Mg ha^{-1} to 130.82 Mg ha^{-1}. AGB showed significant relationship with basal area and diversity indices. The AGB, however, did not show significant relationship with tree densities.

2.3 Soil Carbon stock at different soil layers of homegardens

Subhrajit *et al.* (2009) reported that the soil C stock was directly related to plant diversity of homegarden. Homegardens with higher plant species, as well as higher species richness and tree density had higher soil carbon, especially in the top 50 cm of soil compared to homegarden with lower plant species. Overall, within 1 m profile, soil C content ranged from 101.5 to 127.4 Mg ha^{-1}. Smallersized HG (0.4 ha) that had higher tree density and plant-species density had more soil C per unit area (119.3 Mg ha^{-1}) of land than larger-sized ones (0.4 ha) (108.2 Mg ha^{-1}). Soil C content, especially below 50 cm, was higher in older gardens. The enhanced soil-C storag in species-rich homegardens could have relevance and applications in broader ecological contexts.

Rahman (2012) reported from an study on char dwellers that there is a positive relationship between soil organic content and per capita income of the char area.

Hombegowda *et al.* (2015) reported that establishment of Agroforestry Systems (AFSs) on agricultural land caused SOC stocks to increase. In all AFSs, where SOC gains ranging from 45% in coconut in homegarden of dry sub-humid zones to 103% in humid zones. They also found a significant SOC stock at all soil depths (with the exception of coffee in the subsoil (60–100 cm). Being relatively uniform throughout the soil profile homegardens exhibited the highest overall SOC stock. This was followed by coffee which, in contrast, had the highest SOC stock at the soil surface which decreased with depth and SOC stock in mango and coconut AFSs were comparatively low, but constant throughout the soil profile.

Carter (1996) reported from an study that the extent of C retention in soils depends on the nature of soil aggregation and among other things.

Six *et al.* (2002) stated from a study on soil organic matter that it can be short-term storage in macro aggregates (> 250 μm diameter) and long-term storage in micro aggregates (< 250 μm diameter). They stated that stability of soil C was found in the smallest size class, the silt and clay size fraction (< 53 μm).

Batjes (1996) reported that soil organic matter (SOM) contains more reactive organic carbon (C) than any other single terrestrial pool and plays a major role in determining C storage in ecosystems and regulating atmospheric concentrations of carbon dioxide (CO_2).

IPCC (2000) reported that primarily the resource-poor small holder farmer in developing countries, is recognized as a strategy for soil carbon sequestration (SCS) under the Clean Development Mechanism (CDM) of the Kyoto Protocol.

2.4 Role of homestead as a source of livelihood

WCED (1987) defined livelihood as adequate stocks and flows of food and cash to meet basic needs. Security refers to secure ownership of, or access to resources and income-earning activitie, including reserves and assets to offset risk, ease shocks and meet contingencies. Sustainable refers to the maintenance and enhancement of resource productivity on a long-term basis. A household may be enabled to gain sustainable livelihood security in many ways- through ownership of land, livestock or trees; rights of grazing, fishing, hunting or gathering; through stable employment with adequate remuneration; or through varied repertoires of activities.

Chambers & Conway (1991) stated that a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.

Trinh *et al.* (2003) conducted a survey in the Philippines revealed that 20% of the foods consumed by families are produced in the home gardens whereas in Vietnam 51% of their produce is used by household members.

Okigbo (1990) reported that tree crops and livestock produced in homegardens accounted for more than 60% of household income in Southeastern Nigeria.

Perera and Rajapksa (1991) noted that out of the 125 plant species it was found that about 30% were exclusively used for medicinal uses and about 12% for medical and other purposes in Kandyan gardens in Sri Lanka.

Jacob *et al*. (1987) reported that the economy of Sri Lanka is founded on agriculture and more than 35% of the 20 million people of Sri Lanka are engaged directly or indirectly in the agrarian sectors. Among the rural and urban households in Sri Lanka for centuries has been a long-standing practice of homegardening.

Ranasinhe (2009) reported that homegardens are widely promoted in many countries as a mechanism to alleviate poverty and as a source of income grneration for subsistence families in developing countries. Although home gardens are considered as subsistence-low production systems, they can be structured to be more efficient in sustaining livelihood by growing high-value crops and animal husbandry.

Trinh (2003) reported from a study on agrodiversity in Vietnam that the families in mountain area were able to generate more than 22% of their cash income through homegardening activities.

Ninez (1987) reported that globally, home gardens are being documented as an important supplemental source contributing to food and nutritional security and livelihoods and also stated that food production on small plots adjacent to human settlements is the oldest and most enduring form of cultivation.

Barnard (2003) and Malkmus *et al.* (2006) reported that vegetables and fruits from homegardens can prevent from diabetes; they can reduce use of medicine and could help most people to get off their drugs completely.

Shrestha *et al.* (2002) and Regmi *et al.* (2004) conducted some studies in Nepal and showed that home gardens have multiple uses: as a source of livelihood, firewood and timber, spices and medicinal plants, green manure and pesticides; they are closely associated with the farming practice and are considered to be one of the key components of farming systems. Home gardens are considered to be one of the major contributors of rural livelihoods.

Shrestha *et al.* (2002) reported that in rural areas of Nepal for instance about 90 percent of the total population depend on homegardens where homegardens are an important source of food, supplying most of the vegetables and fruits required by the family.

Rahman and Rahman (2012) conducted a research work in the char Konabari of Rajapur union under Belkuchi Upazilla, Sirajganj district and Dakshin Boro-char of Eklashpur union under Uttar Matlab, Chandpur district and revealed that about 215 households live in the Char Konabari of which about 60 % people are engaged in handloom activities as labor, which are their main source of livelihood. Agriculture is the second highest and about 20% people are engaged in such practice; among the agricultural farmers, 50% have their own land and rests of them are landless. About 4% people are engaged in business (petty business) and rests of the people are engaged in day labor activities, van driver and others (boats men). On the other hand about 586 households live in Dakshin Boro-char of which about 60% and 30% people are agricultural farmer and fishermen. On-farm activities are dominant in Dakshin Borochar. Most of the farmers have their own land as well as they also cultivate khas (public) land. The rest of the people are engaged in day labor activities, petty business and others (boats men).

Haque (2014) had undertaken a study to determine the level of acceptability of homestead agroforestry practices by the farmers of the Northern parts of

Bangladesh especially Aditmari upazilla of Lalmonirhat district and its socio-economic impacts on local people livelihood. He stated that about 66.3% farmers had more income and the joint farm families were highest among all of them with a income of 66.1% and 71% of medium sized farms are working towards homestead agroforestry practices.

Johnson-Welch *et al.* (2000) reported that it is evident from the literature that homegardens are a part of the agriculture and food production systems in many developing countries and are widely used as a remedy to alleviate hunger and malnutrition in the face of a global food crisis.

Gautam *et al.* (2004) reported on enhancing the contribution of homegardens to on-farm management of plant genetic resources and to improve the livelihoods of Nepalese farmers. They stated that home gardens provide 60 % of the household's total fruit and vegetable consumption.

2.5 General Concept of Char island

ISPAN (1995) noted that island chars are defined as land that, even in dry season, can be reached from the mainland only by crossing a main channel. Attached chars are accessible from the main land without crossing a main channel during the dry season (crossing lesser channels may be required), yet is inundated or surrounded by water during the peak of a 'normal' flood.

Islam *et al.* (2015) reported that most of the Char land people is farmer, agricultural labor and day labor. The Char livelihood largely depends on agricultural work and other activities such as farming, fishing, agricultural labor, day labor and business. The study found that food was available to a household engaged in service activities and businessman in Char land people while farmers, laborers, and small vendors had a limited amount of food.

Ann and Hobley (2003) reported that char communities suffer from seasonal flooding, erosion and the river that expected to continue widening suffer and shifting westwards in future. Individual and household mobility is high and temporary or permanent displacement is common.

Islam (1974) reported that erosion is a largely predictable catastrophic livelihood shock as a result household lose their lands and shelters or other assets. Annul monsoon is common in char island and the people are adapted to a range of strategies to cope with seasonal variations.

Ashley *et al.* (2000) reported that an estimated 5 to 10 million people live on the char island and associated flood-prone area between 4% and 8% of Bangladesh population. Sirajganj district of Bangladesh was visited by a team and estimated that char-dwelling population was approximately 4,00,000 .

2.6 General characteristics of homegarden

Ninez (1984) stated that the household garden is a small-scale production system supplying plant and animal consumption and utilitarian items either not obtainable, affordable, or readily available through retail markets, field cultivation, hunting, gathering, fishing, and wage earning. Household gardens tend to be located close to dwelling for security, convenience and special care. They occupy land marginal to field production and labor marginal to major household economic activities. Featuring ecologically adapted and complementary species, household gardens are marked by low capital input and simple technology.

Kumar and Nair (2004) defined home gardens to mean the intimate, multi-storey combination of various trees and crops in association with domestic animals around homestead.

Eyzaguirre and Linares (2004) stated from an ecological and land use perspective that homegardens involve the management of multipurpose trees, shrubs, annual and perennial agricultural crops, herbs, spices, medicinal plants, fish prices and animals on the same land unit, in a spatial arrangement or on a temporal sequence. Odebode (2006) stated that home gardening is refers to the cultivation of small portion of landwhich may be at the back of a home or within a walking distance from home.

2.7 Overview of carbon sequestration

UNFCCC (2007) stated the recognition of the impacts caused by deforestation in developing countries, in the Conference of Parties (COP 13) in Bali it was agreed that reducing emissions from deforestation and degradation (REDD) should be included in a post-Kyoto mechanism.

Burgess *et al.* (2010) reported that recently UN also introduced REDD+ from the original concept of REDD to include emissions from deforestation and degradation of carbon-rich ecosystems.

Sino (2005) reported that the global carbon cycle is one of key research issues in the studies of climate change and regional sustainable development as well as one of main subjects for international coordinated research programs on global change.

De Gier (2003) and Ketterings *et al*. (2001) conducted a research to develop biomass equation that relates dry biomass of trees to its biophysical variables (e.g. diameter-at-breast height (dbh), tree height) and basal area.

Waston *et al*. (2000) and FAO (2005) reported that forests are major contributors to terrestrial carbon sink, mitigating climate change and associated economic benefits.

Dixon (1995); Albrecht and Kandji, (2003); Montagnini and Nair (2004) investigated that as a leading tree based system, especially in the tropics, agroforestry, afforestation and reforestation has been suggested as one of the most appropriate land management systems for mitigating the atmospheric carbon increase.

2.8 Role of Trees in climate change carbon dioxide sequestration

Dwyer *et al.* (1992) investigated that worldwide concern about global climate change has created increasing interest in trees to help reduce the level of atmospheric CO_2.

Sampson *et al.* (1992) investigated that forest are the most critical for taking C out of circulation for long periods of time. Of the total amount of C tied up in earthbound forms, an estimated 90% is contained in the world's forests, including trees and forest soils. For each cubic foot of merchantable wood produced in a tree, about 33 pound (lb) (14.9 kg) of C is stored in total tree biomass.

Watson *et al*. (2000) studied that the deforestation and the burning of forests release CO_2 to the atmosphere.

According to IPCC (2000) the estimation of the total global carbon sequestration potential for afforestation and reforestation activities for the period 1995-2050 was between 1.1-1.6 Gt carbon per year and of which 70% will be in the tropics.

IPCC (2001) estimated that the level of CO_2 in today's atmosphere is 31% higher than it was at the start of the industrial revolution about 250 years ago.

Pandey (2002) reported that forests sequester 1Mg C ha^{-1} annually through the combined effect of reforestation, regeneration and enhanced growth of existing forests.

Funder (2009) reported that Agroforestry systems help to offset the 1.6 billion tons of carbons emitted due to deforestation and forest degradation annually

CHAPTER III
MATERIALS AND METHODS

3.1 Study area

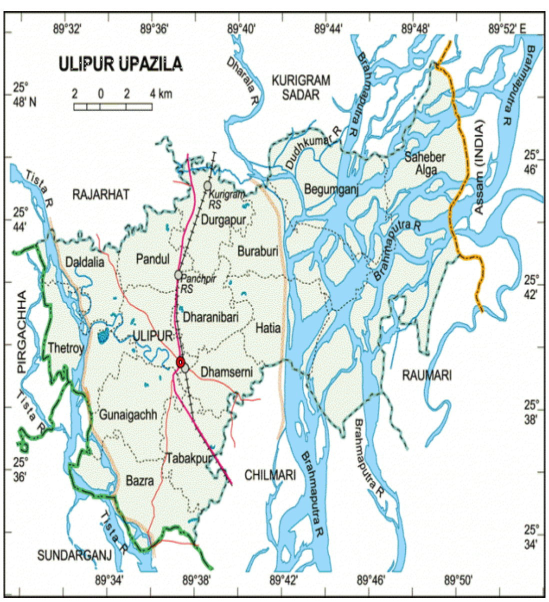
3.1.1 Location

The study was conducted at four villages of two upazillas (administrative unit) in Kurigram district. Kurigram district is located in the northern part of Bangladesh. The total area of the district is 2255.29 sq km, located in between 20°03' and 26°03' N latitudes and in between 89°27' and 89°32' E longitudes. The name of four studied villages are Dagarkuti, Kolakata, Borovita and Charuapara. Among these the villages Dagarkuti, Kolakata are situated in Ulipur upazilla and Borovita and Charuapara are situated in Chilmary upazilla. Ulipur Upazilla is 504.19 sq km, located in between 25°33' and 25°49' north latitudes and in between 89°29' and 89°51' east longitudes. It is bounded by Kurigram shadar and Rajarhat upazillas on the north, Chilmari and Sundarganj upazillas on the south, Raumari upazilla and Assam state of India on the east, Pirgachha and Sundarganj upazillas on the west. Chilmary upazilla ia located in between 25.5667°N 89.6917°E . It has 20129 households and total area is 224.97 km^2. Chilmari upazilla is situated in the northern part of Bangladesh and located by the Indo-Bangladesh frontier. Chilmari Upazilla is intersected by the mighty Brahmaputra river. It has a population of 122,841 and a density of $447/km^2$.

3.1.2 Climatic and Soil

Kurigram has tropical wet and dry climate. The climate is generally marked with monsoon, high temperature, considerable humidity and heavy rainfall. The hot season commences early in April and continues till July. The maximum mean temperature observed about 32 to 36 °C during the months of May, June, July and August and the minimum temperature recorded in January about 7 to 16 °C (BBS, 2012). The highest rainfall observed during the months of monsoon and it was1378.6 mm. The average annual rainfall in the district is about 1587 mm (BMD, 2014). Soil composition of the study area mainly alluvial soil (80%) and the remaining 20% is barind soil (SRDI, 2014).

Plate 1. Location of Kurigram district



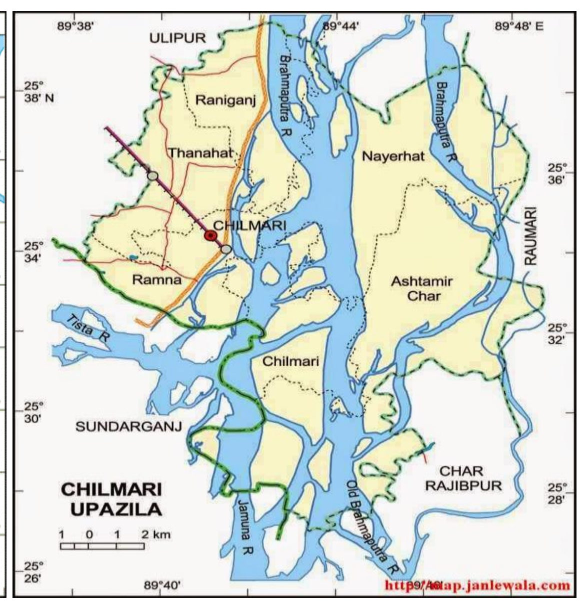


Plate 2. Ulipur upazilla **plate 3. Chilmari upazilla**

3.2 Sampling Procedure

This study was conducted in Kurigram district that was purposively selected. Kurigram district is consisting of 9 upazillas. Out of 9 upazillas, 2 upazillas namely Ulipur and Chilmari was randomly selected. Ulipur and Chilmari Upazilla has 14 unions and 6 unions, respectively. Among 14 unions of ulipur, 2 unions namely Hatia and Buraburi were randomely selected and out of 6 unions of Chilmari Upazilla, 2 union named Ranigang and Chilmary were randomly selected. In the Hatia union of Ulipur upazilla 1 village named Dagarkuti and 1 village named Kolakata from Buraburi union were randomly selected. From Chilmari upazilla 2 villages namely Borovita of Ranigang union and Charuapara of Chilmary union were randomly selected. Out of 712 farm families, a sample of 15%, i.e., 178 household were selected by stratified random sampling method. Then finally 64 representative farm families were selected for questionnaire survey, carbon stocks measurement and tree diversity assessment from each species rich homegardens. Final selection of homegarden has been done by using the following formula (Yamane, 1967):

$$n = N / \{1 + N (e)^2\}$$

Where,

n= Sampling size

N= Population

e= Error of precision.

Table 1: Distribution of population and sample size in four selected villages

Upazilla	Union	Village	No. of total households	No. of households primary selected	No. of households finally selected for data collection
Ulipur	Hatia	Dagarkuti	247	62	22
	Buraburi	Kolakata	135	60	12
Chilmary	Ranigang	Borovita	260	65	24
	Chilmary	Churoapara	70	17	6
	Total		712	178	64

3.2.1 Household characteristics data

A survey was conducted in 64 household owners by a questionnaire in the selected villages. All the data were collected directly from the study area as field data and by the personal contact with the farmers as household biophysical data (distance in kilometer from the household to the nearest market and urban center) and demographic data (household age, head age, education, family size. Other data like household socioeconomic condition and agricultural land possession, earning from homegarden, annual income from agricultural land were also collected and the data, based on land size were recorded in decimal and finally converted into hectare.

3.2.2 Homegarden plot survey

First of all the homegardens were categorized into three group namely small (0.01-0.03 ha), medium (0.03-0.05 ha) and large (> 0.05 ha) for comparison. All perennial trees were selected based on their breast height (1.37 m) and identified and recorded to species level by their local name and botanical name. A measuring tape was used for measuring DBH of each selected species. For measuring tree biomass an allometric equation developed by Chave *et al*. (2005) was used for individual trees species. FAO list of wood densities for tree species from Tropical Asia and Zanne *et al*. (2009), global wood density database were used for collecting wood density for the species under study. As the study plots were devoid of palm and due to difficulty in differentiating stems climbers were not selected in this study.

Plate 4: Homeharden of Dagarkiti village

Plate 5: Homegarden of Kalakata village

Plate 6: Homegarden of Borovita village

Plate 7: Homrgarden of Charuapara village

3.3 Estimation of biodiversity

The biodiversity which is focused on tree diversity was estimated by using Shannon Wiener diversity Index (SWI). Each of the homrstead was considered as sample plot and tree species diversity was measured within the plot by setting an index based on their number and frequency. For this study Shannon-Wiener diversity index (SWI) was used due to its suitability for evaluating diversity of tree species. The Shannon–Wiener diversity index shows the highest diversity when all species are abundant equally to the proportion of species abundance in the population and the lowest when the sample contained one species that means 0 diversity. The proportion of species (i) relative to total number of species (Pi) was calculated and then multiplied by the natural logarithm of the same proportion (Ln Pi). The resulting product is summed across species, and multiplied by -1.

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

Where, Σ= Summation.

p*i* = Proportion of total sample represented by species *i*. Total no. of individual species *i* , divided by total no. of plant species found in a sample community.

H = Shannon index

n = No. of species

Also the species density (number of species per unit area) was measured by dividing the total number of plant species of an homegarden by the total area of that homegarden.

3.4 Allometric equation for above and below ground biomass:

3.4.1 Tree biomass

Biomass equations relate to diameter at breast height (dbh) of tree biomass and biomass may differ among species. It is because trees in similar functional group can differ greatly in their growth forms between different geographical areas (Pearson *et al*., 2007). Considering these factors Chave *et al*., 2005 developed allometric equations for tropical trees that can be used for wide graphical and diameter range.

3.4.2 Above ground biomass:

To measure the above ground biomass, following equation has been used:

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

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

3.4.3 Below ground biomass:

To determine the below ground biomass and carbon, the model equation developed by Cairns *et al*., 1997, which is based on knowledge of above ground biomass was employed. It is the most cost effective and practical methods of determining root biomass.

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

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

3.4.4 Conversion of biomass to carbon

After estimating the biomass from allometric relationship, it was multiplied by wood carbon content (50%). Almost all carbon measurement projects in the tropical forest assume all tissues (i.e. wood, leaves and roots) consist of 50% carbon on a dry mass basis (Chave *et al*., 2005).

Carbon (Mg) = Biomass estimated by allometric equation × Wood carbon content % = Biomass estimated by allometric equation × 0.5.

Plate 8: Measurement of 1.37m height

Plate 9: Measuring GBH (cm)

3.5 Soil sampling and analysis

From 64 homegardens of the 4 selected villages soil samples were collected. From each homegarden (plot), two sampling sites were selected randomly and from each sites soil were collected at two depths 0-10 and 10-20 cm. A composite sample for each depth interval was prepared by mixing soil from two sampling sites resulting one sample per depth level from each study plots. There were total 128 soil samples (64 homestead × 2 depths) from 4 villages. Bulk density of sampled soil was measured. Carbon content in the soil was analyzed by Walkley-Black method. Soil analysis has been done in Soil Resource Development Institute (SRDI), Bangladesh.

$$\text{Bulk density (BD g/cc)} = \frac{\text{Oven dry weight of soil}}{\text{volume of soil in the core}}$$

Organic carbon content percentages were calculated by using following formula:

$$\%\text{OC} = \frac{(\text{B} - \text{T}) \times \text{N} \times 0.003 \times 1.3 \times 100}{\text{ODW}}$$

Where,

B = $FeS0_4 .7H_2O$ Solution required for blank titration

T = Volume of $FeS0_4 .7H_2O$ solution required for actual titration

N = Strength of $FeS0_4 .7H_2O$ or Normality

1.3 = Convention recovery fraction

Soil organic carbon (SOC) was measured by Walkly - Black (1934) formula:

SOC = Depth (cm) × Bulk density (g/cc) × Organic carbon (%)

Plate 10. Inserting auger into soil

Plate 11. Measurimg soil depth

Plate 12. Taking soil sample into poly bag

3.6. Farmer's livelihood

In the present study farmer's livelihood was focused on annual income of the homestead owners. The data were collected by personal contact with the farmers by a questionnaire survey. The data were collected based on annual income from homesteads and from their agricultural source or other source. Annual income was converted into daily income for the purpose of calculation. Income from homesteads was compared with total income of the farmer for each homegarden category.

3.7 Data Analysis

Field data were processed and analyzed using MS excel 2007 and SPSS-23 software which were collected from questionnaire survey. Above ground biomass carbon were computed using international standard common tree allometries combined with local tables of wood density by tree species. To test the relationship among different variables Regression analyses were used.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Measurement of tree diversity and occurrence of species in selected area

Biodiversity conservation is a major issue of theday as it has a great role in regulating ecosystem and maintaining healthy environment. The present study was conducted in Kurigram district with a view to measure biodiversity which is focused on tree diversity.

4.1.1 Tree diversity at various homegardens in Kurigram district

Tree diversity at various homegardens were measured by Shannon-Winner diversity index and a significant difference was found among 64 homegardens in the study area.

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	Meam ± 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

Tree diversity was presented in Table 2 and the Shannon-Winner diversity index showed a range between 0 to 1.84 for diversity value within the homegardens. 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). The result can be compared as: large > medium > small. It was found that large homegarden had 17 different types of species where mean number of trees species per hectare was 13 trees ha^{-1}, medium homegarden had 15 different types of species where mean number of trees species per hectare was 24 trees ha^{-1} and small homegarden had 14 different types of tree species where mean number of tree species was 33 tree ha^{-1} (table 2). The study found that the variation was due to species composition and richness, soil characteristics, climate, tropography and size of the homegardens.

Similar study was conducted by Drescher (1998) and Karyono (1990) and they found that Shannon-Wiener diversity indices in tropical homegardens vary broadly from 0.93 in rural Zambia which was less than the mean value of present study and to almost 3.0 in West Java, Indonesia which was greater than that of the present result. Another study was conducted by Jaman, M.S. (2014) which was also similar to the present study, but the result was opposite. He showed a range between 1 to 2.2 with a mean value of 1.64 ± 0.03, where small size homegardenshad the highest mean diversity of trees (1.66 ± 0.05) followed by medium (1.65 ± 0.05) and large (1.60 ± 0.06) homegardens.

4.1.2 Tree species and their occurrence at different homegardens

A variety of species under different familes were found at different homegardens. 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 3. There were five major spesies found in the homegardens namely, Eucalyptus which is 44.21 % of total number of species followed by Bead Tree (9.5%), Dramstick (8.40%), Guava (7.06%) and ipil-ipil (5.72%) (Table 4).

Table 3. Tree species identified in 64 homegardens in Kurigram district

Sl .no	Botanical name	Local name	Family	Primary use	Total no.	% of total no.
1.	*Eucalyptus camaldulensis*	Eucalyptus	Myrtaceae	Tm, fl	363	44.21
2.	*Psidium guajava*	Guava	Myrtaceae	Fr, fl	58	7.06
3.	*Mangifera indica*	Aam	Anacardiaceae	Fr, fl, wd	45	5.48
4.	*Bombax ceiba*	Shimul	Malvaceae	Co, wd, fl	23	2.80
5.	*Moringa oleifera*	Dramstick	Moringaceae	Vg, fl	69	8.40
6.	*Melia azedarach*	Bead Tree	Meliaceae	Tm, md	76	9.25
7.	*Citrus maxima*	Jambura	Rutaceae	Fr	5	0.60
8.	*Swietenia mahogani*	Mehoguni	Moringaceae	Wd	9	1.09
9.	*Ziziphus jujube*	Boroi	Rahmnaceae	Fr, fl	28	3.41
10.	*Artocarpus heterophyllus*	Khathal	Moraceae	Fr, tm, vg, md, dy	30	3.65
11.	*Litchi sinensis*	Lichu	Sapindaceae	Fr, wd	2	0.24
12.	*Olea europaea*	Jolpai	Oliaceae	Fr, ol, fl	7	0.85
13.	*Annona squamosa*	Ata	Annonaceae	Fr	5	0.60
14.	*syzygium cumini*	Jam	Myrtaceae	Fr, fl, wd	40	4.87
15.	*Tamarindus indica*	Tetul	leguminoseae	Fr, tm	5	0.06
16.	*Leucaena leucocephala*	Ipil-ipil	Fabaceae	Fl, Tm	47	5.72
17.	*Terminalia orjuna*	Arjun	Combretaceae	Wd, md, ol, fr	1	0.12
18.	*Erytheina orientalis*	Mander	Fabaceae	Fr, Tm	8	0.97

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

Table 4. Percent of occurrence of five major species present in study areas

Sl no.	Species name	Scientific name	% of occurrence
1.	Eucalyptus	*Eucalyptus camaldulensis*	44.21
2.	Bead Tree	*Melia azedarach*	9.25
3.	Dramstick	*Moringa oleifera*	8.40
4.	Peyara	*Psidium guajava*	7.06
5.	Ipil-ipil	*Leucaena leucocephala*	5.72

4.1.3 Tree density at various homegardens in Kurigram district

Stem density was measured and a variation was found among the homegarden (table 5). The result showed a range of tree density from 80.95 to 1000. Among the three category of homegardens, small homrgarden (0.01-0.03 ha) had the highest tree density (11763.69 tree ha^{-1}) with a mean value of 490.15 ± 50.43 and large homegarden (>.05 ha) had the lowest tree density value (5464.08 tree ha^{-1}) with a mean value of 237.56 ± 22.64 where medium homegarden (0.03 > 0.05 ha) had medium tree density value (6246.25 tree ha^{-1}) with a mean value of 367.42 ± 39.95. This result can be arranged in an order of small> medium > large in case of density value ha^{-1}.

A study was conducted by Saikia (2012) which was similar to the present study. He found that tree density was the highest in the small (4,574 individuals ha^{-1}) followed by medium (4,046 individuals ha^{-1}) and large-sized (3,448 individuals ha^{1}) homegardens.

Table 5. Tree density of various homegardens in Kurigram district

Homegarden catagories (HG no.)	Lower tree density value (LTDV) per Hectare	Higher tree density value (HTDV) per hectare	Total treedensity (ha^{-1})	Mean ± SE
Small (24)	250	1000	11763.69	490.15 ± 50.43
Medium (17)	120	700	6246.25	367.42 ± 39.95
Large (23)	80.95	411.11	5464.08	237.5 6 ± 22.64

4.1.4 Average basal area (m^2 ha^{-1}) and mean DBH (cm) of various homegarden in Kurigrm district

Data based on average no. of tree (ha^{-1}), mean basal area (ha^{-1}), mean DBH (cm) were calculated from 64 homegardens in Kurigram district. Table 6 showed that large homegardens had the highest basal a (4.4 m^2 ha^{-1}) followed by medium (4.69 m^2 ha^{-1}) and large homegarden (5.16 m^2 ha). In case of mean DBH large homegardens had the highest value of 15.58 cm and small homegardens had the lowest value of 9.69 cm where medium homegardens had moderate mean DBH of 11.31 cm. These variations found in mean number of trees, basal area and mean DBH were due to various age cycle of the species and their occurrence which depend on soil, climate and size of the homegardens.

Table 6. Average basal area (m^2 ha^{-1}) and mean DBH (cm) of various homegardens in Kurigrm district

Parameters	Homegardens		
	Small	Medium	Large
Mean basal area (m^2 ha^{-1})	4.44(0.69)	4.69(0.88)	5.16(0.59)
Mean DBH (cm)	9.69(.34)	11.31(.82)	15.58(0.42)

* Parenthesis are the standard errors.

Similar study was conducted by Saikia, P. (2012) and he found that basal area of the tree species was the highest in medium homegardens (3.51 m^2 ha^{-1}) followed by large (3.22 m^2 ha^{-1}) and small-sized (1.78 m^2 ha^{-1}) homegardens.

Another study was conducted in Rangpur district by Jaman, M. S. (2014) and he found that basal area were 13.56 m^2 ha^{-1}, 9.28 m^2 ha^{-1} and 7.48 m^2 ha^{-1} in small, medium and large homegarden, respectively. The mean DBH of large homegardens (11.23 cm) is comparatively higher than small (10.30 cm) and medium (10.16 cm).

4.2 Carbon stocks at various homgardens in Kurigram district

Global climate is changing day by day with an alarming rate, as a result of increasing rate of atmospheric carbon dioxide. But trees play a great role in climate change mitigation by sequestering a huge amount of CO_2 where homegardens can contribute to mitigating climate change by its multistoried tree and other plant species.

4.2.1. Tree carbon stock at various homgardens in Kurigram district

Carbon stock at various homegarens were measured and significant differences were found. Among 64 homegardens average tree carbon stock (above and below ground carbon stock) was found 18.00 Mg ha^{-1} which ranged from 1.66 Mg C ha^{-1} to 58.93 Mg ha^{-1}. Among the homegardens large homegardens (> 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 homegardens (0.02 > 0.03 ha) with a number of 24 while moderate carbon stock (17.82 ± 4.20 Mg ha^{-1}) was found in medium homegardens with a number of 17 (table 7). As the large homegarden had the highest tree ha^{-1} carbon content was higher in large homegarden.

Table 7. Tree Carbon stocks at various homegardens in Kurigram district

Homegarden category	Number of homegarden	Carbon stock range Mg/Ha		Mean ± SE
		Hightest	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

Similar study was accomplished by Kumar (2011) in central Kerala, India where the average standing carbon stocks of homegardens ranged from 16 to 36 Mg ha^{-1}. Another study was conducted in Rangpur district by Jaman, M. S. (2014) where average carbon stock (AGB C stock + BGB C stock) was 53.53 Mg ha^{-1} ; n=64 which ranging from 6.25 to 193.83 Mg ha^{-1} and small homegarden had higher amount of carbon (69.15 Mg ha^{-1}) than medium (47.96 Mg ha^{-1}) and large (39.93 Mg ha^{-1}) homegardens. The variation in carbon stock within the homegardens in Kurigram district is due to size of homegardens, species composition, soil characteristics, management practices and financial conditions of the owner of the homestead.

4. 2.1. 1 Above and below ground carbon (AGC and BGC) stock in different homegardens

Above and below ground carbon stocks were measured and found that large homegardens had highest amount of above ground (17.28 Mg ha^{-1}) and below ground (3.27 Mg ha^{-1}) carbon and small homegardens 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 homegardens 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)

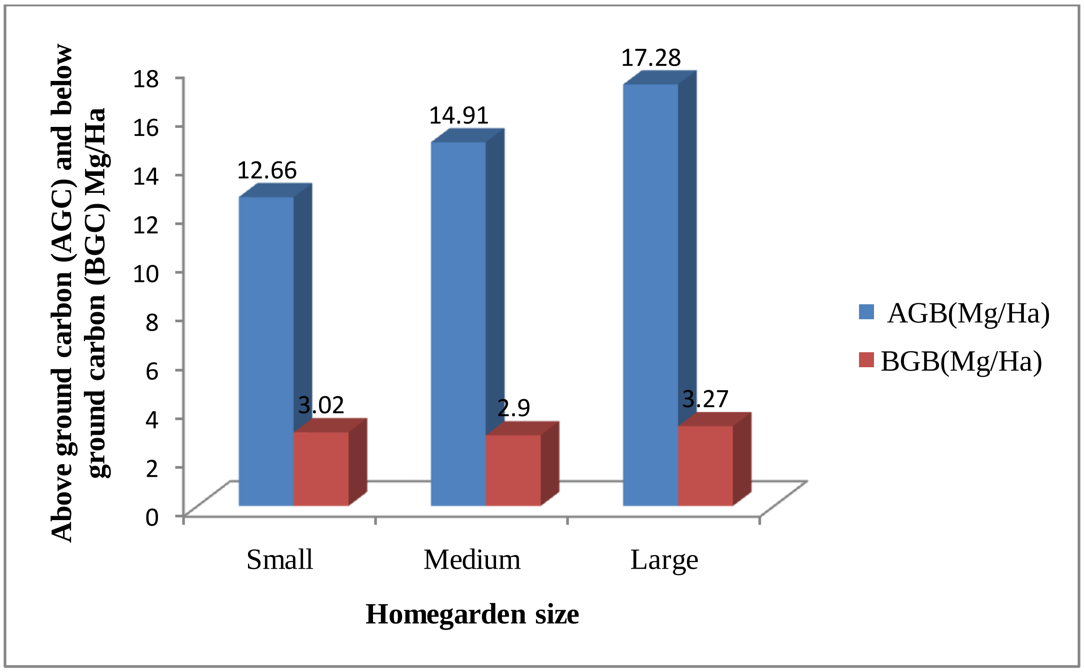


Figure 1. Above and below ground carbon stocks (Mg ha^{-1}) at various homegarden in Kurigram district

4.2.1.2 Major tree species and their carbon content at various homegardens

From the study it was found that the highest amount of carbon was stored by *Eucalyptus camaldulensis* (33.62 Mg) followed by *Moringa oleifera* (29.37 Mg), *Leucaena leucocephala* (4.89 Mg), *Melia azedarach* (3.48 Mg) and *Psidium guajava* (1.18 Mg) (Figure: 2). The present study revealed that number of Eucalyptus was found the highest (363 trees), as a result Eucalyptus contains the highest amount of carbon. Similar study was conducted by Jaman, M. S. (2014) and he found that betel nut was found the most dominant species (453 nos.) which contain 15.59 Mg carbon followed by Mango (362 nos., 26.7 Mg) Jackfruit (178 nos., 29.71 Mg), Mahagani (146 nos., 17.24 Mg), Gora Bead Tree (128 nos., 5.65 Mg) and Eucalyptus (98 nos., 6.4 Mg) at various homegardens.

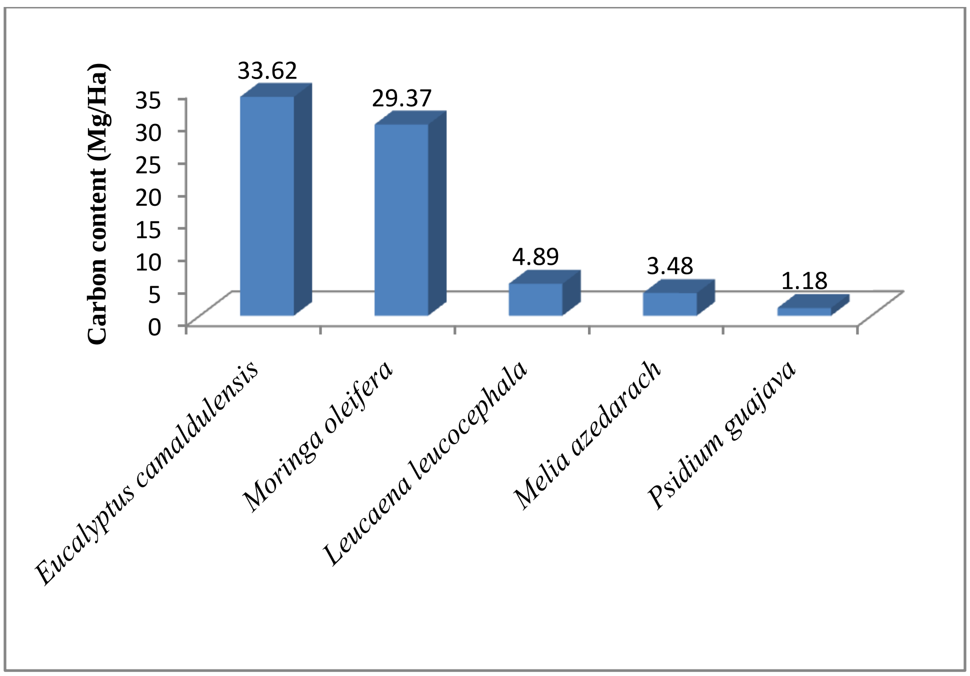


Figure 2. Five major tree species and their C content (Mg)

4.2.1.3 The relationship between mean DBH (cm) and tree carbon stock ($Mg\ ha^{-1}$) per unit area

Relationship between mean DBH (cm) and tree carbon stock were estimated at various homegardens and presented in Figure 3. A linear relationship between mean DBH and carbon stock was estimated as; $y = 2.263x - 9.707$ ($R^2 = 0.289$) where R^2 was positive, $r = 0.053$ and $p < 0.05$ which indicated that the relation was very weak but significant (5% level of significance) between mean DBH (cm) and tree carbon stock. The equation also stated that carbon stock increased at the rate of 2.263 $Mg\ ha^{-1}$ per unit change of mean DBH (cm). The study states that higher the mean DBH higher will be the carbon content. Similar result was found by Jaman (2014) and he found a positive relation between mean DBH and tree carbon stock in his study.

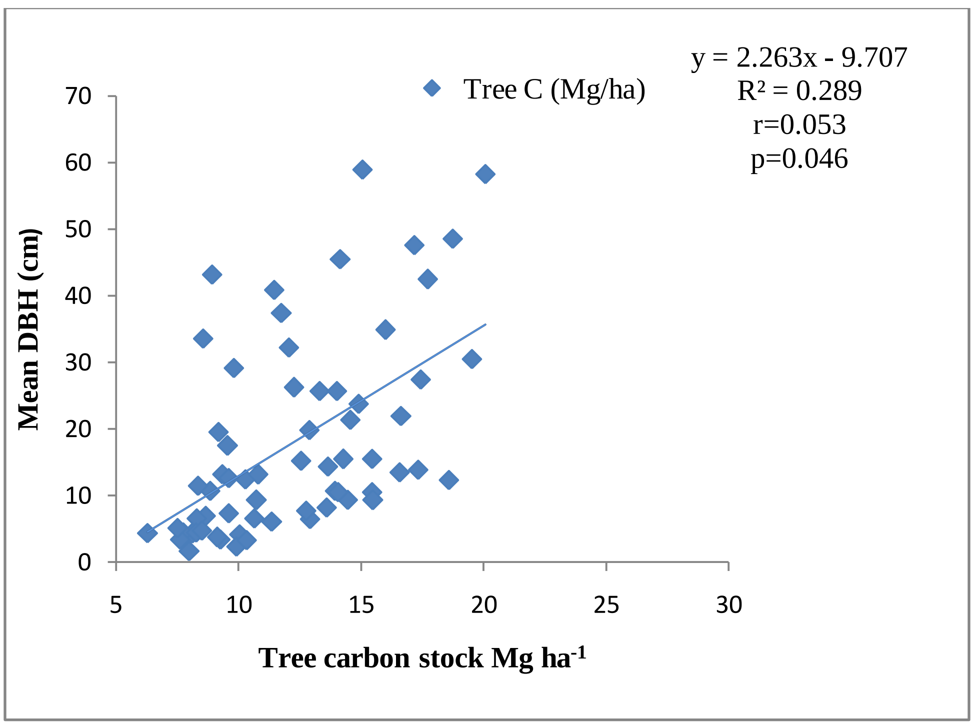


Figure 3. The relationship between mean DBH (cm) and tree carbon stock ($Mg\ ha^{-1}$) in Kurigram district

4.2.1.4 The relationship between basal area (m^2 ha^{-1}) and tree carbon stock (Mg ha^{-1})

A linear relationship between basal area (m^2 ha^{-1}) and tree carbon stock (m^2 ha^{-1}) was estimated as; $y = 4.052x - 1.235$ ($R^2 = 0.803$) and presented in figure 4. The R^2 value was positive, $r = 0.896$, and $p < 0.05$ which indicated that the correlation was strong and significant (5% level of significance) between basal area (m^2 ha^{-1}) and tree carbon stock (m^2 ha^{-1}). The equation stated that tree carbon stock increased at a rate of 4.052 Mg ha^{-1} per unit change of basal area (m^2 ha^{-1}). Similar study was conducted by Jaman, M. S. (2014) found a positive relation between basal area and tree carbon stock in his study.

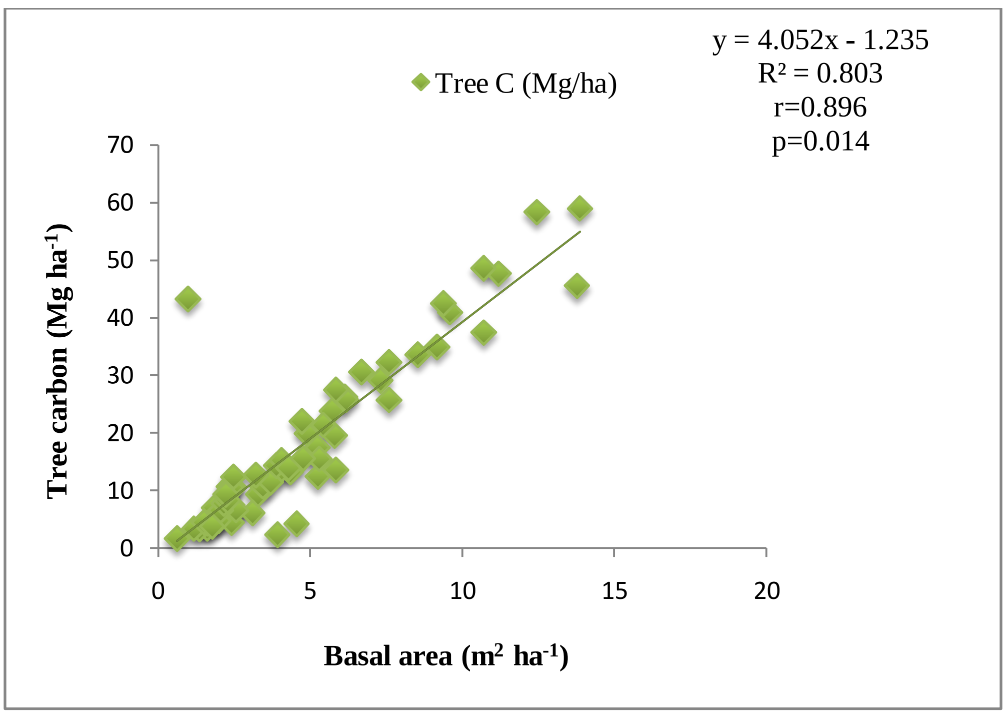


Figure 4. The relationship between basal area (m^2 ha^{-1}) and tree carbon stock (Mg ha^{-1})

4.2.1.5 Relationship between stem density (tree ha^{-1}) and tree carbon (Mg ha^{-1}) at various homegardens

Relationship between stem density (tree ha^{-1}) and tree carbon stocks (Mg ha^{-1}) was estimated at various homegardens and showed in Figure 5. The relationship was linear and estimated as; $y = 0.032x + 6.090$ ($R^2 = 0.220$) where R^2 was positive, $r = 0.469$ and $p > 0.05$. So it indicated that the correlation was weak and non significant (5% level of significance) between stem density (tree ha^{-1}) and tree carbon stocks (Mg ha^{-1}). The equation stated that tree carbon increased at a rate of 0.032 Mg ha^{-1} per unit change of stem density tree ha^{-1}. Similar study was conducted by Jaman, M. S. (2014) and he found a positive relation between stem density (tree ha^{-1}) and tree carbon stock (Mg ha^{-1}) in his study.

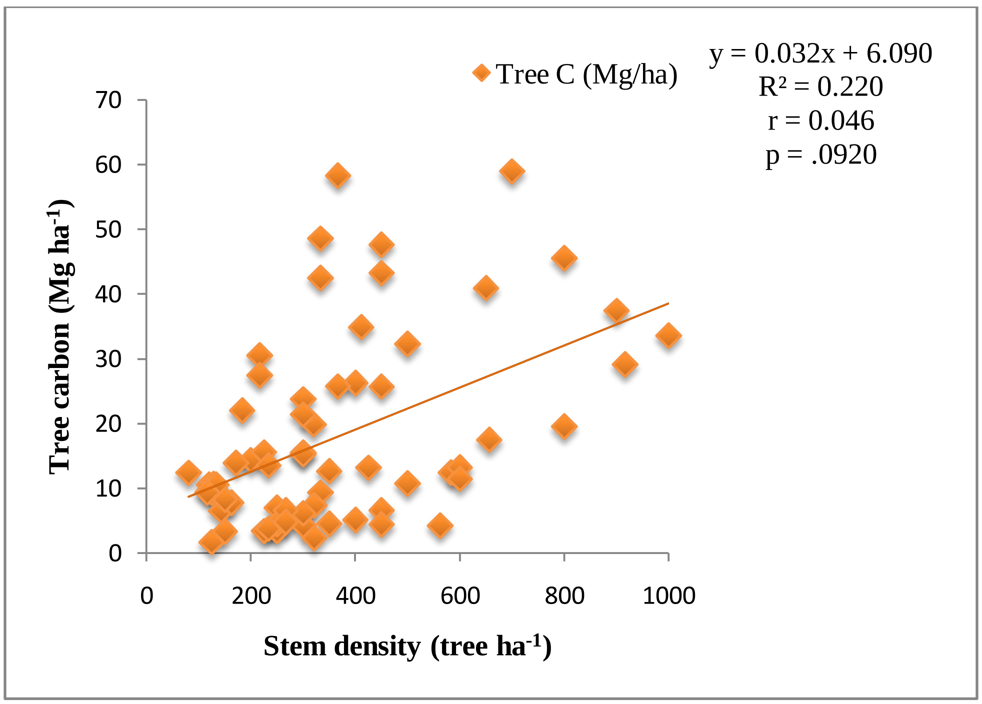


Figure 5. Relationship between stem density (tree ha^{-1}) and tree carbon stock (Mg ha^{-1})

4.2.1.6 The relationship between tree diversity and tree carbon (Mg ha^{-1})

A linear relationship between tree diversity and biomass carbon (Mg ha^{-1}) was explored by an equation; $y = 12.22x + 5.132$ ($R^2 = 0.154$) and showed in Figure 6, where the value of R^2 was positive, r= 0.041 and $p < 0.05$. It indicated that there was very weak and significant correlation (5% level of significance) between tree diversity and tree carbon. The equation stated that carbon stock increased at a rate of 12.22 Mg ha^{-1} per unit change in tree diversity. Similar study was conducted by Jaman, M. S. (2014) and he found a positive relation between tree diversity and tree carbon stock in his study.

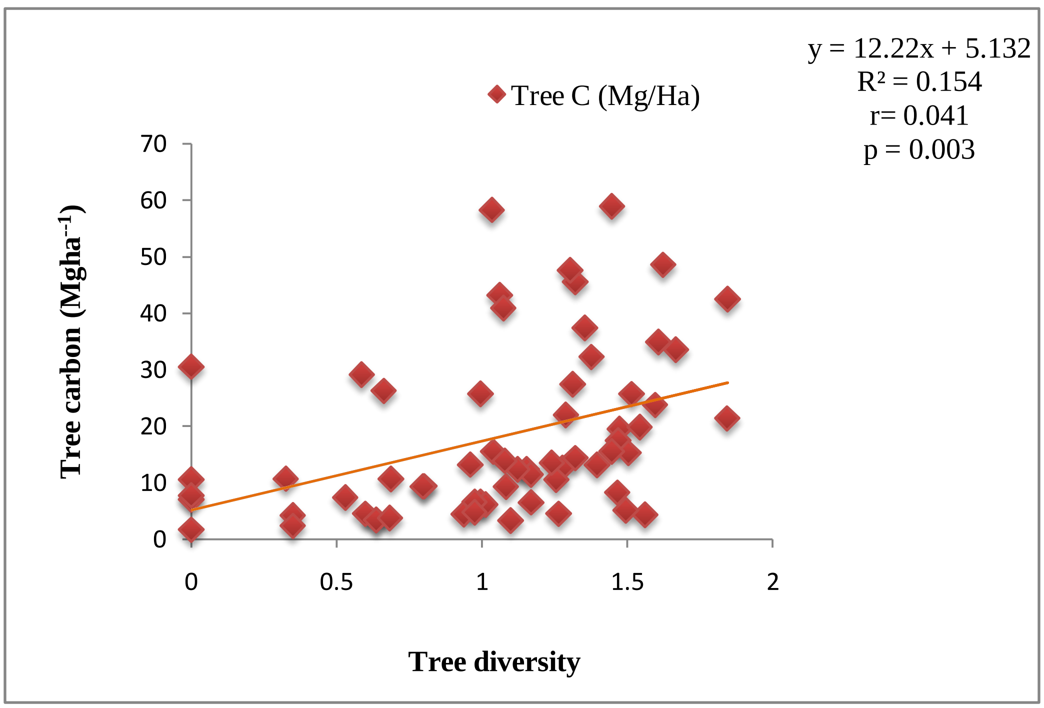


Figure 6. The relationship between tree diversity and tree carbon (Mg ha^{-1}) at various homegarden in Kurigram district

4.2.2 Measurement of soil organic carbon

Homegardens are comprised of multilayered trees, shrubs, herbs and other plant species. Litter fall from trees over top and other microbial activities occur within top layer of the soil. As a result top soil contain much SOC than lower layer. In the present study soil organic carbon was estimated at different homegardens and relationships among SOC and tee diversity and tree carbon were estimated.

4.2.2.1 Soil organic carbon (SOC) at various homegardens

To explore soil organic carbon soil samples were collected from two layers i.e. 0-10 cm and 10-20 cm. It was found that soil carbon varies between 2.29 Mg ha^{-1} to 24.69 Mg ha^{-1} at 0-10 cm depth and it varies between 3.74 Mg ha^{-1} to 21.57 Mg ha^{-1} at 10-20 cm depth among the homegsrdens under study. In case of 0-10 cm depth large homegardens had the highest mean value of 15.06 ± 1.10 and small homegardens had the lowest mean value of 12.9 5± 1.21 Mg ha^{-1} where medium homegardens had a medium mean value of 13.53 ± 1.40 Mg ha^{-1}. In case of 10-20 cm depth large homegardens had the highest mean value of SOC (10.82 ± 0.90 Mg ha^{-1}) followed by small homegardens (8.55 ± 0.63 Mg ha^{-1}) and medium homegardens (9.40 ± 0.86 Mg ha^{-1}) (Table 8).

Table 8. Soil organic carbon at various homegardens in Kurigram district

Homegardens (HG. no.)	Depth(cm)	Range SOC (Mg ha^{-1})		Mean ± CI
		Highest	Lowest	
Small(24)	0-10	13.38	2.59	12.9 5± 1.21
	10-20	21.57	4.46	8.55 ± 0.63
Medium(17)	0-10	24.69	4.69	13.53 ± 1.40
	10-20	13.56	3.74	9.40 ± 0.86
Large(23)	0-10	23.29106	5.19	15.06 ± 1.10
	10-20	16.58816	4.29	10.82 ± 0.90

Similar study was conducted by Saha *et al*. (2009) and he found that average soil organic carbon in two different layer (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 lower than the homegarden of Kerala, India which ranged from 101.5 to 127.4 Mg ha^{-1} in four different soil layers. The study is similar but the result of the study is higher than the present study.

4.2.2.2 Soil organic carbon (SOC Mg ha^{-1}) at different depth of various homegardens

A variation was found in SOC (Mg ha^{-1}) among the homegardens at different layers and showed in Figure 7. Among 64 homegardens mean soil carbon was higher in 0-10 cm soil depth (12.21 Mg ha^{-1}) than 10-20 cm soil depth (11.36 Mg ha^{-1}). The study revealed that SOC was always higher in 0-10 cm than 10-20 cm depth in all the homegardens that means the SOC stock decreased with soil depth across all treatments of the present study area. Due to accumulation of higher quantity of litters and other organic materials on the surface and their rapid decomposition, homegarden act as a vital source of organic carbon in the soil.

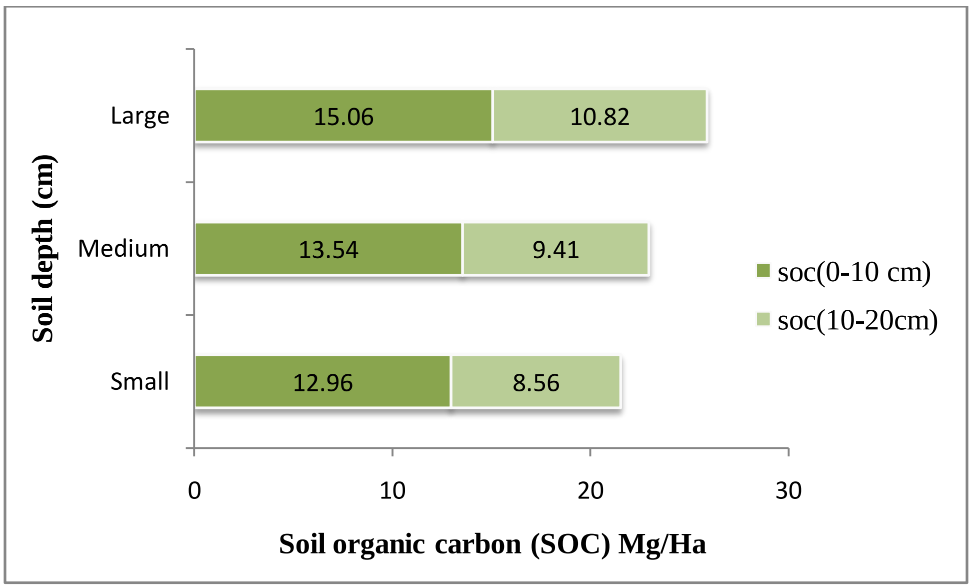


Figure 7. Soil organic carbon (SOC) (Mg ha^{-1}) at various homegardens in Kurigram district

Similar study was conducted by Jaman, M.S. (2014) in Rangpur district in Bangladesh and he also found that upper soil layer contain more organic carbon than lower layer.

4.2.2.3 A Comparison of soil organic carbon (SOC, Mg ha^{-1}) among different homegardens

Mean soil organic carbon (Mg ha^{-1}) at various homegardens were estimated and showed in Figure 8. The result of the study revealed that large homegardens had the highest mean soil carbon (0-10 cm + 10-20 cm) of 25.88 Mg ha^{-1} and small homegardens had the lowest SOC of 21.52 Mg ha^{-1} (0-10 cm + 10-20 cm) where medium homegarden had a moderate amount of SOC of 22.94 Mg ha^{-1} (0-10 cm + 10-20 cm). The result can be compared as; large > medium > small. The study revealed that due to having large area and higher species diversity (SWI= 1.17) the large homegarden had the highest amount of soil carbon.

Similar study was conducted by Jaman, M. S. (2014) and he found smilar but opposite result where small homegarden had the highest SOC (63.62 Mg ha^{-1}) than medium (42.48 Mg ha^{-1}) and large (38.57 Mg ha^{-1}) homegardens.

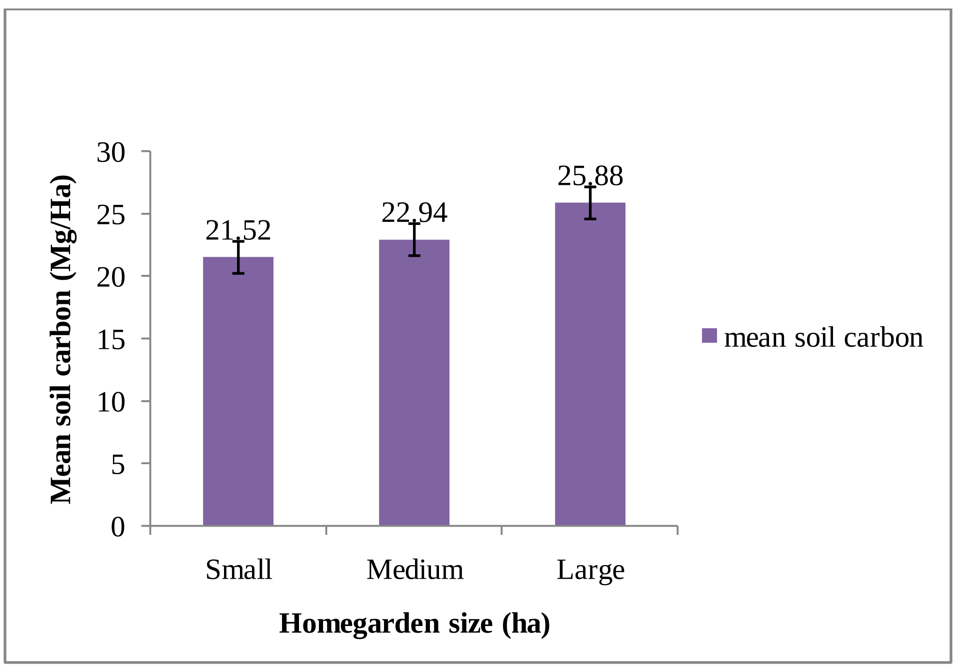


Figure 8. Mean soil carbon (Mg ha^{-1}) in different homegardens in Kurigram district

4.2.2.4 The relationship between basal area (m^2 ha^{-1}) and soil carbon stock (Mg ha^{-1})

Relationships between basal area (m^2 ha^{-1}) and soil organic carbon (Mg ha^{-1}) was estimated by a equation; $y = -0.295x + 25.96$ ($R^2 = 0.009$) which was showed in Figure 9, where R^2 value was positive, $r = 0.09$ and $p < 0.05$. It was indicated that the relationship was very weak but significant (5% level of significance). The equation stated that SOC decreased 0.0295 Mg ha^{-1} per unit change in basal area (m^2 Ha^{-1}).

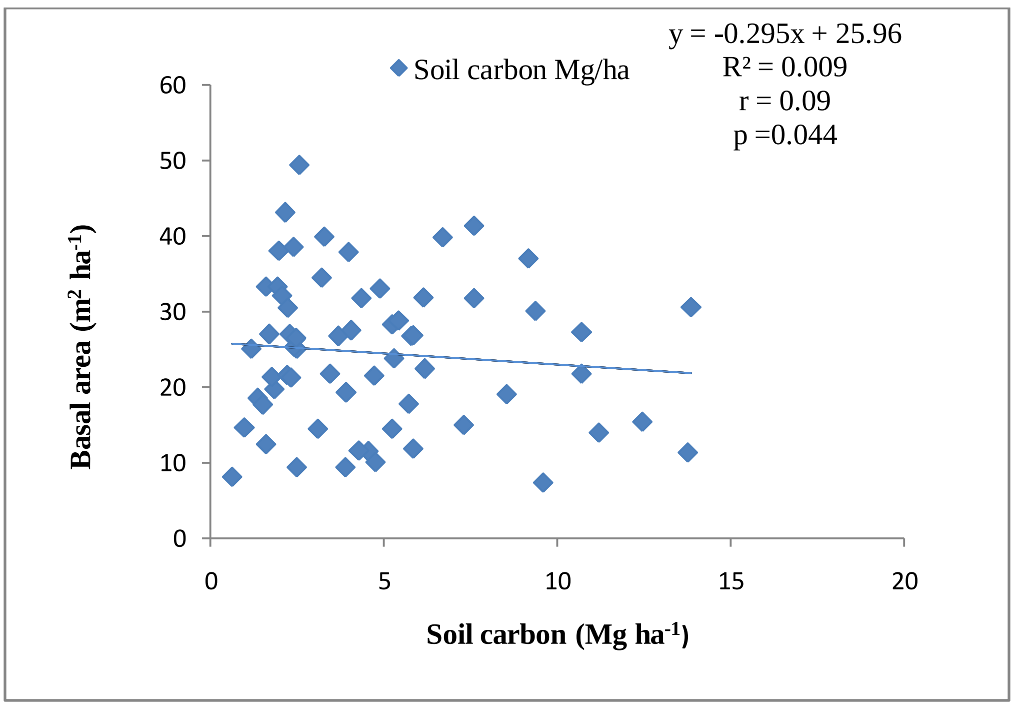


Figure 9. Relationship between basal area (m^2 ha^{-1}) and soil carbon stock (Mg ha^{-1})

4.2.2.5 Relationship between stem density (tree ha^{-1}) and soil organic carbon (Mg ha^{-1})

A relationship between stem density (tree ha^{-1}) and soil carbon stock (Mg ha^{-1}) was estimated at various homegardens and presented in Figure 10. The relationship was estimated by a equation as; $y = -0.005x + 26.94$ ($R^2 = 0.013$) where R^2 is positive, $r = 0.079$ and $p > 0.05$. That means there was a very week and non significant (5% level of significance) correlation between stem density (tree ha^{-1}) and total soil carbon (Mg ha^{-1}). The equation stated that SOC decreased at a rate of 0.005 (Mg ha^{-1}) per unit change in stem density (tree ha^{-1}).

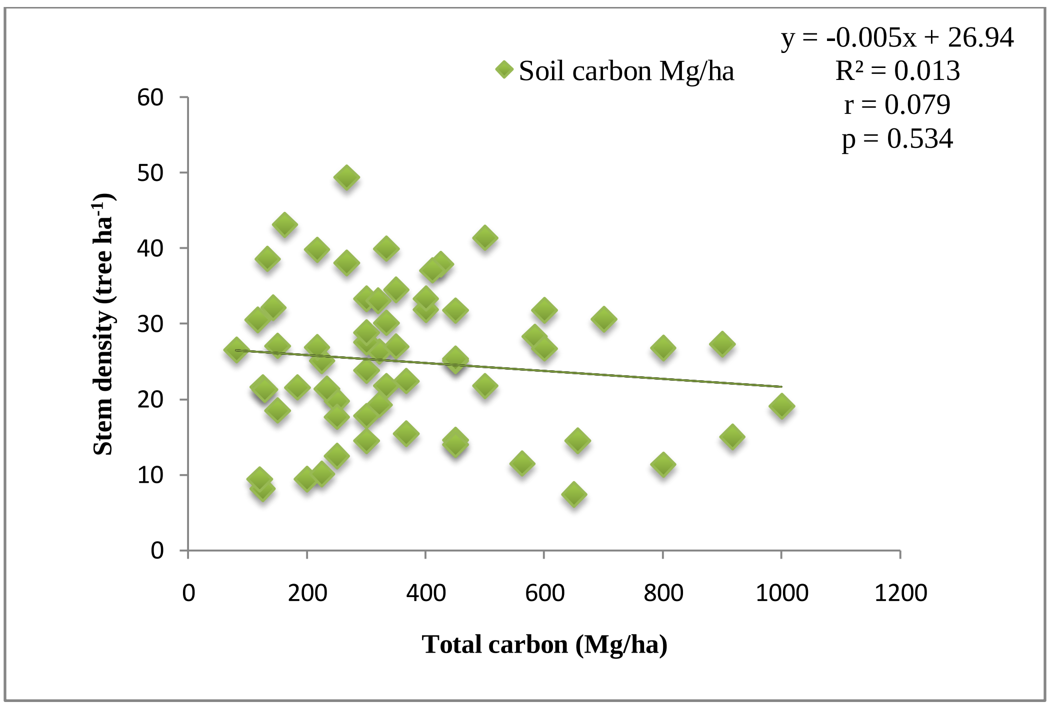


Figure 10. The relationship between stem density (tree ha^{-1}) and soil organic carbon stock (Mg ha^{-1})

4.2.2.6 Relationship between tree diversity and soil organic carbon (Mg ha^{-1})

A linear relationship between diversity and soil organic carbon (Mg ha^{-1}) was estimated by an equation; $y = 2.923x + 21.48$ ($R^2 = 0.019$) and showed in Figure 11, where R^2 value is positive, $r = 0.140$ and $p > 0.05$ and it revealed that there is a very weak and non significant correlation (5% level of significance) between tree diversity and soil organic carbon (Mg ha^{-1}). The equation revealed that an increased in SOC at a rate of 2.923 Mg ha^{-1} per unit change in tree diversity. Similar study was conducted by Jaman, M. S. (2014) and he found a positive relation between tree diversity and soil carbon stock (Mg ha^{-1}) in his study.

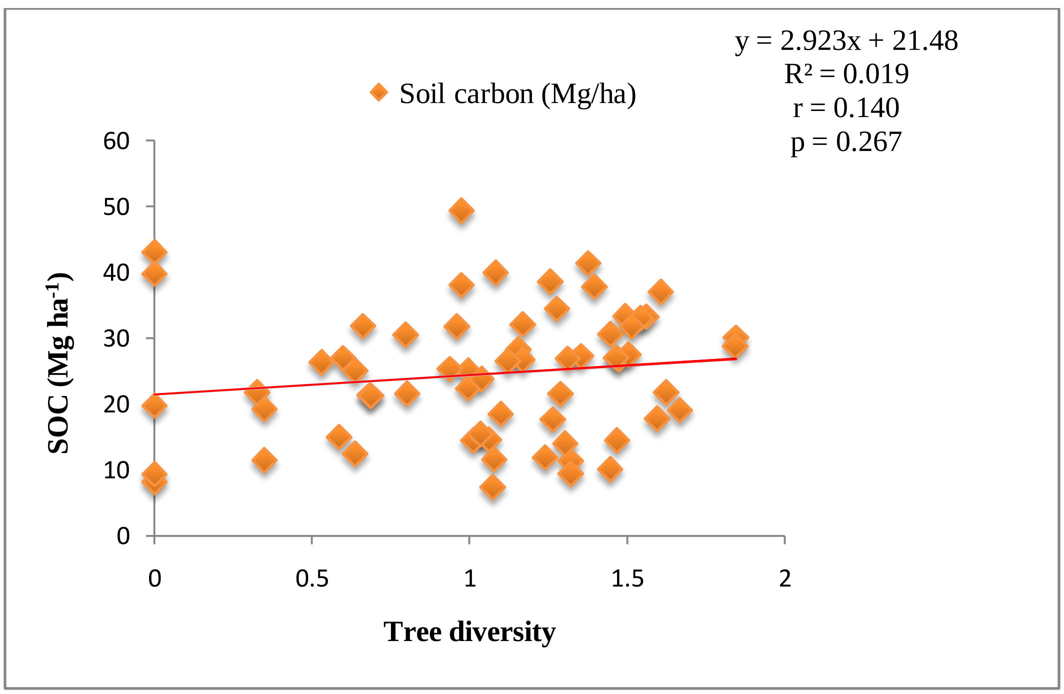


Figure 11. The relationship between tree diversity and soil organic carbon (Mg ha^{-1}) at various homegardens in Kurigram district

4.2.3 Total carbon stock Mg ha^{-1} at various homegardens in Kurigram district

Among the three homegarden categories total carbon stocks (tree C + soil C) was measured and presented in Figure 12. The result found that large homegardens had the highest carbon stocks (46.43 Mg ha^{-1}) and small homegardens had the lowest carbon stocks (31.21 Mg ha^{-1}) where medium homegardens had a moderate amount of carbon stocks (40.75 Mg ha^{-1}).

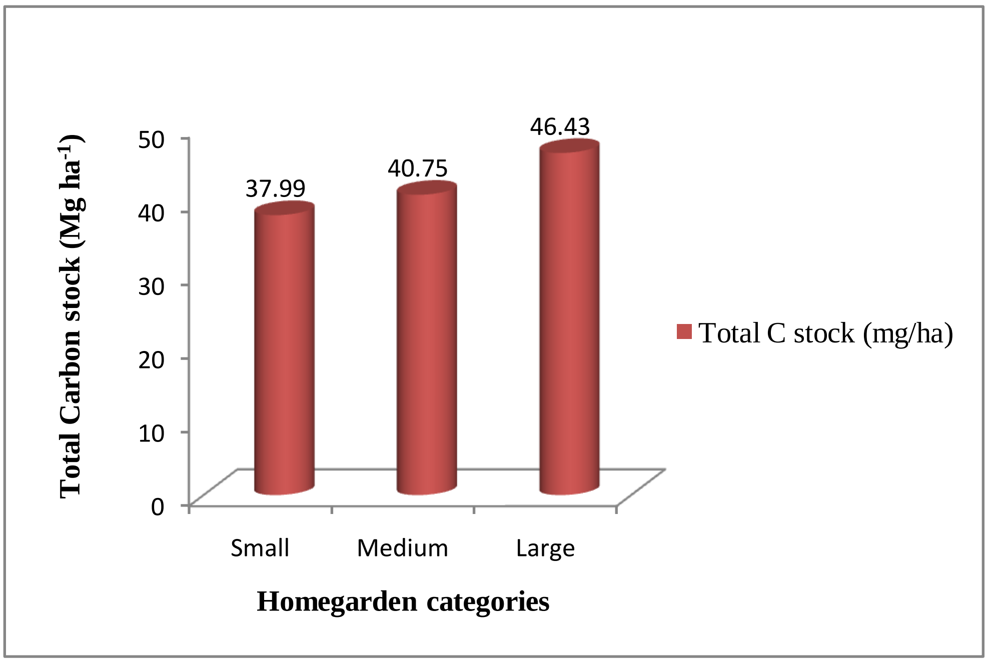


Figure 12. Total carbon stock (Mg ha^{-1}) at various homegarden in Kurigram district

4.3. Homegardens as source of farmer's livelihood

Globaly homegardens are characterized by its multipurpose functions like food security, nutrition, income, gender, biodiversity and ecosystem. The most important functions of a traditional multi-storey, multi-purpose homegardens are to increase biodiversity as a crucial asset for livelihood and health. It also called kitchen garden by development agencies in order to emphasize the food security and income aspects, especially for women. Beside the economic and nutritional value it play a vital role in carbon stock by its multistoried tree species.

4.3.1 Farmer’s livelihood from Char island homegardens in Kurigram district

In the present study the second objective was to establish a relationship between tree carbon stock, tree diversity and farmer’s livelihood. To fulfill the objective it was necessary to find out farmer’s livelihood and the data were collected by personal contact with the homestead owner using a questionnaire. In this study farmer’s livelihood was focused on farmer’s income from their homegardens. The result of the study stated that 95.83% of large farmer earn their income from their homestead, 82.35% of medium farmer and 54.16% of the small farmer earn their income from their homestead (Figure 13). It revealed that all the homestead owners have some partial of their income get from their homestead. The result can be compared as; large > medium > small.

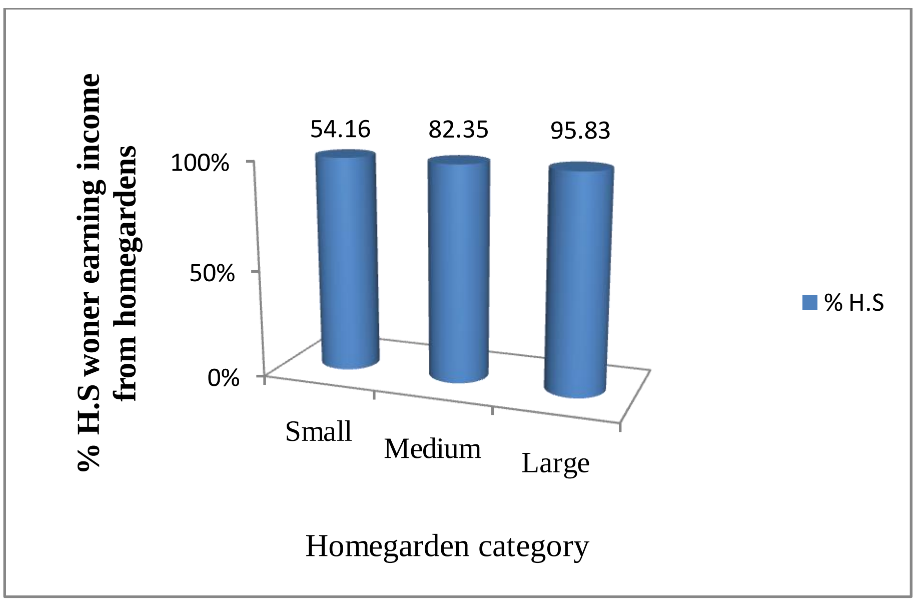


Figure 13. Graph showing percent of farmers who earn income from homesteads in Kurigram district

Similar study was conducted in Thakurgaon, Bangladesh by Sourovi Zaman *et al.* (2010) and she found that about 55% of large farmer had less than 10% income from home garden whereas no household from the marginal farmer category got less than 10% income from their homegarden. 40% of marginal farmer got 20-30% of their income from homegardens.

4.3.2 Income percente, earning from homegardens at various farmer's level in Kurigram district

A variation was found among the present of income that come from the homegardens within the farmer's category and presented in Figure 14. The result from the study stated that large farmers had an average income from homestead that was 31.90 % of their total income followed by medium (17.56%) and small farmer (15.26%).

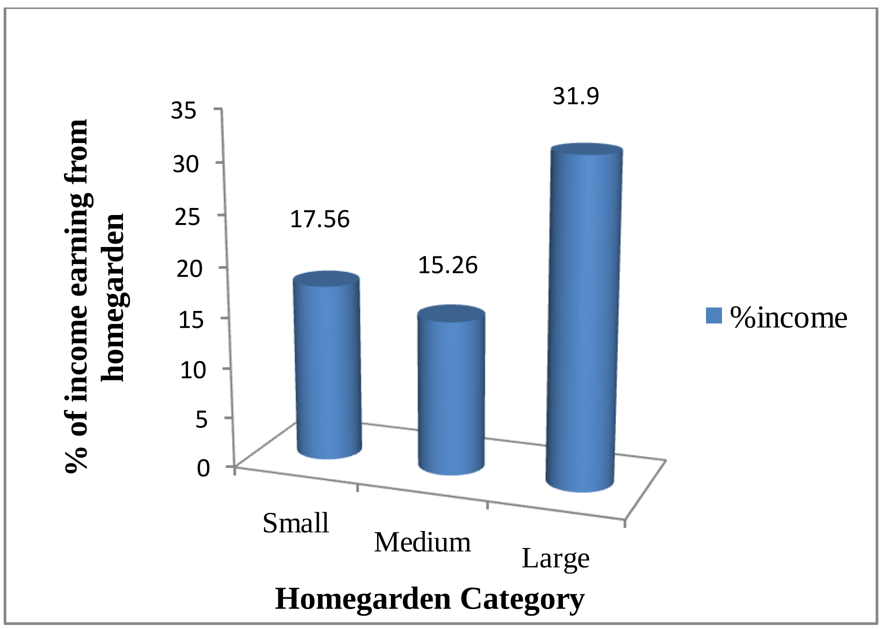


Figure 14. Graph showing percent incom from homegardens at various homegarden in Kurigram district

Similar study was conducted by Trinh (2003) and he found that families in mountain areas of Vietnam were able to generate more than 22% of their cash income through home-gardening activities.

Another study was conducted by Okigbo (1990) and similar result was found. The result stated that tree crops and livestock produced in home gardens accounted for more than 60% of household income in Southeastern Nigeria. So there is no doubt that homegarden is a potential source of income which has a great role in farmer's livelihood.

4.3.3 Farmer's income and total tree diversity (Mg ha^{-1})

A comparison was made among the homegardens on the basis of their income (tk./day) from homegarden and tree diversity which was showed in Figure 15. Study revealed that the large farmer who had the highest farm income of 102.45 tk. per day had the highest diversity 1.17 of (value obtained from Shannon-Winner diversity index) and small farmer who had the income of 37.21 tk. per day had the lowest value of diversity 0.86, where medium farmer had a moderate income (53.66 tk./day) and a moderate diversity value of 1.12. The value of farmer's income and tree diversity can be compared as; large > medium > small.

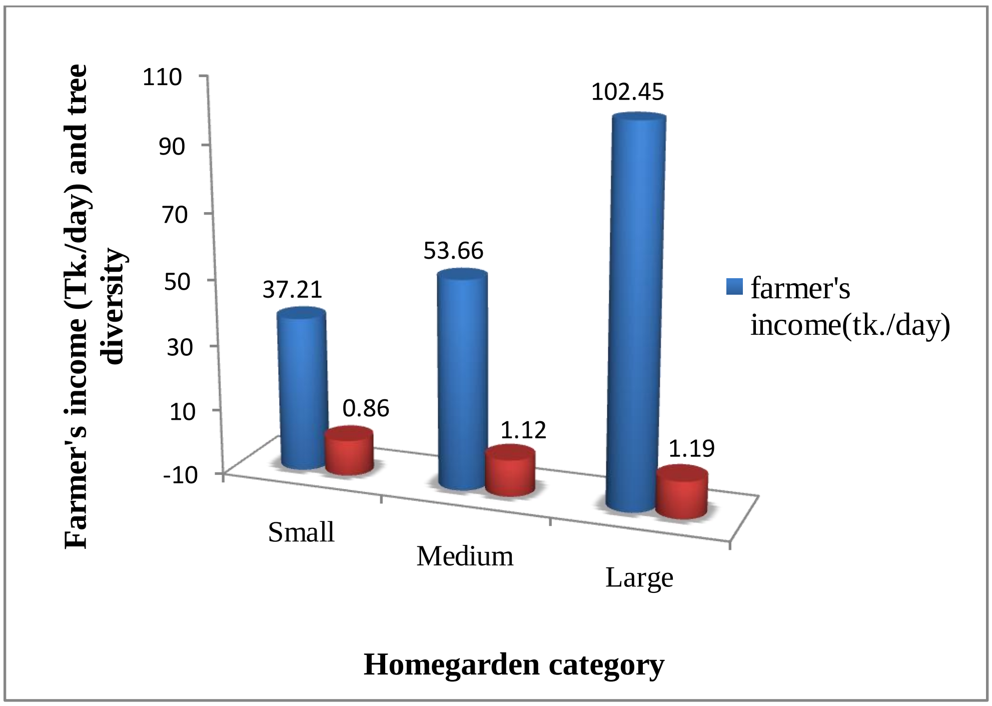


Figure 15. Farmer's income (tk./day) from their homegardens and tree diversity

4.3.4 Income from homegardens and carbon stock (tree C +soil C) at various homestead level in Kurigram district

A comparison was made among the homegardens on the basis of their income from homegarden and their carbon content (tree carbon + soil organic carbon). The result from the comparision showed in Figure 16 and the result stated that the large farmer who had highest income (102.45 tk.per day) had highest amount of total carbon (46.43 Mg ha^{-1}) and the small farmer who had 37.9 tk per day income had lowest amount of total carbon 37.21 Mg ha^{-1} (tree carbon +soil organic carbon) where medium farmer who had moderate income (53.46 tk. per day) and moderate carbon stock (40.75 Mg ha^{-1}). The result stated that the variation in carbon stock is due to species composition and soil characteristics of the homegardens.

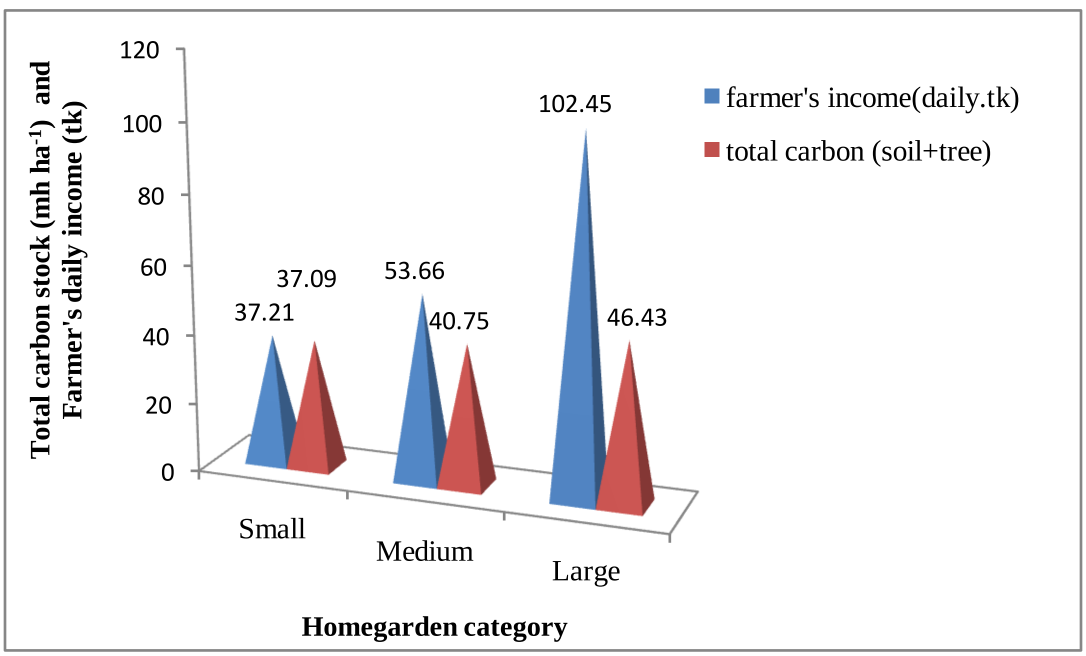


Figure 16. Farmer's livelihood and carbon stock (tree C + soil C) (Mg ha^{-1}) at various homegardens in Kurigram district

4.4 Relationship between tree diversity, carbon stock and farmer's livelihood

4.4.1 The relationship between farmer's income and tree diversity

A linear relationship between farmer's livelihood (tk./day) and biodiversity (focused on tree diversity) was estimated by a equation as; $y = 0.001x + 0.972$ ($R^2 = 0.05$) and presented in Figure 17, where the R^2 value is positive, $r = 0.223$ and $p > 0.05$ that means there is a weak and non significant (5% level of significance) correlation between farmer's income and tree diversity. The equation revealed that tree diversity increased at a rate of 0.001 per unit change in farmer's income (tk. / day).

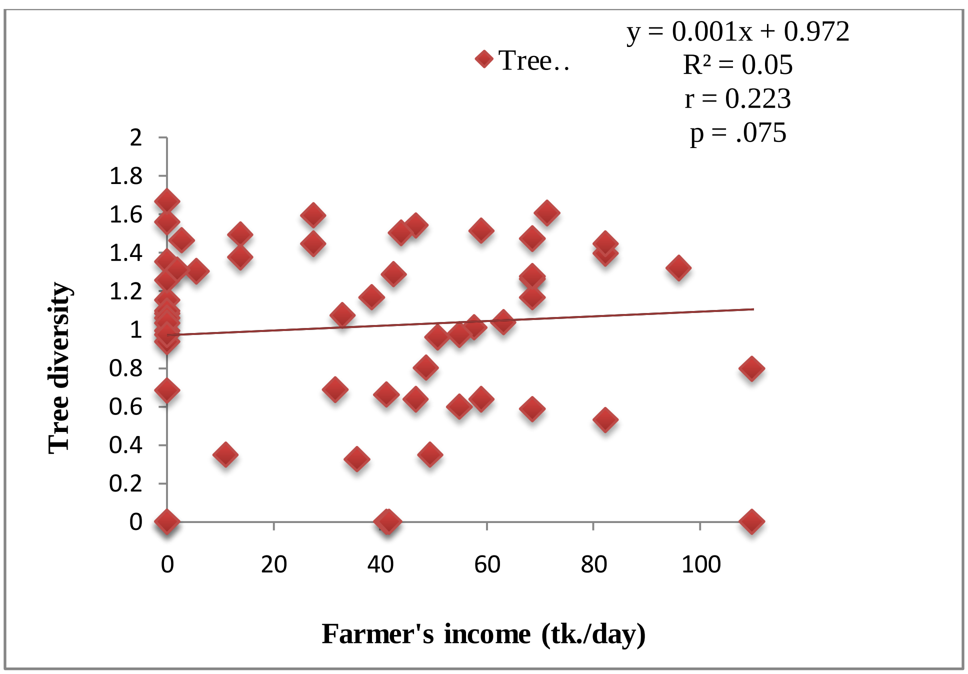


Figure 17. The relationship between farmer's income (tk./day) and tree diversity

4.4.2 The relationship between farmer's income and tree carbon (Mg ha^{-1})

A linear relationship between farmer's livelihood which was focused on farmer's income from homestead and total carbon (Mg ha^{-1}) was estimated by a equation; $y = 0.024x + 16.36$ ($R^2 = 0.021$) and presented in Figure 18, where the R^2 value is positive, $r = 0.146$ and $p = 0.247$ and it revealed that there was a weak and non significant (5% level of significance) correlation between farmer's income and total carbon (tree C +soil C) stock (Mg ha^{-1}). The equation stated that tree carbon stock increased at a rate of 0.024 Mg ha^{-1}per unit change in farmer's income.

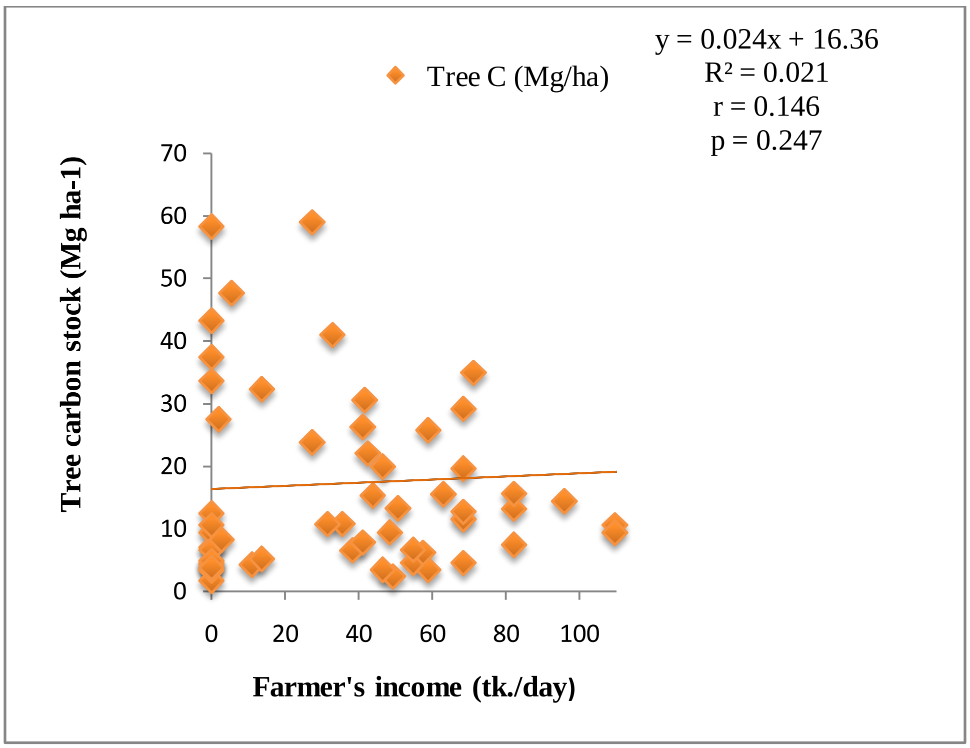


Figure 18. The relationship between farmer's income and tree carbon stock (Mg ha^{-1})

CHAPTER V

SUMMERY, CONCLUSION AND RECOMMENDATIOM

SUMMARY

Climate change and degradation of biodiversity are two burning issues of the present world as a result of carbon dioxide emission, deforestation and over exploitation of human activities which has a negative effect on environment and socio-economic condition of people. But the present study showed that homegardens had a potential role in climate change mitigation and adaption due to their multi-faceted function which provide ecosystem services as well as income. A total of 64 homegardens were selected from four villages of kurigram district and data were collected on the basis of tree diversity, total carbon stock and farmer's livelihood. Shannon-Winner diversity index was used to measure tree diversity. Allometric equations were used to calculate carbon stock. Soil samples were collected from two depths (0-10 cm and10-2 cm) and tested in laboratory of Soil Resource Development Institute (SRDI) and data based on farmer's income collected by using a questionnaire.

In a total of 64 homegardens 18 different species under 14 families were found which is a good indicator of biodiversity. The results of the study found that the most dominating species was eucalyptus with a number of 363 and tamarind was the least dominating species with a number of 1. The mean diversity value of the study area was 1.05 (SWI) with a range from 0 to 1.84. Among the three homegarden categories the highest species diversity (SWI = 1.17) was found in large homegardens with the highest species number (17 nos.) and the lowest diversity (SWI = 0.86) was observed in small homegardens with lowest number of species (14 nos.), where the medium homegarden had a moderate diversity value (SWI = 1.12) with a moderate number of tree species (15 nos.).

The mean tree carbon among 64 homegardens in the study area was 18.00 Mg ha^{-1}, where large homegardens had the highest tree carbon (20.55 Mg ha^{-1}) followed by medium (17.82 Mg Ha^{-1}) and small homegardens (15.58 Mg Ha^{-1}). Due to having large diversity (1.17) and the highest species number (17 nos. of tree species) large homegardens were found to be the highest in carbon content. Among the five major dominating species the highest amount of carbon was stored by Eucalyptus (33.62 Mg) followed by Dramstick (29.37 Mg), Ipil-ipil (4.89 Mg), Bead Tree (3.48 Mg) and Gava (1.18 Mg).

The results of the study found that the mean SOC in 64 homegardens was 24.56 Mg ha^{-1}. Among the three homgarden categories large homegardens had the highest SOC (25.88 Mg ha$^{-1)}$) and small homegardens had the lowest SOC (21.52 Mg ha^{-1}) where the medium homegardens had a moderate amount of SOC (22.94 Mg ha^{-1}). Due to having highest amount of tree species large homegardens had the highest SOC, as SOC depends on litter fall of tree species and their decomposition. The study revealed that in all the homegardens mean soil carbon was higher in 0-10 cm soil depth (12.21 Mg ha^{-1}) than 10-20 cm soil depth (11.36 Mg ha^{-1}). Due to accumulation of litter fall and other organic matter top soil had the highest SOC.

Among the three homegarden categories total carbon stocks (tree C + soil C) was measured and compared. The result found that large homegardens had the highest carbon stocks (46.43 Mg ha^{-1}) and small homegardens had the lowest carbon stocks (31.21 Mg ha^{-1}) where medium homegardens had a moderate amount of carbon stocks.

Livelihood of the farmers was assessed based on their income from homegardens. Among the three homegarden categories 98.83% of large farmers had 31.8% income from their homegarden where 82.35% of medium farmers had 17.56 % income and 54.16% small farmers had 15.26% income from their homegardens.

The study revealed that homegardens are potential source of improving the livelihood of the farmers.

The present study showed a relationship of tree diversity with farmer's livelihood, ($R^2 = 0.05$) and a relationship between farmer's livelihood and tree carbon stock ($R^2 = 0.021$), where both relations were found to be positive but less significant. The result stated that the large farmers who had the highest amount of income (31.8%) from their homegardens had the highest tree diversity (1.17) and highest carbon stocks (46.43 Mg ha^{-1}).

CONCLUSION

The present study was conducted in Kurigram district to assess biodiversity, carbon stock and to explore a relationship between farmer's livelihood and total carbon stock and tree diversity. Based on the result of the study it can be stated as:

1. A variations in species occurrence and tree diversity were found in the study area. Among the homegarden categories large homegaedens had the highest value of tree diversity (SWI) followed by medium and large.
2. The highest amount of tree carbon (20.55 Mg ha^{-1}) was found in large homegardens and the lowest tree carbon (15.58 Mg ha^{-1}) was found in small homegardens where medium homegardens had a moderate value of tree carbon (Mg ha^{-1}).
3. Soil organic carbon was measured and it was found that large homegardens had the highest SOC (25.88 Mg ha^{-1}) followed by medium and small homegardens.
4. There was a variation in carbon stocks (tree C + soil C; Mg ha^{-1}) among the three homegardens categories and it was found that large homegardens had the highest carbon stocks (Mg ha^{-1}) followed by medium and small homegardens.
5. Variations were found in income from homegardens where the large farmers had the highest income from homegardens followed by medium and small.
6. The study found a positive relationship between tree diversity and tree carbon, where tree carbon increased per unit change in tree diversity.
7. The study found an increase in tree diversity and carbon stock in relation to farmer's livelihood.

The study had showed an overall scenario of homesteads of North-Western Char island of Bangladesh in the context of plant diversity and carbon stock and livelihoods of char island farmers, where tree diversity and carbon stock varied with the size of homegaedens and farmer’s livelihood. From the study it can be concluded that Char island homegardens have a potential role in climate change mitigation and adaption with a scope of biodiversity conservation. But the char island people can not improve their homegardens due to adverse climatic condition which force them to shift another place to live. But they can improve their homegardens to combat this adverse climatic condition and to make a healthy ecosystem for improving their livelihood.

RECOMMENDATION

The present study was focused on potential role of homegardens in conserving biodiversity, carbon stock and livelihood improvement. In this consideration homegardens should be well established with sufficient plantation. Carbon sequestration in homegardens can be considered as a permanent carbon storage because complete biomass removal does not occur here, which has been one of the key concerns in carbon sequestration projects within the Clean Development Mechanism (CDM) of the Kyoto Protocol. Based on the results and discussions following recommendations are to be suggested:

1. Homegardens can be taken as a part of carbon treading project under the Clean Development Mechanism (CDM).
2. Farmers should be motivated for homegarden establishment and they should be made aware about the relationship between carbon sequestration, biodiversity and homegarden by different government and NGO's.
3. More intensified and large scale research should be conducted on homegardens, their species composition and carbon sequestration pattern and amount of stored carbon by the plant species at different age cycle. Research should be conducted on harmful and environmentally friendly plant species and their characteristics for the betterment of the environment.
4. Similar to the present study, more and large scale research should be conducted in other districts of Bangladesh including large number of homegardens, all categories of plant like palm, herbs, shrubs and other plant species under a varied climatic conditions.
5. Finally this type of study should be restituted in different Char island and different environments for validate the results.

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APPENDICES

APPENDIX I: Interview schedule used in this study to assess farmer's livelihood

English version of an interview schedule

Department of agroforestry and environmental science

Sher-e-bangla agricultural university

Dhaka-1207

Interveiw schedule for data collection for the research on

''MEASUREMENT OF BIODIVERSITY AND CARBON STOCK IN NORTH-WESTERN CHAR ISLAND HOMEGARDENS OF BANGLADESH''

(The interview schedule is entitled for a research study)

Serial no:

Name of the respondent:

Village:

Upazilla :

(please answer the following question. Secrecy will be strictly maintained)

1. **How old are you?** Age……….. years

2. Education : Please mention your educational status

a. Can you read or write……………….

b.Can you sign only………………………

c. Read up to class………………………..

d. Others…………………………

3. farm size: Please mention your land area

Sl. no.	Type of land	Area (bigha)	Area (hectar)
1	Own homestead		
2	Own land under own cultivation		
3	Own pond or garden		
4	Own land given to borga to others		
5	Land taken on borga from others		
6	Land taken on lease from other		
7	Others		

4. Annual family income: Please state your family income from different sources

a. Agricultural source:

Sl. no.	Source of income	Total production	Price/kg (tk)	Total price (tk)
1	Rice			
2	Wheat			
3	Jute			
4	Sugarcne			
5	Winter vegetable			
6	Summer vegetable			
7	Pulse			
8	Oil seed crops			
9	Other crops			
10	Fruit, forest and seedling			
11	Dairy (milk, meat, calorie)			
12	Poultry (egg, chicken, duck)			
13	Fish			
14	Bamboo garden			
	Total			

b. Other than agricultural source:

Sl. no:	Source of income	Total amount (tk)
1	Business	
2	Service	
3	Daily labour	
4	Other	
	Total	

Total = (a+b)………………………………………………(tk)

5. Credit / Loan

A. Did you take any credit last year? Yes……………
No…………………

B. If yes please mention the source and amount of your credit.

Sl. No.	Source of credit	Amount	Purpose of taking loan	Loan used		Loan used by
				For what	% of amount used for said purpose	
1	Bank					
2	NGO's					
3	Village money lender					
4	Neighbour					
5	Relatives					
6	Other (if any)					

6. **Tree species in homestesd:** Please list of tree species in your homestead

Sl. no:	Name of tree species	Amount
1		
2		
3		
4		
5		

Thank you giving me your valuable time

APPENDIX II: Tree diversity in 64 individual homegardens in Kurigram district

H.G. no	H.G. categories	Tree diversity value	Mean	Standard deviation	Standard error
1	Small	0.34	0.86	0.46	0.09
2	Small	0.34			
3	Small	1.15			
4	Small	0			
5	Small	1.08			
6	Small	0.63			
7	Small	0			
8	Small	0.58			
9	Small	0.52			
10	Small	1.56			
11	Small	0.95			
12	Small	0.99			
13	Small	0.59			
14	Small	1.35			
15	Small	1.66			
16	Small	1.01			
17	Small	1.47			
18	Small	1.09			
19	Small	0.32			
20	Small	0.66			
21	Small	1.06			
22	Small	0.93			
23	Small	1.32			
24	Small	1.07			

H.G. no	H.G. categories	Tree diversity value	Mean	Standard deviation	Standard error
1	Medium	1.46	1.12	0.93	0.09
2	Medium	1.39			
3	Medium	0.63			
4	Medium	1.26			
5	Medium	1.16			
6	Medium	1.49			
7	Medium	1.27			
8	Medium	1.37			
9	Medium	0.97			
10	Medium	1.54			
11	Medium	1.32			
12	Medium	1.03			
13	Medium	0.99			
14	Medium	1.44			
15	Medium	0.97			
16	Medium	0.68			
17	Medium	0			

H.G. no	H.G. categories	Tree diversity value	Mean	Standard deviation	Standard error
1	Large	1.03	1.17	0.48	0.10
2	Large	0.80			
3	Large	1.16			
4	Large	0.68			
5	Large	1.51			
6	Large	1.30			
7	Large	1.50			
8	Large	1.60			
9	Large	1.59			
10	Large	0			
11	Large	1.28			
12	Large	1.25			
13	Large	0			
14	Large	1.46			
15	Large	1.62			
16	Large	1.31			
17	Large	1.84			
18	Large	1.84			
19	Large	1.44			
20	Large	0.79			
21	Large	1.12			
22	Large	1.07			
23	Large	1.23			

APPENDIX III: Above and below ground biomass carbon stock in 64 homegardens in Kurigram District

H.G. no	H.G. categories	AGC (Mg ha^{-1})	BGC (Mg ha^{-1})	Total C (Mg ha^{-1})	Average (Mg ha^{-1})	Standard deviation	Standard error
1	Small	1.66	2.63	4.30	22.83	21.32	4.34
2	Small	0.95	1.45	2.41			
3	Small	23.63	0.11	23.74			
4	Small	4.91	4.91	9.83			
5	Small	9.64	1.97	11.61			
6	Small	3.96	0.90	4.87			
7	Small	1.34	0.32	1.66			
8	Small	27.56	16.18	43.75			
9	Small	7.09	1.55	8.65			
10	Small	3.73	0.87	4.61			
11	Small	23.51	4.80	28.31			
12	Small	6.24	1.46	7.71			
13	Small	3.62	0.87	4.49			
14	Small	5.96	10.76	66.73			
15	Small	43.90	8.15	52.06			
16	Small	4.98	1.13	6.11			
17	Small	58.54	10.85	69.40			
18	Small	4.46	0.93	5.39			
19	Small	8.78	1.93	10.71			
20	Small	23.56	4.36	27.92			
21	Small	36.64	6.58	43.23			
22	Small	11.05	2.10	13.16			
23	Small	37.96	7.56	45.52			
24	Small	34.62	6.30	40.92			

H.G. no	H.G. categories	AGC (Mg ha^{-1})	BGC (Mg ha^{-1})	Total C (Mg ha^{-1})	Average (Mg ha^{-1})	Standard deviation	Standard error
1	Medium	21.41	4.46	25.88	31.40	35.93	8.71
2	Medium	13.20	2.79	16.00			
3	Medium	9.39	1.79	11.19			
4	Medium	9.12	1.84	10.96			
5	Medium	12.13	2.68	14.81			
6	Medium	9.00	1.89	10.89			
7	Medium	19.87	3.73	23.61			
8	Medium	29.90	5.47	35.38			
9	Medium	13.97	2.67	16.65			
10	Medium	27.05	4.84	31.90			
11	Medium	15.80	2.79	18.60			
12	Medium	49.48	8.80	58.28			
13	Medium	36.63	6.40	43.03			
14	Medium	49.55	2.30	58.93			
15	Medium	4.50	0.99	5.49			
16	Medium	5.32	1.12	6.45			
17	Medium	17.44	2.93	20.37			

H.G. no	H.G. categories	AGC (Mg ha^{-1})	BGC (Mg ha^{-1})	Total C (Mg ha^{-1})	Average (Mg ha^{-1})	Standard deviation	Standard error
1	Large	5.55	1.24	6.79	16.47	12.89	2.68
2	Large	2.93	0.64	3.58			
3	Large	4.54	0.93	5.48			
4	Large	8.19	1.52	9.71			
5	Large	14.03	2.92	16.96			
6	Large	38.94	7.17	46.12			
7	Large	11.41	2.30	13.72			
8	Large	22.38	4.28	26.67			
9	Large	16.63	3.15	19.79			
10	Large	3.22	0.71	3.94			
11	Large	17.642	3.13	20.77			
12	Large	8.03	1.49	9.52			
13	Large	22.89	4.18	27.07			
14	Large	2.23	0.50	2.74			
15	Large	41.33	7.22	48.56			
16	Large	14.53	2.53	17.07			
17	Large	31.15	5.50	36.65			
18	Large	10.57	2.04	12.61			
19	Large	6.56	1.36	7.92			
20	Large	3.98	0.81	4.80			
21	Large	10.51	1.85	12.36			
22	Large	11.66	2.22	13.89			
23	Large	10.14	2.00	12.15			

APPENDICES IV: Soil organic carbon stock (SOC) at two different depth in 64 homegardens in Kurigram District

H.G. no	H.G. categories	SOC (Mg ha^{-1}) at 0-10 cm	SOC (Mgha^{-1}) at10-20 cm	Total (Mg ha^{-1})	Mean	Standard deviation	STDV error
1	Small	4.90	6.58	11.48	21.52	8.61	1.75
2	Small	11.77	7.50	19.27			
3	Small	11.21	17.08	28.29			
4	Small	8.94	10.82	19.77			
5	Small	13.38	26.57	39.95			
6	Small	5.49	6.97	12.46			
7	Small	3.67	4.46	8.14			
8	Small	6.34	8.66	15.00			
9	Small	9.00	17.33	26.33			
10	Small	11.72	21.57	33.29			
11	Small	11.16	20.61	31.78			
12	Small	8.36	16.73	25.10			
13	Small	10.36	16.63	26.99			
14	Small	10.47	16.82	27.29			
15	Small	10.72	8.37	19.10			
16	Small	4.71	9.75	14.46			
17	Small	10.05	16.72	26.77			
18	Small	7.98	10.53	18.52			
19	Small	8.91	12.85	21.76			
20	Small	12.55	19.30	31.86			
21	Small	5.93	8.69	14.63			
22	Small	10.92	14.41	25.34			
23	Small	4.12	7.21	11.33			
24	Small	2.59	4.78	7.37			

H.G. no	H.G. categories	SOC (Mg Ha^{-1}) at 0-10 cm	SOC (Mg ha^{-1}) at 10-20 cm	Total ($MgHa^{-1}$)	Mean	Standard deviation	STDV error
1	Medium	7.24	9.56	16.81	22.94	8.55	2.07
2	Medium	18.93	4.22	23.16			
3	Medium	12.55	11.83	24.39			
4	Medium	8.83	8.62	17.45			
5	Medium	13.36	6.81	20.18			
6	Medium	16.67	12.71	29.38			
7	Medium	17.24	12.65	29.89			
8	Medium	20.69	13.56	34.26			
9	Medium	24.69	12.71	37.40			
10	Medium	16.53	10.69	27.22			
11	Medium	4.71	4.34	9.05			
12	Medium	7.72	4.89	12.62			
13	Medium	11.20	7.31	18.52			
14	Medium	15.30	13.36	28.67			
15	Medium	19.03	12.91	31.94			
16	Medium	10.67	9.90	20.57			
17	Medium	4.69	3.74	8.43			

H.G. no	H.G. categories	SOC (Mg Ha^{-1}) at 0-10 cm	SOC (Mg ha^{-1}) at 10-20 cm	Total (MgHa^{-1})	Mean	Standard deviation	STDV error
1	Large	15.30	8.49	23.80	25.88	9.14	1.90
2	Large	12.80	8.79	21.59			
3	Large	20.63	11.49	32.13			
4	Large	15.30	5.94	21.25			
5	Large	16.61	15.14	31.76			
6	Large	9.08	4.92	14.01			
7	Large	16.42	11.08	27.51			
8	Large	21.80	15.26	37.06			
9	Large	9.15	8.62	17.78			
10	Large	23.01	20.09	43.10			
11	Large	13.10	8.45	21.56			
12	Large	23.29	15.30	38.59			
13	Large	23.22	16.58	39.80			
14	Large	11.13	15.93	27.07			
15	Large	12.84	8.91	21.76			
16	Large	15.26	11.63	26.89			
17	Large	16.87	13.23	30.11			
18	Large	18.58	10.24	28.83			
19	Large	5.19	4.90	10.09			
20	Large	18.14	12.391	30.53			
21	Large	13.82	12.71	26.54			
22	Large	7.30	4.29	11.60			
23	Large	7.42	4.46	11.89			

APPENDIX V: Stem density, Basal area and Mean DBH of 64 homegardens in Kurigram District

H.G. no	Homegarden categories	Stem density (tree Ha^{-1})	Basal area (m^2 Ha^{-1})	Mean DBH (cm)
1	Small	562.50	4.68	10.22
2	Small	321.42	4.11	10.22
3	Small	583.33	8.47	12.98
4	Small	250.00	2.22	9.46
5	Small	333.33	3.68	11.14
6	Small	250.00	2.24	10.27
7	Small	125.00	0.61	8.19
8	Small	916.66	10.31	11.77
9	Small	321.42	2.76	10.22
10	Small	300.00	1.67	8.27
11	Small	600.00	7.85	12.38
12	Small	450.00	2.79	8.80
13	Small	350.00	1.69	7.73
14	Small	900.00	16.93	14.81
15	Small	1000.00	11.92	9.76
16	Small	300.00	3.09	11.35
17	Small	800.00	15.39	14.28
18	Small	150.00	2.03	12.01
19	Small	500.00	3.44	8.82
20	Small	400.00	6.55	12.91
21	Small	450.00	0.98	11.74
22	Small	450.00	312.87	39.18
23	Small	800.00	13.76	14.14
24	Small	650.00	9.59	11.44

H.G.no.	H.G. category	Annual H.G income (tk.)	Daily income(Tk.)	Annual income (Tk.) from other source
1	Medium	656.25	7.12	11.26
2	Medium	425.00	4.66	11.71
3	Medium	225.00	2.74	10.75
4	Medium	250.00	2.98	11.55
5	Medium	600.00	4.64	9.60
6	Medium	400.00	3.56	9.56
7	Medium	350.00	5.45	12.41
8	Medium	500.00	8.02	12.23
9	Medium	266.66	5.43	14.25
10	Medium	320.00	6.83	14.70
11	Medium	200.00	4.95	14.98
12	Medium	366.66	19.45	25.27
13	Medium	366.66	8.85	15.11
14	Medium	700.00	26.35	20.01
15	Medium	266.66	2.29	9.27
16	Medium	233.33	3.12	11.03
17	Medium	120.00	3.89	17.54

H.G. no	Homegarden categories	Stem density (tree Ha^{-1})	Basal area (m^2 Ha^{-1})	Mean DBH(cm)
1	Large	300.00	2.21	9.39
2	Large	125.00	1.14	10.70
3	Large	142.85	1.85	12.01
4	Large	128.57	2.06	12.76
5	Large	450.00	5.68	11.77
6	Large	450.00	10.87	16.74
7	Large	300.00	3.62	11.63
8	Large	411.11	7.47	13.99
9	Large	300.00	4.93	13.33
10	Large	162.50	1.27	9.75
11	Large	183.33	4.43	15.84
12	Large	133.33	2.19	13.17
13	Large	216.66	6.01	18.24
14	Large	150.00	1.07	8.76
15	Large	333.33	10.69	18.72
16	Large	216.66	3.48	10.91
17	Large	333.33	7.97	15.43
18	Large	300.00	3.22	10.22
19	Large	225.00	3.06	11.86
20	Large	116.66	1.29	11.16
21	Large	80.95	2.47	18.56
22	Large	171.42	4.28	17.31
23	Large	233.33	5.29	15.44

APPENDIX VI: Farmer' income from 64 homegardens in Kurigram district

H.G. no.	H.G. category	Annual H.G income (tk.)	Daily income(Tk.)	Annual income (Tk.) from other source	Daily income(Tk.)	total income(Tk.)
1	Small	4000	10.95	216000	591.78	602.73
2	Small	180000	493.15	36000	98.63	591.78
3	Small	2000	5.47	24000	65.75	71.23
4	Small	0	0	20000	54.79	54.79
5	Small	1000	2.73	108000	295.89	298.63
6	Small	21500	58.90	20000	54.79	113.69
7	Small	0	0	20000	54.79	54.79
8	Small	25000	68.49	108000	295.89	364.38
9	Small	30000	82.19	20000	54.79	136.98
10	Small	0	0	20000	54.79	54.79
11	Small	18500	50.68	60000	164.38	215.06
12	Small	0	0	108000	295.89	295.89
13	Small	20000	54.79	108000	295.89	350.68
14	Small	0	0	14400	39.45	39.45
15	Small	0	0	108000	295.89	295.89
16	Small	21000	57.53	108000	295.89	353.42
17	Small	25000	68.49	288000	789.04	857.53
18	Small	0	0	108000	295.89	295.89
19	Small	13000	35.61	0	0	35.61
20	Small	0	0	108000	295.89	295.89
21	Small	1600	4.38	18000	49.31	53.69
22	Small	0	0	12000	32.876	32.87
23	Small	60000	164.38	108000	295.89	460.27
24	Small	70000	191.78	108000	295.89	487.67

H.G.no.	H.G. category	Annual H.G income (tk.)	Daily income(Tk.)	Annual income (Tk.) from other source	Daily income(Tk.)	total income(Tk.)
1	Medium	12000	32.87	80000	219.17	252.05
2	Medium	3000	8.21	60000	164.38	172.60
3	Medium	17000	46.57	96000	263.01	309.58
4	Medium	0	0	89000	243.83	243.83
5	Medium	25000	68.49	0	0	68.49
6	Medium	500	1.36	17400	47.67	49.04
7	Medium	21000	57.53	75000	205.47	263.01
8	Medium	0	0	10000	27.39	27.39
9	Medium	0	0	72000	197.26	197.26
10	Medium	0	0	215000	589.04	589.04
11	Medium	35000	95.89	324000	887.67	983.56
12	Medium	0	0	36000	98.63	98.63
13	Medium	67000	183.56	324000	887.67	1071.23
14	Medium	0	0	18000	49.315	49.315
15	Medium	0	0	324000	887.67	887.67
16	Medium	0	0	108000	295.89	295.89
17	Medium	40000	109.58	0	0	109.58

H.G. no.	H.G. category	Annual H.G income (tk.)	Daily income(Tk.)	Annual income (Tk.) from other source	Daily income(Tk.)	total income(Tk.)
1	Large	23000	63.01	72000	197.26	260.27
2	Large	17700	48.49	0	0	48.49
3	Large	14000	38.35	60000	164.38	202.73
4	Large	11500	31.50	0	0	31.50
5	Large	21500	58.90	50000	136.98	195.89
6	Large	2000	5.47	76000	208.21	213.69
7	Large	16000	43.83	87000	238.35	282.19
8	Large	26000	71.23	60000	164.38	235.61
9	Large	10000	27.39	72000	197.26	224.65
10	Large	15000	41.09	0	0	41.09
11	Large	15500	42.46	108000	295.89	338.35
12	Large	0	0	72000	197.26	197.26
13	Large	15200	41.64	324000	887.67	929.31
14	Large	1000	2.73	324000	887.67	890.41
15	Large	60000	164.38	0	0	164.38
16	Large	700	1.91	324000	887.67	889.58
17	Large	161000	441.09	15000	41.09	482.19
18	Large	60000	164.38	0	0	164.38
19	Large	30000	82.19	10000	27.39	109.58
2	Large	40000	109.58	73500	201.36	310.95
21	Large	120000	328.76	0	0	328.76
22	Large	130000	356.16	0	0	356.16
23	Large	70000	191.78	108000	295.89	487.67