PLANT DIVERSITY AND QUANTIFICATION OF ABOVE GROUND CARBON STORAGE OF HOME GARDENS IN SELECTED UPAZILAS OF MANIKGANJ DISTRICT

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CERTIFICATE

*This is to certify that the thesis entitled "**PLANT DIVERSITY AND QUANTIFICATION OF ABOVE GROUND CARBON STORAGE OF HOME GARDENS IN SELECTED UPAZILAS OF MANIKGANJ DISTRICT**" 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 Agroforestry and Environmental Science**, embodies the result of a piece of bona fide research work carried out by **ZANNATUL SIFAT RUMKY**, Registration number: **13-05528** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dr. Md. Forhad Hossain
Professor
Supervisor

Dated: June, 2020
Place: Dhaka, Bangladesh

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

Home garden is considered to hold a large amount for carbon, particularly for climate change mitigation and adaptation under changing environment. This is owing to their multifunctional ecosystem services while declining pressure on natural forests and hence saving and storing carbon. This study was focused on estimating aboveground carbon stock, patterns of tree species diversity and farmer’s livelihood. The study was conducted in Saturia and Manikganj Sadar upazilas of Manikganj district. Four villages namely Malshi, Horgage, Mokimpur and Diyara vobanipur were selected randomly from the selected upazilas. A total of 120 households 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. The farm size of the respondent’s home garden owners ranged from 0.14 ha to 2.85 ha and most of them (57.50%) were small farm holder. In large home garden, the contribution of home garden income to the owners’ daily income was about 30%. In medium home garden, it was around 17%, while in small home garden the contribution was only around 8%. A total of 1990 trees were sampled and 21 different tree species under 16 families were identified and recorded under this study. It was found that large home garden had 21 different types of species where mean number of tree per hectare was 21, medium home garden had 17 different types of species where mean number of trees per hectare was 29 and small home garden had 13 different types of tree species where mean number of tree was 37 tree ha^{-1}. There were seven major species found in the home gardens namely, Mango which is 28.74% of total number of species followed by Guava (14.62%), Jujube (11.11%), Mahagoni (10.65%), Jackfruit (7.59%), Coconut (6.08%) and Eucalyptus (4.92%). The Shannon Wiener index was used to evaluate the tree diversity per home garden and it ranged from 0.32 to 2.17 with a mean value of 1.42. Among 120 home gardens average tree carbon stock (above ground carbon stock) was found 39.29 Mg ha^{-1} which ranged from 22.74 Mg C ha^{-1} to 165.51 Mg ha^{-1}. Among the seven major dominating species, the highest amount of carbon was stored by Mango (41.25 Mg) followed by Jujube (31.45 Mg), Mahogani (27.21 Mg), Guava (15.14 Mg), Jackfruit (11.78 Mg), Coconut (6.39 Mg) and Eucalyptus (4.50 Mg). These results imply that home garden can serve as an important ecological tool in terms of carbon sequestration, conservation of tree species diversity.

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LIST OF ABBREVIATION AND ACRONYMS

AGC	:	Above-ground carbon
AGB	:	Above-ground biomass
C	:	Carbon
CO_2	:	Carbon dioxide
DBH	:	Stem diameter at breast height (over bark)
GBH	:	Girth breast height
UHIE	:	Urban heat island effect
e.g.	:	For example
GHG	:	Greenhouse gas
ha	:	Hectare
IPCC	:	Intergovernmental Panel on Climate Change
Mg	:	Mega gram = 10^6 gram
A/R	:	Aforestation and Reforestation
et al.	:	And others
^0C	:	Degree Celsius
ha^{-1}	:	Per Hectare
cm	:	Centimeter
m^2	:	Square meter
%	:	Percent
t	:	Ton
AEZ	:	Agro-Ecological Zone
BGC	:	Below ground carbon
UNFCCC	:	United Nations Framework Convention on Climate Change
FAO	:	Food and agriculture organization
REDD+	:	Reducing Emissions from Deforestation and Forest Degradation
SOC	:	Soil organic carbon
AR5	:	5^{th} assessment report
SWI	:	Shannon–Wiener diversity index
POM	:	Point of measurement
CF	:	Carbon foot print
CDM	:	Clean development mechanism
BGB	:	Below-ground biomass
AFS	:	Agroforestry system
Gt	:	Giga ton
ρ	:	Wood specific gravity (g/cm^3)
tk	:	Taka

CHAPTER I

INTRODUCTION

Home gardens are Agroforestry systems common throughout the tropics (Nair and Kumar 2006; Mohri *et al.,* 2013). Home gardens are prime examples of multifunctional landscapes: spaces that combine agriculture, forestry and natural ecosystems and are in Bangladesh defined as a complex sustainable land-use system that combines multiple farming components, such as annual and perennial crops, livestock and occasionally fish, of the homestead and provides environmental services, household needs, and employment and income generation opportunities to the households (Weerahewa *et al.,* 2012). In recent years, there has been growing interest in Agroforestry systems due to their large potential for climate change mitigation and adaptation and their role to mitigate household food security and nutrition from soaring food prices (Minang *et al.*, 2012; Nair 2012; Galhena *et al.*, 2013). Home gardens also store higher amounts of carbon than other agriculture systems in the above- and below-ground biomass and soils, but usually inferior to mature forests at the same site (Schroth *et al.,* 2011; Mattsson *et al.,* 2014). The provisioning role of Agroforestry and home gardens to maintain species diversity may also facilitate more stable and longer term stability of carbon stocks as well as diversification of home garden derived products (Yachi and Loreau 1999; Brookfield *et al.*, 2002 and Henry *et al.*, 2009).

With about 158 million people on 14.7 million ha Bangladesh is a densely populated and a developing country of the world and the developing countries are mainly suffer from negative impact of global warming (ICRAF, 2000). Under UNFCCC, countries are negotiating REDD (reducing greenhouse gases from deforestation and forest degradation) as a key that would provide incentive for land based forest mitigation practices and REDD+ which main aim is conservation of forest, sustainable management of forestland and increase forest carbon stock (FAO, 2010). In Bangladesh home garden represent a well-established land use system where natural forest cover less than 10%; homestead garden which are maintained by at least 20 million household and represent one possible strategy for conservation of biodiversity (Kabir, 2007). Not only that home garden also provide some potential ecosystem service such as carbon sequestration, soil conservation, preserving of water and air quality. Natural forest of Bangladesh are shrinking at an alarming rate because of unprecedented anthropogenic pressure. For this reason to meet future challenges of land and water scarcity, to ensure food security as a result to adverse effects of climate change, to conserve biodiversity and to provide daily needs of rural people home garden could be the prime example in all this respect. Beside this home gardens 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 home garden 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 home garden can contribute to 45% fruit and food, 38.71% medicinal plants, 32.26% firewood and 29% timber (Roy *et al.*, 2013). Research on home garden systems in Bangladesh is less intensive than what their importance to the economy, ecology, and livelihoods would warrant. More than 20 million home gardens (Salam *et al.,* 2000) covering 270,000 ha or 2% of the country‘s total land area (FAO, 2000) have been providing approximately 70–90% of round wood (Khan, 2001), 65–75% saw logs, 85–90% fuel wood (Leuschner and Khaleque, 1987) and 73% of bamboo (FMP, 1992). Furthermore, a home garden can act as a safety net in providing alternative livelihood opportunities for the people during periods of stress, such as a bad crop year. Yet most studies on Bangladesh home gardens are descriptive accounts of floristics and structure (e.g., Ahmed and Rahman, 2004; Ali, 2005; Kabir and Webb 2008a, b), management (e.g., MillateMustafa *et al.,* 2000), or production and services (Khan, 2001). With the exception of Salam *et al.* (2000) and Shackleton *et al.* (2008), there has been no quantitative research on the factors underlying farmer investment in home garden diversity and structure.

Home gardens are a vital source for subsistence economy and self-sufficiency of many Bangladeshi households, owing to their diverse products (Millat-e-Mustafa *et al.*, 2000; Salam *et al.*, 2000; Ahmed and Rahman 2004; Ali, 2005). This also is true for many other tropical regions (Das and Das, 2005; Peyre *et al.,* 2006). The role of home garden to household economy may vary depending on the component products and nature of the products utilization. In South and Southeast Asia, from 6 to 54% (Ali, 2005; Kabir and Webb, 2008a, b) of the total household income come from home gardens. Home garden‘s contribution to the household economy in southwestern Bangladesh was at the lower extreme compared to other South and Southeast Asian home gardens. Nevertheless, such contribution is substantial for the households in such a resources poor country like Bangladesh.

To meet future challenges of land and water scarcity, and to ensure food security as a result to adverse effects of climate change, future mitigation and adaptation strategies that can be used by local land users through effective support by stakeholders and policymakers needs further attention (Murthy *et al.,* 2013). To identify such strategies, it is relevant to analyze quantitative information and estimates of tropical home gardens' ability to sequester and store carbon. Although, the importance and recognition of home gardens for carbon storage has been highlighted earlier, there is still a lack of quantitative data on home gardens and their carbon content, especially in dry zone environments in Bangladesh. Few studies have also related species diversity to ecosystem processes (Pushpakumara *et al.,* 2012). Since subsistence agriculture is predominantly practiced in the dry zone, the little research focus on dry zone home gardens warrants further investigation on this subject. Therefore, this study focused on assessing the amount and pattern of plant diversity and above-ground carbon storage in home gardens around two selected upazilas of Manikganj district in Bangladesh.

Objectives:

- To assess the pattern of tree species diversity in home garden;
- To determine the amount of biomass carbon stock (AGC) in the selected home gardens ; and
- To explore a relationship within biomass carbon, tree species diversity, DBH, basal area and stem density in home garden.

CHAPTER II

REVIEW OF LITERATURE

2.1. General Concept of Home garden

Ninez (1984) has 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.

Fresco and Westphal (1988) specify home gardens as a cropping system composed of soil, crops, weeds, pathogens and insects that converts resource inputs - solar energy, water, nutrients, labor, etc. - into food, feed, fuel, fiber and pharmaceuticals.

Kumar and Nair (2004) while acknowledging that there is no standard definition for 'a home garden', summarize the shared perception by referring to it as an intimate, multi-story combinations of various trees and crops, sometimes in association with domestic animals, around homesteads', and add that home garden cultivation is fully or partially committed for vegetables, fruits, and herbs primarily for domestic consumption.

Adding to this, Krishna (2004) have described a home garden as a well-defined, multi-storied and multi-use area near the family dwelling that serves as a small-scale supplementary food production system maintained by the household members, and one that encompasses a diverse array of plant and animal species that mimics the natural eco-system.

2.2. Characteristics of Home gardens

Michelle and Hanstad (2004) listed five intrinsic characteristics of home gardens: 1) were located near the residence; 2) contain a high diversity of plants; 3) production was supplemental rather than a main source of family consumption and income; 4) occupy a small area; and 5) are a production system that the poor can easily enter at some level.

Table 1. The Key Characteristics of a Typical Home Garden.

Characteristic	General Practice
Species density	High
Species type	Staples, vegetables, fruits and medicinal plants
Production objective	Home consumption
Labor source	Family (women, elderly, children)
Labor requirements	Part time
Harvest frequency	Daily, seasonal
Space utilization	Horizontal and vertical
Location	Near dwelling
Cropping pattern	Irregular and row
Technology	Simple and tools
Input cost	Low
Distribution	Rural and urban areas
Skills	Gardening and horticultural skills
Assistance	None or minor

Source: Niñez (1987).

2.3. Home garden in Bangladesh

Alam and Masum (2005) gave baseline information for the policy makers to understand the species richness, species and composition, structure, soil conservation methods, fruit species conservation, household food security and socio-economic importance of household food security, and socio-economic importance of homestead forest, as well as to formulate biodiversity conservation planning highlighting homestead forest of Bangladesh for sustainable production and maintenance of biodiversity.

Tree-dominated habitats often show promise for biodiversity conservation in managed landscapes. In Bangladesh natural forest covered less than10 percent home gardens, which were maintained by at least 20 million households, represent one possible strategy for biodiversity conservation. Kabir and Webb (2008 a,b) investigated the floristic and structural diversity of 402 home gardens from six regions across Southwestern Bangladesh. All plants were censused, totaling 419 species (59% native), including six IUCN Red Listed. The median home garden (800 m^2) contained a mean of 34 species. Each region contained a mean of 293 species in a mean of 67 home gardens. A total of 49,478 individuals (107 per home garden and 1003 per hectare) of trees and shrubs were counted from 45.2 ha total sampled area. Thus, significant botanical richness was exhibited in the home gardens across Southwestern Bangladesh. However, most species were rare: 82 percent of all species including 189 native were found in 50 or fewer home gardens, and 63 species (36 native) were found in only one or two home gardens. Sixty percent of all trees and shrub species had 50 or fewer individuals each. Thus, whereas richness across the landscape was high, serious effort must be made to increase the populations of most of the species. The study proposed three main conservation activities: (1) awareness building; (2) protection of existing individuals of rare species; and (3) propagation. Overlaying all of these activities were the inclusion of local communities in the process, who were the ones to retain these species in home gardens in the first place, and the stakeholders who will determine whether home gardens indeed act as long-term repositories to biodiversity conservation.

Masum *et al.* (2008) conducted the survey to assess the contribution of plant diversity to the ecological and socio-economic condition of the rural household in the offshore island of Bangladesh. The researchers identified different ecological merits for evaluating the general information related to socio-economic and social benefits derived by the local people from their own home gardens. Zaman *et al.* (2010) studied the home gardens in Bangladesh to find out structure and diversity, with particular reference to Thakurgaon district.

The role of women in homestead gardens management in the Northeastern Bangladesh was discussed by (Akhter *et al.*, 2010). Roy *et al.* (2013) evaluated the status, ecological diversity, traditional uses, three dimensional arrangement, and importance of homestead garden for biodiversity conservation in the urban and rural households in Kishoreganj Sadar of Northern Bangladesh.

2.4 Plant Diversity and Species Richness in Home garden

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

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 home gardens. *Eucalyptus saligna* was the most frequent tree species found as individual trees (20%).

Shobuj *et al.* (2010) observed that a total of 32 different tree species recorded in the homestead area of Nator district of which Jackfruit, Eucalyptus, Ipil-ipil, Mango, Neem and Mehagani were dominant species. On an average 21.25 tree species were found in homestead.

Mahmud (2010) studied on species composition and its diversity in the homestead of kolaroa and tala upazilla of Shatkhira district and found that total of 69 different tree species was recorded in the homestead of the study area of which Akashmoni, Mahogani, Jackfruit, Coconut, and Papaya were dominant species.

Jahan (2010) identified that a total of 50 different tree species recorded of which Jackfruit, Betelnut, Raintree, Mango, Mahogani and Banana were dominant in homesteads of Karimgonj upazilla, Kishorgonj district.

Saikia *et al.* (2012) reported that a high variability in density of plant species was noticed in different home garden 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}) home gardens. Similarly, frequency of species occurrence increased with decreasing home garden 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}) home gardens. Medium-sized home gardens, were also more species rich (236 spp.) than large-sized (total 232 spp.) and small-sized (total 210 spp.) ones. Number of species per home garden was variable (17 to 69 with a mean of 44 ± 1.09) but, the difference was not significant in different home garden categories.

Saikia *et al.* (2012) reported that home gardens of Upper Assam, northeastern India are diverse and species-rich. They made a survey on 80 home gardens 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.

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.

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 homestead for fruit and food (85%) followed by building materials (78.75%), subsistence family income (73.75%), and source of firewood (68.75%).

Mattsson *et al.* (2015) reported from a study on quantification of carbon stock and tree diversity of home gardens 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 home garden and ranged from 0.76 to 3.01 with a mean value of 2.05 ± 0.07.

2.5. Carbon Sequestration Potential in Home garden

Roshetko *et al.* (2002) studied that the home gardens and other tree-rich smallholder systems offer potential rate of carbon storage in their woody biomass. He also reported that tree density varied from 13-59 trees sampled per home gardens and contained 260- 1180 Mg ha^{-1} in Indonesian homegardens.

Albrecht and Kandij (2003) has stated that plant stored carbon for long as they live in term of live biomass and once they die the biomass become a part of food chain and eventually enters in the soil as soil carbon. If the biomass is incinerated, the carbon is reemitted into the atmosphere and is free to move in the carbon cycle.

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. Verchot *et al.* (2007) Stated that contribution to climate change mitigation through enhance carbon sequestration is one of the major function of home gardens.

It has been reported by Dissanayake (2009) that the average aboveground carbon stocks of Sri Lankan home garden were 90 Mg ha^{-1} and 104 Mg ha^{-1} in Kandy and Matale district respectively.

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.

FAO (2010) has reported that around 13 million hectares of forest are converted to other uses or lost through natural causes each year between 2000-2010 and the world has estimated 850 million hectares of degraded forests which could potentially be restored and rehabilitated to bring back lost biodiversity and ecosystem services and at the same tome contribute to climate change mitigation and adaptation.

Kumar (2011) has found that above ground carbon stocks of kerala home gardens in India ranging from 16 to 36 Mg ha^{-1} respectively with standard error values in range of 0.74-2.18.

Mattsson *et al.* (2012) estimated that the above ground carbon (AGB) stocks in natural forests range from 22 to 181 Mg C ha^{-1} in six natural forest type and with a tree density ranging from 337-1136 trees ha^{-1} for the same types of forest.

Mandal *et al.* (2013) reported that the estimated carbon stocks at Banke- Maraha, Tuteshwarnath, and Gadhanta-Bardibas CFMs, are 197.10, 222.58, and 274.66 Mg ha^{-1} respectively in Terai, Nepal.

2.6. Soil Organic Carbon and Plant Diversity

Kumar (2006) reported that most agroforestry systems are important in respect to carbon sequestration, carbon conservation and carbon substitution, the home gardens perhaps are unique for all above three mechanisms i.e., they sequester carbon in biomass and soil, reduce fossil-fuel burning by promoting wood fuel production, help in the conservation of carbon stocks in existing forests by alleviating the pressure on natural forests.

IPCC (2007) climate change mitigation is an anthropogenic intervention to reduce the sources or enhance the sink of greenhouse gases and adaptation as the adjustment in natural or human system to a new or changing environment.

Bodansky (2010) has studied that subsistence farming is responsible for 48% of deforestation; commercial agriculture is responsible for 32% of deforestation; logging is responsible for 14% of deforestation and fuel wood removal make up 5% of deforestation.

APN (2012) reported that home gardens of Siwalakulama village in Sri Lanka the mean Shannon Wiener index (SWI) has found 1.77 that is slightly lower than mean Shannon Wiener index (SWI) 2.05.

Roy *et al.* (2013) reported that the Shannon -winner diversity has found (3.39) for trees and (2.36) for shrubs in the urban homestead area and highest tree and shrubs diversity observed (3.5) and (2.48) respectively in rural homestead area in kishorgonj district of Bangladesh.

2.7. Home garden, Carbon dioxide and Climate Change

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 1 Mg 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

This chapter deals with the procedures for the collection of valid information as well as procedure of data coding and also data analysis. For conduction a research work smoothly, proper methodology is an obligatory one and it is very difficult to address the study objectives with a scientific manner without a define methodology. A sequential description of the methodologies that was followed in conducting this research work has been presented in this chapter under the following headings-

3.1 Study area

3.1.1 Location

The study was conducted at four villages of two upazilas (administrative unit) in Manikganj district. The area of Manikganj District (Dhaka division) is 1383.06 sq. km, located in between 23°38' and 24°03' North latitudes and in between 89°41' and 90°08' East longitudes. It is bounded by Tangail district on the North, Faridpur and Dhaka districts on the South, Dhaka district on the East, Pabna, Rajbari and Sirajganj districts on the West. The name of four studied villages are Mokimpur, Diyara vabanipur, Malshi and Horgage, Among these the villages Mokimpur and Diyara vabanipur are situated in Manikganj Sadar upazila, while Malshi and Horgage are situated in Saturia upazila. Manikganj Sadar Upazila (Manikganj district) area 214.81 sq. km, located in between 23°42' and 23°55' North latitudes and in between 89°58' and 90°07' East longitudes. It is bounded by Saturia upazila on the North, Nawabganj (Dhaka) and Harirampur upazilas on the South, Singair and Dhamrai upazilas on the East, Harirampur and Ghior upazilas on the West. Population Total is 261662; where male 130842 and female 130820; Muslim 232407, Hindu 29170, Buddhist 33 and others 52. On the other hand, the area of Saturia Upazila (Manikganj district) is 140.12 sq. km, located in between 23°51' and 24°03' North latitudes and in between 89°55' and 90°08' East longitudes. It is bounded by Nagarpur and Dhamrai upazilas on the North, Manikganj sadar upazila on the south, Dhamrai upazila on the East, Daulatpur (Manikganj) and Ghior upazilas on the West. Total population is 155137 where male 78147 and female 76990; Muslim 141852, Hindu 13269, Christian 8 and others 8.

3.1.2 Climate and Soil

The Manikganj lies on 12m above sea level Manikganj has a tropical climate. The summers are much rainier than the winters in Manikganj. The average annual temperature is 25.6 °C/78.0 °F. The rainfall here is around 1900 mm per year. This area is occupied by permeable silt loam to silty clay loam soils on the ridges and impermeable clays in the basins which are neutral to slightly acidic in reaction. General soil types include predominantly Grey Floodplain soils. Organic matter content is low in ridges and moderate in basins. The climate of the area is tropical monsoon zone. The hot summer, the long rainy season and the pleasant spring cum winter are the main noticeable seasons prevailing in the district. The summer begins at the end of March and is merged with the rainy season that continues up to September. The duration of the winter is recorded from early November to late February.

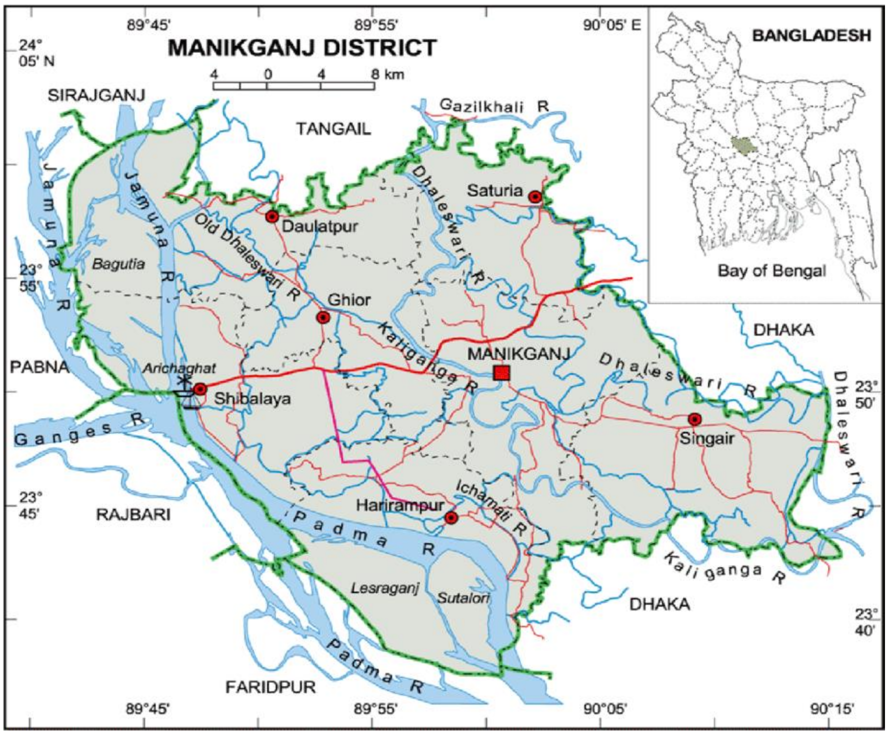
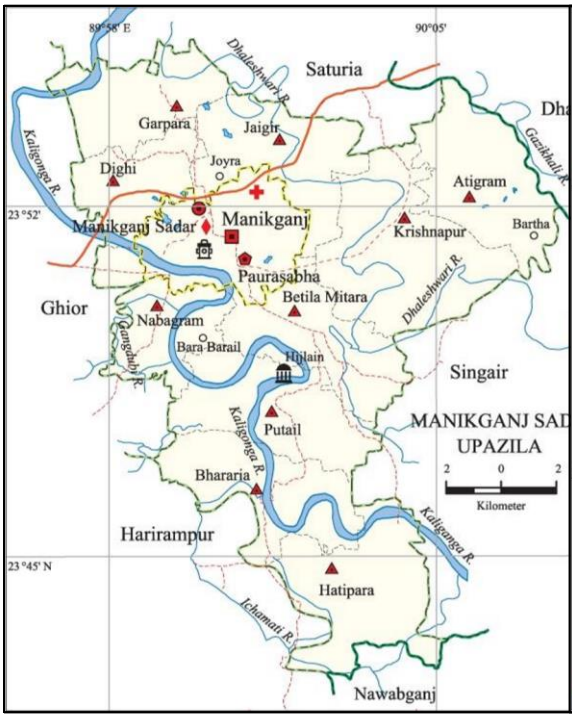


Plate 1. Location of Manikganj District



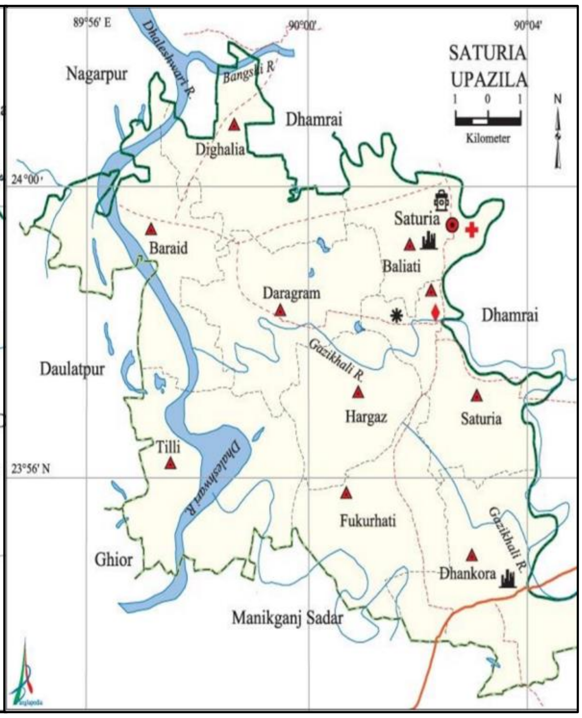


Plate 2. Manikganj Sadar Upazila. **Plate 3. Saturia Upazila.**

3.2 Sampling Procedure

This study was conducted in Manikganj district that was purposively selected. Manikganj district is consisting of seven upazilas. Out of 7 upazilas, two upazilas namely Manikganj Sadar and Saturia was randomly selected. Manikganj Sadar and Saturia consist of 10 unions and 9 unions, respectively. Among 10 unions of Sadar upazila, two unions namely Jagir and Dighi were randomely selected and out of 9 unions of Saturia Upazila, two union named Tilli and Daragram were randomly selected. Then one village was selected randomly from each of the selected union. Thus, total four villages were selected from the selected unions. The name of four studied villages are Mokimpur, Diyara vabanipur, Malshi and Horgage, Thus through multistage random sampling method was used to select the areas. The household owners of Manikganj sadar and Saturia upzailla under Manikganj district constituted the population of the study. An update list of household owners was collected from the union parishad of theses respective villages. Randomly 30 number of homegarden owners from 4 villages of 2 upazilas were selected as the sample of the study by using random sampling method. Thus, 120 household owners constituted the sample of the study. A reserve list of 30 household owners was also prepared by the same method so that the respondents of this list could be used for interview if the respondents included in the original sample were not available at the time of conduction of interview.

Table 2. Distribution of sample size in four selected villages.

District	Upazilas	Villages	No. of home gardens selected for data collection
Manikganj	Sadar Upazila	Mokimpur	30
		Diyara Vabanipur	30
	Saturia Upazila	Malshi	30
		Horgage	30
		Total	**120**

3.3 The Research Instrument

A well-structured interview schedule was developed based on objectives of the study for collecting information with containing direct and simple questions in open form and close form keeping in view the dependent and independent variables. Appropriate scales were developed to measure both independent and dependent variables. The questionnaire was pre-tested with 5 homestead owners in actual situation before finalized it for collection of data. Necessary corrections, additions, alternations, rearrangements and adjustments were made in the interview schedule based on pretest experience. The questionnaire was then multiplied by printing in its final form. A copy of the interview schedule is presented into Appendix I.

Plate 4. Home garden of the study area. **Plate 5.** Photograph of data collection.

Plate 6. Interviewing with the home gardener.

3.4 Data Collection Procedure

Data were collected from the selected villages of Manikganj district and desired information was recorded through interviews with household members. In most cases, the head of the households was male. Wife of the farmer was also present and contributed during interview. In addition to the formal survey, some information especially numbers of tree, spatial or temporal arrangement, height of the trees, girth of the trees, clean bole height, homegarden land use pattern and species diversity etc. were measured by physically and visual observation.

First of all the home gardens were categorized into three group namely small (0.010.03 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.

3.5 Ecological indices

Tree species diversity of the homegarden was estimated by the Shannon Wiener diversity Index (SWI). Species density (number of species per unit area) was measured by dividing the total number of plant species of a homegarden by the total area of that homegarden.

3.5.1 Plant diversity measurement

Tree species diversity was assessed within the fixed boundaries of the sample homegardens acquiring common names that subsequently translated into botanical names. An index was setup based on the number of species and their frequency in homegardens. For this study Shannon-Wiener diversity index (SWI) was used due to its suitability for evaluating diversity of tree species. The Shannon–Wiener diversity characterizes the proportion of species abundance in the population being at maximum when all species are equally abundant and the loWest when the sample contained one species. 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.

$$H = -\sum_{i=1}^{n} Pi\ Ln\ Pi$$

Where,

H = Shannon index

n = No. of species

Σ= Summation.

Pi = 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.

Also the species density (number of species per unit area) was measured by dividing the total number of plant species of a home garden by the total area of that home garden.

3.6 Allometric equation for above and below ground biomass

3.6.1 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.

3.6.2 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, 2.14…..……………0.207 and 0.0281= Constant.

3.6.3 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.

3.7 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 sources. 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 home garden category.

Plate 7. Measurement of 1.3m height.

Plate 8. Measuring GBH (cm).

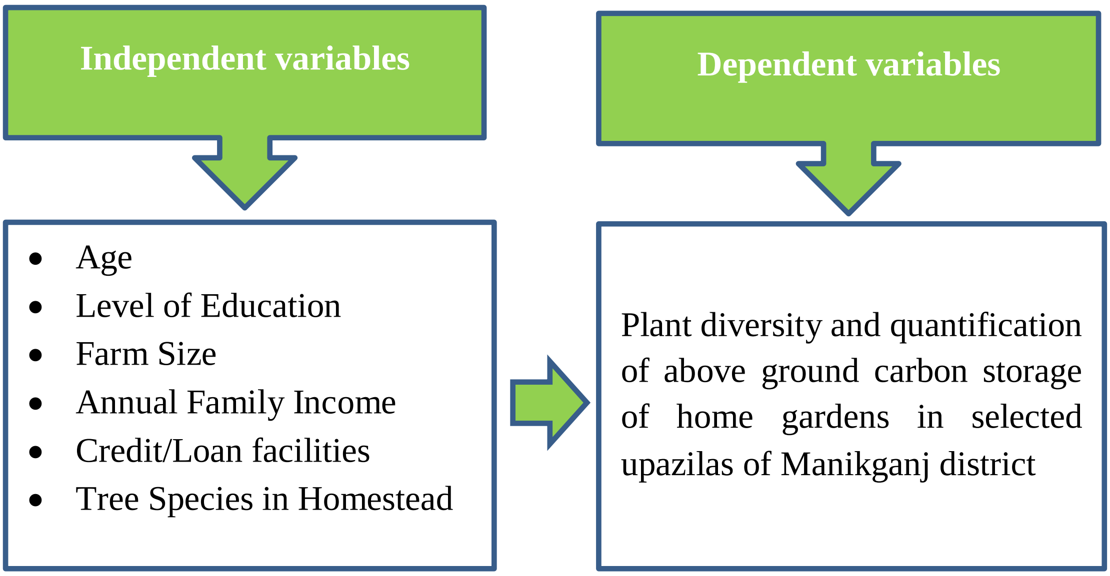
3.8 Data Analysis

Data collected from questionnaire survey were analyzed by SPSS-20 software and other field data were processed and analyzed using MS excel 2007 software. 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.

3.9 Conceptual Framework of the Study

In scientific research, selection and measurement of variables constitute an important task. The hypothesis of a research while constructed properly consist at least two important elements i.e. a dependent variable and an independent variable. A dependent variable is that factor which appears, disappears or varies as the researcher introduces, removes or varies the independent variables (Townsend, 1953). An independent variable is that factor which is manipulated by the researcher in his attempt to ascertain its relationship to an observed phenomenon. Variables together are the causes and the phenomenon is effect and thus, there is cause effect relationship everywhere in the universe for a specific events or issues. This study is concerned with the plant species diversity and quantification of above ground carbon storage of home gardens in selected upazilas of Manikganj district. Thus, the plant diversity and quantification of above ground carbon storage of home gardens by the household owners of Saturia and Manikganj Sadar upazila of Manikganj district was the dependent variable and 6 selected characteristics of the homegardens owners were considered as the independent variables. It is not possible to deal with all of the independent variables in a single study. It was therefore, necessary to limit the independent variables, which include age, level of education, farm size, annual Income, years of homegarden production experiences, types of plants in a homegardens etc. Considering aforesaid discussion, a conceptual framework has been developed for this study, which is diagrammatically presented below.

The conceptual framework of the study



CHAPTER IV

RESULTS AND DISCUSSION

The recorded observations in accordance with the objectives of the study were presented and discussion was made with justifiable and relevant interpretation under this chapter.

4.1 Characteristics of the Home gardens Owners

For assess the plant diversity and quantification of above ground carbon storage of home gardens systems by the home gardens owners, various interrelated characteristics were collected under the present study. It was therefore, hypothesized that the characteristics of the home garden owners correlated with plant diversity and above ground carbon storage in home garden production systems. However, the 6 selected salient features of the homestead owners such as age, level of education, farm size, annual income, credit/loan facilities and types of tree in a home garden by the home gardens owners are presented below.

4.1.1 Age

The age of the home gardens has been varied from 19 to 73 years with a mean and standard deviation of 44.57 and 14.49, respectively. Age of home gardens owners were classified into three categories namely young, middle and old aged following Rashid *et al.*, (2014). The distribution of the home garden owners in accordance of their age are presented in Table 3.

Table 3. Distribution of the Home garden owners according to their age.

Category of age	Range (Years)		Home garden owners (Respondents')		Mean	Standard deviation
	Score	Range	Number	Percent respondent		
Young aged	Up to 35	19-73	41	34.17	44.57	14.49
Middle aged	36-50		54	45.00		
Old aged	Above 50		25	20.83		
Total			**120**	**100**		

From Table 3 it was revealed that the middle-aged home garden owners comprised the highest proportion (45.00%) followed by young aged category (34.17%) and the lowest proportion were made by the old aged category (20.83%). Data also indicated that the middle and young aged respondents constitute almost 80 percent of total. The young and middle-aged respondents were generally more involved in home garden production system than the other.

4.1.2 Level of Education

The level of educational score of the home garden owners ranged from 0-14 with a mean and standard deviation of 7.71 and 4.78, respectively. Based on the educational scores, the respondents were classified into five categories such as can't read and sign (0), can sign only (0.5), primary education (1 to 5), secondary education (6 to 10) and above secondary (above 10). The distributions according to their level of education are presented in Table 4.

Table 4. Distribution of the respondents' according to their level of education.

<table>
<tr><th rowspan="2">Category</th><th colspan="2">Range (School Years)</th><th colspan="2">Home garden owners (Respondents')</th><th rowspan="2">Mean</th><th rowspan="2">Standard deviation</th></tr>
<tr><th>Score</th><th>Range</th><th>Number</th><th>Percent respondent</th></tr>
<tr><td>Can't read and sign</td><td>0</td><td rowspan="5">0-14</td><td>7</td><td>5.83</td><td rowspan="5">7.71</td><td rowspan="5">4.78</td></tr>
<tr><td>Can sign only</td><td>0.5</td><td>11</td><td>9.17</td></tr>
<tr><td>Primary education</td><td>1-5</td><td>31</td><td>25.83</td></tr>
<tr><td>Secondary education</td><td>6-10</td><td>52</td><td>43.33</td></tr>
<tr><td>Above secondary</td><td>>10</td><td>19</td><td>15.83</td></tr>
<tr><td colspan="3">Total</td><td>120</td><td>100</td><td></td><td></td></tr>
</table>

Table 4 shows that respondents under secondary education category constitute the highest proportion (43.33%) followed by primary education (25.83%), above secondary (15.83%) and can sign only category (9.33%). The lowest respondents (5.83%) are in the category of can‘t read and sign. Education broadens the horizon of outlook of home garden owners and expands their home garden production system. An educated home garden owner is likely to be more responsive to the modern facts and ideas of home garden production system. To adjust with the same, they would be progressive minded to adapt with modern technology of their home garden production.

4.1.3 Farm Size

The farm size of the respondent‘s home garden owners ranged from 0.14 ha to 2.85 ha with a mean and standard deviation of 0.87 and 0.63, respectively. Based on their farm size, the respondents were classified into three categories following the categorization of DAE. These categories were marginal farm holder (up to 0.2 ha), small farm holder (0.201 to 1.0 ha) and medium farm holder (1.01 ha to 3.0 ha). The distribution of the homestead owners according to their farm size is presented in Table 5.

Table 5. Distribution of the respondents' according to their farm size.

Category	**Range (Hectare-ha)**		**Home garden owners (Respondents')**		**Mean**	**Standard deviation**
	Score	**Range**	**Number**	**Percent respondent**		
Marginal	Up to 0.2 ha		14	11.67		
Small	0.201-1.0 ha	0.14-2.85 ha	69	57.50	0.87	0.63
Medium	1.01-3.0 ha		37	30.83		
Total			**120**	**100**		

Table 5 indicates that the small farm holder constitutes the highest proportion (57.50%) followed by medium farm holder (30.83%), while the lowest (11.67%) percent marginal farm holder. The findings of the study reveal that majority of the home garden owners were small to medium sized farm holder. The average farm size of the home garden owners of the study area (0.87 ha) was higher than that of national average (0.60 ha) of Bangladesh (BBS, 2014).

4.4 Home garden Size

The home garden size of the respondent‘s home garden owners ranged from 0.014 ha to 0.13 ha with a mean and standard deviation of 0.023 and 0.015, respectively. Based on their home garden size, the respondents were classified into three categories following the categorization of DAE. These categories were small home garden holder (0.010-0.030), medium home garden holder (0.031 to 0.050 ha) and large home garden holder (above 0.051 ha). The distribution of the home garden owners according to their garden size is presented in Table 6.

Table 6. Distribution of the respondents' according to their home garden size.

Category	**Range (Hectare-ha)**		**Home garden owners (Respondents')**		**Mean**	**Standard deviation**
	Score	**Range**	**Number**	**Percent respondent**		
Small	0.010-0.030 ha	0.014-0.13 ha	52	43.33	0.027	0.015
Medium	0.031-0.050 ha		43	35.83		
Large	> 0.051 ha		25	20.83		
Total			**120**	**100**		

Table 6 indicates that the small home garden holder constitutes the highest proportion (43.33%) followed by medium home garden owner (35.83%), while the lowest (20.83%) percent large home garden owner. The findings of the study reveal that majority of the home garden owners had small to medium sized home garden in their homestead. The average farm size of the home garden owners of the study area (0.027 ha) was higher than that of national average (0.023 ha) of Bangladesh (Khan and Alam, 1996).

4.5 Daily Income

Based on daily income, the homestead owners were classified into three categories, viz. low, medium and high daily income. The distribution of the home garden owners according to daily income are presented in Table 7. Daily income of the respondent of small home garden owners ranged from 315.07 to 1679.45 Taka with a mean and standard deviation of 650.05 and 328.71, respectively. Similarly, daily income of the respondent of medium home garden owners ranged from 383.56 to 1219.18 Taka with a mean and standard deviation of 677.16 and 235.17, respectively. On the other hand, daily income of the respondent of large home garden owners ranged from 400.00 to 1150.68 Taka with a mean and standard deviation of 639.23 and 181.61, respectively.

Table 7. Distribution of the respondents' according to their daily income

Homegarden Category	Category	Range		Home garden owners (Respondents')		Mean
		Score	Range	Number	Percent respondent	
Small home garden	Low income (Tk.)	< 500	315.07-1679.45	20	38.46	650.05
	Medium income (Tk.)	501-1000		23	44.23	
	High income (Tk.)	>1000		9	17.31	
		Sub-total		**52**	**100**	
Medium home garden	Low income (Tk.)	< 500	383.56-1219.18	12	27.91	677.16
	Medium income (Tk.)	501-1000		25	58.14	
	High income (Tk.)	>1000		6	13.95	
		Sub-total		**43**	**100**	
Large home garden	Low income (Tk.)	< 500	400.00-1150.68	5	20.00	639.23
	Medium income (Tk.)	501-1000		18	72.00	
	High income (Tk.)	>1000		2	8.00	
		Sub-total		**25**	**100**	

Data revealed that the home garden owners in among the categories having medium daily income constitute the highest proportion, which was followed by low income home garden owners. Overwhelming majority home garden owners have low to medium level daily income.

4.6 Contribution of home garden income to the owners' daily income

From the Figure 1 is revealed that large home garden contributes more daily income to the home garden owners compared to others home gardens. In large home garden, the contribution of home garden income to the owner's daily income was about 30%. In medium home garden, the contribution was around 17%, while in small home garden the contribution was only around 8%.

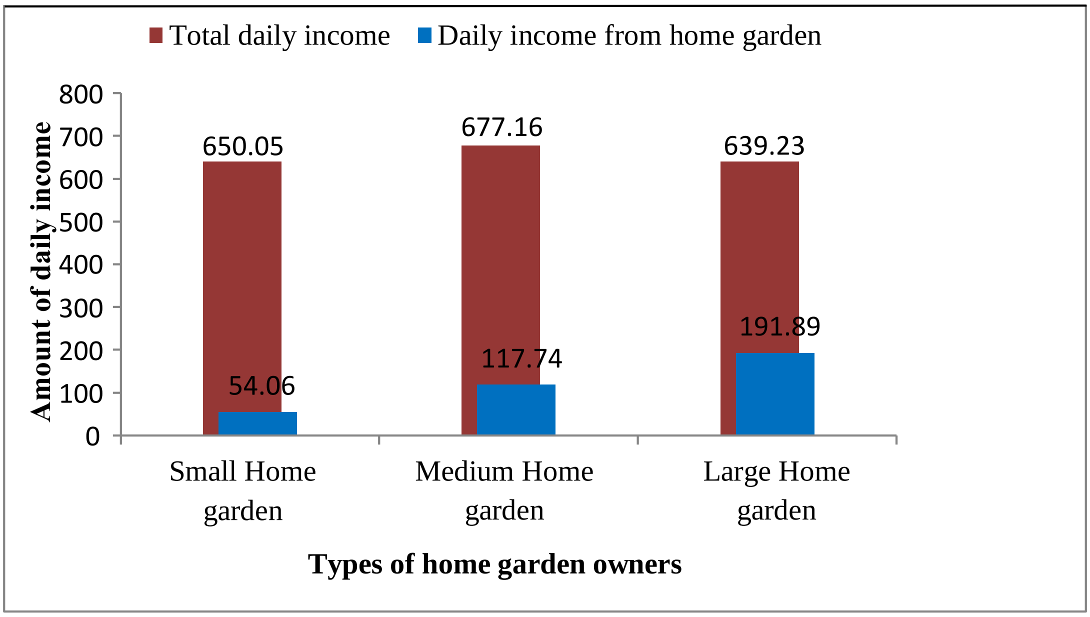


Figure 1. Contribution of home gardens' income to the owner's daily income.

4.7 Measurement of tree diversity and occurrence of species in selected areas

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

4.7.1 Tree diversity at various home gardens in Manikganj district

Tree diversity at various home gardens were measured by Shannon-Winner diversity index and a significant difference was found among 120 home gardens in the study area.

Table 8. Tree diversity at various home gardens in Manikganj district

Category (home garden)	No. of trees per hectare (ha)		Species recorded in home gardens		Shannon-Winner Index (SWI)	
	Range	Mean	Total	Mean	Range	Mean±SE
Small homegarden (52)	7-51	37	13	9.50	0.32-2.17	1.21±0.07
Medium homegarden (43)	13-38	29	17	11.83	0.63-2.06	1.46±0.05
Large homegarden (25)	15-33	21	21	17.40	0.68-2.17	1.47±0.07

Tree diversity was presented in Table 8 and the Shannon-Winner diversity index showed a range between 0.32 to 2.17 for diversity value within the home gardens. This diversity index revealed that large home garden (n=25) had the highest mean value of 1.47±0.07 and small home garden (n=52) had the lowest mean value of 1.21±0.07 where medium home garden (n=43) had moderate mean value of tree diversity (1.46±0.05). The result can be compared as: large>medium>small. It was found that large home garden had 21 different types of species where mean number of tree per hectare was 21 tree ha^{-1}, medium home garden had 17 different types of species where mean number of trees per hectare was 29 tree ha^{-1} and small home garden had 13 different types of tree species where mean number of tree was 37 tree ha^{-1}. The study found that the variation was due to species composition and richness, soil characteristics, climate, topography and size of the home gardens.

Similar study was conducted by Iqbal (2015) and he found that Shannon-Wiener diversity index in large home garden (n=23) had the highest mean value of 1.17±0.1 and small home garden (n=24) had the lowest mean value of 0.86±0.09 where medium home garden (n=17) had moderate mean value of tree diversity (1.12±0.09). Another study was conducted by Jaman *et al.,* (2016) 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 home gardens had the highest mean diversity of trees (1.66 ± 0.05) followed by medium (1.65 ± 0.05) and large (1.60 ± 0.06) home gardens.

4.7.2 Tree species and their occurrence at different home gardens

A Variety of species under different families were found at different home gardens. The study explored 21 tree species under 16 families. Their local name, botanical name, family, total number, % of occurrence and in which purpose they are used are shown in the Table 9. There were seven major species found in the home gardens namely, Mango which is 28.74% of total number of species followed by Guava (14.62%), Jujube (11.11%), Mahagoni (10.65%), Jackfruit (7.59%), Coconut (6.08%) and Eucalyptus (4.92%).

Table 9. Tree species identified in 120 home gardens in Manikganj district.

S.l no	Botanical name	Local name	Family	Primary uses	Total No	% of Total
1	*Mangifera indica*	Aam	Anacardiaceae	fr, wd, fl,	572	28.74
2	*Psidium guajava*	Peyara	Myrtaceae	Fr, fl	291	14.62
3	*Ziziphus jujuba*	Boroi	Rahmnaceae	Fr, fl	221	11.11
4	*Swietenia mahogani*	Mahagoni	Meliaceae	Tm	212	10.65
5	*Artocarpus heterophyllus*	Kathal	Moraceae	Fr, tm, vg, md, dy	151	7.59
6	*Cocos nucifera*	Narikel	Palmaceae	Su, md, fr,ol	121	6.08
7	*Eucalyptus camaldulensis*	Eucalyptus	Myrtaceae	tm, fl	98	4.92
8	*Citrus maxima*	Jambura	Rutaceae	Fr	54	2.71
9	*Moringa oleifera*	Shojna	Moringaceae	Vg, fl	47	2.36
10	*Areca catechu*	Shupari	Arecaceae	fr, st, fl, md,	43	2.16
11	*Tamarindus indica*	Tetul	Leguminoseae	Fr, tm	37	1.86
12	*Syzygium cumuni*	Jam	Myrtaceae	Fr, wd, fl	32	1.61
13	*Samanea saman*	Randi koroi	Mimosaceae	Tm, fl	24	1.21
14	*Litchi sinensis*	Litchu	Sapindaceae	Fr, wd	22	1.11
15	*Dalbergia sissoo*	Sissoo	Papilionaceae	Tm, fr, fl	21	1.06
16	*Spondias pinnata*	Amra	Anacardiaceae	Fr, fl	12	0.60
17	*Azadirachta indica*	Deshi neem	Meliaceae	Tm, md, rs, ol	9	0.45
18	*Aegle marmelos*	Bel	Rutaceae	Fr, md,	7	0.35
19	*Punica granatum*	Dalim	Punucaceae	Fr,fl	7	0.35
20	*Annona reticulata*	Shorifa	Annonaceae	Fr	5	0.25
21	*Erytheina orientalis*	Mander	Fabaceae	Fr, Tm	4	0.20

N.B.: Tm = timber, Fl = flower, Fr = fruit, Wd = wood. Co = cotton, Vg = vegetable, md = medicine, dy = dye, ol = oil.

There were seven major species found in the home gardens namely, Mango which is 28.74% of total number of species followed by Guava (14.62%), Jujube (11.11%), Mahagoni (10.65%), Jackfruit (7.59%), Coconut (6.08%) and Eucalyptus (4.92%) (Figure 2).

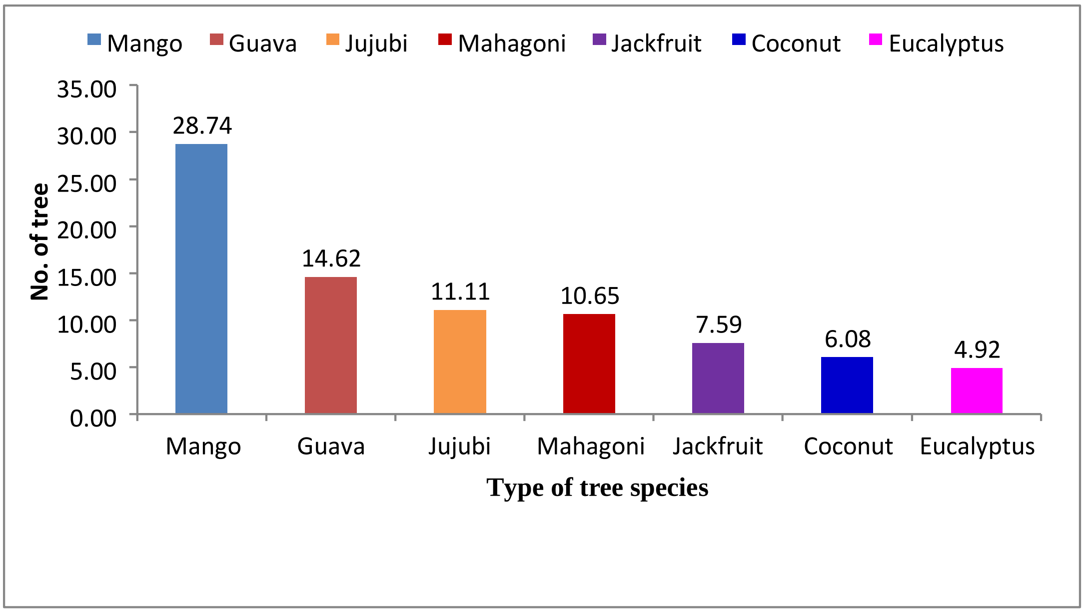


Figure 2. Percent of occurrence of seven major species present in the study areas.

4.7.3 Tree density at various home gardens in Manikganj district

Tree density was measured and a variation was found among the home gardens (Table 10). The result showed a range of tree density from 80.95 to 1333.33. Among the three category of home gardens, small home garden (0.01-0.03 ha) had the highest tree density (30265.01 tree ha^{-1}) with a mean value of 582.02±38.59 and large home gardens (>.05 ha) had the lowest tree density value (6175.14 tree ha^{-1}) with a mean value of 247.01±22.03 where medium home gardens (0.03 > 0.05 ha) had medium tree density value (22660.13 tree ha^{-1}) with a mean value of 526.98±36.46. 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}) home gardens. A similar study was conducted by Jaman *et al.*, (2016). He found that tree density was the highest in the small home gardens (1629.5 individuals ha^{-1}) which was followed by medium (877.5 individuals ha^{-1}) and large-sized (385.3 individuals ha^{-1}) home gardens.

Table 10. Tree density of various home gardens in Manikganj district.

Home garden categories (H. G. No.)	Lower tree density value (LTDV) per Hectare	Higher tree density value (HTDV) per Hectare	Total tree density (ha $^{-1}$)	Mean ± SE
Small (n=52)	125.00	1333.33	30265.01	582.02±38.59
Medium(n=43)	216.66	1130.95	22660.13	526.98±36.46
Large (n=25)	80.95	450.00	6175.14	247.01±22.03

4.7.4 Average basal area (m^2 ha^{-1}) and mean DBH (cm) of various home garden in Manikganj district

Data based on average no. of tree (ha^{-1}), mean basal area (ha^{-1}), mean DBH (cm) were calculated from 120 home gardens in Manikganj district. Table 11 showed that small home gardens had the highest basal area (8.36 ± 1.00 m^2 ha^{-1}) followed by medium (7.86±0.83 m^2 ha^{-1}) and large home gardens (4.36 ± 0.56 m^2 ha^{-1}). In case of mean DBH large home gardens had the highest value of 13.40 ± 0.59 cm and small home gardens had the lowest value of 11.24 ± 0.65 cm where medium home gardens had moderate mean DBH of 11.32 ± 0.67 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 home gardens.

Table 11. Average basal area (m^2 ha^{-1}) and mean DBH (cm) of various home gardens in Manikganj district.

Home garden categories (H.G. No.)	Basal area (m^2 ha^{-1})			DBH (cm)		
	Lowest basal area (m^2ha^{-1})	Highest basal area (m^2ha^{-1})	Mean±SE	Lowest DBH (cm)	Highest DBH (cm)	Mean±SE
Small (n=52)	0.61	29.94	8.36±1.00	5.86	39.18	11.24±0.65
Medium(n=43)	1.6	25.25	7.86±0.83	4.31	21.65	11.32±0.67
Large (n=25)	1.07	10.87	4.36±0.56	8.76	18.72	13.40±0.59

Similar study was conducted in Rangpur district by Jaman *et al.* (2016) 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 home gardens, respectively. The mean DBH of large home gardens (11.23 cm) is comparatively higher than small (10.30 cm) and medium (10.16 cm).

4.8. Above ground carbon stocks at various home gardens in Manikganj 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 home gardens can contribute to mitigating climate change by its multistoried tree and other plant species.

4.8.1 Tree carbon stock (above ground) at various home gardens in Manikganj district

Above ground carbon stock at various home gardens were measured and significant differences were found. Among 120 home gardens average tree carbon stock (above ground carbon stock) was found 39.29±2.78 Mg ha^{-1} which ranged from 22.74 Mg C ha^{-1} to 165.51 Mg ha^{-1}. Among the home gardens, large home gardens (> 0.05 ha) had the lowest carbon stock (32.09±3.77 Mg ha^{-1}) with a number of 25 and the highest carbon stock (47.05±5.05 Mg ha^{-1}) was found in small home gardens (<0.02 ha) with a number of 52 while moderate carbon stock (38.72±4.06 Mg ha^{-1}) was found in medium home gardens with a number of 43 (Table 12). The variation in carbon content of individual home garden may be because of differences in garden composition, site characteristics, and holding sizes in different physiographic zones such as midlands, highlands and river basin area of Manikganj district. Size of gardens was a major factor affecting C stocks per unit area and it decreased in the order of small > medium > large (Figure 1).

Table 12. Above ground tree carbon stocks at various home gardens in Manikganj district

Home garden Category	**Number of home garden**	**Above ground carbon stock range (Mg/ha)**		**Mean±SE**
		Hightest	**Lowest**	
Small	52	165.51	6.11	47.05±5.05
Medium	43	123.11	5.30	38.72±4.06
Large	25	72.44	2.74	32.09±3.77
Total	**120**	165.51	2.74	39.29±2.78

Similar study was conducted in Rangpur district by Jaman *et al.* (2016) where average carbon stock (AGB C stock + BGB C stock) was 53.53 Mg ha^{-1}; n=64 which is ranging from 6.25 to 193.83 Mg ha^{-1} and small home garden had higher amount of carbon (69.15 Mg ha^{-1}) than medium (47.96 Mg ha^{-1}) and large (39.93 Mg ha^{-1}) home gardens. The variation in carbon stock within the home gardens in Kurigram district is due to size of home gardens, species composition, soil characteristics, management practices and financial conditions of the owner of the homestead.

4.8.2 Major tree species and their carbon content at various home gardens

From the study it was found that the highest amount of carbon was stored by *Mangifera indica* (41.25 Mg) followed by *Psidium guajava* (15.14 Mg), *Ziziphus jujuba* (31.45 Mg), *Swietenia mahogani* (27.21 Mg), *Artocarpus heterophyllus* (11.78 Mg), *Cocos nucifera* (6.39 Mg) and *Eucalyptus camaldulensis* (4.5 Mg) (Figure 3). The present study revealed that number of *Mangifera indica* was found the highest (572 trees), as a result *Mangifera indica* contains the highest amount of carbon. Similar study was conducted by Jaman *et al.* (2016) 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 home gardens.

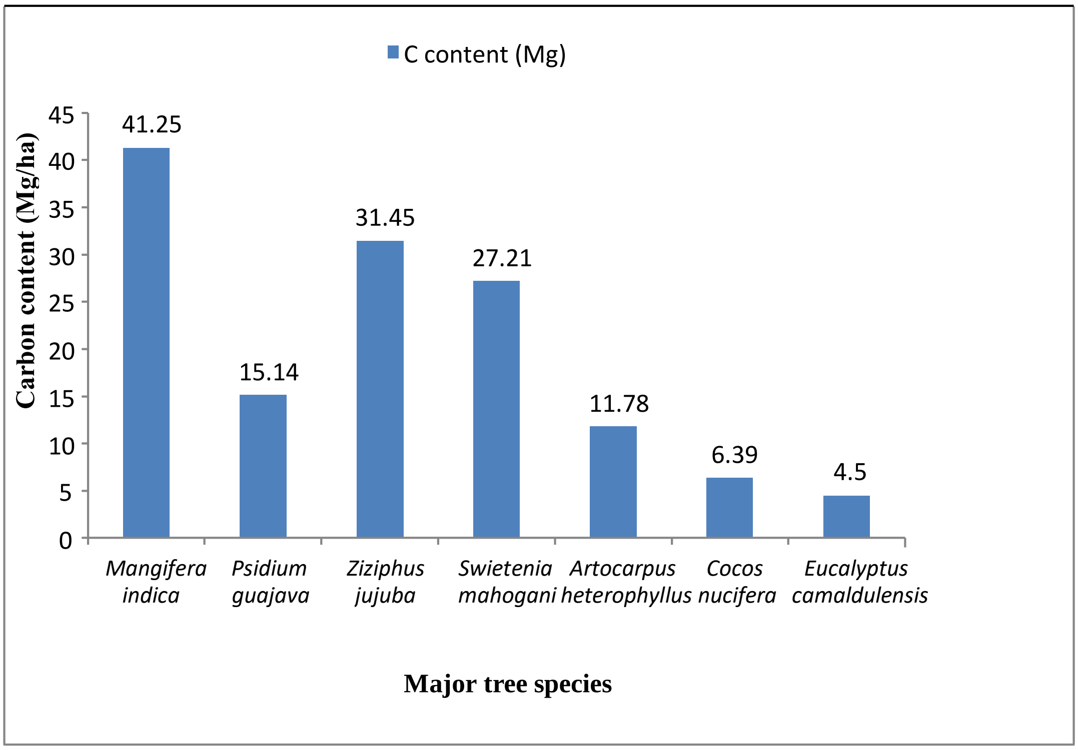


Figure 3. Major tree species and their carbon content in various homegarden in Manikganj district.

4.8.3 Relationship between stem density (tree ha^{-1}) and above ground tree carbon (Mg ha^{-1}) at various home gardens

Relationship between stem density (tree ha^{-1}) and tree carbon stocks (Mg ha^{-1}) was estimated at various home gardens and showed in Figure 4. The relationship was linear and estimated as; $y = 0.0467x + 21.212$ and $R^2 = 0.1396$ where R^2 was positive. So it indicated that there is a positive relationship between stem density (tree ha^{-1}) and above ground tree carbon stock (Mg ha^{-1}). The equation stated that tree carbon increased at a rate of 0.0467 Mg ha^{-1} per unit change of stem density tree ha^{-1}. Similar study was conducted by Jaman *et al.* (2016) and Iqbal (2015) and they found a positive relation between stem density (tree ha^{-1}) and tree carbon stock (Mg ha^{-1}) in their study.

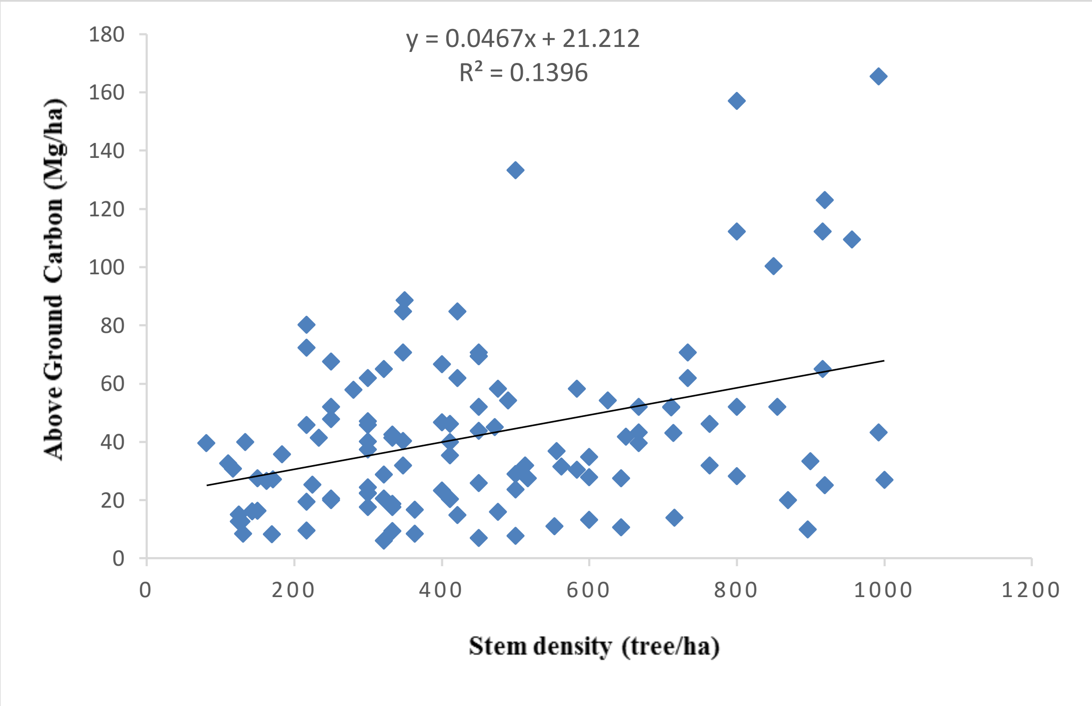


Figure 4. Relationship between stem density (tree ha^{-1}) and above ground carbon (Mg ha^{-1}).

4.8.4. Relationship between basal area ($m^2 ha^{-1}$) and above ground tree carbon ($Mg ha^{-1}$) at various home gardens

A linear relationship between basal area (m^2 ha^{-1}) and tree carbon stock (m^2/ha) was estimated as; $y = 4.8213x + 3.4059$ and $R^2 = 0.7313$ and presented in figure 5. The R^2 value was positive. So it indicates that there is a positive relationship between basal area (m^2 ha^{-1}) and above ground tree carbon stock (Mg ha^{-1}). The equation stated that tree carbon stock increased at a rate of 4.8213 Mg ha^{-1} per unit change of basal area (m^2 ha^{-1}). Similar study was conducted by Jaman *et al.* (2016) and Iqbal (2015) and they also found a positive relation between basal area and tree carbon stock in his study.

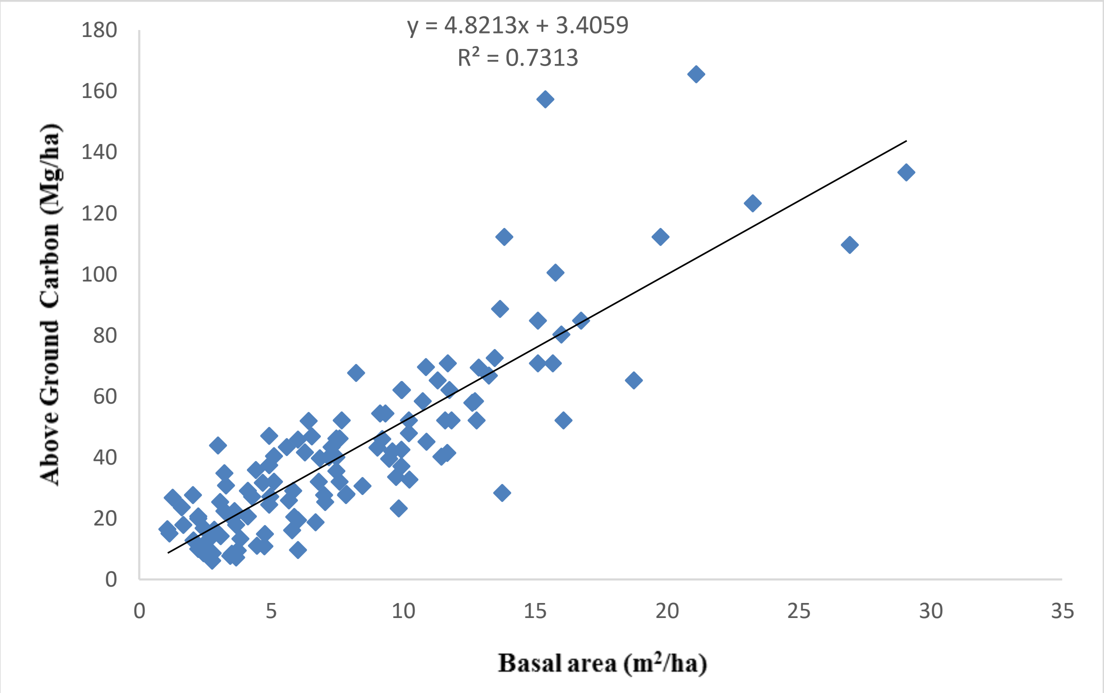


Figure 5. Relationship between basal area (m^2 ha^{-1}) and above ground tree carbon (Mg ha^{-1}).

4.8.5 Relationship between mean DBH (cm) and tree carbon stock (Mg/ha) per unit area

Relationship between mean DBH (cm) and tree carbon stock (above ground) were estimated at various home gardens and presented in Figure 6. A linear relationship between mean DBH and above ground carbon stock was estimated as; y = 3.4889x + 3.3555 and $R^2 = 0.2115$, where R^2 was positive. So, it indicates that there is a positive relationship between DBH and above gorund carbon stock. The equation also stated that carbon stock increased at the rate of 3.4889 Mg/ha 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 *et al.* (2016) and Iqbal (2015) and they found a positive relation between mean DBH and tree carbon stock in their study.

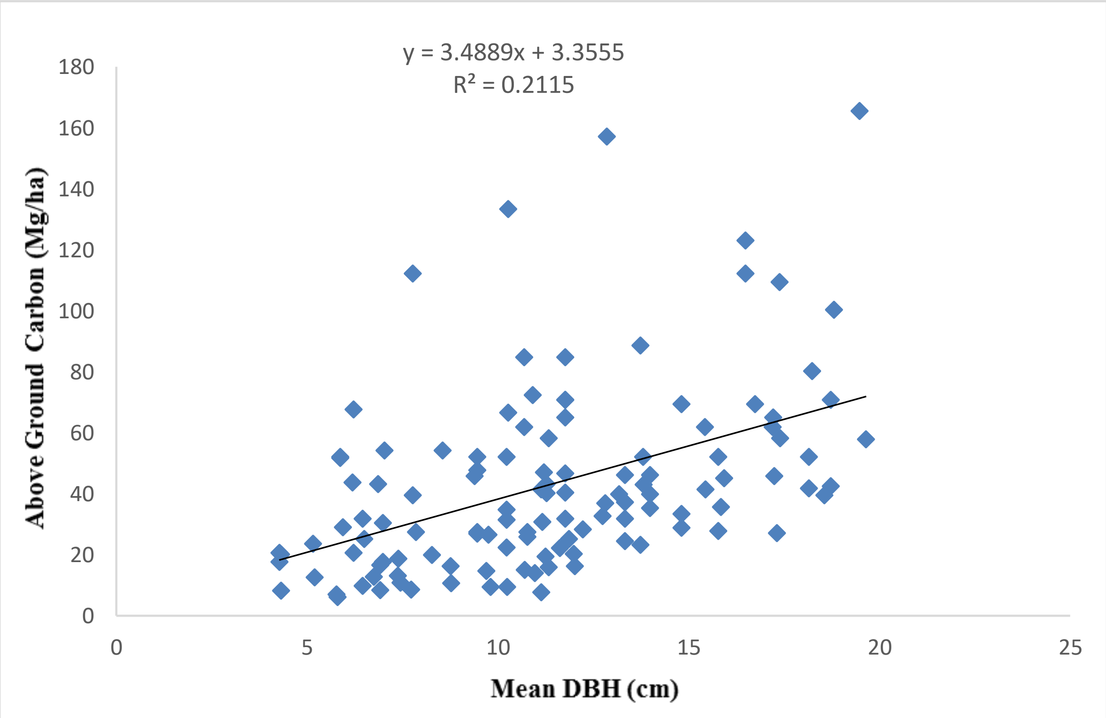


Figure 6. Relationship between mean DBH (cm) and tree carbon stock (Mg/ha).

4.8.6 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 = -3.2591x + 47.31 and R^2 = 0.0072 and showed in Figure 7, where the value of R^2 was positive. It indicated that there was a non-significant and weak correlation (5% level of significance) between tree diversity and tree above ground carbon. The equation stated that carbon stock decreased at a rate of 3.2591 Mg ha^{-1} per unit change in tree diversity. Similar study was conducted by Jaman *et al.* (2016) and he found a positive relation between tree diversity and tree carbon stock in his study. Day *et al.* (2013) found that the relationship between tree species diversity and tree carbon stock was significant but weakly correlated with each other in central African rainforest.

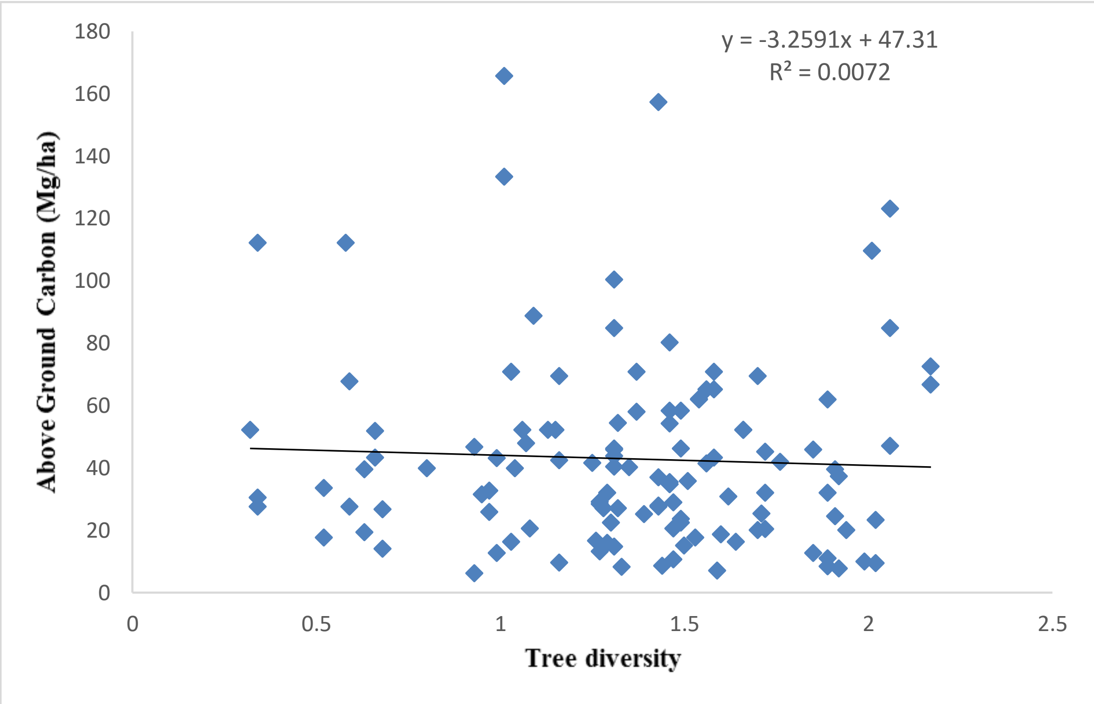


Figure 7. Relationship between tree diversity and tree carbon (Mg ha^{-1}).

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

A total of 120 home gardens were selected from four villages of Manikganj 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. A well-structured interview schedule was developed based on objectives of the study for collecting information with containing direct and simple questions in open form and close form keeping in view the dependent and independent variables. Appropriate scales were developed to measure both independent and dependent variables. The researcher himself collected data through personal contact. The independent variables were: age, level of education, farm size, annual income, type of plant species and their frequencies in a home garden etc. The dependent variable of this study was the plant diversity and quantification of above ground carbon storage of home gardens in Manikganj district. Various statistical measures such as frequency counts, percentage distribution, average, and standard deviation were used in describing data. Co-efficient of correlation test was used to explore relationship between the concerned variables. The major findings of the study are summarized below.

The middle-aged homestead owners comprised the highest proportion (45.00%), whereas the lowest proportion was made by the old aged category (20.83%). The respondent under secondary education category constitute the highest proportion (43.33%), whereas the lowest 5.83% were in can't read and sign category. The small farm holder constitutes the highest proportion (57.50%), while the lowest 11.67% was in marginal farm holder. 43.33% respondents had small home garden, whereas 20.83% had large home garden. The homestead owners having medium daily income constitute the highest proportion, while the lowest proportion in high income.

In a total of 120 home gardens 21 different species under 16 families were found which is a good indicator of biodiversity. The results of the study found that the most dominating species was Mango with a number of 572 and Mander was the least dominating species with a number of 4. There were seven major species found in the home gardens namely, Mango which is 28.74% of total number of species followed by Guava (14.62%), Jujube (11.11%), Mahagoni (10.65%), Jackfruit (7.59%), Coconut (6.08%) and Eucalyptus (4.92%).

The mean diversity value of the study area was 1.42 (SWI) with a range from 0.32 to 2.17. Among the three home garden categories the highest species diversity (SWI = 1.47) was found in large home gardens with the highest species number (21 nos.) and the lowest diversity (SWI = 1.21) was observed in small home gardens with lowest number of species (13 nos.), where the medium home gardens had a moderate diversity value (SWI = 1.46) with a moderate number of tree species (17 nos.). Among the three category of home gardens, small home gardens (0.01-0.03 ha) had the highest tree density (30265.01 tree ha^{-1}) with a mean value of 582.02 ha^{-1} and large home garden (>.05 ha) had the lowest tree density value (6175.14 tree ha^{-1}) with a mean value of 247.01 ha^{-1}.

Among 120 home gardens average tree carbon stock (above ground carbon stock) was found 39.29 mg ha^{-1} which ranged from 22.74 mg C ha^{-1} to 165.51 mg ha^{-1}. Among the home gardens, large home gardens had the lowest carbon stock (32.09 Mg ha^{-1}) and highest carbon stock (47.05 Mg ha^{-1}) was found in small home gardens. Among the seven major dominating species the highest amount of carbon was stored by Mango (41.25 mg) followed by Jujube (31.45 mg), Mahogani (27.21 mg), Guava (15.14 mg), Jackfruit (11.78 mg), Coconut (6.39 mg) and Eucalyptus (4.50 mg).

5.2 CONCLUSION

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

1. A variation in species occurrence and tree diversity were found in the study area. Among the home garden categories large home gardens had the highest value of tree diversity (SWI) followed by medium and large.

2. The highest amount of tree carbon (47.05 Mg ha^{-1}) was found in small home gardens and the lowest tree carbon (32.09 Mg ha^{-1}) was found in large home gardens where medium home gardens had a moderate value of tree carbon (38.72 Mg ha^{-1}).

3. Among different relationships, the relationship of basal area and DBH with above ground carbon stock showed significant positive correlation.

5.3 RECOMMENDATIONS

The finding of present study revealed that home gardens should be established in a small area with diverse tree species so that it sequester substantial amount of carbon and contribute to the global climate change. Considering the findings of the study the following recommendations can be drawn.

1. Farmers should be motivated for home garden establishment and they should be made aware about the relationship between carbon sequestration, biodiversity and home garden by different government and NGO‘s.

2. Other factors might have influenced the climate change adaptation to homestead production system, which need to be identified through further study.

3. Similar to the present study, more and large scale research should be conducted in other districts of Bangladesh including large number of home gardens, all categories of plant like palm, herbs, shrubs and other plant species under a varied climatic conditions.

CHAPTER VI

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APPENDICES

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

Department of Agroforestry and Environmental Science

Sher-e-Bangla Agricultural University

Dhaka-1207

Questionnaire for data collection

On

"PLANT DIVERSITY AND QUANTIFICATION OF ABOVE GROUND CARBON STORAGE OF HOME GARDENS IN SELECTED UPAZILAS OF MANIKGANJ DISTRICT"

(The interview schedule is entitled for a research study)

Serial no:

Name of the respondent:

Address:

Village:

Upazila:

Please answer the following question (put tick mark on the appropriate place where applicable)

1. Age: How old are you? .... years.

2. Level of 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. Home garden 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 homestead: 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 120 individual home gardens in Manikganj district.

H.G. no	H.G. categories	Tree diversity Value	Mean	Standard deviation	Standard Error
1	Small	1.56	1.21	0.49	0.07
2	Small	1.13			
3	Small	0.63			
4	Small	0.34			
5	Small	1.08			
6	Small	1.15			
7	Small	0.34			
8	Small	1.07			
9	Small	1.06			
10	Small	1.56			
11	Small	1.7			
12	Small	0.95			
13	Small	0.99			
14	Small	1.43			
15	Small	0.59			
16	Small	1.58			
17	Small	1.35			
18	Small	1.66			
19	Small	1.27			
20	Small	1.01			
21	Small	1.31			
22	Small	1.47			
23	Small	1.09			
24	Small	0.32			
25	Small	0.66			
26	Small	0.52			

H.G. no	H.G. categories	Tree diversity Value	Mean	Standard deviation	Standard Error
27	Small	0.93			
28	Small	1.32			
29	Small	0.58			
30	Small	1.01			
31	Small	0.59			
32	Small	1.43			
33	Small	1.53			
34	Small	1.43			
35	Small	2.02			
36	Small	1.92			
37	Small	2.17			
38	Small	1.66			
39	Small	1.31			
40	Small	1.7			
41	Small	1.47			
42	Small	1.27			
43	Small	1.58			
44	Small	1.76			
45	Small	2.01			
46	Small	0.34			
47	Small	0.93			
48	Small	0.52			
49	Small	2.02			
50	Small	1.43			
51	Small	0.66			
52	Small	1.47			

H.G. no	H.G. categories	Tree diversity Value	Mean	Standard deviation	Standard Error
1	Medium	0.97	1.46	0.35	0.05
2	Medium	1.46			
3	Medium	2.06			
4	Medium	1.29			
5	Medium	1.31			
6	Medium	1.72			
7	Medium	1.39			
8	Medium	1.46			
9	Medium	0.63			
10	Medium	2.06			
11	Medium	1.94			
12	Medium	1.26			
13	Medium	1.16			
14	Medium	1.31			
15	Medium	1.49			
16	Medium	1.89			
17	Medium	1.27			
18	Medium	1.37			
19	Medium	1.37			
20	Medium	1.99			
21	Medium	1.54			
22	Medium	1.49			
23	Medium	1.32			
24	Medium	1.89			
25	Medium	1.46			
26	Medium	0.99			
27	Medium	1.44			

H.G. no	H.G. categories	Tree diversity Value	Mean	Standard deviation	Standard Error
28	Medium	1.72			
29	Medium	0.97			
30	Medium	0.68			
31	Medium	1.03			
32	Medium	1.49			
33	Medium	1.46			
34	Medium	2.06			
35	Medium	1.29			
36	Medium	1.31			
37	Medium	1.72			
38	Medium	1.33			
39	Medium	1.89			
40	Medium	1.58			
41	Medium	1.31			
42	Medium	1.89			
43	Medium	1.49			

H.G. no	H.G. categories	Tree diversity Value	Mean	Standard deviation	Standard Error
1	Large	0.68			
2	Large	1.51			
3	Large	0.80			
4	Large	1.16			
5	Large	1.03			
6	Large	1.60			
7	Large	1.30			
8	Large	1.04			
9	Large	1.91			

H.G. no	H.G. categories	Tree diversity Value	Mean	Standard deviation	Standard Error
10	Large	1.85	1.47	0.37	0.07
11	Large	1.50			
12	Large	1.64			
13	Large	1.85			
14	Large	1.59			
15	Large	1.16			
16	Large	1.91			
17	Large	1.28			
18	Large	1.25			
19	Large	2.17			
20	Large	1.54			
21	Large	1.46			
22	Large	1.71			
23	Large	1.62			
24	Large	1.31			
25	Large	1.92			

APPENDIX III: Above ground carbon stock in 120 home gardens in Manikganj district.

H.G no.	H.G Categories	AGC (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard deviation	Standard Error
1	Small	65.09	47.05	36.45	5.05
2	Small	52.06			
3	Small	39.55			
4	Small	27.56			
5	Small	20.61			
6	Small	52.06			
7	Small	30.52			
8	Small	47.81			
9	Small	52.06			
10	Small	41.45			
11	Small	19.95			
12	Small	31.53			
13	Small	12.64			
14	Small	36.94			
15	Small	27.56			
16	Small	65.09			
17	Small	40.21			
18	Small	52.06			
19	Small	13.24			
20	Small	165.51			
21	Small	100.37			
22	Small	20.61			
23	Small	88.62			
24	Small	52.06			
25	Small	51.81			

H.G no.	H.G Categories	AGC (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard deviation	Standard Error
26	Small	33.46			
27	Small	46.75			
28	Small	26.95			
29	Small	112.19			
30	Small	133.35			
31	Small	67.66			
32	Small	157.19			
33	Small	17.71			
34	Small	27.56			
35	Small	9.43			
36	Small	7.71			
37	Small	66.73			
38	Small	52.06			
39	Small	43.75			
40	Small	69.4			
41	Small	10.71			
42	Small	28.31			
43	Small	43.23			
44	Small	41.83			
45	Small	109.52			
46	Small	112.19			
47	Small	6.11			
48	Small	17.71			
49	Small	23.24			
50	Small	27.92			
51	Small	43.23			
52	Small	28.88			

H.G no.	H.G Categories	AGC (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard deviation	Standard Error
1	Medium	25.88	38.72	26.65	4.06
2	Medium	35.38			
3	Medium	47.02			
4	Medium	31.9			
5	Medium	40.39			
6	Medium	45.07			
7	Medium	25.21			
8	Medium	58.28			
9	Medium	19.38			
10	Medium	84.75			
11	Medium	20.08			
12	Medium	16.65			
13	Medium	42.46			
14	Medium	14.81			
15	Medium	22.4			
16	Medium	10.96			
17	Medium	29			
18	Medium	70.77			
19	Medium	57.87			
20	Medium	9.94			
21	Medium	61.92			
22	Medium	58.28			
23	Medium	54.29			

H.G no.	H.G Categories	AGC (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard deviation	Standard Error
24	Medium	31.9			
25	Medium	80.24			
26	Medium	43.03			
27	Medium	8.55			
28	Medium	20.37			
29	Medium	32.68			
30	Medium	14.02			
31	Medium	70.77			
32	Medium	23.61			
33	Medium	54.27			
34	Medium	123.11			
35	Medium	16			
36	Medium	45.79			
37	Medium	31.9			
38	Medium	8.3			
39	Medium	8.42			
40	Medium	70.77			
41	Medium	84.75			
42	Medium	61.92			
43	Medium	46.12			

H.G no.	H.G Categories	AGC (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard Deviation	Standard error
1	Large	26.67	32.09	18.86	3.77
2	Large	35.77			
3	Large	39.9			
4	Large	9.52			
5	Large	16.34			
6	Large	18.72			
7	Large	22.35			
8	Large	39.91			
9	Large	24.49			
10	Large	45.83			
11	Large	15.04			
12	Large	16.26			
13	Large	12.76			
14	Large	7.08			
15	Large	69.43			
16	Large	39.53			
17	Large	27.07			
18	Large	41.47			
19	Large	72.44			
20	Large	62.01			
21	Large	34.78			
22	Large	25.31			
23	Large	30.74			
24	Large	46.12			
25	Large	37.35			

APPENDIX IV: Stem density, Basal area and Mean DBH of 120 home gardens in Manikganj District.

H.G. no	Home garden categories	Stem density (tree Ha^{-1})	Basal area ($m^2\ ha^{-1}$)	Mean DBH (cm)
1	Small	916.66	11.31	11.77
2	Small	250	10.22	9.46
3	Small	666.67	6.85	7.77
4	Small	642.86	7	7.85
5	Small	321.42	4.11	6.22
6	Small	711.11	7.67	5.86
7	Small	583.33	8.47	6.98
8	Small	250	10.22	9.46
9	Small	450	12.79	13.8
10	Small	333.33	11.68	11.14
11	Small	250	2.24	8.27
12	Small	562.5	4.68	10.22
13	Small	125	2.61	5.19
14	Small	555.88	9.94	12.81
15	Small	516.66	7.83	10.77
16	Small	321.42	18.76	17.22
17	Small	300	11.45	11.27
18	Small	800	16.09	18.15
19	Small	600	3.83	7.38
20	Small	992.06	21.13	19.48
21	Small	850	15.79	18.8
22	Small	250	2.24	4.27
23	Small	350	13.69	13.73
24	Small	666.67	11.84	15.77
25	Small	711.11	6.43	5.86
26	Small	900	9.73	14.81

H.G. no	Home garden categories	Stem density (tree ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH (cm)
27	Small	400	6.55	11.77
28	Small	1000	4.97	9.46
29	Small	800	19.76	7.77
30	Small	500	29.09	10.27
31	Small	250	8.22	6.22
32	Small	800	15.39	12.86
33	Small	333.33	3.68	6.98
34	Small	150	2.03	9.46
35	Small	333.33	3.74	9.8
36	Small	500	3.44	11.14
37	Small	400	13.25	10.27
38	Small	854.7	11.59	10.22
39	Small	450	2.98	6.19
40	Small	450	12.87	14.81
41	Small	642.86	4.74	8.77
42	Small	800	13.76	12.22
43	Small	666.67	5.59	11.27
44	Small	650	9.59	18.15
45	Small	955.88	26.95	17.38
46	Small	916.66	13.84	16.48
47	Small	321.42	2.76	5.8
48	Small	300	1.67	4.27
49	Small	400	9.83	13.73
50	Small	600	7.85	15.77
51	Small	992.06	7.29	6.86
52	Small	321.42	4.11	14.81

H.G no.	H.G Categories	Stem density (trees ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH (cm)
1	Medium	450	5.68	10.77
2	Medium	411.11	7.47	13.99
3	Medium	300	4.93	11.2
4	Medium	763.16	7.59	13.33
5	Medium	347.22	5.11	11.76
6	Medium	472.22	10.88	15.93
7	Medium	919.28	7.05	6.49
8	Medium	476.19	12.73	11.33
9	Medium	216.66	6.01	11.24
10	Medium	347.22	15.11	11.76
11	Medium	869.57	3.5	4.31
12	Medium	363.64	2.44	6.91
13	Medium	333.33	9.94	18.72
14	Medium	421.05	4.76	9.69
15	Medium	300	3.22	10.22
16	Medium	552.88	4.46	7.45
17	Medium	500	5.83	5.93
18	Medium	347.22	15.11	11.76
19	Medium	280.61	12.62	19.65
20	Medium	896.36	2.24	6.45
21	Medium	421.05	11.76	10.69
22	Medium	583.33	10.74	17.4
23	Medium	490.2	9.34	8.55
24	Medium	513.4	6.81	6.45
25	Medium	216.66	16.01	18.24
26	Medium	714.29	9.03	13.82
27	Medium	130.95	2.79	7.72

H.G. no	Home garden categories	Stem density (tree ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH(cm)
28	Medium	411.11	5.87	11.99
29	Medium	110.53	10.25	12.74
30	Medium	715.79	3.08	10.96
31	Medium	450	15.68	11.77
32	Medium	500	1.6	5.15
33	Medium	625	9.14	7.03
34	Medium	919.28	23.27	16.49
35	Medium	476.19	5.8	11.33
36	Medium	216.66	6.01	17.24
37	Medium	347.22	5.11	11.76
38	Medium	169.57	3.5	4.31
39	Medium	363.64	2.44	6.91
40	Medium	733.33	11.69	18.72
41	Medium	421.05	16.76	10.69
42	Medium	300	9.93	17.2
43	Medium	763.16	7.59	13.33

H.G. no	Home garden categories	Stem density (tree ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH(cm)
1	Large	162.5	1.27	9.75
2	Large	183.33	4.43	15.84
3	Large	133.33	7.19	13.17
4	Large	216.66	6.01	10.24
5	Large	150	1.07	8.76
6	Large	333.33	6.69	7.39
7	Large	300	3.62	11.63
8	Large	411.11	7.47	13.99
9	Large	300	4.93	13.33
10	Large	300	9.21	9.39

H.G. no	Home garden categories	Stem density (tree ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH(cm)
11	Large	125	1.14	10.7
12	Large	142.85	2.85	12.01
13	Large	128.57	2.06	6.74
14	Large	450	3.68	5.77
15	Large	450	10.87	16.74
16	Large	80.95	9.47	18.56
17	Large	171.42	4.28	17.31
18	Large	233.33	6.29	15.44
19	Large	216.66	13.48	10.91
20	Large	733.33	9.97	15.43
21	Large	600	3.22	10.22
22	Large	225	3.06	11.86
23	Large	116.66	3.29	11.16
24	Large	411.11	7.47	13.99
25	Large	300	4.93	13.33

APPENDIX V: Farmer' income from 120 home gardens in Manikganj 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	25000	68.49	150000	410.96	479.45
2	Small	50000	136.99	360000	986.30	1123.29
3	Small	5000	13.70	240000	657.53	671.23
4	Small	25000	68.49	200000	547.95	616.44
5	Small	30000	82.19	108000	295.89	378.08
6	Small	20000	54.79	200000	547.95	602.74
7	Small	10000	27.40	200000	547.95	575.34
8	Small	21000	57.53	108000	295.89	353.42
9	Small	27000	73.97	200000	547.95	621.92
10	Small	8000	21.92	200000	547.95	569.86
11	Small	15000	41.10	500000	1369.86	1410.96
12	Small	10000	27.40	108000	295.89	323.29
13	Small	20000	54.79	108000	295.89	350.68
14	Small	15000	41.10	144000	394.52	435.62
15	Small	18000	49.32	108000	295.89	345.21
16	Small	9000	24.66	108000	295.89	320.55
17	Small	6000	16.44	288000	789.04	805.48
18	Small	25000	68.49	108000	295.89	364.38
19	Small	13000	35.62	600000	1643.84	1679.45
20	Small	10000	27.40	108000	295.89	323.29
21	Small	16000	43.84	180000	493.15	536.99
22	Small	10000	27.40	120000	328.77	356.16
23	Small	60000	164.38	108000	295.89	460.27
24	Small	15000	41.10	500000	1369.86	1410.96
25	Small	25000	68.49	400000	1095.89	1164.38

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.)
26	Small	30000	82.19	300000	821.92	904.11
27	Small	35000	95.89	250000	684.93	780.82
28	Small	45000	123.29	150000	410.96	534.25
29	Small	10000	27.40	300000	821.92	849.32
30	Small	17000	46.58	250000	684.93	731.51
31	Small	40000	109.59	400000	1095.89	1205.48
32	Small	33000	90.41	150000	410.96	501.37
33	Small	35000	95.89	350000	958.90	1054.79
34	Small	12000	32.88	150000	410.96	443.84
35	Small	10000	27.40	200000	547.95	575.34
36	Small	15000	41.10	450000	1232.88	1273.97
37	Small	7000	19.18	108000	295.89	315.07
38	Small	21000	57.53	160000	438.36	495.89
39	Small	11000	30.14	200000	547.95	578.08
40	Small	7000	19.18	230000	630.14	649.32
41	Small	9000	24.66	250000	684.93	709.59
42	Small	10000	27.40	120000	328.77	356.16
43	Small	35000	95.89	240000	657.53	753.42
44	Small	10000	27.40	360000	986.30	1013.70
45	Small	15000	41.10	100000	273.97	315.07
46	Small	20000	54.79	120000	328.77	383.56
47	Small	20000	54.79	120000	328.77	383.56
48	Small	25000	68.49	180000	493.15	561.64
49	Small	15000	41.10	120000	328.77	369.86
50	Small	30000	82.19	180000	493.15	575.34
51	Small	3000	8.22	240000	657.53	665.75
52	Small	18000	49.32	180000	493.15	542.47

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	40000	109.59	200000	547.95	657.53
2	Medium	60000	164.38	150000	410.96	575.34
3	Medium	25000	68.49	300000	821.92	890.41
4	Medium	30000	82.19	200000	547.95	630.14
5	Medium	40000	109.59	400000	1095.89	1205.48
6	Medium	45000	123.29	400000	1095.89	1219.18
7	Medium	50000	136.99	100000	273.97	410.96
8	Medium	60000	164.38	150000	410.96	575.34
9	Medium	60000	164.38	100000	273.97	438.36
10	Medium	20000	54.79	400000	1095.89	1150.68
11	Medium	40000	109.59	200000	547.95	657.53
12	Medium	50000	136.99	120000	328.77	465.75
13	Medium	70000	191.78	80000	219.18	410.96
14	Medium	80000	219.18	80000	219.18	438.36
15	Medium	60000	164.38	120000	328.77	493.15
16	Medium	35000	95.89	300000	821.92	917.81
17	Medium	40000	109.59	360000	986.30	1095.89
18	Medium	80000	219.18	120000	328.77	547.95
19	Medium	60000	164.38	150000	410.96	575.34
20	Medium	10000	27.40	300000	821.92	849.32
21	Medium	15000	41.10	300000	821.92	863.01
22	Medium	25000	68.49	240000	657.53	726.03
23	Medium	35000	95.89	300000	821.92	917.81
24	Medium	50000	136.99	120000	328.77	465.75
25	Medium	75000	205.48	80000	219.18	424.66
26	Medium	35000	95.89	120000	328.77	424.66

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.)
27	Medium	48000	131.51	150000	410.96	542.47
28	Medium	50000	136.99	120000	328.77	465.75
29	Medium	25000	68.49	240000	657.53	726.03
30	Medium	30000	82.19	240000	657.53	739.73
31	Medium	40000	109.59	180000	493.15	602.74
32	Medium	60000	164.38	80000	219.18	383.56
33	Medium	70000	191.78	120000	328.77	520.55
34	Medium	70000	191.78	120000	328.77	520.55
35	Medium	35000	95.89	240000	657.53	753.42
36	Medium	40000	109.59	180000	493.15	602.74
37	Medium	20000	54.79	300000	821.92	876.71
38	Medium	10000	27.40	360000	986.30	1013.70
39	Medium	15000	41.10	200000	547.95	589.04
40	Medium	25000	68.49	200000	547.95	616.44
41	Medium	50000	136.99	120000	328.77	465.75
42	Medium	50000	136.99	180000	493.15	630.14
43	Medium	20000	54.79	360000	986.30	1041.10

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	50000	136.99	240000	657.53	794.52
2	Large	70000	191.78	180000	493.15	684.93
3	Large	90000	246.58	120000	328.77	575.34
4	Large	50000	136.99	240000	657.53	794.52
5	Large	100000	273.97	100000	273.97	547.95

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.)
6	Large	50000	136.99	240000	657.53	794.52
7	Large	60000	164.38	360000	986.30	1150.68
8	Large	75000	205.48	150000	410.96	616.44
9	Large	40000	109.59	360000	986.30	1095.89
10	Large	60000	164.38	120000	328.77	493.15
11	Large	75000	205.48	90000	246.58	452.05
12	Large	80000	219.18	120000	328.77	547.95
13	Large	90000	246.58	120000	328.77	575.34
14	Large	96000	263.01	120000	328.77	591.78
15	Large	84000	230.14	96000	263.01	493.15
16	Large	72000	197.26	120000	328.77	526.03
17	Large	50000	136.99	96000	263.01	400.00
18	Large	60000	164.38	180000	493.15	657.53
19	Large	48000	131.51	240000	657.53	789.04
20	Large	60000	164.38	150000	410.96	575.34
21	Large	75000	205.48	100000	273.97	479.45
22	Large	80000	219.18	120000	328.77	547.95
23	Large	96000	263.01	120000	328.77	591.78
24	Large	80000	219.18	120000	328.77	547.95
25	Large	60000	164.38	180000	493.15	657.53