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Tree Composition and Carbon Sequestration Potential of Homegardens in Khulna District, Bangladesh.

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DECLARATION

I, Aruba Sultana, declare that this thesis is the result of my own work and it has not been submitted or accepted for any degree to other university or institution.

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Aruba Sultana

DEDICATED
TO
MY BELOVED PARENTS
AND
YOUNGER BROTHER

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ABSTRACT

Climate change mitigation and adaptation under changing environment, homegarden systems are suggested to hold a large potential for carbon (C) sequestration. This is because of the multifunctional ecosystem services of homegardens for storing carbon. In this research total above and below ground carbon stock and tree species diversity were quantified in homegarden of Khulna District situated in southwestern part of Bangladesh. A total of 45 homegardens were selected as sample purposively. All trees with DBH $\geq$ 10 cm were censused and their diameters and height measured by using diameter tape and criterion RD 1000. A total 56 species in 22 families were recorded. Mean above and below ground biomass carbon stocks (AGB+BGB) was found 62.65 Mg ha^{-1} by using allometric equations and it was higher than other studies (53.53 Mg ha^{-1}) in homegarden of Rangpur district, Bangladesh (Jaman et al. 2016). Mean carbon stock per unit area in this study was higher in small homegarden (98.99 Mg ha^{-1}) compared to medium (51.83 Mg ha^{-1}) and large (37.13 Mg ha^{-1}) homegarden respectively. The study area is a reservoir of carbon evident that home gardening is an effective way of offsetting CO2 from human sources.

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List of Acronyms

AGB	Aboveground Biomass
AGC	Aboveground carbon
BGB	Belowground Biomass
BGC	Belowground Carbon
C	Carbon
CO_2	Carbon dioxide
IPCC	Intergovernmental Panel on Climate Change
DBH	Diameter at Breast Height
FAO	Food and Agriculture Organization
GHG	Green House Gas
REDD+	Deforestation and Forest Degradation "plus"
SFM	Sustainable Forest Management
GPS	Global Positioning System
UNFCCC	United Nations Framework Convention on Climate Change

List of Units

cm	Centimeter
ha	Hectare
Kg	Kilogram
m	Meter
m^2	Square meter
Mg	Mega gram
Ppm	Parts Per Million

CHAPTER 1

1 Introduction

1.1 Background of the Study

Nowadays the world is facing leading challenges mainly by increasing CO_2 leading to global warming which occurs mostly due to man-made emissions of greenhouse gases (IPCC 2013). These greenhouse gases are emitted mainly due to deforestation and combustion of fossil fuel. (Detwiler et al. 1988). The major portion of these gases resulting from the burning of fossil fuels and the conversion to tropical forests to agricultural production of a rate of 3.5 pg (pg=1015 g or billion tons) per annum carbon (Paustian et al 2000). Speedy post industrialization upsurges in the atmospheric CO_2 concentration have impelled several studies on the global carbon (C) balance (Dixon et al. 1994). The increase of average global temperature 0.74°c is caused by increasing amount of atmospheric CO_2 from 1906 to 2005. (IPCC 2007). The average annual CO_2 increase is about 1.5 ppm that will be doubled at the end of 21st century (Griggs et al. 2002). If the present rate of increasing global temperature continues, the sea level will raise up to 5 m by melting polar ice-cap as well as the earth climate and land use system also change (Detwiler et al. 1988).

Bangladesh is liable to be one of the most defenseless susceptible countries in the world to climate change as it locates low-lying coastal region but it is a low CO_2 emitting country. For instance, the per capita CO_2 emission is estimated at 0.2 ton/year, while the average for developing countries is 1.6 ton/year. In USA the per capita emission is 20 ton/year. The low greenhouse gases emission status however provides no relief from the effects of global warming because 1.5 meter rise in sea level would inundate an area of 22,000 sq.km of Bangladesh, affecting 17 million people. Obviously Bangladesh is likely to be one of the worst suffers of global warming but she is not liable for this rather she is playing crucial role in carbon sequestration (Waste concern & UNDP 2012). The annual yield from rain-fed agricultural field will be reduced 50% due to rising temperature. Food security will also be hampered and the land use system will be changed. As it misplaces land to increasing sea levels, but increases land from sediment deposition. The effects of sea level rise and land deposition in Bangladesh are highly regional and diversified. It has been estimated that the south-eastern part of Bangladesh will go under water due to ice melting within 2050. As a result, Bangladesh would need to prepare for long-term adaptation due to seasonal variations and introducing different variety of species those are capable to adopt the changing climate as well as ice water.

To be prolific and striking for climate change mitigation, forests should have prolonged woody characteristics. Forest can play a vital role in carbon storing by sustained management. According to FAO 60% of the total is under the Unclassified State Forest and the remaining 11% is under homestead forest forest area in Bangladesh is maintained by the Forest Department, 29%. A classical homestead forest is a fundamental portion of the farmer's agricultural structure and an addition to the household, where a number of trees, shrubs, and herbs are grown for eatable products and economic returns, as well as for productive and protective benefits comprising aesthetic and environmental welfares (Dey et al. 2014). It is an old-style agroforestry system typically in link with livestock (Kabir & Edward L. 2008). Both agroforestry system and homestead forests are rich with diversified crops and plant species (Dey et al. 2014). In a tropical homegarden species diversity is higher than others. Its species diversity depends mainly on its geographic location and climate (Kumar & B. Mohan. 2011, Kumar et al. 2004). Ecologists as well as Environmentalists are interested about species diversity of homegardens because it has been proved that homegardens with higher species diversity may promote efficient use of resources and greater net primary production and can store more carbon compare to other sites with the lower diversity of species (Zhang et al. 2011, Vandermeer, John H. 1992, Kirby et al. 2007).

As agroforestry has been recognized as a great potential for carbon sequestration and climate change adaptation and mitigation, homegardens are distinctive in this respect (Kumar & B. Mohan. 2011). Homegardens are not only responsible for carbon sequestration in soil and biomass, but also safeguard biodiversity and promote fuel wood to diminish the rate of fossil fuel burning (Kumar et al. 2004). They furthermore support to keep carbon stock in surviving natural forest by lessening the stress on these areas (Kumar & B. M. 2006). It is a long-lasting agroforestry system to raise carbon stock as there is no clear cutting system practice here (Kumar & B. Mohan. 2011). As more than half of the carbon that woody perennials are adapted in homegardens is also conveyed belowground through root growth or organic matter turnover processes (e.g., fine roots dynamics, rhizode position, and litter dynamics). As a result, soil organic carbon pool is increased day by day (Kumar & B. M. 2006).

Now the world forest current carbon stock is estimated to be (861±66) Pg C, with (363±28) Pg C (42%) in live biomass (above & below ground). Geologically, 55% carbon is stored in tropical forests, (Pan et al. 2011). Uncertain forest degradation and deforestation can fund to shrink about 18% atmospheric CO_2 emission (IPCC 2007). To avert global warming, carbon sequestration should be enriched by swelling forest coverage has been recommended by certain studies (Watson et al. 2000). Under Kyoto Protocol's Article 3.3, A&R (reforestation & afforestation) with agroforestry as a part of it has been documented as an opportunity for alleviating greenhouse gases. According to Kyoto Protocol, the general public are converted to agroforestry practice for carbon sequestration (Atangana et al. 2014).

Now carbon trading is well debated topic in the world. Carbon trading is an economic tool which, in essence, allows for several parties to meet total emission reduction requirements at lower costs by working together. The goal is to recover the whole elasticity and economic efficiency of gaining emission reduction. Bangladesh as previously approved the Kyoto protocol may apply for emission permit for trading and if allowed exchange the amount Bangladesh does not emit with other countries carbon trading compels to keep the emissions of CO_2 within a certain limit. As a whole it is a rewarded to who are emitting less CO_2 and a charge on who are responsible for global warming. It is not far behind that when minor holder farmer will get money in exchange of planting trees surrounding their household. So, it is very much essential for Bangladesh to estimate the biomass or carbon stock of the homegarden for receiving the carbon trading services. In Bangladesh, maximum homegardens studies are about floristic composition, structure, economy of homegarden, uses and the relationship between homegardens characteristics and household (Webb et al. 2009). Kumar (2006) reviewed the countries where studies conducted on homegardens potential for carbon sequestration but no studies have yet been documented on homegardens carbon sequestration particularly for Bangladesh. Thus this study is inspired to be conducted with the following objectives.

1.2 Objectives

- To explore the plant species composition and species frequency of homegardens.
- To Estimate Carbon Sequestration Potential of homegardens.

1.3 Scopes

1. The discoveries of this study will be beneficial to understand the ability of homegardens to contribute to mitigation of global warming and estimate the diversity of species as well as carbon stock.
2. The Kyoto Protocol of the UNFCCC has introduced Clean Development Mechanism concept among the low-income people who can store carbon through a change in their land uses. This study helps to rise sinks for carbon while at the same time improving livelihoods of low-income people.

CHAPTER 2

2 Literature Review

2.1 Introduction

Homegarden in Bangladesh is a joined production system and a stable ecosystem that maintains the diversity of as well as the natural wealth. It is the main source of food, fruits, vegetables, timber and fuel for the household and is a reliable source of household income. Shortage of fuel was common irrespective of farm size but it was more acute in the smaller farm categories. About 75% timber demand and 85% of fuel wood demand are met by homegardens production. It was estimated that about 10% of the standing volume of wood on homestead forests is removed every year, representing that homestead plantations are under inexpensive pressure (Zaman et al. 2009). Continued denudation of the forest vegetation has turned to barren with mostly covered by grass, scrub or bush. Though the forest area of Bangladesh is 17.8%, 40% of the forest area has less than 30% tree cover (Altrell et al. 2007).

2.2 Concepts of Homegarden

Homegardens as the property neighboring a house on which combination of annual and perennial are grown, together with or without animals, and largely managed by the household fellows for their personal use or commercial purpose (Asfaw & Zemede. 2002). Wills (1914) first described mixed garden as a "wild jungle-like mixture of fruit trees, bamboos, vegetables, etc." Torquebiau (2000) further classifies them as agroforestry homegardens in order to avoid possible confusion with domestic vegetable gardens. Its production now commonly serves household and market demand, providing families with much required profits (Michon & Mary. 1994).

Homegardens are broadly experienced in Latin America, Southeast Asia and Equatorial Africa and are the most sustainable cropping system in the tropics, having many different local names in different countries even in different places within a country (Herzog. 1994). Some of the different names are agroforestry homegardens, household or homestead farms, compound farms, mixed garden, house garden, tree garden, kitchen garden, dooryard garden and backyard garden (Kumar et al. 2004). Some of the local names are kebun in Malaysia, shamba and chagga in East Africa, pekarangan in Java (Kumar et al. 2004), kampong in Indonesia, jardin creole in West Indies, dooryard gardens in America (Michon et al. 1983), quintal and calmil in Tropical, kibanja in North West Tanzania, compound farms in Africa, and bagan bari in Bangladesh (Millate-E-Mustafa et al. 1996). A total of 270,000 ha area i.e., 2% of country's total land area and 10% of country's total priory forests area is under homegarden agroforestry systems in Bangladesh (FAO 2005).

2.3 Species Composition and Diversity

Several scholars stated that species diversity in homegardens is influenced by the exact requirements, perceptions, information, abilities, culture, philosophy and practice of the gardeners as well as environmental and financial perspective of the gardens (Hamlin et al. 2003, Ahmed et al. 2004). Depending on the above contemplations crops, trees, animals are retained or excluded within any homegarden (Millate-E-Mustafa et al. 1996). Species composition, richness or diversity also depends on homestead size and vary from region to region (Kumar et al. 2004). When the gardener feels any needs i.e., food, wood, medicinal, religious, ornamental, etc. then he introduced a new species. Species introduction has no fixed time, it depended on space availability and soil condition (Rico-Gray et al. 1990, Kumar et al. 2004).

There is so many indirect factors that can affected or influenced homegardens species composition and diversity. They are age of the household i.e., old age household has more diversity, socio-economic status i.e., wealthy household has more species than the poor one, market availability i.e., household nearer from market are more diversified (Blanckaert et al. 2004, Coomes et al. 2004, Kehlenbeck et al. 2004, Weersum & K. F. 1982). Biophysical reasons such as geographic, physiographic, climatic, population density, labors availability etc. may influence the species diversity in the homegardens (Hoogerbrugge et al. 1993).

In Bangladesh the total land figure, 63.74% are engaged by agricultural land, 9.6% marshy land, 9.21% national forest, 7.26% homestead land, 6.94% unclassed state forest, 2.46% uncultivated land, and 0.79% tea gardens respectively (Das 1986). Composition of species in the homegarden of Bangladesh is going from small to big trees.

2.4 Studies on Species Diversity

In tropical homegarden, species diversity is generally very high and may have species different from those found in neighboring natural structures (Babur et al. 1982). Ecological and socio-economic factors also influence species diversity. In Bangladesh, homegardens represent a well-established traditional land-use system where natural forest cover is less than 10%, which are maintained by at least 20 million households, represent one possible strategy for biodiversity conservation (Kabir & Webb (2008). Since the natural forest of Bangladesh are decreasing day by day, homegardens may be the best way to save the next world.

Several studies showed that species diversity in a homegarden can range from less than five to more than 100 species (Coomes et al. 2004). Summary of literature on values of diversity index and species richness index of homegardens of different part of Bangladesh is given below-

Table 2.1 Values of diversity index and species richness index of homegardens of different part of Bangladesh based on literature

Location	Value of diversity index	Value of richness index	Sources
Sylhet Sadar, Bangladesh	3.1	7.7	Motiur et al. 2005
Kishoreganj Sadar, Bangladesh	3.37	4.78	Roy et al. 2013
Sandwip Sub-district, Bangladesh	3.4	20.65	Alam et al. 2005

2.5 Frequency of the Species in Homegardens

Frequency is the number of times a trees species is present in a given number of quadrats of a particular size or at a given number of sample points. The idea of frequency mentions to the uniformity of a species in its distribution over an area. No counting is involved just a record of species present. In homestead forests it refers to the degree of individual species in the area and is usually expressed in terms of percentage of occurrence. The contribution made by every species in a homegarden can be expressed as a percentage of the total number of species, which is called frequency. Raunkiaer (1934) first introduced, it indicates the number of sampling units in which a given species occurs (Mishra 1968). Since, it often reflects the patterns of distribution of individuals as well as their density. Information about both patterns and abundance is also expressed by it. Species and individuals can be grouped into growth form classes on the basis of their relationships in structure and growth, which displays an understandable relationship to vital environmental aspects.

2.6 Carbon Sequestration

Carbon sequestration can be defined as the amount of carbon that can be additionally stored in an agro-ecosystem (Cerri et al. 2006). At present, carbon sequestration is valued as a function of credit emission reductions (CREs), based on the difference between the amount of carbon stored in scenario projects and baseline, current amount of carbon stored in the system (UNFCCC 2004). The UNFCCC (1992) defines carbon sequestration as the process of removing carbon from the atmosphere and depositing it in a reservoir. According to the U.S. Geological Survey (USGS 2008), The term "carbon sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments) and geologic formations. Finally, carbon sequestration refers to the capture and long-term storage of carbon in forests and soils so that the build-up of CO_2 (one of the principles greenhouse gases) in the atmosphere will reduce or slow.

2.6.1 Types of Carbon Sequestration

According to IPCC (2005), CO_2 sequestration can be done by the following three ways,

I. Terrestrial Sequestration or Vegetative Sequestration:

Terrestrial sequestration is the natural intake of CO_2 by plants, which incorporate in their wood, leaves, and roots and also bind it to the underlying soil so much of this CO_2 is not released into the atmosphere until the plant is destroyed (by decay or burning) or the soil is tilled and exposed to the atmosphere. This can be enhanced by increasing the growth of land plants through planting trees, mitigating deforestation or adjusting forest management practices. It is the easiest and most immediate option for carbon sequestration at the present time.

II. Geologic Sequestration:

Geo-sequestration is burying the CO_2 deep within the earth. It can be done by the mechanical capture of CO_2 from an emission source (e.g., a power plant, fossil fuel burning etc.) and the captured CO_2 is injected and sealed into deep rock units. The most suitable sites are deep geological formations, such as depleted oil and natural gas fields or deep natural reservoirs filled with saline water (saline aquifers).

III. Oceanic Sequestration:

Oceanic sequestration is dumping the CO_2 into the depths of the ocean. This uptake is not a result of deliberate sequestration but occurs naturally through chemical reactions between seawater and CO_2 in the atmosphere. While absorbing atmospheric CO_2, these reactions cause the oceans to become more acidic. Many marine organisms and ecosystems depend on the formation of carbonate skeletons and sediments that are vulnerable to dissolution in acidic waters (USGS 2008).

2.7 Impact of Global Warming in Bangladesh

As Bangladesh is a low carbon dioxide emitting country, the per capita emission rate at 0.2 ton/year, the average for developing countries is 1.6 ton/year. The low greenhouse gases emission status however provides no relief from the effects of global warming because 1.5 meter rise in sea level would inundate an area of 22,000 sq.km of Bangladesh, affecting 17 million people. Obviously Bangladesh is likely to be one of the worst suffers of global warming. The other impacts would be on-

- Agriculture
- Bio-diversity and Forestry
- Human health
- Fisheries
- Drainage
- Fresh water (Waste concern, UNDP. 2012).

2.8 Homegarden as a Climate Change Mitigation Tool

Homegarden has its massive significant in climate change mitigation and greenhouse gas minimization through improve carbon sequestration (Verchot et al. 2007). Numerous planning of plant and relatively high species diversity prevent environmental degradation and deliver financial welfares and keep a complete and sustainable ecology (Mohan & Soumya 2004, Jaman et al. 2016). It is sound recognized that conservation of ecosystem and biodiversity is essential for benefit of the human being. Almost 75% of earthly biomes have changed its features due to several anthropogenic doings (Beaumont et al. 2011). So, forest has an important role in global carbon cycle (Pan et al. 2011) and forestry can contribute to climate change mitigation through three different ways like carbon sequestration, carbon conservation and carbon substitution.

2.8.1 Carbon Sequestration

As they grow, trees absorb CO_2 and through Photosynthesis, sequester carbon to produce wood. Newly established forests (on reforested or afforested sites) and forest re-growth can sequester carbon quickly and will store it for the life of the forest. When trees are harvested efficiently, a large part of the sequestered carbon can be used to produce wood products such as house frames and thus stored in the medium to long term (IPCC 2007).

2.8.2 Carbon Conservation

The most expensive way to mitigate climate change in the forest is to reduce deforestation and forest degradation, thereby reducing GHG emission. In climate change negotiation, this strategy is usually referred to as "reducing emission from deforestation and degradation" (IPCC 2007).

2.8.3 Carbon Substitution

Forest products can substitute for products from other sectors that have a relatively high GHG emission. Wood-based fuels such as fuel wood, Charcoal, black liquor and ethanol can be used as substitutes for fossil fuels in heating, energy generation and transport. When wood is produced in the forest under a sustainable forest management (SFM) regime, it is effectively carbon-neutral. The production of goods made of steel, aluminum, concrete and plastic consumes a large amount of energy and therefore causes significant GHG emission. The substitution of these products with sustainably produced wood products can, therefore, help reduce GHG emission (IPCC 2005).

2.9 Carbon Cycle in Forest

Carbon is the major component of all cellular life forms. Trees utilize carbon as a building material with which to form trunks, roots, stems, branches, and leaves. Trees sequester carbon from atmosphere through photosynthesis (Ferrini 2011), extracting CO2 from the air, separating the carbon atom from the oxygen atoms and returning oxygen to the atmosphere. In doing so, trees store a tremendous amount of carbon in their structures annual growth increases the carbon stored within the structure. Photosynthesis is the chemical process by which plants use sunlight to convert nutrients into sugars and carbohydrates. Although individual plants die and decompose, forests eventually reach steady states in which the amount of CO_2 released by dying plants is offset by new plants.

2.10 Global Forest Carbon Trends

The total carbon stocks in world's living forest was 277.49 Gt in 2010 with 55.74 Gt in Africa, 44 Gt in Asia and Pacific, 104 Gt in Latin America and the Caribbean, 45 Gt in Europe, 25.25 Gt in North America and 3.5 Gt in near east. The total gross carbon uptake by the world established and tropical regrowth forests is 4 Pg C/y (Pan et al. 2011), which is equivalent to half of fossil fuel carbon emissions in 2009. During the period 1990-2007, the cumulative C sink into the worlds established forest is 43 Pg C and for established re-growth forest was 73 Pg C, the latter equivalent to 60% of cumulative fossil emissions in the period (i.e., 126 Pg C). So it is clear that forest play a critical role in earth's terrestrial C sinks and exert strong control on the evolution of atmospheric CO_2 (Pan et al. 2011).

2.11 Carbon Sequestration in Homegardens

As Bangladesh is a densely populated and a developing country of the world it suffer from harmful impression of global warming. In Bangladesh homegarden represent a well-established land use system which are maintained by at least 20 million household and represent one possible approach for conservation of biodiversity (Kabir & Webb. 2008, 2009). Homegarden also offer certain possible ecosystem facility such as carbon sequestration, soil conservation, preserving of water and air quality (Peichl et al. 2006). In Bangladesh natural forest are lessening at an alarming rate because of extraordinary anthropogenic stress. For this reason to meet future challenges of land and water scarcity, to ensure food security, to conserve biodiversity and to provide daily needs of rural people homegarden could be the chief illustration. Although carbon sequestration potential in homegarden has been focus of scientific attention (Srivastava et al. 2005). But quantitative data is not sufficient and very little evidence existing on homegarden in respect of their carbon content, carbon sequestration potential and species diversity in homegarden in Bangladesh (Jaman et al. 2016).

Table 2.2 Summary of literature values on aboveground and root C stocks in some tropical homegardens and agroforestry systems

Land-use system	Methods of estimation	Aboveground C stock (Mg/ha)	Root C stock (Mg/ha)	Sources
Homegardens; Central Kerala, India	Excludes litter, herb, shrub, root, and soil C stocks	16-36	X	Kumar & Mohan 2011
Homegardens; Indonesia	Excludes litter, herb, and soil C	35.3	8.8	Roshetko et al. 2002

	stocks			
Agro-forest (Home and outfield gardens), Panama	Excludes litter, herb, and soil C stocks	93	18	Kirby et al. 2007
AF woodlot; Kerala, India	Root excavation (>1.4 cm in diameter) included	172	8.87	Kumar et al. 1998

The above-ground vegetation in natural forests held on average 54% of the total carbon stocks. In agro-forests aboveground vegetation contribute about 26% of carbon (Kessler et al. 2012). Agroforestry systems in the arid, semiarid, and degraded sites have a lower carbon sequestration potential than those in fertile humid sites. Again temperate agroforestry systems have relatively lower vegetation carbon sequestration potential than the tropical ones (Nair et al. 2009).

Table 2.3 Potential Carbon storage for agroforestry systems in different eco-regions of the world

Continent	Eco-region	System	Mg C ha^{-1}
Africa	Humid tropical high	Agrosilvicultural	29-53
South America	Humid tropical low	Agrosilvicultural	39-102[a]
	Dry lowlands		39-195
Southeast Asia	Humid tropical	Agrosilvicultural	12-228
	Dry lowlands		68-81
Australia	Humid tropical low	Silvopastoral	28-51
North America	Humid tropical high	Silvopastoral	133-154
	Humid tropical low	Silvopastoral	104-198
	Dry lowlands	Silvopastoral	90-175
Northern Asia	Humid tropical low	Silvopastoral	15-18

(Source: Dixon et al. 1994).

[a] Carbon storage values were standardized to 50 years rotation.

In agro-ecosystems i.e., homegardens, although organic stock of carbon is the largest one but aboveground biodiversity may play an important role for carbon sequestration with consequent positive impacts on belowground carbon sequestration (e.g., through litter fall, root exudation and turnover or soil erosion control). Variability in carbon sequestration and biodiversity can be high within complex agro-ecosystems, depending on factors such as vegetation age, structure, species involved, management practices, land uses and landscape (Montagnini et al. 2004).

CHAPTER 3

3 Materials and Methods

3.1 Introduction

This Chapter contains detail methods and materials used to conduct the study. The study was conducted in three sub-district of Khulna district of Bangladesh. Duration of the study was July to November 2017. An exploratory inventory was conducted continuously for exploring the species composition, frequency and carbon stocks of homestead forests.

3.2 Location of the Study Area

The study was conducted at three villages (Gutudia, Choigoriya, and Jabusa) of three sub-district (administrative unite) in Khulna district, located in the southwestern part of Bangladesh. The area covers 82220 ha, which is in between 22.8083°N & 89.4250°E (Dumuria), 22.7417°N & 89.5167°E (Botiaghata), and 22.8333°N & 89.5833°E (Rupsha) respectively **(Figure 3.1)**. Among the studied villages 1st one was in Dumuria sub-district and the rest two of them belong to Botiaghata and Rupsha sub-district. Khulna district lies south of Jessore and Narail, east of Satkhira, west of Bagerhat and north of the Bay of Bengal. It is part of the largest delta in the world. In the southern part of the delta lies the Sundarban, the world's largest mangrove forest. The deltaic landscape of the study sites are a primarily low (<10 m above ASL), flat, and fertile plain (BBS 2012).

3.2.1 Climatic Condition

Three study areas i.e., Dumuria, Botiaghata, and Rupsha sub-district of Khulna district enjoy generally a tropical to subtropical monsoon climate. While there are six seasons (changes every two months) in a year, three namely summer (March to May), monsoon or rainy (June to October) and winter (November to February) are prominent. These three seasons are characteristic of Khulna region. Winds are mostly from the north and northwest in the winter, blowing gently at 1 to 3 km/h in northern and center areas and 3 to 6 km/h near the coast. From March to May, violent thunderstorms produce winds of up to 60 km/h. During the intense storms of the early summer and late monsoon season, southerly winds of more than 160 km/h cause waves to crest as high as 6 meters in the Bay of Bengal, which brings disastrous flooding to coastal areas of this region.

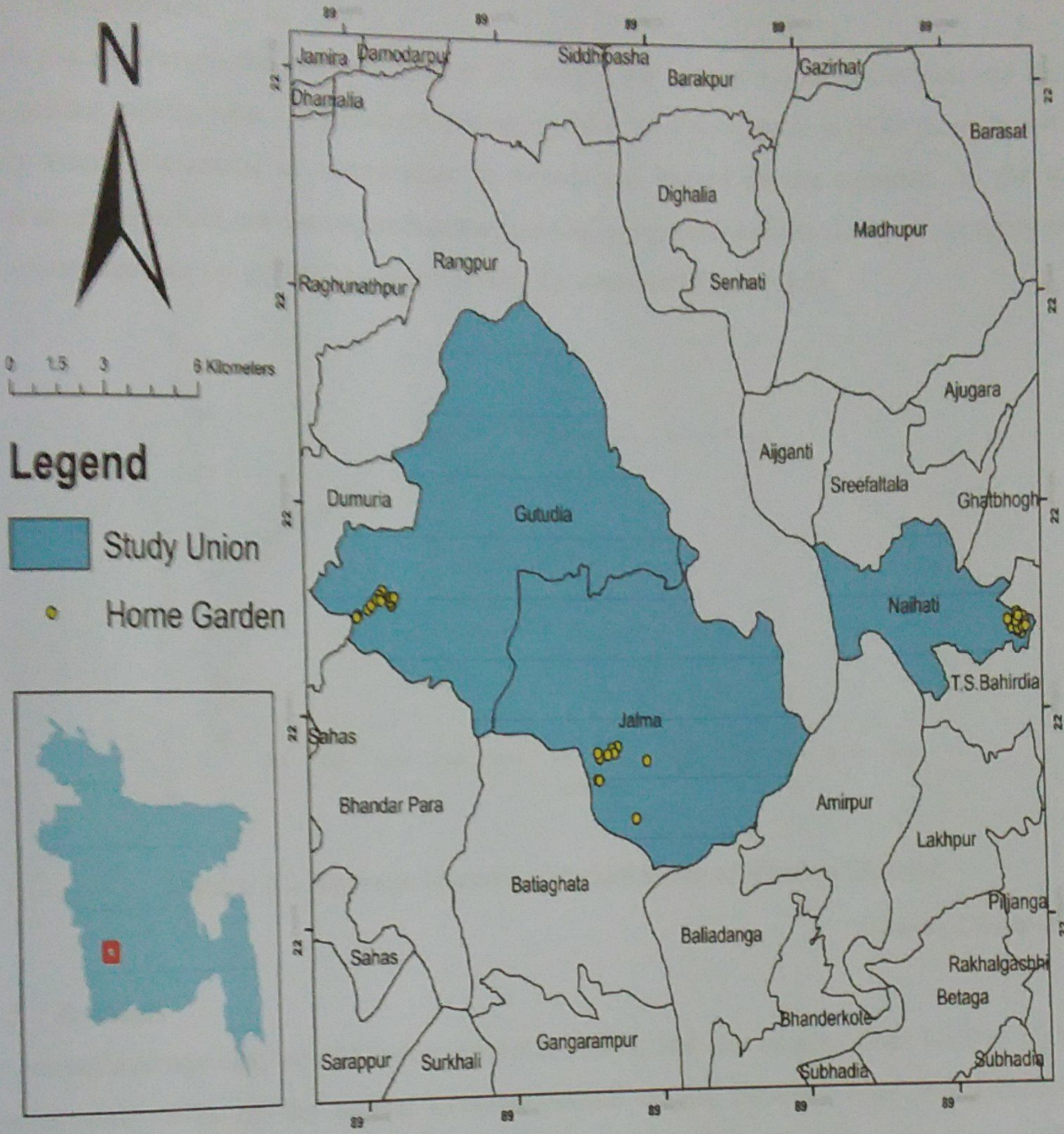

Figure 3.1 Study Area Map

3.2.2 Temperature

Khulna has an average temperature of 29.6 °C. May is the hottest month of the year and January is the coldest month, with temperatures averaging 19.1 °C. The climate is quite pleasant with not usually much fluctuation in temperature in winter and humid during summer. As the winter season progresses into pre-monsoon summer season, temperature starts rising up. In some places temperature reaches up to 40°C or more during the summer **(Figure 3.2)**.

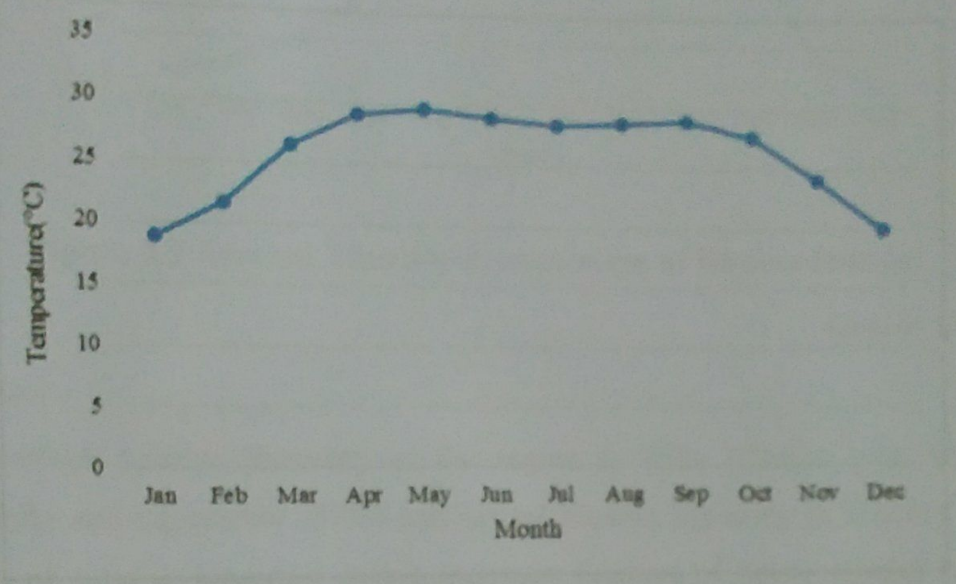

Figure 3.2 Average Monthly Temperature of Khulna District

(Source- Climate-data.org)

3.2.3 Rainfall

The annual average rainfall of Khulna district is 1800 ± 268 mm ranging from 1400 to 2600 mm. the approximately 87% of the annual average rainfall occurs between May and October. The monsoon result from the contrasts between low and high air pressure areas that result from differential heating of land and water. During the hot month of April and May hot air raises over the Indian sub-continent, creating low pressure areas into which rush cooler, moisture-bearing winds from the Indian Ocean. This is the southwest monsoon, commencing in June and usually lasting through September. The driest month is December, with 6 mm of rainfall. Most rainfalls in July, with an average of 348 mm. The difference in rainfalls between the driest month and the wettest month is 342 mm **(Figure 3.3)**.

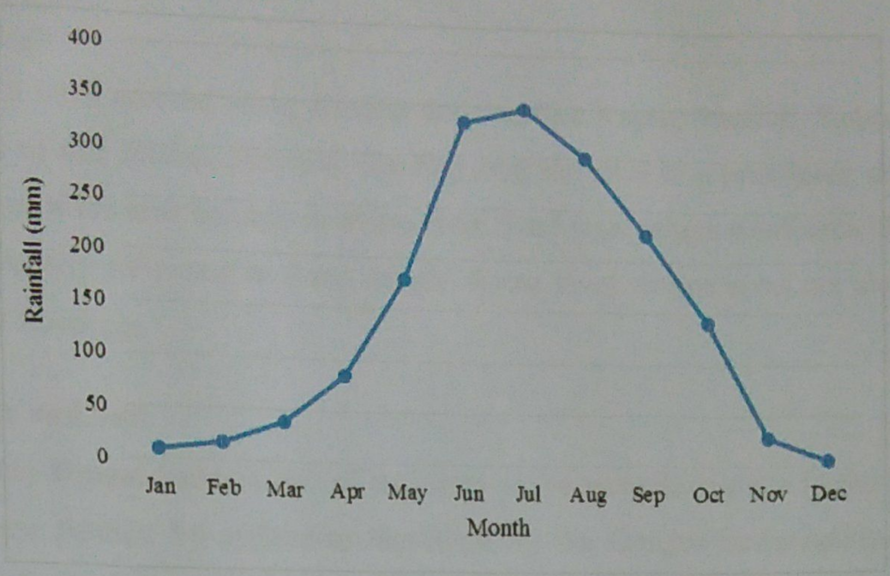

Figure 3.3 Average Monthly Precipitation of Khulna District

(*Source- Climate-data.org*)

3.2.4 Humidity

The annual average relative humidity of the region is 78%. Months with highest relative humidity are July and September (87%) and lowest relative humidity is March (73%) **(Figure 3.4)**. Variation of relative humidity during monsoon because of heavy rainfall but in summer season humidity becomes low.

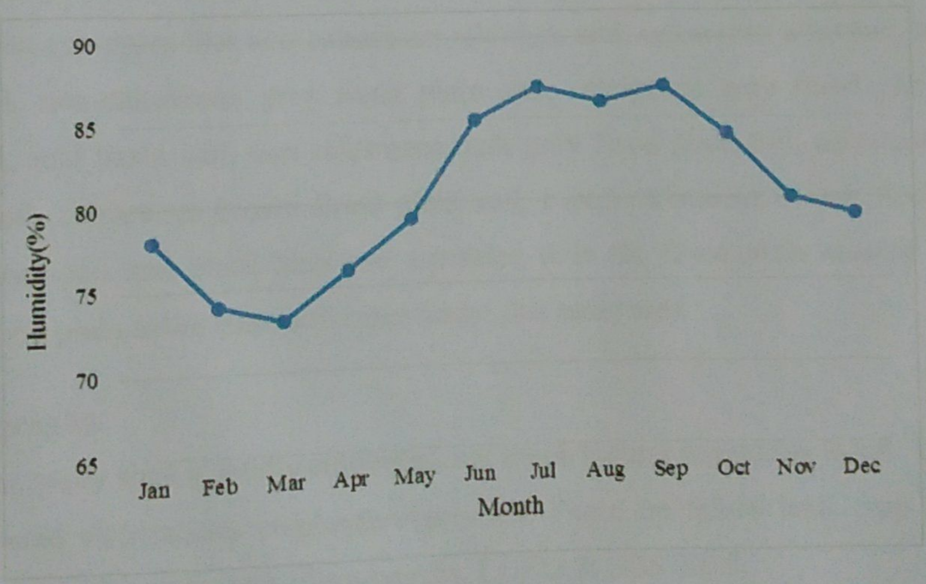

Figure 3.4 Average Monthly Humidity of Khulna District

(*Source- Climate-data.org*)

3.2.5 Hydrology

Few main rivers have crossed along Khulna division like Rupsa, Bhairab, Kobadak etc. (BBS 2012). Because of this reason, seasonal flooding near the river is a prominent characteristic in this region. Most of the area belongs to above river flood level where small area like coastal part of this region usually subjected to flood deeply. Some level terrace areas are also subjected to shallow rainfall flooding.

3.2.6 Geology and Soil

Geologically, the Bengal basin is one of the more active tectonic regions in the world. Khulna district has been formed by sediments deposited by the Ganges-Brahmaputra-Meghna river system. The sediments are thought to be as thick as 10000 feet. Soils in the delta have some localized variation, both aerially and stratigraphically but consists primarily of fine sands, silts, silty sands and clay silts. Remnants of swamp and forest appear in the form of peat layers in Khulna district. Excavation in this district show wood, trees or other vegetation at depts up to 100 feet below ground surface provides evidence of large scale subsidence, caused by compaction of recent sediments and possibily by structural down warping.

According to the report of Bureau of Bangladesh Statistics, Bangladesh has three broad types of soil; flood plain siols (79%), brown hill soils (12.7%) and terrace soils (8.3%). Flood plain soils are of fourtheen sub-types like non-calcareous alluvium soil, calcareous alluvium, acid sulphate soil, peat soil, non-calcareous grey flood plain soil, calcareous grey flood plain soil, grey piedmont soil, acid basin soil, non-calcareous dark grey flood plain soil, calcareous dark grey flood plain soil, calcareous brown flood plain soil, c non-calcareous brown flood plain soil, brown piedmont soil and black terai soil extended over the flood plain area of the country. Calcareous flood plain is the basic soil types under this study area.

3.2.7 Topography

The land of the study sites is totally cultivated, not much natural vegetation is left. The landscape is mostly covered with mosaic croplands/vegetation. There are fallow land, crop fields, ponds, ditches and beels in the study area (Banglapedia, LGED & BBS 2015).

3.2.8 Common Agricultural Pracctices

Main Crops- Paddy, Jute, Sugarcane, Kachu, Sweet Potato, Ground Nut etc. Extinct or nearly extinct crops are Indigo, Arahar, Aus Paddy, Mustard Seed, Khesari etc. Main Fruits- Mango, Banana, Lichi, Jackfruit, Coconut, Guava, Palm etc. (Banglapedia, LGED & BBS 2015).

3.3 Methodology

3.3.1 Sampling Procedure

This study was conducted in Khulna district which consist of 9 sub-district. Out of 9 sub-district, 3 sub-district namely Dumuria, Botiaghata, and Rupsha was randomly selected. Dumuria, Botiaghata and Rupsha Sub-districts consist of 14 unions (Lowest unit of local self-government), 7 unions and 5 unions respectively. Gutudia, Jalma, and Noihati union from Dumuria, Botiaghata and Rupsha sub-district were randomly selected. Finally three village namely Gutudia, Choigoriya, and Jabusa were selected where 1st one from Gutudia union and 2nd one from Jalma union and 3_{rd} one from Noihati union. Finally 45 homegardens from three village were randomly selected (**Table 3.1**) in order to capture a representative mixture of size of homegardens which also provide the cost effective approach to describe two major complementary works (1. Carbon stock computation and 2. Tree diversity assessment).

Table 3.1 Name of the all sampling units and no. of total homegardens in the study area

Sub-district	Unions	Villages	No. of Homegardens
Dumuria	Gutudia	Gutudia	15
Botiaghata	Jalma	Choigoriya	15
Rupsha	Noihati	Jabusa	15
Total	3	3	45

3.3.2 Homegarden Survey

All perennial trees and palms with a diameter at breast height of ≥ 10 cm were identified and recorded to species level or by local name and botanical name. For individual tree species DBH (Diameter at breast height) were measured by using DBH tape and height of palm species were measured by using Criterion RD 1000. For comparison, the homegardens were categorized into three size group namely small (0.01-0.1 ha), medium (0.1-0.3 ha) and large (> 0.3 ha). Allometric equation developed by Chave et al. (2005) was applied for individual trees for determining the tree biomass. Wood density for every species was collected from secondary data such as FAO list of wood densities for tree species from Tropical Asia and, global wood density database (Zanne et al. 2009). No climbers were counted due to difficulty in differentiating stems.

3.3.3 Tools

Diameter tape, Measuring tape, GPS, and Criterion RD 1000 were used for collecting data from the study area.

3.3.4 Secondary Data Collection

The Other Information of the Study were collected from the following sources:

- ✓ Khulna University Central Library.
- ✓ Seminar Library, Forestry and Wood Technology Discipline, Khulna University.
- ✓ Published and Unpublished Reports, Research Papers Articles, National Newspapers and Journals, Books of Govt. and other Organizations.
- ✓ Sub-district Office and BBS Khulna.
- ✓ Internet Browsing.

3.4 Frequency and Relative Frequency

Frequency and relative frequency of species in the study area are measured by using the formulae of Kabir & Webb (2008) which are given below-

$$\text{Frequency} = \frac{\text{Total no. of the sample in which the species occurs}}{\text{Total no. of sample studied}} * 100$$

$$\text{Relative Frequency} = \frac{\text{No of occurrence in particular species}}{\text{Total no. occurrences of all species}} * 100$$

3.5 Tree Biomass

Tree biomass quantification is a boring job using the destructive method, particularly in tropical and subtropical regions because of the presence of numerous species and individuals in multiple layers. For this reason, common allometric equations have been developed for make this job easy (Rahman et al. 2015). Taking this point into account, for aboveground carbon estimation Chave et al. (2005) allometric equation was applied, as it covers a wide geographical and diameter range of vegetation of all types.

3.5.1 Above Ground Biomass

To measure the above ground biomass, following equation has been used (Chave et al. 2005)

$$AGB = \rho \text{ x } \exp(-1.499 + 2.148 \text{ x } \ln(DBH) + 0.207 \text{ x } (\ln(DBH))^2 - 0.0281(\ln(DBH))^3$$

Where, ABG = Aboveground biomass (kg); ρ = Wood density ($gcm{-}3$);
DBH = Diameter at breast height; 1.499; 2.148; 0.207 and 0.0281 = Constant; ln = Natural logarithm.

3.5.2 Below Ground Biomass

Below ground biomass was estimated using the model equation suggested by Cairns et al. (1997) as the most suitable and practical method.

$$BGB = \exp(-1.0587 + 0.8836 \text{ x } \ln AGB)$$

Where; BGB = Belowground biomass, ln = Natural logarithm, AGB = Aboveground biomass, -1.0587 and 0.8836 are constant.

3.5.3 Palms Biomass

Palm species such as *Cocos nucifera, Areca catechu, Phoenix silvestris* are most common species found in the selected homegardens in Khulna district. The following allometric equation was developed by Brown et al. 1997 used to calculate above ground biomass of different palm species but these data were removed for further analysis and not presented here.

$$AGB = 6.666 + 12.826 \text{ x } (HT0.5) \text{ x } \ln(HT)$$

Where, ABG = Aboveground biomass (kg);
HT = Height; 6.666 = Constant; 12.826 = Constant; ln = Natural logarithm.

3.6 Conversion of Biomass to Carbon

Tree biomass was converted to carbon assuming that carbon accounted for 50 % of the biomass (Brown & Sandra 1997). Almost all carbon measurement projects in the tropical forest the total biomass was multiplied by 0.5 to compute actual tree carbon content as 50% of wood's total biomass is considered to be carbon (Chave et al. 2005).

Carbon (Mg) = Biomass estimated by allometric equation x 0.5 (Kauffman et al. 2016).

3.7 Data Analysis

Collected field data were processed and analyzed using R- 3.3.2 version software and MS excel 2013. Two-way ANOVA and t-test has been done to find out the significant differences among biomass carbon and tree diversity at 0.05% level of significance. Regression analyses were used to test the relationship among different variables. The undesirable portion of the collected information and data were discarded from the final paper in order to avoid the bulky size of the paper. In course of data assembling I took sincere guidance from my supervisor time to time. After sorting information, collected data was analysed in percentages for easy explanation with graps and submitted sequentially and systematically.

Chapter 4

4 Results and Discussions

4.1 Results

4.1.1 Introduction

Homegardens are collections of trees around homesteads (Rahman et al. 2005). The findings of this study also confirmed that homegardens in Khulna district was rich in carbon with diversified plant species. It became illuminated too that homegardens of the study sites represented an intensive delicate frequency of species and carbon sequestration potential.

4.1.2 Distribution and Area of Homegardens

The size of the homegardens varied from village to village as well as sub-district to sub-district. The range of surveyed homegardens was 0.057 ha to 0.6789 ha. The total surveyed area was 10.78 ha **(Table 4.1)** from a total of 45 homegardens. The largest area of homegarden (0.6789 ha) was surveyed in Gutudia union of Dumuria sub-district and the lowest area of homegarden (0.057 ha) was surveyed in Noihati union of Rupsha sub-district. Comparison with other studies, the average size of the homegarden in the sub-district was higher than found in other areas of Bangladesh. Kabir & Webb (2008) was found that the southwestern part of Bangladesh, the average size of homegardens was 0.10 ha. But the average homegardens area of this study was 0.24 ha. The average homegardens area in three study sub-district was similar to each other.

Table 4.1 Number and area of homegardens Survey in Khulna District

Sub-district	Union	No. of Surveyed HG	Total Surveyed Area (ha)	Mean Area (ha)
Dumuria	Gutudia	15	3.27	0.22
Botiyagata	Jolma	15	3.04	0.20
Rupsha	Noihati	15	4.46	0.29
	Mean	15	3.59	0.24
	Total	45	10.78	

In the surveyed area Noihati union is dominant than other two unions. The area of homegardens surveyed was 3.27 ha in Gutudia union, 3.04 ha in Jolma union and 4.46 ha in Noihati union respectively.

4.1.3 Tree Species Composition and Diversity

A total 2421 individuals of 56 species were found from 45 homegardens of three Sub-district i.e., Dumuria, Botiaghata and Rupsha Sub-district in Khulna district. Mahagoni (*Swietenia macrophylla* King.), Narikel (*Cocos nucifera* L.), Aam (*Mangifera indica* L.), Supari (*Areca catechu* L.), Neem (*Azadirachta indica* A.Juss), Khatal (*Artocarpus heterophyllus* Lam.), Tal (*Borassus flabellifer* L.), Sissoo (*Dalbergia sissoo* Roxb.*)*, Ipil ipil (*Leucaena leucocephala* (Lam.) de Wit) and Bel (*Aegle marmelos* (L.) Correa) were the top ten most frequented species in the study area **(Table 4.2)**. These ten species comprised 72% of total species. Considering frequency Mahagoni (*Swietenia macrophylla* King.) occupied the rank one and Narikel (*Cocos nucifera* L.) occupied the rank two but both species were rich in the homegardens of the study area. For comparison, the homegardens were categorized into three size group namely small (0.01-0.1 ha), medium (0.1-0.3 ha) and large (> 0.3 ha). Species diversity was calculated according to the homegarden size **(Table 4.3).**

Table 4.2 Ten most important species recorded in Khulna district

Species Number	Scientific Name
1	*Swietenia macrophylla* King.
2	*Cocos nucifera* L.
3	*Mangifera indica* L.
4	*Areca catechu* L.
5	*Azadirachta indica* A.Juss
6	*Artocarpus heterophyllus* Lam.
7	*Borassus flabellifer* L.
8	*Dalbergia sissoo* Roxb.
9	*Leucaena leucocephala* (Lam.) de Wit

10	*Aegle marmelos* (L.) Correa

Table 4.3 Tree diversity of various homegardens in Khulna district

Homegarden Size	Number of HG	Mean Number of trees per hectare	Species recorded in the home garden	
			Total	Mean
Small	15	575	650	12
Medium	15	239	819	15
Large	15	163	920	16

4.1.4 Family Composition

A total of 22 families were counted from the study area. According to speciies number, Leguminosae family was found top of the list and was represented by 7 species. But according to number of individual species, it was found that the family Palmae was recorded top of the list and was represented by 696 individuals. Meliaceae and Moraceae family were represented 6 and 5 species in the sample homegarden. Myrtaceae and Palmae both families were represented by 4 species. Anacardiaceae, Malvaceae, Rutaceae and Sapindaceae families were represented 3 species. Annonaceae, Combretaceae, Euphorbiaceae, Fabaceae and Sapotaceae families denoted 2 species and the rest of the families comprised only one species **(Appendix-1)**.

4.1.5 Frequency and Relative frequency of Tree Species in the Homegardens

The study was found that among the tree species *Swietenia macrophylla* King., *Cocos nucifera* L., *Mangifera indica* L., *Areca catechu* L., *Azadirachta indica* A.Juss, *Artocarpus heterophyllus* Lam., *Borassus flabellifer* L., *Dalbergia sissoo* Roxb., *Leucaena leucocephala* (Lam.) de Wit) and Aegle marmelos (L.) Correa were frequently distributed species with relative frequencies than others **(Appendix-1)**. Among the species *Swietenia macrophylla* King., *Cocos nucifera* L., *Mangifera indica* L., *Areca catechu* L. were dominant species than other trees with the frequencies of 424, 388 and 364 and relative frequencies of 18%, 16% and 15% respectively. Some important species such as *Artocarpus heterophyllus* Lam., *Dalbergia sissoo* Roxb., *Phoenix sylvestris* Roxb., *Albizia lebbeck* (L.) Benth. And *Albizia saman* (Jacq.) Merr. were shown relatively similar frequency than others. But among the species particularly 27 species were shown relatively poor relative frequency.

4.1.6 Above Ground and Below Ground Carbon

Tree and palm species of the selected homegarden were measured based on DBH (Diameter at breast height) and height. Data was computed using selected equations and found significant differences. The above and below ground biomass (AGB+ BGB) carbon for the 45 sampled homegarden ranged from 19.31 to 136.56 Mg C ha^{-1}. Mean carbon stocks per unit area was higher in small homegarden (98.99 Mg C ha-1) where area of the small homegarden was (0.01-0.1 ha) and total number of small homegarden was n=15 compared to medium (51.83 Mg C ha-1., 0.1-0.3 ha., n=15) and large (37.13 Mg C ha-1., >0.3 ha., n=15) size homegarden (**Table 4.7**). The variation in carbon content of individual homegarden may be because of differences in homegarden species composition, age of species, site characteristics, and holding sizes in different physiographic zones such as midlands, highlands and river basin area of Khulna 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 4.1**).

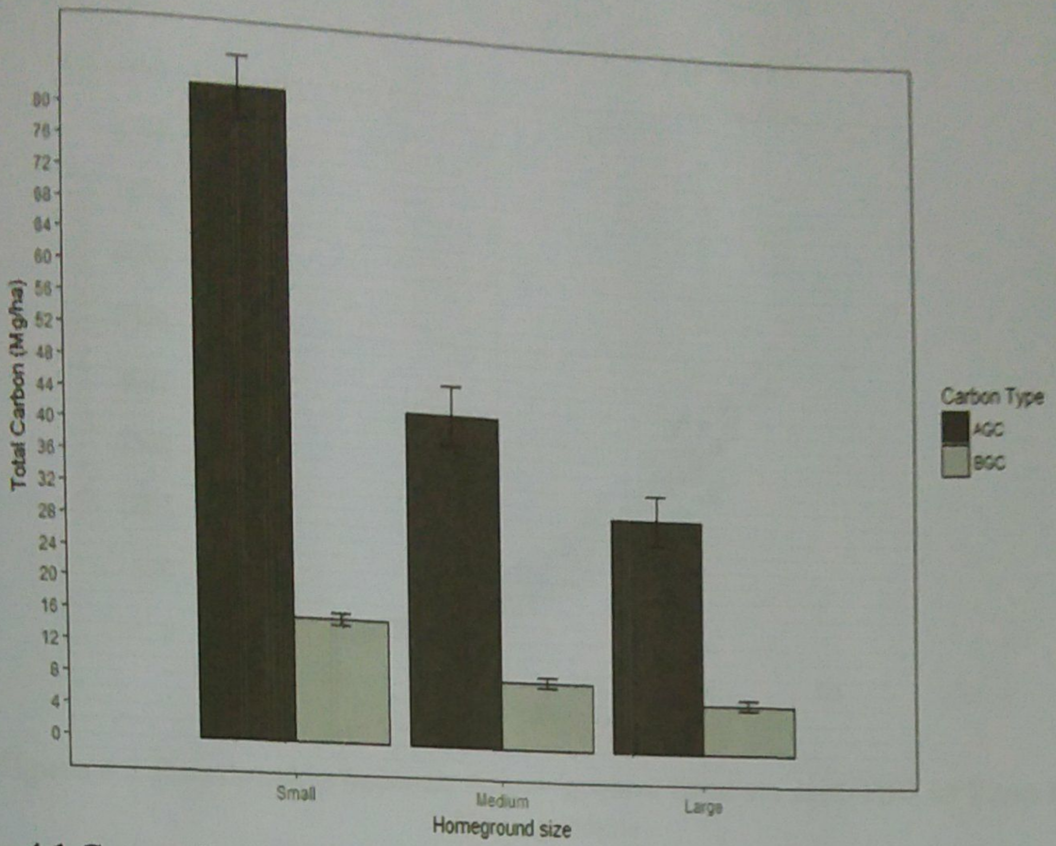

Figure 4.1 Comparison of Above and Belowground Carbon on the basis of Homegarden Size

Table 4.4 Carbon stocks in homegardens of Khulna district

Homegarden Size	Number	Average Total C (Mg ha^{-1})		Mean + SE
		Lowest	Highest	
Small	15	65.53	136.56	98.99+ 3.82
Medium	15	20.59	76.63	51.83 +4.51
Large	15	19.31	76.34	37.13 + 4.79

4.1.7 Relationship between Above-ground Biomass and DBH of Trees in Homegardens

A regression analysis was used to determine the relationship between DBH (Diameter at breast height) with above-ground biomass. The relationship between DBH and above-ground biomass were estimated and presented (Figure 4.2). The result of DBH and above-ground biomass showed that the relationships between these two factors were significant and positive power relationship ($R^2 = 0.9$). This figure also indicates that DBH of tree species are strongly correlated with above-ground biomass.

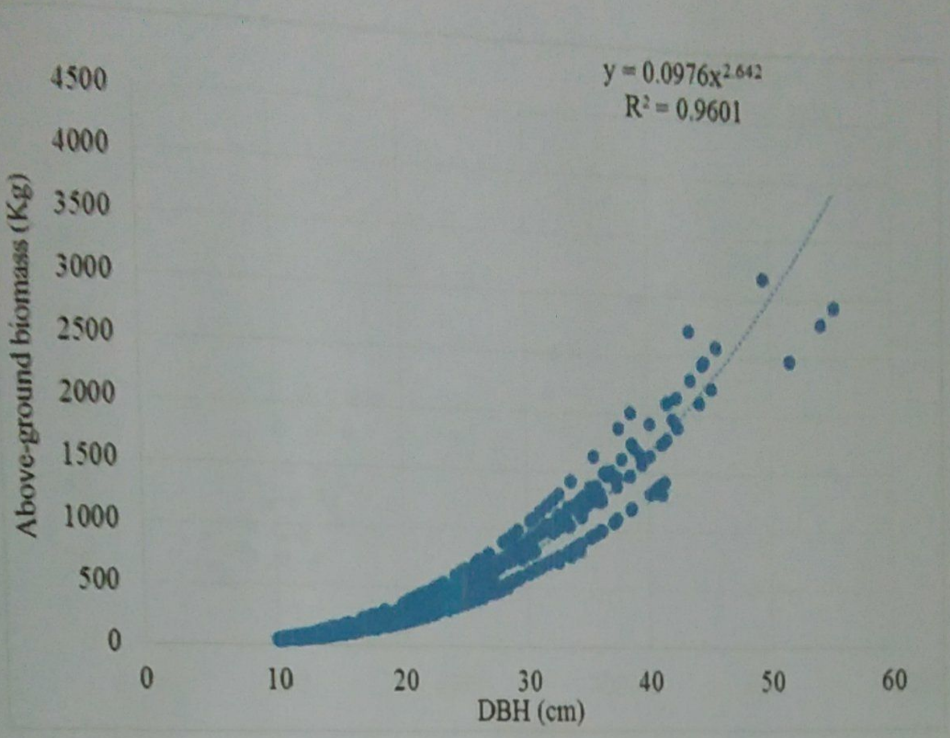

Figure 4.2 Relationship between Above-ground Biomass and DBH of Trees in Homegardens

4.1.8 Relationship between Stem Density and Total Carbon (Mg ha^{-1})

The relationship between stem density and total carbon stock (Mg ha^{-1}) were estimated and presented (**Figure 4.3**). The figure shows significant positive linear relationship ($R^2 = 0.7$) between stem density and total carbon in the study area. The figure also indicates that stem density of tree species are strongly related with carbon stock.

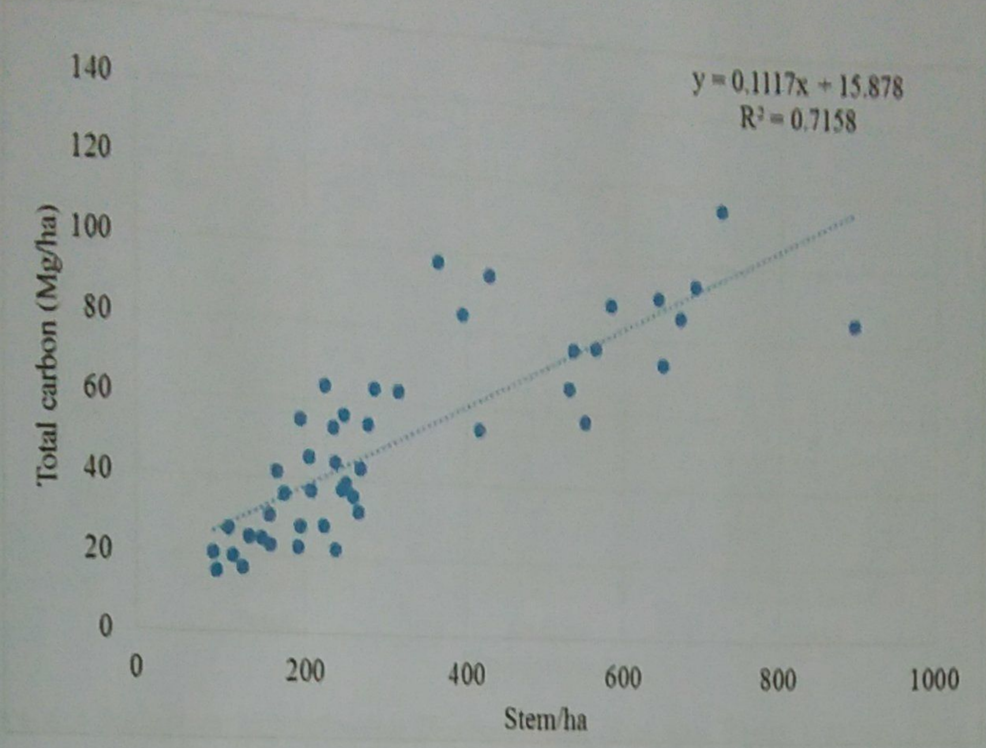

Figure 4.3 Relationship between Stem Density and Total Carbon (Mg ha^{-1})

4.1.9 Relationship between Homegarden Size and Total Carbon (Mg ha^{-1})

The relationship between homegarden size and total carbon stock (Mg ha^{-1}) were estimated and presented (**Figure 4.4**). From the LSD test, the average carbon is significantly higher in small homegarden than medium and significantly lowest carbon was found for large homegarden **(Appendix-2).** The figure indicates carbon stocks increase with the decreasing of the size of homegardens.

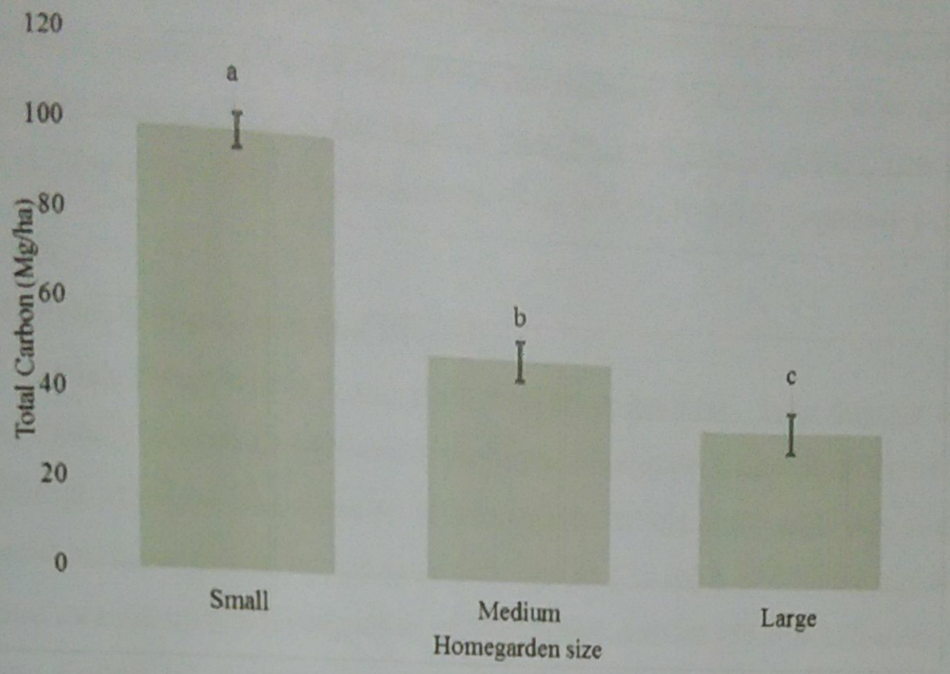

Figure 4.4 Relationship between Homegarden Size and Total Carbon (Mg ha-1)

4.1.10 Relationship between Homegarden Size and Total Carbon (Mg ha^{-1}) in Three Sub-district

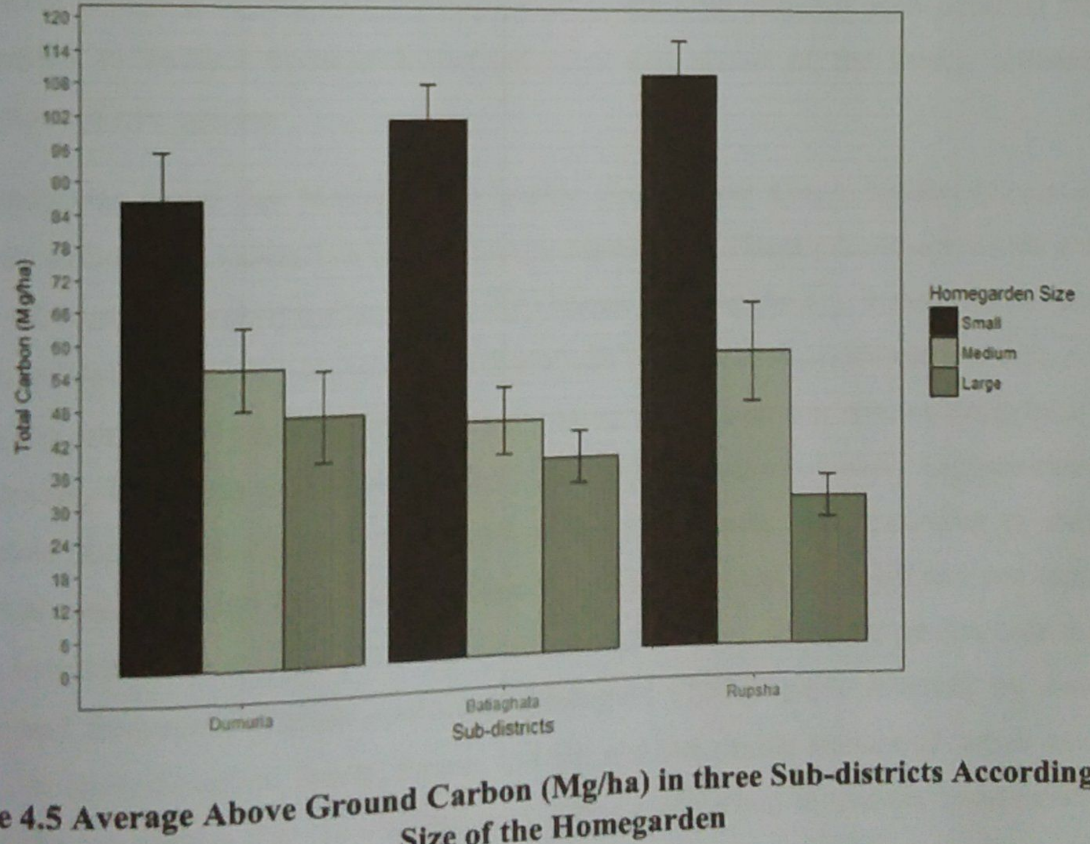

Figure 4.5 Average Above Ground Carbon (Mg/ha) in three Sub-districts According to the Size of the Homegarden

The Relationship between Homegarden Size and Total Carbon (Mg ha^{-1}) in three Sub-district were estimated and presented (**Figure 4.5**). From the two-way ANOVA, the average total carbon varied significantly among different homegarden size ($F_{2,40} = 52.04$, $P<0.001$), However, there is no significant difference in different sub-districts ($F_{2,40} = 0.19$, $P>0.05$) **(Appendix-3).**

4.2 Discussion

4.2.1 Tree Species Composition and Diversity

Homegarden species composition is the most important attribute. Tree density of individual homegarden is closely related to species composition. This study found 56 different tree species within 22 different families. The number of tree species in this study area was slightly smaller than those found in homegarden of Sandwip Sub-district (76 spp.) of Chittagong district (Alam et al. 2005) and coastal area's homegarden of Potuakhali district (57 spp.) (Sarker et al. 2015), but higher than district of Tangail (52 spp.), district of Ishurdi (34 spp.) and Bhola (31 spp.), Borguna (30 spp.) (Islam et al. 2013), Patuakhali (20 sip) and Rajshahi (28 spp.) (Aboding, & Zainul 1988). The present study was conducted considering whole homegarden area in one plot so uniform counting of tree species was possible but little variation also occurred from one homegarden to another because homestead need and choice of the family influenced the distribution of tree species.

This study was found that Mahagoni (*Swietenia macrophylla* King.), Narikel (*Cocos nucifera* L.), Aam (*Mangifera indica* L.), Supari (*Areca catechu* L.), Neem (*Azadirachta indica* A.Juss), Khatal (*Artocarpus heterophyllus* Lam.), Tal (*Borassus flabellifer* L.), Sissoo (*Dalbergia sissoo* Roxb.), Ipil ipil (*Leucaena leucocephala* (Lam.) de Wit) and Bel (*Aegle marmelos* (L.) Correa) are the top ten most frequented species in the study area. These ten species comprised 72% of total species. The study also explored that according to speciies number, Leguminosae family was found top of the list and was represented by 7 species. But according to number of individual species, it was found that the family Palmae ranks top of the list and was represented by 696 individuals. In this study Mahagoni was found the most dominant species both in case of carbon and frequency. Carbon content of Mahagoni (7.57 Mg/ha) followed by Aam (5.20 Mg/ha). In case of Narikel, Neem, Sissoo, Ipil ipil and Bel similar amount of carbon was found. Among the ten species Tal showed the poor amount of carbon in various homegardens. This study only considers trees and palm species. The overall diversity would have been higher if all plants were included.

4.2.2 Above and Below Ground Carbon Stock (AGB and BGB)

The findings of this study is that the average carbon stock (AGB + BGB) of standing homegarden trees (DBH > 10cm) was 62.65 Mg ha^{-1}; n=45 which ranging from 19.31 to 136.56 Mg ha^{-1} and it is expressed earlier that small homegarden had higher amount of carbon (98.99 Mg ha^{-1}) than medium (51.83 Mg ha^{-1}) and large (37.13 Mg ha^{-1}) homegardens respectively. The average carbon stocks presently reported are higher than homegarden (53.53 Mg ha^{-1}) in Rangpur district, Bangladesh. Jaman et al. (2016) was found mean carbon stock per unit area 69.15 Mg ha^{-1} and 47.96 Mg ha^{-1} from small and medium homegarden respectively was lower than this study but 39.93 Mg ha^{-1} from large homegarden was quite higher than this study. This result is also higher than another study was accomplished in central Kerala, India where the average standing carbon stocks of homegarden ranged from 16 to 36 Mg ha^{-1} (Kumar, B. Mohan). Cacao agroforestry in Sulawesi, Indonesia contain carbon stocks ranged from 82 to 211 Mg C ha-1 reported by Michael Kessler *et al*. (2012) which is comparatively higher than the homegarden of Khulna district of Bangladesh. Due to environmental, geo-morphological factors and management practices of individual homegarden the variation of results are occurred.

The variability among the homegardens may be differences in garden composition, site characteristics, management practices, and holding sizes in different physiographic zones such as midlands, highlands of Khulna district. Size of the homegardens was a major factor affecting carbon stock per unit area and it is gradually decreased in the order of small > medium > large homegarden. Large homegarden has small carbon stock because of unplanned management and planting system. During data collection it was observed that large homegarden had water body, vegetables garden, playing space within their holding area. As a result, number of trees and diversity was poor than small homegarden. But carbon stock in three sub-district was more or less similar because within three sub-district lifestyle mode, occupations and traditional homegarden practice were relatively same. So, tree diversity and composition were not different in three studied sub-district.

5 Conclusions

The study of homegardens of three sub-district in Khulna district represent a wide range of biomass carbon and tree species diversity which gives comparatively different result than the homegardens of many different ecological zone. Over a long period of time, it was clear that carbon sequestration in that area was quite satisfactory due to the increasing volume of trees. There were differences between small, medium and large homegardens in terms of their plant-stand characteristics such as trees and tree-species density, and overall tree species diversity. Homegardens with higher number of species retained more carbon in their biomass compared to those with lower number. Tree density and tree diversity were found higher in small homegardens. The carbon estimates found here are reflecting the differences in tree density, tree diversity and management practices between individual homegardens. Smaller homegardens hold a higher carbon content and tree diversity than medium and large homegardens. The finding of present study said that homegardens have a huge amount of carbon stocking capacity which facilitates global climate change issues for playing important role in sequestrating atmospheric carbon.

5.1 Recommendations

- Species specific local allometric equation would yield more accurate estimation.
- Further research is needed with more samples distributed throughout the Khulna district.

REFERENCES

Abedin, M. Zainul, & M. Abdul Quddus. Household fuel situation, home gardens and agroforestry practices at six agro-ecologically different locations of Bangladesh. National Workshop on Homestead Plantations and Agroforestry in Bangladesh, Joydebpur, Bangladesh, 17-19 Jul (1988).

Ahmed, Mir Farid Uddin & SM Lutfor Rahman. Profile and use of multi-species tree crops in the homesteads of Gazipur district, central Bangladesh. Journal of sustainable agriculture24.1 (2004): 81-93.

Alam, M. S., Masum, K. M., Campus, B. F. R. I., & Sholashahor, B. Status of homestead biodiversity in the offshore island of Bangladesh. Research Journal of Agriculture and Biological Sciences, 1(3) (2005): 246-253.

Altrell, D., Saket, M., Lyckeback, L., Piazza, M., Ahmad, I. U., Banik, & Chowdhury, R. M. National forest and tree resources assessment (2005-2007).

Asfaw, Z. Home gardens in Ethiopia: some observations and generalizations. Home gardens and in situ conservation of plant genetic resources in farming systems, (2002): 125.

Atangana, A., Khasa, D., Chang, S., & Degrande, A. Carbon sequestration in agroforestry systems. In Tropical Agroforestry, (2014): pp. 217-225.

Babu, K. S., Jose, D., & Gokulapalan, C. Species diversity in a Kerala homegarden. Agroforestry Today, 4(3) (1982): 15.

Beaumont, L. J., Pitman, A., Perkins, S., Zimmermann, N. E., Yoccoz, N. G., & Thuiller, W. Impacts of climate change on the world's most exceptional ecoregions. Proceedings of the National Academy of Sciences, 108(6) (2011): 2306-2311.

Blanckaert, Isabelle, et al. Floristic composition, plant uses and management practices in homegardens of San Rafael Coxcatlán, Valley of Tehuacán-Cuicatlán, Mexico. Journal of Arid Environments 57.2 (2004): 179-202.

Brown, Sandra. Estimating biomass and biomass change of tropical forests: a primer. Food & Agriculture Org., 134 (1997).

Cairns, M. A., Brown, S., Helmer, E. H., & Baumgardner, G. A. Root biomass allocation in the world's upland forests. Oecologia, 111(1) (1997): 1-11.

Cerri, C. C., Bernoux, M., Cerri, C. E. P., & Lal, R. Challenges and opportunities of soil carbon sequestration in Latin America.Change, IPCC Climate. Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change, (2006).

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., & Lescure, J. P. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145(1) (2005): 87-99.

Concern, Waste. Waste data base of Bangladesh, waste concern. org (2009).

Coomes, O. T., & Ban, N. Cultivated plant species diversity in home gardens of an Amazonian peasant village in northeastern Peru. Economic Botany, 58(3) (2004): 420-434.

Das, S. The Forest Management practices in Bangladesh. Procedings in second National Conference on Forestry. Bangladesh forest Department, Dhaka, (1986): pp 6-18.

Detwiler, R. P., & Hall, C. A. Tropical forests and the global carbon cycle. Science, 239(4835) (1988): 42-47.

Dey, A., Islam, M., & Masum, K. M. Above Ground Carbon Stock Through Palm Tree in the Homegarden of Sylhet City in Bangladesh. Journal of Forest and Environmental Science, 30(3) (2014): 293-300.

Dissanayake, W. A. S. S., D. M. S. H. K. Ranasinghe, and S. Wahala. Estimation of carbon stock in Kandyan Homegardens located in Kandy and Matale. Proceedings of International Forestry and Environment Symposium, 14 (2012).

Dixon, R. K., Brown, S., Houghton, R. E. A., Solomon, A. M., Trexler, M. C., & Wisniewski, J. Carbon pools and flux of global forest ecosystems. Science, Washington, 263(5144) (1994): 185-189.

FAO, The State of World's Forest. Food and Agriculture Organization of the United Nations (2005).

Ferrini, Francesco, and Alessio Fini. Sustainable management techniques for trees in the urban areas. Journal of Biodiversity and Ecological Sciences, 1.1 (2011): 1-19.

Foysal, M. A., Hossain, M. L., Rubaiyat, A., & Hasan, M. B. Economics of homestead forestry and their management activities at Fatickchari Upazila of Chittagong district, Bangladesh. Agriculture, Forestry and Fisheries, 2(4) (2013): 161-176.

Gardner, T. A., Burgess, N. D., Aguilar-Amuchastegui, N., Barlow, J., Berenguer, E., Clements, T., & Khan, S. M. A framework for integrating biodiversity concerns into national REDD+ programmes. Biological Conservation, 154 (2012): 61-71.

Griggs, David J., and Maria Noguer. Climate change, the scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. Weather, 57.8 (2002): 267-269.

Hamlin, Catherine C., and Jan Salick. Yanesha Agriculture in the Upper Peruvian Amazon: Persistence and Change Fifteen Years Down the 'Road'. Economic Botany 57.2 (2003): 163-180.

Herzog, F. Multipurpose shade trees in coffee and cocoa plantations in Côte d'Ivoire. Agroforestry systems 27.3 (1994): 259-267.

Hoogerbrugge, Inge, & Louise O. Fresco. Homegarden systems: agricultural characteristics and challenges, 39 (1993).

IPCC. Summary for Policymakers, (2013): 1-28

Islam, SK Ahiul, Md Abdul Quddus Miah, and Md Ahsan Habib. Diversity of fruit and timber tree species in the coastal homesteads of Southern Bangladesh. Journal of the Asiatic Society of Bangladesh, 39.1 (2013): 83-94.

Jaman, M. S., Hossain, M. F., Islam, M. S., Helal, M. G. J., & Jamil, M. Quantification of Carbon Stock and Tree Diversity of Homegardens in Rangpur District, Bangladesh. International Journal of Agriculture and Forestry, 6(5) (2016): 169-180.

Kabir, Md Enamul, and Edward L. Webb. Floristics and structure of southwestern Bangladesh homegardens. The International Journal of Biodiversity Science and Management, 4.1 (2008): 54-64.

Kabir, Md Enamul, and Edward L. Webb. Household and homegarden characteristics in southwestern Bangladesh. Agroforestry systems, 75.2 (2009): 129.

Kauffman, J. B., & Donato, D. Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Center for International Forestry Research, Bogor, Indonesia, (86) (2012): 40.

Kehlenbeck, Katja, and Brigitte L. Maass. Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. Agroforestry systems, 63.1 (2004): 53-62.

Kessler, M., Hertel, D., Jungkunst, H. F., Kluge, J., Abrahamczyk, S., Bos, M., & Leuschner, C. Can joint carbon and biodiversity management in tropical agroforestry landscapes, 7(10) (2012): 47-192.

Kirby, Kathryn R., and Catherine Potvin. Variation in carbon storage among tree species: implications for the management of a small-scale carbon sink project. Forest Ecology and Management, 246.2 (2007): 208-221.

Krankina, O. N., and R. K. Dixon. Forest management options to conserve and sequester terrestrial carbon in the Russian Federation. World Resour, 6.1 (1994): 88-101.

Kumar, B. M. Carbon sequestration potential of tropical homegardens. Tropical Homegardens. Springer Netherlands, (2006): 185-204.

Kumar, B. Mohan, and PK Ramachandran Nair. The enigma of tropical homegardens. New vistas in agroforestry. Springer Netherlands, (2004): 135-152.

Kumar, B. M., George, S. J., Jamaludheen, V., & Suresh, T. K. Comparison of biomass production, tree allometry and nutrient use efficiency of multipurpose trees grown in woodlot and silvopastoral experiments in Kerala, India. Forest Ecology and Management, 112(1) (1998): 145-163.

Kumar, B. Mohan. Species richness and aboveground carbon stocks in the homegardens of central Kerala, India. Agriculture, ecosystems & environment, 140.3 (2011): 430-440.

Mattsson, E., Ostwald, M., Nissanka, S. P., & Marambe, B. Homegardens as a multi-functional land-use strategy in Sri Lanka with focus on carbon sequestration. Ambio, 42(7) (2013): 892-902.

Mattsson, E., Ostwald, M., Nissanka, S. P., & Pushpakumara, D. K. N. G. Quantification of carbon stock and tree diversity of homegardens in a dry zone area of Moneragala district, Sri Lanka. Agroforestry systems, 89(3) (2015): 435-445.

Michon, G., and F. Mary. Conversion of traditional village gardens and new economic strategies of rural households in the area of Bogor, Indonesia. Agroforestry Systems 25.1 (1994): 31-58.

Michon, G., Bompard, J., Hecketsweiler, P., & Ducatillion, C. Tropical forest architectural analysis as applied to agroforests in the humid tropics: the example of traditional village-agroforests in West Java. Agroforestry Systems, 1(2) (1983): 117-129.

Millate-E-Mustafa, M. D., John B. Hall, and Zewge Teklehaimanot. Structure and floristics of Bangladesh homegardens. Agroforestry Systems, 33.3 (1996): 263-280.

Misra, R. Ecology Work Book Oxford and IBH Publishing Co. Calcutta, India Google Scholar, (1968).

Mohan, Soumya. An assessment of the ecological and socioeconomic benefits provided by homegardens: A case study of Kerala, India. Diss. University of Florida, (2004).

Montagnini, Florencia, and P. K. R. Nair. Carbon sequestration: an underexploited environmental benefit of agroforestry systems. Agroforestry systems, 61.1 (2004): 281-295.

Motiur, R. M., Tsukamoto, J., Furukawa, Y., Shibayama, Z., & Kawata, I. Quantitative stand structure of woody components of homestead forests and its implications on silvicultural management: a case study in Sylhet Sadar, Bangladesh. Journal of Forest Research, 10(4) (2005): 285-294.

Motiur, R. M., Furukawa, Y., Kawata, I., Rahman, M. M., & Alam, M. Role of homestead forests in household economy and factors affecting forest production: a case study in southwest Bangladesh. Journal of Forest Research, 11(2) (2006): 89-97.

Nair, P. R., Nair, V. D., Kumar, B. M., & Haile, S. G. Soil carbon sequestration in tropical agroforestry systems: a feasibility appraisal. Environmental Science & Policy, 12(8) (2009): 1099-1111.

Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., & Ciais, P. A large and persistent carbon sink in the world's forests. Science, 333(6045) (2011): 988-993.

Pulido-Fernández, M., Schnabel, S., Lavado-Contador, J. F., Mellado, I. M., & Pérez, R. O. Soil organic matter of Iberian open woodland rangelands as influenced by vegetation cover and land management. Catena, 109 (2013): 13-24.

Peichl, M., Thevathasan, N. V., Gordon, A. M., Huss, J., & Abohassan, R. A. Carbon sequestration potentials in temperate tree-based intercropping systems, southern Ontario, Canada. Agroforestry systems, 66(3) (2006): 243-257.

Ponce-Hernandez, Raul, Parviz Koohafkan, and Jacques Antoine. Assessing carbon stocks and modelling win-win scenarios of carbon sequestration through land-use changes, 1 (2004).

Rahman, M. M., Khan, M. N. I., Hoque, A. F., & Ahmed, I. Carbon stock in the Sundarbans mangrove forest: spatial variations in vegetation types and salinity zones. Wetlands Ecology and Management, 23(2) (2015): 269-283.

Rahman, M. M., Furukawa, Y., Kawata, I., Rahman, M. M., & Alam, M. Homestead forest resources and their role in household economy: A Case Study in the villages of Gazipur sadar upazila of central Bangladesh. Small-Scale Forestry, 4(3) (2005): 359-376.

Rana, E. Processes and Experiences in REDD Pilot Project in Nepal. International Centre for Integrated Mountain Development, Kathmandu, Nepal, (2011).

Raunkiaer, Christen. The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer. The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer, (1934).

Rico-Gray, V., Garcia-Franco, J. G., Chemas, A., Puch, A., & Sima, P. Species composition, similarity, and structure of Mayan homegardens in Tixpeual and Tixcacaltuyub, Yucatan, Mexico. Economic Botany, 44(4) (1990): 470-487.

Roshetko, J. M., Delaney, M., Hairiah, K., & Purnomosidhi, P. Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage? American Journal of Alternative Agriculture, 17(3) (2002): 138-148.

Roy, Bishwajit, Md Habibur Rahman, and Most Jannatul Fardusi. Status, diversity, and traditional uses of homestead gardens in Northern Bangladesh: A means of sustainable biodiversity conservation, (2013).

Saha, S. K., Nair, P. R., Nair, V. D., & Kumar, B. M. Soil carbon stock in relation to plant diversity of homegardens in Kerala, India. Agroforestry systems, 76(1) (2009): 53-65.

Sarker, C. R., Robbani, M., Rahim, M. A., & Iqbal, T. M. T. Fruit diversity in the coastal homesteads of Bangladesh. Journal of Crop and Weed, 11 (2015): 95-105.

Shukla, R.S. and Chandel, P.S. Plant Ecology. S. Chand and Company Ltd. Delhi,India, (1980): 71-102.

Srivastava, Diane S., and Mark Vellend. Biodiversity-ecosystem function research: is it relevant to conservation? Annu. Rev. Ecol. Evol. Syst., 36 (2005): 267-294.

Torquebiau, Emmanuel F. A renewed perspective on agroforestry concepts and classification. Comptes Rendus de l'Academie des Sciences, 323(11) (2000): 1009-1017.

UNFCCC. Climate change science- the status of climate change science today, (1992).

UNFCCC. Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of Kyoto Protocol, (2004): 13-31.

USGS. Carbon Sequestration to Mitigate Climate Change, (2008).

Vance-Chalcraft, H. D., Willig, M. R., Cox, S. B., Lugo, A. E., & Scatena, F. N. Relationship between aboveground biomass and multiple measures of biodiversity in subtropical forest of Puerto Rico. Biotropica, 42(3) (2010): 290-299.

Vandermeer, John H. The ecology of intercropping. Cambridge University Press, (1992).

Verchot, L. V., Van Noordwijk, M., Kandji, S., Tomich, T., Ong, C., Albrecht, A., & Palm, C. Climate change: linking adaptation and mitigation through agroforestry. Mitigation and adaptation strategies for global change, 12(5) (2007): 901-918.

Watson, R. T., Noble, I. R., Bolin, B., & Ravindranath, N. H. Land use, land-use change and forestry. Summary for policymakers. Intergovernmental Panel on Climate Change, (2000).

Weersum, K. F. Tree gardening and taungya on Java: Examples of agroforestry techniques in the humid tropics. Agroforestry systems, 1.1 (1982): 53-70.

Wills, J.C. Agriculture in tropics. 2nd Edition. Cambridge University press. London, UK, (1914).

Zaman, Sourovi, and Masato Katoh. Homegarden Agroforestry in Bangladesh: Assessment of Its Role for Farmers' Income Source in Thakurgaon District. Journal of Forest Planning, 15.1 (2009): 37-43.

Zanne, A. E., Lopez-Gonzalez, G., Coomes, D. A., Ilic, J., Jansen, S., Lewis, S. L., & Chave, J. Data from: Towards a worldwide wood economics spectrum, (2009).

Zhang, Y., Duan, B., Xian, J., Korpelainen, H., & Li, C. Links between plant diversity, carbon stocks and environmental factors along a successional gradient in a subalpine coniferous forest in Southwest China. Forest Ecology and Management, 262(3) (2011): 361-369.

APPENDIX

Appendix-1

Family with Number of Species and Individuals with their Frequency in Khulna District

Serial no	Local name	Scientific name	Family	Frequency	Relative frequency (%)
1	Aam	*Mangifera indica L.*	Anacardiaceae	364	15.0351095
2	Aata	*Annona reticulata L.*	Annonaceae	16	0.66088393
3	Amloki	*Phyllanthus emblica L.*	Euphorbiaceae	24	0.9913259
4	Amra	*Spondias pinnata (L.f.) Kurz*	Anacardiaceae	44	1.81743081
5	Arjun	*Terminalia arjuna Wight & Arn.*	Combretaceae	1	0.04130525
6	Ash fall	*Euphorbia longana Lour.*	Sapindaceae	1	0.04130525
7	Bel	*Aegle marmelos (L.) Correa*	Rutaceae	55	2.27178852
8	Bokain	*Melia azadarach L.*	Meliaceae	1	0.04130525
9	Bokul	*Mimusops elengi L.*	Sapotaceae	3	0.12391574
10	Bon Amra	*Spondias indica Sol. ex Park.*	Anacardiaceae	4	0.16522098
11	Boroi	*Ziziphus juijuba (Burn.f.) W. & A.*	Rhamnaceae	25	1.03263114
12	Chatian	*Alstonia scholaris (L.) R. Br.*	Apocynaceae	2	0.08261049
13	Chinimisti	*Pimenta diocia (L.) Merr.*	Myrtaceae	1	0.04130525
14	Debdaru	Polyalthia longifolia (Sonn.) Hook.f. &	Annonaceae	9	0.37174721

		Thomson			
15	Dewya	Artocarpus lakoocha Roxb.	Moraceae	3	0.12391574
16	Dumur	*Ficus racemosa L.f*	Moraceae	5	0.20652623
17	Gab	*Diospyros blancoi Gurke*	Ebenaceae	49	2.02395704
18	Ipil ipil	*Leucaena leucocephala (Lam.) de Wit*	Leguminosae	56	2.31309376
19	Jam	Syzygium cumini (L.) Skeels	Myrtaceae	40	1.65220983
20	Jambura	*Citrus maxima L.*	Rutaceae	14	0.57827344
21	Jamrul	*Syzygium Samarangense (Blume)*	Myrtaceae	15	0.61957869
22	Kadom	*Neolamarckia cadamba (Lmk.)*	Rubiaceae	15	0.61957869
23	Kamrangaya	*Averrhoa carambola L.*	Oxalidaceae	9	0.37174721
24	Karpus tula	*Gossypium herbacium L.*	Malvaceae	19	0.78479967
25	Kat badam	*Terminalia catappa L.*	Combretaceae	19	0.78479967
26	Khatal	*Artocarpus heterophyllus Lam.*	Moraceae	73	3.01528294
27	Khejur	*Phoenix sylvestris Roxb.*	Palmae	54	2.23048327
28	Kodbel	*Feronia limonia L.*	Rutaceae	11	0.4543577
29	Koyea	*Pithecellobium dulce L.*	Fabaceae	9	0.37174721
30	Latim	*Trewia nudiflorus L.*	Euphorbiaceae	21	0.86741016
31	Lichu	*Litchi chinensis Sonn.*	Sapindaceae	5	0.20652623
32	Lombu	*Khaya anthotheca King*	Meliaceae	6	0.24783147
33	Mahagoni	*Swietenia macrophylla King.*	Meliaceae	424	17.5134242

34	Mos kondo	*Pterospermum suberifolium L.*	Malvaceae	1	0.04130525
35	Narikel	*Cocos nucifera L.*	Palmae	388	16.0264354
36	Neem	*Azadirachta indica A.Juss*	Meliaceae	88	3.63486163
37	Pepolti	*Ficus religiosa L.*	Moraceae	1	0.04130525
38	Peyara	*Psidium guajava L.*	Myrtaceae	14	0.57827344
39	Pitraj	*Aphanamixis polystachya (Wall.) R.N.Parker*	Meliaceae	6	0.24783147
40	Pitraj	*Erioglossum edulis L.*	Sapindaceae	1	0.04130525
41	RainTree	*Albizia saman (Jacq.) Merr.*	Leguminosae	32	1.32176786
42	Sajina	*Moringa oleifera Lam.*	Moringaceae	13	0.53696819
43	Shate Kanchon	*Bauhinia acuminata L.*	Leguminosae	3	0.12391574
44	Sheora	*Streblus asper Lour.*	Moraceae	10	0.41305246
45	Shimul	*Bombax ceiba L.*	Bombacaceae	6	0.24783147
46	Sil Koroi	*Albizia lebbeck (L.) Benth.*	Leguminosae	18	0.74349442
47	sissoo	*Dalbergia sissoo Roxb.*	Leguminosae	58	2.39570425
48	Sobeda	*Manilkara sapota (L.) P. Royen*	Sapotaceae	30	1.23915737
49	Sonalu	*Cassia fistula L.*	Leguminosae	4	0.16522098
50	Sundori	Heritiera fomes Buch.-Ham.	Malvaceae	1	0.04130525
51	Supari	*Areca catechu L.*	Palmae	187	7.72408096
52	Tal	*Borassus flabellifer L.*	Palmae	67	2.76745147
53	Tejapatta	*Cinnamomum Tamala L.*	Lauraceae	4	0.16522098
54	Tetul	*Tamarindus indica L.*	Leguminosae	52	2.14787278

55	Toon tree	*Toona ciliata L.*	Meliaceae	2	0.08261049
56	White siris	*Albizia procera L.*	Fabaceae	6	0.24783147

Appendix-2

LSD Test

HG type	Total C	Groups
Small	98.99549	a
Medium	51.83042	b
Large	37.13453	c

Appendix-3

Two-way Anova

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)	
Type	2	31336	15668	52.039	7.4e-12	***
Area	2	119	60	0.198	0.821	
Residuals	40	12043	301			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1