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ASSESSMENT OF TOTAL CARBON STOCK IN SWIETENIA MACROPHYLLA WOODLOT IN JHENAIDAH DISTRICT, BANGLADESH.

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DEDICATED

TO

MY BELOVED GRANDFATHER AND PARENTS

DECLARATION

I, Md. Najmus Sayadat Pitol, declare that this thesis is the result of my own works and that it has not been submitted or accepted for a degree in other university.

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ABSTRACT

Woodlot plantations are supposed to have a massive outlook in carbon sequestration. Presence of large area woodlot plantations in Bangladesh would store a significant quantity of carbon. The purpose of this study was to determine the carbon stocks in woodlot plantations in Jhenaidah district, Bangladesh. Sixty sample plots of woodlot plantations were purposively selected from three upazilla (Kotchandpur, Kaligong and Moheshpur) of Jhenaidah district. The plot size was 10 × 10 m. Every individual tree present in the sampling plot was indentified upto special level. Diameter at breast height and total tree height were measured for all individual trees in each sample plot. Above ground biomass was calculated using the equation of Chave et al. (2005) and below ground biomass was estimated using the equation of Cairns.et.al. (1997) and converted into carbon using the equation of Chave et al. (2005). The estimated average tree density was 1340 ± 104.24 stems ha^{-1}ranging between 800 and 2400 stems ha^{-1}. The estimated mean DBH and tree height were 19.52 cm and 12.57 m respectively. The total biomass in Mahagony (*Switenia macrophylla*) woodlot plantations ranged between 52.48 and 824.44 Mg ha^{-1} and the basal area in woodlot plantations ranged between 9.92 m^2ha^{-1} and 86.21 m^2ha^{-1}. The average total biomass was 287.86 ± 22.64 Mg ha^{-1} and average basal area was 37.98 ± 2.31m^2ha^{-1}. In this study, the average carbon stock in Mahagony plantation was estimated to 143.93 ±11.32 Mg ha^{-1} ranging between 26.24 Mg ha^{-1} and 412.22 Mg ha^{-1}. Three allometric models were developed and validated with equal strength (R^2 0.97–0.98) using generalized linear regression. Woodlot plantations in Bangladesh can play a vital role in the UNFCCC's carbon mitigation and adaptation mechanism. So the long-term sustainability of woodlot plantations must be addressed.

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CHAPTER ONE

INTRODUCTION

1.1 Background and justification of study

Global Warming, climate change and biodiversity conservation are the three concurrent issues in the present world. They are the consequence of the rise of greenhouse gases mainly CO_2 (Kumar 2011, Zhang et al. 2011). Human are mainly responsible of raising the amount of CO_2 in the atmosphere through the combustion of fossil fuel and deforestation (Sharma et al. 2010, Detwiler and Hall 1988). According to UNFCCC (2007), the concentrations of atmospheric CO_2 increased from a value of 278 parts per million to 379 parts per million in 2005, and the average global temperature rose by 0.74° C. The last 25 years this increased rate accelerated and recorded that 11 of the 12 months in a year were warmest (IPCC, 2007). Ecologists are worried about that the global warming will continue and the earth could warm by 3° C by 2100. If most of the countries try to reduce their greenhouse gas emissions, the Earth will continue to warm. It considers that the average global temperature will go up to 4° C instead of 1.8° C by 2100 (UNFCCC, 2007). If this raising rate will continue the sea level up to 5m by melting the polar ice-cap (Detwiler and Hall 1988) and as a result some South Asian countries will be the victim of sea level rising like Bangladesh.

Bangladesh is one of the vulnerable countries of global warming in South-Asian. It is one of the most densely populated countries of the world with the area of 14.757 million ha. The tropical climate dominates throughout the year with distinct rainfall and dry period. According to Bangladesh Bureau of Statistics (BBS 2010) population is 145.8 million of which 77% live in the rural areas. Overall per capita availability of land and forest are about 0.12 ha and 0.02 ha respectively. The total forest area in Bangladesh, according to Forest Department, is estimated to be 2.52 million ha corresponding to 17.4% of the land area of the country. This includes 1.52 Million ha Forest Department controlled land, 0.73 million ha Unclassified State Forests (USF) under the control of District Administration and 0.27 million ha village forest land (mostly homesteads). In recent time, natural forests are decreasing very speedily due to anthropogenic activities such as housing, land conversion of other uses, deforestation, industrialization etc. The deforestation rate is faster than the previous time. But it is good that the amount of plantation forests is increasing during last two decades (CRA, Bangladesh 2010). From 2005 to 2010, an average of 5 million ha of tree plantations have been established per year in Bangladesh (FAO, 2010). In 2010, the total amount of plantation forests is 264 million ha that covers up to 7% of the total forest area in the world (FAO, 2010). It assumed that, plantation forests provided about 35% supply of global wood in the year of 2000. It considers that this supply will go up to 44% by the year 2020 (ABARE & Jaakko Pöyry, 1999). So, the importance of plantation forests is increasing undoubtedly.

Bangladesh, a developing country, is one of the lowest CO_2 emitting countries in the world. It is estimated that the per capita CO_2 emission is 0.2 ton/year in Bangladesh, but the average for the developing countries is 1.6 ton/year. In developed countries, the per capita CO_2 emission is 20-50 times higher than the developing countries. In USA the per capita emission is 20 ton/year. Though Bangladesh is in low Green House Gas (GHG) emission category however provides no relief from the effects of Global Warming. If the sea level will rise in 1.5 meter, about 22,000 sq.km land of Bangladesh will be inundated and 17 million people affected. Bangladesh will be the worst sufferer of global warming but she is not liable for this. Rather she is acting fundamental role in carbon sequestration (Waste concern, UNDP, 2012). For minimizing the effects of global warming, Kyoto protocol, REDD+, carbon trading are well discussed issues in the present world. All the treaties try to reduce the emission of CO_2 and enhancing the role of conservation, Sustainable Management of Forests and Enhancement of forest carbon stocks in Developing Countries (Gardner et al. 2011).

Bangladesh has already ratified the Kyoto protocol, REDD+ and involved in the carbon trading mechanisms. In carbon trading mechanisms, Bangladesh reduces the emission of carbon in the atmosphere within a certain limit and gets a certain amount of money in a certain period of time from the highest carbon emitting countries such as USA, Australia, and China etc. It encourages the use of green technology and helps in increasing forestation. It is an alternative ways to recover the effects of global warming. Basically it is a reward to who are emitting less carbon dioxide and a charge on who are liable for global warming. It is not a day dream that one day small holder farmers will get money in exchange of planting trees. So, it is very much necessary for Bangladesh to assess the biomass or carbon stock of the woodlot plantations for getting the carbon trading facilities. Considering the above background and justifications, this present study aims to assess carbon stocks of the woodlot plantations in Jhenaidah district, Bangladesh.

1.2 Objectives

1. To estimate the total Carbon (C) stock of woodlot plantations in Jhenaidah, Bangladesh.

2. To find out the relationships among Diameter at Breast Height (DBH), Total Height (TH) and Basal Area to Total Carbon Stock.

3. To develop Basal area based allometric models for carbon assessment.

CHAPTER: TWO

LITERATURE REVIEW

2.1 Concept of Woodlots

A woodlot is a term used in North America to refer to a segment of a woodland or forest capable of small-scale production of forest products such as wood fuel, sap for maple syrup, saw logs, as well as recreational uses like bird watching, bushwalking, and wildflower appreciation. In Britain a woodlot would be called a wood, woodland or coppice. Many woodlots occur as part of a larger farm or as buffers and undevelopable land between these and other property types such as housing subdivisions, industrial forests, or public properties (highways, parks, watersheds, etc.). Very small woodlots can occur where a subdivision has not met its development potential, or where terrain does not easily permit other uses. Very large woodlots (hundreds of acres) might emerge where profitable wood species have been depleted by commercial logging practices or compromised by diseases, leaving little choice but to divide and liquidate the real estate for other purposes. One distinguishing characteristic of a woodlot is that the parcel size or quality of wood on the parcel does not generally justify full-scale commercial harvesting, leaving many woodlots as private investments by individuals. On the other hand, good forest management practices, even on a small scale, may create a sustainable source of products, which can significantly contribute to the aggregate inventory available to forest-product consumers. (Wikipedia 2007)

2.1.1Benefits of woodlots

The value of the woodlots is often and only measured by the dollar value from timber sales. Many farmers don't know that there are so many others values that indirectly might be worth more than the dollars from timber sales. The woodlots enhance protection and conservation of soil quality which is a key component of a sustainable agriculture production system and ecosystems as well. The value of woodlots on soils quality includes reduces soil erosion and it is known that the effect of soil erosion on crop yields and soil productivity are substantial. Loss of nutrients and minerals in the soil from erosion and reduction on yield and productivity are considerable costs to farmers, trees absorb chemicals from fertilizers, heavy metals and other pollutants through their root systems and store it in the wood, some shrub and tree species might reduce salinity in the soil (Agroforestry &Woodlot Extension Society, 6547 Sparrow Drive Leduc, AB T9E 7C7).

2.2 Mahogany (*Swietenia macrophylla King*)

Swietenia macrophylla King, also known as big leaf mahogany, is a tropical tree species native to Central and South America. *Swietenia macrophylla* has a wide natural distribution, extending from Mexico to Bolivia and central Brazil (Lamb 1966). However, large areas of former *S. macrophylla* forests have been converted to other uses, or the remaining forests are few (Shono and Snook 2006). The depletion of *S. macrophylla* populations has lead to concern for the future of the species and its commercial trade. In 2002, *S. macrophylla* was listed in Appendix II (species that may face extinction if trade is not controlled) of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Grogan and Barreto 2005). The largest plantations of *S. macrophylla* have been reported in South and Southeast Asia and the Pacific region. A significant proportion of the total area, most remarkably in Indonesia and the Philippines, was intended for protection of slopes and water catchments and may not be productive. In addition, *S. macrophylla* is widely used for avenue planting in some Asian countries including Indonesia, India and Sri Lanka. According to Mayhew and Newton (1998), the earliest recorded introduction of *S. macrophylla* into any country is to Indonesia in 1870 with seeds from India. It was then planted as an ornamental and cultivated in plantations in Java between 1897 and 1902.

2.3 Description of the species

2.3.1 Taxonomy

Botanical name: *Swietenia macrophylla King*

Family: Meliaceae

Subfamily: Swietenoideae

Synonyms: Swietenia belizensis Lundell, Swietenia candollei Pittier, Swietenia krukovii Gleason, Swietenia macrophylla King var.marabaensis Ledoux et Lobato, Swietenia tessmannii Harms.

2.3.2 Distribution

Swietenia macrophylla grows naturally in Belize, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru and Venezuela. However, it is nearly extinct in Ecuador, Colombia, Panama and Costa Rica; close to commercial extinction in Bolivia; declining in Mexico, Belize and Brazil; and in severe decline in Guatemala, Peru, Nicaragua and Honduras

2.3.3 Wood characteristics

Swietenia macrophylla is a rather soft, medium weight timber. The heartwood is reddish or pinkish, the color darkening with age to a deep red or brown; the sapwood is usually yellowish. It has an attractive appearance, can be worked easily with hand tools and has excellent finishing qualities and dimensional stability (Martawijaya et al. 2005)

2.4 Concept of Plantation

A plantation is a large piece of land (or water) usually in a tropical or semitropical area where one crop is intentionally planted for widespread commercial sale and usually tended by resident laborers. The crops grown include fast-growing trees (often conifers), cotton, coffee, tobacco, sugarcane, sisal, oil seeds (e.g. oil palms), rubber trees, and various fruits. Protectionist policies and natural comparative advantage have sometimes contributed to determining where plantations were located. Among the earliest examples of plantations were the latifundia of the Roman Empire, which produced large quantities of wine and olive oil for export. Plantation agriculture grew rapidly with the increase in international trade and the development of a worldwide economy that followed the expansion of European colonial empires. Like every economic activity, it has changed over time. Earlier forms of plantation agriculture were associated with large disparities of wealth and income, foreign ownership and political influence, and exploitative social systems such as indentured labor and slavery (Wikipedia 2007).

2.5 Forest as a climate mitigation tool

Forest has an important role in the global carbon cycle (Pan et al. 2011) and forestry can contribute to climate change mitigation (TFD 2008). There are two ways to reduce CO_2 concentrations in the air: (1) do not allowing CO_2 to enter the atmosphere (i.e., control emission or carbon conservation) and (2) removing some of the excess CO_2 already in the atmosphere and sequestering it where it does less harm (Brown 2010).

2.6 Global Warming and Kyoto Protocol

Increasing scientific evidence reveals that the earth is getting warmer due to various human activities resulting in sea level rise and occurrence of extreme events such as cyclones, floods and droughts. In order to tackle Global Warming, United Nations General Assembly took up this issue of Climate Change and adopted the resolution "Protection of Global Climate for Present and Future Generations of Mankind". The United Nations Framework Convention on Climate Change (UNFCCC), adopted in 1992 which came into force in 1994 established an international framework to address global climate change. Parties to the Convention agreed to stabilize green house gas (GHG) concentrations in the earth's atmosphere. In December 1997, Bangladesh along with 160 other countries, completed negotiations at the third session of Conference of Parties (COP3) at Kyoto Japan to finalize a protocol subsequently known as the Kyoto Protocol. This protocol includes reduction targets and time table for six green house gases. The most important aspect of the Kyoto Protocol is its legally binding commitments for 39 developed countries to reduce their GHG emissions by an average of 5.2% relative to 1990 level. These emission reductions must be achieved by 2008 -2012: the so called first commitment period (Waste concern, UNDP, 2012).

2.7 Impact of global warming in Bangladesh

Bangladesh is a low carbon dioxide emitting country. For instance, the per capita carbon dioxide 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 GHG 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 of global warming would be on:

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

2.8 Clean Development Mechanism (CDM)

The Kyoto Protocol allows Annex-B countries to reach their emission reduction targets in different ways through Flexibility Mechanisms. These include Emission Trading (trading of emission between developed countries); Joint Implementation (transferring emission allowances between developed nations linked to a specific emission reduction project); and Clean Development Mechanism (CDM). CDM is the only flexibility mechanism that involves developing countries (Non-Annex B). It allows developed countries (Annex-B) to achieve part of their reduction obligations through investment in projects in developing countries that reduce GHG emissions or fix or sequester carbon dioxide from the atmosphere (Waste concern, UNDP, 2012).

2.8.1 Salient Features of CDM

Industrialized (Annex-B) countries' state or private companies can invest in projects in developing (Non-Annex B) countries that contribute to reduction of GHG emission. Developing (Non-Annex B) countries' state or private companies are allowed to implement such projects. Through CDM projects industries in developing countries can be technologically upgraded and made environment friendly thus contributing to global climate protection as well as promoting sustainable development in the host country. The industrialized countries' investing entities can earn credit for emission reductions achieved through its investment in developing country towards its own emission commitment. (Waste concern, UNDP, 2012)

2.9 Carbon sequestration

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 principle greenhouse gases) in the atmosphere will reduce or slow (Carbon venture 2011). The United Nations Framework Convention on Climate Change (UNFCCC) defines carbon sequestration as the process of removing carbon from the atmosphere and depositing it in a reservoir. Carbon sequestration can be defined as the amount of carbon that can be additionally stored in an agro-ecosystem (Bernoux et al. 2006). At present, carbon sequestration is valued as a function of credit emission reductions (CERs), based on the difference between the amount of carbon stored in scenario projects and the baseline, current amount of carbon stored in the system (UNFCCC 2004). According to USDA Forest Service (2009), "Carbon sequestration is the process by which atmospheric CO_2 is taken up by trees, grass and other plants through photosynthesis and stored as carbon in biomass (trunks, branches, foliages and roots) and soils.

2.10 Types of carbon sequestration

- According to IPCC (2005), CO_2 sequestration can be done by the following three ways.
- Terrestrial sequestration or vegetative sequestration: Terrestrial sequestration is the natural intake of CO_2 by plants, which incorporate it in their wood, leaves, and roots and also bind it to the underlying soil and 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 (Brown 2010. 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.
- 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 emissions source (e.g., a power plant) and the captured CO_2 is injected and sealed into deep rock units (Brown 2010).

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).

- Oceanic sequestration: Oceanic sequestration is dumping the CO_2 into the oceans depths. Pumping CO_2 into the deep ocean basins (350-3000 meters), where it is anticipated it may form lakes of liquid, supercritical or solid hydrates.

2.11 Carbon stocks

'Terrestrial carbon stocks' is the term used for the C stored in terrestrial ecosystems, as living or dead plant biomass (aboveground and belowground) and in the soil, along with usually negligible quantities as animal biomass. Aboveground plant biomass comprises all woody stems, branches and leaves of living trees, creepers, climbers and epiphytes as well as understory plants and herbaceous growth. For agricultural lands, this includes trees (if any), crops and weed biomass. The dead organic matter pool (necromass) includes dead fallen trees and stumps, other coarse woody debris, the litter layer and charcoal (or partially charred organic matter) above the soil surface. The belowground biomass comprises living and dead roots, soil fauna and the microbial community. There also is a large pool of organic C in various forms of humus and other soil organic C pools. Other forms of soil C are charcoal from fires and consolidated C in the form of iron humus pans and concretions. For peat land, the largest C pool is found in soil.

2.12 Concept of Carbon Trading

Carbon trading also referred to as emission reduction trading is a relatively simple concept. 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. Carbon trading allows surplus emission reduction to required limits to be traded to other parties needing to meet emission limits. In theory, if one party can reduce emissions at a lower cost than a second party, then first party could maximize emission reductions and sell any surplus reductions to the second party to help meet its reduction requirements. The aim is to improve the overall flexibility and economic efficiency of obtaining emission reduction (Waste concern, UNDP, 2012).

2.13 Carbon Trading: Bangladesh Perspective

Farmers are not eager to plant trees because trees usually don't earn them money for many years. Now a carbon broker came and offers them to plant trees and keep it alive for a definite period, in exchange he will pay them money. This is the dream of some environmental organizations, economist states and entrepreneurs. They believe a system of carbon trading that allows the buying and selling carbon credit simultaneously help prevent global warning and promote planting of trees. Carbon trading of carbon dioxide emissions by exchanging it from one's limit fixed according to Kyoto Protocol by the state. This earth when created carbon dioxide was used to keep the earth warm for friendly living environment. And it was in a balance amount. But now a day's carbon dioxide exists over the balance amount and causing different problems like global warming and green house effect. United Nations Frame work convention on climate change (UNFCCC) and different organizations are trying to protect global warming by decreasing carbon dioxide emission. Kyoto Protocol is the first step towards decreasing global emissions of carbon dioxide. By 2012, UNFCCC wants to decrease5.2% global emission of Carbon dioxide. Article 17 of the Kyoto Protocol regulates emission trading. Parties who have ratified Kyoto Protocol shall not exceed this carbon dioxide emission from the limit fixed by the UNFCCC. Carbon trading may be in different ways. There is no single format which is internationally recognized. Different formats are given below:

2.13.1 Exchanging From one's Permit

UNFCCC sets a limit on the amount of carbon dioxide that can be emitted by the state. And the state is bound as she has ratified the Kyoto Protocol. The limit is allocated in the form of emissions permits by the state to the bodies that need to emit carbon dioxide. The total number of permit cannot exceed the limit. Firms who need to emit more than the permit, they can buy it from others who are emitting less than the amount permitted. The transfer of this extra amount in exchange of money is an example of carbon trading.

2.13.2 Planting Trees and Forestation

Suppose I have a company. I need to emit 200 metric tons of carbon dioxide. But the state has permitted me of 100 metric tons. Then I plant some trees somewhere of the country that can absorb100 in tones of carbon dioxide annually. Then I showed the authority that through I am directly emitting 200 metric tons of carbon dioxide but 100 metric tons of carbon dioxide is being absorbed by those trees. So, my actual emission of carbon dioxide is 100 metric tons.

2.13.3 Allowance to Non-Profit Organization

Someone who is emitting carbon dioxide is directly and indirectly harming the environment. So it is the corporate social responsibility to take part for the recovery of environment. If he directly can to do so he can take help from others who are working for the protection of global warming. That means, payment of a good amount of money to that nonprofit organization which will be reasonable to recover the amount you are harming through emitting carbon dioxide. It is the alternative way to keep balance the environment.

2.13.4 Individual Limit

Some persons are leading luxurious life in the whole world .Whenever they are using more electricity than the usual; they are taking part to emit more carbon dioxide. At the same way adding fuels to their vehicles, using air conditioner etc. They are taking part in global warming. State can fix a limit of emitting carbon dioxide for every individual. Where ever someone needs more amounts to emit then he has to buy it from the extra amount of others who are emitting less than their limit.

2.13.5 Market Size

According to the World Bank's Carbon Finance Unit, 374 million metric tons of carbon dioxide equivalent were exchanged through projects in 2005. In terms of dollars, the World Bank has estimated that the size of carbon market was 11 billion USD in 2005, 30 billion USD in 2006 and 64 billion USD in 2007.

2.13.6 Opportunity for Bangladesh

Bangladesh has already ratified the Kyoto protocol may apply for emission permit for trading and already she gotten the permission to exchange the amount Bangladesh does not emit with other countries Carbon trading compels to keep the emissions of carbon dioxide within a certain limit. It encourages using green technology. It helps increasing forestation. It is an alternative means to recover global warming through taking part with the activities of global environmental organization. As a whole it is a reward to who are emitting less carbon dioxide and a charge on who are liable for global warming.

2.14 Carbon conservation

The most expeditious way to mitigate climate change in 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" (REDD) (IPCC 2007, Canadell and Raupach 2008, TFD 2008).

2.14.1 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 over the medium to long term (IPCC 2007, TFD 2008).

2.14.2 Carbon cycle in forest

Photosynthesis is the chemical process by which plants use sunlight to convert nutrients into sugars and carbohydrates. CO_2 is essential to building the organic chemicals that comprise leaves, roots and stems.

As more photosynthesis occurs, more CO_2 is converted into biomass, reducing carbon in the atmosphere and sequestering it in plant tissue (vegetation) above and below ground. Plants also respire, using oxygen to maintain life and emitting CO_2 in the process. At times (e. g., at night and during winter seasons in non-tropical climates), living, growing forests are net emitters of CO_2; although they are generally net carbon sinks over the life of the forest.

When vegetation dies, carbon is released to the atmosphere. This can occur quickly, as in a fire or slowly as fallen trees, leaves and other detritus decompose. For herbaceous plants, the above ground biomass dies annually and begins to decompose right away but for woody plants some of the above ground biomass continues to store carbon until the plants dies and decomposes. This is the essence of the carbon cycle in the forests-net carbon accumulation (sequestration) with vegetative growth and release of carbon when the vegetation dies. Thus the amount of carbon sequestered in a forest is constantly changing with growth, death and decomposition of vegetation. In addition to being sequestered in vegetation, carbon is also sequestered in forest soils. Carbon is the organic content of soil, generally in the partially decomposed vegetation (humus) on the surface and in the upper soil layers, in the organisms that decompose vegetation and in the fine roots.

The amount of carbon in soils varies widely, depending on the environment and history of the site. Soil carbon accumulates as dead vegetation is added to the surface and decomposers respond. Carbon is also “injected” into the soil as roots grow (root biomass increases). Soil carbon is also slowly releases to the atmosphere as the vegetation decomposes. Scientific understanding of the rate of soil carbon accumulation and decomposition is currently not sufficient for predicting changes in the amount of carbon sequestered in forest soils.

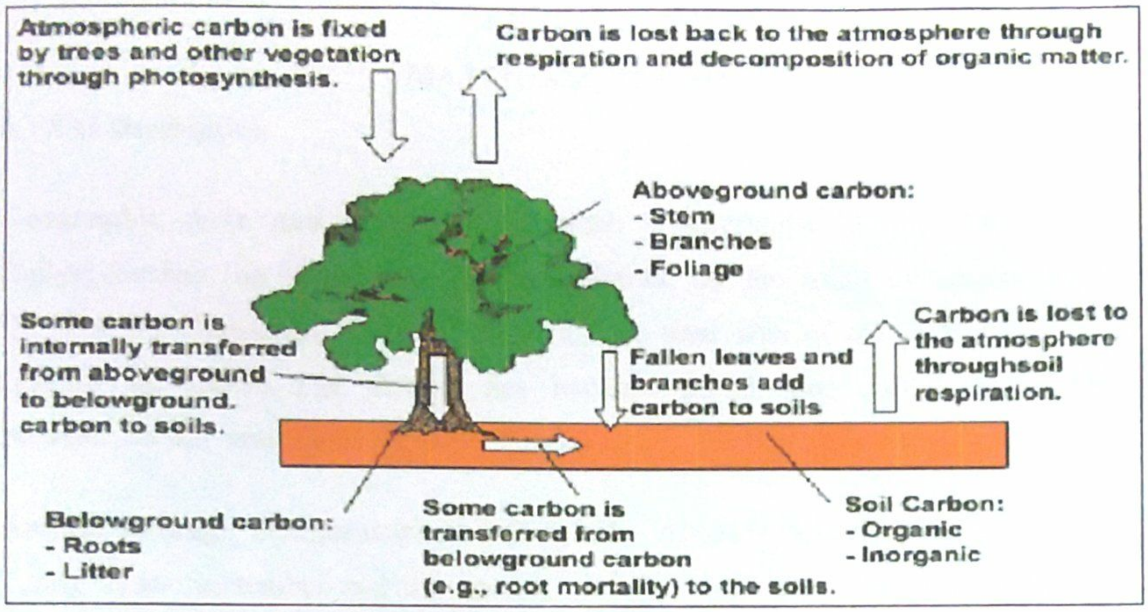

Figure 1 : An illustrated guide to carbon cycle (Source: USEPA at www.epa.gov/sequestration/local_scale.html)

CHAPTER: THREE

MATERIALS AND METHODS

3.1 Site Description

Geographic Area and Location: Jhenaidah is surrounded on the north by Kushtia and Rajbari districts, on the east by Magura district, on the south by Jessore district and on the west by Chuadanga district and India. The total area of the district is 1,964.77 sq.km (758.60 sq. miles). The district lies between 23°13` and 23°46` North latitudes and between 88°42` and 89°23` East longitudes.

Annual Average Temperature and Rainfall: About 90% of the total annual rainfall occurs during June- September and the annual rainfall is 1467 mm. The average daily temperature ranges from 12° C during December-January to about 31° C during May-August. The annual average temperature is 24° C, with the extreme lowest 8.1° C in January and the highest 40° C in May. Annual average maximum temperature is 37.1° C and minimum 11.2° C. Four main seasons namely the dry or winter season (December to February), the pre-monsoon hot season (March -May), the monsoon or rainy season (June-September) and the post monsoon or autumn season (October-November) are recognized. (Banglapedia).

Economic Situation: The economy of Jhenaidah district is predominantly agricultural. Out of total 385,860 holdings of the district, 66.50 % holdings are farms that produce varieties of crops namely local and HYV paddy, jute, sugarcane, wheat, vegetables, spices, pulses, oilseeds and other minor crops. Various fruits like mango, banana, jackfruit, guava, coconut, etc are grown. Varieties of fish are caught from rivers, flowing channels and even from paddy fields during rainy seasons. Besides crops livestock and poultry, fishery and handloom spinning and weaving are the main sources of household income.

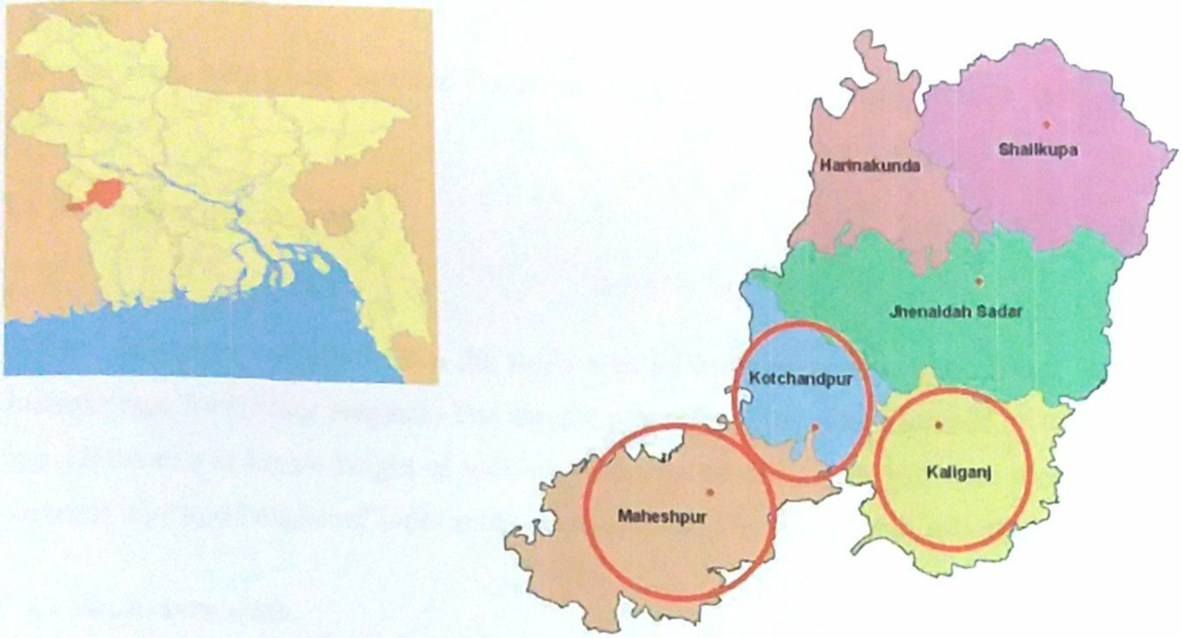

Figure 2: Study Area (Jhenaidah district Map)

3.2 Sample Size and Sampling Design

The most woodlot plantations of the study area are composed of *Switenia macrophylla* and the present study was conducted on woodlots of *Switenia macrophylla*. Purposive sampling was used for the data collection because of the uneven and discrete distribution of woodlots plantation in this region. During the reconnaissance survey, the study areas where woodlots plantation are dominant were selected through snow-ball methods. Twelve villages were selected from the study area (Kotchandpur, Maheshpur and Kaligang Upazila). Five sample plots were selected from each village and total sixty sample plots from twelve villages were selected. The size of the each sampling plot was 10 m × 10m ($100m^2$). The plantation plot whose individual's diameter is less than 8 cm was discarded purposively.

3.3 Tools

Diameter tape, Measuring tape and Haga Altimeter were used for collecting primary data for the study area.

3.4 Data collection process

3.4.1 Primary data

Primary data were collected from the study area by using measuring tape, Spigel Relaskop and diameter tape for further analysis. The sample plot (10m*10m) was alienated by using measuring tape. Diameters at breast height of individual species of the sample plot were measured by using diameter tape and heights of individuals were measured by using Haga Altimeter.

3.4.2 Secondary data

Secondary data and related information were collected from the following sources:

- Khulna university library
- Seminar library, Forestry and Wood Technology Discipline, Khulna University
- Published and Unpublished reports, journals, books.
- Newspapers.
- Regional center, BBS, Jhenaidah.
- Agriculture Information Services, Jhenaidah.
- Internet.

3.5 Data analysis

3.5.1 Allometric computations for aboveground and belowground biomass

Biomass equations relate DBH to biomass and biomass may differ among species as trees in a similar functional group can differ greatly in their growth form between geographic areas (Pearson et al. 2007). Considering these factors Chave et al. (2005) developed allometric equation for tropical trees that was used for wide graphical and diameter range. By using Chave's allometric equation no (1), biomass of the *Switenia macrophylla* woodlots was estimated. The following Chave's universal allometric equation is-

$$AGB = \rho \times \exp(-1.499 + 2.148 \times \ln(DBH) + 0.207 \times (\ln(DBH))^2 - 0.0281(\ln(DBH))^3) \ldots\ldots\ldots(1).$$

Here,

AGB = Aboveground biomass

ρ = Wood density (gcm^{-3}), DBH = Diameter at breast height , ln = Natural logarithm

1.499 = Constant, 2.148 = Constant, 0.207 = Constant, 0.0281= Constant

The wood density data were obtained from the World Agroforestry Database (Carsanetal.,2012) and the Global Wood Density Database(Chaveetal.,2009;Zanneetal.,2009).

Besides this Below Ground Biomass was calculated using the regression model suggested by Cairns.et.al. (1997) as the most cost effective and practical method of determining root biomass.

BGB =EXP(-1.0587 + 0.8836×LN(AGB))..................(2)

3.5.2 Conversion of aboveground biomass to carbon

Estimated biomass was multiplied by the wood carbon content (50%). As almost all carbon measurement projects in the tropical forest assume that all tissues (i.e. wood, leaves and roots) consist of 50% carbon on a dry mass basis (Chave et al. 2005, Prichard et al. 2000, Smith and Heath 2002).

Carbon (Mg) =Biomass estimated by allometric equation × Wood Carbon Content %

= Biomass estimated by allometric equation × 0.5

3.5.3 Density and basal area

Above ground carbon pools was computed using international standard common tree allometries combined with local tables of wood density by tree species. Statistical analysis was done in Microsoft Excel 2007 and SPSS-16 software. Basal area and density were measured to determine the correlation with the biomass of the woodlot.

The basal area/ha was calculated according to the formula (Equation no: 3) (Shukla and Chandel1980):

$$\text{Ba/ha} = \frac{\sum \frac{\Pi}{4} D^2}{\sum area \quad of \quad all \quad quadrats} \text{X} \quad 10000 \quad \text{...........} (3)$$

Where, Ba = Basal area in m^2ha^{-1}

D = Diameter at breast height in meter

$\Pi = 3.14$

Following the formulas of Moore and Chapman 1986, Shukla and Chandel 1980 and Dallmeier et al. 1992 quantitative structure parameters of investigated trees were calculated:

$$\text{Density (stem/ha)} = \frac{\text{Total no. of individuals of one species in all the plots}}{\text{Plot area} \times \text{Total no. of plots studied}} \quad \text{...............} (4)$$

$$\text{Basal area } (m^2/\text{ha}) = \frac{\text{Total basal area of individual species } (m^2)}{\text{Sample plot area (ha)} \times \text{Total no. of plots studied}} \quad \text{..................} (5)$$

3.2.3.9 Statistical analysis

Aboveground Carbon stocks were computed using developed international standard Chave et al. (2005) allometric equation for tropical trees that was used for wide graphical and diameter range. Below ground biomass and carbon were estimated using the regression model suggested by Cairns et al. (1997) as the most cost effective and practical method. A Generalized Linear Regression Model (GLRM) was employed to develop and validate the basal area based carbon estimation model.

CHAPTER: FOUR

RESULTS AND DISCUSSION

RESULTS

4.1 Carbon stocks of the woodlot

The total biomass (AGB and BGB) in Mahagony(*Switenia macrophylla*) woodlot plantations in Kotchandpur, Kaligong and Moheshpur upazilla were 325.97 Mg ha^{-1} , 199.63 Mg ha^{-1} and 337.99 Mg ha^{-1} respectively (Table no: 1, 2 and 3, Figure 3). In this study, the average carbon stocks in Mahagony (*Switenia Macrophylla*) plantations were estimated to 162.98 Mg ha^{-1} , 99.82 Mg ha^{-1} and 168.99 Mg ha^{-1} in Kotchandpur, Kaligong and Moheshpur upazilla where the average density were 1305 stem ha^{-1}, 1390 stem ha^{-1} and 1325 stem ha^{-1} respectively (Table no: 1, 2 and 3, Figure 3). The average DBH were 19.52 cm, 16.09 cm and 19.56 cm; mean tree height were 12.57m, 11.62 m and 11.84 m; average basal area were 42.01 m^{2}ha^{-1} , 29.31 m^{2}ha^{-1} and 42.66 m^{2}ha^{-1} in Kotchandpur, Kaligong and Moheshpur upazilla respectively (Table no: 1, 2 and 3, Figure 3). The biomass and carbon stock of Moheshpur (337.99 Mg ha$^{-1,}$ 168.99 Mg ha^{-1}) and Kotchandpur (325.97 Mg ha$^{-1,}$ 162.98 Mg ha^{-1}) upazilla was higher than the Kaligonj (199.63 Mg ha^{-1}, 99.82 Mg ha^{-1}). Because most of the plantations in Kaligonj upazilla were new and the mean DBH was comparatively lower than the two upazilla. Stem density and tree height have lower effects on biomass and carbon stock in woodlot plantations. The stem density was higher in Kaligang upazilla (1390 stem ha^{-1}) then other two upazilla and mean tree height (11.62 m) was very close to Moheshpur (11.84 m) upazilla but biomass and carbon stock were lower than the two upazilla.

In Jhenaidah district, the estimated tree density was 1340 ± 104.24 stems ha^{-1} ranging between 800 and 2400 stems ha^{-1} (Table no: 4). The estimated mean DBH and tree height were 19.52 cm and 12.57 m respectively (Table no: 4). The total biomass in Mahagony(*Switenia macrophylla*) woodlot plantations ranged between 52.48 and 824.44 Mg ha^{-1} and the basal area in woodlot plantations ranged between 9.92 and 86.21 m^{2}ha^{-1} (Table no: 4) in Jhenaidah district. The average total biomass was 287.86 ± 22.64 Mg ha^{-1} and average basal area was 37.98 ± 2.31 m^{2}ha^{-1} (Table no: 4). In this study, the average carbon stock in Mahagony (*Switenia*

Macrophylla) plantation in Jhenaidah district was estimated 143.93 ±11.32 Mg ha^{-1} ranging between 26.24 and 412.22 Mg ha^{-1} (Table no: 4) where 85% above ground and 15% below ground (Figure 3).

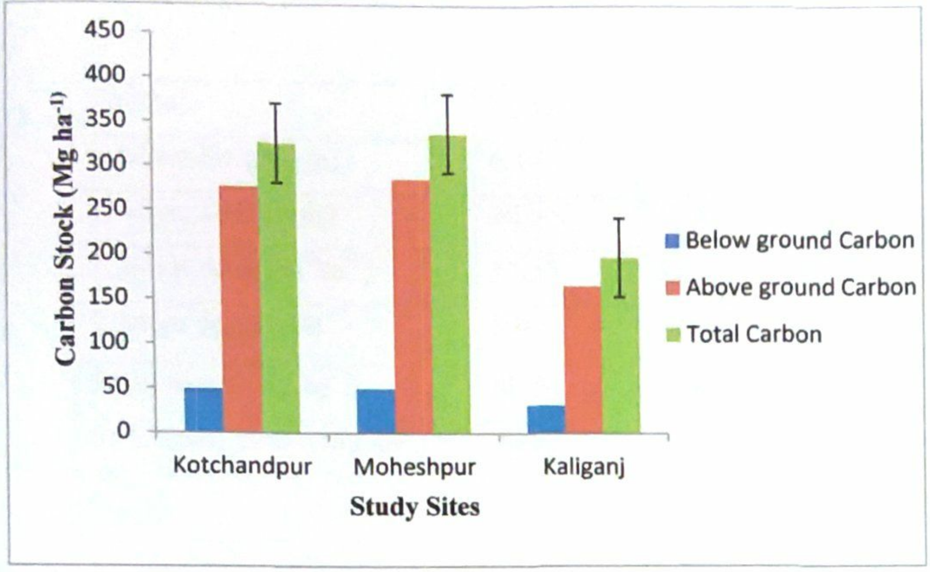

Figure 3: Carbon content of the woodlot plantations at three upazilla in Jhenaidah district

Table 1

Average Height, Diameter at Breast Height, Basal Area, Stem Density, Biomass and Carbon stock in woodlot plantations at Kotchandpur Upazilla

Contents	Minimum	Maximum	Average	SD	SE
1. Mean Height (m)	6.54	15.11	12.57	2.24	0.50
2. Mean DBH (cm)	11.75	26.33	19.52	4.09	0.92
3. Basal Area (m^{2}ha^{-1})	9.92	86.21	42.01	17.11	3.83
4. Stem density ha^{-1}	900	2400	1305	466.19	104.24
5. Biomass (Mg ha^{-1})	52.48	747.79	325.97	157.24	35.16
6. Carbon stock (Mg ha^{-1})	26.24	373.89	162.98	78.62	17.58

Table 2

Average Height, Diameter at Breast Height, Basal Area, Stem Density, Biomass and Carbon stock in woodlot plantations at Kaligong Upazilla

Contents	Minimum	Maximum	Average	SD	SE
1. Mean Height (m)	6.77	15.48	11.84	1.99	0.44
2. Mean DBH (cm)	10.9	33.47	19.56	5.95	1.33
3. Basal Area (m^2ha^{-1})	15.55	83.37	42.66	21.70	4.85
4. Stem density ha^{-1}	800	2200	1325	355.22	79.43
5. Biomass (Mg ha^{-1})	80.84	824.44	337.99	220.85	49.38
6. Carbon stock (Mg ha^{-1})	40.42	412.22	168.99	110.43	24.69

Table 3

Average Height, Diameter at Breast Height, Basal Area, Stem Density, Biomass and Carbon stock in woodlot plantations at Moheshpur Upazilla.

Contents	Minimum	Maximum	Average	SD	SE
1. Mean Height (m)	7.46	15.55	11.62	2.51	0.56
2. Mean DBH (cm)	11.11	24.37	16.09	3.74	0.83
3. Basal Area (m^2ha^{-1})	13.08	51.61	29.31	10.45	2.34
4. Stem density ha^{-1}	800	2000	1390	311.03	69.55
5. Biomass (Mg ha^{-1})	68.52	450.86	199.63	98.05	21.92
6. Carbon stock (Mg ha^{-1})	34.26	225.43	99.82	49.02	10.96

Table 4

Average Height, Diameter at Breast Height, Basal Area, Stem Density, Biomass and Carbon stock in woodlot plantations in Jhenaidah District, Bangladesh.

Contents	Minimum	Maximum	Average	SD	SE
1. Mean Height (m)	6.54	15.55	12.01	2.25	0.29
2. Mean DBH (cm)	10.9	33.47	18.39	4.9	0.63
3. Basal Area (m^2ha^{-1})	9.92	86.21	37.98	17.88	2.31
4. Stem density ha^{-1}	800	2400	1340	378.31	48.84
5. Biomass (Mg ha^{-1})	52.48	824.44	287.86	175.35	22.64
6. Carbon stock (Mg ha^{-1})	26.24	412.22	143.93	87.67	11.32

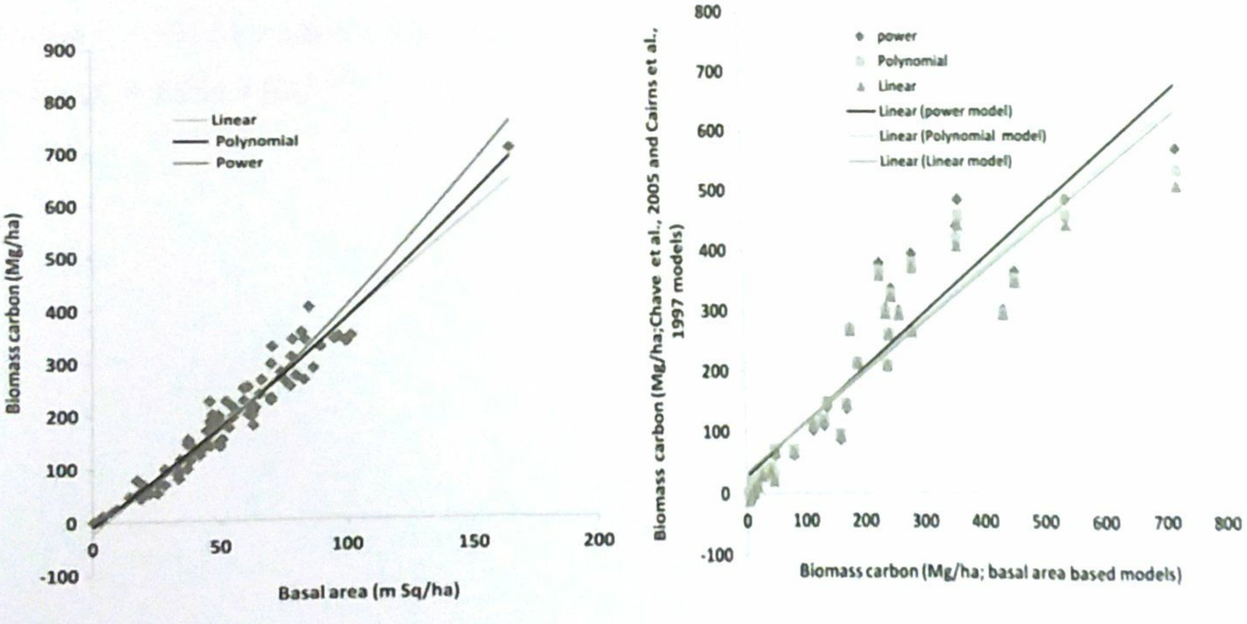

Figure 4: Basal area based biomass models at the left side of this study validated with models established by Chave et al. (2005) and Cairns et al. (1997) at the right side.

4.2 Basal area based allometric models and their validation

Three types of models were developed for carbon assessment from the plot level mean basal area (Eqs. (1)–(3)). We found a strong (mean $R^2 = 0.97$; for Linear 0.97, Polynomial 0.97 and Power 0.98 models) and significant ($P < 0.05$) relationship between mean biomass carbon and mean basal area for *Swietenia macrophylla* woodlot (Fig.4). All three models were tested against 40 plots with Chave et al. (2005) and Cairns et al. (1997) for validation. Results of the GLRM revealed that all three models showed significant ($P<0.01$) and strong relationships ($R^2=0.97$) with established models (Chave et al., 2005; Cairns et al., 1997) based on biomass carbon content (Fig.4). We also tested our three models with Rahman et al. (2015) and found that all three models showed significant ($P<0.01$) and strong relationships ($R^2=0.99$) with three established models (Rahman et al., 2015). Given the high regression R^2 (range: 0.97–0.98), our three models are equally strong in calculating the tree biomass carbon content. Therefore our basal area based allometric models are equally suitable for calculating biomass carbon content from the trees in woodlots.

$$\text{Biomass C} = 4.834 \times \text{BA} - 39.72 \tag{1}$$

$$\text{Biomass C} = -21.51 + 3.855 \times \text{BA} + 0.01 \times \text{BA}^2 \tag{2}$$

$$\text{Biomass C} = 1.256 \times \text{BA}^{1.291} \tag{3}$$

4.3 Relationship assessment

In the plantation forest site, a significant positive correlation was observed among the following variables: DBH and total C, mean tree height and total C and basal area m^2ha^{-1} and total C. Two attributes basal area ha^{-1} (R^2=0.981) (Figure 7) and DBH (R^2=0.828) (Figure 5) were strongly related to aboveground carbon stocks, but stand mean height (R^2=0.572) (Figure 6) was weakly related because similar height of different plots having wide variation in number of trees and DBH.

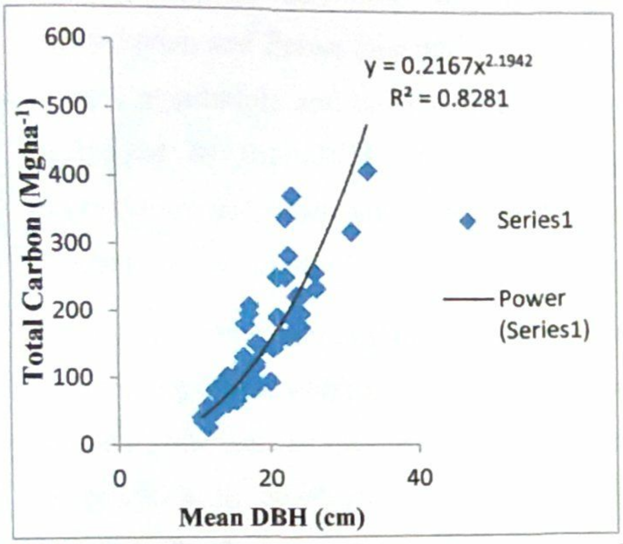

Figure 5: Mean DBH and total carbon

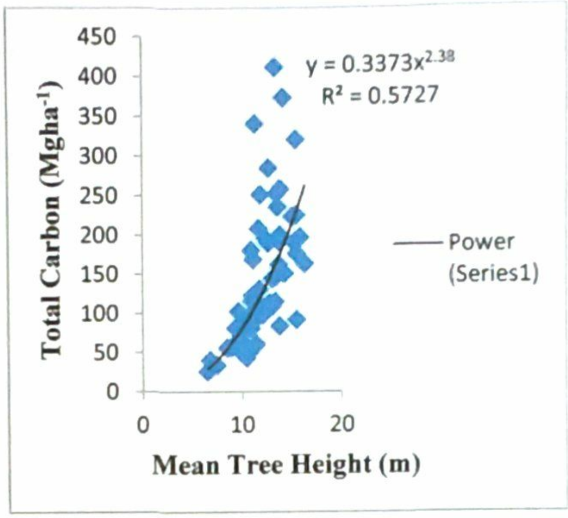

Figure 6: Mean height and total carbon stock

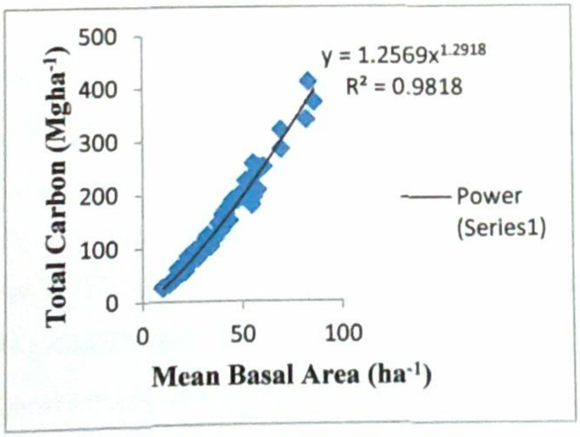

Figure 7: Mean Basal area and total carbon stock

DISCUSSION

Managing the atmospheric carbon dioxide emission through minimizing deforestation, maximizing afforestation or reforestation, and checking global warming are the significant concern among scientists and policy makers (Kanowski et al., 2011; Pandey et al., 2014). The United Nations Framework Convention on Climate Change (UNFCCC) is discussing policies and approaching to reduce CO_2 emissions from deforestation. Various mitigation and adaptation methods such as the Clean Development Mechanism (CDM), Reduced Emissions from Deforestation and Forest Degradation (REDD) and Reducing Emissions from Deforestation and Forest Degradation, and enhancing forest carbon stocks in developing countries (REDD+) are recognized by the UNFCCC. These are planned to connect multi-scale stakeholders in conservation and sustainable management of forest resources for mitigating global climate change (Gardner et al., 2012).

Afforestation and reforestation are the fundamental parts of REDD+ as an effective mechanism for reducing global climate change (Bonan, 2008; Wang et al., 2011; Pandey et al., 2014). The accurate information on carbon stocks, biodiversity and the socioeconomic status of the communities in developing countries participating in the REDD+ financial mechanism is essential (Pandey et al., 2014). So, it is vital to obtain more truthful and precise biomass estimates for plantation forests or woodlots in order to develop about understanding of the role of plantation forests or woodlots in Bangladesh as well as in global carbon cycle.

The stem density (1340 tree ha^{-1}) in our study was higher than recorded from other natural and protected forest in Bangladesh. For example, 381 trees ha^{-1} in Chittagong Hill Tracts (South) Forest Division (Nath et al., 1998), 459 trees ha^{-1} in Chunati Wildlife Sanctuary, Cox's Bazar (Rahman and Hossain, 2003), 464 trees ha^{-1} in Dudpukuria-Dhopachori Wildlife Sanctuary of Chittagong South Forest Division (Hossain et al., 2013), 257 tree ha^{-1} in Ukhiya natural forests of Cox's Bazar Forest Division (Ahmed and Haque, 1993) and 369 stem ha^{-1} in Ramu reserve forests of Cox's Bazar. The basal area (37.98 m^2 ha^{-1}) in our study was higher than 16.88 m^2 ha^{-1} in Chunati Wildlife Sanctuary, Cox's Bazar (Rahman and Hossain, 2003) and 27.07 m^2 ha^{-1} in Dudpukuria-Dhopachori Wildlife Sanctuary of Chittagong South Forest Division (Hossain et al., 2013), but lower than 53.5 m^2 ha^{-1} in Chittagong Hill Tracts (South) Forest Division (Nath et al., 1998). This very high density of trees in woodlot plantations compared to many other natural and protected forest systems in Bangladesh may be because of maintaining a certain tree spacing (2m×2m) along with the higher survival rate from confirmed protection. Woodlot plantations in Bangladesh may therefore play an important role in producing more timber and revenue for the local community and more importantly sequester carbon compared to other natural and restored ecosystems in Bangladesh.

Our established three basal area based allometric models can be useful for carbon calculation from the plot level mean basal area as all three models showed strong relationships in the GLRM analysis (R^2 = 0.98). The mean biomass carbon of woodlot plantations (143.93 Mg ha^{-1}) in our study was also higher than the reported average tree biomass carbon content of 83.72 Mg ha^{-1} (Shin et al., 2007) and 110.94 ton ha^{-1} (Ullah and Al-Amin, 2012) in hill forest of Bangladesh. Even our estimated carbon stock was higher than USA national average urban forest carbon storage (22. 83 Mg ha^{-1}) (Nowak and Crane, 2002). Several measures of stand structure and productivity were also assessed to know the relationship with total carbon stock. Two attributes basal area ha^{-1} (R^2=0.981) (Figure 7) and DBH (R^2=0.828) (Figure 5) were strongly related to aboveground carbon stocks, but stand mean height (R^2=0.572) (Figure 6) was weakly related because similar height of different plots having wide variation in number of trees and DBH. According to Kuyah et al. (2012) DBH is very strongly (R^2=0.98) related with aboveground biomass. Again Henry et al. (2009) has shown tree volume is very strongly related with total aboveground biomass. The more basal area, stem density ha^{-1} and DBH indicate the more amount of biomass and more biomass means more carbon stock. But with similar height of different plots having wide variation in number of trees. For this reason mean tree height is weakly related with aboveground carbon stock. By increasing woodlot plantation with long rotation with good diameter trees, we can increase the amount of total carbon stocks which can play a vital role in global carbon cycle. We estimated a much higher amount of carbon in woodlot plantations compared to other studies from tropical and subtropical regions due to the higher stem density and basal area (Table 4) in our study. This way woodlot plantation in Bangladesh can play an important role in atmospheric carbon sequestration.

CHAPTER FIVE

CONCLUSION

At present, natural forest is declining very hurriedly at shocking speed due to anthropogenic tricks (such as deforestation, industrialization, burning fossil fuels etc.) that boost global warming. According to FAO, the plantation forests and woodlots are increasing more than before. Bangladesh is probable to be one of the worst suffers of Global Warming due to extreme carbon emission and playing fundamental role in carbon sequestration especially through new plantation forest. Woodlot plantation is one of the major steps of plantation forest which has enormous potential in the lessening of global warming and adjustment to climate change. So, estimation of the forest carbon stocks is very essential which will facilitate us to appraise the quantity of carbon loss through deforestation or the amount of carbon that a forest can accumulate when such forests are regenerated. The woodlot plantations in Bangladesh could provide additional benefits to the local communities such as payment for environmental services for their participation in the UNFCCC's financial based carbon mitigation strategies. Their contribution to livelihoods and carbon sequestration could be increased by co-management actions. Further investigation is needed for supporting these findings.

RECOMANDATIONS

Woodlot plantation should be expanded through co-operative systems. Government and non government organizations should be given financial and technical support to the farmers. Further study on financial and biophysical aspect should be carried out in order to identify the effectiveness of woodlot plantation in the study area. One important limitation of this study is the application of universal biomass allometric equations to calculate total carbon stocks in woodlot plantation. Precision of these assessments could be improved by developing species specific local biomass allometric models. Unfortunately, such allometric equations are not available. Although there has been numerous studies carried out to estimate the forest biomass and the forest carbon stocks, but there is still a further need to develop a robust methods to enumerate the estimates of biomass of all forest components, woodlots and carbon stocks more accurately.

References

ABARE & Jaakko Poyry, 1999. *Global outlook for plantations.* ABARE research report 99.9, Commonwealth of Australia, 107 pp.

Ahmed,G.U., Haque,S.M.S., 1993. Percentage distribution of species and diameter class in natural forest of Bangladesh. Univ. Stud.II 17 (1), 109–113.

Asante P, 2011. Carbon Sequestration and the Optimal Economic Harvest Decision. Ph.D. Dissertation, University of Albert. 85pp.

BBS, 2010. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics (BSS), Statistic Division, Ministry of Planning, Bangladesh Secretariat, The Government of the People's Republic of Bangladesh, Dhaka.

Bernoux M, Feller C, Cerri C C, Eschenbrenner V and Cerri C E P, 2006. Soil carbon sequestration. pp. 13-22. In Roose E, Lal R, Feller C, Barthes B and Stewart R (eds.), Soil erosion and carbon dynamics. CRC Press, Boston, USA.

Bonan,G.B., 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. Science 320 (5882), 1444–1449.

Brown D, 2010. Roadside Management Strategies to Reduce Greenhouse Gases. Caltrans Division of Research and Innovation, California, USA. 11-41pp.

Cairns,M.A., Brown,S., Helmer,E.H., Baumgardner,G.A., 1997. Root biomass allocation in the world's upland forests. Oecologia111(1),1–11.

Canadell J G and Raupach M R, 2008. Managing forest for climate change mitigation. *Science* 320: 1456-1461.

CDM and its opportunities in Bangladesh, 2012. Waste Concern, United Nations Development Programme.

Chave J, Andalo C, Brown S, Cairns M A, Chambers J Q, Eamus D, Folster H, Fromard F, Higuchi N, Kira T, Lescure J P, Nelson B W, Ogawa H, Puig H, Riera B and Yamakura T, 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia* 145: 87-99ss.

Community Risk-Assessment (CRA) and Risk-Reduction Action Plan (RRAP) Report 2010

Detwiler R P and Hall C A S, 1988. Tropical forests and the global carbon cycle. *Science* 239: 42-47.

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

Gardner T A, Burgess N D, Aguilar-Amuchastegui N, Barlow J, Berenguer E, Clements T, Danielsen F, Ferreira J, Foden,W, Kapos V, Khan S M, Leesm A C, Parry L, Roman-Cuesta R M, Schmitt C B, Strange N, Theilade I and Vieiram I C G, 2011. A framework for integrating biodiversity concerns into national REDD+ programmes. Biol. Conserv. In press, doi:10.1016/j.biocon.2011.11.018.

Gardner,T.A., Burgess, N.D., Aguilar Amuchastegui,N., Barlow,J., Berenguer,E., Clements,T., Danielsen,F., Ferreira,J., Foden,W., Kapos,V., Khan,S.M., Leesm,A.C., Parry,L., Roman-Cuesta,R.M., Schmitt,C.B., Strange,N., Theilade,I., Vieiram,I.C.G., 2012. A framework for integrating biodiversity concerns into national REDD+ programmes. Biological Conservation. 154, 61–71.

Global Forest Resources Assessment, 2010. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, Rome.

Henry M, Tittonell P, Manlay R J, Bernoux M, Albrecht A and Vanlauwe B, 2008. Biodiversity, carbon stocks and sequestration potential in aboveground biomass in smallholder farming systems of western Kenya. *Agriculture, Ecosystem and Environment* 129: 238-252.

Hossain, M.A., Hossain, M.K., Salam, M.A., Rahman, S., 2013. Composition and diversity of tree species in duddpukuria-dhopachori wildlife sanctuary of Chittagong (South) forest division, Bangladesh. Res. J. Pharm. Biol. Chem. Sci. 4 (2), 1447–1457.

IPCC (Intergovernmental Panel on Climate Change), 2001. IPCC Third Assessment Report-Climate Change 2001. The Scientific Basis: Summary for Policymakers and Technical Summary, Geneva, Switzerland. 98pp.

IPCC, 2007. Fourth IPCC assessment report: climate change 2007. Cambridge University Press, Cambridge, UK. 268pp.

Kanowski,P., McDermott,C., Cashore,B., 2011. Post Copenhagen strategies for the implementation of REDD+. In: Richardson,K., Steffen,W., Liverman,D.,et al. (Eds.), Climate Change: Global Risks, Challenges and Decisions. Cambridge University Press, NewYork USA, pp. 429–430.

Kumar B M, 2011. Species richness and aboveground carbon stock in the home gardens of central Kerala, India. Agriculture, Ecosystems and Environment 140: 430-440.

Kuyah S, Dietz J, Muthuri C, Jamnadass R, Mwangi P, Coe R and Neufeldt H, 2012. Allometric equations for estimating biomass in agricultural landscape: I. Aboveground biomass. *Agriculture, Ecosystem and Environment* 158: 216-224.

Mandal R A, Dutta I C, Jha P K and Karmacharya S, 2013. Relationship between Carbon Stock and Plant Biodiversity in Collaborative Forests in Terai, Nepal. ISRN Botany, Volume 2013, Article ID 625767, 7 pages. http://dx.doi.org/10.1155/2013 /625767.

Nath,T.K., Hossain,M.K., Alam,M.K., 1998. Diversity and composition of trees in Sitapahar forest reserve of Chittagong Hill Tracts (South) forest division Bangladesh. Ann. For. 6 (1), 1–9.

Pandey,S.S., Cockfield,G., Maraseni,T.N., 2014. Carbon stock dynamics in different vegetation dominated community forests under REDD+: a case from Nepal. Forest Ecology Management 327, 40–47.

Paustian K, Six J, Elliott E T and Hunt H W, 2000. Management options for reducing CO_2 emissions from agricultural soils. Biogeochemistry 48: 147-163.

Pearson T, Brown S and Birdsey R A, 2007. Measurement guideline for the sequestration of forest carbon. General Technical Report-NRS-18, USDA Forest Service, Northern Research Station, USA.

Rahman, M.L., Hossain, M. K., 2003. Status of fodder and non-fodder tree species in Chunati wildlife sanctuary of Chittagong forest division, Bangladesh.Int. J. Usuj. Manage. 4 (2), 9–14.

Rahman, M.M., Kabir, M.E., Akon, A.S.M., 2015. High carbon stocks in roadside plantations under participatory management in Bangladesh. Global Ecology and Conservation 3 412–423

Sharma M C, Baduni N P, Gairola S, Ghildiyal S K and Suyal S, 2010. Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. Forest Ecology and Management 260(12): 2170-2179.

Wang, W., Lei, X., Ma, Z., Kneeshaw, D.D., Peng, C., 2011. Positive relationship between aboveground carbon stocks and structural diversity in spruce dominated forest stands in New Brunswick, Canada Forest Science 57 (6), 506–515.

Wang,Y.C., 2011. Carbon sequestration and foliar dust retention by woody plants in the greenbelts along two major Taiwan highways. Ann. Appl. Biol. 159 (2), 244–251.

Zhang Y, Duan B, Xian J, Korpelainen H and Li C, 2011. 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: 361-369.