ESTIMATION OF ECOSYSTEM CARBON STOCK AND TREE SPECIES DIVERSITY AT GREEN AREA IN DHAKA CITY

A THESIS

BY

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CERTIFICATE

*This is to certify that the thesis entitled "**ESTIMATION OF ECOSYSTEM CARBON STOCK AND TREE SPECIES DIVERSITY AT GREEN AREA IN DHAKA CITY**" submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE,** embodies the results of a piece of bonafide research work carried out by **BISHWAJIT KUNDU, Registration no. 09-03390** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2015
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ABSTRACT

Urban forest has a key role in mitigating the consequence of global climate change. Along with natural forest, urban park has also a significant contribution to carbon sequestration which yet not studied completely. This study was conducted to estimate above and below ground carbon stock, tree species diversity and soil organic carbon at Chandrima Uddan and Ramna Park in Dhaka city. A total 46 plots were sampled to determine diameter at breast height of trees, tree height and tree species diversity. Using allometric equations and assuming C as 50% of biomass, the mean above and below ground biomass carbon stock was found 122.19 Mg ha^{-1} in Chandrima Uddan and 247.91 Mg ha^{-1} in Ramna Park. In total 506 trees were sampled and 48 different tree species were identified and recorded. The Shannon Wiener Index was used to evaluate the tree diversity per plot. It ranged from 0 to 1.71 with a mean value of 0.87 in Ramna Park and 0 to 1.33 with a mean value of 0.58 in Chandrima Uddan. For the estimation of soil organic carbon (SOC), soil samples were collected from two depths (5-10cm and 20-25cm) at two different sampling sites of sampled plot. The mean value of SOC was found 28.82 Mg ha^{-1} in Chandrima Uddan and 25.52 Mg ha^{-1} in Ramna Park. Among different relationships, the relationships between basal area and tree carbon stock showed significant ($P<0.05$) and strongly positive correlation in both parks. Therefore, the results of the study confirmed that the selected parks can serve as a valuable ecological tool in terms of carbon sequestration, diverse tree species and storage of soil organic carbon which have a key role in reducing greenhouse gases and contributing to climate change mitigation.

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LIST OF ABBREVIATION AND ACRONYMS

AGC	:	Above ground carbon
AGB	:	Above ground biomass
AEZ	:	Agro Ecological Zone
et al.	:	And others
BGC	:	Below ground carbon
BGB	:	Below ground biomass
C	:	Carbon
CO_2	:	Carbon dioxide
cm	:	Centimeter
CDM	:	Clean Development Mechanism
^0C	:	Degree Celsius
FAO	:	Food and Agriculture Organization
e.g.	:	For example
GBH	:	Girth breast height
GPS	:	Global Positioning System
ha	:	Hectare
IPCC	:	Intergovernmental Panel on Climate Change
Mg	:	Mega gram = 10^6 gram
%	:	Percent
REDD+	:	Reducing Emissions from Deforestation and Forest Degradation
SWI	:	Shannon-Wiener Index
SOC	:	Soil organic carbon
m^2	:	Square meter
DBH	:	Diameter at breast height (over bark)
i.e.	:	Such as
t	:	Ton
UNFCCC	:	United Nations Framework Convention on Climate Change
ρ	:	Wood specific gravity (g/cm^3)

CHAPTER I

INTRODUCTION

Global warming and biodiversity loss are the two key issues among scientists and policy makers (Zhang *et al*., 2011) which is caused by fossil fuel burning and deforestation (Van der Werf *et al*., 2009). In the last century there was an increase in global temperature by 0.74^0C and the atmospheric CO_2 concentration by 379 ppm (IPCC, 2013; UNFCCC, 2007). If this current rate continue to increase, atmospheric CO_2 will be doubled by 2050 that will lead to global temperature rise up to $2\text{-}4^0$C (IPCC, 2013). A projection by IPCC (2013) revealed that the global sea level will rise by 28-98 cm due to melting of polar ice and it will alter low lying coastal countries existence and livelihood pattern like Bangladesh, Maldives etc. Therefore, climate change and its impacts must be studied holistically and thoroughly which needs integration of climate, plant, ecosystem and soil sciences (Grace *et al.,* 2006). To adjust with the increasing carbon dioxide problem, the emerging trend is to reduce the excess carbon level in the environment and its sequestration by using the natural sources like forest ecosystems (Nowak *et al*., 2001).

Importance of forested areas in aspect of carbon sequestration is already well documented (FSI, 2009 and Tiwari and Singh, 1987). Kyoto protocol, the main instrument of the UN Framework Convention on Climate Change (UNFCCC) has inaugurated Clean Development Mechanism (CDM) concept among the low-income people who can store carbon through land use changes (Roshetko *et al.,* 2007; Takimoto *et al*., 2008). Reducing emissions from deforestation and forest degradation and increasing forest carbon stocks in developing countries (REDD+) does not consider small holder trees like urban park but large scale forest trees.

However not many attempts have been made to address the potential of trees in carbon sequestration in urban scenario. In addition to carbon sequestration urban trees also provide a lot of benefits to urban city dwellers such as amelioration of urban climate extremes, mitigation of urban heat islands, reduction of noise pollution, improvement of air quality, reducing consumption of electricity for heating and cooling, improvement of property value, contribution to human health and relaxation etc. (Nagendra and Gopal 2011; Nowak *et al.*, 2013,). Trees act as sink for atmospheric carbon. Therefore, growing trees in urban park can be a potential contributor in reducing the concentration of CO_2 in atmosphere by its accumulation in the form of biomass (Bhadwal, 2002). In terms of atmospheric carbon reduction, trees in urban park offer the double benefit that is direct carbon storage and stability of natural ecosystem with increased recycling of nutrient (Grace *et al.*, 2006).

Soil contains about three times more organic carbon than vegetation and about twice as much carbon than is present in the atmosphere (Dinakaran *et al*., 2008; Kumar *et al*., 2006 and Batjes and Sombroek, 1997). Terrestrial vegetation and soil currently absorb 40% of global CO_2 emission from human activities (Sheikh, 2010). So, soil in the urban park can also play in climate change mitigation.

Millions of plants, animals, and microorganisms are present on earth in various ecosystems we called it biodiversity. Worldwide, the forests and species biodiversity and number of trees are being degraded. So, in this aspect urban green space can play an important role in conserving tree diversity. Diversity of tree species also increases the efficiency of trees to play their roles in urban environment (Zare *et al*., 2009).

Inspite of having these benefits, there is still lack of quantitative data and available information on urban park in respect of their ecosystem carbon stock and tree species diversity especially in Dhaka city. Although some recent studies reveal that urban green spaces are rich in biodiversity and can store a considerable carbon in its biomass (Liu and Li, 2012). So, this research focused on estimating the amount of above and below ground carbon stock, soil organic carbon (SOC) and pattern of tree species diversity at two parks in Dhaka city.

OBJECTIVES:

1. To estimate the amount of ecosystem carbon stock (AGC, BGC and SOC) at two parks in Dhaka city
2. To assess the pattern of tree species diversity in park area and
3. To find out the relationships of biomass carbon, tree species diversity and soil organic carbon

CHAPTER II

REVIEW OF LITERATURE

2.1. Global climate change scenario

IPCC (2013) 5th Assessment Report (AR5) issued in 2013–14 confirmed the 4th Assessment Report's assertion that global warming of our climate system is unequivocal and is associated with the observed increase in anthropogenic greenhouse gas concentrations and it is necessary to keep the temperature rise less than 2 °C relative to preindustrial levels and that CO_2 emissions should be reduced globally by 41–72% by 2050 and by 78–118% by 2100 with respect to 2010 levels

IPCC (2007) indicated that most of the observed increase in global average temperatures since the mid 20th century is very likely due to observed increases in anthropogenic greenhouse gas concentrations.

IPCC (2007) reported that climate changes and global warming are the largest environmental problems of all time; the level of scientific proof achieved in recent years leaves no doubts that human activity is the primary cause of these processes.

IPCC (2007) stated that average global temperatures already register an increase of 0.7°C, caused by the growing concentration of atmospheric greenhouse gases (GHG). The increasing frequency of extreme natural phenomena such as hurricanes, cyclones, torrential rains and prolonged droughts has already affected the lives of millions of people around the world.

United Nations (1992) reported that United Nations Framework Convention on Climate Change (UNFCCC) was formulated aiming at reducing global greenhouse gas emissions. Article 4 of the UNFCCC requires preventing and minimizing climate change by limiting anthropogenic emissions of greenhouse and protecting and enhancing greenhouse gas sinks and reservoirs.

2.2. Overview of global carbon cycle and forest

Brown and Pearce (1994) stated that forest play a critical role in reducing ambient CO_2 levels by sequestering atmospheric carbon into the growth of woody biomass through the process of photosynthesis. They are both sources and sinker of carbon.

Sakin (2012) reported that forest soils are important component of the global carbon cycle which stocks large amount of soil organic carbon (SOC) and are the largest reservoirs in the world. SOC plays an important role in alleviating the effects of greenhouse gases and storing, enhancing soil quality, sustaining and improving food production, maintaining clean water and reducing CO_2 in the atmosphere.

IPCC (2007) observed that forest carbon management must be an important element of any international agreement on climate change. Forest carbon flows comprise a significant part of overall global greenhouse gas emissions.

Sedjo and Sohngen (2007) stated that while global forests as a whole may be a net sink global emissions from deforestation contribute between 20 and 25 percent of all greenhouse gas emissions.

IPCC (2000) observed that the size of the total global carbon pool in forest vegetation has been estimated at 359 Gt C (gigatonnes of carbon), compared to annual global carbon emissions from industrial sources of approximately 6.3 Gt C.

Watson *et al*. (2000) stated that the potential impact on the global carbon cycle of both natural and anthropogenic changes in forests is enormous. In the 1990s, gross deforestation was slightly higher, at 13.1 million ha/yr. Due to afforestation, landscape restoration and natural expansion of forests, it is estimate that net loss of forest is 7.3 million ha/yr. The loss is still largest in South America, Africa and Southeast Asia. There is considerable interest on the role of terrestrial ecosystems in climate change, more specifically on the global carbon cycle. The world's tropical forests covering 17.6 M km^2 contain 428 Gt C in vegetation and soils. It is estimated that about 60 Gt C is exchanged between terrestrial ecosystems and the atmosphere every year. Land Use, Land-Use Change and Forestry (LULUCF) activities, mainly tropical deforestation, are also significant net sources of CO_2, accounting for 1.6 Gt C/yr of anthropogenic emissions.

Schulze *et al*. (2004) reported that the carbon dioxide in the atmosphere is 2% of the amount in the ocean, only slightly higher than the amount of carbon bound in the biomass plants and only half that stored in soil.

IPCC (2000) said that to overcome the conditions, sustainable management strategies are mandatory; therefore, it is necessary to make the forest carbon sinker rather than source. Currently, the biosphere constitutes a carbon sink that absorbs about represents about 30 percent of fossil-fuel emissions.

Kirschbaum (1996) reported that globally, forests act as a natural storage for carbon, contributing approximately 80% of terrestrial above ground, and 40% of terrestrial below ground biomass carbon storage.

.2.3 Carbon sequestration in the ecosystem

FAO (2010) observed that Carbon sequestration means, carbon dioxide is captured from the atmosphere through photosynthesis by the tree or plant to store it in its trunk, branches, twigs, leaves and fruit and oxygen is released to the air in return. Also the roots of the trees and plants take up carbon dioxide. Decomposing organic materials increase the amount of carbon stored in the soil, which is higher than the total amount in the vegetation and the atmosphere. Animals breathe in oxygen and breathe out CO_2 and through their feces carbon and N_2O is released to the soil.

IPCC (2007) reported that the phenomenon for the storage of CO_2 or other forms of carbon to mitigate global warming and its one of the important clause of Kyoto Protocol, through biological, chemical or physical processes; CO_2 is captured from the atmosphere.

WB (1999) reported that the comparison with engineering technologies of geologic or oceanic sequestration, soils and vegetation is a cost-effective option. It is a win-win strategy, a low hanging fruit, and an essential development option regardless of the debate on climate change. It is a strategy that humanity cannot afford to neglect. Carbon sequestration enhances soil quality and the associated water and nutrient cycles and thereby it enhances the productive potential of the land on which all terrestrial life depends.

Mathews and Robertson (2002) stated that terrestrial carbon sequestration is the process through which CO_2 from the atmosphere is sequestered by trees, plants and crops through photosynthesis, and stored as carbon in biomass and soils. Therefore, a carbon sink occurs when carbon sequestration is greater than carbon releases over some time period.

(UNFCCC, 1997) provided a vehicle for considering the effects of carbon sinks and sources as well as addressing issues related to fossil fuels emissions. Carbon sequestration is a way to mitigate the accumulation of greenhouse gases in the atmosphere released by the burning of fossil fuels and other anthropogenic activities. Forest ecosystem plays very important role in the global carbon cycle and climate change mitigation.

Watson (2008) reported that the main components of terrestrial carbon storage are above ground and below ground biomass dead litter and soil organic matter.

Eric *et al.* (2008) stated that geologic carbon sequestration is a mechanism of injecting carbon dioxide directly into underground geological formations.

Sundquist *et al.* (2008) reported that Oceans are natural CO_2 sinks and represent the largest active carbon sink on Earth. Among the global net sequestrated CO_2 about 2 Gts of carbon released as a result of anthropogenic activities.

2.4 Role of urban park in carbon sequestration and other benefits

Tenkir (2011) reported that urban forestry refers to any re-vegetation effort including the planting of trees and shrubs whose design is intended to improve the environmental quality, economic opportunity, or aesthetic value associated with a city's landscape. The perception that comes to mind regarding urban forest is street trees and ornamental woody plants. However, the urban forest is a complex system of trees and smaller plants, wildlife, associated organisms, soil, water and air quality in and around a city.

Pataki *et al*. (2006) observed that in urbanizing regions, organic carbon is stored within and cycled through the air, soils, waters, plants, and the built environment itself. Although it is abundantly clear that cities and urbanizing areas affect local and global sinks and sources of CO_2, the exact magnitude of and mechanisms for carbon exchange remain highly uncertain for urbanizing regions.

Grubler (1994) stated that in excess of 90% of anthropogenic carbon emissions are attributable (directly or indirectly) to cities.

Chiari and Seeland (2004) have highlighted the role of urban forests as a place of social integration as they provide recreation and relief to the urban population from their hectic life.

IPCC (2007) reported that the amount of carbon dioxide in the atmosphere has increased from 280 ppm in the pre-industrial era (1750) to 379 ppm in 2005, and is increasing by 1.5 ppm per year.

Grimm *et al*. (2008) reported that in 1900 just 10% of the global population was living in urban areas which now exceeds 50% and is expected to further rise to 67% in the next 50 years.

2.5. Factor that affect carbon stock in forest

Asner *et al.* (2005) reported that deforestation and conversion of forest to no forestland uses is typically associated with large immediate reductions in forest carbon stock through land clearing. Forest degradation reduction in forest biomass through no sustainable harvest or land-use practices can also result in substantial reductions of forest carbon stocks from selective logging, fire and other anthropogenic disturbances, and fuel wood collection.

FAO (2006) observed that selective logging, fire and other anthropogenic disturbances, and fuel wood collection have also carbon balance implications. Such disturbances affect roughly 100 million ha of forests annually.

Millennium Ecosystem Assessment (2005) scenarios showed that forest area in industrialized regions will increase between 2000 and 2050 by about 60 to 230 million ha. At the same time, the forest area in the developing regions will decrease by about 200 to 490 million ha. The lack of consensus on factors that control the carbon balance is an obstacle to development of effective mitigations strategies.

Gissen (2011) reported that forests are also affected by climate change and their contribution to mitigation strategies may be influenced by stresses possibly resulting from it. Socio-economically, global forests are important because many citizens depend on the goods, services, and financial values provided by forests.

Warn and Patwardhan (2001) stated that the development of sustainable green cities is the need of today's fast urbanizing world. More number of populations will soon be living in urban areas and urbanization is vigorously promoted both politically and socially as a means to enhance average living standards. However, the ever growing urbanization threatens escalating of carbon emission due to higher consumption of goods and services compared to the rural sector. Hence it is crucial that the balance be maintained between the carbon emission and carbon sequestration to achieve sustainability.

Nowak & Crane (2001) reported that tree density and diameter distribution also considered as main factor which affect carbon storage density (t C ha^{-1}) and diameter distribution. Carbon densities will tend to increase with tree density (tree ha^{-1}) and/or increased proportion of large diameter trees.

2.6. Urban forest contribution to climate change mitigation

Lasco *et al*. (2008) stated that tropical forests have the largest potential to mitigate climate change amongst the world's forests through conservation of existing carbon pools by reduced impact logging expansion of carbon sinks through reforestation, agroforestry.

IPCC (2007) stated that forest mitigation options include reducing emissions from deforestation and forest degradation, enhancing the sequestration rate in existing and new forests. Properly designed and implemented forestry mitigation options have substantial co-benefits in terms of employment and income generation opportunities, biodiversity and watershed conservation, provision of timber and fiber, as well as aesthetic and recreational services.

Nowak & Crane (2002) reported that forestland such as urban park can play for climate change mitigation. It is estimated that total carbon stored by the urban trees is 23.8 million tons from an estimated 7.79 million ha urban area, i.e. 3.01 tones of carbon/ha. Urban forests contribute only 2.21% of the carbon stock against 17.11 tons carbon/ha from overall forest and tree cover. Thus, there is an ample scope to increase contribution of urban forests to overall carbon stocks. Urban trees in the USA store 700 million tons of carbon with a gross carbon sequestration rate of 22.8million t C/yr. The national average urban forest carbon storage density is 25.1 t C ha^{-1}, compared with 53.5 t C ha^{-1} in forests stands, model estimated that Torbey's trees store 98100 ton of carbon (15tons of carbon per ha) and sequester a further 4279 tons per year (0.7 tons of carbon per ha).

Nowak (1994) observed that urban trees also remove large amounts of air pollutants that consequently improve urban air quality. It also indicated that 600 trees in the tropics would fill one acre, which could sequester up to 15 tonnes of CO_2 annually.

Gill *et al.* (2007) showed a statistics that include 40 trees will sequester one ton of CO_2 each year; and that one million tree covering 1,667 acres could capture 25,000 ton of CO_2 annually, and have pollution mitigation and carbon sequestration potential. Standing from this point, urban trees help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue, by altering energy use in buildings, there by altering carbon dioxide emissions from fossil fuel based power plants and also by protecting soils, one of the largest terrestrial sinks of carbon. They also be useful in adapting to climate change through evaporative cooling of the urban environment.

Daniel *et al*. (2010) reported that rapid urbanization increased motorization and economic activity, which leads to increased air pollution. Emissions from mobile sources are said to be the principal contributors to urban air pollution and it is becoming a serious health and environmental threat.

2.7 Measuring biomass in different carbon pools

Cairns *et al.* (2003) reported that two methods of measuring sample tree biomass are available: (1) destructive and (2) non-destructive. Direct or destructive method of tree biomass involves felling an appropriate number of trees and estimating their field- and oven-dry weights, a method that is accurate however it is impractical. Rather than performing destructive sampling all the time in the field, an alternative method (non- destructive) can be used that predicts biomass given some easily measurable predictor variable, such as “tree diameter” and “height” can be used.

Brown (1997) reported that carbon pool meaning a reservoir or system which has the capacity to accumulate or release carbon, forest is composed of pools of carbon stored in the living trees and belowground, in dead matter including standing dead trees, down woody debris and litter, in non-tree understory vegetation and in the soil organic matter.

Pearson *et al.* (2005) stated that the carbon stocks of trees are estimated most accurately and precisely by direct methods, e.g., through a field inventory, where all the trees in the sample plots above a minimum diameter are measured. The diameter was wrapped around a tree and is specially designed to convert the tree circumference to tree diameter. Diameter was measured with the forest diameter tape. It was needed to convert each measurement after recorded because the diameter tape are actually measuring tree circumference. This was a very simple equation, just divide circumference by (3.14) use the equation for circumference and solve for diameter. The minimum diameter often is 5 cm in DBH but it can vary depending on the expected size of trees. For arid environments in which trees grow slowly, the minimum DBH may be as small as 2.5 cm; for humid environments in which trees grow rapidly, the minimum DBH may be up to 10 cm. DBH biomass and carbon stock are estimated using appropriate allometric equations applied to the tree measurements.

Dicken (1997) stated that measurement of below ground biomass is much more difficult due to the mass of soil that needs to be excavated and the difficulty in separating fine roots from soil particles even at moderate levels of precision, measuring root biomass is time consuming and expensive due to the wide variability in the way that roots are distributed in the soil. For many projects, it might be best to estimate root, shoot: root ratio ever reported for species any is 5:1 or it help to develop a conservative estimate without measuring roots.

Cairns *et al*. (1997) reported that BGB carbon pool consists of the biomass contained within live roots. As with AGB, although less data exists, regression equations from root biomass data have been formulated which predict root biomass based on above ground biomass carbon.

Cairns *et al*. (1997) also found that root to shoot ratios were constant between latitude (tropical, temperate and boreal), soil texture (fine, medium and coarse), and the tree type.

Wondimu (2013) stated that the AGC and BGC of Biheretsige park in Addis Ababa were 21.7 Mg ha^{-1} and 4.3 Mg ha^{-1}, respectively.

He also added that also the AGC of Central park in Addis Ababa was 29.12 Mg ha^{-1}.

Liu *et al*. (2014) estimated that the AGC and BGC of Lesio-louna tropical rainforest of Congo were 168.60 Mg ha^{-1} and 39.55 Mg ha^{-1} respectively.

Averti *et al*. (2014) reported that the AGC of humid tropical wetland forests of the Republic of Congo was 223 Mg ha^{-1}.

Singh and Singh (1991a) studied the species composition, plant biomass and diversity, index in mixed dry deciduous forests of Vindhyan region. They found that the standing biomass of vegetation averaged 66.98 t ha^{-1} with 46.70 t ha^{-1} in tree layer, 13.97 t ha^{-1} in the shrub layer, 0.35 t ha^{-1} in the herb, 2.83 t ha^{-1} in the litter layer and 3.13 t ha^{-1} in the fine roots.

Roy and Ravan (1996) estimated the biomass in tropical dry deciduous forest of Madhav National Park of Madhya Pradesh, India using two approaches viz., Homogenous vegetation stratification (HVS) and spectral response model. They found that the total biomass of the different community types of dry tropical forests ranged from 7.42 to 52.41 t ha^{-1}.

Haripriya (2000) reported that the above ground biomass density and carbon storage in biomass of major forest strata (21) of India for data collected from

1,70,000 sampling units distributed all over the country in 1993. Biomass densities ranged from 14 to 210 Mg ha^{-1} with a mean of 67.4 Mg ha^{-1}, which equals around 34 Mg C ha^{-1}.

Zheng *et al*. (2004) estimated the above ground biomass of Chequamegon National Forest of Wisconsin USA using Landsat 7 ETM data. Total above ground biomass of the study area was estimated to be 3.3 M tons, of that 76.5 % was hard wood and mixed hardwood/pine forest. Above ground biomass ranged from 1 to 358 Mg ha^{-1}.

Dwivedi *et al*. (2009) reported the case of Kerwa urban forest area in Bhopal is another Indian case that supports several threatened and endangered plant, animal, and bird species. It also plays a critical role as a carbon sink with a total storage of about 19.5 thousand tonnes of above ground carbon.

Montagu *et al*. (2005) reported the assessment of biomass that provides information on the structure and functional attributes of trees. With approximately 50% of dry biomass comprises of carbon biomass assessments illustrate the amount of carbon that may be sequestered by trees.

2.8 Soil organic carbon

Swai *et al*. (2014) estimated that in Hanang forest, Tanzania where soil organic carbon was 64.2, 41.93 and 31.0 Mg ha^{-1} in the upper (0-15 cm), mid (> 15-30 cm) and lower (>30-45 cm) layer, respectively.

Reum *et al*. (2009) reported that the soil carbon stock for a Pinus densiflora forest at Gwangneung, central Korea was estimated using the soil carbon model, Yasso. The soil carbon stock measured in the forest was 43.73 Mg ha^{-1}.

Watson (2008) observed that SOM is influenced through land use and management activities that affect the litter input, for example how much harvested biomass is left as residue, and SOM output rates, for example tillage intensity affecting microbial survival. In SOM accounting, factors affecting the estimates include the depth to which carbon is accounted, commonly 30cm, and the time lag until the equilibrium stock is reached after a land use change, commonly 20 years.

Detailer and Hall (1988) found that SOC storage has been widely considered as a measure for mitigating global climate change through C sequestration in soils .In such case forest soils play an important role in the global C cycle because of the large areas involved at regional/global scale.

Grossman and Reins (2002) stated that bulk density values are also used as a measure of soil quality, indicating the ease of root penetration, water movement, and soil strength.

Dixon and Wisniewski (1995) stated that forests ecosystems covering about 4.1 billion hectares globally are a major reserve of terrestrial C stock.

Batjes (1996) stated that forests ecosystems store more than 80% of all terrestrial aboveground C and more than 70% of all soil organic C.

Pregitzer and Euskirchen (2004) reported that small shifts in the balance of carbon input and decomposition can result in great changes of carbon dioxide (CO_2) globally.

Sakin (2012) reported that the Bulk density depends on several factors such as compaction, consolidation and amount of SOC present in the soil but it is highly correlated to the organic carbon content, soil organic carbon (SOC), soil organic matter (SOM) and the correlation between bulk densities are frequently used to estimate carbon pools.

2.9 Tree species diversity

Gupta *et al*. (2008) reported that urban forest in 43 ha of NEERI campus at Nagpur; Maharashtra has 135 vascular plants including 16 monocots and 119 dicots, belonging to 115 genera and 53 families. The taxa included 4 types of grasses, 55 herbs, 30 shrubs and 46 trees. The large number of species within very small area indicates rich biodiversity in this urban forest.

Fard *et al*. (2015) stated that the tree diversity of two urban parks of Kio and Shariati in Khorramabad Country were (SWI = 1.5) and (SWI = 0.88) respectively.

Knight (1975) reported that tropical forests indicated higher tree diversity in young stand (H = 5.06) and for old stand (H = 5.4).

Stapanian *et al.* (1997) evaluated the diversity of tree species in 14 US states using data from Forest Health Monitoring (FHM) plots. They found large variations in species richness across regions and significant negative effects on anthropogenic disturbances on species richness (except in the mixed western hardwoods in California).

Verghese and Menon (1998) conducted studies in south moist mixed deciduous forests of Agasthyamalai region of Kerala, India. The stand density, species density and basal area of these forests were 535 trees ha^{-1}, 12 species per ha and 26.57 m^2 ha^{-1}, respectively. Shannon index of these forests was 1.89, while evenness index was 0.73. *Terminalia paniculata, Pterocarpus marsupium* and *Careya arborea* were found as dominant plant association.

Kadavul and Parthasarathy (1999) studied the species richness, density and population structure of all trees inventoried in four 1 ha plots of semi evergreen forests of Kalrayan hills, Eastern Ghats. A total of 2064 stems (mean 516 ha^{-1}) covering 89 species (74 genera and 39 families) were recorded. The species richness varied from 42 to 47 species ha^{-1}. Shannon index from 2.31 to 2.87 and stand density from 367 to 667 stems ha^{-1}, mean stand basal area was 33.6 m^2 ha^{-1}. Species richness and density decreased with increasing tree girth.

Rawat and Bhainsora (1999) stated that Shannon index for tree species was 1.84 - 2.46, 1.39 and 0.53 for Shiwaliks, Doon Valley and outer Himalaya, respectively

Singh *et al*. (1995) reported that the diversity values obtained in the Corbett National Park ranged from 1.79 to 3.64.

Jayakumar *et al*. (2009) reported that the floristic inventory and diversity studies of evergreen forest in the Eastern Ghats of Tamil Nadu, India using various sampling methods viz. (a) ad hoc (AH) vegetation survey, (b) stratified random plot (SRP) and (c) bigger plot (BP). The mean stand density and mean basal areas was found to be 547 (SRP) and 478 (BP) stems ha^{-1}, and 46.74 (SRP) and 43.6 m^2 ha^{-1}(BP), respectively on the study sites. Shannon Index (H') was found to be 3.140 (SRP) and 3.340 (BP).

Nowak & Crane (2002) reported that urban trees in the Coterminous USA, store 700 million tons of carbon with a gross carbon sequestration rate of 22.8 million t C/yr. The national average urban forest carbon storage density is 25.1 t C/ha, compared with 53.5 t C ha^{-1} in forest stands.

CHAPTER III
MATERIALS AND METHODS

3.1 Study area

3.1.1 Location

The study was conducted at two green area (Ramna Park amd Chandrima Uddan) in Dhaka city. Dhaka is the capital city of Bangladesh. One study area i.e., Ramna Park was located at 23°44' N latitude and 90°24' E longitude with an elevation of 8.6 meter above sea level. Another studied area i.e., Chandrima Uddan was located at 23°45' N latitude and 90°22' E longitude with an elevation of 8.45 meter above sea level. The total area of Ramna Park was 68.50 acres of which the lake covered 8.76 acres. There were 71 species of flowering trees shrubs, perennials, and annuals, 36 species of fruit bearing plant, 33 species of medicinal plant and 41 species of forestry and 11 other species (Wikipedia). On the other hand the Chandrima Uddan covered an area of 74 acres with many kinds of tree species (Wikipedia). Chandrima Uddan (sometimes called Zia Uddan) was situated in the road beside the Jatiyo Sangshad Bhaban, in Dhaka, Bangladesh.

3.1.2 Climatic and soil

There is a hot, wet and humid tropical climate in Dhaka city. The city has a distinct monsoonal season, with an annual average temperature of 26°C and monthly means varying between 19°C in January and 29°C in May (Weatherbase, 2008). Approximately 87% of the annual average rainfall of 2,123 millimetres occurs from May to October (Weatherbase, 2008). The soil of Dhaka city is silty clay loam. It represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28 (Haider *et al*., 1991).

3.2 Sampling procedure

Transects line method were used both in Ramna Park and Chandrima Uddan for measuring the sample plot.

Plate 1. In experimental site with supervisor

Plate 2. Measuring center point co-ordinates with GPS

3.2.1 Chandrima Uddan

In case of Chandrima Uddan for measuring the sample plot seven transects line were used. Three square plots with a size of 20m × 20m were taken on each transect line. So altogether there were total twenty one plot in Chandrima Uddan. Among each plot hundred meter interval was maintained for the feasibility of determining the sample plot. Plot No.-13, Plot No.-14, Plot No.-16 were avoided due to presence of Zia Mazar and pond. In case of estimating tree carbon Plot No.-19 also was avoided due to absence of tree vegetation.

Plate 3. Sample plot co-ordinates of Chandrima Uddan

3.2.2 Ramna Park

On the other hand in case of Ramna Park for measuring the sample plot nine transects line were used. Number of square plots with a size of 20m × 20m were varied on each transect line due to structural problem of Ramna Park. Above all twenty five plots were selected from the experimental area with a maintaining of hundred meter interval among each plot.

Plate 4. Sample plot co-ordinates of Ramna Park

3.3 Tree diversity measurement

Tree species diversity was determined from the each sample plot acquiring common names that subsequently converted into botanical names. An index was setup based on the number of species and their frequency in sample plot. For this study Shannon-Wiener diversity index (SWI) was used due to its suitability for evaluating diversity of tree species. The Shannon–Wiener diversity characterizes the proportion of species abundance in the population being at maximum when all species are equally abundant and the lowest when the sample contained one species. The proportion of species (i) relative to total number of species (Pi) was calculated and then multiplied by the natural logarithm of the same proportion (Ln Pi). The resulting product is summed across species, and multiplied by -1.

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

Where, **Σ**= Summation.

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

H = Shannon index

n = No. of species

3.4 Soil sampling and analysis

There were total 46 sample plots in two parks. But Soil samples were collected from 42 sample plots of two parks. Four sample plots were avoided in Chandrima Uddan due to presence of Zia Mazar and pond. In each sample plot, two sampling sites were selected randomly and soil samples were collected at two depths measuring 5-10 cm and 20-25 cm from each sites. A composite sample for each depth interval was prepared by mixing soil from two sampling sites resulting one sample per depth level from each study plots. There were total 84 soil samples from 2 parks. Bulk density of sampled soil was measured. Carbon content in the soil was analyzed by Walkley-Black (1934) method. Soil analysis has been done in Soil Resource Development Institute (SRDI), Bangladesh.

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

Organic carbon content percentages were calculated by using following formula:

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

ODW = Oven Dry Weight

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

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

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

1.3 = Convention recovery fraction

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

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

Plate 5. Inserting Auger in the soil

Plate 6. Measuring different depth of soil

3.5 Allometric equation for above and below ground biomass:

3.5.1 Tree biomass

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

3.5.2 Above ground biomass:

To measure the above ground biomass, following equation was used:

$AGB = \rho \times \exp(-1.499+2.148\times\ln(DBH) + 0.207 \times (\ln(DBH))^2 - 0.0281(\ln(DBH))^3)$ (Chave *et al*., 2005).

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

3.5.3 Below ground biomass:

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

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

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

3.5.4 Palm species biomass

Usually palm species such as *Cocos nucifera, Phoenix sylvestris, Areca catechu* are common in park area of south-western Bangladesh (Kabir and Webb, 2009). The following equation for palms was used for AGB calculation:

$AGB = 6.666 + 12.826\times ht^{0.5} \times \ln(ht)$ (Brown *et al*., 2001).

AGB = Above Ground Biomass; ln = Natural logarithm; ht = Height

Plate 7. Measuring GBH of tree in experimental sites

3.5.5 Conversion of biomass to carbon

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

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

3.6 Data analysis

After the collection of field data the information was processed and compiled by MS Excel 2007 and SPSS-20 software. Aboveground C pools were computed using international standard common tree allometries combined with local tables of wood density by tree species. Regression analyses were used to test the relationship among different variables.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Ecosystem carbon stock

The present study was conducted at two parks in Dhaka city. One was Chandrima Uddan and other one was Ramna park. There were total 46 sample plots in this two parks. 21 plots were sampled from Chandrima Uddan and 25 plots from Ramna Park by using transects line. But 4 sample plots were avoided from Chandrima Uddan due to presence of Zia Mazar, building infrastructure and pond. So, data were collected from 42 sample plots from both parks. The ecosystem carbon stocks i.e., above ground carbon, below ground carbon and soil organic carbon were estimated from these two parks.

4.1.1 Above and below ground biomass carbon (AGC and BGC)

The experiment was conducted at two parks in Dhaka city. For the estimation of above and below ground carbon stock, tree species of the selected experimental sites (Chandrima Uddan and Ramna park) were measured on the basis of DBH, height etc. and calculated by using the desired equations. For measuring tree carbon stock total 42 plots were sampled in two parks. The total number of sample plot in Chandrima Uddan was n=17 whose carbon stock ranged from 2.25 to 222.72 Mg C ha^{-1} with a mean value of 122.19 Mg C ha^{-1} was much lower than the carbon stock content of Ramna Park (Ranged from 2.71 to 918.46 Mg C ha^{-1}; Mean, 247.90 Mg C ha^{-1}; n=25) (Table 1).

Table 1. Carbon stock at two parks in Dhaka city

Name of the park	Number of sample plot	Carbon stock range (Mg ha^{-1})		Mean ± CI
		Highest	Lowest	
Chandrima Uddan	17	222.72	2.25	122.19 ± 32.98
Ramna Park	25	918.46	2.71	247.90 ± 97.68

*** CI** = 95% confidence interval

It was also found from this study that above and below ground carbon stock (220.45 and 27.45 Mg C ha^{-1}, respectively) of Ramna Park was much higher compared to Chandrima Uddan (106.61 and 15.57 Mg C ha^{-1}, respectively) (Figure 1).

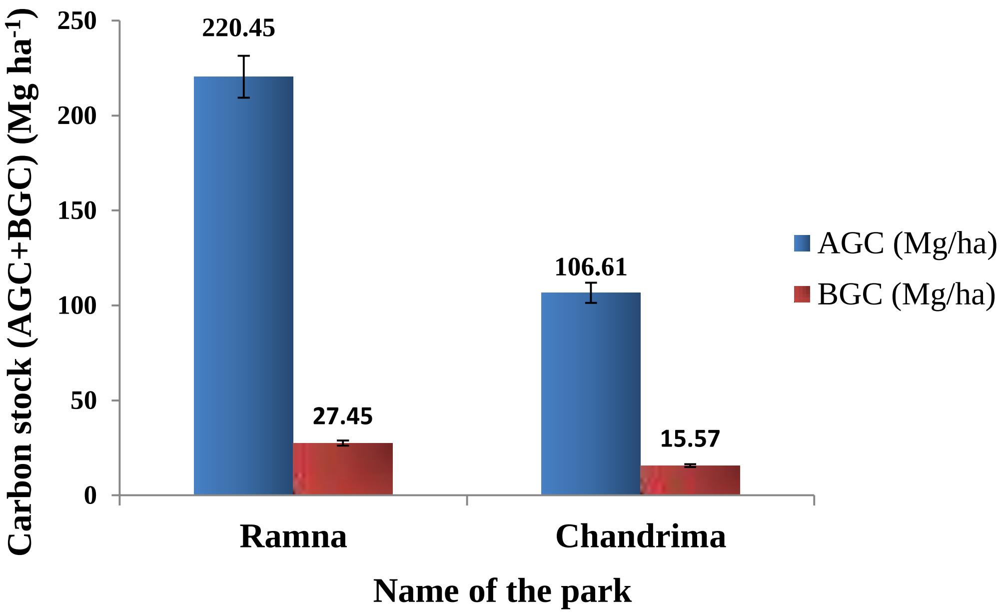

Figure 1. Above and below ground carbon stocks at two parks in Dhaka city

Wondimu (2013) conducted a similar research and found that the AGC and the BGC of Biheretsige park were 21.7 and 4.3 Mg ha^{-1}, respectively and on the other hand the AGC and the BGC of Central park were 29.12 and 8.7 Mg ha^{-1}, respectively in Addis Ababa.Liu *et al*. (2014) conducted another similar research and found that the AGC and the BGC of tropical rainforest in Congo were 168.60 and 39.55 Mg ha^{-1}, respectively.Averti *et al*. (2014) also found that the AGC in humid tropical wetland forests of the Republic of Congo was 223 Mg ha^{-1}. Gibbs *et al.* (2007) found that the mean biomass carbon in Bangladesh was 65-158 Mg ha^{-1}, Shin *et al*. (2007) found the mean biomass carbon 83.72 Mg ha^{-1} in Hill Forest of Bangladesh and Ullah and Al-Amin (2012) found 110.94 Mg ha^{-1} in Hill Forest of Bangladesh. Rahman *et al.*

(2015) conducted a research and found that the mean biomass carbon in roadside plantation was 192.80 Mg ha^{-1} in southwestern of Bangladesh.

4.1.2 Soil organic carbon

Soil organic carbon (SOC) was comparatively lower in experimental area than natural forest. Soil organic carbon ranged from 8.86 to 21.27 Mg ha^{-1} at 5-10 cm depth and 6.20 to 16.92 Mg ha^{-1} at 20-25 cm depth with a mean value of 16.52 Mg ha^{-1} and 12.29 Mg ha^{-1}, respectively in Chandrima Uddan (Table 2). In case of Ramna Park SOC ranged from 5.46 to 23.75 Mg ha^{-1} at 5-10 cm depth and 0.90 to 35.04 Mg ha^{-1} at 20-25 cm depth with a mean value of 13.64 Mg ha^{-1} and 11.88 Mg ha^{-1}, respectively (Table 2).

Figure 2 indicated that soil organic carbon was always higher at 5-10 cm depth in both park than 20-25 cm depth. The differences of soil organic carbon content between two depths were not too high due to structure of soil.

Swai *et al*. (2014) conducted a research and found that the mean soil organic carbon was 64.2, 41.93 and 31.0 Mg ha^{-1} in the upper (0-15 cm), mid (> 15-30 cm) and lower (>30-45 cm) layer, respectively in Hanang forest, Tanzania.

Reum *et al*. (2009) conducted a another research and found that the mean soil organic carbon was 43.73 Mg C ha^{-1} stock for a Pinus densiflora forest at Gwangneung, central Korea estimated using the soil carbon model, Yasso.

The average soil organic carbon of the present study i.e., Chandrima Uddan (28.81 Mg ha^{-1}) and Ramna park (25.52 Mg ha^{-1}) was comparatively much lower than Hanang forest of Tanzania and Pinus densiflora forest of central Korea because leaf falling and its decopmposing were not a common phenomenon in this experimental sites which were most common in natural forest.

Table 2. Soil organic carbon at two parks in Dhaka city

Park (No. of plot)	Depth (cm)	Range SOC (Mg ha^{-1})		Mean ± CI
		Maximum	Minimum	
Chandrima Uddan (21)	5-10	21.27	8.86	16.52 ± 1.58
	20-25	16.92	6.20	12.29 ± 1.62
Ramna park (25)	5-10	23.75	5.46	13.64 ± 2.22
	20-25	35.04	0.90	11.88 ± 3.06

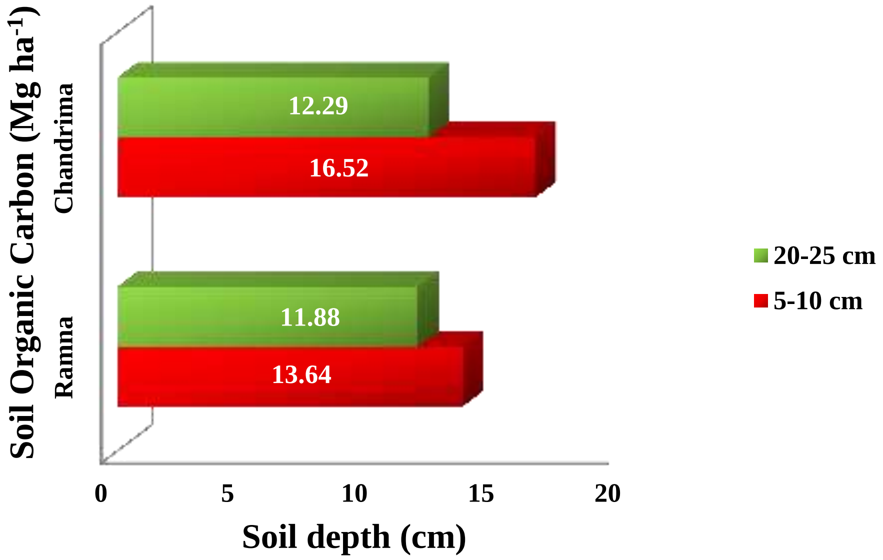

Figure 2. Soil organic carbon (Mg ha^{-1}) at two parks in Dhaka city

4.1.3 Amount of different carbon pool at two parks

Ecosystem carbon stock e.g. Above ground carbon (AGC), Below ground carbon (BGC) and Soil organic carbon (SOC) were 106.61 Mg ha^{-1}, 15.57 Mg ha^{-1} and 28.81 Mg ha^{-1}, respectively in Chandrima Uddan (Figure 3). On the other hand in case of Ramna Park it was 220.45, 27.45 and 25.52 Mg ha^{-1}, respectively (Figure 4).

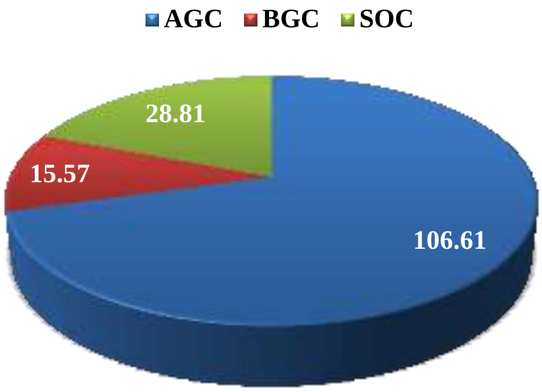

Figure 3. Total mean ecosystem carbon stock (Mg ha^{-1}) (AGC, BGC, SOC) in Chandrima Uddan

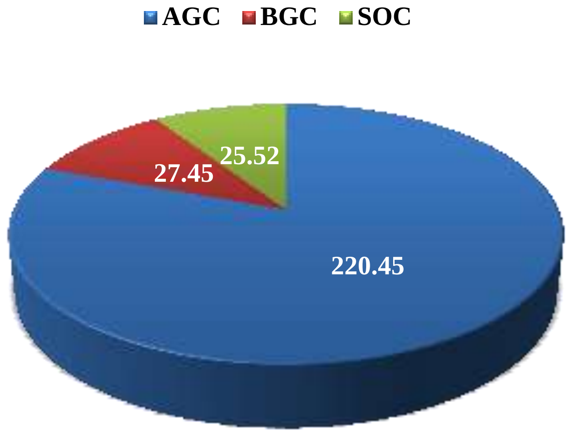

Figure 4. Total mean ecosystem carbon stock (Mg ha^{-1}) (AGC, BGC, SOC) in Ramna Park

4.2 Tree diversity

Tree diversity at two parks were measured by using the Shannon Wiener Index (SWI). SWI showed a variation between two parks. The tree diversity ranged from 0 to 1.7 with a mean value of (0.87 ± 0.09) in Ramna Park followed by Chandrima Uddan whose tree diversity ranged from 0 to 1.33 with a mean value of (0.58 ± 0.12) (Table 3). The average number of tree species per hectare was 10 and 15, respectively (Table 3). Number of species recorded in Ramna Park were 41 with a mean value of 15 followed by Chandrima Uddan whose species were 19 with a mean value of 7 (Table 3).

Table 3. Tree diversity at two parks in Dhaka city

Name of the park	Mean number of trees per hectare	Species recorded at two park		Shannon wiener Index (SWI)	
		Total	Mean	Mean± SE	Range
Chandrima Uddan	10	19	7.29	0.58 ± 0.12	0-1.33
Ramna Park	15	41	15.28	0.87 ± 0.09	0-1.70

Fard *et al*. (2015) conducted a similar research in two urban parks of Kio and Shariati in Khorramabad Country where tree diversity (SWI = 1.5) was higher in Kio park than in Shariati park (SWI = 0.88). In this present study maximum tree diversity (SWI = 0.87) was found in Ramna park than in Chandrima uddan (SWI = 0.58).

4.2.1 Vegetation characteristics

Vegetation characteristics such as average number of trees per hectare, basal area and mean DBH of total 42 plots (Chandrima Uddan 17, Ramna Park 25) were estimated including their standard error (Table 4). From this table it was clear that the average number of trees (10 tree ha^{-1}), basal area (16.82 m^2 ha^{-1}) and mean DBH (32.94 cm) of Chandrima Uddan were lower than Ramna Park whose average number of trees, basal area and mean DBH were 15 tree ha^{-1}, 36.91 m^2 ha^{-1} and 33.43 cm, respectively. This was varied due to structure, composition and abundance of tree species in this park area.

Table 4. Average number of trees (ha^{-1}), basal area (ha^{-1}) and mean DBH (cm) of two parks in Dhaka city

Parameters	Parks	
	Chandrima Uddan	Ramna Park
Mean trees (ha)	10 (1.08)	15 (2.73)
Basal area (ha)	16.82 (2.26)	36.91 (6.76)
Mean DBH (cm)	32.94 (1.28)	33.43 (4.88)

*Parenthesis is the standard errors

4.2.2 Tree density characteristics

Tree density ranged from 25 to 425 trees ha^{-1} with a mean value of 183 trees ha^{-1} in case of Chandrima Uddan was much lower than Ramna park (382 nos. ha^{-1}, ranged from 75-1425) (Table 5).

Table 5. Tree density at two parks in Dhaka city

Name of the park	Lower tree density value (ha^{-1})	Higher tree density value (ha^{-1})	Total tree density (ha^{-1})	Mean ± SE
Chandrima Uddan	25	425	3125	183.82 ± 27.28
Ramna Park	75	1425	9550	382 ± 68.32

4.2.3 Occurrence of major tree species

From the experimental area it was found that the occurrence of major trees were *Acacia auriculiformis* (47.58 %) followed by *Eucalyptus camaldulensis* (8.87 %), *Lagerstroemia speciosa* (5.64 %), *Artocarpus heterophyllus* (4.83 %), *Albizia richadiana* (4.83 %) and *Mangifera indica* (4.03 %) in case of Chandrima Uddan (Figure 5). On the other hand in Ramna Park the occurrence of major trees were *Areca triandra* (35.86 %) followed by *Swietenia macrophylla* (8.63 %), *Mimusops elengi* (7.06 %), *Polyalthia longifolia* (6.54 %), *Lagerstroemia speciosa* (4.71 %) and *Callistemon sp*. (3.4 %) (Figure 6).

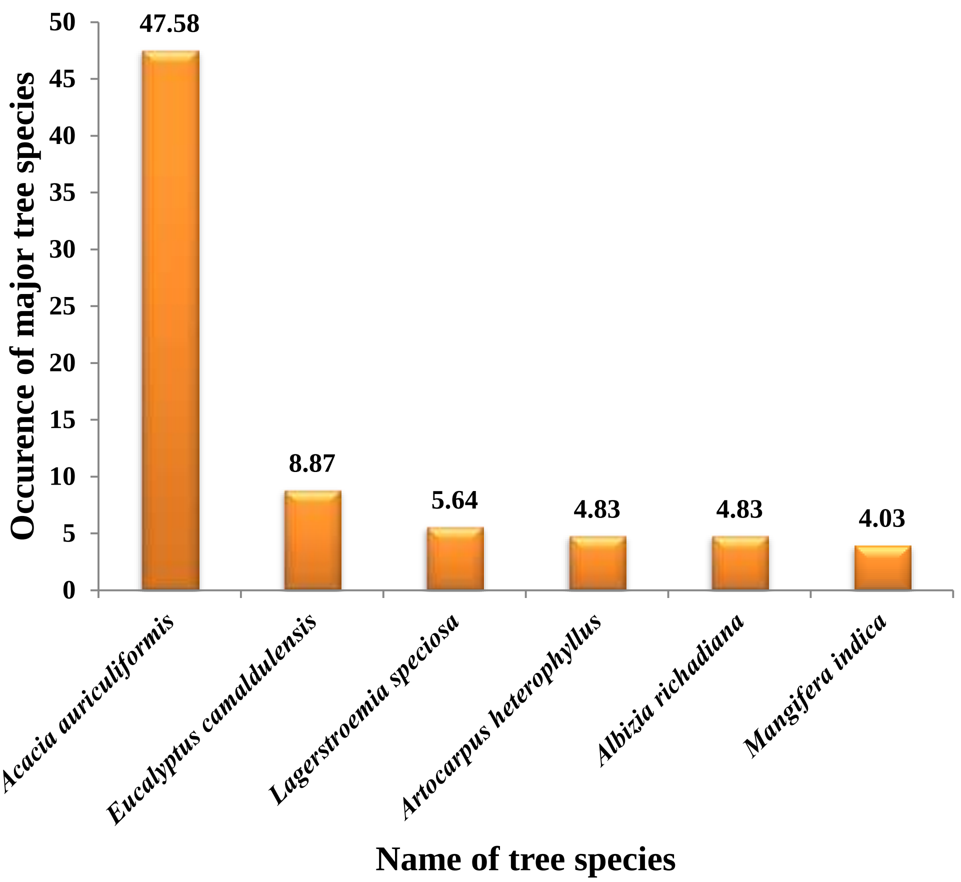

Figure 5. Occurrence of major tree species (%) in Chandrima Uddan

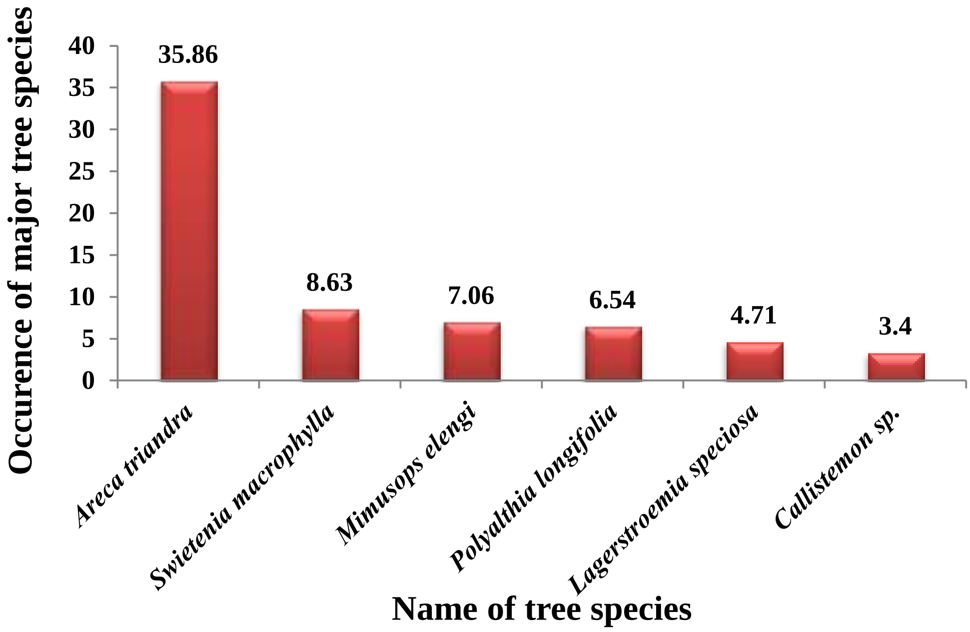

Figure 6. Occurrence of major tree species (%) in Ramna Park

4.2.4 Major carbon containing tree species

From the experimental area it was found that the major carbon containing trees were *Acacia auriculiformis* (51.42 Mg) followed by *Eucalyptus camaldulensis* (9.02 Mg), *Lagerstroemia speciosa* (5.7 Mg), *Mangifera indica* (5.03 Mg) and *Albizia richadiana* (5.01 Mg) (Figure 7) in Chandrima Uddan. But in Ramna Park the major carbon containing trees were unknown 3 (31.7 Mg) followed by *Mimusops elengi* (30.41 Mg), *Thespecia populnea* (27.61 Mg), *Albizia richadiana* (17.03 Mg), *Mangifera indica* (16.13 Mg) and *Albizia saman* (15.07 Mg) (Figure 8).

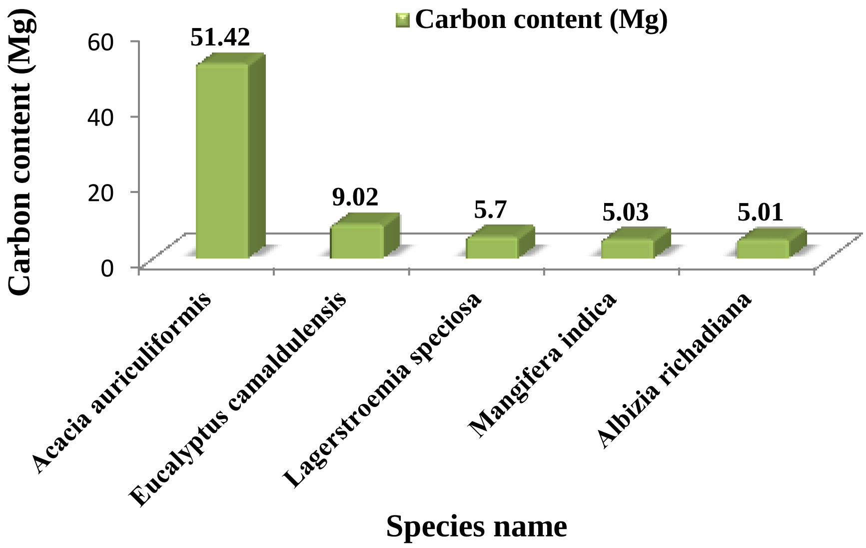

Figure 7. Major carbon containing tree species in Chandrima Uddan

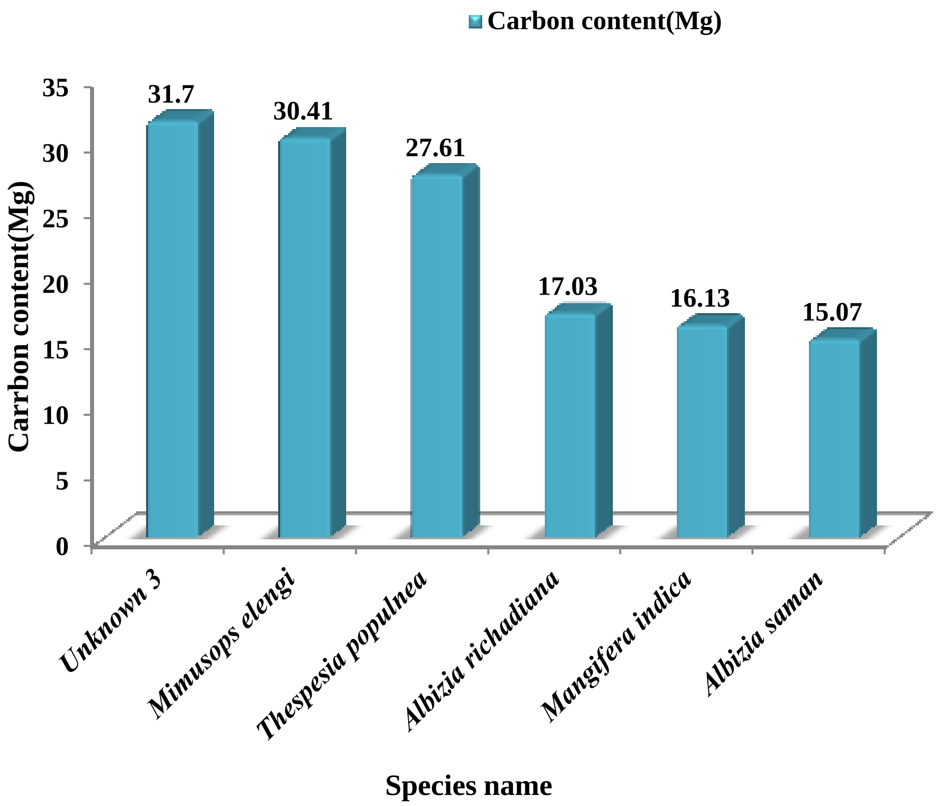

Figure 8. Major carbon containing tree species in Ramna Park

4.3 Relationship between stand structure of tree species and its carbon Stock

Regression and correlation analysis were used to determine the relationship among mean DBH, basal area and stem density with biomass carbon stock of tree species.

4.3.1 Basal area

The relationship between mean basal area and biomass carbon stock was measured and shown in Figure 9 in case of Chandrima Uddan and Figure 10 for Ramna Park.

Figure 9 indicated a linear equation as: $Y = 6.8724x + 6.5644$ ($R^2 = 0.8872$), where R^2 value was positive, $r = 0.94$ and $p < 0.05$. So it indicated that there was a significant and strongly positve correlation between basal area and biomass carbon stock in case of Chandrima Uddan. On the other hand Figure 10 indicated a linear equation as: $Y = 4.7502x + 72.562$ ($R^2 = 0.4334$), where R^2 value was also positive, $r = 0.65$ and $p < 0.05$. So it also indicated that there was a significant and strongly positive correlation between basal area and biomass carbon stock of Ramna Park. Basal area showed significant positive correlation with biomass and carbon stock in the present study area both in Ramna park and Chandrima uddan. Similar trend was observed by several works in tropical forests (Mani and Parthasarathy, 2007; Murali *et al.,* 2005; Vieilledent *et al.,* 2012). A number of studies (Brown *et al*., 1989; Chaturvedi *et al*., 2011; Kale *et al*., 2004; Overman *et al*., 1994; Slik *et al.,* 2010) also reported a high significant correlation of biomass carbon stock with basal area.

So mean carbon stock (247.90 Mg ha^{-1}) of Ramna park was higher than mean carbon stock (122.19 Mg ha^{-1}) due to higher basal area (36.91 m^2 ha^{-1}) of Ramna park than basal area (16.82 m^2 ha^{-1}) of Chandrima uddan.

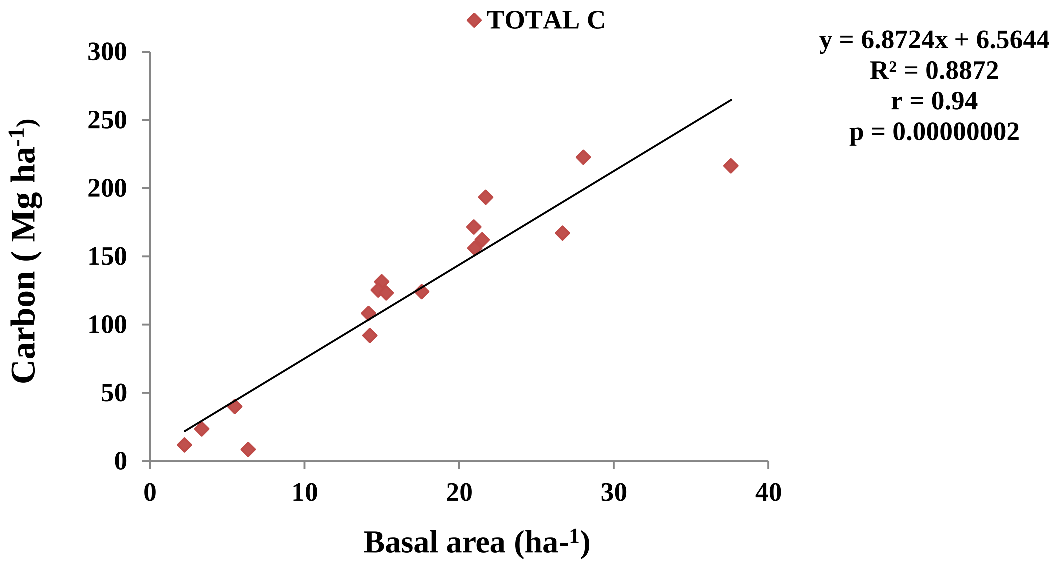

Figure 9. The relationship between basal area (m^2 ha^{-1}) and carbon stock (Mg ha^{-1}) in Chandrima Uddan

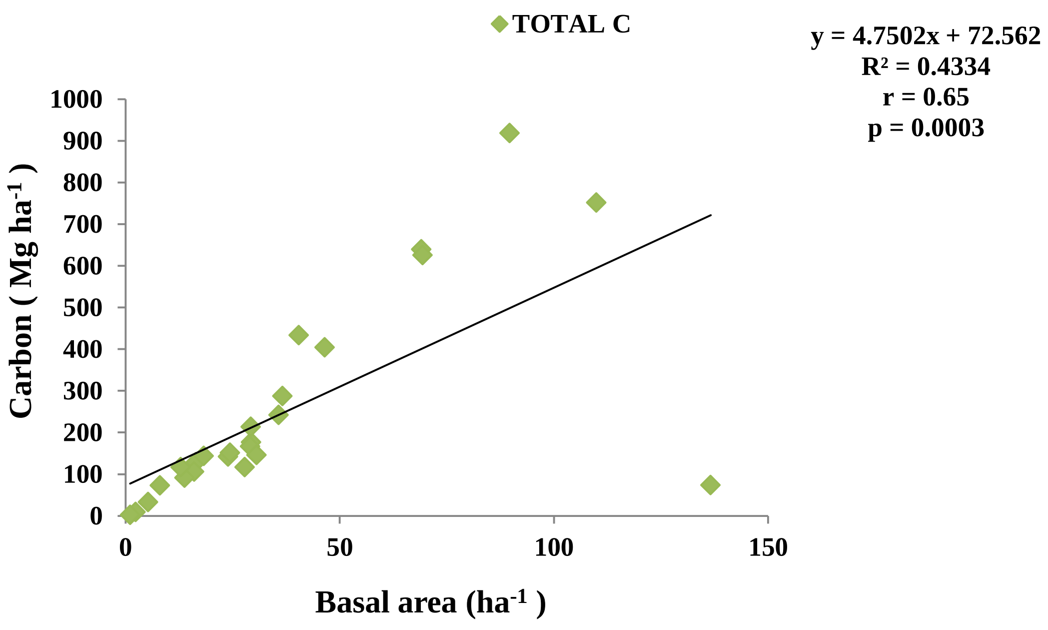

Figure 10. The relationship between basal area (m^2 ha^{-1}) and carbon stock (Mg ha^{-1}) in Ramna Park

4.3.2 Mean DBH

The relationship between mean DBH and biomass carbon stock was measured and shown in Figure 11 in case of Chandrima Uddan and Figure 12 for Ramna Park.

Figure 11 indicated a linear equation as: $Y = -0.2668x + 130.98$ ($R^2 = 0.0004$), where R^2 value was positive, $r = 0.02$ and $p > 0.05$. So it indicated that the relationship between mean DBH and biomass carbon stock was non-significant and at the same time there was a very weak relationship between them in case of Chandrima Uddan. On the other hand Figure 12 indicated a linear equation as: $Y = 6.3872x + 34.351$ ($R^2 = 0.4085$), where R^2 value was also positive, $r = 0.63$ and $p < 0.05$. So it indicated that there was a significant and moderate positive correlation between mean DBH and biomass carbon stock of Ramna Park. In a study it was reported that a significant positive correlation found between mean DBH and carbon stock as well as between basal area and total woody C also showed a high correlation of biomass with diameter at breast height (Mani and Parthasarathy, 2007). Similar trend has been observed by several workers in tropical forests (Murali *et al.*, 2005). In this present study moderate significant correlation was found between mean DBH and biomass carbon stock of Ramna Park. But in case of Chandrima Uddan there was a very weak relationship between them.

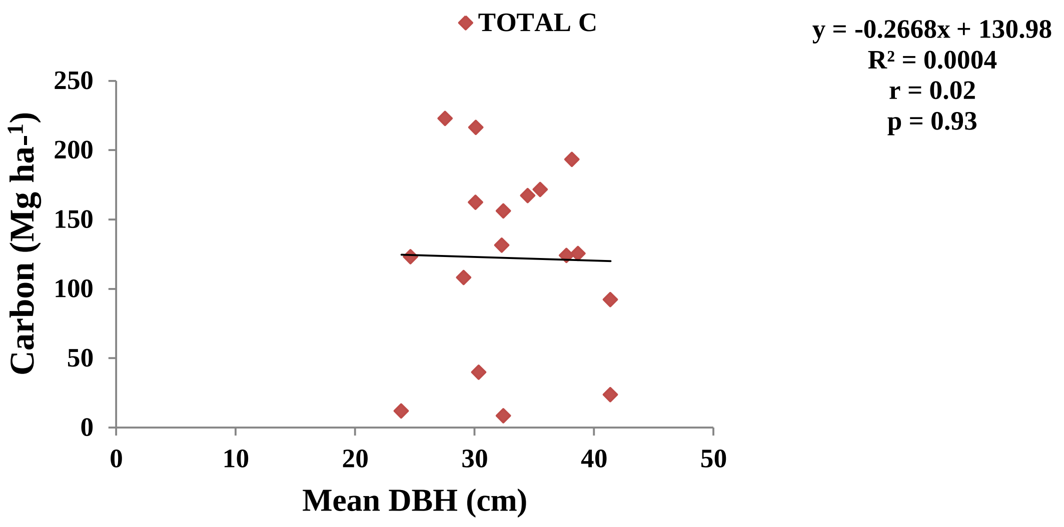

Figure 11. The relationship between mean DBH (cm) and carbon stock (Mg ha^{-1}) in Chandrima Uddan

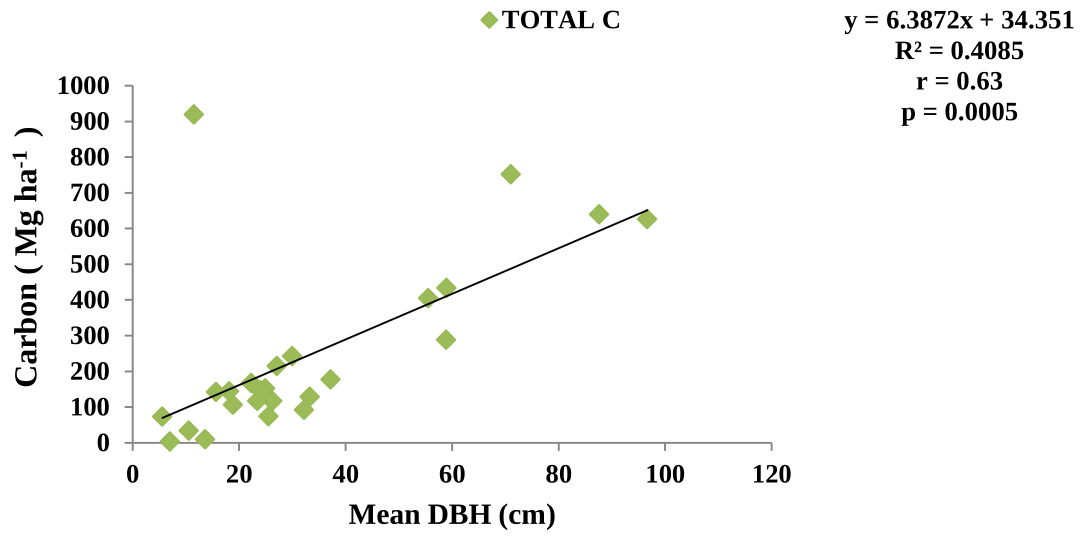

Figure 12. The relationship between mean DBH (cm) and carbon stock (Mg ha^{-1}) in Ramna Park

4.3.3 Stem density

The relationship between stem density and biomass carbon stock was measured and shown in Figure 13 in case of Chandrima Uddan and Figure 14 for Ramna Park.

Figure 13 indicated a linear equation as: $Y = 0.5166x + 27.233$ ($R^2 = 0.7296$), where R^2 value was positive, $r = 0.85$ and $p < 0.05$. So it indicated that there was a significant and strongly positve correlation between stem density and biomass carbon stock in case of Chandrima Uddan. On the other hand Figure 14 indicated a linear equation as: $Y = 0.061x + 224.61$ ($R^2 = 0.0073$), where R^2 value was also positive, $r = 0.08$ and $p > 0.05$. So it indicated that the relationship between stem density and biomass carbon stock was non-significant and at the same time there was a very weak relationship between them in case of Ramna Park. In one study that was carried out in an old growth forest of Costa Rica, Central America, found two plots with a stem density 462 to 504 per ha where the AGC was 139 to 138 Mg ha^{-1} respectively (Clark, 2000). It indicated that the stem density was not a determinant factor of aboveground carbon stocks. AGC was only correlated with basal area, but not with stem density (Slik, 2010). Another study showed that tree density is important to store carbon as it directly related to the carbon sequestration (Roshetko *et al.,* 2007).

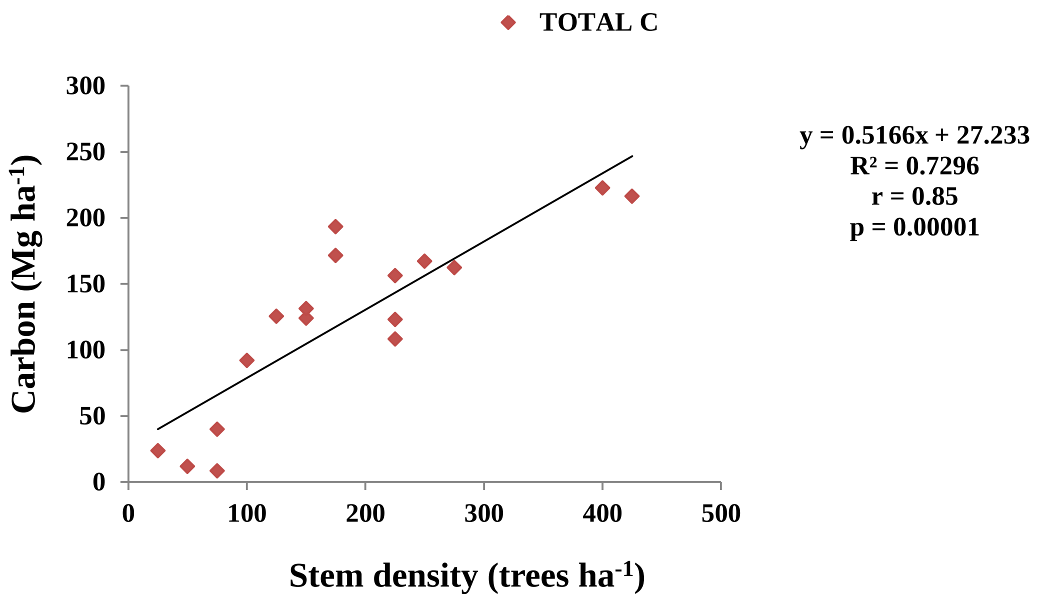

Figure 13. The relationship between stem density (trees ha^{-1}) and carbon stock ($Mg\ ha^{-1}$) in Chandrima Uddan

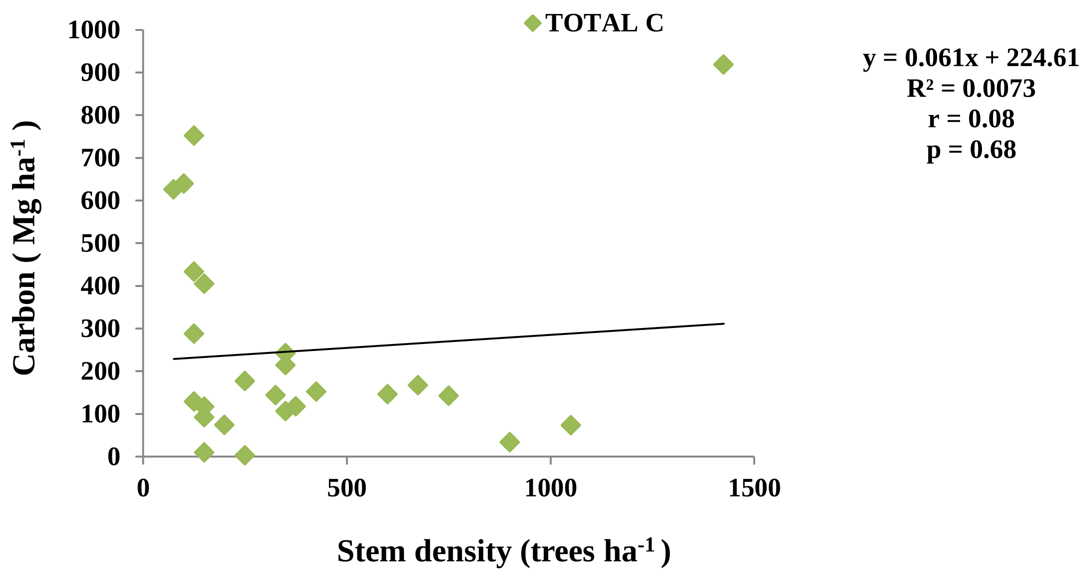

Figure 14. The relationship between stem density (trees ha^{-1}) and carbon stock ($Mg\ ha^{-1}$) in Ramna Park

4.3.4 Relationship between tree species diversity and tree carbon stock (Mg ha^{-1})

The relationship between tree species diversity and biomass carbon stock was measured and shown in Figure 15 in case of Chandrima Uddan and Figure 16 for Ramna Park.

Figure 15 indicated a linear equation as: $Y = 69.013x + 81.536$ ($R^2 = 0.29$), where R^2 value was positive, $r = 0.53$ and $p < 0.05$. So it indicated that there was a significant and moderate positve correlation between tree species diversity and biomass carbon stock in case of Chandrima Uddan. On the other hand Figure 16 indicated a linear equation as: $Y = -36.974x + 280.1$ ($R^2 = 0.005$), where R^2 value was also positive, $r = 0.07$ and $p > 0.05$. So it indicated that the relationship between tree species diversity and biomass carbon stock was non-significant and at the same time there was a very weak relationship between them in case of Ramna Park. Day *et al.* (2013) conducted a similar research and found that the relationship between tree species diversity and tree carbon stock was significant but weakly correlated with each other in central African rainforest where $r = 0.21$ and $p = 0.03$. In the present study area significant and moderate correlation was found bwtween tree species diversity and tree carbon stock in case of Chandrima Uddan because maximum tree species were uniform in respect of basal area and mean DBH which were not uniform in case of Ramna Park.

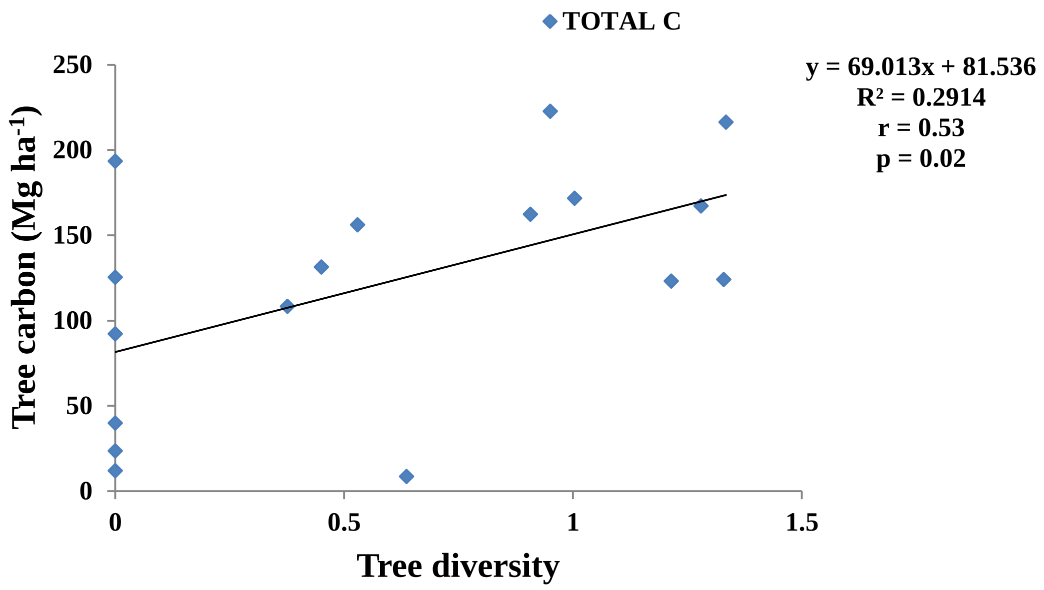

Figure 15. The relationship between diversity of tree species and carbon stocks (Mg ha^{-1}) in Chandrima Uddan

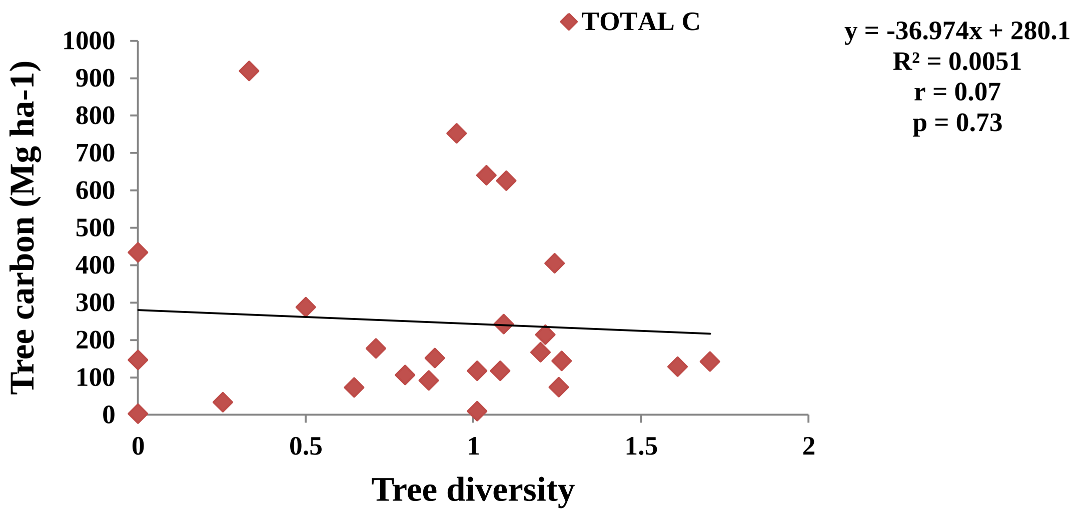

Figure 16. The relationship between diversity of tree species and carbon stocks (Mg ha^{-1}) in Ramna Park

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

The relationship between tree species diversity and soil organic carbon was measured and shown in Figure 17 in case of Chandrima Uddan and Figure 18 for Ramna Park.

Figure 17 indicated a linear equation as: $Y = 0.3232x + 14.22$ ($R^2 = 0.004$), where R^2 value was positive, $r = 0.06$ and $p > 0.05$. So it indicated that the relationship between tree species diversity and soil organic carbon was non-significant and at the same time there was a very weak correlation between them in case of Chandrima Uddan. On the other hand Figure 18 indicated a linear equation as: $Y = -2.135x + 14.619$ ($R^2 = 0.03$), where R^2 value was also positive, $r = 0.18$ and $p > 0.05$. So the relationship between tree species diversity and soil organic carbon was non-significant and very weakly correlated with each other. Liu *et al.* (2016) conducted a similar research and found that soil organic carbon concentrations and stocks were caused by tree species composition rather than tree species diversity in southwestern China. Edmondson *et al.* (2014) conducted another similar research and found that genus selection is important to maximise long term soil organic carbon storage under urban trees.

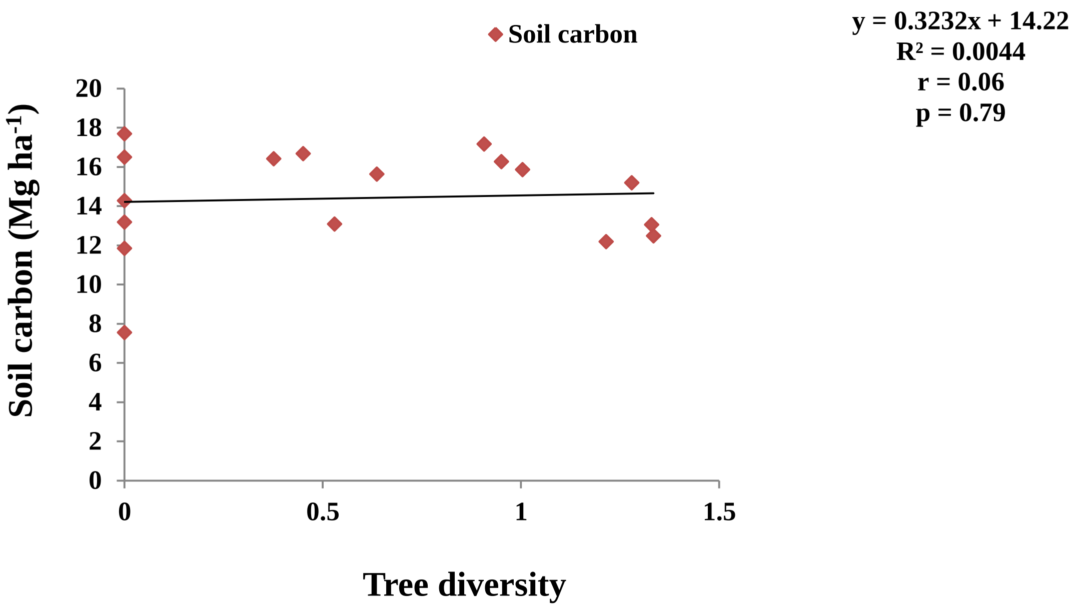

Figure 17. The relationship between diversity of tree species and soil organic carbon (Mg ha^{-1}) in Chandrima Uddan

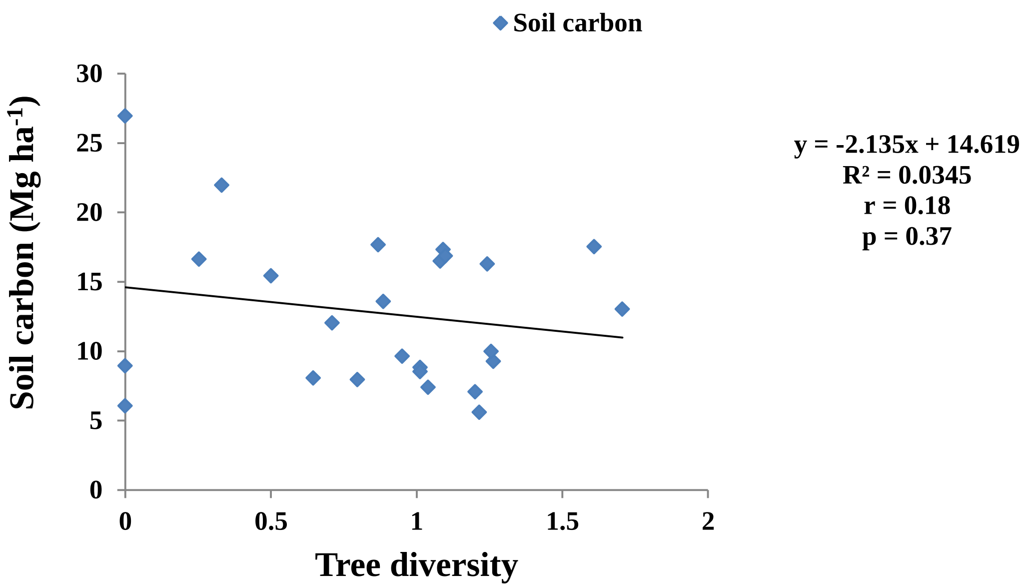

Figure 18. The relationship between diversity of tree species and soil organic carbon (Mg ha^{-1}) in Ramna Park

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

The relationship between tree density and soil organic carbon was measured and shown in Figure 19 in case of Chandrima Uddan and Figure 20 for Ramna Park.

Figure 19 indicated a linear equation as: Y = 0.0018x + 14.075 (R^2 = 0.006), where R^2 value was positive, r = 0.07 and p > 0.05. So it indicated that the relationship between tree density and soil organic carbon was non-significant and at the same time there was a very weak relationship between them in case of Chandrima Uddan. On the other hand Figure 20 indicated a linear equation as: Y = 0.0043x + 11.126 (R^2 = 0.07), where R^2 value was also positive, r = 0.27 and p > 0.05. So the relationship between tree density and soil organic carbon was non- significant and they were weakly correlated with each other in Ramna Park. A study was conducted in Nigerian forests and found a negative relationship between tree density and soil organic carbon (Eni *et al*., 2012).

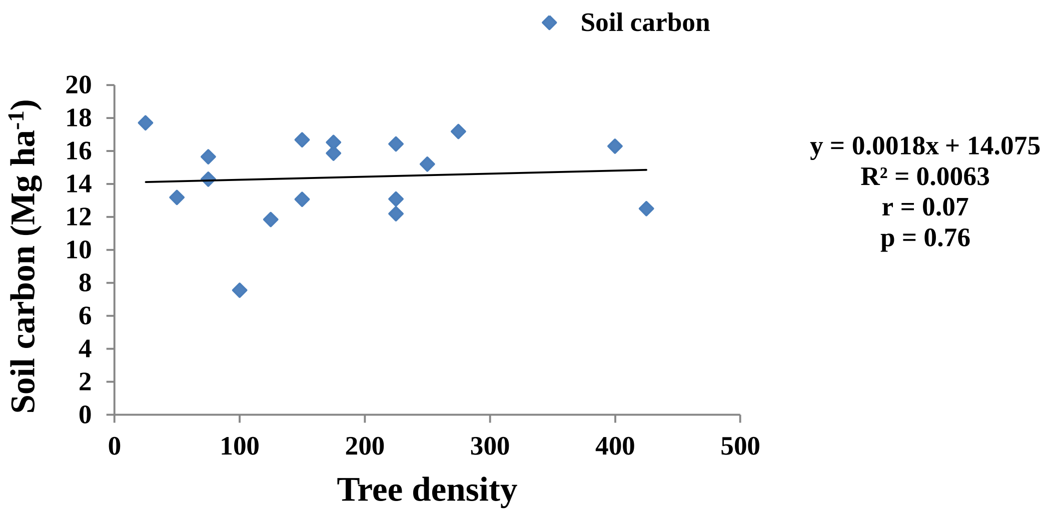

Figure 19. The relationship between mean tree density (trees ha^{-1}) and SOC (Mg ha^{-1}) in Chandrima Uddan

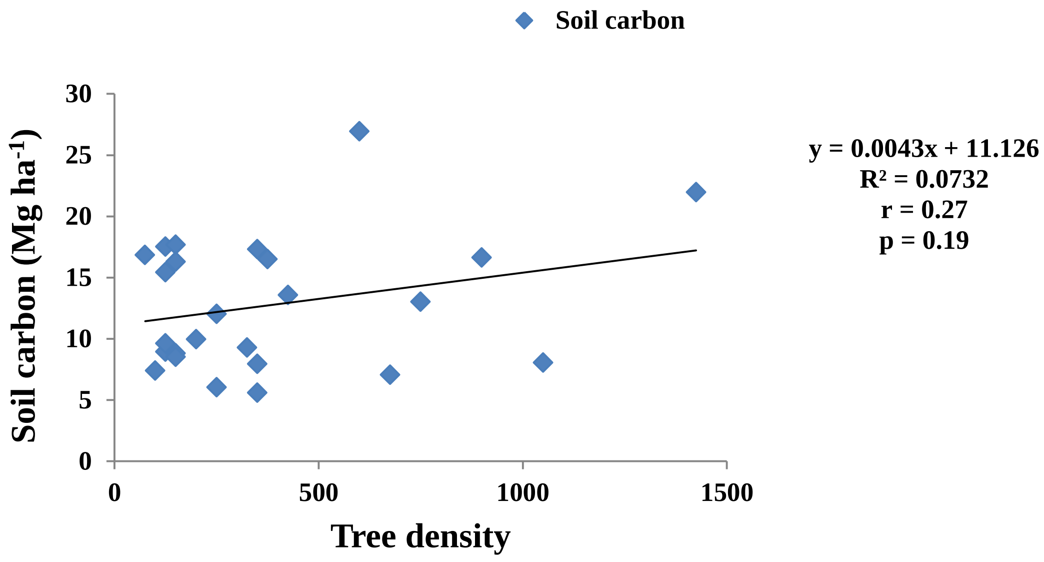

Figure 20. The relationship between mean tree density (trees ha^{-1}) and SOC (Mg ha^{-1}) in Ramna Park

4.4 Overall about tree species at two parks in Dhaka city

From the experimental area it was found that there were a total 19 species under 8 families where 4 species were unknown in case of Chandrima Uddan. On the other hand in Ramna park there were a total 41 species under 20 families where 8 species were unknown. Under Chandrima Uddan a total 19 species, their local name, botanical name, family, primary uses, total number of individuals and % of total were shown in Table 6 followed by Ramna Park in Table 7.

Table 6. **Tree species identified at 17(21) sample plots in Chandrim Uddan**

S.I no	Local name	Botanical name	Family	Primary uses	Total no	% of total
1	Akashmoni	*Acacia auriculiformis*	Fabaceae	Wd, Tm, Fu	59	47.58
2	Eucalyptus	*Eucalyptus camaldulensis*	Myrtaceae	Wd, Tm, Fu	11	8.87
3	Jarul	*Lagerstroemia speciosa*	Lythraceae	Wd, Tm, Fu	7	5.64
4	Kanthal	*Artocarpus heterophyllus*	Moraceae	Fr, Tm,Vg	6	4.83
5	Rajkoroi	*Albizia richadiana*	Fabaceae	Tm, Wd, Fu	6	4.83
6	Am	*Mangifera indica*	Anacardiaceae	Fr, Wd, Fu	5	4.03
7	Narikel	*Cocos nucifera*	Palmaceae	Md, Fr, Oi	4	3.22
8	Unknown 1	------------------	--------------	-----------	4	3.22
9	Dewa	*Artocarpus lakoocha*	Moraceae	Fr, Wd, Fu	3	2.41
10	Kadam	*Neolamarckia cadamba,*	Rubiaceae	Wd, Fr, Fl	3	2.41
11	Bakul	*Mimusops elengi*	Spotaceae	Wd, Fl, Fu	3	2.41
12	Sissoo	*Dalbergia sissoo*	Fabaceae	Wd, Tm	2	1.61
13	Unknown 2	---------------------	--------------	-----------	2	1.61
14	Unknown 3	---------------------	--------------	-----------	2	1.61
15	Unknown 4	---------------------	--------------	-----------	2	1.61
16	Khejur	*Phoenix sylvestris*	Palmaceae	Fr, Fu, Md	2	1.61
17	Bel	*Aegle marmelos*	Rutaceae	Fr, Md	1	0.8
18	Peyara	*Psidium guajava*	Myrtaceae	Fr, Fu	1	0.8
19	Krishnachura	Delonix regia	Fabaceae	Wd, Fl	1	0.8

N.B: Fr = Fruit, **Wd** = Wood, **Md** = Medicine, **Tm** = Timber, **Fu** = Fuel, **Fl** = Flower **Oi** = Oil, **Vg** = Vegetable

Table 7. Tree species identified at 25 sample plots in Ramna Park

S.I no	Local name	Botanical name	Family	Primary uses	Total no	% of total
1	Arecapalm	*Areca triandra*	Arecaceae	Fr, Oi	137	35.86
2	Mehogoni	*Swietenia macrophylla*	Meliaceae	Tm, Wd	33	8.63
3	Bakul	*Mimusops elengi*	Spotaceae	Fl, Fu	27	7.06
4	Debdaru	*Polyalthia longifolia*	Annonaceae	Tm, Wd	25	6.54
5	Jarul	*Lagerstroemia speciosa*	Lythraceae	Tm, Wd	18	4.71
6	Bottlebrush	*Callistemon sp.*	Myrtaceae	Fl, Wd	13	3.40
7	Unknown 8	--------------------	-------------	---------	12	3.14
8	Segun	*Tectona grandis*	Lamiaceae	Tm, Wd	10	2.61
9	Kanthal	*Artocarpus heterophyllus*	Moraceae	Fr, Vg, Tm	10	2.61
10	Rajkoroi	*Albizia richadiana*	Fabaceae	Tm,Wd,Fu	10	2.61
11	Kanchon	*Phanera variegata*	Fabaceae	Fl, Wd	9	2.35
12	Am	*Mangifera indica*	Anacardiaceae	Fr, Wd, Fu	9	2.35
13	Krishnachura	*Delonix regia*	Fabaceae	Wd, Fl	8	2.09
14	Unknown 4	--------------------	-------------	----------	5	1.30
15	Narikel	*Cocos nucifera*	Palmaceae	Md, Fr, Oi	5	1.30
16	Eucalyptus	*Eucalyptus camaldulensis*	Myrtaceae	Wd, Tm, Fu	5	1.30
17	Neem	*Azadirachta indica*	Meliaceae	Tm, Md, Oi	4	1.04
18	Ipil-ipil	*Leucaena leucocephala*	Mimosaceae	Fu	3	0.78
19	Unknown 2	--------------------	-------------	---------	3	0.78
20	Unknown 3	--------------------	-------------	---------	3	0.78
21	Unknown 7	--------------------	-------------	---------	3	0.78

(Cont'd)

S.I no	Local name	Botanical name	Family	Primary uses	Total no	% of total
22	Royal palm	*Roystonea regia*	Arecaceae	Oi, Fu	3	0.78
23	Polash	*Butea monosperma*	Fabaceae	Fl, Fu	3	0.78
24	Majesty Palm	*Ravenea sp.*	Arecaceae	Oi, Fu	3	0.78
25	Unknown 6	--------------------	-------------	----------	2	0.52
26	Sissoo	*Dalbergia sissoo*	Fabaceae	Wd, Tm	2	0.52
27	Rubber	*Hevea brasiliensis*	Euphorbiaceae	La, Fu	2	0.52
28	Raintree	*Albizia saman*	Fabaceae	Fu, Wd	2	0.52
29	Jam	*Acacia acuminata*	Fabaceae	Fr, Tm,Wd	2	0.52
30	Ironwood	*Carpinus caroliniana*	Betulaceae	Tm	2	0.52
31	Akashmoni	*Acacia auriculiformis*	Fabaceae	Wd, Tm,Fu	1	0.26
32	Chalta	*Dillenia indica*	Dilleniaceae	Fr, Fu	1	0.26
33	Dewa	*Artocarpus lakoocha*	Moraceae	Fr, Wd, Fu	1	0.26
34	Gab	*Diospyros blancoi*	Ebenaceae	Fr, Wd	1	0.26
35	Jhau	*Tamarix gallica*	Tamaricaceae	Md, Fu	1	0.26
36	Kadam	*Neolamarckia cadamba*	Rubiaceae	Fr, Fl	1	0.26
37	Pakur	*Thespesia populnea*	Malvaceae	Wd	1	0.26
38	Shimul	*Bombax ceiba*	Malvaceae	Fu, fl	1	0.26
39	Sonalu	*Cassia fistula*	*Caesalpiniaceae*	Tm, Wd	1	0.26
40	Unknown 1	--------------------	-------------	--------	1	0.26
41	Unknown 5	--------------------	-------------	--------	1	0.26

N.B: Fr =Fruit, **Wd** =Wood, **Md** = Medicine, **Tm** =Timber, **Fu** =Fuel, **Fl** =Flower, **Oi** =Oil, **Vg** = Vegetable, **La** =Latex

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

SUMMARY

Due to rapid increasing of population, urbanization and industrialization are increasing as well as natural forests are also degrading. As a result global temperature is increasing day by day. So now-a-days research in urban green area are getting scientific interests. Considering this aspect keep it mind present study was conducted at two parks in Dhaka city. One was Chandrima Uddan and another one was Ramna park.

Ecosystem carbon stock i.e., above ground carbon, below ground carbon and soil organic carbon were estimated from both these parks. Above and below ground carbon stock of Ramna Park were 220.45 Mg ha^{-1} and 27.35 Mg ha^{-1}, respectively which was higher than Chandrima Uddan whose above and below ground carbon stock were 106.61 Mg ha^{-1} and 15.57 Mg ha^{-1}, respectively. In case of soil organic carbon (28.81 Mg ha^{-1}) of Chandrima Uddan was slightly higher than Ramna park whose soil organic carbon was 25.52 Mg ha^{-1}. Soil organic carbon was measured at two depths i.e., 5-10 cm and 20-25 cm, respectively. Soil organic carbon at 5-10 cm depth was higher than at 20-25 cm depth. At 5-10 cm depth both in Chandrima Uddan and Ramna Park ranged from 21.27-8.86 Mg ha^{-1} and 23.75-5.46 Mg ha^{-1} with a mean value of 16.52 and 13.64 Mg ha^{-1}, respectively. In case of 20-25 cm depth both in Chandrima Uddan and Ramna Park ranged from 16.92-6.20 Mg ha^{-1} and 35.04-0.90 Mg ha^{-1} with a mean value of 12.29 and 11.88 Mg ha^{-1}, respectively.

Tree species diversity of the two parks were measured by using Shannon-Wiener Index. Shannon-Wiener Index showed that tree species diversity ranged from 0 to 1.7 with a mean value of 0.87 in Ramna Park and for Chandrima Uddan it ranged from 0 to 1.33 with a mean value of 0.58. Mean number of trees (10 tree ha^{-1}), basal area (16.82 m^2 ha^{-1}) and mean DBH (32.94 cm) of

Chandrima Uddan was lower than Ramna park whose mean number of trees, basal area and mean DBH are 15 nos. ha^{-1}, 36.91 m^2 ha^{-1} and 33.43 cm, respectively. Tree density ranged from 25-425 trees ha^{-1} with a mean value of 183 trees ha^{-1} in Chandrima Uddan which was lower than Ramna Park whose tree density ranged from 75-1425 trees ha^{-1} with a mean value of 382 trees ha^{-1}.

From the experimental area it was found that the occurrence of major tree was *Acacia auriculiformis* (47.58 %) with highest amount of carbon content (51.42 Mg) in Chandrima Uddan but in Ramna Park, the occurrence of major tree was *Areca triandra* (35.86 %) and highest carbon containing tree species was Unknown 3 (31.7 Mg).

Different types of relationship were shown between these two parks individually such as biomass carbon with basal area, mean DBH, stem density as well as soil organic carbon and tree diversity. Among these the relationship between basal area and biomass carbon showed positive significant correlation in both parks. The relationship among different parameters varied from place to place due to structure and composition of tree species as well as soil structure and management of parks. This type of research findings will be helpful to facilitate similar research in other park area in Dhaka city. In this regard if all the green area carried out under similar research then it will represent the overall carbon sequestration potential as well as pattern of tree species diversity in Dhaka city.

CONCLUSION

The present study conducted at two parks in Dhaka city have a key role in climate change mitigation by sequestering carbon in different carbon pool i.e., above ground carbon, below ground carbon and soil organic carbon. At the same time this study showed some differences between two parks in terms of plant stand characteristics (stem density, basal area, mean DBH), tree species diversity, soil organic carbon and various degree of relationships of stand characteristics with carbon stock. However, the following points can be concluded based on the present study:

- The mean carbon stock was higher in Ramna Park compared to Chandrima Uddan whereas soil organic carbon was slightly higher in Chandrima Uddan.
- Tree diversity was also higher in Ramna Park than in Chandrima Uddan and it is well known that enriched tree diversity can help in biodiversity conservation as well as microclimate amelioration.
- Among different relationships, the relationship between basal area and tree carbon stock showed significant positive correlation.

So, green vegetation can help urban dwellers by reducing carbon-di-oxide emission from the atmosphere and maintaining the ecological balance of crowded and polluted environment.

RECOMMENDATION

By considering the overall aspect of this present study the following points can be recommended:

- This study can contribute as a base line research for the contribution of city public park to climate change mitigation in addition to its recreation value.

- There should be an integrated work with different sectors and stakeholders in order to make the value of these parks in the city to be sustained.

- Based on the result of this research, establishing more number of parks in the city with proper management serve as botanic garden, and potentially stabilize urban microclimate.

- Creating awareness for the public, government body and other stakeholders about the woody plant species in these parks helps to improve urban climate by preventing pollutants and sequestering GHGs as well as a means to generate carbon finance.

- The allometric equation applied in the present study was not free of errors in calculating carbon levels in different trees. In this case advanced research should be carried out by using satellite remote sensing techniques and some other suitable modern techniques to get appropriate results.

Further research should be conducted in this study area to find out the CO_2 sequestration rate and other carbon pools such as herbs, shrubs, litter, dead wood etc. for representing total ecosystem carbon stock.

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APPENDICES

APPENDIX I: Above and below ground biomass carbon stock in 21 sample plots of Chandrima Uddan

Plot No.	Name of the Park	AGC (Mg ha^{-1})	BGC (Mg ha^{-1})	Total C (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard Deviation	Standard Error
1	Chandrima	188.42	27.88	216.30	**122.19**	**68.02**	**16.49**
2	Chandrima	108.21	15.88	124.09			
3	Chandrima	141.01	21.189	162.20			
4	Chandrima	136.09	20.05	156.14			
5	Chandrima	115.06	16.30	131.35			
6	Chandrima	145.70	21.35	167.06			
7	Chandrima	150.68	20.90	171.59			
8	Chandrima	10.09	1.738	11.83			
9	Chandrima	93.79	14.41	108.20			
10	Chandrima	20.56	3.01	23.58			
11	Chandrima	34.44	5.37	39.82			
12	Chandrima	169.49	23.81	193.30			
13	Chandrima	0	0	0			
14	Chandrima	0	0	0			
15	Chandrima	7.28	1.23	8.520			
16	Chandrima	0	0	0			
17	Chandrima	80.47	11.59	92.07			
18	Chandrima	109.49	15.89	125.39			
19	Chandrima	0	0	0			
20	Chandrima	107.66	15.41	123.08			
21	Chandrima	193.93	28.78	222.72			

APPENDIX II: Above and below ground biomass carbon stock in 25 sample plots of Ramna Park

Plot No.	Name of the Park	AGC (Mg ha^{-1})	BGC (Mg ha^{-1})	Total C (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard Deviation	Standard Error
1	Ramna	113.29	15.11	128.41	**247.90**	**244.21**	**48.84**
2	Ramna	27.56	5.63	33.20			
3	Ramna	831.09	87.37	918.46			
4	Ramna	92.56	13.62	106.18			
5	Ramna	62.37	10.57	72.94			
6	Ramna	125.77	18.01	143.78			
7	Ramna	154.12	22.88	177.01			
8	Ramna	386.72	46.77	433.50			
9	Ramna	79.72	11.88	91.61			
10	Ramna	122.86	19.06	141.93			
11	Ramna	103.41	13.62	117.03			
12	Ramna	63.75	10.05	73.80			
13	Ramna	8.06	1.58	9.65			
14	Ramna	360.69	44.01	404.70			
15	Ramna	574.29	65.28	639.58			
16	Ramna	143.10	23.92	167.02			
17	Ramna	212.58	29.58	242.16			
18	Ramna	188.09	25.90	214.00			
19	Ramna	130.97	20.65	151.62			
20	Ramna	2.18	0.52	2.71			
21	Ramna	681.93	69.72	751.66			

Cont'd

Plot No.	Name of the Park	AGC (Mg ha^{-1})	BGC (Mg ha^{-1})	Total C (Mg ha^{-1})	Average C (Mg ha^{-1})	Standard Deviation	Standard Error
22	Ramna	101.72	15.35	117.08			
23	Ramna	125.46	20.86	146.32			
24	Ramna	254.78	32.94	287.73			
25	Ramna	564.08	61.45	625.53			

APPENDIX III: Tree diversity characteristics in 21 sample plots of Chandrima Uddan

Plot No.	Name of the Park	Tree diversity value	Mean	Standard Deviation	Standard Error
1	Chandrima	1.33	**0.58**	**0.53**	**0.12**
2	Chandrima	1.32			
3	Chandrima	0.90			
4	Chandrima	0.52			
5	Chandrima	0.45			
6	Chandrima	1.27			
7	Chandrima	1.00			
8	Chandrima	0			
9	Chandrima	0.37			
10	Chandrima	0			
11	Chandrima	0			
12	Chandrima	0			
13	Chandrima	0			
14	Chandrima	0			
15	Chandrima	0.63			
16	Chandrima	0			
17	Chandrima	0			
18	Chandrima	0			
19	Chandrima	0			
20	Chandrima	1.21			
21	Chandrima	0.95			

APPENDIX IV: Tree diversity characteristics in 25 sample plots of Ramna Park

Plot No.	Name of the Park	Tree diversity value	Mean	Standard Deviation	Standard Error
1	Ramna	1.60			
2	Ramna	0.25			
3	Ramna	0.33			
4	Ramna	0.79			
5	Ramna	0.64			
6	Ramna	1.26			
7	Ramna	0.71			
8	Ramna	0			
9	Ramna	0.86			
10	Ramna	1.70			
11	Ramna	1.01	**0.87**	**0.46**	**0.09**
12	Ramna	1.25			
13	Ramna	1.01			
14	Ramna	1.24			
15	Ramna	1.03			
16	Ramna	1.20			
17	Ramna	1.09			
18	Ramna	1.21			
19	Ramna	0.88			
20	Ramna	0			
21	Ramna	0.95			

Cont'd

Plot No.	Name of the Park	Tree diversity value	Mean	Standard Deviation	Standard Error
22	Ramna	1.08			
23	Ramna	0			
24	Ramna	0.50			
25	Ramna	1.09			

APPENDIX V: Soil Organic Carbon (SOC) stock at two different depth classes in 21 sample plots in Chandrima Uddan

Plot No.	Name of the Park	SOC (Mg ha^{-1}) (5-10cm)	SOC (Mg ha^{-1}) (20-25cm)	Total SOC (Mg ha^{-1})	Mean	Standard Deviation	Standard Error
1	Chandrima	18.62	6.34	24.96			
2	Chandrima	15.94	10.15	26.09			
3	Chandrima	19.79	14.54	34.33			
4	Chandrima	10.86	15.28	26.15			
5	Chandrima	16.34	16.99	33.33			
6	Chandrima	16.43	13.92	30.36			
7	Chandrima	17.53	14.16	31.70			
8	Chandrima	14.72	11.62	26.34			
9	Chandrima	21.27	11.53	32.81			
10	Chandrima	18.77	16.60	35.37			
11	Chandrima	0	0	0	**28.81**	**6.65**	**1.61**
12	Chandrima	18.34	10.19	28.53			
13	Chandrima	0	0	0			
14	Chandrima	0	0	0			
15	Chandrima	16.63	16.36	32.99			
16	Chandrima	0	0	0			
17	Chandrima	20.84	10.41	31.26			
18	Chandrima	8.86	6.20	15.07			
19	Chandrima	14.07	9.58	23.66			
20	Chandrima	14.07	10.29	24.37			
21	Chandrima	17.80	14.73	32.53			

APPENDIX VI: Soil Organic Carbon (SOC) stock at two different depth classes in 25 sample plots in Ramna Park

Plot No.	Name of the Park	SOC (Mg ha^{-1}) (5-10cm)	SOC (Mg ha^{-1}) (20-25cm)	Total SOC (Mg ha^{-1})	Mean	Standard Deviation	Standard Error
1	Ramna	22.60	12.44	35.05	**25.52**	**13.22**	**2.64**
2	Ramna	23.75	9.51	33.26			
3	Ramna	22.31	21.60	43.91			
4	Ramna	15.01	0.90	15.91			
5	Ramna	8.57	7.54	16.12			
6	Ramna	9.51	9.03	18.54			
7	Ramna	15.01	9.05	24.07			
8	Ramna	13.16	4.71	17.87			
9	Ramna	15.91	19.42	35.34			
10	Ramna	8.82	17.20	26.03			
11	Ramna	8.96	8.68	17.64			
12	Ramna	16.46	3.47	19.93			
13	Ramna	6.75	10.28	17.03			
14	Ramna	19.09	13.47	32.57			
15	Ramna	7.16	7.62	14.79			
16	Ramna	10.19	3.92	14.12			
17	Ramna	18.53	16.08	34.62			
18	Ramna	5.46	5.73	11.19			
19	Ramna	10.79	16.34	27.13			
20	Ramna	8.46	3.62	12.08			
21	Ramna	8.44	10.82	19.27			

Cont'd

Plot No.	Name of the Park	SOC (Mg ha^{-1}) (5-10cm)	SOC (Mg ha^{-1}) (20-25cm)	Total SOC (Mg ha^{-1})	Mean	Standard Deviation	Standard Error
22	Ramna	11.23	21.76	32.99			
23	Ramna	18.83	35.04	53.87			
24	Ramna	21.65	9.20	30.86			
25	Ramna	14.02	19.68	33.70			

APPENDIX VII: Stem density, Basal area and DBH of 21 sample plots in Chandrima Uddan

Plot No	Name of the Park	Stem density (trees ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH (cm)
1	Chandrima	425	37.58	30.10
2	Chandrima	150	17.57	37.69
3	Chandrima	275	21.50	30.08
4	Chandrima	225	21.02	32.43
5	Chandrima	150	14.99	32.28
6	Chandrima	250	26.68	34.45
7	Chandrima	175	20.96	35.49
8	Chandrima	50	2.24	23.87
9	Chandrima	225	14.15	29.10
10	Chandrima	25	3.36	41.38
11	Chandrima	75	5.49	30.34
12	Chandrima	175	21.72	38.15
13	Chandrima	0	0	0
14	Chandrima	0	0	0
15	Chandrima	75	6.35	32.41
16	Chandrima	0	0	0
17	Chandrima	100	14.23	41.38
18	Chandrima	125	14.76	38.67
19	Chandrima	0	0	0
20	Chandrima	225	15.29	24.65
21	Chandrima	400	28.04	27.54

APPENDIX VIII: Stem density, Basal area and DBH of 25 sample plots in Ramna Park

Plot No	Name of the Park	Stem density (trees ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH (cm)
1	Ramna	125	16.42	33.29
2	Ramna	900	5.28	10.57
3	Ramna	1425	89.70	11.50
4	Ramna	350	16.02	18.87
5	Ramna	1050	8.04	5.60
6	Ramna	325	18.31	18.11
7	Ramna	250	29.32	37.18
8	Ramna	125	40.50	58.95
9	Ramna	150	13.79	32.20
10	Ramna	750	23.97	15.66
11	Ramna	150	12.87	26.26
12	Ramna	200	136.62	25.56
13	Ramna	150	2.36	13.63
14	Ramna	150	46.51	55.54
15	Ramna	100	69.04	87.61
16	Ramna	675	29.14	22.26
17	Ramna	350	35.74	29.96
18	Ramna	350	29.25	27.07
19	Ramna	425	24.43	24.95
20	Ramna	250	1.07	7.00
21	Ramna	125	109.89	71.04

Cont'd

Plot No	Name of the Park	Stem density (trees ha^{-1})	Basal area (m^2 ha^{-1})	Mean DBH (cm)
22	Ramna	375	27.81	23.45
23	Ramna	600	30.63	23.96
24	Ramna	125	36.62	58.88
25	Ramna	75	69.40	96.65

APPENDIX IX: Center point co-ordinates of plots in Chandrima Uddan

Name of the park	Plot No.	Co-ordinates
Chandrima Uddan	**1**	N- 23.76624 E-090.38190
	2	N-23.76700 E-90.38184
	3	N-23.76795 E-90.38174
	4	N-23.76787 E-90.38074
	5	N-23.76698 E-90.38080
	6	N-23.76603 E-90.38103
	7	N-23.76602 E-90.38001
	8	N-23.76688 E-90.37984
	9	N-23.76781 E-90.37979
	10	N-23.76775 E-90.37875
	11	N-23.76688 E-90.37878
	12	N-23.76596 E-90.37899
	13	N-23.76597 E-90.37804
	14	N-23.76679 E-90.37782
	15	N-23.76761 E-90.37777
	16	Pond present
	17	N-23.76665 E-90.37682
	18	N-23.76578 E-90.37700
	19	N-23.76565 E-90.37607
	20	N-23.76656 E-90.37589
	21	N-23.76740 E-90.37578

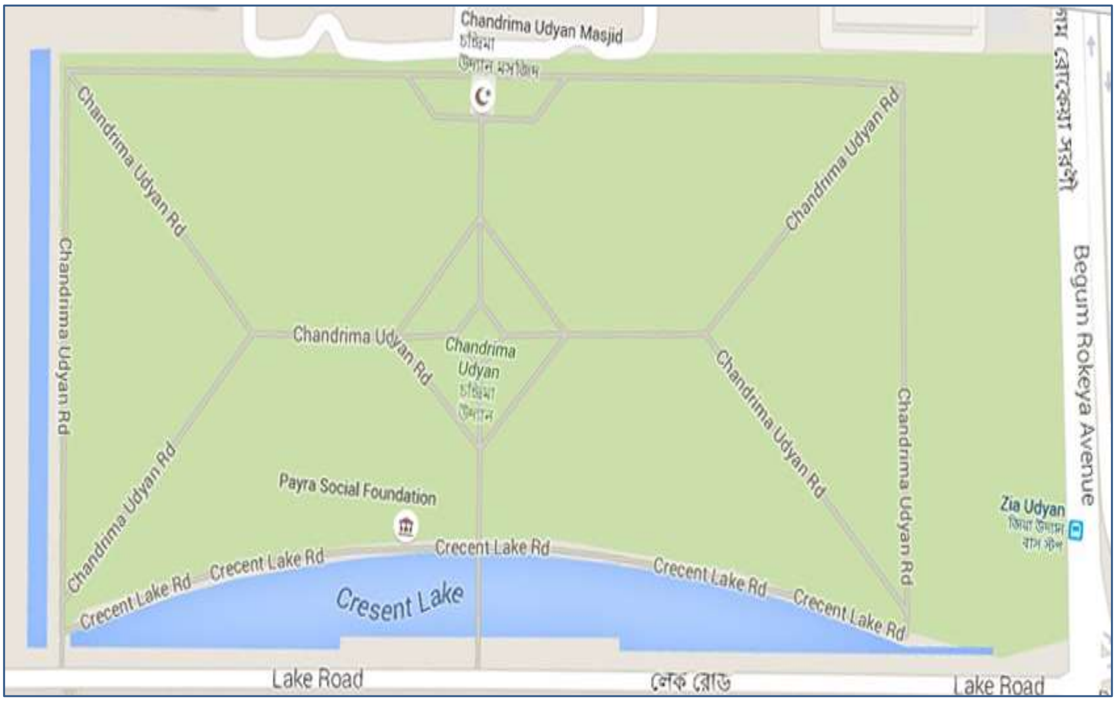
APPENDIX X: Center point co-ordinates of plots in Ramna Park

Name of the park	Plot No.	Co-ordinates
Ramna Park	1	N-23.74144 E-90.39828
	2	N-23.74078 E-90.39901
	3	N-23.74022 E-90.39982
	4	N-23.73973 E-90.39900
	5	N-23.73974 E-90.40082
	6	N-23.73922 E-90.39989
	7	N-23.73862 E-90.39928
	8	N-23.73927 E-90.40164
	9	N-23.73880 E-90.40082
	10	N-23.73834 E-90.39999
	11	N-23.73878 E-90.40244
	12	N-23.73827 E-90.40159
	13	N-23.73767 E-90.40079
	14	N-23.73715 E-90.39986
	15	N-23.73816 E-90.40317
	16	N-23.73767 E-90.40234
	17	N-23.73711 E-90.40156
	18	N-23.73619 E-90.40023
	19	N-23.73724 E-90.40288
	20	N-23.73649 E-90.40229

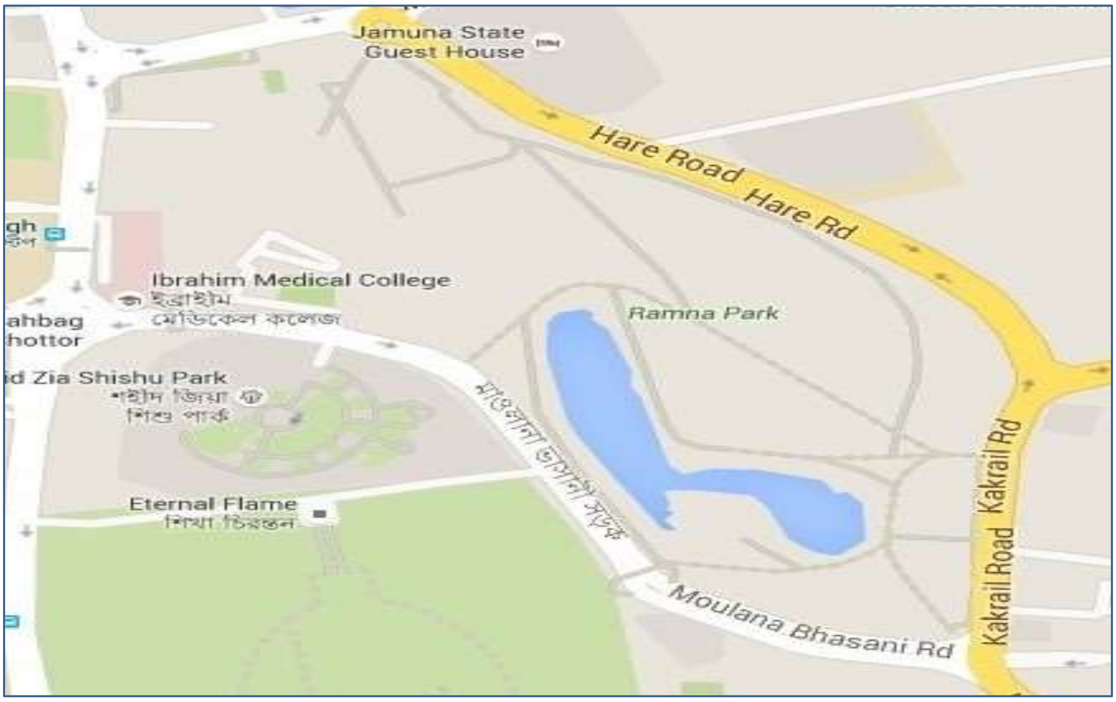
Cont'd

Name of the park	Plot No.	Co-ordinates
	21	N-23.73581 E-90.40146
	22	N-23.73637 E-90.40321
	23	N-23.73482 E-90.40141
	24	N-23.73548 E-90.40322
	25	N-23.73451 E-90.40308

APPENDIX XI: Map of two parks (A. Chandrima Uddan, B. Ramna Park)



(A)



(B)

APPENDIX XII: Value of Regression, Correlation and p value of different relationships in two parks

Name of the park	Relationship	Regression value	Correlation value	p value
Chandrima	BA Vs TCC	0.88	0.94	0.00000002
Ramna	BA Vs TCC	0.43	0.65	0.0003
Chandrima	Mean DBH Vs TCC	0.0004	0.02	0.93
Ramna	Mean DBH Vs TCC	0.40	0.63	0.0005
Chandrima	Stem density Vs TCC	0.72	0.85	0.00001
Ramna	Stem density Vs TCC	0.007	0.08	0.68
Chandrima	Tree diversity Vs TCC	0.29	0.53	0.02
Ramna	Tree diversity Vs TCC	0.005	0.07	0.73
Chandrima	Tree diversity Vs SOC	0.004	0.06	0.79
Ramna	Tree diversity Vs SOC	0.03	0.18	0.37
Chandrima	Tree density Vs SOC	0.006	0.07	0.76
Ramna	Tree density Vs SOC	0.07	0.27	0.19

N.B: BA = Basal area, **TCC** = Tree carbon stock, **DBH** = Diameter at breast height **SOC** = Soil organic carbon