# CARBON STOCK MEASUREMENT OF TREES AND DOCUMENTATION OF PLANT SPECIES AT SHER-E-BANGLA AGRICULTURAL UNIVERSITY CAMPUS

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**DECEMBER, 2020**

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*A Thesis*
*Submitted to the Faculty of Agriculture,*
*Sher-e-Bangla Agricultural University, Dhaka*
*in partial fulfilment of the requirements*
*for the degree of*

**MASTER OF SCIENCE**
**IN**
**AGROFORESTRY & ENVIRONMENTAL SCIENCE**

**SEMESTER: JULY-DECEMBER, 2020**

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## *CERTIFICATE*

*This is to certify that the thesis entitled "**CARBON STOCK MEASUREMENT OF TREES AND DOCUMENTATION OF PLANT SPECIES AT SHER-E-BANGLA AGRICULTURAL UNIVERSITY CAMPUS**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agroforestry and Environmental Science**, embodies the result of a piece of bona fide research work carried out by **MD. MASUD PARVEZ**, Registration number: **18-09157** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

**Dated: DECEMBER, 2020**
**Place: Dhaka, Bangladesh**

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**Dr. Md. Forhad Hossain**
**Professor**
**Supervisor**

**DEDICATED**

**TO**

**MY BELOVED PARENTS**

## *ACKNOWLEDGEMENTS*

*First of all, I express my best gratitude to Almighty Allah for His never-ending blessing to complete this work successfully. It is a great pleasure to express profound thankfulness to my respected parents, who entitled much hardship inspiring for prosecuting my studies, thereby receiving proper education.*

*I would like to express my earnest respect, sincere appreciation and enormous indebtedness to my reverend Supervisor* ***Prof. Dr. Md. Forhad Hossain****, Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work, and preparation of the thesis.*

*I wish to express my gratitude and best regards to my respected Co-Supervisor,* ***Md. Shariful Islam,*** *Assistant Professor, Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207, for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

*I feel to express my heartfelt thanks to all the teachers of the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University Dhaka-1207, for their valuable suggestions and encouragement during the period of the study.*

*I would like to thank Md. Tanvir Zubayer, Md. Muktar Ahmed and Zannatul Sifat Rumky who have helped me so much throughout the research work and preparation of the thesis.*

***December, 2020*** ***The Author***
***Sher-e-Bangla Agricultural University, Dhaka***

# CARBON STOCK MEASUREMENT OF TREES AND DOCUMENTATION OF PLANT SPECIES AT SHER-E-BANGLA AGRICULTURAL UNIVERSITY CAMPUS


## ABSTRACT

Carbon stock inside a vegetation plays a imperative part in relieving $CO_2$ and assurance long-term soundness of carbon in changing situations. The study was conducted to quantify the current carbon stock and documentation of plants in different vegetation sites at Sher-e-Bangla Agricultural University, Bangladesh. 72 plots were purposively selected and divided into seven categories viz. residential area, Horticulture and Agroforestry farm land, hall area, academic area, Block plantation, pond side and roadside. Total 731 plants of 60 different species under 32 families was recorded and 92, 360, 118, 41 and 120 plant species were existed in terms of ornamental, fruit, timber, medicinal and plantation crop, respectively. Academic area (229.06±20.31 Mg $ha^{-1}$) had the highest mean carbon stock followed by Block plantation (191.00±48.60 Mg $ha^{-1}$), Hrt. & Afe. farm land (184.22±20.83 Mg $ha^{-1}$), Roadside (163.46±22.73 Mg $ha^{-1}$), Hall area (157.27±14.32 Mg $ha^{-1}$), Pond side (93.00±13.12 Mg $ha^{-1}$) and Residential area (88.15±13.98 Mg $ha^{-1}$). The five major carbon containing species were *Mangifera indica* (102.53 Mg) followed by *Artocarpus heterophyllus* (46.34 Mg), *Swietenia mahagony* (44.42 Mg), *Polyalthia longifolia* (33.72 Mg) and *Albizia lebbeck* (19.94 Mg). Mango was found the most predominant tree species with 18.33% (no. 134) followed by Kanthal 8.21% (no. 60), Mahogany 7.93% (no. 58), Narikel 6.84% (no. 50) and Supari 6.02% (no. 44). The mean diversity value of the study area was 1.36 (SWI). Carbon stock had a positive relationship with basal area and mean DBH. Anacardiaceae was the most dominating family with a number of 137 plants and Oleaceae and Lythraceae were the least dominating family with a number of single plant. 49.25, 42.54, 16.41, 16.28, 13.95, 12.58 and 5.61% plants were recorded in fruit, resin plants, plantation crop, latex plants, timber, essential oil plants and ornamental plants, respectively with a total number of 360, 311, 120, 119, 118, 102 and 92. The study shows that the tree species found in the campus make an important contribution in conserving diversity and helps to maintain the carbon stock at the University Campus.

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## LIST OF ABBREVIATION AND ACRONYMS

| | | |
|---|---|---|
| AGC | : | Above-ground carbon |
| AGB | : | Above-ground biomass |
| C | : | Carbon |
| $CO_2$ | : | Carbon dioxide |
| DBH | : | Stem diameter at breast height (over bark) |
| GBH | : | Girth breast height |
| UHIE | : | Urban heat island effect |
| e.g. | : | For example |
| viz. | : | Namely/ as follows |
| DAE | : | Department of Agricultural Extension |
| GHG | : | Greenhouse gas |
| ha | : | Hectare |
| Hrt. & Afe. | | Horticulture and Agroforestry |
| IPCC | : | Intergovernmental Panel on Climate Change |
| Mg | : | Mega gram = $10^6$ gram |
| A/R | : | Aforestation and Reforestation |
| *et al.* | : | And others |
| $^0C$ | : | Degree Celsius |
| $ha^{-1}$ | : | Per Hectare |
| cm | : | Centimeter |
| $m^2$ | : | Square meter |
| % | : | Percent |
| t | : | Ton |
| AGC | : | Above ground carbon |
| BGC | : | Below ground carbon |
| UNFCCC | : | United Nations Framework Convention on Climate Change |
| FAO | : | Food and agriculture organization |
| REDD+ | : | Reducing Emissions from Deforestation and Forest Degradation |
| SOC | : | Soil organic carbon |
| AR5 | : | $5^{th}$ assessment report |
| Spp | : | Species |
| AH | : | Ad hoc |
| SRP | : | Stratified random plot |
| SWI | : | Shannon–Wiener diversity index |
| POM | : | Point of measurement |
| CF | : | Carbon foot print |
| CDM | : | Clean development mechanism |

# CHAPTER 1

# INTRODUCTION

On a global scale, there are many indicators that climate change is occurring. If this trend continues it will result in major ecosystems alterations (Smith *et al.*, 2013). The main drivers of climate change are anthropogenic emissions from fossil fuels use and deforestation in conjunction with forest degradation (Clark and York, 2005; Buizer *et al.,* 2014). In the fifth assessment (AR5) of 2014, the Intergovernmental Panel on Climate Change (IPCC) projected a rise of average global surface temperature by 0.3-1.7$^0$C and 2.6-4.8$^0$C, respectively, under the lowest and the highest emission scenarios (Stocker *et al.,* 2013). The level of warming in 2017 was 0.15°C–0.35°C higher than average warming over the 30-year period 1988–2017 (IPCC, 2018). AR6 expected to limit the global warming within 1.5$^0$C (IPCC, 2018) by keeping GHG emission under check through internationally binding instruments (Weitzman, 2017) including carbon quota, Clean Development Mechanism (CDM).

In this context, plantation programs can be used to create carbon credits in developing countries like Bangladesh, since carbon sequestration projects can receive investments from companies and governments wishing to offset their emissions of greenhouse gases (Singh *et al.*, 2011; Losi *et al.*, 2003). Bangladesh government is taking initiatives to meet up nation-wide carbon stock data and prepared the REDD+ Readiness Roadmap (BFD, 2018). The reliable quantification of carbon sequestration by vegetation will help the policy makers, researchers, and entrepreneurs to sell Certified Emission Reduction to developed countries (Ahmed and Glaser, 2016) in global carbon markets under REDD+ and CDM as they need to offset their higher per capita carbon emission and implement climate change mitigation policies (Saatchi *et al.*, 2011). In various studies it is proved that forests, trees and vegetation act as the carbon pool and these can be a vital source of developing mechanisms to cope with the adverse effect of global climate change (Rahman *et al.*, 2013).

Ecosystems contain from 62% to 78% of the total terrestrial carbon (Hagedorn *et al.*, 2002) and about 12-20% of anthropogenic greenhouse gas emissions being attributable to forest degradation (Baccini *et al.*, 2012 and Paoli *et al.*, 2010), the response of forests to the rising atmospheric $CO_2$ concentrations is crucial for the global carbon cycle. Estimation of above and below ground biomass is an essential aspect for the estimation of carbon stocks and effects of deforestation and carbon sequestration on global carbon balance (Ketterings *et al.*, 2001). It is also a useful measure for comparing structural and functional characteristics of a ecosystems across a wide range of environmental condition (Brown, 2001). Plant species identity is an important driver of soil properties, especially in the top soil layer of the forest soil (Augusto *et al.*, 2015 and Dawud *et al.*, 2016). Some studies have demonstrated that tree species diversity can lead to higher mineral soil carbon stocks and pH (Guckland *et al.*, 2009) or increase soil carbon stocks and the C/N ratio (Dawud *et al.*, 2016). Previous studies have shown that species diversity promotes productivity and carbon stock (Paquette and Messier, 2011). It has been argued that increase in plant diversity will increase the probability of including highly productive species into the plant community (Huston 1997, Leps *et al.*, 2001). Urban trees are valuable elements of a city because they store and sequester carbon. In addition it adds visual appeal to urban landscapes (Zhang *et al.*, 2007), help to lower ambient temperatures (Dimoudi and Nikolopoulou, 2003; Armson, *et al.*, 2012), reduce rainwater runoff (Mitchell, 2014), reduce particulate matter in the air (Yang *et al.*, 2005; Yli-Pelkonen *et al.*, 2017), can also reduce energy consumption (McPherson and Simpson, 2003).

Survey and documentation of plant resources of campus area of different Universities have already been done in Bangladesh (Sultana *et al.* 2013, Alam and Pasha 1999). The survey of plant diversity is very much important because it provides baseline information for comparison after modification of the habitats and to monitor changes in biodiversity overtime. Survey results are useful to determine the presence of ornamental, woody, fruit, rare, threatened, exotics, natives, pest and medicinal plant species. Currently the survey results have also been used to investigate the potential impact of planned developments and to inform management programs to make decision for biodiversity conservation. Such document of plant resources is essential for students, faculty members and other enthusiastic persons who fascinated for plants. That is why in the present study an attempt has been made to survey, document plant species growing and estimate of carbon stocks in Sher-e-Bangla Agricultural University (SAU) campus area.

**Objectives:**

1. Estimation of plant species diversity and carbon stock at Sher-e-Bangla Agricultural University (SAU) campus;
2. Documention of plant species at SAU campus; and
3. Finding the relationships of carbon stock with basal area and mean DBH.

# CHAPTER 2

# REVIEW OF LITERATURE

Today carbon sequestration is emerging as an important goal for forestry. Climate change is a burning issue for humankind with having significant effects and it is a major threat not only for mankind, but also for life on earth as a whole. Biodiversity is threatened by human-induced climate change and climate change is already forcing biodiversity to adopt either through shifting habitat or changing life cycles. In climate change perspective some literature reviewed mentioning global climate change scenario, global carbon cycle, carbon sequestration in the ecosystem, importance and carbon stock and measuring biomass in different carbon pools that shown below.

## 2.1 Climate change scenario

Clark and York (2005) stated that the increasing concentration of $CO_2$ and other GHG, such as methane, in the atmosphere has likely contributed to the observed 0.6° C increase in global temperatures over the past one hundred years. Over this century increases in sea level are consistent with warming as well observed decreases in snow and ice extent. An increase in global temperature of 1.5–6.0 °C is expected Mountain glaciers and snow cover on average have declined in both hemispheres. At the moment the rate of produced emissions continue to be faster than natural systems can absorb them, contributing in this way to the creation of a global ecological crisis.

Barker (2007) found that world emissions of anthropogenic greenhouse gases (GHG) increased by 70% between 1970 and 2004.

Falkowski (2000) stated that global carbon cycling consists in the exchange of carbon fluxes between the three main active pools: atmosphere, land and oceans. He conducted a comparison of the present atmospheric concentration of carbon dioxide ($CO_2$) with ice core data reveals that atmospheric $CO_2$ concentration is now nearly 100 ppmv higher than in the past 420,000 years.

Manrique *et al.* (2011) and Ritson *et al.* (2014) said that it is demonstrated by increasing world average ambient and ocean temperatures, changes in precipitation, widespread melting of glaciers, and mounting ocean levels.

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.

Smith *et al.* (2013) found on a global scale there are many indications that climate change is occurring and that this change will continue and could result in major shifts in ecosystems at the end of the century.

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

Koutroulis *et al.* (2013) and Barker (2007) said that numerous long-term changes have been evidenced at continental, regional and ocean basin scales, from 1900 to 2005. One of these is the change in the precipitation patterns that will cause variation of water availability, river discharge, and the seasonal availability of water supply.

Manrique *et al.* (2011) and Buizer *et al.* (2014) concluded that the main source of anthropogenic emissions affecting global climate change is the use of fossil fuels. The second largest contribution to this change is deforestation and forest degradation, contributing to around 18% of total global GHG emissions.

Buizer *et al.* (2014) stated that it is a fact that carbon is essential to our lives: we use it for energy, but as consequence we are changing the atmosphere and transforming the planetary ecosystem.

According to the Intergovernmental Panel on Climate Change (IPCC, 2013), 5th Assessment Report (AR5) that was issued in the year of 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$^{o}$ 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.

Akbari *et al.* (2001) stated that urban trees also reduce building energy used for cooling through their shade and climate amelioration effects, thereby reducing $CO_2$ emissions from decreased energy production.

Dewan and Yamaguchi (2009) stated that Bangladesh is no exception, and the capital city, Dhaka, is a prime example of reduced areas of greenery (17.7%), open space, and land degradation (40%) leading to a decrease in the storage of $CO_2$ from the atmosphere.

Buyantuyev and Wu (2009) reported that the proper management of the urban forest not only improves the urban environment but also stores a potentially significant amount of carbon. For this reason, the protection and management of urban forests have been increasing in importance. Liu and Loveland (2006); Robinson, *et al.* (2009) also supported in other studies.

Gunlu *et al.* (2009) stated in a recent study mentioned that due to rapid change in land use, especially in urban areas, the result was a permanent loss of urban forest resources. Thus, discontinuous and short-term observations are not enough to give an accurate estimation of the impacts of urban forest on carbon storage; it requires long-term and continuous study concluded by Martin *et al.* (2008).

In this sense, the problem of anthropogenic climate change and how human society is going to respond to it, will define the future of the planet. An important challenge for the mitigation of climate change is the management of carbon. Multiple policies exist which tackle this problem, e.g. the UN-REDD program, which stands for reducing emissions from deforestation and forest degradation.

## 2.2 Carbon sequestration potential

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.

Návar (2009) concluded that the estimation of biomass components has become important for environmental projects, since biomass can be related to carbon stocks and to carbon fluxes when biomass is sequentially measured over time.

Brady and Weil (2008) reported that plant tissue, deposited as detritus, is the primary source of soil organic carbon (SOC) in all terrestrial ecosystems. A typical green young plant contains 42% of carbon weight.

Nero *et al.* (2018) included a survey of 470,100 $m^2$ plots based on a stratified random sampling technique and six streets ranging from 50 m to 1 km. A total of 3757 trees, comprising 176 species and 46 families, were enumerated. Tree abundance and species richness were left skewed and unmorally distributed based on diameter at breast height (DBH). Trees in the diameter classes >60 cm together had the lowest species richness (17%) and abundance (9%), yet contributed more than 50% of the total carbon that stored in trees within the city. Overall, about 1.2 million tons of carbon is captured in aboveground components of trees in Kumasi, with a mean of 228 t C $ha^{-1}$.

Schimel *et al.* (2001) explained that the terrestrial biosphere and marine environments are currently absorbing about half of the $CO_2$ that is emitted by fossil-fuel combustion and terrestrial processes (mainly deforestation). This carbon uptake is therefore limiting the extent of atmospheric and climatic change.

Peichl and Arain (2007) stated that the biomass contained in forests represents approximately 80% of all aboveground terrestrial carbon and 40% of belowground carbon. For this reason, forests are considered an important potential sink for atmospheric $CO_2$ and provide a great potential for temporarily storing atmospheric $CO_2$ in terrestrial ecosystems.

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 mitigateclimate 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.

Chen (2015) stated that the aboveground samples contributed 55.0%–93.9% of the total carbon. The content of the Zoysia matrella system increased to 29.51 g TC/kg after six months, while that of the Sansevieria trifasciate system decreased to 37.73 g TC/kg. The *Sedum mexicanum* showed decreased TC contents in the above and the below ground samples.

Watson *et al.* (2000) studied that the deforestation and the burning of forests release $CO_2$ to the atmosphere.
Niranjana and Viswanath (2005) was concluded that a 20-year-old Silver oak shade tree can sequester up to 41.8 Mg/ha of carbon. The study emphasize that when the urban trees are young the standing carbon stock is not substantial, however, the growth of the trees represents a potential increase in biomass and hence carbon sequestration is dependent on the growth rate.

Buizer *et al.* (2014) concluded that the role of forests in any global carbon management and sequestration strategy is fundamental. They play an important role in global climatic regulation as a sink and reservoir of carbon dioxide, but at the same time climate change will have a direct bearing on global forest cover, and the balance of source or sink potential of forests could be fragile.

Nowak and Crane (2002) stated that urban trees in the Coterminous USA stored 700 million tonnes of carbon with a gross carbon sequestration rate of 22.8 million t C/yr. However, on a per unit tree cover basis, C storage by urban trees and gross sequestration may be greater than in forest stands annually. Individual urban trees, on average, contain approximately four times more C than individual trees in forest stands. This difference is largely due to differences in tree diameter distributions between urban and forest areas.

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

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 carbon in the world. SOC playing a very 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.

### 2.3 Carbon and Plant Diversity

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

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

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

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

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

**2.4 Carbon storage in institutional area**

The University of Talca (2017) has promoted its environmental policy, which establishes practices and improvements in relation to energy and water efficiency issues, waste, habitat protection and biodiversity, and the promotion of interdisciplinary research associated with sustainable development. One such institutional action has been measuring the carbon footprint (CF) within its different campuses since 2012.

Xu and Mitchell (2011) reported that KIWI University, California State University, Eastern Illinois University and Auckland University for 4137, 3,900, 4,051, 4,051, and 400 no. of tress Carbon sequestration potential were 1,585, 862, 1,591, and 225.2 tons respectively.

Finkbeiner (2009) stated that the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) develop two standards under their Greenhouse Gas Protocol Product/Supply Chain Initiative: A Product Life Cycle Accounting and Reporting Standard: Guidelines for Value Chain (Scope 3) Accounting and Reporting.

Chavan and Rasal (2012) investigate that aboveground and belowground carbon sequestration potential of *Albizia lebbeik* from nine sectors of Aurangabad city was measured. The standing aboveground biomass and belowground biomass of *Albizia lebbek* were 53.73 t $ha^{-1}$ and 13.97 t ha respectively, while total standing biomass of *Albizia lebbek* in 2847 hectares area was 67.70 t $ha^{-1}$. The standing aboveground biomass and belowground biomass of *Delonix regia* were 30.25 t $ha^{-1}$ and 07.86 t $ha^{-1}$ respectively, while total standing biomass of *Delonix regia* in 2847 hectares area was 38.11 t $ha^{-1}$. The average carbon sequestration and carbon dioxide of *Albizia lebbek* intake is 33.85 t $ha^{-1}$ and 124.23 t $CO_2$ in Aurangabad. The average carbon sequestration and carbon dioxide of *Delonix regia* intake is 19.06 t C $ha^{-1}$ and 63.96 t $CO_2$.

Letete *et al.* (2011) studied in the University of Cape Town, South Africa and found a result of 4.0 t $CO_2$ per student. Larsen *et al.* (2013) concluded a result of 4.6 t $CO_2$ per student and 16.7 t $CO_2$ per employee in the Norwegian University of Science and Technology.

Villiers *et al.* (2013) estimated that the 4,139 trees contain 5,809 tons of $CO_2$ on the university's 68 hectare main campus, ignoring smaller trees that sequester very little $CO_2$. They further estimate the additional $CO_2$ sequestration over the next 10 years to be 253 tons per year.

Pandya *et al.* (2013) reported that the maximum carbon storage was 55.95 tons followed by 44.81 tons among 25 species belongs to Gujarat, India. The lowest carbon storage value estimated by 1.77 tons.

Güereca *et al.* (2013) studied in National Autonomous University of Mexico and found 1.46 t $CO_2$ per person.

Chavan and Rasal (2011) reported that the total above ground biomass carbon stock per hectare as estimated for *Emblica officinalis* was 33.07 Kg C $ha^{-1}$, in *Mangifera indica* it was 30.6 Kg C $ha^{-1}$ and in *Tamarindus indica* it was 36.96 Kg C $ha^{-1}$ and in *Achras sapota* were 12.86 Kg C $ha^{-1}$ in *Annona retiaculata* was 83.1 Kg C $ha^{-1}$ and for *Annona squamosa* it was 73.5 Kg C $ha^{-1}$ in University campus.

Lo-lacono *et al.* (2018) found carbon footprint 0.31 t $CO_2$ per student and 2.69 t $CO_2$ per employee in Polytechnic University of Valencia.

Vásquez *et al.* (2015) stated an average of 3.1 t $CO_2$ per student in University of Madrid, Autonomous University of Mexico, Minnesota State University of Mankato, Duquesne University, Norwegian University of Science and Technology.

### 2.5 Species diversity and Richness in urban areas

Magurran (1988) defined species diversity as the number of species and abundance of each species that live in a particular location.

Prescott and Vesterdal (2013) concluded that tree species is known to affect soil through the absorption of nutrients and water from and addition of litter to different soil layers.

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.

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.

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).

Henry *et al.* (2009) reported that a total of 49 tree species were identified in the two locations of Vihiga and 56 in the two of Siaya in highlands of western Kenya. Tree biodiversity as measured with the Shannon index (H) was significantly (P <

0.05) higher in Siaya (H = 0.62) than in Vihiga (H = 0.50). Values of the Shannon index (H), used to evaluate biodiversity which ranged from 0.01-0.03 in Block plantations, from 0.4–0.6 in food crop plots and from 1.3–1.6 in home gardens. *Eucalyptus saligna* was the most frequent tree species found as individual trees (20%).

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

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

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

## 2.6 Documentation of Plant Communities

Selvi and Parani (2019) conducted a research in Sri Parasakthi Women College and found a huge flora of family consists of 79 tree species belongs to 30 Angiosperms and 4 Gymnosperms families. Overall total number of trees were recorded as 467. These families included both economically important plants and medicinally important plants. Enlisted the economic valued trees available in the campus and their Numbers they observed essential oil containing families: 5, Resin Containing Families: 6, Spooning Containing family: 4, Latex containing families: 6 and Ornamental value: 6.

Uddin and Hassan (2016) focused the status of plant diversity in Dhaka University campus. A total of 541 plant species assigned to 117 families have been recorded from the campus area. Euporbiaceae was the largest family in the dicotyledon having 26 species whereas Liliaceae was the largest family in monocotyledon having 18 species. Among the recorded species 37% herbs, 29% trees, 21% shrubs, 11% climbers, 2% epiphytes and 0.2% parasites were found. The result showed that 59% plant species represented by native species whereas 41% plant species represented by exotics.

Sikder and Rahim (2012) highlighted the diversity of flora in Jahangirnagar University campus. A total of 72 species were documented in which 68 were angiosperm and 4 were pteridophyta. Life forms observed that 11 trees, 8 shrubs, 4 climbers and 45 herb species were found among the variety of distribution.

Sarkar and Devi (2017) found a total of 157 plant species belonging to 136 genera and 78 families were having medicinal and economic values in wildlife sanctuary. These included 69 trees (55 genera and 39 families), 17 shrubs (15 genera and 14 families), 58 herbs (57 genera and 37 families), 5 lianas (5 genera and 5 families) and 8 bamboo/cane/palm (5 genera and 2 families). The study revealed 78% of plant species were having significant values either in terms of medicinal or economic and both. Non timber products consist of wild edible vegetables, resins, gums, fire woods, fodder, wild edible fruits, bamboo, canes, etc.

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 Study area

### 3.1.1 Location

The study was directed at Sher-e-Bangla Agricultural University (SAU) campus, Sher-e-Bangla Nagar, Dhaka-1207, during the period from June, 2019 to December, 2020. The campus stands on 86.97 acres (35.2 ha) of attractive land covered by green plantations with a series of academic, administrative and residential buildings and a number of lands for experimental crop cultivation and farms, gardens and other related facilities. The campus was situated between 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anonymous, 2004). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I. Total 72 sample plots were selected, each were laid out in several study sites. These several vegetation sites had different tree coverage in SAU campus. For the assessment of above and below ground carbon stock, Sher-e-Bangla Agricultural University campus was divided into seven sites namely Roadside, Block plantation, Pond side, Academic area, Hrt. & Afe. farm land, Hall area and Residential area. These sites were selected as major carbon sequestration pool in the study area.

### 3.1.2 Climate of the study site

Dhaka has a tropical wet and dry climate; mild winter (October to March); hot, humid summer (March to June); humid, warm rainy monsoon (June to October). The annual average temperature is 26°C, and the annual average rainfall is 2,123 mm. Monthly average temperatures vary between 19°C in January and 29°C in May based on climate data from 2001–2018. The wettest month in Dhaka is July with an average rainfall of 367.9 mm while the driest month is December with 8.9 mm precipitation.

### 3.1.3 Soil characteristics

The land is characterized by tropical vegetation with a distinct monsoon season and climatic conditions. The soil of the experimental site is mainly categorized as medium high land, containing silt loam, and olive-gray with common fine to medium distinct dark yellowish brown mottles with a pH of 5.6. The soil is belongs to the Tejgaon series under the Agro-ecological Zone, Madhupur Tract (AEZ-28) and the general soil type is Deep Red Brown Terrace Soils with EC-25.28 (Haider, 1991). The morphological characters of soil in the experimental plots were indicated by UNDP and FAO (1998).

### 3.1.4 Vegetation in the study site

Sher-e-Bangla Agricultural University maintain a wide range of plantation. The major green-spaces and vegetated areas of the campus are covered by residential area, farms and fields, hall area, academic area, roadside and pond side plantations. Several taxonomic survey was performed to assess diversity of plant resources at Sher-e-Bangla Agricultural University (SAU) campus, Dhaka, Bangladesh. A total of 8536 (including seasonal) species were recorded in SAU. Plants were represented by trees, shrubs, herbs, climbers and woody grasses. Various ornamental, fruit, vegetables, spices, medicinal, timber and plantation crop were seen in the campus area.

**Plate 1.** Residential area in the study site**.**

**Plate 2.** Hall area in the study site.

**Plate 3.** Roadside area in the study site.

**Plate 4.** Hrt. & Afe.farm land in the study site.

**Plate 5.** Pondside area in the study site.

**Plate 6.** Academic area in the study site.

**Plate 7.** Block plantation area in the study site.

## 3.2 Sampling Procedure

For the overall accuracy of sampling, the sampling method and sample size were based on area and vegetation composition (Lei *et al.,* 2009). Due to the infrastructure and research land requirement the sampling plots were selected using a purposive sampling method and quantitative assessment of the composition of tree coverage was done by a stratified random sampling method. Before the study began, a preliminary survey regarding plant composition and other vegetation characteristics was assessed. The study sites were divided according to vegetation types, into seven categories: residential area, Hrt. & Afe. farm land, hall area, academic area, Block plantation, pond side and roadside. To reduce experimental errors and ensure maximum coverage of the experimental area, a sample of 72 plots were taken. For each category, the plots were different sizes (residential area 10 m × 10 m, Hrt. & Afe. farm land 10 m × 10 m, hall area 10 m × 10 m, academic area 10 m × 10 m, Block plantation 10 m × 10 m, roadside 10 m × 5 m, pond side 10 m × 5 m). The number of each tree species was quantified and the percentage of the most dominant trees from the total tree species in each of the sampling sites was calculated (Table 2). In residential area, Hrt. & Afe. farm land, hall area, academic area, Block plantation, pond side, a 5 meter plot-to-plot distance was maintained. In roadside sampling, roadside with continuous plantation was subjected to consider and plots were taken in a zigzag manner to maintain variation and a 10 meter plot-to-plot distance was maintained according to the model given by Jaman *et al.* (2020) and Rahman *et al.* (2015) (Figure 1).

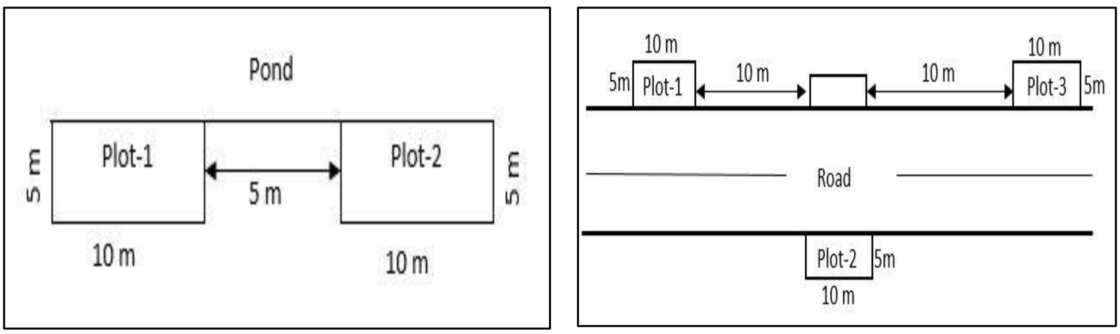


**Figure 1.** Sampling method for Pond side and roadsides.

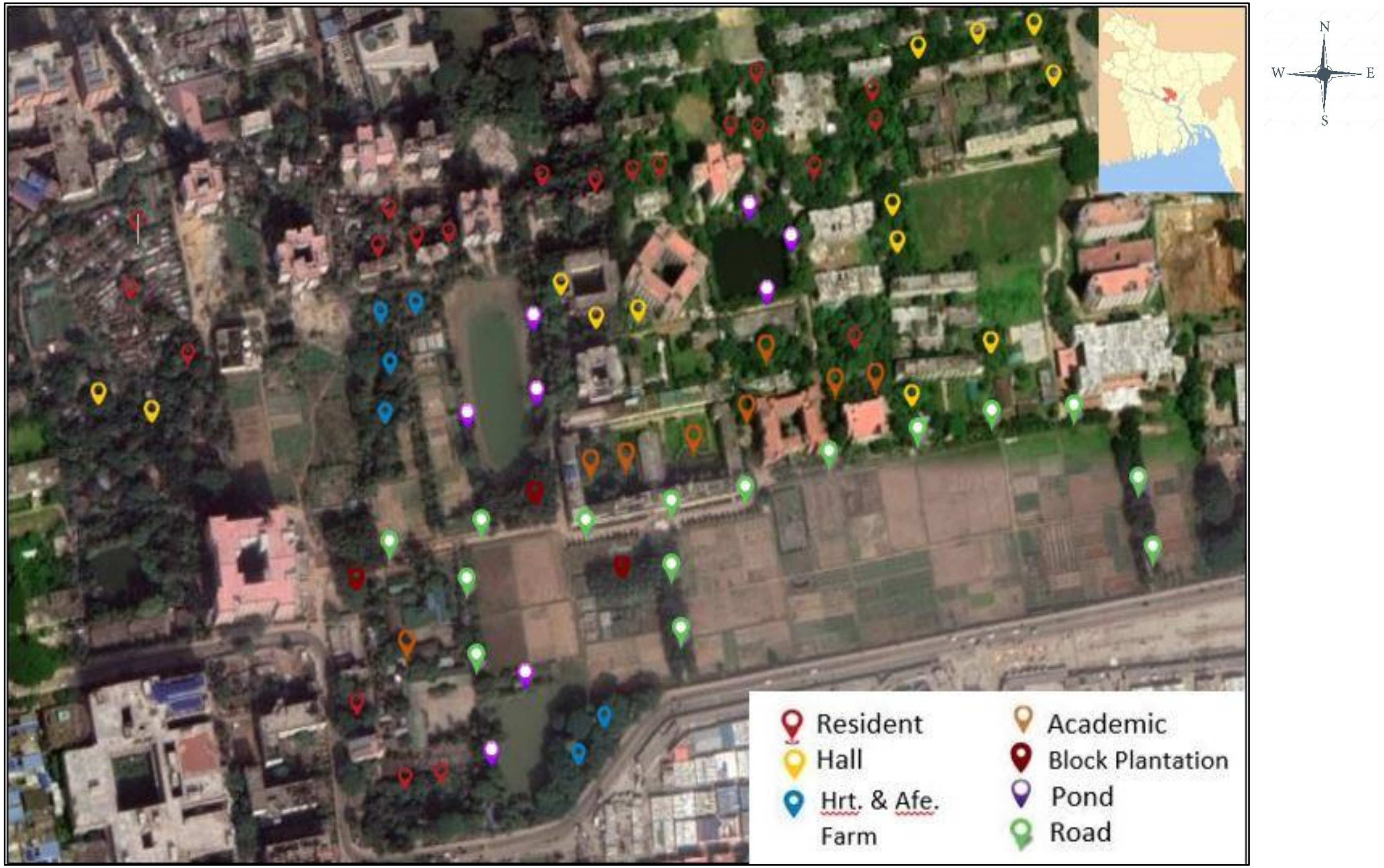


**Plate 8.** Plot location of the study site.

**Table 1.** Distribution of plots, size and number of plots studied.

| Name | No. of plots | Plot size |
|---|---|---|
| **Residential area** | 21 | 10 m × 10 m |
| **Hrt. & Afe. farm land** | 6 | 10 m × 10 m |
| **Hall area** | 13 | 10 m × 10 m |
| **Academic area** | 8 | 10 m × 10 m |
| **Block plantation** | 3 | 10 m × 10 m |
| **Pond side** | 8 | 10 m × 5 m |
| **Roadside** | 13 | 10 m × 5 m |
| **Total** | **72** | |

### 3.2.1 Plot Survey

The procedure given by Chave *et al.* (2009) for measuring aboveground biomass of live tree species using a non-destructive method was followed. The diameter of all identified tree species were measured at breast height (1.37 m height from the ground level) using a measuring tape. Due to the lack of DBH tape GBH was measured first and then it was converted into DBH and the basal area (1.37 m at breast height) of the trees were calculated from the recorded tree diameter (Hairiah *et al.*, 2001). When deformities or buttress roots were present at this height, the point of measurement (POM) was altered and recorded (Phillips *et al.*, 2009). To define POM a pole with 1.37 m marked was used to push firmly into the litter layer over the soil next to the tree (Phillips *et al.*, 2009). In case of multiple stems, all stems greater than 3 cm of diameter at 1.37 m of height were measured and recorded. The height of all sampled trees especially for palm species was measured using a measuring pole. While trees with a diameter of less than 3 cm were excluded for carbon estimation but they were included according to their local name, scientific name, family, habits and uses. All identified plant species were also classified into different categories viz., ornamental, fruit, timber, plantation crop, essential oil, resin, latex containing plants. Different taxonomic books were consulted (Kurz, 1974a; Kurz, 1974b; Rashid, 1990; Khan *et al.*, 1988; Haque, 1993; Gruezo, 1995) for compilation of scientific names and documentation of Sher-e-Bangla Agricultural University campus.

## 3.3 Allometric Equation for Above Ground Biomass Estimation

### 3.3.1 Tree biomass

Allometric equations developed by Chave *et al.* (2009) for dry land forests (rainfall below 1500 mm $year^{-1}$) were used to estimate aboveground biomass for individual trees. Specific wood densities for all sampled species were derived from the FAO global wood density database and tropical wood density data (Chave *et al.*, 2009).

$$Y = exp\ (- 2.187 + 0.917 \times ln\ (D^2 \times H \times S)$$

Where,

Y = represents the above-ground biomass density ($Mg\ ha^{-1}$),

D = the diameter (cm),

H = height (m), and

S = the species specific wood density (S = −1.39, 1.98 …… … 0.207) $g\ cm^{-3}$.

### 3.3.2 Palm biomass

Usually palm species such as *Cocos nucifera*, *Phoenix sylvestris* and *Areca catechu* are common in Sher-e-Bangla Agricultural University (SAU). The following equation for palms developed by Brown *et al.* (2001) will be used for AGB calculation:

$$AGB = 6.666 + 12.826 \times ht^{0.5} \times ln\ (ht)$$

Where,

AGB = Above ground biomass;

ln = Natural logarithm and

ht = Height

### 3.3.3 Below ground biomass

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

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

Where,

BGB = Below ground biomass,

ln = Natural logarithm,

AGB = Above ground biomass, -1.0587 and 0.8836 are constant.

## 3.4 Above and below ground carbon (AGC) estimation

After estimating the biomass from allometric relationship, it was multiplied by wood carbon content (50%). It was assumed that Carbon concentration was 50% of the dry weight of AGB (Losi *et al.*, 2003; Manrique *et al.*, 2011; Preece *et al.*, 2012).

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

% = Biomass estimated by allometric equation × 0.5

## 3.5 Measurement of tree diversity

Tree species diversity was measured within the fixed quadrat of the sample plot. An index called the Shannon–Wiener diversity index (SWI) is suitable for evaluating the diversity of tree species worldwide. Shannon diversity index values typically range from 1.5 to 3.5 and rarely exceed 4.5. The proportion of each species ($i$) relative to the total number of species ($Pi$) was calculated and then multiplied by the natural logarithm of the same proportion ($ln\ Pi$). The resulting product is summed across species and multiplied by −1.

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

Where,

H = Shannon index

$n$ = No. of species

Σ= Summation.

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

The total number of plant species of a plot was divided by the total area of that plot to measure the species per unit area (species density).

### 3.6 Data Processing

After the collection of field data the information was processed and compiled by MS Excel 2013 and SPSS-20 software. Aboveground Carbon 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.

**Plate 9.** Measurements of plots.

**Plate 10.** Measurements of Height.

**Plate 11.** Measurements of GBH.

# CHAPTER 4

# RESULTS AND DISCUSSION

The study was conducted to estimate carbon stock and tree species diversity at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Data were recorded on carbon stock i.e., above ground carbon, below ground carbon of Sher-e-Bangla Agricultural University (SAU). The results of the study were presented under the following headings.

## 4.1 Plant population under different categories and purposes

From the findings, it was revealed that the plant population of residential area was the highest (285) followed by hall area (123), roadside (88), Academic area (84), Hrt. & Afe. farm land (82), pond side (36) where the lowest plant population occurred under the category of Block plantation (33). On the other hand, the highest number of the total plant population was observed with the Fruit (360) followed by Plantation crop (120), Timber (118), Ornamental (92) and the lowest with Medicinal plants (41) when purpose are considered. The different categories of plant species formed in residential area, Hrt. & Afe. farm land, hall area, academic area, Block plantation, pond side, roadside were 38.98%, 11.21%, 16.82%, 11.49%, 4.514%, 4.92% and 12.03%, respectively of total plant population (Table 2).

Islam *et al.* (2014) found a similar result in Sher-e-Bangla Agricultural University. They concluded that the different categories of plant species viz., ornamental, fruit, vegetables, species, medicinal, timber and plantation crops were 54.4%, 9.5%, 12.7%, 14.3%, 4.0%, 1.2% and 4.1%, respectively of total plant population. Occurrences of plants under tree, shrub, herb, climber and woody grass habits were 11.0%, 21.6%, 61.6%, 4.0% and 1.8% of total plant population respectively.

Uddin and Hassan (2016) focused the status of plant diversity in Dhaka University campus. A total of 541 plant species assigned to 117 families have been recorded from the campus area. Among the recorded species 37% herbs, 29% trees, 21% shrubs, 11% climbers, 2% epiphytes and 0.2% parasites were found. The result showed that 59% plant species represented by native species whereas 41% plant species represented by exotics.

Sikder and Rahim (2012) highlighted the diversity of flora in Jahangirnagar University campus. A total of 72 species were documented in which 68 were angiosperm and 4 were pteridophyta. Life forms observed that 11 trees, 8 shrubs, 4 climbers and 45 herb species were found among the variety of distribution.

**Table 2.** Plant population of SAU with their categories and purposes.

| Category | Purpose | | | | | Total | (%) |
|---|---|---|---|---|---|---|---|
| | Ornamental | Fruit | Timber | Medicinal plants | Plantation crop | | |
| **Residential area** | 5 | 206 | 22 | 18 | 34 | 285 | 38.98 |
| **Hrt. & Afe. farm land** | 10 | 28 | 19 | 8 | 17 | 82 | 11.21 |
| **Hall area** | 15 | 64 | 21 | 8 | 15 | 123 | 16.82 |
| **Academic area** | 27 | 27 | 5 | 4 | 21 | 84 | 11.49 |
| **Block plantation** | 0 | 20 | 13 | 0 | 0 | 33 | 4.514 |
| **Pond side** | 4 | 9 | 3 | 0 | 20 | 36 | 4.92 |
| **Roadside** | 31 | 6 | 35 | 3 | 13 | 88 | 12.03 |
| **Total** | 92 | 360 | 118 | 41 | 120 | **731** | |
| **(%)** | 12.58 | 49.25 | 16.14 | 5.61 | 16.41 | | |

**4.2 Measurement of Tree Diversity**

Species diversity means various number of species found in specific area. The diversity index revealed that Hrt. & Afe. farm land had the highest mean value of 2.97± 0.07 followed by Residential area 2.95± 0.08, Hall area 2.94± 0.06, Academic area 2.94± 0.09, Pond side 2.18± 0.09, Roadside 1.87± 0.09 and Block plantation had the lowest mean value of 0.94± 0.07 (Table 3). The result can be compared as: Hrt. & Afe. farm land >Residential area > Hall area > Academic area > Pond side > Roadside > Block plantation. It was found that Hrt. & Afe. farm land had 28 different types of species where mean number of tree species per hectare was 465, Residential area had 42 different types of species where mean number of trees per hectare was 200, Hall area had 30 different types of tree species where mean number of tree per hectare was 230, Academic area had 27 different types of tree species where mean number of tree per hectare was 337, Pond side had 12 different types of tree species where mean number of tree per hectare was 300, Roadside had 10 different types of tree species where mean number of tree per hectare was 154 and Block plantation had 4 different types of tree species where mean number of tree per hectare was 133.

**Table 3.** Tree diversity at Sher-e-Bangla Agricultural University (SAU).

| **Categories** | **Mean number of tree species per hectare** | **Total Species** | **Shannon Wiener index (SWI)** |
|---|---|---|---|
| | | | **Mean ± SE** |
| Residential area | 200 | 42 | 2.95± 0.08 |
| Hrt. & Afe. farm land | 465 | 28 | 2.97± 0.07 |
| Hall area | 230 | 30 | 2.94± 0.06 |
| Academic area | 337 | 27 | 2.94± 0.09 |
| Block plantation | 133 | 4 | 0.94± 0.07 |
| Pond side | 300 | 12 | 2.18± 0.09 |
| Roadside | 154 | 10 | 1.87± 0.09 |

SE ± standard error

Anandan *et al.* (2014) has studied tree species diversity in four campuses of Roever Educational Institutions and found Tree Diversity Index ranges from 0.0578 to 0.3163. From the study it was found that Thanthai Hans Roever College has the highest tree species diversity with the value of 0.0578.

Hossain *et al.* (2014) investigated tree species diversity in the south western human impact hills at Chittagong University (CU) campus in Bangladesh. In the study area Shannon-Wiener Index of diversity (H) was calculated 2.73.

Kundu (2015) observed the tree diversity ranged from 0 to 1.7 with a mean value of (0.87 ± 0.09) in Ramna Park; and in Chandrima Uddan tree diversity ranged from 0 to 1.33 with a mean value of (0.58 ± 0.12) which was similar to the findings of this study.

### 4.3 Species richness

Almost all the plots had mixed vegetation with various perennial trees. Among them 42 species were in Residential area, 28 species were in Hrt. & Afe. farm land, 30 species were in Hall area, 27 species were in Academic area, 4 species were in Block plantation, 12 species were in Pond side and 10 species were in Pond side (Table 4).

**Table 4.** Species richness found in the study area.

| Categories | Species richness |
|---|---|
| Residential area | 42 |
| Hrt. & Afe. farm land | 28 |
| Hall area | 30 |
| Academic area | 27 |
| Block plantation | 4 |
| Pond side | 12 |
| Roadside | 10 |

### 4.4 Species identified in SAU campus

In total 731 trees were identified in this study. It focused on 60 species under 32 families with their common name, family, scientific name, use and their total number of occurrence are shown in Table 5. Trees (94%), Shrubs (4%) and Palms (2%) were found. Amm (Mango) was the most predominant tree species with 18.33% (no. 134) followed by Kanthal 8.21% (no. 60), Mahogany 7.93% (no. 58), Narikel 6.84% (no. 50) and Supari 6.02% (no. 44).

**Table 5.** List of plants identified in the study area.

| Sl No. | Common Name | Scientific name and Family | Habit | Uses | Total No of trees |
|---|---|---|---|---|---|
| 1 | Amm | *Mangifera indica* Anacardiaceae | Tree | Fr,T,Fu | 134 |
| 2 | Kanthal | *Artocarpus heterophyllus* Moraceae | Tree | Fr,T | 60 |
| 3 | Mahogany | *Swietenia mahagony* Maliaceae | Tree | T,Fu | 58 |
| 4 | Narikel | *Cocos mucifera* Palmae | Tree | Fr,Fu | 50 |
| 5 | Debdaru | *Polyalthia longifolia* Annonaceae | Tree | Or,Fu | 44 |
| 6 | Supari | *Areca catechu* Palmae | Tree | Fr,Fu | 44 |
| 7 | Kalo koroi | *Albizia lebbeck* Mimosaceae | Tree | T,Fu | 26 |
| 8 | Kul | *Zizyphus sp* Rhamnaceae | Tree | Fr | 22 |
| 9 | Payera | *Psidium guajava* Myrtaceae | Tree | Fr | 22 |
| 10 | Sil koroi | *Albizia procera* Mimosaceae | Tree | T,Fu | 17 |
| 11 | Sajina | *Moringa olefera* Moringaceae | Tree | Veg | 17 |
| 12 | Litchi | *Litchi chinensis* Sapindaceae | Tree | Fr | 16 |
| 13 | Ata | *Annona reticulata* Annonaceae | Tree | Fr | 13 |
| 14 | Neem | *Azadirachta indica* Meliaceae | Tree | Md,T | 10 |
| 15 | Jam | *Syzygium cumini* Myrtaceae | Tree | Fr,T | 9 |
| 16 | Kamrangga | *Averrhoa carambola* Averrhoaceae | Tree | Fr | 9 |
| 17 | Jamrul | *Syzygium samarangence* Myrtaceae | Tree | Fr | 8 |
| 18 | Segun | *Tectona grandis* Verbenaceae | Tree | T,Fu | 8 |
| 19 | Krishnochura | *Delonix regia* Caesalpiniaceae | Tree | T,Fu | 7 |
| 20 | Chalta | *Dillenia indica* Dilleniaceae | Tree | Fr | 7 |
| 21 | Koromcha | *Carissa carandas* Apocynaceae | Shrub | Fr | 7 |
| 22 | Sofeda | *Manikara achras* Sapotaceae | Tree | Fr | 7 |

| Sl No. | Common Name | Scientific name and Family | Habit | Uses | Total No of trees |
|---|---|---|---|---|---|
| 23 | Arjun | *Terminalia arjuna* Combretaceae | Tree | T | 7 |
| 24 | Khejur | *Phoenix sylvestris* Palmae | Tree | Fr | 7 |
| 25 | Rongon | *Ixora sp* Rubiaceae | Shrub | Fl | 6 |
| 26 | Bel | *Aegle marmelos* Rutaceae | Tree | Fr,T | 6 |
| 27 | Jambura | *Citrus grandis* Rutaceae | Tree | Fr | 6 |
| 28 | Bokul | *Mimusops elengi* Sapotaceae | Tree | Fl,T | 5 |
| 29 | Kadom | *Anthocephalus cadamba* Rubiaceae | Tree | Fl,T | 5 |
| 30 | Dalim | *Punica granatum* Punicaceae | Shrub | Fr | 5 |
| 31 | Tetul | *Tamarindus indica* Fabaceae | Tree | Fr,T,Fu | 5 |
| 32 | Bottle palm | *Mascarena lagenicaulis* Arecaceae | Palm | Or | 5 |
| 33 | Amloki | *Phyllanthus emblica* Euphorbiaceae | Tree | Fr | 4 |
| 34 | Bilimbi | *Averrhoa bilimbi* Averrhoaceae | Tree | Fr | 4 |
| 35 | Dewaa | *Artocarpus lakoocha* Moraceae | Tree | Fr,T | 4 |
| 36 | Shimul | *Bombax ceiba* Boraginaceae | Tree | Co | 4 |
| 37 | Arica palm | *Chrysalidocarpus lutescense* Palmae | Palm | Or | 4 |
| 38 | Oil palm | *Elaeis guineensis* Arecaceae | Palm | Or | 4 |
| 39 | Tal palm | *Barassus flabellifer* Arecaceae | Palm | Fr,T | 4 |
| 40 | Amra | *Spondias mombin* Anacardiaceae | Tree | Fr | 3 |
| 41 | Sissoo | *Swietenia sissoo* Fabaceae | Tree | T,Fu | 3 |
| 42 | Shawra | *Streblus asper* Moraceae | Tree | Md | 3 |
| 43 | Tejpata | *Cinnamomum tamala* Lauraceae | Tree | Veg | 3 |
| 44 | Courbaril | *Hymenaea courbaril* Fabaceae | Tree | T | 3 |
| 45 | Akashmoni | *Acacia auriculiformis* Mimosaceae | Tree | T,Or,Fu | 2 |

| Sl No. | Common Name | Scientific name and Family | Habit | Uses | Total No of trees |
|---|---|---|---|---|---|
| 46 | Kamini | *Murraya sp*<br>Rutaceae | Shrub | Fl | 2 |
| 47 | Mandar | *Erythrina sp*<br>Fabaceae | Tree | Or,Fu | 2 |
| 48 | Naglingam | *Couroupita guianensis*<br>Lycithidaceae | Tree | Or | 2 |
| 49 | Radhachura | *Caesalpinia pulcherrima*<br>Caesalpiniaceae | Tree | T,Or,Fl | 2 |
| 50 | Kathgolap | *Plumeria alba*<br>Apocynaceae | Tree | Fl | 2 |
| 51 | Alachi Lebu | *Feronia limon*<br>Rutaceae | Tree | Fr | 2 |
| 52 | Deshi Gab | *Diospyros peregrina*<br>Ebenaceae | Tree | T,Fr | 2 |
| 53 | Jolpai | *Elaeocarpus floribundus*<br>Elaeocarpaceae | Tree | Fr | 2 |
| 54 | Kodbel | *Feronia limonia*<br>Rutaceae | Tree | Fr | 2 |
| 55 | Gamari | *Gmelina arborea*<br>Lamiaceae | Tree | T,Fu | 2 |
| 56 | Beli | *Jasminum sambac*<br>Oleaceae | Shrub | Fl | 1 |
| 57 | Bot | *Ficus benghalensis*<br>Moraceae | Tree | T,Or,Fu | 1 |
| 58 | Jarul | *Lagerstroemia speciosa*<br>Lythraceae | Tree | Or,Fu | 1 |
| 59 | Sharifa | *Annona squamosa*<br>Annonaceae | Tree | Fr | 1 |
| 60 | Thuja | *Thuja sp*<br>Pinaceae | Shrub | Or | 10 |

**N.B.** Fr = Fruit, Or = Ornamental, Fl = Flower, T = Timber, Co = Cotton, Md = Medicine, Veg = Vegetable, Fu = Fuel.

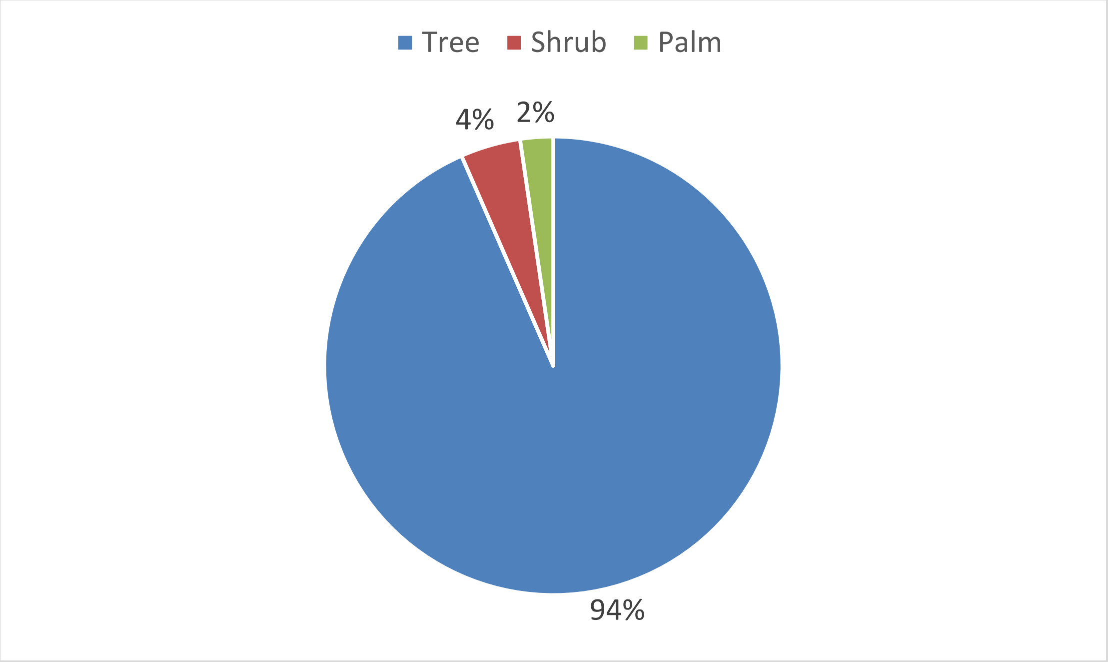


**Figure 2.** Habit wise distribution of plant species in the study area.

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.

Uddin and Hassan (2016) focused the status of plant diversity in Dhaka University campus. A total of 541 plant species assigned to 117 families have been recorded from the campus area. Euporbiaceae was the largest family in the dicotyledon having 26 species whereas Liliaceae was the largest family in monocotyledon having 18 species. Among the recorded species 37% herbs, 29% trees, 21% shrubs, 11% climbers, 2% epiphytes and 0.2% parasites were found. The result showed that 59% plant species represented by native species whereas 41% plant species represented by exotics.

Islam (2013) observed 38 tree species from 32 sample plots in Sher-e-Bangla Agricultural University. He observed *Mangifera indica* showed the highest percentage of 17.2 followed by *Swietenia macrophylla* (17.20%), *Artocarpus heterophyllus* (9.76%) and *Polyalthia longifolia* (8.42%), respectively. The maximum values of this study was found more or less similar to the highest plantations of other studies.

Maximum 137 plants were observed under Anacardiaceae family followed by Palmae (105 plants), Moraceae (68 plants) while minimum (single plant) from Oleaceae and Lythraceae family (**Figure 3**).

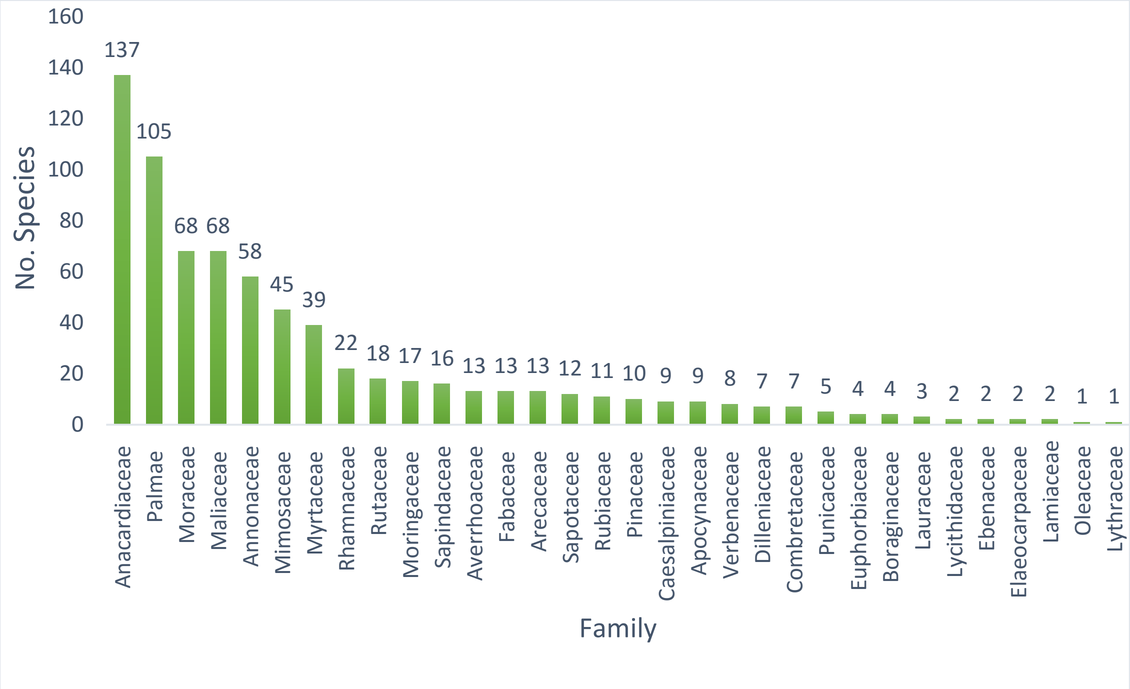


**Figure 3.** Distribution of plant Species according to family.

Hossain *et al.* (2014) found a total of 622 tree individuals of 33 tree species belonging to 16 families. Meliaceae was the dominant family having 4 species followed by Fabaceae, Verbenaceae, Moraceae, Myrtaceae (3 species each) and Euphorbiaceae, Mimosaceae, Bignoniaceae, Combretaceae (2 species each). Families like Dipterocarpaceae, Fagaceae, Lythraceae, Malvaceae, Rhamnaceae and Rubiaceae were represented by one species each.

Jaman *et al.* (2014) found 15 spice plants under 9 families, 46 fruits species under 25 families, 17 vegetable species under 8 families, 10 timber species under 7 families, 29 medicinal species under 25 families, 5 bamboo species under a single family, 8 palm species under 2 families and single rubber plant species were listed under a single family.

In the present study of Sher-e-Bangla Agricultural University campus, 75% plant species was recorded as exotic and 25% species was recorded as native which include 81% Dicots and 19% Monocots (Figure 4, 5).

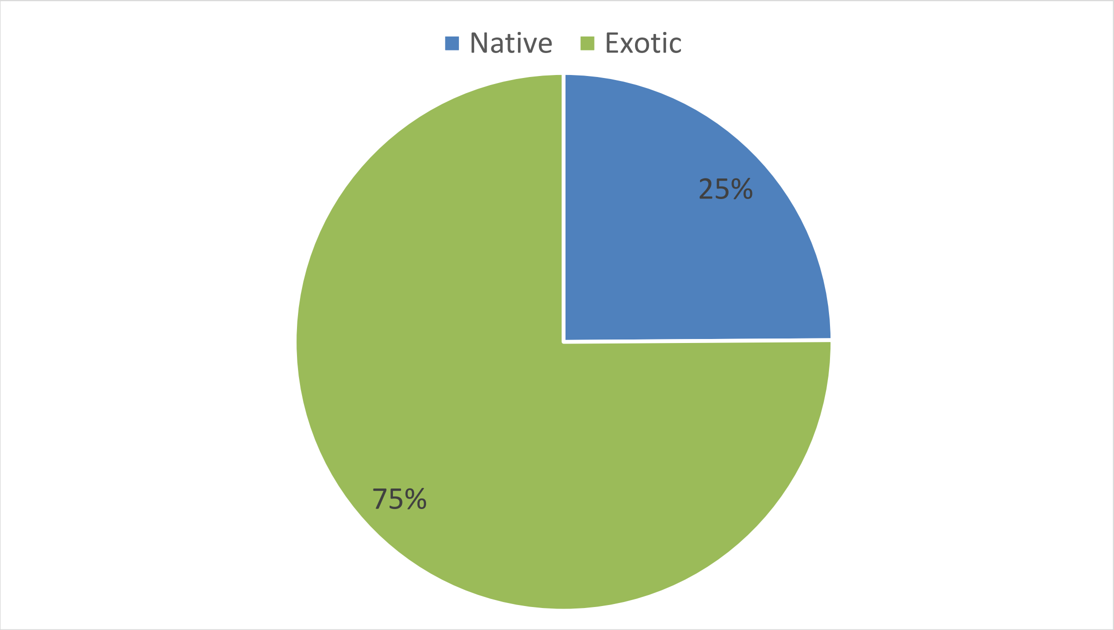


**Figure 4.** State of origin of recorded plant species.

Uddin and Hassan (2016) concluded 59% plant species represented by native species whereas 41% plant species represented by exotics in Dhaka University campus.

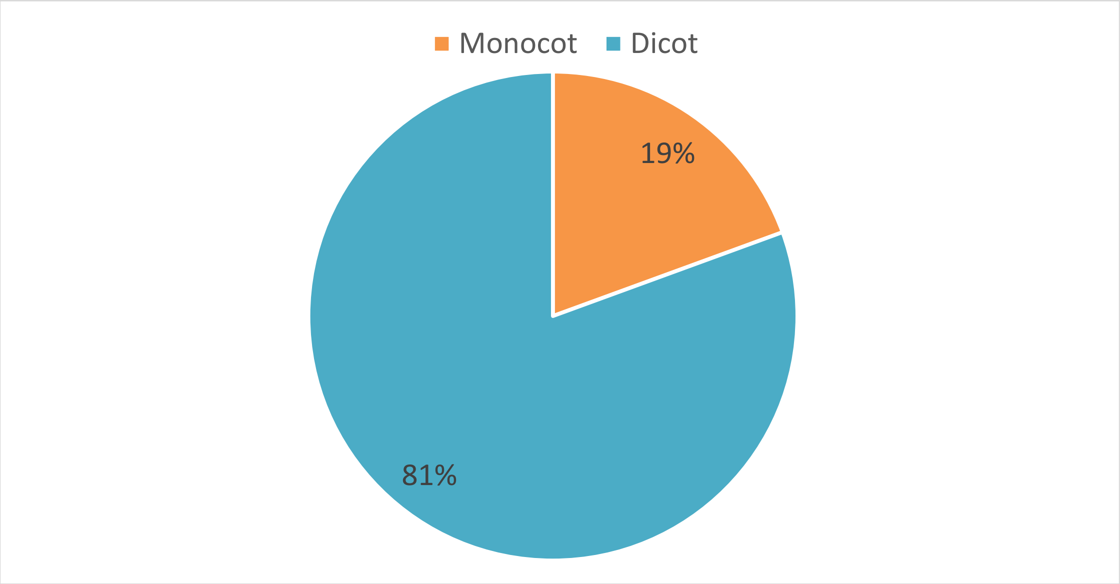


**Figure 5.** Systematic groups of the plants in the study area.

Rajendran *et al.* (2014) identified 334 plant species belong to the angiosperms which include 238 species of Dicotyledons and 96 species of Monocotyledons in the Bharathiar university campus, India.

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.

### 4.5 Occurrence of major tree species

It was found in the study that the occurrence of five major trees in Sher-e-Bangla Agricultural University were Amm (*Mangifera indica*), Kanthal (*Artocarpus heterophyllus*), Mahogany (*Swietenia mahagony*), Narikel (*Cocos mucifera*) and Debdaru (*Polyalthia longifolia*) (Figure 6). Data revealed that the occurrences of the major five trees were more or less eventually distribution. Islam (2013) found that the occurrence of major trees were *Swietenia* (47.58%) followed by *Mangifera indica* (8.87%), *Artocarpus* (5.64%), *Polyalthia* (4.83%) and *Psidium guajava* (4.83%).

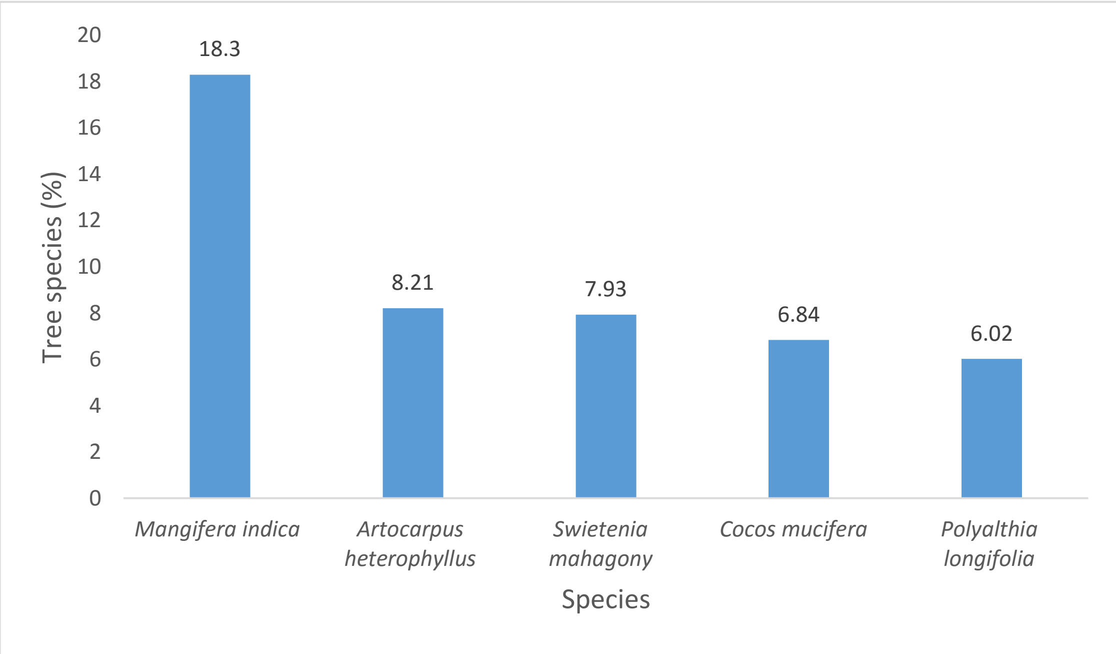


**Figure 6.** Occurrence of major five tree species.

Uddin and Hassan (2016) found *Samanea saman* (Rain tree), *Albizia rechardiana* (Rajkoroi), *Polyalthia longifolia* (Debdaru), *Hopea odorata* (Telsur), *Ptercarpus indica* (Padauk), *Mangifera indica* (Aam), *Petrigota alata* (Budda Narikel), *Cocos nucifera* (Narikel), *Swietenia mahagoni* (Mahogany), *Tamarindus indica* (Tamarind), *Roystenia regia* (Royal palm) *and Diospyros malabarica* (Dehsigab) in the DU campus as the major species.

The percentage of plants was recorded inside the University campus. Maximum 49.25% fruit species were recorded followed by resin containing (42.54%), plantation crop (16.41%) and latex containing (16.28%) were recorded in the University campus (**Figure 7**).

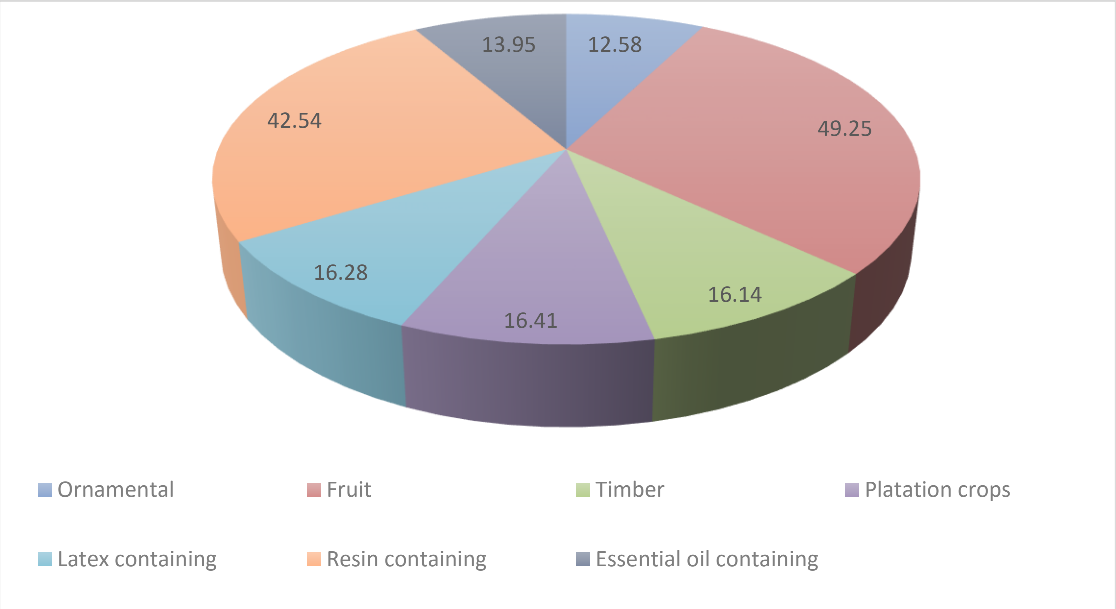


**Figure 7.** Percentage of plant species under different categories.

Jaman *et al.* (2014) found different categories of plant species viz., ornamental, fruit, vegetables, species, medicinal, timber and plantation crops comprised, respectively, of 54.4, 9.5, 12.7, 14.3, 4.0, 1.2, and 4.1% of total plant population of Sher-e-Bangla Agricultural University.

### 4.6 Economical values of trees in SAU campus

A total of 9, 15, 10, 7, 15, 5 species have been recorded under essential oil containing, resin containing, latex containing, timber, ornamental, Rare and threatened category grown in SAU with a total number of plants 102, 311, 119, 118, 92, 22 respectively **(Table 6-11).**

**Table 6.** Essential oil containing species in SAU campus.

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 1 | Narikel | *Cocos mucifera* Palmae | 50 | Resident, Roadside, Hall, Farm, Academic, Pond side |
| 2 | Sajina | *Moringa olefera* Moringaceae | 17 | Resident, Hall, Farm |
| 3 | Jolpai | *Elaeocarpus floribundus* Elaeocarpaceae | 2 | Resident, Farm |
| 4 | Oil palm | *Elaeis guineensis* Arecaceae | 4 | Roadside |
| 5 | Amloki | *Phyllanthus emblica* Euphorbiaceae | 4 | Resident, Farm |
| 6 | Tetul | *Tamarindus indica* Fabaceae | 5 | Academic, Farm, Resident, |
| 7 | Dalim | *Punica granatum* Punicaceae | 5 | Resident, Hall |
| 8 | Bokul | *Mimusops elengi* Sapotaceae | 5 | Academic |
| 9 | Neem | *Azadirachta indica* Meliaceae | 10 | Resident, Hall, Farm, Academic |

Selvi *et al.* (2019) recorded Myrtaceae, Oleaceae, Rutaceae, Meliaceae, Santalaceae Essential oil containing families out of 79 families in Sri Parasakthi College campus.

**Table 7.** Resin containing species in SAU campus.

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 1 | Amm | *Mangifera indica* Anacardiaceae | 134 | Hall, Resident, Roadside, Farm, Academic, Pond side, Block plantation |
| 2 | Mahogany | *Swietenia mahagony* Maliaceae | 58 | Hall, Resident, Roadside, Academic, Pond side, Block plantation |
| 3 | Kalokoroi | *Albizia lebbeck* Mimosaceae | 26 | Resident, Roadside, Hall, Block plantation |

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 4 | Kul | *Zizyphus sp* Rhamnaceae | 22 | Resident, Hall, Pond side |
| 5 | Payera | *Psidium guajava* Myrtaceae | 22 | Resident, Hall |
| 6 | Ata | *Annona reticulate* Annonaceae | 13 | Academic, Farm, Resident, Hall, |
| 7 | Kamranga | *Averrhoa carambola* Averrhoaceae | 9 | Resident, Hall, Farm, Pond side |
| 8 | Chalta | *Dillenia indica* Dilleniaceae | 7 | Resident, Hall |
| 9 | Bel | *Aegle marmelos* Rutaceae | 6 | Resident, Hall, Farm |
| 10 | Shimul | *Bombax ceiba* Boraginaceae | 4 | Resident, Hall, Farm, Academic |
| 11 | Tejpata | *Cinnamomum tamala* Lauraceae | 3 | Hall, Farm |
| 12 | Courbaril | *Hymenaea courbaril* Fabaceae | 3 | Farm |
| 13 | Kathgolap | *Plumeria alba* Apocynaceae | 2 | Academic |
| 14 | Bot | *Ficus benghalensis* Moraceae | 1 | Pond side |
| 15 | Sharifa | *Annona squamosal* Annonaceae | 1 | Farm |

Selvi *et al.* (2019) recorded Caesalpiniaceae, Anacardiaceae, Sapindaceae, Meliaceae, Logainaceae, Araucariaceae resin containing families out of 79 families in Sri Parasakthi College campus.

**Table 8.** Latex containing species in SAU campus.

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 1 | Kanthal | *Artocarpus heterophyllus* Moraceae | 60 | Resident, Hall, Farm, Academic |
| 2 | Sajina | *Moringa olefera* Moringaceae | 17 | Resident, Hall, Farm |
| 3 | Krishnochura | *Delonix regia* Caesalpiniaceae | 7 | Hall, Farm, Pond side |
| 4 | koromcha | *Carissa carandas* Apocynaceae | 7 | Resident, Farm |
| 5 | sofeda | *Manikara achras* Sapotaceae | 7 | Resident, Hall, Academic |
| 6 | Arjun | *Terminalia arjuna* Combretaceae | 7 | Resident, Roadside |

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 7 | Jambura | *Citrus grandis* Rutaceae | 6 | Resident, Hall |
| 8 | Dewaa | *Artocarpus lakoocha* Moraceae | 4 | Resident, Hall, Farm |
| 9 | Akashmoni | *Acacia auriculiformis* Mimosaceae | 2 | Hall, Farm |
| 10 | Deshi Gab | *Diospyros peregrina* Ebenaceae | 2 | Resident, Academic |

Selvi *et al.* (2019) found Apocyanaceae, Sapotaceae, Anacardiaceae, Euphorbiaceae, Moraceae and Meliaceae latex containing families out of 79 families in Sri Parasakthi College campus.

**Table 9.** Timber species in SAU campus.

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 1 | Kalokoroi | *Albizia lebbeck* Mimosaceae | 26 | Resident, Roadside, Hall, Block plantation |
| 2 | Mahogany | *Swietenia mahagony* Maliaceae | 58 | Resident, Road side, Hall, Academic, Pond side, Block plantation |
| 3 | Segun | *Albizia procera* Mimosaceae | 8 | Resident, Hall, Roadside, Block plantation |
| 4 | Shimul | *Tectona grandis* Verbenaceae | 4 | Resident, Hall, Farm Academic |
| 5 | Sil koroi | *Bombax ceiba* Boraginaceae | 17 | Resident, Roadside, Farm |
| 6 | Sissoo | *Swietenia sissoo* Fabaceae | 3 | Resident, Hall |
| 7 | Gamari | *Gmelina arborea* Lamiaceae | 2 | Academic |

Jaman *et al.* (2014) Maximum 33 plants were observed under Maliaceae family followed by Mimosaceae (27 plants) which comprised 33.3 and 27.3% of total timber plants respectively whereas minimum from Fabaceae (3 plants) family comprised 3.0% of total timber plants Uddin *et al.* (2016) also recorded 24 timber species in Dhaka university campus.

**Table 10.** Ornamental species  in SAU campus.

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 1 | Akashmoni | *Acacia auriculiformis* Mimosaceae | 2 | Hall, Farm |
| 2 | Beli | *Jasminum sambac* Oleaceae | 1 | Academic |
| 3 | Bokul | *Mimusops elengi* Sapotaceae | 5 | Academic |
| 4 | Bot | *Ficus benghalensis* Moraceae | 1 | Pond side |
| 5 | Debdaru | *Polyalthia longifolia* Annonaceae | 44 | Road side, Hall, Pond side, Academic |
| 6 | Jarul | *Lagerstroemia speciosa* Lythraceae | 1 | Resident |
| 7 | Kadom | *Anthocephalus cadamba* Rubiaceae | 5 | Resident, Hall, Farm |
| 8 | Kamini | *Murraya sp* Rutaceae | 2 | Academic |
| 9 | Krishnochura | *Delonix regia* Caesalpiniaceae | 7 | Hall, Farm, Pond side |
| 10 | Mandar | *Erythrina sp* Fabaceae | 2 | Resident |
| 11 | Naglingam | *Couroupita guianensis* Lycithidaceae | 2 | Academic |
| 12 | Radhachura | *Caesalpinia pulcherrima* Caesalpiniaceae | 2 | Resident, Pond side |
| 13 | Rongon | *Ixora sp* Rubiaceae | 6 | Academic |
| 14 | Thuja | *Thuja sp* Pinaceae | 10 | Academic |
| 15 | Kathgolap | *Plumeria alba* Apocynaceae | 2 | Academic |

Jaman *et al.* (2014) recorded Mimosaceae, Oleaceae, Sapotaceae, Moraceae, Annonaceae, Lythraceae, Rubiaceae, Rutaceae, Caesalpiniaceae, Fabaceae, Lycithidaceae, Caesalpiniaceae, Rubiaceae, Pinaceae, Apocynaceae families belongs to ornamental plant in SAU campus. Rajendran *et al.* (2014) also found 20 ornamental species in the Bharathiar university campus, india. Selvi *et al.* (2019) found 6 ornamental families out of 79 families in Sri Parasakthi College campus.

**Table 11.** Rare and threatened species in SAU campus.

| Sl No. | Common name | Scientific name and Family | No of plants | Location |
|---|---|---|---|---|
| 1 | Mandar | *Erythrina sp*<br>Fabaceae | 2 | Residential area |
| 2 | Deshi Gab | *Diospyros peregrina*<br>Ebenaceae | 2 | Resident, Academic area |
| 3 | Oil palm | *Elaeis guineensis*<br>Arecaceae | 4 | Roadside |
| 4 | Naglingam | *Couroupita guianensis*<br>Lycithidaceae | 2 | Academic area, Hall area |

Hossen *et al.* (2018) found Titpai, Modanmosta, Moricha, Oil palm, Mandar, Utailla, Naglingam, Goda, Kao, Castoma, Nunia Bura, Kali Batna as a rare and threatened species in Himchari National Park, Cox's Bazar,Bangladesh.

From the observation, it was revealed that the species of resin containing plants was the highest number of population (311 nos.) followed by latex containing (119 nos.) and timber (118 nos.), where the lowest population occurred under the category of rare and threatened plants (10 nos.) (**Figure 8**).

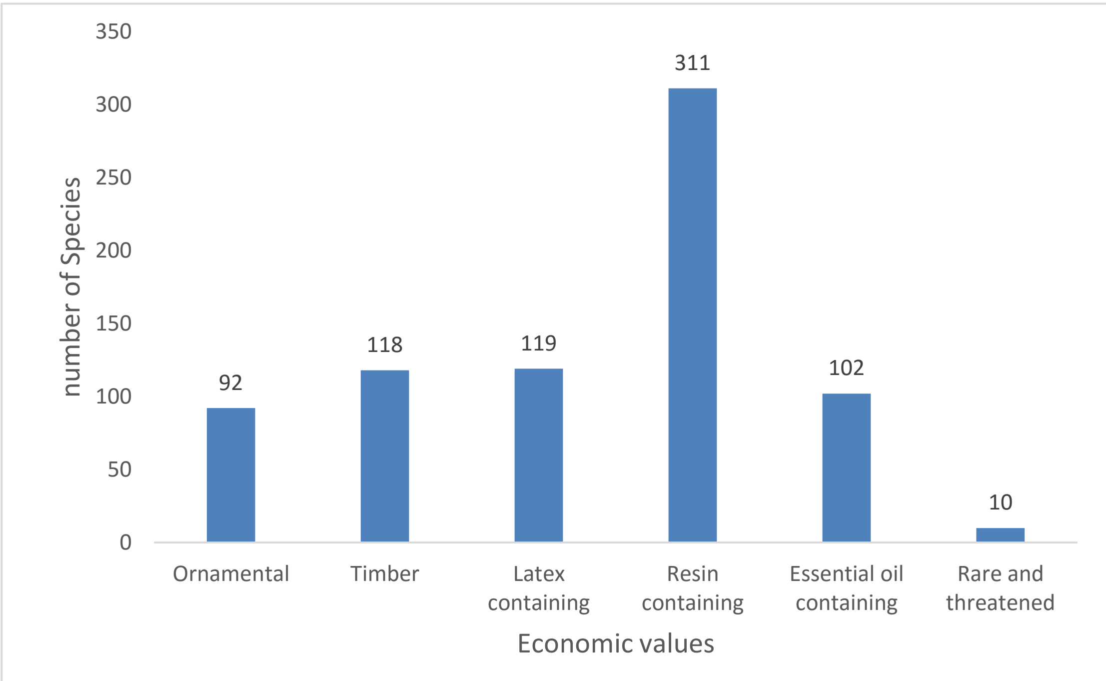


**Figure 8.** Enlisted economic values of trees in SAU campus.

Selvi *et al.* (2019) enlisted 13 Rare and threatened species, 5 Essential oil Containing families, 6 Resin Containing Families, 6 Latex containing families and 6 Ornamental families available in Sri Parasakthi College campus.

Jaman *et al.* (2014) recorded a total of 126, 46, 17, 15, 29, 10 and 14 species under ornamental, fruit, vegetable, spice, medicinal, timber, bamboo and plantation crops categories grown at SAU thus comprised 49.0, 17.9, 6.6, 5.8, 11.3, 3.9, 5.5% in terms of species, respectively. They revealed that the population of ornamentals plants was the highest followed by species and vegetables, where the lowest population occurred under the category of timber plants.

## 4.7 Distribution of Stem Density, Basal Area and Mean DBH

Characteristics such as stem density, basal area and mean DBH of total 72 plots were estimated including their standard error (Table 12). From this Table it was revealed that Academic area had the highest basal area (33.47 $m^2$ $ha^{-1}$) followed by Block plantation (28.41 $m^2$ $ha^{-1}$), Hrt. & Afe. farm land (26.18 $m^2$ $ha^{-1}$), Hall area (24.48 $m^2 ha^{-1}$) and Pond side had the lowest value that was 13.82 $m^2$ $ha^{-1}$. In stand density Hrt. & Afe. farm land (1366.66 trees $ha^{-1}$) had the highest density followed by Residential area (1361.90 trees $ha^{-1}$), Block plantation (1100 trees $ha^{-1}$), Academic area (1037.5 trees $ha^{-1}$), Hall area (946.15 trees $ha^{-1}$), Pond side (925 trees $ha^{-1}$). In case of mean DBH Roadside had the highest value of 31.36 cm and Residential area had the lowest value of 14.2 cm where Hrt. & Afe. farm land 21.63 cm, Hall area 21.85 cm, Academic area 27.87 cm, Block plantation 29.03 cm and Pond side 20.88 cm mean DBH. These variations was found due to various age cycle of the species, types of the species, size, soil and climate.

**Table 12.** Stem Density, Basal area ($m^2$ $ha^{-1}$) and mean DBH (cm) in SAU campus.

| Categories | Stem density (trees/ha) | Basal Area ($m^2ha^{-1}$ ) | Mean DBH (cm) |
|---|---|---|---|
| Residential area | 1361.90 | 13.83(1.95) | 14.2 |
| Hrt. & Afe. farm land | 1366.66 | 26.18(2.47) | 21.63 |
| Hall area | 946.15 | 24.48(2.31) | 21.85 |
| Academic area | 1037.5 | 33.47(2.45) | 27.87 |
| Block plantation | 1100 | 28.41(7.23) | 29.03 |
| Pond side | 925 | 13.82 (1.94) | 20.88 |
| Roadside | 1250 | 22.23 (1.22) | 31.36 |

* Parenthesis are the standard errors.

Deb *et al.* (2016) found 481 individuals were <15 cm DBH, 338 species were 15-25 cm, 321 species were 25-35 cm, 114 species were 35-45 cm and only 47 individuals were >45cm DBH. The highest basal area was *Acacia auriculiformis* with 1.056 $m^2ha^{-1}$ followed by *Trema orientalis* with 0.139 $m^2ha^{-1}$, *Anacardium occidentale* with 0.099 $m^2ha^{-1}$, *Cassia siamea* with 0.076 $m^2ha^{-1}$, *Artocarpus heterophyllus* with 0.072 $m^2ha^{-1}$, *Mangifera indica* with 0.056 $m^2ha^{-1}$ and *Melia azedarach* with 0.053 $m^2ha^{-1}$.

A similar study was conducted by Islam (2013) and he found basal area, stem density, mean DBH were 34.16 ± 3.51 $m^2$ $ha^{-1}$, 1096.87 ± 121.10 trees $ha^{-1}$, 19.83 ± 1.63 cm, respectively which were more or less similar to the present study.

### 4.8 Above and below Ground Carbon (AGC) Estimation

For the estimation of above and below ground carbon stock of the plantation sites of the selected experimental plots were measured on the basis of diameter at breast height (DBH); height (H) and also calculated by using the desired equations. For measuring biomass carbon stock total plantation of 72 plots of Sher-e-Bangla Agricultural University were used. The data revealed that the biomass carbon stock of Sher-e-Bangla Agricultural University ranged from 573.02 to 2044.58 Mg C $ha^{-1}$ (Table 15). Among them Academic area had the highest mean carbon stock (229.06±20.31 Mg $ha^{-1}$) with a number of 8 plots followed by Block plantation (191.00±48.60), Hrt. & Afe. farm land

(184.22±20.83), Roadside (163.46±22.73), Hall area (157.27±14.32), Pond side (93.00±13.12) and the lowest mean carbon stock (88.15±13.98 Mg $ha^{-1}$) was found in Residential area with a number of 21 plots.

**Table 13.** Above and below ground carbon estimation.

| Category | Plot No. | Above ground carbon (Mg/ha) | Below ground carbon (Mg/ha) | Total carbon (Mg/ha) | Mean ± SE |
|---|---|---|---|---|---|
| Residential area | 21 | 75.81 | 12.34 | 1851.33 | 88.15±13.98 |
| Hrt. & Afe. farm land | 6 | 158.43 | 25.79 | 1105.33 | 184.22±20.83 |
| Hall area | 13 | 135.25 | 22.02 | 2044.58 | 157.27±14.32 |
| Academic area | 8 | 196.99 | 32.07 | 1832.5 | 229.06±20.31 |
| Block plantation | 3 | 164.26 | 26.74 | 573.02 | 191.00±48.60 |
| Pond side | 8 | 79.98 | 13.02 | 744.04 | 93.00±13.12 |
| Roadside | 13 | 140.57 | 22.88 | 2125 | 163.46±22.73 |

In previous study Gibbs *et al.* (2007) found that the mean biomass carbon in Bangladesh was 65-158 Mg $ha^{-1}$ which was similar of the findings of this study.

Islam (2013) found that the average biomass carbon stocks for roadside, homegardens and Block plantation were 159.18 ± 36 Mg $ha^{-1}$, 169.37 ± 34 Mg $ha^{-1}$ and 206.19 ± 42 $Mgha^{-1}$, respectively and the mean biomass carbon was 174.24 ± 21 $Mgha^{-1}$.

Kundu (2015) recorded carbon stock ranged from 2.25 to 222.72 Mg C $ha^{-1}$ with a mean value of 122.19 Mg C $ha^{-1}$ in Chandrima Uddan, Dhaka and also for Ramna Park ranged from 2.71 to 918.46 Mg C $ha^{-1}$; Mean 247.90 Mg C $ha^{-1}$ which was also support the findings of this study.

### 4.9 Major carbon containing tree species

Among 60 species from 32 different families, it is clearly mentioned that five major tree species like Mango, Jackfruit, Mahagani, debdaru and kalo koroi were the most dominant tree species found in the sampled plots of Sher-e-Bangla Agricultural University. Estimated data revealed that the major carbon containing tree was *Mangifera indica* (102.53 Mg) followed by *Artocarpus heterophyllus* (46.34 Mg), *Swietenia mahagony* (44.42 Mg), *Polyalthia longifolia* (33.72 Mg), *Albizia lebbeck* (19.94 Mg) (**Figure 9**) in Sher-e-Bangla Agricultural University.

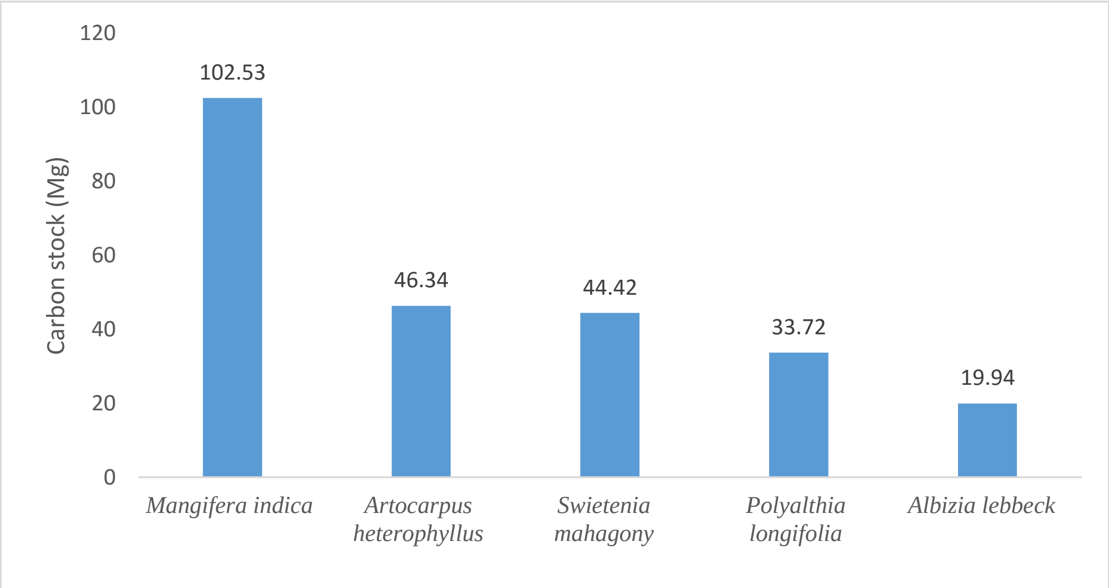


**Figure 9.** Five major carbon containing tree species.

Deb *et al.* (2016) recorded the highest total biomass is *Acacia auriculiformis* with total biomass 6.43 t $ha^{-1}$ and carbon 3.22 t $ha^{-1}$ and *Trema orientalis* 1.122 t $ha^{-1}$. Islam (2013) found that the carbon containing major trees were *Mangifera indica* (44.38 Mg), *Swietenia mahagony* (35.86 Mg), *Polyalthia* (18.13 Mg), *Salmalia* (18.1 Mg), *Litchi chinensis* (14.36 Mg) in Sher-e-Bangla Agricultural University.

### 4.10 Relationship between Basal Area ($m^2$ $ha^{-1}$) and Carbon stock (Mg $ha^{-1}$)

A linear relationship between mean basal area and biomass carbon stock of Sher-e-Bangla Agricultural University was measured and presented in Figure 10. The linear equation as: $Y = 7.2469x - 10.099$ ($R^2 = 0.9314$), where $R^2$ value was positive. So the estimated value indicated that there was a significant and strongly positive correlation between basal area and carbon stock and with the increase of basal area the biomass carbon stock also increases. A number of earlier studies also reported a high significant correlation of biomass carbon stock with basal area (Chaturvedi *et al.*, 2011; Kale *et al.*, 2004 and Slik *et al.*, 2010). Similar study results was also observed by several earlier study. He found that the relationship between basal area ($m^2$ $ha^{-1}$) and total carbon (Mg $ha^{-1}$) was significant ($p < 0.01$) where the value of r is 0.914 and $R^2$ is 0.836 (Islam, 2013).

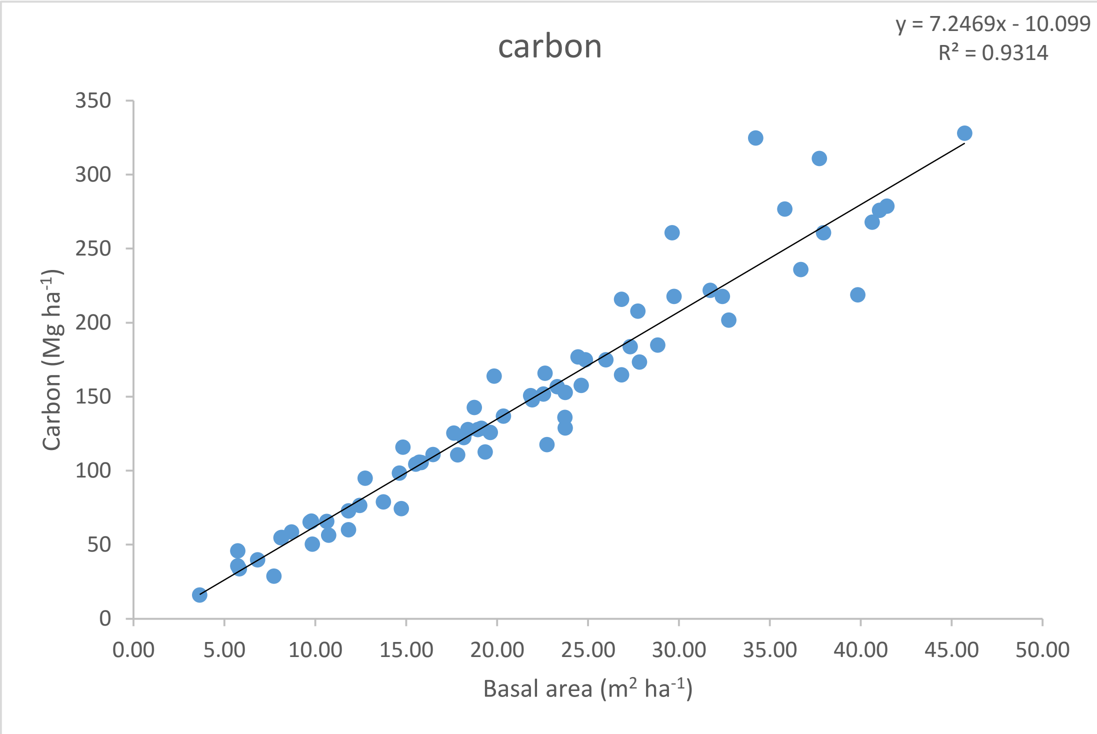


**Figure 10**.Relationship between basal area ($m^2$ $ha^{-1}$) and carbon stock (Mg $ha^{-1}$).

### 4.11 Relationship between mean DBH (cm) and carbon stock (Mg ha$^{-1}$)

A relationship between mean DBH and biomass carbon stock of Sher-e-Bangla Agricultural University was measured and presented in Figure 11. The linear equation as: Y = 6.3235x + 2.4532 ($R^2$ = 0.4723), where $R^2$ value was positive. The estimated value indicated that there was a significant and positive correlation between mean DBH and carbon stock and with the increase of mean DBH the carbon stock also increases. In previous study Deb *et al.* (2016) found a positive relationship between DBH and carbon stock. Islam (2013) there was a moderate relation between mean DBH (cm) and total carbon stock (Mg ha$^{-1}$). Though the relationship was moderate but it was significant ($p < 0.01$). The value of r is 0.5641 and $R^2$ was 0.292.

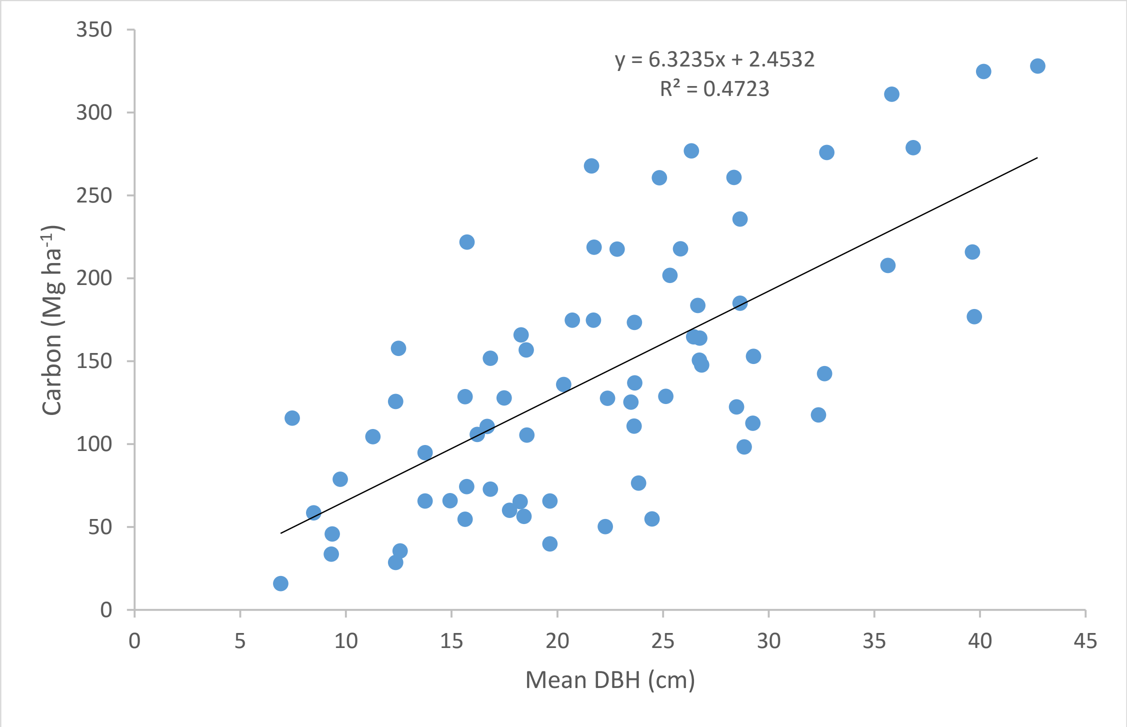


**Figure 11.** Relationship between mean DBH (cm) and carbon stock (Mg ha$^{-1}$).

# CHAPTER 5

# SUMMARY AND CONCLUSION

## SUMMARY

The study represented a reliable result regarding the present status of carbon stocks and documentation with floristic characteristics of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. In the study 72 plots with 60 different species under 32 families were identified and recorded which is a good indicator of biodiversity. The results of the study showed that among the seven areas of SAU campus, Academic area had the highest basal area (33.47 $m^2$ $ha^{-1}$) followed by Block plantation (28.41 $m^2$ $ha^{-1}$), Hrt. & Afe. farm land (26.18 $m^2$ $ha^{-1}$), Hall area (24.48 $m^2$ $ha^{-1}$); and Pond side had the lowest value that was 13.82 $m^2$ $ha^{-1}$. In stand density Hrt. & Afe. farm land (1366.66 trees/ha) had the highest density followed by Residential area (1361.90 trees/ha), Block plantation (1100), Academic area (1037.5 trees/ha), Hall area (946.15 trees/ha), Pond side (925 trees/ha). In case of mean DBH, Roadside had the highest value of 31.36 cm and Residential area had the lowest value of 14.2 cm where Hrt. & Afe. farm land 21.63 cm, Hall area 21.85 cm, Academic area 27.87 cm, Block plantation 29.03 cm and Pond side 20.88 cm mean DBH. Among 72 plots the average carbon stock (above and below ground carbon stock) was found 142.71 Mg $ha^{-1}$ which ranged from 15.83 Mg $ha^{-1}$ to 327.83 Mg $ha^{-1}$. Academic area had the highest mean carbon stock (229.06±20.31 Mg/ha) with a number of 8 plots followed by Block plantation (191.00±48.60), Hrt. & Afe. farm land (184.22±20.83), Roadside (163.46±22.73), Hall area (157.27±14.32), Pond side (93.00±13.12) and the lowest mean carbon stock (88.15±13.98 Mg $ha^{-1}$) was found in Residential area with a number of 21 plots. The reason behind these carbon deposits is highly related to the basal area and the availability of trees found in those areas. The five major dominating species were *Mangifera indica* (102.53 Mg) followed by *Artocarpus heterophyllus* (46.34 Mg), *Swietenia mahagony* (44.42 Mg), *Polyalthia longifolia* (33.72 Mg), *Albizia lebbeck* (19.94 Mg) at Sher-e-Bangla Agricultural University.

Among the seven categories the highest species diversity was found in Hrt. & Afe. farm land with the value of 2.97± 0.07 followed by Residential area 2.95± 0.08, Hall area 2.94± 0.06, Academic area 2.94± 0.09, Pond side 2.18± 0.09, Roadside 1.87± 0.09 and Block plantation had the lowest mean value of 0.94± 0.07. In Sher-e-Bangla Agricultural University 42 species were found in Residential area, 28 species were in Hrt. & Afe. farm land, 30 species were in Hall area, 27 species were in Academic area, 4 species were in Block plantation, 12 species were in Pond side and 10 species were found in Pond side.

The results of the study showed that the most dominating family was Anacardiaceae with a number of 137 plants and Oleaceae and Lythraceae were the least dominating family with a number of single plant. Maximum 49.25% fruit species were recorded followed by resin containing (42.54%), plantation crop (16.41%) and latex containing (16.28%) plants while minimum 5.61% medicinal plants were recorded in the University campus. It was revealed that the population of resin containing plants was the highest number of population (311 nos.) followed by latex containing (119 nos.) and timber (118 nos.), where the lowest population occurred under the category of ornamental plants (92 nos). There were five major species found in SAU campus namely Amm (Mango) was the most predominant tree species with 18.33% (no. 134) followed by Kanthal 8.21% (no. 60), Mahogany 7.93% (no. 58), Narikel 6.84% (no. 50) and Supari 6.02% (no. 44). When plant purpose was considered, the highest no. of the total plant population was observed with the Fruit (360) followed by Plantation crop (120), Timber (118) and Ornamental (92).

## CONCLUSION

The study was conducted in Sher-e-Bangla Agricultural University to assess species diversity, carbon stock and to explore a relationship between species composition and carbon stock. Based on the result of the study it can be stated as-

1. The highest mean carbon stock (229.06±20.31 Mg $ha^{-1}$) was found in Academic area and the lowest mean carbon stock (88.15±13.98 Mg $ha^{-1}$) was found in Residential area.

2. A total of 731 plants with 32 families were recorded where 15 species (no. 92) of ornamental plants, 9 species (no. 102) of essential oil containing plants, 15 species (no. 311) of resin containing plants, 10 species (no. 119) of latex containing plants, 7 species (no. 118) of timber plants, 4 species (no. 10) of rare and threatened plants, 28 species (no. 360) of fruit plants and 7 palm species (no. 120) within the plantation crops.

3. The study found that carbon stock had a positive relationship with DBH and basal area where carbon stock increased per unit change in DBH and basal area.

# CHAPTER 6

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## APPENDICES

**APPENDIX I:** Number of trees per species and per categories. N/A= No information available.

| Sl. No. | Common Name | Residential area | Road side | Hall Area | Hrt. & Afe. Farm land | Academic area | Pond side | Block Plantation |
|---|---|---|---|---|---|---|---|---|
| **Ornamental** | | | | | | | | |
| 1 | Akashmoni | N/A | N/A | 1 | 1 | N/A | N/A | N/A |
| 2 | Beli | N/A | N/A | N/A | N/A | 1 | N/A | N/A |
| 3 | Bokul | N/A | N/A | 4 | N/A | 1 | N/A | N/A |
| 4 | Bot | N/A | N/A | N/A | N/A | N/A | 1 | N/A |
| 5 | Debdaru | N/A | 31 | 8 | N/A | 3 | 2 | N/A |
| 6 | Jarul | 1 | N/A | N/A | N/A | N/A | N/A | N/A |
| 7 | Kadom | 2 | N/A | 1 | 2 | N/A | N/A | N/A |
| 8 | Kamini | N/A | N/A | N/A | N/A | 2 | N/A | N/A |
| 9 | Krishnochura | N/A | N/A | 1 | 5 | N/A | 1 | N/A |
| 10 | Mandar | 2 | N/A | N/A | N/A | N/A | N/A | N/A |
| 11 | Naglingam | N/A | N/A | N/A | N/A | 2 | N/A | N/A |
| 12 | Radhachura | N/A | N/A | N/A | 2 | N/A | N/A | N/A |
| 13 | Rongon | N/A | N/A | N/A | N/A | 6 | N/A | N/A |
| 14 | Thuja | N/A | N/A | N/A | N/A | 10 | N/A | N/A |
| 15 | Kathgolap | N/A | N/A | N/A | N/A | 2 | N/A | N/A |
| **Fruit** | | | | | | | | |
| 16 | Alachi Lebu | 2 | N/A | N/A | N/A | N/A | N/A | N/A |
| 17 | Amloki | 2 | N/A | N/A | 2 | N/A | N/A | N/A |
| 18 | Amm | 76 | 6 | 19 | 4 | 7 | 2 | 20 |
| 19 | Ata | 6 | N/A | 5 | 1 | 1 | N/A | N/A |
| 20 | Bel | 3 | N/A | 2 | 1 | N/A | N/A | N/A |
| 21 | Bilimbi | 2 | N/A | N/A | N/A | 2 | N/A | N/A |
| 22 | Chalta | 5 | N/A | 2 | N/A | N/A | N/A | N/A |
| 23 | Dalim | 3 | N/A | 2 | N/A | N/A | N/A | N/A |
| 24 | Deshi Gab | 1 | N/A | N/A | N/A | 1 | N/A | N/A |
| 25 | Dewaa | 2 | N/A | 1 | 1 | N/A | N/A | N/A |
| 26 | Jam (Jamun) | 5 | N/A | 2 | 1 | 1 | N/A | N/A |
| 27 | Jambura | 4 | N/A | 2 | N/A | N/A | N/A | N/A |
| 28 | Jamrul | 4 | N/A | 1 | 2 | 1 | N/A | N/A |
| 29 | Jolpai/ | 1 | N/A | N/A | 1 | N/A | N/A | N/A |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30 | Kamrangga | 5 | N/A | 1 | 1 | N/A | 2 | N/A |
| 31 | Kanthal | 37 | N/A | 14 | 6 | 3 | N/A | N/A |
| 32 | Kodbel | 1 | N/A | N/A | 1 | N/A | N/A | N/A |
| 33 | Koromcha | 4 | N/A | N/A | 2 | N/A | 1 | N/A |
| 34 | Kul (Jujubee) | 16 | N/A | 4 | N/A | N/A | 2 | N/A |
| 35 | Litchi | 5 | N/A | N/A | 3 | 6 | 2 | N/A |
| 36 | Payera | 15 | N/A | 7 | N/A | N/A | N/A | N/A |
| 37 | Sharifa | N/A | N/A | N/A | 1 | N/A | N/A | N/A |
| 38 | Sofeda | 2 | N/A | 2 | N/A | 3 | N/A | N/A |
| 39 | Tetul | 2 | N/A | N/A | 1 | 2 | N/A | N/A |
| 40 | Amra | 3 | N/A | N/A | N/A | N/A | N/A | N/A |
| **Timber** | | | | | | | | |
| 41 | Kalo koroi | 6 | 4 | 2 | 13 | N/A | N/A | 1 |
| 42 | Mahogany | 5 | 23 | 15 | N/A | 2 | 3 | 10 |
| 43 | Segun | 2 | 3 | 1 | N/A | N/A | N/A | 2 |
| 44 | Shimul | 1 | N/A | 1 | 1 | 1 | N/A | N/A |
| 45 | Sil koroi | 7 | 5 | N/A | 5 | N/A | N/A | N/A |
| 46 | Sissoo | 1 | N/A | 2 | N/A | N/A | N/A | N/A |
| 47 | Gamari | N/A | N/A | N/A | N/A | 2 | N/A | N/A |
| **Medicinal plants** | | | | | | | | |
| 48 | Arjun | 4 | 3 | N/A | N/A | N/A | N/A | N/A |
| 49 | Neem | 3 | N/A | 3 | 2 | 2 | N/A | N/A |
| 50 | Shawra | 1 | N/A | N/A | N/A | 2 | N/A | N/A |
| 51 | Sajina | 10 | N/A | 4 | 3 | N/A | N/A | N/A |
| 52 | Tejpata | N/A | N/A | 1 | 2 | N/A | N/A | N/A |
| **Platation crops** | | | | | | | | |
| 53 | Arica palm | 4 | N/A | N/A | N/A | N/A | N/A | N/A |
| 54 | Bottle palm | N/A | 5 | N/A | N/A | N/A | N/A | N/A |
| 55 | Khejur | 2 | N/A | 1 | N/A | 1 | 3 | N/A |
| 56 | Narikel | 13 | 4 | 8 | 11 | 4 | 10 | N/A |
| 57 | Oil palm | N/A | 4 | N/A | N/A | N/A | N/A | N/A |
| 58 | Supari | 13 | N/A | 6 | 4 | 14 | 7 | N/A |
| 59 | Tal palm | 2 | N/A | N/A | N/A | 2 | N/A | N/A |
| 60 | courbaril | N/A | N/A | N/A | 3 | N/A | N/A | N/A |

**APPENDIX II:** Tree diversity in 72 plots at SAU campus.

| Plots | Types | Tree Diversity | Mean | Standard deviation |
|---|---|---|---|---|
| 1. | Roadside | 0.8 | 1.06 | 0.27 |
| 2. | Roadside | 1.16 | | |
| 3. | Roadside | 0.68 | | |
| 4. | Roadside | 1.45 | | |
| 5. | Roadside | 0.96 | | |
| 6. | Roadside | 1.64 | | |
| 7. | Roadside | 0.95 | | |
| 8. | Roadside | 1.05 | | |
| 9. | Roadside | 0.95 | | |
| 10. | Roadside | 1.1 | | |
| 11. | Roadside | 0.85 | | |
| 12. | Roadside | 1.37 | | |
| 13. | Roadside | 0.94 | | |
| 14. | Pond side | 1.02 | 0.86 | 0.27 |
| 15. | Pond side | 0.32 | | |
| 16. | Pond side | 0.65 | | |
| 17. | Pond side | 1.25 | | |
| 18. | Pond side | 0.93 | | |
| 19. | Pond side | 0.84 | | |
| 20. | Pond side | 0.93 | | |
| 21. | Pond side | 1.01 | | |
| 22. | Block plantation | 1.15 | 1.52 | 0.35 |
| 23. | Block plantation | 1.56 | | |
| 24. | Block plantation | 1.85 | | |
| 25. | Academic area | 1.93 | 1.16 | 0.37 |
| 26. | Academic area | 0.83 | | |
| 27. | Academic area | 1.13 | | |
| 28. | Academic area | 1.24 | | |
| 29. | Academic area | 1.39 | | |
| 30. | Academic area | 0.74 | | |
| 31. | Academic area | 0.92 | | |
| 32. | Academic area | 1.16 | | |
| 33. | Hall area | 1.73 | 1.05 | 0.39 |
| 34. | Hall area | 1.27 | | |
| 35. | Hall area | 1.69 | | |
| 36. | Hall area | 1.09 | | |
| 37. | Hall area | 0.42 | | |
| 38. | Hall area | 0.66 | | |
| 39. | Hall area | 1.06 | | |

| Plots | Types | Tree Diversity | Mean | Standard deviation |
|---|---|---|---|---|
| 40. | Hall area | 0.93 | | |
| 41. | Hall area | 1.26 | | |
| 42. | Hall area | 0.67 | | |
| 43. | Hall area | 1.09 | | |
| 44. | Hall area | 1.17 | | |
| 45. | Hall area | 0.66 | | |
| 46. | Hrt. & Afe. farm land | 1.06 | | |
| 47. | Hrt. & Afe. farm land | 0.93 | | |
| 48. | Hrt. & Afe. farm land | 1.32 | 1.37 | 0.45 |
| 49. | Hrt. & Afe. farm land | 1.07 | | |
| 50. | Hrt. & Afe. farm land | 2.01 | | |
| 51. | Hrt. & Afe. farm land | 1.84 | | |
| 52. | Residential area | 0.97 | | |
| 53. | Residential area | 1.54 | | |
| 54. | Residential area | 1.32 | | |
| 55. | Residential area | 0.71 | | |
| 56. | Residential area | 0.97 | | |
| 57. | Residential area | 1.44 | | |
| 58. | Residential area | 1.37 | | |
| 59. | Residential area | 0.68 | | |
| 60. | Residential area | 1.46 | | |
| 61. | Residential area | 1.39 | | |
| 62. | Residential area | 0.63 | 1.05 | 0.34 |
| 63. | Residential area | 1.13 | | |
| 64. | Residential area | 1.16 | | |
| 65. | Residential area | 1.28 | | |
| 66. | Residential area | 1.48 | | |
| 67. | Residential area | 1.18 | | |
| 68. | Residential area | 0.94 | | |
| 69. | Residential area | 0.74 | | |
| 70. | Residential area | 0.58 | | |
| 71. | Residential area | 0.38 | | |
| 72. | Residential area | 0.83 | | |

**APPENDIX III:** Stand density, Basal area and Mean DBH of 72 plots at SAU campus.

| Plots | Types | Stand Density (trees/ha) | Basal area ($m^2$ $ha^{-1}$) | Mean DBH (cm) |
|---|---|---|---|---|
| 1 | Roadside | 1000 | 18.74 | 32.64 |
| 2 | Roadside | 1400 | 26.84 | 39.63 |
| 3 | Roadside | 1000 | 17.63 | 23.48 |
| 4 | Roadside | 1200 | 21.85 | 26.72 |
| 5 | Roadside | 1000 | 14.63 | 28.83 |
| 6 | Roadside | 1600 | 34.23 | 40.17 |
| 7 | Roadside | 1200 | 24.45 | 39.73 |
| 8 | Roadside | 1600 | 12.45 | 23.84 |
| 9 | Roadside | 1000 | 19.34 | 29.24 |
| 10 | Roadside | 1400 | 37.73 | 35.82 |
| 11 | Roadside | 1200 | 22.74 | 32.35 |
| 12 | Roadside | 1400 | 10.64 | 19.64 |
| 13 | Roadside | 1000 | 27.74 | 35.64 |
| 14 | Pond side | 1000 | 18.95 | 22.37 |
| 15 | Pond side | 800 | 9.79 | 14.92 |
| 16 | Pond side | 800 | 9.71 | 18.23 |
| 17 | Pond side | 1200 | 21.94 | 26.82 |
| 18 | Pond side | 800 | 18.16 | 28.47 |
| 19 | Pond side | 1000 | 8.12 | 15.63 |
| 20 | Pond side | 600 | 8.16 | 24.47 |
| 21 | Pond side | 1200 | 15.73 | 16.2 |
| 22 | Block plantation | 1400 | 27.32 | 26.64 |
| 23 | Block plantation | 1100 | 16.47 | 23.63 |
| 24 | Block plantation | 800 | 41.45 | 36.83 |
| 25 | Academic area | 1200 | 45.73 | 42.73 |
| 26 | Academic area | 1100 | 41.03 | 32.75 |
| 27 | Academic area | 800 | 28.84 | 28.64 |
| 28 | Academic area | 1400 | 32.74 | 25.33 |
| 29 | Academic area | 1200 | 29.74 | 22.83 |
| 30 | Academic area | 800 | 27.84 | 23.64 |
| 31 | Academic area | 600 | 25.99 | 20.7 |
| 32 | Academic area | 1200 | 35.83 | 26.34 |
| 33 | Hall area | 1000 | 32.39 | 25.83 |
| 34 | Hall area | 1200 | 37.95 | 28.36 |
| 35 | Hall area | 900 | 39.85 | 21.73 |
| 36 | Hall area | 600 | 18.40 | 17.48 |
| 37 | Hall area | 1100 | 26.84 | 26.45 |
| 38 | Hall area | 1400 | 23.31 | 18.53 |
| 39 | Hall area | 800 | 23.75 | 25.12 |
| 40 | Hall area | 900 | 20.36 | 23.66 |
| 41 | Hall area | 1300 | 23.75 | 29.27 |
| 42 | Hall area | 1100 | 17.84 | 16.67 |
| 43 | Hall area | 600 | 9.78 | 13.73 |
| 44 | Hall area | 800 | 19.14 | 15.63 |

| Plots | Types | Stand Density (trees/ha) | Basal area ($m^2$ $ha^{-1}$) | Mean DBH (cm) |
|---|---|---|---|---|
| 45 | Hall area | 600 | 24.86 | 21.71 |
| 46 | Hrt. & Afe. farm land | 1500 | 19.84 | 26.73 |
| 47 | Hrt. & Afe. farm land | 1800 | 23.74 | 20.3 |
| 48 | Hrt. & Afe. farm land | 900 | 22.56 | 16.83 |
| 49 | Hrt. & Afe. farm land | 1500 | 24.63 | 12.48 |
| 50 | Hrt. & Afe. farm land | 1600 | 29.63 | 24.83 |
| 51 | Hrt. & Afe. farm land | 900 | 36.70 | 28.64 |
| 52 | Residential area | 2100 | 15.53 | 11.27 |
| 53 | Residential area | 1900 | 31.73 | 15.72 |
| 54 | Residential area | 1300 | 40.63 | 21.61 |
| 55 | Residential area | 800 | 5.83 | 9.3 |
| 56 | Residential area | 1800 | 11.83 | 16.83 |
| 57 | Residential area | 1400 | 9.84 | 22.27 |
| 58 | Residential area | 1600 | 22.64 | 18.28 |
| 59 | Residential area | 1200 | 14.73 | 15.71 |
| 60 | Residential area | 1500 | 19.63 | 12.34 |
| 61 | Residential area | 1700 | 11.83 | 17.73 |
| 62 | Residential area | 900 | 5.73 | 12.56 |
| 63 | Residential area | 1500 | 14.83 | 7.45 |
| 64 | Residential area | 1700 | 15.83 | 18.56 |
| 65 | Residential area | 1100 | 5.73 | 9.34 |
| 66 | Residential area | 1700 | 12.74 | 13.74 |
| 67 | Residential area | 1500 | 8.69 | 8.46 |
| 68 | Residential area | 1200 | 6.83 | 19.64 |
| 69 | Residential area | 800 | 10.73 | 18.42 |
| 70 | Residential area | 900 | 3.64 | 6.9 |
| 71 | Residential area | 600 | 7.73 | 12.35 |
| 72 | Residential area | 1400 | 13.74 | 9.72 |

**APPENDIX IV:** Above and below ground carbon stock in 72 plots at SAU campus.

| Plots | Types | AGC (Mg/ha) | BGC (Mg/ha) | Total Carbon (Mg /ha) | Average Carbon (Mg/ha) | Standard deviation |
|---|---|---|---|---|---|---|
| 1. | Roadside | 122.58 | 19.95 | 142.53 | 163.46 | 81.98 |
| 2. | Roadside | 185.53 | 30.20 | 215.73 | | |
| 3. | Roadside | 107.82 | 17.55 | 125.37 | | |
| 4. | Roadside | 129.54 | 21.09 | 150.63 | | |
| 5. | Roadside | 84.58 | 13.77 | 98.35 | | |
| 6. | Roadside | 279.18 | 45.45 | 324.63 | | |
| 7. | Roadside | 152.08 | 24.76 | 176.84 | | |
| 8. | Roadside | 65.82 | 10.71 | 76.53 | | |
| 9. | Roadside | 96.78 | 15.75 | 112.53 | | |
| 10. | Roadside | 267.34 | 43.52 | 310.86 | | |
| 11. | Roadside | 101.16 | 16.47 | 117.63 | | |
| 12. | Roadside | 56.53 | 9.20 | 65.73 | | |
| 13. | Roadside | 178.57 | 29.07 | 207.64 | | |
| 14. | Pond side | 109.76 | 17.87 | 127.63 | 93.00 | 37.13 |
| 15. | Pond side | 56.70 | 9.23 | 65.93 | | |
| 16. | Pond side | 56.11 | 9.13 | 65.24 | | |
| 17. | Pond side | 127.05 | 20.68 | 147.73 | | |
| 18. | Pond side | 105.22 | 17.13 | 122.35 | | |
| 19. | Pond side | 46.96 | 7.64 | 54.6 | | |
| 20. | Pond side | 47.15 | 7.68 | 54.83 | | |
| 21. | Pond side | 90.93 | 14.80 | 105.73 | | |
| 22. | Block plantation | 157.92 | 25.71 | 183.63 | 191.00 | 84.18 |
| 23. | Block plantation | 95.25 | 15.51 | 110.75 | | |
| 24. | Block plantation | 239.63 | 39.01 | 278.64 | | |
| 25. | Academic area | 281.93 | 45.90 | 327.83 | 229.06 | 57.46 |
| 26. | Academic area | 237.22 | 38.62 | 275.84 | | |
| 27. | Academic area | 158.95 | 25.88 | 184.83 | | |
| 28. | Academic area | 173.50 | 28.24 | 201.74 | | |
| 29. | Academic area | 187.08 | 30.46 | 217.54 | | |
| 30. | Academic area | 149.00 | 24.26 | 173.25 | | |
| 31. | Academic area | 150.27 | 24.46 | 174.73 | | |
| 32. | Academic area | 238.00 | 38.74 | 276.74 | | |
| 33. | Hall area | 187.26 | 30.48 | 217.74 | 157.27 | 51.63 |
| 34. | Hall area | 224.23 | 36.50 | 260.73 | | |
| 35. | Hall area | 188.11 | 30.62 | 218.73 | | |
| 36. | Hall area | 109.85 | 17.88 | 127.73 | | |
| 37. | Hall area | 141.69 | 23.07 | 164.75 | | |
| 38. | Hall area | 134.79 | 21.94 | 156.73 | | |
| 39. | Hall area | 110.73 | 18.03 | 128.75 | | |
| 40. | Hall area | 117.68 | 19.16 | 136.84 | | |
| 41. | Hall area | 131.44 | 21.40 | 152.84 | | |
| 42. | Hall area | 95.14 | 15.49 | 110.63 | | |
| 43. | Hall area | 56.53 | 9.20 | 65.73 | | |
| 44. | Hall area | 110.63 | 18.01 | 128.64 | | |

| Plots | Types | AGC (Mg/ha) | BGC (Mg/ha) | Total Carbon (Mg /ha) | Average Carbon (Mg/ha) | Standard deviation |
|---|---|---|---|---|---|---|
| 45. | Hall area | 150.28 | 24.46 | 174.74 | | |
| 46. | Hrt. & Afe. farm land | 140.91 | 22.94 | 163.85 | 184.22 | 51.02 |
| 47. | Hrt. & Afe. farm land | 116.82 | 19.02 | 135.84 | | |
| 48. | Hrt. & Afe. farm land | 130.40 | 21.23 | 151.63 | | |
| 49. | Hrt. & Afe. farm land | 135.56 | 22.07 | 157.63 | | |
| 50. | Hrt. & Afe. farm land | 224.15 | 36.49 | 260.64 | | |
| 51. | Hrt. & Afe. farm land | 202.74 | 33.00 | 235.74 | | |
| 52. | Residential area | 89.76 | 14.61 | 104.37 | 88.15 | 64.10 |
| 53. | Residential area | 190.69 | 31.04 | 221.73 | | |
| 54. | Residential area | 230.26 | 37.48 | 267.74 | | |
| 55. | Residential area | 28.92 | 4.71 | 33.63 | | |
| 56. | Residential area | 62.56 | 10.18 | 72.74 | | |
| 57. | Residential area | 43.23 | 7.04 | 50.27 | | |
| 58. | Residential area | 142.52 | 23.20 | 165.72 | | |
| 59. | Residential area | 63.86 | 10.40 | 74.26 | | |
| 60. | Residential area | 108.13 | 17.60 | 125.73 | | |
| 61. | Residential area | 51.68 | 8.41 | 60.09 | | |
| 62. | Residential area | 30.56 | 4.97 | 35.53 | | |
| 63. | Residential area | 99.53 | 16.20 | 115.73 | | |
| 64. | Residential area | 90.63 | 14.75 | 105.38 | | |
| 65. | Residential area | 39.33 | 6.40 | 45.73 | | |
| 66. | Residential area | 81.55 | 13.28 | 94.83 | | |
| 67. | Residential area | 50.25 | 8.18 | 58.43 | | |
| 68. | Residential area | 34.18 | 5.56 | 39.74 | | |
| 69. | Residential area | 48.49 | 7.89 | 56.38 | | |
| 70. | Residential area | 13.61 | 2.22 | 15.83 | | |
| 71. | Residential area | 24.63 | 4.01 | 28.64 | | |
| 72. | Residential area | 67.79 | 11.04 | 78.83 | | |