The Contribution of Institutional Forests to Climate Resilience: In EiABC and College of Natural and Computational Science at Addis Ababa University

BY

Hanan Awel Ahmed

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY, ETHIOPIAN INSTITUTE OF ARCHITECTURE, BUILDING CONSTRUCTION AND CITY DEVELOPMENT (EiABC) FOR THE PARTIAL FULFILLMENT OF THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL PLANNING AND LANDSCAPE DESIGN

February 2025
Addis Ababa, Ethiopia

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, Ethiopian Institute of Architecture, Building Construction and City Development (EiABC) for the Partial Fulfillment of the Degree of Master of Science in Environmental Planning and Landscape Design

DECLARATION

I, Hanan Awel Ahmed, the undersigned, declare that this thesis is my own and original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been appropriately recognized, following the scientific guidelines of the institute.

Declared

By

Hanan Awel Ahmed

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Date & Signature

Statement of Certification

This is to certify that the thesis carried out by **Hanan Awel Ahmed** on the topic entitled "*The Contribution of Institutional Forests to Climate Resilience: In EiABC and* College of Natural and Computational Science *at Addis Ababa University*" is her original work and appropriate for submission for the award of Masters of Science Degree in Environmental Planning and Landscape Design.

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ADDIS ABABA UNIVERSITY

ETHIOPIAN INSTITUTE OF ARCHITECTURE, BUILDING CONSTRUCTION AND CITY DEVELOPMENT (EIABC)

ENVIRONMENTAL PLANNING PROGRAM

The Contribution of Institutional Forests to Climate Resilience: In EiABC and College of Natural and Computational Sciences at Addis Ababa University

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ACKNOWLEDGMENT

Above all, I would like to express my deepest gratitude to almighty God for giving me the courage and strength to finish this phase of my life. There were a number of people; without them, this thesis might not have come to an end.

First and foremost, I would like to express my sincere gratitude and heartfelt thanks to my advisor, Dr. Hayal Desta (Ph.D.) for his encouragement, constructive comments, valuable advice, support, and experience sharing from the very beginning of my study to the end. His office door was always open whenever I had a question about my research writing.

I express my honest and sincere gratitude toward my family for their encouragement, support, unlimited love, understanding and patience throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Special thanks to Mr. Zewdu Yilma, who has helped me conduct the data collection process professionally and got all the necessary material support for the field data collection. I am also thankful for all the support and enthusiasm from my colleagues and my classmate.

I would like to forward my profound honor to Addis Ababa University and Ethiopian Forest Development (EFD) for the financial support throughout my study. Lastly, the appreciation goes to everyone who helped me and shared their precious time and energy; I did not mention their names, “Thank you all.”

ABSTRACT

One of the important strategies to address climate change concerns is to improve urban green spaces as an alternative for climate resilience. Thus this study was conducted to evaluate the contribution of forests on the EiABC Campus and the College of Natural and Computational Sciences at Addis Ababa University. Species diversity, Carbon stock potential, and Temperature are the parameters used to assess the contribution of forests in the campuses. Data on the vegetation were collected using a purposive sampling technique. The forest composition revealed a total of 2,641 individual trees, representing 69 species from the all live woody trees that are found in the site under ≥ 5 cm (DBH). Diversity of plant species was examined using the Shannon-Weiner Index and evenness metrics, indicating high woody species diversity based on established standards. The population structure, analyzed through height and diameter class distributions, displayed an inverted J-shape, suggesting a stable population. Carbon stock analysis of the biomass was conducted using the general tropical dry forest biomass regression equation. The results showed a total carbon stock of 92.14 t/ha and 151.60 t/ha for the two sites, with 76.78 t/ha and 15.36 t/ha in the above-ground and below-ground biomass, respectively, at EIABC, and 126.3 t/ha and 25.27 t/ha at the College of Natural and Computational Sciences. Temperature measurements taken inside and around the study sites revealed that the vegetation significantly reduced local temperatures. Overall, the results highlight the stability and productivity of the forests. From the perspective of reducing the effects of climate change and protecting biodiversity, it is recommended that these forests be sustainably managed and protected to ensure ongoing carbon sequestration and biodiversity conservation.

Keywords: *Urban Green, Climate Resilience, Species Diversity, Carbon Stock, Biodiversity Conservation, Addis Ababa University*

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LIST OF ACRONYMS AND ABBREVIATIONS

COP Conference of the Parties

CRC	Climate Resilience City
DBH	Diameter at Breast Height
GHG	Greenhouse Gas
GI	Green Infrastructure
IPCC	Intergovernmental Panel on Climate Change
MEA	Millennium Ecosystem Assessment
NO2	Nitrogen dioxides
O3	Ozone
^{o}C	Celsius
PM	Particulate Matters
PM10	Particulate Matters < 2.5 and >=10 µ
SDG	Sustainable Development Goal
SO2	Sulfur dioxide
TB	Total Biomass
TC	Total Carbon Stock
TON/H	Ton per Hectare
UGI	Urban Green Infrastructure
UHI	Urban Heat Island
UN	United Nation
UNDESA	United Nations Department of Economic and Social Affairs
USEPA	US Environmental Protection Agency

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Numbers of people living in cities are growing quickly as a result of the global increase in urbanization. According to projections made through the UN over 60% of people on earth are predicted to settle in urban areas by 2030 (UN, 2018). Air pollution, the strengthening of the heat island effect, the a decline in biodiversity, urban green spaces and ecosystem services are some of the local environments that are being negatively impacted by the world's fast urbanization and population growth (Gelan and Girma, 2021).

These growing cities account for 70% of greenhouse gas emissions (IPCC*,* 2022). Among GHG, carbon dioxide (CO2) is the most dominant. It has gained international recognition as a primary cause of global warming. It is mostly produced by burning carbonaceous materials used in transportation, power, and domestic activities (Kasim *et al.,* 2018). The "greenhouse effect" is the result of high concentrations of CO2 and other gases trapping heat in the atmosphere and preventing it from escaping into space (American Planning Association, 2007).

Currently, cities are net producers of greenhouse gases (Velasco and Roth, 2010). Future city-based GHG emissions will continue to rise due to urbanization trends. In order to stop this trend, cities must adopt more sustainable practices (Tammeorg *et al.,* 2021). The US Environmental Protection Agency released a report noted that greenhouse gases (GHGs) have an impact on both global warming and human well-being (Kasim *et al.,* 2018).

The connection between poor air quality and climate change has attracted scientific community interest, making it a pressing issue that is creating political and economic challenges on a global scale (Andreucci *et al.,* 2019). The United Nations Sustainable Development proposes a 3rd goal on the 2030 Agenda, to promote the well-being of all people from all ages to ensure a healthy lifestyle (Liu *et al.,* 2021).

According to UNFCC (2018) report the Treaty of Paris that was adopted by the UN Climate Symposium also provide to a multidimensional framework for the global economy's shift toward a low-carbon economy in 2015. Nearly all nations have established national goals for mitigating climate change and committed to implement actions to meet these targets. The COP27 Symposium also indicates that Africa and developing nations worldwide can no longer rely on mitigating the climate crisis. For survival and growth, they must adapt and develop resilience (Global Climate Action, 2022). In response, Ethiopia also further decreased its greenhouse gas emissions, seeking to attain net-zero emissions (climate neutrality) by 2025 (Zwick, 2018).

There is plenty of evidence that polluted environments affect human health. On the other hand, a quality environment could be health-promoting and even therapeutic (Douglas *et al.,* 2020). Several investigations have revealed that components of urban green infrastructure can supply essential ecosystem services to urban environments that have deteriorated ecologically (Gelan and Girma, 2021). Urban Green Infrastructure (UGI) generally denotes a carefully planned, linked network of green spaces with ecological variables that offer multiple uses and conserve biodiversity (Benedict and McMahon, 2002; Pitman *et al.,* 2015).

Parks, gardens, street trees and informally defined green spaces like rivers, forests (both natural and planted), grasslands, marshes, vegetable farms, and croplands are examples of green spaces. Green space ownership may be private, public, or institutional (Gelan and Girma, 2021). Globally, UGIs are becoming a widely adopted tactic to address the problems brought by urbanization. It is currently recognized as a different, affordable, and nature-based solution to these adverse effects (Kabisch *et al.,* 2017). It is becoming more widely acknowledged as being essential to enhance urban environments' resilience (Pitman *et al.,* 2015).

Exposure to nature through urban vegetation improves the standard of living and welfare of people. To adapt to and lessen thermal consequences of both local and global warming processes, green spaces may thus be required to be blended into building construction and urban planning (Feyisa *et al.,* 2014). Further reducing the quantity of pollutants in the atmosphere is the expansion of well-vegetated areas in both size and quantity. Research indicates that in just a single year, an acre of trees can sequester carbon dioxide equivalent to the emission of a car driving 11,000 miles (American Planning Association, 2007).

1.2. Statement of the Problem

Quick expansion of cities because of modernization has caused populations to choose urban areas over rural areas. This results in denser urban areas with a decreased amount of green outdoor spaces (Peschardt and Stigsdotter, 2014; Pouya, 2017). Natural resources in and around cities are in crisis mainly because of climate change, which is connected to a global decline in tree cover as a result of urbanization and its aftereffects (Guadie *et al.,* 2022; Pregitzer *et al.,* 2022).

A number of difficulties with mental health and public health threats are being identified as a result of climate change (Andreucci *et al.,* 2019). In the absence of significant mitigation measures, it is projected that mortality from ambient air pollution alone will likely rise by 50% or more by 2050 (Lelieveld *et al.,* 2015). It is becoming the most urgent issue of the 21st century (Andreucci *et al.,* 2019).

Air pollution has countless adverse impacts on the environment, the welfare of people and the economy. According to the World Bank, air pollution lowers quality of life by causing illness and premature death. Among the most challenging and demanding problems of the twenty-first century is promoting the health of the urban population (Ignatieva and Dushkova, 2020).

Residents in these areas frequently lead stressful lives, which raises the risk of several stress-related illnesses (Peschardt and Stigsdotter, 2014). By directly or indirectly causing climate change, a wide variety of short-lived air pollutants, including CO2, have an adverse effect on ecosystem well-being and human welfare (Kasim *et al.,* 2018).

The consensus is that emerging nations are easily and adversely influenced by climate change because they have the least ability to adapt to these changes (Srivastava, 2015). Ethiopia's fast urbanization and population expansion are putting the country in a position where its urban communities are becoming more demanding. Without carefully designed green infrastructure, the majority of the towns and cities have grown quickly, leading to environmental issues like rising temperatures, rising greenhouse gases and water and air pollution (Hunegnaw, 2017).

A number of factors, including road dust, pollution from vehicles and factory development, large-scale construction and general methods of land use decrease the air quality in Addis Ababa

(Guta, 2019). In Addis Ababa, the concentrations of outdoor air pollutants, including CO, PM10, NOx, and PM2.5, were found to be surpassing 50% of the WHO recommended limit (Nahimi, 2019).

According to Kumie *et al.* (2010) nitrogen oxide, carbon monoxide, and particulate matter become primary causes of polluted air in the capital city. There is a connection between exposure to pollutants and environmental-related illnesses, such as heart attacks, strokes, lung cancer, and acute and chronic respiratory conditions, as well as headaches, vertigo, immune system and reproductive system disruption, and early mortality (Shetty, 2023).

Knowing about how different landscapes and landscape factors affect the climate and health improvement. Landscape can be seen as the mitigation process in which health and well-being can be achieved through the sustainability process. Unfortunately, as a result of increased human population, many cities are experiencing a decline in green spaces and open areas due to development pressures (Bekele, 2021).

To provide new planning solutions concerning climate mitigation in the landscape is crucial. However, the environmental aspect of green areas has not been properly taken into consideration (Pouya, 2017). The green spaces development, management and conservation in Addis Ababa are distinguished by their simple, chaotic, and reactive goals (Woldegerima, 2016).

Recently, research on climate change and evaluations of forests' potential for carbon stock in the developing countries has focused on church forests, parks, and other green areas by Tura et al., (2011), Tefera and Soromessa (2015) and others. However, institutional forests contribution to climate resilience and its implication in carbon sequestration have received little or no attention. Accordingly, this research examined the contribution of institutional forests for ambient air quality in Addis Ababa, as well as its consequences for climate change implications to the urban livability and climate change.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study is to assess the contribution of institutional forests at EiABC and College of Natural and Computational Sciences of Addis Ababa University to enhancing climate resilience.

1.3.2. Specific objectives

The study has the following specific objectives:

- To analyze the diversity, structural characteristics, and species composition of woody vegetation within the institutes' forests.
- To quantify the carbon stock potential of the two institutional forests.
- To analyze and compare the temperatures inside the institutes' forests with those in the surrounding areas.

1.4. Research Questions

- What is the diversity, structural composition, and species distribution of woody vegetation within the institutes' forests?
- What is the carbon stock potential of the two institutional forests?
- How do temperatures inside the institutes' forests compare with those in the surrounding areas?

1.5. Scope of the Study

The geographical extent of this study is restricted to Addis Ababa University, specifically the Ethiopian Institute of Architecture, Building Construction, and City Development (EIABC) Campus and the College of Natural and Computational Sciences. Thematically, the research focuses on analyzing the vegetation diversity, structural characteristics, and species composition of the university's forests while assessing their contribution to temperature regulation and their potential in carbon storage.

1.6. Significance of the Study

This study provides valuable knowledge about institutional forests. It magnifies the environmental roles of institutional compounds, unlike its educational values. Furthermore, the study indicates the significance of institutional forests in increasing diversity of species, regulating air pollution through carbon storage and regulating temperature that enhance the process of providing a healthy environment. It will also draw valuable concepts about the conservation of green areas and urban forests in institutes. Moreover, it will be a guideline to professionals and officials who are responsible for the policy, plan preparation, and implementation of urban green spaces.

1.7. Limitation of the study

There are certain difficulties encountered during this study. Finding the botanist and certain data collection tools on the same schedule is one of the difficulties. The other difficult issue was the absence of communication among campus administration. Security personnel’s ask "what are you doing and where is your permission for these field inventory?" during the data collection process, which causes the progress to be delayed. Additionally, it was difficult to arrange the third objective, which is to record temperature data, because it primarily depends on the seasons; waiting for the right season prolongs the study's completion time.

1.8. Organization of the Study

There are six chapters in this paper.

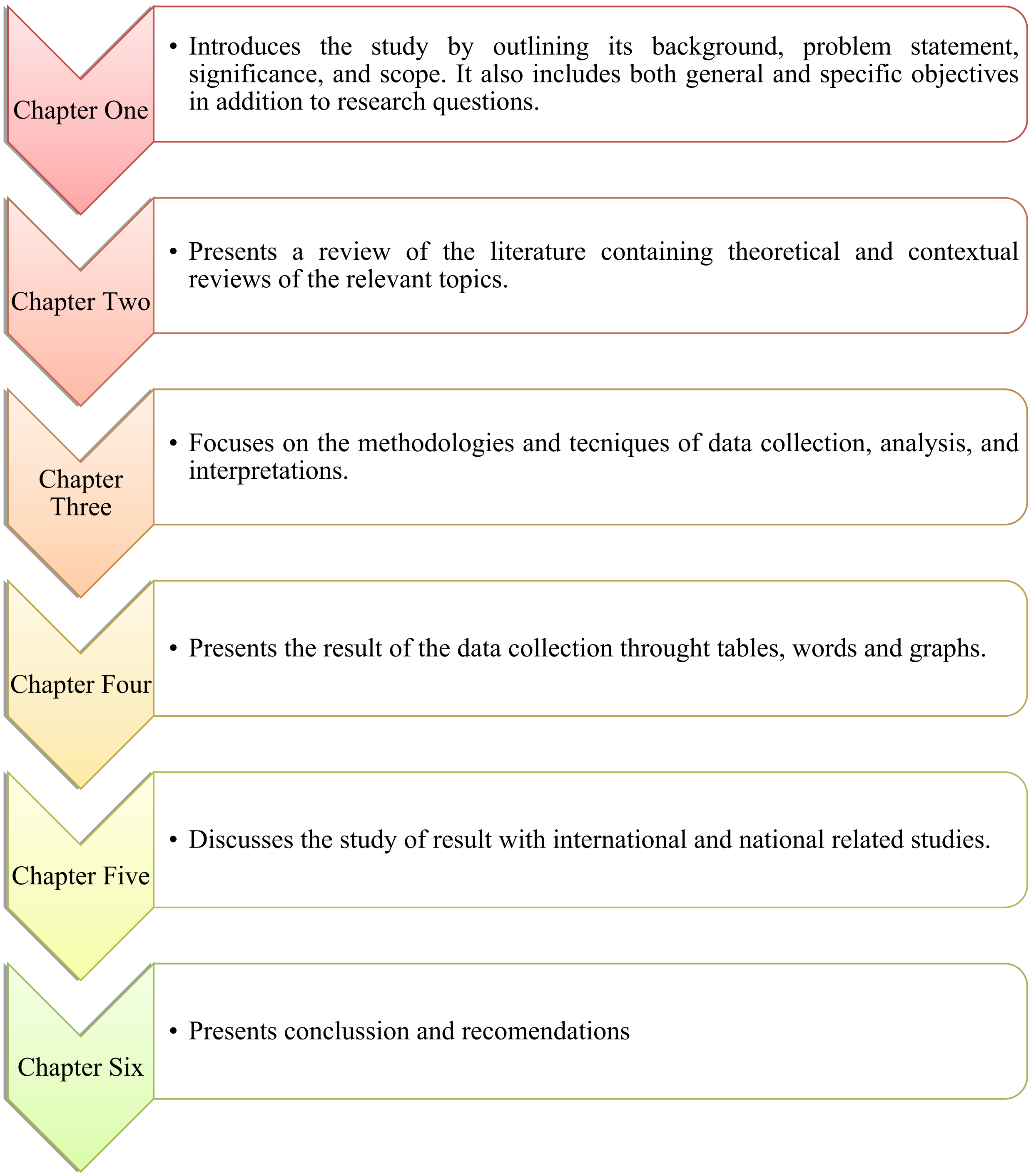

Figure 1.Organization of the study

CHAPTER TWO

2. LITERATURE REVIEW

This chapter comprises definitions and concepts of green areas in detail. It explains the relationship between green areas and climate resilient cities. It covers the benefit of green areas, mainly focusing on climate mitigation through carbon reduction and temperature regulation.

2.1. Definition and Brief Concepts of Terminologies

Climate Change

The term "climate change" refers to the intensity in the frequency and severity of extreme weather events. Particularly developing and low-income groups are the most at risk from climate-related disasters. The entire life systems are mainly affected; mostly it affects the primary production by changing the moisture regime, availability of nitrogen, and duration of growing season in an environment, among other factors (UN, 2016).

The earth's climate system is heavily affected by greenhouse gas emissions (IPCC, 2007). Changes in temperature have more significant effects than any other factor. Its effects on plants and ecosystems are complicated.

‘‘In the environments that contain greater CO2, plants either keep their stomata closed more frequently or open them less widely’’ (Betts et al., 2007). ‘‘There is a reduction in the short-term photosynthetic response following eventual acclimatization to increased CO2. Extended exposure to high CO2 causes the plant's photosynthetic tissues to accumulate carbohydrates, which lowers photosynthetic rates’’ (Bisgrove and Hadley, 2002).

Resilience

In the 1970s, C.S. Holling was the main person who coined and stated the term "resilience" in the field of ecology. “Resilience determines the persistence of relationships within a system and it is a measure of the ability of these systems to absorb the change of state variable, driving variable, parameters, and still persist” (Ahmed, 2006). In order to survive crises, cities must be prepared to withstand future shocks and stresses brought on by climate change while surviving emergencies. For a city to be more resilient, the right infrastructure must be in place (Janet, 2003).

In the direction of this study, the capacity of a vegetation community to bounce back or adjust to subsequent destructions is known as resilience. It additionally functions as a natural consequence of systems functioning at the levels of organism, population, and community interaction (Falk *et al.*, 2022). Increase the resilience of cities while reducing the effects of climate change (Guadie *et al.*, 2022).

Urban forestry

Urban forestry is the term used to describe the whole forest area that is impacted by the urban population. In a more limited sense, it has more to do with trees and forests, or newly formed forests, on abandoned and undeveloped land (Kuchelmeister, 2000). Thus, green belts, parks and gardens, commercial and factory green belts, zoological parks, wooded areas, avenues, and boulevards are all examples of urban forests (Chaudhry and Tewari, 2012).

Green infrastructure

A system of interconnected, adaptable green spaces, carefully planned and maintained, that offer a variety of ecological, social, economic, and cultural advantages is referred to as "green infrastructure" (GI).

Green space typology

Green spaces in the city are available in a wide range of patterns, forms and varieties for the purpose of classifying them based on their purposeful utilization, dimensions, greenery, place, shape, magnitude, and landscape context. Specifically, the classification may vary considerably based on the purpose of green space typologies (Alberti, 2005).

Biodiversity

Biodiversity is a quantifiable parameter to recognize the ecosystem functions, community structure and environmental processes (Dyke, 2008). It is the variation found in all living things. It appears both within species and between species and ecosystems (Keven and John, 2004).

Carbon pool

Carbon pools are structures that possess the ability to gather or discharge carbon content. Forest biomass, wood products, soils and the atmosphere are examples. A mass of carbon in a carbon pool is called its carbon stock (Genene *et al*., 2013).

Biomass

The mass of living or dead organic matter is referred to as biomass. The amount of biomass can be expressed as a percentage of nitrogen, carbon, or dry weight. When determining adaptation as well as mitigation strategies, a worldwide evaluation of biomass and its dynamics is a crucial input into climate change forecasting models (Genene *et al*., 2013).

Climate Resilience

Climate resilience is defined as an infrastructure that is planned, constructed, operated, and maintained so as to adapt physical risks that are linked to changing climate conditions and their implications (Long Term Infrastructure Investors Association, 2022).

A city that possesses the capacity to effectively adapt, mitigate, and manage the consequences of climate change is called a climate resilience city (Navata, 2021). Planning and preparation by society and the municipality for climate consequences has to be strengthened. According to the premise behind the Climate Resilience Cities (CRC) initiative, in order to advance a climate resilient city, are listed below.

- Climate finance has to effectively organize at the local level.
- In order to manage, conserve and restore the environment, cities must implement and oversee strategies based on natural based climate solutions.
- Considering the full use of stakeholder participation and the most recent data, research, and best practices related to climate change.

Following that, cities will guarantee increased resilience to manage the consequences of natural calamities related to climate change (Navata, 2021).

Climate Resilience Development

The goal of climate resilient development (CRD) is to promote universally sustainable development. It includes adaptation strategies and the practice of greenhouse gas mitigation. Sustainable development and climate action are related processes. When this relationship is leveraged, CRD will increase. The key systems for accomplishing CRD are resources, a piece of land and the natural world, cities and amenities and factories (IPCC, 2022).

CRD also strengthens the capacity for climate action by facilitating the implementation of adaptation strategies and assisting in decreasing greenhouse gas emissions. Opportunities for improving social, financial and ecological resilience are provided by CRD (IPCC, 2022). According to Pichola *et al.* (2021) there are five lenses of climate action in building climate resilient cities listed as a multidimensional approach to climate change action.

Figure 2.1 Multidimensional approaches to climate change action

Source: Pichola *et al.,* 2021

Every essential component of resilience (persistence from stress like fire and drought, recovery with young generations, reorganization through win-win benefit and dominance) comprises a number of systematic processes that must be understood in order to assess and predict ecosystem reactions (Falk *et al.*, 2022).

2.2. Advantages of Urban Green Infrastructure

Urban green spaces are used to reduce threats to the environment, human disturbances, and the effects of urban heat islands with the aim to increase the resilience of urban areas (Berhan, 2016). They provide a platform for environmental education, assist in reducing the consequences of climate change, raise the area's air quality, support biodiversity, boost economic development, maintain social integration and provide spaces for kids' play and leisure (Campbell, 2001). These benefits are structured through social, environmental and economic benefits (Chaudhry and Tewari, 2012).

2.2.1. Environmental benefit

In terms of ecology, UGI's function is to protect biodiversity and improve natural processes that aid in water penetration, flood water absorption, shading and windbreak tasks, lowering the effects of urban heat islands (Sandstrim *et al.,* 2006; Tzoulas *et al.,* 2007).

UGI offers habitat corridors for a variety of creatures, including birds. It reduces habitat loss and improves habitat settlement throughout the terrain by establishing connectedness (Rudd *et al.,* 2002). Further, it safeguards urban ecosystems' vitality (Tzoulas *et al.,* 2007).

Moreover, the large scale of waste handled and recycled to organic waste as compost in urban green areas (Werquin *et al.,* 2005). UGI is essential for controlling climate and managing water resources. It acts as a lung for the city by controlling flooding, holding onto precipitation, cleaning contaminated water, and regulating the temperature by discharging oxygen and taking in pollutants (Mohammed and Zhirayr, 2013). Hamada and Ohta (2010) claim that the heat island effect is lessened when paved yards are replaced with urban green areas, as evidenced by the fact that the land surface temperature drops as green spaces grow.

2.2.2. Social benefits

The advantages of UGI that provide for the communities and social well-being are called social benefits. It includes health, educational, social interconnection, recreational benefits and cultural (Lee and Hong, 2013).

The existence of UGI has a favorable impact on the emotional and physical well-being of the urban community (Maas *et al.,* 2009). The advantages for health include relaxation, stress reduction, and personal endurance (Lee and Hong, 2013). Basically, urban parks provide a space for physical activity, which benefits the physical health of people. Moreover, taking in the scenery in parks can lead to improved mental and physical wellness. Research indicates that it lessens stress. Likewise, having a view of the outdoors reduces stress from work, lowers illness, and increases motivation for work (Maller *et al.,* 2006).

For a variety of experts, including environmentalists, biologists, social scientists, and geographers, well-established UGIs can act as labs. Additionally, students can do better academically if they have access to or are provided with natural environments inside the educational environment (Razem, 2021). UGI also provides social cohesion and recreational activities. They provide possibilities for physical enjoyment and relaxation as well as places for social contact (Mpofu, 2013).

Additionally, UGI enriches culture by offering spaces for regional theater productions, festivals, and civic events. Bring people from diverse racial and socioeconomic backgrounds together in a cohesive manner (Mpofu, 2013). Therefore, from a social standpoint, suitable forms of green space can provide a higher diversity of land uses and chances for a variety of activities that can support active urban lifestyles (Guta, 2019).

2.2.3. Economic benefit

"The total amount of welfare that UGI generates for society" is called the economic benefits of UGI (Rodenburg *et al.,* 2001). Direct, indirect, and symbolic values can all be used to determine the economic impact of UGI. Paying for recreational or sporting facilities is considered a direct advantage. Indirect benefits include the positive effects of good health, a low crime rate, commercial prospects, and symbolic values that speak of a feeling of place in the designated area (Abdullah *et al.,* 2011).

Direct advantages were identified in the areas of wood production, recreational services, urban agriculture, urban horticulture, and other market-priced goods. Indirect benefits, or those with no market value, include energy conservation, public health protection, environmental control, and the improvement of the local and regional economy through tourism, investment, and human resources. Businesses can also benefit from increased worker productivity and customer attraction (Tyrvinen *et al.,* 2005).

Additionally, the quality, quantity, and layout of a neighboring park affect the market value of the nearby houses (Crompton, 2001). In the case of real estate and apartments, the project land developers get financial returns between 5% and 15% (Heidt and Neef, 2008). Studies show that people place a higher value on green areas like parks for recreation than they do on forests and agricultural land (Brander and Koetse, 2011).

2.3. Urban Green Infrastructures and Ecosystem Services

A benefit people get from the ecosystem is called Ecosystem service. There are four categories into which it is divided: provisioning, regulating, cultural, and supporting, from which, the supporting service is regarded as a basis for the rest services of categories (Reid *et al*., 2005).

Four ecosystem services are listed in the Millennium Ecosystem Assessment (2005) as

- Providing fresh water, fuel, food, and genetic resources are examples of provisioning services.
- The protection against soil erosion, carbon sequestration and storage, water filtration, pest management, air quality maintenance, and temperature regulation are all included in the regulating service.
- The spiritual experiences and aesthetic facets of an individual's general well-being are covered in the cultural services.
- Services support for habitat to preserve nutrient cycles, primary production, soil formation, and species diversity are embraced as supporting.

According to Lindner (2020) resilient ecosystem service for temperate forest landscape indicators are above-ground biomass, total carbon stock, recreation value, tree species and others.

2.3.1. Regulating services

2.3.1.1. Air purification

The primary issue affecting human health and environmental quality in metropolitan areas is air pollution. Polluted air from domestic heating, industry, transportation, and solid urban waste causes to respiratory and cardiovascular diseases. The air quality of the urban system improves with the presence of vegetation (Edeigba *et al.,* 2024). Pollutants such as sulfur dioxide (SO2), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and particulate matter smaller than 10 µm (PM_{10}) are eliminated from the atmosphere by these plants (Xian *et al.,* 2022).

While in the process of removing pollutants, the performance of the vegetation depends on the species diversity. Species and leaf surface diversity may affect the arrangement of different sizes of particle fractions (Dzieranowski *et al.,* 2011). Their leaves help in filtering out airborne particulates (Diener and Mudu, 2021).

2.3.1.2. Temperature regulation

Urban heat island effects are mitigated by ecological infrastructure. In summer, water areas absorb heat, and in winter, they release it; therefore, they act as a buffer against temperature extremes (Chaparro and Terradas, 2009). Along with offering protection and removing heat from the atmosphere through evapotranspiration, vegetation also lowers temperature during the warmest months (Baggethun and Gren, 2013).

When plant water evaporates, it absorbs heat and cools the surrounding air (Nowak and Crane, 2000). While trees shade surfaces like sidewalks and roadways that would otherwise absorb heat and reflect solar radiation, they also help control the local surface and air temperatures. Reducing the city's temperature loading is the foremost important regulating ecosystem service trees provide to urban areas (McPhearson, 2011).

Forest ecosystems provide resilience to the entire system by helping to regulate the climate (Forzieri et al., 2022).

Therefore, even though it's evident that green spaces can help reduce heat and climate through seasonal difference, daytime and nighttime variation, the green cover's dimensions and form, and plant placement and choosing are variability linked to measurement on site (Wong *et al.,* 2021).

2.4. Biodiversity

2.4.1. Significance of biodiversity

In terms of ecology, a decrease in resilience of necessary forest services is being caused by a fall in biodiversity (Brockerhoff *et al.,* 2017). One component of ecosystem resilience is species diversity. Due to the ecological levels being interlinked, adjustments at one level have a ripple effect at another. For example, alterations in the environment affecting a single species might lead to adjustments in population size, which in turn impacts the distribution, composition, and structure of the community. Although the ecological context acts as a mediator, these alterations have the potential to affect entire ecosystems (Oliver, 2015). The most important aspect of biological variety in the context of protecting the environment is species diversity (Yilma, 2016).

Biodiversity declined as a result of trophic complexity and functional variety disappearing, creating a risky feedback loop that endangers ecosystems. Consequently, it makes ecosystems less able to withstand changes in the environment, which may lead to additional declines in biodiversity (Cantarello *et.al,* 2024). Understanding how biodiversity affects the ecological health of forests and their resilience to climate change requires taking functional diversity into consideration (Fischer *et al*., 2006).

Therefore, enhancing resilience to the biodiversity crisis by maximizing the protection of conservation features is important. Lowering the stresses that combine with disruptions caused by climate change, tree mortality, an insect outbreak, and threshold effects that are speeding up the loss of most ecosystem services and biodiversity will help increase resilience to the biodiversity crisis linked with forests (Cantarello *et.al,* 2024).

- Resilience to biodiversity crisis
- Functional diversity

Figure 2.2. Actions that can enhance the resilience of forest

Source: Cantarello *et al.,* 2024

One of the primary approaches to improving the climate change resistance of forests is to lessen the effects of more extreme disturbances, such as insect outbreaks or wildfires (Seidl *et al*., 2016). Effective methods for regeneration are also crucial because, assuming the recruited populations survive, they can trigger a self-replacing composition (Lloret *et al*., 2012).

2.4.2. Plant species diversity

Species diversity indicates the quantity of species and their proportional abundance within a community. A variety of ecosystem functions like productivity and stability are influenced by plant species diversity (Ganaie and Reshi, 2021). It is one of the main manuals for prioritizing conservation efforts and using sustainable land use techniques (Teshager, 2017). The description of a vegetative community includes an investigation of species richness, evenness, and similarity (Roswell *et al.,* 2021).

Species abundance is defined by the number of plants with variation and changes per given area. These variations are due to the environmental conditions. It is mainly affected by abiotic and biotic factors (Evans *et al.,* 2014). The amount of distinct species found in a region is an extent of species richness, not the relative abundance of those species (Roswell *et al.,* 2021).

Both richness and abundance are the diversity index to measure a given community's species diversity. A popular metric for assessing the variety of woody species is the Shannon Wiener diversity index (Omayio and Mzunugu, 2019).

2.5. Climate Change and Carbon

2.5.1 Effects of greenhouse gases

Greenhouse gases include ozone, carbon dioxide, methane, water vapor, nitrogen oxide and halocarbons. These gases cause Earth's surface to warm by absorbing solar light and reemitting it (Filonchyk, 2024). The process of greenhouse gases collecting long wave radiation and reemitting it to warm the Earth's surface is called the greenhouse effect. The more of these gases there are in the atmosphere, the warmer the Earth's surface gets (IPCC, 2001).

In the last 250 years, atmospheric concentrations of CO_2 have increased by 31%. These greenhouse gases increased with human activity and resulted in an abnormal temperature rise. According to projections, the average global temperature would grow by 1.4 ºC to 5.8 ºC before the century is over. The lifetimes of these gases in the atmosphere are prolonged. CO2 takes over a century to balance after it is released into the atmosphere. It is among the most prevalent greenhouse gases and primary causes of global warming (WHO, 2010).

2.5.2. Global Carbon Cycle and Forest

There are various ways that anthropological activities release carbon as carbon dioxide. Because of photosynthesis, forests are essential to the carbon cycle under these situations. The fundamental method through which plants take in carbon dioxide from the environment and change it into various forms is called photosynthesis (Kassahun, 2014). Due to proper management, forests may be huge carbon sinks and have a considerable influence on climate change (Singh, 2005).

Due to respiration, combustion, and decay, forests act as carbon sinks. However, certain actions, such as deforestation, forest fires, and degradation, serve as carbon sources. As such, forests have the ability to change over time according to the type of activity they are engaging in; they can change from serving as a source to a sink of carbon (Genene *et al.,* 2013).

2.6. Urban Forest and Carbon Storage

It is anticipated that once a significant amount of greenhouse gases are released into the atmosphere, the surface temperature of the earth will increase (IPCC, 2007).

> *''Urban trees and forests are frequently ignored despite their impact on climate change and their ecosystem services are not well understood or quantified'' (Nowak et al., 2013).*

According to studies, urban forests and green areas are important for absorption and keeping carbon in major cities (Strohbach *et al.,* 2012). Other studies indicate that forestry practices have a major role in lowering the quantity of CO2 discharged into the surrounding air globally (Neilson *et al.,* 2006).

These trees contribute significantly to the regular collection, keeping and retention of carbon (Shafique *et al.,* 2020). Trees use a mechanism known as carbon sequestration to convert CO2 retention into biomass both above and below ground through photosynthesis (Nowak and Crane, 2002). Plants are the primary controllers of both local and global climates due to their ability to shrink CO2 from the surroundings through photosynthesis. By means of photosynthesis, plants are able to create plant tissues by converting carbon dioxide, water, and solar energy into carbohydrates. It plays the most significant part in reducing climate change (Woldegerima, 2016).

''As trees evolve, expire and decompose, the net long-term CO2 source/sink patterns of forests shift over time. Emissions from fossil fuels and the harvesting are examples of how human activities, in addition to forest management, can further impact the dynamics of forests'' (Nowak et al., 2013).

Several studies like (Malhi and Grace, 2000; Fearnside and Laurance, 2004) reported that forest sequesters and stores more carbon than any other terrestrial ecosystem. Others also highlighted that significant reductions in the global flux of CO_2 into the atmosphere can potentially be attained through forestry practices (Gustavsson and Sathre, 2006; Fahey *et al.,* 2010).

Therefore, evaluating urban forests' prospects and factual contribution to lowering CO_2 levels in the atmosphere is essential. It improved the process of making decisions about the administration and growth of urban forests through measuring their carbon (C) storage (Nowak and Crane, 2002).

Recently, both developing and developed countries are focusing on this area, particularly landscape planners. Therefore, the evaluation of urban forest carbon storage may offer several chances to enhance the structuring of urban development and carry out scientific investigations (Stoffberg *et al.,* 2010).

2.7. Methods of Measuring Biomass and Carbon Stock

The carbon pools in forest ecosystems are made up of organic matter in the soil, down woody debris and litter, and aboveground and belowground (IPPC, 2006; Genene *et al.,* 2013). Each pool's corresponding portion of carbon stocks is (15-30%) for Aboveground biomass and (4-8%) for Belowground biomass (Zerihun *et al*., 2012). The majority of carbon in tropical forests is stored in biomass, or vegetation, while a large portion of carbon is kept in soils in boreal forests (World Resource Institute, 2022).

2.8. Contextual Review

2.8.1. Ethiopia's urban forests' role in mitigating climate change

Addis Ababa's reliance on forest resources increased. As the amount of greenery began to decline, the city experienced decline in the environment, microclimate problems and subsidence of soil, which made deforestation worse. The Urban Agricultural Office estimates that Addis Ababa's vegetation coverage, encompassing particular trees in private yards /land around house/ is 7,900ha, or 14.6% of the total area. Eucalyptus makes up the majority of planted forests, which make up around 98%. There are still tiny areas of indigenous woodlands, mostly surrounding churches and guarded complexes, figured to be only 250 hectares in total (Horst, 2006).

Pollution of air rises in the role of result of increased motorization and economic activity brought on by rapid urbanization. The primary cause of urban air pollution, which is posing a high-risk to human wellness and the environment, is perceived as emissions from mobile sources. Air pollution in emerging cities like Addis Ababa is caused by both outdated and fast growing car fleets that are not properly maintained. Urban air pollution can also be attributed to a number of reasons, including inadequate or nonexistent of regulations concerning vehicle emissions (Daniel *et al.,* 2010).

The evaluation of Ethiopia's forest carbon stock potential initiated in the last few years. The findings of Tura (2011) from the Assessment of Church Forest in Carbon Stock Potential in Addis Ababa showed that forests can help mitigate climate change, with an average above-ground biomass carbon stock of 129.85 t ha-1.

2.8.2. Description of green infrastructure of Addis Ababa

The 2011 aerial photo shows the evaluation of Addis Ababa's green space by categorized into eight fields as presented in Table 1. The assessment states that the institutional forest coverage increased from 1598.8 hectares in 2011 to 1549.1 hectares in 2014. This shows a slight reduction; however, the institutional forest cover is 10% of the green spaces of Addis Ababa. Forests located on the grounds of governmental and non-governmental organizations fall under this group.

The tree and shrub species that make up this forest are a mix of indigenous and exotic. There is a lot of institutional forest cover in the grounds of the US, UK, Italy, France, and Germany embassies. The grand and national palaces of Ethiopia, compounds of the Ethiopian Orthodox Tewahedo church and various Campus of Addis Ababa University are from large cover that found institutional forest. Indigenous trees, particularly *Juniperus procera* and *Olea europaea*, as well as *Euphorbia candelabrum*, *Croton macrostachyus*, *Grewia amygdalina*, *Grewia auriculata*, and *Cordia africana*, are more prevalent in old Ethiopian Orthodox Church compounds. In fact, the city's institutional forest is predicted to have a higher level of biodiversity (Yeshitela, 2014).

Table 2.1. Coverage of Addis Ababa's green spaces by area in 2011 and 2014

No.	Green spaces	Area/ha/ in 2011	Area/ha/ in 2014
1	Field crop	14,578.3	9834.7
2	Vegetable farm	341.1	341.1
3	Public recreation parks	69.3	69.3
4	Riverside /riparian/ vegetation	1803.8	1535.8
5	Plantation forest	3372.8	3372.8
6	Institutional /mixed/ forest	1598.8	1549.1
7	Grass land	824.9	823.1
8	Street plantation	No data	No data
	Total green area	27112.3	21636.1

Note: Adapted from the article from Yeshitela, 2014.

Ethiopia envisioned becoming a middle-income and carbon-neutral economy by 2025. In addition, Addis Ababa wanted to create a secure, environmentally friendly, inclusive, and viable city that could function as an example for effective urban governance. Accordingly, the capital intends to construct sufficient urban parks in addition to other methods of development (Wondaferew, 2021).

The Urban Planning, Sanitation and Beautification Bureau states that ''the very traditional approach towards development of urban centers had contributed to the complex problems that halted the progress of green spaces in the city'' (Wondaferew, 2021).

2.9. Conceptual framework of the study

The conceptual model shows how to determine the goals of the study and respond to its research questions.

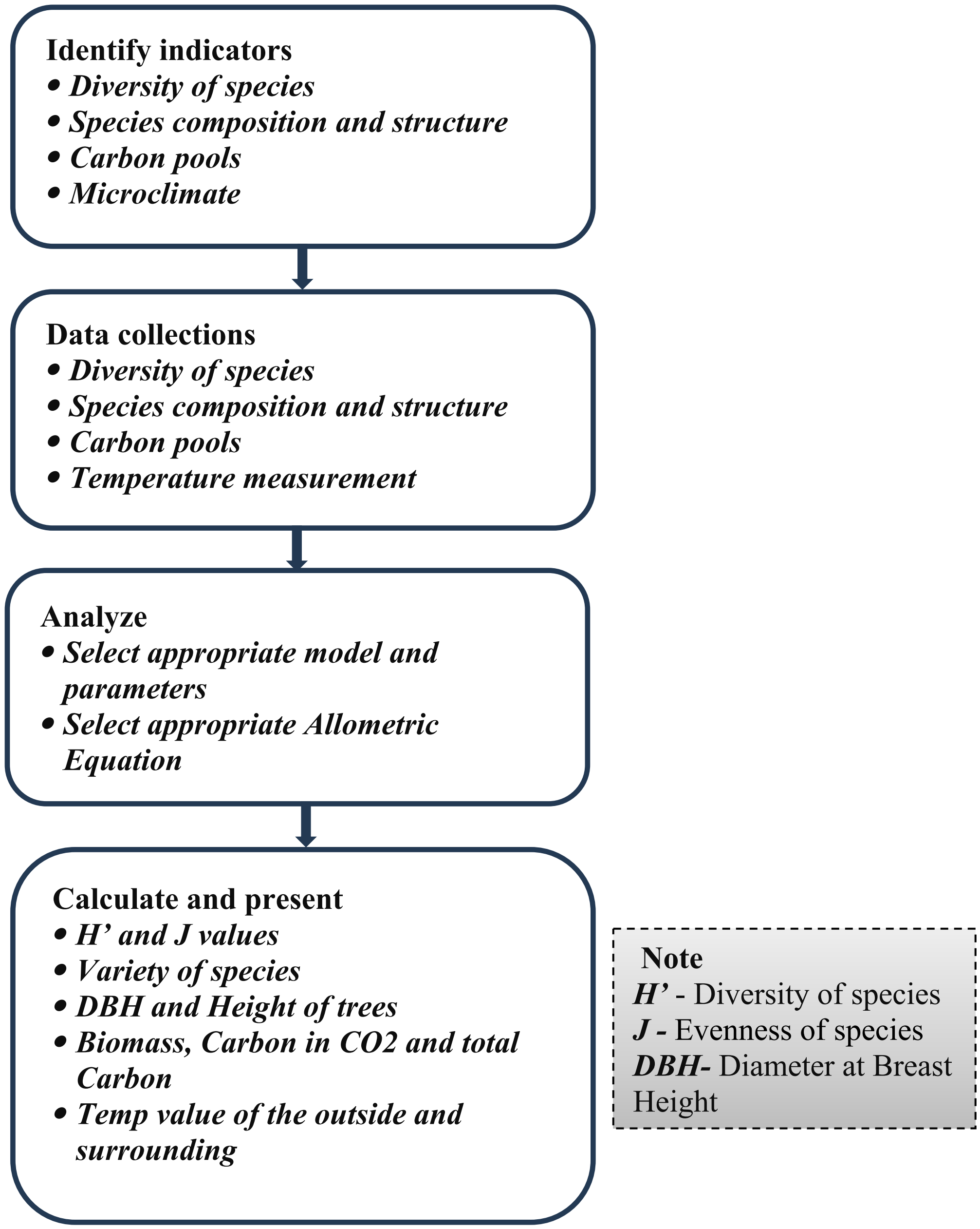

Figure 2.3. Conceptual frame work of the study

Source: (Own computation, 2024)

CHAPTER THREE

3. RESEARCH METHODOLOGY

This section describes the research design and methodology that is used to obtain the necessary information in answering the research questions. It describes how the data's were collected and monitored through different techniques. Lastly it describes how the analysis and presentation of the data was conducted.

3.1. Description of the Study Area

3.1.1. Site selection

Addis Ababa University is one of the higher education institutes found in Addis Ababa. It is the selected site for this study. It is selected due to a lack of research about the contribution of urban forests under the institutes, particularly campuses in Addis Ababa. The vegetation diversity and biomass content on some of Addis Ababa (churches, parks and embassies) are studied, whereas these institutes left without data on their contribution and vegetation characteristics.

Addis Ababa University is the oldest university in Ethiopia. It has 15 campuses from these campuses; the EIABC Campus and the College of Natural and Computational Sciences were selected under these criteria based on the reserved cost and time.

- Status: the study site should be dense vegetation cover on existing status in order to identify the vegetation's with different variables like diversity, structural composition and carbon stock.
- Location: the study site should be located within an active environment in order to measure its significant contribution to the surrounding environment.

3.1.2. Geographical location

The EIABC Campus and the College of Natural and Computational Sciences are the two AAU campuses where the study was carried out. The location of the EIABC Campus is in Lideta sub-city, woreda 4, Addis Ababa city. The geographical regions are: latitude: 9.013242°N; longitude: 38.730349°E. The campus is located between 2343 and 2378 m above sea level. It encompasses

7.8 hectares of land. While the College of Natural and Computational Sciences is in Arada sub-city, woreda 9, Addis Ababa city. The geographical regions are: latitude: 9.034623°N; longitude: 38.767066°E. The campus is located between 2434 and 2448 m above sea level. It encompasses 10.0453 ha of land. It is shown in Figures 3.1 and 3.2.

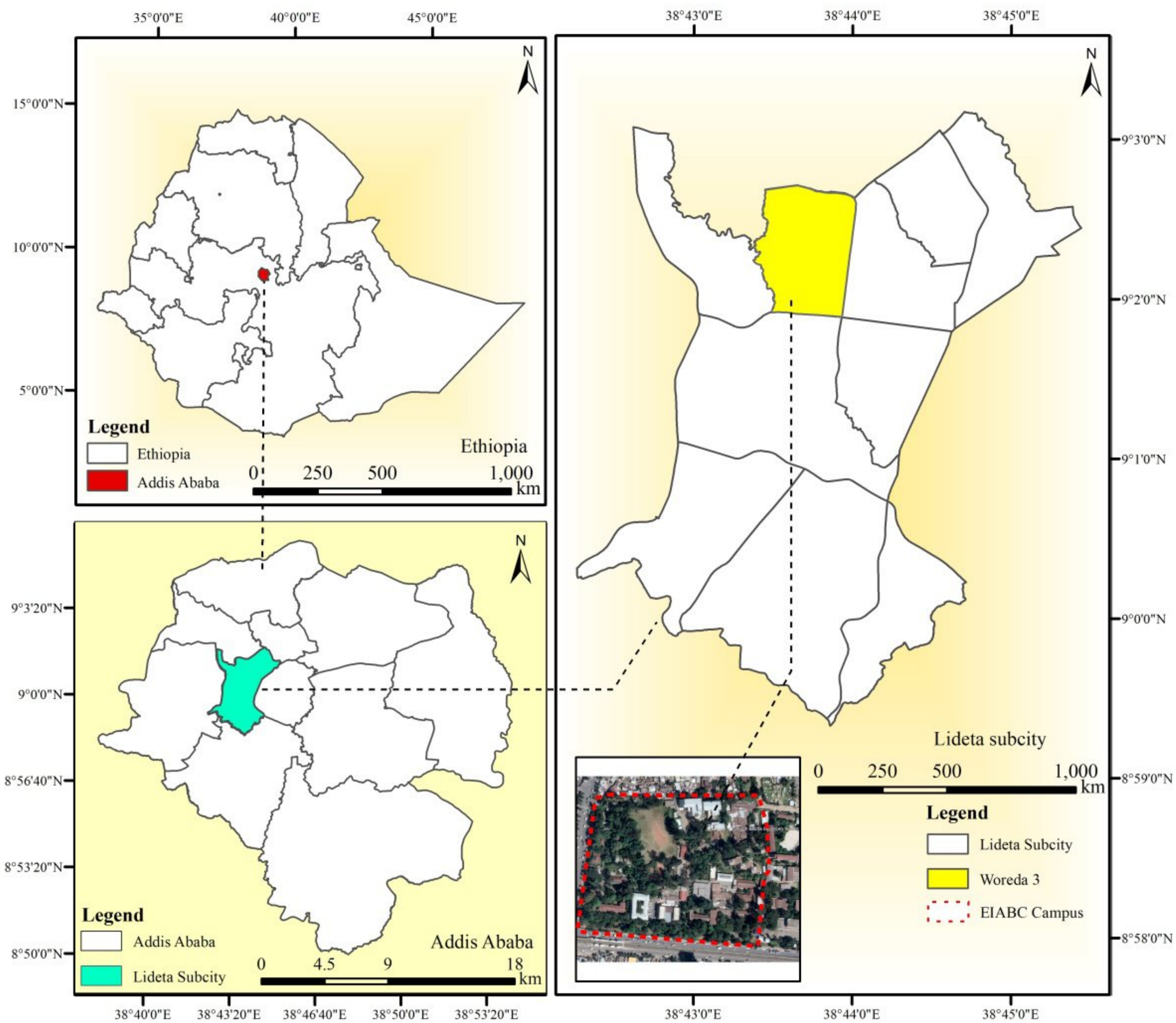

Figure 3.1. Location map of EIABC Campus

Source: (Own computation, 2023)

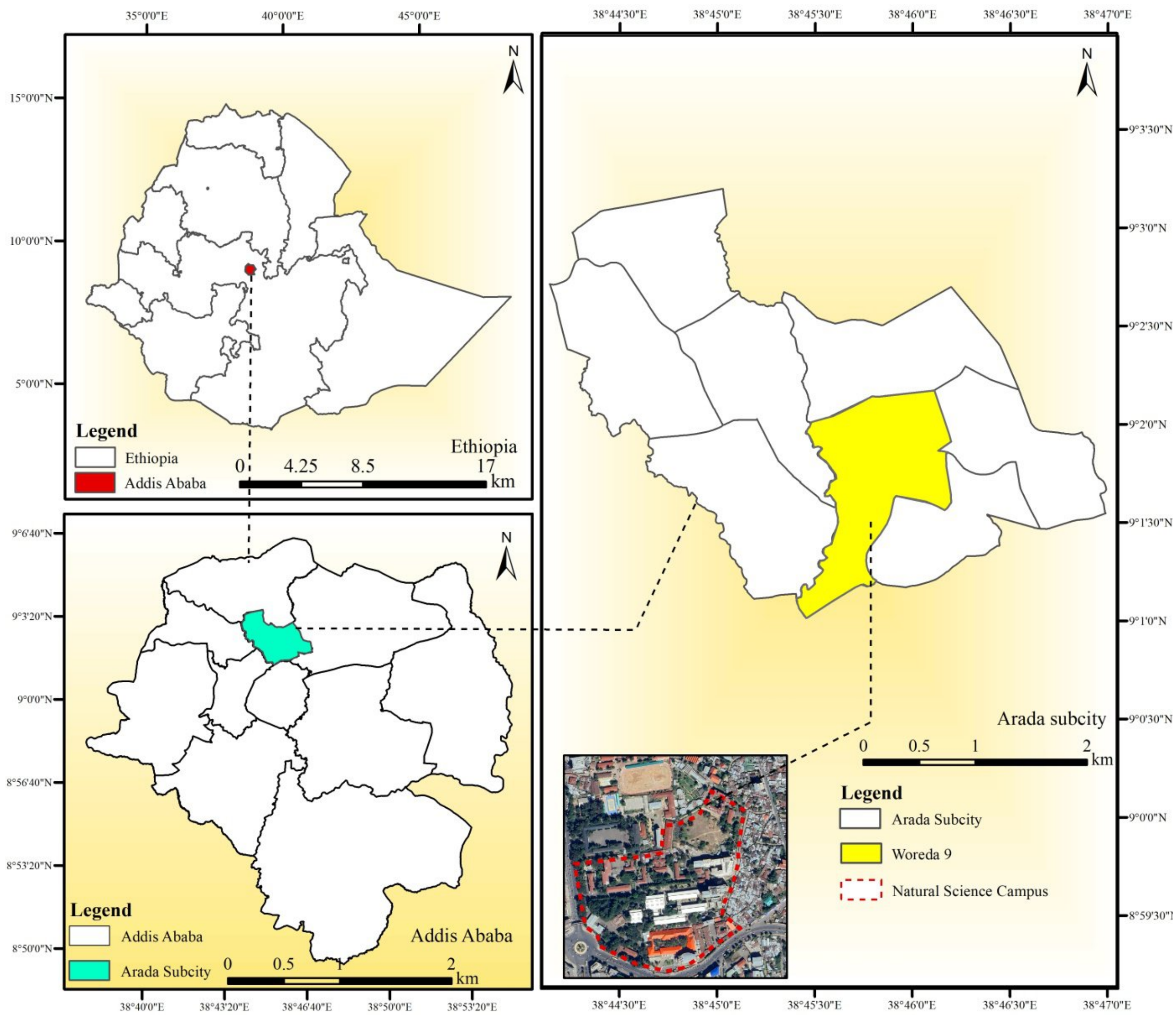

Figure 3.2. Location map of College of Natural and Computational Sciences

Source: (Own computation, 2023)

3.2. Research Design

The research uses a descriptive research method. Its layout ensures that the available data is collected and carefully examined. Based on the objectives set, the vegetation diversity, structure and composition of selected campuses were assessed, in addition to the carbon stock content and the temperature regulation potential.

It is designed to follow a site survey and document review to obtain the necessary information. It employs a mix of quantitative approaches to assess and examine the contribution of vegetation on the campuses. The quantitative data include parameters that define the structural composition of forests, diversity of species, estimation of carbon stock and measuring the temperature on the study site. Then the data was statistically analyzed and presented. Figure 3.3 displays the planned analytical process.

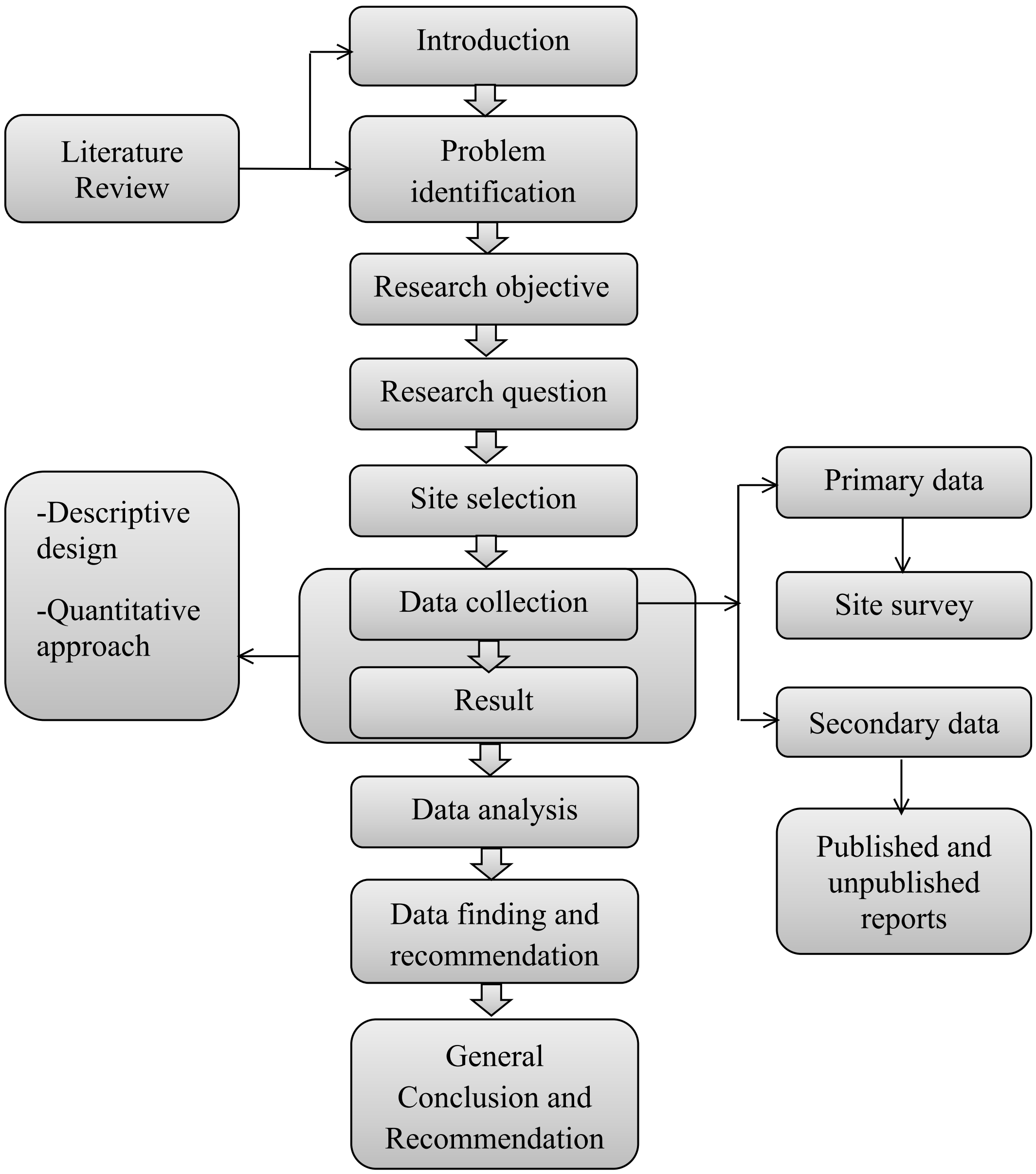

Figure 3.3. General Research Framework

Source: (Own computation, 2024)

3.3. Data Types

The study used quantitative data to assess the vegetation diversity of the study area. Over again, quantitative data were used to investigate the current contribution of the study area in the aspects of carbon stock and temperature regulation.

3.3.1. Primary data

The vegetation underneath the chosen campuses served as the main source of the data. Field inventory on woody plant species, particularly on height and Diameter at Breast Height (DBH) of a tree, was done in each of the sites, in addition to the temperature measurement of the site and surrounding area.

3.3.2. Secondary data

In order to arrange the literature and the study site's location, Google and Google Earth Pro served as the sources for the secondary data. In addition, published and unpublished reports and aerial photographs of the site were used to describe the study area.

3.4. Sampling Design

3.4.1. Sampling techniques

Before any data was collected, a pilot survey was conducted on June 15, 2023, to provide a general idea of the study site. The purpose of the observations was to determine the range of DBH values and representative forests. Then a purposive sampling method was selected to collect the samples. Later, the actual data collection was conducted for five consecutive days for each of the sites starting on July 20, 2023, for the estimation of carbon stock and assessment of diversity and structural composition of the institute.

The data collection for the temperature also used purposive sampling. As the National Metrology Agency reports that Addis Ababa extreme maximum temperature seasons are from February to May. Despite these, the temperature data were also collected in February from 12:00 to 14:00

with DBH ≥5 cm were identified using Diameter Tape

3.4.2. Sample size

All live woody plant species that are found in the selected campus with the DBH values of ≥ 5 cm (a frequently used measurement) considered as the sample size for these study (Pearson *et al*., 2007; Pearson *et al*., 2005). Then, with these conditions, the complete list method was used for sample size.

Through the use of random sampling, the temperature data were gathered from a total of twenty field spots per site. Ten field spots represent inside the compound and the other ten field spots represent the surrounding area within 300-meter distance estimation from the study site.

3.5. Method of Data Collection

The DBH, height and variety of the trees were assessed in order to quantify the biomass, identify tree structures, and determine species diversity. Therefore, the researcher and a professional forest inventor operated the data collection for woody plant species; when one person measures, the other person takes note, for a tree that fulfills the parameter. Initially the nomenclature is identified and then the DBH and height are measured sequentially.

At the same time, these data were recorded on the field inventory format sheet (Appendix 6). Following this structure, the measuring process proceeded to the next tree (Detailed methods are described under the following subheadings). This process headed for five consecutive days only in the morning time until the trees with particular parameters were completed. For precaution, daily recorded data was copied into a computer at the afternoon time. These procedures were followed for both of the sites.

3.5.1. Vegetation identification

A professional forest inventor identified the plants in the field by utilizing both their scientific and local names. Some woody plants that were listed in the field were cross-checked with the scholars.

3.5.2. Estimation of carbon

The approaches utilized to quantify stored carbon are straightforward and follow quantitative techniques that belong to recognized principles and standards for carbon inventories. The methods relied on gathering and analyzing data about the amount of carbon stored in the aboveground and belowground biomass of trees (Pearson *et al.,* 2007; Pearson *et al.,* 2005).

3.5.2.1. Above ground biomass

It includes all forms of live plants above the earth, such as leaves, stems, seeds, stumps, bark, and branches (Moges *et al.,* 2010). As a result, it is the biggest pool and the one most affected by deterioration and deforestation. Around half of biomass is made of carbon (Brown *et al.,* 2004). Thus, the most important stage in determining the amount of carbon stocks is measuring the carbon in aboveground forest biomass (Holly *et al.,* 2007).

3.5.2.2. Below ground biomass

Living roots (fine, small, and big) with diameters of less than 2 mm, 2 to 10 mm, and more than 10 mm, as well as soil fauna, microbial community, and dead roots, are all included in the biomass found below ground. However, in this study, the below-ground biomass was determined by taking 20% of the above-ground biomass as the root-to-shoot ratio, which came out to be 1:5 (Moges *et al.,* 2010).

3.5.3. Tree measurement for species structure, diversity and carbon stock

Each live tree in the study area that had a diameter of ≥ 5 cm (DBH) at 1.3 meters was measured using Caliper (Appendix 7) (Pearson *et al.,* 2005). Then, using a hypsometer, the tree's height was determined at the spot where its top and bottom were observed (Genene *et al*., 2013). Visual inspection was used when capturing a clear view is difficult from the beginning of the truck to the top of the tree and again, visual inspection was used when relatively similar heights of trees occur frequently. This starts from the main entrance, proceeding inwards by dividing the vegetation covers with the main roads of the campuses. To avoid inadvertently counting and measuring twice, marks were placed on measured trees 10 cm above the DBH measurement taken when trees became cramped.

Each tree's scientific and local names were listed separately. For trees with numerous stems under 1.3 meters, counted as a particular tree (Moges *et al.,* 2010). These procedures were followed for both of the sites.

3.5.4. Temperature Measure

Several factors need to be taken into account when measuring the outdoor space's microclimate. One of the factors used to assess the built environment's climatic character is air temperature (Shahidan and Salleh, 2007). The ground-based air temperature survey was conducted using temperature sensor devices (Annex 9). The device measures temperatures between -50°C and 70°C, with an accuracy of ±1 ◦C.

The temperature sensors were mounted 1.5 meters above the ground level (Denur, 2020). Two temperature sensor devices were prepared to measure the temperature of the compound from the inside and the surrounding. The sensors were deployed simultaneously for the inside and outside surroundings. The devices started measuring from number one and proceeded to measure up to number ten, as illustrated in Figures 3.5 and 3.6. This took 2 hours to complete the round.

The average values of the measured data were noted down after the device recorded around a maximum of seven minutes in a single spot and then shifted to the adjacent spot within five minutes. The device was shifted from one spot to the next to encompass all of the sample spots on the site. This process was operated by two people, one for the outside and the other for the inside. Taking notes and moving the device from one spot to another while using umbrellas to shield both the device and themselves from direct sunlight were the duties assigned to each data collector.

The instruments were cabled to the umbrella and turned on regularly at 12:00 EAT for the selected days. Time monitoring starts simultaneously over the cell phone after the data collectors have been set up in their initial spots. Also, communication was verified every hour or every half-hour. For precaution, daily recorded data was copied into a computer. For six days in a row, from February 22 to February 28, 2024, inspections were made daily between 12:00 and 14:00 EAT.

Figure 3.4. Location of temperature measurement

Source: (Own computation, 2024)

Note: Yellow color symbol represents inside the EIABC campus and red color symbol represents outside surrounding of EIABC campus.

Figure 3.5. Location of temperature measurement

Source: (Own computation, 2024)

Note: Yellow color symbol represents inside the College of Natural and Computational Sciences and Red color symbol represents outside surrounding of College of Natural and Computational Sciences.

3.5.5. Data collection Materials

Based on the objectives the following materials are used to collect data's in the field.

- Caliper: - to measure the diameter of trees ≥ 5 cm.
- Hypsometer: - to measure the height of the trees.
- Temperature sensor devices: - to measure the temperature of the site and surrounding.
- Umbrella – used to shade the temperature sensor devices.
- Pen – used to register the vegetation data's and the temperature data's.
- Paper – used to register the vegetation data's and the temperature data's.
- Marker – used to mark the trees to avoid inadvertently counting when trees became cramped.

3.6. Method of Data Analysis

The initial stage of data analysis in this study involves transferring the raw data from paper sheets to computer programs. Then the data that was recorded was ready for further examination. It involves the proper use of models and organizing data in a systematic manner. The quantitative structure (the height, DBH, and species number data) was arranged, and the carbon stock, diversity, structural characteristic and composition of woody species within the institutes were quantified using the appropriate biomass estimation equation and diversity indices.

3.6.1. Compositional and structural analysis

In this section, the abundance and richness of woody species were identified. The vegetation structural characteristic, tree's height, and Diameter at Breast Height (DBH) were categorized into classes.

3.6.2. Species diversity analysis

The ecological worth of a site for conservation tends to be assessed upon its diversity (Tona, 2016). Shannon diversity index (H') and Shannon evenness (J) were diversity indices that were used in the species diversity analysis of this study. The rarity and commonness of the variety of woody species are measured by these diversity indices, which also provide useful information for assessing the diversity of woody species (Mebrat *et al.,* 2014). It is the oldest, simplest and usually used model in the concept of species diversity.

3.6.2.1. Shannon wiener diversity index (H')

It is the most popular way to measure species diversity (Kent and Coker, 1992). According to Zar (2010), the equation is as follows:

$$H^{'} = -\sum_{i=1}^{S} \text{pi} * \text{lnpi} \text{------------------------------} \quad \text{(equ. 1)}$$

Where, H’ = Diversity of species

S = the number of species

Pi = the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N)

ln = log base n (natural logarithm) and Σ is the sum of the calculations.

The index's H' value typically falls between 1.5 and 3.5. The diversity of species becomes higher when the H' value becomes larger (Kent and Coker, 1992).

3.6.2.2. Evenness (Equitability) analysis

When every species in the population is equally abundant, then the level of evenness is at its peak (Lembrechts *et al.,* 2017). In a community, it is the quality of species abundance (Kent and Coker, 1992; Begon *et al.,* 2006). The following is the equation:

$$J = \frac{\sum_{i=1}^{s} Pi \ln Pi}{\ln S} = \frac{H'}{\ln S} \text{------------------------------} \quad \text{(equ. 2)}$$

Where, J = is the evenness or equitability index

H’ = Diversity of species, lns = the natural log of the number of species (s)

The range of evenness values is 0 to 1, where 1 denotes perfect evenness (Kent and Coker ,1992; Begon *et al.,* 2006).

3.6.3 Estimation Carbon stock

3.6.3.1. Aboveground biomass

To calculate the trees above-ground biomass, this study employs a chosen Allometric formula. Numerous Allometric mathematical equations have been created and plenty of investigators use them to calculate the above-ground biomass of trees based on factors such as species, climate, forest types, and geographic locations (Baker *et al.,* 2004). Since both money and time would be needed to chop the trees in order to estimate their biomass using a destructive method, the non-destructive method is employed (Genene *et al*., 2013).

Consequently, Brown *et al.* (1989) suggested using the Allometric equations model (equ. 3) to determine the tree's above-ground biomass if the rainfall was <1500 mm and the DBH range was ≥5 cm. These Brown et al. (1989) equations have become accepted standard procedure because of their broad applicability (Kassahun, 2014). The equation is as follows:

$Y= 34.4703 - 8.0671(DBH) + 0.6589(DBH^2)$.. (equ.3)

Where, Y = above ground biomass

DBH = Diameter at Breast Height

Pearson *et al.* (2005) state that because the study areas are in a tropical region, the biomass's carbon content is calculated through multiplying the biomass of trees above ground by 0.5 (the default value provided by the IPCC). The CO2 content is estimated using the multiplication factor 3.67, which is listed in Equations 4 and 5. The equation is as follows:

AGCS = AGB * 0.5.. (equ.4)

Then the following process is used to transform the biomass carbon stock into CO2 equivalent:

CO_2 = AGCS * 3.67.. (equ.5)

Where, AGCS = Above Ground Carbon Stock

AGB = Above Ground Biomass (kg/tree)

CO_2 = Carbon dioxide

3.6.3.2. Below ground biomass

Comparatively to calculating aboveground biomass, determining belowground biomass is more difficult, time-consuming, and destructive (Genene *et al.,* 2013). According to MacDicken (1997) 20% of above-ground tree biomass (AGB) is equal to below-ground biomass (BGB). Pearson *et al.* (2005) also point out that determining the belowground biomass using the value of the aboveground biomass is a more effective and efficient way. Thus, the MacDicken (1997) formula was used to estimate the study's below-ground biomass. The following is the equation:

BGB = AGB*0.2.. (equ.6)

Where, BGB is below ground biomass

AGB is above ground biomass, 0.2 is conversion factor (or 20% of AGB).

The same methodology as for AGB was used to determine the quantity of CO2 and carbon in BGB.

BGCS = BGB * 0.5.. (equ.7)

Next, the carbon stock from biomass was transformed into CO2 equivalent in the following way:

CO_2 = BGCS * 3.67.. (equ.8)

Where BGCS = Below Ground Carbon Stock

BGB = Below Ground Biomass (kg/tree)

CO_2 = Carbon dioxide

For both carbon pools, the biomass stock density was attained in Kg/m^2 by means of dividing the sum of all individual tree biomass (Kg) in a plot by the area of the plot (m^2), subsequently changed to a tone and the value was multiplied by 10 to convert it to t/ha (Pearson *et al.,* 2005).

3.6.4. Total carbon stock estimation

The total carbon stock was calculated by adding the carbon stocks of the various carbon pools using the equation from Pearson *et al.* (2005). The process for converting biomass into carbon and CO2 is the same.

TC = AGC + BGC...(equ.9)

Where, TC = Total carbon stock density for all pools (t/ha)

AGC = Carbon in above -ground biomass

BGC = Carbon in below-ground biomass

3.6.5. Temperature measurement

The recorded temperature data was converted to an Excel sheet program. Then the data was analyzed using the aggregate function and compared the inside and surrounding values for each site. Then the comparison of the values between the compounds was arranged.

3.7. Statistics Analysis and tools

Descriptive statistical methods were used in order to arrange the quantitative data. Mean, Max, Min, frequency distribution and class distribution through width range are used in order to arrange the height and diameter values. Finally, the data was processed and presented.

Various software programs, including Microsoft Excel 2010 and SPSS software version 20, were utilized to analyze and present the gathered data. Arc GIS Map 10.8 and Google Earth Pro were used to organize the study area, whereas Adobe Illustrator 2023 was also used to present the study area.

3.8. Data Presentation

The existing location of the study site is presented by maps and descriptive words. The collected data was examined and displayed using graphs, tables, and images. Additionally, various tables and comparison graphs were used.

3.9 General methodology framework

Table 3.1. Research strategy method and techniques applied

Objectives	Data type	Source of data	Data collection method and tools	Analysis methods and tools	Data presentation
▪ To analyze the diversity, structural characteristics, and species composition of woody vegetation within the institutes' forests.	primary data Secondary data	Field inventory on variety, DBH and Height of woody plant species. Literatures for some of tree species nomenclature.	Using Caliper, the height of each living tree in the study area that had a diameter of ≥ 5 cm (DBH) at 1.3 meters was measured (Appendix 7) (Pearson *et al.*, 2005). Then, using a hypsometer, the tree's height was determined at the spot where its top and bottom were observed (Genene *et al.*, 2013). Visual inspection was used when capturing a clear view is difficult from the beginning of the truck to the top of the tree and again, visual inspection was used when relatively similar heights of trees occur frequently. This starts from the main entrance, proceeding inwards by dividing the vegetation covers with the main roads of the campuses. To avoid inadvertently counting and measuring twice, marks were placed on measured trees 10 cm	Shannon diversity index (H') and Shannon evenness were diversity indices that used to Species diversity analysis of this study. The abundance, richness and variety of woody species were identified. The Diameter at Breast Height (DBH) and height of the tree were classified through class for description of vegetation structure. The analysis used Microsoft Excel 2010.	Tables and graphs

▪ To quantify the carbon stock potential of the two institutional forests.	primary data	Field inventory on DBH and Height of woody plant species	above the DBH measurement taken when trees became cramped. Each tree's scientific and loca names were listed separately. Fo trees with numerous stems unde 1.3 meters, counted as a particula tree (Moges *et al.,* 2010). Thes procedures were followed for bot of the sites.	Used recommended equation (Allometric equations) model listed as equ.3, if the rainfall <1500 mm and DBH range is ≥5cm to calculate the above ground Biomass of the tree.	Tables
▪ To analyze and compare temperatures values inside the institutes' forests with those in the surrounding areas.	primary data	Field measurement on the temperature value of the site and surrounding.	The temperature data's were collected by temperature sensor from a total of twenty field spot for each site. Ten field spots represent the surrounding and the other ten field spots represent inside the compound. The temperature sensors were mounted 1.5 meters above the ground level (Denur, 2020). Two temperature sensor devices were prepared to measure the temperature of the compound from the inside and the surrounding. The sensors were deployed simultaneously for the inside and outside surroundings. The average values of the measured data were noted down after the device recorded a maximum of 7 minutes in a single spot and then shifted to the adjacent spot within 5 minute	The recorded temperature data converted to excel sheet program. Then the data analyzed using aggregate function and compared the inside and surrounding values for each site. Then the comparison of the values between the compounds arranged.	Tables and graphs

CHAPTER FOUR

4. RESULT

4.1. Structural characteristics and Composition of Woody Species in the EIABC and College of Natural and Computational Sciences

The study campuses displayed a variety of tree species. There were differences in the types of species found on each campus. A total of 2641 trees, representing 68 species, having a common highest DBH value of 120 cm along a height value between a range of 1.3 m and 49 m, were recorded during the data collection period.

There were 2641 distinct trees that present the abundance of trees in the campuses. 1231 trees represented by 50 species recorded in EIABC Campus. 1410 trees represented by 49 species recorded in College of Natural and Computational Sciences, While 31 species were found common for both Campuses.

The most dominant species among EIABC Campus were *Grevillea robusta*, which has 155 trees, or 13% of the total species, followed by *Vernonia amygdalina,* which has 145 trees, or 12% of the total species; *Eucalyptus globulus,* which has 94 trees, or 8% of the total species; *Acacia decurrens,* which has 85 trees, or 7% of the whole species; *Jacaranda mimosifolia,* which has 84 trees, or 7% of the total species; *Acacia melanoxylon* and *Cupressus lusitanican* each with 77 trees that are 6% of the entire species.

The lowest frequency is shown by *Pinus caropus, Hagenia abyssinica, Cassea didbotrea, Cercidiphyllum, Cupressus arizonica, Eucalyptus saligna, and Acacia indica*, all of which have only a single tree available.

Whereas in the case of College of Natural and Computational Sciences the most dominant species were *Podocarpus gracilior*, which has 296 trees, or 21% of the total species, followed by *Juniperus procera,* which has 165 trees, or 12% of the total species; *Jacaranda mimosifolia,* which has 140 trees, or 10% of the total species; *Acacia melanoxylon,* which has 113 trees, or 8% of the total species; *allophylus abyssinicas*, *Cupressus lusitanica*, *Olea europaea* with 52, 61, 60 trees, or 4% of the entire species; and *Vernonia amygdalina* with 47 trees, or 3% of the entire species.

The lowest frequency is shown by *Citrus sinensis, Cassia cinguana, and Acacia cynopyla,* which are all limited to have one tree. The following Table 4.1 and 4.2 presents the summarize form of woody species structure and composition. More detail data presented in the Appendix 1 and 2.

Table 4.1. A brief description of the woody plant species found on the EIABC campus, including data on the quantity of trees, the average DBH, a height, and name of species.

No	*Species Name*		*Total No of trees*	*(Mean)*	
	Local	*Scientific*		*DBH(cm)*	*Height(m)*
1	*Bazra girar*	*Acacia abbyssinica*	5	38.02	7.94
2	*Mimosa/Akacha*	*Acacia decurrens*	85	15.01	8.72
3	*Grar*	*Acacia indica*	1	26.1	20
4	*Omedla*	*Acacia melanoxylon*	77	18.48	8.61
5	*Bottlebrushe*	*Callistemon citrinus*	18	7.43	5.24
6	*Kazamora*	*Casimiroa edulis*	5	18.92	6.74
7	*Asene meka*	*Cassea didymobotrya*	1	32	9
8	*Shewshewie/arzelibanos*	*Casuarina equisetifolia*	41	32.11	13.47
9	*Kawoot*	*Celtis africana*	3	32.67	12.33
10	-	*Cercidiphyllum*	1	41.6	12
11	*Bunna*	*Coffea arabica*	15	6.37	3.57
12	*Wanza*	*Cordia africana*	19	27.06	8.78
13	*Bisana*	*Croton macrostachyus*	26	21.78	8.61
14	*Yeferenji-tid*	*Cupressus arizonica*	1	15.5	7.6
15	*Yeferenji-tid*	*Cupressus lusitanica*	77	20.77	9.84
16	*Yeferenji-tid*	*Cupressus pyramidalis*	4	21.56	9.78
17	*Koshim*	*Dovialic abbyssinica*	3	18.325	5.75
18	*Itsepatos*	*Dracaena steudneri*	52	24.03	6.65
19	*Game*	*Ehretia cymosa*	4	32.5	7.125
20	*Lol*	*Ekebergia capensis*	6	56.95	13.17
21	*Woshmela*	*Eriobotrya japonica*	11	16.2	5.29

22	*Korch*	*Erythrina brucei*	1	15	16
23	*Nech bahir zaf*	*Eucalyptus globulus*	94	43.87	17.37
24	*Saligna bahir zaf*	*Eucalyptus saligna*	1	68	23
25	*Yegoma zaf*	*Ficus Elastica*	9	29.53	8.44
26	*Sholla*	*Ficus sure*	3	70.33	15.33
27	*Grevila*	*Grevillea robusta*	155	18.89	10.76
28	*Koso*	*Hagenia abyssinica*	1	5	2.5
29	*yetebmenja zaf*	*Jacaranda mimosifolia*	84	21.38	7.94
30	*Yehabesha Tid*	*Juniperus procera*	62	14.34	7.34
31	*Nimi*	*Melia aztrach*	6	15.63	5.17
32	*Birbira*	*Millettia ferruginea*	35	21.83	8.99
33	-	*Mussaenda arcuata*	1	30.82	10.83
34	*Sete Weira*	*Olea europaea*	43	18.91	7.78
35	*Avocado*	*Persea americana*	3	11.07	6.53
36	*Zembaba*	*Phoenix reclinata*	4	16.3	6
37	*Yekolla wanza*	*Piliostigma thonningii*	16	14.71	6.58
38	-	*Pinus caropus*	1	14	6.6
39	*Pachula*	*Pinus patula*	4	24.5	9.85
40	*Elaho, Ahot, Kefeta,*	*Pittosporum viridiflorum*	8	29.95	12.59
41	*Zigba*	*Podocarpus gracilior*	28	30.07	10.54
42	*Tkur enchet*	*Prunus africana*	19	30.24	10.35
43	*Galo/Seged*	*Psdrax schimperiana*	6	8	5
44	*Zeituna*	*Psidium guajava*	4	6.58	4.53
45	*Gullo*	*Ricinus communis*	3	8.93	4.67
46	*Gitem/Kokora*	*Schefflera abyssinica*	5	34.4	7.68
47	*Qundo berbere*	*Schinus molle*	12	38.84	6.48
48	*Yebereha nebelbal*	*Spathodea campanulata*	15	28.56	9.39
49	*Dokma*	*Syzygium guineense*	8	23.54	8.94
50	*Grawwa*	*Vernonia amygdalina*	145	13.56	5.14
		Sum	1231		

Table 4.2. A brief description of the woody plant species found on the College of Natural and Computational Sciences, including data on the quantity of trees, the average DBH, a height, and name of species.

No	*Species Name*		*Total No of trees*	*Mean*	
	Local	*Scientific*		*DBH(cm)*	*Height(m)*
1	*Bazra girar*	*Acacia abbyssinica*	26	44.95	12.64
2	*Akacha saligna*	*Acacia cynopyla*	1	44.00	14.00
3	*Akacha, Mimosa*	*Acacia decurrens*	2	36.00	13.50
4	*Omedla*	*Acacia melanoxylon*	113	19.77	9.37
5	*Sesa*	*Albizia gummifera*	7	26.36	9.20
6	*Embus, Qequewe*	*allophylus abyssinicas*	52	16.75	6.12
7	*Azamir*	*Bersama abyssinca*	*3*	33.00	6.30
8	*Zembaba*	*Borassus aethiopum*	*4*	41.20	13.43
9	*Bottlebrushe*	*Callistemon citrinus*	18	19.54	8.23
10	*Kazamora*	*Casimiroa edulis*	*7*	*18.63*	8.57
11	*pillarwood*	*Cassipourea malosana*	*1*	*8.23*	4.75
12	*Asene meka*	*Cassea didymobotrya*	*8*	*23.36*	5.26
13	-	*Cassia singueana*	1	37.30	13.00
14	*Shewshewie /arzelibanos*	*Casuarina equisetifolia*	9	37.12	11.89
15	*Birtukan*	*Citrus sinensis*	1	5.00	3.00
16	*Wanza*	*Cordia africana*	19	28.43	8.92
17	*Bisana*	*Croton macrostachyus*	3	34.50	13.00
18	*Yeferenji-tid*	*Cupressus lusitanica*	61	31.16	11.85
19	*Yeferenji-tid*	*Cupressus pramidalis*	5	27.12	17.20
20	*Itsepatos*	*Dracaena steudneri*	24	25.98	6.10
21	-	*Ehophorbia sp.*	4	22.80	6.50
22	*Game*	*Ehretia cymosa*	7	44.36	11.37
23	*Lol*	*Ekebergia capensis (E. rueppeliana)*	5	11.42	9.26

24	Woshmela	Eriobotrya japonica	20	10.69	4.73
25	Korch	Erythrina brucei	8	54.63	12.31
26	Nech bahir zaf	Eucalyptus globulus	22	27.97	15.06
27	Sholla	Ficus sure	9	27.46	10.11
28	Ash	Fraxinus sp.	36	25.45	7.65
29	Grevila	Grevillea robusta	23	31.98	13.27
30	yetebmenja zaf	Jacaranda mimosifolia	140	22.22	8.17
31	Yehabesha Tid	Juniperus procera	165	33.92	13.08
32	-	Ligustrum ovata	12	12.43	6.52
33	Kelawa, Yeregna qolo	Maesa lanceolata	6	16.78	4.77
34	Nimi	Melia aztrach	4	13.55	7.00
35	Birbira	Millettia ferruginea	27	14.23	7.13
36	yeferenji injori	Morus alba	10	23.23	9.45
37	Shinet	Myrica salicifolia	14	15.03	7.13
38	Sete Weira	Olea europaea	60	16.92	7.37
39	Avocado	Persea americana	15	21.85	9.06
40	Zembaba	Phoenix reclinata	25	19.50	5.42
41	-	Pinus Radiata	4	38.90	13.88
42	Zigba	Podocarpus gracilior	296	21.19	9.34
43	Tkur enchet	Prunus africana	14	14.11	8.14
44	Embus, Qamo	Rhus glutinosa	4	7.93	6.34
45	Yebereha nebelbal	Spathodea campanulata	8	34.68	8.88
46	Dokma	Syzygium guineense	27	22.58	8.27
47	Tacoma	Tecoma stans	25	13.10	5.74
48	-	Teclea simplicifolia	8	15.70	5.17
49	Grawa	Vernonia amygdalina	47	13.86	5.70
		Sum	1410		

4.2. Arrangement DBH and Height of Trees

4.2.1. Arrangement of DBH

Studies classify the class using varying interval widths; however, this study classifies the class interval width using the average DBH number, which is 22. Thus, it is divided into six classes according to these. (≥5-27, 27-49, 49-71, 71-93, 93-115, and ≥115 cm). The maximum DBH values recorded among EIABC Campus were 120 cm by *Eucalyptus globulus*, followed by 118 cm by *Schinus molle*, 104 cm by *Ekebergia capensis,* and 99 cm by *Podocarpus gracilior*.

While the maximum DBH values recorded among College of Natural and Computational Sciences were 120 cm by *Erythrina brucei,* followed by 110 cm by *Acacia abbyssinica*, 104 cm by *Podocarpus gracilior,* and 98 cm by *Cupressus lusitanica*.

The following Figures 4.1 and 4.2 show the DBH arrangement of the campuses. The first DBH class, which is (5-25 cm), has a greater number of species recorded, with 70% value from the total species for the EIABC Campus and 65% value from the total species for the College of Natural and Computational Sciences. The last DBH class is (≥105 cm), which has a lower number of species.

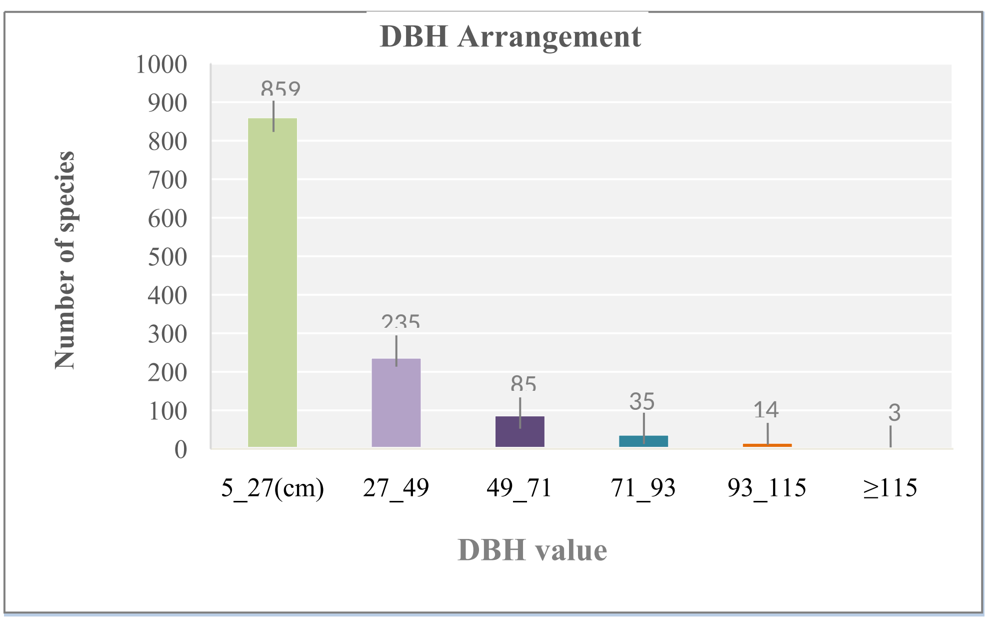

Figure 4.1. Species DBH arrangement on the EIABC campus.

Source: (Own computation, 2024)

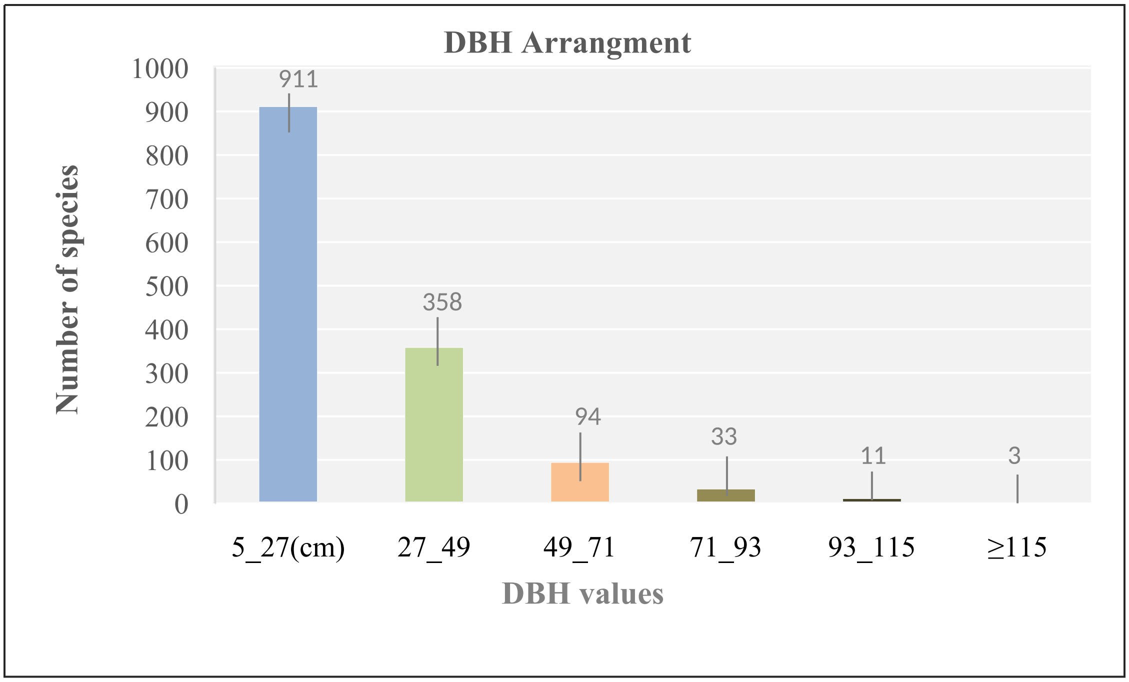

Figure 4.2. Species DBH arrangement on College of Natural and Computational Sciences

Source: (Own computation, 2024)

4.2.2. Arrangement of Height

Studies classify the class using varying interval widths; however, this study classifies the class interval width using the average height number, which is 9. Thus, it is divided into six classes according to these. (1 - 9, 9 - 18, 18 - 27, 27 - 36, 36 - 45 and 45 - 54). The maximum height arrangement recorded among EIABC Campus was 49 m by *Eucalyptus globulus,* followed by 40 m by *Grevillea robusta* and 34 m by *Casuarina equisetifolia*. The minimum height arrangement recorded was 1.3 m by *Millettia ferruginea,* followed by 2.1 m by *Piliostigma thonningii*.

While the maximum height value recorded among the College of Natural and Computational Sciences was 49 m by *Juniperus procera,* followed by 24 m by *Eucalyptus globulus.* However, the minimum height arrangement recorded was 2 m by *Dracaena steudneri*. The following Figures 4.3 and 4.4 show the height arrangement of the campuses. The first height class, which is 1-9 m, has a greater number of species recorded, with 64% from the total species for the EIABC Campus and 66% from the total species for the College of Natural and Computational Sciences. The number of species becomes lower when the value of height becomes higher.

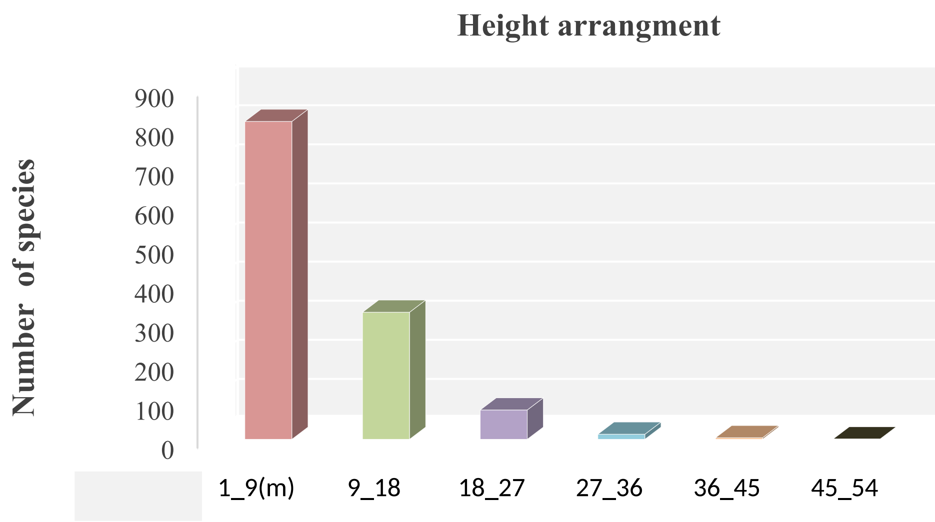

Figure 4.3. Species Height arrangement on EIABC Campus

Source: (Own computation, 2024)

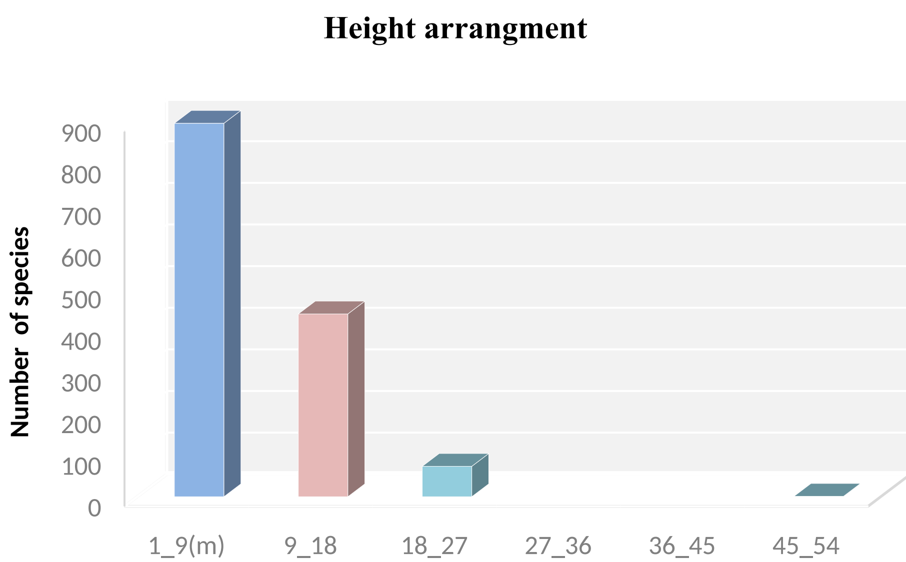

Figure 4.4. Species Height arrangement on College of Natural and Computational Sciences

Source: (Own computation, 2024)

4.3. Diversity of Woody Plant Species Distribution

4.3.1. The diversity indexes

The result showed the abundance of the species with 1231 and 1410 individual trees, in which the species richness is 50 and 49, respectively, for EIABC Campus and College of Natural and Computational Sciences. The overall evenness and diversity values of the species according to Shannon Wiener were (J=0.79) (H'=3.11) for EIABC Campus and (J=0.78) (H'=3.03) for College of Natural and Computational Sciences.

Table 4.3. The diversity indexes for the campuses

No	Campuses	Number of species recorded	Number trees recorded	H'	E_H
1	EIABC Campus	50	1231	3.11	0.80
2	College of Natural and Computational Sciences	49	1410	3.03	0.78

4.3.2. Origin of the species

There were the same amounts of indigenous species for both the College of Natural and Computational Sciences and the EIABC Campus. On the EIABC Campus, there are 25 indigenous and 25 exotic species, with 506 and 725 trees, respectively. *Vernonia amygdalina, Juniperus procera, Dracaena steudneri* and *Olea europaea* were widely seen indigenous species.

Whereas, College of Natural and Computational Sciences had the largest number of indigenous species than exotic species, with 25 indigenous and 24 exotic species, or 866 and 544 trees, respectively. *Podocarpus gracilior, Juniperus procera, Olea europaea* and *Allophylus abyssinicas* were widely seen indigenous species. Accordingly, Figure 4.5 represents the quantity of indigenous and exotic species found on the campuses.

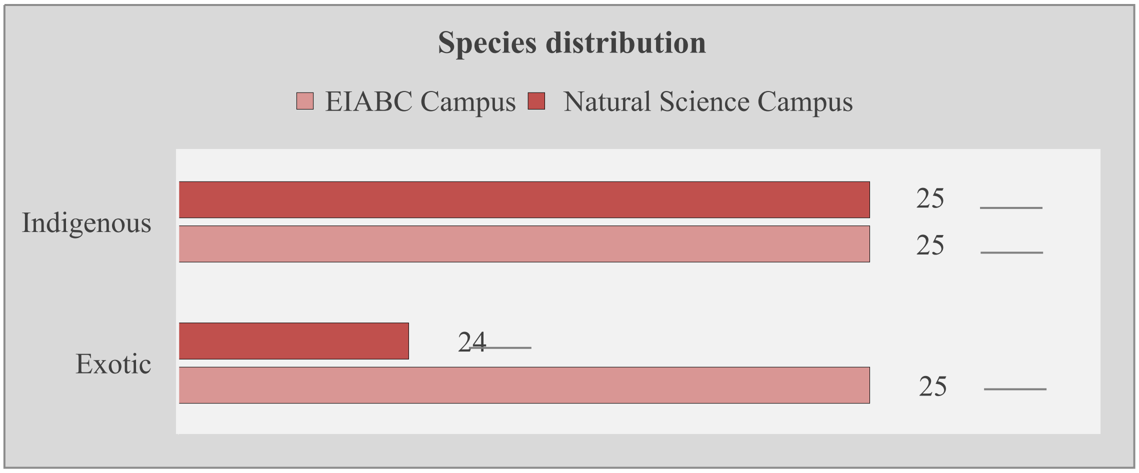

Figure 4.5. Quantity of indigenous and exotic species

Source: (Own computation, 2024)

4.4. Carbon Stock and Biomass

4.4.1. The carbon stock and biomass in EIABC Campus

According to the analyses, the EIABC Campus biomass in the above-ground (AGB) ranged from 40.34 t/ha to 0.003 t/ha, with an average biomass of 3.34 t/ha. The mean carbon stock in aboveground (AGC) was 1.66 t/ha, while the mean carbon dioxide in aboveground (AGCO2) was 6.12 t/ha.

The biomass in the belowground (BGB) ranged from 8.07 t/ha to 0.001 t/ha, with an average biomass of 0.67 t/ha. The mean carbon stock in the belowground (BGC) was 0.33 t/ha, while 1.22 t/ha carbon dioxide in the belowground biomass (AGCO2). These results presented in detail in the following Table 4.4 As a result, the above-ground pool pulled roughly 83% of the total biomass, while the below-ground pool pulled 17%. Detail table presentation attached to Appendix 1.

[illegible] 16.66% and

Table 4.4. Summary of biomass and carbon stock for EIABC Campus.

Campus	Carbon storages					
	AGB (t/ha)			BGB (t/ha)		
EIABC Campus	Min	Max	Mean	Min	Max	Mean
	0.003	40.34	3.34	0.001	8.07	0.67

	AGB	AGC	$AGCO_2$	BGB	BGC	$BGCO_2$
Mean	3.34	1.66	6.12	0.67	0.33	1.22

4.4.2 The carbon stock and biomass in College of Natural and Computational Sciences

According to the analyses, the College of Natural and Computational Sciences biomass in the above-ground (AGB) ranged from 144.36 t/ha and 0.003 t/ha, with an average biomass of 5.37 t/ha. The mean carbon stock in aboveground (AGC) was 2.69 t/ha, while the mean carbon dioxide in aboveground (AGCO2) was 9.86 t/ha.

The biomass in the belowground (BGB) ranged from 28.87 t/ha and 0.001 t/ha, with an average biomass of 1.07 t/ha. The mean carbon stock in the belowground (BGC) was 0.54 t/ha, while 1.97 t/ha carbon dioxide in the belowground biomass (AGCO2).These results presented in detail in the following Table 4.5 As a result, the above-ground pool pulled roughly 83% of the total biomass, while the below-ground pool pulled 17%. Detail table presentation attached to Appendix 2.

[illegible] 16.66% and

Table 4.5. Summary of biomass and carbon stock for College of Natural and Computational Sciences.

Campus	Carbon storages					
	AGB (t/ha)			BGB (t/ha)		
College of Natural and Computational Sciences	Min	Max	Mean	Min	Max	Mean
	0.003	144.36	5.37	0.001	28.87	1.07
	AGB	AGC	$AGCO_2$	BGB	BGC	$BGCO_2$
Mean	5.37	2.69	9.86	1.07	0.54	1.97

4.5. Total Carbon Stock

The campuses' total stock of carbon was calculated by adding together the results of above-ground and below-ground carbon. Totally, 92.14 t/ha stock of carbon from EIABC Campus and

151.60 stock of carbon from College of Natural and Computational Sciences have been calculated.

Table 4.6. Summary of biomass, carbon and CO_2 in aboveground and belowground pools for EIABC Campus and College of Natural and Computational Sciences.

	Total Carbon pools t/ha								
Site	AGB	AGC	$AGCO_2$	BGB	BGC	$BGCO_2$	TB	TC	TCO_2
EIABC Campus	153.55	76.78	281.77	30.72	15.36	56.38	184.28	92.14	338.15
Natural and Computational Sciences	252.67	126.3	463.65	50.53	25.27	92.73	303.21	151.60	556.38
Mean	203.11	101.54	372.71	40.62	20.31	74.555	243.745	121.87	447.265

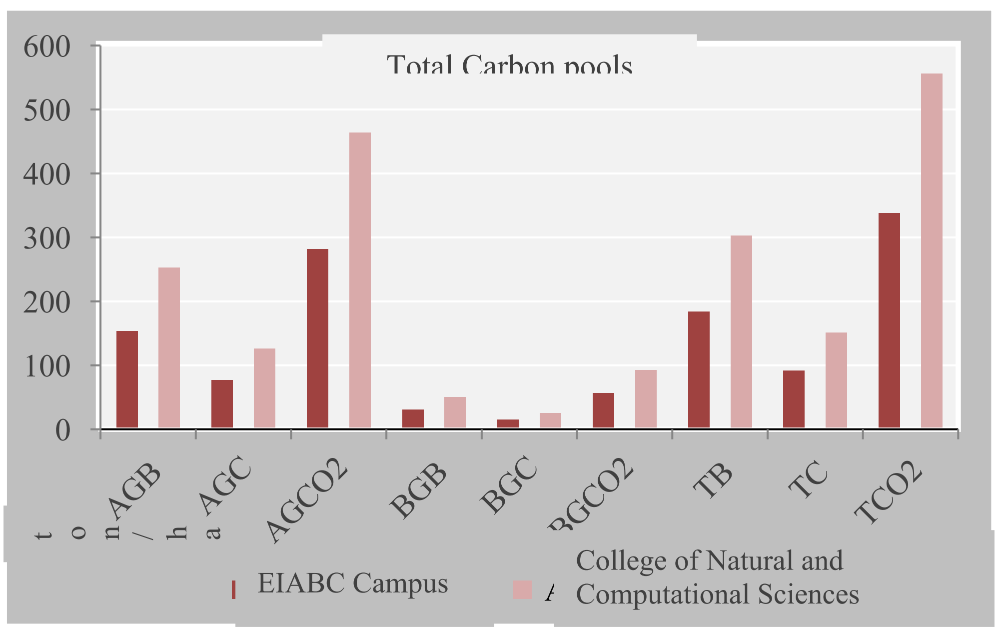

Figure 4.6. Summary of biomass, carbon and CO_2 in aboveground and belowground carbon pools for EIABC Campus and College of Natural and Computational Sciences.

Source: (Own computation, 2024)

4.6. Temperature Comparison between In-side and Out-side the campuses

The final result indicates the temperature value ranges between 26.1°C and 28.73°C for inside the EIABC Campus, with the average value of 27.2°C. Whereas outside the surrounding campus exhibits temperature values ranging between 28.43°C and 33.47°C, with the average value of 30.8°C, as shown in Table 4.7. From the analysis, the temperature of the campus (inside) has reduced by a mean value of 3.6°C from the surrounding.

In the case of College of Natural and Computational Sciences, the temperature value ranges between 23.13°C and 24.63°C for inside, with the average value of 23.9°C. Whereas outside the surrounding campus exhibits temperature values ranging between 27.17°C and 30.2°C, with the average value of 28.3°C, as shown in Table 4.7. Therefore, the temperature of the campus (inside) has reduced by a mean value of 4.4°C from the surrounding. The detail line graph and table that show the recorded values for each day to outside and inside are presented in Appendix 3, 4 and 5.

Table 4.7. Temperature value recorded on February 2024.

	College of Natural and Computational Sciences Temp. in C0				EIABC Campus Temp. in C^0			
	Max		Min		Max		Min	
	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside
Day 1	28.8	24.9	27	23	35.5	29.7	27.5	26.1
Day 2	30.8	24.6	27	23.1	32.9	29.1	29.4	26.1
Day 3	31.1	24.4	27.5	23.3	32	27.4	28.4	26.3
Mean	30.2	24.63	27.17	23.13	33.47	28.73	28.43	26.17

	Mean		Mean	
	Inside	Outside	Inside	Outside
Day 1	23.88	27.83	27.24	30.78
Day 2	23.87	28.65	27.37	31.08
Day 3	23.93	28.52	26.86	30.55
Mean	23.9	28.3	27.2	30.8

The recorded temperature values in Table 4.7 show that the daily average temperature rates for the compounds (inside) are lower than the temperature rate for the surrounding area (outside). This situation occurs correspondingly for both campuses. The line graph in Figures 4.7 and 4.8 also shows these notions. However, the temperature rate in the outside surroundings of the EIABC Campus was higher than that of the College of Natural and Computational Sciences.

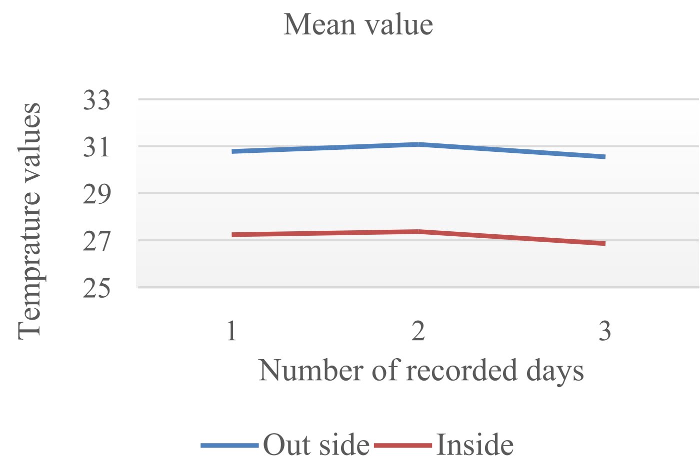

Figure 4.7. Temperature rates for (inside and outside) the EIABC Campus

Source: (Own computation, 2024)

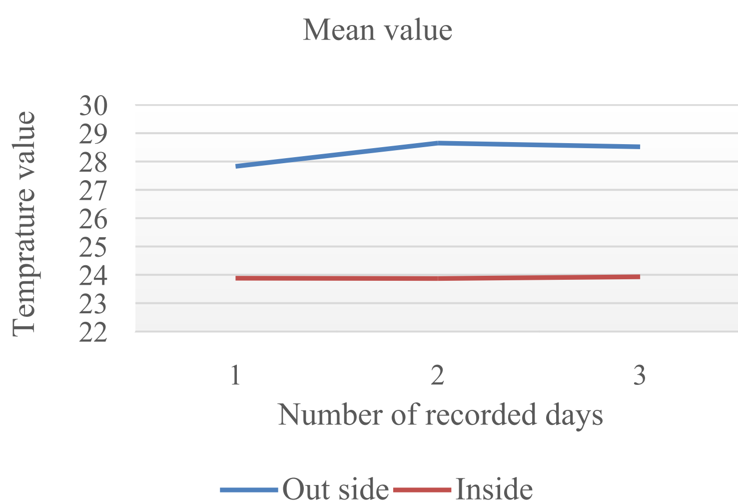

Figure 4.8. Temperature rates for (inside and outside) College of Natural and Computational Sciences.

Source: (Own computation, 2024)

CHAPTER FIVE

5. Discussion

5.1. Structural characteristics and Composition of Woody Species in the EIABC and College of Natural and Computational Sciences

5.1.1. Woody species composition

The forests on the studied campuses were classified as dry Afromontane Forest vegetation. Similar to other dry Afromontane forests, the Campuses forests featured a variety of species with varying DBH classes, and height classes. The Afromontane forests most distinctive plant species, such as *Olea europaea. Podocarpus gracilior. Juniperus procera* and more have been identified on the campuses. In addition, the range of elevations across the campuses is between 2343 m and 2448 m within the dry Afromontane forest's altitudinal range (1500-3400 m) (Yilma, 2016).

The composition of woody species is defined by the richness, abundance, dominance and frequency of a species (Eyassu *et al.,* 2020). The study found that the campus floristic composition included a variety of woody species. There were 50 and 49 woody species identified on the EIABC and the Natural Science campuses respectively.

A study of Selected Park Forests by Tefera and Soromessa (2015) showed results on woody plant species (66 and 48), which is almost comparable to this study. Again, greater value is recorded when it is compared to a study of Four Selected Urban Public Parks by Tsegaye (2015), which showed a result on woody plant species (39, 36, 15 and 19). Research indicates that in order to manage forests wisely with regard to their potential for regeneration, information about species composition and structure is necessary. It further results in the ongoing conservation of biological diversity (Sharma *et al.,* 2023).

The EIABC Campus and the College of Natural and Computational Sciences had species abundances of 1231 and 1410, respectively. A species' relative richness and evenness can be expressed using an abundance measure, which evaluates diversity (Evans and Ochiaga, 2014). At each site, certain species were more dominant than others.

On the EIABC campus, *Grevillea robusta, Vernonia amygdalina, Eucalyptus globulus, Acacia decurrens* and *Jacaranda mimosifolia* were significantly more dominant than the others and *Acacia indica, Cassea didbotrea, Cercidiphyllum, Cupressus arizonica, Eucalyptus saligna, Hagenia abyssinica, Ehretia cymosa,* and *Pinus caropus* were the least frequent species.

On the College of Natural and Computational Sciences, the dominated species were *Podocarpus gracilior, Juniperus procera, Jacaranda mimosifolia, Acacia melanoxylon, Allophylus abyssinicas, Cupressus lusitanica* and *Olea europaea*. The least frequent species were *Citrus sinensis, Cassia cinguana and Acacia cynopyla*. Prioritizing conservation efforts is supported by the discovery of abundant and rare species. Therefore, based on the literature, the species with rare frequency need a higher conservation effort than the high abundance species.

Overall this study reveals that a small number of species dominate in terms of abundance. According to studies with comparable findings, its causes include unfavorable environmental conditions like excessive heat and lack of precipitation, as well as anthropological influences like intensive logging, random dissemination of available resources in the forest, or a lack of equal chances for competition (Teshager, 2017).

5.1.2. Woody species structure

5.1.2.1. Arrangement of Height and DBH Class

Woody species' patterns of diameter and height have been used to study a species' regeneration profile (Siraj and Zhang, 2018). Maintaining a healthy population regeneration of the species is also crucial (Feyissa, 2012). In this study, the number of trees listed at each study site was used to analyze the height and DBH of the trees.

While the highest values of height and DBH were equal with 120 cm and 49 m values, respectively, the two sites displayed distinct patterns for DBH and height distribution. According to Feyissa (2012) in the population structural characteristics, the various species patterns can be used to indicate population dynamics.

The DBH distribution of the forests in this study revealed that there were a lot of trees in both the first and next classes, but the percentage of trees declined as the classes grew. These results were common for both of the sites except for the numerical difference. According to Nowak and Crane (2001) carbon storage (tc/ha) is predominantly affected by tree density and diameter distribution. Tree density and carbon densities are directly proportional to each other. Despite this, the result from the DBH distribution of the trees implies that carbon stock in the site grows gradually with the growth of the diameter of the tree, as more trees are found in the lower class (young generation).

The height distribution of the forests revealed that there are more individual trees in both the first and next classes. These results were common for both sites except for the numerical difference. A study with similar results by Tefera and Soromessa (2015) discusses the positive relationship of heights with DBH and its effect on the above-ground carbon stock. Yilma (2016) also addresses height as a measure of the age of the forest. The comparison of height classes shows that older trees tend to be more prevalent among higher height classes. This implies that there are much younger trees on the site.

The pattern of inverted J-shaped was observed in the arrangement of height and DBH class for both of the sites. This pattern suggests the study site has a stable population status (Siraj and Zhang, 2018). The presence of stable population supports the prospect of a natural forest ecosystem, whereas a unstable population pattern reflects risk in the future and defines the need for a management plan for their sustainable utilization and protection (Siraj and Zhang, 2018).

5.2. Diversity of Woody Plant Species

Species distribution and their relative abundance refer to species diversity. The levels of species evenness and richness are main factors that affect the values of species diversity (Tona, 2016). The Shannon Weiner diversity index (H') is an extensively used technique to determine species evenness and richness (Kent and Coker, 1992).

Therefore, for the purpose of identifying the campuses' species diversity, this study computed the Shannon Wiener diversity index (H'). The College of Natural and Computational Sciences and EIABC have Shannon Wiener diversity indices of 3.03 and 3.11, respectively. As stated, EIABC Campus shows slightly greater value. On the other hand, it reflects that relatively, College of Natural and Computational Sciences has dominant species.

Mitra (2015) states that the Shannon-Weiner diversity index has four values: low when it falls between 2.0 and 1.0, medium when it falls between 3.0 and 2.0, and very low when it is less than 1.0. If the value is higher than 3.0, it is considered high. This value rarely rises above 4.5 and typically falls between 1.5 and 3.5. Both campuses have index values greater than 3. So it implies that the campuses have high diversity.

The evenness values computed for EIABC and College of Natural and Computational Sciences are respectively 0.80 and 0.78. The same as the Shannon Wiener diversity index value, the value of evenness is also slightly greater for the EIABC Campus than the College of Natural and Computational Sciences. Both Shannon and evenness values increase as richness increases. According to Begon *et al.* (2006) the evenness value is a number between 0 and 1, where 0 stands for low evenness and 1 stands for complete evenness.

Overall, the result indicates good woody species diversity and richness, as the (H') and (J) values indicated. These values are also greater when compared to a study of selected park and institute forests by Habtamu *et al.* (2021) in which the results are 2.76, 1.96 and 0.63, 0.266, respectively, for (H') and (J).

5.2.1. Exotic and Indigenous species along the Campuses

The indigenous and exotic woody species distribution throughout the campuses is defined. Studies show that there is a trend toward planting more exotic plants while planting fewer indigenous ones (FAO, 2010; Moges *et al.,* 2010). But the finding of this research shows the College of Natural and Computational Sciences indigenous plants were far superior to its exotic plants. On the other hand, the EIABC Campus has a similar number of recorded indigenous and exotic species but with fewer indigenous trees.

5.3. Biomass and Carbon Stock

According to Mamo (2007) biomass depends on the age of the tree. The age and DBH value of a species determine its AGB. In a similar vein, this study's findings show that older trees with high DBH values also have high AGB. In addition, angiosperms (broad-leaved trees) contain higher wood densities than gymnosperms (coniferous trees) (Jandl *et al.,* 2006).

For EIABC Campus, the AGB ranged from 0.01 to 165.01 tons per tree, with an average value of 13.65 tons per tree. Totally, 153.55 t/ha, in which 628.03 tons of AGB were recorded. The BGB ranged from 0.002 to 33.00 tons per tree, with an average value of 2.73 tons per tree. Totally, 30.72 t/ha, in which 125.65 tons of BGB were recorded. In general, a total biomass (TB) is 753.69 tons with 184.28 t/ha.

On the other hand, for the College of Natural and Computational Sciences, the AGB ranged from 0.01 to 594.8 tons per tree, with an average value of 22.15 tons per tree. Totally, 252.67 t/ha, in which 1041.01 tons of AGB were recorded. The BGB ranged from 0.002 to 118.95 tons per tree, with an average value of 4.43 tons per tree. Totally, 50.53 t/ha, in which 208.20 tons of AGB were recorded. Overall, the total biomass (TB) is 1249.21 tons with 303.21 t/ha.

Accordingly, in this study, more AGB was recorded from the College of Natural and Computational Sciences. This might be as a result of the various kinds and quantities of woody species mentioned in each site. Fisher and Bilkely (2000) state that the age, density, and species of woody plants have an impact on biomass. Similarly, compared to the EIABC Campus, the College of Natural and Computational Sciences had larger area coverage and listed a higher quantity of woody plants.

The highest AGC was calculated in *Podocarpus gracilior* with 297.378 ton/species, 72.1 t/ha and 264.897 t/ha of $AGCO_2$, whereas the lowest AGC was calculated in *Citrus sinensis* with 0.01 ton/species, 0.001 t/ha and 0.005 t/ha of AGCO2 at the College of Natural and Computational Sciences. On the other hand, the highest AGC calculated in *Eucalyptus saligna* was 165.01 tons/species, 20.1 t/ha and 74.031 t/ha of AGCO2, whereas the lowest AGC was calculated in *Hagenia abyssinica* with 0.01 tons/species, 0.001 t/ha and 0.005 t/ha of AGCO2 at the EIABC Campus.

This result reveals that species with a greater number of individuals and higher DBH values provide higher AGB content and a lower number of individuals with low DBH values have a lower content of AGB. In this study, the mean AGC is 101.5 t/ha.

The findings of this study have a nearby mean value in contrast to the findings of those two studies; a study by Tsegaye (2015) shows a mean AGC of 118.74 t/ha for a Selected Urban Public Park, and a study by Tura *et al.* (2011) shows a mean AGC of 122.85 t/ha for a Selected

Church Forest but considerably lower value when compared to a study by Habtamu *et al.* (2021) that reveals a mean AGC of 143.3 t/ha for a Selected Park Forests. However, greater values are recorded when compared to the result of Selected Park Forests by Tefera and Soromessa (2015) a mean AGC of 50.8 t/ha.

In comparison with other studies with similar environmental conditions, the mean value of this study's results is lower, as indicated in Table 5.1 The woody species plants in these study areas are very young, with a lower DBH value than the study areas with higher results. On the other hand, these campuses have a substantial carbon stock holding a mean of 101.5 t/ha. These results fall within the ranges of 13.5-122.85 t/ha for tropical dry forests and 95-527.85 t/ha for wet forests, respectively, which Murphy and Lugo (1986) reported for the global above-ground carbon stock. Often, this range is applicable. Deffersha and Kutie (2016) and Girma and Soromsa (2014) are two studies that discuss it in their research.

As a result, these sites' mean values fall within the range of the suggested carbon stock. By storing significant amounts of carbon in a manner competitive with Addis Ababa's urban public parks and churches, it is evidence that the campus woody plant species take a crucial part in mitigating environmental damage.

Table 5.1. Comparison between the current result and other studies' carbon stock (t/ha)

No	The Studies	AGC (t/ha)	BGC (t/ha)
1	Selected Church Forest (Tura *et al.*, 2011)	122.85	25.97
2	Selected Park Forests (Tefera and Soromessa, 2015)	50.8	10.1
3	Four selected urban Public parks (Tsegaye, 2015)	118.74	23.74
4	Selected park forests (Habtamu *et al.*, 2021)	143.3	28.66
5	EIABC Campus and College of Natural and Computational Sciences	101.5	20.3

5.4. Temperature value of the campuses and the surrounding

Among the ecosystem services offered by urban green spaces is climate regulation. Enhancement of the city's outdoor thermal comfort is primarily promoted by the growth of urban tree cover (Veerkamp *et al.*, 2021). Urban vegetation significantly lowers the temperature of the built environment. The average temperature drop in green parks is 3 °C for the air and 7 °C for the surface temperature. Ground-level vegetation is an important urban heat mitigation technique (Wong *et al.*, 2021).

The temperature of the campuses has a reduced temperature value from their surrounding and the temperature rate of the surroundings is higher than the measured values inside the campuses. The temperature of the campus (inside) has a reduced temperature mean value of 3.6°C and 4.4°C, respectively, for EIABC and College of Natural and Computational Sciences. According to a study, an urban park in Hong Kong was found to be 8°C cooler during the day than its surroundings, but only 2°C cooler at night (Wong *et al*., 2021).

According to a study on the cooling effects of urban green space in cities, water features and larger parks with a variety of vegetation have the greatest cooling effect (Aram *et al.,* 2019). Likewise, the results of this investigation are similar to those of Aram *et al.* (2019). The vegetation data reveals the abundance of trees on the Natural Science campus was greater than from the EIABC campus. The result of temperature values also shows that the Natural Science campus displays a greater reduction of temperature when compared to the EIABC campus. Therefore, it implies that the area with increased tree cover displays improved thermal comfort than that of the less tree-covered area.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Due to urbanization living in cities becomes higher. Climate change is also the result of urbanization and its aftereffects. Knowing about how different landscapes and landscape factors affect the climate. The contribution of landscapes for climate change and related problems is always brought up to the front. Even if the institutes are one of the places that green landscapes appear. The contributions of green landscape that are found in the institutes for climate resilience and environment protection beyond their organizational roles are not gaining consideration. However, this study reveals the contribution of forests in EIABC and the College of Natural and Computational Sciences of Addis Ababa University using valid methodologies.

In general, the composition of the campus vegetation indicates that there is abundance of vegetation, with 2641 trees and 69 species. However, the composition reflects some dominant species like *Grevillea robusta, Vernonia amygdalina, Eucalyptus globulus* and other trees in EIABC, and *Podocarpus gracilior, Juniperus procera, Jacaranda mimosifolia* and other trees in College of Natural and Computational Sciences.

The varieties show that the numbers of indigenous species are comparatively equal to the exotic's species. In general, the campuses had a competitive number of species and individual trees that secure diversity of species. Also the stability and productivity of vegetation were ensured by the Shannon winner diversity and evenness index.

The DBH and height pattern also revealed that there are more young generations of trees in the compound. That indicates the sites have healthy and strong population. So, it can sustain the future of ecosystem service in a better way. *Eucalyptus globulus, Schinus molle, Erythrina brucei and Acacia abbyssinica* were species that exhibit the highest DBH value for both sites.

Once again, the result that there is a younger generation of trees implies that the carbon stock in the site grows gradually with the growth of the diameter of the trees. The abundance of old trees and larger DBH values also increase the capacity of the site to store carbon.

The highest AGC was calculated in *Podocarpus gracilior* and *Eucalyptus saligna,* respectively, for the campuses. A higher AGB content is found in species with a larger number of trees and higher DBH values, whereas a lower number of trees with lower DBH values have lower AGB content. In this study, 184.28 t/ha and 303.21 t/ha of carbon were stored, respectively, for EIABC and College of Natural and Computational Sciences, with the mean value of AGC 101.5 t/ha.

Overall, these studies mean value is lower than that of other comparable studies conducted in Addis Ababa. However the value appears to be in the recommendable range of carbon stock. Therefore, it is evidence that the campus's woody plant species competitively store significant mass of carbon throughout the surrounding air, along with Addis Ababa's urban parks and churches, thereby assisting in the mitigation of climate change.

The results of the temperature values also emphasize the contribution of vegetation characters in reducing high temperatures. In summary, the study's effort reveals that the varieties of woody plants present in the compound hold promise for both vegetation stability and productivity.

Therefore, it can be said that each study site contributes to the country's effort to lower the atmospheric concentration of CO2. Thus, it is an opportunity that biomass and carbon pools will continue to rise in the coming years if proper vegetation management and silvi-cultural management, such as weeding, cultivation, thinning, pruning and pollarding are put into practice. Eventually, this contributes to lower the atmospheric concentration of CO2 and also creates its own print in regulating the temperature with more diversified and productive species.

6.2. Recommendations

6.2.1. Climate Resilience Actions

It is essential to work on mitigation and adaptation in order to maintain climate resilience. Ethiopia is on the threshold of reducing the adverse effects of global warming by increasing the use of electric cars and public transportation, switching to renewable energy sources, and conserving energy. The effects of climate change will persist over time, even if the nation works to mitigate them. Thus, it is important to develop adaptation strategies at macro and micro level; as the result, the practices go on investing in infrastructure updates and climate-smart planning like street trees, cycle lines and other environmental solutions. In the dimension of this study to cope with climate resilience, the first lines of defenses are recommended below.

6.2.2. Adaption Strategies

To develop more diversity of species and to improve the carbon pools (Objective 1 and 2)

Prioritization of less dominant species

- The species with a rare frequency need more conservation effort than the species with a high a frequency (Appendix 10).

Enhance the health of trees

- To treat the forests from disease and cut out dead trees.
- More treatment for the younger trees and indigenous trees.
- Develop a proper management system in order to nourish the tree's growth.

Increase the number of vegetation

- To decrease deforestation
- To increase the number and diversity of trees, including indigenous and edible fruits.

To develop more cooling effects (Objective 3)

- To expand the site's canopy cover (to increase the number of trees).
- Plant a variety of tree species with greater capacity for cooling via evapotranspiration and shading. Such as dense evergreen trees, perennial ground and deciduous tree covers.
- It is important to maximize cooling and shade when choosing and positioning trees.

Coping resilience by focusing only on these campuses is not going to be functional, so developing strategic planning for other related institutes in order to work in a team is important. Overall, enhancing the resilience of the ecosystem enhances the climate resilience. Responsible departments in the institute need to:

- Create a coordinated effort involving various sectors and stakeholders to work on the city's institutional forests.
- Monitoring and tracking progress across the system.
- Share knowledge, experiences and solutions.
- Enrich the natural ecosystems and ecological diversity by investing while preventing disease outbreaks among vegetation.

The following recommendations are generally appointed out in considering the study's findings

- The campuses should further endorse evenness and diversity of species to loosen the number of species that are dominant.
- The campuses should give more attention to the plantation and management of indigenous trees against the exotic and invasive trees.
- Need further studies to fully exploit the benefit of campus forests in fighting climate change by considering other carbon pools that are not included in this study.
- Need further studies on campus forests contribution in maintaining the surrounding temperature and air quality with the consideration of species of trees and particle matter.
- Based on the result establishing more number of institutes in the city with proper management serve as carbon pool, potentially stabilize urban microclimate and maintain diversity of species.
- Needs awareness creation on the institute woody plant species up on carbon sequestration. It also serves as a way to create carbon finance.
- This study can contribute as baseline research and give helpful details for future research on the diversity, structural characteristics, composition and carbon stock capacity of woody species in institutional forests.

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APPENDICES

Appendix 1: **Detail presentation of recorded woody species at EIABC Campus**

Woody species scientific name, mean of DBH and Height, summary of above ground, below ground biomass, Carbon and Carbon dioxide at EIABC Campus (indigenous species are depicted by 'red font", whereas species in 'black font" are non-indigenous trees).

No	Scientific name	No of tree	Average DBH(cm)	Average Height(m)	AGB (t/ha)	BGB (t/ha)	AGC (t/ha)	$AGCO_2$ (t/ha)	BGC (t/ha)	$BGCO_2$ (t/ha)	TC(t/ha)	TCO2 (t/ha)
1	*Acacia abbyssinica*	5	38.02	7.94	1.449	0.290	0.725	2.660	0.145	0.532	0.870	3.192
2	*Acacia decurrens*	85	15.01	8.72	2.924	0.585	1.462	5.366	0.292	1.073	1.755	6.439
3	*Acacia indica*	1	26.10	20.00	0.067	0.013	0.033	0.122	0.007	0.024	0.040	0.147
4	*Acacia melanoxylon*	77	18.48	8.61	4.620	0.924	2.310	8.477	0.462	1.695	2.772	10.173
5	*Casimiroa edulis*	5	18.92	6.74	0.294	0.059	0.147	0.539	0.029	0.108	0.176	0.647
6	*Cassea didbotrea*	1	32.00	9.00	0.110	0.022	0.055	0.202	0.011	0.040	0.066	0.243
7	*Casuarina equisetifolia*	41	32.11	13.47	6.601	1.320	3.301	12.113	0.660	2.423	3.961	14.536
8	*Celtis africana*	3	32.67	12.33	0.785	0.157	0.392	1.440	0.078	0.288	0.471	1.728
9	*Cercidiphyllum*	1	41.60	12.00	0.205	0.041	0.103	0.376	0.021	0.075	0.123	0.452
10	*Coffea arabica*	15	6.37	3.57	0.038	0.008	0.019	0.069	0.004	0.014	0.023	0.083
11	*Cordia africana*	19	27.06	8.78	2.102	0.420	1.051	3.858	0.210	0.772	1.261	4.629
12	*Croton macrostachyus*	26	21.78	8.61	1.876	0.375	0.938	3.443	0.188	0.689	1.126	4.131
13	*Cupressus arizonica*	1	15.50	7.60	0.017	0.003	0.008	0.030	0.002	0.006	0.010	0.036
14	*Cupressus lusitanica*	77	20.77	9.84	5.951	1.190	2.976	10.920	0.595	2.184	3.571	13.104
15	*Cupressus pyramidalis*	4	21.56	9.78	1.106	0.221	0.553	2.029	0.111	0.406	0.663	2.435
16	*Ehretia cymosa*	4	32.50	7.13	0.798	0.160	0.399	1.464	0.080	0.293	0.479	1.757

17	*Ekebergia capensis (E. rueppeliana)*	6	56.95	13.17	3.065	0.613	1.532	5.624	0.306	1.125	1.839	6.749
18	*Eriobotrya japonica*	11	16.20	5.29	0.280	0.056	0.140	0.514	0.028	0.103	0.168	0.617
19	*Erythrina brucei*	1	15.00	16.00	0.015	0.003	0.008	0.028	0.002	0.006	0.009	0.033
20	*Eucalyptus globulus*	94	43.87	17.37	31.246	6.249	15.623	57.337	3.125	11.467	18.748	68.804
21	*Eucalyptus saligna*	1	68.00	23.00	40.344	8.069	20.172	74.031	4.034	14.806	24.206	88.837
22	*Ficus Elastica*	9	29.53	8.44	0.984	0.197	0.492	1.806	0.098	0.361	0.591	2.167
23	*Ficus sure*	3	70.33	15.33	2.126	0.425	1.063	3.901	0.213	0.780	1.275	4.681
24	*Grevillea robusta*	155	18.89	10.76	9.561	1.924	4.780	17.544	0.962	3.531	5.742	21.075
25	*Hagenia abyssinica*	1	5.00	2.50	0.003	0.001	0.001	0.005	0.000	0.001	0.002	0.006
26	*Jacaranda mimosifolia*	84	21.38	7.94	5.659	1.132	2.829	10.383	0.566	2.077	3.395	12.460
27	*Juniperus procera*	62	14.34	7.34	2.485	0.497	1.242	4.560	0.248	0.912	1.491	5.472
28	*Melia aztrachm*	6	15.63	5.17	0.374	0.075	0.187	0.687	0.037	0.137	0.225	0.824
29	*Millettia ferruginea*	35	21.83	8.99	2.609	0.522	1.304	4.787	0.261	0.957	1.565	5.744
30	*Olea europaea*	43	18.91	7.78	2.288	0.458	1.144	4.198	0.229	0.840	1.373	5.038
31	*Persea americana*	3	11.07	6.53	0.031	0.006	0.015	0.056	0.003	0.010	0.018	0.067
32	*Piliostigma thonningii*	16	14.71	6.58	0.372	0.074	0.186	0.683	0.037	0.137	0.223	0.820
33	*Pinus caropus*	1	14.00	6.60	0.012	0.002	0.006	0.023	0.001	0.005	0.007	0.027
34	*Pinus patula*	4	24.50	9.85	0.261	0.052	0.130	0.479	0.026	0.096	0.156	0.574
35	*Podocarpus gracilior*	28	30.07	10.54	6.003	1.201	3.002	11.016	0.600	2.203	3.602	13.219
36	*Prunus africana*	19	30.24	10.35	3.201	0.640	1.601	5.874	0.320	1.175	1.921	7.049
37	*Psidium guajava*	4	6.58	4.53	0.011	0.002	0.006	0.021	0.001	0.004	0.007	0.025
38	*Ricinus communis*	3	8.93	4.67	0.021	0.004	0.010	0.038	0.002	0.008	0.012	0.045
39	*Schefflera abyssinica*	5	34.40	7.68	1.334	0.267	0.667	2.447	0.133	0.489	0.800	2.936
40	*Schinus molle*	12	38.84	6.48	3.622	0.724	1.811	6.647	0.362	1.329	2.173	7.976
41	*Spathodea campanulata*	15	28.56	9.39	1.958	0.392	0.979	3.592	0.196	0.718	1.175	4.311

42	*Syzygium guineense*	8	23.54	8.94	0.739	0.148	0.369	1.355	0.074	0.271	0.443	1.626
43	*unknown Sp.1*	1	30.82	10.83	0.003	0.001	0.001	0.005	0.000	0.001	0.002	0.007
44	*unknown Sp.2*	6	8.00	5.00	0.732	0.146	0.366	1.343	0.073	0.269	0.439	1.612
45	*unknown Sp.3*	8	29.95	12.59	1.105	0.221	0.552	2.027	0.110	0.405	0.663	2.433
46	*Vernonia amygdalina*	145	13.56	5.14	4.168	0.834	2.084	7.649	0.417	1.530	2.501	9.178
Sum		1154			153.553	30.722	76.777	281.770	15.361	56.375	92.138	338.145
Average			25.31	9.32	3.338	0.668	1.669	6.125	0.334	1.226	2.003	7.351
Max			70.33	23.00	40.344	8.069	20.172	74.031	4.034	14.806	24.206	88.837
Min			5.00	2.50	0.003	0.001	0.001	0.005	0.0003	0.001	0.002	0.01

Appendix 2: **Detail presentation of recorded woody species at College of Natural and Computational Sciences**

Woody species scientific name, mean of DBH and Height, summary of above ground, below ground biomass, Carbon and Carbon dioxide at College of Natural and Computational Sciences (indigenous species are depicted by 'red font", whereas species in 'black font" are non-indigenous trees).

No	Scientific name	No of tree	Average DBH(cm)	Average Height(m)	AGB (t/ha)	BGB (t/ha)	AGC (t/ha)	$AGCO_2$ (t/ha)	BGC (t/ha)	$BGCO_2$ (t/ha)	TC (t/ha)	TCO_2 (t/ha)
1	*Acacia abbyssinica*	26	44.95	12.64	9.470	1.894	4.735	17.378	0.947	3.476	5.682	20.854
2	*Acacia cynopyla*	1	44.00	14.00	0.232	0.046	0.116	0.425	0.023	0.085	0.139	0.510
3	*Acacia decurrens*	2	36.00	13.50	0.290	0.058	0.145	0.533	0.029	0.107	0.174	0.639
4	*Acacia melanoxylon*	113	19.77	9.37	6.348	1.270	3.174	11.648	0.635	2.330	3.809	13.978
5	*Albizia gummifera*	7	26.36	9.20	0.836	0.167	0.418	1.533	0.084	0.307	0.501	1.840
6	*allophylus abyssinicas*	52	16.75	6.12	4.107	0.821	2.054	7.537	0.411	1.507	2.464	9.044
7	*Borassus aethiopum*	4	41.20	13.43	0.804	0.161	0.402	1.475	0.080	0.295	0.482	1.770
8	*Casimiroa edulis*	7	18.63	8.57	0.452	0.090	0.226	0.830	0.045	0.166	0.271	0.996
9	*Cassea didbotrea*	8	23.36	5.26	0.722	0.144	0.361	1.325	0.072	0.265	0.433	1.591
10	*Cassia singueana*	1	37.30	13.00	0.158	0.032	0.079	0.290	0.016	0.058	0.095	0.348
11	*Casuarina equisetifolia*	9	37.12	11.89	1.708	0.342	0.854	3.135	0.171	0.627	1.025	3.762
12	*Citrus sinensis*	1	5.00	3.00	0.003	0.001	0.001	0.005	0.0003	0.001	0.002	0.006
13	*Cordia africana*	19	28.43	8.92	2.593	0.519	1.296	4.757	0.259	0.951	1.556	5.709
14	*Croton macrostachyus*	3	34.50	13.00	0.575	0.115	0.287	1.055	0.057	0.211	0.345	1.265
15	*Cupressus lusitanica*	61	31.16	11.85	10.780	2.156	5.390	19.781	1.078	3.956	6.468	23.737
16	*Cupressus pramidalis*	5	27.12	17.20	0.416	0.083	0.208	0.763	0.042	0.153	0.250	0.916
17	*Ehophorbia sp.*	4	22.80	6.50	0.243	0.049	0.121	0.445	0.024	0.089	0.146	0.534
18	*Ehretia cymosa*	7	44.36	11.37	2.016	0.403	1.008	3.700	0.202	0.740	1.210	4.440

19	*Ekebergia capensis (E. rueppeliana)*	5	11.42	9.26	0.043	0.009	0.021	0.078	0.004	0.016	0.026	0.094
20	*Eriobotrya japonica*	20	10.69	4.73	0.154	0.031	0.077	0.283	0.015	0.057	0.093	0.340
21	*Erythrina brucei*	8	54.63	12.31	5.091	1.018	2.545	9.342	0.509	1.868	3.054	11.210
22	*Eucalyptus globulus*	22	27.97	15.06	3.106	0.621	1.553	5.700	0.311	1.140	1.864	6.840
23	*Ficus sure*	9	27.46	10.11	0.944	0.189	0.472	1.733	0.094	0.347	0.567	2.079
24	*Fraxinus sp.*	36	25.45	7.65	3.136	0.627	1.568	5.754	0.314	1.151	1.881	6.905
25	*Grevillea robusta*	23	31.98	13.27	3.587	0.717	1.793	6.582	0.359	1.316	2.152	7.898
26	*Jacaranda mimosifolia*	140	22.22	8.17	8.296	1.659	4.148	15.223	0.830	3.045	4.977	18.267
27	*Juniperus procera*	165	33.92	13.08	29.959	5.992	14.979	54.974	2.996	10.995	17.975	65.969
28	*Ligustrum ovata*	12	12.43	6.52	0.142	0.028	0.071	0.261	0.014	0.052	0.085	0.314
29	*Maesa lanceolata*	6	16.78	4.77	0.160	0.032	0.080	0.293	0.016	0.059	0.096	0.352
30	*Melia aztrachm*	4	13.55	7.00	0.076	0.015	0.038	0.139	0.008	0.028	0.045	0.167
31	*Millettia ferruginea*	27	14.23	7.13	0.639	0.128	0.320	1.173	0.064	0.235	0.384	1.408
32	*Morus alba*	10	23.23	9.45	0.567	0.113	0.284	1.041	0.057	0.208	0.340	1.249
33	*Myrica salicifolia*	14	16.92	7.37	2.237	0.447	1.118	4.104	0.224	0.821	1.342	4.925
34	*Olea europaea*	60	21.85	9.06	0.990	0.198	0.495	1.816	0.099	0.363	0.594	2.179
35	*Persea americana*	15	19.50	5.42	0.867	0.173	0.434	1.591	0.087	0.318	0.520	1.909
36	*Phoenix*	25	38.90	13.88	0.719	0.144	0.359	1.319	0.072	0.264	0.431	1.583
37	*Pinus Radiata*	4	21.19	9.34	144.358	28.872	72.179	264.897	14.436	52.979	86.615	317.877
38	*Podocarpus gracilior*	296	14.11	8.14	0.223	0.045	0.112	0.410	0.022	0.082	0.134	0.492
39	*Prunus africana*	14	15.03	7.13	0.564	0.113	0.282	1.035	0.056	0.207	0.338	1.242
40	*Spathodea campanulata*	8	34.68	8.88	1.520	0.304	0.760	2.789	0.152	0.558	0.912	3.347
41	*Syzygium guineense*	27	22.58	8.27	1.904	0.381	0.952	3.495	0.190	0.699	1.143	4.194
42	*Tecoma stans*	25	13.10	5.74	0.422	0.084	0.211	0.774	0.042	0.155	0.253	0.928
43	*Unknown 1*	8	15.70	5.17	0.056	0.011	0.028	0.102	0.006	0.020	0.034	0.123
44	*Unknown 2*	3	33.00	6.30	0.118	0.024	0.059	0.216	0.012	0.043	0.071	0.260
45	*Unknown 3*	1	8.23	4.75	0.014	0.003	0.007	0.026	0.001	0.005	0.008	0.031

46	*Unknown 4*	4	7.93	6.34	0.060	0.012	0.030	0.110	0.006	0.022	0.036	0.132
47	*Vernonia amygdalina*	47	13.86	5.70	0.967	0.193	0.484	1.775	0.097	0.355	0.580	2.130
Sum		1368			252.671	50.534	126.336	463.652	25.267	92.730	151.603	556.382
Average			24.71	9.12	5.376	1.075	2.688	9.865	0.538	1.973	3.226	11.838
Max			54.63	17.20	144.358	28.872	72.179	264.897	14.436	52.979	86.615	317.877
Min			5.00	3.00	0.003	0.001	0.001	0.005	0.0003	0.001	0.002	0.006

Appendix 3: Detail presentation of recorded Temp value at College of Natural and Computational Sciences.

Table shows the recorded temperature value of College of Natural and Computational Sciences on February 2024.

College of Natural and Computational Sciences Temp. in C^0														
	Recording spots and values										Summary			
	1	2	3	4	5	6	7	8	9	10	Max	Min	Mean	Remark
Day 1	27.8	27.9	27.0	28.6	28.8	27.9	28.4	27.4	27.1	27.4	28.8	27.0	27.83	Out side
	24.9	23.5	23.6	23.8	23.0	24.9	24.2	23.5	23.5	23.9	24.9	23.0	23.88	Inside
Day 2	28.8	30.8	27.9	28.0	27.9	27.0	27.9	28.4	29.8	30.0	30.0	27.0	28.65	Out side
	24.6	24.0	23.1	24.0	23.8	23.8	23.8	23.7	23.9	24.0	24.6	23.1	23.87	Inside
Day 3	27.9	28.3	28.1	28.0	28.5	27.5	28.8	28.4	31.1	28.6	31.1	27.5	28.52	Out side
	24.4	23.9	23.3	23.4	23.4	24.3	24.0	23.9	24.4	24.3	24.4	23.3	23.93	Inside

Total days		
	Out side	Inside
Max	31.1	24.9
Min	27	23
Mean	28.33	23.89

Appendix 4: **Detail presentation of recorded Temp value at EIABC Campuse.**

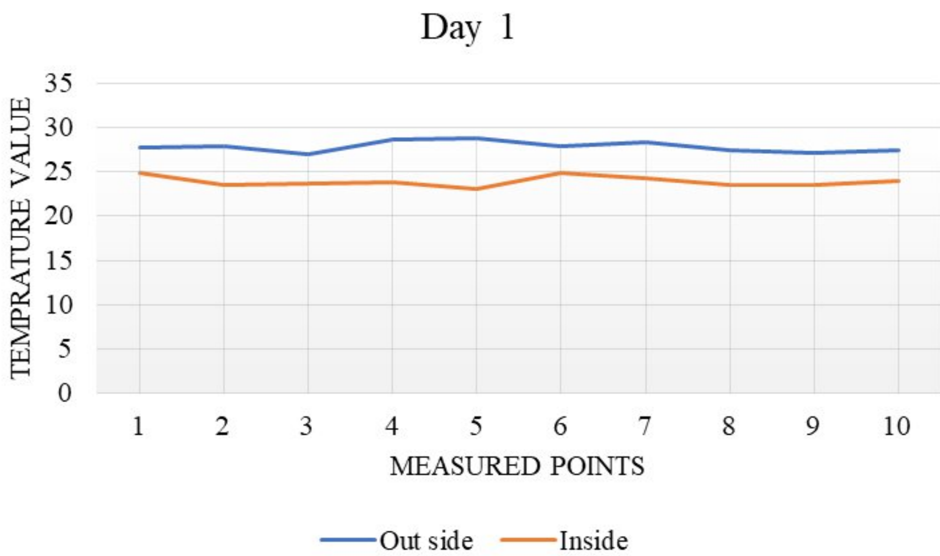
Table shows the recorded temperature value of EIABC Campus on February 2024.

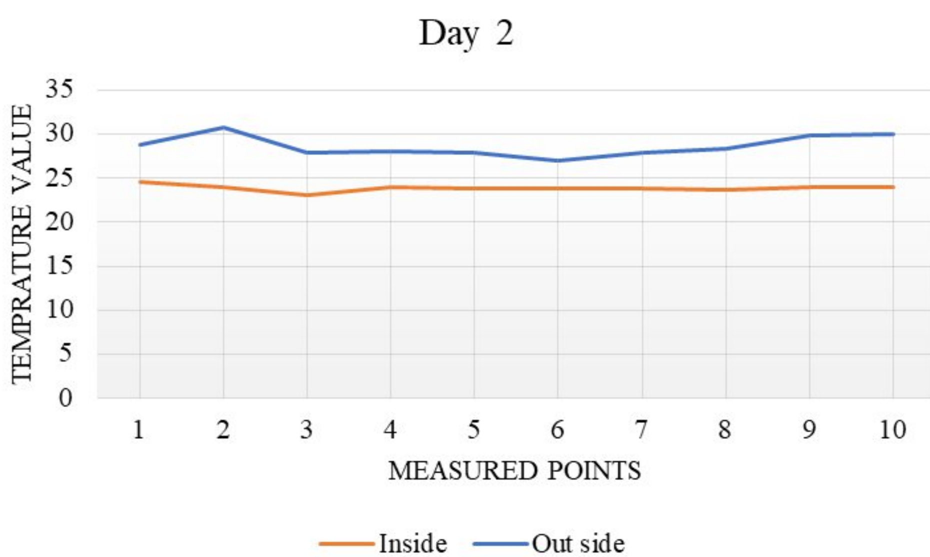
EIABC Campus Temp. in C^0														
	Recording spots and values										Summary			
	1	2	3	4	5	6	7	8	9	10	Max	Min	Mean	Remark
Day 1	31.3	27.5	28.4	30.3	30.3	31.7	35.5	30.0	30.5	32.3	35.5	27.5	30.78	Out side
	29.7	28.1	27.3	26.8	27.1	26.5	26.9	26.1	27.1	26.8	29.7	26.1	27.24	Inside
Day 2	32.3	29.5	29.4	30.9	31.3	32.7	29.5	30.8	31.5	32.9	32.9	29.4	31.08	Out side
	28.7	29.1	26.2	26.9	29.1	27.5	26.2	26.1	27.7	26.2	29.1	26.1	27.37	Inside
Day 3	30.3	31.5	28.4	29.3	30.3	29.7	31.5	30.6	31.9	32.0	32.0	29.3	30.55	Out side
	27.1	26.3	26.7	27.3	26.5	26.8	27.4	26.9	27.3	26.3	27.4	26.3	26.86	Inside

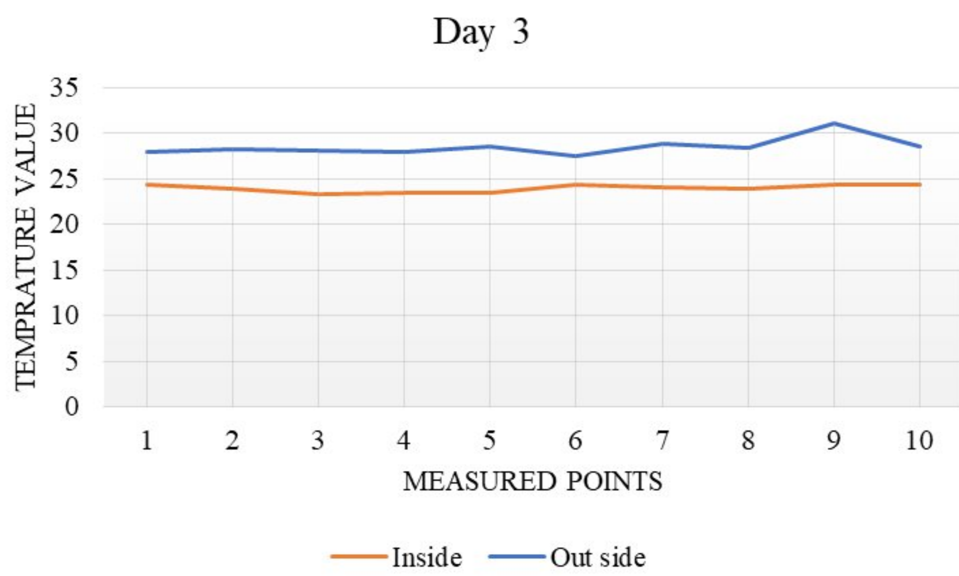
Total days		
	Out side	Inside
Max	35.5	29.7
Min	27.5	26.1
Mean	30.80	27.16

Appendix 5: Graph shows the temp value of the campuses

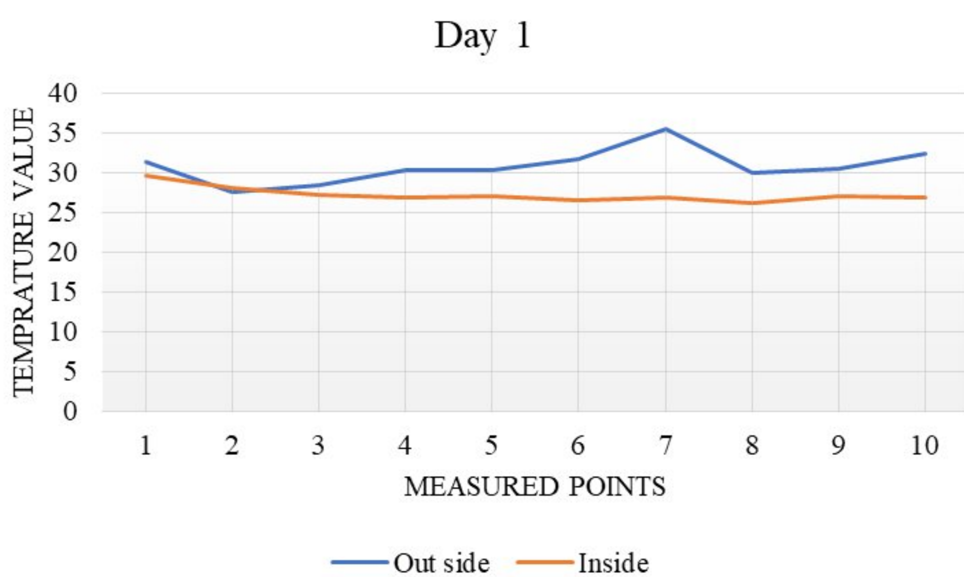
Line graph shows the temperature value of College of Natural and Computational Sciences for each day in the outside and inside the campus.

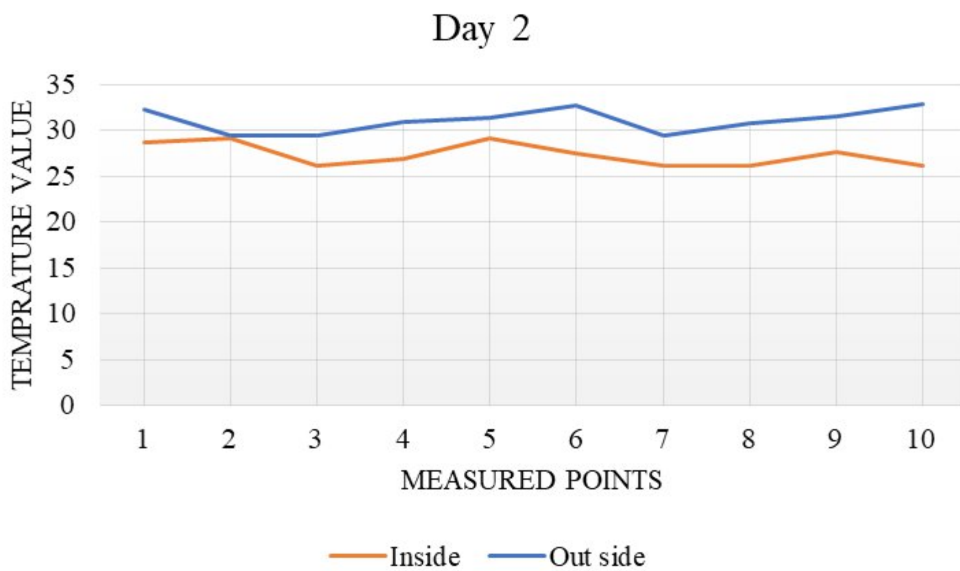


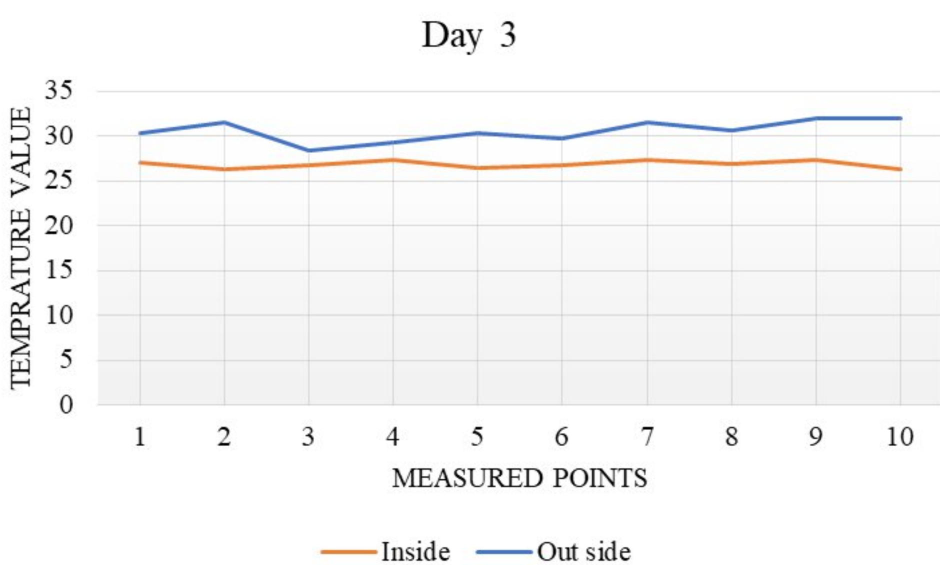




Line graph shows the temperature values of EIABC Campus for each day in the outside and inside the campus.




Day 2
TEMPRATURE VALUE
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
MEASURED POINTS
Inside
Out side


Day 3
TEMPRATURE VALUE
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
MEASURED POINTS
Inside
Out side

Appendix 6: Field inventory format

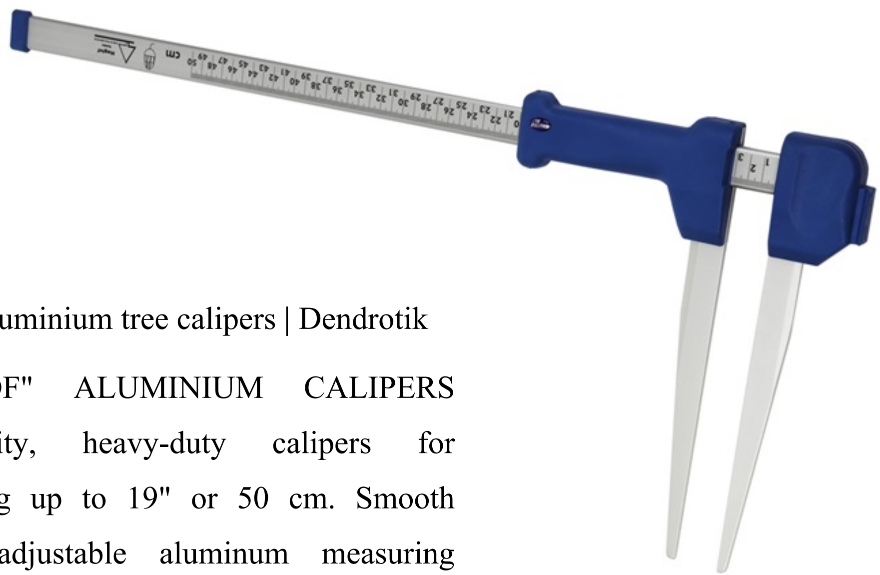
Location _ Date_

This checklist is prepared to the Fulfillment of thesis in Master of Science in Environmental Planning and Landscape Design at Graduate Studies of Addis Ababa University. The table is arranged to assess woody plant species Nomenclature, a DBH value ≥ 5cm and Height.

No	Local name	Scientific name	DBH(cm)	Height (m)	Remark

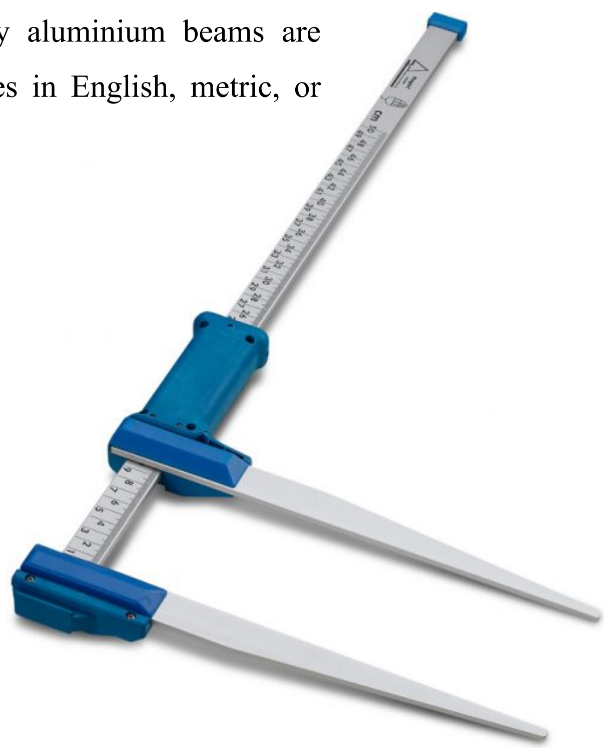
Appendix 7: Caliper

It is the instrument used to measure the tree diameter.



Haglof aluminium tree calipers | Dendrotik

"HAGLOF" ALUMINIUM CALIPERS Top-quality, heavy-duty calipers for measuring up to 19" or 50 cm. Smooth sliding adjustable aluminum measuring arms. Thick, sturdy aluminium beams are graduated both sides in English, metric, or both.



Appendix 8: Hypsometer

It is the instrument used to measure the tree Height.

Suunto PM5-1520 Hypsometer

The Suunto PM-5/1520 height meter is an instrument that allows you to measure heights, especially of trees, with great accuracy and agility. The instrument housing is made of a corrosion-resistant anodized aluminum alloy. The scale moves on a special bearing inside a hermetically sealed plastic container filled with a liquid.

Appendix 9: Temperature sensor

It is the instrument used to measure the temperature of the study site and the surrounding.

Temperature and Humidity Hygrometer Meter

With probe attached letting you record the temperature from two different locations. The humidity reading is from the display unit only.

Records maximum/minimum temperature

Appendix 10: Table shows the conservation priority of species

This table shows the Conservation priority of species for both of the campuses based on the abundance: - The species with rare frequency need high conservation effort than the species with high frequency value. The symbol (*) represents Number of species recorded (**) Conservation priority. The color represents:- high priority = Middle priority = Low priority =

EIABC Campus				College of Natural and Computational Sciences			
Species Name		*	**	*Species Name*		*	**
Local	*Scientific*			*Local*	*Scientific*		
Grar	*Acacia indica*	1	*HIGH PRIOPRITY*		*Acacia cynopyla*	1	*HIGH PRIOPRITY*
	Cassea didbotrea	1			*Cassipourea malosana*	1	
	Cercidiphyllum	1			*Cassia singueana*	1	
Yeferenji-tid	*Cupressus arizonica*	1		*Birtukan*	*Citrus sinensis*	1	
	Erythrina brucei	1			*Acacia decurrens*	2	
Saligna bahir zaf	*Eucalyptus saligna*	1			*Bersama abyssinca*	3	
Koso	*Hagenia abyssinica*	1		*Bisana*	*Croton macrostachyus*	3	
	Mussaenda arcuata	1		*Zembaba*	*Borassus aethiopum*	4	
	Pinus caropus	1			*Ehophorbia sp.*	4	
Kawoot	*Celtis africana*	3		*Neem*	*Melia aztrachm*	4	
Koshim	*Dovialic abbyssinica*	3			*Pinus Radiata*	4	
	Ficus sure	*3*			*Rhus glutinosa*	4	
Avocado	*Persea americana*	3		*Yeferenji-tid*	*Cupressus pramidalis*	5	
Gullo	*Ricinus communis*	3		*Lole*	*Ekebergia capensis (E. rueppeliana)*	5	
Yeferenji-tid	*Cupressus pyramidalis*	4			*Maesa lanceolata*	6	
Game	*Ehretia cymosa*	4		*Sesa*	*Albizia gummifera*	7	
Zembaba	*Phoenix*	4		*Kazamora*	*Casimiroa edulis*	7	

Pachula	*Pinus patula*	4		*Game*	*Ehretia cymosa*	7	
Zeituna	*Psidium guajava*	4			*Cassea didbotrea*	8	
Bazra girar	*Acacia abbyssinica*	5		*Korch*	*Erythrina brucei*	8	
Kazamora	*Casimiroa edulis*	5		*Yebereha nebelbal*	*Spathodea campanulata*	8	
Gitem /Kokora	*Schefflera abyssinica*	5			*Teclea simplicifolia*	8	
Lol	*Ekebergia capensis (E. rueppeliana)*	6		*Shewshewie /arzelibanos*	*Casuarina equisetifolia*	9	
Neem	*Melia aztrachm*	6		*Sholla*	*Ficus sure*	9	
	Psdrax schimperiana	*6*	HIGH PRIOPRITY	*yeferenji injori*	*Morus alba*	10	HIGH PRIOPRITY
	Pittosporum viridiflorum	8			*Ligustrum ovata*	12	
Dokma	*Syzygium guineense*	8		*Shinet*	*Myrica salicifolia*	14	
Yegoma zaf	*Ficus Elastica*	9		*Tkur enchet*	*Prunus africana*	14	
Woshmela	*Eriobotrya japonica*	11		*Avocado*	*Persea americana*	15	
Qundo berbere	*Schinus molle*	12			*Callistemon*	18	
Bunna	*Coffea arabica*	15		*Wanza*	*Cordia africana*	19	
Yebereha nebelbal	*Spathodea campanulata*	15		*Woshmela*	*Eriobotrya japonica*	20	
Yekolla wanza	*Piliostigma thonningii*	*16*		*Nech bahir zaf*	*Eucalyptus globulus*	22	
	Callistemon	*18*		*Grevila*	*Grevillea robusta*	23	
Wanza	*Cordia africana*	*19*		*Itsepatos*	*Dracaena steudneri*	24	
Tkur enchet	*Prunus africana*	19		*Zembaba*	*Phoenix*	25	
Bisana	*Croton macrostachyus*	26		*Tacoma*	*Tecoma stans*	25	
Zigba	*Podocarpus gracilior*	28	MIDDLE PRIOPRITY	*Bazra girar*	*Acacia abbyssinica*	26	
Birbira	*Millettia ferruginea*	35		*Birbira*	*Millettia ferruginea*	27	MIDDLE PRIOPRITY
Shewshewie/ arzelibanos	*Casuarina equisetifolia*	41		*Dokma*	*Syzygium guineense*	27	

Sete Weira	*Olea europaea*	43	MIDDLE PRIOPRITY		*Fraxinus sp.*	36	MIDDLE PRIOPRITY
Itsepatos	*Dracaena steudneri*	52		*Grawwa*	*Vernonia amygdalina*	47	
Yehabesha Tid	*Juniperus procera*	62		*Embus*	*allophylus abyssinicas*	52	
Omedla	*Acacia melanoxylon*	77	LOW PRIOPRITY		*Olea europaea*	60	
Yeferenji-tid	*Cupressus lusitanica*	77		*Yeferenji-tid*	*Cupressus lusitanica*	61	
yetebmenja zaf	*Jacaranda mimosifolia*	84		*Omedla*	*Acacia melanoxylon*	113	LOW PRIOPRITY
Mimosa /Akacha	*Acacia decurrens*	85		*yetebmenja zaf*	*Jacaranda mimosifolia*	140	
Nech bahir zaf	*Eucalyptus globulus*	94		*Yehabesha Tid*	*Juniperus procera*	165	
Grawwa	*Vernonia amygdalina*	145		*Zigba*	*Podocarpus gracilior*	296	
Grevila	*Grevillea robusta*	155					

Analyzing Vegetation Structure and Carbon Stock Potential of EiABC and College of Natural and Computational Sciences at Addis Ababa University

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ABSTRACT

One of the important strategies to address climate change concerns is to improve urban green spaces as an alternative for climate resilience. Thus this study was conducted to evaluate the contribution of forests on the EiABC Campus and the College of Natural and Computational Sciences *at Addis Ababa University. Species diversity and Carbon stock potential are the parameters used to assess the contribution of forests in the campuses. Data on the vegetation were collected using a purposive sampling technique. The forest composition revealed a total of 2,641 individual trees, representing 69 species from the all live woody trees that are found in the site under ≥ 5 cm (DBH). Diversity of plant species was examined using the Shannon-Weiner Index and evenness metrics, indicating high woody species diversity based on established standards. The population structure, analyzed through height and diameter class distributions, displayed an inverted J-shape, suggesting a stable population. Carbon stock analysis of the biomass was conducted using the general tropical dry forest biomass regression equation. The results showed a total carbon stock of 92.14 t/ha and 151.60 t/ha for the two sites, with 76.78 t/ha and 15.36 t/ha in the above-ground and below-ground biomass, respectively, at EIABC, and 126.3 t/ha and 25.27 t/ha at the* College of Natural and Computational Sciences*. Overall, the results highlight the stability and productivity of the forests. From the perspective of reducing the effects of climate change and protecting biodiversity, it is recommended that these forests be sustainably managed and protected to ensure ongoing carbon sequestration and biodiversity conservation.*

Keywords: *Urban Green, Climate Resilience, Species Diversity, Carbon Stock, Biodiversity Conservation, Addis Ababa University*

1. INTRODUCTION

Numbers of people living in cities are growing quickly as a result of the global increase in urbanization. According to projections made through the UN over 60% of people on earth are predicted to settle in urban areas by 2030 (UN, 2018). Air pollution, the strengthening of the heat island effect, the a decline in biodiversity, urban green spaces and ecosystem services are some of the local environments that are being negatively impacted by the world's fast urbanization and population growth (Gelan and Girma, 2021).

These growing cities account for 70% of greenhouse gas emissions (IPCC*,* 2022). Among GHG, carbon dioxide (CO2) is the most dominant. It has gained international recognition as a primary cause of global warming. It is mostly produced by burning carbonaceous materials used in transportation, power, and domestic activities (Kasim *et al.,* 2018). The "greenhouse effect" is the result of high concentrations of CO2 and other gases trapping heat in the atmosphere and preventing it from escaping into space (American Planning Association, 2007).

The US Environmental Protection Agency released a report noted that greenhouse gases (GHGs) have an impact on both global warming and human well-being (Kasim *et al.,* 2018). Ethiopia's fast urbanization and population expansion are putting the country in a position where its urban communities are becoming more demanding. Without carefully designed green infrastructure, the majority of the towns and cities have grown quickly, leading to environmental issues like rising temperatures, rising greenhouse gases and water and air pollution (Hunegnaw, 2017).

Currently, cities are net producers of greenhouse gases (Velasco and Roth, 2010). A number of factors, including road dust, pollution from vehicles and factory development, large-scale construction and general methods of land use decrease the air quality in Addis Ababa (Guta, 2019). Future city-based GHG emissions will continue to rise due to urbanization trends. In order to stop this trend, cities must adopt more sustainable practices (Tammeorg *et al.,* 2021).

A number of difficulties with mental health and public health threats are being identified as a result of climate change (Andreucci *et al.,* 2019). In the absence of significant mitigation measures, it is projected that mortality from ambient air pollution alone will likely rise by 50%

or more by 2050 (Lelieveld *et al.,* 2015). It is becoming the most urgent issue of the 21st century (Andreucci *et al.,* 2019).

The connection between poor air quality and climate change has attracted scientific community interest, making it a pressing issue that is creating political and economic challenges on a global scale (Andreucci *et al.,* 2019). According to UNFCC (2018) report the Treaty of Paris that was adopted by the UN Climate Symposium also provide to a multidimensional framework for the global economy's shift toward a low-carbon economy in 2015. Nearly all nations have established national goals for mitigating climate change and committed to implement actions to meet these targets.

It was also evident at the COP27 Symposium also indicates that Africa and developing nations worldwide can no longer rely on mitigating the climate crisis. For survival and growth, they must adapt and develop resilience (Global Climate Action, 2022). In response, Ethiopia also further decreased its greenhouse gas emissions, seeking to attain net-zero emissions (climate neutrality) by 2025 (Zwick, 2018).

In order to combat challenges imposed by urbanization. Urban green infrastructures (UGIs) are becoming a popular strategy in different parts of the world (Zwick, 2018). It is currently recognized as a different, affordable, and nature-based solution to these adverse effects (Kabisch *et al.,* 2017). It is becoming more widely acknowledged as being essential to enhance urban environments' resilience (Pitman *et al.,* 2015).

Urban Green Infrastructure (UGI) generally denotes a carefully planned, linked network of green spaces with ecological variables that offer multiple uses and conserve biodiversity (Benedict and McMahon, 2002; Pitman *et al.,* 2015). Further reducing the quantity of pollutants in the atmosphere is the expansion of well-vegetated areas in both size and quantity. Research indicates that in just a single year, an acre of trees can sequester carbon dioxide equivalent to the emission of a car driving 11,000 miles (American Planning Association, 2007).

Knowing about how different landscapes and landscape factors affect the climate and health improvement. Landscape can be seen as the mitigation process in which health and well-being can be achieved through the sustainability process. Unfortunately, as a result of increased human population, many cities are experiencing a decline in green spaces and open areas due to development pressures (Bekele, 2021).

To provide new planning solutions concerning climate mitigation in the landscape is crucial. However, the environmental aspect of green areas has not been properly taken into consideration (Pouya, 2017). The green spaces development, management and conservation in Addis Ababa are distinguished by their simple, chaotic, and reactive goals (Woldegerima, 2016).

There is plenty of evidence that polluted environments affect human health. On the other hand, a quality environment could be health-promoting and even therapeutic (Douglas *et al.,* 2020). Several investigations have revealed that components of urban green infrastructure can supply essential ecosystem services to urban environments that have deteriorated ecologically (Gelan and Girma, 2021).

Recently, research on climate change and evaluations of forests' potential for carbon stock in the developing countries has focused on church forests, parks, and other green areas by Tura *et al.,* (2011), Tefera and Soromessa (2015) and others. However, institutional forests contribution to climate resilience and its implication in carbon sequestration have received little or no attention. Accordingly, this research examined the contribution of institutional forests for ambient air quality in Addis Ababa, as well as its consequences for climate change implications to the urban livability and climate change.

2. MATERIALS AND METHODS

2.1 Site selection and Description of the study area

The EIABC Campus and the College of Natural and Computational Sciences are the two AAU campuses where the study was carried out. The location of the EIABC Campus is in Lideta sub-city, woreda 4, Addis Ababa city. The geographical regions are: latitude: 9.013242°N; longitude: 38.730349°E. The campus is located between 2343 and 2378 m above sea level. It encompasses 7.8 hectares of land. While the College of Natural and Computational Sciences is in Arada sub-city, woreda 9, Addis Ababa city. The geographical regions are: latitude: 9.034623°N; longitude:

38.767066°E. The campus is located between 2434 and 2448 m above sea level. It encompasses 10.0453 ha of land. It is shown in Figures 2.1 and 2.2.

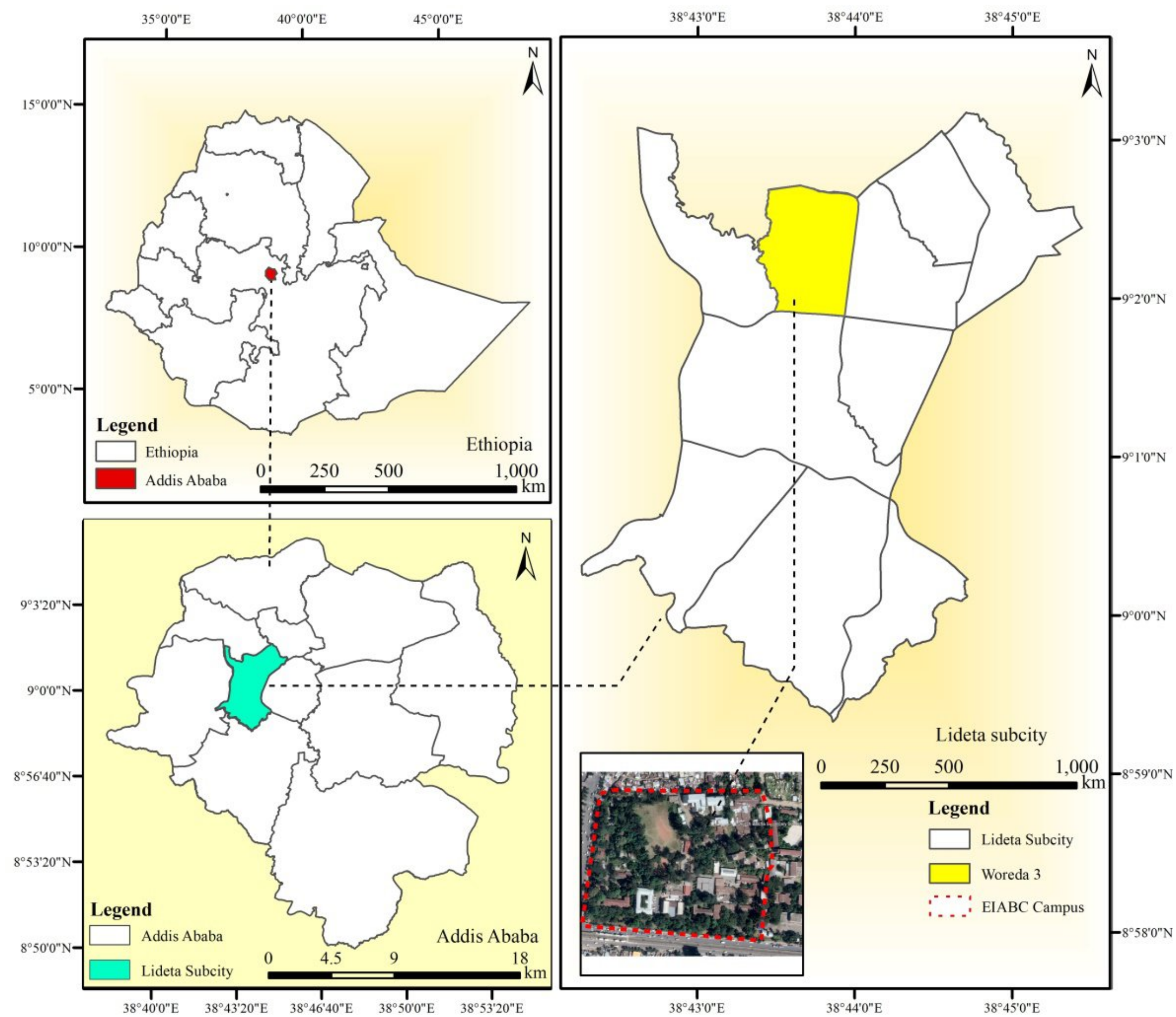

Figure 2.1. Location map of EIABC Campus

Source: (Own computation, 2024)

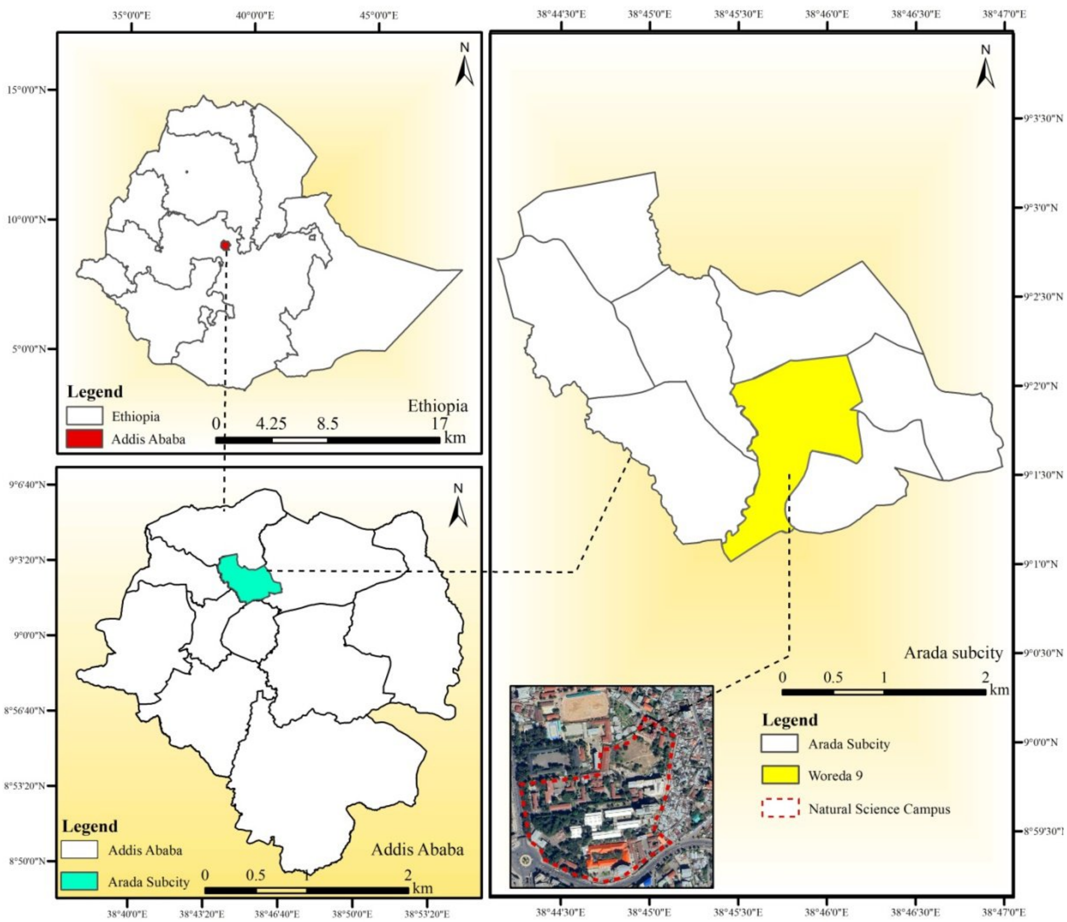

Figure 2.2 Location map of College of Natural and Computational Sciences

Source: (Own computation, 2024)

2.2. Methodology

Data type

Primary and secondary data were used in order to collect the data to meet the objectives of the study. The vegetation underneath the chosen campuses served as the main source of the data. Field inventory on woody plant species, particularly on height and Diameter at Breast Height (DBH) of a tree, was done in each of the sites. In order to arrange the literature and the study site's location, Google and Google Earth Pro served as the sources for the secondary data. In addition, published and unpublished reports and aerial photographs of the site were used to describe the study area. The study used Quantitative data to assess the vegetation diversity and to investigate the carbon stock potential of the site.

Sampling design

Before any data was collected, a pilot survey was conducted on June 15, 2023, to provide a general idea of the study site. The purpose of the observations was to determine the range of DBH values and representative forests. Then a purposive sampling method was selected to collect the samples. Later, the actual data collection was conducted for five consecutive days for each of the sites starting on July 20, 2023, for the estimation of carbon stock and assessment of diversity and structural composition of the institute. Woody plant species with DBH values of at least 5 cm (a frequently used measurement) present in the research locations defined the boundaries of the sample population (Pearson *et al.,* 2007; Pearson *et al.,* 2005).

Woody Plant Species Sampling

The DBH, height and variety of the trees were assessed in order to quantify the biomass, identify tree structures, and determine species diversity. All live woody plant species that are found in the selected campus with the DBH values of ≥ 5 cm (a frequently used measurement) considered as the sample size for these study (Pearson *et al.,* 2007; Pearson *et al.,* 2005). Then, with these conditions, the complete list method was used for sample size. For a tree that fulfills the sample population parameter first the Nomenclature identified and then the DBH and Height measured sequentially at the field.

2.3. Method of Data Collection

Vegetation survey

A professional forest inventor identified the plants in the field by utilizing both their scientific and local names. Some woody plants that were listed in the field were cross-checked with the scholars.

Woody Plant Species measurement for structure, diversity and carbon stock

Each live tree in the study area that had a diameter of ≥ 5 cm (DBH) at 1.3 meters was measured using Caliper (Pearson *et al.,* 2005). Then, using a hypsometer, the tree's height was determined at the spot where its top and bottom were observed (Genene *et al.,* 2013). Visual inspection was used when capturing a clear view is difficult from the beginning of the truck to the top of the tree and again, visual inspection was used when relatively similar heights of trees occur frequently. This starts from the main entrance, proceeding inwards by dividing the vegetation covers with the main roads of the campuses. To avoid inadvertently counting and measuring twice, marks were placed on measured trees 10 cm above the DBH measurement taken when trees became cramped.

Each tree's scientific and local names were listed separately. For trees with numerous stems less than 1.3 meters, counted as a particular tree (Moges *et al.,* 2010). These procedures were followed for both of the sites.

Data collection Materials

Based on the objectives the following materials are used to collect data’s in the field.

- Caliper: - to measure the diameter of trees ≥ 5 cm.
- Hypsometer: - to measure the height of the trees.
- Pen – used to register the vegetation data’s and the temperature data’s.
- Paper – used to register the vegetation data’s and the temperature data’s.
- Marker – used to mark the trees to avoid inadvertently counting when trees became cramped

Estimation of Biomass

The approaches utilized to quantify stored carbon are straightforward and follow quantitative techniques that belong to recognized principles and standards for carbon inventories. The methods relied on gathering and analyzing data about the amount of carbon stored in the aboveground and belowground biomass of trees (Pearson *et al.,* 2007; Pearson *et al.,* 2005).

2.4. Method of Data Analysis

Compositional and structural analysis

In this section, the abundance and richness of woody species were identified. The vegetation structural characteristic, tree's height, and Diameter at Breast Height (DBH) were categorized into classes.

Species diversity analysis

The ecological worth of a site for conservation tends to be assessed upon its diversity (Tona, 2016). Shannon diversity index (H') and Shannon evenness (J) were diversity indices that were used in the species diversity analysis of this study. The rarity and commonness of the variety of woody species are measured by these diversity indices, which also provide useful information for assessing the diversity of woody species (Mebrat *et al.,* 2014). It is the oldest, simplest and usually used model in the concept of species diversity.

Shannon Wiener diversity index

It is the most popular way to measure species diversity (Kent and Coker, 1992). According to Zar (2010), the equation is as follows:

$$H' = -\sum_{i=1}^{S} \text{pi} * \text{lnpi} \qquad \text{(Eq. 1)}$$

Where, H' = Diversity of species

S = the number of species

Pi = the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N)

ln = log base n (natural logarithm) and Σ is the sum of the calculations.

The index's H' value typically falls between 1.5 and 3.5. The diversity of species becomes higher when the H' value becomes larger (Kent and Coker, 1992).

Evenness (Equitability) analysis

When every species in the population is equally abundant, then the level of evenness is at its peak (Lembrechts *et al.,* 2017). In a community, it is the quality of species abundance (Kent and Coker, 1992; Begon *et al.,* 2006). The following is the equation:

$$J = \frac{\sum_{i=1}^{s} Pi \ln Pi}{\ln S} = \frac{H'}{\ln S} \qquad \text{Equation (2)}$$

Where, J = is the evenness or equitability index

H' = Diversity of species, lns = the natural log of the number of species (s)

The range of evenness values is 0 to 1, where 1 denotes perfect evenness (Kent and Coker ,1992; Begon *et al.,* 2006).

Estimation Carbon stock

Above ground biomass

It includes all forms of live plants above the earth, such as leaves, stems, seeds, stumps, bark, and branches (Moges *et al.,* 2010). As a result, it is the biggest pool and the one most affected by deterioration and deforestation. Around half of biomass is made of carbon (Brown *et al.,* 2004). Thus, the most important stage in determining the amount of carbon stocks is measuring the carbon in aboveground forest biomass (Holly *et al.,* 2007).

To calculate the trees above-ground biomass, this study employs a chosen Allometric formula. Numerous Allometric mathematical equations have been created and plenty of investigators use them to calculate the above-ground biomass of trees based on factors such as species, climate, forest types, and geographic locations (Baker *et al.,* 2004). Since both money and time would be needed to chop the trees in order to estimate their biomass using a destructive method, the non-destructive method is employed (Genene *et al*., 2013).

Consequently, Brown *et al.* (1989) suggested using the Allometric equations model (equ. 3) to determine the tree's above-ground biomass if the rainfall was <1500 mm and the DBH range was ≥ 5 cm. These Brown et al. (1989) equations have become accepted standard procedure because of their broad applicability (Kassahun, 2014). The equation is as follows:

$$Y = 34.4703 - 8.0671(DBH) + 0.6589(DBH^2) \qquad \text{(equ.3)}$$

Where, Y = above ground biomass, DBH = diameter at breast height

Pearson *et al.* (2005) state that because the study areas are in a tropical region, the biomass's carbon content is calculated through multiplying the biomass of trees above ground by 0.5 (the default value provided by the IPCC). The CO2 content is estimated using the multiplication factor 3.67, which is listed in Equations 4 and 5. The equation is as follows:

$$AGCS = AGB * 0.5 \qquad \text{(equ.4)}$$

Then Biomass carbon stock was converted in to CO_2 equivalent as follows:

CO_2 = AGCS * 3.67.. (equ.5)

Where, AGCS = Above Ground Carbon Stock, AGB = Above Ground Biomass (kg/tree)

CO_2 = Carbon dioxide

Below ground biomass

Living roots (fine, small, and big) with diameters of less than 2 mm, 2 to 10 mm, and more than 10 mm, as well as soil fauna, microbial community, and dead roots, are all included in the biomass found below ground. However, in this study, the below-ground biomass was determined by taking 20% of the above-ground biomass as the root-to-shoot ratio, which came out to be 1:5 (Moges *et al.,* 2010).

Pearson *et al.* (2005) also point out that determining the belowground biomass using the value of the aboveground biomass is a more effective and efficient way. Thus, the MacDicken (1997) formula was used to estimate the study's below-ground biomass. The following is the equation:

BGB = AGB*0.2... (equ.6)

Where, BGB is below ground biomass, AGB is above ground biomass, 0.2 is conversion factor (or 20% of AGB).

To estimate the carbon content and amount of CO_2 in BGB, the same procedure was applied like that of AGB.

BGCS = BGB * 0.5.. (equ.7)

Then Biomass carbon stock was converted in to CO_2 equivalent as follows:

CO_2 = BGCS * 3.67.. (equ.8)

Where, BGCS = Below Ground Carbon Stock

BGB = Below Ground Biomass (kg/tree)

CO_2 = Carbon dioxide

For both carbon pools, the biomass stock density was attained in Kg/m^2 by means of dividing the sum of all individual tree biomass (Kg) in a plot by the area of the plot (m^2), subsequently changed to a tone and the value was multiplied by 10 to convert it to t/ha (Pearson *et al.,* 2005).

Total Carbon Stock Estimation

The total carbon stock was calculated by adding the carbon stocks of the various carbon pools using the equation from Pearson *et al.* (2005). The process for converting biomass into carbon and CO2 is the same.

TC = AGC + BGC... (equ.9)

Where, TC = Total carbon stock density for all pools (t/ha)

AGC = Carbon in above-ground biomass

BGC = Carbon in below-ground biomass

Statistical Analysis

Descriptive statistical methods were used in order to arrange the quantitative data. Mean, Max, Min, frequency distribution and class distribution through width range are used in order to arrange the height and diameter values. Finally, the data was processed and presented.

Various software programs, including Microsoft Excel 2010 and SPSS software version 20, were utilized to analyze and present the gathered data. Arc GIS Map 10.8 and Google Earth Pro were used to organize the study area, whereas Adobe Illustrator 2023 was also used to present the study area.

3. RESULT

3.1 Structural characteristics and Composition of Woody Species in the EIABC and College of Natural and Computational Sciences

The study campuses displayed a variety of tree species. There were differences in the types of species found on each campus. A total of 2641 trees, representing 68 species, having a common highest DBH value of 120 cm along a height value between a range of 1.3 m and 49 m, were recorded during the data collection period.

There were 2641 distinct trees that present the abundance of trees in the campuses. 1231 trees represented by 50 species recorded in EIABC Campus. 1410 trees represented by 49 species recorded in College of Natural and Computational Sciences, While 31 species were found common for both Campuses.

The most dominant species among EIABC Campus were *Grevillea robusta*, which has 155 trees, or 13% of the total species, followed by *Vernonia amygdalina,* which has 145 trees, or 12% of the total species; *Eucalyptus globulus,* which has 94 trees, or 8% of the total species; *Acacia decurrens,* which has 85 trees, or 7% of the whole species; *Jacaranda mimosifolia,* which has 84 trees, or 7% of the total species; *Acacia melanoxylon* and *Cupressus lusitanican* each with 77 trees that are 6% of the entire species.

The lowest frequency is shown by *Pinus caropus, Hagenia abyssinica, Cassea didbotrea, Cercidiphyllum, Cupressus arizonica, Eucalyptus saligna, and Acacia indica*, all of which have only a single tree available.

Whereas in the case of College of Natural and Computational Sciences the most dominant species were *Podocarpus gracilior*, which has 296 trees, or 21% of the total species, followed by *Juniperus procera,* which has 165 trees, or 12% of the total species; *Jacaranda mimosifolia,* which has 140 trees, or 10% of the total species; *Acacia melanoxylon,* which has 113 trees, or 8% of the total species; *allophylus abyssinicas*, *Cupressus lusitanica*, *Olea europaea* with 52, 61, 60 trees, or 4% of the entire species; and *Vernonia amygdalina* with 47 trees, or 3% of the entire species.

The lowest frequency is shown by *Citrus sinensis, Cassia cinguana, and Acacia cynopyla,* which are all limited to have one tree. The following Table 3.1 and 3.2 presents the summarize form of woody species structure and composition.

Table 3.1. A brief description of the woody plant species found on the EIABC campus, including data on the quantity of trees, the average DBH, a height, and name of species.

No	*Species Name*		*Total No of trees*	*(Mean)*	
	Local	*Scientific*		*DBH(cm)*	*Height(m)*

1	*Bazra girar*	*Acacia abbyssinica*	5	38.02	7.94
2	*Mimosa/Akacha*	*Acacia decurrens*	85	15.01	8.72
3	*Grar*	*Acacia indica*	1	26.1	20
4	*Omedla*	*Acacia melanoxylon*	77	18.48	8.61
5	*Bottlebrushe*	*Callistemon citrinus*	18	7.43	5.24
6	*Kazamora*	*Casimiroa edulis*	5	18.92	6.74
7	*Asene meka*	*Cassea didymobotrya*	1	32	9
8	*Shewshewie/arzelibanos*	*Casuarina equisetifolia*	41	32.11	13.47
9	*Kawoot*	*Celtis africana*	3	32.67	12.33
10	-	*Cercidiphyllum*	1	41.6	12
11	*Bunna*	*Coffea arabica*	15	6.37	3.57
12	*Wanza*	*Cordia africana*	19	27.06	8.78
13	*Bisana*	*Croton macrostachyus*	26	21.78	8.61
14	*Yeferenji-tid*	*Cupressus arizonica*	1	15.5	7.6
15	*Yeferenji-tid*	*Cupressus lusitanica*	77	20.77	9.84
16	*Yeferenji-tid*	*Cupressus pyramidalis*	4	21.56	9.78
17	*Koshim*	*Dovialic abbyssinica*	3	18.325	5.75
18	*Itsepatos*	*Dracaena steudneri*	52	24.03	6.65
19	*Game*	*Ehretia cymosa*	4	32.5	7.125
20	*Lol*	*Ekebergia capensis*	6	56.95	13.17
21	*Woshmela*	*Eriobotrya japonica*	11	16.2	5.29
22	*Korch*	*Erythrina brucei*	1	15	16
23	*Nech bahir zaf*	*Eucalyptus globulus*	94	43.87	17.37
24	*Saligna bahir zaf*	*Eucalyptus saligna*	1	68	23
25	*Yegoma zaf*	*Ficus Elastica*	9	29.53	8.44
26	*Sholla*	*Ficus sure*	3	70.33	15.33
27	*Grevila*	*Grevillea robusta*	155	18.89	10.76
28	*Koso*	*Hagenia abyssinica*	1	5	2.5
29	*yetebmenja zaf*	*Jacaranda mimosifolia*	84	21.38	7.94
30	*Yehabesha Tid*	*Juniperus procera*	62	14.34	7.34

31	*Nimi*	*Melia aztrach*	6	15.63	5.17
32	*Birbira*	*Millettia ferruginea*	35	21.83	8.99
33	-	*Mussaenda arcuata*	1	30.82	10.83
34	*Sete Weira*	*Olea europaea*	43	18.91	7.78
35	*Avocado*	*Persea americana*	3	11.07	6.53
36	*Zembaba*	*Phoenix reclinata*	4	16.3	6
37	*Yekolla wanza*	*Piliostigma thonningii*	16	14.71	6.58
38	-	*Pinus caropus*	1	14	6.6
39	*Pachula*	*Pinus patula*	4	24.5	9.85
40	*Elaho, Ahot, Kefeta,*	*Pittosporum viridiflorum*	8	29.95	12.59
41	*Zigba*	*Podocarpus gracilior*	28	30.07	10.54
42	*Tkur enchet*	*Prunus africana*	19	30.24	10.35
43	*Galo/Seged*	*Psdrax schimperiana*	6	8	5
44	*Zeituna*	*Psidium guajava*	4	6.58	4.53
45	*Gullo*	*Ricinus communis*	3	8.93	4.67
46	*Gitem/Kokora*	*Schefflera abyssinica*	5	34.4	7.68
47	*Qundo berbere*	*Schinus molle*	12	38.84	6.48
48	*Yebereha nebelbal*	*Spathodea campanulata*	15	28.56	9.39
49	*Dokma*	*Syzygium guineense*	8	23.54	8.94
50	*Grawwa*	*Vernonia amygdalina*	145	13.56	5.14
		Sum	1231		

Table 3.2. A brief description of the woody plant species found on the College of Natural and Computational Sciences, including data on the quantity of trees, the average DBH, a height, and name of species.

No	*Species Name*		*Total No of trees*	*Mean*	
	Local	*Scientific*		*DBH(cm)*	*Height(m)*
1	*Bazra girar*	*Acacia abbyssinica*	26	44.95	12.64
2	*Akacha saligna*	*Acacia cynopyla*	1	44.00	14.00

3	Akacha, Mimosa	Acacia decurrens	2	36.00	13.50
4	Omedla	Acacia melanoxylon	113	19.77	9.37
5	Sesa	Albizia gummifera	7	26.36	9.20
6	Embus, Qequewe	allophylus abyssinicas	52	16.75	6.12
7	Azamir	Bersama abyssinca	3	33.00	6.30
8	Zembaba	Borassus aethiopum	4	41.20	13.43
9	Bottlebrushe	Callistemon citrinus	18	19.54	8.23
10	Kazamora	Casimiroa edulis	7	18.63	8.57
11	pillarwood	Cassipourea malosana	1	8.23	4.75
12	Asene meka	Cassea didymobotrya	8	23.36	5.26
13	-	Cassia singueana	1	37.30	13.00
14	Shewshewie/arzelibanos	Casuarina equisetifolia	9	37.12	11.89
15	Birtukan	Citrus sinensis	1	5.00	3.00
16	Wanza	Cordia africana	19	28.43	8.92
17	Bisana	Croton macrostachyus	3	34.50	13.00
18	Yeferenji-tid	Cupressus lusitanica	61	31.16	11.85
19	Yeferenji-tid	Cupressus pramidalis	5	27.12	17.20
20	Itsepatos	Dracaena steudneri	24	25.98	6.10
21		Ehophorbia sp.	4	22.80	6.50
22	Game	Ehretia cymosa	7	44.36	11.37
23	Lol	Ekebergia capensis (E. rueppeliana)	5	11.42	9.26
24	Woshmela	Eriobotrya japonica	20	10.69	4.73
25	Korch	Erythrina brucei	8	54.63	12.31
26	Nech bahir zaf	Eucalyptus globulus	22	27.97	15.06
27	Sholla	Ficus sure	9	27.46	10.11
28	Ash	Fraxinus sp.	36	25.45	7.65
29	Grevila	Grevillea robusta	23	31.98	13.27
30	yetebmenja zaf	Jacaranda mimosifolia	140	22.22	8.17
31	Yehabesha Tid	Juniperus procera	165	33.92	13.08

32	-	*Ligustrum ovata*	12	12.43	6.52
33	*Kelawa, Yeregna qolo*	*Maesa lanceolata*	6	16.78	4.77
34	*Nimi*	*Melia aztrach*	4	13.55	7.00
35	*Birbira*	*Millettia ferruginea*	27	14.23	7.13
36	*yeferenji injori*	*Morus alba*	10	23.23	9.45
37	*Shinet*	*Myrica salicifolia*	14	15.03	7.13
38	*Sete Weira*	*Olea europaea*	60	16.92	7.37
39	*Avocado*	*Persea americana*	15	21.85	9.06
40	*Zembaba*	*Phoenix reclinata*	25	19.50	5.42
41	-	*Pinus Radiata*	4	38.90	13.88
42	*Zigba*	*Podocarpus gracilior*	296	21.19	9.34
43	*Tkur enchet*	*Prunus africana*	14	14.11	8.14
44	*Embus, Qamo*	*Rhus glutinosa*	4	7.93	6.34
45	*Yebereha nebelbal*	*Spathodea campanulata*	*8*	34.68	8.88
46	*Dokma*	*Syzygium guineense*	*27*	22.58	8.27
47	*Tacoma*	*Tecoma stans*	*25*	13.10	5.74
48	-	*Teclea simplicifolia*	*8*	15.70	5.17
49	*Grawa*	*Vernonia amygdalina*	47	13.86	5.70
		Sum	1410		

3.2 Arrangement of DBH and Height of Trees

Arrangement of DBH

Studies classify the class using varying interval widths; however, this study classifies the class interval width using the average DBH number, which is 22. Thus, it is divided into six classes according to these. (≥5-27, 27-49, 49-71, 71-93, 93-115, and ≥115 cm). The maximum DBH values recorded among EIABC Campus were 120 cm by *Eucalyptus globulus*, followed by 118 cm by *Schinus molle*, 104 cm by *Ekebergia capensis,* and 99 cm by *Podocarpus gracilior*.

While the maximum DBH values recorded among College of Natural and Computational Sciences were 120 cm by *Erythrina brucei,* followed by 110 cm by *Acacia abbyssinica*, 104 cm by *Podocarpus gracilior,* and 98 cm by *Cupressus lusitanica*. The following Figures 3.1 and 3.2 show the DBH arrangement of the campuses. The first DBH class, which is (5-25 cm), has a greater number of species recorded, with 70% value from the total species for the EIABC Campus and 65% value from the total species for the College of Natural and Computational Sciences. The last DBH class is (≥105 cm), which has a lower number of species.

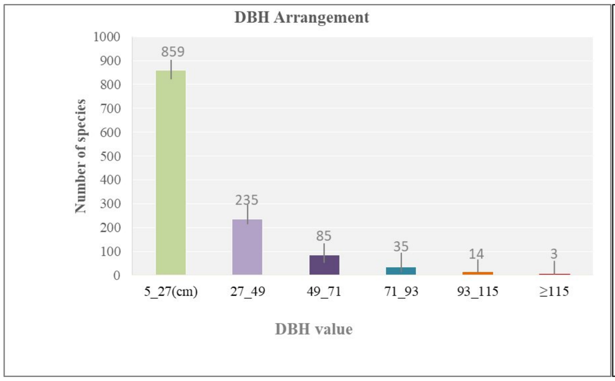

Figure 3.1 Species DBH arrangement on EIABC Campus.

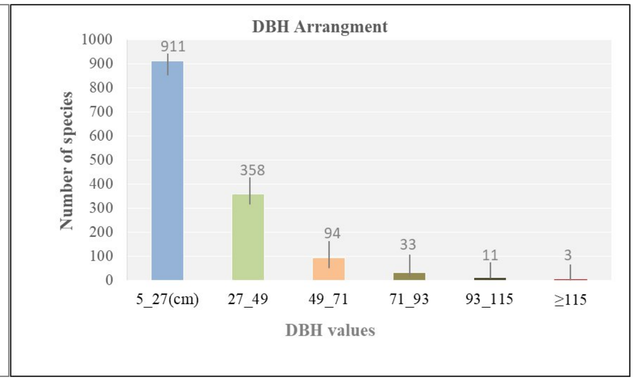

Figure 3.2. Species DBH arrangement on College of Natural and Computational Sciences.

Source: (Own computation, 2024)

Arrangement of Height

Studies classify the class using varying interval widths; however, this study classifies the class interval width using the average height number, which is 9. Thus, it is divided into six classes according to these. (1 - 9, 9 - 18, 18 - 27, 27 - 36, 36 - 45 and 45 - 54). The maximum height arrangement recorded among EIABC Campus was 49 m by *Eucalyptus globulus,* followed by 40 m by *Grevillea robusta* and 34 m by *Casuarina equisetifolia*. The minimum height arrangement recorded was 1.3 m by *Millettia ferruginea,* followed by 2.1 m by *Piliostigma thonningii*.

While the maximum height value recorded among the College of Natural and Computational Sciences was 49 m by *Juniperus procera,* followed by 24 m by *Eucalyptus globulus.* However, the minimum height arrangement recorded was 2 m by *Dracaena steudneri*. The following Figures 3.3 and 3.4 show the height arrangement of the campuses. The first height class, which is 1-9 m, has a greater number of species recorded, with 64% from the total species for the EIABC Campus and 66% from the total species for the College of Natural and Computational Sciences. The number of species becomes lower when the value of height becomes higher.

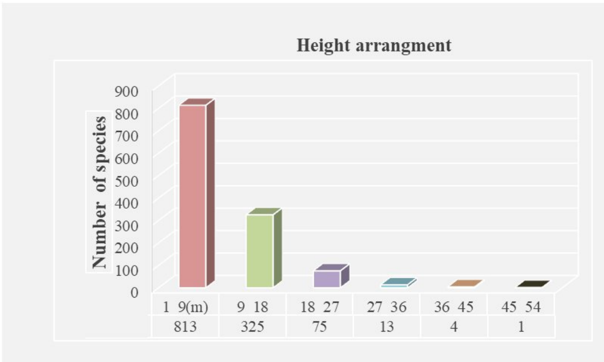

Figure 3.3. Species Height arrangement on EIABC Campus

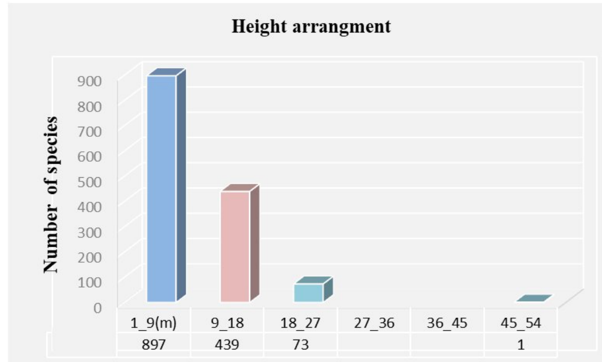

Figure 3.4. Species Height arrangement on College of Natural and Computational Science.

Source: (Own computation, 2024)

3.3. Diversity of Woody Plant Species Distribution

Diversity index

The result showed the abundance of the species with 1231 and 1410 individual trees, in which the species richness is 50 and 49, respectively, for EIABC Campus and College of Natural and Computational Science. The overall evenness and diversity values of the species according to Shannon Wiener were (J=0.79) (H'=3.11) for EIABC Campus and (J=0.78) (H'=3.03) for College of Natural and Computational Science.

Table 3.3. Diversity index for the campuses

No	Study site	Total no species	Total no trees	H'	E_H
1	EIABC Campus	50	1231	3.11	0.80
2	College of Natural and Computational Science	49	1410	3.03	0.78

3.4. Carbon Stock and Biomass

Carbon stock and Biomass in EIABC Campus

According to the analyses, the EIABC Campus biomass in the above-ground (AGB) ranged from 40.34 t/ha to 0.003 t/ha, with an average biomass of 3.34 t/ha. The mean carbon stock in aboveground (AGC) was 1.66 t/ha, while the mean carbon dioxide in aboveground (AGCO2) was 6.12 t/ha.

The biomass in the belowground (BGB) ranged from 8.07 t/ha to 0.001 t/ha, with an average biomass of 0.67 t/ha. The mean carbon stock in the belowground (BGC) was 0.33 t/ha, while 1.22 t/ha carbon dioxide in the belowground biomass (AGCO2). These results presented in detail in the following Table 3.4. As a result, the above-ground pool pulled roughly 83% of the total biomass, while the below-ground pool pulled 17%.

Table 3.4. Summary of biomass and carbon stock for EIABC Campus.

Study site	Carbon pools					
	AGB t/ha			BGB t/ha		
EIABC	Min	Max	Mean	Min	Max	Mean
Campus	0.003	40.34	3.34	0.001	8.07	0.67
	Total Carbon pools(t/ha)					
	AGB	AGC	$AGCO_2$	BGB	BGC	$BGCO_2$
Mean	3.34	1.66	6.12	0.67	0.33	1.22

Carbon stock and Biomass in College of Natural and Computational Science

According to the analyses, the College of Natural and Computational Science biomass in the above-ground (AGB) ranged from 144.36 t/ha and 0.003 t/ha, with an average biomass of 5.37 t/ha. The mean carbon stock in aboveground (AGC) was 2.69 t/ha, while the mean carbon dioxide in aboveground (AGCO2) was 9.86 t/ha.

The biomass in the belowground (BGB) ranged from 28.87 t/ha and 0.001 t/ha, with an average biomass of 1.07 t/ha. The mean carbon stock in the belowground (BGC) was 0.54 t/ha, while 1.97 t/ha carbon dioxide in the belowground biomass (AGCO2).These results presented in detail in the following Table 3.5. As a result, the above-ground pool pulled roughly 83% of the total biomass, while the below-ground pool pulled 17%.

Table 3.5. Summary of biomass and carbon stock for College of Natural and Computational Science

Study site	Carbon pools					
	AGB (t/ha)			BGB (t/ha)		
College of Natural and Computational Science	Min	Max	Mean	Min	Max	Mean
	0.003	144.36	5.37	0.001	28.87	1.07
	Carbon pools (t/ha)					
	AGB			BGB		
	AGB	AGC	$AGCO_2$	BGB	BGC	$BGCO_2$
Mean	5.37	2.69	9.86	1.07	0.54	1.97

Total Carbon Stock

The campuses' total stock of carbon was calculated by adding together the results of above-ground and below-ground carbon. Totally, 92.14 t/ha stock of carbon from EIABC Campus and 151.60 stock of carbon from College of Natural and Computational Science have been calculated. These results presented in detail in Table 3.6 and Figure 3.5.

Table 3.6. Summary of biomass, carbon and CO_2 in aboveground and belowground pools for EIABC Campus and College of Natural and Computational Science.

	Total Carbon pools t/ha								
Site	AGB	AGC	$AGCO_2$	BGB	BGC	$BGCO_2$	TB	TC	TCO_2
EIABC	153.55	76.78	281.77	30.72	15.36	56.38	184.28	92.14	338.15
Natural Sciences	252.67	126.3	463.65	50.53	25.27	92.73	303.21	151.60	556.38
Mean	203.11	101.54	372.71	40.62	20.31	74.555	243.745	121.87	447.265

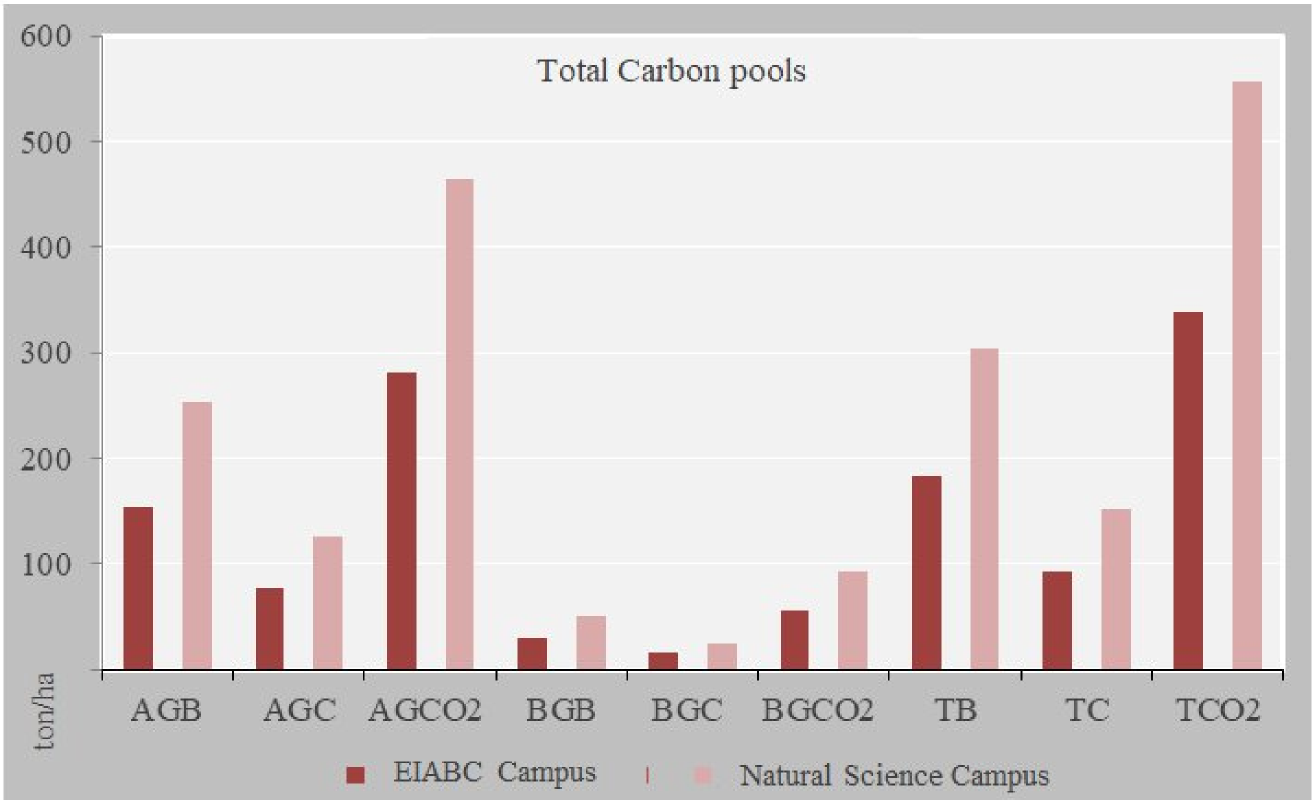

Figure 3.5. Summary of biomass, Carbon and CO_2 in aboveground and below ground carbon pools for EIABC Campus and College of Natural and Computational Science.

Source: (Own computation, 2024)

4. DISCUSSION

4.1. Structural characteristics and Composition of Woody Species in the EIABC and College of Natural and Computational Science

The composition of woody species is defined by the richness, abundance, dominance and frequency of a species (Eyassu *et al.,* 2020). The study found that the campus floristic composition included a variety of woody species. There were 50 and 49 woody species identified on the EIABC and the Natural Science campuses respectively. A study of Selected Park Forests by Tefera and Soromessa (2015) showed results on woody plant species (66 and 48), which is almost comparable to this study.

Again, greater value is recorded when it is compared to a study of Four Selected Urban Public Parks by Tsegaye (2015), which showed a result on woody plant species (39, 36, 15 and 19).

Research indicates that in order to manage forests wisely with regard to their potential for regeneration, information about species composition and structure is necessary. It further results in the ongoing conservation of biological diversity (Sharma *et al.,* 2023).

The EIABC Campus and the College of Natural and Computational Science had species abundances of 1231 and 1410, respectively. A species' relative richness and evenness can be expressed using an abundance measure, which evaluates diversity (Evans and Ochiaga, 2014). At each site, certain species were more dominant than others. On the EIABC campus, *Grevillea robusta, Vernonia amygdalina, Eucalyptus globulus, Acacia decurrens* and *Jacaranda mimosifolia* were significantly more dominant than the others and *Acacia indica, Cassea didbotrea, Cercidiphyllum, Cupressus arizonica, Eucalyptus saligna, Hagenia abyssinica, Ehretia cymosa,* and *Pinus caropus* were the least frequent species.

On the College of Natural and Computational Science, the dominated species were *Podocarpus gracilior, Juniperus procera, Jacaranda mimosifolia, Acacia melanoxylon, Allophylus abyssinicas, Cupressus lusitanica* and *Olea europaea*. The least frequent species were *Citrus sinensis, Cassia cinguana and Acacia cynopyla*. This identification of abundant and rare species supports to prioritize conservation.

Studies with similar result discuss its cause as adverse environmental situations like excessive heat and lack of precipitation, as well as anthropological influences like intensive logging, random dissemination of available resources in the forest, or a lack of equal chances for competition (Teshager, 2017).

The arrangement of DBH and height Class

Woody species' patterns of diameter and height have been used to study a species' regeneration profile (Siraj and Zhang, 2018). Maintaining a healthy population regeneration of the species is also crucial (Feyissa, 2012). In this study, the number of trees listed at each study site was used to analyze the height and DBH of the trees.

While the highest values of height and DBH were equal with 120 cm and 49 m values, respectively, the two sites displayed distinct patterns for DBH and height distribution. According to Feyissa (2012) in the population structural characteristics, the various species patterns can be used to indicate population dynamics. The DBH distribution of the forests in this study revealed that there were a lot of trees in both the first and next classes, but the percentage of trees declined as the classes grew.

These results were common for both of the sites except for the numerical difference. According to Nowak and Crane (2001) carbon storage (tc/ha) is predominantly affected by tree density and diameter distribution. Tree density and carbon densities are directly proportional to each other. Despite this, the result from the DBH distribution of the trees implies that carbon stock in the site grows gradually with the growth of the diameter of the tree, as more trees are found in the lower class (young generation).

The height distribution of the forests revealed that there are more individual trees in both the first and next classes. These results were common for both sites except for the numerical difference. A study with similar results by Tefera and Soromessa (2015) discusses the positive relationship of heights with DBH and its effect on the above-ground carbon stock. Yilma (2016) also addresses height as a measure of the age of the forest. The comparison of height classes shows that older trees tend to be more prevalent among higher height classes. This implies that there are much younger trees on the site.

The pattern of inverted J-shaped was observed in the arrangement of height and DBH class for both of the sites. This pattern suggests the study site has a stable population status (Siraj and Zhang, 2018).

Woody Species Diversity

Species distribution and their relative abundance refer to species diversity. The levels of species evenness and richness are main factors that affect the values of species diversity (Tona, 2016). The Shannon Weiner diversity index (H') is an extensively used technique to determine species evenness and richness (Kent and Coker, 1992). Therefore, for the purpose of identifying the campuses' species diversity, this study computed the Shannon Wiener diversity index (H').

The College of Natural and Computational Science and EIABC have Shannon Wiener diversity indices of 3.03 and 3.11, respectively. As stated, EIABC Campus shows slightly greater value. On the other hand, it reflects that relatively, College of Natural and Computational Science has dominant species. Mitra (2015) states that the Shannon-Weiner diversity index has four values: low when it falls between 2.0 and 1.0, medium when it falls between 3.0 and 2.0, and very low when it is less than 1.0. If the value is higher than 3.0, it is considered high. This value rarely rises above 4.5 and typically falls between 1.5 and 3.5. Both campuses have index values greater than 3. So it implies that the campuses have high diversity.

The evenness values computed for EIABC and College of Natural and Computational Science are respectively 0.80 and 0.78. The same as the Shannon Wiener diversity index value, the value of evenness is also slightly greater for the EIABC Campus than the College of Natural and Computational Science. Both Shannon and evenness values increase as richness increases. According to Begon *et al.* (2006) the evenness value is a number between 0 and 1, where 0 stands for low evenness and 1 stands for complete evenness.

Overall, the result indicates good woody species diversity and richness, as the (H') and (J) values indicated. These values are also greater when compared to a study of selected park and institute forests by Habtamu *et al.* (2021) in which the results are 2.76, 1.96 and 0.63, 0.266, respectively, for (H') and (J).

Biomass and Carbon Stock

According to Mamo (2007) biomass depends on the age of the tree. The age and DBH value of a species determine its AGB. In a similar vein, this study's findings show that older trees with high DBH values also have high AGB. For EIABC Campus, the AGB ranged from 0.01 to 165.01 tons per tree, with an average value of 13.65 tons per tree. Totally, 153.55 t/ha, in which 628.03 tons of AGB were recorded. The BGB ranged from 0.002 to 33.00 tons per tree, with an average value of 2.73 tons per tree. Totally, 30.72 t/ha, in which 125.65 tons of BGB were recorded. In general, a total biomass (TB) is 753.69 tons with 184.28 t/ha.

On the other hand, for the College of Natural and Computational Science, the AGB ranged from 0.01 to 594.8 tons per tree, with an average value of 22.15 tons per tree. Totally, 252.67 t/ha, in which 1041.01 tons of AGB were recorded. The BGB ranged from 0.002 to 118.95 tons per tree, with an average value of 4.43 tons per tree. Totally, 50.53 t/ha, in which 208.20 tons of AGB were recorded. Overall, the total biomass (TB) is 1249.21 tons with 303.21 t/ha.

Accordingly, in this study, more AGB was recorded from the College of Natural and Computational Science. This might be as a result of the various kinds and quantities of woody species mentioned in each site. Fisher and Bilkely (2000) state that the age, density, and species of woody plants have an impact on biomass. Similarly, compared to the EIABC Campus, the college of Natural and Computational Science had larger area coverage and listed a higher quantity of woody plants.

The highest AGC was calculated in *Podocarpus gracilior* with 297.378 ton/species, 72.1 t/ha, whereas the lowest AGC was calculated in *Citrus sinensis* with 0.01 ton/species, 0.001 t/ha at the College of Natural and Computational Science. On the other hand, the highest AGC calculated in *Eucalyptus saligna* was 165.01 tons/species, 20.1 t/ha and 74.031 t/ha, whereas the lowest AGC was calculated in *Hagenia abyssinica* with 0.01 tons/species, 0.001 t/ha at the EIABC Campus. This result reveals that species with a greater number of individuals and higher DBH values provide higher AGB content and a lower number of individuals with low DBH values have a lower content of AGB. In these study the mean AGC value is 101.5 t/ha.

The findings of this study have a nearby mean value in contrast to the findings of those two studies; a study by Tsegaye (2015) shows a mean AGC of 118.74 t/ha for a Selected Urban Public Park, and a study by Tura et al. (2011) shows a mean AGC of 122.85 t/ha for a Selected Church Forest but considerably lower value when compared to a study by Habtamu *et al.* (2021) that reveals a mean AGC of 143.3 t/ha for a Selected Park Forests. However, greater values are recorded when compared to the result of Selected Park Forests by Tefera and Soromessa (2015) a mean AGC of 50.8 t/ha.

In comparison with other studies with similar environmental conditions, the mean value of this study's results is lower. The woody species plants in these study areas are very young, with a lower DBH value than the study areas with higher results.

On the other hand, these campuses have a substantial carbon stock holding a mean of 101.5 t/ha. These results fall within the ranges of 13.5-122.85 t/ha for tropical dry forests and 95-527.85 t/ha for wet forests, respectively, which Murphy and Lugo (1986) reported for the global above-ground carbon stock. Often, this range is applicable. Deffersha and Kutie (2016) and Girma and Soromsa (2014) are two studies that discuss it in their research.

As a result, these sites' mean values fall within the range of the suggested carbon stock. By storing significant amounts of carbon in a manner competitive with Addis Ababa's urban public parks and churches, it is evidence that the campus woody plant species take a crucial part in mitigating environmental damage.

5. CONCLUSION AND RECOMMENDATIONS

The study indicates that the Campuses woody plants have a diversified and productive species plays a significant role in climate change to reduce GHGs from the surrounding by sequestering large amount of carbon dioxide competitively with urban public parks and churches of Addis Ababa. Thus, it can be concluded that the sites have their own contribution on the national effort of curbing CO_2 in the atmosphere. If appropriate management of vegetation implemented, there is a high potential of increasing biomass/carbon stock in the future.

Climate resilience actions

It is essential to work on mitigation and adaptation in order to maintain climate resilience. Thus, it is important to develop adaptation strategies at macro and micro level. In the dimension of this study to cope with climate resilience, the first lines of defenses are recommended below.

Focus on prioritization of less dominant species, Enhance the health of trees and Increase the number of trees through the following listed actions.

- High conservation effort to low frequency species
- To treat the forests from disease and cut out dead trees.
- More treatment for the younger trees and indigenous trees.
- Develop a proper management system in order to nourish the tree's growth.
- To decrease deforestation and to increase the number and diversity of trees, including indigenous trees and edible fruits.

Generally, coping resilience by focusing only on these campuses is not going to be functional, so developing strategic planning for other related institutes in order to work in a team is important. Overall, enhancing the resilience of the ecosystem enhances the climate resilience. Responsible departments in the institute need to:

- Create a coordinated effort involving various sectors and stakeholders to work on the city's institutional forests.
- Monitoring and tracking progress across the system.
- Share knowledge, experiences and solutions.
- Enrich the natural ecosystems and ecological diversity by investing while preventing disease outbreaks among vegetation.

The following recommendations are generally appointed out in considering the study's findings and the field survey's observations.

- The campuses should further endorse evenness and diversity of species to loosen the number of species that are dominant.
- The findings of the study show balanced indigenous and exotic species. However, the campuses should give more attention to the plantation and management of indigenous trees against the exotic and invasive trees.
- Needs awareness creation on the institute woody plant species up on carbon sequestration. It also serves as a way to create carbon finance.
- According to the study's findings, well-managed institutional forests preserve species diversity, act as carbon sinks, and may even stabilize the urban microclimate temperature.

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