CARBON STOCK ESTIMATION AND WOODY SPECIES DIVERSITY ALONG ALTITUIDINAL GRADIENT OF PUBLIC PARKS IN ADDIS ABABA, ETHIOPIA

MSc. THESIS

ZERIHUN LAKEW GEBREMARIAM

HAWASSA UNIVERSITY, WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES, WONDO GENET, ETHIOPIA

OCTOBER, 2020

CARBON STOCK ESTIMATION AND WOODY SPECIES DIVERSITY ALONG ALTITUIDINAL GRADIENT OF PUBLIC PARKS IN ADDIS ABABA, ETHIOPIA

ZERIHUN LAKEW GEBREMARIAM

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES, WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES, HAWASSA UNIVERSITY WONDO GENET, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOREST RESOURCE ASSESSMENT AND MONITORING

OCTOBER, 2020

Approval Sheet 1

This is to certify that the MSc thesis entitled "*Carbon Stock Estimation and Woody Species Diversity along Altitudinal Gradient of Public Parks in Addis Ababa Ethiopia*" submitted to school of graduate studies, Wondo Genet College of Forestry and Natural Resources, Hawassa University in Partial fulfillment of the requirements for the degree of Master of Science in Forest Resource Assessment and monitoring.

Submitted by:

Zerihun Lakew	____________________	________________
Name of Student	Signature	Date
Dr. Mulugeta Zewdie	____________________	________________
Name of major advisor	Signature	Date
____________________	____________________	________________
Head of Department	Signature	Date
____________________	____________________	________________
SGS Approval	Signature	Date

Approval Sheet 2

We, the undersigned, members of the Board of examiners of the final open defense by *Zerihun Lakew* have been read and evaluated his thesis entitled "*Carbon Stock Estimation and Woody Species Diversity along Altitudinal Gradient of Public Parks in Addis Ababa, Ethiopia*" and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science.

______________________	___________________	_________________
Name of the Chairperson	Signature	Date
______________________	___________________	_________________
Name of Major Advisor	Signature	Date
______________________	___________________	_________________
Name of Internal Examiner	Signature	Date
______________________	___________________	_________________
Name of External Examiner	Signature	Date

Acknowledgements

First of all, my praise and thanks is to Almighty God, who creates everything from nothing, and who gave me the mind to think and the ability to face every challenge in my life.

My Sincere gratitude goes to my principal advisor Dr. Mulugeta Zewdie, for his great support and help to undertake my study. This work would have not been completed without his intended contribution. My great thanks also goes to Hawassa University, Wondo Genet College of Forestry and Natural Resources post graduates program coordinators and FRAM department head, soil laboratory staffs for their best cooperation and material also technical supports as well MRV project for their financial support. And I would like to thank Ethiopian Environment Forest Climate Change Commission and all staff worker.

I would like to express my sincere feelings and great thanks to my wife Misrak Getahun, to her endless support, encouragement and tolerance. I express my honest gratitude to families and friends for their encouragement and great care.

Table of Contents

Dedication

“To my Wife Misrak Getahun and My Family, for their

Motivation, love and support throughout my Study.”

List of Tables

List of Figures

List of Appendices

List of Abbreviations

AA	Addis Ababa
AGB	Above Ground Biomass
ANOVA	Analysis of Variance
BGB	Below Ground Biomass
CO2	Carbon Dioxide
DBH	Diameter at Breast Height
FAO	Food and Agricultural Organization of the United Nations
GHG’s	Green House Gases
GPS	Global Positioning System
H	Height
IPCC	Intergovernmental Panel on Climate Change
IVI	Importance Value Index
MEFCC	Ministry of Environment Forest and Climate Change
NGO’s	Non-Governmental Organizations
SD	Standard Deviation
SOC	Soil Organic Carbon
TCS	Total Carbon Stock
UN	United Nation
UNFCCC	United Nations Framework Convention on Climate Change
WD	Wood Density
WGCFNR	Wondo Genet College of Forestry and Natural Resources

Carbon stock estimation and woody species diversity along altitudinal gradient of public parks in Addis Ababa, Ethiopia

Zerihun Lakew Gebremariam

Mobile phone - +251913335932, Email - zeruzeri7@gmail.com

Abstract

Terrestrial carbon stock quantifying is important for the successful implementation of climate change mitigation policies. With the rapid global urbanization rate urban forests are becoming important components of global forest ecosystem. Urban development strongly associated with disturbance of habitats such as urban parks. Most of the urban vegetation resources in Addis Ababa were not based on scientific evidences. The study aims to estimate Carbon stock and woody species diversity along altitudinal gradient of closed urban public Parks. Seven parks were selected purposively based on altitude range, better woody species composition and area coverage. The parks were stratified into two altitude ranges: upper strata 2338-2588 masl and lower strata 2088-2338 masl. Then by applying stratified systematic sampling method and distributing transect line with 100m gap using QGIS software version 3.2 a total of 70 sample plots were determined. Sample plots were distributed by optimal allocation and with circular plot design applied for biomass carbon stock assessment and species identification. Whereas 24 sample plots were selected for soil sampling of five $1m^2$ sub-plot in each main plot. Parameters of carbon stock and species diversity towards altitudinal gradient were tested by descriptive statistics, correlation test and one way ANOVA test analyzed using statistical software R version 3.4.3. According to the study results 125.33 $\pm$40.4 ton ha^{-1} mean carbon stock was contained in the above ground biomass and 25.07$\pm$8.08 ton ha^{-1} mean carbon stock was obtained in belowground biomass. Soil organic carbon stock in the selected public parks ranged from 87.071 to 196.281 ton ha^{-1}. Thus mean carbon stock of 302.3 ton ha^{-1} and 231.9 ton ha^{-1} was estimated on upper and lower altitude respectively. There is a significant increasing amount of carbon stock with increasing elevation (P-value = 0.016). A total of 52 woody species belonging to 28 families were identified with total number of 2123 trees. From the total species 53.8% of the species were indigenous while the remaining were exotic tree species. The study also shows there is higher species diversity on lower strata public parks than upper strata parks 2.81 and 2.64 each. Likewise Simpson index and species richness recorded was higher at lower altitude parks. On the other hand species evenness value implies there is equivalent distribution among each stratum and between selected urban parks. Juniperus procera, Cuppressus lustanica and Grevillea robusta tree species had higher IVI value as compared to others. Based on the study findings forests in public parks altitude has a direct effect on mean carbon stock density, species composition and diversity. So consideration of topographic elevation factor in green area improvement will have better contribution on the performance of green infrastructure development planning and implementation.

***Keywords**: climate change, elevation, green-infrastructure, mitigation, urbanization,*

1. Introduction

1.1 Background

Global forest ecosystems play an important role in the global carbon cycle (Brown, 1997). Forest ecosystem covers large area of the globe terrestrial ecosystem with various biodiversity. Terrestrial carbon stock quantifying is important for the successful implementation of climate change mitigation policies (Chave et al, 2014). Forests of the world contain 80% and 40% of all above-ground and below-ground terrestrial carbon (Leena Finer et al, 2010). Carbon stock sequestration is the most important ecosystem services provided by forests (Leuschner et al., 2013). Through, biophysical processes trees capture and release CO_2 to the atmosphere through photosynthesis (Aguaron and McPherson, 2012).

Ethiopia spans a remarkable number of the world's broad ecological areas in the region due to its geological history, broad latitudinal range and immense altitudinal variability. The varieties of habitats in the country also support rich diversity of different species contributing to the biological mixture of the country (Tamene Yohannes, 2016). Forest coverage of the country has been reduced from 40% a century ago to 11.40% (FAO, 2015) with significant environmental degradation and high deforestation. There are different categories of forest ecologies with various settings in natural, planation or mixed forest types in rural, pre-urban and urban areas in the country.

Green parks and open spaces have strategic importance for the quality of life to highly increasing urbanized society (Rajni, 2017). As defined by Kuchelmeister (1997), urban forestry is considered as planning, management and protection of trees, forests and related vegetation to create or add value to the local community in an urban area. With the rapid global urbanization urban forests are becoming important components of global forest ecosystems particularly in terms of CO_2 sequestration and biodiversity conservation (Wang et al, 2013). The presence of forest and green areas contribute to the quality of life and well-being of urban dwellers. In addition to use for air and water purification, wind and noise filtration of microclimate stabilization. The goal of urban forestry is to design and efficiently manage public and private lands in and adjacent to urban forested landscapes (Richard et al, 1994). Forests in cities have better contribution for climate change mitigation and reducing the carbon emission.

The carbon stocks of urban forests are of great importance because they influence local climate, carbon cycles, energy use and livelihood (Hailiang et al, 2016). Carbon stock sequestration in urban ecosystem it is one of the main part for measuring ecosystem service provision of urban green infrastructure and effects beyond the urban scale as it have a significant impact to national carbon account (Christoph et al, 2013).

Forests currently captures about half of the total heat that causes global warming through removing of atmospheric carbon dioxide and storing it in terrestrial biosphere to meet their national carbon reduction targets (FAO, 2009). Protecting rural or urban forests will contribute to vegetation species diversity which refers to the variety and variability among the organisms and ecosystem complexes (Tarik H. et al, 2011). Promoting woody species in different land setup have a range of benefits besides improving species composition (Belay Tefera et al., 2014).

The rapid rate of urbanization and high human population growth as well as large population influx to urban cities from rural areas has greater challenges for the spatial distribution and development of urban forests (Yin Ren et al., 2012). Human beings are the main actors in the earth’s system by accelerating global warming through the rapid release of greenhouse gases (GHGs) into the atmosphere. Thus, due to anthropogenic factors deforestation and degradation are causing loss of biodiversity and carbon released to the atmosphere. Developing countries will suffer mostly from adverse impacts of climate change especially the society.

The city is suffered from soil erosion, environmental degradation and micro-climate imbalances. Thus, vegetation coverage of Addis Ababa including individual trees in private yards and green belt of plantation as well riverine buffer is estimated at 4,299 ha which is 8.28% of the total area of the city (WGCFNR, 2017). In the city loss of forests has resulted due to loss of genetic resources, severe soil erosion, flooding of the city, damages to houses and infrastructures, wood scarcity, and deterioration of living conditions. To address problems caused by high urbanization rate, population increment and other climate change induced disasters.

Urban trees sequester and store carbon in their tissue at differing rates and amounts based on such factors (Nowak et al., 2002). Urban forest development and management have better potential for fulfilling better place of living with increasing population number and urbanization (MEFCC, 2015). Many ecosystem services of trees improve urban environmental quality by supporting both ecological and social benefits, which make trees a valuable resource to cities and their citizen’s (Dale, 2013).

Several studies have been done on different types of forest biomes in Ethiopia for a long time with different purposes. The existing parks are small in size and few in number, it is verified by the fact that Addis Ababa City has very low public park coverage, estimated to be 15 times less than that of Paris (12.2 m^2/person) and 50 times less than that of Bonn (37 m^2/person) (Maru Abebaw Berhanu, 2008). So the potential of Urban Closed Public Park woody plant species diversity and carbon storage variability through gradient besides recreational value was not addressed before. Generally this study aimed to estimate carbon stock with major carbon pools and determine woody species diversity of urban public parks along altitudinal gradient to identify the dynamics between them.

1.2 Statement of the Problem

Planned and well managed cities can be great places to live, but if not urban developments can cause environmental disaster. In addition to mainly high rate of urbanization or major influx of people to mega cities from rural areas ultimately leading to problems urban rising of temperature, flooding and air pollution. Climate change nowadays is a global and local issue that aggravates different environmental changes. The rise in GHG's has caused an increase in the amount of heat from the sun accumulated in the Earth's atmosphere resulting climate change (UNFCCC, 2007). The change occurs due to increasing of CO_2 concentration in the atmosphere.

Forests are important for climate change mitigation mechanism through afforestation/reforestation or forest management. Urban forestry focuses on every aspects and conditions. The main causes for decreasing urban forests is due to land use change because of land scarcity and population growth through increasing demands for forest and forest products as well as lack of better management system. Sustainable urban forest planning and management contributes to a pleasant and healthy environment and as a valuable natural resource may provide a number of direct and indirect benefits (Aramde Fetenea and Hailu Worku, 2013).

Many of Ethiopia's cities, including Addis Ababa, remain much below the UN recommended standard to have 9 square meters of greenery per person in urban setting (MEFCC, 2015). Forest development activities of the city urban greenery was not based on scientific evidence which is basically done without taking into consideration of increasing emission due to population growth and climate change effects. Besides its mitigation actions having better vegetation coverage around high population density areas will improve the livelihood of the society and increase the livability of the city.

The city were endowed with a variety of forest cover constituted mostly with exotic and few remnants of native tree species in different ecosystem settings (public parks, roadside plantations, riverine forests and others). Studies not done to promote the development of city parks which can indicate capability of park forests on controlling microclimate and atmospheric GHG's concentration in the city. Quantifying carbon stock of the resource and determining species diversity along altitudinal gradient indicates the potential and mainly give scientific evidence for better species choice and management interventions. Also the study entails the potential of city parks contribution for better reduction of CO_2 to regulate the microclimate of the city. Therefore for further development planning to promote urban greenery and to support recent encouraging works of government on city park developments as well as expansion this research work have major contribution.

1.3 Objectives of the Study

1.3.1 General Objective

The overall objective of this study is to estimate Carbon stock and woody species diversity along altitudinal gradient of open and closed urban public Parks in Addis Ababa.

1.3.2 Specific Objectives

- To estimate and compare biomass carbon stock and soil organic carbon stock along urban parks.
- To assess and compare woody species diversity along urban public parks.
- To evaluate the correlation of carbon stock and woody species diversity along altitudinal gradient of urban public parks.

1.4 Research Questions

Is there a variation in carbon stock along closed urban public parks?

Is there variation in woody species diversity along closed urban public parks?

Is there any correlation between carbon stock estimation and woody species diversity along altitudinal gradient of open and closed urban public parks?

1.5 Hypotheses

The upper strata public parks have high carbon stock potential than the lower public parks and comparatively lower altitude public parks have higher woody species diversity than the upper altitude parks.

1.6 Significance of the Study

Urban trees sequester and store carbon in their tissue at differing rates and amounts (David et al, 2002). Urban forest development and management have better potential for fulfilling better place of living with increasing population number and urbanization (MEFCC, 2015). Many ecosystem services of trees improve urban environmental quality by supporting both ecological and population health (Dale M. J, 2013). According various studies urban green areas are facing big problem due to increasing urbanization. Climate change is average change in the distribution of weather conditions around and to a specific region or across the whole Earth (IPCC, 2001).

However there are few amounts of green areas in urban cities of Ethiopia Even though, cities are growing the urban green area coverage should be considered into urban infrastructure development plan and programs. Urban development strongly associated with the loss, fragmentation, and disturbance of habitats. Beyond recreational and educational purposes the conservation and development of the forests in urban area has major impact on regulating the temperature, rainfall pattern and quantity, species biodiversity and mitigation. Quantification of urban parks forest carbon stock and diversity of species to determine the dynamics with in the altitudinal gradient is important for the study area. Ecosystem service provision by urban city parks used to assess the actual and main role in providing environmental, social and economic benefits. The finding have contribution for biomass carbon stock inventory of urban public Park forests as well as species diversity to create better ground for planning of green infrastructure for decision makers.

2. Literature Review

2.1 Urban Forest

Urban forests defined as the sum of all woody and associated vegetation in and around dense human settlements (Munishi et al, 2008). Urban forests are the backbone of the green infrastructure (Fetene and Worku, 2013). It bridges rural and urban areas and ameliorating a city's environmental footprint. In the provision of wood fuel urban forests and woodlands play a very important role; whereas for recreational purpose city parks and urban green spaces are of high importance (FAO, 2016).

Trees are valuable elements of a city because they add visual appeal to urban landscapes, beyond shade and beauty also has practical benefits and a real monetary value that cities sometimes are unaware (Rachel et al, 2016). Urban vegetation helps to reduce increasing temperature; reduce rainwater runoff and lowers particulate matter in the atmosphere (Ngo and Lum, 2018). Urban forests are also important due to their role in preventing soil erosion and associated C losses (Tekle W.G. Kahsay et al, 2017). Urban and peri-urban forestry emerges as a complementary measure to contribute towards the urban ecosystem (Bertrand F. Nero et al, 2018).

Urban forests differ from hinterland forests in several ways (David J. Nowak et al, 2001). Trees in urban areas can be found in stands like in a park, arranged in lines along streets, or as single trees and be close to infrastructure and/or people. Also can be remnants of native forests or be deliberately grown, but they vary in composition, diversity age, health status and ownership patterns (Camilo et al, 2010).

2.2 Forest Carbon Pools

2.2.1 Aboveground Biomass Carbon

Forest biomass carbon pools include above-ground and below-ground biomass carbon parts; hence above ground biomass is the main conduit for CO_2 removal from the atmosphere. Large amounts of CO_2 transfers between the atmosphere and terrestrial ecosystems (Ullah and Al-Amin, 2012), primarily through photosynthesis and respiration. The uptake of CO_2 through photosynthesis is referred to as gross primary production (IPCC, 2006). Also, standing above ground forest carbon is an essential, active participant in the global carbon cycle. Quantifying the amount of aboveground biomass carbon within a forest stand is necessary for property managers to make informed decisions about the value and use of their forested land. Temporal and spatial biomass production patterns in forests are not only a direct measure of productivity, but also of nutrient accumulation and distribution (Mulugeta Zewdie et al, 2008)

Biomass and carbon stock are estimated using appropriate allometric equations applied to the tree measurements (Pearson *et al.*, 2005) Above ground forest carbon can include components such as stem, branch, and foliage (IPCC, 2007); these subdivisions provide additional information for ecosystem management using relative allometric equations. Two methods of measuring tree biomass are available were destructive and non-destructive (Prachi Ugle et al, 2010). Tree carbon components were calculated from DBH and total height (Qisheng et al, 2013; David J. Nowak et al, 2001). Above ground forest carbon is estimated by species and site specific equations also with common allometric equations which are generally applied over a large area and considers variety of factors (Chaturvedi R. K. & A. S. Raghubanshi, 2014).

2.2.2 Below ground Biomass Carbon

Belowground biomass estimation is much more challenging and time consuming. Most of the sites with high fine root ratios were in tropical latitudes, and may be due to the continual growing season, tree architecture, water stress, or soil nutrient status (Cairns et al, 1997). Root systems are an important part of the carbon balance they transfer large amounts of carbon into the soil. Ethiopian urban areas are endowed with a variety of forest cover constituted mainly with exotic and few native species based on this mostly below ground biomass carbon stock varies (MEFCC, 2015).

One of the most common descriptors of the relationship between roots to shoot biomass (IPCC, 2006; MacDicken, 1997). Default values for below-ground biomass to above-ground biomass ratios are to be used to estimate below-ground biomass. This has become the standard method for estimating root biomass from the more easily measurable shoot biomass (Bhishma et al, 2010). Root to shoot ratio is more efficient and effective to apply a regression model to determine belowground biomass from knowledge of biomass aboveground (Pearson et al, 2005).

2.2.3 Soil Organic Carbon

Soil carbon represents the largest carbon pool of terrestrial ecosystems estimated to have the largest potentials to sequester carbon (Abrha, 2018). The importance of carbon storage in the soil becoming increasingly recognized following observations that soil carbon store (IPCC, 2001). Soil Organic Carbon stores major greenhouse gases and it is important for increasing soil quality, maintaining and developing food production (Shaheen et al, 2015). Soil is the largest pool of terrestrial organic carbon in the biosphere, storing more C than is contained in plants and the atmosphere combined and soil affects also affected by plant production (Esteban et al, 2000).

To obtain an accurate inventory of organic carbon stocks in the soil, three types of variables must be measured soil depth, bulk density and the concentrations of organic carbon in the sample (Pearson et al, 2005). The decreasing trend of soil organic carbon with an increase in soil depth because most organic residues are incorporated in, or deposited on the surface, organic matter tends to accumulate in the upper layers (Mohammed Mussa et al, 2017). Reliable measurements of C amount is an important precondition for detecting such small changes in SOC stock because small changes in soil organic C stock could have major impacts on the global C cycle (Walter et al., 2016).

2.3 Woody Species diversity

Vegetation species diversity refers to the variety and variability among the organisms and ecosystem complexes in which they live (Tarik H. et al., 2011). The concept of biodiversity reflects the integration of biological variability across all scales, from genetic level, through species and ecosystems, to the landscapes that they form, and the ecological processes that support them (Walker, 1992, Purvis and Hector, 2000). Diversity is species composition, mixture, age structure, health status and location among others (Camilo et al, 2010). Botanical assessments are crucial in identifying diversity, threatened species and economic species also to monitor the status and understanding the extent of plant diversity in forest ecosystems (Markos, 2016).

Species diversity is a measurable biological character unique to the specific community level of ecological organization. Biodiversity index involves all the species found within the area of interest and consists of Dominance, Shannon index, species Evenness, species Richness and Number of individuals (Barcelete et al, 2016). Diversity and equitability of species in a given vegetation community help to explain the underlying reasons for such a differences (Kent and Coker, 1992). Species richness is a measure of the number of different species in a given site and can be expressed in a mathematical index to compare diversity (Zerihun Woldu, 1985).

In the world 220,000 vascular plants were estimated, but tropical ecosystem covers 10% of the earth whereas it contains 90% of world's species composition (UNEP, 2003). While Ethiopia possesses an estimated number of 6000 species of higher plants of which 10% are endemic that make the country one of the biodiversity hotspot area of the world (Ethiopian Biodiversity Institute, 2014).

2.4 Urban Forest for Carbon Stock and diversity

Urban forests are relatively rich in biodiversity and carbon stock has great potential in maintaining microclimate balances, prevention of desertification, increasing water percolation and wastewater treatments (Alvey, 2006). Urban forests serve as appropriate observatories for tomorrow's rural forests under a changing climatic condition (M.L Parry, 1998). Urban forestry management has big potential in mitigating carbon emissions and performing other environmental services (Munishi et al, 2008). Carbon stocks in urban tree communities were much lower than in forests (Kang Min Ngo and Shawn Lum, 2018).The interactions between climate change and urban forests include urban forest contributions, urban forests contribute to climate change by controlling GHG emissions. Urban parks and open green spaces importance to maintain the quality of life for our increasingly urbanized society (Devi, 2017).

2.5 The Effect of Altitude on Carbon Stock

Biomass carbon stock of a forest varies with increasing or decreasing from lower to medium and higher altitude will affect concentration of carbon pools (Alefu Chinasho et al, 2015). Whereas there is a negative correlation between tree biomass with altitude means biomass carbon storage decreases as altitude increases (Moser et al, 2007). Altitude has significant effect and inverse correlation with all carbon pools except litter biomass and soil organic carbon (Mwakisunga and Majule, 2012). Carbon sequestration in a forest ecosystem is influenced by environmental factors mainly altitudinal gradient (Hamere Yohannes et al, 2015). Carbon pools mostly have significant relationship with increasing or decreasing of elevation (Shaheen et al, 2015). Difference in altitude creates change in rainfall amount and pattern also temperature variability.

2.6 The Effect of Altitude on Woody Species Diversity

Species diversity mostly important for evaluating the sustainability of forest Communities, diversity and equitability of species in a given vegetation community used to interpret the relative variation among and within the community (Bekele Tona, 2016). Altitudinal gradient influences the composition and floristic diversity of communities due to changing of elevation accompanied by variability of climate conditions (Getachew et al, 2008). Altitude has linear relationship with vegetation attributes mainly species richness and diversity (Tarik H. et al, 2011). Vegetation varies from one area to another through variation of altitude gradient its potential and composition (Meragiaw et al, 2018).

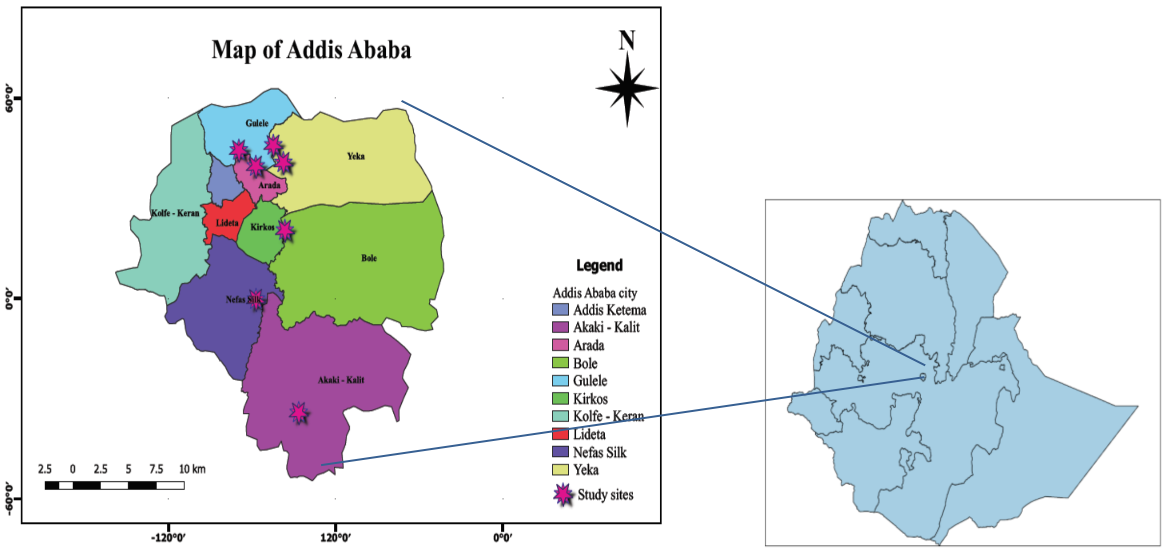
3. Materials and Methods

3.1 Description of Study Area

3.1.1 Location

The study was conducted in Addis Ababa which is the capital city of Ethiopia and diplomatic center for Africa. It is situated at the central highlands of the country with an altitude range from 2000 m a.s.l to over 3000 m a.s.l at Akaki area in the southern periphery and at Entoto Mountains northern part of the city. The upper part of the city is characterized by steep slopes while the lower part is flat terrain. The geographical location of the city lies between 8^{0}4'55" N to 9^{0}5'53''N latitude and 38^{0}38'16''E to 38^{0}54'19''E longitude. It covers an area of 54,000 ha (540km^{2}) (UNEP, 2003). The city is divided with 10 sub cities and newly Lemi Kura sub city is included according to administrative arrangement.

Figure 1: Map of Addis Ababa Administration and study sites



3.1.2 Climate

Addis Ababa has a subtropical highland climate with average maximum temperature ranged from 17 ºC to 22ºC and the average minimum temperature varies between 11 ºC and 14ºC. With average rainfall is 1114 mm per year with the major rain season from June to September.

3.1.3 Geology and Soil

Addis Ababa is found at the southern flank of Entoto ridge (3199 m a.s.l.) all directions. The mountain chain in composed of basalts called Entoto silicic with volcanic topsoil materials of about 1 to 2 meters thick (Alem Tsegaye, 2015). The center of the city lies on an undulating topography with some flat land forms. In most parts of the city the residual soils are commonly seen with varying thickness. There is intensive erosion activity and poor soil development on most parts of the slope.

3.1.4 Vegetation

The Forest coverage of the city is distributed along various ecosystems types with variability and density. The higher altitude covered by vast eucalyptus plantation and natural forests with some patches of ruminants forest around churches. Within the city there are a numbers of public green parks, botanical gardens, street plantations, cemeteries and memorial places which are governed by the local administration besides these dispersed household woodlots (Alexander Horst, 2006).

3.2 Data Acquisition/Data Collection

Preliminary survey was done to define the study areas of each selected closed public parks using GPS ground coordinate measurements in the field and Google Earth to map by QGIS software version 3.2. The fieldwork was done through stratification into homogenous units based on some common grouping factor. Stratification of the study area to more or less homogenous forest units of the study was based on altitudinal gradient. Stratification was done using stratified sampling along elevation segments. It was used to determine the elevation variations as predictor variable to relate with forest carbon estimation and woody species diversity throughout selected closed public parks. The study site was classified into two stratum based on altitude: Lower altitude ranges from 2088-2338 m.a.s.l. and upper altitude from 2338-2588 m.a.s.l.

3.3 Data Sources and Data Types

Generally primary and secondary data sources were used to collect important resources to meet the objectives of the study. The primary data sources collected through field measurements of DBH and Height at plot level and species identification was done through appropriate literatures. Whereas, secondary data was collected from different credential sources and city administration offices data types like published materials (reports and various literatures).

3.4 Sampling Techniques

A stratified systematic sampling method was selected for identification of each sample plots using transect lines. The field work was conducted from November, 2019 to January, 2020. The stratum was developed along altitudinal gradient using GPS measurements. Accordingly from public parks administered the municipality of Addis Ababa 7 public parks were selected; which are Shegir, Hamle 19, Ethio-Korea memorial , Ferency, Central, Beheretsige and Akaki Kality parks were selected based on altitude differences, woody species composition and area coverage. Therefore from the total study sites 4 consecutive parks were stratified as upper strata and the last 3 parks as lower strata based on the criteria stated.

Sample plot were determined based on total areas of selected public parks. Number of sample plots for each selected public parks mapped using QGIS software version 3.2 and with 100m gap between transects lines and 75m between two sample plots on each study areas. Then Sampling points were systematically generated for selected urban green parks by locating intersection points. Therefore a total of 70 sample plots were determined for biomass inventory and species identification assessment. Allocation of plots to each study sites based on the principle of optimum allocation (Pearson et al, 2005) considering the sizes of selected park.

$$n_h = (N_h S_h / \sum_{h=1}^{L} NhSh) * n$$ ……………………………………………..….Equation 1.

Where:

n= the total number of sample plots N_h= the number of sampling units in stratum h

S= the standard deviation S_h= the standard deviation in stratum h.

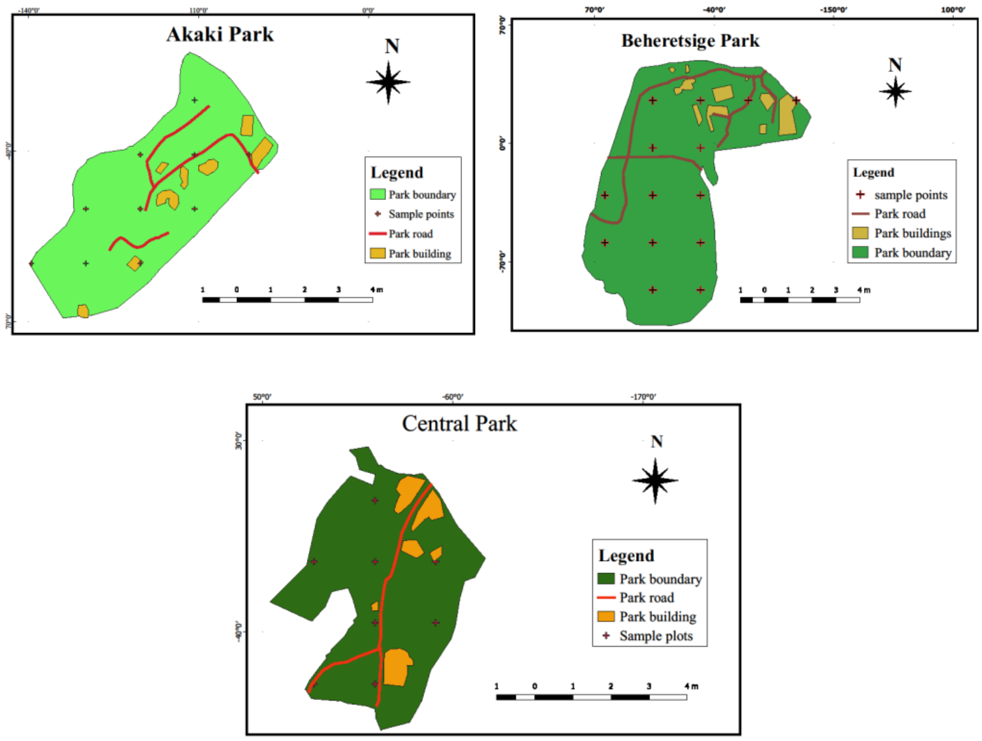
n_h= the number of plots in stratum h. N= the number of sampling units in the population

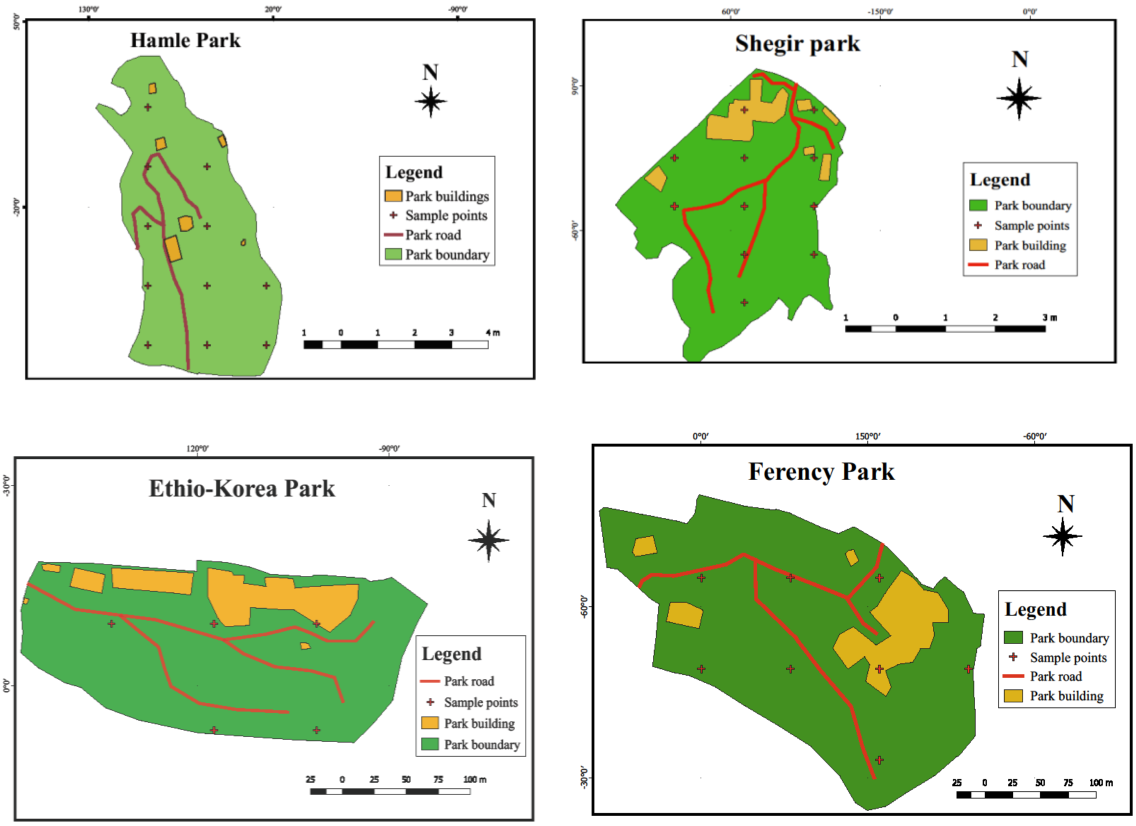
Table 1: Summary data of selected study sites

No.	Park Name	Area (m^2)	Number of sample plot	Elevation	Strata
1	Akaki Kality park	45900	10	2088	Lower
2	Beheretsige park	142796	16	2216	Lower
3	Central Park	42400	9	2328	Lower
4	Ethio-Korea park	34053	5	2487	Upper
5	Ferency park	55908	9	2498	Upper
6	Hamle 19 park	67968	10	2568	Upper
7	Shegir park	70255	11	2585	Upper

Each point was identified on the ground using GPS and Compass on the field with XY coordinates generated by QGIS software of every sample plots of the study areas.

Figure 2: Map layout of selected study sites and sample plots distributions



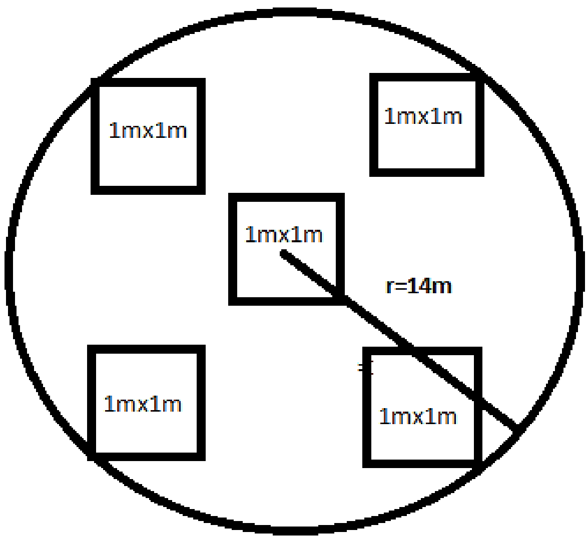


A main plot radius of 14m (616m^2) was laidout for aboveground biomass inventory (Pearson etal, 2007). Every trees and shrub species ≥5cm in diameter DBH and tree height was measured using diameter tape and Suunto Hypsometer. Diameter at breast height (DBH) means at the height of 1.3m above the ground will be measured (Mesele Negash and Mike, 2015).

Also woody species identification as well as density was identified and recorded with in each main sample plots. Trees having multiple stems at 1.3m height were considered as a single individual. Branched tree at 1.3m were measured at the smallest point below 1.3m, where the stem assumes nearly cylindrical shape. A woody plant with multiple stems or fork below 1.3m height was treated as a different individual tree. And those trees on the border were included when ≥50% of their basal area fell within the plot and excluded if <50% fell outside the plot. Species identification was done on the field using their local name and Useful Trees and Shrubs for Ethiopia (Azene Bekele, 2007). Each tree species which was listed at field and verified by using volumes of Flora of Ethiopia and Eritrea (Edwards's etal, 2000).

Whereas soil samples were collected to assess the carbon stock from the total sample plots determined 24 soil samples were collected. For soil organic carbon analysis three sub-plots have chosen from 5 sub plots (Figure 3.). To prepare composite soil samples for each depth range (0-20 cm and 21-40 cm) and taken 250 gm of soil for analysis. And for bulk density analysis samples collected from the center sub plot in each depth classes. Even-though for soil sample collection 1mx1m subplot Quadrants were used, while a 14m radius main circular plot with an area of 0.0616 ha is used for measuring trees biomass measurement and species identification (Pearson et al, 2005).

Figure 3: Design of sample plot for DBH and Ht, soil sample and species identification



□ 1m × 1m ($1m^2$) quadrat sub-plots will be used for soil sampling.

○ 14 m (.0616ha) radius is main plot used for tree or shrub measurement DBH ≥5cm and for species identification.

3.5 Field Measurements

3.5.1 Forest Management system of public parks

The potential of public parks affected by variation of type and status of forest management activities implemented especially enrichment planting, weeding, watering, pruning and species selection. However for estimation of forest carbon stock of selected parks of the study area was considering the same management and tending operations implemented. Therefore, the carbon stock measurement of public parks and comparison will not be affected by factors of management systems applied on each park forests.

3.5.2 Estimation of Forest Carbon Stock

3.5.2.1 Estimation of Above Ground Biomass

The DBH and height were directly measured from the study sites; however wood density was obtained from wood density databases (IPCC, 2003). However, for species where wood density was not found 0.6g/cm^3 was used, which is equivalent to average value reported for wood density of trees in tropical Africa ranges (Henry etal, 2010).

Carbon stock was estimated using specific or generic allometric equations in order to generate a better estimate of forest carbon stocks of AGB, but if there is no available equation developed for forest type of the study site. Thus to make it more reliable many generic allometric equations had been developed globally, so the model of Chave et al. (2014) was used by many studies and has been the best model for carbon stock assessment in tropical Africa and these equation was different depending on the type of species, geographical locations, forest stand types, climate and others. Also it incorporates three parameters of the tree to increases its precision.

Where, AGB– Estimation of the Above-ground biomass (kg), H– Height of tree (m), D– Diameter (cm) at breast (1.3m Height), and ρ– Wood density (g/m^3)

$$AGB = 0.0673 *(\rho*D2*H)^{0.976}$$ ………………………………….Equation. 2

While selected equation of Chave et al. (2014) was recommended for dry tropical forest types, but forest type of the study sites were mixed forests. Hence, *Cuppressus lustanica* species is abundant compare to other species and selected species specific allometric equation for this species to make it more realistic considering species specific local equation with diameter range and better R^2 value of 0.95 Yehualashet Belete (2016).

$$AGB = -193.359+25.869(D)-15.727(H) +90.952(\rho)$$.……………………..Equation 3

3.5.2.2 Estimation of Below ground Biomass

The equation presented used to make estimates of root biomass in a standard manner for forests based on the knowledge of the above-ground biomass. Root biomass is often estimated from root-shoot ratios (R/S) by taking aboveground biomass. Based on this BGB was calculated by considering 26% of the AGB (IPCC, 2006).

BGB – Below Ground biomass (kg)

$$BGB = AGB*0.26$$ ……………………….……………………….Equation 4

3.5.2.3 Estimation of Soil organic Carbon

Soil samples were collected from 1m × 1m sub-plot four sides sub plots and center positions of selected 24 sample plots for soil analysis. In each sub-plot for soil carbon concentration by excavation of 0-20 cm and 21-40 cm depth range from three sub plot by mixing the soil homogenously and composite sample will be obtained for each main plot and taken 250gm of soil per soil depth range. For soil bulk density analysis using 5 cm diameter core samplers with 0-20 cm and 21-40 cm depth from the center sub plot. All samples were placed in paper bags with appropriate label for each depth range and separately submitted to Wondo Genet College soil testing laboratory for analysis.

The soil samples collected for soil carbon analysis were air-dried, well mixed and sieved through a 2mm mesh size sieve. About 100g of composite samples will be taken from each main sample plot for carbon analysis. Soil samples were analyzed using Walkley-Black Method (Walkley and Black, 1934). Soil bulk density analysis were determined by drying the core samples of soil collected with paper bags oven dried at 105^{o}C for 48 hours. Dry weight of the soil were determined and divided by the volume of the core sampler and then we get bulk density of every sample. In order to obtain an accurate inventory of organic carbon stocks in mineral or organic soil, three types of variables must be measured: soil depth, bulk density and the concentrations of organic carbon within the sample. Therefore, soil organic carbon stock pool was calculated using the equation (Pearson et al, 2005).

$$V = h * \prod r^2$$ ……………………………………... Equation 5

Soil Bulk density (BD) = dry Weight of soil/V of the core ……………………..Equation 6

SOC (t/ha) = [(BD (gcm-3) x d (cm) x %C)] x 100 …...…………………Equation 7

Hence, SOC = Soil Organic Carbon [t ha-1]   V = Volume of the Core [cm-3]

BD = Bulk Density [g cm-3]   d = Depth of the Soil Sample [cm]

% C = Carbon Concentration [%]

3.5.2.4 Estimation of Total Carbon Stock

Total carbon stocks were calculated by summing the carbon stock densities of the selected individual carbon pools of each park in the stratum by using the equation (Pearson et al, 2005). It is recommended that any individual carbon pool of the given formula can be disregarded if it does not contribute significantly to the total carbon stock (Bhishma et al, 2010). Some previous studies shown that there is not significant amount of litter or deadwood carbon proportion in other public parks of Addis Ababa; dead litter carbon stock of 4.214 ton ha^{-1} (Alem Tsegaye, 2015). Therefore the litter and dead woods carbon pools in the study were not included because every day the parks were cleaned by workers and remove any litter or deadwood debris inside the public parks.

Also According to IPCC (2006), the biomass estimated of a sample plot is converted to carbon stock by the default carbon fraction of 0.47 in the tropical and sub-tropical region. Then the total carbon stock was then converted to tons of CO2 equivalent by multiplying it by 3.667 (44/12).

$$\mathbf{TCS = (AGB + BGB) * 0.47 + SOC}$$ ………………………………..Equation 8

TCS = Total Carbon Stock [t C ha-1]

AGB = Above -ground tree biomass [t ha-1]

BGB = Below-ground biomass [t ha-1]

SOC = Soil organic carbon [t C ha-1]

3.5.3 Woody Species diversity

3.5.3.1 Species diversity indices, Species Evenness and species Richness

Shannon weiner diversity index, evenness and Simpson diversity index used to determine species diversity. Those diversity indices were easy practical measures of rarity, commonness and can provide relevant information for evaluation and quantification of woody species diversity (Dale et al, 1994).

To calculate Shannon diversity index:

$$H' = -\sum_{i=1}^{s} Pi \ln Pi$$ ……………………………………………………..Equation 9

Where; H' = is Shannon diversity index, pi is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), *ln* is the natural log, Σ is the sum of the calculations and s is the number of species.

The value of the index (*H*') usually lies between 1.5 and 3.5, the larger the *H*' value, the higher the diversity.

Species Evenness (*J*) calculated as:

$$J = \frac{\sum_{i=1}^{s} Pi \ln Pi}{\ln S} = \frac{H'}{\ln S}$$ ……………………………………………………..Equation 10

Where: H′ is Shannon-Wiener Diversity Index, Hmax = lnS, S = total number of species in the sample, Pi = the proportion of individuals abundance of the i^{th} species and *ln* = log base *n* (natural logarithms).

It was measure of equitability and attempts to quantify the unequal representation of species in a community against a hypothetical community in which all species are equally common. The value of evenness index falls between 0 and 1. The higher the value of evenness index, the more even the species is in their distribution within the given area.

Simpson's diversity index (D) calculated as:

$$D = \frac{1}{\sum_{t-1}^{S} Pi^2}$$ ……………………………………………Equation 11

Where; D = is Simpson's diversity index and Pi is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), where S is the number of species in each altitude park forests. Simpson's diversity index gives relatively little weight to the rare species and more weight to the most abundant. The value ranges from 0 (low diversity) to 1(maximum diversity).

Species richness is a common way of measuring biodiversity mainly involves counting the number of individuals or even families in a given area or in a community.

3.5.3.2 Species Composition and structure

All the woody species identified and documented throughout every sample plots were used to assess vegetation composition and structure. The main species composition and structural parameters used in this study were DBH, Height, species abundance, frequency, density, Basal area (BA), Relative density, Relative frequency, Relative dominance and IVI. Importance Value Index (IVI) indicates the structural importance of a species within a stand, so in this study it was computed for all woody species encountered in the forest (Amanuel Ayanaw and Gemedo Dalle, 2018).

Then Kent and Coker (1992) as cited by Tefera et al, (2015) IVI is calculated from Rel. Frequency, Rel. Density and Rel. dominance values. Importance value index used for comparison of ecological significance of species in which high IVI value indicates that the species sociological structure in the community is high.

$$\text{Density} = \frac{\text{Total number of stem of a given species}}{\text{Sample size in ha}} \quad \text{......Equation 12}$$

$$\text{Tree Basal Area } (m^2) = \Pi r^2 = 3.142 \times (DBH/4)^2 \quad \text{......Equation 13}$$

$$\text{Frequency} = \frac{\text{Number of sample plots in which species recorded}}{\text{Total number of sample plots}} \times 100 \quad \text{......Equation 14}$$

$$\text{Relative density} = \frac{\text{Density of species A}}{\text{Total density of all species}} \times 100 \quad \text{......Equation 15}$$

$$\text{Relative dominance} = \frac{\text{Basal area of species A}}{\text{Basal area of all species}} \times 100 \quad \text{......Equation 16}$$

$$\text{Relative frequency} = \frac{\text{Frequency of species A}}{\text{Frequency of all species}} \times 100 \quad \text{......Equation 17}$$

Importance value Index (IVI) = Rel. F. +Rel. Den. + Rel. Dom. …..…………Equation 18

3.5 Data Analysis

Data analysis was recorded, organized and done using MS excel sheet and statistical analysis by R software. The independent tree variables such as DBH and height of each species were used to calculate the dependent variables (biomass carbon stocks). And fresh weight (FW), dry weight (DW) and carbon concentration for Soil sample data also woody species diversity as well as species composition was organized by MS excel 2010. It was analyzed using Statistical software of R software version 3.4.3. The relationships between parameters of carbon stock and species diversity towards altitudinal gradient were tested by descriptive statistics, correlation test and one way ANOVA test at α=0.05.

4 Result

4.1 Biomass and Soil Carbon stock of Public Park Forest

4.1.1 Aboveground and Belowground Biomass Carbon of public parks

The total aboveground biomass was 1112.144 ton with sample plot area of 0.0616ha. The above ground biomass per ha is 257.92 ton ha^{-1} and mean AGC stock is 125.33$\pm$ 40.4 ton ha^{-1} (Figure 4.). AGC is highest at Ferency Park with 199.75 and the lowest is at Ethio-korea memorial park of 86.79 ton ha^{-}1. The total BGB of 222.43 ton and mean BGC is 25.07 $\pm$ 8.08 ton ha^{-1}. The highest BGC is recorded at Ferency park 39.95 ton ha^{-1} and the lowest is Ethio-Korea park 17.36 ton ha^{-1} (Figure 5.).

Figure 4: Above Ground Biomass Carbon ton ha^{-1} for each Public Parks

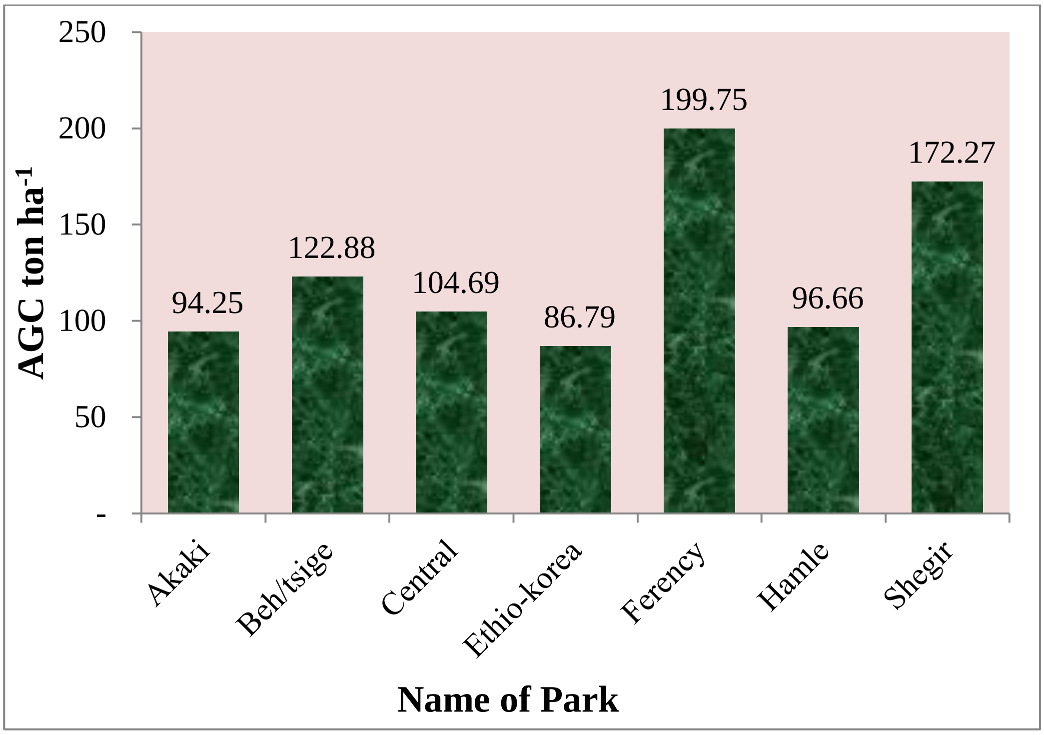
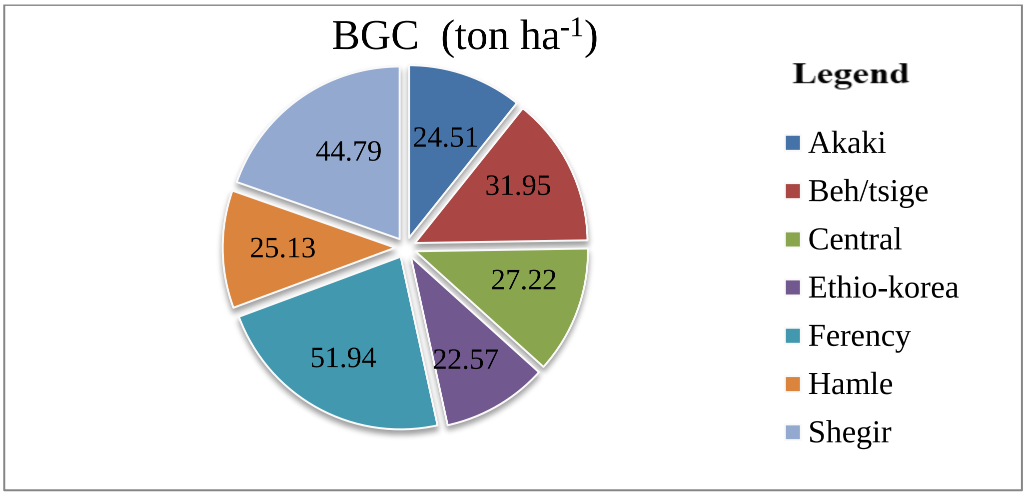


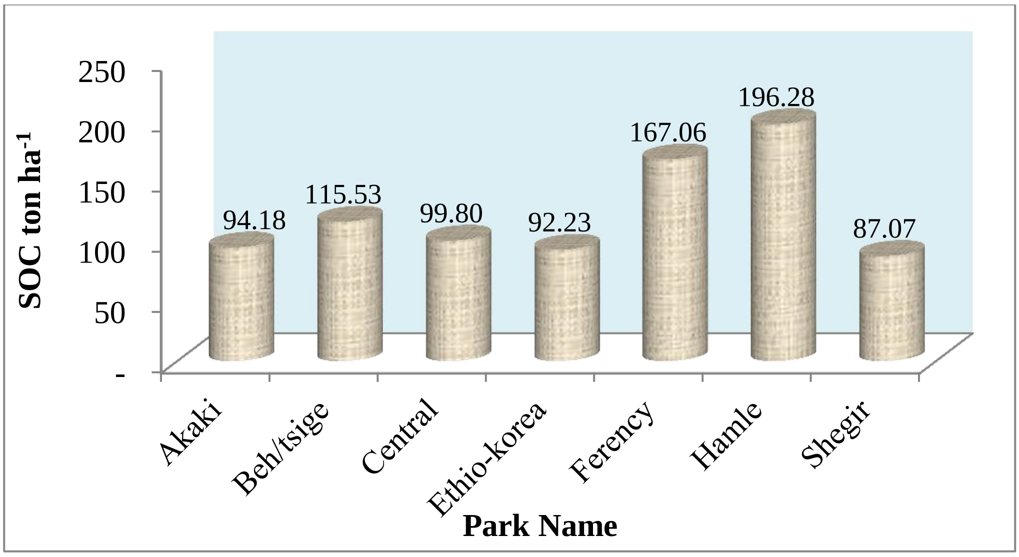
Figure 5: Below Ground Biomass Carbon ton ha^{-1} of selected public Parks



4.1.2 Soil Carbon Stock of urban public parks

The mean soil organic carbon stock of selected urban parks was 121.74$\pm$ 39.53 ton ha^{-1}. The higher is found at Hamle Park 196.281 and the lowest at Shegir park 87.071 ton ha^{-1} (Figure 6). However soil bulk density ranges from higher at Ferency Park 1.453g/cm^3 and the higher amount of carbon concentration per sample is 6.5% at Beheretsige Park (Appendix 2.).

Figure 6: Soil Organic Carbon in ton ha^{-1} of selected urban parks



4.1.3 Total Carbon stock of urban public parks

The total ecosystem carbon stock of selected public parks have different level of carbon stock amount with 877.29 ton ha^{-1} aboveground biomass carbon, 175.46 ton ha^{-1} of belowground carbon and 852.15 ton ha^{-1} of total SOC as indicated below. But the mean biomass carbon stock of AGC, BGC and SOC is 125.33$\pm$ 43.68, 25.07$\pm$ 8.73 and 121.74$\pm$ 42.74 ton ha^{-1} respectively.

Table 2: Total Ecosystem Carbon Stock of urban parks

Name of Park	AGC (ton ha^{-1})	BGC (ton ha^{-1})	SOC (ton ha^{-1})	TBC (ton ha^{-1})
Akaki	94.25	24.51	94.184	207.28
Beh/tsige	122.88	31.95	115.528	262.99
Central	104.69	27.22	99.800	225.43
Ethio-korea	86.79	22.57	92.229	196.38
Ferency	199.75	51.94	167.061	406.76
Hamle	96.66	25.13	196.281	312.27
Shegir	172.27	44.79	87.071	293.79
Min	86.79	22.57	87.071	196.379
Max	199.75	51.94	196.281	406.761
Mean($\pm$ SD)	125.33($\pm$43.68)	31.59($\pm$10.51)	121.74($\pm$42.74)	272.13($\pm$68.05)

* Significant level of α= 0.05

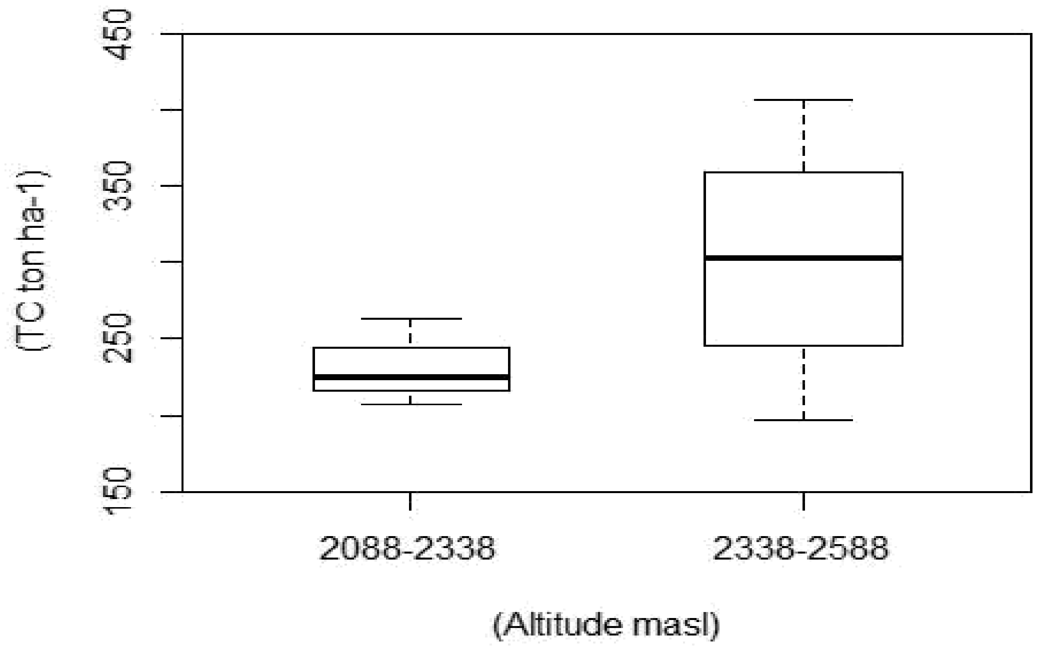
4.1.4 Carbon Stock potential against altitude gradient

The mean above ground biomass carbon ranged from 138.87 ton ha^{-1} on the upper altitude followed by 107.27 ton ha^{-1} at the lower altitude. Whereas mean soil organic carbon was ranged from 135.66 ton ha^{-1} to 103.17 ton ha^{-1} carbon stock for the upper altitude and lower altitude parks respectively. There is large variation of carbon stock within the upper altitude parks; however there is small variation in the lower altitude parks (Figure 8.).

Figure 7: Biomass Carbon and SOC stock along altitude

Carbon Pools	Mean± SD		P-value
	2088-2338	2338-2588	
AGC	107.27 (±15.8)	138.87 (±15.8)	0.016
BGC	27.89 (±4.11)	36.11 (±4.11)	
SOC	103.17 (± 16.24)	135.66 (± 16.24)	0.018
TCS	238.34 (±36.15)	310.63 (±36.15)	

Figure 8: Total carbon stock comparison with altitude



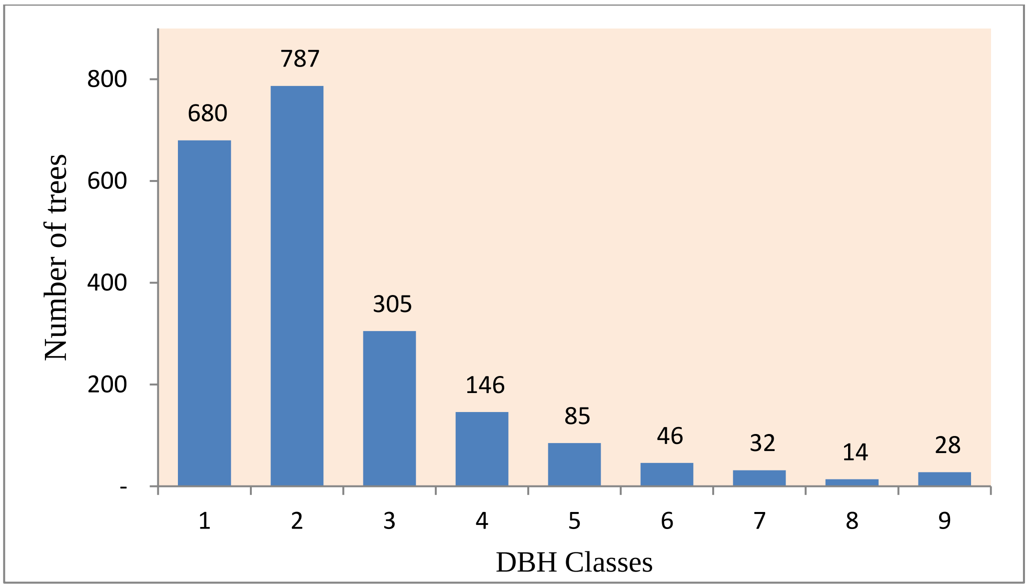
4.2 Woody Species Diversity of Urban Public Parks

4.2.1 Woody Species Composition and Structure

4.2.1.1 Species structure of urban parks

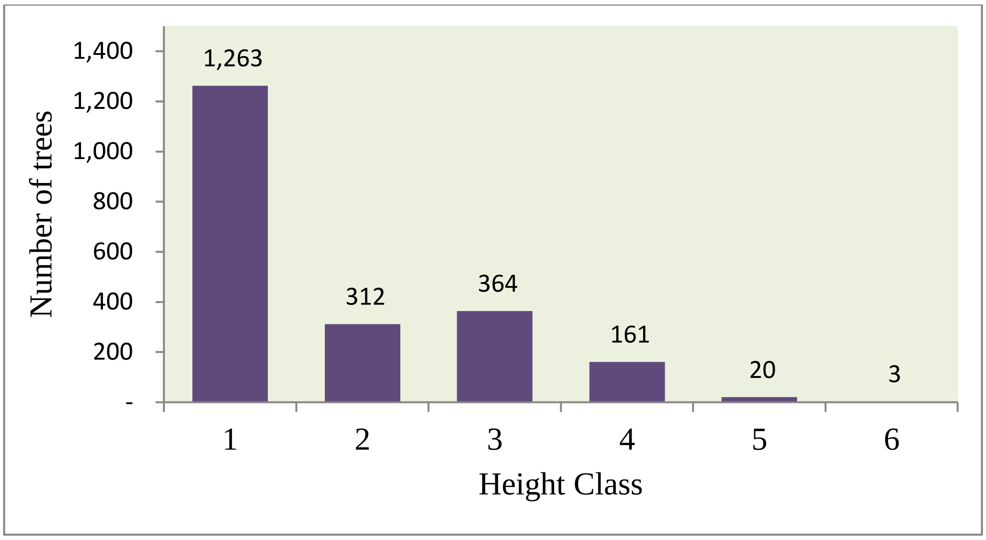
A total of 28 trees were identified with maximum DBH class, but large number of trees recorded within lower DBH classes (Figure 9.). Although higher number of trees were concentrated in the small height class. Due to major differences and height gap have small amount of trees fall in class 5 and 6 commonly species like *Podocarpus falcatus* and *Juniperus procera* (Figure 10).

Figure 9: Number of trees Vs. DBH class



Class 1= 5-10 cm; class 2 = 10-20 cm; class 3 = 20-30 cm; class 4 = 30-40 cm; class 5 = 40-50 cm; class 6 = 50-60 cm; class 7 = 60-70 cm; class 8 = 70-80 cm; and class 9 = >80 cm.

Figure 10: Number of trees Vs. Height Class



class1= 2-10 m; class2 = 10-15 m; class3 = 15-25 m; class4 = 25-35 m; class5 = 35-45 m; and class 6 = > 45 m.

4.2.1.2 Woody Species Composition of Urban parks

The highest recorded abundance and density was found for *Cupressus lustanica*, *Grevillea robusta*, *Cassuarina angustifolia*, *Acacia melanoxylon and Olea europiana.* The highest basal area was recorded *Juniperus procera*, *Eucalyptus camaldunesis*, *Cupressus lustanica*, *Grevillea robusta*, *Olea europiana and Acacia abyssinica.* With higher IVI value of 37.41 *Cuppresss lustanica* is ecologically significant species than the others (Table: 3). The most frequently found species is *Cupressus lustanica* with 94.86%. Whereas the species composition of this study indicates more than 85% of the species is tree component and the rest is shrub species.

Table 3: The list of species composition of ten tree species of the urban Park Forest

No	Species Name	Abundance	Freq.	BA	Density	Relative Freq.	Relative Density	Relative Dom.	IVI	Tree form
1	*Acacia abyssinica*	59	37.14	1.33	13.68	3.51	2.78	4.97	11.26	Tree
2	*Acacia melanoxylon*	126	60.00	0.86	29.22	5.68	5.93	3.20	14.81	Tree
3	*Callistemon citrinus*	96	60.00	0.28	22.26	5.68	4.52	1.04	11.24	Shrub
4	*Cassuarina angustifolia*	116	60.00	1.00	26.90	5.68	5.46	3.73	14.87	Tree
5	*Croton macrostaches*	90	52.86	0.82	20.87	5.00	4.24	3.06	12.30	Tree
6	*Cupressus lustanica*	418	94.29	2.36	96.94	8.92	19.69	8.80	37.41	Tree
7	*Eucalyptus camaldunesis*	88	34.29	2.43	20.41	3.24	4.15	9.09	16.47	Tree
8	*Grevillea robusta*	187	52.86	2.12	43.37	5.00	8.81	7.94	21.75	Tree
9	*Juniperus procera*	75	38.57	4.61	17.39	3.65	3.53	17.22	24.40	Tree
10	*Olea europaea*	95	50.00	1.53	22.03	4.73	4.47	5.72	14.93	Tree

4.2.2 Species Diversity indices, Species Richness and Evenness

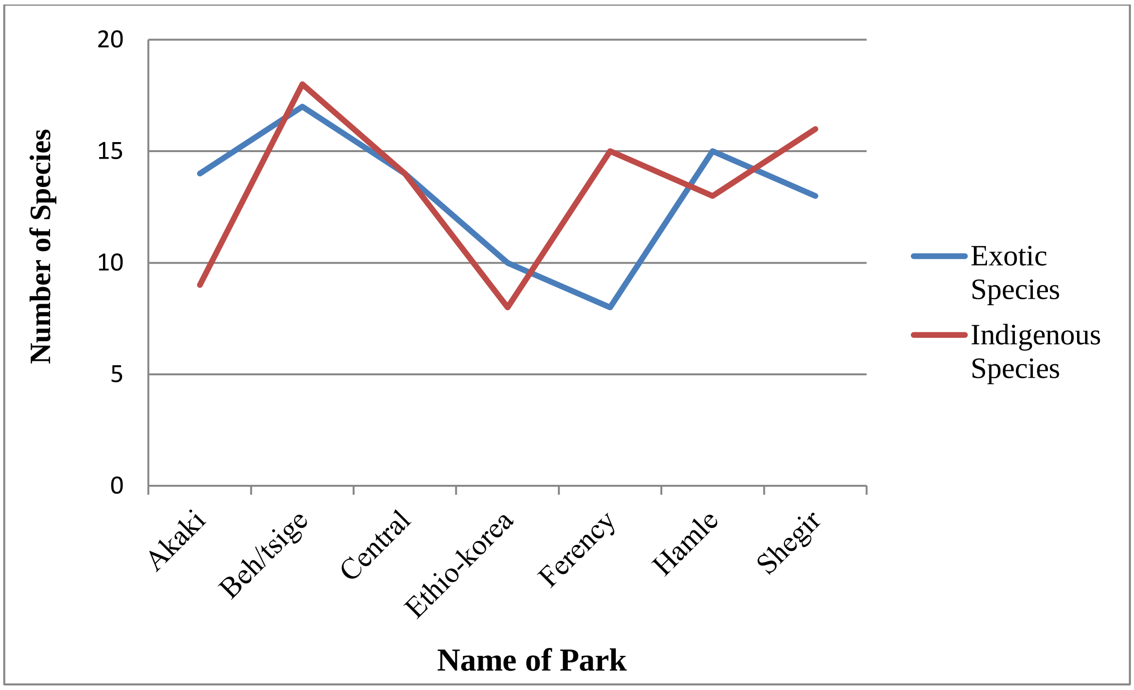
In total 52 woody species were identified from seven different selected public parks. Accordingly 8 indigenous and 3 exotic tree species only recorded in the upper altitude parks and 6 indigenous and 3 exotic species only found on the lower altitude parks (Table:5). However, total of 32 woody species were found in both altitude parks. Shannon Weiner diversity index and Simpson diversity index show there is higher species diversity on lower strata (altitude) public parks and higher at central park with 2.97 (Table: 4). whereas species evenness distribution varies between 0.45 and 0.53. The diversity of species tested along altitudinal variation with one way ANOVA test at $\alpha=0.05$ (p-value=0.99).

Table 4: Public Parks vs. Shannon, Simpson diversity, Evenness and Richness

	Akaki	Beh/tsige	Central	Ethio-korea	Ferency	Hamle	Shegir	Mean(±SD)
Shannon	2.53	2.94	2.97	2.41	2.6	2.61	2.95	2.72 (±0.23)
Evenness	0.45	0.46	0.53	0.49	0.47	0.046	0.51	0.48 (±0.03)
Simpson Index	0.898	0.92	0.929	0.859	0.91	0.87	0.935	0.90 (±0.03)
Richness	23	35	28	18	23	28	29	26.29 (±5.47)

Standard deviations (±SD) mean is shown in parenthesis

Table 5: Indigenous and Exotic species of each park along altitudinal gradient



4.3 Relation of Carbon stock and Species Diversity towards altitude

According to the results of different variables towards each other and with the altitude variation correlation tests were done to identify the relation between them. Consequently species diversity indices and richness have negative correlation with altitude, but evenness indicates positive relation. Nevertheless all carbon pools have positively affected by increasing or decreasing of altitude range.

Table 6: Correlation test of Carbon stock and species diversity versus altitude

Parameters	Altitude	Shannon	Evenness	Simpson Index	Richness	AGC (ton ha^{-1})	BGC (ton ha^{-1})	SOC (ton ha^{-1})	TC (ton ha^{-1})
Altitude	1.000								
Shannon	-0.395	1.000							
Evenness	0.069	0.514	1.000						
Simpson Index	-0.407	0.864	0.430	1.000					
Richness	-0.407	0.836	0.014	0.608	1.000				
AGC (ton ha-1)	0.387	0.282	0.147	0.556	0.138	1.000			
BGC (ton ha-1)	0.386	0.282	0.147	0.556	0.139	1.000	1.000		
SOC (ton ha-1)	0.406	-0.237	-0.448	-0.334	0.091	0.185	0.185	1.000	
TC (ton ha-1)	0.512	0.063	-0.156	0.202	0.152	0.821	0.821	0.713	1.000

*significant at α=0.05

5 Discussion

5.1 Biomass Carbon and Soil organic Carbon Stock of Public Parks

5.1.1 Biomass Carbon Stock of Urban Public Park Forest

Carbon Stock estimation for urban park forests important understanding of present condition for planning and implementation of different strategies. Biomass carbon stock in the mixed forest of the urban setting varies based on the independent variables of tree diameter and height distribution. Biomass carbon stock derived based on measured values of tree weight related to its DBH and height from sample trees (Birhanu kebede and Teshome Soromessa, 2018).

Whereas the above ground carbon stock ranged from 86.79 to 199.75 ton ha^{-1}, at Ethio-Korea memorial Public Park and Ferency Park respectively. So the mean aboveground biomass carbon was 125.33$\pm$ 40.4 ton ha^{-1}. Urban parks it is expressed as Co2 equivalent a total of 3219.64 ton ha^{-1}Co2. Larger aboveground biomass carbon registered by *Juniperus procera* with 44.75 ton ha^{-1} of carbon which implies trees species variability has major influence on biomass carbon stock.

Therefore, Murphy and Lugo (1986) specified the global aboveground biomass carbon in tropical dry and wet forests ranged from 30 to 275 ton ha^{-1} and 213 to 1173 ton ha^{-1} respectively. This study is in line with the above reported range of dry tropical global forest average. While the mean AGC of this study is compared with similar other study findings of selected Church forest in Addis Ababa (Tulu Tolla, 2011) and Beheretsige and Central closed pubic Park in Addis Ababa (Marshet Tefera and Teshome Soromessa, 2013) that found out the mean total AGC stocks were 129.86 ton ha^{-1} and 25.4 ton ha^{-1} respectively, thus the mean AGC of this study is lower than the first finding but higher than the other study. Belowground biomass carbon comparison indicates the same trend as the above ground biomass carbon stock with other studies. Biomass carbon stocks of urban park forests have a better quality to contribute in the sequestration of Co_2 likewise natural forests in the country.

5.1.2 Soil Organic Carbon Stock of Urban Public Park forest

Soil carbon stock analysis was done on 24 sample plots with two depth ranges. The soil bulk density of parks ranged from 0.76 to 1.45 g/cm^3. Whereas, soil organic carbon stock was ranged from 87.071 to 196.281 ton ha^{-1}. The SOC stock of this study compared with other related studies related value with other studies conducted (Tulu Tolla, 2011; Marshet Tefera and Teshome Soromessa, 2013) which had 135.94 ton ha^{-1} and 113.55 ton ha-1 respectively. Therefore this highly indicate soil sequester better carbon stock as biomass carbon stock as well soil organic carbon of green parks of urban cities have good soil management. Also it shows soil can contribute for climate change mitigation mechanism with high amount of atmospheric GHGs sink.

5.2 Woody Species Composition and Structure

The distribution of all individuals with DBH (>5 cm) and height (>2 m) distribution of the study sites were an inverted J-shape distribution. Due to the presence of large amount of individual species had the largest number in the lower DBH and height classes the population structure shows a good regeneration potential. This type of distribution entails stable population of woody species (Tesfay Atsbha et al, 2018). Height can be used as an indicator for older trees which found in higher height classes as compared to lower height classes and had low percentage distribution.

Most of indigenous tree species are fall in higher DBH classes, however exotic types of tree species exists in lower classes (Appendix). This shows species selection for plantation in the strategy and plan of the park administration mainly focuses on exotic tree species because of fast growth of the species and lack of promotion for indigenous species. Therefore DBH and Height identification leads to further management as well planning and implementation options to improve the ecology.

Different patterns of species population structure can indicate variation in population. A total of 52 woody species belonging to 28 families were identified with total number of 2123 trees. From the total species 28 (53.8 %) were indigenous while the remaining 24 (46.2 %) were exotic tree species. The result is comparable with other urban forest ecosystem in Addis Ababa (Tekle Woldegerima et al, 2017; Yilma Getaw, 2016) where 37 species were recorded. The highest number of species exists in the study area is in *Fabaceae* family with 12 species and followed by *Myrtaceae*, but most of the families have a single number of tree species representations.

Addis Ababa urban Park Forest is categorized as mixed forest type vegetation. Information on forest structure is very important to conserve healthy regeneration of the species. Based on the distribution *Cuppressus lustanica, Gravillea robusta and Olea europiana* have the higher abundance and species density; however least abundante species is *Susbania sesban.* Similarly, noticed that *Juniperus procera, Cuppressus lustanica and Eucalyptus camaldunesis* recorded large basal area. Forests which have largest tree cover large basal area (Tulu Tolla, 2011). This identification of species composition can be used to prioritize species for conservation and management; it means species with high abundance need less effort, but rare species relatively high conservation.

Species with the higher importance value index were the leading dominant of specified vegetation, so species which have higher IVI value were *Juniperus procera, Cuppressus lustanica and Gravillea robusta* compare to the remaining species due to high relative frequency, relative density and relative dominance values of those species.

5.3 Comparison of diversity indices and Evenness of Urban Park Forest

Woody species diversity mostly described through different indices particularly many studies uses Shannon and Simpson diversity indexes also species evenness and richness. As indicated the result of this study Shannon wiener diversity range from 2.41 to 2.97. The value of the Shannon index usually lies between 1.5 and 3.5. Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5 value, high when it is above 3.0, medium when it is between 2.0 and 3.0, low when it is between 1.0 and 2.0 and very low when it is smaller than 1.0 (Cavalcanti and Larrazabal, 2004). Therefore the larger the value, the higher species diversity, therefore the result indicates the urban public parks have medium species diversity.

Similarly (Begon et al, 2006), Simpson and Evenness values lies between 0 and 1. So the result measured of the study sites was between 0.859 lower at Ethio-Korea and 0.929 at Central park which shows higher diversity comparatively. However species evenness varies within the range of 0 and 1, but the result of the study ranges from 0.45 to 0.53. Thus there is slight variation among every park which implies species abundance and distribution among public parks almost similar. Although species richness of the parks relatively higher at Beheretsige Park and the lower species is at Ethio-Korea Park.

According to the result of this study shows there is comparative variability of species richness among different public parks as well as along strata. Some scholars said that due to the trend of planting indigenous species was decreasing whereas that of exotic species was increasing (Yitebitu Moges et al, 2010; FAO, 2010) and species richness were decreasing. Both Shannon and Simpson diversities increase as species richness increases.

5.4 Comparison of Carbon Stock and Species Diversity along altitude

Carbon stock potential of urban forests mainly biomass carbon and SOC shows major variation due to altitude differences of species composition with structure. The Altitudinal change in the study indicates variability in vegetation coverage and growth. Carbon stock highly related with the presence of more productive stem density (Hamere Yohannes et al, 2015). Although there is an increasing amount of AGC and BGC due to increasing elevation, so there was significant variation in AGC between the two strata with the statistical test of ANOVA at significance level of α=0.05 (P-value = 0.016).

And mean SOC is larger in higher altitude with 135.66 ton ha^{-1} and 103.57 ton ha^{-1} at lower altitude. SOC stock between altitudinal variations of selected public parks as the statistical result of ANOVA test shows that there is significant different at significance level of α=0.05 (P-value = 0.018). Carbon pools shown increasing or decreasing trend along altitude (Kidanemariam Kassahun et al, 2015).

Carbon stock sequestration potential due to altitude rising or decline, as a result of increasing number of species composition along altitude. There is large number of indigenous species with large diameter as well as height distribution and due to high moisture availability on upper strata will have contribution for high amount of carbon stock sequestration potential.

As a result this study revealed that there is variability between each parks and altitude ranges, whereas the proportion between indigenous and exotic species equivalent because of relatively same management and development attention were given. Eventually statistical test of ANOVA test at significant level α=0.05 (p-value = 0.99) indicates that elevation has significant difference on species type between each strata's.

5.5 Relation between carbon Stock, diversity and altitude gradient

Carbon stocks of public parks have significant (positive) relationship with altitudinal variation. Because carbon stock increases when altitude increases or vice versa. Total ecosystem carbon was significantly influenced by environmental factors (Tesfaye et al, 2019; Asaminew Abiyu et al, 2015). Different changes in carbon cycle components with increasing elevation due to direct effects of temperature and precipitation variability (Leuschner et al, 2013). Carbon stock has no (negative) correlation with biodiversity (Shannon, species richness, Simpsons). However, Public Park forests have significantly positive correlation with species evenness. Even though, forests in public parks of Addis Ababa were not pure natural forest rather they are natural vegetation mixed with plantation forests. In contrary infrastructure development activities have an influence on species evenness and diversity.

Forest carbon storage in the mixed-species plantation was mainly affected by species richness (Yilma Getaw, 2016). The continuous altitudinal shift towards species composition causes significant variations (Zhun et al, 2015). Overall species diversity (Shannon and Simpsons) had negative relation to the environmental factor, towards elevation going up or decline and on average the value recorded on species evenness is equivalent between the two altitudinal ranges.

6 Conclusions and Recommendations

6.1 Conclusion

Carbon stock study of forests is crucial to show forest potential and have a capability to store substantial amount of carbon within their biomass and soil carbon pools. This study has shown that forest carbon stock is affected by environmental variable of altitude. And altitude plays a key role in both aboveground and belowground carbon pool of the selected urban public parks. The upper altitude had higher carbon stock potential than lower altitude because of species type, tree diameter also altitudinal change causes better moisture availability which creates favorable environment for vegetation growth. Also due to the distribution of productive stem density within the forests. Therefore altitude has an effect on carbon stock density as the result indicates there is strong correlation between them. The amount of Co_2 sequestered of the study site shows significant potential that parks can contribute for the reduction of GHG's from the atmosphere.

The species composition and structure of the study sites implies normal distribution and on the contrary healthy population. However species evenness and species diversity indicates there is no significant variability due to intensive tree plantation interventions and management activities implemented. Hence this implies the enrichment plantation or any natural regeneration management activities must give emphasis for indigenous species to promote especially on the lower altitude parks.

Therefore development of public parks have high contribution on regulating the climate of a city by sequestration of better amount of Co_2 from the atmosphere mitigation mechanism, may be as sources of employment also economic benefit besides their recreational as well as psychological values. Generally urban green infrastructure development can have also contribution for livability of cities to its citizens.

6.2 Recommendations

- ⇒ The finding of this study on species diversity and composition towards elevation gradient indicates lack of attention on plant species choices based on altitude difference particularly indigenous species plantation.
- ⇒ Urban parks have better potential on GHG's reduction as indicated in the study therefore besides other benefits promoting the Park Forest ecosystem satisfy needs and demands of increasing population in the city.
- ⇒ For the future other studies can focus on forest management techniques improvement in order to improve resources productivity for better contribution of urban park forests.

7 References

Abrha Brhan Gebre, (2018). *Comparison of bulk density methods in determining soil organic carbon storage under different land use types*, Journal of Soil Science and Environmental Management Vol. 9.1, pp. 13-20. doi: 10.5897/JSSEM2017.0664.

Alefu Chinasho, Teshome Soromessa and Eyale Bayable, (2015), *Carbon Stock in Woody Plants of Humbo Forest and its Variation along Altitudinal Gradients:* Southern Ethiopia. International Journal of Environmental Protection and Policy Vol.3, No.4, pp.97-103.doi: 10.11648/j.ijepp.20150304.13.

Aguaron and McPherson, (2012). *Comparison of Methods for Estimating Carbon Dioxide Storage by Sacramento's Urban Forest*, Carbon Sequestration in Urban Ecosystems. Springer Netherlands, Dordrecht, pp. 43–71.

Alem Tsegaye, (2015). *Carbon Stock Estimation on Four selected Urban Public Parks implication for Carbon Emission Reduction in Addis Ababa*, Thesis for Masters of Science, Addis Ababa University, Ethiopia.

Alexander Horst, (2006): *Rehabilitation of urban forests in Addis Ababa*. Journal of the Dry lands 1(2): pp.4, ISSN 1817-3322.

Alvey AA., (2006). *Promoting and preserving biodiversity in the urban forest*. Urban Forestry & Urban Greening, pp.195–201.

Amanuel Ayanaw Abunie and Gemedo Dalle, (2018), *Woody Species Diversity, Structure, and Regeneration Status of Yemrehane Kirstos Church Forest* of Lasta Woreda, North Wollo Zone, Amhara Region, Ethiopia, International Journal of Forestry Research Volume 2018, Article ID 5302523.

Aramde Fetenea and Hailu Worku, (2012). *Planning for the conservation and sustainable use of urban forestry in Addis Ababa, Ethiopia*. Urban Forestry & Urban Greening 12 (2012) 367–379,doi.org/10.1016/j.ufug.2013.03.004.

Asaminew Abiyu, Teshome Soromessa and Satishkumar Belliethathan, (2015). *The Role of Church Forest for Carbon Emission Reduction, Climate Change Mitigation and Urban Greenery*: The Case of Selected Churches in Addis Ababa, Ethiopia. Addis Ababa University.

Bekele Tesemma A., (2007).*Useful trees and shrubs of Ethiopia: Identification, Propagation and Management for 17 Agroclimatic Zones*. Nairobi: RELMA in ICRAF Project, 552p, ISBN 92 9059 212 5.

Barcelete R.C, Eva Mae, F. Palmero and May G. Bhegie, (2016), *Species diversity and above-ground carbon stock assessments in selected mangrove forests of* Malapatan and Glan, Sarangani Province, Philippines, J. Bio. Env. Sci. Vol. 8, p.265-274.

Begon M and T. C. (2006). *Ecology: From Individuals to Ecosystems* 4thed. Victoria, Australia: By Blackwell Publishing Ltd.

Bekele Tona Amenu, (2016). *Review on Woody Plant Species of Ethiopian High Forests*, Journal of Resources Development and Management Vol.27. ISSN 2422-8397.

Belay Tefera, Morgan L. Ruelle, Zemede Asfaw and Berhanu Abraha Tsegay (2014), *Woody plant diversity in an Afromontane agricultural landscape* Debark District, northern Ethiopia, Forests, Trees and Livelihoods, doi: 10.1080/14728028.2014.942709.

Bertrand F. Nero,Nana Afranaa Kwapong,Raymond Jatta and Oluwole Fatumbi, (2018). *Tree Species Diversity and Socio-economic Perspectives of the Urban (Food) Forest of Accra, Ghana*. Sustainability10,doi:10.20944/preprints201807.0042.v1.

Birhanu Kebede and Teshome Soromessa, (2018). *Allometric equations for aboveground biomass estimation of Olea europaea L. subsp. cuspidata in Mana Angetu Forest.* Ecosystem Health and Sustainability 4 p.1-12.10.1080/20964129.2018.1433951.

Bhishma P. Subedi, Shiva S. P., Ajey Pandey and Eak R., (2010), *Forest Carbon Stock Measurement*: *Guidelines for measuring carbon stocks in community-managed forests,* NORAD, ISBN: 978-9937-2-2612-7.

Brown S., (1997). *Estimating biomass and biomass change of tropical forests*: a primer. FAO Forestry Paper 134. Food and Agriculture Organization of the United Nations, Rome, Italy.

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

Chaturvedi R.k. and A. S. Raghubanshi, (2014). *Species Composition, Distribution, and Diversity of Woody Species in a Tropical Dry Forest of India,* Journal of Sustainable Forestry, 33:8,729-756, DOI: 10.1080/10549811.2014.925402.

Cavalcanti, E. A. H, Larrazabal and M. E. L. (2004). Macrozooplancton da zona economica exclusive do Nordeste do Brasil com enfase em Copepoda (Crustacea). Revista Brasileira de Zoologia. 21 (3), p.467-475.

Chave J., Maxime R.M., Alberto B., Emmanuel C., Matthew S C., Welington B. D., Alvaro D., Tron E., Philip M. F., Rosa C. G., Matieu H., Angelina M. Y., Wilson A. M., Helene C M. L., Maurizio M., Bruce W N., Alfred N., Euler M N., Edgar O. M., Raphael P., Pierre P., Casey M R., Juan G S. and Ghislain V., (2014). *Improved allometric models to estimate the above ground biomass of tropical trees.* Global change biology 20, p.3177–3190.

Christoph S., Emanuele M. and Gerbert R., (2013). *Methodology proposal for estimation of carbon storage in urban green areas*, European Environment Agency.

Camilo O., P.N. DUINKER and J. STEENBERG, (2010). *Climate Change Mitigation and Adaptation in Urban Forests:A Framework for Sustainable Urban Forest Managemen*t.18th Commonwealth Forestry Conference. Edinburgh: Dalhousie University.

Dale M. J., (2013). *Evaluation of Methods for Quantifying Carbon Storage of Urban Trees in New Zealand.* Auckland: New Zealand.

Dale V., (1994). *Landscape Characterization and Biodiversity*, Symposium on Measuring Biology Diversity in Tropical and Temperate, p. chapter 4.

David J.Nowak, (2002). *Effects of Urban Tree Management And Species Selection on Atmospheric Carbon Dioxide*. Journal of Arboriculture 28.

Devi R., (2017). *Carbon storage by trees in urban parks: A case study of Jammu*, Jammu and Kashmir, India. International Journal of Advanced Research and Development, P. 250-253.

Edward S., Mesfin Tadesse, Sebsebe Demissew and Inga H., (2000). *Flora of Ethiopia and Eritrea*, Addis Ababa, Ethiopia and Uppsala, Sweden.

Esteban G. and Robert B. Jackson, (2000). *The Vertical Distribution of Soil organic Carbon and its Relation to Climate and Vegetation*, Ecological Society of America 10(2), doi.org/10.1890/1051-0761, pp. 423– 436. *Duke University, North Carolina 27708 USA.*

Ethiopian Biodiversity Institute, (2014). *Ethiopia's Revised National Biodiversity Strategy and Action Plan*, Addis Ababa Ethiopia.

FAO, (2009). *Apa News Asia Pacific Agro forestry Newsletter.* Rome: World Agroforestry Center. Food and Agriculture Organization of the United Nations.

FAO, (2010). *Rehabilitation of urban forests in Addis Ababa*. Journal of the Dry lands, Food and Agriculture Organization of the United Nations. Rome, p.108-112.

FAO, (2015). *Global Forest Resources Assessment of 2015.* Food and Agriculture Organization of the United Nations. Rome, ISBN 978-92-5-108821-0.

FAO, (2016). *Guidelines on urban and peri-urban forestry,* Forestry Paper No. 178, Rome, Italy. Food and Agriculture Organization of the United Nations.

Fetene, A. and Worku, H., 2013. *Planning for the conservation and sustainable use of urban forestry in Addis Ababa, Ethiopia*. Urban Forestry & Urban Greening 12, p. 367–379. https://doi.org/10.1016/j.ufug.2013.03.004

Getachew Tadesse, Tamrat Bekele and Sebsebe Demissew, 2008. *Dryland woody vegetation along an altitudinal gradient on the Eastern Escarpment of Welo Ethiopia, SINET*: *Ethip.J.Sci.* 31(1):43-54, 2008. Faculty of science, Addis Ababa University.

Hailiang Lv., Wang, W., He, X., Xiao, L., Zhou, W. and Zhang B., (2016). *Quantifying Tree and Soil Carbon Stocks in a Temperate Urban Fores*t in Northeast China, Forests, 7, 200, doi.org/10.3390/f7090200.

Hamere Yohannes, Teshome Soromessa, Mekuria Argaw, (2015). *Carbon Stock Analysis Along Altitudinal Gradient in Gedo Forest: Implications for Forest Management and Climate Change Mitigation*. American Journal of Environmental Protection, pp. 237-244. doi: 10.11648.

Henry,A.Besnard, W.A.Asante, J.Eshun, S.Adu-Bredu, R.Valentini,M.Bernoux and L.Saint-Andre, (2010). *Wood density, phytomass variations within and among trees, and allometric equations in a tropical rainforest of Africa,* Journal of Forest Ecology and Management 260, P.1375–1388, doi:10.1016/j.foreco.2010.07.040.

IPCC, (2001). *IPCC Third Assessment Report of the Intergovernmental Panel on Climate Change* . Cambridge, United Kingdom: Cambridge University Press.

IPCC, (2003). *Good Practice Guidance for Land Use Change and IPCC National Green house Gas Inventories Program.* Japan: Global Environmental Stratefies.

IPCC, (2006). *Volume 4: Agriculture, Forestry and Other Land Use*, IPCC Guidelines for National Greenhouse Gas Inventories.

IPCC, (2007). *The Physical Science Basis. Contribution of working Group I to the Fourth* Assessment Report of the Intergovernmental.

Kang Min Ngo and Shawn Lum, (2017). *Aboveground biomass estimation of tropical street trees*, *Journal of Urban Ecology*, p.1–6. Doi: 10.1093/jue/jux020 Natural Science and Science Education, National Institute of Education, 1 Nanyang Walk, Singapore 637616 Singapore.

Kent and Coker, (1992). *Vegetation Description and Analysis: A Practical Approach*. Journal of Environmental Science, Geography, DOI:10.2307/3451427.

Kidanemariam Kassahun, Teshome Soromessa and Satishkumar Belliethathan, (2015). *Forest Carbon Stock in Woody Plants of Ades Forest, Western Hararghe Zone of Ethiopia and its Variation along Environmental Factors: Implication for Climate Change Mitigation*, Journal of Natural Sciences Research Vol.5, No.21, ISSN 2224-3186.

Kuchelmeister G, (1997). *Urban trees in arid landscapes: multipurpose urban forestry for local needs in developing countries*. Arid Lands Newsletter No. 42, University of Arizona, USA.

Leena Finer, Mizue Ohashi, Kyotaro Noguchi and Yasuhiro Hirano, (2010). *Factors causing variation in fine root biomass in forest ecosystems*, Journal of Forest Ecology and Management 261 (2011) 265–277, doi:10.1016/j.foreco.2010.10.016.

Leuschner et.al, (2013), *The Carbon Balance of Tropical Mountain Forests along an Altitudinal Transect.* Plant Ecology, Albrecht von Haller Institute of Plant Sciences, University of Gottingen, Untere Karspule 2, 37073 Gottingen, Germany.

MacDicken, K. (1997). *A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects.* Arlington, USA: Winrock International.

Markos Kuma, (2016). *Diversity of Woody Plant Species of Gamuwa and Oda Forest*s of Humbo Carbon Project, Wolaita, Ethiopia.

Marshet Tefera and Teshome Soromessa, (2013). *Carbon Stock Potentials of Woody Plant Species in Biheretsige and Central Closed Public Parks of Addis Ababa and Its Contribution to Climate Change Mitigation*, Journal of Environment and Earth Science Vol.5, No.13, 2015, ISSN 2224-3216.

Maru Abebaw Berhanu, (2008). *Current Status and Management Practices of Urban Green Areas in Addis Ababa*, Debre Markos, Ethiopia.

MEFCC, (2015). *National Forest Sector Development Program Vol.2,.* Ethiopia: UNDP/MEFCC Ethiopia.

Meragiaw M, Woldu Z, Martinsen V and Singh BR, (2018). *Woody species composition and diversity of riparian vegetation along the Walga River, Southwestern Ethiopia*. PLoS ONE 13(10): e0204733. doi.org/10.1371/journal.

Mesele Negash and Mike S., (2015). *Biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment, Ethiopia.* International Journal Plant-Soil Relationships, doi/ 10.1007/s11104-015-2469-6.

M. L. Parry, G. M., (1998). *IPCC Agriculture and forestry Chapter 2.* United Kingdom: UNFCCC.

Mohammed Mussa, Abule Ebro and Lissahanwork Nigatu, (2017). *Soil organic carbon and total nitrogen stock response to traditional enclosure management in eastern Ethiopia*, Journal of Soil Science and Environmental Management, Vol. 8(2), pp. 37-43. DOI: 10.5897/JSSEM2015.0545.

Moser, Gerald, Hertel, Dietrich and Leuschner, Christoph, (2007). *Altitudinal Change in LAI and Stand Leaf Biomass in Tropical Montane Forests*: a Transect Study in Ecuador and a Pan-Tropical Meta-Analysis. Ecosystems. 10. P.924-935. Doi 10.1007/s10021-007-9063-6.

Mulugeta Zewdie, Mats Olsson and Theo Verwijst, (2008). *Above-ground biomass production and allometric relations of Eucalyptus globulus Labill. Coppice plantations along a chrono-sequence in the central highlands* of Ethiopia, Elsevier Biomass and bioenergy p. 4 2 1 – 4 2 8. doi:10.1016/j.biombioe.2008.08.007.

Munishi and P. M, (2008). *The Role of Urban Forestry in Mitigating Climate Change and Performing Environmental Services in Tanzania.* Tanzania Journal of Forestry and Nature Conservation, Volume 77.

Murphy, P.G., and Lugo, A.E., (1986). *Ecology of tropical dry forest*. Annual Review of Ecology and Systematics 17: 67-88.

Mwakisunga, B. and Majule, A. E. (2012). *The influence of altitude and management on carbon stock quantities in rungwe forest*, southern highland of Tanzania. *Open Journal of Ecology*. 2(4):pp. 214- 221.

Ngo, K.M., Lum, S., (2018). *Aboveground biomass estimation of Tropical Street trees,* Journal of Urban Ecology 4, pp1-6. Doi/ 10.1093/jue/jux020.

Prachi Ugle, Sankara Rao and T.V. Ramachandra, (2010). *Carbon Sequestration Potential of Urban Trees.* Lake 2010: Wetlands, Biodiversity and Climate Change. Centre for Ecological Sciences, IISc, Bangalore, India.

Pearson T., S. Walker and S. Brown, (2005). *Source book for Land Use, Land-Use Change and Forestry Projects*, BIO carbon fund & Win Rock international, 79548.

Pearson, Timothy R.H., Brown, Sandra L., Birdsey and Richard A., (2007), *Measurement Guidelines for the Sequestration of Forest Carbon*, USDA Forest Service, Northern Research Station General Technical Report NRS-18, USA.

Qisheng He and E. C., (2013). *Above-Ground Biomass and Biomass Components Estimation Using LiDAR Data in a Coniferous Forest* . Forests 2013, 4, 984-1002; doi/10.3390/f4040

Rachel Baker and G. G., (2016). *Urban Forest Managment plan.* United States of America: National Arbor Day Foundation.

Rajni Devi, (2017). *Carbon storage by trees in urban parks: A case study of Jammu*, Jammu and Kashmir, India, International Journal of Advanced Research and Development, Volume 2; Issue 4.

R. K. Chaturvedi and A. S., (2012). *Biomass Estimation of Dry Tropical Woody Species at Juvenile Stage.* Published Scientific World Journal. V.2012: 790219.

Richard Thompson and N. P., (1994). *The Elements of sustainable urban Forestry.* California: Urban Forest Ecosystems Institute California Polytechnic State University San Luis Obispo.

Shaheen, H., Saeed, Y., Abbasi and M.K, (2015). Soil carbon stocks along an altitudinal gradient in different land-use categories in Lesser Himalayan foothills of Kashmir. *Eurasian Soil Sc.*50, p.432–437. doi.org/10.1134/S106422931704010x.

Tamene Yohannes, (2016). *Plant Diversity and Carbon Stock Analysis along Environmental Gradients: the case of Gergeda and Anbessa Forests in Western Ethiopia*, Degree of Doctor of Philosophy in Environmental Sciences, Addis Ababa University, Ethiopia.

Tariq Habib, Zahid Hussain Malik, Muhammad Altaf Hussain and Muhammad Qayyum Khan, (2011). *Plant species diversity along the altitudinal gradient at Garhi Dopatta Hills*, Muzaffarabad, Journal of Medicinal Plants Research Vol. 5(20).

Tefera J., E. Minyishaw, F. Kebenu, A. Nurhusen and M. Gufran Khan, (2015), *Woody Species Diversity, Management and Contribution of Local Community in Protected*

*Forest of Kuneba Distric*t, Afar Region Ethiopia. Journal of Environmental Science and Technology 8 (4), 2015 ISSN 1994-7887 / doi: 10.3923/jest.2015.

Tekle W., Yeshitela K. and Lindley S., (2017). *Ecosystem services assessment of the urban forests of Addis Ababa, Ethiopia*. *Urban Ecosyst* 20, p.683–699, doi.org/10.1007/s11252-016-0624-3.

Tesfay Atsbha, Anteneh Belayneh Desta and Tessema Zewdu, (2018). *Woody species diversity, population structure, and regeneration status in the Gra-Kahsu natural vegetation,* southern Tigray. Heliyon5, doi: 10.1016/j.heliyon.2019.e01120.

Tesfaye M.A., Oliver Gardi, Tesfaye Bekele and Jurgen Blaser, (2019).*Temporal variation of ecosystem carbon pools along altitudinal gradient and slope:* the case of Chilimo dry afromontane natural forest, Central Highlands of Ethiopia.

Tulu Tolla, (2011). *Estimation of Carbon Stock in Church Forests: Implications for Managing Church Forest for Carbon Emission Reduction.* Thesis Masters of Science, Addis Ababa University, Ethiopia.

Ullah, M.R. ,Al-Amin and M., (2012). *Above- and below-ground carbon stock estimation in a natural forest of Bangladesh*. Journal of Forest Science, *58*, pp. 372–379. doi.org/10.17221/103/2011-JFS.

UNFCCC. (2007). *Climate change, Impact, Vulnerabilities and Adaptation in Developing Countries.* UNFCCC Secretariat.

UNEP, (2003). *Global Environmental Outlook 3 (GEO-3): Past, Present and Future Perspectives.* ISSN: 1366-8080, p.446.

Walkley A. and Black I. A. (1934). *An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method*. Soil Sci. 37:29-38.

Walter K., Axel Don, Barbel Tiemeyer and Annette Freibauer, (2016). *Determining Soil Bulk Density for Carbon Stock Calculations: A Systematic Method Comparison*, Soil Science Society of America Journal. doi:10.2136/sssaj2015.11.0407.

Wang Zhe and C. X. (2013). *Characteristics of carbon storage in Shanghai's urban forest.* Chinese Scientific bulletin Ecology Vol.58 No.10.

WGCFNR, (2017). *A Basic Information Report on Plant Diversity, Management Status and Coverage of Green Infrastructure of Addis Ababa City*, Wondo Genet, Ethiopia.

Yehualashet Belete, (2016). *Species Specific Allometric Model For Biomass Estimation of Four Selected Indigenous Trees in Egdu Forest*, Welmera District, Oromia Region Ethiopia. Thesis of Master of Science in Environmental Science, Addis Ababa University. Ethiopia.

Yilma, G., (2016). *Carbon stock potential and woody species diversity patterns* in Addis Ababa church forests along age gradient, Ethiopia: Addis Ababa University.

YinRen,JingYan,XiaohuaWei,YajunWang,YushengYang,LizhongHua,YongzhuXiong,XiangNiu and XiaodongSong, (2012). *Effects of rapid urban sprawl on urban forest carbon stocks: Integrating remotely sensed, GIS and forest inventory data*. Journal of Environmental Management, doi.org/10.1016/j.jenvman.2012.09.011.

Yitebitu Moges and Z. E. (2010). *Ethiopian Forest Resources: Current Status and Future Management Options In View Of Access to Carbon Finances*. Addis Ababa: Review Prepared For the Ethiopian Climate Research and Networking and The United Nations Development Program (UNDP).

Zerihun Woldu, (1985). *Variation in Grassland Vegetation on the Central Plateau of Shewa, Ethiopia, in relation to edaphic factors and grazing conditions*, Doctoral thesis. Uppsala University Dissertations Botanical, 84, J. Cramer, Vaduz.

Zhun Mao, Yan Wang, Christophe Jourdan, Lauric Cecillon, Jerome Nespoulous, Herve Rey, Laurent Saint-Andre and Alexia Stokes, (2015). *Characterizing above- and belowground carbon partitioning in forest trees along an altitudinal gradient using area-based indicators.* Arctic, Antarctic and Alpine Research, p.59-69. University of Colorado. doi.org/10.1657/AAAR0014-014.

Appendices

Appendix 1: Summary of above and belowground biomass carbon of seven parks

Study Site	Plot No.	Number of trees	Mean DBH (cm)	Mean Ht (m)	AGB (ton)	AGC (ton ha-1)	AG CO2 (ton ha-1)	BGB (ton)	BGC (ton ha-1)	BGCO2 (ton ha-1)
Akaki	Ak1	28	13	8	2.36	19.18	70.32	0.47	3.84	14.06
	Ak2	30	14	8	3.11	25.21	92.43	0.62	5.04	18.49
	Ak3	30	25	17	22.45	182.25	668.32	4.49	36.45	133.66
	Ak4	31	17	11	5.41	43.95	161.17	1.08	8.79	32.23
	Ak5	41	17	11	11.20	90.93	333.45	2.24	18.19	66.69
	Ak6	35	15	10	6.38	51.77	189.85	1.28	10.35	37.97
	Ak7	22	18	9	3.71	30.15	110.55	0.74	6.03	22.11
	Ak8	19	33	13	27.81	225.71	827.67	5.56	45.14	165.53
	Ak9	31	27	10	27.61	224.08	821.71	5.52	44.82	164.34
	Ak10	24	18	8	6.07	49.26	180.62	1.21	9.85	36.12
Beh/tsige	Bt1	45	24	14	21.26	172.58	632.84	4.25	34.52	126.57
	Bt2	30	19	12	8.62	69.96	256.53	1.72	13.99	51.31
	Bt3	34	23	16	16.62	134.87	494.55	3.32	26.97	98.91
	Bt4	40	17	7	9.95	80.74	296.07	1.99	16.15	59.21
	Bt5	28	26	15	14.65	118.95	436.19	2.93	23.79	87.24
	Bt6	32	19	13	9.24	75.03	275.15	1.85	15.01	55.03
	Bt7	25	19	11	10.30	83.57	306.46	2.06	16.71	61.29
	Bt8	38	22	13	31.23	253.52	929.66	6.25	50.70	185.93
	Bt9	35	19	13	17.42	141.41	518.54	3.48	28.28	103.71
	Bt10	34	19	10	13.77	111.73	409.72	2.75	22.35	81.94
	Bt11	40	20	11	12.84	104.19	382.05	2.57	20.84	76.41
	Bt12	39	24	10	19.46	157.92	579.10	3.89	31.58	115.82
	Bt13	41	16	9	10.46	84.91	311.37	2.09	16.98	62.27
	Bt14	30	22	14	17.29	140.35	514.67	3.46	28.07	102.93
	Bt15	33	18	9	8.45	68.56	251.40	1.69	13.71	50.28
	Bt16	37	22	13	20.60	167.18	613.05	4.12	33.44	122.61
Central	Cr1	25	26	12	19.38	157.32	576.91	3.88	31.46	115.38
	Cr2	23	28	12	20.02	162.53	595.99	4.00	32.51	119.20
	Cr3	27	21	11	8.84	71.76	263.13	1.77	14.35	52.63
	Cr4	35	24	11	12.54	101.82	373.38	2.51	20.36	74.68
	Cr5	38	17	10	8.03	65.14	238.88	1.61	13.03	47.78
	Cr6	33	24	10	18.00	146.06	535.62	3.60	29.21	107.12
	Cr7	29	19	9	8.84	71.73	263.03	1.77	14.35	52.61
	Cr8	37	17	11	9.21	74.74	274.07	1.84	14.95	54.81
	Cr9	27	20	11	11.21	90.96	333.54	2.24	18.19	66.71
Ethio-	Ek1	25	25	12	13.71	111.29	408.09	2.74	22.26	81.62

Korea	Ek2	27	19	8	5.72	46.40	170.14	1.14	9.28	34.03
	Ek3	29	15	9	4.04	32.75	120.10	0.81	6.55	24.02
	Ek4	24	21	11	12.22	99.16	363.61	2.44	19.83	72.72
	Ek5	27	20	10	17.78	144.28	529.07	3.56	28.86	105.81
Ferency	Fr1	30	22	12	25.23	204.79	750.96	5.05	40.96	150.19
	Fr2	32	26	14	34.40	279.24	1,023.99	6.88	55.85	204.80
	Fr3	24	24	13	33.40	271.08	994.05	6.68	54.22	198.81
	Fr4	19	29	17	28.17	228.64	838.41	5.63	45.73	167.68
	Fr5	29	20	11	17.18	139.43	511.30	3.44	27.89	102.26
	Fr6	27	24	11	19.69	159.84	586.12	3.94	31.97	117.22
	Fr7	24	22	12	16.31	132.42	485.58	3.26	26.48	97.12
	Fr8	30	22	10	39.69	322.16	1,181.37	7.94	64.43	236.27
	Fr9	27	20	11	7.38	59.89	219.63	1.48	11.98	43.93
Hamle	Ha1	24	13	5	3.89	31.61	115.91	0.78	6.32	23.18
	Ha2	25	17	8	12.58	102.12	374.47	2.52	20.42	74.89
	Ha3	39	25	14	30.71	249.27	914.07	6.14	49.85	182.81
	Ha4	26	17	8	6.65	53.99	197.99	1.33	10.80	39.60
	Ha5	30	19	8	15.28	124.06	454.94	3.06	24.81	90.99
	Ha6	33	15	7	8.93	72.44	265.65	1.79	14.49	53.13
	Ha7	25	17	8	4.15	33.67	123.47	0.83	6.73	24.69
	Ha8	30	21	8	9.15	74.28	272.39	1.83	14.86	54.48
	Ha9	30	19	10	13.97	113.40	415.83	2.79	22.68	83.17
	Ha10	38	15	6	13.72	111.33	408.26	2.74	22.27	81.65
Shegir	Sh1	23	26	13	27.38	222.26	815.02	5.48	44.45	163.00
	Sh2	27	19	11	10.92	88.64	325.05	2.18	17.73	65.01
	Sh3	35	16	7	5.16	41.87	153.52	1.03	8.37	30.70
	Sh4	25	17	9	8.99	72.98	267.63	1.80	14.60	53.53
	Sh5	32	22	12	31.58	256.31	939.90	6.32	51.26	187.98
	Sh6	39	20	11	15.95	129.50	474.86	3.19	25.90	94.97
	Sh7	38	17	8	7.20	58.44	214.31	1.44	11.69	42.86
	Sh8	21	32	14	29.82	242.07	887.69	5.96	48.41	177.54
	Sh9	26	28	14	42.59	345.70	1,267.67	8.52	69.14	253.53
	Sh10	21	31	14	49.31	400.26	1,467.76	9.86	80.05	293.55
	Sh11	36	15	8	4.55	36.91	135.36	0.91	7.38	27.07
Total Sum						8,942.51	32,792.18		1,788.50	6,558.44
Mean						125.33	468.46		25.07	93.69
SD						83.36	305.68		16.67	61.14

Appendix 2: Soil samples analysis summary data

Strata	Name of Park	Plot code	Field Code	% of C amount	Bulk density (g/cm^3)per plot	SOC stock ton ha-1	CO2 equiv. ton ha-1
Lower	Akaki	Ak1	Ak1-0-20	3.25	0.895	113.036	413.66
			Ak1-21-40	2.93	0.765		
Lower	Akaki	Ak3	Ak4-0-21	3.36	1.010	127.361	467.03
			Ak4-21-40	2.6	0.792		
Lower	Akaki	Ak4	Ak3-0-20	2.3	0.927	56.493	207.16
			Ak3-21-40	1.3	1.120		
Lower	Akaki	Ak6	Ak6-0-20	2.01	1.05	79.859	292.84
			Ak6-21-40	0.95	1.254		
Lower	Beheretsige	Bt1	Bt1-0-20	2.74	0.889	94.47	346.43
			Bt1-21-40	1.3	0.818		
Lower	Beheretsige	Bt3	Bt3-0-20	2.86	1.019	114.231	414.81
			Bt3-21-40	1.63	1.064		
Lower	Beheretsige	Bt5	Bt5-0-20	3.12	1.039	132.218	461.02
			Bt5-21-40	3.25	0.985		
Lower	Beheretsige	Bt8	Bt8-0-20	1.89	1.132	68.539	251.34
			Bt8-21-40	1.3	1.283		
Lower	Beheretsige	Bt10	Bt10-0-20	6.5	0.986	168.551	581.08
			Bt10-21-40	4.23	0.762		
Lower	Central	Cr1	Cr1-0-20	1.98	0.991	73.717	248.15
			Cr1-21-40	1.63	0.904		
Lower	Central	Cr3	Cr3-0-20	1.95	0.963	111.026	401.60
			Cr3-21-40	1.3	0.799		
Lower	Central	Cr5	Cr5-0-20	2.04	0.989	114.445	415.22
			Cr5-21-40	1.56	0.918		
Upper	Ethio-Korea	Ek2	Ek2-0-20	4.23	0.881	144.659	530.46
			Ek2-21-40	1.95	1.052		
Upper	Ethio-Korea	Ek4	Ek4-0-20	2.1	1.093	39.930	101.11
			Ek4-21-40	1.86	1.359		
Upper	Ferencay	Fr1	Fr1-0-20	5.2	1.219	276.679	901.87
			Fr1-21-40	5.85	1.118		

Upper	Ferencay	Fr2	Fr2-0-20	2.28	1.453	125.842	471.19
			Fr2-21-40	1.95	1.202		
Upper	Ferencay	Fr4	Fr4-0-20	2.05	1.120	84.362	310.63
			Fr4-21-40	1.95	0.857		
Upper	Ferencay	Fr6	Fr6-0-20	3.9	1.198	181.243	664.62
			Fr6-21-40	2.6	1.290		
Upper	Hamle 19	Ha1	Ha1-0-20	5.85	1.001	303.801	1,045.55
			Ha1-21-40	6.37	1.368		
Upper	Hamle 19	Ha3	Ha3-0-20	1.95	1.309	118.192	437.11
			Ha3-21-40	2.6	1.182		
Upper	Hamle 19	Ha8	Ha8-0-20	3.9	1.103	166.850	611.84
			Ha8-21-40	3.25	1.158		
Upper	Shegir	Sh1	Sh1-0-20	1.85	1.267	86.981	473.93
			Sh1-21-40	1.3	1.117		
Upper	Shegir	Sh3	Sh3-0-20	1.89	1.141	76.578	295.42
			Sh3-21-40	1.82	1.334		
Upper	Shegir	Sh5	Sh5-0-20	2.08	1.238	97.517	357.59
			Sh5-21-40	1.3	0.978		

Appendix 3: Species Composition and Structure summary data

No	Species Name	Abundance	Freq.	BA	Density	Rela. Freq.	Rela. Density	Rela. Dominance	IVI
1	*Acacia abyssinica*	59	37.14	1.331	13.68	3.51	2.78	4.97	11.26
2	*Acacia decurence*	19	14.29	0.174	4.41	1.35	0.89	0.65	2.90
3	*Acacia mearnsii*	20	14.29	0.222	4.64	1.35	0.94	0.83	3.12
4	*Acacia melanoxylon*	126	60.00	0.855	29.22	5.68	5.93	3.20	14.81
5	*Acacia saligna*	24	10.00	0.132	5.57	0.95	1.13	0.49	2.57
6	*Acacia seyal*	37	21.43	0.455	8.58	2.03	1.74	1.70	5.47
7	*Allophylus abyssinicus*	37	17.14	0.404	8.58	1.62	1.74	1.51	4.87
8	*Araucaria biramulata*	12	8.57	0.120	2.78	0.81	0.57	0.45	1.82
9	*Bersama abyssinica*	3	4.29	0.048	0.70	0.41	0.14	0.18	0.73
10	*Borassus*	7	5.71	0.318	1.62	0.54	0.33	1.19	2.06

	aethiopum								
11	*Callistemon citrinus*	96	60.00	0.279	22.26	5.68	4.52	1.04	11.24
12	*Calpurnia aurea*	14	7.14	0.034	3.25	0.68	0.66	0.13	1.46
13	*Carissa spinarum*	39	21.43	0.058	9.04	2.03	1.84	0.22	4.08
14	*cassuarina angustifolia*	116	60.00	0.999	26.90	5.68	5.46	3.73	14.87
15	*Ceiba pentandra*	8	4.29	0.480	1.86	0.41	0.38	1.79	2.58
16	*Cordia africana*	20	11.43	0.236	4.64	1.08	0.94	0.88	2.91
17	*Croton macrostaches*	90	52.86	0.818	20.87	5.00	4.24	3.06	12.30
18	*Cupressus lustanica*	418	94.29	2.356	96.94	8.92	19.69	8.80	37.41
19	*Dovyalis abyssinica*	19	7.14	0.046	4.41	0.68	0.89	0.17	1.74
20	*Dracaena steudneri*	29	18.57	0.120	6.73	1.76	1.37	0.45	3.57
21	*Ekebergia capensis*	3	2.86	0.045	0.70	0.27	0.14	0.17	0.58
22	*Entada abyssinica*	2	2.86	0.002	0.46	0.27	0.09	0.01	0.37
23	*Erythrina brucei*	4	2.86	0.011	0.93	0.27	0.19	0.04	0.50
24	*Eucalyptus camaldunesis*	88	34.29	2.432	20.41	3.24	4.15	9.09	16.47
25	*Eucalyptus Citrodora*	6	2.86	0.127	1.39	0.27	0.28	0.48	1.03
26	*Eucalyptus globulus*	17	7.14	0.762	3.94	0.68	0.80	2.85	4.32
27	*Euphorbia abyssinica*	8	7.14	0.086	1.86	0.68	0.38	0.32	1.37
28	*Ficus sure*	11	8.57	1.338	2.55	0.81	0.52	5.00	6.33
30	*Grevillea robusta*	187	52.86	2.125	43.37	5.00	8.81	7.94	21.75
31	*Hibiscus rosa-sinensis*	15	14.29	0.016	3.48	1.35	0.71	0.06	2.12
32	*Hygenia abyssinica*	23	18.57	0.180	5.33	1.76	1.08	0.67	3.51
33	*Jacaranda mimosifolia*	65	38.57	0.428	15.07	3.65	3.06	1.60	8.31
34	*Juniperus procera*	75	38.57	4.609	17.39	3.65	3.53	17.22	24.40
35	*Leucaena leucocephala*	2	1.43	0.003	0.46	0.14	0.09	0.01	0.24
36	*Maesa lanceolata*	13	8.57	0.166	3.01	0.81	0.61	0.62	2.04
37	*Milletia fergunia*	44	27.14	0.166	10.20	2.57	2.07	0.62	5.26
38	*Olea europiana*	95	50.00	1.531	22.03	4.73	4.47	5.72	14.93
39	*Olinia rochetiana*	4	5.71	0.007	0.93	0.54	0.19	0.02	0.75

40	*Persiea americana*	3	4.29	0.012	0.70	0.41	0.14	0.05	0.59
41	*Phoenix reclinata*	31	25.71	0.416	7.19	2.43	1.46	1.55	5.45
42	*Pinus patula*	55	41.43	0.464	12.76	3.92	2.59	1.73	8.24
43	*Pinus radiata*	12	2.86	0.196	2.78	0.27	0.57	0.73	1.57
44	*Pittosporum viridiflorum*	3	1.43	0.006	0.70	0.14	0.14	0.02	0.30
45	*Podocarpus falcatus*	24	20.00	1.123	5.57	1.89	1.13	4.20	7.22
46	*Prunus africana*	23	20.00	0.297	5.33	1.89	1.08	1.11	4.09
47	*Psidium guajava*	5	2.86	0.014	1.16	0.27	0.24	0.05	0.56
48	*Ricinus communis*	3	2.86	0.008	0.70	0.27	0.14	0.03	0.44
49	*Sesbania sesban*	1	1.43	0.002	0.23	0.14	0.05	0.01	0.19
50	*Shinus molle*	33	25.71	0.124	7.65	2.43	1.55	0.47	4.45
51	*Spathodia campanulata*	34	21.43	0.498	7.88	2.03	1.60	1.86	5.49
52	*Vernonia amygdalina*	41	32.86	0.093	9.51	3.11	1.93	0.35	5.39

Appendix 4: Species scientific name, Family Name and abundance

Scientific Species Name	Family Name	Number of trees	Tree/Shrub	Origin
Acacia abyssinica	*Fabaceae*	59	Tree	indigenous
Acacia decurence	*Fabaceae*	19	Tree	Exotic
Acacia mearnsii	*Fabaceae*	20	Tree	Exotic
Acacia melanoxylon	*Fabaceae*	126	Tree	Exotic
Acacia saligna	*Fabaceae*	24	Tree	Exotic
Acacia seyal	*Fabaceae*	37	Tree	indigenous
Calpurnia aurea	*Fabaceae*	14	Shrub	indigenous
Entada abyssinica	*Fabaceae*	2	Shrub	Exotic
Erythrina brucei	*Fabaceae*	4	Tree	indigenous
Leucaena leucocephala	*Fabaceae*	2	Shrub	Exotic
Milletia fergunia	*Fabaceae*	44	Tree	indigenous
Sesbania sesban	*Fabaceae*	1	Shrub	Exotic
Croton macrostaches	*Euphorbiaceae*	90	Tree	indigenous

Euphorbia abyssinica	*Euphorbiaceae*	8	Tree	indigenous
Ricinus communis	*Euphorbiaceae*	3	Shrub	indigenous
Dovyalis abyssinica	*Flacourtiaceae*	19	Shrub	indigenous
Persiea americana	*Lauraceae*	3	Tree	Exotic
Hibiscus rosa-sinensis	*Malyaceae*	15	Shrub	Exotic
Ekebergia capensis	*Meliaceae*	3	Tree	indigenous
Bersama abyssinica	*Melianthaceae*	3	Tree	indigenous
Ficus sure	*Moraceae*	11	Tree	indigenous
Maesa lanceolata	*Myrsinaceae*	13	Tree	indigenous
Callistemon citrinus	*Myrtaceae*	96	Shrub	Exotic
Eucalyptus camaldunesis	*Myrtaceae*	88	Tree	Exotic
Eucalyptus Citrodora	*Myrtaceae*	6	Tree	Exotic
Eucalyptus globulus	*Myrtaceae*	17	Tree	Exotic
Psidium guajava	*Myrtaceae*	5	Tree	Exotic
Olea europiana	*Oleaceae*	95	Tree	indigenous
Olinia rochetiana	*Oleaceae*	4	Shrub	indigenous
Pinus patula	*Pinaceae*	55	Tree	Exotic
Pinus radiate	*Pinaceae*	12	Tree	Exotic
Pittosporum viridiflorum	*Pittosporaceae*	3	Tree	indigenous
Podocarpus falcatus	*Podocarpaceae*	24	Tree	indigenous
Grevillea robusta	*Proteaceae*	187	Tree	Exotic
Hygenia abyssinica	*Rosaceae*	23	Tree	indigenous
Prunus Africana	*Rosaceae*	23	Tree	indigenous
Allophylus abyssinicus	*Sapindaceae*	37	Tree	indigenous
Shinus molle	*Anacardiaceae*	33	Tree	Exotic
Carissa spinarum	*Apocynaceae*	39	Shrub	indigenous
Araucaria biramulata	*Araucariaceae*	12	Tree	Exotic
Borassus aethiopum	*Arecaceae*	7	Shrub	indigenous
Phoenix reclinata	*Arecaceae*	31	Shrub	Exotic
Vernonia amygdalina	*Asteraceae*	41	Shrub	indigenous
Jacaranda mimosifolia	*Bignoniaceae*	65	Tree	Exotic
Spathodia campanulata	*Bignoniaceae*	34	Tree	Exotic

Ceiba pentandra	*Bombacaceae*	8	Tree	Exotic
Cordia Africana	*Boraginaceae*	20	Tree	indigenous
Cassuarina angustifolia	*Casuarinaceae*	116	Tree	Exotic
Cupressus lustanica	*Cupressaceae*	452	Tree	Exotic
Juniperus procera	*Cupressaceae*	75	Tree	indigenous
Dracaena steudneri	*Dracaenaceae*	29	Tree	indigenous

Appendix 5: Sample plot code and Coordinates

No.	Plot Code	X coordinate	Y Coordinate	No.	Plot Code	X coordinate	Y Coordinate
1	Ak01	476777	981487	36	Ek01	472962	999960
2	Ak02	476808	981565	37	Ek02	472904	999892
3	Ak03	476586	981442	38	Ek03	472794	999875
4	Ak04	476685	981493	39	Ek04	472704	999905
5	Ak05	476592	981388	40	Ek05	472672	999946
6	Ak06	476724	981439	41	Ek06	472766	999926
7	Ak07	476649	981329	42	Fr01	475364	1000136
8	Ak08	476751	981559	43	Fr02	475217	1000259
9	Ak09	476568	981340	44	Fr03	475187	1000167
10	Ak10	476827	981495	45	Fr04	475150	1000251
11	Bt01	472796	989893	46	Fr05	475386	1000077
12	Bt02	472966	989782	47	Fr06	475343	1000211
13	Bt03	473077	990051	48	Fr07	475294	1000259
14	Bt04	472915	990134	49	Fr08	475265	1000159
15	Bt05	472840	989637	50	Ha01	474344	1001364

16	Bt06	472886	990047	51	Ha02	474455	1001414
17	Bt07	472812	990000	52	Ha03	474429	1001347
18	Bt08	472803	989710	53	Ha04	474392	1001503
19	Bt09	472755	989810	54	Ha05	474373	1001648
20	Bt10	472899	989766	55	Ha06	474296	1001530
21	Bt11	472948	989628	56	Ha07	474353	1001550
22	Bt12	472882	989823	57	Ha08	474315	1001629
23	Bt13	472838	989930	58	Ha09	474317	1001702
24	Bt14	472852	989723	59	Ha10	474435	1001552
25	Bt15	472902	989690	60	Sh01	471290	1001197
26	Bt16	472909	989970	61	Sh02	471393	1001206
27	Cr01	475427	995036	62	Sh03	471283	1001028
28	Cr02	475484	995174	63	Sh04	471341	1001094
29	Cr03	475464	994935	64	Sh05	471362	1001034
30	Cr04	475374	994926	65	Sh06	471387	1001129
31	Cr05	475498	995084	66	Sh07	471220	1001074
32	Cr06	475346	995064	67	Sh08	471336	1001256
33	Cr07	475437	995107	68	Sh09	471312	1001141
34	Cr08	475357	995189	69	Sh10	471277	1001090
35	Cr09	475394	995136	70	Sh11	471225	1001125

Biographical Sketch

Zerihun Lakew Gebremariam was born in August 1985 Harar, Ethiopia. He completed his elementary, secondary and preparatory school education at Harar in July 2005. He attended a B.Sc. degree in Farm Forestry at Hawassa University, Wondo Genet College of Forestry and Natural Resources from October, 2005 - July, 2008. After graduation, he has been working in many jobs and currently he was employed as Senior Forest expert at Ethiopian Environment Forest and Climate Change commission since March 2015. In September 2018, he has joined again Hawassa University, Wondo Genet College of Forestry and Natural Resources to study Master's degree in Forest Resource Assessment and Monitoring.