Jimma University
College of Natural Sciences
School of Graduate Studies
Department of Biology

Live Carbon Storage and Woody Species Diversity in Urban Forest Patches of Masha and Teppi towns, Sheka Zone, Southwest Ethiopia

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A thesis Submitted to the Department of Biology, College Of Natural Sciences, Jimma University, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Botanical sciences

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LIST OF ACRONYM

ACCRA: African Climate Change Resilience Alliance

AGLB: Aboveground Live Biomass

AGLC: Aboveground Live Carbon

BA: Basal Area

BGLB: Belowground Live Biomass

BGLC: Belowground Live Carbon

M.A.S.L: Meter above Sea Level

C: Carbon

CCS: Carbon Capture Storage

CDIAC: Carbon Dioxide Information Analysis Center

CDM: Clean Development Mechanism

DBH diameter at breast height

EEA: European Environmental Agency

GHG: Green House Gas

IEA: International Energy Agency

M t: Metric ton

SDG: Sustainable Development Goal

t C/ha: Ton of Carbon per hectare

t C/yr: Ton of Carbon per year

Ppg: Part per gram

Ppm: Part per million

WMO: World Meteorological Organization

UNFCCC: United Nation Framework Convention on Climate Change

TLC: Total Live Carbon

IVI: Importance Value Index

AGC: Aboveground Carbon

BGC: Belowground Carbon

Gt: giga ton

Spp - Species

Acknowledgment

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Abstract

Climate change is the current pressing issue across the globe. Green plants are the cheapest choice among the options used to mitigate the impact of climate change. Therefore, this study was conducted to assess the woody species diversity and carbon storage and sequestration potential of the three urban forest patches of Masha and Teppi towns , Sheka Zone, Southwest Ethiopia urban forest patches of Masha and Teppi towns were stratified into three patches namely government institution, churches and indigenous sacred sites. Totally 39 sample plots were randomly placed i.e. thirteen sample plots of size = 20 m × 40 from each Urban forest were laid patches =). All woody species with DBH ≥5cm and H ≥2m were recorded from the plots. 49 woody species belonging to 43 genera and 27 families were identified and recorded. Totally 210.57/ha density of woody species across the three Urban forest patches were recorded. Furthermore 14.37 ± 11.01 mean above and 3.14 ± 1.92 mean belowground carbon storage were estimated. Indigenous sacred forest showed the highest live carbon storage (32.1 t/ha) followed by government institutions (12.981t/ha) and church forest (7.42 t/ha). From the result of the study of the three Urban forest patches it possible to conclude that Urban forests could have contributions in conservation of woody species diversity and climate change mitigation through carbon sequestration and storage. Thus, all stakeholders should pay attention to protection and conservation of Urban forest in Sheka Zone in particular and Ethiopia at large.

Key words

Live carbon storage, sequestration, urban forest, Masha and Teppi

1. Introduction

1.1 Background of the study

One of the most pressing issues in the modern era is the problem of climate change and the role that greenhouse gases play in shifting global temperatures (Ugle *et al.,* 2010). Climate change constitutes a long-term threat to the earth's ecosystems and to the way people lead, their lives (IPCC, 2007). The composition of atmosphere is changing towards conditions that have not yet experienced for millions of years (Cicerone and Nurse, 2010).

Millions of people in the world are already feeling the impacts of climate change and estimated that 150,000 people die each year from its effects (Bjureby *et al*., 2009). It was predicted that from 2008-2018, billions of people, particularly those in developing countries, faced shortages of water and food and greater risks to health and life because of climate change. Changes in climate has significant implications on present and future generations and ecosystems on which humanity depend (UNFCCC, 2007). The atmospheric concentrations of carbon dioxide, methane and nitrous oxides have increased significantly since the beginning of industrial Revolution. Direct measurements of CO_2 in the atmosphere and in air trapped in ice showed that atmospheric CO_2 increased by about 40% from 1800 to 2012. As evaluated by UNFCCC (2007), the CO_2 level in 2012 was about 40% higher than it was in the 19^{th}century. Most of this CO_2 increase has taken place since 1970, about the time when global energy consumption accelerated. Africa is likely to experience higher temperatures, rising sea levels, changing rainfall patterns and increased climate variability, all of which could affect much of its population. By 2020, up to 250 million people in Africa will be exposed to greater risk of water stress (UNFCCC, 2007).

Climate change in Ethiopia is associated with growth of population density, absence of fertile land to cultivation, which poses threat to food security and agricultural livelihoods (Pegasys Institute and Ethio Resources Group, 2017). From 1978-2008, the average annual temperature in Ethiopia had increased by $0.37^{o}C$ per decade, with most warming occurring during the second half of the 1990s (EEA, 2008). Other studies of national climate trends since the 1960s show that mean annual temperatures in Ethiopia have increased by between 0.5°C and 1.3°C (ACCRA, 2012). Extreme events are common in Ethiopia, especially droughts. Ethiopia has been ranked 5^{th} out of 184 countries in terms of its risk of drought (Swarup, *et al.,* 2011). Climate change has strong links with poverty and hunger through its adverse effect on food security and economic development. Ethiopia has historically been vulnerable to food insecurity (Pegasy institute and Ethio resource group, 2017).

Forests serve as important key drivers of regional and local climate systems through biosphere-atmospheric interactions (Dube *et al.,* 2014). Forests have also played, and continue to play, a huge role in slowing the rate of climate change. Forests cover approximately 38.5 million km^2 (Pan *et al*., 2011) or 28% of land surface (Hooke *et al*., 2012) and contain 77% of all terrestrial aboveground carbon (Houghton, 2007). Natural systems dominate the global carbon cycle. Meaning that the atmospheric carbon dioxide emission was significantly minimized by photosynthesis process of plant. Terrestrial vegetation alone cycles over 120 Gt of carbon each year, taking up approximately 123 Gt C and respiring 119 Gt O_2 (Ciais *et al*., 2013). Tropical forests are the largest, most carbon dense and most diverse forests on earth. However, the high levels of deforestation within the tropics amount for nearly all-net forest loss and GHG emissions from forest and other land use across the planet. Over half of the world's remaining forest coverage was found in the tropics (Pan *et al*., 2011). Tropical forests span 19.5 million km^2, 70% of which (13.9 million km^2) are considered to be already in contact by human activities (Pan *et al*., 2011).

The main driving force to this global climate change is mainly urbanization. Cities are responsible for 75% of global anthropogenic carbon dioxide (CO_2) emissions (Seto *et al.,* 2014). The rapid urban population growth and global climate change call for the elaboration and evaluation of different adaptation and mitigation strategies in these anthropogenic modified climatic circumstances (KISS *et al.*, 2015).

All the trees that are located in urban areas are part of an urban forest (Kim, 2016). Urban trees face threats and challenges, which anticipated forcing over the next two decades. Trees considered as major capital assets in urban area as they provide myriad of benefits (Ugle *et al*, 2010). Despite extensive evidence of the critical role played by urban trees in city environments, urban planners and architects have often undervalued the role played by trees (Ugle *et al*, 2010). The ecosystem played by urban forest greatly depends on urban forest structures, which are tree species, number, tree canopy cover, height, health, composition, tree size, location, health (Kim, 2016). Urban forest assessments are essential in supporting urban forest management and planning to improve environmental quality and human health in cities (Nowak *et al*, 2008). Urban expansion may lead to habitat fragmentation, potentially resulting in genetic or demographic isolation of native species (Ricketts 2001). Urbanization is also a major threat to endemic species due to increased incidence of colonization by introduced species (McKinney, 2008). Habitat loss and degradation, altered disturbance regimes, modified soils and other physical transformations caused by the expansion of urban areas are the direct causes of biodiversity loss in urban area (Elmqvist *et al,* no year).

1.2 Statement of the Problem

Urban forests are carbon sinks and biodiversity reservoirs, which can be relevant to climate change mitigation and adaptation as well as the overall wellbeing of urban ecosystem (Agrarwissenschaften, 2016). Most of the urban forests become smaller and fragmented due to buildings, land lease (rent), road construction and other infrastructure. This situation becomes poorer when no replanting programmed implement to increase number of urban forest and greenery area around the development area. The amount of carbon dioxide released to the air increases with increasing urban population. This situation needs a well-planned urban area in order to minimize amount of carbon accumulated in the atmosphere. More carbon dioxide in the air reflects more contribution to global warming and climate change. Therefore, the presence of urban forests is important to absorb the carbon dioxide released from human activities and development works.

Plant species diversity is an important issue for biological diversity. The diversity of woody species is fundamental to total forest biodiversity. As stated by Yakob and Fkadu, (2016) the woody species diversity is the source and cause for the presence of other biodiversity. Due to the presence of varied topography, soil and climate type, Ethiopia is known by its high biodiversity resource (Zegeye *et al*, 2011). The presence of woody species in urban forest may help for the existence of other living organisms and therefore, provides to a wider conservation of biological diversity.

Studies have carried out on the contribution of urban forest in carbon storage across the world. No such study had been conducted on urban forests patches such as (Church, Indigenous sacred forest and forests managed by government institutions) in Sheka Zone. This study was planned to address the above-mentioned research gaps in two administrative towns (Masha and Teppi) of Sheka Zone. The study was planned to answer the following questions;

- How much carbon is stored in urban forest patches of Masha and Teppi towns?
- What are differences between the potential of carbon storage and sequestration in Church, Indigenous sacred forests and forests in compounds of government institutions) in Masha and Teppi towns.
- What are woody species richness and diversity among three urban forest patches of Masha and Teppi towns?

1.3 Objectives of the study

1.3.1 General objective of the study

The general objectives of this study were to assess woody species diversity and live carbon storage of urban forest patches of Masha and Teppi towns.

1.3.2 Specific objectives of the study:

- ✓ To assess woody species richness, diversity and density among the three urban forest patches of Masha and Teppi towns;
- ✓ To estimate the carbon storage and sequestration potential among the three urban forest patches of Masha and Teppi towns

1.4 The significance of the study

The two towns have protected forests under different patches of forest (Indigenous sacred forests, forests of government institution and Church forest) may play important role in climate change mitigation through carbon sequestration and storage. It is crucial to recognize these forests as an opportunity to explore possibilities of using them in future climate change mitigation. Moreover, this study might help urban greenery management and planners of municipality to consider urban greenery in its multidirectional benefits. The research output this study might help as reference for further study.

2. Literature Review

2.1 global carbon emission

One of the persistent issues in today's world is carbon-dioxide emission and climate change. Carbon dioxide is one of the most abundant greenhouse gases and a primary cause for global warming. Climate is changing rapidly at a global scale and projected to change at an even faster rate in the coming decades (IPCC, 2014). Millions of people in the world are already feeling the impacts of climate change and an estimated 150,000 people die each year due to climate change. The accumulation of greenhouse gases in the atmosphere, particularly atmospheric carbon dioxide, has increased the need for multiple mitigation options to stabilize or reduce its concentrations (Hansen *et al.,* 2008).

More than half of the world's population now lives in urban areas, and this figure will continue to increase at a rate of 4% a decade by 2050. Globally, the urban population is projected to reach 66% by 2050 (UN, 2014). More than half of the increase in CO_2 has occurred since 1970. Increases in all three gases contributed to warming of Earth, with the increase in CO_2 playing leading role. Industrialization is the main cause for global carbon emission. For example, in 1999, total U.S carbon dioxide emission was 6.2 billion tons, or over 1.8 million tons carbon equivalent. On average, each person in the U.S emits 15 thousand pounds annually. The primary reasons for such high levels of emissions are the burning of fossil fuels and byproducts, and automobile exhaust.

Worldwide rapid increase of infrastructure and production demanding high-energy consumption in urban areas would increase carbon emission. The rate of energy consumption varies from sector to sector. For example, Industries, use 30% and transport sector 11% while the building sector uses 3% of the available energy. Economic and population growth are the most important drivers behind the increase of CO_2 emissions from fossil fuel combustion (IPCC, 2014). The global CO_2 emission per capital from 2006-2011 was estimated to 4.6-4.9 metric ton and for each individual 11.1metric ton for high-income countries 3.4 for middle-income and 0.3 for low income (World Bank, 2015).

Studies show human activities, especially the burning of fossil fuels such as coal, oil, and gas, has caused a substantial increase in the concentration of CO_2 in the atmosphere. This increased the atmospheric CO_2 from about 280 to more than 380 parts per million (ppm) over the last 250 years or pre industrial era is causing measurable global warming which is equivalent with an increase of 1.5 ppm per year (IPCC, 2007).

2.2 Importance of Urban Forest

It is the target of the sustainable development goal (SDG) for cities make cities and human settlements inclusive, safe , resilient and sustainable) to reduce environmental impact of cities, provide universal access to green and public spaces for all, and preserve nature (environment) networks in cities and their environs (Agrarwissenschaften, 2017). Cities are an organic form of government and often express the aspiration of their citizens more succinctly and quicker than higher levels of government. Cities are where change is happening; the fastest and we must seize the opportunities we have been presented with to make that change significant and permanent. Economic growth and urbanization move in tandem, as economic growth and greenhouse gas emissions have for at least the last 100 years. Because most economic activities are concentrated in urban areas, cities have a key role in climate change. The world is urbanizing quickly and under the business-as-usual scenario, greenhouse gas emissions will increase dramatically. Economic growth, urbanization and greenhouse gas emissions are on increasing. Urban forests in are affected by various problems such as encroachment, illegal cuttings, low legal enforcement and improper tree selection (Shikur, no year)

Understanding the type of urban forest used to estimate the environmental benefits and ecosystem services provided, thus improving our understanding of the role of trees play in creating healthy, habitable and sustainable cities. All the trees that are located in urban areas are part of an urban forest. Studies showed that forests in urban areas are most of the time out of public. Only 10% are public forest. The remaining 90% are found on private property such as residential yards, corporate park systems, natural areas, industrial sites, street trees and trees around residences are managed by their owners, or not managed at all (Kim, 2016). However, some Urban forests include trees managed by municipalities and other public agencies, such as trees along streets and highways, and trees in parks and around public buildings.

Yard trees provide great variety in urban forests and reflect the preferences of individual landowners rather than the professional guidelines. Parks and greenways offer great variety of space and growing conditions for trees within urban areas. Greenways such as stream corridors, abandoned rail lines, and hiking trails are a special case; they contain largely natural vegetation. The extent to which land use can provide ecosystem services depends on the current urban forest structure (e.g., tree species, number, tree canopy cover, height, health, composition, tree size, location, health), which can provide useful information for estimating trees' structural characteristics such as leaf biomass and total leaf area, and quantifying multiple ecosystem services and forest functions.

Forest trees self-prune as a result of close spacing and shading of the lower branches, but city trees are open grown and do not self prune (Miller, 1997). In natural forest, new trees always planted through natural seeding. Unlike forest trees, many urban trees lack protection from wind and elevated temperatures that neighboring trees have to offer. They receive light from above and sides, and often exposed to artificial light at night. Increased light may raise growth rates, but usually results in increased air temperatures, which increase water loss from the leaves (Society of Municipal Arborists, 2001).

2.3 Carbon sequestration

The term carbon sequestration is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations (Anonym, 2008). Plants convert the gaseous carbon dioxide to a solid form in sugars such as carbohydrates, glucose and starch that can be stored in leaves, stems, trunks, branches and roots, and contribute to growth of the plant. Carbon storage in forest biomass (i.e. biological material) is an essential attribute of stable forest ecosystems and a key link in the global carbon cycle. As Forest Service scientists estimate the volume of biomass and the corresponding amount of carbon using models that show the relationship between trunk size and the weight of branches, leaves, roots, and forest floor litter classified in to five components as above ground, below ground, dead wood, forest floor litter and soil organic carbon storage.

Carbon capture and storage (CCS) has emerged as a potential solution to the climate change (Ref). If we are to make the cities of the future more sustainable, we must learn to minimize and manage the ecological effects. Before human caused CO_2 emissions began, the natural processes that make up the global "carbon cycle" maintained a near balance between the uptake of $CO_2$and its release back to the atmosphere and the existing CO_2 uptake mechanisms (sometimes called

CO_2 or carbon "sinks") are insufficient to offset the accelerating pace of emissions related to human activities (Anonym, 2008). Terrestrial sequestration or biological sequestration is typically accomplished through forest and soil conservation practices that enhance the storage of carbon by restoring and establishing new forests, wetlands, and grasslands or reduce CO_2 emissions through reducing agricultural tillage and suppressing wildfires.

Forest carbon sequestration specifically involves fixing atmospheric carbon dioxide during photosynthesis and storing the carbon as biomass. Forest ecosystem plays important role in the global carbon cycle by sequestering a substantial amount of carbon dioxide from the atmosphere (Vashum and Jay Kumar, 2012). Assessment of biomass provides information on the structure and functional attributes of trees. By estimating the amount of carbon removed by trees, we can determine the role of urban forests in mitigating climate change and assign an economic value to the amount of carbon sequestered by urban forest. Several studies estimated that 50% of dry biomass comprises of carbon (Montagagnini *et al*., 2005). Carbon storage is due to the accumulation of woody biomass as trees grow over time; the amount of carbon stored in a tree is proportional to its biomass, which increases with its diameter, height, and canopy spread, while the amount stored in urban area also increases with the tree density and canopy cover.

Urban trees can reduce concentrations of atmospheric carbon dioxide by storing carbon in their roots, stems and branches. Urban forests can also help to reduce carbon dioxide emissions from fossil-fuel-based power plants because their shade and wind protection reduces energy consumption for heating and cooling buildings (Escobedo *et al*., 2011). One ton of carbon storage in a tree represents removal of 3.67 ton of CO_2 from the atmosphere, and the release of 2.67 tons of oxygen back into the atmosphere (Ugle *et al*., 2010). The U.S.A national average urban forest carbon storage density is 25.1 t C/ha, compared with 53.5 t C/ ha in forest stands (Nowak and Crane, 2002). A survey undertaken urban tree in the Coterminous USA, store 700 million ton of carbon with a gross carbon sequestration rate is 22.8 million tC/yr (Ugle *et al.*, 2010).

Few studies indicated that 600 trees in the tropics would fill one acre, which could sequester up to 15 ton of CO_2 annually (Nowak, 1994). Another study showed that 40 trees would sequester one ton of CO_2 each year; and that one million trees covering 1,667 acres could capture 25,000 tons of CO_2 annually. It is also possible to evaluate the carbon market value since carbon value traded in carbon-offset markets in units of carbon dioxide; carbon estimates then converted to carbon dioxide (CO_2) equivalents. Values were multiplied by $ 4 per metric ton (mt) CO_2 equivalent and the current market value August 2008 on the Chicago Climate Exchange (2008). .

2.4 Urban Growth and Urban Green Spaces

Urban greenery has recently gained popularity as a climate change adaptation/mitigation measure (Velasco *et al.,* 2015). Green spaces also act as a filter to improve air quality, in this case, vegetation has a great contribution to improve air quality through removing gas and dust related pollutants (Bolund and Hunhammar 1999). In developing countries, about 44% of the population currently lives in urban area. One of the great challenges to urban greening is high expansion of urban area due to urban population increase. Important example is study carried out in Asia shows that during the early 1990s, more than a quarter of green spaces in Asia, expected to be lost within two decades due to continued urbanization and suburbanization. Cities are more susceptible to environmental change impacts and become inhospitable. Thus, monitoring and mapping tree cover is critical for conserving trees and for making decisions to increase green cover in cities (Kanniah and Siong, 2017). According to Gondo (2012) studies in Ethiopia shows that there is great problem in open space area management and conclude as urban planning practices of many cities are in constant mutation owing to a myriad of driving forces. His study Results revealed that most public open spaces are less attractive and difficult to access. The three major factors to the problem to blame are, absence of a land use (re)mixing strategy, weak development controls that have seen some open spaces giving way to illegal land uses and the general absence of quality infrastructure in existing open spaces.

Analysis of the forest and tree cover in the four main cities in Malaysia shows that all cities have lost trees over time at different rate (Kanniah and Ho Siong, 2017). Cities account for 78% of carbon emissions. In 1800, there was only one city Beijing, in the entire world that had more than million people, there are 326 such cities 200 years later. Indeed, such rapid change has been the pace of growth that in 1900 just 10% of the global population was living in urban areas, which now exceeds 50% and expected to further rise to 67% in the next 50 years (Ugle *et al*., 2010).

However, Urban forests, due to their relatively low tree cover, typically store less carbon per hectare in trees (25.1 t C/ha) than forest stands (53.5 t C/ha) Nowak and Crane (2002). However, on a per unit tree cover basis, carbon storage by urban trees and gross sequestration may be greater than in forest stands (Gann, 2003). As Empirical Study on the relationship between Urban Spatial form and CO_2 in Chinese Cities by Yanchun *et al.* (2017) estimated that global, carbon emissions increased from 3 million tons in 1751, to 9855 million tons in 2014. According to the Carbon Dioxide Information Analysis Center (CDIAC), China is the largest carbon dioxide emitter in the world, and accounted for 29% of the global emission in 2013. According to Yanchun *et al.* (2017**)** even though cities only occupy 2% of the world's entire area, they account for approximately 75% of the global greenhouse gas emissions. The International Energy Agency (IEA) estimates that urban areas currently account for over 67 percent of energy-related global greenhouse gases, which is expected to rise to 74 percent by 2030.

Many policy and robust scientific evidences in last two decades have emphasized on the necessity of green areas within urban socio-ecological systems to improve several problems of city living; however, the trend of urban ecology and application of its principles is still lagging behind (Ugle *et al.,* 2010). A study of 439 cities in China in 1991 showed that the overall green space was 380,000 ha (20.1%) of the urban area. Some 40% of the cities had more than 30% green cover in 1991. In 1986, the green space coverage and public green area per capital were 16.9%, and $3.5m^2$, respectively. This increased to 23.0% and $6.52m^2$ by 2000 (Wang, 2009). By the end of 2006, green area coverage in China's cities had increased to 32.54%. In fact, trees can provide substantial long-term environmental, ecological, social and economic benefits to urban ecosystems.

2.5 Aboveground Biomass and Carbon Stock

Forests sequester more than 92% of the world's terrestrial living carbon and store much more carbon per hectare than agricultural lands (Shepherd and Montagnini, 2001).The aboveground live biomass of a tree constitutes the major portion of carbon pools (Vashum and Jayakumar, 2012). Aboveground biomass refers to the sum of the dry weight of stems, branches and leaves and the barks (Chen, 2015). Most of the carbon in trees and shrubs accumulated in aboveground biomass (AGB) and 50% of the total biomass considered as carbon stock (Chave *et al*., 2014).

Carbon dioxide is one of the greenhouse gases that can removed from the atmosphere by trees through photosynthesis. This process involves plant cells converting the carbon from carbon dioxide to a solid form in sugars (the carbohydrates glucose and starch) that can be stored in different parts of plants (Deressa, 2017). Carbon sequestration is the potential of removed CO_2 from the atmosphere and it can be stored indefinitely through the process of photosynthesis (Watson *et al*., 2000). Among the carbon stored by the tree biomass, majority is stored in above ground biomass. To convert biomass to carbon storage, the 50% of the woody species biomass was used (Baishya *et al*., 2009).

2.6 Estimation of Below Ground Carbon Stock (BGC)

Below ground biomass, estimation is much more difficult and time consuming than estimating aboveground biomass (Geider *et al*., 2001). Roots play an important role in the carbon cycle as they transfer considerable amounts of Carbon to the ground, where it may be stored for a relatively long period. Standard method for estimation of below ground biomass can be obtained as 20% of above ground tree biomass i.e., root to shoot ratio value of 1:5 is used (MacDicken, 1997). Root biomass in ecosystems often estimated from root-to shoot ratios. The ratio ranges from 0.18 to 0.30, with tropical forests in the lower range and the temperate and boreal forests in the higher range (Cairns *et al*., 1997). Roots make a significant contribution to SOC (Strand *et al*., 2008). About 50% of the carbon fixed in photosynthesis transported belowground and partitioned among root growth, rhizosphere respiration, and assimilation to soil organic matter (Lynch and Whipps, 1990).

2.7 Factors Affecting Carbon Storage Level

The amount of carbon sequestered and stored varies greatly based on a large number of factors. Such as the type of forest, its net primary productivity, the age of forest, and its overall composition and the growth rate also (Pragasan *et al.,* 2013). The study conducted by Pragasan and Karthick, (2013) shows that the carbon sequestration potential of the fast growing Eucalyptus plantation is 11% higher than the mixed species plantation. This comparison shows that the plant growth rate has also one factor. Forest types and climate zones have a substantial impact on the carbon storage processes. Forest types can be broken down into "biomes" based on their climate zones: tropical, temperate, and boreal forests. Temperate forested regions sequester the least amount of carbon when compared to the other regions.

Other important factors include the species of trees present and the overall age of the forest. Faster growing species sequester carbon for longer periods. On average, hardwood trees sequester more carbon over their lifetime than do evergreen species. Trees and plant matter do not actively sequester carbon throughout their lifetime, so the relative age of the forested region is important as well. For example, an old-growth forest will not sequester as much carbon as a younger forest. Annual uptake of carbon related to tree vigor and growth rate, so healthy, fast growing trees could accumulate carbon faster. These are all important considerations when creating or implementing a forest management plan.

3. Materials and Methods

3.1 Description of the Study Area

3.1.1 Geographical Location

The study was conducted in Masha and Teppi towns of Sheka Zone, Southern Nation Nationalities and Peoples Regional State Sheka Zone is located in the southwestern part of Ethiopia at a distance of 711 km from Addis Ababa. It bordered with Illu Aba Bor Zone (Oromiya Regional State of Ethiopia) in North and Northwest, Bench Maji Zone in South, Kefa Zone in East and Gambella Regional State in southwest. Sheka Zone has three districts and two Administrative towns. The administration center of Sheka Zone is Masha and it lies between 7º 73' to 7º 74 N latitude and 35º46' to 35º 48' E longitudes with elevation range of 2100m-2500m (Sheka Zone Finance and economy Dep't annual report, 2013/14). Teppi is another town found at 624 km from Addis Ababa and lies between 7^{o} 17' to 7^{o} 22' N latitude and 35^{o}40' to 35^{o} 44' E longitudes (Yasin *et al,* 2015).

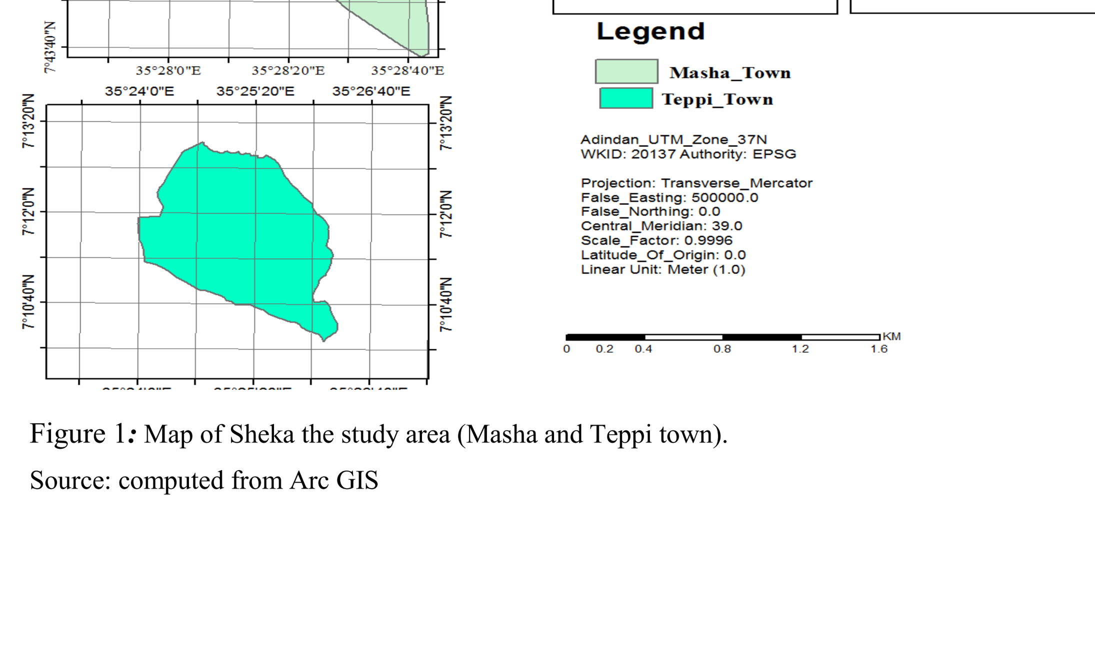

Figure 1**:** Map of Sheka the study area (Masha and Teppi town).

Source: computed from Arc GIS

3.1.2 Climate and Elevation

The altitudinal range of the Zone is 900-2700 m a.s.l. The Zone divided in to "Dega (22.58%), "Woina-dega (59.81%) and "Kolla (17.61%) agro-climatic Zones (Legesse, 2010). Masha town has the mean annual rainfall of 2100 mm to 2200 mm and average temperature of 15.1^{o}C to 17.5^{o}C. Teppi is the second study site with annual rainfall of 1800 mm to 2000mm and average temperature of 22.6^{o}c to 25^{o}c. For both study sites high rainfall experienced from April to September and minimum rainfall and maximum temperature from October to March (National Meteorological Agency Jimma and Gambela center).

3.1.3 Land cover and land use

The estimated total area of the Zone is 2387.55 km^2, which is 2.19% of the region (Woldemariam and Fetene, 2007). The area coverage of Teppi town is 23 km^2 (0.96%) of the Zone. Its elevation ranges from 1001-1500m above sea level, which is under "kolla agro ecological Zone and Masha town has land coverage of 12 km^2. Sheka Zone is one of the few areas with high vegetation cover in Ethiopia. About 47% land of the Zone covered by forest including bamboo and other broad-leaved tree (Woldemariam and Fetene, 2007).

3.1.4 Human Population

The Zone has three major ethnic groups (Shekacho, Sheko and Mejengir) and others with their own distinct language, cultures, and social identities living together (Yasin *et al,* 2015). Some of these ethnic groups belong to the Omotic while others are in Nilo-Sahara language families. According to the CSA and Housing Census of Ethiopia (2013), the population of the Zone was about 269, 243 where 49.7% were females and 50.3 % males. About 72.99% of the population lives in the rural areas and about 27.01% are urban dwellers. Of the total population14440 live in Masha, (and 52719 in Teppi) (CSA, 2013).

3.1.5 Socioeconomic activity in the Zone

The current agricultural system of the Zone is classified under Enset based mixed- cropping system. The main crops growing with *Ensete ventricosum* are *Eragrostis teff, Hordeum vulgar* and *Vicia faba* (Yasin *et al.,* 2015*).* Moreover products such as such as wild honey), Bamboo and bamboo products; Enset-fiber source of starch for industrial application, coffee, and fruits (avocado, mango, and banana), different types of spice are common means of livelihoods (Yasin *et al.,* 2015).

3.2. Data Collection Methods

3.2.1. Sampling Design

The urban forests of the study towns had already been stratified into patches of indigenous sacred forests, Church forests (Mariyam church in Masha, Michel church in Teppi, Mechanyesus church in Masha and Full gospel church in Teppi) and forests of government institution. Each forest patch further stratified into 20 m × 40 m grids. From the strata of each fores patches (Indigenous sacred forest, Church forest and forests belonging to government institutions), 13 plots were selected (total = 39 plots) by random sampling technique. From 25 (plots), 13 plots were randomly selected for each forest management type. Vegetation data Were collected from thirty-nine plots of 20 m ×40 m size. Nested plots of size 16 m × 25 m for DBH 20.1- 50cm and 5m×10m for DBH 5-20cm were placed within each main plot (Pearson *et al.*, 2005). According to MacDicken (1997), trees on the border whose basal area > 50% of their basal area falls within the plot were included and BA < 50% of their basal area in side plot were excluded. Trees overhanging into the plot were not considered, but trees with their trunks inside the sampling plot and branches outside were included.

3.2.2 Data collection

The preliminary survey was carried out from March 8-11/2018. Data on diameter at breast height (DBH, in cm) and height in m of all living woody species (DBH ≥ 5 cm) were recorded by using a meter tape and clinometers respectively. For stem abnormalities, Rainfor protocol (Phillips *et al.,* 2009) was used. The elevation and location of each plot were recorded by using GPS GARMIN 72. Local names of each woody species were recorded during inventory. Species were identified by comparing with the identified sample specimens from Jimma University Herbarium and using Flora of Ethiopia and Eretria. Voucher Specimens of all species were, pressed dried and deposited in Jimma University Herbarium for further identification. Every measured tree in the plot was marked to avoid double count and helps to check that every tree was measured.

3.2.3 Data analysis

3.2.3.1. Forest vegetation data analysis

All individual species registered in 39 plots were used in the analysis of vegetation and for the diversity indices. The DBH, H, basal area, tree density, frequency and important value index were variables used for description of vegetation structure. The data was summarized by frequency, graph and percentage.

3.2.3.2 Height

Height is a straightforward parameter used for direct measurement of carbon storage. Individual shrubs and trees having height greater than or equal to 2m and 5m within the plot were collected and analyzed by classifying into eight classes (2-5m, 5.1-10m, 10.1-15m, 15.1-20m, 20.1-25m, 25.1-30m, 30.1-35m and above 35.1m) for all three-forest management (Hundera and Deboch, 2008).

3.2.3.3 Diameter at Breast Height (DBH)

DBH defined as the tree diameter measured at 1.37 m above ground line on the uphill side of the tree. Woody plant species obtained from the study area were classified into eight DBH classes for convenience of analysis.

3.2.3.4 Density

Density is simply the count of stems in the study area or stem count per hectare. It is very important in determining the dominance of species in the area. Calculated by:

$$\text{Density} = \frac{\text{the number of individuals}}{\text{sampled area in hectare}}$$

$$\text{Relative Density(RD)} = \frac{\text{number of stems of individual tree}}{\text{total number of all individual tree}} \times 100$$

3.2.3.5 Frequency

Frequency is the number of times a particular species found in sample area. Thus, it shows the presence or absence of a given species within each sample plot. It is also important to determine the ecological importance of the species. It was calculated as calculated as:

$$Frequency = \frac{t\ \ e\ number\ of\ plots\ in\ w\ \ ic\ \ t\ \ e\ species\ occur}{total\ number\ of\ plots}$$

$$Rf = \frac{t\ \ e\ frequency\ of\ individual\ species}{t\ \ e\ frequency\ of\ total\ species} \times 100$$

3.2.3.6 Basal Area (BA)

Basal area is a measure of dominance that defines the area of a given section of land occupied by the cross-section of trees (Suratman, 2012). It is expressed in meter square per hectare. Basal area also used to calculate the dominance of species (Mueller-Dombois and Ellenberge, 1974).

$$BA = \pi\ (DBH/2)^2$$

Where: BA= Basal Area (m^2), DBH -is diameter at breast height (cm)

$RDM = \frac{BA\ of\ spp\ A}{BA\ of\ all\ spp} \times 100$ Where: RDM: is relative dominance, BA is basal area.

$$RDM = \frac{Basal\ area\ of\ spp\ A}{Total\ Basal\ Area\ of\ all\ spp} \times 100$$

3.2.3.7 The Importance Value Index (IVI)

Importance value index is a sum of relative density, relative dominance and relative frequency. IVI was calculated for each species. The vegetation data of the tree species was calculated using the following formula.

$$IVI = \text{Relative density} + \text{Relative dominance} + \text{Relative frequency}$$

3.2.3.8 Species diversity, richness and evenness

Diversity refers to the number of tree species that can be differentiated, and to the proportions (or relative abundances) of the number of trees in each category (Kindt and Coe, 2005). Species richness is simply the number of species present in an area. Species evenness refers to the proportion that each species comprises of the whole (Nolan and Callahan, 2006). Thus, species diversity and species evenness indices were calculated for each forest patches.

I. Shannon-Weiner diversity index

Shannon-Weiner Species Diversity Index; is calculated by taking the number of each species, the proportion of the number of individual of each species to the total number of individuals Since this is a negative number, we then take the negative of the negative of this sum . The higher the number, the higher is the species diversity (Nolan and Callahan, 2006). Shannon-Wiener diversity index was used to measure species diversity.

$$H' = -\sum (p_i \ln p_i)$$

$$P_i = n_i/N,$$

Where: H'- Shannon's diversity index, pi- the number of individuals found in the i^{th} species as a proportion of the total number of individuals found in all species, ln- natural logarithm to base (Nolan and Callahan, 2006). However, species diversity was determined separately for each plot and the mean diversity was calculated from the indices by stand.

II. Evenness (E): Species evenness is a diversity index, a measure of biodiversity, which is used to measure the homogeneous distribution of tree species in sample plot. It was calculated using the Shannon evenness index using the following equation:

$$E = H'/ H_{max}$$

$$H_{max} = \ln S$$

Where: H'- is the Shannon-Weiner diversity index and S-is the total number of species at a site (Alatalo, 1981). The higher the value of E, the more even the species is in their distribution. Similarly, the higher the value of H', the more diverse are the sites.

III Similarity index (Ss)

Similarity index measures the degree to which the species composition of different systems is alike. The Sorensen similarity coefficient is used to qualitative data and is widely used because it gives more weight to the species that are common to the samples rather than to those that only occur in either sample (Kent and Coker, 1992). The similarity was calculated by the following equations.

$$Ss = \frac{2a}{2a + b + c}$$

Where: Ss = Sorensen similarity coefficient

a = number of species common to both sites

b = number of species in site 1

c = number of species in site 2

3.3Above and Belowground Live Biomass and Carbon Storage

There are different equations in use to calculate the aboveground live biomass (AGB) and carbon storage. For this study, revised non-destructive allometric equation developed by Chave *et al.* (2014) was used. To calculate the aboveground live biomass of each species the following equation was used.

$$\text{AGB} = 0.0673 \times (\rho D2H)\ 0.976$$

Where: AGB= aboveground live biomass, D = diameter at breast height (cm), H= Height and ρ = wood specific gravity.

Aboveground live carbon storage (AGC) is 50% of AGB

Below ground, live carbon storage (BGC) is 20% of AGB

Total Live carbon storage (TLCS) is the sum of AGC and BGC

TLCS = AGC + BGC

3.4 Variations in carbon storage and density of woody species

The data for carbon storage and density of woody species were checked for their distribution and finally were log transformed to attain the assumption of normal distribution. One way ANOVA was used to analyze the variation in carbon storage and density of woody species among the three urban forest patches for by using SPSS version 21.

4. Results and Discussions

4.1. Results

4.1.1 Woody species composition

Totally 49 woody species, belonging to 27 families and 43 genera were recorded from three Urban forest patches (i.e. Government institutions, Church forest and indigenous sacred forest) (Table 1). Among the 27 families, *Moraceae* was composed of six species (12.24%) belonging to three genera, Rubiaceae has four species (8.16%) belonging to four generea. The remaining families were listed in appendix 2 . Out of 49 species in the study area, institution and church forest contain 27 species (55.1%) each and indigenous sacred forest contains 19 species (38.78%).

Table 1: Families with genera and species ≥ 2 in the urban forest of Sheka Zone

Family	**No of genera**	**Perecent (%)**	**No of sepecies**	**Percente (%)**
Rubiaceae	4	9.52	4	8.16
Moraceae	3	7.14	6	12.24
Euphorbiaceae	3	7.14	3	6.12
Fabaceae	3	7.14	3	6.12
Meliaceae	3	9.52	3	8.16
Myrtaceae	2	4.76	3	4.08
Asteraceae	2	4.76	3	6.12
Rutaceae	2	4.76	2	4.08
Araliaceae	2	4.76	2	4.08
Celastraceae	2	4.76	2	4.08
Boraginaceae	1	2.32	2	4.08
Total	27	62.8	33	52%
Other 16 family with 1 genera	16	37.2	16	48%
Total family = 27	43	100	49	100%

4.1.2 Species Diversity, Richness and Evenness

4.1.2.1 Shannon-Wiener diversity index

Forests in the compounds of Government institution showed relatively the highest species diversity where as indigenous sacred forests indicated low diversity (Table 2). For all forest patches, Shannon equitability was not high (Table 2).

Table 2: Shannon–Wiener diversity index, equitability and H max of three urban forest patches of Masha and Teppi towns (Hmax- maximum diversity and H'- diversity index)

Forest type	Species richness	H	H max	Equitability
Government institution	27	2.863	5.53	0.52
Church forest	27	2.74	5.48	0.5
Indigenous sacred forest	19	2.38	5.15	0.46

4.1.2.2 Evenness

The equitability of three forest patches was displayed in table 2. Government institution, Church and indigenous sacred forest has 0.52, 0.5 and 0.46 respectively

4.1.2.3 Similarity in species composition

The similarity between pairs of the three-forest management types between government institution and Church forest showed more similarity, where as government institution and indigenous sacred forest showed the least similarity (Table 3).

Table 3: Sorensen's similarity for pairs the three of urban forests patches (i.e. government institution and church, government institution and indigenous sacred, church and indigenous sacred forest) Masha and Teppi towns

No	Forest patches	Ss similarity	Percent similarity
1	Government institution and church	0.2545	25.45%
2	Government institution and indigenous sacred	0.0667	6.67%
3	Church and indigenous sacred	0.1915	19.15%

4.1.3 Analysis of the Species structure

All woody species recorded from all study plots were used in the analysis of vegetation structure. Height, DBH, Basal area, density, frequency and important value index were the parameters used for description of vegetation structure in the three forest management types.

4.1.3.1 Height class size distribution

The height class distribution shows that government institution and church forest has high tree density in the same manner inverted J shape distribution. Height class between 1- 4 (below 20m) accounts about 89.43% and 87.45% from total density respectively (Figure 2).

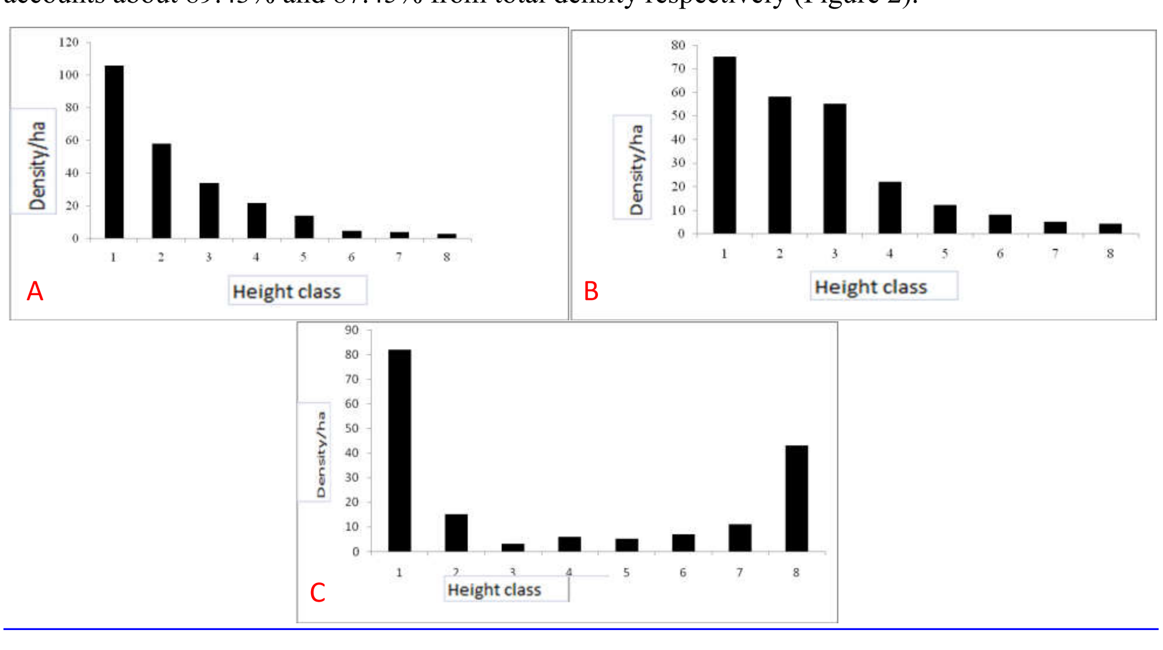

Figure 2: Height class distribution of density of woody species of (A) government institution forest Patch; (B) Church forest patches; and (C) indigenous sacred forest patches of Masha and Teppi towns, Sheka Zone. (Where: 1= 2-5, 2=5.1=10, 3=10.1-15, 4=15.1-20, 5=20.1-25, 6=25.1-30, 7=30.1-35 and 8=>35.1).

4.1.3.2 Diameter at breast height (DBH) class size distribution

A total of 657 individuals whose height greater and equals to 2m and DBH greater or equals to 5cm were used in the analysis of DBH distribution. Eight DBH class have established for three forest managements each.

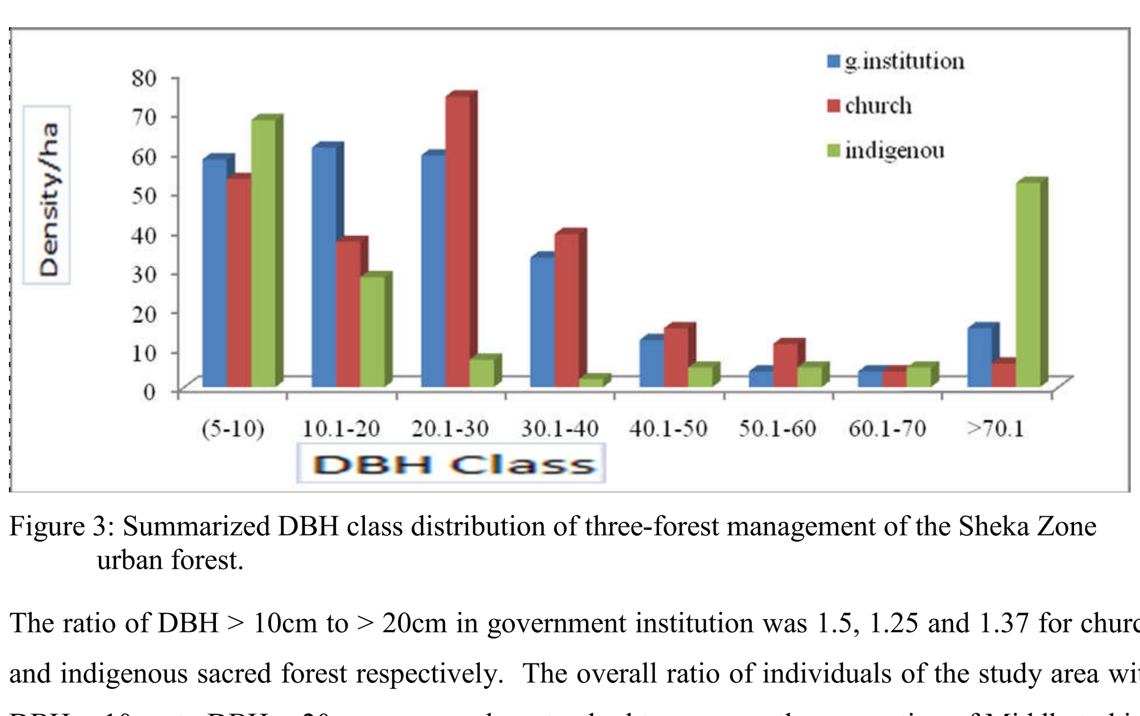

Figure 3: Summarized DBH class distribution of three-forest management of the Sheka Zone urban forest.

The ratio of DBH > 10cm to > 20cm in government institution was 1.5, 1.25 and 1.37 for church and indigenous sacred forest respectively. The overall ratio of individuals of the study area with DBH > 10cm to DBH > 20cm were used as standard to measure the proportion of Middle to high DBH class (Gemechu *et al.*, 2015). The proportion was 478/299 =1.59 for the total study site. This DBH ratio shows that the dominance of middle DBH class woody species. The middle DBH class tree in decreasing sequence from government to church as well as indigenous sacred forest.

4.1.3.1 Basal Area

The highest basal area was calculated for indigenous sacred forest patches followed by of government institution and Church forest (Table 4). Among the tree species recorded from the study area, *Schefflera abyssinica* contributed the highest basal area followed by *Syzygium guineense*, *Cordia africana* and *Pouteria adolfi-friederici.* Where as *Maytenus gracilipes* and *Justicia shimperiana* had the lowest basal area (Table 4)

Table 4: BA, BA/ha, RDM, the top ten ranked species of government institution forest in Sheka Zone (Where: BA-basal area, BA/ha-basal area per hectare, RDM-relative dominance)

No	Species Name	BA	BA/ha	RDM	Rank
1	*Cordia africana*	6.253	6.0125	24.47	1
2	*Pouteria adolfi-friedrici*	6.102	5.87	23.42	2
3	*Grevillea robusta*	2.881	2.77	10.71	3

4	*Ficus sur*	2.4	2.31	8.92	4
5	*Ficus ovata*	0.963	0.93	3.58	5
6	*Antiaris toxicaria*	0.92	0.88	3.42	6
7	*Albizia gummifera*	0.915	0.88	3.4	7
8	*Ficus exasperata*	0.864	0.83	3.22	8
9	*Diospyros abyssinica*	0.789	0.76	2.93	9
10	*Cordia alliodora*	0.71	0.68	2.64	10

Table 5: BA, BA/ha, RDM of top ten species of urban Church forest of Sheka Zone (Where: BA-basal area, BA/ha-basal area per hectare, RDM-relative dominance)

No	Species name	BA	BA/ha	RDM	Rank
1	*Crotton macrostachyus*	2.084	2	18.23	1
2	*Persea americana*	3.37	3.24	18.15	2
3	*Syzygium guineense*	2.629	2.53	14.16	3
4	*Grevillea robusta*	2.589	2.5	13.95	4
5	*Cordia africana*	1.88	1.81	10.13	5
6	*Eucalyptus camaldulensis*	1.455	1.39	7.84	6
7	*Jaccaranda mimosifolia*	1.35	1.29	7.27	7
8	*Ficus ovata*	0.949	0.91	5.11	8
9	*Albizia gummifera*	0.451	0.43	2.43	9
10	*Vernonia amygdalina*	0.315	0.3	1.69	10

Table 6: BA, BA/ha, RDM, urban indigenous sacred forest of Sheka Zone (Where: BA-basal area, BA/ha-basal area per hectare, RDM-relative dominance)

No	Species name	BA	BA/ha	RDM	Rank
1	*Schefflera abyssinica*	36.77	35.36	53.4	1
2	*Syzygium guineense*	19.33	18.58	28.07	2
3	*Ekebergia capensis*	3.92	3.78	5.69	3
4	*Croton macrostychus*	2.185	2.1	3.17	4
5	*Schefflera volkensii*	2.117	2.04	3.07	5
6	*Ilex mitis*	1.841	1.77	2.67	6

7	*Maesea lanceolata*	0.505	0.48	0.74	7
8	*Bersama abyssinica*	0.414	0.39	0.6	8
9	*Vernonia amygdlina*	0.352	0.34	0.52	9
10	*Canthium oligocarpum*	0.249	0.24	0.36	10

4.1.3.2 Density of Tree and shrub plant species

Government institution forest patches had relatively high stem density compared to the indigenous sacred forest and Church forest patches (Table 7). The variation in three-forest patch density is statistically significant as shown in (table 8).

Table 7: Density and percentage of tree and shrubs in three Urban forest patches of Masha and Teppi towns

Type Forest patches	Tree /ha	Percent	Shrubs /ha	Percent	Total density/h
Government institution forest	226	91.86%	20	8.13%	246
Church forest	211	88.28%	28	11.72%	239
Indigenous sacred forest	137	79.65%	35	20.35%	172
Total	574	87.46%	83	12.54%	657

Table 8: Summary of ANNOVA for variation of density between each forest management types (Df- degree of freedom, F- F statics)

	Sum of Squares	Df	Mean Square	F	P
Between Groups	255.846	2	127.923	5.693	0.007
Within Groups	808.923	36	22.470		
Total	1064.769	38			

4.1.3.3 Frequency

Highly frequent species in forest patches of Government institution was *Cordia africana (54%), Ficus sur* (38%) and *Ficus exasperata* (38%) which were first, second and third ranked species (Table 9). Whereas *Croton macrostachyus (54%), Vernonia auriculifera* (54%) and *Eucalptus camaldulensis* (46%) were the frequent species in church forest (Table 10). Finally, *Vernonia* *auriculifera* (77%), *Croton macrotachyus* (62%) and *Schefflera abyssinica (62%)* were frequent species in indigenous sacred forest (Table 11).

Table 9: Shows the frequency of top ten frequently encountered species in government institution forest of Sheka Zone (Where: RF- relative frequency)

No	Species Name	No of plots	Frequency	RF	Rank
1	*Cordia africana*	7	0.54	11.1	1
2	*Ficus sur*	5	0.38	7.84	2
3	*Ficus exasperata*	5	0.38	7.4	3
4	*Grevillea robusta*	4	0.31	6.4	4
5	*Vernonia amygdalina*	4	0.31	6.4	4
6	*Ficus ovata*	4	0.31	6.3	6
7	*Cordia alliodora*	3	0.23	4.7	7
8	*Albizia gummifera*	3	0.23	4.7	7
10	*Ficus sur*	3	0.23	4.7	7
12	*Pouteria adolfi-friederici*	2	0.15	3.1	10
13	*Coffea arabica*	2	0.15	3.1	10
17	*Croton macrostachyus*	2	0.15	3.1	10
18	*Diospyros abyssinica*	2	0.15	3.1	10
19	*Millettia ferruginea*	2	0.15	3.1	10
20	*Persea americana*	2	0.15	3.1	10
21	*Antiaris toxicaria*	2	0.15	3.1	10

Table 10: Frequency of the top ten frequently encountered species in church forest of Sheka Zone (Where: RF- relative frequency)

No	Species Name	No of plot	Frequency	RF	Rank
1	*Croton macrostachyus*	7	0.54	10.78	1
2	*Vernonia auriculifera*	7	0.54	10.78	1
3	*Eucalyptus camaldulensis*	6	0.46	8.55	3
4	*Maesa lanceolata*	5	0.38	7.84	4
5	*Grevillea robusta*	5	0.38	7.1	5
6	*Vernonia amygdalina*	5	0.38	7.1	5

7	*Persea americana*	3	0.23	4.27	7
8	*Albizia gummifera*	3	0.23	4.27	7
9	*Cordia africana*	3	0.23	4.27	7
10	*Ficus exasperata*	2	0.15	2.79	10
11	*Jacaranda mimosifolia*	2	0.15	2.79	10
12	*Annona senegalensis*	2	0.15	2.79	10
13	*Mangifera indica*	2	0.15	2.79	10
14	*Ficus sur*	2	0.15	2.79	10

Table 11: Frequency of the top ten frequently encountered species in indigenous sacred forest of Sheka Zone (Where: RF- relative frequency)

No	Species name	No of plot	Frequency	RF	Rank
1	*Vernonia auriculifera*	10	0.77	14.89	1
2	*Croton macrostachyus*	8	0.62	13.35	2
3	*Schefflera abyssinica*	8	0.62	11.99	3
4	*Syzygium guineense*	8	0.62	11.99	3
5	*Maesa lanceolata*	5	0.38	7.4	5
6	*Ilex mitis*	4	0.31	5.99	6
7	*Galinera saxifraga*	4	0.31	5.99	6
8	*Vernonia amygdalina*	3	0.23	4.45	8
9	*Ekebergia capensis*	3	0.23	4.45	8
10	*Bersama abyssinica*	2	0.15	2.9	10
11	*Brucea antidysenterica*	2	0.15	2.9	10
12	*Schefflera volkensii*	*2*	0.15	2.9	10

4.1.3.4 Important value index

Compared to forest patches of Government institutions and Church forest, the indigenous sacred forest patch has more IVI plant species. *Schefflera abyssinica, Cordia africana* and *Croton macrostachyus* were the top ecologically important species in the three forest patches (Table 12, 13 and 14).

Table 12: Importance value index (IVI) of top ten ecologically important woody species in government institution forest of Sheka Zone (Where: RDM –relative dominance, RD- relative density and RF. - relative frequency)

No	Species	RDM	RD	RF	IVI	Rank
1	*Cordia africana*	24.47	10.22	11.1	45.79	1
2	*Grevillea robusta*	10.71	22.4	6.4	39.51	2
3	*Pouterea adolfi-friderici*	23.42	0.81	3.2	27.43	3
4	*Ficus sur*	8.92	4.5	7.9	21.24	4
5	*Cordia alliodora*	2.64	13.4	4.8	20.77	5
6	*Ficus sur*	1.87	2.85	4.8	16.42	6
7	*Ficus exasperata*	3.22	5.3	7.9	16.36	7
8	*Vernonia amygdalina*	1.11	7.7	6.3	15.23	8
9	*Ficus ovata*	3.58	3.7	6.3	13.69	9
10	*Albizia gummifera*	3.4	1.62	4.7	9.72	10

Table 13: Importance value index (IVI) of top ten ecologically important species of church forest of Sheka Zone (Where: RDM –relative dominance, RD- relative density and RF. - relative frequency)

No	Species	RDM	RD	RF	IVI	Rank
1	*Croton macrostachyus*	18.23	16.32	10.78	45.33	1
2	*Grevillea robusta*	13.95	15.1	7.1	36.15	2
3	*Persea americana*	18.15	7.1	4.27	29.52	3
4	*Eucalyptus camaldulensis*	7.84	10.04	8.55	26.43	4
5	*Vernonia auriculifera*	0.53	9.62	10.78	20.93	5
6	*Syzygium guineense*	14.16	3	2.27	19.43	6
7	*Cordia africana*	10.13	4.6	4.27	19	7
8	*Vernonia amygdalina*	1.69	7.53	7.1	16.32	8
9	*Jacaranda mimosifolia*	7.25	5	2.27	14.52	9
10	*Maesea lanceolata*	0.4	2.5	7.1	10	10

Table 14: Importance value index (IVI) of top ten ecologically important species indigenous sacred urban forest of Sheka Zone (Where: RDM –relative dominance, RD- relative density and RF. - relative frequency)

No	Species	RDM	RD.	RF.	IVI	Rank
1	*Schefflera abyssinica*	53.4	11.05	11.99	76.44	1
2	*Syzygium guineense*	28.07	18.62	11.99	58.7	2
3	*Croton macrostachyus*	3.17	16.29	13.35	32.81	3
4	*Vernonia auriculifera*	0.14	16.88	14.89	31.91	4
5	*Maesea lanceolata*	0.74	9.31	7.4	17.45	5
6	*Ekebergia capensis*	5.69	1.74	4.45	11.9	6
7	*Ilex mitis*	2.67	2.94	5.99	11.6	7
8	*Vernonia amygdalina*	0.52	6.39	4.45	11.36	8
9	*Galiniera saxifiraga*	0.05	2.92	5.99	8.96	9
10	*Schefflera volkensi*	3.07	1.73	2.9	7.7	10

4.1.4 Carbon storage

4.1.4.1Aboveground carbon storage and sequestration

Above ground carbon storage of the three forest patches were, government institution (10.9/ha), Church forest (5.51 t/ha) and indigenous sacred forest (26.7t/ha). The mean carbon storage of the three forest patches were 14 ± 11.01.

4.1.4.2 Aboveground carbon storage of government institution

The aboveground carbon storage in the forest managed by government institution was 10.9 t/ha. With average value of 0.046 t/tree shows, that conserving one woody species or planting one tree can store 0.046 carbons on above ground carbon pools. Overall, this forest has sequestered about 40 t/ha CO_2. The minimum (0.032 t/ha) in plot 4 and the maximum (3.127t/ha) in plot 11 was recorded in the aboveground carbon pools of this forest.

4.1.4. 3 Aboveground carbon storage and sequestration in Church forest

The amount of carbon stored in the aboveground biomass of woody species in church forest was 5.51 t/ha, with average value of 0.023 t/tree. This forest sequestered about 0.084 ton CO_2 per tree on average. The maximum and minimum carbon stored in plot level was 1.25 (plot15) and 0.067 ton in plot 18 respectively.

4.1.4. 4 Aboveground carbon storage and sequestration in indigenous sacred forest

The aboveground carbon storage in indigenous sacred forest was 26.7 t/ha with average value of 0.161 t/tree. A single tree in indigenous sacred forests of the study area, on average, has stored about 0.161-ton carbon. The amount of CO_2 sequestered in this forest patch was about 0.591t/tree. The amount of carbon dioxide sequestered all over the indigenous sacred forest patches of the study site was 97.26 t/ha. Saving a single tree in such forest type will conserve 0.591-ton CO_2 emission from the environment. The minimum (0.067 t/ha) in plot 39 and the maximum (6.83 t/ha) in plot 27 was recorded in the aboveground carbon pools of this forest.

4.1.4.5 Belowground carbon storage in three different forest types under different institutions

4.1.4.6 Belowground carbon storage in government institution forest

The belowground carbon storage in forests managed by Government institutions was 2.15 t/ha. About 7.89 t/ha CO_2 was sequestered. A single tree in government institution can store 0.009-ton carbon in their live root. The minimum and maximum carbon storage in this forest in belowground carbon pool was in plot 4 and 11 with 0.0057 t/ha and 0.626 t/ha respectively.

4.1.4.7 Belowground carbon storage in Church forest

Belowground carbon storage in church forest was 1.03 t/ha. About 3.8 t/ha CO_2 was sequestered due to belowground carbon pool in this forest. The minimum and maximum carbon storage in this forest in belowground carbon pool was in plot 15 and 18 with 0.24 t/ha and 0.013 t/ha respectively.

4.1.4.8 Belowground carbon storage in indigenous sacred forest

The belowground carbon storage in indigenous sacred forest was 5.3 t/ha. From this carbon storage, the fact is 19.451 t/ha, CO_2 is absorbed. The mean carbon storage of tree was 1.99 ± 1.4. The minimum and maximum carbon storage in this forest in belowground carbon pool was in plot 39 and 27 with 1.4 t/ha and 0.0125t/ha respectively

Total live carbon in the study area was calculated by summing up the AGC and BGC of each forest patch. Total aboveground and belowground carbon storage of the study area were 43.12t/ha and 9.41t/ha respectively. The mean of total above and below ground carbon storage were 14.37± 11.01 and 3.14 ± 1.92t/ha respectively. The mean value of above and below ground CO_2 sequestered were 54.04 ± 39.86 and 11.98 ± 7.32 respectively.

The summarized total carbon storage is displayed in table 15. Relatively, indigenous sacred forest of the study area has more carbon storage and sequestration than the two forest managements. This might be due to high DBH and height of individual trees in indigenous sacred sites than government institution and church forests.

Table 15: Live Carbon storage in three-forest management types of urban forest in Masha and Teppi towns

Forest system	AGC/ha	AG CO_2/ha	BGC/ha	BG CO_2	TLC t/ha	TL CO_2 t/ha
Government institution	10.9	43.9	2.15	8.22	13.05	47.64
Church forest	5.51	20.22	1.91	7.3	7.42	27.23
Indigenous sacred forest	26.7	97.99	5.35	20.41	32.05	117.65
Total	43.12	162.11	9.41	35.93	52.4	192.52

Among the 49 woody species, only 10 species have contributed about 88% of total live carbon storage in the study area. *Schefflera abyssinica* has contributed the highest share while *Solanecio mannii* contributed the least in carbon storage in the study area. The high value of *Schefflera abyssinica* is due to the preference of people for honey production and this species is not preferred for other purpose when compared with other species by the community. Araliaceae is the family with the highest carbon storage followed by Myrtaceae. The mean carbon storage of each forest patch in plot level was government institution has a mean of 1.16 ± 0.56, 0.74 ± 0.43 and 0.7 ± 0.35 TLC for church and indigenous sacred forest respectively.

Table 16: Top ten woody species and their family in carbon storage in urban forest of Sheka Zone

No	**Name of species**	**Family**	**AGCt/ha**	**BGCt/ha**	**TLC**	**TL CO_2**
1	*Schefflera abyssinica*	Araliaceae	14.643	2.93	17.57	64.5
2	*Syzygium guineense*	Myrtaceae	9.95	1.99	11.94	43.82
3	*Cordia africana*	Boraginaceae	3.3	0.37	3.67	13.47
4	*Pouteria adolfi-frederici*	Sapotaceae	1.67	0.34	2	7.34
5	*Ekebergia capensis*	Meliaceae	1.913	0.38	2.293	8.42
6	*Grevillea robusta*	Proteaceae	0.923	0.18	1.1	4.04
7	*Persea americana*	Lauraceae	0.5	0.099	0.599	2.2
8	*Croton macrostachyus*	Euphorbiaceae	0.31	0.062	0.372	1.37
9	*Eucalyptus camaldulensis*	Myrtaceae	0.45	0.09	0.54	1.99
10	*Schefflera volkensii*	Araliaceae	0.697	0.139	0.836	3.07
	Total		34.36	6.6	40.92	150.22

4.1.4.5 Variation in live carbon storage

The difference among the three forest management types in live carbon storage was computed by using one-way analysis of variance (ANOVA) (Table 17). Significant statistical difference ($F = 5.207$, $P = 0.01$) within forest types was observed. Tukey's multiple comparison computed and the variation between each forest management were shown in (Table 17).

Table 17: Summary of values of significance for one-way ANOVA between the different forest management for TLC (Where: Df- degree of freedom, F- F statics, and P- p value)

	Sum of Squares	Df	Mean Square	F	P
Between Groups	2.587	2	1.294	5.207	0.010
Within Groups	8.943	36	0.248		
Total	11.530	38			

Table 18: Summary of TLC significance test for one-way ANOVA among each forest management (Where: P- significant level)

(I) forest	(J) forest	Mean Difference (I-J)	Std. Error	P	95% Confidence Interval	
					Lower Bound	Upper Bound
g. institution Church		0.120	0.195	0.813	-0.36	0.60
Church Indigenous		-0.596*	0.195	0.012	-1.07	-0.12
Indigenous institution	g.	0.476	0.195	0.051	0.00	0.95

4.2 Discussion

Woody species composition

The current study prevail different woody species diversity in urban forest management. About 49 woody plant species were recorded from the study site. This was higher than woody species richness in selected church forests of Addis Ababa (Tura and Eshetu, 2017), central public park (Tefera and Soromessa, 2015), but less than Biheretsige Closed Public Park in Addis Ababa recorded by Tefera and Soromessa, (2015).

Urban forests belonging to government institution and Church compounds have 27 species each, while the indigenous sacred forest has 19 species. In terms of density (stem count/ha), the indigenous sacred forest is the least compared to both forests in the compounds of government institution and Churches. The variation is due to forest management difference between institutional, church and indigenous sacred forests, which agrees with Deresse (2017). Moraceae and Rubiaceae were the leading family by three genera and six species and four genera and four species respectively.

Species Diversity, Richness and Evenness

The diversity and distribution analysis showed that the urban forest belonging to government institution has relatively higher diversity and evenness. Government institution forest is better in evenly distribution of species than church and indigenous sacred forest. This higher diversity and evenness of government institution and church forest is due to management and protection difference among three forest patches. Both institutional and church forests have higher woody species diversity compared to Dalomena (Mengistu and Asfaw, 2016), Belete forest (Egiso, 2016), Keja Araba (Yakob and Fikadu, 2016). Among the three forest management types, indigenous sacred forest is the least in species evenness due to more disturbance of the forest compared to the two other forest management types.

The similarity between three-forest managements shows that institutional and church forests share relatively more species with similarity of about 25%, while church and indigenous sacred forests share relatively less number of species with similarity of about 19%. In all cases, the similarity coefficient is below 0.5, indicating that each forest has its own characteristic species (Yakob and

Fikadu, 2016). Nevertheless, similarity between indigenous sacred and institutional forest is lower (ca. 7%). This less similarity between indigenous sacred forests and the two other forest types might be due to altitudinal variation.

Analysis of the Species structure

The total basal area of the urban forests in our study is 35.35 m^2/ha. This result is less than the basal area in semi forest coffee system of Shabe Sombo District (Deresse, 2017) and Gurra Farda (Hundera and Deboch, 2008). This might be due to differences in the level of disturbances (more in urban forest than in semi forest coffee). On the other hand, the basal area of indigenous sacred forest is greater than the basal area reported for semi forest coffee of Shabe Sombo District by Deresse (2017) and nearly equal with Gurra Farda forest (Hundera and Doboch, 2006). The higher basal area for the indigenous sacred forest of our study area is mainly due to the presence of trees of higher DBH. The overall BA of the study area is higher from Adelle and Boditi, (Yinger *et al.,* 2008). Among the tree species in the indigenous sacred forest patch, about 85% basal area was contributed by two species (*Schefflera abyssinica* and *Syzygium guineense*). Seventeen species have contributed only about 15% of basal area per hectare. Due to its location (in the town), other woody species are preferred for firewood, construction, material culture and other purposes.

About 657 (210.6/ha) stems were recorded from all plots across the study area. A forest of government institution was relatively the highest in density (ca.237/ha), which is 37.4% of the total density in the study area. This is because of the strong protection provided by the institution, which does not allow the local community to extract resources freely, while the remaining two have no such strong protection by the government. *Grevillea robusta* is the first in density with 22.4% and *Cordia alliodora* and *Cordia africana* were the second and third with 13.4% and 10.2% density respectively. These trees have been planted in the government institution purposely except few individuals of *Cordia africana* which was naturally growing in the compound and the second was exotic species (has not been included in the Ethiopian flora books). The dominance of these *Grevillea robusta* and two *Cordia* species is purposely because of their multiple importances in the area. One is for their function as a support and shade provision for climbing species of spices; other is to conserve *Cordia africana* from logging. The second density recorded was from church forest, which has good management than indigenous sacred forests. More than

33.3% species in church forest were planted for different purposes. The least density recorded was from indigenous sacred forest with 165/ha and dominated by *Schefflera abyssinica* and *Syzygium guineense* with 19% and 44.4% density respectively. From these we can say that management difference makes density difference.

The frequency analysis showed the variation in species distribution. The most frequent species in institution forest were *Cordial africana, Ficus sur and Ficus exasperata* with about 11%, 8% and 7% respectively. The study conducted by Deresse (2017) on three land use types of Shabe-Sombo district also showed that *Cordia africana* was the most frequent species. In church forest, *Croton macrostachyus* and *Vernonia auriculifera* were the two most frequent species occurring in about 11% of the study plots and the third was *Eucalyptus camaldulensis* occurring in about 9% of the study plots. The frequency of *Croton macrostachyus* was similar with its frequency in Gendo moist montane forest (Gemechu *et al.*, 2015). *Vernonia auriculifera, Croton macrostachyus* and *Schefflera abyssinica* were the species frequently occurring in indigenous sacred forests in about 15%, 13% and 12% of the study plots respectively.

4.2.4 Live biomass and Carbon storage of the study area

The descending order of the three forest categories was indigenous sacred forest, forests of government institution and church forests with 32.4, 13.3 and 7.42 t/ha of live carbon storage respectively. The difference among these three-forest types was statistically significant (P = 0.01). The total carbon storage of the study area 52.52 t/ha and the total CO_2 stored and removed from the atmosphere was 192.75t/ha. Compared to the study conducted on Wenago District (16.66t/ha) Seta and Demissew, (2014) and Sub-Saharan Africa (4.5-19t/ha) Unruh *et al*. (1993), the carbon stored in the woody species biomass in our study is more higher, but less than the carbon storage reported for Shabe Sombo (Deresse, 2017), Biheretsige and central closed public park with AGC of 25.4 t/ha (Tefera and Soromessa, 2015). The main reason for deviation in carbon storage from Biheretsige Park and in the Ethiopian central highland may be due to variation in the allometric equations used and the number of stems inventoried.

When we compare forest management specifically with others' finding, indigenous sacred forest has high AGC (26.5 t/ha) than *Risa Adibarate Entoto Kidist Mariam* (20.03 t/ha) and Yeka Debre Sehil Kidus Micheal (21.13 t/ha) (Tura and Eshetu, 2013). This indicates that indigenous sacred forests have a remarkable contribution in climate change mitigation through carbon sequestration and storage. The indigenous sacred forest of the study area is home for indigenous trees like *Syzygium guineense* and *Schefflera abyssinica, which* have the highest carbon storage than the exotic species recorded from the study area.

5. Conclusions and Recommendations

5.1 Conclusions

The urban forest of Sheka Zone is part of moist Afromontane rain forest of Southwest Ethiopia. Forty-nine species, 43 genera and 27 families with 657 individuals were recorded from Teppi and Masha towns. Government institution and church forests have better species diversity, tree density and richness, while the indigenous sacred forests have lower diversity of species. The population structure indigenous sacred forest shows irregularity of distribution showing the back history of disturbance of the area.

The variation in forest management plays an enormous role in species diversity as well as richness. The highest woody species diversity, evenness and richness in the forests of government institution was due to the control from cutting for timber, deforestation and management and introduction of new species by federal spice institute of Ethiopia Teppi branch. As the management and protection of forests increases the ecological importance of the forest increases. Urban forest has significant contribution in climate change mitigation through carbon sequestration and storage

Indigenous sacred forest patch has a remarkable contribution in woody species conservation and carbon storage. The amount of carbon sequestered and stored in indigenous sacred forest is more than the amount sequestered and stored in the woody biomasses of the two other forest categories.

5.2 Recommendation

Based on the result obtained from the study conducted, the following recommendations have been forwarded.

1. The status of indigenous sacred forest of the area is poor due to selective cutting of plants especially in middle DBH and height class. Therefore, all stakeholders have to work together to conserve this sacred forest path.
2. Each patch of forest in the two towns of Shaka Zone needs protection and good management for its sustainability as a home for biodiversity and plays great role in climate change mitigation through carbon sequestration and storage.
3. Different institutions in urban area should do plantation of forest as part of their strategic plan to play their role in environment protection because urban areas are at risk of climate change.
4. Religious institutions have to focus on selecting environmentally friendly and ecologically important indigenous trees species for their church compounds.
5. This study did not include other carbon pools and hence further study has to be done to make the study complete on the carbon pool of urban forests of Sheka Zone.

6. References

African Climate Change Resilience Alliance (ACCRA), (2012). Climate trends in Ethiopia: Summary of ACCRA research in three sites. https://cdkn.org/resource/climate-trends-in-ethiopia-accra-research-in-three-sites/?loclang=en_gb Accessed on 10 November 2017

Agrarwissenschaften, D. (2017). Urban green spaces enhance carbon sequestration and conserve biodiversity in cities of the Global South case of Kumasi, Ghana. https://www.sciencedirect.com/science/article/pii/S187770581732917X accessed on 21 October 2017.

Alatalo R. V., 1981. Problems in the measurement of evenness in ecology. *Oikos* **37:** 199-204.

Allen, S. E., Grimshaw, H. M. and Rowland, A. P. (1986). Chemical Analysis. In: Moore, P. D. and Chapman, S. B. (eds.), Methods in Plant Ecology. *America, Blackwell Scientific Publications*, pp 285-344.

Anonym (2008). USGS. Carbon Sequestration to Mitigate Climate Change. Available on https://pubs.usgs.gov/fs/2008/3097/pdf/CarbonFS.pdf. Accessed 8 October 2017.

Bhishma, P. S., Shiva, S. P., Ajay, P. and Eak, B. R. (2010). Forest Carbon Stock Measurement: Guidelines for measuring carbon stocks in community-managed forests. Funded by Norwegian Agency for Development Cooperation (NORAD). Asia Network for Sustainable Agriculture and Bio resources (ANSAB) publishing, Kathmandu, Nepal, 17-43. http://ansab.org/wp content/uploads/2010/08/

Bjureby, E., Rochon, E. and Gulowsen, T. (2009). Reality check on carbon storage. http://www.globalislands.net/greenislands/docs/norway or at: www.greenpeace.org/international/ accessed on 11 October 2017

Bogale, T., Datiko, D. and Belachew, S. (2017). Structure and Natural Regeneration Status of Woody Plants of Berbere Afromontane Moist Forest, Bale Zone, South East Ethiopia; Implication to Biodiversity Conservation. *Open Journal of Forestry*. **7:** 352-371.

Bolund, P. and Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics*. **29(**2**):** 293-301.

Brown, S., Gillespie, A. J. R. and Lugo, A. E. (1989). Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest Science*. **35:**881-902.

Cairns, M. A., Brown, S., Helmer, E. H. and Baumgarder, G. A. (1997). Root biomass Allocation is the Worlds Upland Forests. *Oecologia*. **111:** 1-11.

Central Statistical Agency (CSA), 2013. Population Projection of Ethiopia for All Regions At Wereda Level from 2014 – 2017. pp 118.

Ciais, P. C., Sabine, G., Bala, L., Bopp, V., Brovkin, J., Canadell, A. and Chhabra, R. (2013). Carbon and Other Biogeochemical Cycles. In Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, T.F. Stocker, D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (edd). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. 465-570. http://www.oalib.com/references/15765990 accessed on 25 October 2017

Cicerone R. J and Nurse S. P. (2010). Royal Society, Climate Change: A Summary of the Science. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, Solomon, S., Qin D., Manning M., Chen Z., Marquis M., Averyt K. B., Tignor M. and Miller, H. L. (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.(pp.19) ipcc.ch/publications_and_data/ar4/wg1/en/contents.html accessed on 23 October 2017.

Chen, Y., Liu, Z., Rao, X., Wang, X., Liang, C., Lin, Y., Zhou, L., Cai, X. and Fu, S. (2015). Carbon storage and allocation pattern in plant biomass among different forest plantation stand in Guangdong, china. *Forests.* **6:**794-808.

Choi, H., Lee, W. and Byun, W. (2012). Determining the Effect of Green Spaces on Urban Heat Distribution Using Satellite Imagery. **6(2):** 127-135.

Conway, D., Schipper, L., Yesuf, M., Kassie, M., Persechino, A. and Kebede, B. (2007) Reducing vulnerability in Ethiopia: addressing the implications of climate change: integration of results from Phase I UK. University of East Anglia, Overseas Development Group 38pp.

Denu, D., Platts, P. J., Kelbess, E., Tadesse, T .W. and Marchant R. (2016). The role of traditional coffee management in forest conservation and carbon storage in the Jimma Highlands, Ethiopia. *Journal of Forests, Trees and Livelihoods*. **25(4):** DOI: 10.1080/14728028.2016.1192004

Dube, T., Mutanga, O., Adam, A. and Ismail, R. (2014). Intra-and-Inter Species Biomass Prediction in a Plantation Forest: Testing the Utility of High Spatial Resolution Space borne

Multispectral Rapid Eye Sensor and Advanced Machine Learning Algorithms. *Sensors* **14:** 15348-15370; DOI: 10.3390/s140815348

Elmqvist, T., Zipperer, W. C. and neralp, B. G. (2016). Urbanization, Habitat Loss and Biodiversity Decline Solution Pathways to Break the Cycle. Available on: https://www.srs.fs.usda.gov/pubs/ja/2016/ja

Escobedo, F. J., Kroeger, T. and Wagner, J. E. (2011). Urban forests and pollution mitigation: analyzing ecosystem services and disservices. *Environmental pollution.* **159:** 2078–87.

European Environmental Agency (EEA) (2008). Climate Change and Development Adaptation Measures, Addis Ababa: Ethiopian Economic Association.

Gann, S. B. (2003). A Methodology for Inventorying Stored Carbon in an Urban Forest. Msc. thesis Falls Church, Virginia. https://www.researchgate.net/publication/33762833

Geider, R., Delucia, E., Falkowski, P. G., Finzi, A. C., Grime, P., Grace, J *et al*, 2001.primary productivity of planet earth: biological determinnts and physical constraints in terrestrial and Aquatic habitats. *Global change biology* **7:** 849-882.

Gemechu, T., Soromessa, T and Kelbessa E. (2015). Structure and Regeneration of Gendo Moist Montane Forest, East Wellega Zone, Western Ethiopia. *Journal of Environment and Earth Science*. **5 (15):** 148-168.

Gondo, T. (2012). Spatial Planning and Open Space Integration in Urban Ethiopia: a Sustainable Accessibility Exegesis. SCHRENK, M., POPOVICH, V. V., ZEILE, P. and Elisei, P. (Editors).

Hagem, Cathrine and Holtsmark, B. (2004). Kyoto Protocol: Insignificant Impact on Global Emissions. In V. Grover, I, ed. Climate Change Five Years after Kyoto. pp. 53–68.

Hansen, J. M., Sato, P. Kharecha, D., Beerling, R., Berner, V. (2008). Target atmospheric CO_2: Where should humanity aim? *Open Atmos. Sci. J.*, **2:** 217-231.

Heath, L. S., Smith, J. E., Skog, K. E., Nowak, D. J. and Woodall, C. W. (2011). Managed forest carbon estimates for the U.S. Greenhouse Gas Inventory, 1990 to 2008. Journal of Forestry. 167- 173. **doi**:10.1.1.546.2756.

Hoe, S., Matsuoka, Y., Simson, J. and Gomi, K. (2013). "Low carbon urban development strategy in Malaysia The case of Iskandar Malaysia development corridor , Habitat International. **37:** 43-51.

Hooke, R., J., Martín-Duque, J. F. and Pedraza J. (2012). "Land transformation by humans: A review."*GSA Today*no. **22(12):**1-10.

Houghton, R. A. (2007). "Balancing the global carbon budget". Annual Review of Earth and Planet.Sci. **35:** 313-347. doi: 10.1146/annurev.earth.35.031306.140057

Hundera, K., Bekele, T. and Kelbessa, E. (2007). Floristic and Phylogeographic Synopsis of a Dry Afromontane Coniferous Forest in Bale Mountains, Ethiopia: Implication to Biodiversity Conservation. SINET: Ethiopian Journal of Science. 3**0:** 1-12

IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IPCC (2014). Climate change 2014: synthesis report. In: Core Writing Team, Pachauri, R. K., Meyer, L.A. (Eds.), Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, p. 51-151.

Jim, C. Y. and Chen, W. Y. (2009). Ecosystem services and valuation of urban forests in China Cities. *Journal of Cities.* **26:** 187–194.

Kanniah, K. D. and Siong, H. C. (2017). Urban Forest Cover Change and Sustainability of Malaysian Cities. *Chemical Engineering Transactions.* **56:** 673-678.

Kent, M. and Coker, P. (1992). Vegetation description and analysis: A practical approach, Belhaven press, London, UK.

Kindt R and Coe R. (2005). Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies. Nairobi: World Agroforestry Centre (ICRAF).

Kiss, M., Takács, Á., Pogácsás, R. and Gulyásá, A. (2015). The role of ecosystem services in climate and air quality in urban areas: Evaluating carbon sequestration and air pollution removal by street and park trees in Szeged (Hungary). *Moian Geographical Reports.* **23:**36-46

Kiran, G. S. and Kinnary, S. (2011). Carbon sequestration by urban trees on roadsides of Vadodara city. International Journal of Engineering Science and Technology. **3(4):** 3066–3070.

Kim, G. (2016). Assessing Urban Forest Structure, Ecosystem Services and Economic Benefits on Vacant Land. *Journal of Sustainability.* ***8*****:** 679; **DOI:** 10.3390/su8070679

Konijnendijk, C. C., Annerstedt, M., Nielsen, A. B., Maruthaveeran, S. (2013). Benefits of Urban Parks A systematic review A Report for IFPRA. Copenhagen and Alnarp. 70 p.

Legesse, Y. (2010).Assessment of the distribution and spread of invasive alien plant species with major emphasis on *mimosa invi sa mart*.ex Colla in the high lands of Ethiopia: the case of south western zones of Oromia and SNNPRS. MSc. Thesis Addis Ababa University, Addis Ababa.

Lynch, J. M., and Whipps, J. M. (1990). Substrate flow in the rhizosphere. *Plant and Soil.* **129:** 1-10.

MacDicken, K. G. (1997). A Guide to Monitoring Carbon Storage in Forestry and Agro-forestry Projects. In: Forest Carbon Monitoring Program. Win rock International Institute for Agricultural Development, Arlington, Virginia. http://planvivo.org/docs/2015/05/Winrock

McKinney, M. L. 2008. Effects of urbanization on species richness: A review ofplants and animals. *U1ba11 Ecosystems* 11(2): 161-176.

McPherson, E. G., Van Doorn, N. S. and Peper, P. J. (2016). Urban Tree Database and Allometric Equations. *United States Department of Agriculture.* **DOI:** 10.13140/RG.2.2.35769.98405.

McSweeney, C., New, M., Lizcano, G. and Lu, X. (2010). Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries. Bulletin of the American Meteorological Society. **91(2):** 157-167.

Montagnini, F. D., Cusack, P. B. and Kanninen, M. (2005). Environmental Services of Native Tree Plantations and Agro forestry Systems in Central America. *Journal of Sustainable Forestry.* **21(1):** 51-67

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York. 547

Nolan, K. A. and Callahan J. E. (2006). Beachcomber biology: The Shannon-Weiner Species Diversity Index. Pages 334-338, *in* Tested Studies for Laboratory Teaching, Volume 27 (O'Donnell M. A., Editor). Proceedings of the 27th Workshop (Conference) of the Association for Biology Laboratory Education (ABLE), 383 pages.

Nowak, D. J. (1994b). Understanding the structure of urban forests. Journal of Forestry. **92(10):** 36–41.

Nowak, D. J., Rowntree, R .A, McPherson, E. G., Susan, M. S., Esther, R., Kerkmann, A. and Stevens J. C. (1996). Measuring and analyzing urban tree cover. *Landscape and urban planning.* **36:**49-57.

Nowak, D. J. and Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. Environmental Pollution. **116:** 381-389.

Nowak, D. J. (2004). Assessing environmental functions and values of veteran trees. In: Nicolotti, G, and P. Gonthier (eds). Proc. of the International Congress on the Protection and Exploitation of Veteran Trees. Regione Piemonte and Universitadi. *USDA Forest Service.* **5:** 45–49.

Nowak, D. J., Crane, D. E., Stevens, J. C., Hoehn, R. E., Walton, J.T., Bond, J. (**2008**). A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services. *Arboric. Urban For.*, ***34*:** 347–358.

Nowak, D. J., Greenfield, E. J., Hoehn, R. E. and Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community. *Environmental pollution.* **178:** 229-236

Pegasys Institute and Ethio Resources Group (2017). The Climate Change and Energy Debate in Ethiopia. Available at http://www.citiesalliance.org. Accessed 10 December 2017.

Phillips, O., Baker, T., Feldpausch, T. and Brienen, R. (2009). RAINFOR field manual for plot establishment and remeasurement. Available on: http://www.rainfor.org/upload/ManualsEnglish/RAINFOR.accessed on 5 January 2018.

Pragasan, L. A. and Karthick, A. (2013). Carbon Stock Sequestered by tree plantations in University campus at Coimbatore, India. *International journal of environmental science*. **3(5):**1700-1710.

Rasineni, G. K., Guha, A. and Reddy, A. R. (2011). Responses of Gmelinaarborea, a tropical deciduous tree species, to elevated atmospheric CO_2: growth, biomass productivity and carbon sequestration efficacy. Plant science : International journal of experimental plant biology. **181(4):** 428–38.

Ricketts,T.H. 2001.The matrix matters: effective isolation in fragmented landscapes. *American Natumlist* **158:** 87-99

Roy, S., Byrne, J. and Pickering, C. (2012). A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban Forestry and Urban Greening. **11(4):** 351–363.

Seto K. C., Dhakal, A., Bigio, H., Blanco, G. C., Delgado, D., Dewar, L., Huang, A., Inaba, A., Kansal, S., Lwasa, J. E., McMahon, D. B., Müller, J., Murakami, H., Nagendra, H. and Ramaswami, A. (2014). Human Settlements, Infrastructure and Spatial Planning. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc.accessed on 12 October 2017.

Seta, T. and Demissew, S. (2017). Diversity and standing carbon stocks of Agroforestry trees in Wenago District, Ethiopia. International Journal of Agroforestry and Silviculture. **4 (1):** 246-256.

Sheka Zone Finance and Economic Development annual Statistical Abstract (2013/14).

Shepherd, D. and Montagnini, F. (2001). Above ground carbon sequestration potential in mixed and pure tree plantations in the humid tropics. *Journal of Tropical Forest Science* **13(3):** 450-459.

Shikur, E. T. (no year). Challenges and problems of urban forest development in Addis Ababa, Ethiopia. Available at: https://www.forestry.gov.uk/pdf/Trees-people-and-the-buit accessed on October 15/2017.

Strand, A. E., Pritchard, S. G., McCormack, M. L., Davis, M. A., and Oren, R. (2008). Irreconcilable differences: Fine-root life spans and soil carbon persistence. *Science.* **319:** 456-458.

Swarup, A., Dankelman, I., Ahluwalia, K. and Hawrylyshyn, K. (2011). *Weathering the storm: Adolescent girls and climate change,* s. l.: Plan UK. Available on http://research3.fit.edu/sealevelriselibrary/documents/doc_mgr/389/

Tesfaye, G., Teketay, D., and Fetene, M. (2002). Regeneration of 14 Tree Species in Harenna Forest, Southeast Ethiopia. *Flora*. **197:**461-474. Accessed on 5 November 2017.

Tefera, M. and Soromessa, T. (2015). 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.* **5(13):** 1-15 http://www.iiste.org/Journals/index.php/JEES/article/viewFile/24115/24685. Accessed on 7 November 2017.

Tura, T., T. and Eshetu, Z. (2013). Estimation of carbon stock in church forests: implication for managing church forest to help with carbon emission reduction. **DOI:** 10.1007/978-3-642-37753-2_30

Ugle, P., Rao, S. and Ramachandra T. V. (2010). Carbon sequestration potential of urban trees. *Wetlands, Biodiversity and Climate Change.* Available at: *http://www.ces.iisc.ernet.in/energy/lake2010/Theme%201/prachi_u.p* accessed on 21 October 2017.

UNFCCC (2007). Climate change: Impacts, vulnerabilities and adaptation in developing countries. Available on https://unfccc.int/resource/docs/publications/impacts.accessed on 21 September 2017

UN (2014). World Urbanization Prospects. The 2014 Revision. Accessed on 16 November 2017 https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf

Vashum, K. T. and Jayakumar, S. (2012). Ecosystem and Ecography Methods to Estimate Aboveground Biomass and Carbon stock in Natural Forests. A Review. **2(4):** 2157-7625.

Velasco, E., Roth, M., Norford, L. and Molina, L. T. (2015). Does urban vegetation enhance carbon sequestration? *Landescape and urban planning.* **148:** 99-107.

Vieilledent, G., Vaudry, R., Andriamanohisoa, S. F. and Rakotonarivo, O. S. (2012). "A universal approach to estimate biomass and carbon stock in tropical forests using generic allometric models," Ecological Applications. **22(2):** 572–583.

Wang, W., Wei, X., Liao W., Blanco, J. A. and Liu Y. (2013). Evaluation of the forest management strategies on carbon sequestration in evergreen broad – leaved plantation forest using Forecast ecosystem model. Forest ecology and management. **300:** 21-32.

Watson, R. T., Noble, I. R., Bolin, B., Ravindranath, N. H., Verardo, D. J., Dokken, D. J. (2000). Land Use, Land-Use Change, and Forestry. Intergovernmental Panel on Climate Change (IPCC), Special report. Cambridge University Press, UK. pp. 375.

Woldemariyam T., and Fetene M., 2007. Forests of Sheka: ecological, social, legal and economic dimensions of recent land use or land cover changes, overview and synthesis. *In* Masresha Fetene (ed.), multidisciplinary case study on impact of land use or land cover changes, south west Ethiopia, MELICA Ethiopia, Addis Ababa. PP. 1-20.

Woodbury, P. B., Heath, L. S. and Smith, J. E. (2006). Land use change effects on forest carbon cycling throughout the southern United States. Journal of environmental quality. **35(4):** 1348–1363.

World Bank (2015). World Development Indicators Washington DC: 3. License: Creative Commons Attribution CC BY 3.0 IGO. DOI: 10.1596/978–1-4648– 0440–

Yakob, G. and Fekadu, A. (2016). Diversity and Regeneration Status of Woody Species: The Case of Keja Araba and Tula Forests, South West Ethiopia. Open Access Library Journal. **3:** 2576.

Yanchun Y., Ma S., Guan, W. and Li, K. (2017). An Empirical Study on the Relationship between Urban Spatial Form and CO2 in Chinese Cities. Yigitcanlar, T. (editor). *Sustainability,* **9:** 672. **Doi:** 10.3390/su9040672

Yineger H., Kelbessa, E., Bekele ,T. and Lulekal, E. (2008). Floristic composition and structure of the dry Afromontane forest at bale mountains national park, Ethiopia. *SINET: Ethiop. J. Sci.* **31(2):**103–120.

Yong, S. M., Miah, D. M. and Lee, K. H. (2007). Potential contribution of the forestry sector in Bangladesh to carbon sequestration. Journal of environmental management. **82(2):**260–76.

Zegeye, H., Teketay, D. and Kelbessa, E. (2011). Diversity and Regeneration Status of Woody Species in Tara Gedam and Abebaye Forests, Northwestern Ethiopia. *Journal of Forestry Research*, **22:** 315-328.

Zhang, C. (2012). Impacts of urbanization on carbon balance in terrestrial ecosystems of the Southern United States. *Environmental pollution*. **164:**89–101

7. Appendices

Appendix 1: Scientific Names, Local names and the family of inventoried woody species from the study area

No	Scientific Name	Local name	Family	Habit
1	*Albizia gummifera* (J.F.Gmel.) C.A.sm.	C ato(sh1)	Fabaceae	T
2	*Annona senegalensis* Pers.	Gishit t a(Amh)	Annonaceae	T
3	*Antiaris toxicaria* Lesch.	Tengi (Mgr, sh2)	Moraceae	T
4	*Bersama abyssinica* Fresen.	Book o(sh1)	Melianthaceae	T
5	*Brucea antidysenterica* J. F. Mill.	Nuqaasho(sh1)	Simaroubaceae	T
6	*Canthium oligocarpum* Hiern	C ochi-aafo(sh1)	Rubiaceae	T
7	*Carica papaya*	Papaya(sh1)	Caricaceae	T
8	*Celtis africana* N.L.Burm.f	Gonji(Mgr)	Ulmaceae	T
9	*Citrus sinensis* (L.) osb	Burtukano(sh1)	Rutaceae	T
10	*Coffea arabica* L.	Buno(sh1)	Rubiaceae	T
11	*Cordia africana* lam.	Dı o	Boraginaceae	T
12	*Cordia alliodora*	Wuc h waniza(Amh)	Boraginaceae	T
13	*Croton macrostachyus* Del.	Shomo(sh1)	Euphorbiaceae	T
14	*Diospyros abyssinica (*Hiern) F.white	Kuri(Mgr)	Ebenaceae	T
15	*Ekebergia capensis* Sparrm.	Ororo(Sh1)	Meliaceae	T
16	*Erythrina abyssinica* Lam.	Bero(Sh1)	Fabaceae	T
17	*Eucalyptus camaldulenes* Dehnh.	C ela barizafo(Sh1)	Myrtaceae	T
18	*Eucalyptus viminalis*	wuc hi Barzafi(Amh)	Myrtaceae	T
19	*Ficus exasperata* Vahl	Balantay (Mgr)	Moraceae	T
20	*Ficus ovata* Vahl	Ac ha (Sha2)	Moraceae	T
21	*Ficus sur.* Forssk.	Et o(Sh1)	Moraceae	T
22	*Ficus vasta* Forssk.	Warika (Amh)	Moraceae	T
23	*Galiniera saxifraga (*Hochst) Bridson	Diido(Sh1)	Rubiceae	T
24	*Grevillea robusta* R.Br	Giravilea (sh1)	Proteaceae	T
25	*Hippocratea goetzei* loes.	T ero(Sh1)	Celastraceae	Vine
26	*Ilex mitis* (L.) Radlk.	Qeto(sh1)	Aquifoliaceae	T

27	*Jacaranda mimosifolia*	Jacaranda(Sh1)	Bignoniaceae	T
28	*Juniperus procera* Hochst.ex Endl.	T ido(Sh1)	Cupressaceae	T
29	*Justicia schimperiana (*Hochst.ex Nees)T.Anders.	Shesharo(Sh1)	Acanthaceae	Sh
30	*Lepidotrichilia volkensii(*Gurke) Leroy	Shaayo(sh1)	Meliaceae	T
31	*Macaranga capensis(*Baill.) Benth	Werango(sh1)	Euphorbiaceae	T
32	*Mallotus oppositifolius (*Geisel) Muell.Arg.	Birekechi (Mgr)	Euphorbiaceae	T
33	*Mangifera indica* L.	Manigo(Sh1)	Anacardiaceae	T
34	*Measa lanceolata*	C ego(Sh1)	Myrsinaceae	T
35	*Millettia ferruginea subsp.darassana* (Hochst.) Bak.	Yaago(Sh1)	Fabaceae	T
36	*Mytenus gracilipes(*welw. Ex Oliv.)	Attatto(sh1)	Celastraceae	Sh
37	*Pavetta abyssinica* Fresen.	Qorbadaro (Sh1)	Rubiaceae	T
38	*Persea americana* Mill.	Avocado(Sh1)	Lauraceae	T
39	*Pouteria adolfi-friederici* (Engl.)Baehni	Shao(Sh1)	Sapotaceae	T
40	*Prunus africana*	Oomo(Sh1)	Rosaceae	T
41	*Schefflera abyssinica* (Hochst.ex A.Rich.) Harms	Manijo(Sh1)	Araliaceae	T
42	*Schefflera volkensii (*Engl.) Harms	Qero(Sh1)	Araliaceae	T
43	*Solanecio manni* (Hook.f.) C.jeffrey	Ekibelo(Sh1)	Asteraceae	T
44	*Syzygium guineense*	Yino (Sh1)	Myrtaceae	T
45	*Trichilia dregeana* Sond.	Luya (Sh1)	Meliaceae	T
46	*Trilepsium madegascariense* Dc.	Gebo(Mgr)	Moraceae	T
47	*Vernonia amygdilina* Del.	Giraawo(Sh1)	Asteraceae	T
48	*Vepris dainelli (pichi-serum.)* kokwaro	Merigat t o(Sha1)	Rutaceae	T
49	*Vernonia auriculifera*	Denigirato(Sh1)	Asteraceae	Sh/T

Appendix 2: families and the genera and species they constitute (%- percentage)

No	**Family**	**No of genera**	**(%)**	**No of sepecie**	**(%)**	**No**	**Family**	**No of genera**	**(%)**	**No of sepecie**	**(%)**
1	Rubiaceae	4	9.52	4	8.16	15	Myrsinaceae	1	2.32	1	2.04
2	Moraceae	3	7.14	6	12.24	16	Cuperasaceae	1	2.32	1	2.04
3	Euphorbiac eae	3	7.14	3	6.12	17	Annonaceae	1	2.32	1	2.04
4	Fabaceae	3	7.14	3	6.12	18	Aquifoliaceae	1	2.32	1	2.04

5	Meliaceae	3	9.52	3	8.16	19	Bignoniaceae	1	2.32	1	2.04
6	Myrtaceae	2	4.76	3	4.08	20	Simaroubaceae	1	2.32	1	2.04
7	Asteraceae	2	4.76	3	6.12	21	Melianthaceae	1	2.32	1	2.04
8	Rutaceae	2	4.76	2	4.08	22	Caricaceae	1	2.32	1	2.04
9	Araliaceae	2	4.76	2	4.08	23	Anacardiaceae	1	2.32	1	2.04
10	Celastraceae	2	4.76	2	4.08	24	Acanthaceae	1	2.32	1	2.04
11	Boraginaceae	1	2.32	2	4.08	25	Ulmaceae	1	2.32	1	2.04
12	Proteaceae	1	2.32	1	2.04	26	Rosaceae	1	2.32	1	2.04
13	Lauraceae	1	2.32	1	2.04	27	Myrsinaceae	1	2.32	1	2.04
14	Ebenaceae	1	2.32	1	2.04						

Appendix 3: BA, BA/ha, RDM, the top ten ranked species of institutional forest in Sheka Zone, 2018. (BA-basal area, BA/ha-basal area per hectare, RDM-relative dominance

No	Species	BA	BA/ha	RDM	No	Species	BA	BA/ha	RDM
1	*Cordia africana*	6.253	6.0125	24.47	*15*	*Eucalyptus camaldulines*	0.205	0.19	0.76
2	*Pouteria adolfi-friedric*	6.102	5.87	23.42	*16*	*Persea americana*	0.328	0.32	1.22
3	*Grevelea robusta*	2.881	2.77	10.71	*17*	*Milletia ferrugnia*	0.366	0.35	1.36
4	*Ficus sur*	2.4	2.31	8.92	*18*	*Vernonia amygdalina*	0.298	0.29	1.11
5	*Ficus ovata*	0.963	0.93	3.58	*19*	*Coffea arabica*	0.077	0.07	0.27
6	*Antiars toxicaria*	0.92	0.88	3.42	*20*	*Trichilia dragenea*	0.152	0.15	0.57
7	*Albizia gummifera*	0.915	0.88	3.4	*21*	*Trilepisum madegascariense*	0.078	0.075	0.29
8	*Ficus exasperate*	0.864	0.83	3.22	*22*	*Mallotus oppstifolius*	0.005	0.004	0.02
9	*Diospyrous abyssinica*	0.789	0.76	2.93	*23*	*Solanecio mannii*	0.022	0.02	0.08
10	*Canthium oligocarpium*	0.249	0.24	0.36	*24*	*Perunus africana*	0.515	0.49	1.91
11	*Croton macrostachyus*	0.058	0.056	0.22	*25*	*Citris sinensis*	0.035	0.033	0.13
12	*Ficus vasta*	0.489	0.47	1.87	*26*	*Celtius africana*	0.329	0.32	1.22
13	*Cordia alliodora*	0.71	0.68	2.64	*27*	*Vepris dainelli*	0.12	0.11	0.45

14	*Eucalyptus viminalis*	0.336	0.32	1.25

Appendix 4: BA, BA/ha, RDM, of top ten species of urban Church forest of Sheka Zone in 2018. (BA-basal area, BA/ha-basal area per hectare, RDM-relative dominance)

No	Species name	BA	BA/ha	RDM	No	Name species Species	BA	BA/ha	RDM
1	*Crotton macrostachyus*	2.084	2	18.23	15	*Ficus ovata*	0.949	0.913	5.11
2	*Persea americana*	3.37	3.24	18.15	16	*Ficus sur*	0.169	0.163	0.91
3	*Syzsgium guineense*	2.629	2.53	14.16	17	*Annona senegalensis*	0.095	0.091	0.51
4	*Grevillea robusta*	2.589	2.5	13.95	18	*Vernonia auiriculifera*	0.098	0.094	0.53
5	*Cordia africana*	1.88	1.81	10.13	19	*Maesea lanceolata*	0.075	0.072	0.4
6	*Eucalyptus camaldulense*	1.455	1.39	7.84	20	*Pavetta abyssinica*	0.024	0.023	0.13
7	*Jaccaranda mimosifolia*	1.35	1.29	7.27	21	*Ilex mitis*	0.147	0.141	0.79
8	*Ficus ovata*	0.949	0.91	5.11	22	*Brucea antidysentrica*	0.004	0.0038	0.02
9	*Albizia gummifera*	0.451	0.43	2.43	23	*Bersama abyssinica*	0.003	0.0028	0.02
10	*Vernonia amygdalina*	0.315	0.3	1.69	24	*Diospros abyssinica*	0.004	0.003	0.02
11	*Coffea arabica*	0.026	0.025	0.14	25	*Carica papaya*	0.039	0.038	0.21
12	*Juniperus procera*	0.168	0.162	0.91	26	*Mangifera indica*	0.073	0.07	0.39
13	*Trichilia dragenea*	0.088	0.085	0.47	27	*Antiaris toxicaria*	0.006	0.0057	0.03
14	*Ficus exasperata*	0.188	0.181	1.01					

Appendix 5: BA, BA/ha, RDM, urban traditionally sacred forest of Sheka Zone (BA-basal area, BA/ha-basal area per hectare, RDM-relative dominance)

No	Species name	BA	BA/ha	RDM	No	Species name	BA	BA/ha	RDM
1	*Schefflera abyssinica*	36.77	35.36	53.4	11	Vernonia auiriculifera	0.095	0.091	0.14
2	*Syzygium guineense*	19.33	18.58	28.07	12	Hippocratea goetzei	0.051	0.05	0.07
3	*Ekebergia capensis*	3.92	3.78	5.69	13	Galinera saxifiraga	0.037	0.035	0.05
4	*Croton macrostychus*	2.185	2.1	3.17	14	Maytenus gracilipes	0.004	0.0038	0.006

5	*Schefflera volkensii*	2.117	2.04	3.07	15	Pavetta abyssinica	0.002	0.0019	0.003
6	*Ilex mitis*	1.841	1.77	2.67	16	Brucea antidysentrica	0.004	0.0038	0.006
7	*Maesea lanceolata*	0.505	0.48	0.74	17	Justicia schimperiana	0.005	0.0048	0.007
8	*Bersama abyssinica*	0.414	0.39	0.6	18	Macaranga capensis	0.007	0.0067	0.01
9	*Vernonia amygdlina*	0.352	0.34	0.52	19	Lepidotrichilia volkensi	0.002	0.0019	0.003
10	*Canthium oligocarpum*	0.249	0.24	0.36					

Appendix 6: Relative dominance, Relative density, Relative frequency and important value index of church forest of Sheka Zone

No	**Species**	**RDM**	**Rdens**	**Rfre**	***IVI***	**Rank**
1	*Croton macrostachyus*	18.23	16.32	10.78	45.33	1
2	*Grevillea robusta*	13.95	15.1	7.1	36.15	2
3	*Persea americana*	18.15	7.1	4.27	29.52	3
4	*Eucalyptus camadulinesis*	7.84	10.04	8.55	26.43	4
5	*Vernonia auriculifera*	0.53	9.62	10.78	20.93	5
6	*Senegalensis guineense*	14.16	3	2.27	19.43	6

7	*Cordia africana*	10.13	4.6	4.27	19	7
8	*Vernonia amygdalina*	1.69	7.53	7.1	16.32	8
9	*Jacaranda mimosifolia*	7.25	5	2.27	14.52	9
10	*Albizia gummifera*	2.43	4.6	4.27	11.3	10
11	*Maesea lanceolata*	0.4	2.5	7.1	10	11
12	*Cordia africana*	0.14	4.6	4.29	9.03	12
13	*Ficus ovata*	5.11	0.42	1.65	7.18	13
14	*Ficus exasperata*	1.01	1.3	2.79	5.1	14
15	*Annona senegalis*	0.51	1.7	2.79	5	15
16	*Ficus vasta*	1.34	0.84	2.79	4.97	16
17	*Mangifera indica*	0.39	0.84	2.79	4.02	17
18	*Ilex mitis*	0.79	0.84	2.27	3.9	18
19	*Ficus sur*	0.91	1.3	1.65	3.86	19
20	*Juniperus procera*	0.91	1.3	1.65	3.86	19
21	*Trichilia dragenea*	0.47	0.84	1.65	2.96	21
22	*Carica papaya*	0.21	0.42	1.65	2.28	22
23	*Pavetta abyssinica*	0.13	0.42	1.65	2.2	23
24	*Antiaris toxicaria*	0.03	0.42	1.65	2.1	23
25	*Brucea antidysentrica*	0.02	0.42	1.65	2.09	24
26	*Bersama abyssinica*	0.02	0.42	1.65	2.09	24
27	*Diospyrus abyssinica*	0.02	0.42	1.65	2.09	24

Appendix 7: Relative dominance, Relative density, Relative frequency and important value index of traditionally sacred forest of Sheka Zone

No	Species	RDM	Rdens	Rfre	*IVI*	Rank
1	*Schefflera abyssinica*	53.4	11.05	11.99	76.44	1
2	*Syzygium guineense*	28.07	18.62	11.99	58.7	2
3	*Croton macrostachyus*	3.17	16.29	13.35	32.81	3
4	*Vernonia auriculifera*	0.14	16.88	14.89	31.91	4
5	*Maesea lanceolata*	0.74	9.31	7.4	17.45	5
6	*Ekebergia capense*	5.69	1.74	4.45	11.9	6

7	*Ilex mitis*	2.67	2.94	5.99	11.6	7
8	*Vernonia amaygdalina*	0.52	6.39	4.45	11.36	8
9	*Galinera saxifiraga*	0.05	2.92	5.99	8.96	9
10	*Schefflera volkensi*	3.07	1.73	2.9	7.7	10
11	*Hippocratea goetzeoles*	0.07	4.65	1.55	6.27	11
12	*Bersama abyssinica*	0.6	1.74	2.9	5.24	12
13	*Brucea antidysentrica*	0.006	1.16	2.9	4.1	13
14	*Macaranga gracilipes*	0.006	1.16	1.55	2.72	14
15	*Justchia schimperiana*	0.007	1.16	1.55	2.72	14
16	*Canthium oligocarpum*	0.36	0.58	1.55	2.49	16
17	*Macaranga capensis*	0.01	0.58	1.55	2.14	17
18	*Pavetta abyssinica*	0.003	0.58	1.55	2.133	18
19	*Lepidotrichilia volkensi*	0.003	0.58	1.55	2.133	18

Appendix 8: Relative dominance, Relative density, Relative frequency and important value index of institutional forest of Sheka Zone

No	**Species**	**RDM**	**Rdens**	**Rfre**	***IVI***	**Rank**
1	*Cordia africana*	24.47	10.22	11.1	45.79	1
2	*Grevilea robusta*	10.71	22.4	6.4	39.51	2
3	*Pouterea adolfi friderici*	23.42	0.81	3.2	27.43	3
4	*Ficus vasta*	8.92	4.5	7.9	21.24	4
5	*Cordia alliodora*	2.64	13.4	4.8	20.77	5
6	*Ficus sur*	1.87	2.85	4.8	16.42	6
7	*Ficus exasperata*	3.22	5.3	7.9	16.36	7
8	*Vernonia amaygdalina*	1.11	7.7	6.3	15.23	8
9	*Ficus ovata*	3.58	3.7	6.3	13.69	9
10	*Millitea ferrugnea*	1.36	2.43	3.1	6.86	10
11	*Albizia gummifera*	3.4	1.62	4.7	9.72	11
12	*Diospyrous abyssinica*	2.93	2.03	3.1	8.06	12
13	*Cofea arabica*	0.27	4.56	3.1	7.93	13
14	*Eucalyptus viminalis*	1.25	4.56	1.65	7.46	14
15	*Antiars toxicaria*	3.42	0.81	3.1	7.33	15
16	*Persea americana*	1.22	0.81	3.1	5.13	16
17	*Croton macrostachyus*	0.22	1.22	3.1	4.54	17
18	*Celtis africana*	1.22	1.22	1.65	4.09	18
19	*Eucalyptus camaldulnes*	0.76	1.62	1.65	4.03	19
20	*Prunus africana*	1.91	0.41	1.65	3.97	20
21	*Vepris dainelli (pichi-serm.) kokwaro*	0.45	1.62	1.65	3.72	21
22	*Erythrina abyssinica*	0.13	2.03	1.65	3.81	22
23	*Trichilia dragenea*	0.57	0.81	1.65	3.03	23
24	*Solanecia mannii*	0.08	0.81	1.65	2.54	24
25	*Mallotus opposfolia*	0.02	0.81	1.65	2.48	25
26	*Cetris sinensis*	0.13	0.41	1.65	2.13	26
27	*Trilepsium madagascariense*	0.29	0.39	1.65	2.33	26

Appendix 9: All plant species and their family as well as their carbon storage in urban forest of Sheka Zone

No	Name of species	Family	AGC t/ha	BGC t/ha	TLC	$TLCO_2$
1	*Schefflera abyssinica*	Araliaceae	14.643	2.93	17.57	64.5
2	*Syzygium guineense*	Myrtaceae	9.95	1.99	11.94	43.82
3	*Cordia africana*	Boraginaceae	3.3	0.37	3.67	13.47
4	*Pouteria adolfi-frederici*	Sapotaceae	1.67	0.34	2	7.34
5	*Ekebergia capensis*	Meliaceae	1.913	0.38	2.293	8.42
6	*Grevillea robusta*	Proteaceae	0.923	0.18	1.1	4.04
7	*Persea americana*	Lauraceae	0.5	0.099	0.599	2.2
8	*Croton macrostachyus*	Euphorbiaceae	0.31	0.062	0.372	1.37
9	*Eucalyptus camaldulensis*	Myrtaceae	0.45	0.09	0.54	1.99
10	*Schefflera volkensii*	Araliaceae	0.697	0.139	0.836	3.07
11	*Maesea lanceolata*	Myrsinaceae	0.084	0.017	0.101	0.371
12	*Vernonia auiriculifera*	Asteraceae	0.0134	0.0027	0.016	0.059
13	*Vernonia amygdalina*	Asteraceae	0.0905	0.0185	0.11	0.404
14	*Bersama abyssinica*	Melianthaceae	0.122	0.0244	0.15	0.54
15	*Canthium oligocarpum*	Rubiaceae	0.098	0.0196	0.1176	0.432
16	*Hippocratea goetzei*	Celastraceae	0.0179	0.0036	0.022	0.079
17	*Ilex mitis*	Aquilifoliaceae	0.605	0.121	0.726	2.664
18	*Galinera saxifiraga*	Rubiaceae	0.0041	0.0006	0.005	0.02
19	*Maytenus gracilipes*	Celastraceae	0.0005	0.0001	0.0006	0.0022
20	*Lepidotrichilia volkensi*	Meliaceae	0.0006	0.00003	0.00063	0.0023
21	*Brucea antidysentrica*	Simaroubaceae	0.000843	0.00008	0.00092	0.0034
22	*Justcia schimperiana*	Acanthaceae	0.0005	0.0001	0.0006	0.0022
23	*Macaranga capensis*	Euphorbiaceae	0.0008	0.0002	0.001	0.004
24	*Pavetta abyssinica*	Rubiaceae	0.0075	0.0014	0.0089	0.033
25	*Ficus sur*	Moraceae	0.583	0.12	0.703	2.58
26	*Ficus vasta*	Moraceae	0.172	0.0344	0.2064	0.757
27	*Ficus exasperata*	Moraceae	0.26	0.051	0.311	1.14
28	*Erythrina abyssinica*	Fabaceae	0.0376	0.0075	0.045	0.166

29	*Ficus ovata*	Moraceae	0.604	0.121	0.725	2.661
30	*Eucalyptus viminalis*	Myrtaceae	0.133	0.027	0.16	0.59
31	*Cordial alliodora*	Boraginaceae	0.072	0.0142	0.086	0.32
32	*Milletia frruginea*	Fabaceae	0.134	0.027	0.161	0.591
33	*Coffea arabica*	Rubiaceae	0.0143	0.0029	0.02	0.063
34	*Celtis africana*	Ulmaceae	0.0424	0.0085	0.051	0.187
35	*Albizia gummifera*	Fabaceae	0.635	0.122	0.757	2.78
36	*Malltous oppositifolius*	Euphorbiaceae	0.0004	0.00008	0.0005	0.002
37	*Vepris dainelli*	Rutaceae	0.0021	0.00052	0.003	0.0096
38	*Diospyros abyssinica*	Ebenaceae	0.33	0.066	0.396	1.45
39	*Trichilia dragenea*	Meliaceae	0.066	0.013	0.079	0.289
40	*Solanecio manni*	Asteraceae	0.00021	0.00003	0.00024	0.0009
41	*Trilepsium madegascariense*	Moraceae	0.03	0.006	0.036	0.132
42	*Citerus sinensis*	Rutaceae	0.004	0.0008	0.005	0.018
43	*Prunus africana*	Rosaceae	0.204	0.041	0.245	0.899
44	*Antiaris toxicaria*	Moraceae	0.24	0.047	0.287	1.053
45	*Juniperus procera*	Cuperessaceae	0.076	0.0152	0.0912	0.335
46	*Jacaranda mimosifolia*	Bignoniaceae	0.135	0.027	0.162	0.595
47	*Annona senegalensis*	Annonaceae	0.0162	0.00324	0.019	0.0713
48	*Mangifera indica*	Anacardiaceae	0.00874	0.002	0.011	0.04
49	*Carica papaya*	Caricaceae	0.0043	0.00086	0.0052	0.09