ABOVE GROUND BIOMASS AND SOIL CARBON STOCK ESTIMATION OF WOODY SPECIES IN URBAN RELIGIOUS AREA OF HAWASA CITY ALONG AGE GRADIENT

MSc. THESIS

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WONDO GENET,ETHIOPIA

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We, the undersigned, members of the board of the Examiners of the final open defense by Alembeju kifle have read and evaluated his thesis entitled *''*Above ground biomass and soil carbon stock estimation on selected urban religious areas forest based on an age gradient, Hawassa City Administration, Ethiopio.*''* and examined the candidate's oral presentation. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Masters in forest resource assessment and monitoring...

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Abbreviations/Acronyms

AGB Above-Ground Biomass

BA Basal Area

BGB Below-Ground Biomass

CBD Convention on Biological Diversity

DBH Diameter at Breast Height

EFAP Ethiopian Forestry Action Plan

EMA Ethiopian Mapping Authority

EOTC Ethiopian Orthodox Tewahido Churches

GHGs Green House Gasses

GPS Global Positioning System

IPCC Intergovernmental Panel on Climate Change

IUCN International Union for Conservation of N ture and Natural Resources

MEA Millennium EcosystemAssessment

NBSAP National Biodiversity Strategy and Action Plan

UNEP United Nations Environmental Program

UNFCCC United Nations Framework Convention on Climate Change

The USEPA United States Environmental Protection Age groupncy

SCB Secretariat of the Convention on Biological Diversity

TCD Total carbon densit

Abstract

A study was conducted to investigate above ground biomass and soil carbon stock of religious compounds in diferent age groups of Hawasa city adminstration, Ethiopia. First taking a list of religious compounds from Hawasa city adninstration 54 compounds were recorded, then by using age group of compounds as criteria for classifying in to three age groups, ten religious compounds from different religion types were selected in a stratified random sampling. The strata were three age groups of compounds , those 50 and above years,age group one,those 30-50 years old ,age group two, and those below 30 years represent age group 3. Biomass and twenty three plots for soil samples All woody species DBH ≥5cm and height at1.30 cm were measured by caliper and digital tap meter from 36 plots. and soil samples were collected from 23 plots and relationships between religious compounds age group and tree parameters in each compounds (ACD, BCD.SOC), along age group of religious compounds) was (218.60 ±43.523 193.98±65.07 176.0±102.9), (58.83.±35.86, 50.44±16.92 50.29±33),(105.96±21.62, 94.37±26.17, 106.05±33.6) age group 1,age group 2,age group 3 respectively .The mean amount of ecosystem carbon stock contained in in different religious forest of study area was 351±26.7 tons/ha. A total of 32 woody species belonging to 18 families were identified, of which 59.6% were exotic whereas the remaining 40.4% were native. There was no significant difference (Above ground carbon stock and soil carbon stock among age groups, however compound age group showed positive significant relationship with, carbon stock and, but not with soil carbon, and. Over all results confirmed that the religious forest of Hawasa city stored high above ground, and remarkable soil, carbon were accumulating over the years. Thus forests in different religious compounds were playing indispensable role in carbon sequestration in different carbon pools, the purpose of the study was to determine the effect of age group of religious compounds on amount of carbon density in different carbon pools

Key words: religious forest, religious compounds. Carbon sequstration climate change,

INTRODUCTION

1.1. Background and justification

Global climate change is an environmental problem in today's modern world and a wide spread concern that has led to extensive international discussions and negotiations because of the colossal threat and risks of global weather patterns, global warming, natural disaster, loss of biodiversity, rise of oceans, the existence of future human life on planet (Streck and Free stone,2009). This is mainly caused by anthropogenic green house gas emissions of carbon dioxide,burning of fossil fuels, deforestation, and emission of other greenhouse gas (IPCC, 2000;IPCC,2003; Penman *et al*., 2003; IPCC, 2007; IPCC, 2014). Concern about this issue investigate innovative methods that can be used for a sink of greenhouse gasses effect (Capturing carbondioxide) is one of the primary global focuses to the reduction of green house gas (IPCC, 2007;IPCC, 2014). It is a mechanism of capturing and strongly storing carbon dioxide (green house gas) from the atmosphere (IPCC, 2000). To achieve this, mitigation and adaptation are complementary approaches for reducing risks of climate change impacts over different time scales (IPCC, 2014).

To mitigate the effects of climate change, more comprehensive understanding of stand structural diversity and Carbon sequestration capacity within forest ecosystems (Bosworth *et al*., 2008).Ethiopian Orthodox Tewahido Churches (EOTC) is an indigenous, integral Christian Church of Africa and the most ancient churches in the world (Aerts*et al*., 2016). There is a long history of planting, protecting and preserving old age groupd trees in churchs and monastries (Abiyou Tilahun *etal*., 2015; Aerts*et al*., 2016). Thus forest resources around churches are important for biodiversity conservation and mitigating climate change (Alemayehu Wasie *et al*., 2010). Assessing the dynamics of this resource is very important to assist policy maker, monitoring and better implement protection strategies (puumalainen*et al*., 2003)

1.2. Statement of the problem

Urban forests are relatively rich in biodiversity and great role in maintaining micro climate balances, prevention of desertification, increasing water percolation and waste water treatments (Alvey, 2006). Church compounds and other sacred places are valuable for *in-situ* and *ex-situ* biodiversity conservation (Aerts s*et al*., 2016). Mainly indigenous trees and shrubs of Ethiopia give prestige to the religious sites (Alemayehu *et al*., 2005). It is one of the forest manage groupment practices that increase carbon sequestration and contributes to climate change mitigation (FAO, 210). Church forest is now the refuge for remaining forest resources that canbe considered as in situ biodiversity conservation (Alemayehu *et.al*, 2007). Intensifying this indigenous knowledge for biodiversity conservation, climate change mitigation and urban greening option is very important (Tulu Tolla, 2011). However,Ethi opia does not have carbon stock data base to monitor and enhance carbon sequestration potential of different forests. Similarly, only small efforts have been done so far to assess the carbon stock evaluation in urban religious forest that helps to manage the forests sustainably from the ecological, economic and environmental points of view for the welfare of human society besides their spiritual cultural aesthetic value.

In response to this problem, the purpose of this study was to quantify Carbon stock of urban religious forests in aboveground biomass and soil organic carbon pool. This will help to bridge the current research gap in carbon related study in urban religious forests, and give relevant information for local or city administration, policy makers and other organization focused on urban conservation and management.

1.3. Objectives of the study

1.3.1. General objective

To estimate the amount of carbon stock potential of selected religious forests in Hawasa city along age group

1.3.2. Specific objectives

- To estimate carbon stock potential in standing aboveground biomass and soil of woody species in the study area
- To determine and evaluate the relation between above ground biomass an soil carbon stocks, and age groups of religious forests.

1.4. Research question

The study will be answering the following research questions:

- ✓ How much the carbon stock potential of selected religious forest areas?
- ✓ Is there significance difrence on carbon stock amounts along age group of selected religious forests?

1.5. Significance of the study

As several litrature indicates, EOTC has considerable protected forests of Ethiopia. However, a carbon sequestration potentials of these forests including other religious compounds have not been studied so far .particularely no study has been done with regard to muslim compounds . Thus, available information on this area is lacking in the country. As a result, the country couldn't benefit from carbon trade schemes available in UNFCCC. This research is expected to fill this knowledge gap and open door for future researchers in this area by providing relevant base line information on carbon sequestration potential of religious compounds forests in the country. Also it will give information for policy makers regarding the management value of forests, amount of stock, and rates of changes in urban religious compounds.

2. LITRATUR REVIEW

2.1 .Concept and definition

2.1.1. Urban forestry

According to Jiban *et al*. (2013), urban forestry is a specialized branch of forestry,which means planting and managing trees for the environmental, physiographical and economic well being of urban areas, or for aesthetic beautification of urban landscapes. Also Pradeep *et al*. (2011) added that urban forestry is defined as the art ,science and technology of managing trees and forest resources in and around urban community in order to provide for society physiological, sociological, economic and aesthetic benefits. Most of the time people consider urban Public Park as only street trees and ornamental woody plants. However, the urban public park is a complex system of trees and smaller plants, wildlife, associated organisms, soil, water and airquality in and around a city (Meseret, 2013).

An urban public park includes road sides,walkways, city squares, private gardens, cemeteries,church yards, school yards, and trees in home land scapes and any where else (Margaret, 2008; Eyob, 2010). At present urban public parks get more attention in developing countries, especially in Ethiopia *(*Margaret, 2008). However, Ethiopia has one of the largest urbanization rates (about 4-5%) in the world, and its urban population is expected to increase from15% in 2000 to almost 30% in 2030 (UN Population Division, 2004). The population of Hawasa is exponentially growing. According to Zeleke and Serkalem (2007), private house residence, road and industrial sites occupy about 3.99 %, 0.12% and 5.92% of the total land area, respectively. Open recreational area (0.46%), institutional sites (7.39%) and religious sites (0.98%) are some of the other types of land uses occupied the town Water body (Lake Hawassa) of the city accounts for 94 km^2.

Urbanization at a rapid pace is a reality at present (Rama, 2013). Urbanization, in the developing world is frequently accompanied by the deterioration of the urban environment. Especially, this phenomenon in Ethiopia has been associated with environmental problems in most cities, including Hawassa Among the problems are urban sprawl, solid and liquid waste manage groupment; water, air, and noise pollution; illegal settlements and the degradation of open green areas (Thomas, 2013). Properly planned and managed urban green areas can solve the problems such as:water, air, and noise pollution, illegal settlements, and the degradation of open green areas. It improve the quality of urban life in various ways, by providing tangible (food, energy, timber, fodder) and social benefits (health, employment) to meet local needs as well as important environmental services.

2.1.2. The Benefits of urban forests

Urban forestry besides urban greening in developing countries is an important contributory factor in the cities for environmental enhancement, control of air and noise pollution, micro climatic modification and recreational purposes of the urban population (Rama, 2013; IUFRO, 2014). In addition, urban forestry benefits can be varying in time and according to the developmental stage of urban public parks in different countries. For example, indeveloped countries, a prime focus in the past was management of the urban forest for aesthetic purposes. Whereas now, forests have multiple functions in today's society as urban populations have grown, and expanded, urban public parks are managed for enhancing ecosystem services including biodiversity conservation, removal of atmospheric pollutants, oxygen generation,noise reduction, mitigation of urban heat island effects, micro climate regulation, stabilization of soil, ground water recharge,prevention of soil erosion, and carbon sequestration (Vijai *et al*., 2010). In developing countries, a more important focus may be managing vegetation to provide materials, such as firewood, fruit and timber, at very local scales (Margaret, 2008). However, enhancing material and environmental quality benefits on urban climate, energy use, CO_2 emissions and water flow in at both the neighborhood and broader city scales urban forestry has a significant role (Eyob, 2010; Pauleit and Duhme, 2000).

In Ethiopia, energy balance is dominated by biomass fuels (firewood, charcoal, branches, leaves and twigs, agricultural residues and cow dung) which are the main source of energy to both urban and rural areas. Of the total biomass energy supply,about 86% is derived from woody biomass. Ninety three percent (93%) of woody biomass is used for meeting household energy needs for cooking and heating,especially in Addis Ababa. Biomass fuels remain the most important fuel source forthe urban population, despite now a days easier access to modern energy sources. It has also been shown that the urban household consumption accounts for almost 70% of the charcoal consumption in Ethiopia (Arnold, 2003). Over time, each city and region manage its urban forest for an increasingly broader and more inclusive range of benefits. However, the benefits are frequently over looked in developing country such as Ethiopia, ecosystem services urban Public Park such asair and water purification, waste detoxification and decomposition of organic matteror offsetting carbon dioxide in the atmosphere, soil protection, and carbon absorption,cultural & aesthetic values (Kuchelmeister and Park, 2000).

2.1.3. Urban Forest Contribution to Climate Change Mitigation in Ethiopia

Forestry mitigation options include reducing emissions from deforestation and forest degradation, enhancing the sequestration rate in existing and new forests. Properly designed and implemented forestry mitigation options have substantial co-benefits in terms of employment and income generation opportunities, biodiversity and water shed conservation, provision of timber and fibber, as well as aesthetic and recreational services (IPCC, 2007). Rapid urbanization increased motorization and economic activity, which leads to increased air pollution. Emissions from mobile sources are said to be the principal contributors to urban air pollution and it is becoming a serious health and environmental threat.

In Ethiopia, assessment of carbon stock potential of forest begun in recent years.However, UGI contribution in climate change mitigating value further has not yet studied well. Valuing such forest is at a premature level. The result made from the assessment of carbon Stock Potentials of Church forest in Addis Ababa by Tullu Tola, (2011) indicated that urban forests have a contribution to climate change mitigation and their mean value of above ground biomass carbon stock was 129.85t ha^{-1},.another study conducted in Addis Ababa church forests by Getaw Yilma ,(2016) indicated that mean carbon stock contained within each church forest was 147.5±26.7 metric t/ha In developing and tourist attraction cities like Hawassa, air pollutants are released by rapidly expanding vehicle fleets. Poor/or lack of regulatory frame work specific to vehicular hous hold wastes and industrial emissions can also be taken as a set of contributing factor for urban air pollution (Daniel *et al*., 2010). Thus UGI enhances stabilization of this pollution and helps to mitigate its impacts. In this regard, the Hawassa City administration has a clear vision to make the city a safe and effective tourist centre for rregional as well as national economic growth.

Therefore, urbanization is one of the cause for city environmental pollution. Parikh *et al.(* 1994) reported that carbon emissions are much higher in urban, consumerist societies than rural, and biomass dependent land scapes.The direct or indirect consumption of each resource including food items,manufactured goods, energy, transport, durable goods, fuel etc. was converted to the carbon emitted during the production and consumption of that resource.

2.1.4. Potential of EOTC for biodiversity conservation and climate change Mitigation and adaptation

Church and monastery forests did not come into existence by mere chance; it is by the commitment and effort of the holy fathers and mothers based on a strong theological basis and biblical thoughts. According to the prominent church scholars Alemayehu Wassie, (2002) including the Archbishop and the Holy Scriptures of the church (The Holy Bible, King James Version), the main theological bases and religious perspective in conserving forest resources were stated as; the Church on the earth signifies and symbolizes the new heaven, the holy city, New Jerusalem coming down from God out of heaven, prepared as a bride, adorned for her husband. Thus, it should have the same resemblance and appearance as the Eden heaven was. The Holy Bible states about Eden as "And the Lord God planted a garden east-ward in Eden; and there he puts the man whom he had formed. And out of the ground made the lord God to grow every tree that is pleasant to the sight, and good for food.And a river went out of Eden to water the Garden; and from thence it was parted, and became in to four heads. " (Genesis 2: 8-10). Therefore, the church like Eden was beautified with many plants, animals and other organisms and the holy water/streams infinitely had been surpassing from these forests that was believed as proceeding out of the throne of God. When the first man was placed in Eden there was a task given for him along with the freedom and pleasure he had. That task was conservation and development of nature as "And the Lord God took the man, and put him in to the Garden of Eden to dress it and to keep it" (Genesis 2: 15). The EOTC followers who are supposed to be the generations of Adam and children of God should respect and exercise this dictate at least in the church compound if not possible in the whole landscape (Alemayehu Wassie, 2002).

The Ethiopian Orthodox Tewahido Church has long history of planting, protecting and preserving of trees. If a traveler can see a patch of indigenous old age trees in the northern highlands of Ethiopia, most probably he/she can be sure that there is an Orthodox Church in the middle. Although the main purpose of churches is as places for worship, burials and meditating religious festivals, they also provide valuable and secured habitats for plants and animals, as well as micro organisms and green spaces for people to rest the stressed mind (Taye Bekele, 1998; Alemayehu Wassie, 2002 and Asseged and Taye unpublished).

Church compounds are the monasteries of trees and other biodiversity resources where one can animate trees escaped from being destroyed forever under the shelter of the church value and esteem. Many indigenous trees and shrubs, which in some places were destroyed completely over the last century, are still found standing in the compounds of remote rural churches (Taye Bekele 1998),there fore the value of religious compounds is paramount important to be focused in climate change mitigation strategy

2.1.5. The potential of urban public parks in Carbon sequestration

Carbon sequestration is the capture and storage of carbon that would otherwise be remain in the atmosphere and enhance the green house effect process (Houghton *et al.*,1996). Forests can act as sink through the process of trees growth and resultant biological carbon sequestration. Thus, increasing the amount of trees can potentially slow the accumulation of atmospheric carbon (Brown, 2002; Fearnside and Laurance, 2003; 2004; Houghton, 2005). During productive season, carbon dioxide from the atmosphere is taken up by vegetation and stored as plant biomass. However, when forests are cleared or degraded, their stored carbon is released into the atmosphere as carbon dioxide (Fearnside and Laurance, 2004; Houghton, 2005).

Although urban areas continue to expand, urban Public Park is not expanding inparallel. Re gardless of its significant role in environmental quality only little is known about this resource. As urban public parks both sequester CO_2, and affect the emission of CO_2 from urban areas, urban forests can play a critical role with regard to the carbon cycle and associated climate variability (Nowak and Crane, 2002). Trees moderate the amount of carbon dioxide in the atmosphere through the process of photosynthesis. Carbon that re-mains locked up in trees from year to year is referred to as carbon storage. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue. As Prachi *et al*. (2010), one tone of carbon storage in the tree therefore represents removal of 44/12 or 3.67 tons of CO_2e (carbon dioxide equivalent) from the atmosphere, and the release of 2.67 tons of oxygen back into the atmosphere.Therefore, the urban trees also remove large amounts of air pollutants tha t consequently improve urban air quality. Few studies indicated that 600 trees in the tropics would fill one acre, which could sequester up to 15 tons of CO_2 annually Nowak (1994) other statistics include 40 trees could sequester one tone of CO_2 each year; and that one million trees covering 1,667acres could capture 25,000 tones of CO_2 annually. For example, in South Africa115,200 indigenous street trees planted during the period 2002–2008. Between these years it has been estimated that the tree planting would result in 200,492 tons CO_2 equivalent reduction and that 54,630 tones carbon would be sequestrated. However when the urban trees are young the standing carbon stock is not substantial, there fore,the growth of the trees represents a potential increase in biomass and hence carbon sequestration is dependent on the growth rate.

2.2 Biomass and Carbon Stock in Forests

2.2.1. Biomass Stock in Forests

Forests act as a sink through the process of tree growth and resultant biological carbon sequestration for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass (Nowak and Crane, 2002). Biomass assessments illustrate the amount of carbon that may be sequestered by trees. FAO (2004a), defined biomass as"organic material both above-ground and below-ground, and both living and dead, e.g.,trees, crops, grasses, tree litter, roots etc." Above-ground biomass consists of all living biomass above the soil including stem, stump, branches, bark, seeds, and foliage group. Below-ground biomass consists of all living roots excluding fine roots (less than 2 mm in diameter). In forest biomass studies, two biomass units are used, fresh weight (Araujo, *et al*.,1999) and dry weight (Ketterings *et al*., 2001; Aboal *et al*., 2005; Montagu *et al*,2005; Saint-Andre *et al*., 2005). For carbon sequestration application, the dry weightis more relevant because 50% of it is carbon (Montagnini and Porras, 1998; Losi *etal*., 2003; Montagu *et al*., 2005). Many biomass assessment studies conducted are focused on above-ground forest biomass (Brown, 1997; Kraenzel *et al*., 2003; Laclau,2003; Losi *et al*., 2003; Aboal *et al*., 2005; Segura and Kanninen, 2005) because it accounts for the majority of the total accumulated biomass in the forest ecosystem. Biomass is an important indicator in carbon sequestration there fore estimating the biomass in trees is the first step in carbon accounting (Prachi *et al*., 2010).u (2006) mentioned three approaches to biomass assessment. These are field measurement, remote sensing, and GIS-based approach. The field measurement is considered to be accurate (Lu, 2006) but proves to be very costly and time consuming (DeGier, 2003). In any of these approaches, ground data is important for validation. Two methods of measuring sample tree biomass are available: (1) destructive and (2) non-destructive. Direct or destructive method of tree biomass involves felling an appropriate number of trees and estimating their field- and oven-dry weights, (Zianisand Mencuccini, 2004; Saint – Andre *et al.*, 2005) a method that is accurate however it is impractical. Rather than performing destructive sampling all the time in the field,n alternative method (non- destructive) can be used that predicts biomass given some easily measurable predictor variable, such as "tree diameter" and "height" can be used Many studies were conducted to develop biomass equation that relates dry biomass ofrees to its biophysical variables (e.g. diameter-at-breast height (DBH), tree height)(Brown, 1997; Ketterings *et al.*, 2001; Zianis and Mencuccini, 2004; Aboal, 2005; Cole and Ewel, 2006; Arevalo, 2007) and basal area.Therefore an estimate of the vegetation biomass can provide us with information about the nutrients and carbon stored in the vegetation as a whole. To measure the biomass of vegetation which includes trees is not easy, especially in mixed, uneven-aged stands. Thus, it is hardly ever possible to measure all biomass on a sufficiently for large sample area by destructive sampling.

2.2.2. The Forest Carbon Pools

Carbon pool is a system which has the capacity to accumulate or release carbon. According to the IPCC report (2006), carbon pools in forest ecosystems comprises of carbon stored in the living trees: Above-ground, Bbelow-ground (roots),leaf litter, dead wood and soil organic matter.

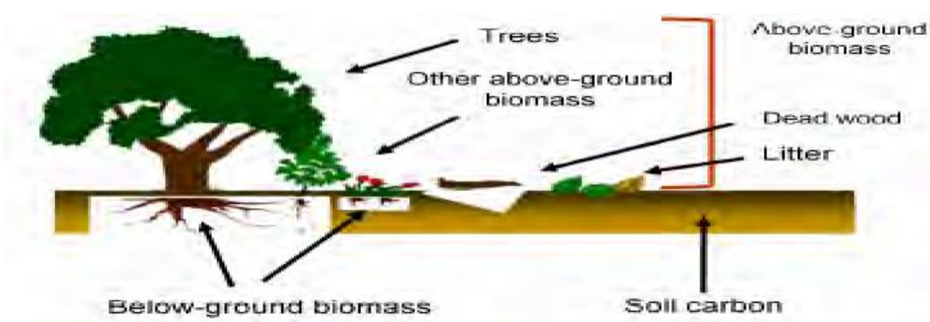

Figure 1 the carbon dioxide by fixed plants during photosynthesis is transferred across the different carbon pools. (Source: USAD-CIFOR-ICRAF Project, 2009)

The above-ground biomass of a tree constitutes the major portion of the carbon pool.It is the most important and visible carbon pool of the terrestrial forest ecosystem(Ravindranath, *et al.*, 2008). Any changes in the land use system like forest degradation and deforestation has a direct impact on this component of the carbon pool.The below-ground biomass which constitutes all the live roots (Eggleston *et al.*2006) plays an important role in the carbon cycle by transferring and storing carbon in the soil. The dead mass of litter and woody debris are not a major carbo n pool as they contribute merely a small fraction to the carbon stocks of forests (Ravindranath, *et al.*2008).Soil organic matter is also a chief contributor to the carbon stocks of forests Kumar *etal.* (2006) next to the above-ground biomass and soils are a major source of carbon emissions following deforestation. Generally, the estimated biomass components are the aboveground live biomass which includes the trees and shrubs excluding the roots, dead biomass like litters and fallen branches or stem, and the below-ground biomass which comprise of the roots.

2.2.3. Carbon Storage and Sequestration

Climate change is an issue of global concern. Trees can help mitigate climate change by sequestering atmospheric carbon in tissue. Carbon dioxide can be controlled by reducing energy use in buildings, and consequently reducing carbon dioxide emissions from fossil-fuel based power plants (David *et al*., 2013). Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new tissue growth every year. The amount of carbon annually sequestered is increased with healthier trees and larger diameter trees (Nowak *et al*., 2010). According to McHale *et al*. (2007), mature tree size (large >15 m, medium = 10–15 m, small <10 m) and tree type (evergreen vs. deciduous), directly control the maximum potential carbon storage; larger growing trees contain more biomass and generaly half of biomass is carbon .Also as GOFC-GOLD (2010), carbon stocks vary by forest type, for example tropical pine forests have a different stock than tropical broad leaf forests which again have different stock than woodlands or mangrove forests. Even within broad leaf tropical forests, stocks are varying greatly with elevation, rainfall and soil type. Then even within a given forest type in a given location the degree of human disturbance leads to further differences in stocks.for this reason the UNFCC and its Kyoto Protocol recognized the role of forests in carbon sequestration. Specifically, Article 3.3 and 3.4 of the Kyoto Protocol pointedout forest as potential carbon storage (Brown, 2002; United Nations, 1998).

According to Yitebitu Moges *et al*. (2010), at a national level, forest inventories, woody biomass assessments and scientific research can prove useful data for acquisition of forest carbon accounting. In this context the forest resources of Ethiopia store an estimated 2.76 billion tons of carbon, playing a significant role in the global carbon balance.The largest store of carbon in the country is found in the woodlands (45.7 %) and theshrub lands (34.4 %), while the high forests store about 16%. Another report estimated that the national carbon stocks 2.5 billion tons of carbon in 2005 (Sisay *et al*., 2009). However, despite their great potential in influencing carbon balance, these vegetation types are largely neglected in forest related discussions, including carbon negotiations. Carbon storage by trees is another way trees can influence global climate change. As trees grow, they store more carbon by holding it in their accumulated tissue. As trees die and decay, they release up to 80 % of the stored carbon back to the atmosphere (McHale *et al*., 2007).

Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees keep the carbon stored in trees.

When trees die, utilizing the wood in long-term wood products or tohelp heat buildings or produce energy help reduce carbon emissions from wood composition.

2.3 .Guidance and tools for forest carbon accounting

2.3.1. IPCC Guidelines

The IPCC has provided a number of guidance documents for national GHG emission inventories. One of such guide lines is the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2000) that offers guidance on methodologies and carbon accounting processes. In 2006, the IPCC consolidated this information into a single Agriculture, Forestry and Other Land Use (AFOLU) (IPCC, 2006). This AFOLU represents the integration of the agriculture sector with the LULUCF sector, providing a more complete and neat carbon accounting frame work. The IPCC recognizes trade-offs to be made between cost accuracy and precision of carbon accounting and provides a three-tiered specification of methods, parameters and data sources. IPCC guidance is comprehensive and represents a good source of default and regional data parameters. However, the content of the guide line is dense and not simple to navigate. Less opaque forest carbon accounting guidance documents exist in Pearson *et al.,* 2005, although much of this litrature is focused on accounting for projects rather than at a larger scale or national scale for carbon stock or carbon emissions accounting. As a leading inter-governmental scientific body for the assessment of climate change, the IPCC is in the foremost position to form the basis of any future accounting guidance under an international climate change convention. Hence countries need to develop their own carbon monitoring accounting guide lines considering local capacity while meeting international standards.

2.3.2. Carbon Accounting Tools

Under the UNFCCC, developed countries are obliged to conduct carbon accounting inventories in the land use sector, inclusive of forests. For this purpose and for project emission reductions accounting, a number of tools and models have become available. Produced by national governments, international organizations and research institutions, these vary in geographical coverge, forest activities and carbon pools included, and the level of detail required for the model parameters.

Largely, in developed countries, a number of forest carbon accounting models exist. For instance, from the United States: COLE, the Carbon On-Line Estimator, The Center for Urban Forest Research Tree Carbon Calculator (CTCC), FORCARB and the Landscape Manage ment System (LMS). From the 27 United Kingdom: CARBINE, C-Flow and C-Sort. From Europe: the European Forest Information Scenario model (EFI-SCEN). However, these tools are genage grouplly applicable only to forests of the nation, or region, in which they have been developed and are thus limited in application. Other tools which are developed in Canada is applicable over wider geographical areas is $CBM\text{-}CFS_3$.

Further broad forest carbon-inventory models include CO_2 FIX and Graz/Oak Ridge Carbon Accounting Model (GORCAM). The version 3 of CO_2 FIX has detailed modules for biomass, soil, wood products and bio-energy, as well as modules for finance and carbon accounting. These models assume relatively homogenous forest stands in terms of vegetation structure, growth dynamics and species composition. GORCAM, also a stand-level accounting model, considers changes of carbon in biomass, reduction of carbon emissions due to replacement of fossil fuels or energy-intensive materials, carbon stored in wood products, and the recycling and burning of waste wood (Marland & Schlamadinger, 2003).

More complex models, in which growth is driven by simulating photosynthesis, also exist for example CENTURY (Methage groupll *et al.*, 1993), which simulates carbon, nutrient and water dynamics for ecosystems; Physiological Principles Predicting Growth (3PG); and Bio-Geochemical Cycles (BIOME-BGC), which simulates net primary productivity for multiple biomass pools. However, the detail of parameters required mean that these models are best suited to very small scale accounting applications.

Further models have evolved purely for forestry project carbon accounting, AR in particular. TARAM, developed by the Bio-Carbon Fund of the World Bank and the Forma Project, for example, assists in the application of AR methodologies approved for use in CDM projects. Environment and Community based framework for designing aforestation, reforestation and re-vegetation projects in the CDM (ENCOFOR), developed by the World Agro forestry Centre, is similar in aim, but has the additional objective of maximizing environment and local benefits in developing countries.

The other methods developed for carbon accounting is Bilan Carbone which developed by the French for the Environment and Energy Manage groupment (ADEME) together with the Interministerial Mission on the Greenhouse Effect, is a tool for commercial and service companies to establish their carbon balances. Although designed for the business and tertiary sector, it is being developed and extended by UNDP to include LULUCF and to be applied in developing countries. The Bilan Carbone approach is based on activity data and utilizes average emission factors. The rapid assessment methodology aims to provide orders of magnitude in GHG emissions rather than accounting for project emission reductions or to give stock accounting estimates: the main goal is to instigate action to reduce GHG emissions by assessing relevant sectors.

The development of the LULUCF sector within the Bilan Carbon toolkit represents a pragmatic first step towards forest carbon accounting in territories, especially those in developing countries where forest inventory data is rare or sparse. As a spreadsheet model, rather than a closed programmed model, it allows both flexibility and transparency in forest carbon accounting with scope to develop, validate and calibrate parameters to better reflect local conditions. It also provides a starting point for ongoing forest inventories by highlighting the sources of data required, aiding in the planning of new surveys and providing basic accounting guidance for the LULUCF sector. There is a Global and regional level data valuable for forest carbon accounting. International land-use and land cover datasets exist, largely from remote sensing imagery, although image resolution and the accuracy of ground-referenced data are generally limited. Sources of data include international experts, international organizations publishing statistics, such as the United Nations and OECD, and international scientific journals. In particular, the FAO Forest Resources Assessment, the IPCC Agriculture, Forestry and Other Land Use (AFOLU) inventory guidance volume (IPCC, 2006), and FAO's primer for estimating biomass (Brown, 1997) all provide parameter information that can be used in carbon accounting. The IPCC recognizes that trade-offs exist and so presents a multi-tiered approach to emissions accounting. Three levels of detail with differing mathematical specification of methods, information requirements and sources of activity data are offered to estimate net emissions.

Generally, Tier 1 reporting requires very little primary data collection to generate estimates of forest biomass. IPCC guidance reports a number of parameters and emission factors that can be applied, based on region-specific climate and vegetation data. With the use of such default parameters, the uncertainty in accuracy is inevitably large; further more, not all carbon pools and GHGs are accounted for. Tier 2 also utilizes default forest biomass information, but in combination with country-specific data. Tier 3 uses highly detailed localized data, often with repeated measures of permanent forest sample plots. With increasing data requirements and analytical complexity from Tier 1 to Tier 3, the accuracy and precision of the carbon estimate also increases. In order to verify or improve the quality of carbon accounting estimates, and for project-level accounting, remote sensing data and field measurements tend to be required. Growing acceptance that the environmental benefits of forests extend beyond traditional ecological benefits and include the mitigation of climate change (Sathaye and Andrasko, 2007).The main carbon pools in tropical forest ecosystems are the living biomass of trees and understory vegetation and the dead mass of litter, woody debris and soil organic matter.

Thus, estimating aboveground forest biomass carbon is the most critical step in quantifying carbon stocks and fluxes from tropical forests (Westlake, 1966). The most direct way to quantify the carbon stored in above ground living forest biomass is to harvest all trees in a known area, dry them and weigh the biomass. While this method is accurate for a particular location, it is prohibitively time-consuming, expensive, destructive and impractical for country-level analyses. No methodology can yet directly measure forest carbon stocks across a landscape. Consequently, much effort has gone into developing tools and models that can 'scale up' or extrapolate destructive harvest data points to larger scales based on proxies measured in the field or from remote sensing instruments (Brown *et al*., 1989 and 1993; Brown, 1997; Chave *et al.,* 2005 and Saatchi *et al.,* 2007). Genage grouplly now a day there are different models developed for carbon sequestration estimation: - Thus Forest Inventory, Optical remote sensors, Very high-res Airborne optical remote sensors, Radar remote Sensors, Laser remote sensors all this methods have its advantage and disadvantage in case of cost, accuracy, and knowledge of using the sensors, (Houghton, 1999; Fearnside, 2000; Watson *et al*., 2000; Houghton *et al.*, 2001, IPCC, 2006).

In general, forest carbon accounting models vary in aim, scale, and forest management activities included and carbon pools accounted. As a result, they are highly variable in the number and detail of input parameters and the accuracy of the output. At present, no single model is considered as standard. With a growing need to generate information on carbon stocks and stock changes cost-effectively and over large spatial scales, forest carbon accounting models are likely to continue to prolifate, especially those adhering to the guidelines of international conventions.

3. MATERIALS AND METHODS

3.1. Description the study area

3.1.1. Location

This study was conducted at Hawassa city located on the shores of Lake Hawassa (from which the name of the city was driven) in the fringes of the Great Rift Valley. It is the capital city of Southern Nations, Nationalities and Peoples Regional State (SNNPRS) and Sidama Zone, located 273 km from Addis Ababa, capital of Ethiopia. It is surrounded by Lake Hawassa in the west, Hawassa zuria woreda in the south and east part and Oromiya Region in the north (Tadesse, 2012). It is geographically located on 6^{o} , 55” – 7^{o}, 5” North and 38°, 23”-38^{o}, 35” East with mean altitude of 1680 m above sea level and covers the total area of 157.2 km2 and has the mean annual rainfall and tempature are estimated ranges 1000 -1400 mm and 11.6°c-26.6°c respectively (SNNPRS, 2005).

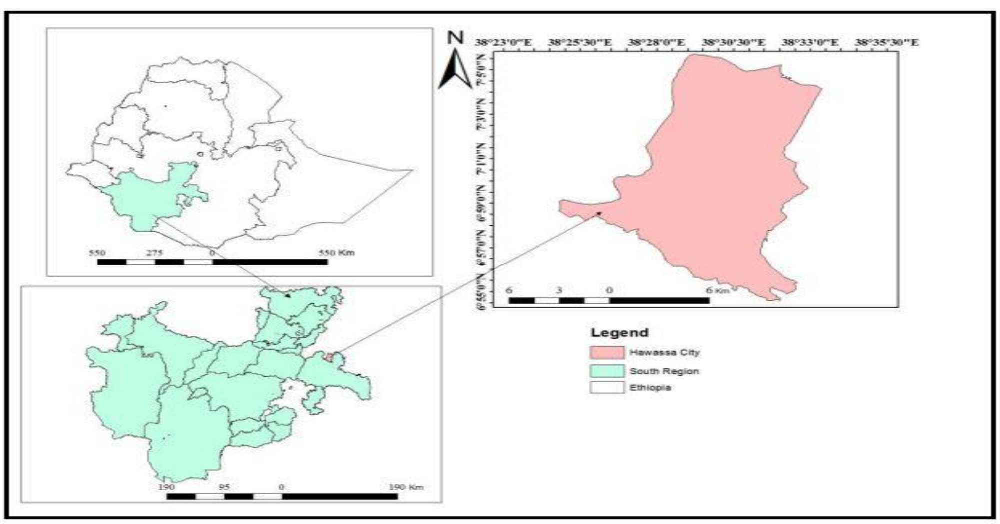

Figure 2. Map of study area

3.1.2. Population

Based on the census conducted by the Central Statistical Agency (CSA, 2007) of Ethiopia,the city has a total population of 258,808, of whom 133,123 were men and 125,685 were women. The city had fast population growth rate of 4.8% with 14 years of doubling time. It is subdivided in to 8 sub cities; namely, Tabore, Hayekdar, Menaharia, Misrak, Bahale adarash, Addis Ketema, Mehale Ketema and Awela Tula in which is currently added as the sub-city of Hawassa (Samson 2009).

3.1.3. Vegetation

The types of vegetation found in the city have not yet well documented but some areas like squares, streets, parks and recreational areas are covered by some indigenous and exotic tree species. The major species of woody plant species in the study area include; *Duranta erecta, Grevillea robusta, Borassus aethiopum, Melia azendrachta, Jacaranda mimosifolia, and Terminalia mentalis* (Abel Feyisa, 2018). From the field observation point of view, most of the urban green infrastructures such as street, squares, etc. of the city are dominated by exotic tree species.

3.1.4 .Climate and soil type

According to the City Administration Office of Hawassa city, Hawassa has a moderate type of climate. The mean annual precipitation of the city is 998.2 mm. Temprature vary between 6^0c in winter and 34^0c in summer. It has the highest and the lowest temprature of 32^0c and 6^0c, respectively. The average annual temprature of the city is 20.3^0c. Hawassa gets rainfall twice in a year; it falls during ‘belg’ and ‘keremt’. Due to the city’s location is in rift valley and nearby lake; there is weather condition change from day to night (Zeleke and Serkalem, 2007). According to the data collected about the soil type by Zeleke and Serkalem (2007) from the

Hawassa Agricultural Research center, the soil types of the city are classified as loamy sands or sand loamy of light color; parent materials for these soils are lacustrine sands and silt in alternate layer with pumice a kind of stone that comes from volcanoes and it is very light.

3.1.5. Data type and sources

For this study primary data was collected in order to achieve the aim of the study. The primary data was obtained through observation, field measurements and laboratory analysis to estimate carbon stocks of the study area.

3.2. Methodology

In order to achieve the objectives stated above, the simple step-by-step procedures was followed to estimate carbon stocks by using standard carbon inventory principles and techniques. Procedures were used on data collection and analysis of carbon accumulated in the above-ground tree biomass, below-ground biomass, and soil organic carbon of trees. Therefore, during the field data collection the followings steps were followed in carbon measurement.

3.2.1. Sample selection of religious compounds

Taking a list of religious compounds in the city from Hawassa city Adminstration (2011) different religious instutions comprising 54 religious compounds were identified. From the total religious compounds, 16 religious compounds were selected, depending on age groups; the selected compounds were then divided into three age group classes (strata).Those compounds with age group of 50 and above, those between 30-50 years, and those below 30 years to represent. The number of compounds in each category was 4, 3 and 9, respectively. By deciding to sample around 75% age group 1 compounds 100% age group 2 ,50 % age group 3 compounds , samples were selected randomly 3,3,4, with a proportional sample size of each age group respectively. These respective compounds from each group were selected randomly by generating random numbers in Excel. Finally a list of selected compounds was grouped in three age groups. age group 1 contains 3 compounds which were greater than 50 years old, age-group 2 contains 3 compounds between 30 and 50 years old, age-group3 contains 4 compounds were less than 30 years old,finally the selected compounds were subjected to detail biomass and soil carbon stock study

Table 1. List of the selected ten religious compounds and their respective age group and area

No	Name of religious compound	Division of age group	Year of establishment	Age group of religious compounds	Type of religious
1	Geberel	Age group 1	1953	58	Ortodox
2	Rahma mosque	Age group 1	1954	57	Muslim
3	Bahi center	Age group 1	1958	53	Bahula
4	Rufael	Age group 2	1973	38	Ortodox
5	Kidanmehret combony	Age group 2	1975	36	Catolic
6	Silase	Age group 2	1970	41	Ortodox
7	Haik Dar Kalheiwot	Age group 3	1998	13	Protestant
8	Diaspora maryam	Age group 3	2004	7	Ortodox
9	Dato kidanmehret	Age group 3	1998	13	Ortodox
10	Atote Mulu wengel	Age group 3	1985	26	Protestant

3.2.2. Sample plot shape and size

The size and shape of the sample plots was a trade-off between accuracy, precision, time and cost for measurement. According to Genene *et al*. (2013) there are two types of plots – circular and square or rectangular plots. However, as stated by Genene *et al*.(2013) the square plots can be the most cost-efficient and it includes more of within-plot heterogeneity, and thus be more representative than the circular plots of the same area (Hairiah *et al.,* 2001).Therefore, for the study sampling quadrats of square shape which have dimensionsof 20 m ×20 m was established. Inside 20 m × 20 m plot , five 1 m × 1 m sub-sampling units were located. In each site, sample plots were laid systematically and at each sampling site transects were established at 30 m between plots and walking around circular transect in wider compound and 50m diagonally within smaller compounds by using GPS instrument, i.e., beginning from the lower parts of the vegitation to the higher parts, to measure vegetation biomass and soil carbon stock.

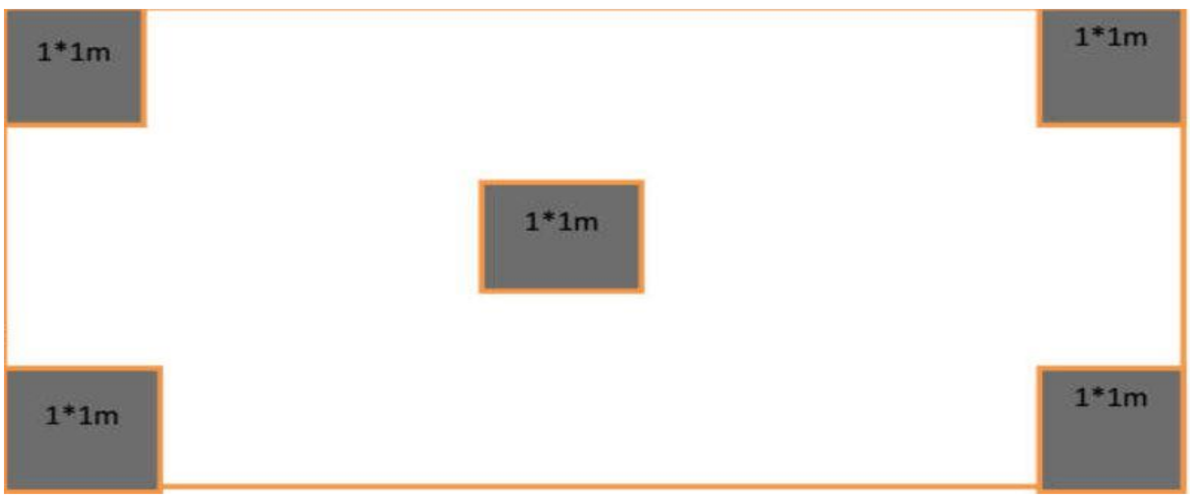

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Figure 3 Shape and sampling plot design

The above design of nested quadrats was required for collecting the soil sample and for estimation of biomass. This means that, within the 20m x 20m plot the 1m x 1 m quadrat was used to collect soil samples. The number of nested quadrats varied depending on the area of the compounds and homogeneity and heterogeneity of species in the compounds.

3.2.3. Number of sample plots

To be accurate in the study,36 plots were used to take samples of biomass and soil from 23 plots of compounds by using systematic sampling method. The number of samples varied from site to site due to different existing conditions of the study area like vegetation coverage, availability of litter within the study sites. However, in study sites which have large vegetation coverage the sample plots were some what greater than that of smaller ones.

3.2.4. Field data collection and measurements

DBH measurements

To estimate the carbon stock of each study site, only woody species were measured. All trees/shrubs that havig DBH greater than or equal to 5 cm and height at 1.3 m were measured by using diameter tape/caliper. Diameter at breast height (DBH) is the basic measurement standard for trees. This measurement was recorded for all trees. (Note that, for stems with irregularities measurement was carried out according to the principles. Therefore, in this study when the tree is on a slope, always measurements was on the uphill side; when the tree is leaning, the DBH tape was wrapped according to the tree's natural angle (not straight across, parallel to the ground). In some parts when it is impossible to measure below the fork, DBH of the largest stem was taken. Traditionally forestry dictates that forked stems are measured as two separate trees but when the focus is on biomass, it is more accurate to measure as a single tree (Holly *et al.,* 2007). The study was done to estimate the carbon stocks and changes, using the parameters measured and monitored in the field and in the laboratory. The analysis and calculation of carbon stocks and changes involve conversion of field and laboratory estimates of various parameters from diameter at breast height (DBH), height and sample plots, such as soil organic carbon content into tones of carbon per hectare.

a) Height measurement

The height of all tree species was measured by using Silva Clino-mater made by Sweden in a position which is possible to observe the tips as well as the bottom of the trees. A tree with multiple stems at 1.3 m height was treated as a single individual.

b) Woody species identification method

Identification of the existing tree species in the field with diameter greater than or equal to or 5cm was done by using Useful trees and shrubs for Ethiopian Azene Bekele (1993)and Flora of Ethiopia and Eritrea volume 2, part 1 and part 2 (Edwards *et al*., 1995 & 2000), and Flora of Ethiopia volume 3 (Hedberg and Edwards, 1989) ther was no species found difficalt to be identified in this study.

3.4.2.1. Field carbon stock measurement methods

3.4.2.2. Above ground tree biomass (AGTB)

Above ground tree biomass consists, all living biomass above the soil including stem,stump, branches, bark, seeds, and foliage group (IPCC, 2003). The carbon stored in the aboveground living biomass of trees is typically the largest pool and the most directly impacted by deforestation and degradation. Thus estimating above ground forest biomass carbon is the most critical step in quantifying carbon stocks (Holly *et al*., 2007). However, the DBH at 1.3 m and height of individual trees greater than or equal to 5 cm DBH was measured in each study site by using diameter tape, starting from the edge and working inwards, and marking each tree to prevent accidentally counting it twice in the study site. Each tree was recorded individually, together with its species name.

3.4.2.3. Below ground biomass (BGB)

According to Genene *et al*. (2013), below ground biomass comprises dead roots, living roots including fine roots (< 2 mm diameter), small roots (2 – 10 mm diameter),and large roots (> 10 mm diameter), soil fauna and the microbial community.However it was calculated by considering of the above-ground biomass root-to shoots ratio value of 26% of above ground biomass (Macdicken, 1997).(IPCC.2003)

3.2.2.4.Soil sampling and analysis

For the purpose of obtaining an accurate inventory of soil organic carbon stocks in minage groupl or organic soil, three types of variables must be known: (1) depth, (2) bulk density (calculated from the oven-dried weight of soil from a known volume of sampled material), and (3) the concentrations of organic carbon within the sample (Pearson *et al.*, 2005). The soil samples for carbon determination collected from the designed five sub plots only three plots were randomly taken for SOC while one point from the plots were randomly selected for bulck density analysis taken by 20 cm core sampler ,a total of 46 soil samples 23 samples from the debth at 0-20 cm and the remaining 23 samples from 20-40 cm were colected using core sampler with a diameter of 5 cm.three equal weight of each sample from each quadrant wase taken and mixed homogenously while a composite sub sample of 100 gm of wet weight from each plots submitted to the laboratory analysis. Then Carbon fraction of each sample was measured in the laboratory using Walkley-Black Method (Walkley and Black,1934).

3.2.4.5. **Estimation of carbon stocks in different carbon pools**

3.2.4.6. Estimation of above ground tree biomass (AGTB)

To estimate the above ground biomass of the trees different mathematical allometric equations have been developed and used by many researchers. The equations are different on the type of species, geographical locations, forest stand types, climate and others (Baker *et al.*, 2004, Brown *et al.*, 1989). From the environmental point of view, cost of estimation and time required, it is not possible to cut the trees to estimate their biomass. Thus, according to Brown *et al.*(1989), if the rainfall <1500 mm and DBH range is ≥5cm, the below allometri equations model was recommendable to calculate the above ground biomass of the tree, for those species whicha have specific alometric equation ,specific alometric equations were applied list species and their alometric equations are found on table 2.

Table 2: Specific alometric equations applied for ABGB estimation of selected species

No	Species name	Model	Authors name
1	*Gravelia robusta,C.equsitofolya*	AGB=(1.01005*(DBH^1.81))	Tumwebza 2013
2	*Federia albida*	AGB=0.057*(DBH^2.5)	Bedy 2015
3	*Cupersus lustanica*	AGB=(1.01005*(DBH^1.81))	Berhe 2013
4	*A.syal,A.decrense.c.areha,A.nilotica*	AGB=0.2058*(DBH^2.1347)	Ubay 2018
5	*E.camaldulenses*	AGB=0.0155*DBH^2.5823	Hailu 2002
6	*J.procera*	AGB=0.09953*(DBH^2.32)	Eyosias+teshome2015
7	*C.mychrostatus.C.megalocarpus*	AGB=22.601*DBH-242.74	Asferachew2004
8	*Olia .spp*	AGB=1.089*(DBH^1.684)	Birhanu kebede 2017

$\boldsymbol{Y = 34.4703 - 8.0671(DBH) + 0.6589A(DBH^2)}$**...................... *(equ 1)***

Where, Y is above ground biomass (unit), dB (unit) is diameter at breast height:

According to Pearson *et al*. (2005), since the plot areas are part of tropical region carbon content in the biomass was estimated by multiplying 0.47 while multiplication factor 3.67 is used to estimate CO_2 equivalent. Therefore, the tree biomass is converted into C by multiplying the above ground tree biomass by 0.5 (Brown, 2002).

Biomass C stock = AGB * 0.5, Then Biomass carbon stock is converted into CO_2equivalent as follows:

$$\boldsymbol{CO2\% = biomass\ C * 3.67} \text{ .... } \textbf{\textit{(equ.2)}}$$

3.2.4.7. Estimation of Below Ground Biomass (BGTB)

According to Geider *et al.* (2001), and Genene *et al*. (2013), the below ground-biomass estimation is more difficult and time consuming than estimating above ground biomass. As MacDicken (1997) standard method for estimation of below ground biomass were obtained as 26% of above ground tree biomass i.e., root-to-shoot ratio value of 1:5 is used. In the same way, Pearson *et al.* (2005) described this method as it is more efficient and effective to apply a regression model to determine belowground-biomass from knowledge of biomass of AGB. Thus, as the equation developed by MacDicken (1997) was used to estimate below-ground biomass of the study. The equation is follow:

$$\boldsymbol{BGB = AGB * 0.26} \text{ .... } \textbf{\textit{(equ.3)}}$$

Where, BGB is below ground biomass, AGB is above ground biomass, 0.26 isconversion factor (or 26% of AGB).

3.4.2.8. Estimation of Soil Organic Carbon (SOC)

To calculate the soil carbon stock density of organic carbon, the equation

recommended by Pearson et al. (2005) from the volume and bulk density of the soil.

$$SOC = BD * D * \% \text{ .... } \textit{(equ4)}$$

Where, SOC= soil organic carbon stock per unit area (ton/ha),

BD = soil bulk density (g cm^{-3}),

D = soil depth(cm)

%C = Carbon concentration (%)

3.2.5.9. Total Carbon Stock Density

The carbon stock density was calculated by sum ming the carbon stock densities of the individual carbon pools of the stratum by using the (Pearson et al., 2005) formula. In addition, it is recommended that any individual carbon pool of the given formula can be ignored if it does not contribute significantly to the total carbon stock (Bhishma et al., 2010). Carbon stock density of a study area:

$$C_{density} = C_{AGB} + C_{BGB} + SOC \text{.................................} (equ5)$$

Where: $C_{density}$ = Carbon stock density for all pools [ton ha^{-1}]

C_{AGTB} = Carbon stock in above -ground tree biomass [t C ha^{-1}]

C_{BGB} = Carbon stock in below-ground biomass [t C ha^{-1}]

SOC = Soil organic carbon

The total carbon stock is then converted to tons of CO_2 equivalent by multiplying it

by 44/12, or 3.67 (Pearson et al., 2007).

3.3. Data Analysis

After the data collection was completed, data analysis of various carbon pools measured in the study site was accomplished by organizing and recording on the excel data sheet. The data obtained from DBH, height of each species , soil and the amount of carbon and CO_2 in each group of religious compounds were analyzed by using Statistical Package for Social Science (SPSS) software version 20 The height and diameter data was arranged in classes for applying appropriate model of biomass estimation equation. The relationship between each parameter was tested by one way ANOVA. Which means analysis of variance (one-way ANOVA) was used to determine statistically significant differences of carbon stocks of above ground -biomass and soil along age gradients

4. Results and discussion

4.1. DBH and height distribution of plant species

The tree species with highest percentage of their distribution were trees with DBH class 15-cm-30 cm (50 %) that followed by DBH class 30 cm-45 cm (25.66 %), DBH class ≤15 cm (20 %), DBH class 45 cm-60cm (2.9 %), DBH class 60 cm-75cm (0.55%,) 75-90 cm 0%) 90-10cm (0.27%) with, and the least DBH class were tree species with DBH class ≥106 cm(0.27 %) were distributed (Figure 4). The DBH a distribution indicates that the large numbers of individuals are distributed in the lower and middle DBH classes .which later decreases in the successive upper classes, 15-30 cm. hasthe highest density with 342 plants and 30-45 with 175 plants. While DBH class ≥106 cm was the least dominate in number contains 4 plants and in DBH clas (Apendix 1) The most contrubiting species in three age groups is *Gravelia robusta* 30 %and *Jacaranda mimosifolia* 17% followed by the least was recorded by *A.abcynica* and *pinus patula* which contains only 1 % of total apecies Apendix 5

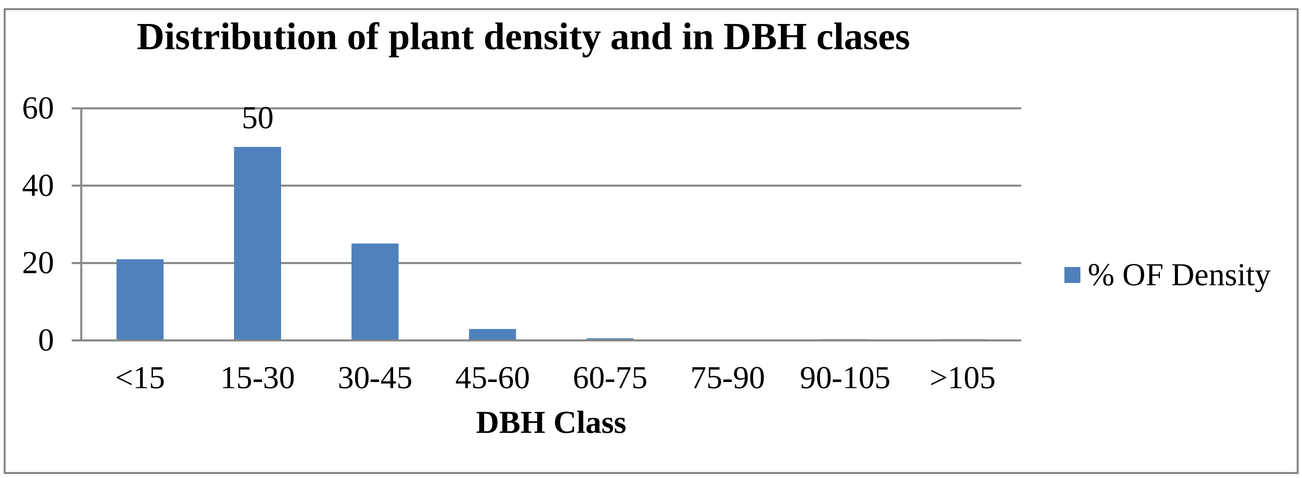

Figure 4 Distribution of plant in DBH class

The vegetation structure result showed that the majority of Plant species were found in middle DBH class. This pattern gradually showed a decreasing trend in higher DBH and Height Plant specie.the number of species in height class 10-20m was higher (67.77%) and his was followed by class with lower height ≤10m (29.33%) and middle height 20-30m (2.74%) (Figure,5). The DBH and height of trees in urban religious forests of Hawas acity shows the same pattern, Height could be used as an indicator of the age group of the forest in which the older trees are found in higher height classes compared to the lower classes.

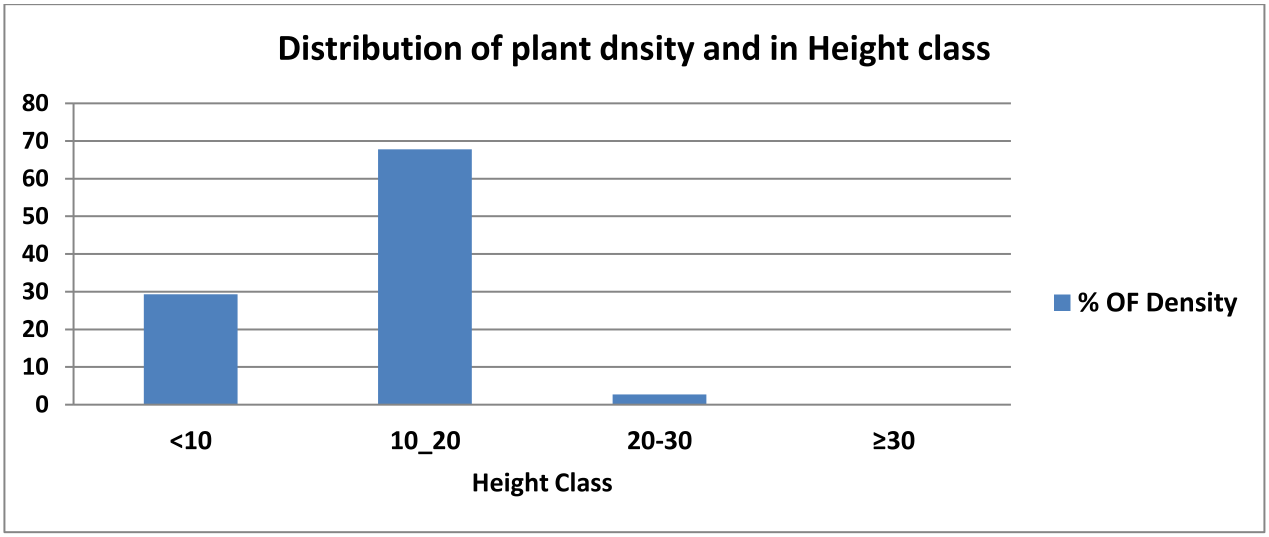

Figure 5. *Distirbution of plant in height class*

4.2 Biomass Carbon Stock

The Mean ACD and BCD of the three studied religious clusters are shown in Table 2 The highest total biomass carbon stock was recorded age group 1 (*277.41±79.10*. t C ha-1) while the lowest was age group 3 (*226.38±126.62*C ha-1).ACD stocks were not significantly Differed (p=*.633*) among the three age groups. The BCD stock was not significantly differed (p=0 *.693*) between clusters.The average proportion of the total ACD to BCD was78% for all religious clusters.

Table 3 Mean (± SD), ACD, BCD, TBC stock (t C ha -1) for each of the three age groups.

BC	Age group 1	Age group 2	age group 3	F –value	P-value
ACD	218.60±43.523a	193.98 ±65.07a	176.0±102.9a	0.464	.633
BCD	58.83. ±35.86a.	50.44±16.921	50.29±33a	0.371	.693
TBCD	277.41±79.10a	244.4±.82a	226.38±126.62a	0.441	.647

(Similar leters superscripted along rows means indicates no significant diference among age groups)

ACD=above ground biomas carbon densityBCD=below groqnd carbon densityTCD=total biomass carbon density

The present study calculated the standing biomass carbon of both the ACD and BCD of the trees and shrubs on three age group groups of Hawassa city. The ACD of species depend on their DBH value and also on their age group. Hence age group and DBH are directly proportional to the biomass of the tree (Negash, 2007). In general, the religious clusters having larger trees and shrubs exhibited higher ACD and BCD in all studied cluster The study clusters were holding the remarkable ACD and BCD with mean of 196.20 t C ha-1 and 53.19 t C ha-1 respectively.

The mean biomass carbon stock in the three age group groups exhibited 249.37t/ C ha-1 was lower than the findings reported by Egdu Forest (Adugna Feyissa*et al.*, 2013. The finding of the study was higher than other findings reported by (Alem, 2015), (Mesfin, 2011), (Tulu Tolla, 2011), and (Meseret,2013), from Urban Public parks in Addis Ababa, Menagasha Suba State Forest, Selected Church Forest, and Selected Park Forests in Addis Ababa Ethiopia. The study result in different forest and different tree species in Ethiopia shown as age of tree increase basal area and biomass also increase (Negash Mamo *et al.*, 1995 and Negash Mamo, 2007), ther fore the present study result is in line agreement with the previous results In Ethiopia, a review document by Yitebitu Moges *et al*. (2010) presented carbon sequestration potentials of Ethiopian forests. The Humbo project was the one which also did such exercise of estimating the sequestration potential of thirteen year old forest. The present study was however, the first study estimating the carbon sequestration potential of forests in different religious types in Ethiopia.

Globally according to Brown (1997) and Acharde *et al.* (2004) above ground carbon stock is 47 t ha^{-1} for tropical dry forest and 36 t ha^{-1} for sub- Sahara Africa country. According to IPCC (2006) assessment, 126 t ha^{-1} was reported for tropical dry forest and 72 t ha^{-1} for open sub-Sahara Africa country. Houghton (1999) and Defries *et al.* (2002) recorded 55 t ha^{-}C for tropical dry forest and 30 t ha^{-1} C for open forest in sub- Sahara Africa country. Geneally, all litatures recorded carbon stock in the above ground biomass for tropical dry forest life zone which receiving annual rain fall between 900–1500 mm were ranged between 30–126 t ha^{-1} carbon stock. Forest while the result recorded in three studied clusters of Hawasa city urban religious site was) found more than one and half folds recommended for tropical moist and wet forest life zone receiving annual rain fall greater than 1500 mm (Houghton, 1999; Defries *et al.*, 2002; and IPCC, 2006)

The reason for higher in Biomass carbon in three age groups religious forests of Hawassa city could be due to the existence of age groupd trees and shrubs with higher DBH class. Moreover, non-accessibility to litter and dead wood because of continuous sweeping in all of the three age group groups included in the study, the significance of the litter in carbon accumulation was not understood in all three age groups, and it has been discarded and in some cases burnt.

4.3 Soil Bulck density of study area

The soil bulk density ranged from 0.82 cm-3 - 2.89g/ cm-3, with the mean value of 1.12 cm-3. Thevalue of bulk density obtained in this study was not within the range of (Alem, 2015and (Meseret, 2013); these authors confirmed that the mean bulk density of 1.04 g/ cm-3 and 0.72 g/ cm-3 from selected urban public parks, in Addis Ababa Ethiopia .this is due to the presence of repetitive human induced disterbunce of religious compounds reconstruction of buildings and infrastructures resulted haigh compaction on the soil ,absence of liter and luck of undisturbed soil in most of compounds of three age groups

4.4 Soil Carbon Stock

The SOC stock of the religious clusters which consists of 0-20 and 20-40cm ranged from 66 - 178 t Cha-1. The lowest SOC stock was recorded in age group 2 and the highest carbon stock was in age group3 Mean soil carbon stocks did not significantly vary among the three age groups (Table3However SOC stock was significantly lower thanthe biomass carbon in three age group .There was no significant difference observed among the over all mean figure of biomass and SOC stock across the ecosystem (t=0.551, df= 2, p =0.169).

Table 4**: Mean (± SD), soil carbon (SOC) stock (t C ha -1) for each of the three age groups.**

Soc(t/ha)	Age group 1	Age group 2	Age group 3	F	P-value
SOC 0-20cm	45.706±63a	55.332±0.13a	52.69±17.04a	.697	.509
SOC 20-40cm	60.30+_22.97a	39.04+_11.22a	53.36±23.73a_	.413	.667
SOC 0-40cm	105.96±21.62a	94.37±26.17a	106.05±33.60a	1.940	.169

(Similar leters superscripted along rows mean indicate no significant diference among age groups)

SOC stock plays a vital role in the global carbon cycle, forming large carbon pools with long residence times (Post *et al*., 1982). The finding reveals thathigh human interference and disturbance of soil especially; in age group 1, age group 2 and in many parts of religious compounds. Further more a repetitive reconstruction of churches and infrastructures of compounds thus which results the loss of top soil and vegetation cover,. Therefore the process of making composite soil from other places such as forest soil from the peri-urban areas and dung from the urban farming place to improve and enhance the soil fertility for better improvement in the religious compounds of Hawassa city. Due to this reason, it was difficult to find undisturbed soil in the study area, hence difficult to really understand the actual potential of the original soil carbon stock in the study clusters.

The amount of SOC stock in religious clusters of Hawassa City ranged from 94.3 t C ha-1-106. t C ha-1 with the mean of 105.48 t C ha-1. This result was higher than the Park Forests (Meseret, 2013). But it is similar with the finding of (Marshet, 2013) and (Alem, 2015) due to compensation of the soil enrichment in the religious clusters of Hawassa city with that of the organic carbon obtained from the litter mulch to the soil

4.5 Ecosystem carbon stock

Ecosystem carbon stocks of the urbun religious forests of hawasa city which consists of the sum total of ACD, BCD and SOC 0-40cm ranged from 332 - 383 t ha-1. The highest ecosystem carbon stock was recorded in age group 1 (383 t C ha-1), while the lowest was recorded in age group 3(332 t C ha-1). However the carbon stocks would not significantly differ among the three age groups of urban religious forests of Hawasa city, the over all disirbution of ecosystem carbon in different pools ACD,BCD.SOC , 55.81% 15.13% 29.05% respectively,the reason behind for non significance difrence is even if age of trees is one the main factor to affect the variation of carbon stock .the older clusters of the study sites were under the restructuring thier infrastructure constructing of new church and mosque buildings they lost their old vegetations and excavate the original soil and the top sioil was exposed to heavy machinery compaction ,thus they are forced to plant fast growing exotic tree species as a alternative options,the same holds true for the younger clusters .that's why proportion of ACD is higher in all clusters of the study area and soc is not found as expected as other related studies of the country,the higher percentage group of ACD in the study area is a good implication of greater carbon sequestration potential of religious inistitutions of hawasa city.

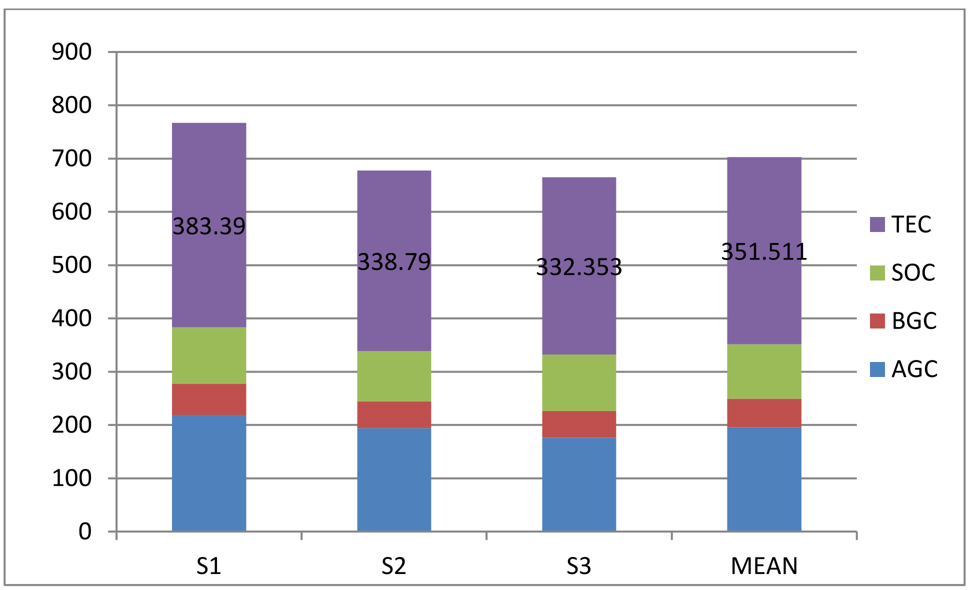

Figure 6*Total ecosystem carbon stock in urban religious forests of Hawassa city Southern Ethiopia (Source: Excel output, 2019)*

4.6 Variation of carbon stock along age group of religious compounds

Total of 684 tres were recorded in the study area from this 205,195,284of individuals and DBH of 26.97, 25.60, 25.40 were found in age group 1,age group 2,age group 3 respectively,the biomas carbon stock shows patern of decreasing order from older age groups to younger age groups this indicates that the higher DBH and existence of larger trees like *Ficus sur, Ficus elastic* in age group 1,contribute higher biomass stock followed by age group 2,with and age group 3 there fore the DBH of trees and the existence some reminant old paches of forests in older compounds resulted variations in biomass carbon stock along age groups of religious compounds,how ever ther is no significant diference among age groups ststically the reason behind for non significance difrence is even if age of trees is one the main factor to affect the variation of carbon stock .the older clusters of the study sites were under the restructuring thier infrastructure constructing of new church and mosque buildings they lost their old vegetations and excavate the original soil and the top sioil was exposed to heavy machinery compaction ,thus they are forced to plant fast growing exotic tree species as an alternatinive option ,the same holds true for the younger clusters that's why proportion of ACD is higher in all clusters of the study area and soc is not found as expected as other related studies of the country,the higher percentage group of ACD in the study area is a good implication of greater carbon sequestration potential of religious inistitutions of Hawasa city

Soil carbon stockof the study area was found 105.96t/ha.94.37±26.17t/ha 106.05±33.60t/ha age group 1,age group2,age group3 with mean of 102t/ha respectively is greater than Park Forests (Meseret Habtamu, 2013)and comparable with Park Forests (Marshet Tefaye, 2013 and less than Church Forest (Tulu Tolla, 2011 ther is variation of SOC among age group decreasing from age group 1 to age group 2 and slightly increases to age group 3 with out keeping usual trend ,however no significance diference among religious compounds along age group, this is may be there is a repetitive reconstruction of churches and infrastructures of compounds thus ther is loss of top soil and vegetation cover ,therefore the process of making composite soil from other places such as forest soil from the peri-urban areas and dung from the urban farming place to improve and enhance the soil fertility for better improvement in the religious compounds of Hawassa city. Due to this reason, it was difficult to find undisturbed soil in the study area, hence difficult to really understand the actual potential of the original soil carbon stock in the study cluster

Table 5, **Comparison of the present study with other related studies**

No	Study places	AGC	BGC	LC	SOC	TC
1	Egdu Forest (Adugna Feyissa*et al.*, 2013	278.08	55.62	3.47	277.5	616.73
2	Menagasha Suba State Forest (Mesfin Sahile, 2011)	133	26.99	5.26	121.28	286.53
3	Church Forest (Tulu Tolla, 2011	122.85	25.97	4.95	135.94	289.71
4	Park Forests (Meseret Habtamu, 2013)	143.3	28.1	10.5	69.2	251.1
5	Park Forests (Marshet Tefaye, 2013	25.4	5.1	5.17	113.55	149.22
6	Present study(urban religious forest Hawasa city)	196.22	53.18	-	102.12	351.52

5. Conclusion and Recommendation

The over all finding of the present study confirmed that urban religious forest of Hawassa city southern Ethiopia, play a major role in the remarkable carbon stock storage haigh potential to sequester1288.87co2 t/ha equivalents from the atmosphere. The urban religious institutions of Hawassa city is not only used religious purpose and and socio economic role for the communities but are also important in reducing the urban heat island effect by absorbing and storing carbon in the form of biomass stock (in larger extent) and in the soc of the study area. However, No significant differences observed among the three age groups for any of the carbon stocks. SOC stocks were not correlated to both above, below or total carbon stock. SOC stocks were significantly lower than the biomass carbon stocks in all three age groups.

The urban religious forest of hawasa city was found to be the reservoir of potentially high amount of carbon compared to similar areas in the country and the continent

Generallyy, the urban religious forests of Hawassa which provides the multi-functional services for local residents as well as domestic and international visitors is also the major sink of carbon stocks that actually and potentially help to reduce the urban heat island effect of the City, hence has the great role in carbon sequstration.

A contribution for the provision of a carbon sequestration potential of 1288.87co2 t/haequivalents could be significantly appreciable role to the global climate change mitigation efforts. Hence, the potential of the religious institutions protection knowledge that made carbon stocking possible should be recognized and valorized.

Since the urbun religious institutions of Hawassa city exhibited remarkable carbon stock, urban religious institutions should be a clear priority for the city planners, national and local governments.

Research in carbon sequestration potential of religious forests and different religious types such as Muslim. Catholic, protestant compounds in the country are not conducted. Therefore, it is pertinent to recommend a similar study in similar or other combinations types in the study region and country.

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APENDIX

Apendix 1 Avage groupge DBH and Height class by plant and carbon density of study site DBH class

DBH CLASS	% OF Density	% of carbon
<15	20.94972067	3.778910065
15-30	50	32.78335528
30-45	25	38.61980929
45-60	2.932960894	7.824347499
60-75	0.558659218	1.216663239
75-90	0	0
90-105	0.279329609	4.194892471
>105	0.279329609	11.58202215

Height class

H. Class(cm)	% OF Density	% of carbon
<10	29.33526012	13.20324903
10_20	67.77456647	82.32843479
20-30	2.74566474	4.435708383
≥30	0.144508671	0.032607804

Apendix 2, Distrbution of carbon stock in different pools

% of AGC	% of BGC	% of SOC
55.81522816	15.13115284	29.053619

Apendix 3, Soil data for religious compounds

Depth 0-20cm						Depth 20-40cm					
No.	**Ecosystem**	**Plot no.**	**Carbon content (%)**	**BD, g/cm^3**	**Scs0-20**	**No.**	**Ecosystem**	**plot no**	**Carbon content (%)**	**Bdgm /cm3**	**scs 20-40**
1	Kidus gebrel	1	2.05	1.1	45gm/cm 3	1	Kidus gebrel	1	1.87	1.27	47.49
		3	1.97	1.06	41.76gm/ cm^3			3	1.72	1.24	42.65
		5	1.9	1.01	38.38			5	2.05	1.25	51.25
2	Rahma mosque	1	2.14	1	42	2	Rahma mosque	1	3.92	1.17	91.72
		3	1.94	1.04	40.35			3	3.07	1.14	69.96
3	Bahula center	1	3.18	0.82	52.15	3	Bahula center	1	3.79	1.15	87.17
		2	2.9	0.97	56.26			2	2.49	1.1	54.78
4	Silasie	1	1.87	1.04	38.89	4	Silasie	1	1.87	0.88	32.91
		3	1.77	1	35.4			3	1.41	1.09	30.73
		5	2.3	1.07	49.22			5	1.55	1.15	35.65
5	Combony	1	1.97	1.12	44.12	5	Combony	1	1.37	1.07	29.31
		3	4.18	1.12	93.63			3	1.52	1.13	34.35
6	Rufael	1	2.32	1.3	60.32	6	Rufael	1	2.41	1.16	55.91
		3	2.61	1.26	65.77			3	2.23	1.22	54.41
7	Kalehiwot	1	1.81	1.06	38.37	7	Kalehiwot	1	1.54	0.9	27.72
		3	3.43	1.02	69.72			3	1.85	1.19	44.03
8	Muluwongel	1	1.83	1.01	36.42	8	Muluwongel	1	1.85	1.01	37.37
		3	1.97	0.97	38.21			3	2.03	1.03	41.81
9	Saelete maryam	1	3.59	1.01	72.51	9	Saelete maryam	1	4.17	1.27	105.91
		3	1.34	0.98	26.81			3	2.1	1.25	52.5
10	Dato kidanmeheret	1	2.86	1.08	61.77	10	Dato kidanmeheret	1	0.81	2.89	46.81
		3	2.21	1.07	47.29			3	3.62	1.14	82.53
		5	3.18	1.04	66.14			5	2.15	1.12	48.16s

Apendix 5 major species with their frequency in the study area

Species		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Gravelia	211	30.8	30.8	30.8
	Jacaranda	117	17.1	17.1	48.0
	melia.a	38	5.5	5.6	53.5
	A.albida	20	2.9	2.9	56.4
	B.age groupptica	4	.6	.6	57.0
	cordia. A	24	3.5	3.5	60.5
	cupersus .l	3	.4	.4	61.0
	Morninga	2	.3	.3	61.3
	kazmarino	4	.6	.6	61.8
	borasum	5	.7	.7	62.6
	A.sial	7	1.0	1.0	63.6
	zeytun	2	.3	.3	63.9
	Delionix .r	14	2.0	2.0	65.9
	C.equsitofolia	32	4.7	4.7	70.6
	E.comaldulensus	72	10.5	10.5	81.1
	J.procage group	4	.6	.6	81.7
	C.mycrostastus	5	.7	.7	82.5
	C.megalocarpus	10	1.5	1.5	83.9
	F.elastica	5	.7	.7	84.6
	F.sur	3	.4	.4	85.1
	Esepatos	1	.1	.1	85.2
	S.mole	6	.9	.9	86.1
	T.mentalis	14	2.0	2.0	88.2
	A.decrense	2	.3	.3	88.5
	Casia arereh	29	4.2	4.2	92.7
	A.nilotica	13	1.9	1.9	94.6
	A.gumifage group	7	1.0	1.0	95.6
	olia.a	23	3.4	3.4	99.0
	A.abysinyca	1	.1	.1	99.1
	C.citronum	2	.3	.3	99.4
	P.patula	1	.1	.1	99.6
	mangifage group	3	.4	.4	100.0
	Total	684	99.9	100.0	
Missing	System	1	.1		
Total		685	100.0		