CARBON STOCK CHANGE DUE TO OPEN GRAZING IN COMPARISON ACACIA WOODLAND WITH RESTRICTED GRAZING IN CENTRAL RIFTVALLEY, ETHIOPIA

MSc THESIS

ADUGNA ABEBE DOLU

HAWASSA UNIVERSIT

WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES, ETHIOPIA

JUNE, 2018

CARBON STOCK CHANGE DUE TO OPEN GRAZING IN COMPARISON ACACIA WOODLAND WITH RESTRICTED GRAZING

ADUGNA ABEBE DOLU

A THESIS SUBMITTED TO

SCHOOL OF NATURAL RESOURCES AND ENVIRONMENTAL STUDIES WONDO GENET COLLEGE OF FORESTRYAND NATURAL RESOURCE, HAWASSA UNIVERSITY, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER IN FOREST RESOURCE ASSESSMENT AND MONITORING

JUNE, 2018

APPROVAL SHEET- I

This is to certify that the thesis entitled "Carbon stock of closed acacia wood land in relation to adjacent open grazing land in central rift valley, Ethiopia " submitted in partial fulfilment of the requirement for the degree of master's with specialization in forest resource assessment and monitoring (MRV program), the graduate program of the school of natural resources and environment studies, wondo genet college of forestry and natural resources, Hawassa university, Ethiopia, and has been carried out by Adugna Abebe Dolu, Id. no. MSc./0001/09, under our supervision. therefore, I recommend that the student has fulfilled the requirement and hence here by submitted to the department.

Dr. ____________________	______________________	____________________
Name of major advisor	Signature	Date

APPROVAL SHEET- II

We, undersigned, members of the Board of Examiners of the final open defence by Adugna Abebe Dolu have read and evaluated his thesis entitled "Carbon stock of closed area Acacia woodland in relation to adjacent open grazing land", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfilment of the degree.

______________________	___________________	______________
Name of Chair person	Signature	Date
_____________________	____________________	_____________
Name of Internal Examiner	Signature	Date
_________________	________________	______________
Name of External Examiner	Signature	Date
_________________	________________	____________
SGS Approval	Signature	Date

ACKNOWLEDEMENTS

First, I would like to thank the almighty God for making me whom I am today. Second, to my advisor, Dr. Motuma Tolera for his continuous efforts and effective supervision from proposal planning and write up of this thesis. His inputs are highly valuable. Special thanks to the MRV programme coordinators for their full supportive advices in my studies at WGCFN. Also to my employer Ministry of Environment, Forest and Climate Change for granting me leave to pursue my studies. I would also like to extend my appreciation to

Mr. Zeleke Asaye (PhD candidate) and to my late friend Mr. Tilahun Firomsa for their useful comments during concept note write up. I am grateful to all my student colleagues, their moral support made my academic life in the college comfortable. I am also grateful to Adami Tullu Research Centre and Vender Beef Management for their cooperation and allowing me to collect data of my study in their area. I thank field assistants and local guides for their exhausting effort during data collection in both ecosystem.

Lastly, to my family for all their support, for coping with my long absence from home, I say thank you very much and proudly present this product to them!

DECLARATION

I hereby declare that this MSC thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: Adugna Abebe

Date: ________________________________

ACRONYMS AND ABRREVATION

ATRC	Adami Tullu Research Centre
ATJK	Adami Tullu Jiddo Komblcha
AGB	Above-Ground Biomass
BD	Bulk Density
BGB	Below-Ground Biomass
CLFa	Closed forest area
CO_2	Carbon dioxide
DBH	Diameter at breast height
FAO	Food and Agricultural Organization
GHGs	Green house gases
IPCC	Intergovernmental panel for climate change
Lab	Laboratory
LU	Land use
N_2O	Nitrous oxide
OC	Organic carbon
ODS	Oven dry sample
OGL	Open grazing land
TS	Total Carbon
TSB	Total standing biomass
UNFCCC	UN Framework Convention on Climate Change
ZSTLC	Zeway soil test laboratory code

List of figures

List of Table

Content

Abstract

Trees on closed woodlands and open grazing lands play a crucial role in storing biomass carbon and soil carbon. These trees have received much attention recently due to their contribution to climate change mitigation through carbon storage. This research study done in quantification of biomass carbon and soil carbon stocks in closed woodland and adjacent open grazing lands in Adami Tullu Jiddo Kombolcha district. Converting the biomass to biomass carbon, the carbon stock stored in different pools of closed woodland were 10.87t c/ha, 2.94t c/ha and 0.58t c/ha for the aboveground, belowground and litter respectively. Similarly, in the open grazing land 6.77t c /ha, 1.83t c/ha and 0.05t c/ha was resulted in the aboveground, belowground and litter respectively. The sum of biomass carbon from different pools ranges from 8.6 t c/ha to 14.3 t c/ha in closed woodland and open grazing. It shows significant difference at $P < 0.05$. In the above result, the total biomass carbon (AG, BG and LC) of closed woodland contributed more 5.74 t c/ha than open grazing land. The mean soil organic carbon of closed woodland (89.36t c/ha) was more than that of open grazing land 84.67t c/ha). The total carbon stock for ecosystem is calculated by summing the carbon stock densities of the individual carbon pools in the ecosystem. In the present study, comparing the four carbon pools, the largest carbon stock was contributed by the soil carbon pool, which accounted 92.71% in closed woodland and 90.73% in open grazing land of the four carbon pools and the second was the aboveground carbon pool which accounted for 10.48% in closed woodland and 7.25% in open grazing land of the four carbon pools. The lastly recorded was in litter carbon pool which accounted for 0.56% in closed woodland and 0.05% in open grazing land. In general, comparing the total carbon stock of the two ecosystems, closed woodland area accounts 52.45% total carbon stock as compared to open grazing land which accounted 47.35% to the ecosystem. The study investigated the effectiveness of closing woodlands help to restore aboveground, belowground and soil carbon stock in the central rift valley of ATJK, Ethiopia. The results showed that the closing and improved management practice of woodland had a significant potential to increase carbon storage.

Key words *: Carbon storage, Allometric equations., Estimation of carbon, Soil organic carbon.*

1. INTRODUCTION

1.1 Background

Woodlands are known to play an important role in regulating the global climate. International agreements on climate change recognized woodlands playing an important role in mitigating climate change by naturally taking carbon out of the atmosphere, thereby reducing the impact of CO_2 emissions (IPCC, 2007b; Perschel *et al.*, 2007). The rising of atmospheric CO_2 concentration is crucial for the global carbon cycle, but forests and wood lands can improve the influence as they have huge potential in storing more biomass carbon than any terrestrial ecosystem. Despite their existence in closed woodland or open grazing land, plants take up carbon dioxide from the atmosphere and incorporate it into plant biomass through photosynthesis. Higher tree densities in grass dominated or mixed tree-grass systems significantly increases the carbon storage capacity of the grassland systems (Yusuf *et al.*, 2013). Forests and woodlands can accumulate more than 80% of all terrestrial biomass and soil carbon than other sources.(Jandl *et al*., 2006; Sundquist *et al.*, 2008).

Globally there is a high need for biomass carbon measurement particularly with respect to mitigating carbon dioxide emissions. The ability to accurately and precisely measure the carbon stored and sequestered in forest is increasingly gaining attention in recognition of the role forests have in the global carbon cycle (Kauppi and Sedjo, 2011). The Global countries seek this accurate and precise measurement to comply with agreements under the UN Framework Convention on Climate Change (UNFCCC, 2012).

Ethiopia is endowed with different vegetation cover in different ecosystems. The quantity of biomass in a woodlands determines the potential amount of carbon that can be added to the atmosphere or sequestered on the land when forests are managed for meeting emissions targets (Shama *et al*., 2010). Acacia- Commiphora woodlands are the dominant vegetation types that cover large parts of the dry land areas in Ethiopia (Eshete *et al*., 2011). Loss of woodland biomass through deforestation and forest degradation makes up 12 to 20% of annual greenhouse gas emission, which is more than all forms of transport combined (Saatchi *et al*., 2011). Forestry emissions are driven by deforestation for agricultural land (50% of all forestry-related emissions) and forest degradation due to fuel wood consumption (46%) as well as formal and informal logging (4%). Deforestation leads to CO_2 emissions, and is mostly caused by the conversion of forested and woodland areas to agricultural land. (CRGE, 2011). To reduce the problem, working on forest sectors including woodlands has gained widespread acceptance for greenhouse gas mitigation strategy as they capture and store carbon in their biomass.

Ethiopian is facing rapid deforestation and degradation of land resources and experiencing the effects of climate change such as an increase in average temperature, and rainfall pattern variability (Saatchi *et al*., 2011). Accurate data on carbon stocks and carbon stock change over time are of particular interest for countries like Ethiopia in the light of possible future financial mechanisms that are discussed in relation to reducing emissions from deforestation and forest degradation, or managing and the amount of carbon released to the atmosphere. However, enough study has not been conducted on the contribution of wood lands and the individual trees found in closed woodland area or open grazing land in this study area. Closed woodland areas are one of the biggest reservoirs (sink) of carbon, and hence they help to keep carbon cycle and other natural processes working and help to sequester carbon (Prentice *et al.,* 2001).

The central rift valley in Adami Tullu Jiddo Komblcha has closed woodlands and trees on open grazing land ecosystems that have a potential of storing carbon from the atmosphere. Individual plants in the open grazing land store carbon in their live biomass and once they die the biomass becomes a part of the food chain and enters the soil as a soil carbon. If the biomass is incinerated the carbon is re-emitted in to the atmosphere. Since the woodlands and individual plants pull CO_2 out of the atmosphere, this double role makes woodland forests more important (Bennington, 2009). Average values of biomass carbon densities for the major ecosystems are used as inputs to climate-carbon models, estimating regional and national carbon accounts, and informing policy debates.

With regard to soil, small changes in soil organic carbon (SOC) stocks could have severe impacts on the global carbon cycle. Reliable measurements of carbon concentration in soil are an important prerequisite for detecting such small changes in SOC stocks (Goidts *et al*., 2009). With the increasing concentration of carbon dioxide in the Earth's atmosphere as the result of deforestation, there is a pressing need to assess the carbon stock in woodland forests and soils. Therefore, estimate of the living carbon stock for acacia woodland in CRV is vital. There is an importance at closed woodland area and open grazing land, with the purpose of providing data for sustainable forest management and baseline data for carbon monitoring.

1.2 Statement of the problem

The vegetation cover is the most important part of woodland ecosystem. A mis-management practice was commonly observed in Central Rift Valley (CRV) of Ethiopia.(Biyensa *et al.*,2015). Deforestation, especially acacia woodland clearance, frequent cultivation, crop residue removal and mono-cropping are among the major land mis-management practices in the area. The removal of woodland vegetation resulted in climate change. In this regard, the potential of carbon storage of woodland and Woody Plant Species and its role for climate change mitigation was not addressed before at the study sites. Hence, investigation of the influences upon vegetation changes can make the people to exploit the ecosystems via ecologic concepts (Alder, 2000).

Sustainable management of woodland forest is a practical way of retaining the existing carbon reserves and thus avoiding emission of carbon dioxide. These local-scale ecological functions of woodlands and individual trees in open grazing land is not well studied as a potential for climate change mitigation.

In general, to see these gaps and show the carbon stock storage potential of closed woodland area in relation to adjacent open grazing land detail study has been conducted in the area. The contribution of existing woody plant species, and soil carbon should be understood. Trees at woodlands, closed or open grazing land have high role in climate change mitigation and reducing GHGs beyond its aesthetic/ recreational value. Therefore, for many purposes it is important to know the spatial distribution of biomass carbon within ecosystems of the study area and the effects of human land-use activities on forest conditions and resulting carbon stocks

Adami Tullu Jiddo Kombolcha District which is found in East Shoa Zone of Oromia Region can be raised as part of a central rift valley to have huge area of acacia woodland managed by the local community. Even though these woodland forest area can be raised as a part of natural forest of the rift valley, the advantage in relation to its biomass and carbon source is not well understood. Additionally, lack of researches in measuring carbon storage potentiality of closed woodland forests in relation to open grazing land at a large scale in Ethiopia and in Adami Tullu Jiddo Kombolcha District in particular contributes for the non-sustainable management of trees in the woodland areas.

A good understanding of the carbon dynamics of woodlands (IPCC, 2006) is therefore important, particularly about how carbon stocks vary in relation to land use and human land-use activities. Despite the fact that closing areas for periodic rotational grazing have been practiced in the district for long time, empirical data on the biomass carbon stock potential of the area are lacking. Particularly, a comprehensive study in comparing the potential of closed woodland and open grazing land to restore ecosystem carbon is needed for an effective management.

1.3 Objectives of the study

1.3.1 General objective

The overall objective of this study is to assess carbon stock of closed area and open grazing land ecosystems in central rift valley.

1.3.2 Specific objectives

The specific objectives of the study are;

1. To assess biomass carbon stock of closed acacia wood land in relation to adjacent open grazing land of the study area.

2. To assess the soil carbon stock of closed acacia wood land in relation to adjacent open grazing land of the study area.

3. To document the major contributing tree species to higher biomass carbon stock in both closed and open woodlands of the study site.

1.4 Significance of the study

This research study provides information about the carbon stock of closed woodland area and open grazing land found in Adami Tullu Jiddo Kombolcha district. Information in relation to contribution of tree species in storing carbon was also be revealed.

The obtained findings from the study can assist decision makers to take appropriate action in conserving and managing woodlands so as to maintain their role in climate change impact mitigation and to make other ecological and socio-economic values sustainable.

The information can be useful for any institutions whether governmental or non-governmental that have a special interest to conserve woodlands so as to increase their carbon sequestration capacity. Furthermore, it is also believed that the information which is generated in this study can serve as a basis or secondary data for further research and other works of related fields. In general, it provides organized document for researcher, decision maker, legislative body, government and nongovernmental organizations and other concerned body endeavors for the study of wood lands as contributors of climate change mitigation.

The carbon storage potential of dominant individual tree species which exist in closed woodland or open grazing land is not well studied. Likewise, the contribution of both areas, which preferably requires more attention is not clearly investigated and identified.

Therefore, this study is taken up to estimate the carbon stock of the closed woodland forest area and open grazing land to compare and to see the variations of the carbon stock density of different carbon pools in both ecosystems; major potential pools of organic carbon (above and below ground; dead litter and soil organic carbon pool).

In addition, beyond all these, the findings of this study are also expected to create a strong awareness on the community regarding the importance of applying best management practices of woodlands in assuring their climate change mitigation capacity and other services. This study has helped in understanding the carbon stock in both closed woodland forest area and open grazing land and help to inform the government and policy makers give due attention to the area.

2. LITERATURE REVIEW

2.1 Forests resources in Ethiopia

Forest cover more than one third of the world's land area and constitute the major terrestrial carbon pool. The amount of carbon sequestered and stored in forest varies greatly based on a large number of factors, including the type of forest, its net primary production, the age of the forest, and its overall composition (Millard, 2007). Forests and woodlands are sinks and reservoirs which naturally absorb carbon dioxide (FAO, 2008). The CO_2 gas is stored in the vegetation biomass and soil. In these regard, forests and woodlands help to mitigate the challenges of climate change (Stern, 2006; UNFCC, 2008).

Ethiopia's forest resources supply most of the wood products used within the country, as well as a large volume of diverse non-timber forest products (NTFPs), besides their ecological functions. According to woody biomass inventory strategic planning project (WBISPP, 2005) the proportion of woodland area covers 29,549,016 ha which accounts 25.8 percent. Moreover, livelihoods of significant number of people depend on forests and woodlands through provision of many forest products and environmental services (Katerere *et al.*, 2010).

Global warming is real and there is a growing interest in the role of different land use systems in stabilizing atmospheric CO_2 concentration (1PCC, 2014). Global warming has increased during the last century due to the greenhouse gas effect in the atmosphere. Carbon dioxide is one of the greenhouse gases (GHGs) from the atmosphere causing global warming (UNFCC, 2008). However, trees in woodlands and forests play a great role in mitigating global warming in reducing atmospheric carbon dioxide, the major greenhouse gas, through carbon sequestration and storing in the form of above and below ground biomass (Breuer, 2012; Nair *et al.*, 2009).

2.2 Biomass estimation in forest ecosystem

In the global carbon cycle biomass is an important building block. Biomass is an important element in the carbon cycle it is used to help quantifying (measure the quantity of) pools and fluxes of greenhouse gases (GHG) from the terrestrial biosphere to the atmosphere associated with land-use change and land cover changes (Cairns *et.al.*, 2003).. The quantity of biomass is expressed as a dry weight or as the energy, carbon, or nitrogen content. Thus, biomass is defined as mass of live or dead organic matter. Biomass includes the total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass (Woldemariam, 2014). Predicting tree biomass is important for developing indicators of forest productivity, quantifying patterns of forest succession, estimating potential carbon sequestering in forest stands and modelling forest growth at both tree and stand levels Biomass is an important carbon pool in forest ecosystems (Fahey *et al.*, 2010), especially tree biomass, including the trunk, branches, foliage, and roots. Most of the total carbon in plants is stored in aboveground biomass (trunk, branches, foliage. (Aholoukpè *et al.*, 2013). Many researchers have focused only on carbon sequestration by the tree (Sharma *et al.*, 2010); less is known about the carbon pool in understory vegetation.

Changes in time of vegetation biomass per unit area, biomass density, and can be used as an essential climate variable, because they are a direct measure of sequestration or release of carbon between terrestrial ecosystems and the atmosphere. Therefore when using the term "biomass" we refer to the vegetation biomass density, that is mass per unit area of live or dead plant material. Unit of measure as kg/m^2 or multiples. In recent years, the estimation of biomass components has become important for environmental projects, since biomass can be related to carbon stocks and to carbon fluxes when biomass is sequentially measured over time (Návar, 2009). Biomass can be a source for carbon in different forms in the pools; aboveground, belowground and soil carbon. Therefore, a global assessment of biomass and its dynamics are essential inputs to climate change forecasting models and mitigation and adaptation strategies.

2.3 Estimation of Carbon stock

Carbon storage in forest ecosystems involves numerous components including biomass carbon and soil carbon Worldwide numerous ecological studies have been conducted to assess carbon stocks based on carbon density of vegetation and soils (Saugier, 2001). The results of these studies are not uniform and have wide variations and uncertainties probably due to aggregation of spatial and temporal heterogeneity and adaptation of different methodologies (Kishwan *et al.*, 2009). Carbon estimates, and particularly the estimates of changes in different carbon pools, are highly relevant for the international conventions and processes related to climate change, such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. To know the carbon stored, much information is need on the amount of woodland biomass in different regions. The estimation of total biomass in a given pools have great importance for the description of structure and function of ecosystem, for applying sustainability, reducing emissions of carbon dioxide and also important to know what are the ecological indicator for sustainability (Chave *et al*., 2003).

Carbon inventory/carbon estimation is new techniques and it is difficult to get the practical guidance at variety of land uses nationally and even not widely available globally (woldemariam, 2015). Therefore, carbon estimation will require appropriate guideline to undertake biomass inventory in various land uses. Biomass carbon includes carbon stored in above- and below-ground live plant components (such as leaf, branch, stem and root) as well as in standing and down dead woody debris, and fine litter.

A comparison between the different biomes of the world shows that the highest mean annual increment of carbon biomass occurs in the tropics (Djomo *et al.*, 2011). This increment includes photosynthesis and autotrophic respiration represented by aboveground and belowground (fine and coarse roots) biomass growth being the principal components of the carbon budget in tropical forests (Djomo *et al.*, 2011). Therefore, carbon sequestration in tropical and subtropical regions has been receiving increased attention because these forests grow year round and have intense photosynthetic activity and a wide diversity of species (Chen *et al.* 2012), which would also applicable for wood lands.

2.4 Methods to estimate biomass carbon stock

The measurement of tree biomass in the field is a resource-consuming process, in terms of both time and budget. The direct method of estimating biomass in a forest is to harvest all trees in a known area and weigh their biomass (Gibbs *et al.*, 2007). Although this method is the most accurate, it is impractical for implementation over a large area because it is time and resource consuming, destructive, and expensive (Henry *et al.,* 2011; Akashi *et al*., 2012). This method is often used for validation purposes (Basuki *et al.*, 2009). Allometric equations developed on the basis of direct biomass measurements from destructive sampling are related to different tree biometric variables that are more easily and directly measured in the field during forest inventory (Basuki *et al.,* 2009). Consequently, a simple methodology such as the formulation of allometric equation is required to quantify accumulation of biomass. Allometric equations are most widely used method for estimating biomass of forest (Razakamanarivo *et al.*, 2011).

Forest managers and researchers require biomass equations to predict the growth of young forest stands and woodland trees. However, the landmass of African is primarily with a wide variety of vegetation communities (Brown *et.al.,*1995). Because of this diversity, it is practically difficult to develop allometric equations for all species present in the ecosystem. The literature review also didn't find allometric equations developed to estimate above ground biomass (AGB) of the woodland tree species inventoried.(Ahmedin *et al.,* 2013). There are different trees/shrub biomass estimating methods employed by forest researchers and scientists of which the destructive method is the one mostly recommended to have plausible (apparently reasonable) estimation (Cleemput *et al.*, 2013, Negash *et al.*, 2013a and Negash *et al.*, 2013*b*). In the contrary, destructive methods have many limitations in practical applications. It is not cost effective and is more laborious when studying large forest and wood land areas or many sample plots (Zhao *et al.,* 2014). Additionally, it is also difficult to apply for endangered and rare tree species, and destructive sampling creates the opportunity for illegal forest harvest by the local people. Therefore, procedurally estimation of tree biomass by whole-tree harvesting is an old approach that consists of cutting down sample trees, separating various parts (stem, leaves, inflorescence, *etc*.), digging out and washing the roots, determining their dry weights from samples of each part, and adding them up to get the total biomass. After dividing up the harvested representative trees into their various components (branches, dead branches, branch lets, leaves, roots and fine roots), and determining their dry weight, the carbon content in each is measured.

In opposing to destructive method (old method), determining tree/shrub biomass in allometric equations using some measured biophysical tree parameters (like DBH, Height) has become the most preferable method in many forest biomass studies. The non-destructive method of determining tree biomass is extremely time and labour intensive, especially for large trees. It is often used less costly methods, such as the estimation of carbon stock using non-destructive in-situ measurements and remote sensing.

With increasing understanding about the role of forests and woodlands in sequestering carbon, various allometric equations have been developed for different forest types (FAO, 2004; Pearson *et al.,* 2005; Chave *et al.,* 2005, Chave *et al.,* 2014, Basuki *et al.,* 2009, Fernández-Núñez *et al.,* 2010, Hunter *et al.,* 2013, Vieira *et al.,* 2014, Djomo *et al.,* 2010). These allometric equations developed based on biophysical properties of trees and validated by occasional measurements of non-destructive sampling which are widely used in forestry for estimating standing volumes of forests. Tree measurements in sample plots are converted in to tree biomass either by using allometric equations (tree biomass equations) or by using volume equations in combination with wood density and biomass expansion factors (UNFCCC, 2015). Instead of volume equations, allometric equations or tree biomass equations has been adopted in this study.

2.5 Aboveground Carbon Stock

The carbon stock in aboveground tree biomass is estimated from measurements conducted in sample plots. Estimating of the carbon stock on an area can be achieved by taking a representative sample rather than measuring the carbon in all components over the whole area. A small, but carefully chosen sample can be used to represent the population. The sample reflects the characteristics of the population from which it is drawn. For carbon sampling, measurements should be accurate (close to reality for the entire population) and precise (short confidence intervals, implying low uncertainty) (Hairiah *et al.*, 2001), cited by (woldemariam, 2015).

Above-ground carbon (AGC) is expressed as tonnes of biomass or carbon per hectare. Above ground biomass is the most important and visible carbon pool, and the dominant carbon pool in woodland forests and plantations, although not in grasslands and croplands. Aboveground measurements of carbon stock (and, by implication, carbon sequestration) are assuming of estimates of the above ground biomass, the amount of harvested and standing biomass, and the measurements are relatively straight-forward compared to those of 50% of carbon.

2.6 Belowground Carbon Stock

Below-ground biomass is defined as the entire biomass of all live roots, although fine roots less than 2 mm in diameter are often excluded because these cannot easily be distinguished empirically from soil organic matter. Below ground biomass is an important carbon pool for many vegetation types and land-use systems. 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. 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 of time. The Below Ground Biomass (BGB) includes all biomass includes live roots excluding fine roots having <2mm diameter (Chavan and Rasal, 2012). The belowground biomass (BGB) has been calculated by multiplying above-ground biomass taking 0.26 as the root to shoot ratio (Cairns *et al.*, 1997; Ravindranath and Ostwald., 2008; Chavan and Rasal, 2012). Similarly, below-ground or live root biomass is expressed as tonnes of biomass or carbon per hectare.

2.7 Soil carbon sock

Soil is a vital natural resource that is not capable of being renewed on the human time scale (Liu *et al.*, 2006). Because soils are very heterogeneous by nature, the spatial variability in both SOC and BD is high. Moreover, BD is variable with time due to soil shrinking and swelling and due to tillage and other agricultural management operations (Hopkins *et al.*, 2009). It is a living and dynamic natural body that plays many key roles in terrestrial ecosystems, for instance, as sources of available nutrients to plants, maintenances in hydrological stability and biological diversity.

Soils are among the largest terrestrial reservoirs of carbon and hold potential for prolonged carbon sequestration. Soils sink carbon and release to the atmosphere when the equilibrium (i.e. inflow and outflow) carbon content is disrupted due to human actions such as land use change, precipitation, temperature, etc. During this process, soil may act as a carbon source or a carbon sink according to the ratios between inflows and outflows. Thus, they are critically important in determining global carbon cycle dynamics and can provide a potential way to reduce atmospheric concentration of carbon dioxide (Woldemariam, 2014).

Soil Organic carbon in mineral soil to a specified depth chosen and applied through a time series. Live and dead fine roots within the soil (less than the suggested minimum for belowground biomass) are included where ever they cannot be empirically distinguished from the soil organic matter. Soil physical properties could be affected not only by land use changes but also by land management practices (Liu *et al.*, 2006; Snyder *et al.,* 2009; Alberti *et al.*, 2010; Rouw *et al.,* 2010.

The mechanism of species driven carbon sequestration in soil is influenced by two major activities, aboveground litter decomposition and belowground root activity (Lemma et al., 2007). Litter decomposition is one of the major sources of soil organic carbon and the quality of litter is very important in this regard (Mafongoya *et al*., 1998; Issac and Nair, 2006., Lemma *et al.*, 2007).

2.8 Litter biomass and litter carbon

All non living biomass with a size greater than the limit for soil organic matter (the suggested minimum is 2 mm) and less than the minimum diameter chosen for deadwood (e.g. 2 cm) lying dead and in various states of decomposition above or within the mineral organic soil is defined as litter. In the ecosystem with high plant diversity, litters are represented with different degrees of chemical resistance. Creating the possibility of carbon through slow decomposition of litters from some species.

In general, to estimate the total amount of carbon stocks within an ecosystem, simply sum the carbon stocks in all measurable pools; aboveground, belowground, litters and soils.

The total standing biomass (TSB) is obtained from the sum of AGC and BGC which is multiplied with 3.67 (44/12, where Molecular weight of CO_2 = 44 and Atomic weight of carbon = 12) for equivalent CO_2t ha-1.This can be attained through estimating the biomass of the existing woodland resources.

3. Materials and methods

3.1 Description of the Study area

3.1.1 Location

This study has been conducted in Adami Tulu Jiddo kombolcha (ATJK) district, East Shoa Zone, Oromia regional state, Ethiopia. Adami Tulu Jiddo Kombolcha is located at 167 km from central government city, Addis Ababa, and 114 km from zone central town, Adama. The research study has focused on a total area of 340.48 ha (160.48 ha closed and 180 ha open grazing land) for carbon stock assessment to compare the better management practice that will serve to other land uses. The study area lies between 38^0 24'and $38^0$42' East longitudes and 7^0 30'and 7^0 42' North latitude, in East Shoa Zone, Oromia Regional state (Map 1). The altitude of the site ranges between 1600-1700 m a. s. l. specific to the study area.

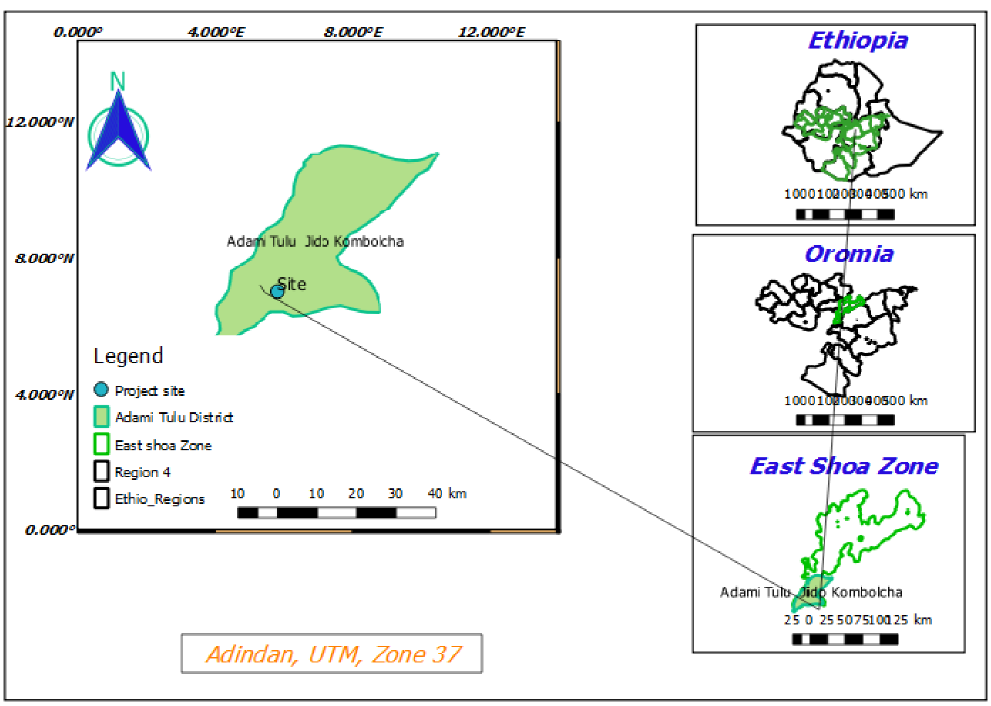

Figure 1: Location Map of the study area

3.1.2 Climate

The climate of the study area is characterized by distinct wet and dry seasons (i.e., it demonstrates bimodal rainfall). Even though it is not periodical, there is early rain in April, usually a short dry spell in late May and early June, and then more extended rain from July to September. During November to February, a long period of dry weather usually occurs with little or no cloud cover. The area receives average annual rainfall of 600 and 800 mm. The mean monthly temperature varies from 18.5°C to 21.6°C with mean annual temperature of 20°C. (Biyensa *et al.,* 2015).

3.1.3 Geology and soil

The soils are developed on lake deposits inter-bedded with pumice and classified as Andosols (Mekuria *et al.,* 1999). They are coarse textured (loamy sand to fine sand), alkaline, especially where high ionic strength has caused a precipitation of calcium carbonate, low bulk density and hence weaker structure which render them vulnerable to wind and water erosion.

3.1.4 Vegetation

The natural vegetation similar to most areas of central rift valley dominated by sparse umbrella shaped *Acacia species* and *Balanites species* woodland. High number of seedlings of the same species are observed in the closed woodland and open grazing land during data collection. 325 *Acacia tortilis*, 257 *Acacia seyal* and 280 *Balanites egyptiaca* were counted in closed woodland area. Similarly, 274 *Acacia tortilis*, 10 *Acacia seyal* and 13 *Balanites egyptiaca* were counted in open gazing land. This could be an indicator for regeneration capacity of the area based on the favourable conditions.

3.1.5 Population and land use system

The number of population of ATJK district is about 179840 (86747 male and 93093 female). The population of the district depends on subsistence mixed farming of both livestock and agricultural crop production.

3.2 Method

3.2.1 Sampling Design

The study site was selected based on accessibility, representativeness and suitability to the study design. At the beginning, both closed and open grazing land was observed and delineated by taking geographic coordinates with GPS at each turning point. The recorded GPS points helped for mapping the study site. The total area is 160.48 ha for acacia woodland and 180 ha for open grazing land.

After delineating and mapping the total area, transect lines has been laid in both closed forest area and open grazing land starting from main road. To reduce the boarder effect 50 meter distance was measured from the forest boarder during the construction of transect lines. The distance between each transect line was 200m and the distance between consecutive plots within transect line was 200m. Accordingly, 60 sample plots (30 sample plots for closed forest area and 30 sample plots for adjacent open grazing land) were laid. The first point was randomly selected, then subsequent points were placed at the transect lines. The coordinates of the intersections were recorded as the centre of the plots and were uploaded in GPS receivers for location of the plots in the field. Nested rectangular plots were used to collect the data (Figure 2).

From the nested plot major plot size is 1000 m^2 (20 m x 50 m) and other smaller plots of 10 m X 20 m within larger plot for collection of soil and litter sample from their corner as described in the plot design (Figure: 2). The Litter sample were collected from four quadrants of smaller plot and from the centre of the plot. A total of five samples were collected using wooden frame in each plot and in each ecosystem to replicate. This simply for the ease of access and make portable the amount of litter.

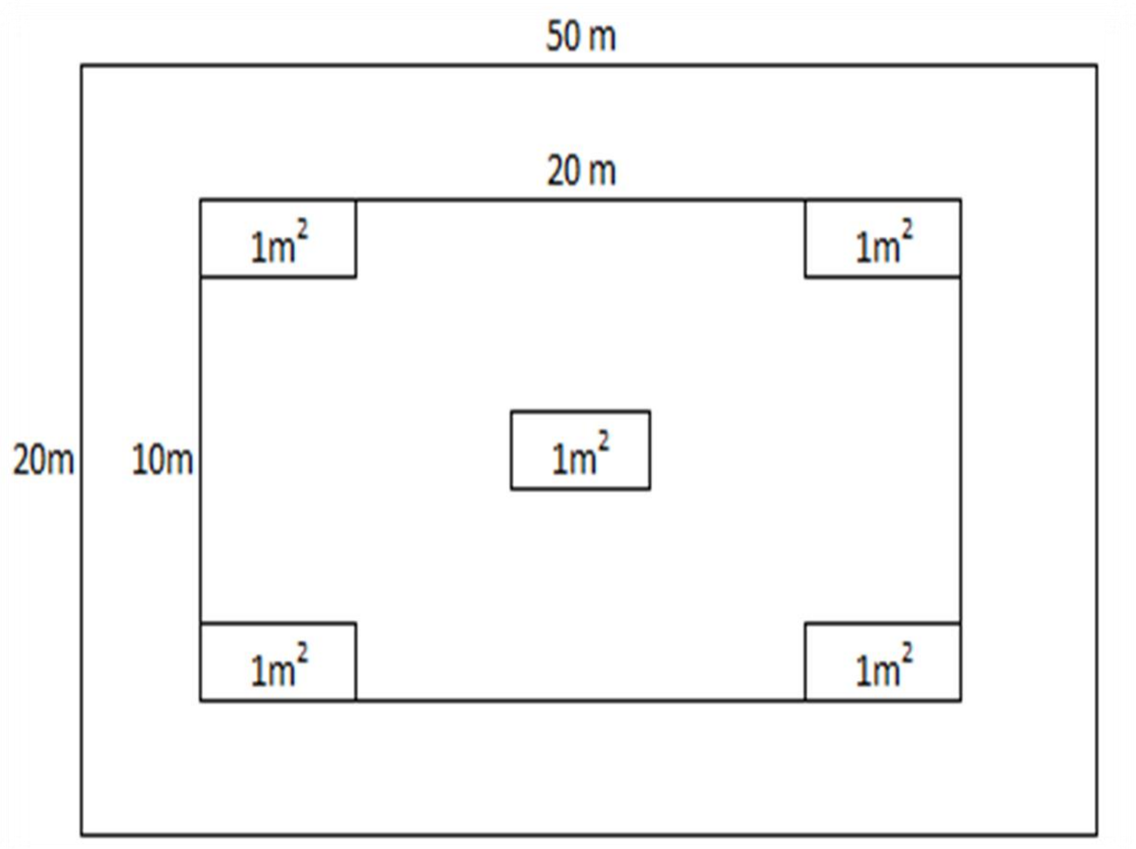

Figure 2: Plot shape and plot design

After plots were distributed trees found in the main plots with DBH ≥ 2cm were measured using calliper and tree height ≥ 2m were measured using hypsometer.

Allometric models (equations) are a fundamental tools for estimation of biomass in woody vegetation and their value depends on the empirical data used to construct such equations (Kuyah et al., 2012). Allometric equations used to estimate the biomass for carbon. These equations express tree biomass as a function of easy-to-measure parameters such as diameter (DBH), height (Ht), wood basic density, or a combination of these (Chave *et al*., 2005; Brown, 2012). The equations are generated from a small sample of trees and are then used to estimate biomass on a larger scale. Measured tree parameters such as DBH and Ht are the most preferable predicators of biomass of woody species.(Chave *et al*., 2014). Accordingly, allometric equation of (Chave *et al*., 2014) was selected for this study to estimate the aboveground biomass. The allometric equation is;

AGB(kg) = 0.0673*(WD*DBH^2*H)^0.976

Where; AGB(kg) = aboveground biomass in kg, WD= wood basic density(g/cm^3), DBH=diameter at breast height and H= Height of the tree

This model was selected;

For its use for all forest type in the Globe,

Suitable for Ethiopian vegetation equivalent type.

Moreover, this model uses the most important biomass predictor variables like DBH, Height and Wood basic density.

It's quality is high,

Covers a wide geographical range, and

Serve for DBH range from 2 to 158 cm.

3.2.2 Data collection

The primary and secondary data had been used in order to collect the important data to meet the objectives of this study. Primary data has been obtained from field observation and measurements in the study area and the secondary data has been collected from different sources like published and unpublished materials, books, journals, articles and, from Adami tullu research centre (ATRC) and Adami tullu Jiddo Kombolcha (ATJK) district agricultural and natural resource office.

3.2.3 Estimation of Biomass carbon

The mean biomass in hectare base (t/ha) was multiplied by the total woodland area in each ecosystem to obtain total mean biomass density. Biomass is a measure of biological matter, customarily expressed in kg/m^2 or multiples. The biomass of a forest is a complex topic that includes all organisms, trees, fungi and insects. In this study, the estimation of biomass includes components of tree stems and litter. As a pools the biomass estimation includes the aboveground biomass, belowground biomass, and litter biomass. Aboveground biomass estimation of the forest ecosystem enables us to estimate the amount of carbon that can be sequestered from the atmosphere by the forest through measuring individual tree in the forest or trees on the grazing land.

Tree data;

Aboveground biomass

The above ground biomass (AGB) 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 (Ravin dranath *et al., 2*008).

Belowground biomass

The Belowground Biomass (BGB) includes all biomass of live roots excluding fine roots having < 2mm diameter (Chavan and Rasal, 2012). Based on age, site condition, different literatures calculate belowground biomass (BGB) by multiplying above-ground biomass taking root to shoot ratio (Cairns *et al*, 1997; Ravindranath and Ostwald, 2008; Chavan and Rasal, 2012). In this study, belowground biomass is estimated by using root-shoot ratio of 27% (IPCC, 2003). This is because by assuming that dry land vegetations allocate more resources to their root part. The aboveground carbon (AGC) as well as belowground carbon (BGC) were estimated as 50% of biomass (IPCC, 1996; Chavn and Rasal, 2012).

Dead wood :

Even though dead wood is one of the carbon pool, it was not found specially in open grazing land. The local community removed the dead wood from open grazing land since it was open access to the community. In closed woodland the amount observed was less than 5% and it was insignificant to for comparison of two ecosystems. Therefore, the study was limited to the significant carbon pools.

Wood basic density:

The specific density of 0.590 g cm^3 for *A.tortilis*, 0.497 for *A.seyal* and 0.542 for *Balanites agypitiaca* was used to perform the estimation.

Identified trees were named at the field using local guides. The name of the trees that were not identified at the field were identified by the help of identification book "Useful Trees and Shrubs for Ethiopia" (Bekele, 2007). All the identified tree species greater than the specified DBH were measured for the assessment of biomass carbon estimation.

Even though not stated in the objectives, from the observation, tree sapling species that are less than 2 cm DBH were also counted. Because they are the future indicators of forest of the area The regenerating vegetation are the same species to that of the existing measured trees. This shows there may be seeds stored in the soil as a bank for the future replacement for the natural forest based on favourable conditions.

3.2.4 Determination of Litter carbon content

The litter samples were collected from five 1m x 1m sub- smaller plots, (four at corners and one at the centre). The litters collected from the sub smaller plots (30 litter sample for each ecosystem) were weighed when fresh in the field and a composite of sub samples were taken to the laboratory for further analysis.

At laboratory, before conducting ash method, fresh sample from field was mixed evenly and a composite of sub sample of 100 g was weighed to be dried in the oven. In this method, freshly taken weight of samples has been dried at $65^0{}_C$ in the oven for 48 hours to get oven dry weight. In the laboratory, the oven dried samples were grind (using mortar) and 5g were added in to pre-weighted crucibles, and then put in the furnace at 550^0C for one hour to ignite (Ullah and Al-Amin, 2012). The crucibles cooled slowly inside the furnace. After cooling, the crucibles with ash has been weighed and percentage of organic carbon content has been calculated accordingly (Allen *et al.*, 1986) as follows;

$$\text{Ash} = \frac{(W3 - W1)}{(W2 - W1)} * 100$$

C (%) = (100-%Ash) × 0.50

Where;

W_1 =weight of crucible,

W_2 = weight of the oven-dried grind sample and crucible,

W_3 = weight of ash and crucible

0.50 in the given formula. is the default correction factor.

After determination of %C, the amount of biomass in litter was estimated (Pearson *et al.*, 2005) for the calculation of carbon stock in litter.

$$LB= \frac{Wt\ field}{A} * \frac{Wt\ sub\ sample(dry)}{Wt\ sub\ sample\ (fresh)} * \frac{1}{10000}$$

Where: LB = Litter (biomass of litter t/ha)

W field = weight of wet field sample of litter sampled within an area of size 1 m^2 (g);

A = size of the area in which litter were collected (ha);

W sub-sample (fresh) = weight of the fresh sub-sample at the laboratory to determine moisture content (g).

W sub-sample (dry) = weight(g) of the oven-dry sub-sample of litter at the laboratory

Finally, carbon stock in litter was determined by the following equation;

$$CL = LB \times \%C$$

Where; CL= Carbon stock of litter.

LB= Litter biomass and

%C= carbon content of litter.

3.2.5 Determination of carbon content in the Soil

The soil samples have been collected from five smaller plots (1m x 1m) (four from the corner of smaller plots and one from the centre of the plot). The Samples have been collected using auger at depth of 0 - 20 cm and 20 - 40 cm from each quadrant and from the plot in the centre.

The soil samples of the same depth were mixed up to make a composite of 100 g that was taken to the laboratory for organic carbon nutrient analysis. Mixing of soils have been performed evenly by taking equal amount of soil from each smaller plots and each depth to make a composite in order to make homogeneity for carbon nutrient analysis (Tefera, 2016). After organized in such a way, the samples were taken to Zeway soil laboratory, Institute of Oromia branch for laboratory analysis. The total of 60 composite soil samples from different depth (0 - 20cm) and (20 - 40cm), and different ecosystem (15 for closed forest area and 15 for open grazing land) taken to the laboratory. At laboratory, it had dried at 105^0C in the oven for 48 hours to get oven dry weight. After removing moisture the dried soils burned in the Furness (loss on Ignition) for 550^0C and cooled for one hour to calculate carbon percent (C%).

3.2.6 Determination of Bulk density

In addition, separate soil samples for soil bulk density determination were collected from the centre using 5 cm height and 5 cm diameter core sampler (98.125 cm^3) from the respective depths, 0 - 20cm and 20 - 40cm. The soil samples that have been collected for soil bulk density measurement by using core sampler- at the centre of 0-20 and 20-40cm from pit. The undisturbed fresh soil samples extracted by sample corer bagged in a plastic bag, sealed and labelled. Pre to bulk density, the volume of soil was calculated by using volume equation (Tefera, 2016);

$V = h * \pi r^2$,

Where;

V = volume of the soil in the core sampler in cm^3,

h = the height of core sampler in cm, and

r = the radius of core sampler in cm., π is 3.14

To estimate bulk density, soil samples with a known volume were oven dried at 105^{o}C for two days (48 hours) until they reached constant weight, cooled down to room temperature in a desiccators, and weighed (Kauffman and Donato, 2012). This was recommended for bulk density determination to boil away any water from the sample. Weight of sample was recorded after oven-drying. Bulk density was determined by the following equation;

$$\text{Soil bulk density(gcm}^3) = \frac{Oven\ dry\ sample(g)}{sample\ volume(\text{cm3})}$$

3.2.7 Determination of Soil Organic Carbon Concentration

After soil bulk density and soil carbon (%C) is determined soil organic carbon concentration at different depth were calculated by the following equation;

SOC = BD * D * %C... Equation.1

Where; SOC = Soil Organic Carbon, D = Soil depth in cm

BD = Bulk Density(g/cm3), and %C = Soil carbon nutrient content in percent.

The total carbon stock is calculated by summing the carbon stock densities of the individual carbon pools of the ecosystem using Pearson *et al*,.2005 formula, carbon stock density of study area (Table 5):

CT =AGC + BGC + LC + SOC;

Where, CT = Total carbon stock for all pools (t/ha), AGC = Aboveground carbon stock(t/ha), BGC = Belowground carbon stock(t/ha), LC = Litter carbon stock (t/ha) and SOC = Soil organic carbon.

3.3 Data analysis:

The collected data from closed area and open grazing land were recorded and arranged in excel work sheet. Required biomass is calculated for aboveground, belowground, and litter.

Similarly, the carbon stock was derived from dry weight of aboveground biomass, belowground biomass and litter biomass is calculated and recorded. The soil organic carbon from their respective carbon nutrient, depth and bulk density is calculated and recorded for further analysis.

The equation that was used to estimate the above ground biomass (Chave *et al*., 2014) is;

AGB (kg) =0.0673*(WD*DBH^2*Ht)^0.976..................... Equation.2

The belowground biomass derived from the aboveground biomass (IPCC, 2003) is calculated by the equation;

BGB = ABG x 0.27 .... Equation 3

Accordingly, aboveground carbon and belowground carbon has been derived from the dry weight (biomass) calculated above by using equations (IPCC, 1996 ; Chavan and Rasal, 2012)

AGC = AGB/2... Equation. 4

BGC = BGB/2 .... Equation. 5

The biomass of total ecosystem was calculated by summing the biomass of measured individual pools in closed forest area and open grazing land separately so as to compare the ecosystem carbon. In the same manner, the carbon stock was calculated by summing the carbon stock of measured individual carbon pools in closed forest area and open grazing land separately so as to compare them.

Total carbon stock (TC) = AGC + BGC + LC + SOC .... Equation 6

Where; Total C stock = the sum of carbon pools within respective ecosystem, closed forest area or Open grazing land

3.4 Statistical analysis

The recorded data from closed forest area and open grazing land were calculated by their respective equation. The assessment effect of the site variation on biomass carbon as well as soil carbon stock was tested using t-test and analysis of variance (ANOVA) for the study of carbon stock of the biomass carbon and the soil carbon. It was performed to separate means when test results indicated the presence of significant differences in mean differences between the two land uses.

4. Results

4.1 Mean biomass carbon stock of different pools of the Ecosystems

Vegetation structure and biomass density

The tree species found in the study area was *Acacia tortilis, Balanites agyptiaca, Acacia seyal* and few number of *Acacia abbyssinica*. Larger number of trees were measured in closed woodland(3990 trees/ha) as compared to open grazing land (2680 trees/ha). The average number of individual trees were 133 stems/ha in closed woodland and 89 stems/ha in adjacent open grazing land. The biomass variation observed resulted from larger number of trees and larger diameter class (which is > 15 cm DBH) distribution (Figure 3) in closed woodland as compared to open grazing land.

The mean biomass fraction of 0.16 tone per tree was resulted in the study area (total average biomass for the two ecosystems (35.29 t/ha) divided by total mean number of trees (222). Therefore, a significant difference in biomass between closed woodland and open grazing land has been observed and also a structural difference between trees sampled from both closed and open ecosystem were seen.

The tress found in both ecosystem were *Acacia tortilis, Acacia seyal* and *Balanites aegpytiaca*. From these tree species *Acacia tortilis* were dominant and very large in number of diameter and hence contribute more to the biomass potential in the ecosystem. Likewise, the counted regenerating seedlings *Acacia tortilis* (599) followed by *Balanites egyptiaca* (293) also reveals that the reality these tree species are dominant in both closed woodland and open grazing land of the ecosystem.

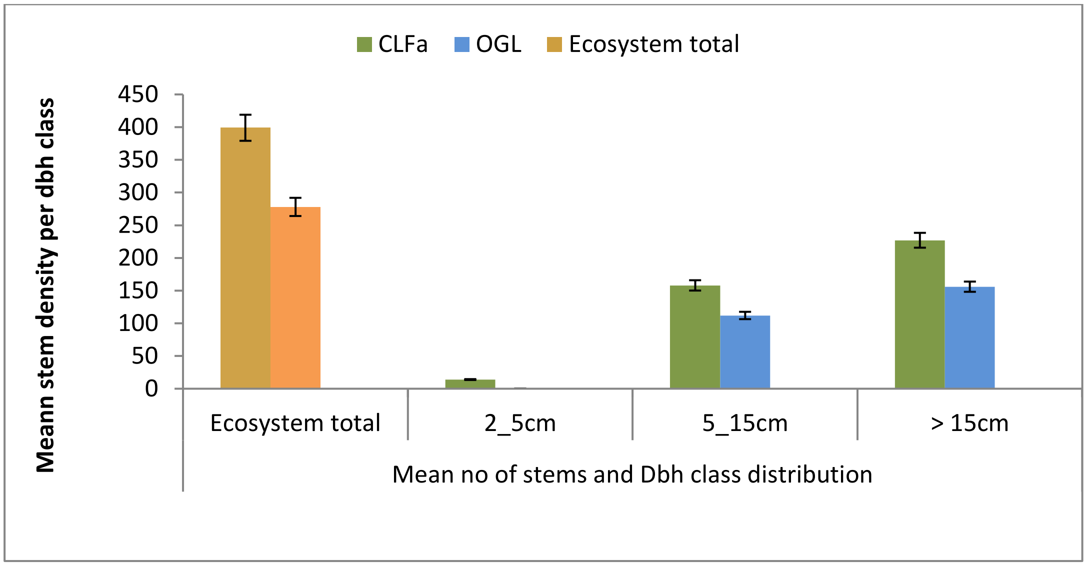

Figure 3: Total stem density/ ha and dbh classes in closed forest area and open grazing land.

CLFa= Closed forest area, OGL= open grazing land,

Dbh= Diameter at breast height

The carbon stock stored in Above ground pool of closed woodland exceeds by 4.10 t c/ha than that of open grazing land. Similarly the below ground carbon stock of Closed wood land exceeds by 1.11 t c/ha than Open grazing land.(Table 1).

Table 1: Comparison of the ecosystem mean biomass carbon stock(t ha^{-1}):

Land use	AGC	BGC	LC	Total
CLFa	10.87	2.94	0.58	14.39
OGL	6.77	1.83	0.05	8.65

In general, from the above result, the total biomass carbon (AG,BG and LC) of closed woodland contributed more 5.74 tc/ha than open grazing land. Within each carbon stock pools, mean values indicate a significant difference at $P< 0.05$.

4.3 Soil carbon

A standardized approach to the soil depth for SOC pool estimations is required, since SOC can be unevenly distributed over varying soil depths (Jandl *et al.*, 2014; Laurenz and Lal, 2016). This difference was magnified due to the storage of carbon on the upper layer of the soil. This is mainly due to the presence of fine roots at the upper layer, hence the accumulation of organic matter at upper layer is high. As one can observe from the study the carbon storage is decreasing from upper layer to lower in both case.(Table 3).

The average soil organic carbon of closed woodland was 89.36t C/ha) and that of open grazing land was 84.67t C/ha (Table 3). Though the average soil organic carbon stock is higher in the closed forest, the difference was not significant. Hence, no magnified interaction between closed forest area and open grazing land ecosystems in terms of soil carbon stock.

Table 2: Depth wise Mean (±SE) comparison of SOC of CLFa and open grazing land in Abarnosa ranch. ATJK district.

Land use versus soil depth

Depth	Mean ± SE
0-20	60.35 ± 1.79[a]
20-40	58.53 ± 1.86[b]
0-20	58.43 ± 1.79[a]
20-40	55.48 ± 1.79[b]
0-40	87.02 ± 3.74
P_value	0.387

Means with the different letters along column are insignificantly (P > 0.05) different

CLFa = Closed forest area   OGL = Open grazing land

Table 3:Comparison of soil carbon CLFa and Open grazing land

Comparison of mean soil carbon

Lu	Mean soil carbon
CLFa	89.36 ± 5.49
OGL	84.67 ± 5.14

4.4 Total Carbon Stock of Ecosystem

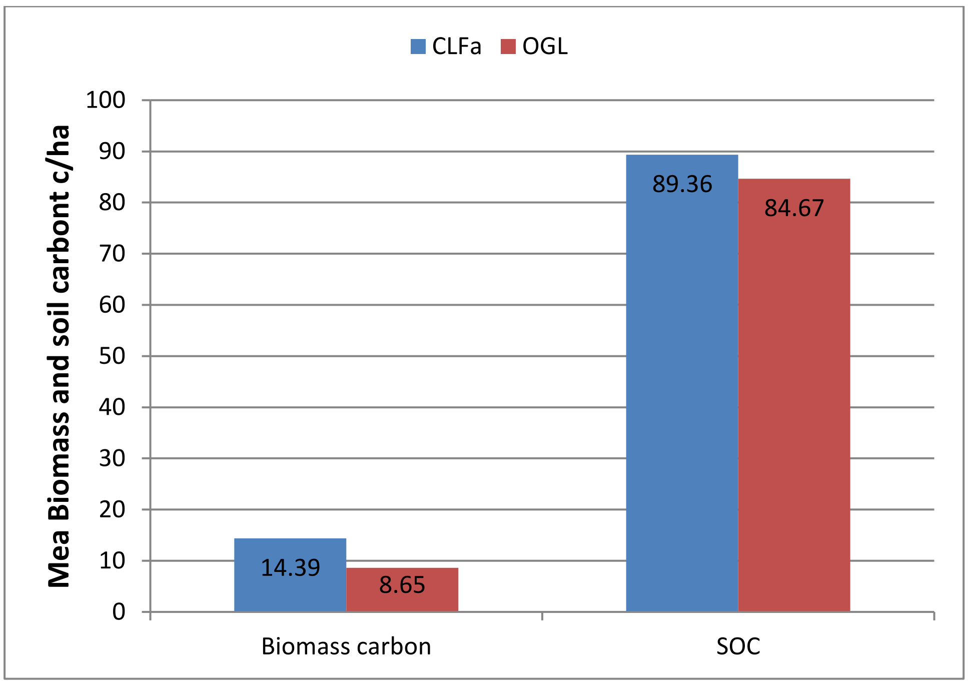

Figure 4 :Total carbon stock of ecosystem in Abarnosa ranch, ATJK district

5. Discussions

5.1 Biomass Carbon

The result showed that the mean biomass carbon of 14.39 t c/ha (62.46%) was obtained in this study for closed woodland area as explained in the result session. However, 8.65t c/ha (37.54%) was obtained in adjacent open grazing land (Table 1). The difference of 24.92% biomass carbon is obtained from closed woodland area due to closing, less intervention and better management practice. The result coincide with, the amount of biomass carbon stored in forest varies based on several factors including forest types, management practices (Peter, 2012), and level of human and natural disturbances.

5.2 Soil organic carbon stock

The highest soil carbon stock/storage was found in the upper layer of the soil in both closed woodland and open grazing land. The open grazing land is open for livestock to graze in the fields. The trampling of livestock makes the open grazing land proportional to the closed woodland area. In general, the contribution of organic carbon from soil to the ecosystem carbon stock was higher than the carbon stock from the biomass. The change in soil carbon is gradual as compared to carbon in biomass which is supported by Nelson *et al*, (1999).

5.3 Estimation of total Carbon stock of the ecosystem.

In the present study, comparing the four carbon pools, the largest carbon stock was contributed by the soil carbon pool, which accounted 92.71% in closed woodland and 90.73% in open grazing land of the four carbon pools and the second was the aboveground carbon pool which accounted for 10.48% in closed forest area and 7.25% in open grazing land of the four carbon pools. The lastly recorded was in litter carbon pool which accounted for 0.55% in closed forest area and 0.05% in open grazing land.(Table 4).

In general, comparing the total carbon stock of the two ecosystems, closed forest area accounts 52.05% total carbon stock as compared to open grazing land which accounts 47.95% to the ecosystem. In this study, closed woodland ecosystem with a better vegetation cover, better management practice (Closing) and soil conditions were found to have the best carbon storage potential as compared to open grazing land. Closing an area can improve the biomass carbon storage as compared to open grazing land due to the management practice. This is coincide with (Woldemariam, 2011). This was again revelled by (Tesfau, 2016) in his study on Carbon sequestration potentials of selected sites of closed forest and grazing land. The forest has a large potential for temporary and long term carbon storage as stated Houghton (2001). A large amount of carbon stock has been observed in a species which has counted long lived in the study site and also species which are densely populated in the pool.

6. Conclusion and Recommendations

6.1 Conclusion

We investigated the effectiveness of closing woodland areas help to restore aboveground, belowground and soil carbon stock in the central rift valley of ATJK, Ethiopia. Our results showed that the closing and improved management practice of woodland area has a significant potential to increase carbon storage. The findings of the study provide important information for local decision makers, which might enhance closing and improving management practices of woodlands that are ecologically sound, economically profitable and widely accepted by the local communities in central rift valley.

6. 2 Recommendations

Based on the result of the study, the following points were recommended;

- The closed woodland area shows large number of trees as compared to open grazing land. Consequently, closing the woodlands have more promoted by the local community.
- The community and different stakeholders should own the woodlands in their surrounding and should be responsible for their action and work together to sustainably manage the woodlands for their environmental benefits.
- The government should work on awareness creation activities on the community through education so as to understand the multiple advantages' of closing
- Since this research was conducted using the previously adopted model of estimating biomass of woodland species, species specific models for woodland natural forest species should be developed by further study for accurate estimation of biomass as well as carbon stock from the biomass.

References

Aalde, H., Abdelkadir, J., Penman, M., Gytar sky and T., Hiraishi. 2003. Good practice guidance for land use, land-use change and forestry. Institute for Global Environmental Strategies (IGES) for the IPCC, Kanagawa, Japan.

Aholoukpè, H., Dubos, B., Flori, A., Deleporte, P., Amadji, G., Chotte, J.L., Blavet, D. 2013. Estimating aboveground biomass of oil palm. Allometric equations for estimating frond biomass. *For. Ecol. Manag.292*, 122–129

Akashi, Z., Oldeland, J., Dengler. J., Finckh, M. 2012. Volume–biomass functions reveal the effect of browsing on three Moroccan dwarf shrubs.African Journal of Range and Forage Science, 29: 31–36

Alberti, G., Vedove, G.D., Zuliani, M., Peressotti, A., Simona, C.S., Giuseppe, Z.G. 2010. Changes in CO_2 emissions after crop conversion from continuous maize to alfalfa. Agric. *Ecosyst Environ 136:139–147*

Alder, P.B., Lauenroth, W.K. 2000. Livestock exclusion increases the spatial heterogeneity of vegetation in Colorado short grass steppe. *Jour. Applied vegetation science*, **(3):** 213-222.

Allen, S.E., Grimashaw, H.M. and Rowland, A.P. 1986. Chemical analysis*. In:"Methods in plantecology", Moore, P.D., Chapman, S.B.(eds). Blackwell Scientific Publications, London, UK*,Pp. 285-344.

Argaw, M., Teketay, D., Olsson, M. 1999. Soil seed flora, germination, and regeneration pattern of woody species in Acacia woodland of the rift valley of Ethiopia. Journal of arid environments 43, 411-435.

Asaye, Z. 2016. Effects of scattered Acacia tortilis (Forssk) hayne on soil properties in different land uses in Central Rift Valley of Ethiopia.

Basuki, T.M., Van Laake, P.E., Skidmore, A.K., Hussin, Y.A. 2009. Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forest. *Forest Ecology and Management, 257: 1684-1694.*

Bekele, A. 2007. Useful trees and shrubs of Ethiopia. Identification, Propagation and Management for 17 Agro climatic Zones. Technical Manual No 6.RELMA in ICRAF Project, Nairobi, Kenya. 552.

Bennington, J.B. 2009. The carbon cycle and climate change Blackwell, B. and K.Lassen, H. 'Study Design and Supplemental Literature Review MoFLNRDO Coast OGMA Wild fire project'.

Biyensa, G., Demissie, A., Lemma, B. 2015. Susceptibility of soil to wind erosion in arid area of the Central Rift Valley of Ethiopia.

Breuer, B. 2012. Effects of Vegetation Type and Species Composition on Carbon Stocks in semi-arid of Ethiopian. Savannahs University of Hohenheim .3, 11-15.

Brown, S. 1997. Estimating biomass and biomass change of tropical forests: A primer, FAO-Forestry-Paper 134. Forest Resources Assessment Publication, Illinois.

Brown, S. 2012. Measuring carbon in forests. Current status and nature challenges. *Environ. pollute*, *116*, *363- 372*

Brown, S., Gatson, G. 1995. Use of forest inventories and geographic information systems to estimate biomass density of tropical forests. Application to tropical Africa. Environmental Monitoring and Assessment 38: *157-168*.

Brown, S., Gibbs, H.K., Niles J.O., Foley, J.A. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Environmental Research. Letters, 2: p13.

Brown, S., Gillespie, A., Lugo, A. 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. *For. Sci. 35, 881–902*

Burgess, N.D., Bahane, B., Clairs, T., Danielsen, F., Dalsgaard, S., Funder, M., Hagelberg, N., Harrison, P., Haule, C., Kabalimu, K., Kilahama, F., Kilawe, E., Lewis, S.L., Lovett, J.C., Lyatuu, G., Marshall, A.R., Meshack, C., Miles, L., Munishi, P.K.T., Nashanda, E., Shirima, D., Swetnam, R.D., Willcock, S., Williams, A., Zahabu, E. 2010. Getting ready for REDD+ in Tanzania: a case study of progress and challenges. *Oryx* 44 (3):339– 351.

Cairns, M.A., Olmsted, L., Granados, J., Argaez, J., 2003. Composition and above ground tree biomass of a dry semi-evergreen forest on Mexico's Yucatan Peninsula, Forest Ecology and Management, 186(1-3; 125-132.

Canadell, J. 2013. Carbon and other biogeochemical cycles. In: T.F., Stocker et al., editors. Climate hange.

Chavan, B.L., Rasal, G.B. 2012a. Carbon Sequestration potential and status of *Peltophorum pterocarpum*(DC.), K. Heyne. *Science Research Reporter. 2(1): 51-55.*

Chen, Q. 2012. Aboveground biomass and corresponding carbon sequestration ability of four major forest types in south China.

CRGE,.2011. Green Economy Green economy strategy; Federal democratic republic of Ethiopia

Djomo, A.N., Knohl, A., Gravenhorst, G. 2011. Estimations of total ecosystem carbon pools distribution and carbon biomass current annual increment of a moist tropical forest. Forest Ecology and Management.

Engelsen, A. (2009). Incentives to sustain forest ecosystem services: A review and lessons for REDD. Natural Resource Issues No. 16. International Institute for Environment and Development, London, UK. 68pp.

Eshete, G.1999. Assessment of fuel wood Resources in Acacia Woodlands in the Rift Valley of Ethiopia. Toward the development of planning tools for sustainable management. Doctorial thesis. Swedish University of Agricultural Sciences, Umea.

Fahey, T.J., Woodbury, P.B., Battles, J.J., Goodale, C.L., Hamburg, S.P., Ollinger, S.V., Woodall, C.W. 2010. Forest carbon storage. Ecology, management, and policy. *Front. Ecol. Environ*., *8*, 245–252

Food and Agriculture Organisation(FAO). 2008. Terrestrial Essential Climate Variables for Climate Change Assessment, Mitigation and Adaptation *(GTOS 52)*.

Gedefaw, M. 2015. Estimation of Above and Belowground Carbon Stocks of Forests. Implications for Sustainable Forest Management and Climate Change Mitigation: *A Case Study of Tara Gedam Forest*, Ethiopia. *J Earth Sci Clim Change 6: 286. doi:10.4172/2157-7617.1000286*

Geider, J.R., Delucia, H.E., Falkowsk, G.P., Finzi, C.A., Grime, P.J., Grace, J., Kana, M.T., Roche, J. 2001. Primary productivity of planet earth: biological determinants and physical constraints in terrestrial and aquatic habitats. *Global Change Biology* 7: 849-882.

Goidts, E.B., Van Wesemael and Crucifix, M. 2009. Magnitude and sources of uncertainties in soil organic carbon (SOC) stock assessments at various scales. Eur. J. Soil Sci. 60:723–739. doi:10.1111/j.1365-2389.2009.01157.x

Goll I.I., Nick, B., Jianhua, Li., McKay, Jr., John S. 2014. Analysis on the Causes of Deforestation and Forest Degradation in Liberia: Application of the DPSIR Framework, *Research Journal of Agriculture and Forestry Sciences*, **2(3)**, 20–30.

Gorte, R.W. 2009. Carbon Sequestration in Forests. Congressional Research Service. CRS Report for Congress, Eggleston, H. S, Buendia, L. and Miwa, K. (eds). *Prepared for Members and Committees of Congress.* Greenhouse Gas Inventories Programme.CRS Publishing, USA, and Pp. 1- 23.

Hairiah, K., Sitompul, S.M., Van Noordwijk, M., Palm, C. 2001. Carbon Stocks of Tropical Land Use Systems as Part of the Global Carbon Balance: Effects of Forest Conversion and Options for 'Clean Development' Activities. *ICRAF*, Indonesia.

Henry, M., Picard, N., Trotta, C., Manlay, R.J., Valentini, R., Bernoux, M., Saint-André L. 2011. Estimating tree biomass of sub-Saharan African forests: a review of available allometric equations. Silva Fennica, 45: 477–569.

Hiederer & Köchy. 2011. *Global Soil Organic Carbon Estimates and the Harmonized World Soil Database*. Luxembourg. JRC-IES.

Hopkins, D.W., Waite, J.W., McNicol, P.R., Poulton, A.J., Macdonald, A.G., O'Donnell. 2009. Soil organic carbon contents in long-term experimental grassland plots in the UK (Palace Leas and Park Grass) have not changed consistently in recent decades.

Houghton, R. 2007. Balancing the global carbon budget. Annu Rev Earth Planet Sci 35:313–347

Hunter, M.O., Keller, M., Victoria, D., Morton, D.C. 2013. Tree height and tropical forest biomass estimation. Bio geosciences. 10, 8385–8399

Intergovernmental Panel on Climate Change (IPCC). (2007a). Facts on Climatic Change: A Summary of the 2007 Assessment Report of IPCC. Cambridge University Press, Cambridge, UK.

Intergovernmental Panel on Climate Change(IPCC). 2003. Good practice guidance or land use, land-use change and forestry. Institute for Global Environmental Strategies (IGES), Hayama.

Intergovernmental Panel on Climate Change(IPCC). 2006. Guide line for national greenhouse gas inventory.

Intergovernmental Panel on Climate Change(IPCC).1996. Technical Summary. In: Climate Change. Ed: J. T. Houghton *et al*. Cambridge University Press, Cambridge, UK, pp.9-49.

Irvin, K., Samalca. 2005. Geo-Information Science and Earth Observation for Environmental Modelling and Management.

Jandl, R., Rasmussen, K., Tome and Johnson. 2006. The Role of Forests in Carbon Cycles, Sequestration and Storage. Forest management and carbon sequestration, Federal Research and Training Centre for Forests, Natural Hazard and Landscape, Vienna, Austria.

Jandle, R., Rodeghiero, M., Martinez, C., Cotrufo, M.F., Bampa, F., Van Wesemael, B., Harrison, R.B., Guerrini, I.A., de Richter, Jr., Rustad, D., Lorenz, L., Chabbi, K., Miglietta, F. 2014. Current status, uncertainty and future needs in soil organic carbon monitoring. *Science of the Total Environment*, 468-469: 376-383.

Jansen, H., Hengsdijk, H., Dagnachew,L., Ayenew, T., Hellegers, P., Splietoff, P. 2007. Land and water resources assessment in the Ethiopian CRV. In: Project: ecosystems for water, food and economic development in the Ethiopian CRV, Alterra rapport. Wageningen University, the Netherlands.

Janssens, M.J.J., Cleemput, S., Muys, B., Kleinn, C. 2013. Biomass estimation techniques for enclosures in a semi- arid area*. a case study in Northern Ethiopia.* University of Gottingen, Institute for Forest Management. 2*, 1–6*.

Katerere, Y.P., Dewees, B., Campbell. 2010. Managing the miombo woodlands of Southern Africa: "policies, incentives and options for the rural poor," *Journal of natural Resources Policy*

Kauffman, J.B., Donato, D.C. (2012). Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Working Paper 86. CIFOR, Bogor, Indonesia.

Kishwan, J., Pandey, R., Dhadwal, V.K. 2009. India's Forest and Tree Cover: Contribution as a Carbon Sink, 130 *Indian Council of Forestry Research and Education Bulletin*.

Kuyah, S., Dretz and Muthuri., Jamnadass, R., Mwang, P., Coe, R., Neutldt, H. 2012. Allometric equation for estimating biomass in agricultural landscapes: I. Aboveground biomass. *Agric. Ecosysts. Environ.158, 21 -224.*

Lemma, B., Kleja, D., Olsson, B.M., Nilsson, I., 2007. Factors controlling soil organic carbon sequestration under exotic tree plantations: A case study using the CO2 Fix model in south western Ethiopia. *Forest Ecology and Management* 252(1- 3): 124-131.

Liu, X., Herbert, S.J., Hashemi, A.M., Zhang, X., Ding, G. 2006. Effects of agricultural.

Mafongoya, P.L., Nair, P.K.R., and Dzowela, B.H., 1998. Mineralization of nitrogen from decomposing leaves of multipurpose trees as affected by their chemical composition. *Biol. Fertil. Soils* 27: 143-148.

Manning, A.D., Fischer, J., Lindenmayer, D.B. 2006. Scattered trees are keystone structures: Implication for conservation, 2. doi:10.1016/j.biocon.2006.04.023.

Mekuria, W., Veldkamp, E., Mitiku, H., Nyssem, J., Muys, B., Kindeya, G. 2007. Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. Journal of Arid Environments 69: 270–284.

Mohammed A. 1993. *Impact of human activity on Abijata Shalla lakes national park ecosystem*. MSc thesis. Agricultural University of Norway.

Nair, P.K.R., Kumar, B.M., Nair, V.D. 2009. Agroforestry as a strategy for carbon sequestration. J. Plant Nutr. Soil Sci. 172, 10–23.

Parent, G., Sutcliffe, P.J., Mamo, A., Tilimo, S., Tellier, R. 2000. Woody Biomass Inventory and Strategic Planning Project: Manual for Woody Biomass Inventory. Tecsult International, Addis Ababa.

Pearson, T. 2005. The methodology and procedures to be used to estimate carbon stocks.

Pearson, T. 2007. The methodology and procedures to be used to estimate carbon stocks.

Pearson, T., Walker, S., Brown, S. 2005. Source book for land-use, land-use change and forestry projects: Win rock International and the Bio-carbon fund of the World Bank. Arlington, USA, pp. 19-35.

Pearson, T.R., Brown, S.L., Birdsey, R.A. 2007. Measurement guidelines for the sequestration of forest carbon: Northern research Station, Department of Agriculture, Washington, D.C, pp. 6-15.

Perschel, R.T., Alexander, M.E., Marcia, J.S. 2007. Climate Change, Carbon, and the Forests of the Northeast. Forest Guild, Merck and Surdna Foundation, Santa Fe, Davis Conservation, French, pp. 1-10.

Phelps, J., Webb E.L., Agrawal, A. 2010. Does REDD+ threaten to recentralize forest governance? *Science*, 328, 312–313.

Prentice, C., Farquhar, G., Fasham, M., Goulden, M., Heimann, M., Jaramillo, V., Kheshgi, H., Quéré, C.L., Scholes, R., Wallace, D. 2001. The carbon cycle and atmospheric CO2 , in Climate Change. The Scientific Basis: Contribution of WGI to the Third Assessment Report of the IPCC, edited by J.T. Houghton et al., pp. In Press, Cambridge University Press, New York, 2001.

Ravindranath N.H., Ostwald. M. 2008. Methods for estimating above-ground biomass. In N. H. Ravindranath, and M. Ostwald, Carbon Inventory Methods: Handbook for greenhouse gas inventory, carbon mitigation and round wood production projects. Springer Science + Business Media B.V 113-14.

Razakamanarivo, R.H., Razakavololona, A., Razafindrakoto, M., Vieilledent and Albrecht. 2011. Below-ground biomass production and allometric relationships of eucalyptus coppice plantation in the central highlands of Madagascar. Biomass and Bioenergy, 45: 1-10.

Rouw, A., Huon, S., Soulileuth, B., Jouquet, P., Pierret, A., Ribolzi, O., Valentin C., Bourdon, E., Chantharath, B. 2010. Possibilities of carbon and nitrogen sequestration under Conventional tillage and no-till cover crop farming (Mekong valley, Laos). Agric Ecosyst Environ 136:148-161

Saatchi, S.M., Harris, S., Brown, M., Lefsky, E., Mitchard, W., Salas, B., Zutta, W., Buermann, S., Lewis, S., Hagen, S., Petrova, L., White, M., Silman, A. (2011). Benchmark map of carbon forest carbon stocks in tropical regions across three continents. *Proc. Natl. Acad. Sci.* **108**(24): 9899-9904.

Sahile, M. 2011. Estimating and Mapping of Carbon Stocks based on Remote Sensing, GIS and Ground Survey in the Menagesha Suba State Forest. M.Sc. Thesis (unpublished), Addis Ababa University.

Saugier, B., Roy, J. 2001. *Estimations of global terrestrial productivity; converging towards a single number?* In: *Global terrestrial productivity: past, present and future*. (Eds.: Roy, J.; Saugier, B. and Mooney, H.A.), Academic Press, New York.

Sharma, C. M., Baduni, N.P., Gairola, S., Ghildiyal, S.K., Suyal, S. 2010. Tree diversity and carbon stocks of some major forest types of Garhwali Himalaya, India. *For. Ecol. Manag. 260*, 2170–2179.

Shokri, M., Tavili, A., Kandolosi, J.M. 2007. The impacts of grazing intensity on species richness of upland grassland in Alborz. The Iranian *Jour. rangeland research*, 1(3): 269-277. (In Persian).

Smith , J.E., Heath, L.S., Woodbury, P.B. 2004. How to estimate forest carbon for large areas from inventory data. Journal of Forestry: 25-31.

Snyder, C.S., Bruulsema, T.W., Jensen, T.L., Fixen, P.E. 2009. Review of greenhouse gas.

Soode Miarrestami[–A] and Mohammad Hassen Jouri[–B]. 2012. Comparison between some vegetation traits and bio indicators in two grazing and exclosure area.(case study: Sorke- Graz and Volkbon range land.

Stern, N. 2006. The Economics of Climate Change: The Stern Review, Cambridge University Press, Cambridge UK.

Stone, S. 2009. Climate change and change in the role of forests.

Sundquist, E., Robert, B., Stephen, F., Robert, G., Jennifer, H., Yousif, K., Larry, T., Mark, W. 2008. Carbon Sequestration to Mitigate Climate Change. U.S. Geological Survey, Science for a changing world, New York, USA, pp. 1-4.

Tadase W., Getu, Z., Gonfa, T., Andargachew, A. 2011. Report of the capacity building training on measuring and assessing carbon stocks.

Tadesse, K. 2002. Five Thousand Years of Sustainability? *A Case study on Gedeo Land Use, Southern Ethiopia. Treenail publishers, Heel sum, the Netherlands.*

Tadesse, W. 2015. GHG Emission Assessment Guide line Volume II: above Ground Biomass, Field Guide for Base line survey; Federal Democratic Republic of Ethiopia Ministry of Agriculture, Addis Ababa, Ethiopia.

Tadesse, W., Motuma Didita and Sileshi Nemomissa., Gole. 2010. Floristic and structural analysis of the Wood land vegetation around Dello Menna, Southeast Ethiopia. *Journal of Forestry Research* 21(4):395-408.

Tefera, D. 2016. Carbon stock of Meskel Gedam forest and its contribution to climate change mitigation

Tefera, M. 2013. Carbon stock potential of woody plant species in Biheretsige and central parks of Addis Ababa and its contribution to climate change.

Thomas, I., Bekele, M. 2003. Role of planted forests and trees outside forests in sustainable forest management in the Republic of Ethiopia. In working papers of the planted forests and trees. Forest Resource Division, FAO, Rome.

Tsegaye, T. 2006. “An overview of the forest ecosystems of Ethiopia :functions, trends and future directions,” in *Environment for Survival Taking Stock of Ethiopia’s Environment: Proceedings of the First Green Forum Conference Held in Addis Ababa, Ethiopia*, M. Seyoum and C. Stoop, Eds., pp. 18–34, Green Forum, 2006.

Ullah, M.R. and Al-Amin M. 2012. Above-and belowground carbon stock estimation in a natural forest of Bangladesh, Journal of Forest Science, 58(8), pp.372–379.

UNFCCC, 2012. Guide to Climate Change, Conference of Party. Qatar, DOHA.

UNFCCC, 2008. “Adaptation under the UNFCCC—The Road from Bonn to Poznan ” http://www.germanwatch.org/klima/ bonnadapt08e.htm.

UNFCCC, 2015. Measurements for Estimation of Carbon Stocks in Afforestation and Reforestation Project Activities under the Clean Development Mechanism: A Field Manual.

Vashum, K.T., Jayakumar, S. 2012. Methods to estimate above-ground biomass and carbon stock in natural forests – A review. J Ecosystem Ecology 2:116. doi:1.4172/2157-7625.1000116.

Walker, SM., Pearson, T., Casarim, FM., Harris, N., Petrova, S., Grais, A., Swails, E., Netzer, M., Goslee, K.M., Brown, S. 2012. Standard Operating Procedures for Terrestrial Carbon Measurement. Winrock International.

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. 375 pp.

WBISPP, 2005. A national strategy plan for the biomass sector. Addis Ababa, Ethiopia.

Woldemariam. 2014. GHG Emission Assessment Guide line Volume I, Soil carbon and Nitrogen stock assessment in agricultural land and agroforestry system, field guide for practitioners.

Wondrade N., Dick O.B., Tveite, H. 2015. Estimating above Ground Biomass and Carbon Stock in the Lake Hawassa Watershed, Ethiopia by Integrating Remote Sensing and Allometric Equations. Forest Res 4: 151. doi:10.4172/2168-9776.1000151.

Yimer F., and Abdelkadir A. 2010. Soil property changes following conversion of Acacia woodland into grazing and farmlands in the rift valley area of Ethiopia. Land Degradation Dev. doi:10.1002/ldr.1022.

Yusuf, H., Treydte A.C.[a], Abule, E[b]., Sauerborn, J[a]. 2013. Predicting aboveground biomass of woody encroacher species in semi-arid rangelands, Ethiopia management on soil organic matter and carbon transformation – a review. Plant Soil Environ 52(12):531–543).

Zhao, J., Kang, F., Wang, L., Yu, X., Zhao, W., Son, X., Zhang, Y., Chen, F., Sun, Y., He, T., Han, H. 2014. Patterns of biomass and carbon distribution across a chronosequence of chinese pine (Pinus tabulaeformis) forests. *PLoS One 9*

Appendices

Appendix 1 Location of plots in relation to altitude, latitude, longitude

Closed Forest Ecosystem				Open Grazing land Ecosystem			
Plot no	**N**	**E**	**Altitude**	**Plot no**	**N**	**E**	**Altitude**
1	747083	3838764	1660	1	746707	3839387	1654
2	747117	3838719	1658	2	746634	3839455	1654
3	747125	3838851	1652	3	746698	3839415	1655
4	747208	3838765	1662	4	746608	3839502	1647
5	747320	3838859	1654	5	746739	3839402	1655
6	747272	3838882	1653	6	746722	3839445	1654
7	747327	3838879	1661	7	746694	3839479	1653
8	747293	3838924	1657	8	746770	3839424	1656
9	747368	3838910	1660	9	746758	3839449	1655
10	747346	3838951	1660	10	746686	3839535	1659
11	747405	3838943	1656	11	746724	3839501	1652
12	747390	3838979	1657	12	746708	3839520	1649
13	747457	3838968	1659	13	746821	3839456	1649
14	747502	3838965	1654	14	746808	3839484	1652
15	747435	3839011	1659	15	746790	3839512	1649
16	747445	3839037	1655	16	746774	3839536	1646
17	747597	3839016	1655	17	746753	3839560	1653
18	747517	3839010	1654	18	746741	3839575	1654
19	747518	3839070	1653	19	746764	3839580	1649
20	747560	3839028	1653	20	746815	3839536	1650
21	747491	3839053	1654	21	746837	3839516	1654
22	747508	3839103	1657	22	746858	3839484	1655
23	747609	3839062	1616	23	746913	3839515	1652
24	747585	3839120	1652	24	746938	3839538	1650
25	747682	3839108	1652	25	746934	3839573	1649
26	747645	3839164	1652	26	746965	3839617	1645
27	747755	3839163	1653	27	747033	3839593	1650
28	747745	3839221	1651	28	747025	3839656	1656
29	747838	3839219	1651	29	747072	3839717	1648
30	747860	3839250	1660	30	747142	3839677	1648

Appendix 2 Biomass Carbon results by using SPSS soft ware version-16

CLFa T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
LU	30	1.0000	.00000[a]	.00000
AGC	30	10.8723	6.55464	1.19671
BGC	30	2.9355	1.76967	.32310
LC	30	.0576	.02170	.00396

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
AGC	9.085	29	.000	10.87233	8.4248	13.3199
BGC	9.086	29	.000	2.93550	2.2747	3.5963
LC	14.546	29	.000	.05764	.0495	.0657

Appendix 3: Descriptive Statistics: ClFa SOC t/ha, OGL SOC t/ha

OGL T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
LU	30	1.0000	.00000[a]	.00000
AGC	30	6.7722	3.84545	.70208
BGC	30	1.8285	1.03823	.18955
LC	30	.0459	.01167	.00213

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
AGC	9.646	29	.000	6.77223	5.3363	8.2081
BGC	9.646	29	.000	1.82853	1.4409	2.2162
LC	21.550	29	.000	.04593	.0416	.0503

Appendix 4: Comparison of Soil Organic carbon by depth

Land use	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CLFa	59.441	1.293	56.849	62.033
OGL	56.956	1.271	54.409	59.503
11	58.798[a]	6.961	44.848	72.748

a. Based on modified population marginal mean.

Tests of Between-Subjects Effects

Dependent Variable:Soil organic carbon

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	27758.466[a]	3	9252.822	1.382	.258
Intercept	566025.075	1	566025.075	84.568	.000
LU	3616.626	1	3616.626	.540	.465
Depth	17028.274	1	17028.274	2.544	.116
LU * Depth	7113.566	1	7113.566	1.063	.307
Error	374813.607	56	6693.100		
Total	968597.148	60			
Corrected Total	402572.073	59			

a. R Squared = .069 (Adjusted R Squared = .019)

Appendix 5 T-test for soil organic carbon

SOC

CLFa T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
lu	30	1.0000	.00000[a]	.00000
depth	30	3.5000	.50855	.09285
SOC	30	89.3637	30.08608	5.49294

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
depth	37.696	29	.000	3.50000	3.3101	3.6899
SOC	16.269	29	.000	89.36367	78.1293	100.5980

OGL T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Lu	30	1.0000	.00000[a]	.00000
SOC	30	84.6693	28.16378	5.14198

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
SOC	16.466	29	.000	84.66933	74.1528	95.1859

Appendix 6

Field Instruments for measurement and sampling

Measurement in the open grazing land

Transect road to closed forest area