CARBON STOCK CHANGES IN EXCLOSURE AFFORESTATION: THE CASE OF CRGE PROJET IN AKAKI WOREDA, OROMIA, ETHIOPIA.

MSc THESIS

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CARBON STOCK CHANGES IN EXCLOSURE AFFORESTATION: THE CASE OF CRGE PROJECT IN AKAKI WOREDA, OROMIA, ETHIOPIA

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Approval sheet I

This is to certify that the thesis entitle "Carbon stocks changes in exclosure afforestation: The case of CRGE project in Akaki woreda, Oromia, Ethiopia, Submitted in partial fulfillment of the requirement for the degree of Master's of science in with specialization in Forest Resources Assessment and Monitoring of the school of graduate studies in Hawassa University Wondo Genet College of Forestry and Natural Resources. The thesis is a record of original research carried out by Dereje Ejigu, Id.No.MSc/ FRAM / R010/2010, under our supervision and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the courses of this investigation have been duly acknowledged.

Therefore, we recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the department.

Approved by:

1. Mulugeta Lemenih (PhD) ________________ ______________

   Main Advisor Signature Date

2. FantawYimer (PhD) ______________ _______________

   Co Advisor Signature Date

EXAMINERS' APPROVAL SHEET-1 (Submission Sheet-2)

We, the undersigned, members of the Board of Examiners of the final open defense by Dereje Ejigu have read and evaluated his/her thesis entitled "Carbon stocks changes in exclosure afforestation: The case of CRGE project in Akaki woreda, Oromia, Ethiopia ", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

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'Glory to God! .The Lord is my strength and shield

DECLARATION

I hereby declare this MSc thesis report entitled "Carbon stocks changes in exclosure afforestation: The case of CRGE project in Akaki woreda, Oromia, Ethiopia", 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.

Author's Name; Dereje Ejigu Gutama

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Contents

List of Table

List of Figure

Abbreviations or Acronym

A/R – Afforestation / Reforestation

AE – Area Enclosure

AGB –Above Ground Biomass

AGC – Above Ground carbon

Al – Aluminum

BGB – Below Ground Biomass

BGC – Below Ground Carbon

BoANR – Bureau of Agriculture and Natural Resource

CaCO3 – Calcium carbonate

CDM – Clean Development Mechanism

CO2 – Carbon dioxide

CRGE – Climate Resiliency Green Economy

D.A – Development Agent

DBH – Diameter at Breast Height

EU – European Union

FAO – Food and Agriculture Organization

GHG – Green House Gases

Ha – Hectare

IPCC – Intergovernmental Panel on Climate Change

Mt CO2e – Mega tons of carbon dioxide equivalents

OC – Organic Carbon

REDD+ – Reduction emission from deforestation and forest degradation +

SE – Standard errors

SIC – Soil inorganic carbon

SLM – Sustainable Land management

SOC – Soil Organic Carbon

SOM – Soil Organic Matter

UNFCCC –United Nations Framework Convention on Climate Change

Abstract

Forest and soils constitute a major terrestrial carbon pools sequestrate and store carbon dioxide (CO_2) from the atmosphere. Ethiopia is implementing diverse land management based carbon projects that can help mitigate climate change. Plantation establishment with exotic or indigenous tree species, and/or area exclosures supplemented with Reforestation /afforrestoration to restore degraded vegetation and soil are among the major carbon project initiatives in the country. However, the effectiveness of such initiatives in terms of carbon sequestration is not much investigated. This study aims to contribute to such knowledge by investigating carbon sequestration potential of area exclosure supplemented with afforestation of exotic tree plantations in central Ethiopia. The study assessed both biomass and soil carbon stocks. For above ground biomass estimation, plots of the dimension 10 x 10 m were systematically laid in the exclosure area and adjacent open land, and trees diameter at breast height (DBH) of all trees with size greater than 5cm measured using a caliper. Height of each tree was also measured by using hypsometer. For soil carbon stock and stock change analysis, soil samples were collected from five plots laid systematically over the area including from adjacent open / bare lands. Soil samples were taken from 0-20 cm and 20-40 cm depths. Soil samples from the same depth were mixed up to make a composite of 300g that was taken to the laboratory for organic carbon analysis. The exclosure afforestation is 8 years since established. The results of the study showed that area exclosure combined with afforestation /reforestation increases biomass carbon but reduces soil carbon, and the later may be temporarily. The soil carbon in 0-40cm soil depth was 115.84 ton/ha in exclosure area compared to 141.46 ton/ha in open area. The low soil carbon in exclosure may show many things: i) temporary decrease in soil carbon due to site disturbances during planting; ii) original very low level of soil carbon in the exclosure compared to the adjacent site since often most degraded sites are given priority in management, and/or iii) temporary suppression in soil carbon due to microbial activities in decomposition freshly added organic matter that will be followed by increase once decomposable components are exhausted. Overall, the rapid buildup in biomass carbon in the exclosed area will soon lead to increase in soil carbon too, hence overall increase in carbon stock in the managed ecosystem than unmanaged ecosystem. At the current rate, the net carbon gain is 9.62 ton/ha/yr. In conclusion, area exclosures combined with A/R are likely one good solution to ensure carbon neutral growth in Ethiopia.

Key words: - Above ground biomass; Afforestation/ Reforestation: land use: Soil Carbon

1. INTRODUCTION

1.1 Background

Deforestation and inappropriate land-use practices have resulted in several environmental problems including declining SOC through decreased carbon sequestration and increased carbon dioxide (CO_2) emission to the atmosphere(Paustian *et al*., 2000). Widespread deforestation and forest degradation decline environmental goods and services, including climate stabilization and loss of biodiversity and reduction in human well-being in general (Lamb and Gilmour, 2003).

Forest and soils constitute a major terrestrial carbon pools with the potential to absorb, sequestrate, or uptake and store carbon dioxide (CO_2) from the atmosphere. The CO_2 source and sink dynamics as trees grow, die, vegetation type, topographic dynamics, temperature variations and decay are subjected to disturbance and forest management, which in recent decades have inclined towards making it a source instead of sink. Evidence of climate change linked to activities increase in greenhouse gas (GHG) concentrations is well-documented in international studies (Haywood and Schulz, 2007). Mitigation strategies to reduce the impact of climate change and global warming (Lal, 2006) by augmenting carbon sequestration and reducing CO_2 emissions from soils and biosphere include proper forest management and afforestation or reforestation programs. Therefore, quantification and continuous monitoring of changes in above ground and below ground carbon pool sizes and fluxes are fundamental to understanding the effects of any mitigation action in removing and limiting greenhouse gas emissions (Usuga *et al*., 2010).

Ethiopia is implementing diverse land management practices that can help mitigate climate change. Establishment of exotic or indigenous species plantations, area closure for restoration of degraded vegetation and soil, and watershed management through SLM programs are among those actions implemented across the country. The relatively fast growth rate of exotic species provides significant carbon sequestration potential besides good volume of wood used for various purposes. Trees also have beneficial effects associated with improved soil structure through root action and inputs of organic matter (Lemma and Olsson, 2006).

Afforestation on exclosure area is a management option for increasing terrestrial carbon sequestration and mitigating rising atmospheric carbon dioxide because, compared to non-forested land uses, afforestation increases carbon storage in above ground pools. However, because terrestrial ecosystems typically store most of their carbon in soils, afforestation impacts on soil organic carbon (SOC) storage are critical components of ecosystem carbon budgets.

Ethiopia has begun taking measures to rehabilitate degraded forests and forest lands and develop Climate Resilient Green Economy strategy which could help the country achieve its development goals while limiting 2030 GHG emissions to around today's 150Mt CO2e – around 250 Mt CO2e less than estimated under a conventional development path by 2030. Despite actions being taken, effectiveness of most of these actions in terms of increasing carbon sequestration is yet to be assessed and analyzed, which this study also aims to contribute to by taking the case of area closure followed by Afforestation / Reforestation in Akaki woreda.

1.2. Statement of the Problem

Ethiopia is facing rapid deforestation and degradation of land resources. Fast growing population has resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forests for fuel wood, fodder, and construction materials. Forest areas of the country have reduced enormously resulting in high risk of soil carbon depletion for nearly half of its total land mass (Solomon *et al*., 2000). Ethiopia showed the desire to grow green including restoring of degraded lands and making this an opportunity for a carbon sink. CRGE has set a target to afforest 2 million ha, reforestation on 1 million ha and improved management of 3 million ha of natural forests and establish one million ha of area exclosure.

Area exclosure followed by afforestation / reforestations practiced over large areas of the country, particularly in the north and central Ethiopia. The initiative also targets improvement of local livelihoods by diversifying their income sources as well as improvement of flow of environmental services, hence to ensure climate resilience. However, despite the initiatives to implement the various actions, their effectiveness in GHG removal under various settings is not yet assessed, and their contribution to the set CRGE target is yet to be understood. This study therefore aims to investigate carbon sequestration potential of area exclusure A/R mixed initiative around Addis Ababa as a contribution to understand the effectiveness of some of the CRGE initiatives.

1.3. Objectives of the study

1.3.1. General objective

Investigate the contribution of exclosure plus afforestation/reforestation practices to the GHG emission reduction goals of CRGE.

1.3.2. Specific objectives

- Quantify AGC stock and BGC stock in exclosure plus afforestation/reforestation practices established as part of CRGE project.
- Investigate the soil carbon stock change (gain or loss) of exclosure plus afforestation /reforestation practices compared to open adjacent area.

1.4. Significance of the study

The study was conducted on carbon stock change following one of Ethiopia's strategic land management practices aiming to ensure CRGE initiatives, which was area exclosure combined with afforestation/reforestation. This was essential in providing essential understanding of how effective this land management strategy was to help the country achieved its set green growth target, and what need to be improved to make it serve the purpose. Although in a project site exclosure afforestation/ reforestation and on adjacent open land, land use change adaptive mechanism for climate change and provide carbon financing to local level society, regional government and country level.

2. Literature review

2.1. Carbon Accounting

Carbon accounting is the practice of making scientifically robust and verifiable measurements of net GHG emissions. Although there have been many inventories for various purposes (determining merchantable timber volumes, land use planning). Accounting for carbon is a more recent addition to forest inventories. It followed the growing need to quantify the stocks, sources and sinks of carbon and other GHGs in the context of anthropogenic impacts on the global climate. Carbon accounting varied globally and the net accounting result is positive in tropical regions than the sub tropical and temperate regions. However, this should not undermine the contribution of GHG emission from deforestation, forest degradation and land use change in the tropical regions.

Carbon pool: A system which has the capacity to accumulate or release carbon. Examples of carbon pools are forest biomass, wood products, soils and atmosphere. Biomass: is defined as mass of live or dead organic matter. It includes the total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass. The quantity of biomass is expressed as a dry weight or as the energy, carbon, or nitrogen content. Therefore, a global assessment of biomass and its dynamics are essential inputs to climate change forecasting models and mitigation and adaptation strategies.

2.1.1. Forest Carbon Pools

According to the IPPC (2006), carbon pools in forest ecosystems comprises of carbon stored in the living trees aboveground and belowground (roots); in dead matter including standing dead trees, down woody debris and litter; in non-tree understory vegetation and in the soil organic matter. When trees are cut down there are three destinations for the stored carbon dead wood, wood products or the atmosphere. The decreased tree carbon stock can either result in increased dead wood, increased wood products or immediate emissions. Dead wood stocks may be allowed to decompose over time or may after a given period, be burned leading to further emissions. Forest carbon pools can be grouped as key categories or minor categories based on ecosystems and land-use changes. Key categories represent pools that could account for more than 25% of the total emissions resulting from deforestation or degradation

2.1.2. Estimating Tree Biomass

The determination of aboveground tree biomass has been conducted to ensure sustainable management of forest resources. Fuel wood management has motivated the calculation of biomass equations, whereas timber management has mainly driven volume equations. Today the accurate estimation of forest biomass is crucial for many applications, from the commercial use of wood Morgan and Moss (1985) to the global carbon cycle (Bombelli *et al*., 2009). Because of interest in the global carbon cycle, estimating aboveground biomass with sufficient accuracy to establish the increments or decrements of carbon stored in forests is increasingly important. Forests form a major component of the carbn reserves in the world's ecosystems (Houghton, 2007) and greatly influence both the lives of other organisms and human societies (Whittaker and Likens, 1975). Trees also play a key role in the global carbon cycle. Managing forests through agroforestry, forestry and plantation systems is seen as an important opportunity for climate change mitigation and adaptation (Swart, R.O.B. and Raes, F., 2007; Canadell and Raupach 2008). Afforestation and reforestation (A/R) project activities are eligible under the Clean Development Mechanism (CDM) of the Kyoto Protocol (Nakicenovic *et al.*, 2000) Consequently, allometric equations are needed to estimate the changes in C stocks that result from afforestation activities with the aim to implement A/R CDM projects worldwide (including Africa). Furthermore, the current (2010) negotiations on Reducing Emissions from Deforestation and forest Degradation and the role of conservation, sustainable forest management and enhancement of forest C stocks in developing countries (REDD+) under the next commitment periods of the Kyoto protocol have focused even more attention on methods for estimating biomass and C stocks (Asner, G.P., 2011). Under the UNFCCC, countries have to regularly report the state of their forest resources. Under emerging mechanisms such as REDD+, they are likely to require high resolution temporal and spatial assessments of C stocks. Except in the very rare cases where a whole tree population can be harvested to determine its biomass the tree biomass is generally determined based on forest inventory data and allometric equations (Augusto *et al*., 2009).

2.1.3. Plantation forest and carbon

Plantations forest are defined as forest stands that have been established artificially with exotic or indigenous species and that have a minimum area requirement of 0.5 ha, have a tree crown cover of at least 10 % of the land cover and a total height of mature trees above 5 m (FAO, 2001). Considering the use of plantations for mitigation of greenhouse gas emissions in the Kyoto Protocol, plantations are classified as afforestation and reforestation.

Global forest Plantation biomass which is mainly contributed by forest land on earth contains around 550 Gt of carbon (Novak *et al.*, 2013). Photosynthesis captures about 120 Gt of carbon every year while respiration and microbial decomposition returns almost the same amount.

There are ecological and environmental risks for growth of forest plantations for the sake of carbon sequestrations, particularly when they remove long lived native species that stores more carbon stores on short-lived species (Stickler *et al.*, 2009).

According to a review done by Davis and Condron, (2002) on a series of paired sites in New Zealand, they found conversion of native forest to forest plantations decreased organic carbon in the upper layers of the soil by 9.5 percent in the short term; however, organic carbon accumulated on the forest floor which exceed the loss of carbon in long term. Another study by (Smith *et al.*, 2000) found that conversion of native forest to plantation forests has also change the amount of carbon in the soil. Trees can alter the soil properties by interactions between plants and various microbes, root exudation, root turnover, and inputs of organic on forest floor. In addition quantities of carbon sequestered in plantation or natural forests or woodlands or farmlands are attributed to various factors such as growth rate, tree species, size at maturity, life span, study sites, climatic factors, stand age and management practices including harvest cycles, thinning, pruning, fertilizer application, control of pests among others (Rautiainen *et al.*, 2010).

2.1.4. Plantation forests in restoration ecology

Increasing concern about the impacts of anthropogenic emissions of carbon dioxide has stimulated interest in the potential of reforestation projects to sequester carbon (Greenhalgh 2008). In the Australian context, for example, it has been estimated that broad scale tree plantations could sequester a high proportion of national carbon dioxide emissions (Furbank, R.T., 2009. However, there is concern amongst some ecologists that markets for carbon offsets will promote the establishment of fast-growing monoculture plantations rather than more diverse and structurally complex environmental plantings, resulting in poor outcomes for biodiversity (Kanowski, J. and Catterall, C.P., 2010). In part, this concern stems from a commonly held assumption that plantations will accumulate carbon more rapidly than diverse environmental plantings, because plantations are primarily designed and managed to maximize fiber production (e.g. by utilizing trees selected for rapid growth, planted at optimum spacing's, fertilised, and with control of weeds and other competitors (Keith.*et al*., 2014)

The carbon stored in AGB of live trees in reforested sites ranged from 51 tc ha^{-1} in a 12 year old mixed species cabinet timber plantation to 152 tc ha^{-1} in a 21 year old environmental restoration planting. On average, young monoculture plantations stored 62 ± 4.2 (SE) tc ha^{-1} in the AGB of live trees, mixed species plantations 83 ± 12 tc ha^{-1} and environmental restoration plantings 103 ± 9.0 tc ha^{-1}. Stags and woody debris contributed only a small proportion (size class to total carbon stocks varied among the different types of reforestation. On average, small diameter trees (5–10 cm dbh) made up 46% of stems in restoration plantings, 21% of stems in mixed species plantations and 4% of stems in monoculture plantations, but contributed only 6% of AGB in restoration plantings and less than 2% in other site types. Larger trees (>10 cm dbh), which contributed most to AGB, were nearly twice as abundant in restoration plantings as in monoculture plantations. In particular, trees in the 10– 20 cm dbh size class were four times more abundant in restoration plantings than monoculture plantations. While restoration plantings had fewer stems in the 20–30 cm dbh class than monoculture plantations, they had more stems in larger diameter classes (>30 cm dbh). These differences resulted in restoration plantings having 20 t carbon per ha more in stems 10–20 cm dbh than monoculture plantations; 17 t carbon per ha less in stems 20–30 cm dbh than monoculture plantations, but 30 t carbon per ha more in stems >30 cm dbh, than monoculture plantations.

In fact, several authors have stressed that time since afforestation/reforestation has a significant effect on the magnitude of soil fertility improvement (Paul *et al*., 2003; Bhojvaid and Timmer, 1998), three distinct stages of soil development can be recognized following plantation establishment: (i) an initial establishment phase (0-5 years) characterized by either nominal soil changes or even a decline in soil properties; (ii) a brief transitional phase (5-7 years) characterized by a canopy closure of the tree plantations and a rapid change in soil properties; and (iii) fallow enrichment phase (7-30 years) characterized by a gradual stabilization of soil properties. Similarly, several studies that assessed change in soil C stocks following afforestation and reforestation of former arable soil showed loss of soil C, at early stages of plantation development (< 10 years) as there is relatively little input of C from biomass. However, this trend gradually improves as the plantation matures to a phase where C continues to accumulate (Paul *et al*., 2002).

2.1.5. The effect of land use change on organic carbon

Land-use change of tropical forests for agricultural production is considered as a major cause for a decline in soil organic carbon (SOC) stocks. However, the extent of the impact of land-use change on SOC storage is highly uncertain, especially for tropical Africa. Interactions with the soil mineral phase can modify such impacts because of high contents of pedogenic Fe- and Al-oxides and clay in these highly weathered soils and their potential for carbon stabilization. The aim of the current study was to determine land-use change impacts on SOC storage for soils commonly found in tropical Africa (Powlson, D.S., *et al*., 2011)

The restoration of soil attributes and native forest flora on degraded sites in Ethiopia can be fostered with the help of fast-growing tree plantations. However, it was also observed that considerable differences exist between the plantation tree species involved both in fostering the regeneration of native woody species and restoring soil attributes. Therefore, one of the most important silvicultural precautions in using plantation forestry for ecological restoration is the decision on which species to use. The choice of species needs careful consideration and should be based on knowledge of the species' effects on soil attributes and local biodiversity (Lemenih, 2004).

2.1.6. Forest Carbon accounting

Forest carbon accounting identifies the carbon-density of areas, providing information for low-carbon-impact land use planning. It prepares territories for accounting and reporting of emissions from the forestry sector. It allows comparison of the climate change impact of the forestry sector relative to other sectors, as well as allowing comparison between territories. Finally, it enables trade of project emission reductions on carbon markets and for emission reductions to be included in policy targets. The practice of forest carbon accounting requires clear identification of the accounting boundary in both space and time. Stratifying the forest into areas with similar carbon characteristics further improves the accuracy of carbon accounting. Data for accounting can be gathered from a variety of sources, including existing secondary data, remotely sensed data and primary data through field surveys. The amount of data from each source depends on the quality of the source as well as the trade-offs that must be made between accounting accuracy and costs of resources and time (Zewdie *et al*., 2014).

All forest carbon accounting estimates contain uncertainty. Practitioners should identify, minimize where possible, and quantify this uncertainty through statistical analysis, published information and expert judgment. The existence of substantial uncertainty can undermine efforts to reduce carbon emissions from forestry and can erode political support for the accounting process. Forest carbon accounting guidance from the Intergovernmental Panel on Climate Change (IPCC) has become the primary source of information for methods, accounting equations and parameters (Zewdie *et al*., 2014).

2.2. Soil carbon pool

Soil is a major carbon pool in terrestrial ecosystems, containing nearly 1500 Pg of carbon as soil organic carbon (SOC) in the first meter of depth. The dynamics of SOC, which is prone to loss or gain due to land-use changes Guo and Gifford (2002), are critical to understand, owing to the increasing carbon dioxide (CO_2) concentration in the atmosphere. Losses of soil carbon caused by the cultivation of grassland and by deforestation are the second greatest source of anthropogenic greenhouse gas emissions (Change, 2007). Land carbon emissions contributed about 36 % of the anthropogenic CO_2emitted into the atmosphere from 1985–2000 (Houghton, 2007). Among the shrub-dominated afforestation plots, SOC content in the shrub-grass ecosystems increased significantly at a rate of in surface soils with a depth of 0–10 cm.

The SOC content in layers deeper than 10 cm and the total nitrogen content in each soil layer increased slightly but not significantly. In contrast, SOC content in pure shrub plantations increased significantly in the deeper soil layers, but not in the top 10 cm. Differences in the rates of change in SOC and total nitrogen contents between the shrub-grass ecosystems and pure shrub plantations were not significant, except for total nitrogen content at 0–10 cm.

Overall, the mean rates of change in SOC and total nitrogen contents within the top 60 cm of the soil(Shi *et al*., 2015).

2.2.1. Soil carbon

The soil carbon stock consists of two components: SOC and soil inorganic C (SIC). SOC is the carbon component of soil organic matter (SOM), a heterogeneous pool of C comprised of diverse materials including fine fragments of litter, roots and soil fauna, microbial biomass carbon, products of microbial decay and other biotic processes (i.e. such as particulate organic matter), and simple compounds such as sugar and polysaccharides (Schaeffer *et al*., 2015). Soil inorganic carbon comprises pedogenic carbonates and bicarbonates, which are particularly abundant in alkaline soils. For the purpose of these guidelines, only SOC is considered in relation to measuring soil carbon stocks and stock changes, and the standard operational definition of SOC is used organic carbon present in the fraction of the soil that passes through the 2 mm sieve (Whitehead *et al*., 2012).

Soil organic carbon (SOC) is an important component of soil organic matter with SOC making up 58 % of SOM. Soil organic carbon is an important store of carbon globally as it is the largest store in most terrestrial ecosystems Jobbágy and Jackson(2000).The turnover of SOM and thus SOC depends up on the chemical quality of the carbon compounds (labile or passive), climate and soil properties such as clay content, soil moisture, pH and nutrient status and several of these factors can be influenced by afforestation and subsequent forest management (Jandl *et al*., 2007).

2.2.2. Soil carbon change following afforestation

It has been well established that the carbon stored within the biomass increases upon afforestation. However, the impact on soil carbon stocks and the controlling factors are still uncertain. Afforestation is the establishment of forest plantations that, until then, was not plantation forest, i.e. pastures, crop land, rough grazing, scrub etc. The change in soil carbon following afforestation is controlled by a number of factors, including: species planted, pre- afforestation land use, soil texture, soil pH, forest age, site management, topography, cultivation method and climate (Laganiere *et al*., 2010). There have been a number of studies that have been conducted around the globe assessing the change in soil carbon following afforestation and the factors that control the change, with differing concussions Studies by (Wellock, 2011).

2.2.3. Impact of afforestation on the carbon stock

Vegetation is an unstable carbon store due to quick turn over and man induced land use changes, with global deforestation being one of the main inputs of CO_2 in to the atmosphere. Plants take up CO_2 from the atmosphere through photosynthesis where it is stored within the biomass of the plant. Carbon is eventually transferred to the soil when plant material dies and is in corporate in to the soil. Plants are the mechanism by which CO_2 is transferred from the atmosphere to the soil. Forests contain large amounts of carbon within the biomass and an estimated 80 % of all carbon stored in the biomass globally (Wellock, *et al*., 2011). Within Ireland, forests contain over 50 % of all biomass carbon on only 10% of land. This proportion will increase in the coming decades as much of the national forest estate was only recently planted, and so have a number of years of growth and potential to sequester greater amounts of carbon in soils present a much more stable carbon store than the forest biomass as the residence time of soil organic carbon (SOC) can be >1000 years with in stable fractions (Lutzow *et al*., 2006).

2.2.4. The effect of afforestation on soil carbon sequestration

Afforestation is the conversion of non-forested land into forest, is one of the cost-effective strategies for climate change mitigation, owing to the ability of forested land to sequester CO_2 from the atmosphere, storing it in woody biomass via plant photosynthesis and soil organic matter via humification (Pan *et al*., 2011). Reforestations of former farmland showed positive changes in soil carbon and total nitrogen with respect to the soils of the adjacent farmland (Lemenih *et al.*, 2005).

2.2.5. Soil organic carbon stock and fluxes

In the study we make a clear distinction between soil organic carbon stocks and fluxes. Soil organic carbon stocks are based on soil type, long term climate and long term land use. It use spatial analysis to combine predicted land use changes with the topsoil soil organic content map of Europe (Schrempf *et al.*, 2011) to assess the impact of land use changes on soil organic carbon stock. They make the assumption that the average soil organic carbon stock of the surface horizon reflects the equilibrium state; therefore, the differences between SOC stocks under different land uses reflect the change from one equilibrium state to another. Soil organic carbon fluxes on the other hand are like snapshots in time of the impact of resource management on the soil. They provide an estimate of humified organic content from agriculture and from forests. Carbon fluxes are therefore snapshots of carbon input and cannot be directly compared or added on to carbon stocks. For Peat lands, another approach again is adopted whereby carbon stocks and GHG fluxes are assessed.

2.2.6. Area Enclosures

Area Enclosures (AEs) in the Ethiopian context can be defined as the degraded land that has been excluded from human and livestock interference for rehabilitation. In principal, human and animal interference is restricted in the AEs to encourage natural regeneration. Change the vegetation coverage of degraded areas in a relatively short period of time. The evaluation made between area enclosures and adjacent open sites in the study area indicated that vegetation parameters such as composition, richness and diversity of woody species were improved in the enclosure (Mulugeta, 2014). Differences in species composition, richness and diversity of species vary among enclosures. As clearly observed in this study, enclosures can only be successful in rehabilitating degraded areas if they are well managed and protected from human and animal disturbances.

2.2.7. Sustainable resource management

Sustainable and renewed resource management practices need to address the widespread land degradation, declining soil fertility, unreliable rainfall, and even desertification, in a context of global climate change (Messerli *et al*., 2004). Therefore, rehabilitation of those degraded areas needs urgent attention before conditions become irreversible. In response to the problem of land degradation and other environmental problems, different natural resource conservation and rehabilitation interventions have been carried out in Ethiopia. Among the various rehabilitation techniques used, the predominant is probably area enclosure (Lemenih, 2004), and establishment of fast growing plantations of exotic species & physical conservation measures such as terracing. The idea of area enclosure involves a protection system, exclusion of the degrading agent, to allow the lands to restore itself through natural succession process.

3. MATERIAL AND METHODS

3.1. Description of study Area

3.1.1. Geographical location

The study area was located in Oromia Region of special zone surrounding Finfinne in Akaki woreda. The Woreda town was Dukam, it was situated in the central rift valley at 37 km from Addis Ababa in south direction. The area lies between 38º 40’ 00” E to 39º 50’00” ’East longitudes and 7^0 30’-7^0 42’North latitude. The elevation of the site ranges between 1500 to 3100 masl. Akaki Woreda boundaries were Ada’a woreda in the East, Sebeta Hawas and Kersa-Malima woreda in the West, Liben Zukala woreda in the South and Finfinne city, Ginbichu and Barak woreda in the North (Bekele *et al.*, 2012)

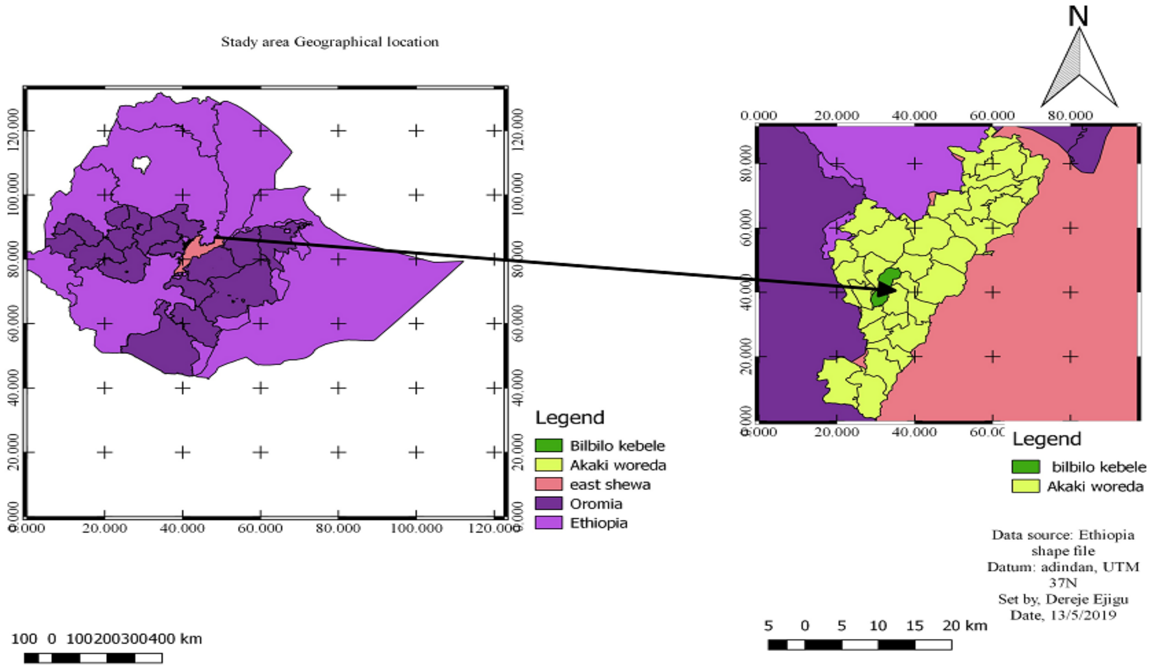

Figure 1; Location map of study area

3.1.2. Topography and climate

The Mountain Yarer, on the border with Adea woreda, was the highest point in Akaki. The topography of the woreda is 56 % plain, 36 % mountainous and 17 % hilly. The woreda covers two agro-ecological zones: 2 % "Dega" (highlands) and 98 % "Winna Dega" (midlands). The dominant soil in Akaki woreda is Vertisols. The temperature ranges between 15-27 °C with the mean annual temperature of 21 °C. Rainfall ranges between 800-1800 mm with the mean annual rainfall of 900 mm. There are two rainy seasons in this area denotes the winter "Kiremt" extends from June to half of September, which shows the big rains, and are the most economically important rains for crop production (Bekele *et al.*, 2012).

3.1.3. Land use system in the woreda

Land use planning to make the best use of land was not a new idea, over the years farmers have made plans season after season to deciding what to grow and where to grow. Their decisions have been made according to their own needs, their knowledge of the land and the available technology, labor and capital. Planning involves anticipation of the need for change as well as reactions to it. In many places the existing situation cannot continue because the land itself was being degraded due to unwise land use include; the clearance of forest on steep lands or on poor soils for which sustainable systems of farming have not been developed; overgrazing of pastures, and industrial, agricultural and urban activities that produce pollution (Oromia land administration and land use plan bureau .2011).

The woreda have possesses various land uses/land covers: forest/vegetation land, farmland, grazing land and settlement. Important forests in the woreda are those government-protected Yerer and Addis Baha forests. Others vegetation include shrubs around hillsides and scattered parkland trees on farmlands as well as woodlots. The tree species found scattered on farmland are mostly of the acacia species preferred by local farmers for soil conservation and soil fertility improvement. Of the total land cover of the woreda, which is 41,341 hectares, 72.2 % is cultivation land , 7.6 % pasture, 4.4 % forest, and the remaining 15.8 % was considered other land use, degraded or otherwise unusable. Many crops are grown in the woreda and these include, Teff which was the leading crop in area coverage. Livestock production was important farming system of the woreda. They source of food and income has been depending on mixed farming of animals rearing with other agricultural activities. Now a day in a woreda livestock production was minimize due to a lack of grazing lands (Bekele *et al*., 2012; Elias. 2017).

3.1.4. Soil

There was a woreda difference between soils found at the up slope and valley bottom of the watershed. Vertisol soils or black-cotton (clay) soil was dominating the valley bottom, while black - clay soil was prevalent in the up slope areas. The Vertisol soil in up slope was highly dominated with coarse textured soil. The part of the soil texture was Vertis soil. The fertility of the soil was diminishing from time to time due to deforestation, inappropriate farming and limited conservation practices and the consequences resulting in low production and productivity of the area

3.1.5. Degradation of natural resource base

The woreda, has different land forms, specifically most of its steep slope areas were densely covered with indigenous forests comprising species such as *Podocarpus falcatus, Acacia albida, Olea Africana*, *Acacia abyssinica*, *Juneperos procera* and *Cordia africana* as well as wild animals like monkey, baboon and the like. However these were degraded following the resettlement program implemented by the Derg regime as well as due to population growth.

3.2. Sampling and data collection

3.2.1. Sample size (sample plot numbers)

A total of 60 sample plots, with 10 x 10m, 30 for one stratum, i.e. for the exclosure area and adjacent open land, were taken in the study. The 60 plots were used for biomass carbon assessment, and for soil carbon, a sub-sampling was done from the 60. Data was collected according to the below procedures for biomass and soil carbons respectively.

To determined the distance (d) between the samples plots on the square sample in 72 hectares of a two stratum area of land.

$$d = \sqrt{(72/60)}$$

$$= \sqrt{0.15\text{ha}} = \sqrt{1500\text{m}^2} \approx 39\text{m}$$

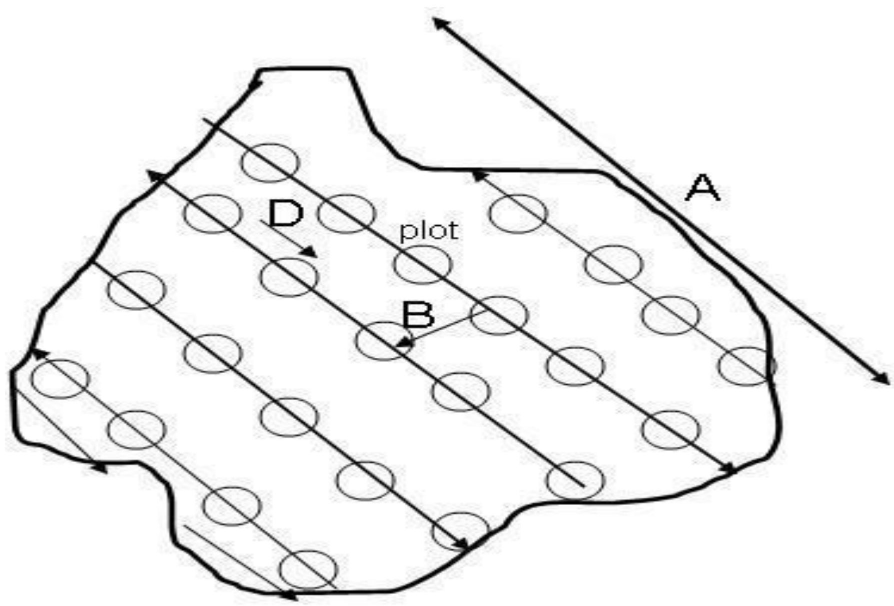

Figure 2; sampling plot design

3.2.2. Data collection for Biomass carbon

The 60 sample plots, 30 in each of the stratum, were established by systematic sampling. Trees in the sample plots were measured for their diameter at breast height (DBH) using caliper and for their heights using hypsometer. These inventory data was used to calculate density (stems ha^{-1}) and biomass carbon stock.

Figure 3; open land & adjacent exclosure afforestation area.

3.2.3. Sample design for soil carbon

The design was a comparative analysis of two sites with a pseudo replication. The effects of exclosure afforestation and open nearby site on soil carbon change would be compared by taking soil samples from each site with five replications. Soil samples were collected from five plots laid from among the 30 samples established for the biomass sampling. One sample from every 6^{th} sample was picked. Plot would be demarcating using (10 m × 10m= 100m 2). Five pits of 50cm were dag as shown below and composite soil samples were collected from two depths; 0-20 and 20-40 cm per plot.

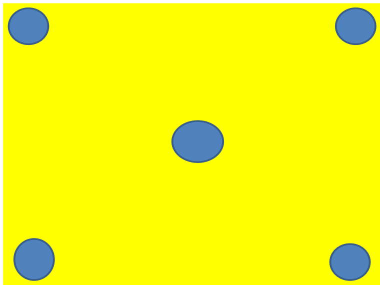

Figure 4; Composite sampling of soils

A total of 20 soil samples were collected from each layer. The composited soil sample should be put in plastic bag that prepared for soil sample and take to soil laboratory. In soil laboratory the soil sample should be dried on air at room temperature. Separate soil samples were also collected for bulk density determination from the plots.

Figure 5; when I will take soil bulck density & make soil Composite

3.3. Data Analysis

3.3.1. Carbon Stock Estimation

3.3.2. Above ground biomass measurement of forest

As a usual methods for determining of the above- ground biomass (AGB) of forests. The combination of forest inventories with allometric tree biomass regression models were applied (Houghton, 2005). This estimation of AGB in the forests ecosystem is based on plot inventories that involve the following three steps (Chave *et al.*, 2014). These are:

1. The selection and application appropriate allometric biomass equation for the estimation of individual tree biomass based on the forest type.

2. The summation of all individual tree AGB to estimate plot AGB, and

3. The calculation of an across plot average to hectare bases.

For this study applied species specific allomteric equations as few tree species were involved in the A/R namely *Acacia saligna* used allometric equation developed by Jonson and Freudenberger (2011).

Grevillea robust using allometric equation developed by(Tumwebaze *et al*., 2013). The equations are the following

For *Acacia saligna:* $AGB = -(1.624) + 2.254 \times \log10 * DBH$…………………..equation (1)

For *Grevillea robust:* $\ln TAGB = 0.01 + 1.81 \ln DBH$ ……………………………equation (2)

Above ground carbon stock of each tree biomass was converted to carbon using the IPCC (2003) default value, which is

AGC = AGB * 0.5 ……………………………………………………….…equation (3)

Where,

AGC = Above Ground Carbon Stock,

AGB = Above Ground Biomass (kg/tree)

3.3.3. Belowground biomass

Belowground biomass (BGB), which is commonly called root biomass, is not easy as AGB to calculate (Geider *et al*., 2001).The belowground biomass (BGB) was calculated by multiplying above-ground biomass taking 0.26 as the root to shoot ratio (Ravindranath *et al*., 2008).

Belowground biomass tc ha^{-1} = 0.26 × above-ground biomass (tc ha^{-1})…………equation (4)

Finally, carbon content in the biomass was estimated by summing the AGC and BGC expressed in CO_2eq by multiplying the sum by the factor 3.67 as per IPCC (2003) recommendation.

3.3.4. Estimation of Soil Organic Carbon

Organic carbon of the soil was estimated in the laboratory using Walkley and Black (1934) method. The soil samples was air dried, mixed ground and sieved through a 2 mm mesh size sieve for soil carbon analysis following the right technique Walkley and Black (1934). Soil bulk density determination was done using a core sampler of 5 cm length and 6.25 cm diameter. Bulked density was determined for the respective depths of 0-20 cm and 20-40 cm. The carbon stock density of soil organic was calculated as recommended by (Pearson *et al*., 2005) from the C % and bulk density of the soil.

3.4. Laboratory analysis

Solid organic matter is oxidized under standard conditions with potassium dichromate in sulfuric acid solution. A measured amount of $K_2Cr_2O_7$ is used in excess of that needed to destroy the organic matter and the excess is determined by titration with ferrous ammonium sulfate or ferrous sulfate solution, using diphenylamine indicator to detect the first appearance of un oxidized ferrous ion. Titration is a common laboratory method of quantitative/chemical analysis that can be used to determine the unknown concentration of a known reactant (analyte). The basis of the method is a chemical reaction of a standard solution (titrant) with a solution of an analytic. The analytic (described A) is a solution of the substance whose concentration is unknown and sought in the analysis.

3.4.1. Estimate Soil Organic Carbon Stock

After soil bulk density and soil carbon (% C) is determined soil organic carbon concentration at different depth were calculated by the following equation (Pearson *et al*., 2005).

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

Where; SOC =Soil Organic Carbon in tone

D = Soil depth in cm

BD = Bulk Density (g cm3), and %

C = Soil Carbon nutrient content in percent (%)

3.4.2. Estimate bulk density

Bulk density is critical for converting organic carbon percentage by weight to content by volume (e.g. kg m−2 to 1-m depth), but it varies with the structural condition of the soil, in particular the mineralogy water content and packing. In general bulk density determined by the core sampling method is comparable with values obtained by the clod method (Batjes,. 1996). Linear regressions of bulk density against combinations of the controlling variables described earlier often give rather small coefficients for linear determination (*r*2) (Post *et al.*, 1982), which restricts their predictive use. An alternative is to use pedo transfer rules based on expert judgment.

A soil samples with a known volume were oven dried at 105 ^{0}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;

$$\text{Soil bulk density (g cm3)} = \frac{\text{oven dry sample (g)}}{\text{sample volume (cm3)}}$$

The total carbon stock is calculated by summing of carbon stock in sample plot of each layer of a two strata of ecosystem.

3.5. Statistical Data analysis

The difference soil carbon was statistically analyzed using the different depth in a plot design. They were considered the land use land cover types (Exclosure afforestation and open land, were compared to each of the land cover types. Data were input and summarized using Microsoft Excel software. The different soil carbon were statistically compared for the two strata using a one-way ANOVA was used for the data Analyses of variances and using Minitab 17- Software for determining significance of a difference carbon in the two land use land cover types.

4. Results and Discussion

4.1. Results

4.1.1. Aboveground Forest Biomass and the Carbon stock

The conversion of long pried degraded land to exclosure combined with A/R has increased above ground biomass and biomass carbon as well. The biomass carbon would be gain 9.62 tc ha^{-1}.

Table 1; Show carbon stock deference b/n different Land use

Land use categories	Difference of mean	SE of Difference	95% CI	T-Value	P-Value
Open land - Exclosure afforestation 0-20 cm	10.58	5.94	(-3.13, 24.28)	1.78	0.113
Open land - Exclosure afforestation 20-40 cm	15.05	4.61	(4.41, 25.68)	3.26	0.011
Open land - Exclosure afforestation 0-40 cm	25.62	8.16	(6.80, 44.45)	3.14	0.014

4.1.2. Soil Organic Carbon

These investigations indicate soil carbon stock was decreased after afforestation and non-significant among soil depth and land use type P- Value ≤ than 0.05 that show on (Table,1) and significant difference of average soil carbon stock loss following afforestation across layer/depth two that was in 20 – 40 cm of P- ≤ 0.05 that show on (Table,1). As indicated on (Fig, 8) open land was higher soil carbon stock and when compared in 8 years of exclosure afforestation site, open land and exclosure afforestation land of soil organic carbon content has been calculated to a depth of 0 - 40 cm indicated (**141.46** and **115.84** tc ha^{-1}) respectively.

The soil organic carbon difference of two adjacent land use was (25.62 tc ha^{-1}) that cover 18.1 % of soil organic carbon lose in between 8 years following afforestation.

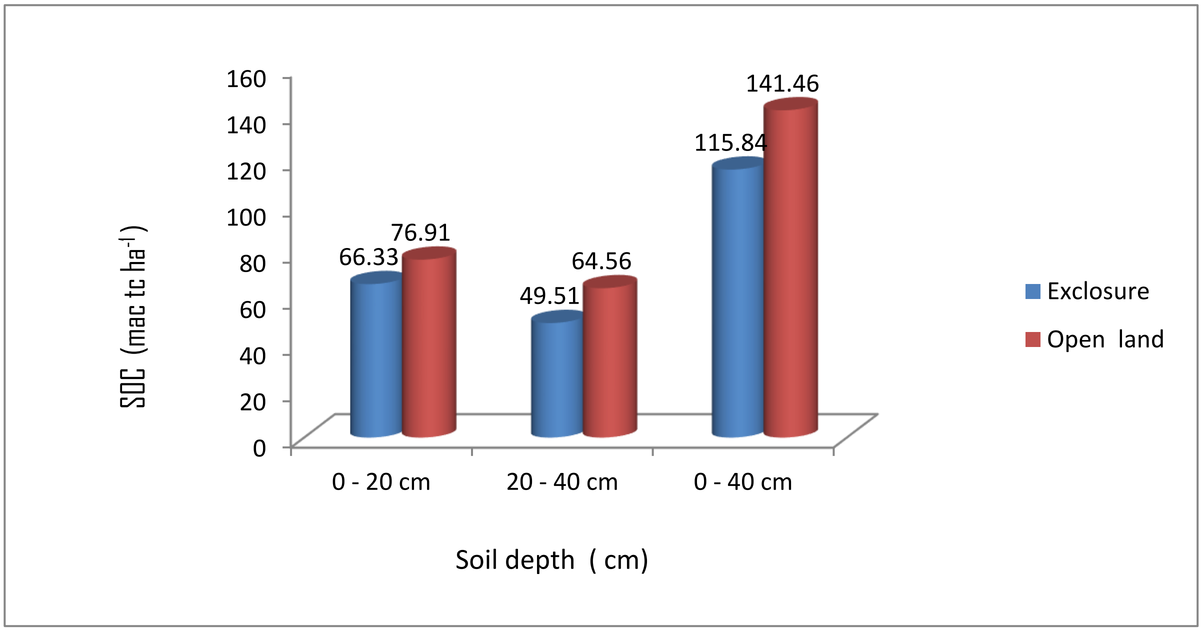

Figure 6; Show the soil carbon stock in depth of 0 -20cm, 20 - 40cm and 0-40cm

4.1.3. Bulk density

The mean bulk density of 0 - 20 cm indicated decline in open land than exclosure afforestation P- $\leq$ 0.02 that implies significant change. In the second soil layer/ depth (20 - 40 cm), bulk density decline in open land than exclosure afforestation site, although P-$\leq$ 0.023. But total calculated bulk density indicated open land decline than exclosure afforestation site its significant change p- value would be 0.044 show on (Table, 2) respectively.

Table 2; Soil bulck Density deference of g cm3

Land use categories	Difference of mean	95% CI	T-Value	P-Value
Bulk density open land – Exlosure site 0-20 cm	-0.0912	(-0.1660, -0.0163)	-2.81	0.023
Bulk density open land – Exlosure site 20-40 cm	-0.0296	(-0.0768, 0.0176)	-1.44	0.023
Bulk density open land – Exlosure site 0-40 cm	-0.1213	(-0.2386, -0.0041)	2.39	0.044

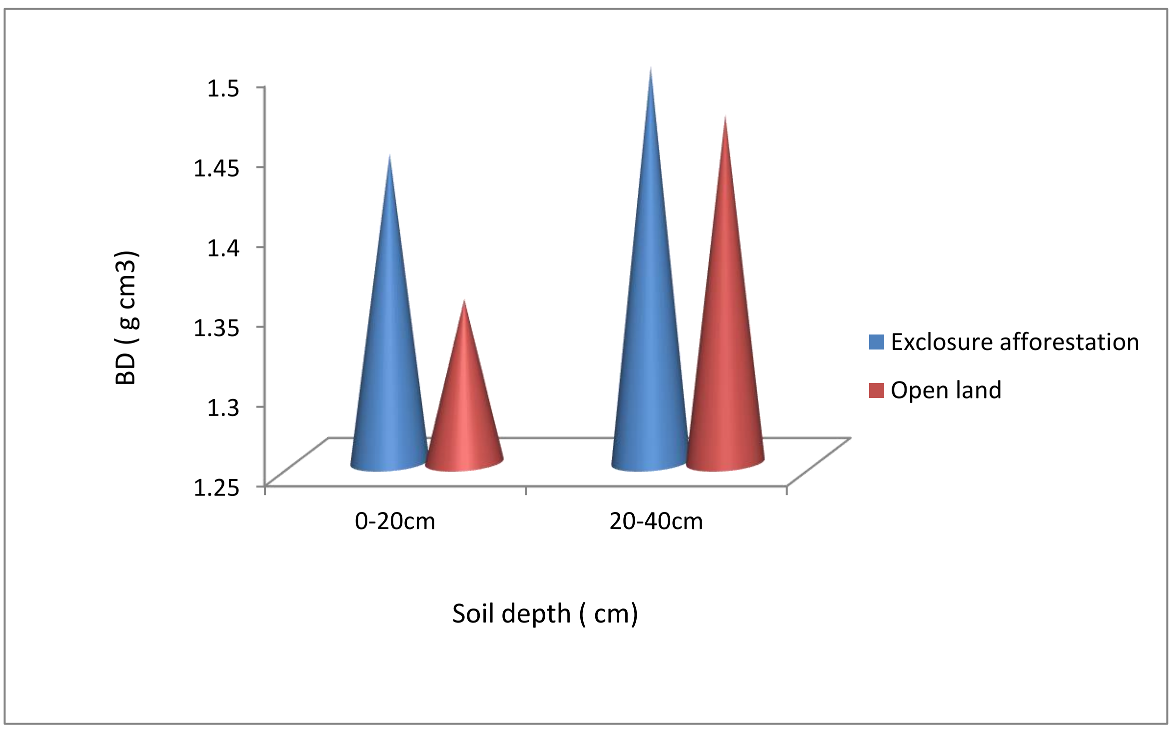

Figure 7; Show bulk density

4.1.4. Total Soil Carbon

These studies observed an initial decrease in soil carbon after afforestation in CRGE projects site. SOC in open land and exclosure a forestation site of 0–20 cm depth decline from 76.90 tc ha^{-1} to 66.33 tc ha^{-1} respectively, that was indicate non significant changes p- values was 0.113 and in the 20–40 cm depth decline from 64.56 to 49.51 tc ha^{-1} respectively, that was indicate significant changes p- values are 0.011 and also in depth of 0–40 cm decline from 141.46 tc $ha^{-1}$to 115.84 tc ha^{-1} respectively (show table1;), that are indicate significant changes p-values are 0.014 show (table 1;). SOC stock was generally higher in the open land site than in the exclosure afforestation site, but the differences were positively significant Show in (table1;). They was demonstrates the wide variation of changes in soil carbon observed following afforestation.

4.1.5. Total ecosystem carbon stock

The carbon stocks over exclosure afforestation site would be calculated from above ground biomass and below ground soil organic carbon contents in CRGE project site may change with a changing in biomass density. Total ecosystem carbon stock = AGC + SOC (9.62 Ct/ha + 115.84 tc ha^{-1}), total ecosystem carbon stock in exclosure afforestation site was 125.46 tc ha^{-1}. It's indicated 9.62 tc ha^{-1} was gain in project site in above ground carbon stock. When compare with adjacent open land haven't any above ground biomass that indicate 0 in above ground carbon stock, its hold 141.46 tc ha^{-1} only, but following aforestation in 8 years above ground carbon stock would be gain by1.22 tc ha^{-1} per years.

4.2. Discussion

4.2.1. Above ground Biomass

Carbon stocks in aboveground biomass (AGB) of afforested/reforested in case CRGE projects were initial sequester more carbon in AGB than open land in the first decade years. As different study indicated the average amount of carbon stocks in AGB of restoration plantings surveyed in (mean age 14 years) was nearly 80 % in north-east Australia (Liddell *et al*., 2007) and 70% in tropical forests elsewhere (Malhi 2012; Keeling and Phillips 2007). While these figures may seem high, rates of carbon accumulation are most rapid in young plantings, and are likely to decline as plantings age: show growth rates in environmental plantings and timber plantations declining markedly after 20–30 years. A/R projects are the most management intensive and 'artificial' forestry projects to sequester carbon. They usually represent a great potential for carbon sequestration and economic benefit when not disturbing natural carbon rich ecosystems. Often, non-native species of rapid growth are used to install mono specific, even aged and less diverse stands that are often far from being site adapted. Exclosure A/R projects are the reconversion to forest it might imitate or accelerate natural succession. In some cases remnants of a primary or secondary forest remain, and usually some forest is located close to the site, providing seed input for natural regeneration

The carbon accumulation by reforested sites of degraded land of a study site (1.22 tc ha $^{-1}$yr $^{-1}$) data was related with data from plantations and re-growth forests other studies by (Silver *et al*., 2004) reported that carbon stocks in secondary (re-growth) forests in the tropics increase by an average of 6.2 tc ha $^{-1}$yr $^{-1}$ in the first two decades after establishment. One of the few relevant studies is that conducted by Redondo Brenes and Montagnini (2006) a carbon stocks in AGB of 12 to 13-year-old mixed species plantations in Costa Rica were 47–91 tc ha $^{-1}$. It's much related to this study of 8 years old mixed *Acacia seligna* and *Gravilia robusta* species. Previous studies of the different sites have shown that restoration plantings provide better habitat for rainforest biota than monoculture or mixed species timber plantations (Kanowski *et al*. 2006, 2008) and are also more resistant to cyclone damage than timber plantations (Kanowski *et al*. 2008b). However, as authors are indicated restoration plantings are unlikely to be favored by carbon markets over timber plantations, because they are so much more expensive to establish on current practice, by an order of magnitude: (Erskine *et al*. 2007; Hunt 2008).

4.2.2. Soil carbon stock

The determination of the baseline for soil carbon is a major issue while assessing and comparing the carbon sequestration potentials of land-use systems, if soil carbon is taken into account. Soil sampling depth is a significant factor in estimating the amount of carbon stored, as well as the potential for carbon sequestration, because substantial amounts of soil carbon are stored in lower depths in all land use systems (Fig.8).While comparing and discussing carbon sequestration potential of different land uses. It will be important to specify soil sampling depth. Some studies in Africa reported that planting trees for carbon sequestration will not immediately retain soil carbon equal to the baseline level nor increase it in the short term (Kaya and Nair, 2001; Walker and Desanker, 2004). These studies observed a decrease in soil carbon after afforestation similar with reported by (Richter *et al*., 1999) they conducted out the initial decline has been observed to last for 3–35 years following agricultural abandonment.

In this study the soil organic carbon following afforestation of degraded land in 8 years life time show decline from the initial one its identified by comparing with adjacent open land that have similar states before a project implementation. This demonstration was a wide variation of changes in soil carbon stock difference following afforestation soil carbon was depended upon, among other factors, time (years) since afforestation and the depth of soil considered (Paul *et al*., 2002). It follows a greater capacity for long-term recovery of soil carbon following afforestation of cooler sites compared with warm temperate sites.

For different factors carbon was decline following afforestation

Climate effects on soil carbon, the soil microclimate also changes with land-use change. Surface soils are generally cooler and drier under plantations than under pasture (e.g. Myers et al., 1996; Grove et al., 2000) due to shading under plantations and greater rates of transpiration. It is likely that these differences may contribute to slower decomposition rates following afforestation. Further work is required to provide evidence of the influence of changes in microclimate on soil carbon following land-use change,

Site preparation mechanical disturbance may accelerate by increasing the surface area of soil and mounding may also increase loss of carbon through erosion by wind and water,

Previous land use, most of the time degraded sites are given priority in management,

Forest type there was a significant effect of on change in soil carbon at all sampling depths carbon increased under hard wood than soft-woods.

This study indicated soil carbon under project site would be decline following afforestation at all depth, its similar result with (Paul et al., 2002). The wide variation of changes in soil carbon observed following afforestation, as the authors indicated rates of change in soil carbon varied from a mean maximum of 17 % per year (< 30 cm depth). The average change in soil carbon was 0.05 % per year for < 10 cm depth), 0.03 % per year for >10 cm depth and 0.37 % per year for < 30 cm depth as author suggested high positive correlation with this study investigated. As my observation also soil carbon stock following afforestation was declined 2.27 % per years (in <40cm depth), the average change in soil carbon was 1.72 % per year for <20 cm depth (Fig; 8). The loss of soil organic carbon stock following afforestation in the first soil depth of 0-20 cm and in the second soil depth of 20-40 cm or at all layers or depth the result was similarly with Post and Kwon (2000). That was shown a results are consistent with those observed for surface soils on sites repeatedly measured over time (Richter *et al*., 1999). These studies observed an initial decrease in soil carbon after afforestation.

4.2.3. Total carbon (biomass + soil) stock

The carbon sequestration potential is usually calculated based on land use type of exclosure afforestation land and open land is consider the difference in carbon content in the system ‘‘before’’ and ‘‘after’’ the project as the carbon sequestration potential and express it by time averaged quantities. The results of this study indicate that carbon sequestration potential based on time-averaged carbon stock computed from soil analysis data, and without consideration of land use history of the sites, may be unrealistic. Furthermore, new exclosure afforestation development projects are initiated based on the premise that improved above ground carbon. The above and below ground carbon stocks in every category of exclosures duration than the adjacent open lands suggesting the significant potential of exclosures to restore degraded lands and enhance ecosystem carbon content.

Differences in ecosystem carbon found between exclosures and the adjacent open lands increased with exclosure duration indicating that exclosure duration influences the amount of carbon stored in exclosures. This general increment can be explained by the decrease in soil erosion rate and the increase in the overall species diversity and aboveground biomass with exclosure site. The importance of increased vegetation cover in exclosures to reduce soil erosion has been shown in studies where soil loss decreased with exclosure duration (Mekuria et al., 2009). Additionally, with the increase in naturally regenerated plant species diversity and biomass with exclosure duration, inputs to the soil carbon increase as well as the conversion of plant carbon to soil carbon through increased microbial activities. This argument was supported by the significant positive correlation between soil carbon and aboveground vegetation biomass was increasing soil organic carbon pool with the addition of biomass to soils when the pool has been depleted as a consequence of land use.

According to Bhojvaid,P.P., and Timmer, V. R. (1998), three distinct stages of soil development can be recognized following plantation establishment:

(i) an initial establishment phase (0-5 years) characterized by either nominal soil changes or even a decline in soil properties;

(ii) a brief transitional phase (5-7 years) characterized by a canopy closure of the tree plantations and a rapid change in soil properties; and

(iii) Fallow enrichment phase (7-30 years) characterized by a gradual stabilization of soil properties. Similarly, several studies that assessed change in soil C stocks following afforestation and reforestation of former bare lands soil showed loss of soil carbon at early stages of plantation development (< 10 years) as there is relatively little input of carbon from biomass.

5. Conclusions and Recommendation

5.1. Conclusions

Effects of land cover change on carbon stock the study showed how carbon stocks in exclosure afforestation and open land varied in above ground biomass and soil across land cover types. The study was investigated the effectiveness of exclosures A/R to restore above and below ground carbon in the central Oromia. Our results showed that the conversion degraded open lands to exclosures A/R have a significant potential to increase carbon sequestration, even in strongly additional aboveground carbon storage. However, expansion of exclosures A/R increases on the remaining communal open land. Exclosures A/R projects can produce a diverse range of ‘products’ including, sequestered carbon, habitat for plants and animals, erosion control and water quality. As demand for all these products increases, reforestation projects will face increasing pressure to deliver multiple benefits to landholders and the wider community. The conserving of long pried degraded land from human and animal’s intervention by local community engagement through exclosure afforestation of exotic tree species. In CRGE project site would provide they increasing of biomass to sequestered carbon, habitat for plants and animals, erosion control and prevent gaily formation at down steam of farm lands.

5.2. Recommendation

- ❖ Rehabilitation of degraded land through exclosure afforestation, for carbon sequestration in above and below ground stock should be cost effective technology to combating climate change impact and biodiversity loss.
- ❖ The temporary decrease in soil carbon due to site disturbances during planting temporary suppression in soil carbon due to microbial activities in decomposition freshly added organic matter that will be followed by increase once decomposable components are exhausted.
- ❖ The rapid buildup in biomass carbon in the exclosure area will soon lead to increase in soil carbon too, hence overall increase in carbon stock in the managed ecosystem than unmanaged ecosystem.
- ❖ The trade-offs between carbon sequestration and biodiversity conservation has yet to be considered in detail for reforestation projects.
- ❖ Restoration of degraded land by planting trees species through community engagement for different purposes was produce more Above ground biomass in short period of time to achieved Climate resilience Green economy strategic goal of our country.
- ❖ Ecologically focused restoration of degraded landscapes in akaki woreda have the potential to sequester substantial quantities of atmospheric carbon, while also combat land degradation and biodiversity loss
- ❖ CRGE implementing sector or government & non-government origination should be investigate the above ground and blow ground carbon stock change following exclosure afforestation /reforestation site at least once a year.

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Appendices

Table 3; Soil laboratory result of Exclosure afforestation site

Serial	Field Code	Depth	B. Density	O.C	O.M
No.	(Profile No.)	Cm	g/cm^3	%	
1	Plot - 1	0-20	1.46	2.45	4.23
2		20-40	1.49	1.44	2.47
3	Plot - 2	0-20	1.32	3.05	5.26
4		20-40	1.44	1.61	2.77
5	Plot - 3	0-20	1.47	1.95	3.36
6		20-40	1.52	1.60	2.77
7	Plot - 4	0-20	1.48	2.41	4.15
8		20-40	1.53	1.91	3.30
9	Plot - 5	0-20	1.49	1.71	2.95
10		20-40	1.5	1.69	2.92

Table 4; Soil laboratory result of open land

Ser. No	Field Code	Depth	B. Density	O.C	O.M
	(Profile No.)	Cm	g/cm^3	%	
1	Plot - 01	0-20	1.38	2.57	4.42
		20-40	1.49	1.97	3.39
2	Plot - 02	0-20	1.34	2.98	5.14
		20-40	1.45	2.54	4.37
3	Plot - 03	0-20	1.33	3.17	5.46
		20-40	1.43	2.59	4.47
4	Plot - 04	0-20	1.36	2.61	4.50
		20-40	1.47	2.02	3.48
5	Plot - 05	0-20	1.35	2.90	5.00
		20-40	1.5	1.91	3.29

Table 5; above ground biomass Inventory and carbon stock of each plot in CRGE project site

Plot NO.	AGB kg	Carbon fraction	Carbon kg	Ckg/ha	Ct/ha
1	157.0058	0.5	78.5029	7850.29	7.9
2	244.993		122.4965	12249.65	12.25
3	133.88088		66.94044	6694.044	6.72
4	173.66174		86.83087	8683	8.7
5	227.9606		98.2688	98268	9.9
6	168.4088		84.2044	8420	8.42
7	150.7611		75.38055	7538	7.54
8	235.4394		117.7197	11771	11.8
9	239.0661		119.53305	119533	12
10	204.4469		102.22345	102223	10.23
11	207.7614		103.8807	10388	10.42
12	182.9009		91.45045	9145	9.14
13	193.3672		96.6836	9668	9.7
14	134.7214		67.3607	6736	6.74
15	174.37966		87.18983	8718	8.8
16	226.21942		113.10971	11310	11.31
17	246.43892		123.21946	12322	12.34
18	149.8798		74.9399	74939	7.5

19	213.292		106.646	10664	10.72
20	120.127		60.0635	6006	6.01
21	247.3394		123.6697	12366	12.37
22	204.01864		102.00932	10200	10.2
23	144.2336		72.1168	72116	7.21
24	182.3374		101.1759	10117	10.22
25	103.9444		51.9722	5197	5.23
26	161.8722		115.5553	11555	11.6
27	122.0226		98.61705	9861	10
28	212.2694		106.1347	10613	11
29	184.59028		128.60484	12861	13
30	189.8421		94.92105	9492	9.5
					288.47
Above ground carbon stock in exclosure afforestation site tc ha^{-1}					**9.62**

Table 6; Location of plots in relation to altitude, latitude and longitude

Exclosure/ Afforestation				Open bare land			
Plot no.	easting	northing	altitude	Plot no.	easting	northing	
1	476400	968547	2212	1	476160	968466	2111
2	476388	968535	2228	2	476183	968493	2108
3	476380	968498	2259	3	476243	968510	2116
4	476378	968474	2172	4	476319	968466	2112
5	476386	968448	2136	5	476363	968489	2125
6	476427	968974	2215				
7	476464	968474	2185				
8	476474	968511	2164				
9	476483	968531	2209				
10	476451	968566	2246				
11	476497	968590	2241				
12	476455	968572	2213				
13	476438	968550	2192				
14	476405	968530	2178				
15	476309	968186	2242				
16	476299	968235	2281				

17	476279	968304	2256
18	476311	968328	2171
19	476374	968359	2264
20	476501	968612	2231
21	476581	968673	2242
22	476623	968719	2158
23	476656	968746	2274
24	476689	968774	2169
25	476331	968385	2217
26	476216	968273	2254
27	476622	968537	2269
28	476698	968612	2178
29	476410	968527	2293
30	476487	968594	2265

Figure 8; On Field soil sample collection Technical

Figure 9; IN Exclosure afforestation site when measure DBH