SOIL CARBON SEQUESTRATION, SOCIOECONOMIC IMPACT AND FARMERS' PERCEPTION OF THE ROLE EXCLOSURE: THE CASE OF GIMBICHU WOREDA, CENTRAL ETHIOPIA.

M.Sc. THESIS

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February, 2016

Jimma, Ethiopia

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M.sc. Thesis

Submitted to the School of Graduate Studies, Jimma University College of Agriculture and Veterinary Medicine in Partial Fulfillment of the Requirements for the Degree of Master of Science in Natural Resource Management (Watershed Management)

Major Advisor: Debela Hunde (PhD, Associate Professor)

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DEDICATION

I dedicate this thesis work to my mother Chaltu Gudeta, my father Bekele Negesh and my sister Birtukan Bekele; for helping me with care, financial help and love in the success of this work and my life.

DECLARATION

This thesis is my original work it has never been submitted in any form to other university, it has never been published nor submitted for any journal by another person, and all sources of materials used for the thesis are largely acknowledged.

Name: Birhanu Bekele

Signature ______

Place: Jimma University, Collage of Agriculture and Veterinary Medicine

Date of submission: ___/___2015

BIOGRAPHY

Mr. Birhanu Bekele was born on 12th of October 1989 in east showa zone of oromia regional state, central Ethiopia. He attained his junior elementary school at Man-Jigso, secondary school at Bishoftu Ada`a Model secondary school and his preparatory at Bishoftu Comprehensive secondary school from 2006-2007. Then he joined Wollega University College of Agriculture and Veterinary Medicine in 2008 and awarded B.Sc.in Natural Resource Management in 2010 G.C. with a distinction. After graduation he was employed by Ministry of Agriculture as the expert of Soil and water conservation at Gimbichu *woreda* Agricultural office until he joined the school of graduate studies at Jimma University, College of Agriculture and Veterinary Medicine in September, 2014 to follow M.Sc study in Natural Resource Management (Watershed Management).

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LIST OF ABBREVIATION (ACRONYMS)

AE	Area Exclosure
AJB	African Journal of Biotechnology
CDM	Clean Development Mechanism
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization of the United Nation
FGD	Focus Group Discussion
FGE	Foundation Green Ethiopia
GHG	Green House Gas
GWADO	Gimbichu Woreda Agricultural and Development Office
IPCC	Intergovernmental Panel on Climate Change
MoA	Ministry of Agriculture
NMSA	National Meteorological Services Agency
OC	Organic Carbon
OM	Organic Matter
PA	Peasant Association
PGRC	Plant Genome Resources Center
SAS	Statistical Analysis Software
SIC	Soil Inorganic Carbon
SC	Soil Carbon
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SPSS	Statistical package for Social Science
WFP	World Food Program

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ABSTRACT

Land degradation is the most challenge in sustainable development. To overcome the problem of land degradation that cause climate change and poverty in Ethiopia, exclosure is used as strategy to minimize this environmental and livelihood threats. The overall objective of the study was to identify soil carbon sequestration, socioeconomic impact of exclosure and farmers' perception on its role: the case of Gimbichu Woreda, Central Ethiopia. *To achieve this objective Gara Girmi exclosure area was selected from Gimbichu woreda. Soil samples were collected from open land and 4 years exclosed land. Soil samples were collected by auger and core sampler from the same landscape positions; replicated four times in both land management(exclosure and open land) and two soil depts. (0-20 and 20-40cm) to determine BD and soil SOC and finally to calculate soil carbon stock. Besides, socio economic survey was conducted using structured questioner, focus group discussion and key informant and analyzed by SPSS (version 20). The result showed that exclosed lands had significantly ($P<0.05$) different from adjacent degraded open land for mean value of soil bulk density (BD), soil organic carbon (SOC), and soil carbon stock (SC). The study showed that the mean value at exclosure and open lands of soil BD, SOC, and SC were 1.03 and 1.23 g/cm^3, 2.40 and 0.96% and 49.38 and 26.2 ton/ha respectively. With regard to soil depth SOC and SC show significantly ($P<0.05$) different in the first depth where as soil BD didn`t show any difference as their mean value in 0-20cm and 20-40cm indicate 2.09 and 1.28% SOC, 1.11and 1.16 g/cm^{3}BD and 45.75 and 29.63 ton/ha SC respectively. The soil carbon also highly stored in surface depth of excloed land (59.16 ton/ ha) whereas the lowest is stored under the subsurface depth of degraded open land (*20.07*ton/ha) which indicate that the area exclosure play a vital role in climate change mitigation by sequestering atmospheric carbon in the form of CO_2 in to the soil . Concerning exclosure impacts on socioeconomics' of local farmers; all respondents under exclosure land (74.4%) perceived that they were getting economic, social and environmental benefits but all respondents (25.6%) from the degraded open land replied that they didn`t get any direct economic benefit from their non-exclosed land. The exclosure is on improving the livelihoods of the local community where they have probably harvested about 2550 kg/ha/yr or 1275ETB/ha/yr forage grass and 1400kg/ha/yr or 840ETB/ha/yr thatching grass which used for fattening purpose and house shade respectively or additional income by selling these products. Local community perceived exclosures positively and are optimistic to the performance of exclosure. The entire respondents agreed that the exclosure is an option for land rehabilitation and they obtain economic, social and environmental benefits. Besides, most of the respondents from open land decided to expand exclosure to the adjacent degraded lands. Generally, exclosure has a great role in climate change mitigation by sequestering carbon in the form of CO_2 from atmosphere and also improve economic and social benefits of local community. Therefore, the local community living in degraded land could be adopting the area exclosure practice from the present studied area.*

Key words: *Exclosure, carbon sequestration, soil carbon stock, socio- economic, perception*

1. INTRODUCTION

1.1 Background and Justification

Climate change is attributed directly or indirectly to human activity and natural phenomenon that alters the composition of the atmosphere (IPCC, 2001). The increase in greenhouse gases (GHG) in the atmosphere and the resulting climatic change will have major effects in the 21st century. This causes of global warming which have direct effect on the health of aquatic and terrestrial life. Those gases are effective on carbon and soil characteristics by changing aerial and underground biomass so that this event leads to decrease soil fertility, quality and quantity of reversal biomass (Lal, 2004).

Climate change and global warming is one of the most challenges in sustainable development (Brooks et al., 2004). According to Gert (2014) over the last few decades increased atmospheric concentrations of greenhouse gases have induced global warming which, if no actions are taken, is expected to raise the average temperature on earth by 4^{o}C within the next century. Although current scenarios are still fraught with uncertainty, serious negative effects are expected – though some positive effects are also expected- and it is essential that a number of actions be undertaken in order to reduce GHG emissions and to increase their sequestration in soils and biomass. In this connection, new strategies and appropriate policies for agricultural and forestry management must be developed. One option concerns carbon sequestration in soils or in terrestrial biomass, especially on lands used for agriculture or forestry (IPCC, 2000).

Carbon dioxide is considered as the most important element of greenhouse gases. It is a dynamic element which cycles between the atmosphere, biosphere and lithosphere, alternating from gaseous to solid states through different processes of fixation and release. In photosynthesis, carbon dioxide is incorporated into plant biomass (Reynaldo *et al.,* 2012).It is temporarily stored as organic compounds in living organisms, and as debris in the soil.

During the decomposition of organic matter, the bonds that connect these compounds are cut and the carbon returns to the atmosphere as carbon dioxide. The soil organic carbon (SOC) content depends mainly on the current balance between primary production and microbial respiration and is therefore immediately affected by land-use changes (Paustian *et al.,* 2006).

Today, one of the major challenges facing the world is the degradation of land. In Ethiopia land degradation contributes to decline in agricultural productivity, persistent food insecurity, and rural poverty (World Bank, 2008) by increasing soil loss, nutrient depletion and declining of soil quality. Thus soil erosion has drastic effect on soil quality and soil organic carbon (SOC) which result the depletion of carbon stock both in biomass and in soils (Abebe et al., 2013). Thus changes of climate because of land degradation can be mitigated by sequestration of atmospheric carbon dioxide in to soil carbon. The term “sequestration” is used in the Kyoto Protocol which is equivalent to the term “storage” or it describe the process that removes carbon from the atmosphere either through natural and artificial processes (FAO, 2001b) or it is one of the mitigation measures to offset one of the GHG emissions, namely CO_2 (NMSA, 2001).

With the ratification of the Kyoto Protocol, several technical problems and policy issues have arisen that must be solved if practical implementations are to become a reality, in particular the implementation of projects under the Clean Development Mechanism. The agreement of Kyoto Protocol implements specific initiatives and projects that stimulate carbon sequestration. The Clean Development Mechanism (CDM) enables developed countries to buy carbon credits from developing countries by establishing specific projects that enhance carbon sequestration in these areas. The major technical issues for the inventory and monitoring of stock and sequestration of carbon in current and potential land management approaches. Deliberate land management actions that enhance the uptake of carbon dioxide (CO_2) or reduce its emissions have the potential to remove a significant amount of CO_2 from the atmosphere in the short and medium term (FAO, 2004).

Exclosure is rehabilitation of degraded land in arid and semiarid environments often by excluding livestock from degraded sites, creating what are usually but unfortunately not consistently to allow native vegetation to regenerate as a means of providing fodder and woody biomass, to reduce soil erosion and to increase rain water infiltration (Mekuria *et al.,* 2007). In practice, cattle are not allowed to free graze in several of the exclosures. Cutting grass and collection of fuel wood from dead trees and bee keeping is also allowed. In some areas, soil and water conservation activities are also being undertaken (Betru *et al.*, 2005).

As a strategy, its establishment is to reverse land degradation, biodiversity loss and fragmentation of habitats has gained great acceptance due to its effectiveness in improving land productivity and reducing soil erosion (WFP and MoA, 2002; Mengistu, 2011). It also improve the loss of forest biomass through deforestation and forest degradation which makes up 12% to 20% of annual greenhouse gas emissions (Saatchi *et al.,* 2011), which is more than all forms of transport combined. In Ethiopia, the establishment of exclosure also has been extensive, and the economic and ecological significance were considerable (Betru *et al.*, 2005).

Most of the lands are individual grazing lands in Gimbichu *woreda;* particularly in Girmi *kebeles* where free grazing occurs are degraded and unproductive due to accelerated rate of over grazing and poor management practices which led to soil erosion. To alleviate the problem, many projects were initiated and began practices on land management including area exclosure, as a viable strategy to rehabilitate degraded lands on each *kebeles.* Therefore, Gimbichu *woreda* in collaboration with Foundation Green Ethiopians' (FGE) project initiated AE since 2011 to rehabilitate the degraded lands of Girmi *kebele* by including afforestation and different physical activities with exclosure practice.

Currently the area is well rehabilitated and became productive land, but the long term effects of this exclosure land on soil carbon sequestration and socio-economic impacts were not investigated. Therefore, this research focused on this exclosure investigation of its adverse impacts on soil carbon sequestration by comparing with the adjacent degraded open land and its socioeconomic impacts on the livelihoods of the community in the study area. Finally the recommendation was forwarded to enhance exclosure practice thereby improving the living standard of the local people and to minimize land degradation.

1.2 Objective of the Study

1.2.1 General objective

- The overall objective of this study was to investigate the role of exclosure for climate change mitigation and its impact on livelihoods of the community.

1.2.2 Specific objectives

- To assess the contribution of exclosure for soil carbon sequestration in the study area.
- To study the effects of exclosure on socioeconomics of the community of the study area.
- To assess the perception of local community towards exclosure.

2. LITERATURE REVIEW

2.1 Exclosure

Exclosures and enclosures are related terms, but cannot be used as synonyms. The word enclosure comes from Latin word “*in*" and *claudere*" which means closing, confinding and restricting or keeping objects, usually animals, inside a given area. Exclosure is a more recent word, was later formed as an analogy to enclosure, and has the opposite meaning: keeping things (animals) out. It has been widely used to exclude the effects of predators, large herbivores, livestock, small mammals or birds on the species richness and recruitment in plant communities (Fraser and Madson, 2008; Jacobs and Naiman, 2008; Negussie *et al.,* 2008 cited in Raf *et al.,*2008) and on processes such as sediment deposition, litter production, soil carbon sequestration and woody plant invasions (Descheemaeker *et al.,* 2006a; Pei *et al.,* 2008 and Shrestha and Stahl, 2008 cited in Raf *et al.,*2008).

2.1.1 Exclosure in Ethiopia

In Ethiopia land degradation in the form of soil erosion, deforestation, and gully formation has been taking place for millennia. Subsequently, soil fertility loss and severe soil moisture stress led to a decline in agricultural productivity. Land is being converted primarily for subsistence and commercial agriculture, timber used for fuel wood and construction, protected grasslands used for livestock grazing. The loss of forests and other protected land is underpinned by a growing population, unsustainable natural resource management, poor enforcement of existing legislation, uncertain land tenure and very low public awareness of the impact of climate change and the importance of biodiversity and ecosystems (Esser *et al.,* 2002; Mastewal and Wolder, 2013). But it is a widely practiced intervention of restoring degraded lands in northern Ethiopia. Besides, the restoration of vegetation and biodiversity, area exclosures play a major role in sequestering carbon that addresses the mitigation of climate change as stated in the Kyoto protocol (Ermias *et al.,* 2007). Establishing exclosure is considered advantageous since it is a quick, cheap and lenient method for the rehabilitation of degraded lands. As a result rehabilitation of degraded lands through exclosure recently received attention in many parts of the Ethiopian especially northern and central highlands (Temesgen, 2012).

2.2 Carbon Sequestration

Carbon sequestration implies transferring atmospheric CO_2 into long-lived pools and storing it securely so it is not immediately reemitted (www.sciencemag.org Vol. 304 Jun 2004). It is commonly used term to describe any increase in soil organic carbon (SOC) content caused by a change in land management, with the implication that increased soil carbon (C) storage mitigates climate change (Powlson *et al.*, 2011). It is the removal of carbon in the form of CO_2, either directly from the atmosphere or industrial processes; stored either in growing plants in the form of biomass or absorbed by oceans which helps to reduce or slow the buildup of CO_2 concentrations in the atmosphere (EPA, 2012). Carbon is temporarily stored as organic compounds in living organisms, and as debris in the soil. During the decomposition of organic matter, the bonds that connect these compounds are broken and the carbon returns to the atmosphere as carbon dioxide. The soil organic carbon (SOC) content depends mainly on the current balance between primary production and microbial respiration and is therefore immediately affected by land-use changes (Paustian *et al.*, 2006).

Exclosure enhance vegetation cover which decrease in atmospheric CO_2 and associated global warming by affecting the rate of uptake of CO_2 into plants through the processes of photosynthesis, could affect overall tree productivity (Lewis *et al.*, 2001).When grasslands are cultivated, the carbon concentrations close to the surface might therefore decrease. A degraded soil that is rehabilitated through promotion of grassland vegetation, with an increased input of debris to the soil, will instead act as a carbon sink. Restoration of degraded land in developed countries is often prescribed as a way to increase carbon sequestration, while simultaneously alleviate poverty (Reynaldo *et al.*, 2012).

2.2.1 Carbon sequestration in the soil

Soil Carbon sequestrations mean increasing soil organic carbon (SOC) and soil inorganic carbon (SIC) stocks through judicious land use and recommended management practices (www.sciencemag.org Vol. 304 Jun 2004). Soil carbon sequestration is gaining global attention because of the growing need to offset the rapidly increasing atmospheric concentration of carbon dioxide (CO_2). This carbon dioxide enrichment is associated with an increase in global warming potential and changes in the amount and effectiveness of precipitation (Warren, 2010). Several scientists pointed out that carbon dynamics in the soil ecosystems has been one of the major factors affecting CO_2 concentration in the atmosphere (IPCC, 2000; Houghton et al., 2011; IPCC, 2001). Carbon sequestration in soil organic matter is increasingly advocated as a potential win–win strategy for reclaiming degraded lands mitigating global climate change, and improving the livelihoods of resource-poor farmers (Batjes, 2001; FAO, 2001; Lal, 2004; Ringius, 2002).

The carbon stock value is different with different carbon pools shows different storage of carbon. Accordingly, *45.24*% of carbon stock stored in the above ground biomass, *45.15*% of carbon stock stored in the soil, *9.05*% of carbon stock stored in below ground carbon pool and least (*0.56*%) amount of carbon was stored in litter carbon pool. In relation with depth; SOC and soil bulk density was varied at different soil depths. The average increased with depth increment however, SOC decreased with depth increment. The pattern indicates that soil carbon decreased significantly with soil depth which revealed major trends in carbon accumulation in the upper soil layers. This may be due to the accumulation and rapid decomposition of forest litter in the top soil (Adugna *et al.*, 2013).

Plant functional types significantly affected the vertical distribution of SOC. The percentage of SOC in the top 20 cm (relative to the first meter) averaged 33%, 42%, and 50% for shrub lands, grasslands, and forests, respectively. In shrub lands, the amount of SOC in the second and third meters was 77% of that in the first meter; in forests and grasslands, the totals were 56% and 43%, respectively. Globally, the relative distribution of SOC with depth had a slightly stronger association with vegetation (Batjes, 1996, Jobb`agy and Jackson, 2000).

2.2.2 Causes of high atmospheric CO2 concentration

Human activities have significantly disturbed the natural carbon cycle by extracting long buried fossil fuels and burning them for energy, thus releasing CO_2 to the atmosphere. The CO_2 level in 2012 was about 40% higher than it was in the nineteenth century which was primarily caused by deforestation (which reduces the CO_2 taken up by trees and increases the CO_2 released by decomposition of the detritus), and other land use changes which released carbon from the biosphere (living world) where it normally resides for decades to centuries. The additional CO_2 from fossil fuel burning and deforestation has disturbed the balance of the carbon cycle, because the natural processes that could restore the balance are too slow compared to the rates at which human activities are adding CO_2 to the atmosphere. Greenhouse gases such as carbon dioxide (CO_2) absorb heat (infrared radiation) emitted from earth's surface. Increases in the atmospheric concentrations of these gases cause earth to warm by trapping more of this heat. Human activities; especially the burning of fossil fuels since the start of the Industrial Revolution have increased atmospheric CO_2 concentrations by about 40%, with more than half the increase occurring since 1970. Since 1900, the global average surface temperature has increased by about 0.8 °C (1.4 °F) (IPCC, 2013).

According to (IPCC, 2007 cited in Justin, 2010) reports, most of the observed increase in globally averaged temperatures since the mid-20th century is very likely [i.e. greater than 90% certainty] due to the observed increase in anthropogenic greenhouse gas concentrations. This is an advance since the (IPCC, 2001) conclusion that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures extremes and wind patterns.

2.3 Potential of Exclosure

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 exclosure and establishment of fast growing plantations of exotic species & physical conservation measures such as terracing (Mulugeta, 2004).

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. Yaynishet *at al.* (2008) also stated that the establishments of exclosures have been effective in restoring plant species composition, diversity, biomass, cover, and structure of both herbaceous and woody vegetation, factors that normally lead to improved ecosystem function.

Exclosure has a great environmental benefit in soil erosion protection and enhancing land productivity through rapid vegetation restoration which increase the capacity for infiltration and sediment trapping. If vegetation coverage is chosen to be the best alternative form of land use, not only is prevent the loss of soil also, but also that it is not deposited in river bottoms, lakes and dams (FAO, 2005). It also plays an important role in conserving remaining soil resources and improving soil fertility by adding soil organic matter (SOM). The accumulation of SOM within soil is a balance between the return or addition of plant residues and their subsequent loss due to the decay of these residues by micro-organisms. Organic matter existing on the soil surface as raw plant residues helps protect the soil from the effect of rainfall, wind and sun (Habtamu *et al.*, 2008).

Exclosures contained a significantly higher percentage of SOC than the open-grazed areas, in the upper part of the soil. This, together with an observed increase of ground vegetation cover after fencing, indicates that more carbon is sequestered in the soil when a pasture is fenced (Gert, 2014 and Haile, 2012). It also reduced nutrient loss from a site by controlling runoff (vegetation acting as a physical barrier to soil erosion). This eventually improves the capability of the land to support other vegetation types, including exotic plantations and/or support livestock production (Tefera *et al.*, 2005).

Additionally exclosure enhances a diversity of woody plant species and facilitates conditions for healthy ecosystem. In ecosystem; levels of species and species richness typically characterize the ecosystem as healthy and robust. In comparison enclosure and open sites, enclosure site is healthier than the open site. The protection and restoration of degraded lands can significantly improve the functioning of the ecosystem though increasing the diversity of species and their interactions in the protected areas (Kibret, 2008).

Restoration of degraded lands reduces the loss of biodiversity is also another best environmental potential of exclosed area. As biodiversity plays a critical role in overall sustainable development and poverty eradication. High levels of biodiversity of species in ecosystem typically characterized that ecosystem as healthy, robust and integrity. Since a loss of biodiversity can significantly affects the functioning of the ecosystems (Darwin and Wallace, 1858).

According to (Yaynishet *et al.*, 2008 cited in Haile, 2012) found biomass of area closure twice of free grazing and also (Mekuria *et al.*, 2009 cited in Haile, 2012) found biomass of some species higher in closed than non-closed and he estimated aboveground carbon stocks increased by 39-68% through the conversion of degraded grazing lands to enclosures.

Generally, Exclosure increase the total ground cover which enhances carbon sequestration and this implies the increment in plant biomass, production increase, improve soil fertility, increase water-holding capacity of the soil and prevent wind and water erosion. Thus the carbon sequestration has economic value and protective values due to increasing of biomass production (Haile, 2012).

2.3.1 Socio-economic potential of exclosure

For exclosures to continue playing their environmental conservation role, socio economic needs of local people is very important. A sustainable and socially fair harvesting system of the wood resources or a rotational grazing system initiates local people to have positive attitude towards exclosure (Descheemaeker *et al.,* 2006). The vegetation in the exclosures most useful to the communities are mainly the herbaceous and woody plants, specifically grass, tree and shrub species and helpful in achieving conservation based sustainable agriculture in its source of Non-timber forest products (Betru *et al.,* 2005).

The successful colonization of many of the native species in many of the degraded lands, underline their potential in wasteland reclamation. These would serve as sources of fuel-wood, fodder (using cut-and-carry system), grasses for thatching and other tree products while reclaiming the marginal lands. Its contribution in augmenting the high demand of tree products might be of paramount importance (Kindeya, 2004 in Kibret, 2008).

Exclosure has also a high economic potential in community livelihood improvement by provide forest products including trees though increasing incomes, improving food security, reducing vulnerability and enhancing well-being (FAO, 2001).

Rehabilitation of mountain supports livelihoods by increasing productivity and biodiversity of fragile ecosystems. In addition it protect downstream areas from flood hazard and clotting with silt concomitantly improving infiltration and ground water conditions besides replenishing springs and providing water for longer periods of time for downstream communities (Mitiku and Kindeya, 1997).

2.4 Perception of local community on Exclosure

Local communities` perception on the role exclosure was quite well because of created awareness and the benefit obtained from the exclosure. The optimistic view of local community to rehabilitate degraded lands and make them productive may be interpreted as an asset for projects working to rehabilitate degraded dry land (Wolde *et al.*, 2000).

Communities` view of economic benefits of exclosures also agrees with Lovejoy (1985) research result states that resources from exclosure contribute to the households' economy, suggesting that economic and social wellbeing is enhanced by focusing on rehabilitation of degraded lands. Exclosures are effective strategies in controlling accelerated soil erosion and agricultural lands below area exclosures become more productive than lands below grazing. In addition; exclosures also facilitate natural regeneration thereby reducing surface runoff. This will promote accumulation of soil organic matter and other plant nutrients that excel soil quality and capable of support diverse communities (Girma, 2009).

3. MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location

Gimbichu *woreda* is located at 85km to east away from Addis Ababa, capital city of Ethiopia and 90km to north from Adama, the city of Oromia regional state central Ethiopia (figure 1). Geographically the area is located at $08^{0}56'\ 21''$ - 09^{0} 4918N latitude and 039^{0} 09' 42" - 39^{0} 06' 34"E longitude. The altitudinal range of the study district is between 1300 and 2500 meters above sea level. Gimbichu *woreda* is bordered by Amhara region, Ada`a *woreda* of East Showa *zone*, Akaki unique *zone* of Oromia and Barah Aleltu of Oromia zone in Waste ,South, East and North respectively. The study was conducted in *'Gara* Girmi*'* exclosure *at* Gumbichu *woreda*, east showa zone, Oromiya regional state. The study was conducted in an area of about 36ha excluded and its adjacent degraded open land. In 2011 G.C, the area was put under plan to be managed and protected with participation of local people and Foundation Green Ethiopians' project, as part of the exclosure land and has been managed from any disturbance by humans and livestock. Since then, exclosure has been under continuous protection (GWADO, 2014).

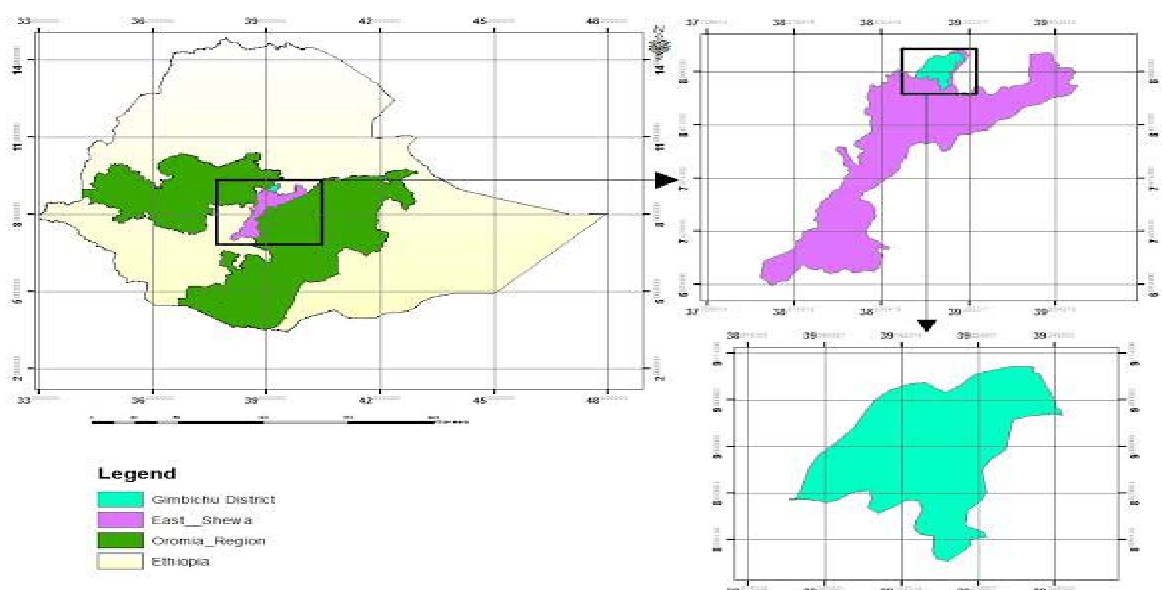

Figure 1: Location of the study area

3.1.2 Climate

Gimbichu *woreda* has *Dega* (52%); kola (21%) and *W/dega* (27%) agro-ecological system which are available diversity for crop productions. The mean annual rain fall ranges from 800 to 1000mm. The study area has a mono-modal rainfall distribution pattern. The main rainy season"*Kiremt*", extends from mid June to September. More than 85% of the total rain falls during this season and the highest rainfall occurs in July and August. Rain that occurs during this season is very intensive and, hence the majority of soil loss by erosion occurs during this time. Although the rainfall has mono-modal distribution, most of the crop production takes place during the "*Kiremt*" season. Mean annual temperature of the area is 16 ^{o}C and mean minimum and maximum temperature of the area are 12^{0}C and 20^{0}C respectively. The warmest months of the area are between February and May. In these months, average temperature of the area reaches to 19.5^{0}C. The coldest months of the study area range between October and November where the average monthly temperature reaches to 12^{0}C (GWADO, 2014).

3.1.3 Topography and soil

Physiographically; the Gimbichu *woreda* is characterized by Low land and Mid-land. Have a diversified land form of valley (13%), mountain (1%), hill (1%) and dominated by plain (85%). The major soil type of Gimbichu *woreda* is Vertisol which covers about 80% of the *woreda* including the study site. Other soil types are Nitosols 12%, Cambisols 6% and 2% other. Black clay soil, in the area is locally called *marare*, where as light sand soil and hillside soil-locally called *gombore. Vertisols* are generally fertile with good moisture holding capacity. They are hard and crack during dry, and sticky when wet (GWADO, 2014).

3.1.4 Vegetation and water resource

Gimbichu *woreda* has a total area of hectare 74,446 land; that 37.6% is arable or cultivable, 14.2% pasture, 2.6% forest, and the remaining 45.6% is considered degraded. The land cover is dominated by scattered trees and shrubs which are found around settlements and trees and grasses in the exclosure areas. There are six temporary rivers (Menjigso, Habru-Miti, Garmama, Dowatu, Girmi and Dobi River) dna three permanent water source (Modjo River, Kuba Lake and Waddecha River). Those permanent rivers are the major source of drinking waters for human and their cattle's (GWADO, 2014).

3.1.5 Population and their Economic activities

According to data obtained from the Gimbichu *woredas*` Agriculture and Rural Development Office the *woreda* has 33 rural *kebeles* and 3 rural administrative towns with a total population of 86,902; female 41,776 and 45,126 male (GWADO 2014). In the study area agriculture is the dominant economic activity, which includes crop farming and livestock production. Cropping patterns in the area follow rainfall. Teff *(Eragrostis tef)*, Lentils (*Lens culinaris*), wheat (*Triticum*), Chick pea (*Ciceratctinum*), and Peas (*Pisum sativum*) are the dominant crops with regard to area coverage. Other than these crops, many other crops are also grown, but economically less important (GWADO, 2014).

3.2 Methods of Data Collection

3.2.1 Soil sampling techniques

A preliminary field survey was conducted to get a general overview on the physical and biological condition of the area such as topography, land use type, and vegetation cover of the study area. There were several exclosure sites in the communal and individual lands supported by "Foundation Green Ethiopia" to rehabilitate degraded land and also improve communities' livelihood. But 'Gara Girmi' exclosure area was purposively selected from other closed areas of the woreda because during the field survey we observed that this area has been well rehabilitated as compare to other areas` exclosure. Gara Girmi exclosure was on practicie since 2011 G.C and currently with the good ground cover (Figure 2).

Figure 2: Partial views of *Gara* Girmi Exclosure (Photograph by Birhanu Bekele 2015)

Soil samples were collected from four year closed area and adjacent degraded open land at two depths (0-20 and 20-40cm) with four replications on the similar slope ranges (15-20%) for the identification of exclosure impacts on soil carbon sequestration. Detwiler (1986) showed that most studies found no effect of land use on soil carbon below 40 cm in the tropics, therefore, samples from 0-40cm soil depth was collected for present study. Soil sampling from the two depths were taken by inserting auger into the soil depth. For each replication, the soil samples were taken from five points (from the four corners and centre) and mixed to make a composite soil samples. A total of 16 (**2** land use type (exclosure and open land)***2** depth***4** replication) samples were taken in a Complete Randomized Block Design and separately handled in plastic bags to determine soil organic carbon (SOC) and to calculate soil organic matter (SOM). In addition undisturbed soil samples were taken from the same points of closed and adjacent degraded open land by core sampler to determine soil bulk density.

3.2.2 Soil Analysis

The selected soil parameters were analyzed using standard procedures at Jimma University College of Agriculture and Veterinary Medicines` Soil Laboratory. Soil samples were air dried at room temperature then homogenized and passed through a 2mm sieve. The selective soil properties determined were bulk density and SOC. Soil bulk density (BD) was determined by core method (FAO, 2007) using core sampler and determining the mass of soil and water content of the core by weighing the wet core, drying it to constant weight in an oven at a temperature of 105°c for 24 hours and calculated as:

$$\mathbf{BD}\left(\frac{\mathbf{g}}{\mathbf{cm3}}\right) = \frac{\mathbf{W2 - W1}}{\mathbf{V}}$$

Where W2 and W1 were the weight of oven dry soil plus core and oven dry soil respectively and V is the volume of core (Warrick, 2002).Percent of soil organic carbon was determined by Walkley and Black method (Nelson and Somers, 1996) and organic matter was computed by multiplying OC with a factor of 1.724.

3.2.3 Soil Carbon Stock Estimation

The soil organic carbon stock at a depth of 0-20cm and 21-40 cm were estimated using frequently applied model which stated by Pearson *et al. (*2005) as:

$SC = 100 \times OC \times BD \times d$

Whereas, SC = soil organic carbon (ton/ha), O.C = organic carbon (in numeral), BD = soil bulk density (g/cm^3), and d = study depth (cm).

3.2.4 Socioeconomic Survey

Gara Girmi exclosure which is found in Girmi peasant association (PAs) was purposely selected for study and simple random sampling was also used to select the sampled house hold. After selection of the peasant association; the next step was the selection procedures of the household heads from peasant associations of the district (William, 1977). For this study an attempt has been made to include a success site in terms of rehabilitation order to capture the factors contributing to the success of exclosure.

This is because management factors such as sustainability, economic viability and environmental stability to be influenced by success of exclosure.The study has been as detailed and explicit as possible in order to obtain sufficient information on socio-economic situations. For the present study; semi structured questionnaires, focus group discussions and key informant were used for primary data collection.

3.2.4.1 Key Informants

The key informants used were Gimbichu *woredas*` Agricultural Office experts, Rural Land administration and Environmental protection office experts and the Development Agents (DA) those are assigned on the peasant associations were sampled. Based on the questionnaires designed; the information required to know the socio-economic factors which hinder farmers to adopt the exclosure practices were discussed.

3.2.4.2 Focus Group Discussion

The focus group discussion was under taken at community level; meetings were held selected from the *kebeles*` farmer sampled. The government assigned leaders of the development groups those are found in the each development zones of Girmi *kebeles*` were selected for the focus group discussion. Three development group leaders were selected by using simple random sampling techniques by conducting with elders, women, youth groups, sector office experts and associations directly involved with the exclosure areas (figure 3).


Figure 3: Focus groups` view (photograph by Birhanu Bekele 2015)

3.2.4.3 Structured questionnaires

The structured questionnaires were designed to collect the required information from the household heads sampled (Appendix II). The questionnaires have three parts; in the first part there were questions which concern the background information of the household head and his family. The second part of the questionnaires contains questions which help to know the perception of the household head to the area enclosure and management practices. The third part of the questionnaires contains the questions which help to assess the contribution of area exclosure to the livelihoods of the community using both open and close ended questions using local language *Afan Oromo*. The sampled households were selected from closed areas farmers by using simple random sampling technique.

The sample size of the interviewee was determined by the Cochran's sample size formula for categorical data (Cochran, 1977).

$$n = \frac{X^2 * (p)(q)}{d^2}, \quad n = \frac{(1.96)^2 * (p0.1)(0.9)}{0.05^2}, \quad \mathbf{\underline{n = 138}}$$

Where, n= sample size

X^2 = the table value of chi-square for degree of freedom at the desired confidence level

N = the population size.

p = the population proportion (assumed to be 0.10 since this would provide the maximum sample size). q= 1-p, d^2 = the degree of accuracy expressed as a proportion (α = 0.05). Since the percentage of the sample size was preferably greater than 5%, Cochran's corrected sample size were calculated as $n' = \frac{n}{1+n/N}$, $n' = \frac{138}{1+139/259}$, $\mathbf{\underline{n' = 90}}$

According to the above formula; a total of 90 households were interviewed from a total of 259 household heads of Girmi *kebele*. Economic, environmental and social impacts of exclosures were asked. The perception of local community and its management forlosures` sustainability were also assessed.

3.3 Statistical Data Analyses

Analysis of variance (ANOVA) was performed to assess the significance differences in selected soil parameters; using the Complete Randomized Block Design of statistical analysis system (SAS software, version 9.2). Mean separations were conducted using least significant difference (LSD) test at α= 0.05. Correlation analysis by SPSS was also performed to analyze the relationship between the selected soil parameters. Relative change in soil properties was computed as:

$$\text{Relative Change} = \frac{(Pe - Pd)}{Pd} X\,100$$

Where Pe is the soil property measured on the exclosure area and P_d is the soil property measured on the adjacent degraded open land.

For socio-economic survey, descriptive statistics such as mean, percentages and frequency by using statistical package for social studies (SPSS) version 20 software packages were used and also chi-square test and logistic regression were also used to identify significance difference of respondent in terms of environmental and management impacts of exclosure, and to assess the perception of local community on exclosure land respectively.

Table 1: Definitions and units of measurement of variables included in the logistic regression model (n=90)

Variable	Variable code	Variable type	Unit of measurement
DEPENDENT			
Perception of Exclosure	PERCEx	Dummy	0 if positive, 1 else
INDEPENDENT			
Age of house hold	AGE	Continuous	Measured in number
Sex of household	SEX	Dummy	0 if male, 1 female
Marital status of household	MrSt	Dummy	0 if married, 1 else
Educational status of household	EDU	Dummy	0 if literate, 1 else
Households total land size	HHLS	Continuous	Measured in hectare
Households exclosure land size	HHExLS	Continuous	Measured in hectare

Those variables are selected because their decision role on local communities' perception toward exclosure.

4. RESULTS AND DISCUSSION

4.1 Soil Bulk Density

The result of the study revealed that the mean values of soil bulk density for both depths under exclosed and degraded open land were 1.03 and 1.23g/cm^3 respectively. Soil bulk density showed significant ($p<.0.001$) (Table 2) variation due to land management practices. The present study showed that the soil BD is higher in open land than in exclosure land. As compared with adjacent degraded open land, soil bulk density at exclosure land was reduced by 16.26%. This was in agreement with the finding of Nichols *et al.* (2004). The mean values of soil bulk density at the depth of 0-20 and 20-40cm were 1.11 g/cm^3 and 1.16 g/cm^3 respectively measured under this soil depth didn`t show significantly different ($p<0.05$) but numerically increase with increasing of soil depth (Table 2). The smaller bulk density at exclosure land was due to high amount of organic matter source from restored grass and different woody species. Moreover, the high amount of bulk density at degraded site may be because of trampling effect of livestock during grazing and reduction of organic matter through intensive grazing. This result agrees with earlier findings of Descheemaeker *et al.* (2005) who reported that exclosure was prevent physical soil loss. Mulugeta (2004) also reflect the idea like the increase in soil bulk density was the reflections of the low OM content. Similarly Brady (2002) and Weil Gupta (2004) reported that Bulk densities of soil horizons are inversely related to the amount of soil organic matter. Furthermore, soil BD exclosure was negatively and significantly correlated with total OM ($r=0-.628^{**}$) and OC ($r=-0.628^{**}$) (Table 3).

Table 2: The (Mean ± MSD) main effects of land management type and depths on selected soil properties.

Land use type	BD (gm/cm^3)	OM (%)	OC (%)	SC (ton/ha)
Open land	1.23±0.08[a]	1.66±0.83[b]	0.96±0.48[b]	26.2[b]
Exclosed land	1.03±0.064[b]	4.15±1.23[a]	2.40±0.71[a]	49.38[a]
LSD (0.05)	0.08	0.8203	0.4763	9.31
P-value	***	***	***	***
Depth (cm)				
0-20	1.11±0.07[a]	3.61±1.70[a]	2.09±0.99[a]	45.75[a]
20-40	1.16±0.17[a]	2.20±1.31[b]	1.28±0.76[b]	29.63[b]
LSD (0.05)	0.0747	0.8203	0.4763	9.31
P-value	NS	**	**	***
CV (%)	6.11	26.15	26.19	22.81

Main effect means within a column followed by the same letter are not significantly different ($p<0.05$), *significance at $p<0.05$, **significant at $p<0.01$ ***significant at $P<0.001$, CV = coefficient of variance, LSD = least significant difference, BD = Bulk density, OM = Organic matter, OC = Organic carbon, SC = Soil carbon stock

In case of interaction effect; the soil bulk density in open land at the depth of 0-20cm and 20-40cm were $1.30g/cm^3$ and $1.16g/cm^3$ and in exclosure land at the depth of 0-20cm and 20-40cm were $1.01g/cm^3$ and $1.06g/cm^3$, respectively (Table 3) Which showed significant difference ($p<0.001$) among both land uses at surface layer (0-20cm) and subsurface (20-40cm). Soil BD was highest (1.30 g/cm^3) at first depth (0-20cm) of degraded open land. This may be due to the impact of soil erosion and compaction effects of livestock herds higher on surface soil. This study is in line with Abinet (2011) who report that the higher value of bulk density of the grazing land is due to the higher compaction effect of the grazing and erosion of the top soil because of absence of vegetation cover. Interestingly, there was no, however, significance ($p<0.05$) different among soil depths (0-20 and 20-40cm) under area exclosure land (Table 3).

This statistical non significance variation of bulk density reflects the relatively homogenous soil physical conditions with depth and most likely show that the soil compacted during open land had been rehabilitated by recently introduced exclosure. Furthermore, it might be the reason for non significant change of overall bulk density of the study soil (Table 2).

Table 3: The (mean ± MSD) interaction effects of land management type and depths on selective soil properties.

Land use	Depths (cm)	BD (gm/cm^3)	OM (%)	OC (%)	SC (ton/ha)
Open land	0-20	$1.30±0.02^{a}$	$2.14±0.45^{bc}$	$1.24±0.27^{bc}$	32.34^{bc}
	20-40	$1.16±0.02^{b}$	$1.18±0.88^{c}$	$0.69±0.51^{c}$	20.07^{c}
Exclosed land	0-20	$1.01±0.07^{cd}$	$5.10±0.91^{a}$	$2.94±0.53^{a}$	59.16^{a}
	20-40	$1.06±0.06^{c}$	$3.22±0.65^{b}$	$1.87±0.38^{b}$	39.60^{b}
P-value		***	***	***	***
LSD(0.05)		0.072	1.152	0.669	13.43
CV (%)		4.12	25.75	22.28	23.07

The mean of interaction effect within a column followed by the same letter are significantly different (P<0.001), CV = coefficient of variance, LSD = least significant difference, BD = Bulk density, OM = Organic matter, OC = Organic carbon, SC = Soil carbon stock

4.2 Soil Organic Carbon and Organic Matter

Soil organic carbon and/or organic matter were the most major parameters used in this study to know the impacts of exclosure on soil carbon stock. They showed significantly (P <0.001) affected by land management system (Table 2). The analysis of variance for organic carbon and organic matter of the two areas indicate that, there was higher soil organic carbon (2.40%) and organic matter (4.15%) in the soils taken from the exclosure than the open degraded land (OC 0.96%, OM 1.66%)(Table 2). The reason for this high rate of SOC is the high accumulation of SOM in exclosure land which could be the higher vegetation coverage of exclosure which resulted in higher litter input and thus higher accumulation of SOM and SOC in the soil (Benites, 2005).

According to the classification by Tan (1996), the soil organic carbon under the exclosure was observed as medium while that of the open grazing land was low.

The improvement in soil organic matter content following the exclosure is an important sign of soil restoration. Beside the higher SOM contents in exclosed areas compared to that of adjacent degraded open land can be explained by the difference in soil erosion and biomass return which shows the storage of SOC in the soil. Reduced erosion is expected to occur in well developed exclosed areas because the canopy formed by the mature shrubs and under-story vegetation shields the soil from the erosive energy of the falling raindrops and thereby protects it from splash erosion and surface or sheet erosion. This finding is in agreement with work done several authors (Abiy, 2008; Kibret, 2008; Wolde et al, 2009).

There was significant difference ($p<0.001$) in mean of OM and OC measured due to depths and also the interaction of land managent with depths ($P<0.001$) (Table 2 and 3). The highest OC accumulation (2.09%) was at 0-20cm depth and the smallest (1.28%) was recorded at 20-40cm depth of soil. In general soil OM and OC content decreased with increasing soil depth which similar with the investigation of Muluken *et al.* (2014) who said that soil organic carbon decrease significantly with depth increment.

With regard to the interaction effect of land management in soil depth, the highest value of OM (5.10%) and OC (2.94%) content recorded at 0-20 cm depth of exclosure whereas the lowest values of OM (1.18%) and OC (0.69) contents were recorded at depth of 20-40cm layer of adjacent degraded open land (Table 3). Soil OM and OC contents in the 0-20 cm and 20-40 cm soil depths were higher in the Exclosure lands and lower under the adjacent open degraded lands. The result is agreed with Gert (2014) and Haile (2012) who stated that exclosures contained a significantly higher percentage of soil organic matter than the open-grazed areas, in the upper part of the soil. The result also in line with Descheemaeker *et al*. (2005) and Gebeyaw (2007) which suggests that Exclosure improves the soil in several ways: they prevent physical soil loss, maintain or increase soil water holding capacity and protect or increase top soil depth which increase organic matter at surface soil.

Table 4: Pearson's correlation of selected soil properties

	BD	OC	OM	SC
BD	1			
OC	-0.628**	1		
OM	-0.628**	0.99**	1	
SC	-0.519*	0.979**	0.969**	1

**significantly different at P<0.01, *significantly different at P <0.05, Bulk density, OM = Organic matter, OC = Organic carbon, SC = Soil carbon stock

4.3 Soil carbon stock

The most commonly applied methods` to determine total soil carbon at different depths was taking the soil bulk density into account. The result of estimated soil carbon stock by taking soil bulk density into consideration showed that, the mean value of soil carbon stock in exclosure land (49.38 ton/ha) was significantly higher (P<0.001) than degraded open land (26.2 ton/ha) (Table 2). The relative change indicates that exclosure land is 88.47% greater than degraded open land in soil carbon storage. This higher soil carbon sequestration indicates a direct role of exclosure because of its indirect role in reducing carbon in vegetation and soil erosion. Similarly, Wolde *et al.* (2009) in his study on "Carbon stock changes with relation to land use conversion in the lowlands of Tigray, Ethiopia" reported that exclosure had significantly higher soil carbon stocks than in the adjacent grazing lands.

Statistical analysis revealed significant effects (p≤0.001) for depths of soil sample, and the interaction between land use and soil depths on soil carbon stock (table 2 and 3). The values of soil carbon stock in degraded open land ranges from 32.34 - 20.07 ton ha-1 and 59.16 - 39.60 ton ha-1 in closed lands at the depth of 0-20cm and 20-40cm depth respectively. Generally, the SC was decrease as soil depth increase.

The total carbon stock of the study area ranged from 722.52 - 2,129.76 ton per 36ha with the lowest in second depth (20-40cm) of degraded open land and the highest in first depth (0-20cm) of exclosure (calculated from Table 3). The lowest carbon stock size in adjacent degraded open land might be due to low total organic carbon and loss of soil structure by livestock compaction.

The high total organic carbon is the main cause for increase of carbon stock size in the exclosure land at 0-20cm. Similarly, Ermias *et al.* (2007) and Li *et al. (*2004) who reported that exclosures play a major role in sequestering carbon that addresses the mitigation of climate change as stated in the Kyoto protocol and conversion of natural forests in to continuous cultivation and grazing had resulted in statistically significant decrease of both the concentration and stocks of carbon respectively. Several studies (Batjes, 2001; FAO, 2001; Lal, 2002; Ringius, 2002; Bartel, 2004) shows carbon sequestration in soil organic matter is increasingly advocated as a potential strategy for reclaiming degraded lands, and mitigating global climate change.

4.4 Socioeconomic of the local community

4.4.1 Household profile

About 90 house hold was interviewed randomly after the identification of farmers at exclosure land. Among 90 selected house hold; 24 (26.7%) were female whereas 66 (73.3%) of them were male. About 67.8% of the respondents' age range between 31-50 years; about 25% above 50 years and 4.4% ranges between 18-30 years. Their education status showed that 34% of the house hold attain school grade 5-8 whereas the least 4% did not attend school. About 84% of the respondents were married whereas 9% and 5% were divorced and widowed respectively (Appendix Table 1).

4.4.2 Perception towards Exclosure

All selected house hold, focus group and key informant were asked about their feeling during the establishment of the encloxure.

The respondents' general attitude toward social benefit of exclosure in their locality was positive (93.3%) (Appendix Table 5). The reason for that is that they are getting Economic, Environment and Social benefit, especially fodder and thatching grass from the exclosure area. All the farmers interviewed explained that they have seen change on soil quality within the exclosure because of the exclosure and soil conservation structures done on the degraded land.

As information revealed focus group discussion and key informant; there were debatable ideas before the establishment of this exclosure. Only few farmers (15.6 %) responded negative attitude towards its establishment in their locality whereas the majority of the farmers (48.9%) responded that they had positive attitude and others (35.5%) are neither had positive nor negative attitude. They had accepted the establishment of this exclosure probably due to presence of stakeholders meeting prior to the actual establishment of the exclosure (Table 5).

Table 5: Respondents' reaction towards exclosure establishment and soil erosion of the study area (*N=90*)

Questions		Freq.	(%)
Exclosure initiating body	Government	32	35.6
	NGO	24	26.7
	Participatory	34	37.8
Feeling during establishment	Positive	44	48.9
	Negative	14	15.6
	Neither	32	35.5
Soil erosion problem	present	90	100
	No erosion	-	-
Severity of erosion problem before exclosure	Severe	85	94.4
	Medium	5	5.6
	Low	-	-
Opportunity to overcome the problem of land degradation	Exclosure	-	-
	Other SWC practice	-	-
	Both	90	100

As the focus group and key informant informed us the result indicate that the community members participated from planning stage to implementation stage. After establishment of the exclosure, looking the change brought on the locality, and the benefit that the exclosure have given to them, some changes on perception have been seen on those farmers who had negative attitude during establishment of the exclosure. Farmers were asked why the enclosure is established in their locality. All of them (100%) responded that the objective was rehabilitation of degraded lands besides to tackling of further environmental degradation in the area. All interviewed farmers were responded that the soil quality and vegetation (natural and plantation) cover within the exclosure was increased because of this closed area. In line of this result, Emuru *et al.* (2006) reported that the improvement of good attitude towards exclosures helps in the protection of degraded lands for better rejuvenation of woody species.

All of the respondents in the study area perceived that the presence of soil erosion (table 5). About 62% of 90 respondents rank the cause of soil erosion as “1^{st}- over grazing, 2^{nd} – poor government policies, 3^{rd} - deforestation, 4^{th} - over cultivation, 5^{th} - cultivation of steep slopes, 6^{th} - poor agricultural practices and 7^{th} - excess rainfall” before exclosure. They reveals they were try many action to tackle the problem of land degradation before this exclosure but didn’t success because the above soil erosion problem (Appendix table 2).

They are also experiencing soil erosion reduction and down land gully rehabilitation in their locality, around to the exclosure area. All of the respondents showed interest on further conservation and establishment of exclosures as the main option to tackle the problem of land degradation in the area. As information revealed from FGD and key informant local farmers considered the exclosure area as their own property and social acceptance is one of the criteria for its sustainability. From this, it can be predicted that the local community accepted, and probably cooperates on the management of the exclosure area in this district. This is in line with Wolde *et al. (2000*) who confirm that optimistic view of local community to rehabilitate degraded lands and make them productive may be interpreted as an asset for projects working to rehabilitate degraded dry land.

Table 6: Logistic regression results of perception on exclosure (N=90)

Dependent variable	Explanatory variable					
Local community perception on Exclosure	AGE	SEX	EDU	MrSt	HHLS	HHExLS
Odds ratio	1.272	1.08	0.701	5.062	1.946	97.379
Std. Error	0.122	0.0424	0.160	3.727	0.624	353.86
p-value	>0.012	>0.206	>0.089	>0.028	>0.038	>0.208
Coefficient	1.054**	-0.138ns	0.449 *	1.196**	1.038**	0.079 ns
					Number of obs = 90	
					Wald $chi^2(5)$ =14.66	
					Prob > chi^2 = 0.0119	
					Pseudo R^2 = 0.5040	

**, * Significant at 0.1 and 0.05 probability levels respectively.

Logistic regression model was used to analyze households' perception level toward exclosure (Table 6). The result (R^2=0.504) indicate that the variable explained the perception of communities on excolosure, and there is a relative strong association between the perception and the groups of explanatory variables. Prob > chi^2 = 0.0119 indicates that the model is significant at 5% which shows that it fits the data and Pseudo R^2 = 0.504 shows that about 50.4% of the variation in the dependent variables (local communities perception) is due to explanatory variables included in the model.

Age of the households head (AGE) and educational status of household (EDU) are both significantly and positively related to communities' perception toward exclosure (Table 6). The result showed us that productive levels ages of house hold increase the positive perception toward exclosure. In addition educated farmers also resolve the problems of land degradation by improving positive perception of exclosure. Similarly Households Marital status (MrSt) and households land size (HHLS) are indicating significant and positive determination on communities` perception toward exclosure land management practice while the effect of sex and household land size of exclosure were not significant contribution for perceptions of local community. In general the result revealed that the perception of the community towards exclosure as a means of rehabilitation of degraded land and its socioeconomic and environmental role determined by back ground conditions of the households.

4.4.3 Economic Roles

According to focus group discussion and key informant; "*Gara* Girmi" exclosure lands have major economic values for all local community. All the respondents said that they were directly getting benefits from the exclosure land. From all respondents from exclosure land, 74.5% of the household get a benefit for forage while 25.5% they did not get benefit of forage from exclosure land. About 57.8% of the beneficiaries are responded us that they use this forage grass for both fattening and sell for other local farmers whereas 11.1% for only sell and 5.6% for only fattening. Majority of the respondents (74.5%) were obtained thatching grass from exclosure land. Around 61.1% of the respondent uses thatching grass for both house shade and sell whereas 8.9% for only house shade and 4.4% only for sell (Table 7).

Under degraded open land, 25.5% of the respondents used the area for livestock free grazing during summer and for herding space during winter while 74.5% of the respondents from exclosure land said that they get considerable socio-economic benefit. All of respondents from open land confirmed that they did not get any thatching grass throughout the year from open degraded land. This may be because of free grazing at open land which restricts the regeneration of new vegetation.

Table 7: Uses of grass harvested from exclusure land

	Uses of harvested grass	Freq.	%
Forage grass	Free graze	23	25.6
	For fattening	5	5.6
	For sell	10	11.1
	For both	52	57.8
Thatching grass	Free graze	23	25.6
	For house shade	4	4.4
	For sell	8	8.9
	For both	55	61.1

According to the respondent they mainly harvest forage grass form exclosure. Most of households (36.7%) respond that annually they harvest 2400 to 2700kg/ha/yr of forage grass or 1200 to 1350 ETB/ha/yr where 20% of the respondent got 2700 to 3000kg/ha/yr or 1350 to 1500 ETB/ha/yr and the rest 15% harvest above 3300kg /ha/yr or 1650ETB/ha/yr. They also harvest thatching grass which is used for house shade and as an additional income by selling it. Accordingly 35.6% of the respondents harvest 1200 to 1600kg/ha/yr or 720 to 960 ETB /ha/yr where as 15.6% harvest 800 to 1200kg/ha/yr or 480 to 720 ETB/ha/yr and 23.3% of the got above 2400 kg/ha/yr or 1440 ETB/ha/yr (Table 8).

Table 8: Amount of grass harvest from exclosure land and its economic value

Use of grass	Benefit of community		Freq.	(%)
	Load (kg/ha/yr)	**Value (ETB/ha/year**		
Forage	0	0	23	25.6
	2400 -2700	1200-1350	33	36.7
	2700 - 3000	1350-1500	20	22.2
	Above 3300	1650	14	15.5
Thatching	0	0	23	25.6
	800 -1200	480 -720	14	15.6
	1200k -1600	720-960	32	35.6
	Above 2400	1440	21	23.3

NB: *1load forage grass=150kg=75ETB*

: 1load thatching grass=200kg=120ETB

: Total area of exclosure =36ha.

This could be due to the restriction of livestock free grazing, trampling and human intervention from the exclosure. Similarly, Emuru *et al*. (2006) found that the area coverage of herb is high in closure than non closed. Moreover, Betru *et al.*, (2005) confirmed that in most exclosure, short term benefit of local people are forage and thatching grasses and their care depend on the availability of these grasses Therefore, the closure had significant short term local people inspiring resources which might make them interesting to maintain sustainably if they utilized it optimum.

Generally, exclosure area have more forage and thatching grass, and carbon dioxide sequestration than degraded open land area which show us it is economically and environmentally more valuable than open land (figure 4). Similarly, FAO (2000) stated that, exclosure has also a high economic potential in community livelihood improvement by provide natural resource products though increasing incomes, improving food security, reducing vulnerability and enhancing well-being.

Figure 4: View of grass output from exclosure (photograph by Birhanu Bekele, 2015)

4.4.4 Environmental and Social Impacts

The interview, FGD and key informants result revealed that land productivity increased, downstream water source increased in amount, wild life were appearing from migration and also decrease of soil erosion which increase soil fertility and decrease down land siltation due to exclosure. All respondent also explained that the land in the exclosure is restored i.e., the land is covered by above ground biomass when seen in relation with adjacent open degraded land (Appendix Table 4, figure 4). Lewis *et al.* (2001) also agreed with this assessment who reported that exclosure enhance vegetation cover which decrease in atmospheric CO_2 and associated global warming by affecting the rate of uptake of CO_2 into plants through the processes of photosynthesis, could affect overall tree productivity.

In line with this study, Tefera *et al. (*2005) said that exclosure also reduce nutrient loss from a site by controlling runoff (vegetation acting as a physical barrier to soil erosion).

As shown in Table 8 below, soil moisture in exclosure land is significantly different (x^2=8.66, p=0.003) over the adjacent degraded open land as well as the amount of downstream water source of exclosure is significantly different (x^2=8.35, p=0.003) than the adjacent degraded open land. The FGD and key informant also insure that the amount of downstream water source of exclosure has been dried within three month after rainy season before this exclosure establishment is currently extends all over the year. This study was also supported by Mitiku and Kindeya (1997) who say "the exclosure protect downstream areas from flood hazard and clotting with silt concomitantly improving infiltration and ground water conditions besides replenishing springs and providing water for longer periods of time for downstream communities". Likely, Sheidai (2011) reported that exclosure increase the total ground cover which enhance of water-holding capacity of the soil and prevent water erosion. Furthermore, bout 93.3% of respondent insure that exclosure has positive impact by serving them as shade for local meeting, as a wind break and prevent flood during rainy season whereas only 6.7% of them say that wild animals from closed area harm their crop on the surround farm land and tame animals (Appendix Table 5).

Table 9: Environmental value of Exclosure land

Environmental benefits		**Exclosure land**	**Open land**				
		%	%	N (%)	df	X^2	p-value
Soil moisture	Moist	44 (48.9%)	7 (7.8%)	51(56.7%)	1	8.66	.003
	Dry	23 (25.6%)	16 (17.8%)	39(43.3%)			
Downstream water source	Increase	51 (56.7%)	10 (11.1%)	61 (67.8%)	1	8.35	.004
	No change	16 (17.8)	13 (14.4%)	29 (32.2%)			
Wild life presence	Present	41 (45.6)	5 (5.6%)	46 (51.1%)	1	10.67	.001
	Not present	26 (28.9%)	18 (20%)	44 (48.9%)			

4.3.5. Management Problems and Its Solution

Even though the households explained that exclosure has many benefits; local farmers are also complaining that the benefits obtained from the exclosure product is not satisfactory; because they are allowed to access the same product only once in a year. But the community can benefit more through introducing improved honey production system, fruit trees and improved fodder species. The exclosure area lacks the local communities' management. The local community (land owners) has less attention to the exclosure with respect to strengthening the management i.e., they only care for the product they harvest without management which may impede its sustainability. They felt that there was management problems since the majority of closed land was communal land. Over harvesting, free grazing and new farm land formation interest of land owners are major causes of *'Gara Girmis`'* management problems (Table 10). FGD also confirmed that the problems of cattle herd entering exclosure land from neighbor village, exclosure borders expansion of farm land and illegal product harvest are the main management problems.

Since the exclosure land has been budgeted up to its full reclamation it`s guarded under the supervision of GWADO and PA administration has made the exclosure land owner (local community) to give less attention on its management. Most of the respondent forward continuous refreshment awareness for land owner, using participatory problem solving approach, policy and bylaws and other as opportunities to overcome management problems of the closed area for its sustainability; which shows highly significance ($p=0.001$) at closed land than in degraded open land (Table 10). Therefore, those bodies should have to give clear awareness on their ownership and making them in cooperation for strong management of the exclosure area to sustain benefits obtained from this exclosure.

Table 10: Management problems and opportunity to overcome these problems

Managemntal Problems and Solution raised		Exclosure land	Open land				
		%	%	N (%)	df	X^2	p-value
Presence of problem	Present	59 (65.6%)	9 (10%)	68(75.6%)	1	25.2	.001
	Not as much	8 (8.9%)	14 (15.6%)	22(24.4%)			
Types of problems	Over harvesting	18(20%)	-	18(20%)			
	Free grazing	21(23.3%)	-	21(23.3%)	1	23.03	.001
	New farm land formation interest	17(18.9%)	7(7.8%)	24(26.7%)			
	Other	11 (12.2%)	16 (17.8)	30 (30%)			
Opportunities to overcome those problems	To make land owner responsible	18 (20%)	-	18 (20%)			
	Participatory problem solving approach	26 (28.9%)	8 (8.9%)	34 (37.8%)	1	27.81	.001
	policy and bylaws	16 (17.8)	-	16 (17.8)			
	Other	7 (7.8%)	15 (16.7%)	22 24.4%)			

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The result of the study has shown that, the conversion of degraded open lands to exclosures has a significant potential to increase soil carbon sequestration at Girmi *kebeles* of Gimbichu *woreda*. A comparison of SC stock values at both soil dept (0-20cm and 20-40cm) shows that the highest SC was stored under excosure land than in degraded open land. Similarly, percentage SOC is highest in exclosure land at both of soil depth. On average for both land management, SC stock decrease with increasing of soil depth. However, the SC was highly stored in exclosure land when compared with adjacent degraded open land which shows the potential of area exclosure to reduce greenhouse gas emissions to the atmosphere by storing large stocks of carbon in to the soil. Therefore, this proves the great roles of exclosure in mitigating climate change.

The high level of awareness and good attitude of local people towards exclosures could be explained from the fact that environmental, economic and social benefits obtained from exclosures. Based on the environmental rehabilitation and restoration through exclosure which enables local people increase their source of income from thatch and forage grass, improved soil conditions of the area and increase social values, it is possible to conclude that the establishment of exclosure in the degraded lands is a viable option for soil quality improvement, biodiversity conservation and local livelihood improvement. Therefore; communities` perceived exclosures positively and are hopeful to the performance of exclosure. Generally, exclosure is the major land management practice which plays a great role in soil carbon sequestration and socioeconomic benefits for the local societies.

5.2 Recommendation

Based on finding and conclusion of the study the following recommendations are forwarded;

- Recognizing the open lands of the study area severe soil erosion due to over grazing; the exclosure should be expanded supported with proper SWC measures. To sustain this exclosed land and for farther ecxlosure, to reduce soil erosion by overgrazing and increase biomass of the area; alternative livestock management system like cut and carry system is needed instead of letting livestock to move freeTo maximize the exclosure benefits; introducing improved forage plantation, to increase the fodder for livestock or for additional source of income, management and conservation activities should be strengthened in the future.
- There should be one community network supported by extension to manage the exclosure and also clear and well organized operational manual in order to manage effectively the exclosure area.
- Since this study concentrate only on exclosure areas` the same slope range and soil carbon sequestration; further studies on the impacts of different land slope on soil Carbon sequestration and also above ground biomass carbon sequestration needs to be undertake

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APPENDEX

Appendix I: Questioners

I. Background Information of the Respondents

1. Name of the Peasant Association ___________________________________
2. Age of the household head ______________________
3. Sex of the household head ___________________
4. Educational background of the household head

☐ Illiterate ☐ Adult Basic education ☐ Grade 1-4

☐ Grade 5-8 ☐ Grades 9-12 ☐ Above Grade12

5. Marital status

☐ Married ☐ Unmarried ☐ Divorced ☐ Widowed (Widower)

6. Number of families in the household including the household head

Number of males in the household	Number of females in the household	Total number of people in the household

7. The total size of landholding of the household in hectare

____

8. The land use types of the total landholdings of the household

Area of Farm land in hectare	**Area of Grazing land in hectare**	**Area of exclosed grazing land in hectare**	**Area of land used for other purposes in hectare**	**Total area of landholding in hectare**

Specify their utilization types and area in hectare if there is a land used for other purposes

_____ ____.

II. Perception of Exclosure

1. Who initiate the establishment of the Exclosure land? 1) Government____
   2) NGO______
   3) Community_____
   4) Participatory
2. Why was the Exclosure established?
   1) To restrict the community from assessing the land______
   2) To rehabilitate degraded land_____
   3) Other_____
3. What was your feeling during establishment?
   1) Positive___
   2) Negative____
   3) Neither__
4. Is there attitude change after establishment of this exclosure? 1) Yes____2) No____
5. Do you think there was soil erosion problem on this land before Exclosure?
   1) Yes____
   2) No____
6. Give rank to the following major causes of soil erosion in the area?

1) Over grazing ____2) Deforestation ____3) Over cultivation _____ 4) Cultivation of steep slopes _____ 5) Poor agricultural practices _____6) Excess rainfall ____7) Poor government polices _____8) others (specify) ________________________________.

7. What do you think is the consequences of land degradation soil erosion?

1) Land productivity (yield) decline 2) downstream siltation problem

3) Reduces plantation growth 4) all 5) 1&3 6) others (specify) _______

8. Farmers' perceptions of land degradation hazards on excloxure

8.1. Whether soil erosion was perceived a problem exclosure land 1) Yes__

2) No__

8.2. If yes, what was the severity of the problem 1) Severe

2) Medium

3) Low

8.3. Believing that land degradation can be controlled? 1) Yes_____

2) No____

4.4. What opportunity did you think to overcome the problem of land degradation? ______.

5. Do you think that Exclosure the best practice to rehabilitate the degraded land?

1) Yes_____

2) No _____

III. Economical

1. Do you think about this area has economic value for you? 1)Yes _____, 2)No_____.

2. If yes; can you list and rank your benefit

- Forage grass____
- Thatching grass____
- Honey production____
- Other benefits____.

3. If you got forage grass from how did you get per hector and for what purpose did you youth it? _____load/per Ha. Or ____birr/ha ☐ For se☐ for fattenin☐ for both

4. If you are keeping bee; is your honey production: increasing_____, decreasing_____, no change _____not known_____. If increasing: do you believe, the exclosure land has contribution? Yes _____, No_____. If yes, how much may it contribute? (0-1/4, 1/4-1/2, 1/2-3/4, ¾ -1, 1, not known)

5. Do you get? Yes_____, No_____

6. If you got thatching grass from the closure; how did you get per hector and for what purpose did you youth it? _____load/per Ha. Or ___birr☐ For se☐ for house ☐de for both

6. Do you have crop farm? Yes_____, No_____. If yes, is your crop production: increasing _____decreasing_____, no change_____ not known Yes _____, No_____. If increasing: do

you believe, the closure has contribution? Yes _____, No_____. If yes, how much may it contribute (0-1/4, 1/4-1/2, 1/2-3/4, ¾ -1, 1, not known)

7.Others____

____________________________________.

VI. Environmental/Ecological

1. What did you think about the environmental benefits of this exclosed area giving you?

____.

2. Did you think the soil in your closed area moist than the side open? Yes _____No_____.

3. Is there water source to down exclosed land? Yes _____No_____.

3.1 If yes, is the amount different from year to year? Yes _____No_____.

4. Is there wild animals in the afforestation/exclosed area? Yes _____No_____.

4.1 If yes, list their name________________________________.

4.2 If no, why not become the home for local wild animal?

____.

5. If there is other environmental/Ecologically benefits?

____

____.

V. Social and Management

1. What do you think about social benefits of this exclosure land?

____

___________________________.

2. Is the closure has negative side effect on you? Yes _____No_____.

2.1 If yes, what are the side effects?

____.

2.2. What should be done to tackle the side effects?

____

___________________________.

3. Is there any managemental problem on the exclosure? Yes _____No_____.

3.1. If yes what are the problems____.

3.2 What do you recommend to solve the problem? ________________________________.

4. Do you participate in the management of the exclosure? Yes _____No_____.

If No who manage it? ____ and do you want to participate in the management? Yes _____No_____.

Appendix II: Tables

Appendix Table 1: Backgrounds of the Respondent

Variables	Range	Frequency	Percent
Age	18-30	4	4.4
	31-50	61	67.8
	Above 50	25	27.8
	Total	90	100
Sex	M	66	73.3
	F	24	26.7
	Total	Total	90
Educational status	uneducated	4	4.4
	Adult Basic Education	25	27.8
	1-4	20	22.2
	5-8	34	37.8
	9-12	7	7.8
	Total	90	100
Marital status	Married	76	84.4
	Divorced	9	10.0
	Widowed	5	5.6

	Total	90	100

Appendix Table 2: Respondents' reaction towards question on perception

(*N=90*)

Questions		Freq.	(%)
Who initiate the establishment of the Exclosure land?	Government	32	35.6
	NGO	24	26.7
	Community	-	-
	Participatory	34	37.8
Why was the Exclosure established?	To restrict the community from assessing the land?	-	-
	To rehabilitate degraded land Other?	90	100
What was your feeling during establishment?	Positive	44	48.9
	Negative	14	15.6
	Neither	32	35.6
Is there attitude change after establishment of this exclosure?	Yes	90	
	No	-	
Do you think there was soil erosion problem on this land before Exclosure?	Yes	90	100
	No	-	-
Give rank to the following major causes of soil erosion in the area?	1234567	28	31.1
	1723456	62	68.9

What do you think is the consequences of land degradation soil erosion?	All	90	100
Was soil erosion perceived a problem before the land enclosed?	Yes	90	100
	No	-	-
If perceive what was the severity of the problem	Severe	85	94.4
	Medium	5	5.6
	Low	-	-
Believing that land degradation can be controlled?	Yes	90	100
	No	-	-
What opportunity did you think to overcome the problem of land degradation?	Exclosure	-	-
	Other SWC practice	-	-
	Both	90	100
Do you think that Exclosure the best practice to rehabilitate the degraded land?	Yes	90	100
	No	-	-

***1234567:** Rank; 1st- Over grazing, 2nd - Deforestation, 3rd - Over cultivation, 4th - Cultivation of steep slopes, 5th - Poor agricultural practices, 6th - Excess rainfall and 7th – Poor government polices*

***1723456:** Rank; 1st- Over grazing, 7th – Poor government policies, 2nd - Deforestation, 3rd - Over cultivation, 4th - Cultivation of steep slopes, 5th - Poor agricultural practices and 6th - Excess rainfall*

***All: 1**) Land productivity (yield) decline 2) downstream siltation problem and 3) Reduces plantation growth (consequence of soil erosion*)

Appendix Table 3: Respondents' reaction towards question on economic value

Questions		Freq.	(%)
Do you think about this area has economic value for you?	Yes	90	100
	No	-	-
If yes; can you list and rank your benefit	forage grass, thatching grass and income from projects physical work	90	100
How forage grass you get from exclosure	Nothing	23	25.6
	2400kg or 1200ETB-2700kg or 1350ETB	33	36.7

	2700kg or 1350 ETB - 3000kg or 1500ETB	20	22.2
	above 3300KG or 1650ETB	14	15.5
For what purpose you use it?	Nothing	23	25.6
	Fattening	5	5.6
	for sell	10	11.1
	Both	52	57.8
How thatching grasses you get per hectare?	Nothing	23	25.6
	800kg or 480 ETB -1200kg or 720 ETB	14	15.6
	1200kg or 720ETB - 1600kg or 960 ETB	32	35.6
	Above 2400 kg or 1440 ETB	21	23.3
For what purpose you use it?	Nothing	23	25.6
	for sell	4	4.4
	for house made	8	8.9
	Both	55	61.1

1load forage grass =150kg = 75ETB, 1load of thatching grass = 200kg= 120ETB,

Appendix Table 4: Respondents' reaction towards question on environment value

Questions		**Freq.**	**(%)**
What did you think about the environmental benefits of this exclosed area giving you?	Increase soil fertility, improve micro climate, decrease down land siltation and other benefits	90	100
Did you think the soil in your closed area moist than the side open?	Yes	90	100
	No	-	-

Are there water source to down exclosed land?	Yes	90	100
	No	-	-
If yes, is the amount different from year to year?	Yes	90	100
	No	-	-
Are there wild animals in the afforestation/exclosed area?	Yes	90	100
	No	-	-
If yes, list their name	Tortoise, rabbit, fox and hyena	90	100

Appendix Table 5: Respondents' reaction towards question on social and management

Questions		Freq.	(%)
What do you think about social effects of this exclosure land?	Positive	84	93.3
	Negative	6	6.7
What was its negative impact on social?	Wild animals affect on crop and tame animals.	6	6.7
What was its positive impact on social?	Exclosure used as shade for local meeting, as a wind break	84	93.3

	and prevent flood during rainy season.		
Is there managemental problem in to sustain exclosure?	Yes	90	100
	No	-	-
List the problem	Over harvesting, free grazing and new farm land formation interest of land owners	90	100
Do you participate in management?	Yes	58	64.4
	No	32	35.6
What opportunity you use to overcome these problems?	refreshment awareness for land owner	18	20
	using participatory problem solving approach	34	37.8
	policy and bylaws	16	17.8
	other	23	24.4

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Please elucidate the expected results and the relevance of your research-based proposal to climate change (with regard to reducing emissions, adapting to climate change and conserving biodiversity). (2,000 characters max)

Please explain how you intend to communicate the results of your project during and after the sponsorship period and which target groups you particularly want to address. (2,000 characters max)

Please request letters of recommendation from two people who can give well-founded accounts of your professional, academic and personal background as well as your leadership skills, e.g.

- your current supervisor / mentor
- previous supervisors / mentors

Please note: The host's statement does not count as a letter of recommendation!

In case one of the persons is your partner or a relative of yours, you must include this information in parentheses following his or her surname.

Examples: Type of (university) degree (title as used in your country) and field of study/research/work. Please state the reasons for any interruptions (e.g. parental leave, military service, severe illness). In case of parental leave, please state the child's date of birth.