



ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

CENTER FOR THE ENVIRONMENTAL SCIENCE

THE ROLE OF AREA ENCLOSURES FOR SOIL AND WOODY VEGETATION  
REHABILITATION IN HAWZEN DISTRICT, NORTHERN ETHIOPIA.

Zufan Gebremariam Gebreyohans

Advisor Prof. Eyasu Elias

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This is to certify that the thesis prepared by Zufan Gebremariam Gebreyohans: the Role of Area Exclosures for Soil and Woody Vegetation Rehabilitation in Hawzen District, Northern Ethiopia And submitted in fulfillment of the requirements for the Degree of Master of Environmental Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining committee

Prof.Eyasu Elias (Advisor) \_\_\_\_\_

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## Acronyms

ANOVA	Analysis of variance
CEC	Cation Exchange Capacity
CSA	Central Statistical Agency of Ethiopia
Ha	Hectare
FAO	Food and Agricultural Organization
FGD	Focus -Group discussion
GPS	Global Positioning System
GDP	gross domestic product
FDRE	Federal Democratic Republic of Ethiopia
M.a.s.l	meters above sea level
NGOs	Nongovernmental organizations
EFAP	Ethiopian Forestry Action Program
EPA	Environmental Protection Authority
FDRE	Federal Democratic Republic of Ethiopia
IBCR	Institute of Biodiversity Conservation and Research
SPSS	Statistical Package for Social Science Students
UN	United Nations
TARI	Tigray Agricultural Research Institution documents
TFAP	Tigray Forestry Action Plan
TNRS	Tigray National Regional State

## Abstract

Continuous losses of biodiversity and soil fertility in northern Ethiopia particularly the mid-highlands of Tigray have become serious threats as the consequences of anthropogenic processes. To overcome such problems, the government and peoples of Tigray Regional State has been practicing on soil and water conservation initiatives for decades. This study investigated the woody species composition, structure, regeneration, density and diversity in the area enclosure and in grazing area; and to assess the socioeconomic importance of area enclosure to the local communities. A total of 70 sample plots were used, 35 plots in enclosure and 35 in the grazing area. Within transects, nested quadrats having a size of 20 m × 20 m, 4m × 4m and 1m × 1m were laid out to collect biophysical data. In each plot, heights, diameters and numbers of existing woody species were recorded. A total of 56 and 22 woody species were recorded in the Enclosure and Grazing area, respectively, belongs to 33 families in enclosure and 14 families were recorded in the grazing area. The result showed that the densities ( $\text{ha}^{-1}$ ) of the woody species 1903 in the Enclosure and 30 in the Grazing area were determined. Total basal area ( $\text{m}^2\text{ha}^{-1}$ ) 71.01 for the Enclosure and 29.07 for the Grazing area were calculated. *Acacia albida* and *Acacia tortilis*, *Acacia etbaica* woody species were the dominant species in the study site. High species richness was found in the Enclosure than the Grazing area. The population structures in each Enclosure were healthier and higher in recruitment potential than the adjacent Grazing area which was almost hampered. To assess the socioeconomic importance of the area enclosure, survey, and focus group discussions were made. The majority of the local people expressed a positive attitude towards the benefits of area enclosure in rehabilitation of woody species in the area. The impact of area enclosure on soil quality was assessed using soil physicochemical parameters such as soil organic matter, cation exchange capacity, total nitrogen, available potassium, available phosphorus, pH, electrical conductivity and texture. Fourteen soil samples were taken randomly from the two sites (7 from each), and analyzed. Soil laboratory analysis result revealed that the enclosure had significantly ( $p < 0.05$ ) higher levels for OM, CEC, TN, Av Ca, Av Mg and Av K compared to the grazing land. This showed that excluding degraded communal grazing lands from human and livestock disturbances is a viable option to restore degraded woody species in the mid-highlands of Tigray. To enhance the recruitment potential of some rare species, appropriate silvicultural practices are highly recommended for the Enclosure. Thus, wider promotion of enclosure in the region and across the nation should be guided by a scaling up strategy, formulated on the basis of lessons drawn from effective enclosure establishment and management practices.

**Key words/phrases:** Enclosure, Grazing area, Woody species, Rehabilitation, Mid-highlands of Tigray, Northern Ethiopia.

# 1. Introduction

## 1.1 Background

Land degradation is one of the serious problems of the developing countries with its multifaceted effects. The decreased productivity of land, gradual decline of soil fertility, and vegetation cover are the major consequences of land degradation. According to Blay et al., (2004) land degradation is one of the biggest problems in Sub-Saharan Africa, threatening the lives of millions of people. The Blay et al., (2004) described the main consequences of land degradation, which negatively affect human livelihoods and the environment to be shortages of firewood and other wood, shortages of non-timber forest products, increased sediment deposits, floods and landslides, drying up of springs and water bodies, siltation of dams, increased incidence of water-borne diseases, and loss of biodiversity, climate change and desertification.

In developing countries, it causes a severe crisis to the livelihoods of the rural community and the environment (Mengistu and Mekuria, 2015).Tigray contains many of the areas of greatest land degradation concern in Ethiopia's highlands (Fitsum, 1999). According to the World Bank report, the rate of deforestation in the highlands is estimated to be 150,000 ha per year. Forests have shrunk from the original cover of 65 percent of the country, and 90 percent of the highlands, to currently 15 percent. As a result, land degradation has reached an alarming state in the highlands. Rapid population growth, over-exploitation of natural resources, limited arable land, and a shortage of employment opportunities in the industrial and service sectors have increased pressure on forests and grazing land resources in Ethiopia. The inevitable human-induced land degradation through the persistent need for food and firewood over the centuries led to the cutting down of forests in the mountain areas (Tagel and van der Veen, 2014).

In response to the environmental problems, communities in the Northern Highlands of Ethiopia started to establish exclosures about three decades ago. Exclosures are areas closed off from the interference of human and domestic animals with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands. Exclosures are usually established in steep, eroded, and degraded areas that have been used for grazing in the past (Descheemaeker et al., 2006). Establishing exclosures 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 Ethiopian especially the northern and central highlands.

In Ethiopia, the inception of exclosures dates back to the 1980s and coincided with the introduction of large-scale land rehabilitation and soil and water conservation programmes (Nedessa et al., 2005). Priority areas for establishing exclosures are normally identified as a joint initiative of local communities and governmental and nongovernmental organizations (Descheemaeker et al., 2006). As the exclosures are not fenced, guards are hired by the local administration on a food-for-work basis (Yayneshtet et al., 2009). Grazing impacts on soil properties have generally been shown to be dependent on grazing intensity. With moderate grazing of 33years compared with an ungrazed control, higher values were found for soil nutrients. In addition, heavy grazing resulted in lower water infiltration (Hiernaux et al., 1999) and higher soil loss Tadesse and Penden,( 2002) compared with moderately grazed sites. KP) Similarly, Cheng et al. (2011) indicated that 20-year exclusion of livestock grazing significantly increased aboveground and belowground biomass and species richness for five different communities compared with that before exclusion of livestock grazing in a typical steppe of the Loess plateau, northwest China. Similar trends were also reported from case studies conducted

on exclosures in the central and northern highlands of Ethiopia: exclosures had twice the plant species richness and diversity value compared with communal grazing lands after 22 years of exclosure establishment (Tefera et al., 2005), an increase in woody species richness of 13 after 8 years of exclosure establishment (Emiru et al., 2006), and an increase in soil organic matter. Also, a considerable decrease in soil loss was reported after the establishment of exclosures on communal grazing lands (Descheemaeker et al., 2006; Girmay et al., 2009; Mekuria et al., 2009).

The existence of land degradation in the study area was the main threat (Tewoldeberehan, 1989), opportunities to restore ecosystems do exist, and exclosures that protect an area from grazers and other human interventions promote successions and suffice to restore the vegetation in degraded areas (Benz, 1986; Tefera, 2001; Emiru, 2002). Though TNRS has made significant efforts to promote wider use of exclosures, the efforts have not been guided by a management plan. Success rates vary from site to site, affected by geographic and management related variables.

The success of restoring degraded soils and vegetation through exclosures directly depends on economic incentives for the local communities. Unless the local communities benefit economically from restoration projects they will hardly initiate and support. Thus, the determination and economic valuation of exclosures' carbon and soil nutrient pools provide crucial information on potential tangible benefits, which is critical for the planning and establishing of future exclosures (Naidoo, 2008).

## **1.2. Statement of the problem**

Mid-highlands of Tigray are among the areas affected by land degradation and associated consequences. Combined with unreliable rainfall, steep topography and unwise resource utilization have posed major threats to natural resources. The unmanaged land uses especially in

the marginal dry mountain grazing lands have resulted in ecological degradation and loss of ecosystems with their endemic components of biodiversity. To overcome such problems, the regional administration has attempted to combat degradation through exclosures in communal grazing land (Grzing area) for decades. Following exclosure establishment, several changes in the degraded communal lands have been reported by different authors such as vegetation rehabilitation, regeneration status, vegetation distribution, and ground-cover.

These changes especially woody plant species compositions may be easily influenced by time sequence and management of the practice. Designing sustainable management plan and scaling-up in wider context need continuous assessment of the exclosure. Both management plan and scaling-up should be guided by tangible changes on ecological and socio-economic variables. It is important to establish equitable benefit sharing mechanism which needs reliable estimation of the actual and potential woody biomass of exclosures.

Further, the aim of exclosure establishment in degraded communal lands is to reduce erosion and increase soil organic matter through vegetation cover and litter fall. The input of organic matter to soil results in improved soil organic carbon stock. This is one of the promising assets of exclosures for the carbon trading in the green economy and one of the measures of success in exclosures establishment. The research findings will have significances for stakeholders by providing concrete scientific evidences about the performance of exclosures to reclaim degraded lands and become a basis for future studies in the field area. Therefore, this study is designed to evaluate the contributions of exclosures in the study area with a special emphasis on the rehabilitation status of woody vegetations (composition and diversity) and soil chemical properties.

### **1.3 Significance of the study**

The main purpose of this study was to investigate the role of area Exclosure on the rehabilitation of woody species biodiversity on degraded lands and its ecological features. The findings would hopefully enrich information on benefits and challenges of the Exclosure in the study district in particular and northern highlands of Ethiopia. Moreover, the outcome of the study was believed to be an important source for policy makers and planners during further design and implementation of Exclsure area. More importantly, Woreda experts and Kebele development agents can use this finding for local people awareness creation The compiled results can also be used as a reference for further studies and basis for scaling-up the best practices of exclosure else where in the mid-highland agro-ecology of Ethiopia.

## **1.4 Objectives**

### **1.4.1 General Objective**

The general objective of this study was to evaluate the contribution of area Enclosures as an approach for rehabilitating soil fertility and vegetation cover in the degraded landscape of the Eastern Tigray National Regional State, Northern Ethiopia.

### **1.4.2 Specific Objectives**

- To assess the role of area Enclosure in restoring plant population and vegetative cover of the watershed in terms of composition, structure and diversity of woody vegetations on the study area.
- To investigate the impacts of enclosures on soil quality in terms of soil nutrient status and moisture content and soil quality in comparison to Grazing area.
- Explore institutional arrangements for area Enclosure management systems of the area enclosures.

## 2. Literature Review

### 2.1 Definitions and Concepts of area enclosure

Enclosures are a type of land management, implemented on degraded land for environmental Restoration (Tucker and Murphy, 1997). Area enclosure in the Ethiopian context can be defined as the degraded land that has been excluded from human and livestock interference for rehabilitation (Betru et al., 2005). Area closure is land unit protected from some animals by appropriate barriers (Young, 1958). Similarly Mengistu et al. (2005) reveals that areaEnclosure is protecting the degraded land from tree cutting and free grazing of domestic animals. From these concepts it can be said that enclosures are former degraded lands protected from disturbing animal and human entrance for natural recovery.

In most cases to be set a land as area enclosure, the area should be abandoned because of nothing with it for animal and human. The area is identified and set as enclosure by Woreda and Kebele agricultural experts, and user groups who agreed to strictly protect them from any form of grazing, manual harvesting of grass and tree cutting. Area Enclosure was started during Derg regime although activities were mainly planned and implemented using a top-down approach without any form of community participation and resource utilization which in turn adversely affected the sense of ownership (Dessalegn, 1994). The inception of enclosure dates back to the early 1980s, which coincides with the beginning of large-scale land rehabilitation and soil and water conservation programs in Ethiopia. The establishment of enclosure has been one of the strategies for rehabilitating the degraded hillsides within the catchments delineated for the rehabilitation and soil and water conservation programs (Betru et al., 2005) which was firstly for ecological rehabilitation but now recent studies found increased expectations of the community about economic benefits on enclosure and became major managerial challenges of the

exclosure (Gebremedhin et. al., 2000). Establishment of area exclosures has been an important strategy for the rehabilitation of degraded hillsides. This practice has become very common; Exclosures are areas that are enclosed to allow restoration and rehabilitation of degraded lands by natural means. The context and definition of area exclosures vary from country to country (Abera et al., 2016). In the Ethiopian context, it can be defined as the degraded land that has been closed-off or otherwise protected from human and domestic animal disturbances to allow regenerating native vegetation (Emiru et al., 2017; Wolde et al., 2017). Most parts of Ethiopia are generally regarded as heavily deforested, natural forest has been decreasing at an alarming rate (Cheng et al., 1998). To ameliorate this situation, different initiatives and strategies have been implemented to increase the forest area in Ethiopia.

In response to the 2011 Bonn Challenge, Ethiopia has committed to restoring 15 million ha of degraded forest. In the climate resilient green economy (CRGE) document, the government has set afforestation and re-forestation targets to cover 3 million ha of land by 2030 (FDRE, 2011). The practice of exclosures has become popular in most regions of Ethiopia. Different studies indicated that establishment of area exclosures enhanced biodiversity, floristic composition, structure and density in different regions of Ethiopia. Establishment of exclosures improved composition, density, richness, and diversity of woody species in comparison to open adjacent sites.

This is known that increased vegetation density in exclosures results in increased infiltration and higher transpiration, which in its turn triggers vegetation restoration through increased biomass production (Nyssen et al., 2007). The composition of woody vegetation also depends largely on age of the exclosures establishment (Tefera, 2001). Similarly, Mastewal et al. (2006) reported

that the older exclosures had higher woody species density and diversity than the younger ones. Establishing exclosures is considered advantageous since it is cheap, fast and productive method for the rehabilitation of degraded lands (Tucker & Murphy, 1997; Emiru et al., 2006,). Exclosures have a significant positive effect on the restoration of degraded soils. It has effective role in improving soil nutrient content and properties. The higher soil organic matter content in exclosure can potentially improve the soil physical properties such as soil structure and total porosity (Yimer et al., 2015). A study that was conducted in Hawzen Woreda in Tigray region indicated that the soil moisture percentage is higher in exclosure than in the open site, this could also be attributed to the higher organic matter accumulation. Exclosures were effective in soil conservation, restoring degraded soils and increasing soil carbon in the highlands of Tigray.

The higher soil nutrients content and properties in all exclosures indicate the positive effect on the restoration of degraded soil (Mekuria et al., 2011). Area exclosures have great role to enhance biomass carbon stock. Establishing exclosure on degraded lands leads to increased carbon absorption or sequestration (Wolde, 2005; Wolde et al., 2009). Plant species diversity and aboveground biomass increased with exclosure age (Mastewal, 2013). Exclosure land management can support to diversify the livelihood options of local communities, as most of the regenerated woody species are economically important, and once vegetation is restored, income generating activities can be integrated (Mekuria et al., 2018).

Exclosures are boosting annual household income of local people (Tefera et al., 2005). The existing wider implementation of exclosures in Ethiopia especially in the high lands is related to the multifaceted benefits of exclosures (Wolde et al., 2018). After Yaynishet et al. (2008), exclosures established 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 in Tigray region of northern Ethiopia. The main objective of establishing exclosures better socio-economic benefits to the local communities. In this regard, Bendz (1986) reported that establishing exclosures is considered advantageous since it is a quick, cheap and a lenient method for the rehabilitation of degraded lands. is to improve the overall ecological conditions of degraded areas.

## **2.2 The extent and impact of land degradation in the Ethiopian highlands**

The definition of land degradation is taken to mean a loss of forest structure, productivity and native species diversity (David and Don, 2003). It broadly defined as also, it is the reduction or loss of the biological or economic productivity resulting from natural processes, land uses or other human activities and habitation patterns such as land contamination, soil erosion and the destruction of the vegetation cover (Erika *et al.*, 2010) and deforestation is the conversion of forests to another land uses system (FAO, 2001). Different causes are reported worldwide to these critical issues such as forest-cover changes, desertification, cropland expansion and expansion of urban settlements (Erika *et al.*, 2010). Deforestation and land degradation, therefore, are minimizing evenly damage the capacity of forests and the land to contribute to food and to provide other benefits.

Ethiopian is faced with rapid deforestation and degradation of land resources as a cause of population increment have resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forest for fuel, fodder and construction materials (Badeg Bishaw, 2001). Other consequences also being biological, chemical and physical, the major types affecting productivity includes degradation of vegetation cover, soil degradation, and nutrient

depletion (Eswaran *et al.*, 2001). This refers that unsuitable land use is responsible for the degradation of soil and biodiversity. It is therefore, important to recognize the interactions between different elements and consider the site conditions in the landscape (Lal *et al.*, 1989) and prior to designing the best conservation options to combat environmental degradation. To address these environmental problems a number of interventions have taken place. One of such measures is the establishment of exclosures, which are areas protected from human and animal interference to promote natural regeneration of plants and reduce land degradation of formerly degraded communal grazing lands (Wolde Mekuria *et al.*, 2010) and it is a land reclaiming practices in highly degraded areas (Kidane Gidey *et al.*, 2013).

### **2.2.1 Deforestation and Loss of biodiversity**

Biodiversity is critical for the functioning of ecosystems and the provision of ecosystem services (MEA, 2005). These issues are demanding attention; the problem of the loss of biodiversity faces significant challenges in gaining the municipal attention. Deforestation is a major cause of the loss of biological diversity and a significant global concern (Laurance, 2007) as it is estimated that more than half of the known terrestrial plant and animal species live in forests (MEA, 2005). Additional Ecological factors such as genetic diversity and competition among species, and other biotic and a biotic factors are vital elements of biodiversity.

Another cause of biodiversity loss also reported by Walther *et al.* (2001) as, over exploitation, the introduction of alien species, pollution, and climate change are factors that influence biodiversity. Deforestation has been practiced by humans for thousands of years before the beginnings of civilization. With the diversification of agriculture, fire became the prime tool to clear land for crops. A typical progress trap is that settlements were often built in a forested area providing wood for some (Tigabu Dinkayoh, 2016).

The long history of deforestation and subsequent land degradation in Ethiopia was one of the many factors that have led to an untenable situation for future sustainable livelihood in the country. At present, the forest cover is estimated at less than 5 % of the total land surface (EFAP, 1993 ;). There is no accurate or reliable information about the extent and location of the past and present natural forest and woody vegetation cover in Ethiopia. However, historical sources indicate that, on the basis of potential climatic climax, high forests might have once covered about 35-40 % of the total land area of the country.

The Ethiopian Forestry Action Plan outlines the pattern of deforestation. The current rate of deforestation is estimated at 150,000 ha per year (Ethiopian Forestry Action Plan) or 62,000 ha/yr (World Bank, 2001). Deforestation has been a major problem for quite a long time with serious consequences to Ethiopia. These consequences include decline or loss of biodiversity, degradation of land and water bodies, possible negative effects on the local, regional and global climatic conditions as well as negative impacts on the welfare of human beings (Emru et al, 2006). The major reasons for deforestation are clearing of forests and woodlands for cultivating crops and cutting of trees and shrubs for various purposes, notably for fuel wood, charcoal, construction material, etc.

The fact that plantation forestry has been very far from meeting the demand for wood for various purposes indicates the inevitability of deforestation. The underlying causes of deforestation are poverty, population growth, poor economic growth and the state of the environment. Declining standard of livelihood of the farming communities and their close dependence on forests and woodlands have led to clearing / burning for subsistent farming, cutting of trees/shrubs for fuel wood and charcoal production (both for consumption and sale), construction material, overgrazing, burning associated with traditional apiculture, etc. However, to sustain the potential

of biodiversity function concerned bodies should be work to minimize the cause of biodiversity loss through different conservation practices. For instances, implementation of exclosure as well as integration with other land use practices are increasing the productivity of the ecosystems with properly designed interventions is important as reported by different authors (e.g. Mestwal Yami *et al.*, 2006; Yaynishet Tesfaye *et al.*, 2009; Wolde Mokria, 2013).

### **2.2.2 Soil erosion and loss of soil quality**

Erosion is the displacement of soil particles by wind or water. Soil erosion by water increases when water at the soil surface exceeds water infiltration (Hillel, 1998). The most serious effect of erosion is loss of soil organic matter and nutrients, and the resulting reduction in crop yield (Nair, 1993). Soil can be moved out of place by splashing or by the effect of raindrops on the soil surface. Also, sheet erosion comes about when soil particles are dislodged by raindrops on the soil surface. Sheet erosion most of the time develops into rill erosion. Small and slow channels form. Once, these channels are developed, gully erosion occurs. Soils that have good structure resist erosion when they are not disturbed. Good cohesiveness between soil particles and soil cemented by organic matter may resist water and wind erosion (Hillel, 1998). Because of high smectite clay content vertisols are prone to erosion. In fact, when clay particles are swollen, infiltration becomes negligible, so surface runoff increases (Pimentel, 2006). Pimentel *et al* (1987) report that land degradation reduces food production by 15 to 30%. Also, Taddese (2001) argued that unsustainable increase of population is the main cause of soil erosion in the highlands areas.

With a reduction of food production coupled with an escalating population increase in the highlands of Ethiopia, massive efforts are focusing on land cover. Forest loss has been a major

threat to food security in Ethiopia by the way it affects soil erosion. Ethiopian soils are still very productive as reported by Dubale (Dubale, 2001). Soil erosion has caused loss topsoil. As a result crop roots are exposed to soil with high clay content, pH, and CEC and lower organic matter, phosphorous, and nitrogen. Soil quality is the ability of the soil to “function, within natural or managed ecosystems boundaries, to sustain plant and animal productivity or enhance air and water quality, and support human health and habitation. Soil erosion can affect water quantity and quality.

Cattle alter the landscape and affect soil quality through grazing. Animal grazing changes the land cover by decreasing soil organic matter and soil aggregate, promoting surface crusting and inhibiting water infiltration (Mwendera, et al, 1997). Reduced organic matter (OM) in soil can affect a lot of other soil quality indicators. For example, it reduces the amount of water in soil. As a result biodiversity can suffer. Also, soil water chemistry is not the same. In the case of vertisols, the cracks stay open.

On the other hand, Donahue (1972) noticed a change in many soil properties following burning. For example, burning changes texture of highland vertisols. A soil changes from 34% sand to 78% sand after burning (Donahue, 1972). Also, according to Donahue (1972) available phosphorus and pH greatly increase in the short-term.

Nevertheless, burning of soil destroys organisms and other soil quality indispensable for crop production in the long-run. Burning and removal of crop residue, deforestation, overgrazing, high human habitation, and crop production on steep terrains are among the major problem causing land degradation and subsequent loss of soil quality.

### 2.2.3 Soil nutrient depletion and soil quality deterioration

Soil degradation is the rate of adverse change in soil qualities (Lal, 2009) and encompasses the deteriorations of physical, chemical, and biological attributes of the soil (Enters, 1998). It is a severe universal ecological problem, with implications in food security, climate change, agricultural resilience in the face of crop diseases, biodiversity, and future genetic resources (Young et al., 2015). Accelerated erosion, depletion of the soil organic carbon pool, and loss in biodiversity, loss of soil fertility and elemental imbalance, acidification, and salinization are the major soil degradation processes (Lal, 2015). Soil degradation processes have accelerated rapidly in the last century, with an estimated 24 billion tons of fertile soil lost to erosion in the world's croplands (Solaw, 2011). Globally, soil degradation affects 33% of the earth's land surface (Bini, 2009) and it reduced the soil ecosystem services by 60% (Leon and Osorio, 2014).

Consequently, it costs the world between 6.3 and 10.6 trillion dollars per year (Nkonya et al., 2016). In arid and semi-arid regions, it has been estimated that over the last 20 years, 2,000 ha of agricultural land per day, has been lost due to salinization (Young et al., 2015). This is equivalent to a global economic loss of 27.3 billion dollars per year (Qadir et al., 2014). Recent estimates indicate that if the current scenario of soil degradation continues over the next 25 years, it may reduce global food production by 12% and in turn, this will result in a 30% increase in world food prices (Kuyvenhoven, 2012).

Various human activities, including inappropriate irrigation management, deforestation, and land misuse lead to accelerated soil degradation through salinization, flooding, drought, erosion, and water logging in Ethiopia. However, there is a lack of reliable and consistent data on the extent and rate of soil degradation in the country. Soil erosion by water is the dominant degradation

process and occurs particularly on cropland, with annual soil loss rates on average of 42 tons per ha per year (Hurni, 1993). Soil degradation due to nutrient depletion also poses a serious problem in Ethiopia (Getachew and Wagayehu, 2007) that has been reducing the productivity of agricultural land, and affects the livelihoods of smallholder farmers (Amdihun et al., 2014).

Some findings estimated that the depletion rate for Nitrogen (N), phosphorus (P), and potassium (K) in the country is 40, 6.6 and 33.2 kg per ha per year, respectively (Stoorvogel and Smaling, 1990). To meet the needs of the ever-increasing population, improving soil health by adopting sustainable land management practices is the best solution for mitigating and reversing current soil degradation trends. Thus, the main objective of this paper is to give an overview on the causes and impacts of soil degradation in Ethiopia, and to present its restoration management options.

### **2.3 The role of area exclosures in land rehabilitation**

Ethiopia, and particularly the Tigray region, has been facing continuous deforestation and consequent land degradation due to mainly agricultural expansion, overgrazing and unsustainable extraction of wood products (Bishaw 2001). In an attempt to reverse this trend, many efforts have been made in the region since the 1970s (Pohjonen and Pukkala 1990, Tekle 2001). The rehabilitation of degraded lands through establishing exclosures was among such efforts (Birhane 2002, Mekuria et al. 2011, and Mengistu et al. 2005).

Exclosures are areas protected from human and animal interference by a physical boundary or a social fence (meaning communal restriction to access) to promote natural regeneration of plants and thus reduce further degradation of formerly degraded lands. Rehabilitation of degraded communal grazing lands through establishing exclosures has become increasingly important in

the Tigray region of northern Ethiopia. Similarly, Yayneshet et al. (2009) reported that exclosures can be effective in enhancing the composition, diversity and density of vegetation on degraded grazing lands. Moreover, exclosures can be effective in restoring degraded soils and increasing soil carbon in the highlands of Tigray (Mekuria et al. 2011). An exclosure allows degraded lands to rest for a number of years and this encourages the regeneration of natural vegetation (Bendz 1986). Exclosures have previously been used to restore communal grazing lands, mainly located on steep slopes.

Rehabilitation of degraded lands has been practiced in some form in most rural societies around the world. Rotational grazing and deferred pasturing, which allow vegetation to regenerate during the rainy season, have been common practice in Tunisia, Algeria, Niger, Somalia and Ethiopia for many centuries (Birhane 2002, FAO 1979). The selective protection of forest cover is also commonly practiced for various reasons. One of the main reasons why this restoration measure is so popular is that it is a relatively fast way to restore vegetation compared to conventional reforestation.

Indigenous or adapted species of grasses, weeds, shrubs and trees are already present, suppressed or dormant in the form of roots or seeds. Existing vegetative material may invade the site faster and with better coverage than planted seedlings, which are often exotic or less well adapted to site conditions (Bendz 1986). The second main reason is that establishment of exclosures is relatively easy and inexpensive, requiring less investment in planting material, site preparation and management compared with plantation establishment. Recently, through exclosures, several previously degraded areas have regained forest vegetation via natural succession. Several studies show exclosures to be efficient tools in terms of vegetation restoration and thereby in soil and water conservation in enhancing water infiltration and stream and ground water recharge, in

reducing flood hazards, and in restoring and maintaining plant and wild fauna diversity (Aerts et al. 2009, Descheemaeker et al. 2006, Mastewal et al. 2006, Mengistu et al. 2005, Seyoum et al. 2015). Exclosures are an important source of animal feed (Yayneshet et al. 2009) as well as a potential source of biomass energy.

Moreover, exclosures can potentially play an important role in climate regulation by serving as carbon sink. Exclosures can help vulnerable communities to increase their resilience by sustaining ecosystems services that provide opportunities for sustainable economic prosperity while providing a defence against the negative effects of climate change (UNEP 2010). The Government of Ethiopia has planned to increase the area of land under exclosures in recognition of the economic and environmental roles that exclosures could play at the national level. The Climate Resilient Green Economy (CRGE) strategy of the country, which is a national overarching development strategy designed for the upcoming 10–15 years, recognizes protecting and re-establishing forests as one of its four major pillars.

The strategy envisages rehabilitation of degraded pastureland and farmlands by converting the lands into exclosures (FDRE 2011). In the CRGE document, the government has set afforestation and re-forestation targets to cover 3 million ha of land by 2030 (FDRE 2011). Exclosures are one of the strategies expected to contribute towards the efforts of achieving reforestation targets. Successful scaling-up requires a well-formulated strategy based on the best experiences gained from critical evaluations of empirical data and the successes and failures of past efforts. The aim of this study was therefore to identify institutional, legal and socioeconomic factors that contribute to the success of the forest restoration efforts through exclosures. Such information serves as a key input for developing scaling-up programmes that are responsive to specific socio-economic and ecological set-ups.

### 2.3.1 The role of area exclosures in restoring vegetation cover

The practice of establishing enclosures has emerged as a promising practice in different parts of Ethiopia (Bendz, 1986), namely in Tigray (Kindeya, 1997; Mitiku and Kindeya, 2001; Emiru, 2002; Kidane, 2002; Tesfaye, 2002), Welo (Kebrom, 1998; Tefera, 2001) and Shewa (Tefera, 2001). Enclosures are areas selected for natural regeneration of the native flora as a means of land reclamation through protection of the areas from human and animal interference (Bendz, 1986; Alemneh, 1992). Since the objective of most exclosures is for site rehabilitation/reclamation, restoring and they are usually established in steep, eroded and degraded areas used for grazing and crop production in the past (Bendz, 1986).

The practice of exclosure has been traditionally exercised for centuries around church boundaries in Ethiopia by restricting the use of forests around churches as prestige for the religious sites (Alemayehu, 2002). Hence, establishment of exclosures has been recognized as a promising method in the of degra restoring ded areas, particularly, in Northern Ethiopia where degradation of natural resources has been considerably higher than in other parts of the country. The regeneration of natural grasslands and forest areas increase biomass production and improve the plant species diversity, resulting in more diverse soil biota and other associated beneficial organisms, which may be more reliable where land is not productive (FAO, 2005b).

Where they had been established, exclosures are among the green spots with considerable species diversity (Tefera, 2001; Emiru, 2002). The local people have reported that species that disappeared long time ago have been restored following establishment of exclosures. For instance, species that could not be observed for many years in some parts of eastern Tigray, reappeared, densities and diversities of the flora, particularly of grasses, and fauna increased, soil erosion decreased and even dead springs started to flow after different exclosures were

established (Emiru, 2002). As a result, enclosures are becoming promising assets as sources of not only biomass energy, which accounts for about 80% of the total household energy supply in the country (EFAP, 1994), but also wood for construction, agricultural implements and several other purposes. Non-timber forest products, e.g. grass for feed and thatching, are becoming important outcomes of enclosures. Encouraged by these results, efforts are underway currently to replenish denuded areas of northern Ethiopia through the establishment of exclosures to promote conservation-based sustainable agriculture along with maintaining and enhancing the biodiversity of drylands (Kindeya, 1997; Emiru, 2002).

In particular, such information is crucial for developing strategies, programs or technical guidelines for their conservation and sustainable utilization. Therefore, this study was initiated as a step towards understanding the actual and potential contribution of exclosures in the recovery of woody vegetation on degraded drylands. Specifically, the objectives of the study were to: (i) investigate the species composition, density and diversity of both the above-ground component of woody plants and soil seed banks; (ii) determine the regeneration status of some selected woody plants; (iii) compare the similarity of species composition of woody plants between exclosures and open areas as well as the standing vegetation and soil seed banks at two distantly located study sites in central and northern Ethiopia.

### **2.3.2 The role of area exclosures in restoring plant communities**

Ethiopia is gifted with topography, location, climate, ecology, natural resources and diverse sets of ecosystems. This suitable condition is attributable to the existence of higher biodiversity in the country (Mengistu & Asfaw, 2016). The diversity of fauna and flora of the country ranging from 5,999 and 6,999 species, of this 15% are endemic. According to Gebretsadik (2016), Ethiopia is also rich in large mammals and endemic to it such as Walia Ibex, Simien Fox and Gelada

Baboon mainly concentrated in the Southwestern borders of the country. The economic loss due to deforestation in the country ranges between 0.4 and 1.5 billion USA per year (Shumi et al., 2021; Sintayehu, 2018; Srinivasan, 2014). In this study to assess the impact of land management and conservation practices, enclosure (enclosure) area and adjacent open grazing land uses were tested for their plant species diversity and richness.

Area enclosure is a land use which is protected from anthropogenic activities and animal disturbances in order to recover its natural plant species and to reduce additional removal of vegetation and soil erosion of the previously affected lands (Asmare and Gure, 2019; Aerts et al., 2009; Mekuria et al., 2011). According to (Meron, 2010; Mekuria et al., 2011; Yami et al., 2006; Teketay et al., 2018; Fenetahun et al., 2021). Rehabilitation of affected areas using enclosures system has been achieved in northern part Ethiopia, which was totally closed from any anthropogenic and animal contact using recruited guards with the goal of regeneration of natural vegetation.

Area enclosures have a significant role in biomass production, enhancement of biodiversity, maintenance of plant species diversity, restoration of native vegetation, rehabilitation of degraded forest wood land, hostage of wild animals, source of animal feed and extraction of medicinal plants for human and animals (Sinore & Dobocho, 2021; Melkamu and Abdella, 2019; Mengistu & Asfaw, 2016; Molla & Kewessa, 2015; Giday et al., 2019). In the study area, there is one successful area enclosure locally named Danguar watershed which has 507.5 hectare area size. Regenerated enclosures vegetation land uses provide various environmental and economical benefit including as a source of traditional medicine plants to local communities (Mengistu & Asfaw, 2016). For instances, Wolde Mekuria *et al.* (2011) list out the most common woody vegetation species in Tigray where enclosure practiced like *Acacia seyal*, *Euclea racemosa*

*subsp. schimperi*, *Maytenus arbutifolia*, *Acacia etbaica*, *Juniperus procera*, *Becium grandiflorum* and *Dodonea angustifolia*. Other study report by Tefera Mengsitu *et al.*, (2005b) in danguar district in Tigray dominant woody species are also listed as below: *A. etbaica*, *Euclea racemosa subsp. Schimperi*, *Rhus natalensis*, *A. tortilis*, *Maytenus arbutifolia*, *Oromocarpumtrichocarpum*, *Dichrostachys cinerea*, *Jasminum abyssinicum*, *Becium grandiflorum* and *Dodonea angustifolia*. Almost all these woody plant species are broadly classified as montane evergreen thicket and savanna vegetation types of northern Ethiopia (Pichi-Sermolli, 1957).

### **2.3.3 The role of area exclosures in restoring soil fertility and soil quality**

In Ethiopia, inadequate agricultural practices such as cultivation on steep slopes, clearing of vegetation and overgrazing are the main factors leading to soil erosion and nutrient loss. For instance, cultivation on the steep slopes in northern Ethiopia resulted in a loss of 35 tons of soil per hectare of land annually (Wolde Mokria, 2013). But today such a devastating loss of soil is being reduced by exclosures. For this reason, it was established as a form of land management with a spatial focus to improve environmental conditions and control soil erosion. The role of exclosure on soil fertility is measured through considering the availability of essential nutrient (micro and macro nutrient) for plant growth.

And the variation in soil type, land-use history, land cover, climate, topography and vegetation cover creates difference in the content of soil organic carbon stock of a converted grazing lands (exclosure land). Due to such variability the contributions of exclosure for soil physical and chemical properties were studied in different way by different authors. For instance, (Abay et al, 2020). The converting open grazing land into an exclosure improved most soil properties except soil pH, avP and EC. Also recently reported that management of degraded land by converting

open grazing land to enclosure significantly enhances the total available N and SOC than open grazing lands. The presence of improved soil structure (high level of leaf litter and vegetation cover) in the enclosure land reduces the soil erosion better than open grazing land (Damene et al, 2020). While for soil loss reduction issue alone, use of area enclosure is suitable land management practices<sup>14</sup>. The improvement in canopy and ground cover in area enclosure with increasing age of enclosure reduces sediment associated nutrient loss through lowering raindrops and soil erosion

#### **2.4 Area enclosure as a strategy to restore degraded landscapes**

In Ethiopia establishment of area enclosures have been an important strategy for the rehabilitation of degraded hillsides. This practice has become very common, especially in the highlands, due to the remarkable improvement of productivity and reduction in soil erosion in the areas enclosed in the early 1980s by (WFP and MoA, 2002). Maintaining adequate vegetative groundcover is the first defense against soil erosion (George et al., 2004). Whereas, the less the soil is covered with vegetation the more the soil is exposed to the impact of raindrops due to less organic matter content in the soil (FAO, 2005b). Natural regeneration involves deliberately managing of a land to enhance and accelerate the natural processes of ecological succession in order to reestablish a healthy and resilient ecosystem. Establishment of area enclosures, as a strategy to reverse land degradation, biodiversity loss and fragmentation of habitats has gained great acceptance due to its efficiency in improving land productivity and reducing soil erosion in the areas enclosed in early 1980s (WFP & MoA, 2002). The strategy has been realistic to reestablish degraded lands in terms of cost, time of revival and the advantage it offers to the society (Kindeya, 1997; Emiru, 2002; Kidane, 2002).

The overall ecological conditions of degraded lands will be improved resulting with superior socioeconomic and environmental services to the society (Verma et al., 1999). Area Enclosures are determinant ways of rehabilitating severely exploited vegetations and degraded dry land environments and are established due to their advantages in being cheap, quick and lenient to return degraded sites (Bendz, 1986).

Studies indicated that enclosures often involve restriction of humans and live stocks and had improved biomass production, species composition, density, richness and diversity as well as soil diversity than the open sites (Kebrome Tekle, 1998). Rehabilitation of natural vegetation improves the microclimate and biodiversity of the area and enclosures often provide multipurpose benefits like animal fodder, fuel wood access, fiber, access of medicinal plants, rehabilitation of soil fertility (Example: Leguminous plants) and provide habitats for various beneficial species (pollinators and biological control) and wildlife as well (FAO, 2005).

## **2.6. Measurement of Land Restoration Success**

The success of land restoration project can be quantified when targets are set prior to project initiation (Bakker *et al.*, 2000). The primary goal of land restoring particularly in Ethiopia is to restore ecosystem health by altering vegetation structure to more closely resemble the range of variability evident in pre-land restoration and by reintroducing ecosystem maintaining processes such soil and water conservation and area enclosure. Another element affecting the success of land restoration is the formal institutional arrangements put in place and while, internal factors such as homogeneity or heterogeneity of members, the number of households included (indicating the level of pressure on the forest resources), as well as the skills and integrity of local administrators of the institution also affect outcomes (Aklilu Ameha *et al.*, 2014).

These provided that the framework within which land restoration is implemented and are therefore critical to the performance how to sustain the ecological functions. However, more information is required to make judgments about whether the development of ecosystem components are on a trajectory that will lead to the restoration of a fully functioning, self-sustaining natural system or delay behind for some reasons (Reay and Norton, 1999). Easily observable measures of success are including vegetation density and woody plant basal area and herbaceous standing crop or percent cover (Daniel *et al.*, 2006). Particularly, vegetation development is one of the most fundamental indicators of restoration progress and one of the simplest to measure. Estimating cover abundance, frequency scores, and floristic composition using nested quadrast/plot can be used as methods to assess restoration progress. If these criteria's are achieved or progress in the practiced area incomparable to the nearby adjacent unmanaged or communal grazing land as a references, reveals the project is significant in success or it is in progress.

This indicated that land restoration targets can be met on a landscape-scale through site-specific prescriptions and use of prescribed land restoration have been incorporated into suggested management strategies for land-use agencies across the particular site (Friederici, 2003). In general, the measurement of improvements, some aspects of increased ecological function, and progress of a site against some nearby untreated reference is much more readily accomplished and is considered valuable (Ruiz-Jaen and Aide, 2005). Further, the success also easily need measurement based on the satisfactions of the local communities as a whole and well acceptance of the new practice for example establishment of exclosure.

### 3. Materials and Methods

#### 3.1 Description of study area

##### 3.1.1 Geographic Location

The study area is located in Northern Ethiopia, particularly in the eastern zone of Tigray Regional State. It is located in the western tip of Hawzen Woreda. It is situated some 27 km south west of Hawzen town and covering an area approximately 397ha. The area is accessed through dry weather road which runs from Hawzen through Megab westward. Debrehiwot is one of the 25 administrative villages that make up the Hawzen Woreda. Debrehiwot Tabia is further divided to 4 sub villages (Kushets) known as Danguar, Awuda', my zagra and Ahrab.

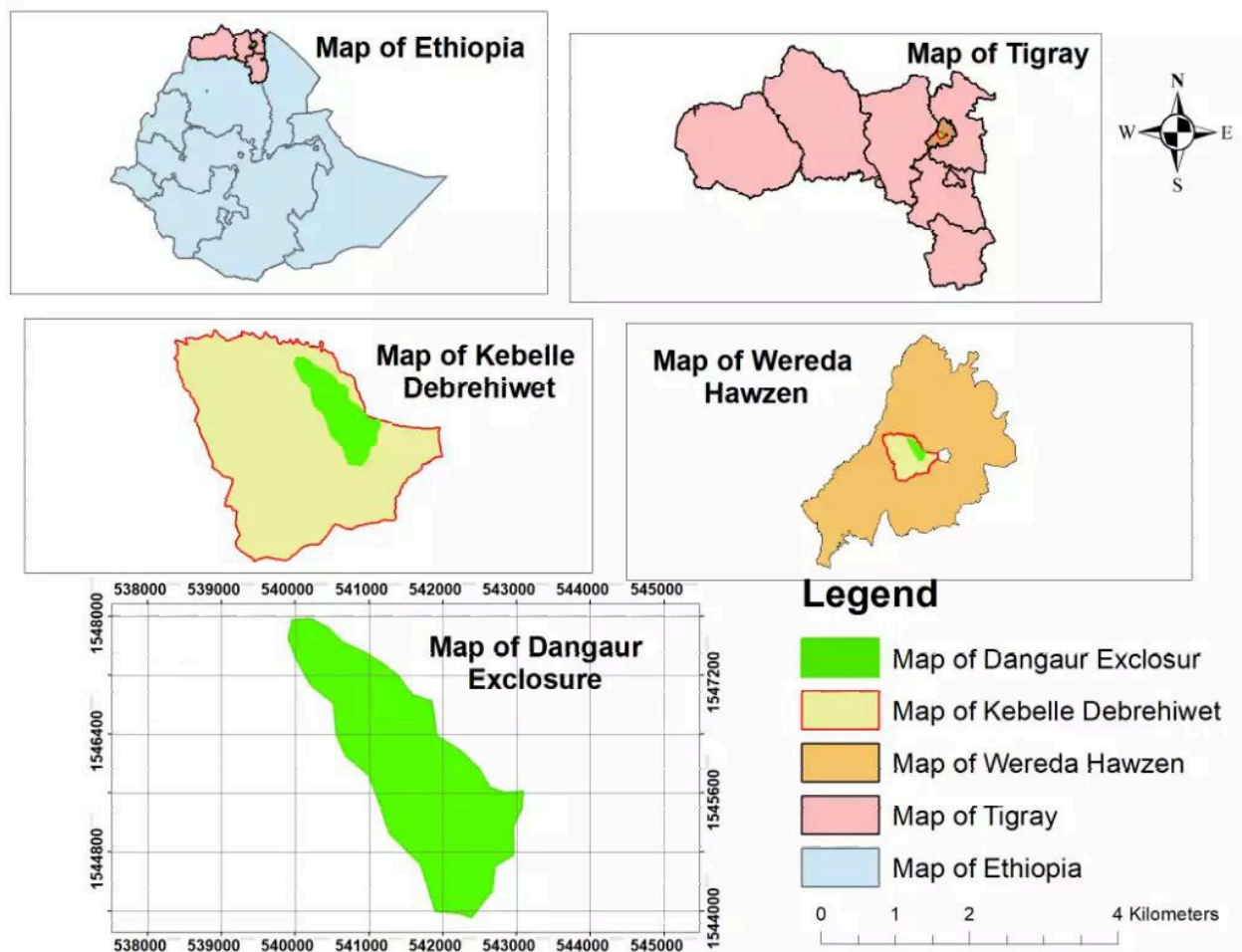


Figure 1: Location of the study area.

### **3.1.2 Topography**

The area is characterized by a highly elevated land in southeast and east, and a relatively flat and lower elevation portion in the west and northwest. According to the socio-economic baseline survey carried out by the Eastern Zone Department of Planning and Economic Development (2012), the village has a very undulating nature of topography with sharp pointed mountains and lowland areas. Generally, the altitude of the village varies from the lowest point, which is as low as 1600 meters above sea level at Tala and 2400 meters above sea level at a particular place called DaTsion Mountain.

### **3.1.3 Soil and Climate**

The dominant soil is stony loam soils (Eutric Cambisols and Eutric Regosol). According to Hawzen office of agricultural and rural development (2012E.C), the climatic zone of the study area is generally characterized by Kolla climate. The average annual rainfall is between 81 and 177.2 mm. February, March and May are the hottest months and November and December are the coldest months. The long-term (1997–2020) total and mean annual rainfall Recorded by Hawzen Office of Agricultural and Rural Development was described. But the rainfall for the months of October, November, December and January were not Recorded. According the Hawzen office of agricultural and rural development, the minimum and maximum daily temperature ranges between 170°C to 250°C respectively with its averages of 210°C.

### **3.1.4 Population**

According to the Population and Housing Census of Ethiopia (2007), the study area had an estimated total population of 3821, of which 1901 and 1920 were males and females respectively. According to Hawzen office of agricultural and rural development in 2016 E.C the

study area had an estimated total population of 3921, of which 1928 and 1993 were males and females, respectively.

### **3.1.5 The source of Livelihood**

According to Hawzen Office of Agricultural and Rural Development (2020), agriculture is the backbone of the village's economy which is dominated by mixed farming. Farmers produce food crops like Teff, Maize, Sorghum and Millet and rear animals such as cattle, sheep, goat, donkey, poultry as well as honeybees. Nevertheless, it is traditional, backward and peasant farming dominated. Hence production and productivity were always extremely low, which do not allow the Woreda (district) to have self-sufficiency in food. The village had severe natural resource degradation and severe soil erosion prevails throughout the village. Vegetation covers were scanty. Gully erosion was another problem of the village, coupled with surface run off and lowering water table. Although efforts were being made to increase production and productivity of the Woreda, satisfactory outputs had never been achieved due to various factors such as recurrent droughts, poor implementation capacity and lack of application of appropriate agricultural technologies, etc. To mitigate the above mentioned problems, different international donors like, the Millennium Village project had discussed and reached in a consensus with the community and Office of Agriculture and Rural Development of the Region and District to implement different activities such as soil and water conservation, gully plugging and reforestation.

## **3.2 Site selection and sampling method**

### **3.2.1 Site selection**

As one of the objectives of the study was to compare woody vegetation of the area enclosure to that of grazing areas, the surrounding of Hawzen Woreda was surveyed to look for suitable sites for the study. That kebele have enclosure area and grazing lands adjacent to each other were deliberately considered for selection as sample kebele. In addition, the two areas should be similar in geological parent material, altitude, rainfall, aspects, and drainage. From the ten kebele, only debrehiwet kebele were found to fulfill the above characteristics. Therefore, that kebele was taken for the study.

### **3.2.2 Study Design**

Reconnaissance field survey was conducted in the middle of December 2020 in order to be familiar with the study area and to observe vegetation distribution of study area. The vegetation and socioeconomic sampling survey were carried out in the month of December to May 2020. The study sites are located in Eastern Tigray, Hawzen wereda where Dangaur enclosure and adjacent grazing. The grazing land was freely accessible to livestock grazing and used as a control (Tefera, 2001) to compare restoration against the area enclosures. Hence, the changes could be described using important parameters such as species richness, abundance, diversity, regeneration status and chemical constituents of the soil in the area (Tefera, 2001; Wolde et al., 2007). Secondary data had been collected from the wereda Agriculture and Rural Development Office and other sectoral offices. The biophysical survey was conducted by systematically laid parallel transects in the area enclosures and in the grazing site.

### 3.2.3 Data Types and Sources

To achieve the objectives of the study, data were collected from both primary and secondary sources. The primary data were collected, in-depth interview of selected informants, focus group discussions and field observation. Secondary data were collected from published and unpublished materials which are available in the form of books, journal articles, and government policy briefs, annual plans, and performance reports, research papers prepared and presented for policy discussions and conferences, and other relevant documents from the concerned administrative offices.

### 3.2.4 Vegetation sampling

Transects and quadrant method was the recommended survey method to assess the plant species. Parallel and straight transect lines were laid and a systematic sampling strategy was used to collect vegetation and soil data. A total of seven line transects were laid in the enclosure and seven in the grazing land. The first transect was laid 40 m from the border of the enclosures and the remaining transects were laid at 200 m distance from the previous transects (e.g. Emiru *et al.*, 2006; Mulubrhan *et al.*, 2006) to avoid the effect of disturbances. The first sample quadrat was laid out randomly at 40 m from the border and the others systematically at 100 m intervals Demel , (2001). In each transect lines, seven sample plots with 20m x 20m, 10m x 10m and 5m x 5m size were established for trees, saplings, and seedlings respectively (Abebe, 2007)

Using this system, from the whole samples a total of 70 plots were laid out. To assess the regeneration status of woody plants, individual woody categorization was made and structural attributes such as diameter and height were recorded in each plot. The diameter was measured for all individual trees and shrubs using a diameter tape. In the study tree species considered as DBH > 5.00 cm and height > 3.00m , saplings were considered with a DBH < 5 cm and DBH >

2.00 cm, and 0.50 m to 3.00 m height. Similarly seedlings were considered as those stems with DBH < 2.00 cm and height < 0.50 m (Tefera et al., 2005). Here the difference between trees and shrubs were; trees are woody, perennial plants that have one central stem, are generally more than 3 m in height and normally have a distinct head, while shrubs are woody, perennial plants that have number of stems usually produced from near the soil line of the plant. Shrubs are generally less than 3 m in height. The measurement taken in each compartment was Vernacular names of species were identified by plant knowledgeable of local elders during fieldwork. In each plot, structural attributes such as diameter and height were recorded. GPS, plant press, newspapers, and clinometers were the main instruments and tools used during the survey.

### **3.2.5 Soil sampling**

In order to assess and investigate soil fertility status through the analysis of physical and chemical soil properties, soil samples were taken from five 1 m<sup>2</sup> nested quadrats along each transect with a depth of 0-15 and 16-30 cm through by digging a hole of 15 cm × 15cm. From the two land use types a total of 14 composite soil samples were collected (seven samples from each). The sample plots (20 m × 20 m) were established and five small soil pits (from four corners and at the center) were taken in both areas. From each small and shallow pit, soil samples were collected and samples from the same depth were thoroughly mixed in a large bucket to form composite soil samples for the plot. The soil samples were air-dried at room temperature and sieved (<2 mm) prior to the laboratory analysis except for soil moisture content determinations. Samples from the two areas (exclosure and grazing land) were separately handled in sacks.

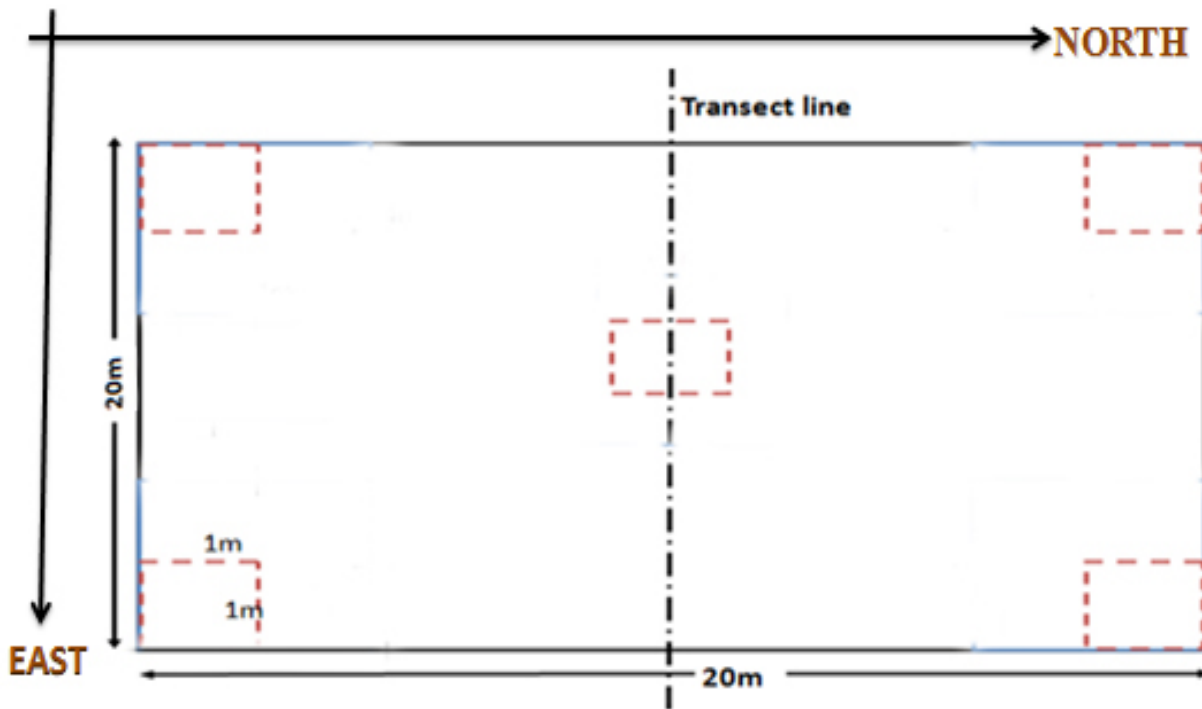


Figure 2 Diagrammatic representation of the design of the soil study sample plot with subplots

### 3.2.6 Socio economic sampling method

First, a preliminary survey was carried out that included field observation, formal and informal discussion with professionals, administrative officers, in-depth interview of selected informants, focus group discussions and field observation, focus group and representatives of the local people. This survey was used to identify the users of the selected communal forests. So, purposive selection of household or local communities of the two area users (Exclosure and Grazing land), was done from the kebele. The household was stratified into male and female household heads from the local communities in order to include female household heads. This is because male and female household heads could have different attitude and perception towards the Exclosure area

### 3.3 Vegetation data analysis

The woody vegetation of the exclosures was described in terms of species Tree density, height abundance, frequency and important value index (IVI), basal area and dominance were used for description of vegetation structure. The basal area of each species was calculated using the formula used by (Kent and Coker 1992):

#### Density

It is a count of the numbers of individuals of a species within the quadrant (Kent and Coker, 1992). It is closely related to abundance but more useful in estimating the importance of a species. Counting is usually done in quadrants placed several times in vegetation communities under study.

$$\text{Density} = \frac{\text{Total number of stems of all woody plant trees count}}{\text{Sample area in hectare}} \times 100$$

$$\text{Relative density} = \frac{\text{Density of species} \times 100}{\text{Density of all species}}$$

Frequency: Defined as the probability or chance of finding a species in a given sample area or quadrant. It is dependent on quadrant size, plant size and patterning in the vegetation (Kent and

$$\text{Coker, 1992) : Frequency} = \frac{\text{number of plots in which species occurs}}{\text{Total number of plots}} \times 100$$

The higher the frequency, the more important the plant is in the community. Although a high-frequency value means that the plant is widely distributed through the study area. A better idea

of the importance of a species with the frequency can be obtained by comparing the frequency of occurrences of all of the tree species present.

$$\text{Relative frequency} = \frac{\text{frequency of woody plant species} \times 100}{\text{Frequency of all species}}$$

$$\text{Relative Dominance} = \frac{\text{basal area of individual woody plant species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Important value index (IVI)} = \text{R.density} + \text{R. Dominance} + \text{R.frequency}$$

$$\text{Expansion factor} = \frac{(10000 \text{ m}^2)}{\text{Area of plot}}$$

## Species Richness

As a measure of species richness, the number of species in a community or sample, S and also two nonparametric estimators of species richness, the Chao1, and the first order jackknife were used (Gimaret-Carpentier et al., 1998; Krebs 1999 as cited in Alemayehu Wassie, 2002).

## Species Evenness

$$\text{Equitability or evenness: } J = H' / H' \text{ max} = \frac{\sum p_i \ln(p_i / \ln(s))}{H'} = H' / \ln S$$

Where H' is Shannon-Wiener Diversity Index;

S is the number of species found when all sample plots are pooled;

P<sub>i</sub> is the proportion of total individuals in the i<sup>th</sup> species.

Species Evenness (a measure of species balance) is a measure of the relative abundance of the different species making up the richness of an area. Species evenness; as a measure of species diversity which is the relative abundance in which each species is represented in an area. An ecosystem where all the species are represented by the same number of individuals has high species evenness. An ecosystem where some species are represented by many individuals, and other species are represented by very few individuals has low species evenness (Kibret Mamo, 2008). Evenness compares the similarity of the population size of each of the species present that means it is a measure of the relative abundance of the different species making up the richness of an area.

## Diversity indices

Shannon diversity index ( $H'$ ) is taking into account the number of individuals as well as the number of species. Shannon diversity Varies from 0 for a community with only a single species of a high value for a community with many species, each with few individuals. For biological communities,  $H$  does not exceed 5.0 (Krebs, 1999 as cited in Alemayehu Wassie, 2002). Shannon diversity index is high when it is above 3.0, medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it is smaller than 1.0 (Cavalcanti and Larrazabal, 2004). The two main components of measuring diversity are species richness and evenness. Species richness is a measure of the number of different species in a given site. Species richness index has a great importance in assessing the taxonomic, structural and ecological value of a given habitat. Evenness is a measure of the abundance of the different species that make up the richness of the area.

Species diversity shows the product of species richness and evenness. Shannon-Wiener diversity index is the most popular measure of species diversity (Kent and Coker, 1992; Krebs, 1999). because it accounts both for species richness and evenness, and it is not affected by sample size. Thus, Shannon-Wiener diversity index, species richness, and Shannon's evenness were computed to describe species diversity of the study area. Shannon-Wiener diversity index was calculated as follows:  $-H = -\sum_{i=1}^S P_i \ln P_i$

H' = Shannon-Wiener diversity index

S = the number of species,

P<sub>i</sub> = the proportion of individuals or the abundance of the i<sup>th</sup> species expressed as a proportion of total cover and ln = log base ten

### 3.3.1. Structural data analysis

The structure of the vegetation was described using dendrogram of plant community, frequency distributions of DBH, height and Importance value index (IVI). The woody plant density and basal area values were computed on a hectare basis. Importance value indices (IVI) were computed for dominant woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine their dominance (Kent and Coker, 1992). The following structural parameters were calculated.  $IVI = \text{Relative Density (abundance)} + \text{Relative Dominance (basal area)} + \text{Relative Frequency}$ , Where:  $\text{Relative Dominance (RDO)} = \frac{\text{total basal area of all individuals of a species}}{\text{total basal area of all species}} \times 100$  and Basal area (BA) was calculated using DBH as,  $BA = \frac{\pi d^2}{4}$ , Where,  $\pi = 3.14$ ; d is diameter at breast height.

### 3.3.2 Laboratory analysis of soil samples

Soil properties were analyzed at the Soil Fertility Laboratory of Tigray agricultural research institute (TARI) following standard procedures outlined in Reeuwijk 2006. according to the standard soil analysis procedures provided by Sahlemedhin Sertesu and Tekalign Tadese:(1991). Soil samples were analyzed for pH and electrical conductivity on 1:2.5, soil: water suspension method, organic carbon by oxidation with potassium dichromate ( $K_2Cr_2O_7$ ) in a sulfuric acid medium (Walkley and Black, 1934), total nitrogen by the Kjeldahl method and available phosphorus by sodium bicarbonate ( $NaHCO_3$ ) extraction procedures.

Available potassium extracted by sodium acetate method and measured by a flame photometer, cation exchange capacity by ammonium acetate (1N  $NH_4OAc$ ) extraction and, exchangeable calcium and magnesium by ammonium acetate extraction and measured by the atomic absorption spectrometry method (Page et al., 1982). The density of a soil suspension at a given depth becomes less as the particles settle. Its value at different times is related empirically to particle size, so that, by selection of times, a density reading can be a measure of silt + clay or clay. Bouyoucos advocates that the settling time for silt + clay and sand based on his method (without removal of organic matter or calcium carbonate). bulk density is the oven dry weight of the soil over the volume of the soil. Data was analyzed using the Statistical Package for Social Sciences (SPSS) (Bryman and Cramer, 2001)

## **4. Results and Discussion**

### **4.1. Composition of Woody Species**

A total of 56 woody plant species representing 33 families were recorded and identified in the 35 plots (Appendix 1). Of all the families, Fabaceae was the most dominant (16.071%) with contributing 9 species followed by Myrtaceae, Sapindaceae and Lamiaceae. On the other hand, in the grazing adjacent to the enclosure 20 woody plant species were recorded. They belong to 14 families, of which Fabaceae was the dominant family represented by 6 species (30%). The difference observed in woody species composition between the two sites showed the positive effect of area enclosure on woody plant species restoration.

According to Kibret (2008), the reduction of species diversity in the grazing area could be an indication of increased vulnerability of the plant species to animals and/or humans' intervention at maturity or early stage of regeneration. This might indicate that individual in the grazing area either harvested at their early age by the local inhabitants and/or their domestic animals or unable to resist the harsh environmental conditions such as water shortage due to extensive soil degradation in the grazing land of the study area.

Table1: List of woody species with their corresponding number of families in the enclosure and grazing area

Exclosure area				Grazing area		
No	Family name	Number of species	Percentage (%)	Number of species	Percentage (%)	
1	<i>Acacia abyssinica</i>	Fabaceae	9	16.071	6	30
	<i>Acacia albida</i>					
	<i>Acacia saligna</i>					
	<i>Acacia tortilis</i>					
	<i>Accacia etbaica</i>					
	<i>Astragalus atropilosulus</i>					
	<i>Calpurnia aurea</i>					
	<i>Ptrollobium stellatum</i>					
	<i>Senna sinqueana</i>					
2	<i>Agave sisalana</i>	Agavaceae	1	1.786		
3	<i>Aloe vera</i>	Aloeaceae	1	1.786	1	5
4	<i>Azadirachta indica</i>	Azadirachtaceae	1	1.786		
5	<i>Bersama abyssinica</i>	Melanthaceae	1	1.786		
6	<i>Buddleja polystachya</i>	Loganiaceae	2	3.571		
	<i>Capparis tomentosa</i>					
7	<i>Carissa edulis-</i>	Apocynaceae	1	1.786	1	5
8	<i>Cassipourea malosana</i>	Rhizophoraceae	1	1.786		

9	<i>Clematis hirsute</i>	Ranunculaceae	1	1.786		
10	<i>Clerodendron myricoides</i>	Lamiaceae	3	5.357		
	<i>Otostegia fruticosa</i>					
	<i>Otostegia integrifolia</i>					
11	<i>Ehretia cymosa</i>	Boraginaceae	2	3.571		
	<i>Cordia africana</i>					
12	<i>Croton macrostachyus</i>	Euphorbiaceae	4	7.143	1	5
	<i>Euphorbia tirucalli</i>					
	<i>Jatropha carriaca</i>					
	<i>Ricinus communis</i>					
13	<i>Leucena leucocephala</i>	Mimosoideae	2	3.571		
	<i>Dichrostachys cinerea</i>					
14	<i>Dodonoa angustifoha</i>	Sapindaceae	1	1.786	1	5
15	<i>Echinopsis hispidus</i>	Asteraceae	3	5.357	1	5
	<i>Vernonia amygdalina</i>					
	<i>Vernonia bipontinnii</i>					
16	<i>Erythrina abyssinica</i>	Papilionoideae	1	1.786		
17	<i>Eucalyptus camaldulensis</i>	Myrtaceae	2	3.571		
	<i>Eucalyptus globulus</i>					
18	<i>Euclea racemosa</i>	Ebenaceae	1	1.786	1	5
19	<i>Dichrostachys cinerea</i>	Moraceae	1	1.786	1	5
20	<i>Gravillea robusta</i>	Proteaceae	1	1.786		

21	<i>Grewia bicolor</i>	Tiliaceae	2	3.571		
	<i>Grewia ferruginea</i>					
23	<i>Maerua angolensis</i>	Capparidaceae	1	1.786		
24	<i>Maytenus arbutifolia</i>	Celastraceae	2	3.571	1	5
	<i>Maytenus senegalnesis</i>					
25	<i>Myrsine Africana</i>	Myrsinaceae	1	1.786		
26	<i>Opuntia ficus</i>	Cactaceae	1	1.786		
27	<i>Rhus glutinosa</i>	Anacardiaceae	2	3.571	1	5
	<i>Schinus molle</i>					
28	<i>Rumex nervosus</i>	Polygonaceae	1	1.786	1	5
29	<i>Schim perianum</i>	Rubiaceae	1	1.786		
30	<i>Stereo spermum</i>	Bignoniaceae	1	1.786		
31	<i>Terminalia brownie</i>	Combretaceae	1	1.786		
32	Rhamanaceae	Rhamanaceae	1	1.786	1	5
33	<i>Olea europaea</i>	Oleaceae			2	10
			2	3.571		
			56	100	20	100

#### 4.2 Woody plant species Diversity, Richness and Evenness

Based on the Shannon-Wiener diversity index the calculated value of species diversity and evenness in the enclosure were 3.92 and 0.97 respectively. According to Kent and Coker (1992), ratings, the result of the present study showed that the Debrehiwet enclosure has an even species

distribution. This result was also in agreement with the studies of Kibret (2008) in the KalluWoreda forest of southern Wello. However, in the grazing sites adjacent to the exclosure the Shannon-Wiener diversity and evenness indices were 2.75 and 0.91 respectively, indicating lower species diversity in the grazing area than the exclosure. This could result from repeated habitat disturbances in the grazing area due to the frequent and intensive interference of both humans and livestock for grazing.

The higher diversity indices of Shannon indicated that there was better species diversity in the exclosure than the grazing area due to protection from environmental interference. Thus, the exclosure has more diverse and evenly distributed compared to the grazing area. The species evenness in the exclosure was higher than in the grazing site (Table2). This shows that protection of the exclosure from human and animal disturbance helps individual plant species to have better regeneration and abundance than the grazing area where there was repeated human and livestock interference. As evenness compares the similarity of the population size of each of the species present that it was a measure of the relative abundance of the different species making up the richness of an area Kibret (2008). A low value of evenness indicates that the one or a few species were highly dominant, while others were present with few individuals..

Table 2: Comparison of various diversity indices of woody plant species in the Exclosure and grazing areas.

Diversity indices	Exclosure area	Grazing area
Shannon (H')	3.92	2.75
Evenness (J)	0.97	0.91
Species richness (S)	56	20

#### 4.2.1 Vegetation Structure of woody species

The Pattern of diameter class distribution is an indication of the general trends of population dynamics and recruitment processes of a given species. Based on this, population structures of forests have showed different patterns, such as reversed J-shaped and hampered shape (Anteneh and Sebsibe (2011). These frequency distribution patterns exhibits the recruitment capacity and healthiness of the forest (Molla *et al.*, 2009; Borah *et al.*, 2014). Various reports in Ethiopia, stated that the healthy regeneration status of natural forests have a pattern of inverted J-shape Distributions forests.(e.g. Getachew *et al.*, 2010).

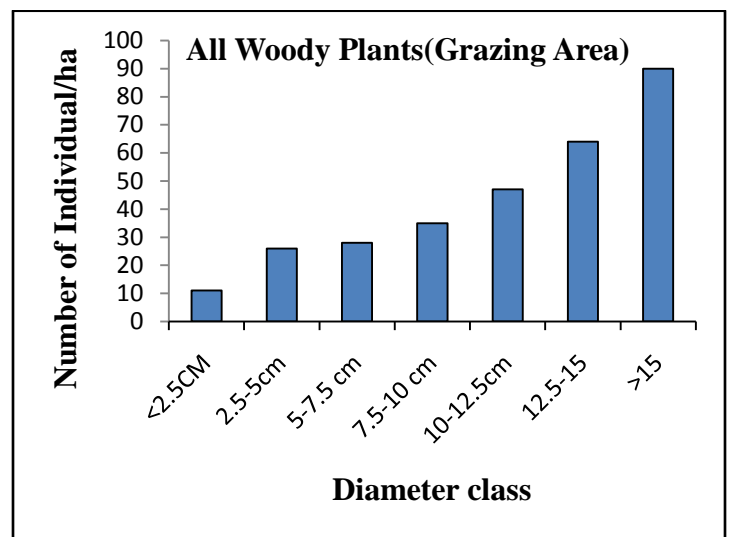
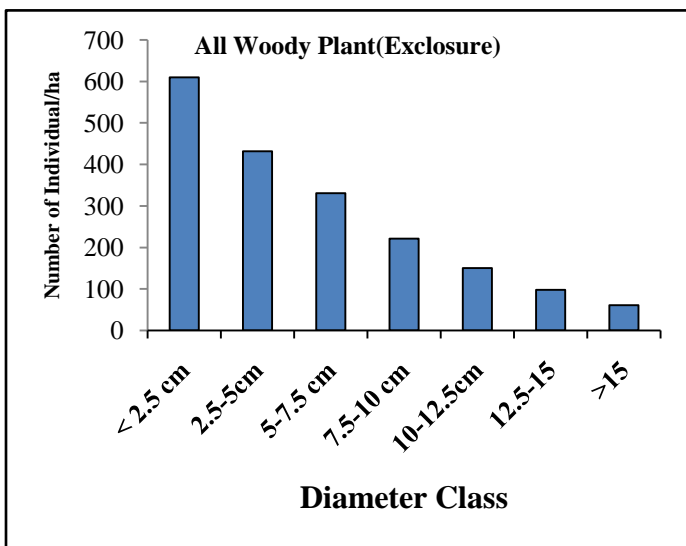
Conversely, disturbed forest showed irregular or hampered shape. In this study, at population level, the diameter class distribution shows an inverted J-shape distribution for the Debrehiwet or danguar exclosure. This general pattern shows the majority of species had considerably higher number of individuals at relatively low diameter class with gradual decrease towards next higher diameter classes. It illustrated that, the number of seedlings and saplings were higher than trees/Shrubs in exclosure (Table 3) which reveals active seed recruitments and growth. Similar results were also reported in exclosure by (Abrham *et al.*, 2011) and Mohammed *et al.*, 2015). The population structure of the Debrehiwet (Danguar) exclosure indicated that exhibited a healthy population dynamics. Such a population pattern is a characteristic of natural forest of Ethiopia (Alemnew *et al.*, 2007; Abyot *et al.*, 2014). On the Open site, the population structures exhibited irregular pattern, this resulted from over grazing and cutting of the woody species. Every seedlings and new rising branches may be trimmed by cattle and by the local people because of the fact that it is freely accessed. The population structure helps to study the regeneration pattern of a species (Swamy *et al.* 2000).

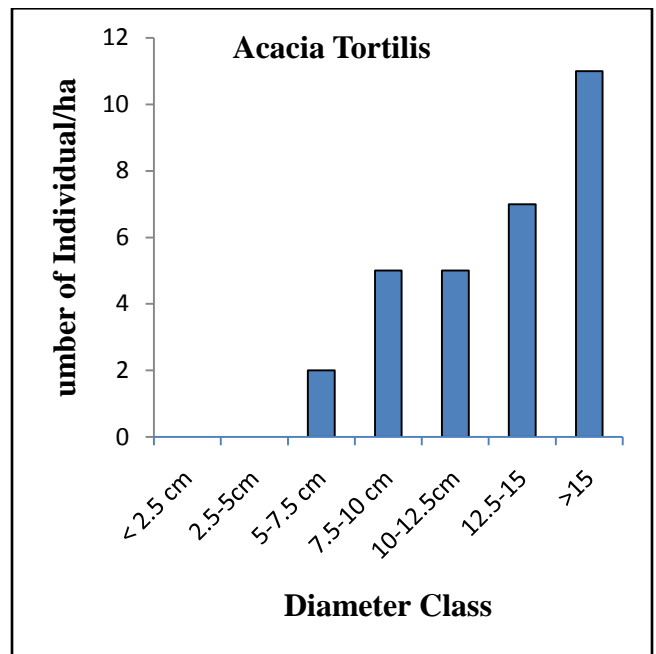
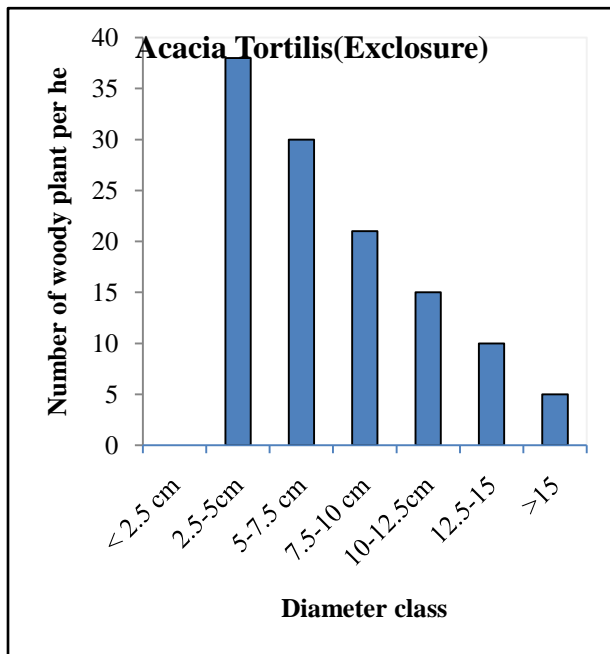
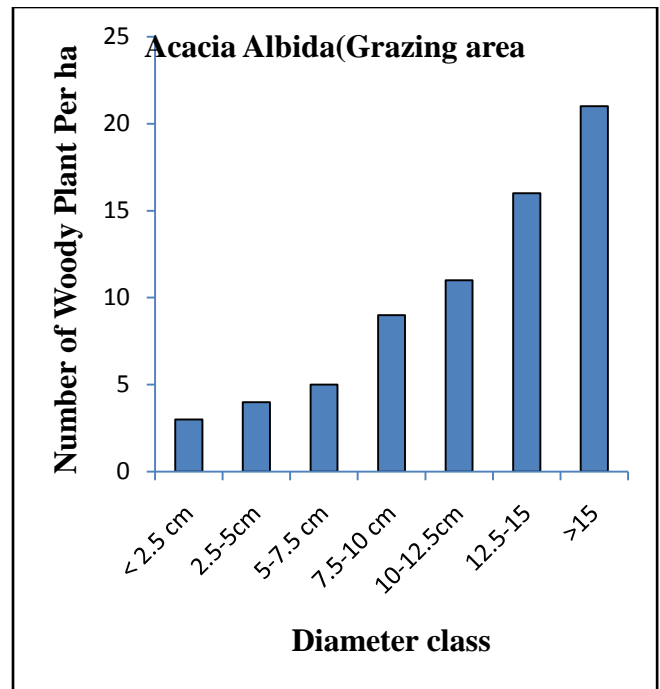
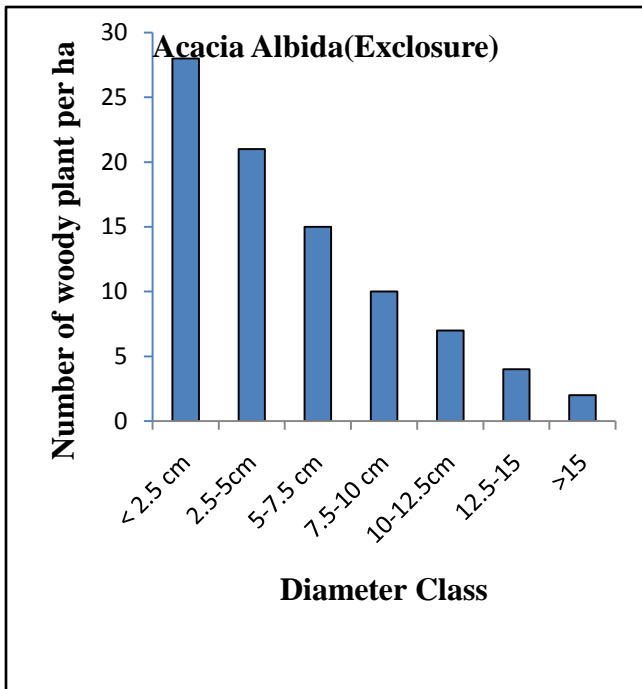
Height and DBH measurements were used to construct the density distribution for the various categories. The distribution of trees in different height classes is shown in Fig.4. A considerable proportion of the individuals (32.1%) belong to the lowest height classes i.e. (<2m). Only few individuals (3.2%) attain heights of more than 20m. DBH measurements reveal a trend similar to that of the height distribution. Most individuals have a diameter less than 20 cm (86%). About 34.3% belong to the lowest diameter class (<2 cm), and 22.7 % to the next higher class (2.5-5 cm). Only 0.3 % has DBH greater than 40 cm. The result confirms that the number of individuals decreases as the height and DBH of the individual's increase.

The mean basal area of the woody species was higher in an exclosure area and lower in the grazing land. This shows that higher diameter class vegetation was higher in exclosure area than grazing area which means there was high vegetation growth rate in the exclosure area. The population pattern of the woody species in the exclosure was an indication of health regeneration. The observed pattern in Figure 3 where most individuals in the smaller size classes, and where they decrease in number progressively towards big size classes suggests the presence of stratification in the exclosure area which shows inverted J shape. This pattern implies that the area exclosure vegetation had good reproduction and regeneration potential. *Eucalyptus globulus* Labill contributes most to the largest height class of closed area, while *Maytenus arbutifolia* contributes most to the lower height class of closed area.

The diameter distribution of the plants for all woody species show higher number of individuals in the lower diameter class than the higher diameter class in the area exclosure. There were a relatively higher number of individuals with lower diameter class than higher diameter class in the grazing area. The high proportion of seedlings shows a self-maintaining population structure implying the probability of being the main species in the recovery of the woody community

(Emiru Berhane, 2002). More than 85% of the forest population had a diameter distribution of less than 20cm. the exclosure had possessed the highest number of individuals of trees than the grazing area. In general, excluding communal lands from domestic animal and human interferences enhances good regeneration and growth of woody species.





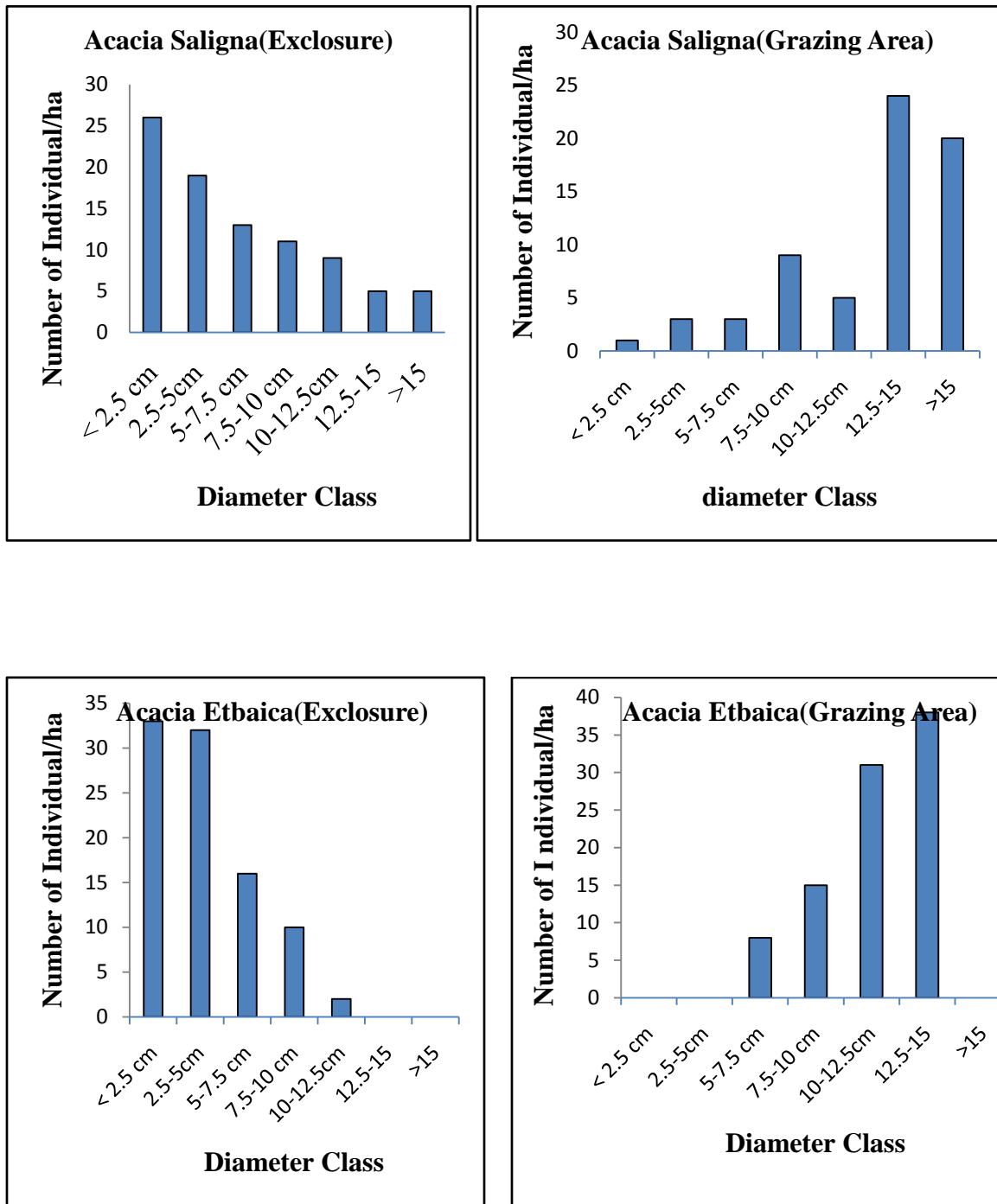
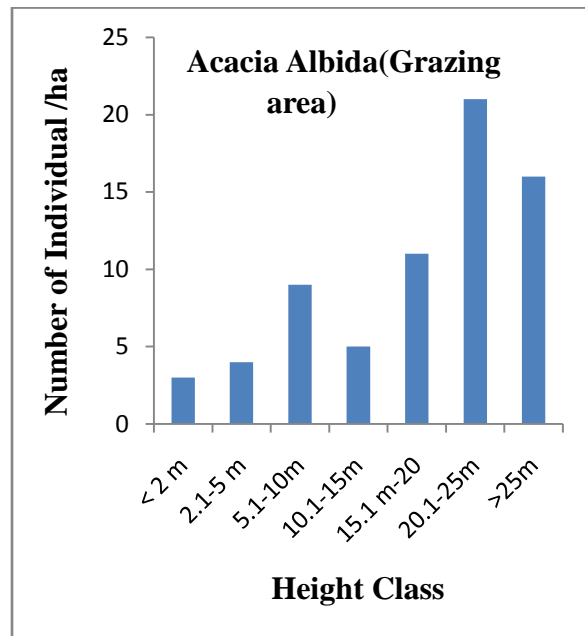
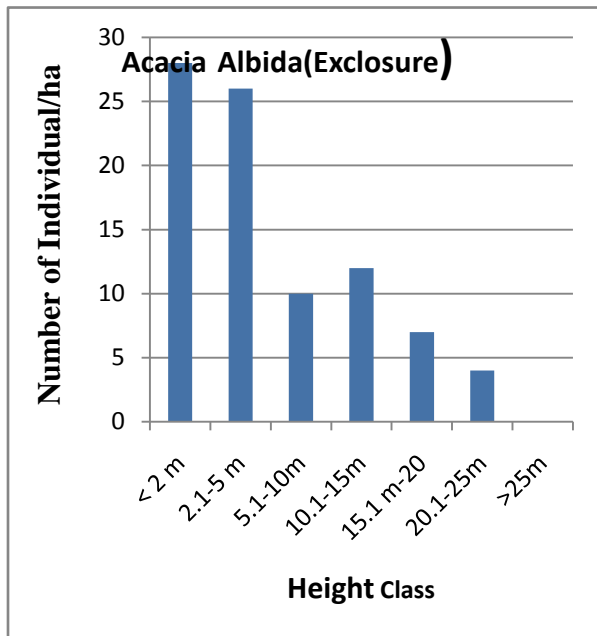
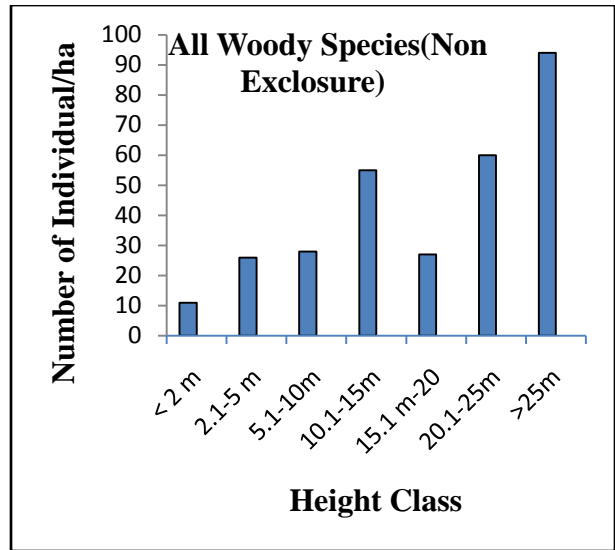
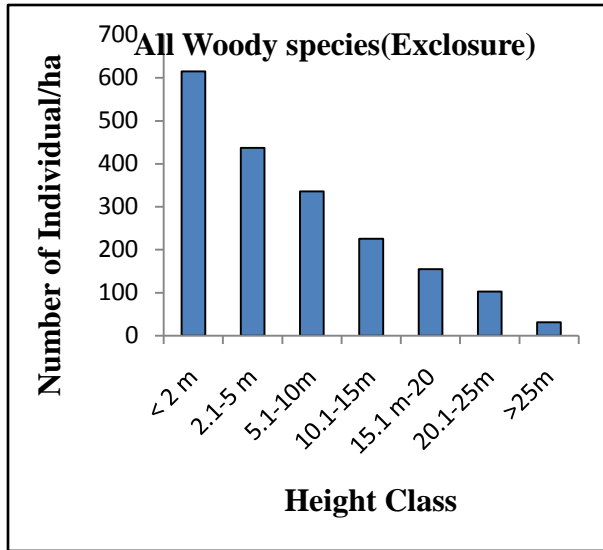
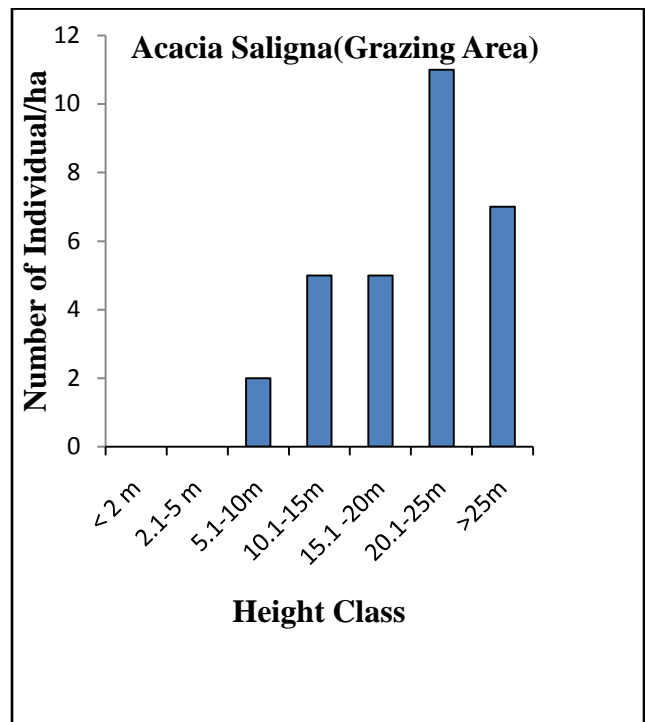
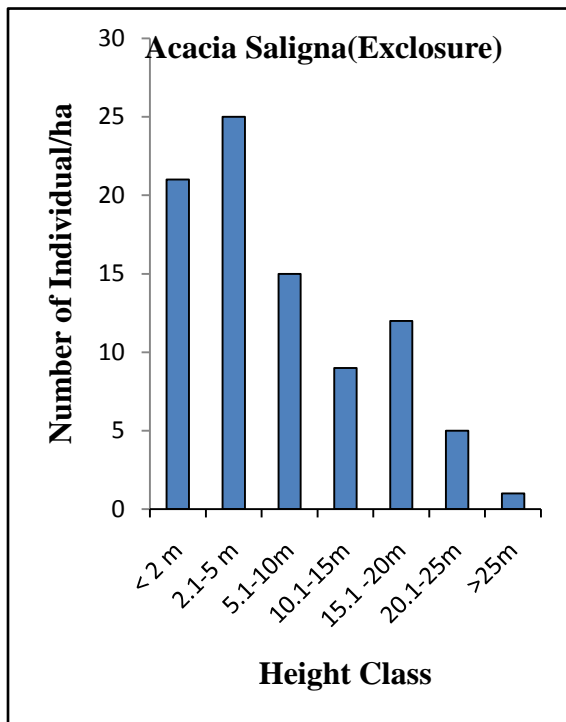
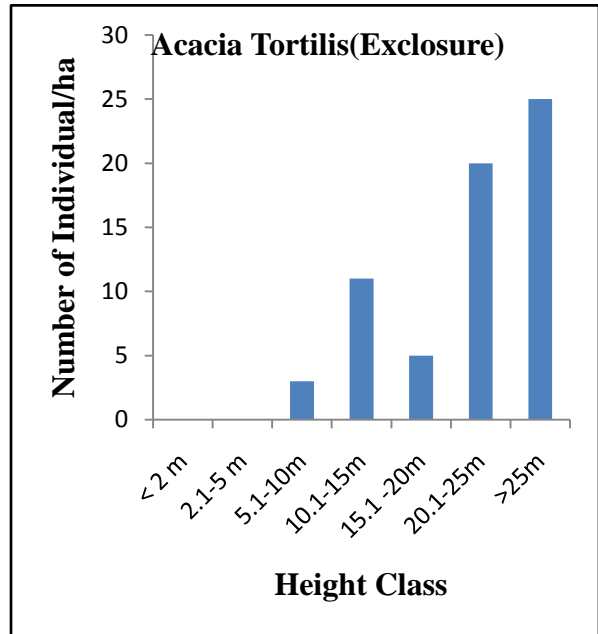
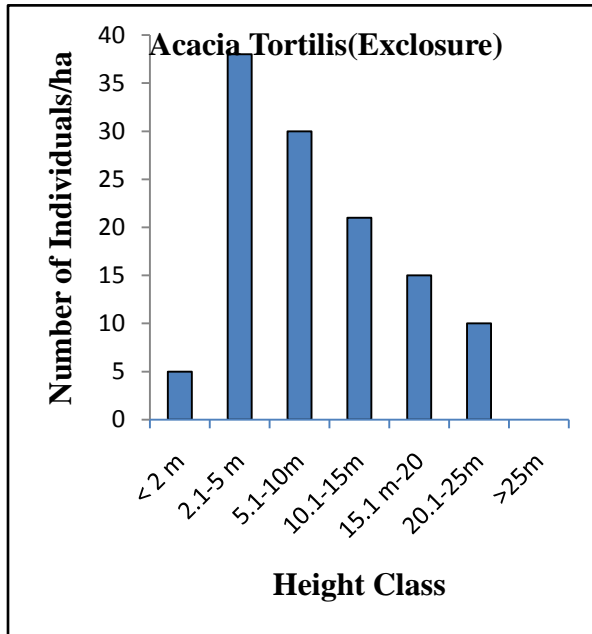


Figure 3: woody plants Diameter class in area exclosure and grazing area. In the above (Figure 1, 2& 3), the population structure for all exclosures exhibited an inverted J-shape pattern than the adjacent non-exclosures which is hampered or showing irregular pattern. Which mean higher density occurred in the lower class (seedling, saplings and some shrubs) and numbers of large trees considerably decline in the higher diameter classes?





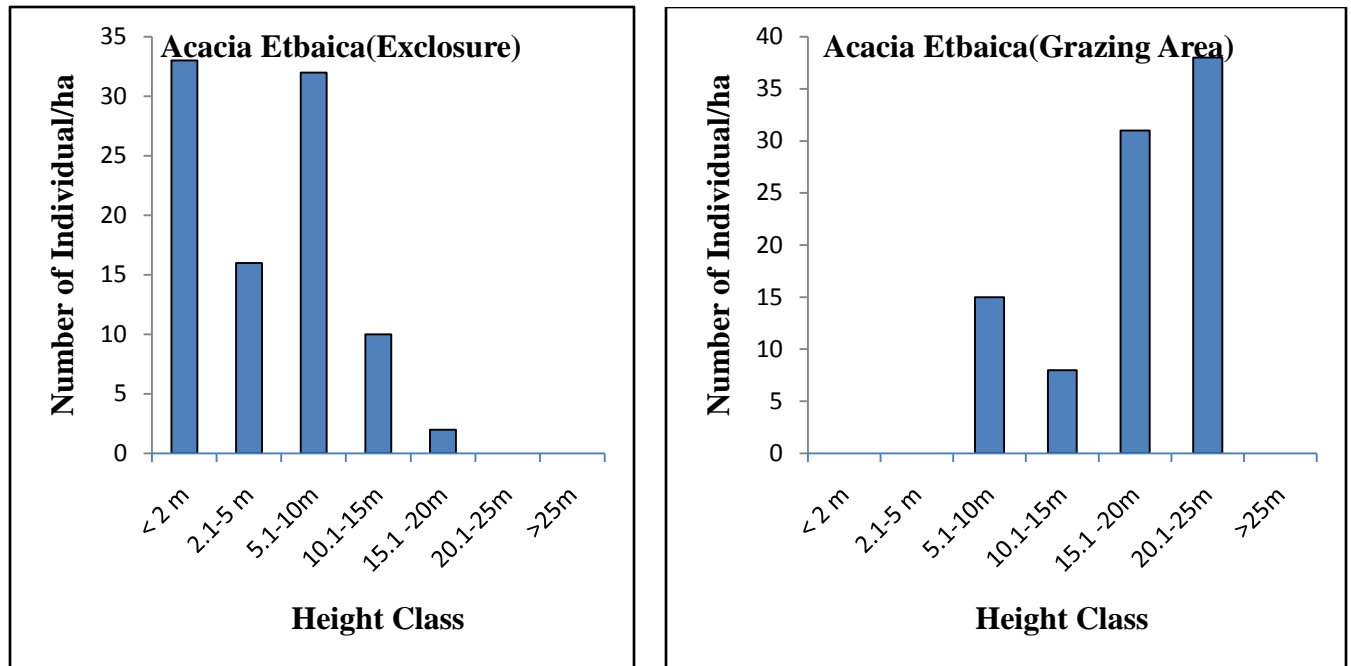


Figure 4: Woody plants height class in area Exclosures and grazing lands

Thus the study confirms that the number of individuals decreased as the height of the individuals increased indicating long time disturbance in the exclosure site. Such result was also observed in Chilmo forest by Tamrat Bekele (1993).in the open site, the number of individuals decreased as the hight of the individual decreased.

Distribution of individuals at different DBH classes also showed a similar trend as that of height class distribution. It indicates the dominance of small-sized individuals in the exclosure. The pattern of such individual can be an indicator for regeneration of the plant species in the exclosure. The total number of trees in each DBH classes decreased with an increase in DBH classes in the exclosure site. This relationship also was observed in Dessa forest by Gebremedhin (2000); in Chilmo and Menagesha forests (Tamrat, 1993).

#### 4.2.2 Woody Species Regeneration Status

Plotting woody plant frequency using parameters such as density Vs diameter or height Vs density is common practice and important to see the status of forest ecosystem health. The regeneration status of the woody species in Debrehiwet was determined. A total of 710 Seedlings/ha, 612 Saplings/ha and 581/ha Tree or mature individuals/ha in enclosure area and 37 Seedlings/ha, 85/ha Sapling and 179/ha Tree in the grazing area were recorded (Table 6). The composition, distribution, and density of seedlings and saplings are indicators of the future regeneration status of any forest (Fekadu Gurmessa, 2010). The major species in the enclosure such as *Acacia albida*, and *Acacia Tortilis* are represented by high seedling proportion. A lower proportion of seedlings of the same species in the grazing area were less promising. The total density of woody species in the enclosure and grazing land sites were 1903, and 301 individuals/hectare, respectively. The Higher density of woody species was recorded in the enclosure area as a result increases water use efficiency of plants by conserving rainwater which increases soil moisture which leads to soil seed germination and higher survival rate of emerged seedlings, the human induced disturbance and animal grazing have a strong negative effect on seed germination and seedling growth. Similar researcher work also reported that (Tefera Mengistu et al. 2005) grazed lands had less seedling density as compared to area enclosures. From the total density of woody plants in the enclosure, the proportion of seedling, sapling, and adult accounted for 37.3%, 32.2%, and 30.5% respectively.

Comparatively, the corresponding grazing area had a proportion of 12.3%, 28.2%, and 59.5% respectively. Based on the IVI of woody species, dominants species in enclosure exhibited different types of regeneration status. The visible variation observed among individual species within maybe attributed to the variation in propagation (high or low) capacity, resistances to

disturbances, seed dispersal and socio-economic value of the woody species. In addition, awareness and empowerment of the society on the potential of exclosures may improve the species regeneration capacity and specie maturation. Report by Mastewal Yami *et al.* (2012) showed that, the high expectations of long-term benefits of users from the potential of exclosures, the willingness of the majority of the users to obey their own bylaws strengthened the rule enforcement in restricting grazing and preventing wood cutting.

In this study, the absences or weakness of bylaws might have resulted in illegal cutting for household uses and considerably declined the higher diameter classes. This may also hamper the regeneration structure of some dominant species In conclusion, the regeneration of individual woody species in the studied exclosure was highly pronounced because of the site condition and extent of management.

Table 3: Total density per hectare of woody vegetations in area Exclosures and grazing lands.

Area exclosure			Grazing lands	
Form of life	total density/ha	%	total density/ha	%
Trees	710	37.3	37	12.3
Seedling	612	32.2	85	28.2
Sapling	581	30.5	179	59.5
Total	1903	100	301	100

From this result, it is possible to suggest that the difference in density of seedlings sapling and adult between the exclosure area and grazing land might have resulted from the provision of the favorable environment of low disturbance in exclosures to sustain new regenerated species and

the existed ones. In addition, the available species in the grazing land sustained probably because they had tolerance to disturbance and hence, are very important in the recovery of degraded vegetation in the area. However, still, the density of each plant category, especially seedlings in enclosure site, was far more than the grazing lands indicating the effect of management to promote woody vegetation density. It is supported by a study that states disturbance, especially overgrazing causes a reduction in palatable species leading to a reduction in plant density and impairs the natural regeneration including the development of seedlings (Bot & Benites, 2005).

#### 4.2.3 Importance Value Index (IVI)

Higher basal area, density and frequency distribution of woody species in the study site provides a better measure of the relative importance of the species than simple stem count. Importance value index combines data for three parameters (relative frequency, relative density and relative dominance). That is why ecologists consider it as the most realistic aspect in vegetation study (Fekadu Gurmessa, 2010). *Acacia albida* (35.27), *Acacia tortilis* (30.28), *Acacia Saligna* (26.92) *Accacia etbaica* (25.62) and *Eucalyptus globulus* Labill (11.54) in the enclosure area and *Acacia albida* (27.95), *Acacia abyssinica* (25.90), *Acacia Salina* (19.86), *Accacia etbaica* (16.75) and *Dodonoaangustifoha/ angustifolia* (10.92) in the grazing area have high IVI value. The reason why they have the highest IVI value is that they had the highest Relative Dominance. that means the enclosure, which is May the total basal area is contributed by the higher basal area of *Acacia albida* (35.27 %). The higher contribution of these species may show the occurrences of the species during the early enclosure establishment, resistance to disturbances and growth of the species.

And also the occurrence of high number of trees/shrubs in the enclosures increases the value of the basal area than the non-enclosures. This indicated that enclosures are found in early succession and in advanced stage of development than non-enclosures. Species like *Agave sisalana* (2.20), *Calpurnia aurea* (2.27)

and *Buddleja polystachya* (3.86) in the exclosure site and *Rumex nervosus* (2.11), *Echinopis hispidus* (2.17) and *Aloe Vera* (2.19) in the grazing site each have the lowest IVI value. The result indicates that much of IVI was attributed by few species. These species were those well adapted to the high human pressure (disturbance), natural and environmental factors. Species like *Acacia albida* having high IVI are dominant in the study area where as species like *Rumex nervosus* that had the least IVI which are the least dominant. Relative frequency, relative density and relative dominance are expressed the important value index (IVI) of one woody species which indicated the dominance (Neelo *et al.*, 2013). And Species with the largest contribution in basal area, abundance, density and frequency distribution can be considered the most important woody species in the three exclosures and adjacent non-exclosures.

Table 4: Importance Value Index of the most dominant woody species of the study area.

Exclosure area					Grazing area			
Scientific name	RD	RF	RDO`	IVI	RD	RF	RDO`	IVI
Acacia abyssina	1.91	2.52	2.783	7.221	14.40	9.46	2.043	25.903
Acacia albida	3.91	3.40	27.960	35.271	14.70	9.36	3.785	27.945
Acacia tortilis	3.31	3.29	23.680	30.282	4.41	3.45	3.063	10.923
Acacia saligna	3.38	3.18	20.790	26.920	11.4	6.40	2.000	19.860
Eucalyptus globulus	2.97	2.21	6.409	11.543				
Eucalyptuscamaldulensis	1.65	1,76	1.839	5.254	-	-	-	-
Dodonoa angustifoha	3.46	2.63	1.333	7.414	3.82	5.42	2.555	11.795
Accacia etbaica	3.01	3.07	19.370	25.621	7.05	5.91	3.785	16.745
Otostegiaintegla	3.16	2.63	1.897	7.693	-	-	-	-
Ficus vasta	1.43	1.67	1.260	5.440	2.06	2.96	3.109	8.129
MyrsineAfricaa	3.00	2.20	2.073	7.275	-	-	-	-
Jasminum abyscum	1.39	1.43	5.464	8.280	3.23	3.94	1.700	8.870

RD=Relative Density RF= Relative Frequency RDO=Relative Dominance

IVI=Important value index

#### 4.2.4 Plant Communities

Three plant community types were identified from the hierarchical cluster analysis in the study site (**Fig. 6**). The plant analysis was derived from the abundance data of species. Following plant communities have been named by two dominant species based on highest mean cover/abundance value within a cluster. Giving Priority to trees and shrubs, the description of the plant community types with their altitudinal distribution is provided below.

##### **1. *Acacia albida* \_\_*Ziziphus spina-christi* community type**

This community type is the most species rich of the communities found in the study area. . It consists of 31 plots and 104 species. The altitudinal range of this community was from 2032 to 2052 m.a.s.l. The upper canopy was occupied by *Eucalyptus globulus* Labill, *Leucena leucocephala*, and *Terminalia brownie*, *Terminalia brownie*, *Dichrostachys cinerea*, *Stereospermum –kunthianum*, *Myrsine Africana*, *Croton macrostachyus*, *Acacia saligna* were the common Trees species in this Community. And *Capparis tomentosa* was the common shrub specie in this Community.

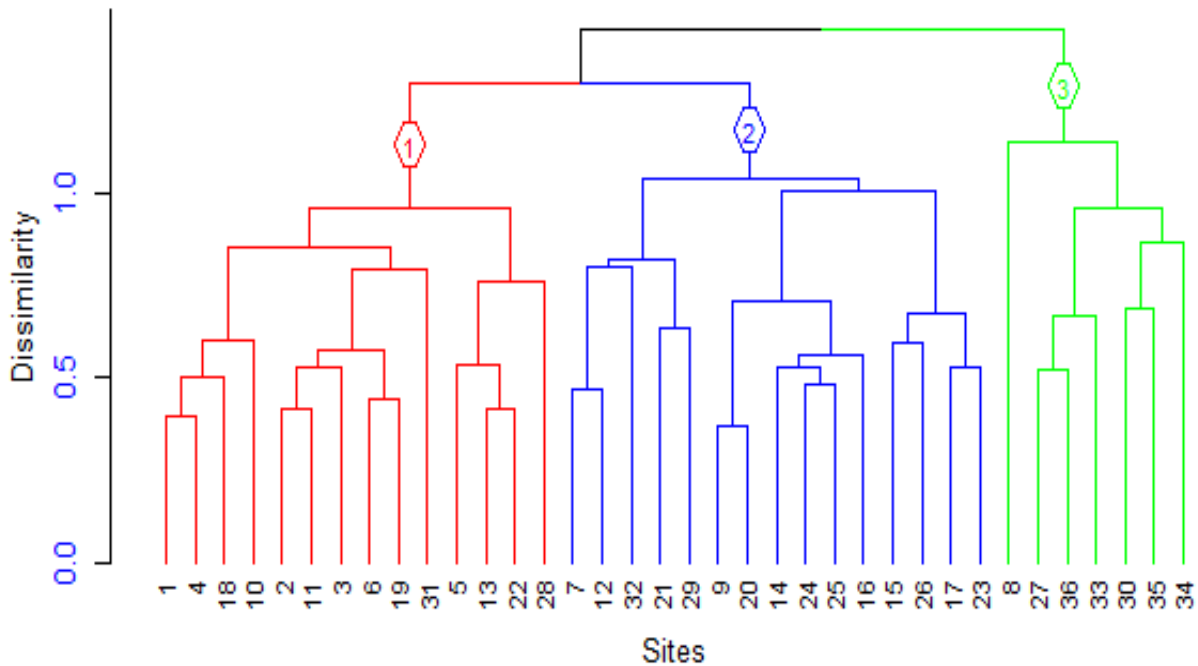


Figure5. Dendrogram of the vegetation data from Agglomerative hierarchical cluster analysis using similarity ratio

**2 *Acacia tortilis*---- *Dodonoaangustifoha/ angustifolia* community type**

It is the second richest community type in the study area. It consists of 30 plots and 88 species the altitudinal range of this community was from 2033 to 2047 m.a.s.l. The upper canopy was dominated by *Schinus molle*, *Grewia ferruginea*, *Schinus molle*, *Ehretia cymosa*, *Aloe vera* And *Maesa lanceolata* were the common Trees species in this Community. And *Echinopis hispidus* washerb and *Ptrollobium stellatum*, *Maytenus senegalnesis* were the common shrub specie in this Community.

Table 5. Synoptic cover abundance values of species in each community type.  
 Values in Bold refers to species used to name community type

Community size	Cluster 1	Cluster 2	Cluster 3
	14	14	7
Acac.albi	<b>2.71</b>	1.8	0.57
Zizi.spin	<b>1.86</b>	0.73	0.29
Euca.glob	1.86	1.47	0.29
Leuc.leuc	1.79	0.53	0.14
Term.brow	1.79	0.73	0.43
Dich.cine	1.71	0.27	0.14
Ster.kunt	1.57	1.2	0.43
Myrs.afri	1.57	1.07	0.14
Crot.macr	1.57	0.8	0.29
Acac.sali	1.57	0.87	0.29
Capp.tome	1.36	1.07	0.14
Acac.tort	1.07	<b>2.13</b>	0.14
Dodo.angu	1.64	<b>1.73</b>	0.14
Echi.hisp	0.29	1.67	0.14
Schi.peri	0.5	1.53	0.43
Pter.stel	0.5	1.47	0.57
Grew.ferr	0.71	1.4	0.43
Schi.moll	1.29	1.33	0.29
Mayt.sene	0.71	1.13	0.29
Aloe.vera	0.71	1.13	0.29
Ehre.cymo	0.43	1.27	0.29
Rhus.nata	0.43	1.2	0.14
Eucl.race	1.29	0.27	<b>1.43</b>
Budd.poly	1.07	0.87	<b>1.29</b>
Opun.ficu	0.36	0.6	1.29
Euca.cama	1.43	1.2	1.14
Acac.abyss	1	1.27	0.86
Calp.aure	1	1.27	0.86
Bers.abyss	1	1.27	0.86
Cord.afri	1.14	0.4	0.71
Grav.rob	1.57	0.27	0.71
Acac.etba	1.57	1.33	0.57
Otos.frut	0.29	0.87	0.71
Cass.amal	0.07	1.2	0.71
Astr.atro	0.5	0.53	0.71

### 3. *Euclea racemosa* subsp. *Buddleja polystachya* Community type

The altitudinal range of this community was from 2234 to 2605 m.a.s.l. It consists of 10 plots and 39 species. The upper canopy was dominated by *Eucalyptus camaldulensis* Dehnh, *Acacia abyssinica*, *Cordia africana*, *Acacia etbaica*, *Acacia tortilis*, *Gravillea robusta* and *Cassipourea malosana* were the common Trees species in this Community. and *Opuntia ficus-indica*, *Otostegia fruticosa*, *Astragalus atropilosulus* and *Bersama abyssinica* were the common shrub specie in this Community.

#### 4.2.5 Species diversity, richness and evenness of the plant communities

Shannon's diversity indices showed, Community 1 had the highest species diversity followed by communities 2 and 3 (Table 10). On the other hand, Community 1 had the highest number of species (104) and Community 2 the lowest (88). Community 1 followed by communities 2 had the highest evenness value. While, Community 3 had the least evenness value.

Table 6: Species diversity, richness and evenness of the plant communities

Community	Altitudinal range	Species richness(S)	Shannon-Wiener Diversity(H)	Shannon-Evenness(J)
1	2032-2052	104	3.89	0.72
2	2033-2047	88	3.53	0.65
3	2034-2051	34	3.19	0.59

### **4.3 Local community perception on land degradation**

The local community perceived that land degradation, mainly soil erosion was a major challenge in their locality and its impact was very severe. Accordingly, soil erosion, deforestation and lack of fodder were the most common land degradation types in the area by their degree of severity. And also various possible causes of land degradation and stressed that Overgrazing, Charcol making and Constraction materials were believed to be possible causes of land degradation in the site. However, none of the households pointed that population growth, drought, and soil characteristics as possible causes of land degradation. Communities' awareness about the possible causes and existence of land degradation may be a basis to alleviate the problem. However, it might be due to the perception of local community that considering large family size as an asset and labor force for agricultural activities in rural Ethiopia, respondents did not recognize population growth as possible cause to land degradation. This calls for continuous education to raise peoples' attitudes. Similarly, studies conducted in northern Ethiopia reported that a rapid population growth causes a negative impact on agricultural land and in turn declines the carrying capacity of the environment (Ejigu Belay, 1999).

### **4.4 Local communities' perception on area cxlosures**

The communities' Attitude towards the existence of area enclosure in their locality is positive. The reason for that is that they are getting the benefit, especially fodder from the exclosure. Fodder is the major benefit for the households for maintaining their livestock. All farmers responded that the soil quality, as well as the natural vegetation cover within the exclosure, is increased. Farmers were asked about their feeling during the establishment of the exclosure. Only a few farmers responded that they had a negative attitude towards the establishment of the

area enclosure in their locality. But the majority of the farmers (85%) responded that they had a positive attitude towards the enclosure at the time of establishment.

The majority had accepted the establishment of the enclosure of the area probably due to the presence of stakeholders meeting prior to the actual establishment of the enclosure. The community members participated from planning stage to implementation stage. After the establishment of the enclosure, looking the change brought on the locality, and the benefit that the enclosure has given to them, some changes on perception have seen on those farmers who had a negative attitude during the establishment of the enclosure. Farmers were asked why the enclosure is established in their locality.

All of them responded that the objective was the rehabilitation of degraded lands beside to tackling of further environmental degradation in their locality. Most of the community members showed interest in further conservation and establishment of enclosures as the main option to tackle the problem of land degradation in the area. Farmers' perception is supported by studies made in Tigray that state irrespective of the increase in population size, soil and water conservation and land rehabilitation efforts such as enclosures resulted in decreased sheet and rill erosion (Nyssen et al., 2007). Besides, studies concluded that increased vegetation density in enclosures result in increased infiltration, that in turn triggers vegetation rehabilitation through superior biomass production thereby improved land productivity including spring discharge (Nyssen et al., 2002; Wolde Mekuria et al., 2009).

It agrees with studies that state proper land management practice that maintains extensive ground cover is a guarantee to reduce soil erosion. Hence, run off and soil loss are inversely related to ground cover, vegetation cover increase surface roughness and reduce soil detachment

and transport of soil particles (Costin, 1980). Moreover, Girma Kelboro (2009) research result states that for overall vegetation rehabilitation, excluding of live stocks ensures the growth of woody vegetations which provide shelter for next generation of succession; as a result a better regeneration could be achieved by excluding of humans and animals from degraded sites (Girma Kelboro, 2009).

#### **4.5 Local communities' perception on management of Exclosure**

As explained by communities, were the extent of degradation (the more the degraded the area, it is likely to be abandoned for rehabilitation), which could be evaluated by its productivity history and sensitivity to hazards (like erosion); being marginal and communal lands to ensure common sharing of cost and benefits leading to sustainable management in the future. Respondents pointed out that the local community should be involved in decision making and bottom up approach management of area exclosures develop sense of belongingness among the community. Consequently, communities responded that for future sustainability of exclosures, demarcation should be collaborative (Local community, Kebele and Agricultural office) concluded that sense of belongingness could be developed if the management is designated to the local community after demarcation.

#### **4.6 Economic importance of the Exclosure on the Livelihood of the Farmers**

As development agents and key informants forwarded, initially the main purposes of exclosures were meant for environmental rehabilitation and as a strategy for soil erosion reduction from farmlands but later on, the communities decided to harvest and share the grasses. Grass availability of the area of the livestock notably for oxen used for plowing has significantly increased following the establishment of area exclosure.

The establishment of enclosure on previously degraded hillsides and huge gullies has significant value on the vegetation cover in the study area. Moreover, past work by Emiru, (2002) shows that area enclosure improved the vegetation cover as compared to the grazing area. Similarly, a comparative study between area enclosure and its adjacent grazing land shows that there was a significant difference between the treated and untreated land use (Haile, 2012). Enclosure is a source of firewood for local farmers at harvested at regular. Particularly, harvesting dead branches and trees for domestic energy is practiced by the nearest dwellers around the area enclosure. Moreover, the farmers revealed area enclosure provide environmental services such as microclimatic regulation and soil conservation.

#### **4.7 institutional arrangements in the area enclosure managements**

Land degradation in Ethiopia has been affected by increasing human and livestock populations, climatic variations, recurring droughts, inappropriate land use practices, and top-down resource conservation approaches. Less responsive policies have also exacerbated land degradation and heightened poverty levels. The result is a widespread degradation of the land base. A variety of conservation practices, which include terraces, soil bunds, and area enclosures, have been introduced into individual and communal lands in massive scales in Ethiopia.

Although efforts made thus far to tackle land degradation have yielded some success, there is still a long way to go to address this critical challenge in the country. The federal government and several non-government agencies have launched watershed development initiatives to tackle some of the generic problems, aiming to develop soil conservation, improve land productivity, and promote appropriate technologies for efficient and sustainable use of natural resources (Melesse, 2011). Today, there is a massive movement in watershed management in almost all regions of Ethiopia. However, watershed management has merely been considered a practice of

soil and water conservation where only technological approaches were adopted from the earlier successful projects and from the lessons related to institutional arrangements were neglected. Yet, integrated watershed management goes beyond the conservation activities. In general, watershed management creates opportunities for reclaiming degraded land, improving soil fertility, water resources development, increasing agricultural production, off-farm activities, diversifying income sources and providing access to markets, where the benefits are realized at household and community level. The most common land management technologies that have been practiced in the watersheds include soil and stone bunds, hillside terraces, deep trenches, check dams, diversion ditches and sediment storage dams. Soil fertility improvement measures, such as the use of compost and nutrient-fixing plants, are mostly used on cultivated lands.

It emphasizes strengthening local institutions, income-generating activities through alternative sources and creating markets to improve financial livelihoods. The existing institutional arrangements for watershed development programs have been hierarchical in nature. They include higher level entities, which are engaged in planning, coordination, and control, and the grassroots-level entities that operate closer to the farming community. In the hierarchical structure of Ethiopia's Federal Ministry of Agriculture (MoA), development agents (DAs) are the responsible persons at the kebele or community level for the direct implementation of the components. Generally, village-level institutions do have the required managerial capabilities to coordinate the complexities that are involved in the natural resources.

## 4.8 Soil nutrient and quality data

Soil fertility is the ability of a soil to sustain plant growth by providing essential plant nutrients and favorable chemical, physical and biological characteristics as a habitat for plant growth (FAO, 2019c). Plants require essential nutrients to complete their life cycle (Hodges, 2010). A healthy soil functioning at nearly full capacity stores and cycles nutrients and allows crops to grow and use nutrients efficiently. Soil quality integrates the physical, chemical, and biological components of soil and their interactions. The integral concept of soil fertility encompasses physical, chemical, and biological properties, as well as the confluence of soil components including water, air, minerals, and biota. Among the soil parameters investigated, the variables that showed significant differences were soil organic matter, soil CECs, soil moisture and exchangeable  $\text{Ca}^{2+}$  (Table 5). There was higher Organic matter content in the soils taken from the Enclosure than the Grazing area site. The reason for soil organic matter accumulation in the enclosure site could be the higher vegetation coverage of enclosure which results in higher litter input and thus higher accumulation of organic matter in the soil (Sachs, 1999; Bot and Benites, 2005).

The table shows some examples of those processes. Therefore, to capture the holistic nature of soil quality or health, all of the parameters should be measured. Soil quality is simply defined as “the capacity of a specific kind of soil to function.” It is generally assessed by measuring a minimum data set of soil properties to evaluate the soil’s ability to perform basic functions (i.e., maintaining productivity, regulating and partitioning of water and solute flow, filtering and buffering against pollutants, and storing and cycling nutrients). This guide describes a measure of selected field procedures to evaluate or indicate the level of one or more soil functions.

Table 7: Mean value comparison for physical and chemical variables of soil between the enclosure and the grazing site.

Soil parameter	Exclosure area	Grazing area	P. value
Sand (%)	50.43±1.21	56.14±1.72	0.021
Silt (%)	28.29±2.80	24.43±1.80	0.273
Clay (%)	21.29±1.76	19.43±2.50	0.555
Bulk density (g/cm <sup>3</sup> )	1.6±0.1	1.8±0.7	0.157
Moisture content (%)	3.26±0.55	1.56±0.12	0.021
electric conductivity	0.05±0.01	0.05±0.00	0.395
PH-H <sub>2</sub> O	6.90±0.05	6.57±0.12	0.032
Exchangiable Na meq/100g	0.16±0.01	0.12±0.01	0.003
Exchangiable K meq/100g	0.67±0.02	0.56±0.03	0.010
Exchangiable Ca meq/100g	21.57±0.44	20.70±0.43	0.184
Exchangiable Mg meq/100g	10.88±0.46	10.63±0.30	0.654
Organic matter content (%)	3.56±0.28	2.24±0.04	0.003
CECmeq/100g	39.10±0.56	36.53±1.18	0.084
Avialable Phosporos (ppm.)	12.31±0.34	11.51±0.39	0.149
Total nitrogen (%)	0.17±0.02	0.14±0.03	0.433

Regarding to textural classes soil containing 20 % to 30 % clay are clay loams i.e. clay loam (From 20 % to 50 % silt and 20 % to 50 % sand) (Brade-Birks 1947). Based on the percentages of clay, silt and sand compositions, the textural classes of the soils of the two sites belongs to clay loam. However, clay and silt percentage in the exclosure site was higher than in the open site, whereas sand percentages were higher in the open site than in the exclosure.

These textural differences may reflect the difference in soil erosion rate between the two sites. The higher clay content in the enclosure means that there is relatively low soil erosion in the site, while the lower clay in the open means there is relatively higher soil erosion (particularly sheet erosion) at the open site, which may reflect the differences in their vegetation cover. The presence of good vegetation covers reduce erosion through various mechanisms such as addition of organic matter and surface litter, and thus improve soil coherence, soil anchoring through root system, and physical blockage, and thus reduction of surface run off (Skarpe, 1991).

Among the soil parameters investigated, the variables that showed significant differences were soil organic matter, soil CECs, soil moisture and Exchangeable Ca<sup>2+</sup> (Table 5). There was higher organic matter content in the soils taken from the enclosure than the open site. The reason for soil organic matter accumulation in the enclosure site could be the higher vegetation coverage of enclosure which results in higher litter input and thus higher accumulation of organic matter in the soil (Sachs, 1999; Bot and Benites, 2005). In fact the higher clay content of the soil of the enclosure site might have also contributed to a higher accumulation of organic matter in the soils of the enclosure site. Several studies have proved that the positive correlation between organic matter and clay content, and this depends on two mechanisms.

First, bonds between the surface of clay particles and organic matter retard the decomposition process. Second, soils with higher clay content increase the potential for aggregate formation; physically protect organic matter molecules from further mineralization caused by microbial attack (Wild, 1993; Rice, 2002). For example some of the soil properties influenced by organic matter include soil structure, moisture holding capacity, diversity and activity of soil organisms (Max et al., 1996).

According to Hudson (1994) for each 1 percent increase in soil organic matter, the available water holding capacity in the soil increased by 3.7 percent. Similarly, the soil in the enclosure site showed higher in CEC than the soil in the open site. This could be attributed to the higher soil organic matter and clay percentage of the soil in the enclosure site (Table 6). Soil CEC is associated with clay and organic matter colloids, and especially organic matter renders soils a better CEC (Wild, 1993; Max et al., 1996). Thus, slight difference in organic matter can make a big difference in soil CEC as observed in this study.

Organic matter accumulation means more nutrients recycling as shown for the significantly higher available  $\text{Ca}^{2+}$  in the soils of enclosure site. Soil with high organic matter and clay has more exchange sites and high CEC (Sachs, 1999). Soil pH in both sites grouped in neutral pH scale. The neutrality of pH of the soil in the enclosure may be attributed to lower break down of the soil organic matter due to higher clay percentage. There is no significant difference in the soils in the soil pH except in the slight variation between the two sites. The total nitrogen (total N), available P, exchangeable K, exchangeable Mg, and clay percentage were relatively higher in the enclosure site.

The higher values of total N and exchangeable cations could be attributed to the nutrient cycling role of increased biomass in the enclosure site (Wild, 1993), as well as improved organic matter content (Hodges and Plank, 1988). In fact, the two colloidal substances (clay and OM) are essentially the cations' warehouse or reservoir of the soil and are very important because they improve the nutrient and water holding capacity of the soil (Sachs, 1999).

## **5. Conclusion and Recommendation**

### **5.1 CONCLUSION**

The results of the study demonstrate that enclosure is a viable option to restore woody vegetation composition. The Enclosure has contributed to the restoration of the communal lands by improving ecological variables such as richness, density, basal area and diversity. Population structure and recruitment potential in the Enclosure was noted healthier as and higher than the Grazing area. There fore, land excluding from anthropogenic disturbances and extended protection have a determining effects on the restoration of woody species. The result of the study indicated that the enclosure had high species diversity that was 56 woody species that belong to 33 families.

Among these Fabaceae was the most dominant family with 9 species, followed by Myrtaceae, the second dominant famiy. In the grazing site also 20 woody plant species belonging to 14 families were identified. Fabaceae was also found to be dominant family with 6 woody plant species. The comparison made between area enclosure and the grazing area showed that composition, density, richness, diversity of woody species and structure difference were higher in the enclosure than the grazing area. The enclosure was more diversified and evenly distributed. The variation in species diversity, richness and evenness between two sites could be due to human and livestock interference in the open site. Sapling and seedlings were highly diversified and evenly distributed in the enclosure due to this the enclosure was at high rate of regeneration status. Results of the present study clearly demonstrated that area enclosure can contribute to rehabilitation of degraded areas in a relatively short period of time, while contributing to improved livelihoods of local community. And enclosure can achieve the rehabilitation of both vegetation coverage and soil quality. The status of rehabilitation in the grazing area was in poor

condition due to increased grazing pressure while the status in the exclosure area was in a good condition as a result of reduced disturbances. The regeneration of plant species was increasing in the exclosure and the restoration of the soil quality in the exclosure area was rated successful when compared to the grazing area. The Exclosure showed significantly higher soil organic matter (OM), organic carbon (OC) total soil nitrogen content (N), moisture, exchangeable Calcium (Ca), Exchangeable Magnesium (Mg) and CEC than the grazing lands. The higher values of vegetation diversity and soil fertility content in exclosures indicate that exclosure are one of the viable options to restore degraded soils. Based on the increased vegetation cover and improved soil conditions of the exclosure, it is possible to conclude that the establishment of area Exclosure in the degraded lands is aviable option for soil physicochemical properties improvement and biodiversity conservation. Local communities are aware that exclosures generate socioeconomic benefits. Such perception is a base mark for future sustainability of the practice.

## 5.2. Recommendation

In order to strengthen the sustainable protection and enhance the potentials of exclosure the following recommendations are forwarded:

- ❖ In these exclosures, woody species composition depends on the sustainable protection and conservation. To address these determinants successfully, awareness creation, empowerment and incentives to the local community should be practiced by the concerned bodies (e.g. local governments and NGOs).
- ❖ The exclosure should have also clear and well organized operational manual in order to manage effectively, there should be alternative livestock management systems like tethering, instead of letting livestock to move freely, this will reduce overgrazing and increase land productivity in order to increase soil nutrient level in adjacent grazing lands.
- ❖ Impact of selective cutting and competition from dominant species on the rarity and/or poor recruitment of some species in the exclosure require scientific management intervention (such as silvicultural operation and enrichments) and strong protection should be implemented in the exclosure.
- ❖ This research addresses only the impacts of exclosures on woody species, above-ground woody biomass and carbon potential (AGC and SOC) in a single period of data collection. To scale-up and diversify the relevance's of these exclosure, further supports through research findings on their potential will be needed. Future researches in areas such as species specific growth potential of woody species in the exclosures to determine the actual long term potentials of exclosures in biomass, carbon storage and assessments to understand the carbon trading potential are encouraged.
- ❖ For addressing the environmental problems as well as socio-economic benefits by establishing exclosures, collaboration among concerned bodies, mainly office of agriculture, local extension workers, administrative bodies and active participation of the local people, etc., is quite indispensable.

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## 7. Appendices

### APPENDICES I. List of species identified in the Exclosure

Scientific Name	F.name	Local name	Form of Life
<i>Acacia abyssinica</i>	Fabaceae	Tsaeda chea	Tree
<i>Acacia albida</i>	Fabaceae	Momona	Tree
<i>Acacia saligna</i>	Fabaceae	Akacha	Tree
<i>Acacia tortilis</i>	Fabaceae	Chea	Tree
<i>Accacia etbaica</i>	Fabaceae	Seraw	Tree
<i>Agave sisalana</i>	Agavaceae	Eiqa Tliyan	Shrub
<i>Aloe vera</i>	Aloeaceae	Ere	Shrub
<i>Astragalus atropilosulus</i>	Fabaceae	Tetem-Agazen	Shrub
<i>Azadirachta indica</i>	Azadirachtaceae	Nim	Tree
<i>Bersama abyssinica</i>	Melianthaceae	Mirkuz-zibe	Shrub
<i>Buddleja polystachya</i>	Loganiaceae	Metere	Tree
<i>Calpurnia aurea</i>	Fabaceae	Hitswuts	Tree
<i>Capparis tomentosa</i>	Loganiaceae	Andel	Shrub
<i>Carissa edulis</i>	Apocynaceae	Agam	Shrub
<i>Cassipourea malosana</i>	Rhizophoraceae	Keyh -om	Tree
<i>Clematis hirsute</i>	Ranunculaceae	Hareg-hazo	Climbing Shrub
<i>Clerodendron myricoides</i>	Lamiaceae	Shewha	Shrub
<i>Cordia africana</i>	Boraginaceae	Awhi	Tree
<i>Croton macrostachyus</i>	Euphorbiaceae	Tambok	Tree

<i>Dichrostachys cinerea</i>	Mimosoideae	Gonoq	Tree
<i>Dodonoaangustifoha</i>	Sapindaceae	Tahsos	Shrub
<i>Echinopis hispidus</i>	Asteraceae	Dander	Herb
<i>Ehretia cymosa</i>	Boraginaceae	Kirawih	Tree
<i>Erythrina abyssinica</i>	Papilionoideae	Zwawue	Tree
<i>Eucalyptus camaldulensis</i>	Myrtaceae	Keyih bahirzaf	Tree
<i>Eucalyptus globulus</i>	Myrtaceae	Tsaeda kelamitos	Tree
<i>Euclea racemosa</i>	Ebenaceae	Kuliow	Shrub
<i>Euphorbia tirucalli</i>	Euphorbiaceae	Kinchib	Tree
<i>Rhus natalensis</i>	Anacardiaceas	Atami	Tree
<i>Gravillea robusta</i>	Proteaceae	Gravilla	Tree
<i>Grewia bicolor</i>	Tiliaceae	Dawa	Shrub
<i>Grewia ferruginea</i>	Tiliaceae	Tsnqya	Tree
<i>Jasminum abyssinicum</i>	Oleaceae	Habi-tselim	shrub
<i>Jatropha carriaca</i>	Euphorbiaceae	Jatropha	Tree
<i>Leucena leucocephala</i>	Mimosoideae	Lusinia	Shrub
<i>Maerua angolensis</i>	Capparidaceae	Qeremo	Tree
<i>Maytenus arbutifolia</i>	Celastraceae	At-at	Shrub
<i>Maytenus senegalnesis</i>	Celastraceae	Argudi	Shrub
<i>Myrsine Africana</i>	Myrsinaceae	Saweria	Tree
<i>Olea europaea</i>	Oleaceae	Awlie	Tree
<i>Opuntia ficus</i>	Cactaceae	Beles	Tree/Shrub

<i>Otostegia fruticosa</i>	Lamiaceae	Sasa	Shrub
<i>Otostegia integrifolia</i>	Lamiaceae	Chiendog	Shrub
<i>Ptrollobium stellatum</i>	Fabaceae	Konteftefe	Shrub
<i>Rhus glutinosa</i>	Anacardiaceae	Tetaelo	Tree/Shrub
<i>Ricinus communis</i>	Euphorbiaceae	Gulie	Tree
<i>Rumex nervosus</i>	Polygonaceae	Hahot	Herb
<i>Schimperianum</i>	Rubiaceae	Tselimo	Tree
<i>Schinus molle</i>	Anacardiaceae	berbere-tsellim	Tree
<i>Senna sinqueana</i>	Fabaceae	Hambahambo	Shrub
<i>Stereospermum</i>	Bignoniaceae	Adgi-zana	Tree
<i>Terminalia brownie</i>	Combretaceae	Weiba	Tree
<i>Vernonia amygdalina</i>	Asteraceae	Girawa	Tree
<i>Vernonia bipontinnii</i>	Asteraceae	Mechalo	Shrub
<i>Ziziphus spina</i>	Rhamanaceae	Gaba	Tree

APPENDICES 2. List of species identified in the Grazing area

Scientific Name	Family Name	Local Name	Tree/shrup counts
<i>Acacia abyssinica</i>	Fabaceae	Tsaeda chea	Tree
<i>Acacia albida</i>	Fabaceae	Momona	Tree
<i>Acacia etbaica</i>	Fabaceae	Seraw	Tree
<i>Acacia saligna</i>	Fabaceae	Akacha	Tree
<i>Acacia tortilis</i>	Fabaceae	Chea	Tree
<i>Aloe vera</i>	Aloeaceae	Ere	Shrub
<i>Carissa edulis</i>	Apocynaceae	Agam	Shrub
<i>Croton macrostachyus</i>	Euphorbiaceae	Tambok	Tree
<i>Dodonoa angustifoha</i>	Sapindaceae	Tahsos	Shrub
<i>Echinopsis hispidus</i>	Asteraceae	Dander	Herb
<i>Euclea racemosa</i>	Ebenaceae	Kuliow	Shrub
<i>Ficus vasta</i>	Moraceae	Daero	Tree
<i>Jasminum abyssinicum</i>	Oleaceae	Habi-tselim	Shrub
<i>Maytenus arbutifolia</i>	Celastraceae	At-at	Shrub
<i>Olea europaea</i>	Oleaceae	Awlie	Tree
<i>Rhus glutinosa</i>	Anacardiaceae	Tetaelo	Tree/Shrub
<i>Rumex nervosus</i>	Polygonaceae	Hahot	Herb
<i>Senna sinqueana</i>	Fabaceae	Hambahambo	Shrub
<i>Ziziphus spina</i>	Rhamanaceae	Gaba	Tree

Appendix 3: Number of tree and shrub species per sample plots in the Exclosure

Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35			
<i>Acaciaabyssinica</i>	3	2	1	0	0	1	2	3	1	1	2	1	0	0	3	2	2	1	1	1	0	0	1	2	2	1	0	0	3	0	0	1	0	0	1	0	1	
<i>Acacia saligna</i>	2	2	1	0	1	0	1	2	0	2	0	0	2	1	0	0	1	2	0	1	1	1	1	0	0	0	1	1	0	1	1	0	1	1	0	1	0	
<i>Accacia etbaica</i>	2	2	1	2	3	2	2	3	1	2	1	2	2	2	2	1	1	1	2	0	2	1	1	1	1	1	0	0	1	0	0	1	0	0	1	0	1	
<i>Aloe vera</i>	1	1	2	1	0	0	0	3	1	0	0	1	1	1	1	1	0	0	3	1	0	2	0	2	2	0	1	1	0	1	0	0	1	1	0	1	0	
<i>Astragalus atropilosulus</i>	0	2	3	0	1	1	1	0	0	1	2	1	2	0	0	1	2	0	0	0	1	0	1	0	0	1	0	0	2	0	1	1	0	0	1	0	1	
<i>Azadirachta indica</i>	1	1	0	1	0	0	2	1	0	0	0	0	1	2	1	0	0	1	1	1	0	1	0	1	0	1	0	2	1	0	1	0	0	1	1	0	1	
<i>BersamaAbyssinica</i>	0	2	1	1	1	1	0	0	1	1	2	1	0	0	0	1	1	1	0	0	1	0	0	0	0	2	0	0	1	0	1	1	0	0	1	0	1	
<i>Carissa edulis</i>	2	0	2	2	0	0	1	1	0	0	1	0	2	1	0	0	1	0	1	1	0	2	3	1	0	1	2	0	1	0	0	1	0	1	0	1	0	
<i>Calpurnia aurea</i>	1	1	0	0	1	2	0	0	2	1	0	2	0	0	2	0	0	1	0	0	2	0	0	2	1	0	1	2	0	1	0	0	1	1	0	1	0	
<i>Clerodendron myricoides</i>	2	0	0	1	0	0	1	2	0	0	2	0	1	2	0	0	3	0	1	0	0	1	1	0	2	2	0	0	1	0	1	1	0	0	1	0	0	
<i>Clematis hirsute</i>	0	1	2	0	1	2	0	0	1	1	0	0	0	0	1	1	0	1	0	0	1	0	0	1	0	0	2	1	0	1	0	0	1	1	0	1	0	
<i>Cassipourea malosana</i>	2	0	0	2	0	0	3	1	0	0	4	0	1	0	0	0	1	0	1	1	0	1	1	2	1	1	0	0	2	0	1	1	0	0	1	0	1	
<i>Cordia africana</i>	1	0	1	0	2	2	0	0	1	1	0	2	0	2	1	0	0	1	0	0	2	0	0	0	2	1	4	0	1	0	0	0	1	1	1	1	1	
<i>Dodonoaangustifoha</i>	5	2	3	1	0	2	3	1	1	1	3	2	3	0	4	2	1	2	2	1	0	1	1	1	0	0	0	2	0	2	2	1	0	0	0	0	0	
<i>Euclea racemosa</i>	1	0	0	0	2	0	0	0	1	2	0	1	0	0	1	1	1	0	0	0	0	0	1	0	1	2	1	0	1	0	0	0	1	4	2	2	2	
<i>Eucalyptus camaldulensis</i>	3	2	2	2	4	0	2	3	2	2	1	4	1	1	1	2	0	1	3	1	1	1	2	2	1	1	4	1	0	0	0	4	0	1	2	2		
<i>Euphorbia tirucalli</i>	0	0	1	1	0	0	0	1	1	1	2	2	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	2	0	1	1	1	0	0	0	0	0	
<i>Opuntia ficus</i>	1	1	0	0	2	1	0	0	0	0	0	0	3	0	1	1	0	1	0	2	2	0	1	0	2	1	1	4	1	0	0	0	4	1	2	2		
<i>Olea europaea</i>	2	2	1	1	0	0	1	0	1	1	0	1	0	1	0	0	3	0	0	0	0	2	0	1	0	0	0	1	0	2	1	1	0	0	0	0	0	
<i>Otostegia fruticosa</i>	0	0	0	0	2	0	0	1	0	0	1	0	1	0	1	3	0	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	1	1	
<i>Otostegia integrifolia</i>	2	1	3	2	1	1	4	2	1	1	2	1	1	1	2	0	1	1	0	2	2	0	2	1	1	0	0	3	0	1	1	1	0	0	0	0	0	
<i>Ptrollobium stellatum</i>	1	2	1	0	0	2	0	3	0	1	1	0	0	4	2	2	0	0	2	1	1	3	1	0	3	1	0	0	0	0	0	2	1	1	1	1	1	
<i>Ricinus communis</i>	2	0	0	3	1	0	1	0	0	0	1	1	1	0	2	0	1	2	0	1	1	0	0	2	0	0	3	1	1	1	1	0	0	0	0	0	0	
<i>Rhus glutinosa</i>	0	2	1	0	0	2	0	2	0	1	0	0	0	4	0	1	1	0	3	0	0	2	0	0	1	1	0	0	0	0	0	4	1	1	1	1	1	
<i>Senna sinqueana</i>	2	0	0	1	1	0	1	0	1	2	1	1	1	0	3	0	0	2	0	2	2	0	1	1	0	0	2	1	1	1	1	1	0	0	0	0	0	
<i>Vernonia amygdalina</i>	1	1	1	0	0	1	0	2	0	0	0	0	0	3	0	2	2	0	3	0	0	2	0	0	2	1	0	2	0	0	0	1	0	0	0	0	0	
<i>Schinus molle</i>	0	0	1	0	0	2	0	2	0	1	0	0	1	1	0	2	3	0	3	0	0	4	2	3	1	1	0	1	0	0	0	1	0	0	0	0	0	
<i>Acacia saligna</i>	4	3	1	1	2	4	2	3	0	1	1	2	2	1	2	1	4	1	1	3	2	2	0	2	0	0	1	0	1	1	1	0	1	1	1	1	1	
<i>Agave sisalana</i>	1	1	0	0	2	0	0	1	1	0	0	1	0	1	0	0	1	0	1	0	1	0	0	1	1	1	0	4	0	0	0	2	0	0	0	0	0	
<i>Aloe vera</i>	2	0	1	2	0	1	2	0	0	2	2	0	3	1	2	2	0	3	0	1	2	2	1	2	0	0	1	0	0	1	1	0	1	1	0	1	1	
<i>Terminalia brownie</i>	0	3	0	0	1	2	0	2	2	0	0	3	0	1	0	0	3	0	1	1	4	2	3	0	1	1	0	0	1	0	0	1	0	0	0	0	0	
<i>Ehretia cymosa</i>	4	1	0	3	0	0	2	2	0	1	1	0	2	0	2	1	0	2	1	2	0	0	0	3	0	0	1	2	0	1	1	0	0	1	0	0	1	1
<i>Maytenus arbutifolia</i>	0	2	2	0	1	2	0	0	1	1	0	2	1	2	1	2	2	0	0	0	2	3	1	1	1	1	0	0	1	0	0	1	1	0	0	0	0	
<i>Maytenus senegalnesis</i>	2	0	0	2	0	0	3	2	0	0	2	0	1	0	1	0	0	3	2	1	0	0	2	2	0	0	2	1	0	1	1	0	0	1	0	0	1	1
<i>Ziziphus spina</i>	0	1	1	0	1	2	0	0	1	2	0	2	0	1	0	3	2	1	0	0	1	3	0	0	1	0	0	2	0	0	1	0	0	2	0	0	2	0
<i>Acacia albida</i>	5	4	1	2	2	4	0	3	4	1	1	1	2	1	2	4	1	4	1	3	1	2	1	2	0	1	3	0	1	1	0	2	1	0	1	0	1	
<i>Acacia tortilis</i>	5	2	1	2	0	1	2	5	2	0	0	1	2	2	1	1	2	2	2	5	1	3	2	2	1	0	0	2	0	0	1	0	0	1	0	0	1	0

<i>Buddleja polystachya</i>	2	1	0	1	1	0	2	0	1	0	0	2	1	0	1	0	0	0	3	2	0	1	0	0	1	0	0	1	4	0	0	1	0	5	0
<i>Schimperianum</i>	0	0	3	3	0	1	0	3	0	1	1	2	0	5	0	2	1	1	0	0	2	0	2	4	3	0	0	2	0	0	5	0	0	2	1
<i>Carissa edulis-Commiphora</i>	2	1	0	0	2	0	4	0	2	0	2	0	2	0	4	1	0	0	3	2	0	5	0	0	1	0	0	2	0	0	0	1	0	0	1
<i>Dichrostachys cinerea</i>	0	0	0	1	0	2	0	1	0	4	0	1	0	2	0	0	2	3	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	
<i>Echinopsis hispidus</i>	2	4	1	0	1	0	1	0	2	0	3	0	2	0	1	1	0	0	3	1	0	2	3	2	2	0	0	4	0	0	1	0	0	1	0
<i>Erythrina abyssinica</i>	0	0	1	0	1	1	0	1	0	1	0	2	0	2	0	0	1	2	1	4	1	0	0	0	1	0	0	1	0	0	2	1	0	0	1
<i>Rhus natalensis</i>	0	1	2	2	0	0	5	2	0	0	4	0	2	0	3	2	1	0	1	0	0	3	2	4	2	0	1	1	0	0	1	0	1	0	0
<i>Gravillea robusta</i>	4	2	0	0	1	3	0	0	3	2	0	3	0	2	0	0	1	2	0	2	4	0	0	0	0	1	0	0	1	1	0	1	0	1	1
<i>Grewia ferruginea</i>	0	0	3	1	0	0	2	3	0	0	2	0	1	0	2	2	0	0	1	0	0	2	4	5	1	0	2	0	2	0	1	0	1	0	0
<i>Jasminum abyssinicum</i>	3	2	0	0	2	2	0	0	2	1	0	3	0	4	0	0	0	2	0	1	2	0	1	0	0	2	0	1	0	1	0	1	0	1	1
<i>Jatropha carriaca</i>	1	1	2	1	0	0	1	1	0	0	2	0	1	0	2	2	1	0	2	1	0	2	0	4	4	0	1	0	1	0	1	0	2	0	0
<i>Leucena leucocephala</i>	0	1	0	1	1	2	0	1	2	2	0	0	2	0	0	0	2	3	0	1	2	0	1	0	0	0	3	0	0	0	1	0	0	1	0
<i>Rumex nervosus</i>	3	0	1	2	0	0	3	0	0	0	1	2	0	3	1	2	0	0	1	0	0	1	0	1	2	0	0	0	0	2	0	0	0	0	2
<i>Stereospermum</i>	0	3	1	0	1	1	0	4	2	1	0	0	3	0	1	0	2	1	4	1	1	0	3	2	0	1	0	0	0	3	0	0	1	0	1
<i>Capparis tomentosa</i>	2	0	1	3	1	0	3	0	0	1	2	3	2	1	0	2	0	1	0	1	2	5	0	0	0	0	3	0	0	1	0	0	1	0	0
<i>Croton macrostachyus</i>	1	2	2	0	0	2	0	2	2	1	0	0	0	1	2	0	4	1	2	0	0	0	2	3	0	0	4	0	0	1	0	0	0	1	1
<i>Maerua angolensis</i>	1	2	0	2	2	1	2	0	0	0	3	0	1	0	0	1	2	0	1	2	1	1	0	1	1	0	0	3	0	0	2	0	0	0	1
<i>Rumex nervosus</i>	1	1	0	1	0	1	1	0	0	2	1	0	0	0	1	1	0	1	2	0	1	0	1	0	0	2	0	0	2	0	0	1	0	1	0
<i>Grewia ferruginea</i>	0	1	2	1	1	0	0	2	1	0	1	1	2	1	1	0	1	1	1	0	1	1	2	1	0	0	2	0	0	3	0	0	1	0	0
<i>Vernonia bipontinnii</i>	3	1	0	0	0	2	1	0	2	1	0	1	0	1	0	3	1	0	0	2	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
<i>Myrsine Africana</i>	1	1	1	2	4	3	1	1	0	1	1	0	3	0	2	0	1	3	1	0	2	1	2	2	0	0	0	1	0	0	0	1	0	0	0
<i>Grewia bicolor</i>	2	1	3	0	0	4	1	0	2	1	1	3	0	1	2	1	1	0	0	2	0	1	2	1	0	0	0	2	0	0	0	1	0	0	1

Appendix 4: Tree and shrub species per sample plots in grazing area

Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35						
<i>Acacia abyssinica</i>	1	0	3	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1					
<i>Acacia saligna</i>	2	0	1	0	1	0	1	0	0	1	0	0	2	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0					
<i>Accacia etbaica</i>	0	2	0	1	0	1	0	3	0	1	0	1	1	0	3	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0					
<i>Aloe vera</i>	1	1	0	1	0	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1					
<i>Dodonoaangustifoha</i>	2	0	1	0	1	2	0	2	1	0	0	3	1	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0				
<i>Euclea racemosa</i>	1	0	0	0	1	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0				
<i>Olea europaea</i>	2	0	0	1	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	1				
<i>Rhus glutinosa</i>	0	2	1	0	0	1	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0				
<i>Senna sinqueana</i>	2	0	0	1	0	0	1	0	1	0	1	0	1	0	1	0	0	0	0	2	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1				
<i>Habessinica</i>	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0			
<i>Maytenus arbutifolia</i>	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
<i>Ziziphus spina</i>	0	1	1	0	1	2	0	0	1	2	0	2	0	1	0	3	2	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0			
<i>Acacia albida</i>	2	1	1	4	0	1	0	2	1	2	1	1	2	0	1	3	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1			
<i>Acacia tortilis</i>	3	2	2	1	1	0	2	0	0	1	1	3	0	1	0	1	1	0	1	1	0	1	1	0	2	1	0	0	1	0	0	0	0	0	1	0	0	0			
<i>Carissa edulis</i>	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Ficus vasta</i>	0	1	0	0	0	0	0	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
<i>Jasminum abyssinicum</i>	1	0	0	0	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
<i>Rumex nervosus</i>	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
<i>Croton macrostachyus</i>	1	0	2	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
<i>Echinopis hispidus</i>	1	0	1	0	1	0	1	0	0	0	1	0	2	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Appendix 5: Aspect, altitude, latitude and longitude of vegetation sample plots of the Exclosure area

Transects	Plots	Slope	Aspect	altitude	Latitude	Longitude
One	1	35	SW	2039	1358675	3922650
	2	34	SE	2038	1358676	3922653
	3	33	SW	2039	1358675	3922651
	4	34	SE	2040	1358656	3922650
	5	30	SE	2032	1358658	3922649
Two	6	37	SE	2033	1358676	3922696
	7	35	SE	2034	1358675	3922692
	8	37	SE	2032	1358655	3922690
	9	30	SE	2035	1358658	3922691
	10	28	SW	2033	1358674	3922694
Three	11	36	SW	2043	1358676	3922689
	12	34	SE	2044	1358678	3922683
	13	33	SE	2048	1358668	3922686
	14	37	SW	2047	1358615	3922712
	15	29	SW	2046	1358658	3922730
Four	16	36	SE	2048	1358657	3922724
	17	38	SW	2051	1358659	3922721
	18	32	NE	2051	1358660	3922729
	19	27	NE	2049	1358643	3922710
	20	34	NE	2048	1358673	3922722
Five	21	38	NE	2049	1358678	3922714
	22	29	NE	2048	1358658	3922733
	23	33	NE	2050	1358675	3922720
	24	29	NE	2051	1358697	3922702
	25	37	NE	2052	1358659	3922722
Six	26	36	SE	2032	1358658	3922692
	27	34	SE	2035	1358674	3922690
	28	33	SE	2033	1358676	3922691
	29	37	SE	2043	1358678	3922694
	30	29	SW	2044	1358668	3922689
Seven	31	34	NE	2043	1358658	3922724
	32	33	NE	2044	1358657	3922721
	33	34	NE	2048	1358659	3922729
	34	30	NE	2047	1358660	3922710
	35	37	NE	2046	1358643	3922722

APPENDICES 6

Aspect, altitude, latitude and longitude of vegetation sample plots of the grazing area

Transects	Plots	Slope	Aspect	altitude	Latitude	Longitude
One	1	32	NS	2096	1357663	3923427
	2	29	NS	2092	1357661	3923430
	3	34	NS	2090	1357659	3923428
	4	30	NS	2089	1357672	3923437
	5	32	NS	2094	1357662	3923432
Two	6	28	NS	2085	1357677	3923439
	7	31	NE	2083	1357679	3923431
	8	32	NE	2088	1357675	3923440
	9	29	NE	2095	1357622	3923431
	10	27	NE	2090	1357629	3923438
Three	11	30	NE	2085	1357624	3923444
	12	33	SW	2088	1357672	3923546
	13	27	SW	2086	1357709	3923549
	14	29	SW	2096	1357712	3923543
	15	31	SW	2090	1357753	3923525
Four	16	34	SW	2088	1357711	3923511
	17	35	NS	2085	1357769	3923509
	18	31	NS	2090	1357707	3923539
	19	29	NS	2093	1357712	3923520
	20	27	NS	2096	1357762	3923539
Five	21	34	NS	2088	1357721	3923541
	22	32	NS	2091	1357766	3923532
	23	28	SW	2089	1357768	3923512
	24	30	SW	2092	1357770	3923519
	25	28	SW	2088	1357765	3923530
Six	26	32	NS	2096	1357663	3923427
	27	29	NS	2092	1357661	3923430
	28	34	NS	2090	1357659	3923428
	29	33	SE	2048	1358668	3922686
	30	37	SW	2047	1358615	3922712
Seven	31	27	NS	2096	1357762	3923539
	32	34	NS	2088	1357721	3923541
	33	32	NS	2091	1357766	3923532
	34	28	SW	2089	1357768	3923512
	35	30	SW	2092	1357770	3923519

## Appendices 7

### Soil physical and chemical variables in the Exclosure and open area

sample	Sand y	Silt	Clay	Moisture Content	pH	BD	Bulk density	WP	EC	Porosi ty	Exch Na	ExchK	Exch Ca	Exch Mg	OM	CEC	FC	Av P(ppm)	TN
Sex 1	53	35	22	2.32	6.8	2.35	1.3	14.5	0.04	53.6	0.18	0.73	22.1	9.16	3.2	40.3	28.2	13.7	0.2
Sex 2	49	19	22	2.44	6.89	3.15	1.1	13.9	0.04	43.6	0.15	0.65	21.1	10.3	2.3	39.1	25.5	12.3	0.2
Sex 3	47	33	20	2.12	7.1	1.3	1.1	13.9	0.05	50.8	0.13	0.71	20.1	10.1	4.2	37.9	26.6	13	0.1
Sex 4	53	17	30	5.77	6.9	2.05	1.3	19.3	0.06	60.2	0.17	0.67	22.1	11.1	3.4	38.2	30.5	12.2	0.1
Sex 5	49	29	22	1.95	7	1.3	0.8	14.3	0.05	50.6	0.19	0.56	20.1	10.8	4.3	37.2	27.3	11.1	0.2
Sex 6	47	35	18	3.62	6.9	1.41	0.9	13.4	0.04	54.8	0.15	0.65	22.3	12.9	4.3	39.3	28.3	11.4	0.2
Sex 7	55	30	15	4.63	6.7	1.24	1.6	12.8	0.09	52.4	0.15	0.72	23.2	11.8	3.2	41.7	31.2	12.5	0.2
Snex1	59	19	22	1.304	6.4	1.25	1.4	14.9	0.04	51.9	0.13	0.49	19.1	11.7	2.2	30.8	25.3	13.3	0.1
Snex2	57	31	12	1.36	6.7	3.67	2	9.2	0.04	55	0.11	0.61	20.7	9.75	2.2	38.7	20.7	11.3	0.1
Snex3	55	25	20	1.75	6.4	1.19	1.8	14.8	0.04	54.1	0.15	0.48	20.1	10.1	2.1	37.8	27.5	10.9	0.3
Snex4	51	25	24	1.98	7.2	3.25	1.3	14.7	0.05	54	0.13	0.53	22.1	10.6	2.3	35.7	30.6	11.7	0.1
Snex5	50	20	30	1.91	6.3	1.3	1.3	10.7	0.03	53	0.11	0.58	22.3	9.93	2.2	37	26	10.1	0.1
Snex6	63	21	16	1.44	6.6	3.23	1.9	13.8	0.06	52.3	0.11	0.61	20.4	11.7	2.4	40.6	28	11	0.1
Snex7	58	30	12	1.17	6.4	1.2	1.4	14.5	0.06	48	0.12	0.66	20.2	10.6	2.3	35.1	26.9	12.3	0.2

Sex=Sample of exclosure

Snex=Sample of none exclosure

Appendix II: questionnaire designed to collect data from the agricultural experts

Dear participant, these questions are designed purely for academic purpose and to come up with appropriate recommendation to assess the aforementioned vegetation cover change. Your voluntary participation and truthful responses have great value, on the one hand, for the successful completion of my study and, on the other hand, for valuable recommendations for policy makers, to continue or amend the coverage at hand. In the study while only aggregate results will be used, your individual responses will be mentioned confidential.

Part II: Respondent's personal data

1. Age \_\_\_\_\_ 2. Gender A) Male B) Female

3. Educational level a) illiterate b) Write and read only c) elementary d) secondary high school e) 1st Degree F) If other please mention \_\_\_\_\_

4. Marital status A) single B) Married C) divorced

1. For what purpose the area was closed? A. To restrict from overgrazing B. To rehabilitate degraded area C. other (specify)

\_\_\_\_\_

2. Why this Tabia is selected for area exclosure than from the other Tabias?

\_\_\_\_\_

3. What was the area before exclosure?

\_\_\_\_\_

4. Is there any change in vegetation cover after establishment of area exclosure?

A. Increased    B. No change

5. What is the impact of area enclosure on the livelihood of the farmers?

A. positive        B. Negative

6. What is the importance of area enclosure? A. To increasing agricultural production

B. To decreasing soil erosion    C. If there any other specify it

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7. The agricultural production near the area enclosure is:

A. Increasing    B. Decreasing    C. No change

8. Do you think that area enclosure is effective to rehabilitating the degraded lands?

A. Yes    B. No

9. What is the attitude of the society towards area enclosure to the future?

A. Positive    B. Negative

10. Were there obstacles during the establishment of area enclosure?

A. Yes, what are \_\_\_\_\_

B. No

12. What measures do you suggest for sustainability of land rehabilitation practices in the area?

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