ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES

COLLEGE OF NATURAL SCIENCE

ENVIRONMENTAL SCIENCE PROGRAM

The Role of Area Closures for Soil and Woody Vegetation Rehabilitation in Kewot District, North Shewa

MSc Thesis

By: Mengistu Asmamaw Mengesha

May, 2011

Addis Ababa, Ethiopia

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A Thesis submitted to the Environmental Science Program of College of Natural Science in partial fulfillment of the requirements for the Degree of Master of Science in Environmental Science.

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Abbreviations and Acronyms

ANRS	Amhara Nationa Regional State
ACs	Area Closures
CBD	Convention on Biological Diversity
DBH	Diameter at Breast Height
EARO	Ethiopian Agricultural Research Organization
EC	European Commission
EFAP	Ethiopian Forestry Action Plan
EPA	Environmental Protection Authority
FAO	Food and Agriculture Organization of United Nations
GACGCS	German Advisory Council on Global Change Secretariat
GEF	Global Environmental Facility
IUCN	International Union for the Conservation of Nature and Natural resources
KWOA	Kewote Woreda Office of Agriculture
LUCID	Land covers Change Impacts and Dynamics
LSD	Least Significant Difference
MEA	Millennium Ecosystem Assessment
SER	Society for Ecological Restoration
SHARC	Sheno Agricultural Research Center
SPSS	Statistical Program for Social Sciences
TADO	Tobacco Agriculture Development Organization
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Convention on Environment and Development
UNEP	United Nations Environmental Program
WCMC	World Conservation Monitoring Center
WFP	World Food Program
WMO	World Meteorological Organization
WRI	World Resource Institute

Abstract

This study was conducted in Kewot District, North Shewa, to assess the contributions of area closures for soil and woody vegetation rehabilitation. A cross-sectional survey was employed to collect woody vegetation and soil data; as well as local community perception towards area closures. Samples for woody vegetation and soil quality were taken from 10 years and 23 years old area closures and the adjacent open grazing lands on systematically laid plots. A total of 168 households were selected and questionnaire was used to assess local communities' perception. Data were analyzed using excel spread sheet and SPSS software. The results indicate that a total of 2,394 woody vegetations, of which trees, shrubs, saplings and seedlings constituting 26%, 44%, 17%, and 13% in the area; belonging to 46 species, 26 families and 38 genera were recorded and identified. The overall density of woody vegetation in area closures was 4,683.2 ha^{-1} while it was 785.9 ha^{-1} in open grazing lands. The frequency, height and DBH analysis of trees in area closures exhibited a regeneration curve of inverted 'J' shaped distribution. The species richness and diversity difference was significant ($P<0.05$) and further the LSD comparison of stem groups, except saplings among enclosures, indicated very significant ($P<0.01$) difference across study sites. Soil chemical properties such as AvP, AvK, and pH showed no significant differences but SOM and TN showed significant difference ($P<0.05$) across study sites. The correlation analysis among soil parameters revealed a significant positive linear correlation ($P=0.002$, $r=0.716$), ($P=0.004$, $r=0.672$),($P=0.03$, $r=0.543$),($P=0.016$, $r=0.592$) between SOM and TN, SOM and C/N, TN and C/N, TN and AvK in the area. SOM content in area closures was significantly higher than their adjacent grazing lands. There was positive correlation between SOM and diversity of woody vegetations indicating the influence of management and age to rehabilitate soil qualities and woody vegetation diversities. Local farmers were aware of the socioeconomic and ecological contributions of area closures and were optimistic to the establishment and performance of area closures which is a basis for future rehabilitation projects. The study showed that area closures play a key role to rehabilitate woody vegetation diversity and soil qualities of degraded sites.

Keywords*: Area closure, Open grazing land, Rehabilitation, Species diversity, Woody vegetation.*

1. Introduction

1.1 Background

The world is currently in a period of rapid, anthropogenic driven environmental changes occurring without historic patterns. These rapid environmental changes are brought about by land cover changes, fragmentation, invasive species, and pollution (MEA, 2005). Fragmentation of natural systems occur whenever removal of pre-existing land cover and replacement of other cover types occur, be it urban, agriculture, forestry production or other anthropogenic land uses (Hobbs & Saunders, 1993; Schwartz, 1997).

The technological revolution requiring machinery and chemicals had altered the holistic human-environment relationships and overtaken the trends and efficiency of ancient farming system, which was environmentally the golden era, but farming was subsistence (Bradshaw, 2003). It is summarized in the Millennium Ecosystem Assessment (MEA) report (2005) that in the last 30 years more croplands has been converted from natural vegetations than in 150 years between 1700 and 1850. Unsustainable utilization of land resources impair ecosystem functions such as regulation of water supplies and quality, soil fertility maintenance, carbon sequestration, climate change mitigation and food security leading to ecosystem fragmentation as a whole (UNEP, 2010).

Land degradation, mainly in the form of soil erosion, is the prime factor affecting the sustainability of biodiversity especially agricultural production in the world (FAO, 1996; Genanaw Bekele & Alemu Mekonnen, 2010). Globally, about 80% of the current degradation of agricultural land is caused by soil erosion (Angima *et al.,* 2003) and anthropogenic agents cause more severe land degradation nowadays than natural processes (FAO, 1996). Some countries in the world, especially developing countries are facing food insecurity due to land degradation through removal of agricultural soils. The problem is exacerbated by habitat fragmentation and limited amount of productive land. Hence, 78 % of the earth's surface is unsuitable for agriculture. From the 22% of agricultural land, 13% of land has low productive capacity, 6% has medium and only 3% of land has high capacity for intense crop production (Lal & Stewart, 1992).

Land use changes in East Africa have transformed natural land covers to farmlands, grazing lands, human settlements and urban centers at the expense of natural vegetation. These changes are associated with deforestation, biodiversity loss and agricultural extensification (Maitima *et al*., 2004; 2009). Likewise, land degradation, which comprises degradation of vegetation cover, soil and nutrient depletion, is a major ecological and economical problem challenging the food supply and the general sustainable development of agrarian counties including Ethiopia (Haileslassie Tsegaye *et al*., 2005). Land degradation in Ethiopia is the main threat in dry lands, which is expected to cover about 75 million hectare (ha) of land (EFAP, 1994; EARO, 2000), due to agricultural extensification without soil and water conservation leading to unsustainable crop production (Tewoldeberhan G/Egziabher, 1989).

The trend of rehabilitation is becoming an increasingly significant tool to manage, conserve, and repair the world's degraded ecosystems (Young, 2000; Hobbs & Cramer, 2008) that caused due to overuse or mismanagement of landscapes (Macmahon, 1998). Hence, management of intact ecosystems and rehabilitation of degraded ecosystems are seen as critical to the protection of both biodiversity and ecosystem services in this period of strong human alteration ecosystem (Hobbs & Cramer, 2008). Rehabilitating natural vegetation is an important strategy to reverse land degradation, rehabilitate landscape integrity, and realize the environmental and socioeconomic benefits of natural resources; and is now widely accepted and practiced around the world to rehabilitate degraded lands within short period of time (Mengistu Tefera *et al*., 2005; Vanandel & Aronson, 2006).

Area closures (enclosures) are degraded lands that have been excluded from human and livestock interference and left to regenerate naturally (Betru Nedessa, 2003). Enclosures, among various land management and rehabilitation mechanisms, are flourishing strategies practiced to improve species diversity, soil quality and ecosystem productivity (Lal & Stewart, 1992; Cairns, 1994; UNEP, 2010). Cairns (1998) argues that unless ecological rehabilitation and preservation are not well practiced, by the current trend, human societies will not survive on this planet for the future.

Ecological rehabilitation creates sustainable environment and less destructive relationship between humans and natural systems. If the basic rehabilitation planning is done appropriately while removing ecological stresses, ten or less years may often be enough for nature to recover from damage (Caldwell, 1972; Cairns, 1994). Although enclosures are suggestive land management options and have been practiced in various parts of Ethiopia, especially in the highlands, knowledge and documentations on the diversity, and status of regeneration of rising flora, soil quality as well as the actual and potential socioeconomic profit resulting from enclosures is limited (Emiru Berhane *et al*, 2006).

1.2 Statement of the Problem

Land degradation poses a severe problem to the livelihoods of the rural population and the environment in developing countries (Nedessa Betru *et al.,* 2005). It has both ecological and socioeconomic consequences. For example deforestation in upland watershed often causes accelerated flooding, sedimentation, reduced water quality and displacement of the low land settlements (Rowe *et al.,* 1994). The extreme dependence of the Ethiopian rural population on natural resources, particularly land, as a means of livelihood makes Ethiopian vulnerable for land resources degradation (EPA, 1998). Land use conversion mainly deforestation for arable land expansion in response to the demand of increased population, has resulted in reduction of crop production due to erosion and loss of biodiversity in Ethiopia (Hadgu Tesfa *et al.,* 2008).

Studies indicated that the efforts made in the past have rehabilitated degraded farmlands, improved soil water holding capacities, increased woodlots, and improved the productivity of the pastured lands in some watershed in Ethiopia (Sonneveld & Keyzer, 2003). However, the current rate and status of environmental degradation still calls for more extended and coordinated intervention actions to rehabilitate degraded lands (Edward, 2000; Kindeya G/Hiwot, 2004).

The Amhara National Regional State (ANRS) has been delineating degraded lands as area closures to prevent environmental degradation, and combat desertification by rehabilitating soil quality and biodiversity in various areas of the region and Kewot district is one of areas where enclosure is being exercised. Area closure practices have been instrumental especially in severely degraded areas like Kewot district, to rehabilitate degraded lands so as to reclaim denuded vegetation, access livestock fodder and also to maintain biodiversity (Emiru Berhane, 2002; Sarah Tewoldeberhan *et al*., 2002).

Therefore, this study is designed to evaluate the contributions of enclosures in one of the Amhara National Regional State Districts, Kewot, Northeastern Ethiopia, with a special emphasis on the rehabilitation status of woody vegetations (composition and diversity) and soil chemical properties such as Nitrogen (N), Phosphorus (P), Potassium (K), Potential for Hydrogen (pH) and Organic Carbon (OC) as possible indicators to assess the performance of area closures. The perception of local communities to the establishment and contribution of enclosures was assessed as well.

The outcomes of the practice are not studied so far in the study area. Thus, assessing the implication of enclosing communal lands to mitigate the effects of unsound land use practices is imperative and this evoked the researcher to evaluate measurable land resource improvements. The research findings will have significances for stakeholders by providing concrete scientific evidences about the performance of enclosures to reclaim degraded lands and become a basis for future studies in the field area.

1.3 Objectives

1.3.1 General Objective

The general objective of this study was to evaluate the contribution of area closures for the rehabilitation of soil and woody vegetations in Kewot district, northeastern Ethiopia.

1.3.2 Specific Objectives

Specific objectives are:

- to assess the role of area closures on composition, structure and diversity of woody vegetations
- to examine changes in the soil quality as a result of management interventions
- to assess the perception of local community on area closures and their contributions

2. Literature Review

2.1 Linkages between Biodiversity, Ecological Functions and Land Degradation

2.1.1 Biodiversity, ecological functions and sustainable ecosystems

Biodiversity is the variability among living organisms from all species including, inter-alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; including diversity within species, between species and of ecosystem (UNCED, 1992). It encompasses genetic, species and ecosystem diversity each inter-related and exist inseparable determining the function of the ecosystem (UNEP, 1992).

Biodiversity comprises the variation in ecosystems, habitats, communities, species and intra-specific genetic makeup. Diversity of organisms is crucial in providing resilience to the ecosystem, community and population of the given habitat (Kawanabe, 1996). Living organisms contribute to a wide variety of environmental services, such as regulation of the gaseous composition of the atmosphere; regulation of the hydrological cycle and climate; generation and conservation of fertile soils; production of food and medicine; recreational and cultural values; dispersal and breakdown of wastes; pollination of many crops etc. Biodiversity also provides genetic resources for food and agriculture, and therefore constitutes the biological basis for world food security and support for human livelihoods (UNEP, 1995).

The environment delivers the expected ecosystem goods (food, medicine) and services (carbon sequestration, infiltration, decomposition, nitrogen fixation, pollination etc.,) when its biodiversity is maintained and kept sustainable (SER, 2004). However, nature in all its diversity is being threatened primarily with habitat modification and fragmentation mainly due to anthropogenic activities leading to extinction of organisms at rate above 50 to 1,000 times than the natural rate. Landscape fragmentation largely impacts the biodiversity and sustainability of the landscape as well as the composition of species (the functional unit of the biodiversity) and ecological processes (WCMC, 1992; UNEP, 1995).

The ecological services supplied by the ecosystem are directly determined by the extent of diversity of organisms in the system (Kiros Meles, 2008). Studies reported that during 1945 to 1990, 17% of the whole vegetated land had been degraded on this planet (WRI, 1992). Loss of biodiversity due to vegetation clearance leads to leaching of nutrients, decline in organic matter and accelerated surface erosion ending with reduced land productivity (Holzel *et al*., 2002) and has adversely affected ecosystem health, resilience, biodiversity and ecological function provision of nature (SER, 2008).

It may be due to rising demand for food production and unsuitable natural resource use policies of mankind, biodiversity and ecosystem functions are declining in the world (MEA, 2003) causing severe environmental degradation manifested with loss of biodiversity and low agricultural productivity, especially in Sub-Saharan African countries (Kiros Meles, 2008). The land use land cover changes for settlement and production have exacerbated environmental degradation (Lambin *et al.,* 2000; Amalu, 2002). Accordingly, nowadays, the issue of biodiversity loss and its consequences on ecosystem functions that provide to human society is becoming a global agenda (MEA, 2005). IUCN (2008) concluded that agricultural intensification has threatened more than 4, 000 plant and animal species in the world. In contrast to its crucial role for providing economic, social and ecosystem services, agriculture remains the foremost driver of land use changes, genetic erosion, species loss and conversion of natural habitats (MEA, 2005). Maintaining the trade-off between economic development and ecosystem diversity through efficient land use and improved agricultural productivity is a base mark to reclaim the deteriorating biodiversity and ecosystem services, such as water resources (UNEP, 2010).

Although the magnitude varies across ecosystems (Example: Overfishing in marine, forest conversion for terrestrial environments), biodiversity is declining at alarming rate as a result of both direct and indirect derivers. Principally, factors such as habitat fragmentation (due to land use change); over-exploitation of resources (degradation, deforestation, erosion, desertification); introduction of invasive species and pollution (mainly due to excessive level of nutrients in soil and water due to agricultural activities); climate change induced biodiversity loss etc., being triggered by underlying causes are main derivers of biodiversity loss (MEA, 2010).

2.1.2 Biodiversity and land use land cover change

Land cover refers to the biophysical envelop of the land (Example: Savanna, broad leaf forest, etc.). Land use implies to the human use of land (Example: Small scale agriculture, grazing, wildlife reserves). Land use change is the use of particular land to a different use than before through time (Example: from natural vegetations to cultivation, cultivation to grazing etc.,) (Maitima *et al*., 2004). Land use change has been increasing since people first began to manage their environment (Lambin *et al.,* 2003). It is now recognized that the current land use practices have caused substantial biodiversity loss and damaged natural systems, including the provision of ecosystem services (Foley *et al.,* 2005).

Biodiversity is affected by land use change (Example: deforestation) and land degradation (decline in land productivity) (FAO, 1983). Therefore, assessing the linkages between biodiversity loss, land cover land use change and land degradation is indispensable. Biodiversity loss, due to land use change, is most readily expressed in terms of species extinctions. Inappropriate land management practices have also degraded the biophysical environment upon which agricultural production depends. Such threats have generated an urgent need for remedial work in agricultural landscapes to rehabilitate ecosystem processes that strengthen sustainable agriculture and natural ecosystems (GEF, 2006).

All the current land use systems have been developed from the initial natural vegetation covers which were self regulating and sufficient enough to provide goods and services for mankind. The land quality and biodiversity in man modified ecosystems have been degraded becoming incapable to sustain productivity in the future (Maitima *et al.,* 2004). The overall conceptual interaction between land use and biodiversity, land use and land degradation and consequences of land degradation on biodiversity and land uses is indicated in Figure 1 as follows.

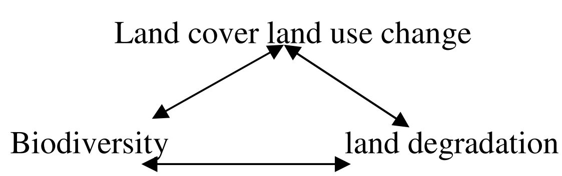


Figure 1: Conceptual linkages between land cover land use change, biodiversity and land degradation (Maitima *et al.,* 2004).

Landscape changes due to agriculture, urbanization, and infrastructures are recognized as the most important causes of land use change leading to biodiversity loss. Agricultural expansion is the foremost proximate cause of land use change globally, followed by infrastructure development and deforestation (EC, 2009). Infrastructure development requires expansion of settlement and transport networks leading to deforestation and fragmentation of habitats. In Africa, for example, commercial logging and timber production are strongly associated to infrastructure construction. Similarly, road and hydroelectric power buildings which access settlements and commercial logging in Latin America and Caribbean countries resulted substantial land use changes and loss of biodiversity in tropics (EC, 2009). Deforestation is also among the major forms of ecosystem destructions that has profound consequences on biodiversity. Tropical forests are homes for half of organisms in the world. As a result their safeguarding is indispensable for maintaining species richness and the health of the environment (Kerr *et al.,* 2004).

Obviously, each land use practice involves utilization of biological resources of the land often involving modification of land cover. According to Maitima *et al.* (2004) the following land use changes are the main causes of biodiversity loss. First, conversions of land cover from natural vegetation to farmlands. Cultivation usually requires clearance of natural vegetation to create farmlands which encompass agro-ecosystems that are modified by man. Man removes native species and replace fast growing and commercially valuable crop plants and exotic species leading to loss of native species in natural habitats; destruction of habitats for animals; exposing soils to erosion and increases abundance of unpalatable grasses and introduction of new species (Maitima *et al.,* 2004).

Second, conversion of natural land covers vegetation to grazing land. Livestock grazing is the most familiar land use change involving elimination of tree and bush covers to allow grass cover for feed leading to loss of plants, loss of habitat for animals and selective reduction of palatable grass species. Third, changes from grazing land to cultivation land. It is a universal action in agro-pastoralists who practice mixed farming system. They often clear woodlands for crop cultivation leading to depletion of land covers which exposes soils to erosion and increased land intensification leading to depletion of biodiversity (Maitima *et al.,* 2004).

Land use involves replacing of more complex natural vegetation with less complex agro-ecosystems with fewer species impacting stratification of the ecosystem. Surface cover depletion in overgrazing directly influences the stratification and complexity of an ecosystem leading to land degradation. On the other hand, selective removal of certain species (high economic value) will adversely impact both the species diversity and complexity of organisms especially in forests experiencing logging and charcoal production. Land cover land use change often accelerates soil erosion, which is the prime land degradation in the world (Majule, 2003).

2.1.3 Biodiversity and land degradation

Land degradation is a reduction or loss in arid, semi-arid and sub-humid areas of biological or economic productivity or complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and wild lands resulting from land use or from a process or combination of processes, including processes arising from human activities and habitation pattern such as: soil erosion caused by wind and /or water; deterioration of physical, chemical and biological or economic properties of a land; and long term loss of natural vegetations (UNCCD, 2003).

Reduction in vegetation cover reduces the capacity of soil to retain moisture for plant productivity. This in turn leads to increased soil erosion and loss of soil fertility causing to land degradation. Changes in plant diversity especially those leading to loss in vegetation complexity affect the potential of soil to replenish its nutrients particularly soil organic matter. Free grazing is also a fundamental cause for loss of biodiversity and thereby land degradation (Maitima *et al.,* 2004). Soil erosion is a common occurrence in intensively grazed areas (with no appropriate pasture management practice). These practices tend to remove vegetation cover leaving the land exposed to severe sheet and gully erosion. Soil erosion significantly contributes to soil fertility loss and thus to poor crop yield, increasing to poverty level (Majule, 2003).

The causes of land degradation are multiple, complex, and vary across the region, but to a greater extent deterioration and exhaustion of land resources due to incorrect and destructive agricultural practices, overgrazing, deforestation, loss of biodiversity and natural disasters, which in general involve habitat modification, are the foremost and common causes elsewhere (Misana *et al.,* 1996; Squires, 2007). Overgrazing, especially in Sub-Saharan Africa (SSA), is among the leading causes of land degradation which is manifested with soil compaction, erosion and loss of biodiversity (Rowe *et al.,* 1994; Kaoneka, 1999; MEA, 2005). Studies disclosed that deterioration of biophysical components (degradation in soil, water and vegetation); socioeconomic parts (poverty and food insecurity) and institutional failure (failure in policy, market and civil conflict) are fundamental indicators for each land degradation types (physical, chemical and biological) (Kaen, 1999).

2.1.3.1 Environmental impacts of grazing

Grazing lands are vegetated lands those are grazed or have the potential to be grazed by animals. These lands include rangelands that incorporate livestock use into a natural system, natural rangelands planted to forage species, croplands incorporating livestock use, pastures planted to native or introduced grasses and legumes, and forestland with the potential to be grazed. Grazing animals, known as herbivores, depend on plants such as grasses, forbs (broadleaf herbs), and shrubs for sources of energy and nutrients (Forage and Grazing Terminology Committee, 1991). Mismanagement of grazing lands may cause to deterioration of soil quality through compaction and erosion, water pollution, changes in plant community, and accelerated erosion and sedimentation in water bodies. Invasive species that threat the productivity, stability and ecological functioning of the system may also result from poor management of grazing lands (Krueger, 2002).

2.1.3.2 Effects of grazing on vegetation and soil quality

At the level of individual plant, grazing may promote, reduce or not affect plant growth. For example, grazing may stimulate basal shoot production in grasses and lateral branching in shrubs. On the other hand, seed production may be reduced while vegetative reproduction actually may increase. Certain plants have evolved defense mechanisms such as thorns, toxic chemicals, fibrous and less nutritious tissue, and altered morphology to protect growing points, and rapid re-growth after defoliation, either to avoid or to tolerate the effects of grazing (Briske & Richards, 1995).

Studies indicated that animal grazing, especially goat grazing, has a negative effect on biodiversity, which has reinforced the desire to restrict animals out of area closures (Oba, 1998). On the other hand, Oba *et al*. (2000) concluded that grazing homogenous animals will result in dominance of non palatable species. For example, heavy grazing by cattle and exclusion of goats may cause to bush encroachment but reduction of grasses (Oba *et al*., 2000).

Grazing promotes nutrient cycling through rapid breakdown of organic matter into smaller particles in the system, so organic matter is available more readily for soil microorganisms such as soil bacteria and fungi. Thus, grazing may increase the rate of nutrient recycling by bounding them into plant matter (Krueger, 2002). Other findings suggest that long term exclusion of herbivores may decline species richness; instead it can be higher in grazing lands than enclosed sites (Oba *et al.,* 2001qouted in Nedessa Betru *et al*., 2005). Likewise, studies concluded that excluding of herbivores from grazing lands, drought, uncontrolled heavy grazing and single species grazing cause damage to the quality of soil, water and vegetation on grazing lands (Anderson & Inouye, 2001). In contrast, Beukes & Cowling (2003) reported that heavy grazing severely affects soil physical and chemical properties (like C, TN and P) and negatively impacts vegetation composition and diversity. In general however, a better strategy recommended to promote species diversity is controlling multiple species of animals, a common practice in African dry land pastoralists (Oba, 1992).

2.1.3.3 Consequences of land degradation

Consequences of land degradation exert on social, economic and environmental segments; thereby directly impact on the livelihood of the population. Human land uses (such as deforestation, unsustainable agricultural practices, and overgrazing) often cause severe removal of agricultural soils (Fu *et al.,* 2002), which leads to ecosystem degradation and environment deterioration. Major impacts of land degradation include: pasture degradation and lack of emergency fodder; population reduction of target species caused by over harvesting and habitat destruction; deterioration of drinking water quality and resultant health problems; and shortage of timber and non-timber forest products, especially for local vulnerable groups, and loss of environmental services from forests as a result of fragmentation (Squires, 2007).

I) Fragmentation

Fragmentation is the process by which a natural landscape is broken up into small packages of natural ecosystems isolated from one another in a matrix of other ecosystems, usually dominated by human activities. Globally, the largest share of land is suffering from habitat fragmentation and modification due to human behavior and actions (WRI, 2001). Evidently, the main impact of ecosystem transformation is the dramatic habitat reduction and loss of biodiversity due to land use changes (Simberloff, 1982; Lomolino, 1994; Boecklen, 1997). As a result fragmentation as a whole leads to modified range of microclimate, hydrological and biotic changes (Saunders *et al.,* 1991).

Fragmentation can diminish biodiversity because small, isolated patches of habitats have fewer species than larger, less isolated patches. This is true because: (1) small patches have less environmental heterogeneity than large patches; (2) some area sensitive species and uncommon species are unlikely to be found in small patches; (3) small patches have small populations that are more vulnerable to local extinction. Besides affecting biodiversity by reducing patch size and increasing isolation, fragmentation also creates more edges between different types of ecosystems. These edge zones represent degraded habitat for many species (Lindenmayer & Fischer, 2007).

II) Effects of ecosystem fragmentation

Ecosystem fragmentation occurs when landscapes are disconnected by human or non human determinants, including short term, unsustainable exploitation of land resources (SER, 2008). Consequently, natural areas are broken in to patches resulting in shrinkage, erosion and isolation of ecosystems collectively called fragmentation. This creates discontinuities in ecological processes (Example: Nutrient flow, energy transfer and genetic exchange), which impede the flow of goods and services to the health of ecosystem and human wellbeing (Aronson *et al.,* 2007). Fragmentation can result in shifts of habitats when losses of keystone species alter ecosystem functions and composition. Hence the provision, regulation and cultural services provided by healthy ecosystems are critical to the sustainability of lives on earth (SER, 2008).

Environmental degradation, due to its multifaceted impact on humans and environment (food insecurity, biodiversity loss, soil erosion, euthrophication, global warming, pollution etc.), is currently a universal problem and is a burning concern of nations in the world (Mulugeta Zewudie, 2008). Globally, it has affected 1.9 billion hectare (ha) of land (UN, 1997); 900 million of people; 50% of the pasture and 80% of the cultivated lands (UN, 1994). It has threatened 50% of the world dry lands which cover 47% of the world surface hence they are with increased population densities, fragile soils and low agricultural inputs that accelerate desertification (Mganga *et al.,* 2010). If it continues uncontrolled, developing countries especially those in arid zones will be highly threatened with limited land productivity and food insecurity (UNEP, 1986).

The problem of land degradation is more severe and has threatened 46% of the African continent (WMO, 2005) and evident in declined soil production, loss of biodiversity, habitat destruction and increased soil erosion (Beukes & Cowling, 2003; Visser *et al*., 2007). It is fact that as population increase, more lands will be converted from forest and other land uses to farm land and settlements (Rowe *et al.,* 1994). In general, it is vital to stress that poverty, hunger and environmental degradation in Africa are closely interrelated, and thus any action to reduce poverty and hunger will support in minimizing environmental degradation too (Cleaver & Schreiber, 1994; Quinones *et al.,* 1997).

Land degradation in developing nations is an indicator of under development resulted from amalgamation of social and economic factors such as poverty and inequitable distribution of land resources, inappropriate land use systems and farming practices. In the dry areas, these factors are accelerated by climate and the fragility of ecosystems. Hence agriculture in developing countries is the principal source of income and employment; effects of land degradation are often disastrous and lead to famine and political instability (UNEP, 1986).

2.1.3.4 Land degradation in Ethiopia

Due to varied topographic and climatic conditions, Ethiopia is known to be rich in biodiversity and has been a source of agricultural development and other basic needs for millennia. However, this biophysical potential has been threatened by interlinked and reinforcing problems of land degradation and extreme poverty (Gete Zeleke *et al.,* 2006).

According to Ethiopian Environmental Protection Authority (EPA) (2005), 75% of the Ethiopian livestock populations graze in the highlands often at the expense of remnant vegetation causing to serious degradation on the environment. Studies predicted that nearly 1.9 billion tons of top soil has been washed away mainly from the highlands, every year in Ethiopia (FAO, 1984; 1986) and its onsite effects significantly reduced agricultural production with an estimated cost ranging from 2 to 6.75% of the Agricultural Gross Domestic Productivity (AGDP) per annum (FAO, 1986; Sonneveld, 2002). Land degradation, mainly manifested with deforestation and soil erosion, has become an alarming environmental problem deteriorating biodiversity and land productivity in Ethiopia. These further caused reduction in agricultural production, loss of biodiversity, water quality depletion, disturbed hydrological conditions, poverty and food insecurity (Danano, 2002) as indicated in Figure 2 below.

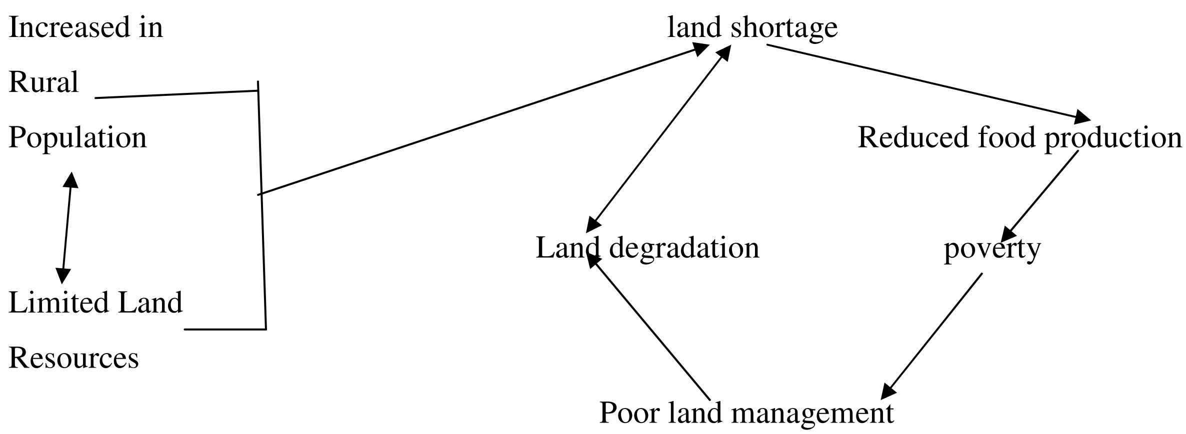


Figure 2: Linkage between population, poverty and land degradation (FAO, 1994).

2.2 Rehabilitation as an option for biodiversity conservation

In response to increased population pressures on ecological systems, efforts have been made to fix the impacts that the society causes. Over time, the science of rehabilitation has developed into a more established field to ameliorate damaged ecosystems (Cairns & Heckman, 1996; Hobbs & Norton, 1996). In recent decades, the management of land resources has received great importance due to the global ecological and socioeconomic crises and apparent dependency of many of the world's poor on common resources, particularly in Asia and Africa (Bromley & Coernea, 1989; Singh, 1994). Rehabilitation is an approach designed to tackle challenges of land degradation such as erosion, food insecurity and loss of biodiversity and loss of soil fertility etc., so as to improve ecosystem goods and services (UNEP, 2010). It is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It involves attempting to reestablish ecosystem services, such as clean water, to humankind (Blay *et al*., 2004).

Ecological rehabilitation is more concerned with the recovery of an ecosystem that has been degraded as result of agricultural expansion, overgrazing and settlements. Improving the qualities and functions of ecological systems such as upland forests or wetlands and their surrounding landscapes is often the final goal of rehabilitation attempts. These ecological functions are the basis for all ecosystem services, which are an essential component of human society's life support system (Ehrlich & Mooney, 1983). Enhancing plant communities is a field of special concern for re-establishment activities (Chapman & Younger, 1995; Heckman & Cairns, 1997). Common targets for vegetation establishment in rehabilitation usually include the establishment and maintenance of sufficient ground cover to control erosion, a degree of resistance to invasion by exotic colonizers, and low maintenance costs (Hobbs & Norton, 1996).

2.2.1 Rehabilitation and soil quality

Soil quality is the capacity of a soil to address the crucial role that it plays in an ecosystem (sustain biodiversity and productivity; regulate hydrological cycle; store and recycle nutrients; buffer and detoxify organic and inorganic materials etc.,) (Karlen *et al*., 1997). It is specific to each kind of soils; however, measuring dynamics of soil properties such as Soil Organic Matter (SOM), pH, soil structures etc., used to compare the effectiveness of different soil management practices among soils on similar land escapes or temporal changes on same soil (Karlen *et al.,* 2001).

Following the 1992 Earth Summit in Rio de Janeiro, Hagvar (1998) highlighted that the broad acceptance of the significance of soil organisms, in particular their ecological significance, has led to increased consideration of soil biological properties within the wider context of sustainable management of our soil resources and the assessment of soil health (Hagvar, 1998). In well structured soils, the infiltration of water is enhanced at the expense of runoff. Under sustainable land management, SOM is a sink to atmospheric gases through Carbon (C) sequestration. However, under poor land management it is a source of green house gases through the formation of Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O). Thus, SOM is a major soil component impacted with soil degradation and that need to be considered during soil rehabilitation as well (Vancamp *et al*., 2004).

Soil Organic Matter, containing 50-80% of humus, is a significant contributor and source to the overall nutrient demand of plants (≥ 95% of N and S (Sulfur); possibly ≥ 25% of P) particularly in zero external in puts. It serves as a buffer against changes in soil reaction and it is the main energy source for soil microorganisms, without which biochemical activity of soil ceases. It also provides a great diversity of habitats and food sources for soil organisms. Cultivation and overstocking significantly affect SOM content of soils by exposing it to rapid desiccation and decline in SOM is an indicator for soil degradation. Soil degradation being initiated by deforestation, desertification, overgrazing, accelerates soil erosion and poor land management depletes SOM causing to loss of soil biodiversity as well (Vancamp *et al*., 2004). Consideration of the rehabilitation of soil quality and biodiversity along with vegetation communities is instrumental in rehabilitation activities. Hence, an effort to rehabilitate degraded lands without careful concern of soil systems is impractical (Aronson *et al*., 1993; Harris *et al*., 1996).

2.2.2 Area closures (ACs) as strategy to rehabilitate degraded areas

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 AC, 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 G/Hiwot, 1997; Emiru Berhane, 2002; Kidane Giday, 2002). The allover ecological conditions of degraded lands will be improved resulting with superior socioeconomic and environmental services to the society (Verma *et al*., 1999).

Area closures 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 (FA0, 2005).

2.2.2.1 Contributions of area closures

I) Protecting soil erosion and enhancing land productivity

Vegetation rehabilitation through enclosures is competent measures for soil and water conservation; because they are the best alternative forms of land uses to overcome erosion and deposition (FAO, 2001). Vegetation cover promotes infiltration rate, structure and permeability of underlying soil. Soil with good structure absorb water quickly and minimize surface runoff (Wild, 1993). In Ethiopia, the practice of ACs have become an important strategy in rehabilitating degraded hillsides, especially in the highlands due to their remarkable improvement of land productivity and soil erosion reduction (WFP & MoA, 2002). According to Kidane Giday (2002), establishing intergraded watershed management (involving conserving, upgrading and using of the natural resource base of the land, plant, water, animal and human resources) through enclosures with effective local people participation is a basis to prevent further ecological imbalance.

Maintaining sufficient vegetation cover is the primary resistance means against soil erosion and stabilizes slopes ensuing improved soil quality (George *et al*., 2004). Besides vegetations deposit litter on soil surface which will build up inorganic nutrients (cations) (Skarpe, 1991). The leaves and barks made available soil nutrients with shallow depth. There is a positive correlation between organic matter and exchangeable cations of a soil (Wild, 1993). Stable SOM pool also improves soil fertility by holding plant nutrients and preventing them from leaching in to the subsoil.

Area closures promote vegetation coverage which enhances the amount of accumulated SOM leading to improved physical and chemical properties of soil and overall health of the ecosystem. Soil organic matter often influences soil properties such as soil structure, moisture, diversity and activities of soil organisms (Bot & Benites, 2005). The available water holding capacity of a soil will increase by 3.7% for every 1% increase in soil organic matter (Hudson, 1994). Soil organic matter is an essential soil component hence it helps to improve soil physical conditions, increase water infiltration, decrease soil erosion, supply available plant nutrients and augment soil's cation exchange capacity (Bandel *et al*., 2002).

II) Biodiversity conservation

Rehabilitation of degraded sites, as result of enclosures, improves biodiversity from which the livelihoods of people depend on and it ensures sustainable development and ecological integrity (Kindeya G/Hiwot, 1997). Species exploitation due to human misuse significantly threatened biodiversity all over the world. This calls for restriction of humans and livestock from sites to reclaim degraded sites which can promote sustainable development and the health of an ecosystem through reducing erosion, increasing biological productivity and improving soil quality (Aradottir *et al*., 2000).

III) Livelihood improvement of the community

Establishing conservation areas and rehabilitation of degraded sites support agricultural growth because they protect watersheds; stabilize local climate and hydrological system. Protection of rural environment also ensures the sustainable provision of crucial forest products and environmental services (Cleaver & Schreiber, 1994). Area closures contribute a lot in improving the opportunity of local people in sustainable utilization of common resources leading to improved land productivity (Emiru Berhane, 2002). The practice enables the local community to alleviate poverty by enhancing vegetation cover; hence erosion is central to reduce land productivity (Medhin Zewudu, 2002). Rehabilitation activity (Example: Hillside vegetation) helps to maintain valuable ecosystem services, reduce flood damage and is reinforced as a base mark building block of development support of the rural community (GACGCS, 2005).

According to FAO (2001), area closures provide forest products that can improve the food access, and economic well being of the rural poor. Area closure in Ethiopia has been effective in maintaining vegetation resources for energy sources, on which 78-80% of the total household's energy supply of Ethiopian depend (EFAP, 1994). Rehabilitated mountains and fragile ecosystems reduce risk of flooding, improve biodiversity and land use planning in a watershed. It protects downstream area from flood hazard and clotting with silt by improving infiltration resulting in replenishing of springs and access water for long period of time for downstream communities (Mitiku Haile & Kendeya G/Hiwot, 1997).

2.2.3 Measuring the success of rehabilitation

Historically, anthropogenic land uses fundamentally change the biophysical environment resulting in new ecosystems that differ in vegetation structure, species composition and function. Rehabilitation often reverses these environmental imbalances and is measured based on the status of (i) species composition and diversity (ii) ecosystem processes (Example: Nutrient contents of soil). Soil is a dynamic resource; its quality is altered in response to management and is one of the measures of the success of rehabilitation as well. At the site or patch scale, vegetation structure (Example: Stem density, height, DBH, frequency, basal area, important value index, number of strata) and plant diversity are frequently used to monitor rehabilitation success (Hobbs & Harris, 2001).

Species diversity, often synonymous with heterogeneity (Krebs, 1999), has been evolved as the most universally accepted index to evaluate the conservation potential and ecological value of an area (Magurran, 1988; Krebs, 1999). Diversity consists of species richness and species evenness where the former implies the total number of species in a community; while the later which also referred as equitability, explains a measure of the relative abundance of the different species making up the richness of the community (Magurran, 1988).

The higher the diversity of the community, the higher the evenness is and vice-versa. A community is said to have high species diversity if nearly equally abundant species occupy the area. But it is said to have low species diversity if the area is occupied by only few species (Brower *et al*., 1984). The value of species diversity ranges from zero, for a community with a single species, to high value for a habitat constituted with diverse community. The value increases with an increase in number of species in a community and expected to vary from 1.5 to 3.5 and rarely reaches 4.5 (Kent & Coker, 1992) however, it does not exceed 5 for biological communities (Krebs, 1999).

3. Materials and Methods

3.1 Description of the study area

3.1.1 Location

The study area, Kewot is one of the North Shewa Administrative zone Districts of Amhara National Regional State, covering a surface area of 715.85 km^2 and has 22 rural Kebelles. Its capital city Shewa Robit is located at 225 km northeast of Addis Ababa. Shewa Robit is situated at the high way which runs from Addis Ababa to Dessie. Meriyena insirt (Merye) and Abomsana wuruba (Abomsa) Peasant Associations (PAs) were selected as study sites due to their better experience in area closures (23 and 10 old years, respectively), similarity in agro-ecology and availability of comparable adjacent open grazing lands.

The Abomsa site

The PA is located at 1,108,250 to 1,116,250 m N latitude and 594,800 to 604,200 m E longitude with an elevation range of 1,226 to 1,388 meter above sea level (m.a.s.l). Abomsa site was primarily fenced for soil and water conservation by Sheno Agricultural Research Center (SHARC). After 3 years, however, the management was handed over to the local community and a total of 125 ha area of land was partitioned to 186 households who formulated the local bylaw to manage the land resources. Accordingly, every member of the association is allowed to use resources on his own delineated areas (grass for fodder and thatching and dry fire wood collection), contributes 2 Birr per month for guards and will be penalized from Birr 5.00 to 50.00 when violates the law. The regeneration status of the area is illustrated in plate 1 as follows.

Plate 1: A portion of 10 years area closure in Abomsa site.

The Mereye site

It is located at 1,099,300 to 1,106,300 m N latitude and 597,500 to 605,500 m E longitude with an elevation range of 1,243 to 1,360 m.a.s.l. It covers a surface area of 20 ha and was enclosed in 1980 E.C. by an individual as intervention for accelerated soil erosion, since then it is administered according to the local bylaw formulated by the local development committee. The study sites are presented below in Figure 3.

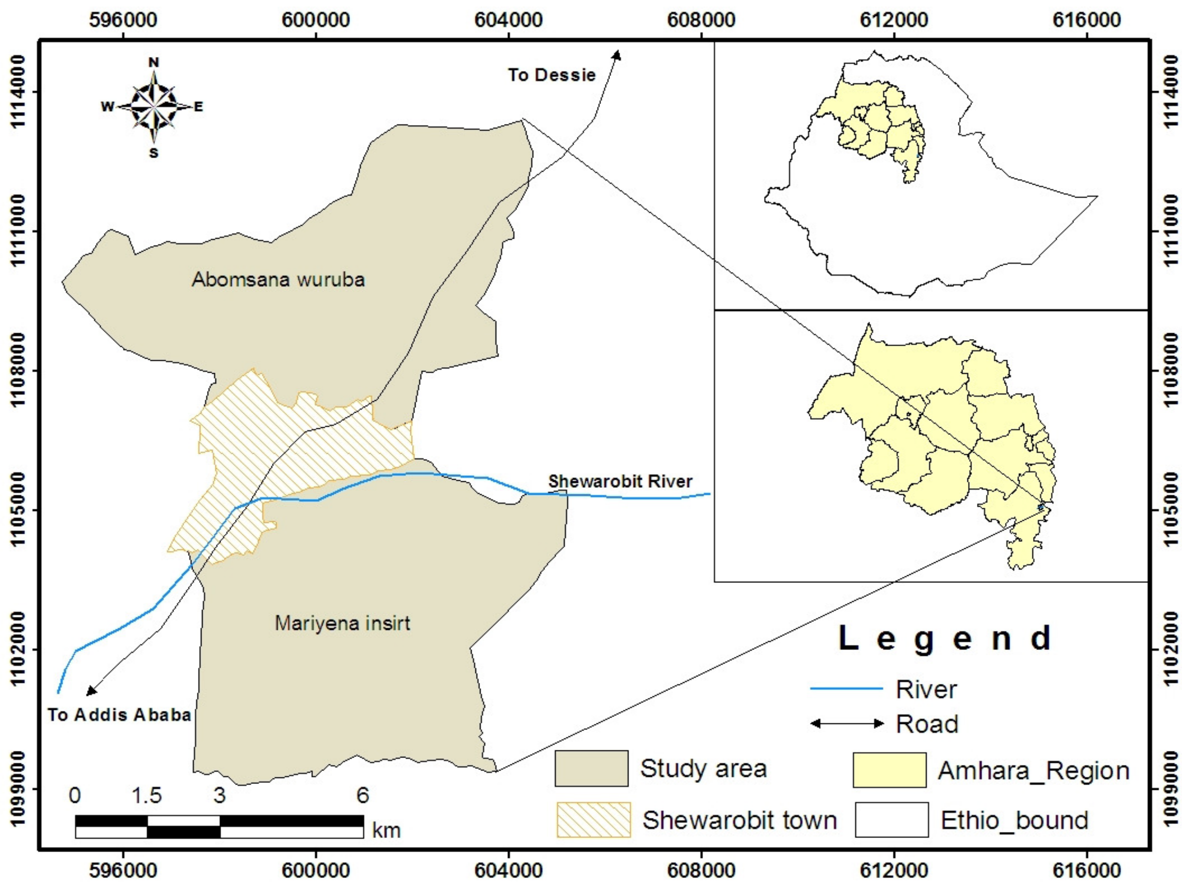


Figure 3: Map of study area

3.1.2 Population

The district has an estimated total population of 119,836, of which 60,699 are males and 59,136 are females and an estimated population density of 167 people per square kilometer of land. The family size of the district ranges from 6 to 8 per person and households account a total of 21,910 and the land holding per household is 3.27 ha of land. The community in the study area is dependent on subsistence agriculture with dominant cereal crops cultivation and livestock mixed farming system. The district is endowed with perennial and seasonal rivers, springs and ponds. Shewa Robit river is the largest, multipurpose perennial river drained in to Awash. It is a source of water for about 250-300 households (SHARC, 2002).

3.1.3 Topography and soil

The district is characterized by rugged topography where 26% of the land is plain, 38% is mountainous, 17% gorge and 19% undulating. Black, brown, red and grey soil types accounts for 55%, 22%, 15 % and 8% are the most dominant soils in the district (SHARC, 2002).

3.1.4 Climate

The study site is characterized with semiarid climate where mean minimum and maximum temperature are 23.87 ^{o}C and 24.44 ^{o}C, respectively. The mean annual rain fall is 1071.4mm. The six years annual rainfall and mean temperature graph is indicated in Figure 4 below.

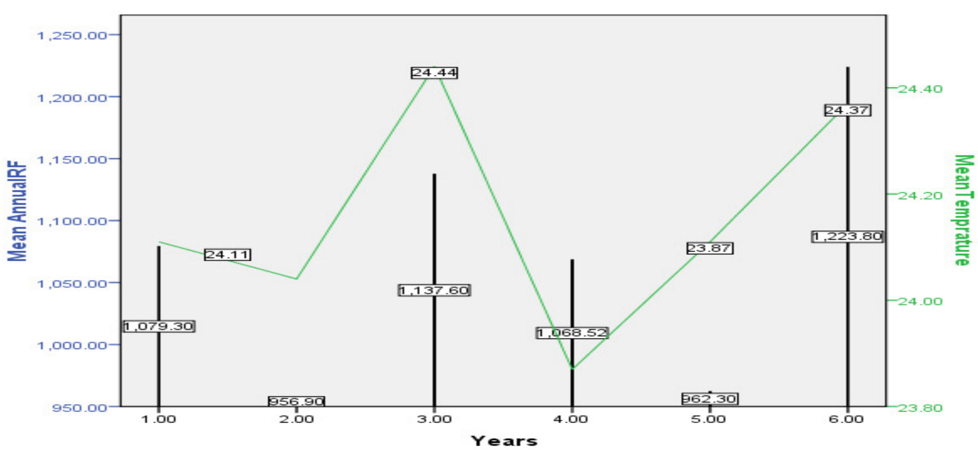


Figure 4: Six years annual rainfall (mm) and mean temperature (^{O}C) between August 2004-July 2010 in the study area (1=August 2004-July 2005; 2=August 2005-July 2006; 3=August 2006-July 2007; 4=August 2007-July 2008; 5=August 2008- July 2009; 6=August 2009-July 2010) (TADO, 2010).

3.1.5 Land use and farming system

Most of the areas have fairly poor vegetation cover. Plain and gently sloping lands are used for cultivation; whereas grazing lands only found on the hillsides and marginal lands consisting of the least share of land surface in the study area. Agriculture in the study area is rain fed, with a subsistence mixed farming system. Therefore, land and live stocks are the major assets for the community. Cereals like Tef, Barely, Wheat, Maize, Sorghum; vegetables like cabbage, tomato and fruits such as, mango, banana, orange, papaya etc., are the major crops grown in the area (KWOA, 1994). In the district, livestock is kept for multiple purposes including source of traction (plowing and land preparation), source of meat and milk, transportation and means of income. Live stocks such as cattles, small ruminants, equines and poultry accounting 76,895, 54,449, 13,464 and 75,296, respectively are the main domestic animals and assets of the community (KWOA, 1994).

Because of increasing population pressure, fallow periods are shortened and the fields are given less chance to regenerate. This results in decreasing yields due to decreasing fertility of the soil, increasing erodibility and ultimately total degradation. Farmers have limited income and are unable to buy artificial fertilizers to improve the productivity of the land and to slow the process of degradation. Furthermore, organic fertilizers, like livestock dung are used for cooking fuel (SHARC, 2002).

Agro-pastoralists who are engaged in livestock production and cultivation of crops are the most dominant households in the district. The principal fodder sources for their animals include crop residue, grass, shrubs, post harvest grazing and ranges. Rangelands take the largest share being available feed source for agro-pastoralists (KWOA, 1994). The land is exposed to erosion due to natural and anthropogenic factors (SHARC, 2002). However, nowadays there are flourishing efforts to rehabilitate degraded lands by interventions like area closures and soil and water conservation strategies.

3.2 Study Design

3.2.1 Reconnaissance survey

Reconnaissance field survey was made to obtain an overview of the study sites, before the actual survey operation, followed by detailed preliminary survey on biophysical components and community perception evaluation that was made between 4^{th} week of October to the end of November, 2010. A cross-sectional survey research design was used to collect primary qualitative and quantitative data from the field.

It is assumed that the enclosed and open grazing lands were homogenous in biophysical factors before the enclosures are fenced (restricted for rehabilitation) and are similar in topographic and climatic characteristics. Accordingly, parameters such as soil chemical properties, woody vegetation cover and diversity (species richness, species evenness, and species diversity) (Ludwig & Reynolds, 1988; Magurran, 1988) were used to evaluate the rehabilitation status of the area.

3.2.2 Data collection and sampling technique

Systematic sampling technique was used to study the woody vegetation following the Muller –Dombois & Ellenberg (1974) procedure. Transects were systematically laid in South-North direction from area closures towards the open grazing lands and were used to collect quantitative primary data on the status of woody vegetations from each enclosed and open grazing land. Soil samples were collected from sample plots laid for vegetation. Data related to households' perception on area closures and benefits gained from the practices were collected using questionnaire.

3.2.2.1 Vegetation sampling

Three transects each with 1000 m long at 300 m interval were laid for each study sites. The first and last transect lines were laid at a distance of 100 m from the edges to avoid the effect of disturbances. A total of 12 transect lines and 36 plots each with a size of 400 m^2 (20 m x 20 m) were laid at 250 m interval between plots. In each plot: (i) all woody vegetation categories were identified, counted and recorded by their local and /or scientific names (using a field guide of Woldemichael Kelecha 1987; Azene Bekele *et al*., 1993); (ii) the height of mature plants (height > 2 m), saplings (1< height < 2 m) (Muller-Dombois & Ellenberg, 1974; Lu *et al*., 2010) and Diameter at Breast Height (DBH, at a height of 1.3 m above the ground) of saplings (DBH < 2.5 cm) ; trees and shrubs (DBH > 2.5 cm) (Jiangshan *et al*., 2009) was measured and recorded using clinometer and caliper, respectively. Seedlings were recorded only by their counts. Tree and shrub are both perennial woody plants where the former is often distinguished with its single central aerial stem; while the later often has numerous stems.

Voucher specimen representatives of woody vegetations were collected, recorded and systematically pressed and transported to the National Herbarium of Addis Ababa University for identification. The nomenclature of plant species followed the published Flora of Ethiopia and Eriteria (Hedberg & Edwards, 1989; Edwards *et al*., 1995; Tewoldeberhan G/Egziabber *et al*., 1995; Edwards *et al*., 1997; Edwards *et al*., 2000; Hedberg *et al*., 2004; Hedberg *et al*., 2006; Hedbergs *et al*., 2009).

3.2.2.2 Soil sampling

Composite soil samples were taken at a depth of 20 cm depth using an auger from 16 of 36 study plots systematically laid for vegetation sampling. Soil was sampled from the four corners and the middle of each plot and subsequently mixed. These soil samples were packed with plastic bags, coded and taken to Debrebirhan Agricultural Research Center (DARC) and to Debreberhan University for laboratory analysis.

3.2.2.3 Sampling of local communities

A total of 168 households were systematically selected from the list of local community members received from the Kebele administration. Semi-structured questionnaire was provided to these households with language translator to collect their perception on area closure and benefits gained from it. The Abomsa and Merye Kebeles have 186 and 112 households, respectively; among which 105 from Abomsa and 63 from Merye, a total of 168 respondents were included using a statistical formula as follows.

i.e. $$n = \frac{Z2pqN}{Nd2 + Z2pq}$$

Where, n= sample size

N= total population of households in both sites

Z^2= confidence interval (1.96, constant)

d^2= margin of error

p= proportion of population (0.5, constant)

q= 1- p

Assumption: let d= 0.05 and q= 0.5 (Daniel, 1995)

Thus, $n = \frac{(1.96)^2 (0.5)(0.5)(298)}{(298)(0.05)^2 + (1.96)^2(0.5)(0.5)}$

n= *168*

Hence the data was categorized in two strata, the number of households in each site was calculated as:

$$n1 = \frac{n * N1}{N}$$

Where, n_1= sample size in the first site

n= number of households in the first site

N1= total number of households included in the study

N= total number of households in both sites

$$n1 = \frac{186 * 168}{298} = \underline{105}$$

Similarly, $n2 = \frac{n * N1}{N}$

Where, n_2= sample size in the second site

n= number of households in the second site

N1= total number of households included in the study

N= total number of households in both sites (Daniel, 1995)

$$n2 = \frac{112 * 168}{298} = \underline{63}$$

3.3 Data Analysis

3.3.1 Vegetation diversity and structural data analysis

3.3.1.1 Diversity and Sorensen's similarity data analysis

Shannon-Wiener diversity and Shannon evenness indices were calculated using Shannon-Wiener (1949) and computed to describe species diversity of the area. Hence it accounts for both species richness and evenness and does not affected by sample size, the Shannon-Wiener diversity index is considered to be the most popular measure of species diversity (Kent & Coker, 1992; Krebs, 1999). For each woody plant categories (seedlings, saplings, shrubs and trees), species richness was expressed as number of species per unit area. Hence, the larger the sample, richness would expect to increase, S is divided by the square root of the number of individuals in the sample. This particular measure of species richness is termed as Menhinick's index (D) (Menhinick, 1964).

i.e. $D = S/\sqrt{N}$, where: D= Species richness (Menhinick's index)

S= number of species in the sample

N= number of individuals in the sample

The species diversity in different age of enclosures and open grazing lands were calculated using Shannon-Wiener index (H') (Shannon-Weiner, 1949) as follows.

$$H' = -\sum_{i=1}^{S} Pi\ Inpi$$

Where: H' = Diversity of species

S = Number of species

Pi = the proportion of individuals abundance of the i th species

ln = long base

Evenness index (J) of species was calculated using the Shannon Evenness index by the equation:

$$\frac{H'}{H'max} = \frac{-\sum_{i=1}^{S} Pi\ Inpi}{\ln S}$$

Where: $H'max$ = lnS ; H' = Shannon diversity index

lnS = the natural logarithm of the total number of species in each community

S= number of species in each community (Shannon-Weiner, 1949).

The higher the values of Shannon evenness (J), the more even the species are by their distribution. Likewise, the higher the value of Shannon diversity index (H'), the more diverse the community is.

The collected data from each area closure, based on the parameters indicated above, was compared to its adjacent open grazing land to evaluate the effect of land management on species richness and diversity.

Sorensen's similarity index

The Sorensen's similarity coefficient was computed to determine the patterns of species turnover among successive communities. It is used to measure similarities between two habitats and described using the following formula (Kent & Coker, 1992).

SC = 2a/2a +b+c

Where: a =number of species common to both habitats

b= number of species present in the first habitat but absent in the second

c = number of species present in the second habitat but absent in the first.

3.3.1.2 Structural data analysis

According to Muller-Dombois & Ellenberg (1974), the vegetation structure, biomass structure, life form structure, stand structure (its numeric distribution of different sized individuals) etc., are considered in vegetation ecology to deal with vegetation structure (organization). In woody vegetation structure analysis, the growth stages such as seedlings, saplings and mature plants (Muller-Dombois & Ellenberg, 1974) could be one of the elements of diversity that determine the rate of recover after disturbance. Thus, parameters like species density, frequency, tree height and diameter at breast height (DBH) (Kent & Coker, 1992) were used to describe vegetation structure in this study. The vegetation data were computed and summarized in Microsoft Excel spread sheet using the following formula:

Density (D) = total number of stem counts/sampled area in hectare

Relative density = Number of individuals of tree species * 100/ total number of individuals. (Muller-Dombois & Ellenberg, 1974)

Frequency (F) is the number of times a species is present in a given number of sampling points. It refers both the patterns of distribution as well as diversity and often expressed in percentages as follows (Goldsmith *et al*., 1986).

Frequency (%) = Number of quadrants in which species is found * 100/ total number of quadrants laid in the study site

Frequency is often categorized in to five classes: A=0-20; B=21-40; C=41-60; D=61-80 and E=81-100.

Relative frequency = Frequency of a specie * 100 ⁄ sum of frequency of all species

The species diversity results were fed into Statistical Package for Social Sciences (SPSS) version16 and computed using ANOVA (one way Analysis of Variance) statistics, and LSD (Least Significant Difference) to examine whether or not difference exists in vegetation diversity across the study sites.

3.3.2 Laboratory analysis of soil samples

The collected soil samples were air dried, crushed and sieved with 1mm mesh for total Nitrogen (TN) and Organic Carbon (OC) and with 2 mm size mesh for the remaining soil parameters. The soil chemical properties were analyzed with element specific laboratory methods such as pH by potentio-metric method (Schoffield & Taylor, 1995) in the supernatant suspension of 1:2.5 soil: water), available potassium (K) by flame photometer method (Black *et al.,* 1967), available phosphorus (P) by Olsen method (Olsen *et al.,* 1954), Organic Carbon and total Nitrogen (TN) content by titration method (Walkley & Black, 1934).

ANOVA was computed to test whether or not a significant difference exists across the study sites within mean soil parameters. Likewise, Pearson correlation test was used to assess the correlation among soil parameters and their relation to species diversity.

3.3.3 Local communities' perception data analysis

Each questionnaire was collected and tallied after it has been checked as filled properly.

The local communities' perception data were fed on Excel spread sheet and described in descriptive statistics.

4. Results and Discussion

4.1 Impact of area closures on floristic composition, diversity and vegetation structure

4.1.1 Floristic composition

A total of 2,394 individual stems consisting of 46 species, 26 families and 38 genera were counted and recorded. Out of which, 15 species (32.6%) belonging to 10 families were common to enclosures and open grazing lands, while 31 species (67.4%) belonging to 16 families were found only in enclosures. But no species was identified only in open grazing lands. Although shrubs and trees constituted the majorities of floristic composition in both area closures and open grazing lands, the proportion of woody plants, especially seedlings are significantly diminutive in open grazing lands (Appendix1, 2). The result of vegetation composition analysis indicated that enclosures are far more enriched with vegetation composition than open grazing lands.

Species such as *Acacia dolichocephalia, Acacia nilotica, Dichrostachys cinerea, Acacia brevispica, Acacia tortilis, Acalypha fruticosa, Ziziphus mucronata, Ziziphus mauritiana, Grewia tembensis, Grewia villosa* were the most dominant vegetation species in the area closures. Whereas *Acalypha fruticosa, Acacia nilotica and Sagertia thea* were the most dominant species in open grazing lands. The complete list of floristic composition of the study site is given in Appendices 1 and 2.

In enclosures, Fabaceae was the most diverse and dominant family in number of species as well as in individual composition (9 species (19.56%) and 424 individuals (32%)) followed by Tiliaceae, Rhamnaceae, Euphorbiaceae and Anacardiaceae and Rosaceae each represented by 5 (10.9%), 4 (8.7%), 3 (6.5%) and 2 (4.35%) number of species and 186, 170, 120, 66 and 40 individual populations in the areas (Appendix 3). On the other hand, with 3 species (20%) and 76 individuals (21.96%), Fabaceae was the most dominant family followed by Rhamnaceae, and Tiliaceae with 74 (21.39%), and 58 (16.76%) individuals but with 2, and 3 number of species in the open grazing lands (Appendix 4). The remaining families were represented each with a single species in both enclosed and open sites (Appendices 3 and 4).

Generally, the floristic compositions of open grazing lands were three times lower to the enclosed sites, which may be due to the consequence of interference and modification by humans in open grazing lands that declined the species composition. But it may be due to the contribution of management that assisted the proliferation of floristic composition and encouraged the ecosystem to sustain advanced vegetation species especially those tolerant to disturbance**.** This study result agrees with studies that concluded as humans modify the floristic composition and structure of forests during the process of utilization for their immediate purpose of best goods and services (Wiersum, 1997; Bakes, 2001) but protection like area closure establishment, among other factors, may assist in improving the overall ecological conditions of degraded areas (Mengistu Tefera *et al*., 2005) and allowed regeneration of shrubs and trees in the area (Kebrome Tekle, 2001; Tefera Mengistu, 2001) boosting the species composition of the area (Zerihun Woldu, 1991).

4.1.2 Vegetation similarity and diversity

4.1.2.1 Floristic similarity

The Sorensen's similarity coefficient for the study sites was indicated in Table 1 with a similarity coefficient ranging from 0.52 to 0.63. Accordingly, the coefficient values of all sites are above 0.5. It may be due similarity in altitudinal range, geographic location and climatic conditions, the floristic composition showed similarity across the study sites. However, it may be due to the role of protection, the similarity across the sites is not even. Variation in floristic composition among study sites, especially between enclosures and grazing lands may be the positive impact of management supported the enclosures to be enriched in species composition than grazing lands. The study result agrees with studies that concluded due to difference in management, open and enclosed sites significantly differ in floristic composition (Kidane Giday, 2002; Tefera Mengistu *et al*., 2004).

Table 1: Sorensen's similarity coefficient of study sites

	Open grazing lands	10 years area closure	23 years area closure
Open grazing lands	1		
10 years area closure	0.52	1	
23 years area closure	0.54	0.63	1

4.1.2.2 Species richness, diversity and evenness of woody plants

In contrast to findings that pointed out long term exclusion of herbivores may decline species richness (Oba, 1992; Oba *et al*., 2001 cited in Nedessa Betru *et al*., 2005), the Menhinick's index in this study, especially in shrubs and trees, showed improvement as a result of management and age (Appendix 11). In line with this study result, Teshome Soromessa *et al*. (2004); Kidane Giday (2002) and Hubbel & Foster (1986) showed that it could be due to optimal environment and minimum disturbance, species richness in enclosures was higher than open grazing lands (Hubbel & Foster, 1986; Kidane Giday, 2002; Teshome Soromessa *et al*., 2004). This higher proportion of woody vegetations in enclosures suggests the existence of an active succession (recruitment) of woody vegetations in the sites as a result of restriction of humans and animals interference.

According to Appendix 11, the evenness values of stem groups in area closures significantly exceeds than the species in open sites. Low evenness of woody species in open grazing lands reveals that the areas are dominated with few species and this could be attributed to excessive disturbance and selective cutting of some species by humans (Alemayehu Wassie, 2002) resulted in dominance of few species. Hence, dominance is inversely related to evenness, the open sites are considered to be with less species diversity than enclosed sites (Wilson *et al*., 1996).

The Shannon diversity (H') values of woody plants in enclosed sites were much higher than their adjacent open grazing lands. The highest mean diversity value being 3.9 was recorded in 23 years area enclosure which was more than twice of the open grazing lands (1.6) (Appendix 11). As a result, area closures have high diversity values (H'> 3) (Cavalcanti and Larrazabal, 2004 quoted in Kibret, 2008) in all stem categories. The diversity differences analysis among vegetation categories indicated an improvement in diversity indices in area closures than open grazing lands as well as within the age of enclosures (Fig. 5). This implies that management and age of enclosure considerably contributed to the diversity of woody vegetation categories. Moreover, it may be due to their vulnerability to disturbances, the diversity of seedlings became very diminutive in open grazing lands (Fig. 5).

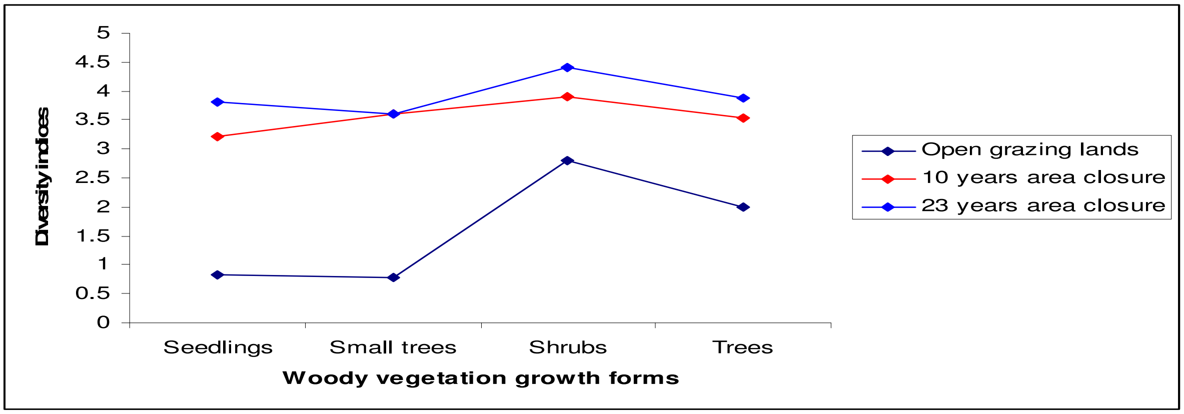


Figure 5: Diversity differences among the two area closures and open grazing lands for different vegetation categories (seedlings=height<1m; small tree=single trunk with height up to 15m; trees=single trunk with height >15m; shrub= several stems with height up to 5m (Muller-Dombois & Ellenberg, 1974; Lu *et al*., 2010)).

The result of different diversity indices analysis of woody vegetation growth forms indicated that enclosed sites are significantly higher in all indices than their adjacent open grazing lands (Appendix 11 and Figure 5). This confirms the positive impact of management that favored species composition in area closures and this likely promotes the biological diversity (Bot & Benites, 2005) of the area.

Similarly, the ANOVA result of the impact of management and age revealed significant difference in diversity (p=000) and richness (p=0.015) across study sites (Table 2). Moreover, the LSD result of management and age on diversity and richness of woody vegetation stem groups showed significant difference (P=000) among enclosures and between enclosures and open grazing lands at 0.05 level (Appendix 12).

Table 2 : ANOVA (Analysis of Variance) result of the impact of management and age on diversity and richness of woody vegetations

		Sum of Squares	df	Mean Square	F	P-value
Species Diversity	Between Groups	33.505	3	11.168	1701.609	.000
	Within Groups	.210	32	.007		
	Total	33.715	35			
Species Richness	Between Groups	6.465	3	2.155	4.073	.015
	Within Groups	16.931	32	.529		
	Total	23.396	35			

In line with this research result, studies state that land management options through natural regeneration often improve soil conditions resulting in enhanced species diversity and ecosystem productivity (Cairns, 1994; SER, 2008). Likewise, Oba (1998; 2000) summarized that animal grazing, especially goat grazing, has a negative impact on biodiversity and that is why restriction of humans and animals is reinforced (Oba, 1998; 2000). Moreover, other studies shown that disturbance like free grazing is agreed to be the main threat to species diversity, ecosystem structure and function (Mcintyre & Hobbs, 1999). Consequently, degraded lands are with deficient plant nutrients and low biological diversity (Verman *et al*., 1999).

4.1.3 Vegetation structure

4.1.3.1 Density and frequency of woody species

The overall density of woody vegetations in area closures was 4,683.2 ha^{-1} and the proportion of mature plants, saplings and seedlings were 67.7%, 17.4% and 14.9% in that area. Whereas the corresponding open grazing lands had a total density of 785.9 ha^{-1}, of which mature plants, saplings and seedlings constituted of 78.6%, 15.9% and 5.5% in the sites (Table 3). All the stem groups' total density of Woody vegetations in enclosures significantly exceeds the density of their relatives in open grazing lands.

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

Categories	Densities in area closures	Total density in open grazing lands
	total density ha-1	total density/ha
Mature plants (Shrubs and trees)	3102.14	617.9
Saplings	782.05	125
Seedlings	617.1	42.86
Total	4501.29	785.72

The presence of each vegetation categories in both sites indicates the regeneration potential of the sites. However, still the density of each plant category, especially seedlings in enclosed sites, is far more than the open grazing lands indicating the effect of management to promote woody vegetation density. It is supported by a study that states disturbance, especially overgrazing causes reduction in palatable species leading to reduction in plant density and impairs the natural regeneration including development of seedlings (Bot & Benites, 2005).

Besides, studies reported that successful regeneration promotes seed dispersal by attracting disseminating agents (Example: Birds, bats) resulting in seed development under tree crown than in open sites (Blay, 2002). Similarly, other studies concluded that density of seedlings, among other factors, is often influenced by the density of large trees (Janzen &Vazyue-yanes, 1991).

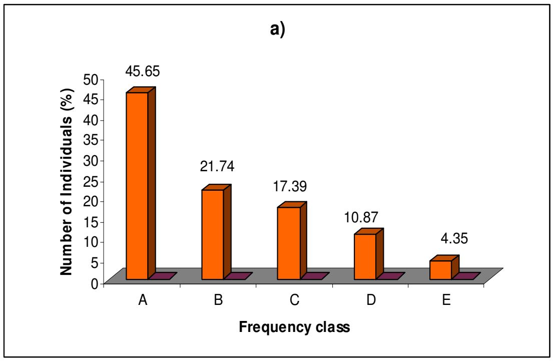
The density of woody species with DBH >10 cm (10.01-20 cm) and DBH >20 cm is often taken as a measure of size class distribution (Grubb *et al*., 1963). As a result, although it is far lower than the species densities of virgin forest, the density of tree species (DBH > 10 cm) in area closures is 247.46 ha^{-1}, which is significantly higher than the density of the same size species in open grazing lands (Table 4), indicating the role of protection to promote species density and development to higher diameter sizes in area closures. Thus, management ensures the probability of plant growth to high diameter size which will enhance the probability of seed bearing plants for seed dispersal and germination to seedlings (Demel Teketay, 1996); hence seedlings in the tree fall gaps grew to higher DBH classes almost four times quickly than in open sites (Nepstad, 1991). The complete list of tree species density distribution by DBH in area closures and open grazing lands is given in Appendices 5 and 6.

Table 4: Density per hectare distribution of tree species with DBH ≤10 cm, DBH between 10.1 to 20 cm and DBH ≥20.1 cm in the study area.

Sites	Tree densities ha^{-1} by DBH		
	DBH≤10 cm	DBH from10.1- 20 cm	DBH≥20.1cm
Area closures	1221.18	202.62	44.84
Open grazing lands	437.32	34.74	63.4

Based on frequency distribution, species were classified in to five frequency classes (A, B, C, D and E). The frequency distribution of species decreased towards higher frequency classes in area closures. Accordingly, 45.65%, 21.74%, 17.39%, 10.87% and 4.35% of species were distributed to A, B, C, D and E frequency classes. Likewise, 7%, 13%, 20%, 20% and 40% of species were distributed to the same frequency classes in open grazing lands and the species population increased along with increase in frequency classes (Fig. 6). The complete list of woody species frequency distribution is given in Appendices 7 and 8.

The frequency distribution of vegetation indicates the heterogeneity or homogeneity of a community (Lamprecht, 1989). Accordingly, the woody vegetation frequency distribution in area closures showed inverted J shape pattern of distribution (Fig. 6a), indicating high degree of floristic heterogeneity (Simon Shibru & Girma Balcha, 2004). Whereas, the frequency distribution of vegetations in open grazing lands showed normal J shape pattern of distribution (Fig. 6b), representing similar floristic composition (homogeneity) (Lamprecht, 1989) in the area.



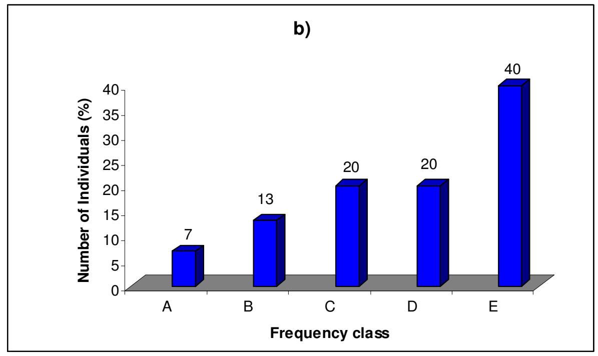


Figure 6: Frequency distribution of Woody plant species in area closures (a) and open grazing lands (b) (A-E are frequency classes; A=0-20; B=21-40; C=41-60; D=61=80; E=81-100).

4.1.3.2 Tree Height and DBH

The height and DBH classes were divided into five height and DBH classes. The tree height analysis result showed that trees in open grazing lands constituted only the lower and higher height classes. Whereas, in area closures, the majority (55%) of total tree height constituted the first height class (height< 2 m) and the tree height percentage distribution decreased with an increase in height class showing inverted J shape pattern of distribution (Fig. 7), indicating good recruitment potential of species in the area (Kumelachew Yeshitela & Taye Bekele, 2003). The majority this count was contributed by *Acacia nilotica, Acacia tortilis, Acacia dolichocephalia, Dichrostachys cinerea* etc., in area closures. The complete height distribution of trees is given in Appendices 9 and 10.

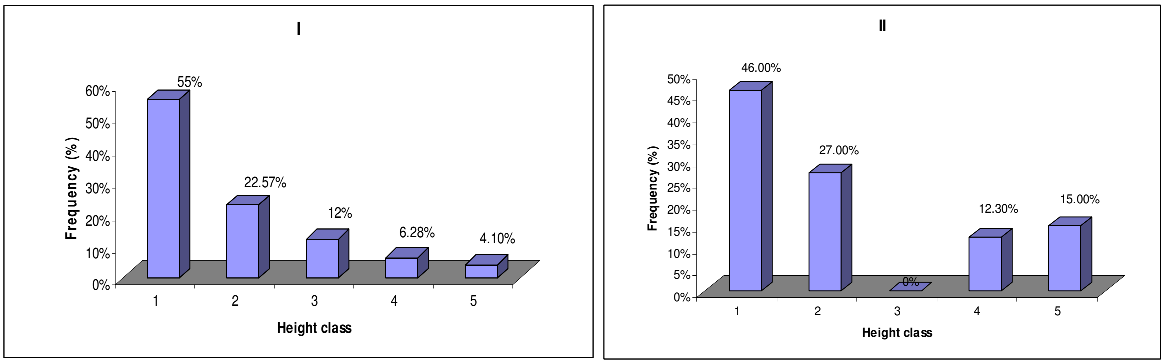


Figure 7: Percentage distribution of Trees in height class in area closures (I), open grazing lands (II) (Height class 1.≤ 2 m; 2. 2.1-5 m; 3. 5.1- 10 m; 4. 10.1- 15 m; 5. ≥15.1m).

The DBH distribution analysis of trees revealed that the first DBH class (DBH ≤ 5 cm) constituted the majorities of tree densities in both open grazing lands and area closures. The tree species extremely obstructed in the middle DBH classes in open grazing lands. But the species distribution followed an inverted J shape pattern in area closures (Fig. 8), showing high rate of regeneration status of tree species in enclosures (Simon Shibru & Girma Balcha, 2004).

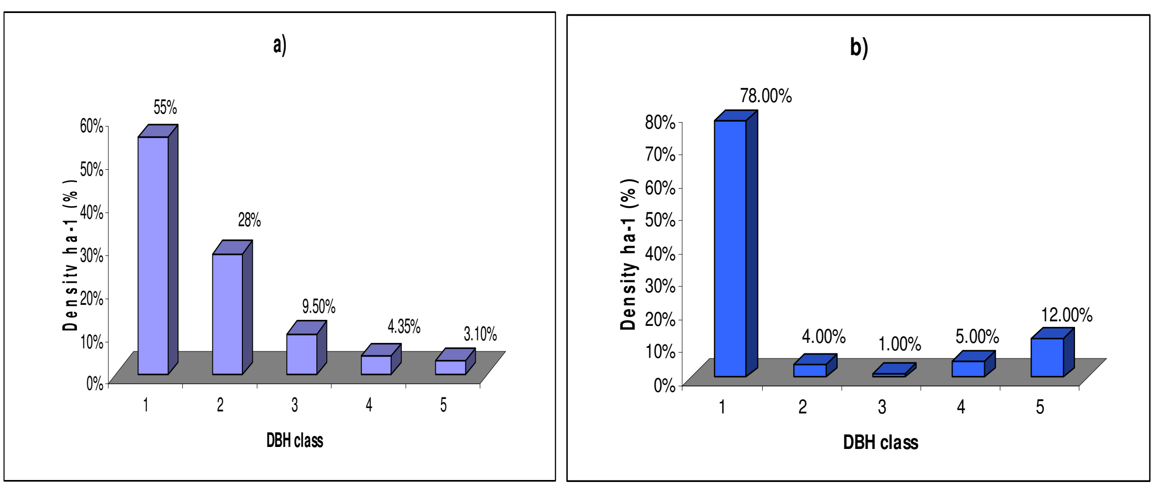


Figure 8: DBH by density per hectare distribution of Trees in area closures (a); open grazing lands (b) (DBH class 1. ≤ 5 cm; 2. 5.1- 10 cm; 3. 10.1-15 cm; 4. 15.1- 20 cm; 5. ≥ 20.1 cm).

Higher proportion of trees in lower diameter class indicates the regeneration potential of both sites. It may be the contribution of management, the tree populations in area closures showed ongoing recruitment than their adjacent grazing lands. In contrast, it may be due to either selective removal by humans for domestic purposes or being vulnerable to extreme disturbances of lower diameter class tree species in open grazing lands, seedling development to higher diameter classes was hindered (Emiru Berhane *et al.,* 2006), resulting in reduced tree species populations in the middle classes showing unstable population structure (Couralet *et al*., 2005).

4.1.3.3 Tree species population structure

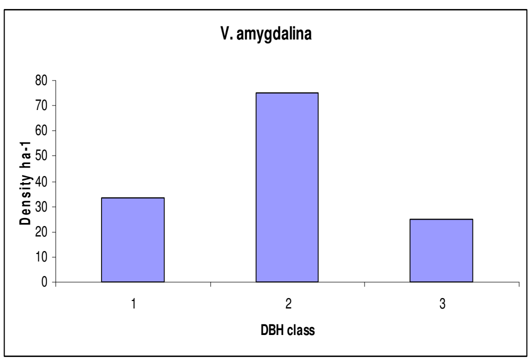
According to Peters (1996), population structure is the distribution of species in arbitrarily diameter-height size classes to provide an allover regeneration status of the species population. Population structure could be taken as indicator for population dynamics variation that may resulted from either inherent characteristics of the species or anthropogenic activities (Pompa *et al*., 1988 quoted in Tamrat Bekele, 1993). This plays fundamental role for sustainable utilization, management and conservation measures (Simon Shibru & Girma Balcha, 2004).

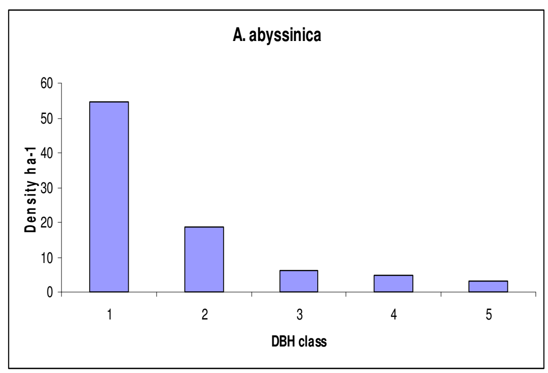
Based on density per hectare distribution by DBH, tree species in the study sites showed four patterns of distributions. The first pattern was exhibited by small number of individuals both in lower and higher DBH classes but many individuals in the middle diameter classes. According to Feyera Senbeta *et al*. (2007) such a bell-shape follows a Gauss distribution pattern and indicates poor reproduction and recruitment, that may have resulted from complete removal or presence of only few seed bearing tree species. Such a pattern was represented by *Vernonia amygdalina* (Fig. 9).

The second pattern exhibited an inverted J shaped distribution where the number of individuals decreased towards higher DBH classes. Such a pattern was represented by eight species (38.1% of the total populations) in area closures, and represented by species like *Acacia nilotica, Dichrostachys cinerea, Acacia abyssinica* etc., (Fig. 9). It is an indication for healthy regeneration status with good reproduction and recruitment capacity of a given species (Feyera Senbeta *et al.*, 2007) and considered to be with stable population structure (Silvertown & Dorst, 1993; Demel Teketay, 1997; Getachew Tesfaye *et al*., 2002).

However, it may have resulted from natural and /or anthropogenic disturbances including exploitation of individual woody plants with desirable diameter classes for domestic purposes (Bonger *et al*., 2006), other patterns show more or less unstable population structure (Couralet *et al*., 2005).

The third pattern was represented by species like *Cordia africana, Acacia dolichocephalia* (in grazing lands), *Eucalyptus camaldulnesis* etc., and possesses few individuals only in one or two of the lower DBH class (es), showing an early regeneration stage of the species (Alemayehu Wassie *et al*., 2005). The fourth pattern was characterized by reduction or complete absence of individuals in the middle classes and represented by *Acacia Abyssinia* and *Acacia nilotica* in the grazing lands (Fig.9). In general, the enclosures showed sound regeneration status both in the community and in individual species revealing the role of protection to foster woody species regeneration. The complete density per hectare by DBH distribution of trees is provided under Appendices 5 and 6.





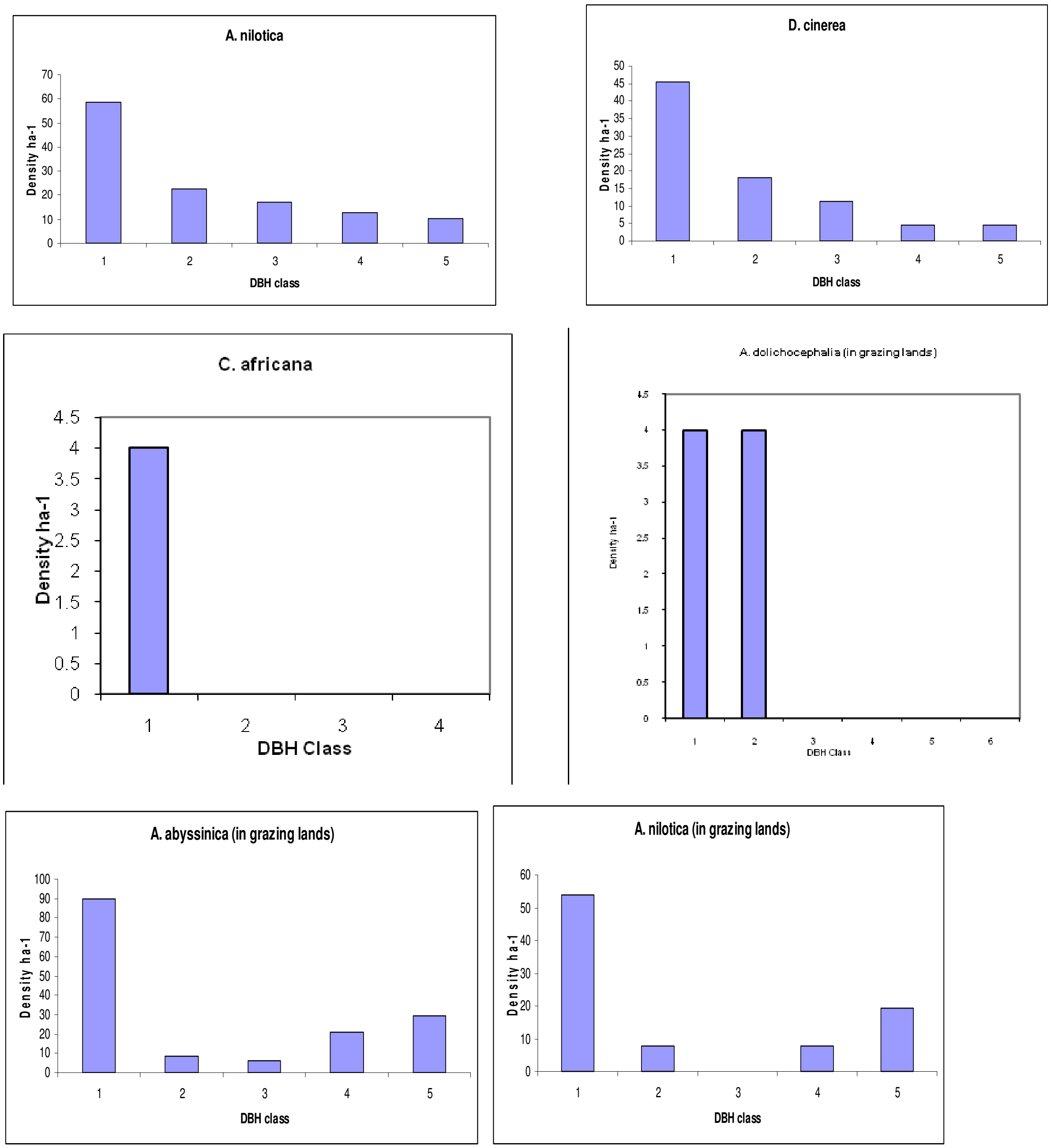


Figure 9: Some typical representatives of Tree population distribution patterns in the study area (DBH class 1. ≤ 5 cm; 2. 5.1- 10 cm; 3. 10.1-15 cm; 4. 15.1- 20 cm; 5. ≥ 20.1 cm).

4.2 Impact of area closures on soil quality

4.2.1 Available Phosphorus, available Potassium and pH

The soil laboratory analysis results indicated in Appendix 13, were entered in to SPSS and computed with one-way Analysis of Variance (ANOVA) to assess whether there exist significant difference among area closures (10 years and 23years old since establishment) as well as between enclosures and open grazing lands in mean values of the following soil parameters. As a result, there were no significant differences (P=0.913, P=0.812 and P=0.731) in mean soil AvP, AvK and pH among the study sites, respectively (Table 5). This probably be management and age of area closure had no profound effect on these soil parameters in the study area.

Table 5: The ANOVA result of soil parameters (Potential for Hydrogen (pH), available Phosphorus (AvP), available Potassium (Avk), total Nitrogen (TN %), and Soil Organic Matter (SOM %) in the study area.

		Sum of Squares	df	Mean Square	F	P
pH	Between Groups	.397	3	.132	.436	.731
	Within Groups	3.645	12	.304		
	Total	4.042	15			
AVP	Between Groups	1.031	3	.344	.173	.913
	Within Groups	23.907	12	1.992		
	Total	24.938	15			
AVK	Between Groups	.084	3	.028	.319	.812
	Within Groups	1.050	12	.087		
	Total	1.133	15			
TN	Between Groups	.173	3	.058	4.066	.042
	Within Groups	.170	12	.014		
	Total	.343	15			
SOM	Between Groups	15.755	3	5.252	2.438	.016
	Within Groups	25.851	12	2.154		
	Total	41.606	15			

α=0.05level

4.2.2 Soil organic matter (%) and total Nitrogen (TN %)

The ANOVA result revealed that there were significant differences (p=0.016 and P=0.042) in mean values of SOM content and TN among the two area closures and their corresponding open grazing lands at 0.05 level, respectively (Table 5). The LSD result of TN also indicated that there was significant difference (P < 0.05) in TN between enclosures and their adjacent open grazing lands, but the difference among enclosures was not significant (P=0.657) at 0.05 level (Table 6). Likewise, The LSD analysis result of SOM also revealed that there was significant difference between 10 years area closure and its adjacent open grazing land (P=0.026), 23 years area closure and its adjacent open grazing land (P=0.011). However, the difference among area closures was not significant (p=0.673) (Table 7). As a result, although age (>10 years) showed insignificant difference, management in general plays a great role in TN and SOM improvement in the study area.

Table 6: LSD result of total Nitrogen (TN) in the study area (open grazing land 1 and 2 = grazing land adjacent to 10 years and 23 years area closure, respectively).

Dependent Variable	(I) study site	(J) study site	Mean Difference (I-J)	P
TN (%)	10 years area closure	Open grazing land1	.21500*	.038
		23 years Area closure	.03833	.657
	23 years area closure	Open grazing land 2	.22000*	.048

*. The mean difference is significant at the 0.05 level.

Hence free grazing significantly affects the Nitrogen cycle by increasing Nitrogen (N) loss from the ecosystem thereby declining organic Nitrogen (Burke *et al*., 2002), probably the removal of disturbance assisted: (i) accumulation of SOM thereby enhancing availability of Nitrogen (ii) favored vegetation cover and the growth of plants, especially leguminous plants might have retarded the loss of N from the system resulting in higher TN in area closures than open grazing lands. This assumption is supported by studies that concluded as accumulation of SOM increases availability of plant nutrients, including total Nitrogen

(Rezaei & Gilkes, 2005) and land management options through natural regeneration are effective in enriching total Nitrogen, due to development of leguminous plants (FAO, 2005).

Table 7: LSD result of SOM (%) in the study area (open grazing $land_1$ and open grazing $land_2$ are grazing lands adjacent to 10 years and 23 years area closure, respectively).

Dependent Variable	(I) study site	(J) study site	Mean Difference (I-J)	P
SOM (%)	10 years area closure	Open grazing land1	2.10333*	.026
		23 years area closure	-.32583	.673
	23 years area closure	Open grazing land2	2.65917*	.011

*. The mean difference is significant at the 0.05 level.

Area closures had significantly high SOM (%) content compared to their adjacent open grazing lands. Although statistically insignificant, SOM in 23 years area closure also showed better improvement than 10 years area closure, indicating the positive effect of age in SOM accumulation. The improvement in SOM between area closures and their corresponding open grazing lands was 40.42% and 48.01% in 10 years and 23 years area closures respectively; moreover, 5.78% improvement was observed among area closures too (Fig. 10).

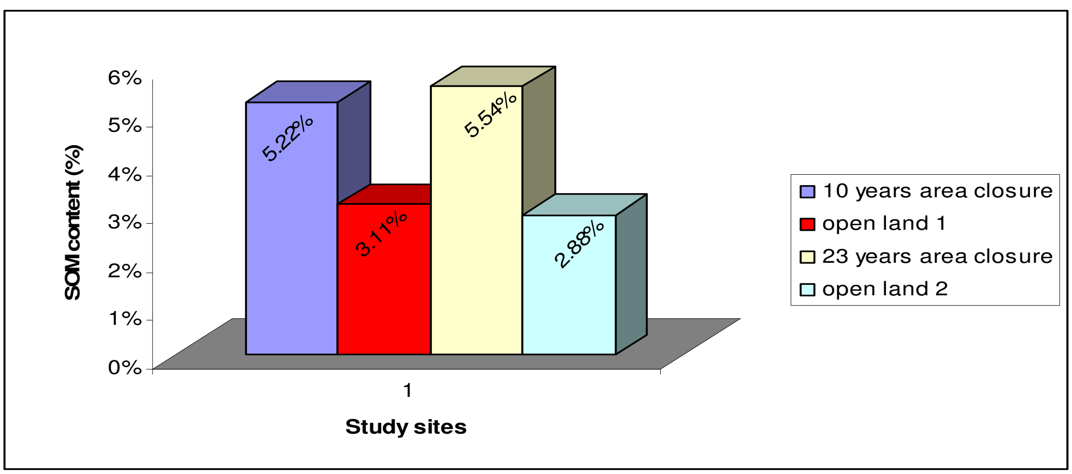


Figure 10: Mean soil organic matter (%) content in the study sites (Open land1 and 2= grazing land adjacent to 10 years area closure and 23 years area closure, respectively).

Improvement in soil organic matter probably attributed to vegetation cover as result of management. Hence, optimum mean soil pH values in area closures (Appendix 13) probably might have accelerated biomass production leading to high accumulation of SOM (FAO, 2005). This confirms the positive impact of abandonment to improve soil conditions, especially SOM accumulation in ACs than open grazing lands. This assumption is in line with study results that state improved soil organic matter content resulted from litter and dead root decompositions is an indicator of recovery or revival from degradation of an ecosystem (Amezketa, 1999).

Accumulation of SOM, among other factors, improve soil stability and the health of a rangeland and is an indicator for improved soil fertility, based on the rationale that it contributes significantly to soil physical, chemical and biological properties that influence vital ecosystem processes and to sustain plant growth (Lu *et al*., 1998; Hopmans *et al*., 2005). On contrary, disturbance (heavy grazing) breaks the soil apart exposing the soil organic matter to degradation and loss by erosion (Caravaca *et al*., 2002) and drastically reduces vegetation cover leading to decline in inputs of SOM (Shrestha *et al*., 2007). Long term grazing intensity can alter litter, plant basal and canopy cover, which affect soil water dynamics by altering microclimate and soil temperature (Day & Detling, 1994). Similarly, Li *et al*. (2007) summarized that disturbance of grazing lands have negative impact on soil structural properties and water holding capacity, which are highly related to losses of SOM pools leading to declined in soil infiltration and water retention and accelerated soil erosion (Li *et al*., 2007).

The correlation analysis among soil parameters and with vegetation diversity revealed a significant positive linear correlation (P=0.002, r=0.716), (P=0.004, r=0.672), (P=0.03, r=0.543), and (P=0.001, r=0.744), between SOM and TN, SOM and C/N, TN and C/N, SOM and species diversity, in the area (Appendix 14). This may be due to the role of ACs to improve soil fertility which could enhance biomass accumulation thereby increased organic C and N contents. Improvement in soil qualities would promote the capacity of the land to support higher species composition, especially grasses (that accumulate large residues) and leguminous plants (due to their rapid decomposition) enrich the soil with organic C and N, respectively (FAO, 2005).

Reduction in vegetation cover reduces the amount of soil organic matter in the soil and poor soils tend to have certain specific plant species. Land degradation, beyond affecting soil properties (physical, chemical and biological), particularly declines SOM, soil structure, availability of major nutrients (N, P, K), and disturbs the microclimate and increase toxicity of an area (Maitima *et al*., 2009). However, high content of soil organic matter promotes the capacity of a soil to supply essential plant nutrients (N, P, and K) and is an indicator for the health of an ecosystem (Rezaei & Gilkes, 2005).

The equilibrium of SOM could be disturbed by human activities such as cropping and overstocking (Preez *et al*., 2010), hence removal of vegetation directly reduces litter accumulation that had profound significance on soil moisture and nutrients, particularly to SOM, Nitrogen (N) and available Phosphorus (P) (Xiong *et al*., 2009). Thus, it is apparent to conclude that disturbance significantly affects the diversity of vegetation and quality of soils but establishment of area closures could help to rehabilitate the ecosystem functions and biological integrity so that the soil quality, especially SOM, could be improved and capable of supporting diverse floristic composition in contrast to open grazing lands

Moreover, it may be due to improvement in soil qualities like SOM, assisted availability of essential plant nutrients that improved the health and function of environment for the growth and development of woody vegetation stem groups in enclosures than open grazing lands. This assumption is supported by Tilman *et al*. (1996) research result that states improved soil condition due to proper land management promotes accumulation of environmental variables like SOM; as a result, enhances ecosystem health, species composition and diversity and land productivity as a whole (Tilman *et al*., 1996).

Thus, environmental factors mainly SOM (%) had positive correlation to the improvement of vegetation diversity. The study indicated that an increase in SOM had increased diversity of vegetation categories or it may be due to improvement in vegetation cover accumulated litter on soil surface that resulted in improvement of soil quality including soil organic matter (Fig.11).

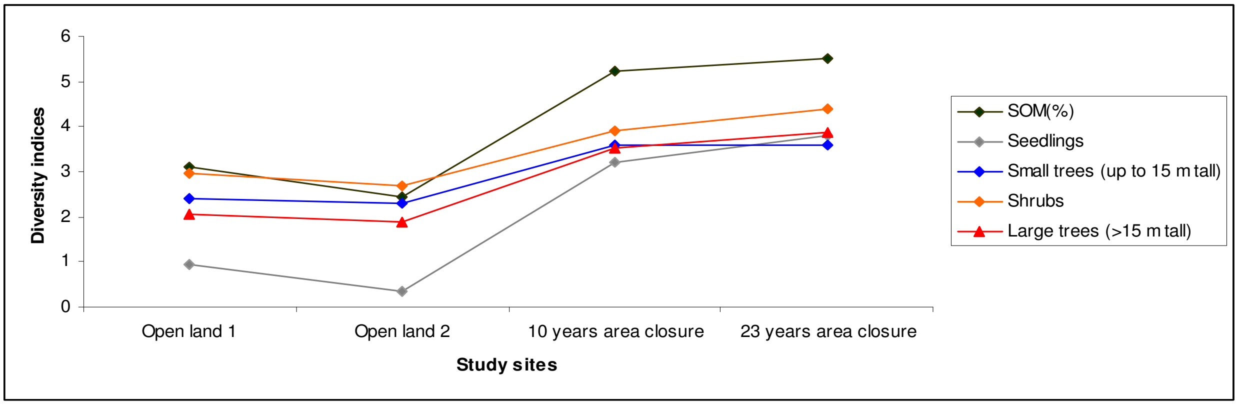


Figure 11: Impact of management and/ age of area closures on SOM (%) improvement and their implication on vegetation cover and diversity in the study area (open land1 is grazing land adjacent to 10 years area closure; open land 2 is grazing land adjacent to 23 years area closure).

This study result agrees to studies that state regeneration of natural habitats increase biomass production and plant species diversity, thereby resulting in more diverse soil biota and other associated beneficial organisms (FAO, 2005). Likewise, Zewudu Eshetu (2002) reported that trees planted for rehabilitation of degraded sites have improved SOM (Zewudu Eshetu, 2002) and this will also leads to seedling recruitment and survival, enhancing plant succession and ecosystem development compared to open degraded sites (Zewudu Eshetu, 2002). In addition, Tilman *et al*. (1996) concluded that land cover and productivity and ecosystem variability (like SOM) increase in diverse communities resulting in stable ecological functions (Tilman *et al*., 1996).

On the other hand, overgrazing reduces plant biomass causing reduced vegetation cover and productivity (Oztas *et al*., 2003) and replaces preferred species by less preferred species leading to species dominance (Keya, 1997). As a result, overgrazing severely affects not only soil properties but also vegetation composition and diversity (Beukes & cowling, 2003), which are evident in this study (Fig. 11). Therefore, area closures are suggestive mitigation measures for carbon sequestration beyond their primary purpose of biodiversity conservation and rehabilitation of degraded sites; hence high quality soils capable to restore (sequester) atmospheric Carbon (FAO, 2005), contributing to climate change mitigation.

4.3 Local communities' perception on land degradation, management and contribution of area closures

4.3.1 Local community perception on land degradation

All the respondents 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 (105 households (63.6%), 95 households (57.58%) and 118 households (71.52%)) in the area by their degree of severity (Table 8).

Table 8: The degree of severity of land degradation as perceived by respondents

	1st		2nd		3rd	
Rank of land degradation as perceived by households	frequency	%	frequency	%	frequency	%
Soil degradation	105	63.6	25	15.15	12	7.27
Deforestation	27	16.4	95	57.58	35	21.21
Lack of fodder	33	20	45	27.27	118	71.52
Total	165	100%	165	100%	165	100%

Respondents explained various possible causes of land degradation and stressed that deforestation, poor land management and overgrazing were believed to be the most possible causes of land degradation (82 households (50%), 42 households (25%) and 21 households (13%)) in the site. However, none of the households pointed that population growth, drought, and soil characteristics as possible causes of land degradation (Table 9).

Table 9: Possible causes of land degradation as perceived by local communities

Farmers' perception on possible causes of land degradation	value	Percent (%)
Deforestation	82	50%
Poor land management	42	25%
Overgrazing	21	13%
Poverty	15	9.0%
Topography	5	3.0%

Population growth	0	0%
Soil characteristics	0	0%
Drought	0	0%
Total	0	0%

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).

4.3.2 Local communities' perception on area closures

Respondents stressed that enclosures are effective land management options that promote surface cover and mitigate soil degradation resulting in enhanced land value and productivity (Table 10). This positive attitude of local communities is fundamental for the sustainability of enclosures (Heitschmidt *et al*., 2004) and also for future rehabilitation projects (Wolde Mekuria *et al.,* 2009).

Table10: Local communities' perception on area closures

Farmers' opinion	yes	Percent (%)	no	Percent (%)
Provide grass for fodder	137	83	28	17
Provide grass for sales	143	86.7	22	13.3
Sources of fuel wood	50	30.3	115	69.69
Means of finance	120	72.7	45	27.27
Promote surface cover	154	93.3	11	6.67
Reduce land degradation	165	100	0	0
Reduce available grazing land	126	76.4	39	23.6
Limit access of fuel wood	119	72.1	46	27.9
Restrict the use of common resources	117	70.91	48	29.09

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).

The majorities of respondents are optimistic to the performance of enclosures and reported that enclosures are effective in rehabilitating degraded lands; hence they support vegetation growth on degraded lands. However, a few respondents explained that the performance of enclosures could be enhanced with integrated soil and water conservation mechanisms (Appendix 15). This households' perception is in consistence with Wolde Mekuria *et al*. (2007) study that states enclosures are effective in controlling soil degradation (Wolde Mekuria *et al*., 2007). Similarly, Vanandel & Aronson (2006) found that re-establishing natural vegetations is an option to reverse land degradation, rehabilitate landscape integrity, and realize the environmental and social benefits of natural resources; it is now widely practiced around the world (Vanandel & Aronson, 2006).

Respondents reported that enclosures are among rehabilitation mechanisms mostly practiced in their locality to return degraded lands and improve agricultural productivity as well. 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). As a result soil erosion rates in unprotected areas may be 100-1000 times higher than fields with permanent vegetation cover (Deploey, 1989).

The majorities of respondents agreed that humans and livestocks should be restricted from enclosed sites for effectiveness of area closures. However, some disagree with complete restriction of human activities and livestocks. According to the later assumption, selective grazing (goat and oxen) and cutting of construction materials (occasionally) could better be allowed to ensure the use of communal resources (Appendix 15). However, studies reported that fencing involves restricting of damaging agents to maintain degraded lands (Hayward &

Kerley, 2009) and it is a recommended practice to facilitate land rehabilitation (Hurdin, 1968 qouted in Girma Kelboro, 2009). 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).

4.3.3 Local communities' perception on management of area closures

As indicated in Table 11, a total of 132 households (80%) had participated in onsite selection and the majorities of respondents agreed on selection criteria (Appendix 15).

Table 11: The number of households involved in site selection of area closures.

Households involved in site selection	frequency	Percent (%)
Participated in on site selection	132	80
Not participated in site on selection	33	20
Total	165	100%

As explained by respondents, the selection criteria 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 closures develop sense of belongingness among the community. Consequently, a total of 90 households (54.55%) responded that for future sustainability of enclosures, demarcation should be collaborative (Local community, Kebele and Agricultural office) (Fig.13), and most (140 households (84.85%) concluded that sense of belongingness could be developed if the management is designated to the local community after demarcation (Fig. 12).

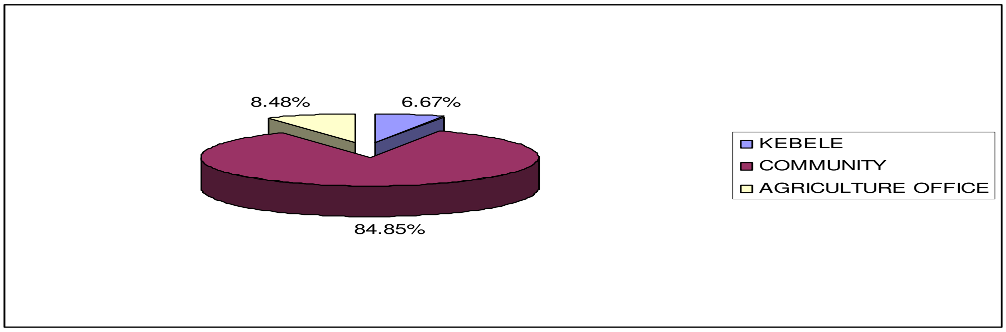


Figure 12: Expected institutions that need to manage area closures as perceived by local communities.

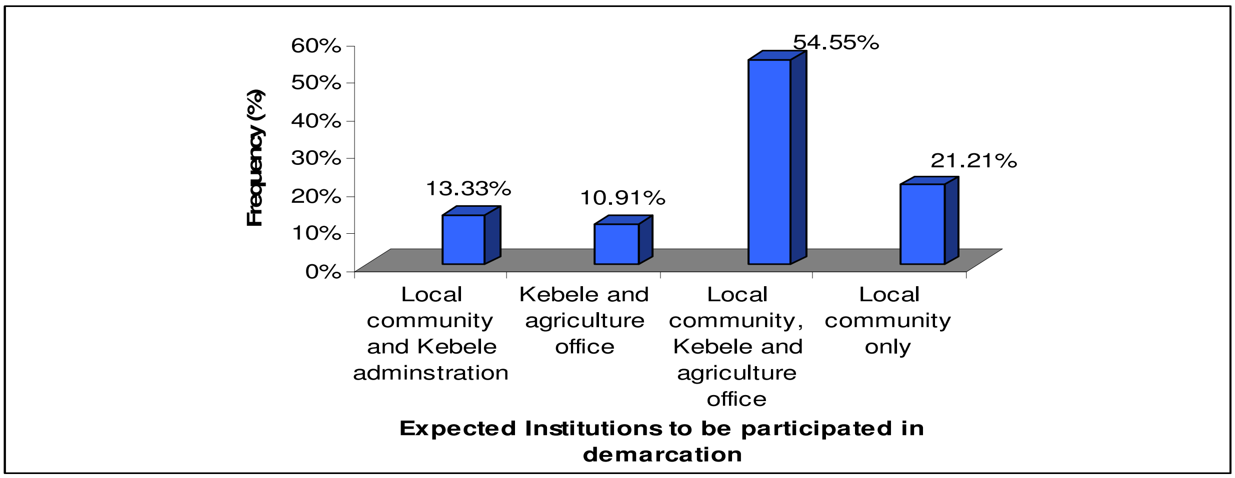


Figure 13: Institutions expected to be involved in demarcation of area closures as perceived by local communities.

Households' conclusion is supported by studies that state although establishment of enclosures in Ethiopia have considerable economic and ecological significances, it might be due to top-to-down implementation and limited participation of local community in decision making and utilization of resources during the Derg regime, the community denied the contribution of enclosures (Dessalegn Rahmato, 1994). This has significantly affected the sense of ownership and community's commitment for effective protection and sustainable management of land resources (Nedessa Betru *et al*., 2005).

4.3.4 Local communities' perception on benefit sharing and contributions of area closures

Respondents replied that cut-and-carry mode of using grass and beekeeping are activities allowed in the area closures. However, the use of common resources in the enclosures was negatively assessed by the majorities of the respondents (117 households (70.91%)) (Table 10). Besides, though half of the respondents replied that the befit sharing has moderately satisfied the community (84 households (51%)), a quarter of respondents (42 households (25.5%)) explained that the benefit sharing has satisfied the community poorly (Table 12). This might be due to an assumption that enclosures will be permanently owned and no possibility to share benefits to youth in the future and those who were not accepted the establishment of area closures at the beginning are not benefited from the resources. In line with assumption, the Abomsa Kebele administration has initiated to partition enclosures for youth associations which will ensure benefit sharing considering the landless youth.

Table 12: Local communities' satisfaction on benefit sharing of area closures

Community satisfaction in benefit sharing of area closures	value	Percent (%)
High	25	15
Moderate	84	51
Low	14	8.5
Poor	42	25.5
Total	165	100%

The local communities appreciate the contribution of enclosures stating that ACs provide three fundamental benefits to the local community. These include (i) Social value: accordingly, they were asking for resettlement due to accelerated soil erosion. However, nowadays the practices of enclosures have enabled them to control soil erosion and have increased land productivity. (ii) Economic value: respondents replied that enclosures provide considerable fodder access for live stocks and are efficient to increase financial income for households (137 households (83%) and 120 households (72.7%), respectively) (Table 10). This has helped them to save the cost of grass purchase for fodder and thatching. Besides, more than 1200 Ethiopian Birr could be gained from grass sales on annual basis.

This optimistic perception of the local community is supported by studies that state enclosed sites provide grass and wood access for local community beyond their aim of establishment (Mengistu Tefera *et al*., 2005) and are also attractive in financial terms, as people could had to purchase grass from other areas (Girma Kelboro, 2009). Respondents' view of economic benefits of enclosures also agrees with Lovejoy's (1985) research result that states resources from area closures contribute to the households' economy, suggesting that economic and social wellbeing is enhanced by focusing on rehabilitation of degraded lands (Lovejoy, 1985). Moreover, biophysical composition increased by 50% after enclosure leading to economic development of the community (Hanusin *et al*., 2001cited Tefera Mengistu *et al*., 2005).

(iii) Environmental value: respondents explained that area closures are effective strategies in controlling accelerated soil erosion and agricultural lands below area closures become more productive than lands below grazing. This agrees with studies that state agricultural lands below free grazing were strongly affected by water erosion than below enclosed sites (Wolde Mekuria *et al*., 2007). In addition, studies concluded that enclosures facilitate natural regeneration thereby reducing surface runoff. This will promote accumulation of soil organic matter and other plant nutrients that excel soil quality and capable of support diverse communities (Girma Kelboro, 2009).

In general, although some claim area closures due to their restriction of free access of resources, the majorities of the respondents are optimist towards enclosures as they promote surface cover, reduce surface erosion and provide grass access for fodder and sale. The majorities developed sense of belongingness and ready to expand the practice in the future, as they are involved in decision making and management of enclosures. Respondents reported that limited support from higher officials to promote awareness of the community, variation in the use of resources in enclosures especially the nearby Oromia and Afar Kebele communities were allowed to cut trees and in some even free grazing. Moreover, during establishment of enclosures, communities like in Afar Kebeles were reinforced with incentives (food for work) which will promote their future actions but not in the study site communities.

5. Conclusion and Recommendations

5.1 Conclusion

The results of the study show that natural resources management strategies like area closures basically have shown quite higher improvement in vegetation and soil rehabilitation. Management, among other factors, has enhanced woody vegetation composition and diversity, reduced soil erosion and improved the land productivity as a whole. As a result, it is plausible to conclude that area closures could be possible options to rehabilitate degraded sites.

It is evident that area closures considerably promoted soil conditions; especially improvement in SOM content is a key indicator of soil quality. It is the main determinant of soil biological, chemical and physical properties. Consequently, the capacity of the soil to sequester Carbon and support diverse communities will be enhanced. Besides, it upgrades the capacity of the soil to supply major plant nutrients and reliable to sustain plant growth. It also enhances water holding capacity, cation exchange capacity and micro biota of the soils. As a result, it promotes land productivity, resilience and sustainability of the ecosystem ensuring food security and alleviating poverty as well. Thus, establishment of area closures is a 'win-win' strategy to counter act land degradation and to mitigate climate change through carbon sequestration.

The majorities of the local communities developed sense of belongingness and developed positive attitude to the performance of enclosures. It may probably be due to their active participation in site selection, demarcation and management of enclosures, which need to be enhanced in the future to ensure local acceptance and sustainability. Hence, the use of resources and their power in decision making will ensure sustainable utilization of resources by local communities and positive attitude towards resource protection and expansion can only be acquired through the development of fair benefit sharing mechanisms and active participation of the local community.

Local communities are aware that enclosures generate ecological and socioeconomic benefits. Such perception is a base mark for future sustainability of the practice. However, some of the communities are not comfortable with benefit sharing suggesting that enclosed sites could be redistributed for all of the community members and fear that their decedents will be landless. In favor of equitable befit sharing the initiative in Abomsa site is encouraging that distributed certain portion of sites to youth associations that could be scaled up to other sites too. However, the primary goal of area closures establishment, attaining ecological objectives (Example: Plant diversity), should not be left aside while resources are partitioned to individuals and /or association.

5.2 Recommendations

- Although natural regeneration practices have potential to rehabilitate woody vegetation diversities and degraded sites, the strategies by themselves alone may not be enough to reverse the current rate of degradation. As a result, supportive management options such as agro-forestry, soil and water conservations, assisted natural regenerations and enrichment planting should be practiced to hasten the recovery process so as to achieve the expected ecological and socioeconomic objectives.
- Hence disturbance like free grazing declines soil fertility and exacerbates gas emissions (Ammonia, (NH_3) and Nitrous oxide, (N_2O)), a special focus should be given for leguminous plants for their ability of drought tolerance, nitrogen fixation and increased litter fall that promote soil nutrients and organic matter accumulation thereby maintain soil conditions.
- Free grazing is a major threat to soil quality and vegetation diversity. Area closures often reduce land availability for free grazing and having large number of livestock is a common trend in local communities, which is a main threat to area enclosures establishment. Thus, strategies like animal fattening, apiculture and biogas technology could be suggestive options to ensure resource conservation while meeting the demands of the community.
- Finally, this study did not assess the status of herbaceous plants, animal species diversity and the extent to which enclosures in the study area could reduce soil loss compared to open grazing lands involves quantifying the magnitude of soil rate regarding the amount they maintain soil particles in enclosures. Thus, it demands further studies to evaluate the performance of area closures considering these parameters.

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Appendices

Appendix 1: List of species identified in the area closures

Botanical Name	Family	Category	Seedling counts	Sapling counts	Shrub / Tree counts	Total
Abutilon angulatum	Malvaceae	Shrub/S			24	24
Acacia dolichocephalia (Harns.)	Fabaceae	Tree/T	20	32	56	108
Acacia abyssinica (Hochst.) Ex Benth.	Fabaceae	T		22	34	56
Acacia nilotica (L.) Del.	Fabaceae	T	32	50	60	142
Acacia tortilis (Forsk.) Hay.	Fabaceae	T	30	26	62	118
Acacia brevispica (Harms.)	Fabaceae	S	18		66	84
Acalypha fruticosa (Forssk.)	Euphorbiaceae	S	20		68	88
Aloe abyssinica (Lam.)	Liliaceae	S			38	38
Acokanthera schimperi (DC.) Oliv.	Apocynaceae	S			20	20
Calpurnia aurea (Picc.) Ait.	Fabaceae	S			20	20
Clausena anisata (Wild.) Hook. F. Ex. Benth.	Rutaceae	S			16	16
Clutia abyssinica Jaub. & Spach.	Euphorbiaceae	S			20	20
Coffea arabica (L.)	Rubiaceae	T			10	10
Commiphora species	Burseraceae	T		12	12	24
Cordia africana	Boraginaceae	T			4	4
Crotalaria spinosa (Benth.)	Fabaceae	S	12		22	34
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae	T	18	28	48	94
Dombeya torrida	Tiliaceae	S	14		44	58
Eucalyptus camaldulensis	Myrtaceae	T		4	16	20
Euphorbia cactus	Euphorbiaceae	S			32	32
Ficus sur (Forssk.)	Moraceae	T			4	4
Grevilea robusta R. Br.	Proteaceae	T		14	6	20
Grewia tricocarpa (Hochst.) Ex A. Rich.	Tiliaceae	T		14	18	23
Grewia bicolor (Juss.)	Tiliaceae	S	26		28	54
Grewia tembensis (Fresen.)	Tiliaceae	S	20		54	74
Grewia villosa (Wild.)	Tiliaceae	S	22		42	64
Hyphaene thebaica (L.) Mart.	Arecaceae	T		22	28	50
Jacaranda mimosifilia (D.) Don.	Bignoniaceae	T		4	16	20
Juniperus procera (Hochst.) Ex Endl.	Cupressaceae	T			10	10
Lantana trifolia	Verbenaceae	S			18	18
Mangifera indica (L.)	Anacardiaceae	T		14	8	22
Maytenus senegalensis	Celastraceae	S			22	22

(Lam.)						
Melia azedarach (L.)	Meliaceae	T			8	8
Pterolobium selatum (Forsk.)	Fabaceae	S			56	56
Rhus natalensis (Benth.) Ex Krauss.	Anacardiaceae	S			36	36
Rhus retinorrhea Steud. Ex Oliv.	Anacardiaceae	S			22	22
Rosa abyssinica R. Br.	Rosaceae	S			20	20
Rubus pinnatus (Wild.)	Rosaceae	S			20	20
Rumex nervosus (Vahl.)	Polygonaceae	S			20	20
Rhamnus staddo (A.) Rich.	Rhamnaceae	S			36	36
Sageretia thea	Rhamnaceae	S	10		46	56
Solanum incanum (L.)	Solanaceae	S			34	34
Terminalia brownii (Pers.)	Combretaceae	T		12	12	24
Vernonia amygdalina (Del.)	Asteraceae	T		22	10	32
Ziziphus mauritiana (Lamk.)	Rhamnaceae	T	20	30	46	96
Ziziphus mucronata (Wild.)	Rhamnaceae	T	18	34	42	94
Total			280	340	1334	1,954

Appendix 2: List of species identified in open grazing lands

Botanical Name	Family	Category	Seedling counts	Sapling count	Tree/shrub count	Total
Aloe abyssinica (Lam.)	Liliaceae	S			6	6
Acacia nilotica (L.) Del.	Fabaceae	T		28	46	74
Acacia tortilis (Forsk) Hay.	Fabaceae	T	20	8	18	46
Acalypha fruticosa (Forssk.)	Euphorbiaceae	S	2		66	68
Clausena anisata (Wild.) Hook. F. Ex. Benth.	Rutaceae	S			6	6
Dichrostachys cinerea (L.) Wight &Arn.	Fabaceae	T		14	12	26
Dombeya torrid	Tiliaceae	S			14	14
Grewia tembensis (Fresen.)	Tiliaceae	S			8	8
Grewia villosa (Wild.)	Tiliaceae	S			36	36
Lantana trifolia (L.)	Verbenaceae	S			8	8
Maytenus senegalensis (Lam.)	Celastraceae	S			18	18
Sageretia thea	Rhamnaceae	S			44	44
Solanum incanum (L.)	Solanaceae	S	2		30	32
Vernonia amygdalina (Del.)	Asteraceae	T		4	4	8
Ziziphus mucronata (Wild.)	Rhamnaceae	T		16	30	46
Total			24	70	346	440

Appendix 3: Woody vegetation species composition in area closures

N0.	Family	Number of species	Percent (%)	Number of individuals	percent
1	Fabaceae	9	19.56	424	32%
2	Tiliacaea	5	10.87	186	14%
3	Rhamnaceae	4	8.69	170	13%
4	Euphorbiaceae	3	6.5	120	8.9%
5	Anacardiaceae	3	6.5	66	4.9%
6	Rosaceae	2	4.35	40	2.9%
7	Apocynaceae	1	2.17	20	1.49%
8	Verbenaceae	1	2.17	18	1.35%
9	Polygonaceae	1	2.17	20	1.49%
10	Celasteraceae	1	2.17	22	1.65%
11	Rutaceae	1	2.17	16	1.19%
12	Liliaceae	1	2.17	38	2.85%
13	Malvaceae	1	2.17	24	1.79%
14	Solanaceae	1	2.17	34	2.55%
15	Moraceae	1	2.17	4	0.29%
16	Boragnaceae	1	2.17	4	0.29%
17	Prtoteaceae	1	2.17	6	0.45%
18	Cupressaceae	1	2.17	10	0.75%
19	Asteraceae	1	2.17	10	0.75%
20	Rubiaceae	1	2.17	10	0.75%
21	Arcecaceae	1	2.17	28	2.09%
21	Meliaceae	1	2.17	8	0.59%
23	Myrtaceae	1	2.17	16	1.19%
24	Bigniniaceae	1	2.17	16	1.19%
25	Combretaceae	1	2.17	12	0.89%
26	Burseraceae	1	2.17	12	0.89%
	Total	46	100%	1334	100%

Appendix 4: Woody vegetation species composition in open grazing lands

N0.	Family	Number of Species	Percent (%)	Number of individuals	Percent (%)
1	Fabaceae	3	20	76	21.96
2	Tiliaceae	3	20	58	16.76
3	Rhamnaceae	2	13.3	74	21.39
4	Asteraceae	1	6.67	4	1.16
5	Euphorbiaceae	1	6.67	66	19.1
6	Celasteraceae	1	6.67	18	5.2
7	Liliaceae	1	6.67	6	1.73
8	Verbenaceae	1	6.67	8	2.3
9	Solanaceae	1	6.67	30	8.67
10	Rutaceae	1	6.67	6	1.73
	Total	15	100%	346	100%

Appendix 5: Density per hectare (ha^{-1}) by DBH distribution of Tree species in area closures (DBH class 1. ≤ 5 cm; 2. 5.1- 10 cm; 3. 10.1-15 cm; 4. 15.1- 20 cm; 5. ≥ 20.1 cm).

Botanical name of species	Density ha^{-1} by DBH				
	1	2	3	4	5
Acacia abyssinica	54.69	18.75	6.25	4.69	3.13
Acacia dolichocephalia	48.86	17.05	14.77	11.36	7.95
Acacia nilotica	58.51	22.73	17.05	12.5	10.23
Acacia tortilis	47.73	18.18	13.64	12.5	10.23
Cordiana africana	25				
Coffee arabica	25	6.25			
Commiphora species	45.8	4.17			
Dichrostachys cinerea	45.45	18.18	11.36	4.55	4.55
Eucalyptus camaldulensis	21.88	9.4			
Ficus sur	25				
Grevillea robusta	58.3	25			
Grewia tricocarpa	22.18	22.2			
Hyphaene thebaica	52.05	27.1	25		
Jacaranda mimosifolia	10.71	25			
Juniperus procera	12.5	18.75			
Mangifera indica	43.75	25			
Melia azedarach	12.5	12.5			
Terminalia brownii	62.47	37.5			
Ziziphus mauritiana	55.95	14.29	11.9	8.3	

Ziziphus mucronata	46.25	16.25	13.75	10	8.75
Vernonia amygdalina	33.3	75	25		
Total	807.88	413.3	138.72	63.9	44.84
Percent (%)	55%	28%	9.50%	4.35%	3.10%

Appendix 6: Density (ha^{-1}) by DBH distribution of tree species in open grazing lands (DBH class 1. ≤ 5 cm; 2. 5.1- 10 cm; 3. 10.1-15 cm; 4. 15.1- 20 cm; 5. ≥ 20.1 cm).

Botanical name of species	Density ha^{-1} by DBH				
	1	2	3	4	5
Acacia tortilis	45	5			15
Acacia nilotica	53.87	7.69		7.69	19.23
Acacia abyssinica	89.6	8.3	6.25	20.8	29.17
Acacia dolichocephalia	35.72	7.14			
Dichrostachys cinerea	50				
Commiphora species	25				
Ficus sur	25				
Ziziphus mucronata	50				
Vernonia amygdalina	50				
Total	424.19	23.13	6.25	28.49	63.4
Percent (%)	78.00%	4.00%	1.00%	5.00%	12.00%

Appendix 7. Frequency (F) and frequency class (F-class) of woody vegetations in area closures.

Botanical Name	Family	Number of individuals	Occurrence	F	F class
Cordia africana	Boragnaceae	4	2	9.09	A
Ficus sur	Moraceae	4	2	9.09	A
Grevillea robusta	Proteaceae	6	2	9.09	A
Vernonia amygdalina	Asteraceae	10	3	13.64	A
Terminalia brownii	Combretaceae	12	4	18.2	A
Coffee arabica	Rubiaceae	10	3	13.64	A
Calpurnia aurea	Fabaceae	20	4	18.2	A
Juniperus procera	Cupressaceae	10	3	13.64	A
Mangifera indica	Anacardiaceae	8	2	9.09	A
Melia azedarach	Meliaceae	8	2	9.09	A
Acokanthera	Apocynaceae	20	4	18.2	A

schimpri					
Crotalaria spinosa	Fabaceae	22	4	18.2	A
Clausena anisata	Rutaceae	16	3	13.64	A
Commiphora species	Burseraceae	12	4	18.2	A
Hyphaene thebaica	Arcecaceae	28	4	18.2	A
Jacaranda mimosifolia	Bigniniaceae	16	3	13.64	A
Rubus pinnatus	Rosaceae	20	4	18.2	A
Rumex nervosus	Polygonaceae	20	3	13.64	A
Acacia abyssinica	Fabaceae	34	4	18.2	A
Clutia abyssinica	Euphorbiaceae	20	4	18.2	A
Eucalyptus camaldulensis	Myrtaceae	16	4	18.2	A
Euphorbia cactus	Euphorbiaceae	32	6	22.27	B
Lantana trifolia	Verbenaceae	18	5	22.73	B
Maytenus senegalensis	Celastraceae	22	7	31.82	B
Sageretia thea	Rhamnaceae	46	8	36.36	B
Aloe abyssinica	Liliaceae	38	7	31.82	B
Abutilon angulatum	Malvaceae	24	6	22.27	B
Grewia tricocarpa	Tiliaceae	18	5	22.73	B
Rhus retinorrhea	Anacardiaceae	22	8	36.36	B
Solanum incanum	Solanaceae	34	8	36.36	B
Grewia tembensis	Tiliaceae	54	8	36.36	B
Dombeya torrid	Tiliaceae	44	13	59.09	C
Rhus natalensis	Anacardiaceae	36	12	54.55	C
Acacia brevispica	Fabaceae	66	13	59.09	C
Acalypha fruticosa	Euphorbiaceae	68	13	59.09	C

Pterdobium stallatu	Fabaceae	56	11	50	C
Rhamnus staddo	Rhamnaceae	36	10	45.45	C
Rosa abyssinica	Rosaceae	20	12	54.55	C
Ziziphus mucronata	Rhamnaceae	42	13	59.09	C
Grewia bicolor	Tiliaceae	28	16	72.73	D
Grewia villosa	Tiliaceae	42	15	68.18	D
Ziziphus mauritiana	Rhamnaceae	46	17	77.27	D
Acacia nilotica	Fabaceae	60	17	77.27	D
Acacia dolichocephalia	Fabaceae	56	14	63.64	D
Acacia tortilis	Fabaceae	62	22	100	E
Dichrostachys cinerea	Fabaceae	48	22	100	E

Appendix 8: Frequency (F) and frequency class (F-class) of woody vegetations in open grazing lands.

Botanical Name	Family	No of Individuals	Occurrence	F (%)	F-class
Aloe abyssinica	Liliaceae	6	2	14.29	A
Clausena anisata	Rutaceae	6	4	28.57	B
Vernonia amygdalina	Asteraceae	4	3	21.43	B
Grewia tembensis	Tiliaceae	8	7	50	C
Lantana trifolia	Verbenaceae	8	6	42.86	C
Dichrostachys cinerea	Fabaceae	12	7	50	C
Dombeya torrida	Tiliaceae	14	9	64.29	D
Acacia tortilis	Fabaceae	18	10	71.43	D
Mytenus senegalensis	Celastraceae	18	9	64.29	D
Solanum incanum	Solanaceae	30	12	85.7	E
Ziziphuz mucronata	Rhamnaceae	30	13	92.86	E
Acacia nilotica	Fabaceae	46	12	85.7	E
Acalypha fruticosa	Euphorbiaceae	66	14	100	E
Grewia vilosa	Tiliacaee	36	14	100	E
Sageretia thea	Rhamnaceae	44	14	100	E

Appendix 9: Tree height distribution in area closures (Height class 1.≤ 2 m; 2. 2.1-5 m; 3. 5.1- 10 m; 4. 10.1- 15 m; 5. ≥15.1m).

Species	Height class				
	1	2	3	4	5
Acacia abyssinica		16	12	6	4
Acacia dolichocephalia	42	32	14	6	
Acacia nilotica	64	26	24	10	13
Acacia tortilis	84	20	17	14	4
Cordial africana	24				
Coffee arabica		6	4		
Commiphora species		8	4		4
Dichrostachys cinerea	30	26	14	4	4
Eucalyptus camaldulensis	28	8		4	4
Ficus sur	4				
Grevillea robusta		4	2		
Grewia tricocarpa	14	10	6	2	8
Hyphaene thebaica	14	10	4	6	
Jacaranda mimosifolia	22	8	4	4	2
Juniperus procera	4	4	2	2	
Mangifera indica		8			3
Melia azedarach	14	2	2	1	
Terminalia brownii		7	3	2	
Ziziphus mauritiana	32	20	16	10	
Ziziphus mucronata	48	30	8	4	
Grewia bicolor	60				
Acacia brevispica	18				
Grewia tembensis	20				
Grewia vilosa	22				
Dombeya torrida	14				
Crotalaria spinosa	12				
Acalypha fruticosa	20				
Sageretia thea	10				
Vernonia amygdalina		10			40
Total	600	245	136	75	46
Percent (%)	55.00%	22%	12.00%	7.00%	4.00%

Appendix 10: Tree height distribution in open grazing lands (Height class 1.≤ 2 m; 2. 2.1-5 m; 3. 5.1- 10 m; 4. 10.1- 15 m; 5. ≥15.1m).

Species	Height class				
	1	2	3	4	5
Acacia tortilis	28	8		8	2
Ziziphus mucronata	16	18			12
Acacia nilotica	28	24		14	8
Dichrostachys cinerea	4	5		3	4
Veronina amygdalina	2				4
Commiphora speices	2				
Acacia abyssinica	2				
Acacia dolichocephalia	6				
Ficus sur	2				
Acacia brevispica	2				
Solanum incanum	2				
Total	94	55	0	25	30
Percent (%)	46.10%	26.90%		12.30%	14.70%

Appendix 11: Comparison of different diversity indices of woody vegetation stem groups in area closures and open grazing sites

Diversity indices of vegetation life forms	Area closures		Open grazing lands
	23 years	10 years	
Species Richness (Menhinick's Index= D)			
Trees	1.035	0.77	0.48
Shrubs	1.005	0.76	0.65
Saplings	0.87	1.07	1.07
seedlings	0.95	1.04	0.6
Shannon Index(H')			
Trees	3.87	3.53	2
Shrubs	4.4	3.9	2.8
Saplings	3.6	3.6	0.79
seedlings	3.8	3.2	0.82
Species Evenness(E)			
Trees	0.94	0.98	0.87
Shrubs	1.008	0.98	0.83

o Saplings o Seedlings	1.00 1.02	0.98 0.96	0.79 0.5

Appendix 12: LSD result of the impact of management and age on diversity and richness of woody vegetation stem groups (open land=open grazing lands adjacent to 10 years and 23years area closures, AC= area closure)

Dependent Variable	(I) impact of age and management	(J) impact of age and management	Mean Difference (I-J)	P
species diversity of seedlings	Open lands	10 years AC	-2.56000*	.000
		Years AC	-3.16000*	.000
	10 years AC	Open lands	2.56000*	.000
		23 years AC	-.60000*	.000
	23 years AC	Open lands	3.16000*	.000
		10 years AC	.60000*	.000
species diversity of saplings	Open lands	10 years AC	-1.25000*	.000
		23 years AC	-1.25000*	.000
	10 years AC	Open lands	1.25000*	.000
		23 years AC	.00000	1.000
	23 years AC	Open lands	1.25000*	.000
		10 years AC	.00000	1.000
species diversity of trees	Open lands	10 years AC	-1.55000*	.000
		23 years AC	-1.89000*	.000
	10 years AC	Open lands	1.55000*	.000
		23 years AC	-.34000*	.000
	23 years	Open lands	1.89000*	.000
		10 years AC	.34000*	.000
Species diversity of shrubs	Open lands	10 years AC	-1.07500*	.000
		23 years AC	-1.57500*	.000
	10 years AC	Open lands	1.07500*	.000
		23 years AC	-.50000*	.000
	23 years AC	Open lands	1.57500*	.000
		10 years AC	.50000*	.000

Species richness of seedlings	Open lands	10 years AC	-.32000*	.000
		23 years AC	-.23000*	.000
	10 years AC	Open lands	.32000*	.000
		23 years AC	.09000*	.001
	23 years AC	Open lands	.23000*	.000
		10 years AC	-.09000*	.001
species richness of saplings	Open lands	10 years AC	.13000*	.000
		23 years AC	.33000*	.000
	10 years AC	Open lands	-.13000*	.000
		23 years AC	.20000*	.000
	23 years AC	Open lands	-.33000*	.000
		10 years AC	-.20000*	.000
species richness of shrubs	Open land	10 years AC	.06000*	.000
		23 years AC	-.18056*	.000
	10 years AC	0penlands	-.06000*	.000
		23 years AC	-.24056*	.000
	23 years AC	0penlands	.18056*	.000
		10 years AC	.24056*	.000
Species richness of trees	0pen lands	10 years AC	-.15508*	.000
		23 years AC	-.42444*	.000
	10 years AC	0penlands	.15508*	.000
		23 years AC	-.26937*	.000
	23 years AC	0penlands	.42444*	.000
		10 years AC	.26937*	.000

*. The mean difference is significant at the 0.05 level. ♦ AC= Area Closure

Appendix 13: Laboratory result of soil parameters (OS1, 2 and 3= Soil samples taken from grazing land adjacent to10 years area closure; O'S1, 2 and 3= Soil samples taken from grazing land adjacent to 23 years area closure; E1, 2, 3, 4, 5 and 6 are Soil samples taken from 10 years area closure; E'1, 2, 3 and 4=Soil samples taken from 23 years area closure).

	Soil Parameters						
Site Code	Lab. Code	pH	OC (%)	OM (%)	AvP (ppm)	AvK	TN (%)
OS1	006/2003	7.17	2.75	4.74	3.78	0.32	0.44
OS2	007/2003	7.2	0.78	1.34	3.24	0.08	0.14
OS3	008/2003	7.29	1.89	3.26	1.74	0.1	0.18
O'S1	014/2003	8.23	1.13	1.95	1.98	0.19	0.17
O'S2	015/2003	7.96	2.35	4.1	4.2	0.35	0.35
O'S3	019/2003	6.5	1.5	2.6	3.3	0.25	0.13
ES1	009/2003	6.96	2.94	5.07	2.82	0.4	0.69
ES2	010/2003	7.43	1.89	3.26	1.98	0.18	0.40
ES3	011/2003	8.16	3.73	6.4	6.54	0.23	0.38
ES4	012/2003	7.32	3.63	6.3	3.78	0.15	0.41
ES5	013/2003	7.54	3.33	5.7	4.32	0.04	0.43
ES6	020/2003	7.9	2.65	4.57	1.8	0.84	0.50
E'S1	016/2003	7.2	2.9	4.99	4.08	0.29	0.41
E'S2	017/2003	8.05	2.97	5.12	2.46	0.17	0.29
E'S3	018/2003	7.31	3.36	5.8	1.8	0.04	0.41
E'S4	021/2003	8.2	3.6	6.26	3.8	1.03	0.50

Appendix 14: Correlation among soil parameters and between soil parameters and species diversity (SOM= Soil Organic Matter; TN=total Nitrogen; AvP=available Phosphorus; AvK=available Potassium; pH=Potential for Hydrogen; C/N=Carbon to Nitrogen ratio) in the study area.

		SOM	TN	AVP	AVK	pH	C/N	Species Diversity	Species Richness
SOM (%)	Pearson Correlation	1	.716**	.442	.263	.191	.672**	.744**	.255
	Sig. (2-tailed)		.002	.086	.325	.479	.004	.001	.340
	N	16	16	16	16	16	16	16	16
TN (%)	Pearson Correlation	.716**	1	.153	.592*	.099	.543*	.634**	-.024
	Sig. (2-tailed)	.002		.571	.016	.714	.030	.008	.931
	N	16	16	16	16	16	16	16	16
AVP	Pearson Correlation	.442	.153	1	.016	.090	.061	.130	.143
	Sig. (2-tailed)	.086	.571		.955	.740	.823	.630	.598
	N	16	16	16	16	16	16	16	16
AVK	Pearson Correlation	.263	.592*	.016	1	.382	.271	.213	.003
	Sig. (2-tailed)	.325	.016	.955		.144	.309	.428	.991
	N	16	16	16	16	16	16	16	16
pH	Pearson Correlation	.191	.099	.090	.382	1	.265	.167	-.067
	Sig. (2-tailed)	.479	.714	.740	.144		.321	.536	.805
	N	16	16	16	16	16	16	16	16
C/N	Pearson Correlation	.672**	.543*	.061	.271	.265	1	.884**	.249
	Sig. (2-tailed)	.004	.030	.823	.309	.321		.000	.335
	N	16	16	16	16	16	17	17	17
Species Diversity	Pearson Correlation	.744**	.634**	.130	.213	.167	.884**	1	.258
	Sig. (2-tailed)	.001	.008	.630	.428	.536	.000		.129
	N	16	16	16	16	16	17	36	36
Species Richness	Pearson Correlation	.255	-2.370E-2	.143	.003	-.067	.249	.258	1
	Sig. (2-tailed)	.340	.931	.598	.991	.805	.335	.129	
	N	16	16	16	16	16	17	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 15: Farmers' response rate and perception on site selection criteria, effectiveness and management of area closures.

Total response rate of respondents	value	Percent (%)
Male	111	66
female	54	32
total	165	100 %
Do you agree with the restriction of human and livestocks from area closures	Value	percent
Yes, I agree	142	86
I do not agree	23	14
total	165	100%
Households' perception about the site selection criteria for enclosures	value	percent
I agree with the criteria	151	91.52
I do not agree	14	8.48
total	165	100%
Do you think that area closures are effective in rehabilitating degraded lands?	value	percent
Yes	153	93
No	12	7
total	165	100%

Appendix 16: Questionnaire filled by households

This questionnaire is designed to evaluate the contribution of area closures to the socioeconomic well being of the society and their ecological implications as well. Besides, farmers' participation in establishment and management of enclosures will be assessed. The findings of this thesis will contribute much to the future plan of area closures and involvement of stakeholders. I therefore, kindly request you to fill each question honestly.

I. General information

- Kebele …………… Sex :M… F…. Age: <25…; 26 - 35 …; >35…….
- Educational status: Adult educ….; 1^0 educ….; 2^0educ….None……. Others……….
- Climatic condition of this area:kola….;Dega……; Weynadega…….; Others……
- Common crops cultivated in this area: Cereals…; Pulses….; Vegetables&fruits…All..

1. What is your main means of income?

a. Mixed farming system(farm +livestock) b. Livestock raring c.Trading d. others

2. Where do you graze your livestocks? A. communal land b. private land c.others……….
3. What is your domestic energy source? a.Firewood b. charcoal c. petroleum d. others…….
4. What is your commodity that earns you income (1st, 2nd, 3rd…)?

a. Farm products b. livestocks c. forest products d. residues &cow dung e. others…….

5. Which land degradation type is common in you locality?a. Soilerosion… b. deforestation… c. decline in soil fertility….. d. lack of fodder….
6. How do you rate the extent of land degradation in this area?

a. Very severe… b. severe… c. medium…. d. low

7. Which do you think is the causes for land degradation?

   A. Population growth… B. Drought…. C.Topography….. D. Overgrazing… E.Deforestation…….. F.Poor land management….. G.Poverty…………..

8. What do you think the effects of these land degradation?...
   ....
9. What do you think be the solutions to reduce/avoid such land degradation? ……………………………………………………………………………………………………

10. Is there area closure practice in your kebelle? Yes… No…..

a.If yes, is it private…. Communal……or Governmental……….?

b. Have you participated in site selection? Yes…. No……….

c.What were the criteria for enclosing the land? ....

d. Do you agree with these criteria? Yes…… No……. Why?..

11. How an area could be evaluated based on these criteria?...

12. Who should you think be involved in demarcation of area closure? Why?

a. The local community b. Kebele c. Agricultural office d. all

13. Have you participated in formulating local by-laws? Ye…… No……

14. Do you believe that this by-law satisfied most community members?

a. Yes ….. b. No…….. c. I do no………

15. Why do you think that enclosures are established? ....

16. What activities are allowed in enclosures? (Circle permitted once) a. free grazing b. bees keeping c. Cutting grass d. collecting firewood e. cutting construction materials

17. Do you agree that humans and livestocks should be restricted from enclosures? Why? Yes……………………………………………………………………………………………….No………

18. Do you think that area closures are effective in rehabilitating degraded lands?

Yes……. No………..

19. Do you think that enclosures increase land productivity? Yes… No…… How?.........................

20. Who keeps the enclosure resources against illegal cutting?...

21. Do you think such a keeping system is effective? Why?Yes… No….

22. . Tick(√) on the benefits or disadvantages of enclosures

	Farmers' Opinion	yes	No
	Provide sufficient grass for animals		
	Access sales of grass for thatching		
	Sources of wood for household fuels		
	Provide financial income from sale of forest products		
	Increased surface cover and vegetation abundance		

	Decreased land degradation		
	Reduced available grazing land		
	Limited fuel wood		
	Restricted the use of common resources		

23. Who do you think needs to manage enclosures? A. kebelle b. Community c. MoA; d. all…..Why?...

24. How do you rate the degree of community satisfaction in benefit sharing from enclosures? A. High…. B. Medium… c. low…. D. poor….

25. What do you think the role of local community in establishment and management of area closures?

    ……………………………………………………………………………………………………

26. What is the benefit (s) for local people to be involved in such activities?...

27. Who do you think be involved in management of area closures among the communities?

a. Men….. b. Women…. c. Both…..

28. Do you want to shift enclosures from communal to individual ownership? Yes….. No……Why?..........

29. Do you want to expand the practice in the future? Yes… No…. Why?...

30. What do you think some common contributions of area closures to the local community?..................

    31.What do you think the strengths and weaknesses of enclosure? Strengths……………………………………….. Weakness………………………………………….

31. Any comment you suggest in establishing and management of area enclosures…………………………………………………………………………………

================ Thank you!==================

Declaration

I would like to declare that this research under the title of "*The Role of Area closures for Soil and Woody Vegetation Rehabilitation in Kewot Ditrict*, North Shewa" was my original work and done based on the real data collected from the study site. It has not been presented for a degree in any other universities and the source materials used for the thesis are fully acknowledged.

Mengistu Asmamaw Mengesha

Signature---------------------

Date------------------------

This thesis has been submitted for examination with my approval as a university advisor.

Mekuria Argaw (PhD)

Signature----------------------

Date----------------------