AREA EXCLOSURE AS A STRATEGY TO RESTORE WOODY PLANT SPECIES DIVERSITY AND SOIL FERTILITY STATUS IN DEGRADED LAND: CASE STUDY IN *MITIJA* WATERSHED, SOUHERN ETHIOPIA

M.Sc. THESIS

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JIMMA UNIVERSITY

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M.Sc. Thesis

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

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APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

As thesis research advisors, we hereby certify that we have read and evaluated this thesis prepared, under our guidance, by **Temesgen Abebe Tekenso**, entitled **Area Exclosure As A Strategy To Restore Woody Plant Species Diversity And Soil Fertility Status In Degraded Land: Case Study In Mitija Watershed At Hulbarag *Woreda*, Siltie Zone.** We recommend that it be submitted as fulfilling the thesis requirements.

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As member of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read, evaluated the Thesis prepared by Temesgen Abebe and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Natural Resource Management (Integrated Watershed Management).

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External Examiner Signature Date

DEDICATION

I dedicate this thesis to my father **Abebe Tekenso**, and my mother **Workinesh Jajinko** for nursing me with affection, love and for their dedicated partnership in the success of my life.

DECLARATION

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

Name___________________________________

Signature________________________________

Place ___________________________________

Date of submission________________________

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BIOGRAPHICAL SKETCH

The Author, Temesgen Abebe, was born on 9^{th} of August 1986 In Misha District of Hadiya Zone, Southern Ethiopia. He Attained His Junior Elementary School at Wasgebeta School, Junior Secondary School at Mendida Cistercian Monastery Secondary School and his secondary school at Wachemo Comprehensive Secondary School from 2002 to 2004. He then joined Jimma University, College of Agriculture and Veterinary Medicine in 2007 awarded B.Sc. in Natural Resource Management. After graduation, he was employed by the Ministry of Agriculture where he served as Deputy Head of Agriculture within Misha District of Hadiya Zone until he joined the School of Graduate Studies at Jimma University, College of Agriculture and Veterinary Medicine in September 2010 to pursue his M.Sc study in Natural Resource Management (Integrated Watershed Management).

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LIST OF ACRONYMS

SNNPRS	Southern Nations Nationalities and Peoples Regional State
CSA	Central Statistical Authority
ADLI	Agricultural Development Led Industrialization
FAO	Food and Agricultural Organization of the United Nations
MoA	Minister of Agriculture
PH-H2O	Power of Hydrogen with water solution
GPS	Geographic Positioning System
GACGCS	German Advisory Council on Global Change Secretariat
UN	United Nations
UNFPA	United Nations Population Fund
POPIN	United Nations Population Information Network
SCRP	Soil Conservation Research Project
EHRS	Ethiopian Highland Reclamation Study
TLU	Total Land Use
EFAP	Ethiopian Forestry Action Plan
WFP	World Food Program
OoARD	Office of Agriculture and Rural Development
SAS	Statistical Analysis System
HWRDO	Hulbarag Woreda Rural Development Office
HWCB	Hulbarag Woreda Capacity Building

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ABSTRACT

Land degradation is revealed in the form of vegetation and soil fertility degradation. It is becoming a major ecological and agricultural problem in Ethiopia. To overcome the problems of land degradation area exclosure is used as strategy to restore degraded lands in Hulbarag Wereda, Siltie Zone, SNNPRS. The general objective is to assess and evaluate the usefulness of exclosure technique in enhancing rehabilitation of degraded ecosystem and thereby increase the natural capital in the area. Woody plant species and soil samples were collected with the transects from area exclosure for eight year and adjacent degraded land with similar landscape positions. Both soil and woody plant species were collected from transects by systematic sampling plot design technique. The woody plant species were identified by using a field guideline. The woody species diversity was determined by Shannon diversity. To determine soil fertility status of area exclosure and adjacent degraded soil, samples were analyzed for soil organic carbon (SOC), cation exchange capacity (CEC), total nitrogen (TN), pH, electrical conductivity (EC), available phosphorus (Av. P), exchangeable bases *(K^+, Na^+, Ca^+, Mg^{2+}), soil texture, moisture content and bulk density (BD). Comparative assessment result of woody plant species analysis showed that the density of woody species in the exclosure and degraded site were 778 and 222 individuals per hectare, respectively. A total of 16 woody species, representing 12 families were recorded in the study site. Out of the 12 families, all were recorded in the exclosure while 5 were recorded in the degraded site. Out of the 16 species, 15 were recorded in the exclosure while six were in the degraded site. A total of 10 species were recorded in the exclosure, which were absent in the degraded site. Similarly a species was recorded in the degraded sites, which were not present in the exclosure. Exclosed areas had significantly ($P<0.05$) different values for all soil parameters except for bulk density, EC and pH. The higher bulk density, sand, EC, and pH were recorded in the degraded site, whereas the rest of soil properties were high in exclosure. The present study indicated that, the mean values for degraded and exclosure sites in soil of OC, TN and Av.P were 2.21 and 1.61, 0.19 and 0.14, and 7.92 and 5.88, respectivily. Apart from increasing woody plant species and soil fertility improvement, these local communities has benefited from the exclosure by collecting of forage for livestock via cut-and-carry system and farmland protection from clotting with silt and mud from the upper catchments. This has enabled this local community to develop a positive attitude towards exclosure development. Generally, area exclosure has a great contribution to restore woody plant species and soil fertility status in the study area. Therefore, to improve the livelihood of the local community area exclosure practices should be expanded to other degraded watersheds and private farmlands.*

***Keywords**: area exclosure, degraded land, land restoration, woody species, soil fertility*

1. INTRODUCTION

1.1. Background and Justification

Land degradation is one of the serious problems of the developing countries with its multifaceted effects. The decreased productivity of land, gradual decline of soil fertility, and vegetation cover are the major consequences of land degradation. According to Blay *et al.,* (2004) land degradation is one of the biggest problems in Sub-Saharan Africa, threatening the lives of millions of people. The authors described the main consequences of land degradation, which negatively affect human livelihoods and the environment to be shortages of firewood and other wood, shortages of non-timber forest products, increased sediment deposits, floods and landslides, drying up of springs and water bodies, siltation of dams, increased incidence of water-borne diseases, loss of biodiversity, climate change and desertification. On the other hand, Gardner (2002) reported that nearly three billion people in developing countries live in rural areas, but most of the land available to meet the current and future food requirements is already in production, and further expansion will involve fragile and marginal lands. As a result, the increasing scarcity of land forced farmers to apply intensive agriculture that in turn result in soil erosion, salinization, deteriorating water quality, and desertification (Gardner, 2002).

The dominant cause for land degradation is human interference to the environment, which will lead to the loss of productivity of soil and natural vegetation. "The major causes of land degradation in Ethiopia are the rapid population pressure, soil erosion, poor farming practices, deforestation, low vegetative cover, overgrazing, use of livestock manure and crop residue for fuel as energy resource of the rural households, salinity and alkalinity problems and unbalanced crop and livestock production" (Tadesse, 2001). These causes are rooted in population pressure in a sense that population pressure is the root cause that result in the other mentioned causes like deforestation, severe soil fertility loss, low vegetation cover and so forth. The problem resulted from manmade cause and needs human intervention to avert the situation. As a result, there are restoration efforts taking place in the areas where land degradation is severe problem.

One of the possible mechanisms to rehabilitate the problems of land degradation is exclosure techniques to restore degraded environment to counter act land degradation to address environmental problems. In Ethiopia, there are restoration attempts on degraded lands aimed at abating the effects of poverty. The national government of Ethiopia realized the significance of environmental restoration specifically on deforested and degraded land after the 1973 and 1984/85 major famines that struck the country (Aklilu *et al.*, 2007). At this stage, farmers were mobilized by government through "food-for-work" arrangements in building terraces and planting trees on degraded areas. After 1991, the economic policy of the country has been framed in Agriculture Development Led Industrialization (ADLI). The intensified use of land has become now the aggravating factor of land degradation and a turning point to start integrated restoration programs. The implementation of a restoration program and the results expected out of it begin with identifying the problem of land degradation, the interrelated factors determining the process of restoration and the actors involved in the process.

The recurrent drought over the last three decades threatens the livelihood of households. However, recently the government has taken initiatives to run restoration programs on degraded lands through integrated community participation. Due to the government political structure, power and resource are decentralized and restoration program is supposed to be integrated in development plans of each administration level to contribute to the goal of the government on environmental conservation. Eventually, the restoration efforts have been started aimed in abating the effects of land degradation and securing food-self-sufficiency. However, in the country in general and in the study area in particular the integrated and coherent implementation of restoration programs on degraded land started recently. Government as a key role player in the development process and local community members as main parties and beneficiaries are the main actors, involved in the restoration process with the minimal role of NGOs. The role and interest of actors differs, and the difference in interest and role determines the restoration results.

In Ethiopia, where sustainable land management is a priority for the overall development, availability of relevant land management information at all levels is very crucial (Million, 2000). However, there are limited studies in the area dealing how the conversion of free grazing lands and degraded lands by exclosures to restoring woody vegetation (Emiru, 2002; Mastewal *et al.,* 2006) and increasing biomass accumulation (Kidane, 2002; Ermias *et al.,* 2006). Considering, the diverse agro-ecological condition of the area, these studies are not sufficient to conclude about the strength of exclosures to restore degraded vegetation and soil fertility increment. This calls for systematic and focused research and developmental activities on restoration of degraded land (Mishra *et al.,* 2004).

At the beginning of 2012, the survey conducted in *Siltie* Zone shows that there is variation in performance of the restoration programme among *woredas*. Due to the deterioration of the physical, chemical and biological properties of the soil, most of the communal grazing lands in worebatshama Kebele were degraded and unavailable. To evaluate this problem this study was carried out.

Exclosures are areas closed off from the interference of human and domestic animals with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands. Exclosures are usually established in steep, eroded, and degraded areas that have been used for grazing in the past (Descheemaeker *et al.,* 2006). Studies indicated that land use change affects the composition, structure, diversity and landscape pattern of vegetation (MatejkovaIvona *et al,* 2003; Walters *et al.,* 2006), and biomass accumulation (Ray *et al.,* 2003).

The aim of this study is to evaluate the efforts made by the development organization on restoring degraded lands and to better understand how the exclosure techniques is efficient and effective to rehabilitate once degraded lands interims of vegetation restoration and soil fertilities.

1.2. Objective of the Study

1.2.1. General objective

- The general objective is to assess and evaluate the usefulness of exclosure technique in enhancing rehabilitation of degraded ecosystem and thereby increase the natural capital in the area

1.2.2. Specific objectives

- To assess and compare woody plant species diversity in *Mitija* exclosure and adjacent degraded land

- To evaluate the physico-chemical properties of soils in the exclosure and the adjacent degraded land

- To assess benefits of exclosure to the local community

2. LITERATURE REVIEW

2.1. Concepts and components of land degradation

Land degradation is a broad term, reflecting the fact that land itself is a broad term, including more than just the soil. The U.N. Convention to Combat Desertification defines land as "the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system", and land degradation as "reduction or loss of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from processes such as (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, biological or economic properties of the soil; and (iii) long-term loss of natural vegetation" (WBISPP, 2004).

Land degradation is defined by various scholars in relation with their field of study. In the context of this study land degradation refers to decreased productivity of land, gradual decline of soil fertility, and vegetation cover. These are the major consequences of land degradation. In recent years, land use in Africa has been characterized by a significant amount of land degradation and conversion (CAADP, 2009). Population pressure, overgrazing, fuel wood and charcoal making, and agricultural activities are major causes of land degradation across Africa. Many poor African pastoralists and farming households respond to declining land productivity by abandoning their existing degraded pasture and cropland, and moving to new lands for grazing and cultivation. Similar practices are certainly true in Ethiopia where agriculture accounts for most land use and thus is probably the single most powerful influence on environmental quality. At the same time, agriculture remains the principal livelihood source of the rural poor in the country (Malik, 2005).

Soil erosion is greatest on cultivated land, where the average annual loss is 42 tons/ha, compared with five tons/ha from pastures. As a result, nearly half the soil loss comes from land under cultivation, even though these lands cover only 14.2 percent of the country. Yet patterns of rural population growth, agricultural expansion and intensification and income growth projected currently and for the next few decades pose serious challenges to achieving environmental improvements and rural poverty reduction (Pinstrup *et al.,* 2001). The present status and rate of soil erosion in Ethiopia call for immediate action to retard and reverse this degradation process. However, the present population growth rate of 2.6%, in comparison with the annual agricultural growth rate of 10.4% will lead to even more intensive use of cultivatable and pasture land to produce more food and feed for the growing human and livestock populations (Hammond, 2001).

In the highlands of Ethiopia, deforestation and subsequent unsustainable agricultural management, as well as use of dung and crop residues for energy, have resulted in soil organic matter and nutrient depletion, hydrological instability, reduced primary productivity, and low biological diversity (Solomon *et al.,* 2002; Mulugeta *et al.,* 2005). Brhane and Mekonen (2009) reported soil loss of 35t ha^{-1} y^{-1} from cultivated steep slopes (30–50%) in the Northern Highlands of Ethiopia, which is about twice the maximum tolerable soil loss of the region. Furthermore, owing to overgrazing, the natural vegetation in the Northern Highlands of Ethiopia has virtually disappeared, leaving degraded communal grazing lands with irregularly spaced trees and shrubs and vast areas of bare lands devoid of vegetation (Nedessa *et al.,* 2005).

2.2. Causes of land degradation

Although degradation processes do occur without interference by the mans, these are broadly at a rate which is in balance with the rate of natural rehabilitation. So, for example, water erosion under natural forest corresponds with the subsoil formation rate. Accelerated land degradation is most communally caused as a result of human intervention in the environment (FAO, 2005).

2.2.1. Population growth

With increasing numbers of people there has not been a related change in the pattern of agriculture, which is still essentially smallholder relying on expanding the cultivated area, often into additional land, rather than adopting intensification techniques. Lack of viable land use policy and corresponding law also aggravated the rate of degradation. New settlements in forests are increasing from time to time and hence resulted in the conversion of forested land into agricultural and other land use systems (Million, 2001b).Population increases have resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forests for fuel wood, fodder, and construction materials. This problem is further increased by the domination of short-term economic and market forces over environmental considerations, which frequently results in the acceptance of unsustainable activities (Million, 2001a).

Poor rural families are more likely to support themselves with subsistence agriculture; use forest products as fuel, fodder, and building materials and live in ecologically fragile zones. In poor rural communities, the continuing need for family labor supports high fertility and rapid population growth that places additional strain on natural vegetations (De Souza *et al*., 2003). Unchecked population growth, coupled with overstocking, has brought about the encroachment of marginal areas as steep slopes and ecologically precarious lands to meet the need for food, fuel and grazing. The subsequent removal of natural vegetation and the improper land use practice have resulted in the degradation of the land and eventually conversion into wastelands (Medhin, 2002).

A very high population growth rate is a typical feature of rural Ethiopia. The total population more than doubled during the past three decades, from 29.1million in 1972 to 67.2 million in 2002 (Mulat *et al.,* 2006). Particularly, the highlands of Ethiopia are the area of most intense population pressure, the area of greatest livestock density and the area of greatest land degradation (Berry, 2003). The Ethiopian population is about 77.4 million in 2007 (CSA, 2007). It is expected to go up to 130 million by 2030 and the majority of this population will make their livelihood in lands that are currently classified as to severely degraded areas (mainly in Ethiopian Highlands) (FAO, 2003b). For example, the population size of Hulbarag *Wereda* was 87132 of whom 41,710 male and 45422 female (CSA, 2007).

2.2.2. Expansion of agricultural lands

Land degradation manifests itself in many ways. Vegetation, which may provide fuel and fodder, becomes increasingly scarce. Watercourses dry up. Thorny weeds predominate in once-rich pastures. Footpaths grow into gullies. Soils become thin and stony. All of these manifestations have potentially severe impacts for land users and for people who rely for their living on the products from a healthy landscape (Berry, 2003).

Accelerated water and wind erosion occur wherever the soil surface is bare of vegetation, and where rainfall or wind events can be very intense. Human-induced erosion occurs either as a result of clearing vegetation (by wholesale clearance of woody vegetation, and by bare-soil cultivation) or by overgrazing stock, leading to soil surface exposure (Hamblin, 2001). The fact is that tree cover no longer dominates many forest landscapes of Ethiopia. In some areas, the current land-use configuration has led to a dramatic and detrimental decline in the availability of forest goods and services. In such degraded landscapes, agricultural production tends to suffer, local shortages of timber and fuel-wood, household income falls, and biological diversity declines. Often, the effects of landscape degradation are felt further downstream siltation loads increase and water quality declines (Maginnis and Jackson, 2003). Conventional farming is widely practiced in the highlands of Ethiopia. This practice exposed soil to water and wind erosions that deteriorate soil productivity. Due to this reason, farmers prepare additional farmland by clearing the remaining fragmented forest in steeply slopes and in accessible areas.

The greatest threat for the land degradation in Ethiopia is clearing forest for the expansion of agricultural land at the peasant level, the clearing of forests by investors for coffee and tea plantations, and in the uncontrolled exploitation of the timber and fuel-wood in the remaining woody vegetation. This increasing demand for more food and farmland remains point of conflict between agricultural development and sustainable forest management. The core of the conflict is that agricultural areas have to expand to increase the production of food and farmers are continuously looking for land to clear for agriculture. The result of this is that farmers clear vast areas of forest every year (Million, 2001a).

According to Mulugeta (2004) the rapid degradation and depletion of the land resource base is already finding its expression in the different sectors of the economy such as agriculture, water resources, energy and biodiversity. Agriculture is the sector most affected by the deteriorating natural resource base. With a decline in the availability of firewood, animal dung and crop residues are increasingly required for use as household fuel instead of serving as natural fertilizers for the soil, thereby further depressing agricultural yields (Badege and

Abdu, 2003; Mulugeta, 2004). The rapid population growth coupled with accelerated forest degradation has lead to an increasing demand for agricultural land (Mulugeta, 2004).

2.2.3. Fuel wood and charcoal making

Traditional fuels such as firewood and biomass fill the energy needs of millions of people in less developed countries. These fuels often are collected from common or publicly shared resources such as open land and woodlands. The collection and burning of these fuels create their own environmental problems, including soil erosion, loss of watershed areas, and emission of particulates and other pollutants (De Souza *et al.,* 2003). Firewood gathering and charcoal making have contributed significantly to forest destruction and land degradation. Despite the cooking advantages of charcoal and charcoal's ranking on the cooking ladder, charcoal may be far more damaging to the environment than the less preferable biomass fuels, biomass residues and firewood (Kammen and Lew, 2005). Fuel-wood consumption is one of the main causes of degradation as well as deforestation, and excessive cutting of trees for firewood before they are fully-grown, leads to the loss of growth potential of the forest stands. In most developing nations, more than 80 % of wood extracted are being used for fuel (Union of Myanmar, 2000).

Felling of tree for various domestic uses and making charcoal have decimated the vegetation and most of the land is now cultivated leaving the woodlands fragmented into small patches (Zerihun, 2003). Charcoal making and selling is a major non-farm employment along the main roads of the country (Mulat *et al.,* 2004). Ninety-four percent of the Ethiopian population relies on wood-based and biomass fuel for household energy. Scarcity of firewood has become acute in many parts of the country causing a continuous rise in prices, and thus increasing the economic burden on the household budget. Animal dung and crop residues are increasingly being used for household fuel rather than being added to the soil to improve soil fertility, thus further exacerbating the problems of environmental degradation and deforestation (Jabbar *et al.,* 2002; Badege and Abdu, 2003; Mulugeta, 2004). In Ethiopia, the size of commercial energy consumption is low; other source of energy is more of traditional in nature. At present, the country is excessively dependent on traditional fuels, consisting mainly of wood, crop residues and animal waste. Traditional fuels (firewood, charcoal, twigs, leaves, straw, stalks, crop residues and animal dung) contribute about 94 percent of the gross energy supply of Ethiopia, which is one of the highest, if not the highest, in the world (Milliom, 2001a).

The situation with energy use is one of the most critical land degradation issues in Ethiopia. Estimates of current demand for fuel wood approach 55 million m^3 per year with an estimated sustainable production of 13 million cubic meters per year (Berry, 2003). Most households almost exclusively depend on wood to meet their energy needs with average daily per capita consumption of fuel wood varying from 7 kg in the biomass rich regions to 0.8 kg in the arid areas. More than 50 % of primary energy used in Ethiopia for baking "Injera". This energy intensive activity accounts for more than 75% of the total energy consumed in Ethiopian households. Natural forests and woodlands are the most important sources of woody biomass resources. An estimate of $38m^3$ tones of woods was consumed in 1995/1996 (Thomas and Million, 2002).

2.2.4. Poverty and local livelihoods

Poverty affects more than half of the inhabitants of Ethiopia and this situation is probability responsible to many activities contributing to land degradation and deforestation in the country (Thomas and Million, 2002). Nearly all dry lands are at risk of land degradation as a result of deforestation, climate change, increasing human population, land over use and poverty. This represents a threat to food security and survival of the people living in these areas as well as vegetation conservation which can be the result of more likely to arise from human activity (FAO, 2003b). The prolonged degradation of dry-land areas continues to affect the productivity and genetic diversity of forest, woodland and bush-land resources (Tefera *et al.,* 2004).

Poverty-led environmental degradation of marginal lands, deforestation, overgrazing of fragile rangelands, cultivation of steep slopes, consequently affect majority of the rural poor rely heavily on forests and woodlands for income and subsistence (Chamshama and Nduwayezu, 2002). Declining of the standard of living of the farming communities lead to close dependent on forests and woodlands like clearing forests for subsistence farming and cutting of trees and shrubs for fuel wood, charcoal making, construction materials and overgrazing. The loss of forests and woodlands reduced the opportunities of local people, increase disasters and led local communities to absolute poverty. Studies indicated that poverty is viewed as a cause of environmental degradation and its consequences push the rural poor people to live in fragile ecosystems (Shyamsundar, 2002).

2.3. Consequences of land degradation

2.3.1. Soil fertility loss

Water is the main cause of erosion in the highlands of Ethiopia. The rain is concentrated into a three- to four-month period in the summer, with more than 72 percent of the highlands receiving over 600 millimeters of rain between May and September (Asano and Leavine, 2004). The consequences of soil erosion and sediment deposition occur both on and off-site. Onsite effects are particularly important on agricultural land where the redistribution of soil within a field, the loss of soil from a field, the breakdown of soil structure and the decline in organic matter and nutrients result in a reduction of cultivable soil depth and a decline in soil fertility. The net effect is a loss of productivity, which at first, restricts what can be grown and results in increased expenditure on fertilizers but later might lead to land abandonment (FAO, 2005).

2.3.2. Loss of biodiversity

Article 2 of the Convention on Biological Diversity (CBD) defined Biodiversity as the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Myers, 2003)

Ecological factors (e.g. climatic or edaphic), genetic diversity and competition among species, and other biotic and abiotic factors are important elements of biodiversity. Three main components of biodiversity have been widely recognized (Spanos *et al*., 2006), as composition, structure, and function, which contribute to the biodiversity quality of an area (Peter and Kimberly, 2006) and are essential for productivity and ecosystem sustainability (Nathan and Casagrandi, 2004).

Diversified ecosystems are rich in resources. Thus, they sustain many life forms, and withstand stresses better than diversity poor ecosystems (Ruiz-Jaen and Aide, 2005). This implies that, the more diversified the ecosystem, the better resilient it becomes to resist disturbances, and provide services and functions. Therefore, to keep these potentials prolonged, effort by either decreasing the unwise anthropogenic stress and/or increasing the productivity of the ecosystems with properly designed interventions is crucial.

2.3.3. Depletion of forests

It is estimated that about 34% of the total area or 87% of the Ethiopian highlands above 1500 m have originally been covered by dense forests and about 20% by woodland/savannah (Dufey, 2006). Up to the beginning of this century, about 40% of the highlands were still covered by natural vegetation. Some sources indicate that the country is now left bare with the forest cover reduced to only 2-6 percent2. The annual rate of depletion of forests has been estimated to be in the order of 150,000-200,000 hectares, which is equivalent to about 6 percent of the remaining forest cover (Aklilu, 2000). Of the causes of deforestation, land clearing for agriculture accounts for the highest portion (see Table 1). Cutting of forests to get firewood explains about 19% of the deforestation.

Table 1 Forest loss by source

Sources of forest loss	Annual loss (ha)
Natural high forest for farming by subsistence agriculturalist	80,000
Acacia woodlands for charcoal and for state farms	50,000
Woodland, thickets and brush for fuel wood	30,000
Total	160,000

Source: (Aklilu, 2000)

2.3.4. Desertification

Desertification is considered as a process by which dry land environments are degraded to a less productive state (CACILM, 2006.). Degradation of soil and vegetation cover is regarded as one of the indicators of desertification (SPRINGER, 2006). The other indicators listed by MENSCHING include decrease in underground water and change in the morphological process (like formation of sand dunes and accumulation of dust in the air). It is to be noted that some of the causes of land degradation are at the back of formation of deserts in Africa and elsewhere.

An otherwise productive semi-arid region could be converted into a useless desert when soil quality and moisture content decline (MULVANEY, 2009). Desertification may also be attributed to overgrazing and desertification results from mans over exploitation of arid lands, and can be stopped almost as easily as the world population explosion that is when the world population has been halted, the deserts of the world may cease to expand (Reynolds *et al*, 2007).

2.4. Socio-economic impact of land degradation in Ethiopia

Ethiopia is among the poorest of countries and poverty and land and resource degradation appear to feed off each other. The irony is that Ethiopia is a country with high biodiversity and distinctive ecosystems and the natural resource base is critical to the economy and the livelihood of a high percentage of the population. All physical and economic evidence shows that loss of land resource productivity is an important problem in Ethiopia and that with continued population growth the problem is likely to be even more important in the future. There are several studies that deal with land degradation at the national level in Ethiopia (Sonneveld and Keyser, 2001).

2.5. Magnitude of soil degradation in Ethiopia

Land degradation, especially in the highlands, has been identified as the most serious environmental problem in Ethiopia (Hagos and Holden, 2002; Aune *et al.,* 2001). Deforestation, overgrazing, inappropriate agricultural practices such as over-cultivation, fertilization, and nutrient depletion are reported to be the major human caused factors of land degradation (NEPC, 2001). FAO, (2005) reported that on two million ha of cultivated land, the soil depth is so reduced that the land is no longer able to support any vegetative cover. The Hararghae highlands in Eastern Ethiopia, Tigray, Wollo, and Semen Shoa highlands in the North and the Gamo-Gofa highlands and the Bila-te River basin, which starts in Eastern slopes of Gurage highlands and stretches through Eastern Hadiya and Kembatta highlands, are some of the seriously eroded land surfaces in Ethiopia (Mitiku and Kindeya, 2001).

The rate of deforestation of high forests, for example, has been estimated to range from 150,000 to 200,000 hectares per year (SANREM, 2005). Likewise, overgrazing is considered as a major cause of land degradation in Ethiopia, particularly in the highlands. The issue of overgrazing, however, is not a straightforward one. It is clear that in many areas of the highlands vegetation loss is severe, and that this degraded land no longer has the capacity to support large animal populations (SANREM, 2005).

Exactly how much soil loss is a result of grazing, and how many animals the highlands can support both now and in the future, however, are issues under both scientific and political debate. The natural and institutional environments across the highlands are variable, as is the extent to which grazing activities interact with agriculture and forests. Combined with climatic variability, it is difficult to generalize as to which processes actually led to overgrazing and the resulting land degradation, and how this might be remedied in the short and long term. Soil conservation research project (Mitiku and Kindeya, 2001) and National Conservation Strategy 1992 claim that soil losses may have been severely over-estimated by FAO, (2005). The figures for the soil loss by erosion from 6 SCRP sites range from 18 to 214.8 tons per ha per year (Table 2).

Table 2 Soil erosion loss on 6 SCRP sites in various parts of Ethiopia

Site	Soil loss (tons/ha/year)
South Wollo	36.5-53.8
Sidamo	41.2-49.5
Harar	25.5-27.8
North Showa	152.4-214.8
Gojam	40.2-199.2
Illubabor	18.0-135.3

Source: Mitiku and Kindeya, (2001)

Soil degradation is among the most serious environmental problems in Ethiopia (Aune *et al.,* 2001). It can be caused either by natural hazards or by unsuitable land use and inappropriate land management practices (FAO, 2001). The immediate consequence of soil degradation is reduced crop yield followed by economic decline and social stress (Gebremedhin, and

Swinton, 2003). Among different forms of land degradation processes in Ethiopia, soil erosion by water is the most important environmental problem that poses an ominous threat to the food security of the population and future development prospects of the country (Wagayehu and Lars, 2003).

Ethiopia has been described as one of the most serious soil erosion areas in the world with an estimated annual soil loss of about 42 t/ha/yr from croplands (Kessler, 2006). In 2001, it was estimated that only 20% of the total area of the Ethiopian highlands have relatively minor problems of erosion; 76% are significantly or seriously eroded and 4% have outstripped their capacity to be of any value for production (Naipier, 2001). Nutrient depletion, which results from strong dependency on crop residues and animal dung for household energy and from inappropriate land management practices, is also one form of soil degradation causing low agricultural productivity in the country.

2.6. The impact of soil degradation on agricultural production

Land resources constitute the most important natural resources for countries like Ethiopia where agriculture is the mainstay of the national economy. Agricultural production in Ethiopia is highly dependent on smallholder rain-fed farming, and it has been practiced for several thousands of years. The country still relies greatly on the agricultural sector. About 90 percent of the population lives by cultivating the land and more than 50 percent of the export earnings derive from the sale of farm produce. However, natural resource degradation in general and soil degradation in particular, resulting from population pressure and inappropriate land use, are considered the major problems threatening agricultural development and food security in the country (Tadesse, 2001).

It is widely recognized that accelerated erosion is one of the major factors responsible for soil degradation. It is also one of the most important environmental problems among various forms of land degradation in Ethiopia; it reduces the production potential of land, and thus makes it difficult to produce enough to feed the growing population. It also increases farmers' vulnerability to food shortages and becomes a threat to the mere survival of the people (Sonneveld and Keyzer, 2003).

2.7. Soil fertility and sustainable agriculture

Soil is the foundation for nearly all land uses (Herrick, 2000). Together with water, soil constitutes the most important natural resource of our physical environment. The wise use of this vital resource is essential to promote sustainable development, feed the growing world population and maintain environmental health (Arshad and Martin, 2002). In the past few decades alone, the global grain production growth rate has dropped from 3% in the 1970s to 1.3% in the early 1990s, which is one of the key indicators of declining soil quality on a global scale (Yirdaw and Luukkanen, 2003). Many agree that no agricultural system can be claimed to be sustainable without ensuring the sustainability of soil quality (fertility) (Arshad and Martin, 2002).

Many authors have defined soil quality in recent years (Herrick, 2000; Arshad and Martin, 2002). Although the definitions are slightly different, all refer to the functions of the soil to supply plant nutrients and other physico-chemical conditions to plant growth, promote and sustain crop production, provide habitats to soil organisms, ameliorate environmental pollution, resist degradation and maintain or improve human and animal health (Shukla, 2004). Generally, soil quality (fertility) encompasses three basic components: physical, chemical and biological attributes of the soil (Ouedraogo, 2004). These chemical, physical and biological soil attributes determine the wise nutrient supply capacity of the soil for plant growth. Soil physical properties determine the capacity of the soil to provide plants with a foothold, moisture and air; and soil chemical conditions determine the capacity of the soil to provide plants with nutrition.

The magnitude of nutrient losses and the extent of input substitutions vary considerably depending on the socio-economic and cultural setting of the agricultural system. Poor farmers in the tropics seldom lack the resources to sufficiently compensate for nutrient losses from the agro ecosystem during production cycles. The maintenance or enhancement of soil fertility is even more difficult in cases such as the smallholders' cropping system in the highlands of Ethiopia, where crop residues and cow dung are considered important components of the harvest and removed from the crop fields. The removal of crop residues and cow dung not only interrupts recycling of plant nutrients but also contributes to a considerable depletion of the SOM, which exacerbates the decline in plant nutrient levels and soil productivity (Murage *et al.,* 2000).

2.8. Sustainability of conservation structures in Ethiopia

Since the 1960s, various conservation strategies have been introduced to enhance agricultural development and rural livelihoods (Keeley and Scoones, 2000). Studies conducted in different parts of the country came-up with different factors that explains the low level of success of conservation initiative. These studies attributed the low level of success of the initiative to several possible reasons. First, the introduction of the measures did not consider local conservation and farming practices and in many cases did not fit in with traditional methods. Second, since interventions normally include such activities as reforestation, terrace construction, etc., they are generally characterized by high initial costs that poor farmers could not afford and by benefits that only become apparent in the long run. Third, the extensive and uniform application of similar soil and water conservation (SWC) measures disregarded local agro-ecological and socio-economic variations (Aklilu, 2006).

Livestock interference owing to the prevailing free grazing practices in Ethiopia is also among the major limitations to sustainable management of soil and water conservation measures. In the last three decades, a lot of effort was made to introduce a number of biological conservation techniques, but unfortunately suffered from the open grazing systems widely practiced in the country as a whole. It is also to be noted that livestock interference is not only limited to vegetative conservation measures but it is also on structural measures such as stone and soil bunds that collapse when trampled by livestock during grazing. The absence of Government set policies and regulations have seriously affected sustainability of SWC structures in the country. On the other hand, however, if community and local governments set regulations and laws, which ensure the involvement of the public in conservation activities and encourage conservation approach that helps to meet the short-term needs of the farmers and long-term conservation objectives simultaneously, there will certainly be a possibility to attain sustainability in soil and water conservation structures (Daniel, 2002).

2.9. Efforts to tackle the problems of land degradation

Efforts to contain the problem of land degradation have been made at several levels. Two of the main activities have been soil and water conservation works and the establishment of area exclosures. The implementation of the soil and water conservation activities on a large scale started in the mid 1970s with the help of the World Food Program (WFP) through food for work projects. In 1980, World Food Programs (WFP) relatively small-scale, fragmented projects were consolidated under one support program called "rehabilitation of forest, grazing and agricultural lands (ETH-2488)". The beginning of the ETH-2488 project marked the beginning of large-scale soil and water conservation and land rehabilitation programs in the country (Betru, 2003).

2.9.1. Area exclosures

Area exclosures in the Ethiopian context can be defined as the degraded land that has been excluded from human and livestock interference for rehabilitation. Human and animal interference is restricted in the area exclosures to encourage natural regeneration. In practice, however, cattle are allowed to free graze in several of the area exclosures. Cutting grass and collection of fuel wood from dead trees and bee keeping is also allowed. In some areas, soil and water conservation activities are also being undertaken (Tenna *et al.,* 2001).

Study by Alemayehu Wasie (2002) confirmed that in Ethiopia protecting natural forests and rehabilitating vegetation around churches, mosques and graveyards has been practiced as parts of human endeavor for millennia. Ecological restoration of degraded habitats is now regarded as an effective response to check and reverse the negative effects of habitat loss, degradation, and fragmentation on native biological diversity and ecological processes (Shankar *et al,* 2006).

Establishing exclosures is considered advantageous since it is a quick, cheap and lenient method for the rehabilitation of degraded lands. As a result, rehabilitation of degraded lands through exclosure recently received attention in many parts of Ethiopian especially the northern and central highlands. In Tigray Region alone a total of 262,000 ha have been exclosed so far, this figure included degraded land which has some remaining forest species and forest land exclosed by the government. In Tigray Region no *"Kebele"* is found without exclosure(s). Likewise, in Amhara Regional State, many hectares of degraded lands are rehabilitated though exclosures although their sizes are not available in consolidated form (Betru *et al.,* 2005).

The regeneration of natural grasslands and forest areas increase biomass production and improve the plant species diversity, resulting in more diverse soil biota and other associated beneficial organisms, which may be more reliable where land is not productive (FAO, 2005b). Among the various ways of overcoming environmental degradation, loss of biodiversity and deforestation problem of the country, exclosure is the most crucial and determinant way of rehabilitating severely exploited vegetation and degraded dry land environment (Million, 2001a). Moreover, natural vegetation rehabilitation is also essential to improve biodiversity and microclimate of the areas. Besides, it is also recognized for its multipurpose benefits like fuel wood, animal fodder, fiber, medicinal species, restoration of soil fertility (*Acacia albida* and other *leguminous species*) and habitats for various beneficial species (pollinators and biological control) and wildlife (FAO, 2005b).

2.9.2. The establishment objective of exclosures

The major objective behind establishing exclosure areas is to halt and reverse land degradation to check the adverse effect of runoff, improve the micro climate and create conducive atmosphere for humans and livestock by maintaining environmental stability in the trees, shrubs, herbs and grasses. Area exclosure is the most crucial method of rehabilitating lands through natural regeneration. It is a method for land restoration by protecting the area from human and animal's interference for limited period of time depending on the revegetation capacity of the area (REST, 1996 as cited by Tefera, 2001).

2.9.3. Environmental benefits of area exclosure

Rapid vegetation restoration through area exclosures are an efficient measure for soil and water conservation because of their increased capacity for infiltration and sediment trapping. If vegetation coverage is chosen to be the best alternative form of land use, not only the loss of soil prevented, but also that it is not deposited in river bottoms, lakes and dams (FAO, 2001). The influence of trees in soil physical properties is also very important in augmenting the overall capacity of the land to be productive. Exclosures played an important role restoring soil resources and improving soil fertility. They improved soil fertility by adding soil nutrients from decomposed plant remains. Exclosures also reduced nutrient loss from a site by controlling runoff (vegetation acting as a physical barrier to soil erosion). This eventually improves the capability of the land to support other vegetation types, including exotic plantations and/or support livestock (Tefera *et al.,* 2005).

Promoting integrated watershed development through area exclosure or plantation program with effective participation of local people is a key to preventing further ecological imbalance. Since an integrated approach is needed for conserving, upgrading and using the natural resource base of land, water, plant, animal and human resources (Kidane, 2002). In the past, efforts to contain the problem of land degradation have been made at several levels. Two of the main activities that been done were soil and water conservation works and the establishment of area exclosures (Betru, 2003). Soil and water conservation and establishment of area exclosures promoting alternative livelihood opportunities, particularly through development of employment schemes that increase the productive bases, will have a significant role in improving the standard of living among the large rural population living in mountainous ecosystems (FAO, 2003c). In Ethiopia establishment of area exclosures have been an important strategy for the rehabilitation of degraded hillsides. This practice has become very common, especially in the highlands, due to the remarkable improvement of productivity and reduction in soil erosion in the areas exclosed in the early 1980s by (WFP and MoA, 2002).

Maintaining adequate vegetative groundcover is the first defense against soil erosion (George *et al.,* 2004). Whereas, the less the soil is covered with vegetation the more the soil is exposed to the impact of raindrops due to less organic matter content in the soil (FAO, 2005b). Clay and organic matter in the soil have negative charge; naturally, it attracts positively charged nutrients and repels negatively charged nutrients (easily leached away). The active fraction of soil organic matter (SOM) has been most closely associated with nutrient supply. However, the stable soil organic matter pool also improves soil fertility by holding plant nutrients and preventing them from leach into the subsoil. Since SOM has a net negative charge, nutrients such as calcium, magnesium, potassium and ammonium (called cations) because of their positive charge they can be easily attracted and held by soil organic matter (Cooper, 2002). Organic matter may provide nearly all of the CECs and pH buffering in soils (Bot and Benites, 2005).

As vegetation coverage of area exclosure increased the amount of soil organic matter accumulation also increased. The presence of organic matter also affects both the chemical and physical properties of the soil and its overall health. Soil properties influenced by organic matter include; soil structure, moisture holding capacity; diversity and activity of soil organisms (Bot and Benites, 2005). According to Brady and Weil (2002) for each 1 percent increase in soil organic matter, the available water holding capacity in the soil increased by 3.7 percent. The availability of soil organic matter is very important soil component and it helps to improve soil's physical conditions, increase water infiltration, and water holding capacity, decreased soil erosion losses, supply available plant nutrients and augment soil's cat ion exchange capacity (Bandel *et al.,* 2002). Basically, organic matter reacts in the soil like a tiny, spongy solid with a large amount of negative charge. Because of it is complex and open structure, the ability of humus to pull water from the surrounding saturated atmosphere of the soils approaches 80 to 90 % of its weight, as compared to 15 or 20 % for soil clays (Bot and Benites, 2005).

Land abandonment or systems of fallow (Rezaei and Gilkes, 2005) are the common conservation strategies to promote restoration of biodiversity in degraded agricultural and grazing lands worldwide (Hobbs and Harris, 2001). Restoration of degraded lands reduces the loss of biodiversity. In the absence of restoration, the overall sustainability of ecological/ecosystem processes, including species diversity, will be further threatened.

Recently in highland and central parts of Ethiopia establishment of exclosures is emerging as a major and important practice to conserve vegetation biodiversity. As biodiversity, which plays a critical role in overall sustainable development and poverty eradication, is essential to the human well-being and to the livelihood and cultural integrity of people. In Tigray Region (Kindeya, 2004), Welo (Tefera, 2001) and Shewa (Tefera, 2001). Indeed, if degraded lands are restored or rehabilitated, they can have the potential to generate significant environmental and livelihood benefits, besides the fulfillment of ecological functions and biodiversity conservation.

These days, efforts are underway to replenish the denuded vegetation of northern Ethiopia in line with the need to supply livestock fodder and other tree products. To realize those effects, exclosing areas has been helpful towards the major goal; achieving conservation based sustainable agriculture (Emiru, 2002). The successful colonization of many of the native species in many of the degraded lands, underline their potential in wasteland reclamation. These would serve as sources of fuel-wood, fodder (using cut-and-carry system) and other tree products while reclaiming the marginal lands. Its contribution in augmenting the high demand of tree products might be of paramount importance (Kindeya, 2004).

The main contributions of area exclosure is that provide forest products including trees that can make to the livelihoods of the rural poor through increasing incomes, improving food security, reducing vulnerability and enhancing well-being (FAO, 2001). Poverty reduction and alleviation remain central to livelihood perspectives and efforts to reduce poverty focus on strengthening people's command of assets, expanding their opportunities to pursue different livelihoods strategies, and enhancing resilience in the face of risks, stresses and shocks. In this sense, establishments of area exclosure has contributed a lot improve livelihoods of local communities by ensuring their wellbeing and capabilities (Emiru, 2002). Here, in times of crisis, the “safety net” role of forests and trees becomes more pronounced. Poor people often live precariously with no cushion against adversity. In times of special hardship, and in the absence of a welfare state, the poor often look to the nearby forests and trees for the means to keep going. Although not as important overall as the goods that those families can produce from farming, trees and forests help families through the “lean season” between the end of one harvest and the next when food is short, or through periods of seasonal unemployment (Shimizu, 2006).

Community livelihood can be improved by utilizing natural resources in a more sustainable way. Options like common pool resources, then, are extremely important in preventing people from slipping further into poverty. As soil erosion is the main cause of poverty of the country, protecting soil at the site is by the presence of vegetation cover can effectively disconnect the coarse sediment transfer by encouraging deposition and preventing sediment supply. It also tends to reduce flood transmission so attenuating flood peaks through increased roughness (Medhin, 2002). Resource restoration (e.g. hillside vegetations) help maintain valuable ecosystem services, reduces flood damage, provides further benefits, and reinforced as a key building block of development support of the rural communities (GACGCS, 2005).

2.10. On-site and off-site SWC effects of exclosures

Exclosures provide essential functions in terms of trapping incoming sediments and increasing water infiltration. They accelerate fertile soil build up and prevent important sediment loads leaving the catchment or silting downstream water reservoirs. More generally, the soil and water conservation effects of exclosures may be described by classifying the effects into three categories on the basis of the locations where the actual or potential effects may occur (Descheemaeker *et al.,* 2006).

2.10.1. On-site effects: the exclosures itself

Exclosures improve the hydrology and soil inside the forested land in several ways: they prevent physical soil loss, maintain or increase soil water holding capacity, protect or increase top soil depth, prevent the loss of soil nutrient content and increase soil organic matter. These functions of exclosures improve soil fertility within the forested land itself (Descheemaeker *et al.,* 2006). An increase in soil fertility within exclosures has a number of biophysical and socioeconomic implications. As a result of improved soil fertility and soil water content the total amount of biomass production will increase with its subsequent ecological and economic benefits. Different authors (Wisborg, 2000) reported positive effects of exclosures. In all cases, the natural vegetation is regenerating. Observations of reduced runoff and sheet and rill erosion, land stabilization and increased soil water availability are reported by these authors for several exclosure sites.

2.10.2. 0ff-site effects: nearby/adjacent land use types

By improving the hydrology of a catchment, besides the forested land, exclosures also have effects on land adjacent to them. The reduction in surface runoff may decrease in the smothering of crops by sediments or reduce washing of the crop field by floods. Some insects and wild bees residing in exclosures may increase the pollination of crops. Of course, there may be some possibilities that exclosures may contribute negatively to the nearby land use types, such as harboring rodents and pests that can damage crops and increased pressure on the remaining pasture. But from the practical point of view exclosures can be considered as effective means of soil and water conservation measure (Descheemaeker, 2006).

2.10.3. 0ff-site effects: downstream locations

By stabilizing the hydrological processes and regulating total water runoff and flooding, vegetation cover controls and/or reduces soil erosion and the problems of downstream sedimentation and siltation (Kumar, 2000). Besides its negative effects to the source area, erosion also has downstream off-site effects. The eroded sediments can be deposited in reservoirs and reduce hydroelectricity generation and water supplies for irrigation. The sediment can also reduce the operational efficiency of irrigation systems and impair the quality of drinking water. Because of their sediment trapping capacity, exclosures can prevent sediment loads from leaving the catchment and silting up water reservoirs. Vegetation restoration in exclosures also acts as a ‘sink’ area where the incoming water infiltrates and/or deeply percolates beyond the root zones and contributes to the ground water recharge and induces new springs.

3. MATERIALS AND METHODS

3.1. The Study Area Description

3.1.1. Location

The study was conducted in Worebitishama *Kebele* Mitija exclosure at *Hurbarag Woreda*, *Siltie* Zone, Southern Nations, Nationalities and Peoples Regional State (SNNPRS). Geographyically, the area is located at 7°47′N latitude and 38°08′E Longitude. The study site is located 182 Kms away from Addis Ababa, capital city of Ethiopia, and 215 Kms from Hawassa, the regional city of SNNPRS at *Siltie* Zone on the way to Worabe-Hossana road, in South Ethiopia. The altitudinal range of the study district is between 1891 and 2040 meters above sea level (m.a.s.l). For the present study, two land use types, exclosure and adjacent degraded sites with an area of 27.5ha and 19.1ha were selected respectively. Similar to other parts of the country, many decades of cutting woody plants and uncontrolled grazing left these areas to the level of being devoid of woody plant species. However, in 2004, the area was put under plan to be managed and protected with participation of local people, as part of the exclosure launched by the community, and has been managed against any disturbance by humans and livestock. Since then, exclosure has been under continuous protection. The sites have an altitude ranging between 1880 and 1960m with the slope ranging between 2% and 35% (HWCB, 2012).

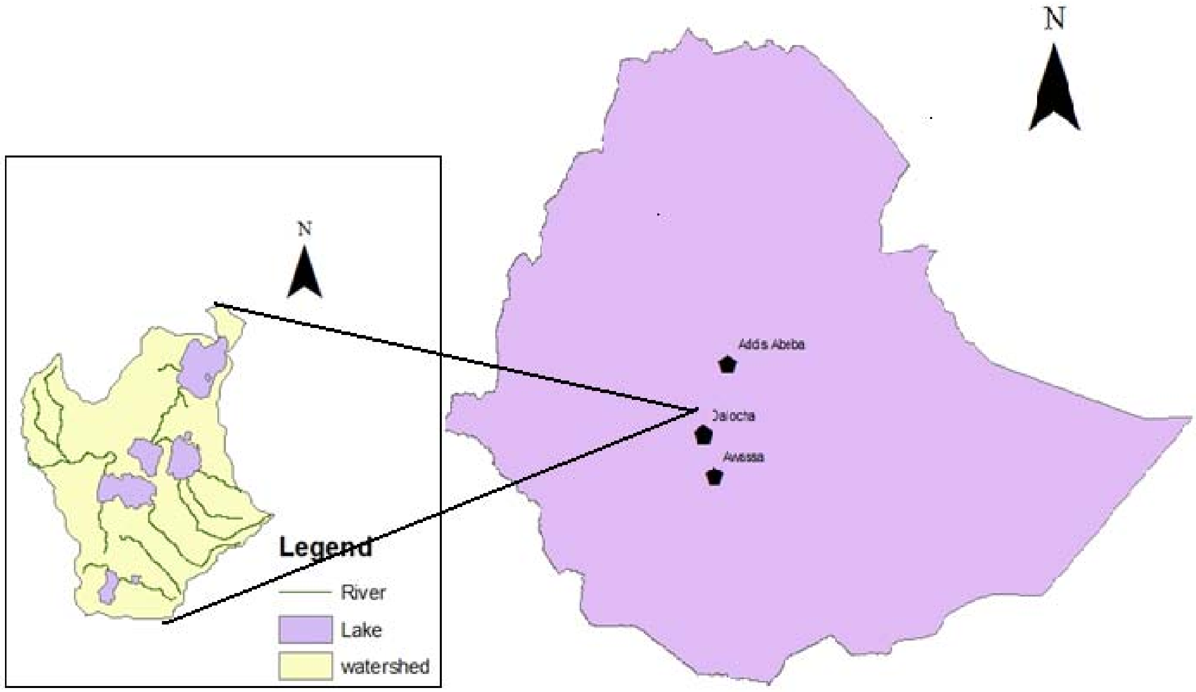

Figure 1 Map of the study area

3.1.2. Climate

The mean annual rainfall of the study area is about 900- 1200mm. The study area has bimodal rainfall distribution. Accordingly, it has two rainy seasons "*Belg*" and "*Kiremt*". "*Belg*" is the short rainy season that lasts between March and May. During this period, the area receives total average rainfall of about 460mm. The "*Kiremt*" season, which is the longest rainy season, lasts between June and September. More than 75% of the total rain falls during this season and the highest rainfall occurs in July and August. Rain that occurs during the "*Kiremt*" season is very intensive and, hence, the majority of soil loss from erosion occurs during this time. Although the rainfall has bimodal distribution, most of the crop production takes place during the "*Kiremt*" season. At the national level, as well, about 85% to 90% of the harvest is due to the "*Kiremt*" rain (Kassaye, 2004). During the shortest rainy season, "*Goya* (Lathers sativa) and *Shimbura*" (Cicero aretinum) is grown and failure to get rain during this season, often results in starvation, especially, during the "*Kiremt*" season (June to September). The dry months in the area extends from October to February. During these months, the area in average receives only 35mm of rain. The data obtained from Ethiopian

Metrological Service Agency showed that most of the area receives no rain during these months. People in the area indicated that there is severe shortage of water for people and livestock (HWORD, 2012).

Mean annual temperature of the area is 17.7 ^{0}C and mean minimum and maximum temperature of the area are 10.4^{0}C and 23^{0}C respectively. The warmest months of the area are between February and May. In these months, average temperature of the area reaches to 22.5^{0}C. On the contrary, the coldest months of the study area range between June and August where the average monthly temperature reaches to 10.6^{0}C. Frost occurs in October and November occasionally (HWORD, 2012).

3.1.3. Topography and soil

The study area falls in the central rift valley physiographic region, formed by quaternary rocks of the rift floor and recasting deposits. The landform belongs to the volcanic lacustrine plains of the rift valley. Ash and pumice tuffs also exist in the floor of the valley. Flat to undulating plain areas are associated with hill fault scarp, which dissect steep and rough land terrain, predominantly covered with exposed rock surface (Seifu, 1999). The major soil type of *Hulbarag Woreda* is Vertisol which covers about (65%) of the *Woreda* including the study site. Other soil types are Nitosols (18%) and Cambisols (17%). Black clay soil, in the area is locally called *marare*, whereas light sand soil and hillside soil-locally called *barbaro*, a mixture of black and red light soil, is locally called *abolse* and, stony soils, locally called *unni afar*. Nitosols in *Hulbarag Woreda* are highly degraded, infertile soils while vertisols are generally fertile with good moisture holding capacity. They are hard and crack when dry, and sticky when wet FAO (2000).

3.1.4. Vegetation

The land cover is dominated by scattered trees and shrubs, which are found around settlements, in farmlands, and shrubs, trees and grasses in the exclosure areas. The vegetation in the area has been categorized under the semi-humid woodland with a mixture of broad and narrow leaved species (Aalbaek, 1993). This vegetation type is characterized by several species of *(Acacia saligna, Acacia seyal, Acacia abysinica and Acacia lahai), Croton* *macrostachyus, Dodonaea angustifolia, Euclea schimperi, Phonex reclinata, Rosa abysinica, Carissa spinarum, Syzygium guineense, Olea europaea subsp, cuspidate* (Aalbaek, 1993). On large hills of the area, the vegetation is extremely threatened because of intense grazing and fuel wood extraction.

3.1.5. Water resource

In the *woreda* catchment, there are six temporary rivers and one permanent river. These water bodies are used by both people and livestock. The water from these rivers is unsafe for drinking; people are using it due to lack of any other alternative. When those temporary rivers dry-up, the majority of community use water from the permanent one, named *Furfuro* river. For majority of the people, the source of water is not clean, because both livestock and humans use the same source of water (HWORD, 2012).

3.1.6. Population

Hulbarag Woreda is the fourth populous district, from the total of eight *woredas* in *Siltie* zone. Based on figures published by the Central Statistical Agency in 2007, the *woreda* has an estimated total population of 87,132 of whom 41,710 are men and 45,422 are women. With an estimated area of 347km^2. According to data obtained from the *Hulbarag Woreda* Agriculture and Rural Development Office, in the village where exclosure and adjacent degraded sites are hold, there are about 150 households (HWRDO, 2012).

3.1.7. Livelihood and economic activities

Sedentary mixed farming is the main stay of farmers in the *woreda*. The people of the area practice various livelihood and income-generating activities mainly crop production and animal husbandry in addition to petty trading and daily labor. Crop production plays a major role in income generation in the area are, *chat (Catha edulis), teff (Eragrostis teff)* and wheat (Tritium spp). Cereals such as *teff,* wheat, maize (Zia mace), barley (Hoodlum vulgate) and sorghum (Sorghum bicolor) are the major crops grown. Pulses crops, such as, beans (Pismo) and pea (Sot rum) are grown to a lesser extent in the area. There are a number of rivers flows at the rainy season, from those not all are being used for irrigated agriculture, particularly the one being used for irrigation is Furfuro River, and it is functional for horticultural crops production. Especially, the area is known for its quality teff production nationally. Crop production is mainly rain fed. Agriculture has expanded towards steeper slopes, which are cultivated for their marginal outputs or yields. This has speedup soil erosion and vegetation degradation in the area. A survey of the land in this *woreda* shows that 60%, is arable or cultivable, 7.3% grazing land, 7.6% degraded land, 9.2% natural and plantation forests covered, 8.6% villages and cash crops 7.3%. The farmers also keep cattle, equine, but small numbers of sheep and few farmers keep goats. Hillside areas are used as communal grazing land (HWoRD, 2012).

3.1.8. Key Informant interviews and Focus Group Discussion

To obtain the primary data, focus group discussions and key informant interviews, were carried out. Key informants including *Kebele* administrations, development agents, religious leaders, community based organizations office bearers, and area exclosure association leaders. Focus group discussion was conducted with elders, women, youth groups, sector office experts, religious leaders and associations directly involved with the area exclosures.

Figure 2 Partial view of focus group discussion with the exclosure at back ground

3.2. Methods of Data Collection

To achieve the intended objectives both survey and laboratory analyses were conducted.

3.2.1. Field sampling technique

A field survey was carried out by using stratified systematic sampling techniques from area exclosed before eight year and adjacent degraded lands. Data was collected to determine forest community attributes (species richness, diversity, and regeneration) and soil fertility status in with exclosure and without. The line transect method (Bullock, 1996) was used for inventory of vegetation. In each block line transects were determined using a Suunto compass. Plots, measuring 20mx20m (400m^2), nested plots of 10mx10m (100m^2), 2mx2m (4m^2), were laid along the transects lines which is approximately at 100m intervals a total of 18 plots were sampled from each sites and from each plots. Within each four sided sample plot, the number of individual seedlings, saplings, coppicing and trees of different species was directly counted. In each plot, all woody plant species categories were identified, counted and recorded by their local and /or scientific names using a field guide of Azene *et al*., (2007). In each major plot, altitude and geographical positions in degrees were taken using GPS (Global Positioning System).

3.2.2. Woody plant species diversity determination

The diversity of woody species was determined using the Shannon-wiener diversity index H' and evenness or equitability index (E) (Barnes *et al*., 1998; Krebs, 1999). The similarity in species composition between the exclosure and adjacent degraded was computed by using Jaccard's Similarity Coefficient (Sj) (Krebs, 1999). The density and percentage frequency of woody species was calculated using (Philip, 1994).

Alpha and beta diversity indices were calculated using Shannon diversity index accounts for both species diversity and evenness present in a community. Shannon diversity index: accounts for both species diversity and evenness present in a community.

$$H' = -\sum_{i=1}^{S} pi \ln pi \qquad \text{(Shannon, 1949)}$$

Where: H'= diversity index; ln= natural logarithm; Pi=n/N; and n=number of individuals of a given species; N = total number of individuals of all species.

H' is taking in to account the number of individuals as well as the number of species. Shannon diversity varies from 0 for a community with only a single species to a high value for a community with many species, each with few individuals. For biological communities H' does not exceed 5.0 (Krebs, 1999). H' is high when it is above 3.0, medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, very low when it is smaller than 1.0 (Cavalcanti and Larrazabal, 2004).

Evenness (Equitability): $J = \frac{H}{HMax} = -\sum pi \ln\left(\frac{pi}{\ln s}\right)$

Where:

ln= natural logarithm and s = the number of species.

Species evenness; as a measure of species diversity which is the relative abundance in which each species is represented in an area.

3.2.3. Woody plant species density and regeneration status

The quantitative structure analysis was made using data from density, abundance and frequency distribution of each species in the study site. Population structure was analyzed using table, figure, and woody density per hectare and abundance was constructed in frequency table.

a. Species density: was determined by counting the number of individuals in the sample plots and converting the count into hectare basis

Density of all species= $\frac{Total\ number\ of\ individuals\ of\ all\ species}{Sample\ size\ in\ hectare}$

Density of a species= $\frac{Total\ Number\ of\ individuals\ of\ a\ species}{Sample\ size\ in\ hectare}$

b. Species frequency= $\frac{Number\ of\ sample\ plots\ in\ which\ a\ tree\ species\ occured}{Total\ sample\ plots\ surveyed} * 100$

Coefficient of Jaccard (Sj): The Sj gives the percentage of similarity of woody species between two communities interims of species composition. In this study coefficient of Jaccard, which is one of the most commonly used binary similarity coefficient was employed (Krebs, 1999).

$$Sj = \left(\frac{c}{a+b-c}\right) * 100$$

Where: a = total number of species in exclosure site; b = total number of species in adjacent degraded site; and c = the number of species common in the exclosure and in the adjacent degraded site.

The range of all similarity coefficients for binary data is supposed to be from 0 (no similarity) to 1 (Complete similarity).

3.4. Soil Sampling and Analysis

3.4.1. Soil sampling

Surface soil (0-30cm depth) samples were collected by using auger from each of the five subplots and mixed to make a composite and representative sample for each plot independently. In both sites (exclosure and adjacent degraded) six transect lines were laid at a distance of 100m between them. On each transect line three sampling plots were laid at a distance of 100m from each point and a total of 18 plots were obtained from each of the exclosure and adjacent degraded land, a total of 36 plots were used for this study. In addition, undisturbed soil samples were taken from each plot by core sampler to determine soil bulk density and soil moisture content.

Samples collected from exclosure and degraded site were separately handled in plastic bags to determine soil texture, content, pH, electric conductivity (EC), organic carbon (SOC), total nitrogen (TN), available phosphorus (Av.P), exchangeable cations (potassium K^+, calcium Ca^+, magnesium Mg^{2+} and sodium Na^+) and cation exchange capacity (CEC).

3.4.2. Laboratory analysis of soil samples

Soil parameters were analyzed at the National Soil Laboratory of Ethiopia, using standard procedures. Physical degradation was assessed using texture, moisture content and bulk density. Soil texture was analyzed using Hydrometer method (Day, 1965) after destroying organic matter and dispersing the soil. Soil moisture was determined by Gravimetric Method collect.

$$Percent\ of\ moisture\,(wt\,\%) = \frac{(A-B)x100}{B-C}$$

Where A=air dry + tin weight, B=weight of oven dry soil in gram + tin weight and C=weight of the empty tin

Bulk density of undisturbed soil sample was determined by core method (Blake, 1965) using core sampler and determining the mass of solids and the water content of the core, by weighing the wet core, drying it to constant weight in an oven at 105°C for 24 hours and calculated as:

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

Where W2 and W1 are weights of moist and oven dry soils, respectively and V is the volume of the cylindrical core.

Soil pHs were measured by using a pH meter in a 1:2.5 soil: water ratios, (Peach, 1965), Electrical conductivity (EC) was measured in soil to water ratio of 1:2.5 and soil organic carbon by the Walkley-Black oxidation method with potassium dichromate (K_2Cr_2O7) in a sulfuric acid medium (Allison, 1965), total nitrogen by semi-micro Kjeldahl, and phosphorus by sodium bicarbonate (NaHCO3) extraction (Olsen) procedures. Exchangeable potassium and sodium extracted by sodium acetate method and measured by flame photometer, exchangeable calcium and magnesium by ammonium acetate extraction and measured by the atomic absorption spectrometry (AAS) method (Page *et al.,* 1982) and cation exchange capacity by ammonium acetate (1 N NH4OAc) extraction.

3.5. Data Analyses

Independent t-test was used in order to assess the significances in soil parameters between soils at exclosure and adjacent degraded sites using the Statistical Analysis System (SAS, 2006). Correlation analysis was also performed in order to analyze the relationship between the selected soil parameters. Relative change in soil properties was computed as:

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

Where P_e is the soil property measured on the exclosure site and P_d is the soil property measured on the adjacent degraded site.

4. RESULT AND DISCUSSION

4.1. Species Composition

A total of 16 different woody species representing 12 plant families and 12 genera were recorded in the eight years exclosure and adjacent degraded sites (Appendix 3). Among these, 6 woody plant species (in 2 families) were recorded in the exclosure and adjacent degraded sites. From all woody plants species recorded the remaining eleven species are not planted and it may regenerated from soil seed bank and the contribution of mammals and birds which spread from another area. From all woody plants species recorded in the exclosure site, 88% were seedlings, 9% sapling and 3% tree/shrub.

In the exclosure site, family *Fabaceae* and *Leguminosae* was the most diverse family in species number comprised both of them are three species families this means with the total of six species families (40%) while the remaining nine families comprised one species per family. This means with the total of nine species families (60%) (Appendices 3).

Jaccaranda mimosifolia, Phonex reclinata and *Syzygium guineense* which contributed one individual out of the 36 sample plots in the exclosure site had no much influence on the richness of exclosure site as *Acacia saligna* which account 345 individuals of the same number of plots (Appendices 1).

The difference in the woody plant species compositions in the study areas might have resulted from the effects of management that assisted the biological and soil factors to create conducive environment to sustain those species with fast colonizing ability. On the contrary, the degraded site consists of fewer woody plant species compositions that could resist the disturbed environment. Similar studies in other parts of the country and abroad showed that following disturbed land, woody plant species composition increased in the protected areas as compared to degraded site (Dereje *et al.,* 2003; Oba *et al.,* 2000).

4.1.1. Woody vegetation diversity

Shannon diversity index result revealed that, the woody plant species diversity in area exclosure and adjacent degraded land were 1.41 and 1.1, respectively. Similarly, species evenness in area exclosure and degraded site were 2.41 and 1.84, respectively; whereas species richness (total number of individual of a species in a community) in area exclosure and degraded land were 15 and 6, respectively.

Table 3: Comparison of diversity indices of woody plant species in the exclosure and in the degraded site

Diversity Indices	Exclosure site	Degraded site
Shannon Diversity Index (H')	1.41	1.1
Evenness(J)	2.41	1.84
Species richness(S)	15	6
Coefficient of Jaccard (Sj)	31	

The diversity indices, Shannon and Alpha diversity index for woody plant species are higher in the exclosure (1.41 and 15) than in the adjacent degraded site (1.1 and 6), respectively. A higher number of diversity indices (Shannon indices) indicate that there is better species diversity in the exclosure than in the degraded (Table 3). The Shannon index of diversity value higher in the exclosure site, which indicates the exclosure, is more diverse in species than the degraded. According to Cavalcanti and Larrazabal (2004) woody plant species diversity for Shannon index in both area exclosure and adjacent degraded land is low (H' ranges from 1 to 2). The similarity index indicates there is similarly between the two sites. The Coefficient of Jaccard (Sj) explains that the sites are similarly about 31%.

High species abundance was observed in exclosed area than the adjacent degraded lands. This is due to presence many woody plant species in exclosed area than the degraded area. This result agreed with the findings of (Lecointre and Guyader 2001; Harrison *et al*., 2004), they reported that an ecosystem where some species are represented by many individuals, and other species are represented by very few individuals has high and low species evenness, respectively. Species evenness in the exclosure (2.41) is higher than in the degraded site

(1.84). The result indicated that the protection of the site from human and livestock disturbances helped each species to have better abundance of its individuals unlike the degraded site (Table 3). Conversely, degraded site where many individuals represent some species, and very few individuals represent other more species has low species evenness. As evenness compares the similarity of the population size of each of the species present that means it is a measure of the relative abundance of the different species making up the richness of an area. A low value of evenness indicates that the one or a few species are highly dominant, while others are present with few individuals (Wolde *et al*., 2007).

A community with many equally distributed species is considered high in species diversity, usually indicates a complex community because the greater variety of species allows more species interactions in the given community. Since species richness (S), equitability (J) and diversity (H) are positively correlated (Krebs, 1999), still the exclosure has better uniformity of species distribution throughout the site than in the degraded site.

4.1.2. Density and frequency

The density (number of individuals per ha) and frequency (the percentage of the quadrants in which a species was found) of the woody species recorded in the study quadrants varied considerably among species. The density of number of woody plant species in exclosure and degraded sites were 788 and 210 individuals ha^{-1} respectively. In the exclosure, *Acacia saligna* is the densest species with 479 individuals ha^{-1}, followed by *Euclea schimperi* (101 individuals ha^{-1}), *Carissa spinarum* (64 individuals ha^{-1}), *Acacia seyal* (61 individuals ha^{-1}), *Dodonaea angustifolia* and *Sesbania sesban* both with 22 individuals ha^{-1}, *Acacia lahai* and *Ficus sycomorus* (11 individuals ha^{-1}) and the remaining seven species *Croton macrostachyus*, *Acacia abysinica, Olea europaea, Rosa abysinica*, *Jaccaranda mimosifolia*, *Phonex reclinata* and *Syzygium guineense* each were fewer than (5 individuals ha^{-1}). On the other hand, in the degraded site *Euclea schimperi* is the most dominant woody species with 119 individuals ha^{-1}, followed by *Carissa spinarum* (36 individuals ha^{-1}), *Dodonaea angustifolia* (33 individuals ha^{-1}), *Rosa abysinica* (17 individuals ha^{-1}), and the remaining two species from the total of six fewer than (5 individuals ha^{-1}).

Most frequent woody plant species in the study plots was *Acacia saligna*, its frequency was 60% and *Euclea schimperi* 56.5% in the exclosure and degraded site, respectively. The second highly distributed species in exclosure site was *Euclea schimperi* (13 %), followed by *Acacia seyal* and *Carissa spinarum* (8%) and the remaining each less than 5%. On the other hand, in the degraded site second highly distributed species was *Carissa spinarum* (17.3%), followed by *Dodonaea angustifolia* (15.5%), *Rosa abysinica* (8%) and the remaining two species were distributed are less than 5% (Table, 4).

Table 4: List of woody plant species recorded in the exclosure and in the degraded site with their densities and frequencies

Plant nomenclature	Family name	Exclosure site		Degraded site	
		Density/ha	Frequency (%)	Density/ha	Frequency (%)
Acacia abysinica	*Leguminosae*	3	0.4	_	_
Acacia decurrens	*Fabaceae*	_	_	4	2
Acacia lahai	*Leguminosae*	11	1.4	_	_
Acacia saligna	*Fabaceae*	479	60	_	_
Acacia seyal	*Leguminosae*	61	8	1.4	0.7
Carissa spinarum	*Apocynaceae*	64	8	36	17.3
Croton macrostachyus	*Euphorbiaceae*	4	0.5	_	_
Dodonaea angustifolia	*Sapindaceae*	22	3	33	15.5
Euclea schimperi	*Ebenaceae*	101	13	119	56.5
Ficus sycomorus	*Moraceae*	11	1.4	_	_
Jacaranda mimosifolia	*Bignoniaceae*	1.4	0.17	_	_
Olea europaea	*Oleaceae*	3	0.4	_	_
Phoenix reclinata	*Arecaceae*	1.4	0.17	_	_
Rosa abysinica	*Rosaceae*	3	0.4	17	8
Sesbania sesban	*Fabaceae*	22	3	_	_
Syzygium guineense	*Myrtaceae*	1.4	0.17	_	_
Total		788	100	210	100

Plant nomenclature follows: Edwards *et al*., (2000; Hedberg *et al*., (2006; and Azene *et al*., (2007)

Density/ha= the number of individuals/hectare
Frequency= the proportion of individuals occurred in sample plots (%); "-"= absent in the sample plot

The number of woody plant species and families identical in both (exclosure and degraded) sites were 5 and 6 respectively. A total of 10 species and 6 families were recorded in the exclosure. However, a species *Acacia decurrens* were recorded in the degraded site but not in the exclosure. A total of 720 number of plant species belonging to 12 genera 12 families were identified from the both exclosure and adjacent degraded sites. Total of 12 families, all were recorded in the exclosure whereas, six families were absent in the degraded site which is present in the exclosure site, namely; *Arecaceae, Bignoniaceae,* , *Euphorbiaceae, Oleaceae, Moraceae,* and *Myrtaceae* (Table 4).

4.1.3. Vegetation community structure

Of the total density of woody plant species in seedling (502) individuals, sapling (48) individuals and tree/shrubs (18) individuals in the exclosure site, the proportion were 88%, 9%, and 3%, respectively, there is no stamp or coppicing at the exclosure sites. On the other hand, out of the total density of (152) individuals in the degraded site, the proportions of coppicing were 100%, there is no any woody plant species in the other stage (Table 5). In the exclosed sites, the proportions of individuals at seedling stage exhibited highest number of woody plant species compared to degraded site. This implies there are potentials of regenerations of woody species in the exclosure site than the degraded site. There is protection of the site from different disturbances; proportions of individuals at seedling and sapling stage in the exclosure site were higher than the degraded site. The proportions of tree individuals were few in number in the exclosure site, but still better than degraded site where there is no tree individuals recorded in degraded site (Table 5). There is no regeneration in the degraded site, the development of seedlings, saplings, trees were absent in the degraded site than in exclosure (Table 5). Density and abundance of woody plant species were higher in the exclosure and very less in the degraded site, because it is found at the stamp or coppicing stage (Table 5). The difference observed in seedling, sapling and tree size stages at exclosure site showed the positive effect of area exclosure on woody plant species restoration and protecting human and animal interference.

Table 5: Density of seedlings, saplings, stamp and trees all plot in the exclosure and degraded sites in the all plots

	Exclosure site				Degraded site			
Species name	Seedling	Sapling	Coppicing	Tree/shrub	Seedling	Sapling	Coppicing	Tree/shrub
1. *Acacia abysinica*	2	0	_	0	_	_	0	_
2. *Acacia decurrens*	0	0	_	0	_	_	3	_
3. *Acacia lahai*	8	0	_	0	_	_	0	_
4. *Acacia saligna*	293	38	_	14	_	_	0	_
5. *Acacia seyal*	42	2	_	0	_	_	1	_
6. *Carissa spinarum*	45	1	_	0	_	_	26	_
7. *Croton macrostachyus*	3	0	_	0	_	_	0	_
8. *Dodonaea angustifolia*	9	5	_	2	_	_	24	_
9. *Euclea schimperi*	69	2	_	2	_	_	86	_
10. *Ficus sycomorus*	8	0	_	0	_	_	_	_
11. *Jacaranda mimosifolia*	1	0	_	0	_	_	0	_
12. *Olea europaea*	2	0	_	0	_	_	0	_
13. *Phoenix reclinata*	1	0	_	0	_	_	0	_
14. *Rosa abysinica*	1	0	_	0	_	_	0	_
15. *Sesbania sesban*	16	0	_	0	_	_	0	_
16. *Syzygium guineense*	1	0	_	0	_	_	0	_
Total	502	48	_	18	_	_	152	_

- = refers no species

The absence of seedling, sapling and tree individuals in the degraded site was indication of increased vulnerability or susceptibility of seedlings damage by animal and/or human at their early stage. Those individuals in the degraded site are either cut at their early age for various purposes by the local inhabitants and/or their domestic animals and/or unable to resist water shortage during dry season and/or frost and/or sun scorch due to each of shade from mother trees.

Most woody species from the *Fabaceae* family are commonly preferred as fuel wood sources because of their high calorific values, and also used as sources of fodder for cattle and other domestic animals especially during dry seasons (Kindeya 2004).

The higher density of some woody plant species like *Acacia saligna*, *Euclea schimperi*, *Carissa spinarum, Acacia seyal, Dodonaea angustifolia,* and *Sesbania sesban* in the exclosure site indicate effects of protection against fuel-wood collection, farm implement cutting, free grazing and other disturbances. In the degraded sites, those species were not found at the seedling sapling and tree/shrub stage. Even those that are coppicing or stamp are very scattered in number and they are still under disturbance. From the degraded site, *Dodonaea angustifolia, Carissa spinarum, Euclea schimperi* and *Rosa abysinica* are stamp dominated species (Table 5).

Vegetation community structure

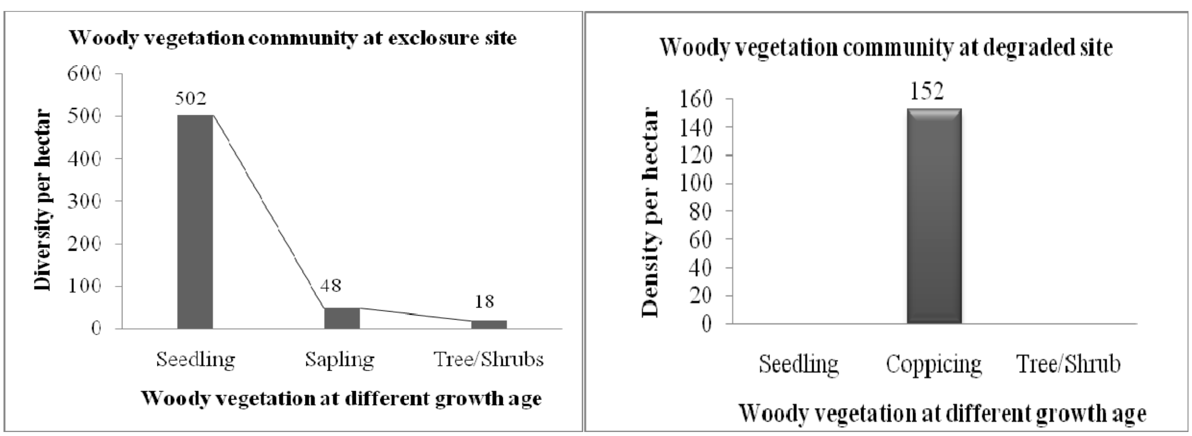

Figure 3: Vegetation community structure of woody plant species (seedling, sapling, coppicing and tree) in the exclosure and in the adjacent land

Structure and composition differences of the two sites emerge from human and/or livestock disturbances (in the degraded sites) and absences (in the exclosure). The results showed that protecting of degraded site from human and animal disturbances promotes woody plant species regenerations and productivity (Figure 3).

4.2. Effects of Exclosure on Soil Physico Chemical Properties

4.2.1. Effects of exclosure on soil physical properties

4.2.1.1. Soil bulk density, moisture content and Soil Texture

Soil bulk density was one of the major parameters used in this study to assess the fertility status of soil in terms of physical property. The mean values of the soil bulk density (Figure, 4) under exclosed and degraded site were 1.20 and 1.57 respectivily. As compared to adjacent degraded site, bulk density at exclosure site was reduced by 23.4%. However, it was not significantly ($P>0.05$) affected by exclosure (Table 6). The smaller bulk density at exclosure site was due to high amount of organic matter source from restored woody plant species. The correlation matrix (Table, 10) also showed a negative and but significant relationship between bulk density and organic carbon ($r= -0.31^{*}$). Moreover, the high amount of bulk density at degraded site may be because of trampling effect of livestock during grazing. This result agrees with earlier findings of Descheemaeker *et al*., (2005) who reported that exclosure prevented physical soil loss.

Table 6: Relative change and statistic test for soil physical parameters

Soil parameter	T-statistics	P-value	Relative change (%)
Bulk density (g/cm3)	6.9	ns	-23.4
Sand (%)	-0.55	ns	-4.1
Silt (%)	2.6	*	28.6
Clay (%)	2.18	*	18.7
Textural class (clay loam)			
Moisture content (%)	2.69	*	34.1

*** = very highly significant $P<0.001$; **= highly significant at $P<0.01$; * = significant at $P<0.05$; ns = not significant at $P>0.05$

The mean value of the soil moisture content under exclosed and degraded site were 18.5 and 13.8 respectivily (Figure, 4). It was increased at exclosure site by 34.1%. There was significant ($P<0.05$) difference in moisture content between soil at exclosure and adjacent degraded site (Table 6). Higher moisture percentage in exclosure site could be attributed to the higher organic matter accumulation. Besides, the higher clay percentage (Figure, 4) of the soil in the exclosure might have contributed to the higher moisture retention of the soil in the exclosure site than in the adjacent degraded site. The increase in relative change in moisture content with regard to large clay content and organic carbon at the exclosure site could be because of the presence of woody plant residues and biomass. The amount of moisture content (Table 8) also showed that a positive and significantly correlated with clay content ($r=0.31^{*}$) and organic carbon content ($r=0.22^{*}$). The presence of forest conservation for the different purpose may affect soil physical properties such as soil water retention and aggregate stability, leading to enhanced crop water availability (Brady and Weil, 2002). Nichols *et al.,* (2004) reported that aggregation is important for increasing stability against erosion, for maintaining porosity and soil water movement, and for improving fertility.

Based on the percentages of clay, silt and sand compositions, the textural classes of the soils of the two sites belongs to clay loam. The mean values of the soil texture: sand, silt and clay under exclosed and degraded site were 35.3 and 36.8, 25.2 and 19.6, and 45.1 and 38 respectivily (Figure, 3). The clay and silt fraction of the soils were significantly ($P<0.05$) affected by exclosure while there was no significant ($P>0.05$) difference in sand content (Table 6). As compared to the adjacent degraded lands, sand content was reduced at exclosure site by 4.1%, but the clay and silt fraction was increased by 18.7 and 28.6% respectivily. The higher clay content in the exclosure means that there could be relatively low soil erosion in the site, while the lower clay in the degraded means there is relatively higher soil erosion (particularly sheet erosion) at the degraded site, which may reflect the low organic matter, the trampling effect of livestock and the sparse vegetation aggravate soil erosion which selectively removes clay from the adjacent degraded land. Gachene and Kimaru (2003) reported that clay particles are lighter than sand particles, and once detached by erosion they are easily transported.

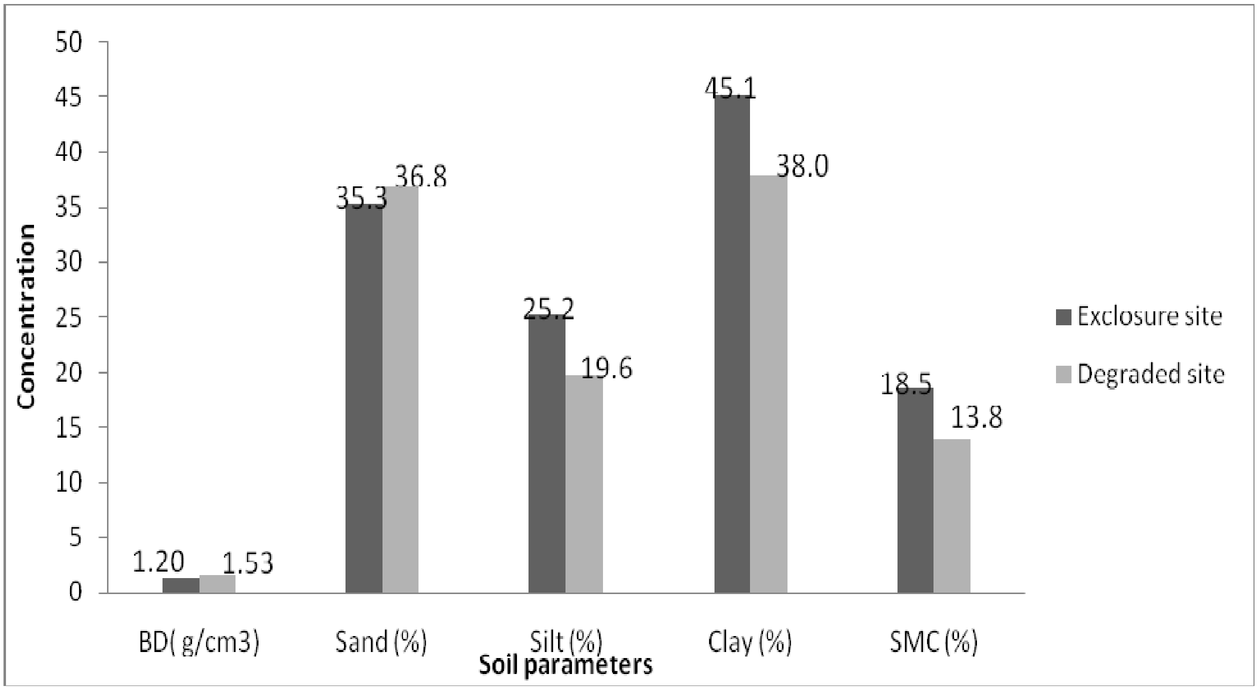

Figure 4: mean values of bulk density (Bd), sand, silt, clay and soil moisture content at degraded and exclosure site

4.2.2. Effects of exclosure on chemical properties of the soil

4.2.2.1. Soil pH and electrical conductivity (EC)

Soil pH was reduced at exclosure site by 2.2%. However, there was no significant (P>0.05) difference in soil pH between exclosure and adjacent degraded sites (Table 7). This is probably attributed to similarity in climatic conditions, especially rainfall. Rainfall is the most determinant factor for pH in soils. The present study indicated that, the mean values of soil pH under exclosed and degraded sites were 7.13 and 7.29 respectively (Figure 5). Based on the classification by Pandey (2000), soil pH in both sites was grouped in the neutral pH range. The low pH value of soil in the exclosure site could be due to the accumulation and decomposition of leaf litter which release organic acids. The mean value of the electrical conductivity (Figure 5) under exclosed sites and degraded sites were 0.156 and 0.159 respectivily. It was reduced at exclosure site by 1.9%. There was no significant (P>0.05) difference in EC between exclosure and adjacent degraded site (Table 7). The lower values of EC at exclosure site could be because of the absence of salinity or/sodacity and the study site is located in high rainfall area. The correlation matrix (Table 8) also showed positive and significant relationship between pH and EC ($r=0.83^{*}$). In line with this, Noellemeyer *et al.* (2006) reported no significant difference in electrical conductivity at exclosure site.

Table 7: Relative change and statistical test for soil chemical parameters

Soil parameter	T-statistics	P-value	Relative change (%)
pH H_2O (1:2.5)	0.97	ns	-2.2
Electrical conductivity (EC)	-0.35	ns	-1.9
Soil organic carbon (%)	3.85	***	37.3
Total N (%)	2.87	***	35.7
Available P (ppm)	7.58	***	34.7
Exchangeable Na^{+} (Meq/100gm)	12.52	***	78.9
Exchangeable K^{+} (Meq/100gm)	10.44	***	69.4
Exchangeable Ca^{+} (Meq/100gm)	3.72	***	43.7
Exchangeable Mg^{2+} (Meq/100gm)	12.89	***	151.3
Soil CECs (Meq/100gm)	11.65	*	19.8

*** = very highly significant at P<0.001; **= highly significant at P<0.01; * = significant at P<0.05; ns = not significant at P>0.05

4.2.2.2. Organic carbon, total nitrogen and available phosphorus

This study indicated that, the mean values of soil organic carbon, total nitrogen and available phosphorus of the soil under exclosed sites and degraded sites were 2.21 and 1.61, 0.19 and 0.14 and, 7.92 and 5.88 respectively (Figure 5). Soil organic carbon, total nitrogen and available phosphorus were significantly ($P<0.05$) higher at exclosure site than adjacent soil. Similarly, Katrien *et al.* (2007) also found that total nitrogen was significantly increased when an area has been closed for 20 years, compare to degraded or recently closed area in north Ethiopia, Tigray. As compared to adjacent soils, organic carbon, total nitrogen and available phosphorous were increased at exclosure site by 37.3, 35.7 and 34.7%, respectively (Table 7). The total N and available P restoration were influenced by exclosure. The relatively large increase in the total soil N and available P storage in the exclosure site may have resulted from the management, establishment and subsequent of increased organic matter input derived from herbaceous species biomass and from reduced soil erosion through effective ground cover. The correlation matrix (Table 8) also showed that organic carbon was directly and significantly associated with total nitrogen (r=0.99*) and available P (r=0.44*). Besides, there was a synergetic and significant association between on total nitrogen and available P (r=0.47*). This is in harmony with the findings of Bot, Bentites (2005) who reported area exclosure increased the accumulation of soil organic matter, and the presence of this organic matter affected both the chemical and physical properties of the soil and overall health. Furthermore, the increase in canopy cover with the increase in exclosure duration could decrease sediment-associated soil nutrient losses by reducing the erosive impact of raindrops and soil erosion (Tsetargachew, 2008; Girmay *et al.,* 2009; Mekuria *et al.,* 2009).

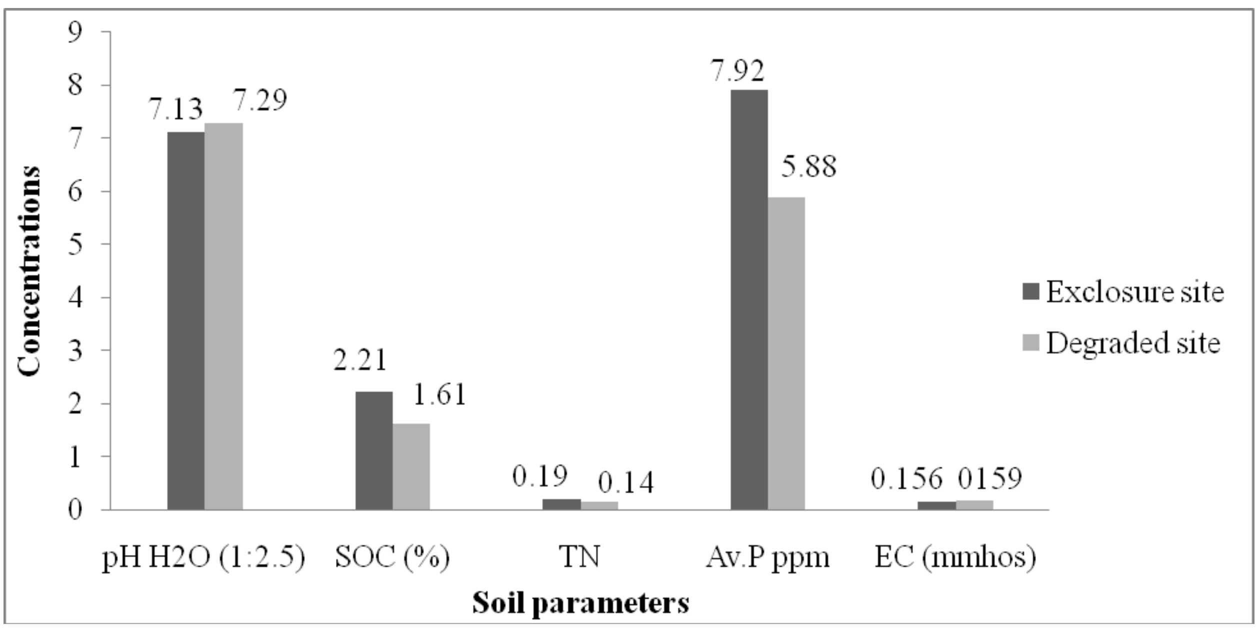

Figure 5: Mean values of pH, SOC, TN, Av.P, C/N and EC at exclosure and degraded sites

Table 8: Person correlation matrix for the selected soil properties

	MC	BD	Sand	Silt	Clay	K^{+}	Na^{+}	Ca^{+}	Mg^{2+}	Av.P	TN	CEC	EC	pH	OC
MC	1.00^{*}														
BD	0.23^{*}	1.00^{*}													
Sand	-0.22^{*}	0.05^{n}	1.00^{*}												
Silt	-0.17^{n}	0.37^{*}	0.02^{n}	1.00^{*}											
Clay	0.31^{*}	-0.24^{*}	-0.60^{*}	-0.66^{*}	1.00^{*}										
K^{+}	0.36^{*}	-0.46^{*}	-0.16^{n}	-0.26^{*}	0.22^{*}	1.00^{*}									
Na^{+}	0.49^{*}	-0.60^{*}	-0.30^{*}	-0.38^{*}	0.35^{*}	0.72^{*}	1.00^{*}								
Ca^{+}	0.38^{*}	-0.43^{*}	-0.17^{n}	-0.29^{*}	0.74^{*}	0.83^{*}	0.46^{*}	1.00^{*}							
$Mg2^{+}$	0.47^{*}	-0.44^{*}	-0.38^{*}	-0.35^{*}	0.58^{*}	0.76^{*}	0.80^{*}	0.83^{*}	1.00^{*}						
Av.P	0.30^{*}	-0.47^{*}	0.00	-0.21^{*}	0.17^{*}	0.94^{*}	0.65^{*}	0.35^{*}	0.70^{*}	1.00^{*}					
TN	0.12^{n}	-0.30^{*}	-0.17^{n}	-0.23^{*}	0.32^{*}	0.44^{*}	0.29^{*}	0.60^{*}	0.66^{*}	0.47^{*}	1.00^{*}				
CEC	0.18^{n}	-0.16^{n}	-0.71^{*}	-0.06^{n}	0.60^{*}	-0.05^{n}	-0.16^{n}	-0.06^{n}	-0.03^{n}	0.39^{*}	0.34_{*}	1.00^{*}			
EC	-0.24^{*}	0.01^{n}	0.07^{n}	0.23^{*}	-0.07^{n}	-0.31^{*}	0.93^{*}	-0.16^{n}	-0.13^{n}	-0.19^{n}	-0.56^{*}	-0.14_{n}	1.00^{*}		
pH	-0.33^{*}	-0.04^{n}	0.17^{n}	-0.30^{*}	-0.35^{*}	-0.01^{n}	0.31^{*}	-0.30^{*}	0.37^{*}	-0.04^{n}	-0.41^{*}	-0.05^{n}	0.83^{*}	1.00^{*}	
OC	0.22^{*}	-0.31^{*}	-0.16^{n}	-0.30^{*}	0.37^{*}	0.42^{*}	0.21^{*}	0.05^{n}	0.66^{*}	0.44^{*}	0.99^{*}	0.36^{*}	-0.57^{*}	-0.40^{*}	1.00^{*}

*-refers for significant, n- for no significant, MC=Moisture Content, BD=Bulk Density, K^{+}=Potassium, Na^{+}=Sodium, Ca^{+}=Calcium, Mg^{2+}=Magnesium, Av.P=Available Phosphorous, TN=Total Nitrogen, CEC=Cation Exchange Capacity, EC=Electrical Conductivity, pH=Potential for Hydrogen, OC=Organic Carbon

4.2.2.3. Effect of exclosure on CEC and exchangeable bases

The mean values of the cation exchange capacity (CEC), Na^{+}, K^{+}, Ca^{+} and Mg^{2+} under exclosed and degraded sites were 29.7 and 24.8, 0.34 and 0.19, 1.22 and 0.72, 28.6 and 19.9 and, 6.66 and 2.65 respectivily (Figure 6). Cation exchange capacity was significantly ($P<0.05$) affected by exclosure (Table 7). As compared to adjacent degraded sites, the higher value of CEC was observed at exclosure site and it was increased by 19.8%. This could be attributed to the higher soil organic matter and clay percentage of the soil in the exclosure site. Besides, CEC of the soil was positively and significantly correlated with clay ($r=0.60^{*}$) and organic carbon ($r=0.36$) (Table, 8). In line with this Wild (1993) and Max *et al.* (1996 cited in Kibret (2008) reported that soil CEC is associated with clay and organic matter colloids, and especially organic matter renders soils a better CEC. Thus, slight difference in CEC can make a big difference in soil organic matter as observed in this study. Similarly, Kibret (2008); Abiy (2008) also reported a higher mean value of CEC in exclosure than in adjacent degraded site.

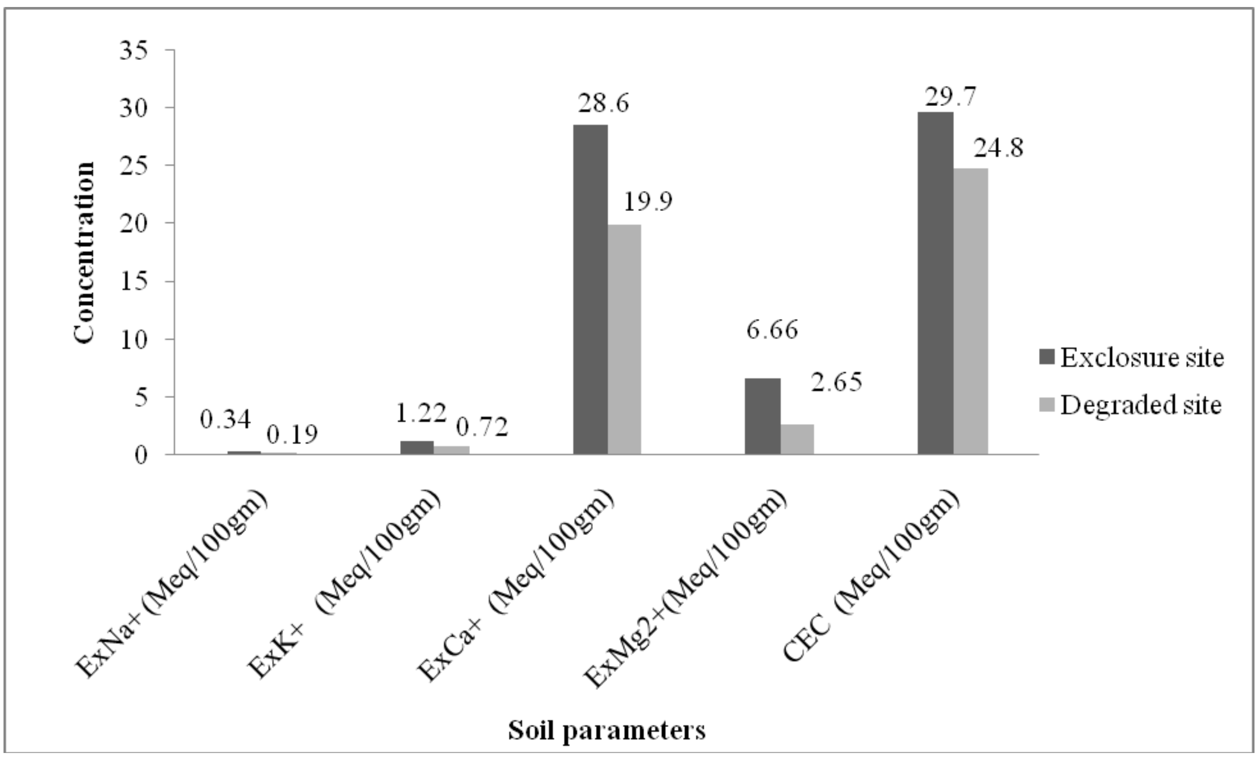

Figure 6: Mean value of cation exchange capacity (CEC), exchangeable (Na+, K+, Ca+ and Mg2+ at exclosure and degraded site

The exchangeable bases also showed a significant ($P<0.05$) difference between the soils at exclosure site and adjacent degraded lands (Table 7). As compared to adjacent degraded land, exchangeable Na^{+}, K^{+}, Ca^{+} and Mg^{+2} showed increase at exclosure site by 78.9, 69.4, 43.7 and 151.3%, respectively (Table 7). The highest relative change was observed in magnesium while the least relative change was observed in calcium. The higher values of exchangeable bases at exclosure site are quite logical. The increase in basic cations at exclosure site was due to the accumulation of woody biomass. Higher values of exchangeable cations could be attributed to the nutrient cycling role of increased biomass in the exclosure site (Bot and Benites, 2005), as well as improved organic matter content (Hodges and Plank, 1988). In fact, the two colloidal substances (clay and OM) are essentially the cations' warehouse or reservoir of the soil and are very important because they improve the nutrient and water holding capacity of the soil (Sachs, 1999). This finding is in agreement with work done elsewhere (Kibret, 2008; Ediyo, 2005) cited in Abiy, 2008).

4.3. The contribution of area exclosures to livelihood through income generation

Most rural household surveys, in Ethiopia only capture conventional rural activities, such as crop production and livestock rearing, and rarely incorporate incomes from environmental resources. The goods and services provided by environmental resources, such as forest environmental products, are often omitted. Either this is because forests or grasslands tend to be communally owned or, if privately owned, not expressing factored in as livelihood sources. As a result, there is a substantial gap in our understanding of the actual socioeconomic contribution of environmental resources, the functioning of rural economies and the extent of rural poverty and inequality (Bedru *et al*, 2010).

In the study area as indicated by key informant and focus group discussion in extracting non-timber products from area exclosure products like grass, firewood and medicinal plants and they are earning incomes from sale of these products, which supports their livelihoods. This is also true aboard and in other areas of the country as verified by other researchers, which indicated that incomes from environmental sources play an important role in rural livelihoods in developing countries. Particularly, products from forest environmental sources contribute significantly to rural households' economic wellbeing (Mulugeta, 2004; Wolde *et al,* 2007 and Fisher, 2004).

4.3.1. Access and benefits to area exclosures products and services

Focus group discussions and key informants interview revealed that the households in the study area have access rights to the exclosure area generally. Those 150 household members of area exclosure association particularly have full involvement. Community members are allowed to harvest some forest products from the exclosures (Table 9). The main forest products that communities are allowed to harvest are grass, medicinal plants and dead branches/ trees via regulated access scheme.

Table 9: Access of the exclosure for local community

Resources/benefits	Can get access	Cannot get access
Forage	✓	
Fuel wood	✓	
Medicinal plant access	✓	
Recreational access	✓	
Tree cutting		x
Site of demonstration for model farmers	✓	
Site for tour for higher education	✓	

✓ =Can get access, x= Cannot get access

Livestock are not allowed to graze after periodic harvesting of grass. Harvesting dead branches and trees for domestic energy is also conducted by the nearest dwellers around the exclosure even though it is illegal. It was visited as a recreational area with some government institutions and as demonstration site for development agents and farmers of the surrounding zones and *weredas*. In addition, the FGD and key informants indicated environmental benefits of area exclosure such as microclimatic regulation, preventing soil and water loss, regeneration of vegetation, wild life were appearing from migration and restoration of springs were the most common ones. Area exclosure is the most crucial one because it is specially the determinant way of rehabilitating severely exploited vegetation and degraded dry land environment. It is generally believed that the land resources such as soil, wild flora and fauna or water will be protected from degradation through area exclosure (Ediyo 2005 cited in Abiy, 2008).

However, at the degraded site all these benefits and services were unavailable because of the currently unproductive nature of soil, lack of protection from livestock and human interference.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

The results of the study showed that natural resources management strategies like area exclosures have shown quite higher improvement in woody species diversity and soil fertility at *Mitija*. The different floristic composition and species diversity observed in the exclosures and the income generated from exclosures enable to conclude that the establishment of area exclosures in the degraded lands is a viable option for biodiversity conservation and local livelihood contribution.

The comparison made between area exclosure and adjacent degraded site showed that composition, density, richness, diversity of woody species and structure difference were improved in the exclosure. Soil qualities (fertility) like soil chemical and physical property were significantly higher in the exclosure just within eight years except, those bulk density, electric conductivity and pH. This shows that the vast degraded areas in the study area can quickly and cheaply be restored if the degrading agents such as human and animal disturbances are managed.

Although there is recorded data on original floristic composition of the degraded site, but all are under the stamp/coppicing stage. Therefore, this study provides evidence that the degraded site has resilience to maintain woody plant species of diversified floristic composition and could use as conservation sites if they are protected well and managed in a sustainable way. Environmental rehabilitation and restoration through area exclosure enables the community to diversify their source of income. The revenue from the products (thatch, firewood, medicinal plants) and reduced rate of erosion on and off sites of the exclosures due to the increment of woody plant species provides evidence that communities around the exclosures are gaining benefits both in the form of products and services even if it was not satisfactory. This implies that even with limited access of exclosure products, area exclosures products have contributed to the local livelihood through household income. Due to woody plant species increment, large gullies around the exclosures have stabilized. From management point of view, the exclosures require much attention from all concerned bodies: the inadequate benefit gain from the exclosure products, the fragmented farm and degraded land size, population size increment, lack of concern from the government, and other similar factors might force the communities not to keep the sites sustainably in the future.

Ecological restorations through natural regenerations may need interventions in the management to maintain and diversify the outcomes from the interaction of environmental components.

5.2. Recommendations

Based on the major findings of the study the following recommendations are forwarded.

The success in maintaining these exclosures with conservation of diversified vegetation compositions highly depends on locally-specific and community-based management systems, including maximizing the benefits to the local communities in the form of both products and services. Hence, for addressing the problem successfully, siliviculture practices like enrichment planting should be implemented by the concerned bodies: namely government, non-governmental organizations, with the involvement of local people.

Even though the communities are getting benefit from the exclosures, they are complaining that they are not satisfactory with the current quantity especially in terms of fodder and other products. For instance, they are only allowed to access grass for their livestock once in a year. Therefore, in order to increase productivity in the exclosures, practices such as introduction of adequate forage plantations and beekeeping is necessary.

Exclosure management will only succeed if all stakeholders are fully aware of own impact on its and are held accountable for their actions. Thus, building the communities capacity through provision of adequate training and experience sharing visit of similar areas in the country could be better way of promoting area exclosure as a strategy of improving the overall ecological conditions of degraded lands.

As exclosure is a natural/passive rehabilitation conservation measure, it takes a long period before it starts giving returns, so based on further scientific study and community interest; integration of productive species in the form of enrichment planting is helpful to diversify income sources of local communities.

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7. APPENDICES

Appendix 1 Woody species per sample plots in the exclosure site

Species Name	Plot																		Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
2. Acacia abysinica	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
3. Acacia lahai	0	0	0	0	0	0	1	0	5	0	0	0	0	0	0	2	0	0	8
17. Acacia saligna	39	57	33	0	0	26	28	0	0	0	0	50	25	0	0	0	38	49	345
18. Acacia seyal	0	0	13	3	3	0	1	1	0	4	7	1	10	0	1	0	0	0	44
19. Carissa spinarum	0	0	1	4	0	0	6	10	6	8	1	0	4	0	2	4	0	0	46
20. Croton macrostachyus	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	3
21. Dodonaea angustifolia	2	1	2	2	1	0	0	3	0	0	2	0	0	1	0	0	1	1	16
22. Euclea schimperi	0	0	0	14	0	0	0	1	14	2	39	0	0	0	1	2	0	0	73
23. Ficus sycomorus	0	0	0	2	0	0	0	0	0	3	0	0	0	3	0	0	0	0	8
24. Jacaranda mimosifolia	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
25. Olea europaea	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
26. Phoenix reclinata	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
27. Rosa abysinica	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2
28. Sesbania sesban	2	0	0	0	0	4	8	0	0	0	0	0	2	0	0	0	0	0	16
29. Syzygium guineense	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

Appendix 2 Woody species per sample plots in the degraded site

Species Name	Plot Number																		Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Acacia decurrens	0	1	0	0	2	n	0	0	0	0	0	0	0	0	n	n	0	0	3
*Acacia seyal**	0	0	0	0	0	n	0	0	0	0	0	0	1	0	n	n	0	0	1
*Carissa spinarum**	5	3	0	0	0	n	0	0	0	6	2	0	5	0	n	n	0	5	26
*Dodonaea angustifolia**	0	0	0	8	0	n	0	10	6	0	0	0	0	0	n	n	0	0	24
*Euclea schimperi**	2	2	3	0	5	n	5	0	5	0	2	15	10	15	n	n	12	10	86
*Rosa abysinica**	0	4	0	0	3	n	0	2	0	0	0	0	2	0	n	n	1	0	12

* refers the species common in both sites

Appendix 3 Species number per family in the exclosure and in the degraded

	Species number per family		
Family name	Exclosure site	Degraded site	Total
Apocynaceae	1	1	1
Arecaceae	1	0	1
Bignoniaceae	1	0	1
Ebenaceae	1	0	1
Euphorbiaceae	1	0	1
Fabaceae	3	1	3
Mimosoideae	3	1	3
Moraceae	1	0	1
Myrtaceae	0	1	1
Oleaceae	1	0	1
Rosaceae	1	0	1
Sapindaceae	1	0	1

Appendix 4 Soil physical and chemical variables in the exclosure and degraded site

		SOM (%)		TN (%)		EC (dS/m)		CEC(meq/100g)		AP (ppm)		pH-H20 1:2.5		BD gm/cm^3	
Plot	Transect	Ex	Deg	Ex	Deg	Ex	Deg	Ex	Deg	Ex	Deg	Ex	Deg	Ex	Deg
1st	1	4.53	1.94	0.23	0.10	0.19	0.18	31.6	23.4	7.69	7.15	7.52	6.96	1.18	0.97
2nd	1	3.05	2.68	0.15	0.13	0.18	0.11	14.1	23.9	7.75	6.93	7.72	6.34	1.41	1.79
3rd	1	3.05	2.31	0.15	0.12	0.17	0.18	13.0	11.1	7.77	6.50	7.72	7.23	0.96	1.82
4th	2	4.35	1.20	0.22	0.06	0.12	0.23	31.2	12.9	9.00	4.15	6.76	7.41	1.08	1.46
5th	2	4.53	2.61	0.23	0.13	0.16	0.18	33.6	30.7	8.92	4.56	7.27	7.72	1.47	1.52
6th	2	3.05	3.42	0.15	0.17	0.16	0.18	31.6	34.3	7.95	4.82	7.45	7.56	1.32	1.48
7th	3	3.68	3.79	0.18	0.19	0.14	0.12	33.9	22.1	7.69	7.75	7.2	6.43	1.18	1.58
8th	3	4.90	1.94	0.25	0.10	0.17	0.18	30.3	15.0	7.59	7.49	7.4	7.3	1.19	1.36
9th	3	5.08	2.31	0.25	0.12	0.10	0.18	12.5	31.1	7.61	7.07	6.12	7.49	0.95	1.64
10th	4	4.90	3.05	0.25	0.12	0.13	0.16	31.3	30.6	8.13	4.92	6.71	7.42	1.35	1.35
11th	4	2.87	3.42	0.14	0.17	0.18	0.13	25.2	24.3	7.95	4.90	7.69	6.79	1.32	1.36
12th	4	2.68	2.61	0.13	0.13	0.17	0.16	13.4	24.7	7.83	5.20	7.7	7.23	1.07	1.36
13th	5	3.42	3.79	0.17	0.19	0.18	0.14	34.3	27.1	7.93	5.56	7.63	6.81	1.10	1.68
14th	5	3.61	2.68	0.18	0.13	0.17	0.18	15.1	34.9	7.51	5.94	7.72	7.71	1.34	1.69
15th	5	4.16	2.87	0.21	0.14	0.11	0.17	32.8	31.2	8.11	5.70	6.5	7.69	1.34	1.75
16th	6	5.27	3.61	0.26	0.18	0.12	0.12	32.0	14.7	7.51	5.52	6.64	6.61	1.15	1.41
17th	6	3.05	2.50	0.15	0.13	0.17	0.13	15.4	24.5	8.03	5.70	7.72	6.61	1.25	1.56

18th	6	2.50	3.24	0.13	0.16	0.17	0.13	6.3	30.1	7.57	5.92	7.76	7.11	1.18	1.68

Appendix 4. Continued

		Texture (%)						SM (%)		Na		K		Ca		Mg	
Plot	Transect	Sand Ex	Sand Deg	Clay Ex	Clay Deg	Silt Ex	Silt Deg	Ex	Deg	Ex	Deg	Ex	Deg	Ex	Deg	Ex	Deg
1st	1	28	42	45	39	27	19	14.7	15.9	0.15	0.21	0.72	0.95	21.96	21.96	2.96	2.39
2nd	1	40	40	48	37	12	23	16.1	5.1	0.38	0.13	1.19	0.91	35.03	35.03	7.41	2.63
3rd	1	42	42	50	13	8	45	17.4	8.0	0.37	0.21	1.20	0.83	22.01	22.01	5.68	1.23
4th	2	34	42	45	21	21	37	20.1	15.6	0.36	0.28	1.21	0.40	21.16	21.16	5.60	1.23
5th	2	32	30	49	49	19	21	21.5	11.1	0.30	0.22	1.43	0.47	24.50	24.50	7.41	3.29
6th	2	34	26	43	55	23	19	15.0	17.1	0.35	0.22	1.24	0.52	36.58	36.58	7.65	3.87
7th	3	22	50	53	29	25	21	23.6	6.0	0.35	0.15	1.19	1.06	33.68	33.68	7.24	1.48
8th	3	38	46	41	23	21	31	18.9	16.3	0.32	0.21	1.18	1.01	35.58	35.58	7.49	1.48
9th	3	42	30	49	45	9	25	15.2	30.1	0.36	0.22	1.18	0.93	34.58	34.58	7.41	3.21
10th	4	36	47	43	49	21	4	12.0	11.0	0.27	0.19	1.27	0.54	21.11	21.11	5.60	3.37
11th	4	32	42	39	35	29	23	22.5	15.8	0.31	0.16	1.24	0.54	35.38	35.38	7.49	2.80
12th	4	36	30	44	39	20	31	18.3	16.7	0.37	0.19	1.22	0.59	27.69	27.69	6.50	2.72
13th	5	22	36	55	39	23	25	13.4	17.6	0.36	0.17	1.24	0.66	21.66	21.66	5.68	3.13
14th	5	48	25	47	59	5	16	26.9	9.9	0.37	0.22	1.16	0.73	35.58	35.58	7.49	3.79
15th	5	28	36	49	43	23	21	27.2	13.7	0.35	0.20	1.27	0.68	21.76	21.76	5.68	3.29

16th	6	34	42	43	23	23	35	12.4	9.3	0.28	0.14	1.16	0.65	35.48	35.48	7.49	1.56
17th	6	38	34	39	39	23	27	20.2	15.1	0.30	0.16	1.26	0.68	36.48	36.48	7.65	3.29
18th	6	50	22	29	47	21	31	13.0	15.9	0.35	0.21	1.16	0.95	22.01	22.01	5.68	2.39

Appendix 5 Altitudes and coordinates of woody plant species and soil sample plots of the exclosure and the degraded site

plot number	Exclosure site			Degraded site		
	Vegetation and soil sample plot			Vegetation and soil sample plot		
		Coordinates			Coordinates	
	Altitude (m)	x	y	Altitude (m)	x	y
1	2055	405233	860309	2053	405261	860391
2	2045	405345	860264	2052	405211	860419
3	2041	405457	860197	2055	405135	860448
4	2038	405384	860100	2059	405134	860491
5	2040	405255	860099	2055	405171	860483
6	2052	405116	860138	2054	405233	860461
7	2049	405077	860028	2054	405226	860468
8	2044	405194	859951	2056	405247	860507
9	2032	405299	859907	2054	405523	860553
10	2036	405230	859831	2058	405210	860557
11	2043	405131	859844	2056	405192	860582
12	2046	405012	859878	2060	405156	860605
13	2049	404946	859779	2057	405166	860625
14	2044	405048	859741	2056	405202	860636
15	2034	405171	859687	2053	405230	860637
16	2033	405080	859590	2056	405267	860612
17	2041	404993	859668	2057	405324	860595
18	2037	404950	859575	2053	405377	860543