IMPACTS OF LANDSCAPE RESTORATION ON THE ENVIRONMENT AND FARMERS' LIVELIHOOD IN HITA-BORKENA WATERSHED, NORTHEASTERN ETHIOPIA

by

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Dedication

This thesis is dedicated to my mother, Almaz Wasihun Haile (Emewa), who has paid lots of sacrifices for the advantage of me and my brothers. God Bless you.

Declaration

I, **Alemayehu Assefa Ayele,** hereby declare that the thesis, which I hereby submit for the degree of **Doctor of Philosophy in Geography** at the University of South Africa, is my own work and has not previously been submitted by me for a degree at this or any other institution.

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October, 2019

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Abbreviations and Acronyms

ANOVA	Analysis of Variance
ANRS-BoFED	Amhara National Regional State Bureau of Finance and Economic Development
AvK	Available Potassium
AvP	Available Phosphorus
BLM	Interior Bureau of Land Management of the U.S. Department
CEC	Cation Exchange Capacity
CRS	Creative Research Systems
CSA	Central Statistical Agency
DEM	Digital Elevation Model
DFID	Department for International Development
EDHS	Ethiopia Demographic and Health Survey
EDRI	Ethiopian Development Research Institute
EEPFE	Environmental Economics Policy Forum for Ethiopia
EPTD	Environment and Production Technology Division
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization of the United Nation
FCND	Food Consumption and Nutrition Division
FFW	Food-For-Work
F-G-S	Forestland-Grassland-Shrubland
FRA	Forest Resource Assessment
GHGs	Green House Gases
GIS	Geographic Information System
GOs	Governmental Organizations
ha	Hectare
HSD	Honestly Significant Difference
IDS	Institute of Development Studies
IFPRI	International Food Policy Research Institute
ISFM	Integrated Soil Fertility Management
IUCN	International Union for Conservation of Nature and Natural Resources
LSP	Livelihood Support Program
LUCC	Land Use/Cover Change
m asl	meter above sea level
MERET	Managing Environmental Resources to Enable Transitions to More Sustainable Livelihoods
NDVI	Normalized Difference Vegetation Index
NGOs	Non-governmental Organizations
NRCS	Natural Resources Conservation Service (of USDA)

ODI	Overseas Development Institute
OM	Organic Matter
PES	Payment for Ecosystem Services
SER	Society for Ecological Restoration
SLCP	China's Sloping Land Conversion Program
SLF	Sustainable Livelihoods Framework
SLM	Sustainable Land Management
SOC	Soil Organic Carbon
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
SS Dam	Sediment Storage Dam
STM	State and Transition Model
SWC	Soil and Water Conservation
TANGO	Technical Assistance to Non-Governmental Organizations
TM	Thematic Mapper
TN	Total Nitrogen
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
USCB	United States Census Bureau
USGS	United States Geological Survey
WB	World Bank
WFP	World Food Program
WLRC	Water and Land Resource Center
WOCAT	World Overview of Conservation Approaches and Technologies

Abstract

Land degradation has been a global agenda. It has been affecting both developed and developing nations (including Ethiopia). The overall objective of the study was to assess the impact of landscape restoration (including area closure) on the environment and farmers' livelihood in Hita-Borkena watershed, northeastern Ethiopia. Three Landsat images (1986, 2001 and 2015) were used to detect land cover dynamics. Laboratory analysis of selected soil physico-chemical properties were made to compare the soil properties of closed/restored and open grazing areas. Household questionnaire was administered to investigate environmental problems before and after landscape restoration, the role of area closure and different conservation measures, and the impact of the restoration on farmers' livelihood. A total of 255 household heads were selected randomly for the questionnaire survey. This survey was also substantiated by interviewing agricultural experts, observation and reviewing reports prepared by Kalu District Agriculture Office. Both descriptive and inferential statistics were employed to analyze quantitative data. Besides, qualitative approach was implemented in order to analyze qualitative data. The study found out that forestlands and shrublands shrunk through 1986 – 2015, grasslands expanded mainly due to the implementation of area closure under MERET project since 2001. The study revealed that better organic matter, total nitrogen, clay and silt contents, CEC and total porosity were recorded under area closure than under open grazing land. However, both available P and K were found minimum under the former land use type. This may be due to the reason that such nutrients exist more in unavailable form or it may be because of the fact that large amount of those nutrients are extracted by the restored vegetation. The study showed that rates of soil erosion, overgrazing and illegal cutting of trees were relatively higher before landscape restoration. The respondents also appreciated the positive role of land restoration in improving the fertility of the soils of the study watershed and then the positive impact to their livelihood. Based on the results of the study, it is recommended that similar restoration activities shall be implemented in similar environments in Ethiopia to improve both the environment and farmers' livelihood.

Key words: Land cover, soil properties, livelihood, environment, area closure, landscape restoration, Hita-Borkena watershed, Ethiopia

Chapter 1

1. Introduction

1.1. Background of the study

Globally, landscape degradation in general and agricultural land in particular is a serious environmental problem, however with wide disparity on the extent, depth, type and drivers of the problem (FAO, 2004; FRA, 2005). The problem is severe in developing countries, particularly in the Sub-Saharan Africa (SSA) (FAO, 2004; Vlek et al., 2008). Globally, each year greater than 11.6 million hectares of forests are cleared so as to replace degraded agricultural lands (Pimentel, 1993).

Land degradation is an evolution that occurs when land loses its quality and productivity. It is the process that lowers the original/current and/or the future capacity of the land to produce goods and services such as agricultural yield, water, and vegetation. Due emphasis should be given for loss of vegetation (trees, grasses, agricultural plants), the declining of soil productivity (caused by soil erosion, biological or chemical deterioration), and the depletion of water quantity and quality. Among others, inappropriate human actions on landscape resources are primarily responsible for landscape degradation.

A global survey shows that 40 % of agricultural land is already degraded to the level that yields are highly minimized, and a further 9 % is degraded to the level of no recovery for productive use by farm level measures. Without mitigating such rate of land degradation, it is impossible to meet the demand for more food over the next 50 years (Bossio et al., 2010).

It is believed that greater than 97 % of the world's food comes from the land than the oceans and other aquatic systems, with most portions being derived from steep lands found in tropical climates that are susceptible to degradation. It has been reported that agricultural production decreases because of land degradation by a rate of 2 % per year (Hurni, 1993). Unchecked land degradation would seriously affect the livelihood of people in the long run due to the differences between actual rates of extraction or the replacement (social) and actual costs of using land (Reddy, 2003). Thus, in order to overcome such problem, restoration of agricultural landscape in particular and environment system in general is one of the crucial strategies for achieving success in the programs of food security and environmental conservation (Pimentel, 1993). Shimelis et al. (2013) indicated that in order to address land degradation problem in the Ethiopian highlands, which has occurred due to inappropriate agricultural practices and conversion of marginal land to cultivation and grazing, the government has made efforts in investing resources in Soil and Water Conservation (SWC).

Through landscape restoration programs, it is possible to bring back the productivity of vast tracts of lands which are now lying barren and less productive. However, since one of the challenges of restoration programs is its expensiveness, some studies (for example, Lal, 1993; Holl et al., 2003) suggest that the costs needed for restoring degraded lands should be borne by governments. Thus, in most recent days, government supported landscape restoration programs are becoming common practices in different parts of the world (Zhang et al., 2011).

Landscape restoration refers to the act of returning an area/landscape to its original state. Leaving terms like “natural” or “pristine”, we can have different original states of landscape to which we will be able to restore it. Likewise the restoration activities will be determined by the kind of landscape characteristics and local practices (Allison, 2004a). The success of restoration efforts can vary among sites because of sites’ variation in hydrology, microclimate, and movement of plants, animals, and disturbance regimes (Holl et al., 2003). On the other hand, in order to bring back the productivity of landscapes which are now lying barren and less productive to more productive and sustainable or to take back the existing natural landscape in its intact state, three types of interventions such as complete restoration, limited restoration or protections of landscape could be applied (Zhang et al., 2011). The same source indicated that environmental and livelihood benefits of complete restoration > limited restoration > protection.

In general, the goal of landscape restoration is to convert the site which is less natural and degraded to a more natural and original condition of states under consideration. Such restoration is essential to ensure better ecosystem health and sustainability (Allison, 2004b). Zemenfes (1995) described that the goal of restoration of degraded land can be achieved by diversifying the rural economy. Overexploitation of land can be tackled by allowing farmers to gain income from off-farm activities. Cao et al. (2009) indicated that it is impossible to restore degraded land unless the livelihood of farmers is improved.

Different studies (for example, Hurni, 1993; Gao et al., 2011; Nyssen et al., 2007; Mengistu, 2011; Wendwessen, 2009) have described the successes and benefits gained from landscape restoration or area exclosure as described hereafter. Gao et al. (2011) described that in the Tibetan Plateau, exclusion of livestock grazing from degraded landscape for 10-years enhanced vegetation recovery (increased biomass production and growth of the perennial grass); improved soil organic carbon, and nutrient (total N, and P) contents; and improved soil physical properties (for example, soil structure and soil moisture holding capacity).

The recent coordinated efforts of administrators and farmers on natural resources conservation in Tigray, Ethiopia has led to tangible enhancements in soil conservation, infiltration, crop yield, biomass production, groundwater recharge, and prevention of flood hazard (Nyssen et al., 2007; Wolde et al., 2007; Wolde & Ermias, 2011; Haile, 2012). This is assured using in situ analyses of landscape changes, which indicates that the status of natural resources has improved since 1975. The area is recovered due both to improved vegetation cover and to physical soil and water conservation structures. For example, Nyssen et al. (2007) have reported that because of physical soil and water conservation practices in Tigray, the average soil loss due to sheet and rill erosion in 2007 was about 68% of its rate of 1975.

Area closure as one of natural resources management technique can lead to improvements in vegetation and soil rehabilitation. Together with other factors, area closure can improve composition and diversity of woody vegetation, reduce soil erosion and improve land productivity as a whole (Mengistu, 2011). Moreover, area closure is essential for recovering vegetation diversity and for land rehabilitation on degraded grazing lands. It also increases the soil seed bank and soil organic matter (Wendwessen, 2009).

In Ethiopia, although restoration efforts in terms of afforestation and SWC are promising, there have to be continued activities if it is needed to have sustainable land-use systems for the coming generation (Hurni, 1993). In different parts of Ethiopia, area closure has been practiced as one of degraded land restoration programs, among which Hita-Borkena watershed is the one. However, there is lack of empirical data as to the effectiveness of such programs in the study watershed. Therefore, in order to gain more benefits from restoration projects, it is not only highly needed to investigate its impacts on the environment and to explore the existing landscape restoration strategies as most similar previous studies did, but it is also highly required to analyze its role in local farmers' lives so as to inform development agents and policy makers sound and locally valid practices in the Amhara National Regional State of Ethiopia in general and in the study area in particular. For this purpose, the study principally employed both quantitative and qualitative types of study. In the process of quantitative approach, field data collection, household survey questionnaire and secondary data were used. For qualitative data, in-depth interviews (with local farmers and experts) were administered. Soil samples were collected and their physical and chemical characteristics were analysed and comparison between restored/closed and degraded sites in terms of such characteristics were made. Land cover dynamics in 1986, 2001, and 2015 were determined using ArcGIS and ERDAS IMAGINE software. Semi-structured questionnaire and interview were used so as to collect data/information on the environmental problems and household livelihood before and after the landscape restoration of the study area, to see the role of area closure in addressing such restoration and problems, and to identify the different methods used to restore the area.

1.2. Statement of the Problem

It is recommended to view land degradation within the context of landscape. Landscape consists of different components. These are soils, plants and water with or without the interferences of human activities. The complex interactions among these components can positively or negatively affect human beings. Human beings can in turn positively or negatively affect such interactions. From this, we can understand that land degradation is the destruction of all or one of these components and their inter-relationships (EDRI/EEPFE, 2005). In the world, dry land regions as a result of land degradation are alarmingly losing soil and biodiversity (Reubens et al., 2011).

In the Ethiopian highlands, land degradation in the form of deforestation of the natural vegetation cover, accelerated soil erosion, loss of soil fertility and moisture stress, is a serious environmental problem (Nyssen et al., 2004 cited in Descheemaeker, 2006). It is estimated that in Ethiopia, the average total soil loss of 42 t/ha/year from croplands will remove the soil of the present croplands within 100 – 150 years. As a result, the soil loss could lead to an annual production loss of 1 – 2 % (Hurni, 1993).

In addressing their demands for food and for others, Ethiopians have given little concern for the future generations' means of existence over the course of centuries. In Ethiopia, the major factors of soil erosion are intensive cultivation, overgrazing, deforestation and inappropriate land use practices (Mahdi & Sauerborn, 2001).

In most of the developing countries, land degradation exerts a major threat on future growth and development. The real costs of such degradation are reflected in terms of health costs, reduction in productivities of land, water, grasslands, etc (Reddy, 2003). In west China in recent 15 years, frequent floods, droughts, sandstorms, and soil erosion have threatened both local people's daily life and the nation's sustainable development (Wang & Shen, 2009).

The implementation of sustainable agricultural practices being in combination with ecological restoration methods is helpful to boost agricultural production. It is required to make sure that SWC activities and/or restoration efforts can benefit both the land owners and biodiversity (Wade et al., 2008). In doing so, integrated conservation, rehabilitation and community-based management of natural resources are all very crucial (Reubens et al., 2011).

It is a clear fact that land degradation and poverty are linked. For having successful landscape restoration, the precondition is that poverty should be eliminated, together with the establishment of green enterprises that improve the livelihood of farmers in the long term (Cao et al., 2009). Landscape restoration and farmers' livelihood are complementary. This situation is more common in rural areas where life is dependent on natural resources exploitation (Cao et al., 2010). Rural development programs like landscape restoration that aim at reducing land degradation must be livelihood-oriented; i.e., their primary goal must be to improve the livelihood of farmers, and not to restore land alone without considering the livelihood of farmers (Zemenfes, 1995). This is because the involvement of poor rural households living in developing countries with small land holdings in landscape restoration is hampered by the problems of unskilled labour, shortage of land and limited cash (Barbier, 1997).

Considering the threat of land degradation in degraded and drought prone areas, the government of Ethiopia has practiced area closures. Wendwessen (2009) indicated that area closures are not new practices in Ethiopia. Ethiopians have been practicing area closure for centuries in a traditional way around churches for religious purpose.

As one of the restoration efforts for degraded lands, area closures could play a major role in partly addressing the problems of the society and the environment. Nyssen et al. (2007) found out that exclosures enhanced infiltration, decreased sediment deposition and downstream flooding. Exclosures also provide ecosystem services such as growth of grass and trees, increase in wildlife and biodiversity, climate regulation, drought mitigation and carbon sequestration.

Wendwessen (2009) indicated that degraded lands may not only be recovered by natural regeneration. That is, there have to be other options such as agroforestry, silviculture, and enrichment of planting to support the restoration efforts. This can be successful with full participation of the local people, government, development workers, and researchers. Here, for the sake of boosting the productivity of area closures, interventions should consider conservation of biodiversity, land rehabilitation, and environmental sustainability.

The study area, Hita-Borkena watershed, is found in Kalu district, South Wollo Zone, Amhara region, northeastern Ethiopia. It is one of the areas in the district which doesn't receive sufficient amount of rainfall and is among the severely degraded parts of Ethiopia. Several efforts have been made by district's office of agriculture being in combination with WFP's MERET program to restore the area and thereby benefit the residents (Kalu District Agriculture Office, 2013).

Although a few studies have been conducted focusing on area closure in Amhara National Regional State (for example, Gebrehaweria et al., 2016; Getachew, 2014; Gete et al., 2014; Kibret, 2008; Mengistu, 2011; Shimelis, 2012; Tesfaye, 2011; Wendwessen, 2009; Wolde et al., 2015; Wolde et al., 2016; Wolde et al., 2017), most of them studied the role of area closure in improving soil characteristics and vegetation diversity. There is, thus, lack of attention to the multiple effects of area closure on environmental degradation, land cover dynamics, soil characteristics and farmers' livelihood. The present study contributes to the existing literature by assessing the impacts of landscape restoration (including the role of area closure and other restoration measures) at the micro-level (i.e. at the watershed level). Therefore, this study investigated the impacts of landscape restoration on the environment and farmers' livelihood in the study watershed.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study was to investigate impacts of landscape restoration on the environment and farmers' livelihood in Hita-Borkena watershed, Amhara region, northeastern Ethiopia .

1.3.2. Specific objectives

The specific objectives of the study were:

Objective 1: To examine the demographic and socioeconomic profile of the study area. [Chapter 4 of Thesis]

Objective 2: To analyze land cover dynamics for the period 1986-2015. [Chapter 5 of Thesis]

Objective 3: To analyze selected soil physico-chemical properties in the study area. [Chapter 6 of Thesis]

Objective 4: To examine environmental problems faced by farmers before the restoration program. [Chapter 7 of Thesis]

Objective 5: To examine the impact of landscape restoration on livelihoods through the Sustainable Livelihoods Framework (SLF) approach. [Chapter 8 of Thesis]

1.4. Research Questions

The questions which were prepared based on the above specific objectives include the following:

1. How does the demographic and socioeconomic profile of the study area looks like?

2. How does the land cover looks like in 1986, 2001 and 2015? Is there difference and similarity between the land cover conditions in the three periods?

3. Can area closure improve the physico-chemical characteristics of soil of the study area? Are the characteristics of soil of the closed area better than the adjacent open grazing land?

4. What were the environmental problems that farmers were facing before the introduction of landscape restoration in the study area? What are the major roles of area closure in reducing environmental problems? What are the methods used in the study area for the sake of landscape restoration?

5. What kind of relationship exists between landscape restoration and household livelihood? Does landscape restoration affect the asset base, livelihood activities and livelihood outcomes of sampled households?

1.5. Significance of the Study

It is undeniable fact that land degradation is a worldwide problem. Ethiopia, which is part of developing nations and whose people are mainly agrarian, has been facing problems partly related with land degradation. In order to address such problems, as shown by Temesgen (2015), the Government of Ethiopia in collaboration with international donors mainly WFP had implemented mainly physical SWC measures in 1970s. The Government has also been putting into practice watershed management since 1980s, which give rise to reduced run-off, soil erosion and associated downstream siltation, increased vegetation cover and surface roughness, increased soil depth, increased recharge of groundwater table, increased production area and green environment, increased crop production and productivity and improvement in fodder availability. Gete et al. (2014) indicated that the present land restoration project of Ethiopia, which is known as MERET, is people-centered and has resulted in improvement of environmental resources and livelihoods of targeted communities. In such project, different SWC measures, area closure, water harvesting and income diversification have been implemented to acquire the desired goal of the Government and in turn to benefit the targeted community.

Hence, this study is conducted to shade light on the impacts of landscape restoration in the form of area closure on soil fertility by comparing the physico-chemical characteristics of soil found in area closure and in degraded open grazing land, to assess environmental degradation and farmers' livelihood using semi-structured questionnaire survey, observation and interview, and to analyze the land cover conditions before and after the restoration project in the study area. It is a study that can pinpoint how much restoration activities are crucial in addressing different environmental problems and improving community's livelihoods.

As far as the contribution of the study to the present body of knowledge is concerned, when we see previous similar researches, most of them focused on the role of landscape restoration and/or area closure on soil fertility, species diversity and richness. And, little has done so far in assessing the relationship between landscape restoration and farmers' livelihood. Thus, the study differs from other similar researches (as for example the study conducted by Shimelis, 2012) explored the impact of the restoration project on the asset base, livelihood activities and livelihood outcomes of the community based on SLF.

This study is significant to administrators of Kalu district in particular to take measures so as to enable the community living in the study watershed gain benefit from the landscape restoration project. It provokes the NGOs to assist the Government of Ethiopia in dealing with restoration projects. It can inform policy makers to make decisions on restoration projects. It puts pressure on the beneficiaries of the project to scale up their care for the watershed by magnifying the benefits of landscape restoration and/or area closure. It gives crucial information for watershed management experts, natural resources management experts, soil geographers, soil scientists, ecologists and the like. It can also function as a spring board for other researchers to undergo similar studies filling the research gap either at the study watershed or at other watersheds in the future.

1.6. Scope of the Study

The study was conducted to investigate the impacts of landscape restoration including area closure on the environment and on farmers' livelihood in Hita-Borkena watershed, Kalu district, South Wollo zone, Amhara national regional state, northeastern Ethiopia. It mainly focused on two sub-watersheds, namely Shehana-Borkena and Tikuro, to compare the soil physico-chemical characteristics of area closure and degraded adjacent open grazing land, and in addition to this, semi-structured questionnaire survey and interview were prepared to assess the impacts of landscape restoration in dealing with environmental problems and farmers' livelihoods, to identify the role of area closure, and to investigate various SWC techniques being undertaken. Shehana-

Borkena and Tikuro sub-watersheds, which were purposefully selected for the availability of area closure, are located in Addismender (01) and Birko Debele (031) kebeles of Kalu district, respectively, but the watershed also touches Chorisa (06) and Kedida (07) kebeles. This does mean that area closures are not available in Chorisa and Kedida kebeles, but it means that the delineated watershed contains area closures found in Addismender and Birko Debele kebeles. On the other hand, the whole watershed was taken into consideration in showing the land cover conditions in three separate years: 1986 (before the restoration project), 2001 (reference year, i.e. the year that the restoration project started), and 2015 (after the restoration project).

1.7. Limitations of the Study

This study is not free from limitations. The researcher recognizes that the result of this study represents local specific conditions and couldn't be generalized to other part of the country or to Sub-Saharan Africa. Hence, the researcher encourages other researchers to undertake studies in other parts of Ethiopia filling the gap of this study.

It is a clear fact that in landscape restoration impacts assessment, biomass and/or NDVI (Normalized Difference Vegetation Index), species diversity and richness of restored and degraded areas shall be compared. However, such kinds of analyses are intentionally ignored in this study so as to make the study size manageable.

The other limitation of the study is that some sample farmers were not free to inform their possessions and income. Though errors of deliberate falsification are expected, due to various reasons, in order to reduce such errors grate care has been taken while asking respondents about their possessions and income. Another limitation of the study that could affect the quality of data is the recall method used collect data from household heads about the status of crops, fruits, vegetables and perennial crops productions before 15 and 20 years.

1.8. Organization of the thesis

The thesis is organized into 9 chapters including chapter 1.The rest of the thesis is organized as follows. The second chapter is concerned with review of related literature and conceptual framework of the study. In this chapter, empirical data on impacts of landscape and/or area closure are reviewed to identify the research gap. The third chapter indicates methodology of the study and description of the study area. The demographic and socio-economic characteristics of the respondents are presented in chapter four. The fifth chapter discusses analysis and interpretation of land cover conditions of the study area in 1986, 2001, and 2015. In this chapter, attempts are made to evaluate the land cover conditions of the study area before and after the restoration project taking the year 2001 as a reference. The sixth chapter depicts analysis and interpretation of some selected physico-chemical characteristics of soils of restored/closed and degraded adjacent open grazing areas. The seventh chapter shows farmers' and experts' responses on environmental problems that happened before and after landscape restoration, and it also discusses the methods used to restore the landscape of the study watershed giving special emphasis on area closure. The eighth chapter deals with the linkage between landscape restoration and household livelihood giving emphasis on the asset base, livelihood activities and livelihood outcomes of target households. The ninth chapter indicates conclusions and recommendations.

Chapter Two

2. Literature Review

2.1. Introduction

This section of the thesis deals with the concept of restoration and other related terms or activities, and also the differences and relations among area closure, enclosure and exclosure. It discusses about land degradation problem of the world in general and of Ethiopia in particular. It provides empirical evidences as to the positive impacts of area closure, exclosure and/or landscape restoration on the environment as well as on the society. It indicates how State and Transition Model can be employed as a strategy for developing restoration goals. It also presents Sustainable Livelihoods Framework, as a tool to capture basic livelihood variable, and conceptual framework of the study.

2.2. Overview of Restoration

Restoration of the Earth is an ancient practice. It is an ancient Judaeo-Christian tenet, but the ones to be restored at that time were God's temple and teaching and His people, not nature. Restoration of nature had started only half a century ago in response to renew the environment urgently (Lowenthal, 2013). Currently, restoration is widely practiced at a global scale in order to manage, conserve and repair ecosystem (Hobbs et al., 2004). Restoration plays a key role in the development and maintenance of sustainable production systems. In order to maintain sustainable systems, it is obligatory to restore the damages that have been caused by the past and the current practices in the systems (Hobbs and Harris, 2001).

Restoration is the process of bringing back a degraded land to its original/perfect/healthy/vigorous state (Bradshaw, 2002; Allison, 2004a and 2004b; Eden et al., 1999). Thus, a restored ecosystem would ideally become indistinguishable (for all but the experts, at least) from the pre-disturbance ecosystem (Eden et al., 1999). According to Gross (2001), there are two core definitions of what restoration is and how it has to be realized as an environment paradigm: (1) bringing back to the historical ecosystem and (2) rehabilitating some portions of an ecosystem to create a more sustainable landscape. Hobbs et al. (2004) argued that in areas where natural processes govern ecosystem dynamics, we should aim at restoring historical ecosystem (pre-disturbance system, but we may leave such goal if the landscape dynamics is made via human processes. In line with the later thought, Walker et al. (2007) noted that restoration of changed landscape doesn't mean a full recovery of an ecosystem to its pre-disturbance state since such goal is generally unrealistic. Therefore, in this thesis, restoration refers to managing, conserving and repairing the damaged landscape so as to convert it into its approximate pre-disturbance state.

Different studies (for example SER, 2004; Clewell and Aronson, 2005; Hobbs and Harris, 2001; Higgs, 1997; Palmer, 2009) have documented the importance and/or how restoration efforts could be successful.

SER (2004) indicated that collective decisions, systematic planning and a monitored approach are needed to restore an ecosystem.

Clewell and Aronson (2005) reported that the dedication of grassroots efforts and the sympathetic support of governments are vanguard for the restoration of ecosystems and landscapes.

Hobbs and Harris (2001) claimed that the success of restoration projects have to be linked back to clear and specific definitions of goals for restoration. And, the assessment of the success of such projects should not be complicated and expensive.

Higgs (1997) mentioned that issues that are required for the successful development of restoration in the long term can be arrayed under the categories of historical, cultural, political, aesthetic and moral value perspectives.

Palmer (2009) challenged that politics and social agendas will always affect the desired goal of a restoration effort, but the process by which restoration is implemented should be science driven. He further argued that science is not currently playing a role it should not because of lack of political or social will by the public, but because much of the science produced so far has not been communicated to the potential users, or, because implementing a scientific finding in a specific restoration context is not easy.

2.2.1. Restoration compared with other related activities

While restoration is an act of changing a degraded ecosystem and landscape to its pre-disturbance state (Bradshaw, 2002; Allison, 2004a,b; Eden et al., 1999), rehabilitation, remediation, reclamation, replacement and mitigation have been used for the improvement of ecosystem and landscape, but not to bring back the original ecosystem.

Rehabilitation is an act of improving a degraded ecosystem and landscape, but it doesn't mean bringing back an ecosystem to its original state and function (Bradshaw, 2002). It is repairing a damaged ecosystem and landscape for the sake of benefitting the local people (Aronson et al., 1993). Choi (2007) argued that almost all actions of restoration fall into the definition of "rehabilitation." As to Eden et al. (1999) rehabilitation and enhancement are similar, both indicate the action of improvement of some environmental aspects or species. On the other hand, Bradshaw (2002) defined enhancement as making a good ecosystem better, not making a bad ecosystem better.

Remediation is the process of making an ecosystem good, i.e. the emphasis, in this case, is on the process rather than the end point reached (Bradshaw, 2002).

Reclamation is an action mostly employed in the context of mined lands in North America and the UK. Its main objectives are stabilization of the terrain, assurance of public safety, aesthetic improvement, and usually converting the land to a useful one (SER, 2004). Bradshaw (2002) defined reclamation as an act of making land fit for cultivation. It doesn't mean bouncing back a given land to its pre-disturbance state, it rather means changing it into a useful one.

Mitigation is an action employed to compensate environmental damage. It is usually needed as a requirement for the issuance of permits for private development and public works projects that can result in damage to wetlands (SER, 2004). According to Bradshaw (2002), mitigation means simply reducing the heinousness of an ecosystem.

Rehabilitation, reclamation and restoration are a continuum of outcomes from the least to the most, almost similar, to the pre-disturbance/original/pristine ecosystem (Jackson et al., 1995). The relationship of the above-mentioned activities with restoration is given in Figure 2.1.

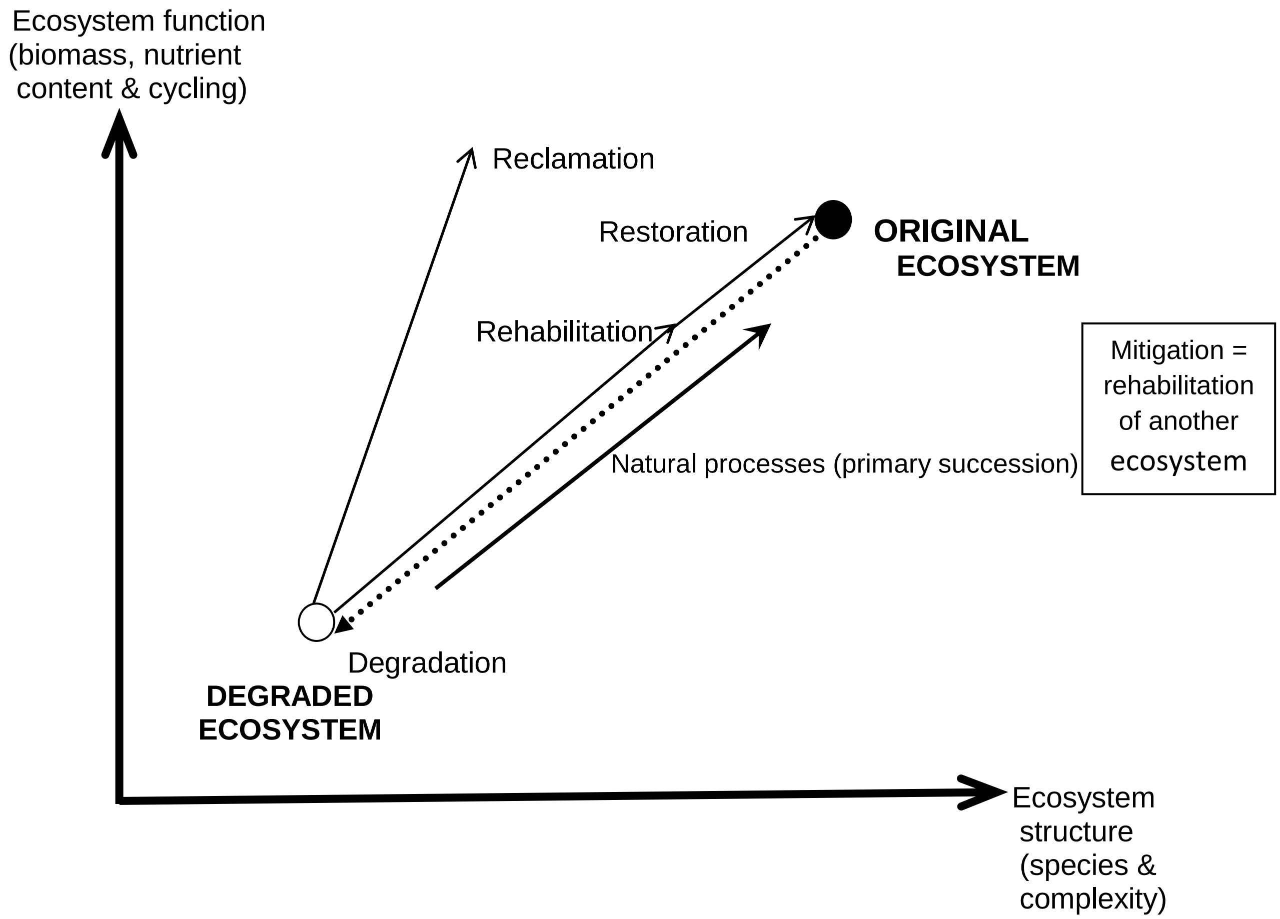


Figure 2.1. Different options used for the improvement of a degraded ecosystem and landscape (Bradshaw, 2002)

2.2.2. Landscape Restoration

Landscape is **'**a land–area mosaic of interacting natural ecosystems, production systems and spaces dedicated for social and economic use**'** (Rietbergen-McCracken et al., 2007 cited in Keenleyside et al., 2012). Ermischer (2004) stated that landscape is not static and is always under change and development, which implies that it is just a process. Hence, in order to manage landscape, we have to first understand the landscape process. It is, therefore, important to consider landscape not only as three dimensional, but also as four dimensional. It is again crucial to understand the history and development of landscape.

For millennia, human beings have shaped landscapes practicing different activities, especially through agriculture (Navarro and Pereira, 2012). This condition calls for the restoration of landscape. Landscape restoration is a process by which organic-rich topsoil is removed from lower slope positions and is moved to the knoll positions where it is applied and incorporated as additional topsoil. Field studies on this matter have shown increases in crop yield productivity due to land restoration on the convex upper slope positions (Hacault, 2010). Metzger (2001) cited in Metzger and Brancalion (2013), on the other hand, defined landscape restoration as a process that encompasses different initiatives that emphasize on the restoration of landscape structure, dynamics or function, while considering the landscape as a mosaic of interactive landscape units. In this thesis, landscape restoration refers to returning the components of landscape (both biotic and abiotic) to their close approximate original condition. This can be achieved by applying different measures like area closure, tree planting, terracing, cut off drains, check dams, eye brow basins, waterways, etc which lead to the restoration of soil quality and biodiversity as a whole.

Conservation, resource enhancement and sometimes economic objectives (Maron and Cockfield, 2008) are among the objectives of landscape restoration projects. Lal (2016) also indicated that the goal of landscape restoration is to enhance ecological complexity and environmental sustainability and to mimic natural ecosystem.

At present day, so as to avert the problems initiated due to degradation of landscapes, there is a need for implementation of landscape restoration at different scales with various goals. In relation to this, Lindenmayer et al. (2002) noted that there is an urgent need for implementing landscape restoration in many parts of the world so as to conserve biodiversity. Besides, Lal (2016) reported that the current problems of the world (i.e. climate change, food and nutritional insecurity, water pollution and scarcity, eutrophication, and dwindling biodiversity) could be resolved by landscape restoration and by employing different practices based on sound ecological principles.

2.2.3. Ecological Restoration

There have been continuous interactions between nature and human beings. The rise in human population at a global level (Sarr and Puettmann, 2008) leads to the increment in demand to conserve, restore and sustainably manage ecosystems. Otherwise, undesired outcomes will happen up on the earth's ecosystem and on human population. Clewell and Aronson (2005) depicted that failing to response to environmental destruction or failing to implement restoration will lead to suffering of mankind and again the Earth will become less habitable. This indicates the essence of ecological restoration in reversing ecosystems as well as landscapes degradation. In support of such idea, Hobbs and Harris (2001) stated that ecological restoration is an essential part of our future survival strategy for it addresses human-induced damages to Earth's ecosystem.

In a strict sense, ecological restoration is returning a system to its original state although this is an unachievable goal (Jackson et al., 1995; Palmer, 2009). Ecological restoration is a practice that involves the recovery of a degraded, damaged, or destroyed ecosystem (SER, 2004). It is now growing fast and is providing new ideas and opportunities for biological conservation and natural resources management (Choi, 2004).

The general goal of ecological restoration should be improving ecological complexity (Clewell and Aronson, 2005). Ecological restoration aims at averting biodiversity losses and ecosystem degradation that have occurred through time as mankind have impacted landscapes (Geist and Galatowitsch, 1999). To achieve such aims, Hobbs et al. (2004) believed that restorationists should understand how ecosystem worked before it was modified or degraded, and then make use of such understanding to reassemble it and reinstate necessary processes. Hobbs and Harris (2001), on the other hand, revealed that since most ecosystems are dynamic, ecological restoration shouldn't be based on static attributes.

There are two major challenges that arise while implementing ecological restoration: (1) challenges related to implementation of restoration across large areas containing different land use types, and (2) problems on balancing the trade-offs between biodiversity and improvements in human wellbeing (SER and IUCN, 2004).

As a whole, it is possible to conclude that ecological restoration continues to be implemented at various scales with various goals in the world as long as humans' life is partly in one way or another related with ecosystems and landscapes. In agreement with this fact, SER and IUCN (2004) noted that there is now a growing realization that it is not feasible to conserve existing biodiversity through the protection of critical areas alone.

2.2.3.1. State and Transition Model (STM)

State and transition model (STM) is a conceptual model of ecosystem change that represents a non-linear dynamics (Westoby et al., 1989). It is currently used as a tool for ecosystem management (Kachergis et al., 2013), and as a decision-making tool for the purpose of identifying and achieving short-and-long-term restoration goals (Wilkinson et al., 2005). For example, BLM (2013) described that STM is a way for showing plant succession, ecological thresholds, non-equilibrium dynamics, and functional and structural change resulted due to disturbances and management actions. The same source indicates that STM should consider historical data from records, recent data in relation to soil, vegetation, climate variability and management intervention, and process-based studies to examine the mechanisms causing or limiting ecosystem responses, a diagram showing the dynamics of state-and-transition model (Stringham et al., 2001) is presented in Figure 2.2.

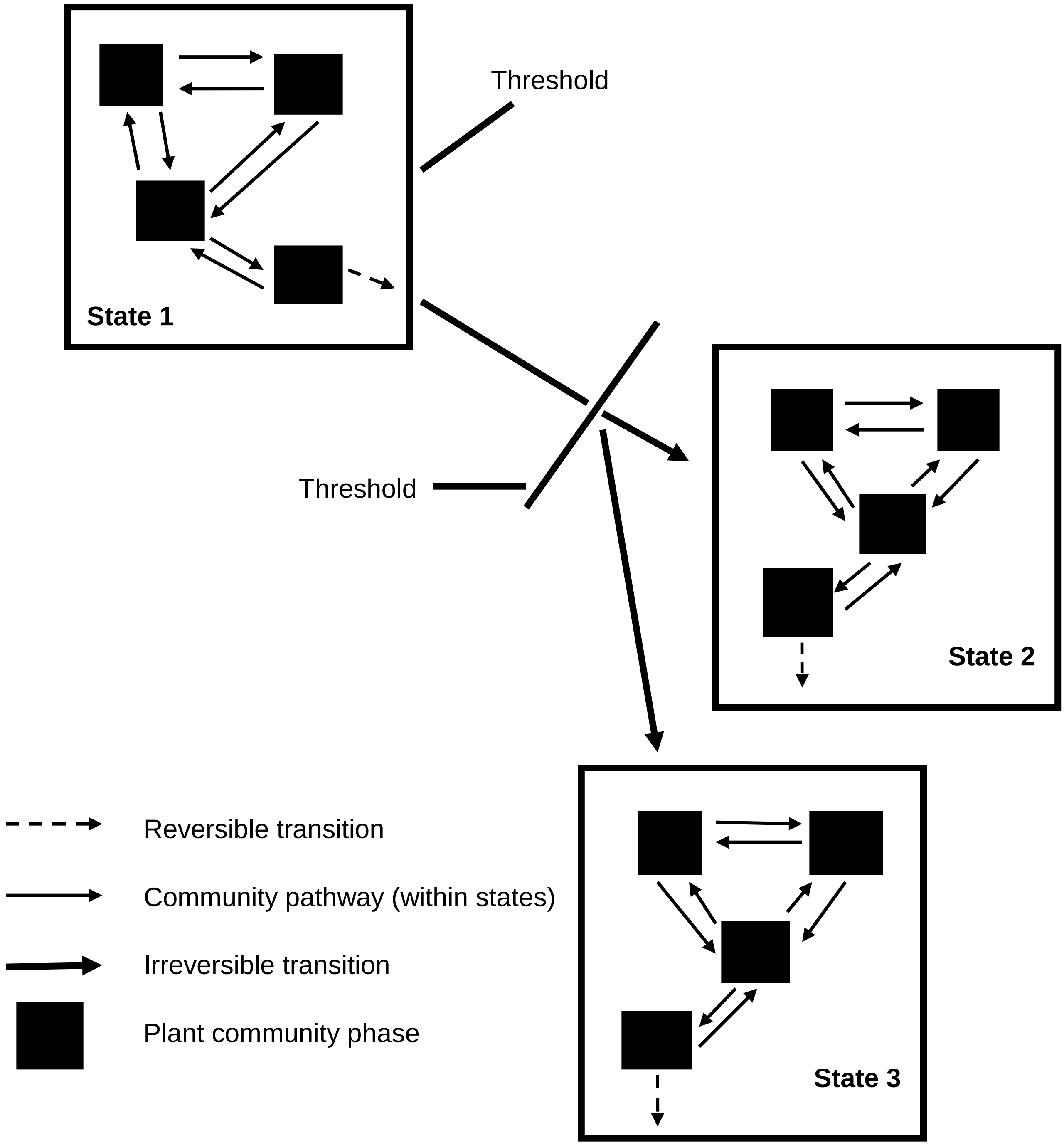


Figure 2.2. A diagram showing the dynamics of state-and-transition model (Stringham et al., 2001)

The different terms shown in the above figure are explained as follows:

- **State** is a system composed of different plant communities that in turn is affected by the soil properties and climate. It is dynamic for it contains deviation that occurs due to climatic events, management actions or both (NRCS, 2003). Stringham et al. (2001) and (2003) defined state as "a recognizable, resistant and resilient complex of the soil base and the vegetation structure." As BLM (2013) explains, state is a set of community phases that integrate with the environment in order to generate a distinctive plant species.

- **Community phases** are distinctive or characteristic collection of plant species and their respective soil bases that are found in a given state (BLM, 2013).

- **Thresholds** are limits or conditions that break up states and indicate the demand for the restoration of distorted ecosystems for they are implying that beyond such limits the aforementioned ecosystems do not regenerate by themselves (Bestelmeyer et al., 2010). As to Stringham et al. (2001) and (2003), due to the absence of appropriate restoration actions, a new state containing another community phases with a new threshold is generated.

- **Transitions** are lines of change that are caused by natural events (e.g. fire) or by management actions (e.g. fire suppression, burning) or by both (Stringham et al., 2001 and 2003; BLM 2013). So as to predict transitions, one has to understand the changes in variables in relation to threshold responses in soil base and vegetation structure (Bestelmeyer et al., 2003).

  There are two properties of transitions: 1) reversible that occurs within a state and indicates that the change can be restored, and 2) irreversible that occurs while a threshold is violated (Stringham et al., 2001 and 2003).

  It must be noted that all transitions do not happen with the same rate, i.e. some may happen with the same rate, i.e. some may happen very rapidly while others over a long period of time (NRCS, 2003).

- **Community pathways** are those indicating the change in phases within a given state and such change can be arrested as a result of succession, natural disturbances, short-term climatic deviation, and facilitating practices (BLM, 2013).

Yates and Hobbs (1997) noted that STM is an essential framework for organizing knowledge and identifying areas where further information is needed and is a useful spring board for a restoration program or for developing restoration strategies.

As indicated by Kachergis et al. (2013), STM can be applied by considering the following four steps: (i) local data elicitation with the help of semi-structured interviews; (ii) conducting an observation study in order to gather ecological data; (iii) having participatory workshops for the purpose of integrating the model with local knowledge and ecological data; and, (iv) model simplification by reviewing literatures that is performed by a multidisciplinary team.

Since STM is a tool for making decisions (Wilkinson et al., 2005) and for restoring landscape (Kachergis et al., 2013), the writer of this thesis recommends the identification of possible states and transitions available in the study watershed and similar environments in Ethiopia. This is important to improve resilience of vegetation of the area by assessing causes for its degradation through observation and interview. Then, a specific STM can be developed that may indicate possible restoration strategy, which may be similar or different from the current restoration activities prevailing in the watershed. This doesn’t mean that this model is complete by itself. Hobbs (1994) stated that STM has a limitation of considering quantitative aspect and recommends to develop a model that incorporates both qualitative and quantitative data of the problem under study. In relation to the limitation of STM, Bestelmeyer (2005) also showed that STM gives more emphasis for grazing, their presentation is inconsistent and does not consider the issue of climate change.

2.3. Differences and relations among Enclosure, Exclosure and Area Closure

Exclosure is the rehabilitation of degraded land environments, often involves excluding livestock from degraded sites. Some alternative names for such kind of practice are enclosure, area enclosure, range enclosure, and grazing reserve enclosure. The use of these terms in place of exclosure creates confusion, because exclosure and enclosure are not synonyms. Enclosures are "areas surrounded by walls, objects or other structures" and serve to keep objects, usually animals, inside a given area. Oppositely, exclosures are "areas from which unwanted animals, etc., are excluded" and their main purpose is to keep things (animals) out of a given area. Other terms used to refer to exclosures but not enclosures are closed area, and protected area. Similarly, "area closure" can be used for describing the act of establishing an exclosure, but not as a synonym for it (Aerts et al., 2009). In contrary to Aerts et al. (2009) views, the researcher considers in this thesis that area closure and exclosure are similar. This is because in the study area, domestic animals and local people are restricted in the area closure, which in turn implies the availability of exclosure in the study watershed. In this paper, the terms area closure and closed area are interchangeably used.

Area closure, which is the concern of this study, is one of the land management practices needed to arrest loss of soil, vegetation cover and water (Getachew, 2014; Tizita, 2014; WRLC, 2015) and to protect wild fauna as well (Betru et al., 2005; Tizita, 2014). It improves natural resource bases, productivity as well as ecosystem functions (WRLC, 2015). As explained by Betru et al. (2005), in Ethiopia there is nowadays a tendency to move beyond the economic benefits of area closure and the government is also giving attention to rural development, livelihood and empowerment of local people both at implementation and policy levels.

Area closure is used to protect and to give rest for a severely degraded landscape aiming to achieve restoration/rehabilitation (Betru et al., 2005; Haile, 2012; WOCAT, 2014; Tizita, 2014). The rehabilitation of a degraded land through area closure usually takes place after 7 – 10 years of its implementation depending on the intensity of land degradation and of management. Two types of area closures are being practised in

Ethiopia: 1) the most common one that involves restricting livestock and human interference to allow rehabilitation of natural vegetation, and 2) the other type that engrosses closing off a degraded landscape and concomitantly practicing SWC measures to improve the rehabilitation process (WOCAT, 2014). The second type of area closure is being practised in the study area and is the focus of this study. In support of such type of area closure, Lemma et al. (2015) pinpointed that it is essential to integrate SWC measures with area closure so as to facilitate the restoration of a degraded land.

It is a well known fact that in Ethiopia, different land management practices have begun to be implemented following the serious famines that had happened in the 1970s and 1980s. One of the practices that have emerged during the aforementioned years was area closure (Tizita, 2014; Tsegaw and Temesgen, 2015). During the Derg regime (1974 – 1991) in Ethiopia, people didn't enjoy roles in making decisions in relation to the benefits of area closure. Though people are being allowed to participate in relation to area closure in recent years, there is still ambiguity in government policy (Betru et al., 2005). Furthermore, presence of landless households, mismatch between size of grazing land and number of livestock, increase in number of human population and communal resources use rights can be considered as challenges for the success of area closure (WLRC, 2015).

A collective action is required in order to gain benefits from area closure. WLRC (2015) pointed out that the benefits of area closure are mainly determined by active participation of beneficiaries, effective arrangements of institutions, and good co-ordinations of participating organizations.

2.4. Land Degradation: a Global Context

Land degradation, which is a very complex process (Ponce-Hernandez and Koohafkan, 2004; Anderson and Johnson, 2016) and a global problem (Bojo, 1990;Gisladottir and Stocking, 2005; Bai et al., 2008; Nkonya et al., 2011; Nkonya et al., 2016a; Nkonya et al., 2016b), is defined as a long-term reduction in ecosystem function (Bai et al., 2008) that occurs gradually (Ponce-Hernandez and Koohafkan, 2004; Omuto et al., 2011). It is the problem not only for low income countries but also for high income countries and it is occurring in all agro-ecologies and terrestrial biomes of the world (Nkonya et al., 2016a).In order to meet their needs, people have alarmingly degraded the Earth's ecosystem in the last 50 years (MEA, 2007).

Land degradation is the depletion of beneficial natural resources like soil, vegetation, water that could be caused either by natural or manmade factors (Nkonya et al., 2011). Only about 3 percent of the total global surface is arable (Chabay et al., 2016), but as a result of the problems of land degradation in the developing countries, large portion of the productive agricultural land is being depleted (Barbier, 1997). As a result of this degradation, there becomes immense pressure on the lives of billions of people of the world (Le et al., 2016) and its impact is more pronounced on poor people (Ellis-Jones, 1999; Gisladottir and Stocking, 2005; Nkonya et al., 2016a) and also on the drylands of the world (Gisladottir and Stocking, 2005).

According to Bai et al. (2008), about 24 percent of the total global land is degraded and the main degraded areas are mainly found in swaths of boreal forest in North America and Siberia, the Pampas, North-Central Australia, South-East Asia and South China, and Africa south of the equator. Le et al. (2016), on the other hand, depicted that about 29 percent of the total global land is degraded and about 3.2 billion people live in such degraded land that covers all agro-ecological zones and land cover types. As indicated by Nkonya et al (2016a), SSA received the most severe land degradation problem in the world in the last decade, and as Nkonya et al (2016b) explained, this problem challenged the region's ability to achieve the goal of United Nations Convention to Combat Desertification (UNCCD) to have zero net land degradation by the year 2030. Bai et al. (2008) estimated that the lives of about 1.5 billion people of the world directly depend on the degrading land while Nkonya et al. (2011) believed that about 42 percent of poor people of the world directly depend on degrading lands for the sake of nutrition and income. Many of the hot spots of land degradation of the world are located in the hillsides (Scherr and Yadav, 1996 cited in Ellis-Jones, 1999: Table 2.1).

Table 2. 1. Hot spots of land degradation on hillsides in the world (Scherr and Yadav, 1996 cited in Ellis-Jones, 1999)

Type of land degradation	Africa	Asia	Latin America
Soil erosion	Mountain regions of Lesotho, South Africa, and Ethiopia	Foothills of the Himalaya sloping areas in Southern China and Southeast Asia	Sub-humid Central American hillsides Semi-arid Andean valleys
Nutrient depletion	Large areas under transition to short fallow densely populated highlands in Rwanda, Burundi, Kenya, and Uganda	Mid-altitude hills of Nepal (with decline in nutrient supplements from forests)	Sub-humid central American hillsides Semi-arid Andean valleys
Vegetation degradation	Devegetation due to over-stocking and intensive collection of wood fuel in many parts	Grazing lands in mid-altitude hills of Nepal, India, and Pakistan	Deforestation in threatened habitats in Central American hillsides, Chaco region in Bolivia

There are numerous causes of land degradation. Omuto et al. (2011) and Rey Benayas et al. (2012) mentioned agriculture as the main driver of land degradation. The other major causes of land degradation as described by different authors are: population pressure (Ellis-Jones, 1999), Land Use/Cover Change (LUCC) (Nkonya et al., 2016a), and population density, poverty, and government (Nkonya et al., 2011).

The severe consequences of land degradation call for an organized and multidimensional solutions. The measures that could be employed to reverse land degradation shall consider the behavioral change of land users (Baumgartner and Cherlet, 2016). Gisladottir and Stocking (2005) suggested that the solutions for land degradation shall be location-specific, such as local policies and better SWC measures, and also proposed to adopt Sustainable Land Management (SLM) practices so as to gain global benefits by reversing biodiversity loss, climate change and land degradation. Anderson and Johnson (2016) recommended proper identification of a degraded land so as to devise policies that emphasize on landscape restoration. Nkonya et al (2016b) pinpointed that the gain of investment, which is implemented to tackle land degradation, is at least twice as compared with the cost that could incurred due to failure in arresting land degradation in the first six years. Besides, taking a 30 years plan of investment into consideration, the returns of investment is about 5 US Dollars per a Dollar of investment employed to reverse land degradation. The other solutions for tackling land degradation and in turn used for restoring degraded land are:

A. Securing land tenure that provokes land users to invest in the land (Nkonya et al., 2011)

B. Employing Payment for Ecosystem Services (PES) that involves giving incentives for land users to conserve the ecosystem. China's Sloping Land Conversion Program (SLCP) is a good example of PES scheme that gives incentives for farmers and encourages conversion of farmland into forested land (Baumgartner and Cherlet, 2016). Another example in this respect is Costa Rica's policy (Nkonya et al., 2011).

C. Improving farmers' access to roads, extension services, markets, communication infrastructure and other rural services facilitates in increasing returns from investment employed to combat land degradation (Nkonya et al., 2011). Short-term trainings shall be given to agricultural extension agents and new paradigms such as Integrated Soil Fertility Management (ISFM), ecosystem services, climate change and others shall be included in the agricultural curriculum to enable the future agents give better and up-to-date services to land users (Nkonya et al., 2016a).

2.5. Land Degradation in Ethiopia

High rate of land degradation combined with production fluctuations, non-farm employment, low income, regional fragmentation of markets, low level of farm technology, high level of illiteracy and inadequate quality of basic education, poor health and sanitation, high population growth, large indebtedness, poor governance, and interstate and intra-state military conflicts and wars are major causes for Ethiopia's current state of food insecurity and poverty (Sisay, 2003). One of the obstacles that challenge an attempt to develop Ethiopia is environmental degradation which takes place in the form of land and water resources degradation and loss of biodiversity. Land degradation includes soil erosion and loss of soil fertility. The problem of soil erosion is especially more pronounced in the highland areas (Demel, 2001). The Ethiopian farmers depend on the natural conditions and are unable to withstand further decline in soil productivity that is resulted due to soil erosion. This is because the current economic conditions of Ethiopia do not allow them to effectively control the problem of soil erosion (Sonneveld and Keyser, 2003).

In Ethiopia, environmental problem has been perceived as a result of “acts of God” or “acts of irrational peasants”, and real causes of the problem have not been fully assessed until very recent times. It is clear that there is not only one cause for such problem. The causes are interlinked and are difficult to discriminate one from the other. As a result, the solutions to the problem are difficult to be achieved (Tadesse, 1995). The causes of the problem as given by different authors are shown hereunder.

According to Hurni (1993), the problem of land degradation, which concerns processes of deforestation, soil erosion, biological soil deterioration and over-grazing, happened because of the introduction of agriculture several thousand years ago in the Ethiopian highlands and mountains.

Soil erosion resulted in the Ethiopian highlands due to past agricultural practices. In addition, the dissected terrain, availability of more area with slopes above 16 percent, high intensity of rainfall lead to accelerated soil erosion once deforestation occurs, some farming practices aggravate the erosion problem in that the cultivation of *teff*(*Ergrotis tef*) and wheat(*Triticum sativum*) require fine-grained seedbed, single cropping of fields and down-slope final plowing to foster drainage, and another cause may be sociopolitical influences, that is insecurity of land-and tree tenure, have discouraged farmers from the activities of SWC (Badege, 2001).

Land degradation in Ethiopia is closely related with the country's political economic realities that determined the resource access profile of Ethiopian societies. The factors that forced the peasants to use their farm plots far beyond their capacities are excessive rents imposed on them, ineffective tenurial legislation, incompatible development programs and projects, and unsuccessful extension works and credit arrangements that benefitted the non-target people (Zemenfes, 1995).

According to Demel (2001), there are three fundamental causes of land degradation in Ethiopia that efforts in addressing this problem should emphasize on: 1) rapid population growth, 2) low agricultural productivity and 3) high dependence on fuel wood as a source of household energy. From the above paragraphs, it is possible to infer that the land degradation in Ethiopia is a result of interrelated factors. Following this, the consequences of land degradation in Ethiopia are presented.

Paulos (2001) described that since land degradation leads to decline in the productive capacity of the land, it has also been a significant factor for the low yield of crops and livestock in Ethiopia. Because of land degradation, the valley bottoms, which could have been put to irrigation, are filled with sediments. Several irrigation projects and structures have failed because of the fact that the canals and micro-dams are filled by sediments (e.g. the Borkena micro-dam in South Wollo). Demel (2001) noted that in Ethiopia, land degradation is causing low agricultural productivity and production. In 1990, a grain production loss of 57,000 (at 3.5 mm soil loss) to 128,000 tons (at 8 mm soil depth) is resulted due to reduced soil depth caused by soil erosion. It has been assumed that the grain production loss that occurred in 1990 could have been enough to feed more than four million people.

It is undeniable fact that land degradation has been a serious threat to Ethiopia's people in general and Ethiopia's farmers in particular. Therefore, to tackle the poverty and boost the country's economy, it is required that effective conservation practices should be implemented. The following paragraphs deal with the conservation activities and measures put into practice to arrest land degradation in Ethiopia.

The severe land degradation problem especially in the northern parts of Ethiopia caused different problems to the people as well as to the physical environment. This situation initiated the government and non-governmental organizations to give emphasis to SWC measures. Stone bunds and earth banks have been implemented in the northern highlands through the Food-For-Work (FFW) program. Other measures that have been applied in different parts of the country are contour bund, hedgerow planting of agro-forestry trees, and planting of vetiver and elephant grasses on the contour. Afforestation of degraded lands is another practice that farmers have been applying to avert land degradation (Paulos, 2001).

Since the mid 1970s World Food Program (WFP) of the United Nations (UN) has been involving in soil conservation, afforestation and small scale irrigation projects in Ethiopia. Its assistance in this regard is mainly through the FFW program and in this case farmers who engage in conservation projects are awarded with grain and vegetable oil (Badege, 2001).

The conservation programs implemented so far in Ethiopia are inadequate and are not as such successful for they ignored the socioeconomic realities of the community and because of institutional and technical constraints (Demel, 2001; Paulos, 2001; Asrat et al., 2004). The life of impoverished people can damaged by adverse environmental problem like land degradation, but it can also be harmed by conservation programs if these programs don’t consider their needs (Cao et al., 2010).

In contrary to Demel (2001), Paulos (2001) and Asrat et al. (2004), Nyssen et al. (2014) argued that even though there was strong gully incision in 1960 in the northern Ethiopia, since 2000 gully erosion rates are reducing due to improved conservation activities and vegetation cover. The total cereal production in Ethiopia is now higher than ever and the food production per capita in 2005-2010 was 160% of that in 1985-1990. Attempts are now to increase flower and vegetable exports and there is also a growing export of a mild narcotic *chat* which needs much water. Similarly, Hurni et al. (2010) noted that in the past 35 years, various SWC measures have been implemented successfully in some parts of the Ethiopian highlands. This is an encouraging task, but a lot has to be done in the coming decades.

2.6. Impacts of Area Closure and/or Landscape Restoration: Empirical Evidences

So far, several scholars have tried to explore the impacts of restoration on soil physico-chemical properties, socioeconomic development of farmers, vegetation cover and diversity. They are given below:

2.6.1. Impacts on Land Cover Change

Land cover change results due to either manmade activities or natural forces (Wen et al., 2011). Detecting such change by using aerial photographs and satellite imageries is crucial for designing a plan for the sake of management of available resources (Kebrom and Hedlund, 2000). It is generally believed that one of the factors that lead to land cover change is area closure. Area closure is one of the SWC measures that the Ethiopian government has been putting in place in order to restore degraded lands. It is mainly practiced on hillsides. The impacts of area closure / exclosure / restoration projects on the land cover of different areas as given by different scholars are given below.

As Gao et al. (2011) depicted, exclusion of livestock from grazing lands led to improvements in vegetation coverage and plant biomass due to enhancements in perennial grasses and sedges. Wolde et al. (2007); Wendwessen (2009); Gao et al. (2011); Mengistu (2011) pinpointed that area closure/exclosure restores vegetation cover and diversity as compared to the open sites. Descheemaeker et al. (2009a) found out that exclosures improve vegetation cover and total leaf area that in turn lead to the increment in litter production. On the other hand, Emiru et al. (2006) investigated that exclosures positively affect density but they don’t have positive impacts on diversity as compared with open sites. In such study, it was also confirmed that the ground cover of exclosures is higher than the corresponding cover found in open sites.

2.6.2. Impacts on Soil Characteristics

One of the reasons that area closures/exclosures are implemented is to improve soil characteristics and in turn to restore soil fertility. Tefera et al. (2005) explained that area closures enhance fertility of the soil through their role in the supply of nutrients from litter. With regard to such impacts of area closures/ exclosures, the below-mentioned scholars investigated the following.

In an attempt to study the restoration of degraded alpine meadow, it was obtained that there is a difference in vegetation cover and soil characteristics between overgrazed and exclosed areas. There was also an increase in soil organic carbon and total nitrogen in the 0 - 10 cm soil layer with the increase in exclosure time. Higher soil clay and water were exhibited in the exclosed sites than in the grazed sites. This implies that degraded alpine meadow can be recovered and this recovery leads to improvements in soil fertility (Gao et al., 2011). In the study conducted in Guba Lafto, North Wollo, Ethiopia on effectiveness of exclosures, it was found out that higher organic carbon (9 g/kg) and total nitrogen (1.2 g/kg) exhibited in the exclosure soils than in open sites (Shimelis, 2012). Furthermore, in another study implemented in Ethiopia, it was obtained that soil organic matter content in area closures is significantly higher than their adjacent grazing lands (Mengistu, 2011). Wolde (2013) revealed that higher available phosphorus, soil organic matter, Cation Exchange Capacity (CEC) and total nitrogen are exhibited in exclosures than in adjacent grazing sites.

As a result of age and management of exclosures, climate, soil condition, and other related factors, there could also be impacts of exclosures/area closures different from the aforementioned ones. In agreement with this, Wendwessen (2009), who conducted a study in Habru district, North Wollo, Ethiopia found out that no significant difference exhibited between area closure and open-grazed area and among the three different aged area closures in terms of soil pH, available phosphorus, available potassium and Cation Exchange Capacity (CEC). However, there was an increasing trend for soil organic matter with an increase in the age of area closure. Similarly, in a study done in

South Africa by Moussa et al. (2009), it is deduced that short-term exclusion of livestock from communal plots doesn't lead to as such a significant improvement in soil fertility.

2.6.3. Impacts on Household's Livelihood

Area closure directly or indirectly plays a major role in socioeconomic as well as ecological aspects (Mengistu, 2011: WLRC, 2015). In support of this, the following scholars depicted the impacts of exclosures/area closures/conservation projects on the livelihood of households.

Haile (2012) confirmed that households in closed sites get forage, thatching grass and cactus fruits, and some of them also produce honey. WLRC (2015) also investigated that area closures are important sources of income through fruits, honey and timber production, and animal fattening. As given by the same source, area closures increase fodder production and livestock's productivity, and also increase area of production of pasture. In addition to this, in Yanchang county, China in an attempt to evaluate the impacts of the conservation project, which was implemented in 1999 in order to tackle land degradation and restore the ecology, it was found that after 13 years, grain production rapidly decreased, and income sources for households varied for there was a rise in number of people searching for job in towns and cities. It was also investigated that land-dependent incomes (e.g., orchard income) and non-land-dependent incomes (e.g., migrant worker income) are the major sources of total household income. Besides, rural people's activities transformed from farming to non-farming jobs which led to less pressure on local land and the environment (Zhen et al., 2014).

The most essential point that restorationists should consider is not only the restoration of physical environment but they also should take into account of the improvement of household's livelihood. In connection with this, Cao et al. (2010) described that the environment restored at the expense of human needs is totally unfair.

2.6.4. Impacts on Soil Erosion

The government of Ethiopia has been practicing integrated watershed management that incorporates various SWC measures including area closures in severely degraded areas. One of the reasons for doing so is to reduce soil erosion. The impact of area closure/exclosure on soil erosion is given below.

Nyssen et al. (2007) explained that besides their effects on enhanced infiltration, decreased sediment deposition and downstream flooding, exclosures provide ecosystem services such as growth of grass and trees, increase in wildlife and biodiversity, climate regulation, drought mitigation and carbon sequestration' (Nyssen et al., 2007). Descheemaeker et al. (2006) also pointed out that exclosures can trap water and sediment which in turn implies that they contribute to the conservation of soil and water.

Area closure reduces run off and soil loss (Tefera et al., 2005; WLRC, 2015), meaning it reduces soil erosion (Tefera et al., 2005; Emiru et al., 2006; Wolde et al., 2007; Descheemaeker et al., 2009a and 2009b; Haile, 2012) and it even causes streams to be recharged (Emiru et al., 2006; Haile, 2012; WLRC, 2015).

For the sake of controlling soil erosion effectively, area closure shall not be dominated by a single tree or shrub species. This is because all species don't possess the same potential to withstand drought, pest and disease, and again the choice of tree species shall be based on the ecological condition of the area where the area closure is going to be established and the interest of the community (Betru et al., 2005).

2.7. Sustainable Livelihoods Framework

It is a tool used for analyzing livelihood (Adato and Meinzen-Dick, 2002; Dirwayi, 2010). It is a conceptual framework which can be employed for analyzing peoples' poverty causes, their access to resources, their diverse livelihoods activities, the association between relevant factors at micro, intermediate, and macro levels, and for assessing and prioritizing interventions (Adato and Meinzen-Dick, 2002).

It is an analytical structure used for assessing the complexity of livelihoods, understanding impacts on poverty and for the purpose of identifying where interventions can best be done. Here, the assumption is that people pursue diverse livelihood outcomes (health, income, reduced vulnerability, etc.) by making use of different assets so as to pursue various livelihood activities. Peoples' preferences and priorities influence the kind of livelihood activities they adopt and the way they re-invest in asset building. Peoples' livelihoods can also be influenced by the types of vulnerability, including shocks (such as drought), overall trends (in, for instance, resource stocks) and seasonal variations. The structures (such as the roles of government or of the private sector) and processes (such as institutional, policy and cultural factors) which people face influence peoples' options (Farrington et al., 1999).

It doesn't exactly represent reality. It simply considers people as performing their activities with the presence of vulnerability. In this case, people have different assets/poverty reducing factors. These assets are defined and valued based on the existing social, institutional and organizational environment. This environment affects the livelihood strategies, i.e. ways of combining and using assets. These strategies can be applied to achieve beneficial livelihood outcomes which are essential to address people's livelihood objectives (DFID, 2001). Figure 2.3 shows the conceptual framework for sustainable livelihoods.

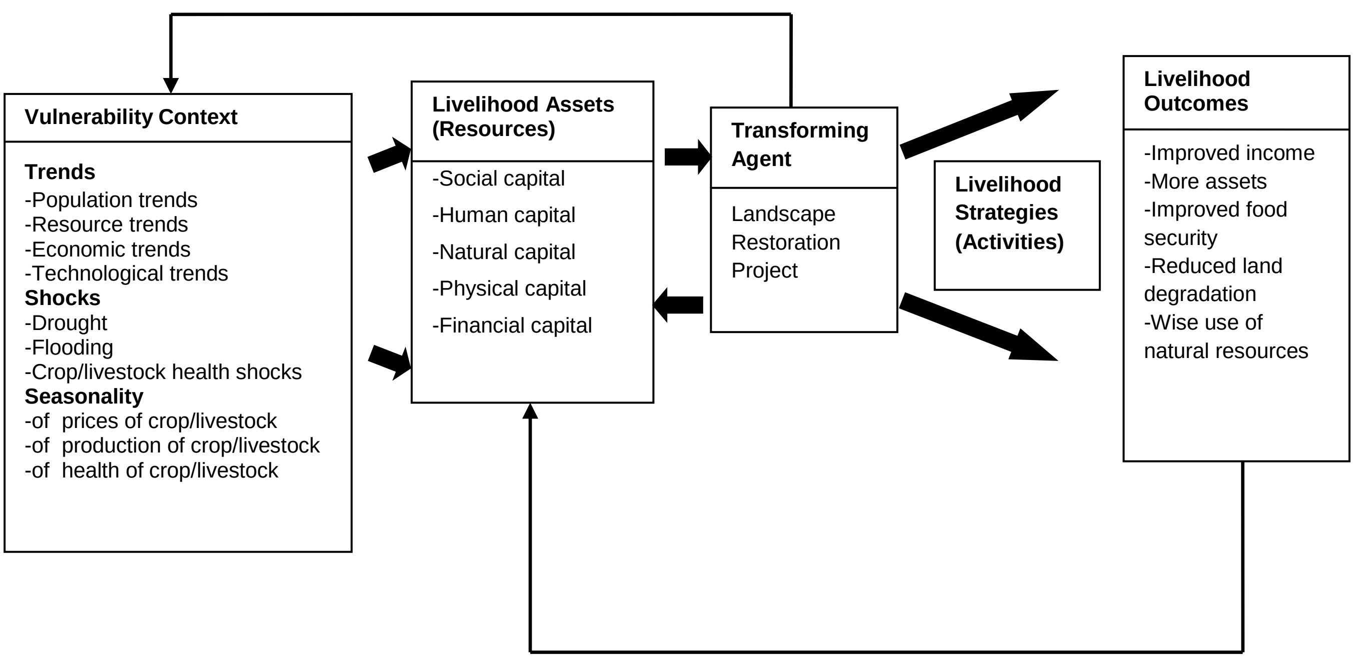


Figure 2.3. Sustainable livelihoods framework (Adapted from DFID, 2001)

As shown in the figure above, SLF comprises five major sections: i) vulnerability context, ii) livelihood assets, iii) transforming agent, iv) livelihood strategies and v) livelihood outcomes. The detail of each component is given below.

i) Vulnerability implies shocks (such as natural disasters, conflict, changes in human/animal health condition, and sudden economic changes), trends/changes in (such as population, resource, economic, and technology) and seasonality of prices, agricultural production, health, resource availability and employment opportunities (Adato and Meinzen-Dick, 2002).

ii) Livelihood assets refer to resources/capitals and there are five major capital types: human capital (includes skills, education, health), physical capital (includes produced investment goods), financial capital (includes money, savings, loan access), natural capital (includes land, water, trees etc.), and social capital (includes networks and associations) (Ellis and Allison, 2004).

iii) Transforming agent shape the asset base. It is mostly explained by the presence of new equipment resulted due to landscape restoration project becoming part of the physical capital that improve the natural capital like land and water. It strengthens human and social capital asset bases, as for example when new knowledge is gained and farmers work together on the process of restoration. The asset base can in turn affect the transforming agent. For example, social capital like social networks and social relationships may determine the implementation of restoration project (Adato and Meinzen-Dick, 2002). Transforming agent can determine people's choice of livelihood strategies (activities) and associated outcomes (returns), and it also affects vulnerability (DFID, 2001; Adato and Meinzen-Dick, 2002).

iv) Livelihood strategies imply the activities and choices that households and individuals employ in order to achieve more income, security, well-being, productive and reproductive goals (Adato and Meinzen-Dick, 2002).

According to Scoones (1998), there are three broad clusters of livelihood strategies. These are:

a) Agricultural intensification (i.e. gaining more output per unit area through capital investment or increases in labour inputs) or agricultural extensification (more land under cultivation).

b) Livelihood diversification: It means diversifying livelihood activities by farm and off-farm income earning activities.

c) Migration: It means moving away in search of better livelihood opportunity, either temporarily or permanently.

Livelihood diversification is one of the main livelihood strategies of households (Ellis, 1999; Ellis and Allison, 2004; Degefa, 2005). Livelihood diversification is essential for tackling vulnerability because it allows for positive adaptation of changing circumstances (Ellis, 1999).

v) Livelihood outcomes are the attainments of livelihood strategies (DFID, 2001). They include conventional indicators such as income, food security, and sustainable use of natural resources. They can also comprise a strengthened asset base, reduced vulnerability, and improvements in well-being such as health, self-esteem, sense of control, and even maintenance of cultural assets (Adato and Meinzen-Dick, 2002).

2.8. Conceptual Framework of the Study

As shown in Figure 2.4, the implementation of landscape restoration affects the livelihood of people, size of cultivated land, the land cover including the vegetation cover, soil fertility and productivity. Cao et al. (2009 & 2010) stated the role of considering the livelihood of households in conservation programs and also noted that both of them go hand in hand. Zhen et al. (2014) described that the China's restoration project of Grain for Green resulted soil erosion reduction, a decrease in size of farmlands, a coverage of large portion of farmlands by forests and grasslands, a reduction of grain production, income diversification, a decrease in land dependence and a flow of people to towns and cities in search of job. These changes in livelihood activities of people have contributed positively to conservation of the environment.

The conservation or landscape restoration programs of Ethiopia in 1970s and 1980s were not participatory and also failed to consider the livelihood of land users. As a result, such programs were not successful. So, in order to improve livelihood of households and restore damaged landscapes, the government of Ethiopia initiated relatively the successful MERET project in early 2000's (Gete et al., 2014). The study area, Hita-Borkena watershed, is established as a result of the MERET project. As a result of the project, different conservation measures have been implemented with the involvement of the community in the study watershed. And it is the researcher's belief that the area closure together with the other SWC measures employed in the study area are important means for addressing the problem of land degradation and for improving the livelihood of households.

The figure presented below depicts that landscape restoration occurred due to the different SWC measures including area closure is the cause for land cover change, livelihood diversification and reduction of soil erosion. The land cover change leads to the increase in conservation of vegetation, the increment in income from the production of crops, fruits and vegetables, an increase in income sources, a change in society and an increase in environmental conservation. In the study area, though most households are practicing crop production, there are some who do have a diversified source of income. The study watershed also witnessed good conservation of the available forestland, grassland and shrubland especially on steep slopes (> 36%). The increased coverage of cropland on the mid slope (12 – 36 %) compared to the available vegetation shall be addressed through afforestation or other appropriate means.

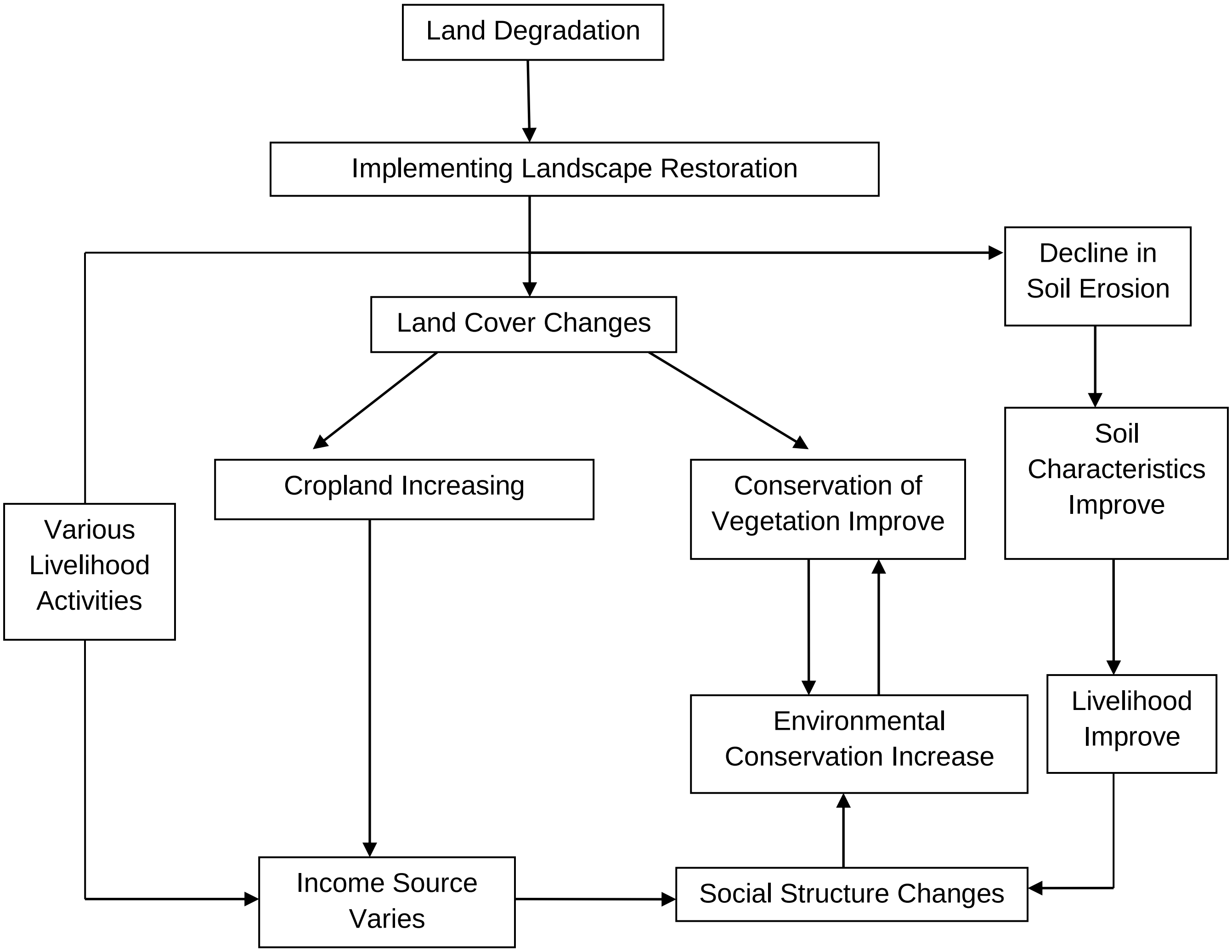


Figure 2.4. Effects of landscape restoration on the environment and community (Adapted from Zhen et al., 2014)

2.9. Conclusion

In Ethiopia, landscape restoration efforts that took place in 1970s were not successful for they ignored the people giving priority for the physical environment. Hence, the government of Ethiopia in collaboration with WFP implemented MERET project in the selected severely degraded areas of Ethiopia since 2000s. It was attempted so because it was learnt that conserving the environment ignoring the people didn't bring the desired outcome. From this, it can be inferred that impacts of area closure (landscape restoration) on the environment and the community shall be investigated at the micro level in order to gain lessons for future restoration efforts.

Chapter Three

3. Study Area Setting and Methodology

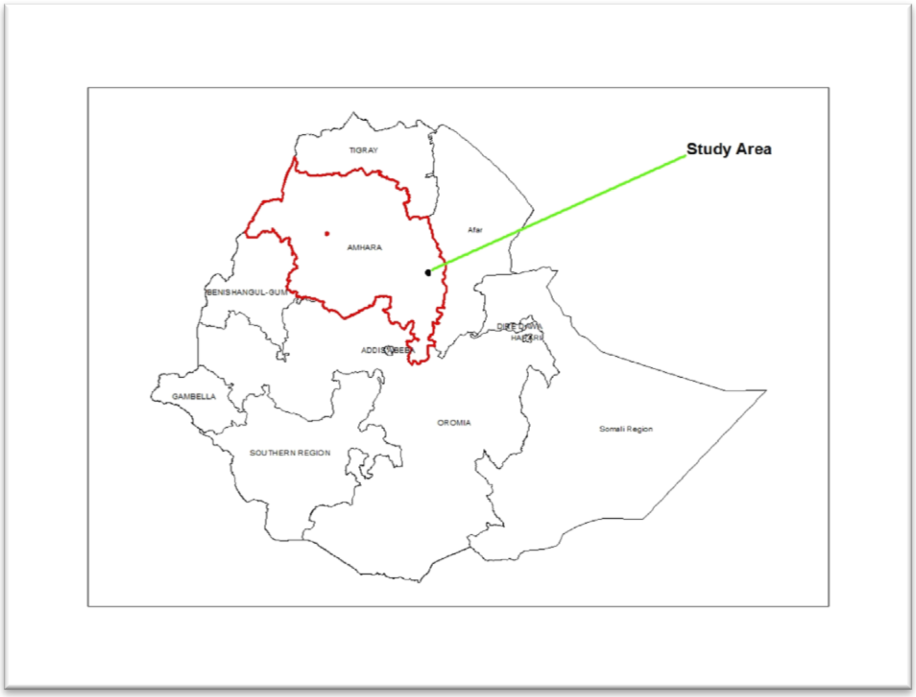
This chapter comprises two sections: description of the study area and the methodology employed for generating and analyzing the data. It deals with location, size, topography, climate, geology, soil, drainage, vegetation, population, farming system, natural resources management activities of the study area. It also includes the research design, data sources, sampling size and techniques, and data collection and analysis techniques.

3.1. Description of the Study Area

3.1.1. Location and Size

Hita-Borkena watershed is found in the southern part of Kalu district, South Wollo Zone of Amhara National Regional State of Ethiopia. It is located between $10^{0}55'10''$ – $10^{0}59'4''$ N and between $39^{0}44'53''$ – $39^{0}47'30''$ E (Figure 3.1). Its total area is 20.94 square km. It is about 40 km southeast of Dessie, South Wollo zone's capital, and is 360 km northeast of Addis Ababa, Ethiopia's capital. It is located along the main asphalt road that connects Addis Ababa to Kombolcha -Dessie-Mekele.

a)



b)

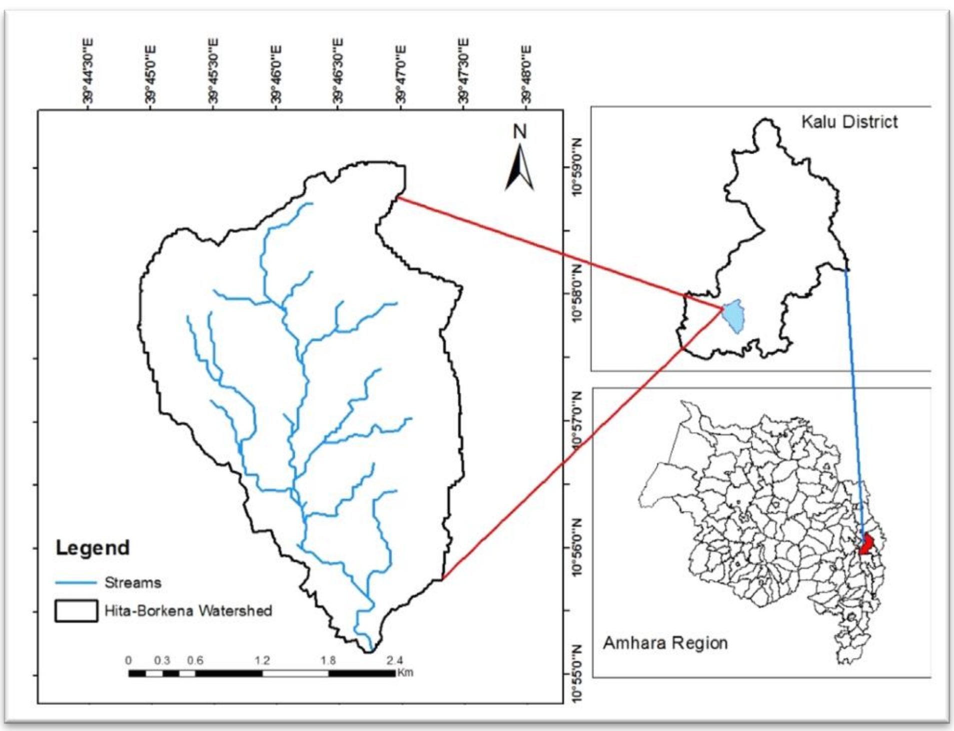
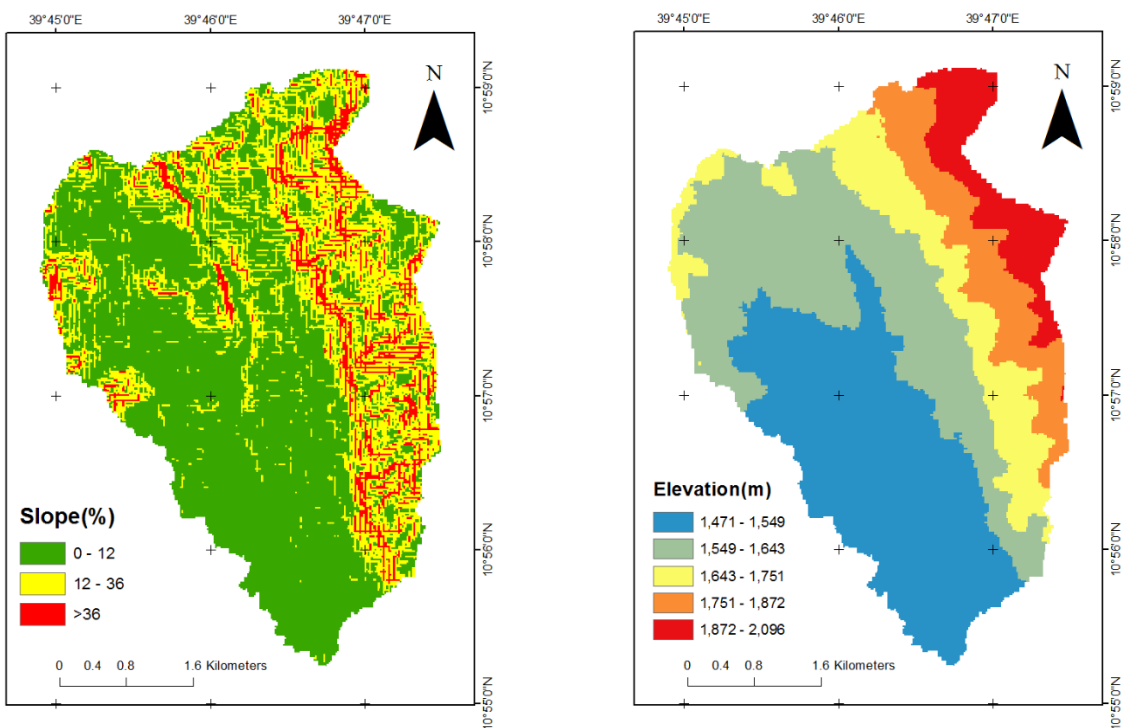


Figure 3. 1. Map of Ethiopia (a) and Hita-Borkena watershed, northeastern Ethiopia (b)

3.1.2. Topography

The watershed is found in the western escarpment of the rift valley of Ethiopia and at the tip of the northern highlands of Ethiopia. Like most parts of Wollo, the watershed is with various topographic features. Its topography comprises hills, undulating landscape and gorges. The south and southwestern parts of the watershed are dominated by mostly a gentle slope (0-12%), whereas its eastern section is more of steeper (>36%). Its elevation ranges from 1471 – 2096 m asl. The Digital Elevation Model (DEM) of the watershed reveals that the highly elevated areas are found in the east while the lowest ones in the south.



a) Slope (%) b) Elevation (m)

Figure 3. 2. Slope (a) and elevation (b) maps of Hita-Borkena watershed, northeastern Ethiopia

3.1.3. Climate

The mean annual temperature for the years 2000 – 2011 was 21.6 ^{0}C (Kombolcha Meteorology Station, 2013). During these years, the highest mean annual temperature (22.76^{0}C) was recorded in 2003 whilst the lowest mean annual temperature (18.73^{0}C) was recorded in 2000.The daily range of temperature usually increases in the months of April, May, June and July. The study area enjoys two rainy seasons: *Kiremt* (main rainy season usually exist between July and September) and *Belg* (small rainfall occurs mainly in March and April). The two seasons together contribute about 78 % of the annual rainfall distribution of the area. The mean annual rainfall for the years 2000 – 2011 was 1069.47 mm. During these years, the highest annual rainfall (1635.4 mm) was recorded in 2001 and the lowest annual rainfall (798.9 mm) was recorded in 2011. The maximum rainfall occurs mostly in the months of July and August. According to Hurni et al. (2016) classification, the study area is found under moist *weyna dega* (moist midland) agro-ecological zone.

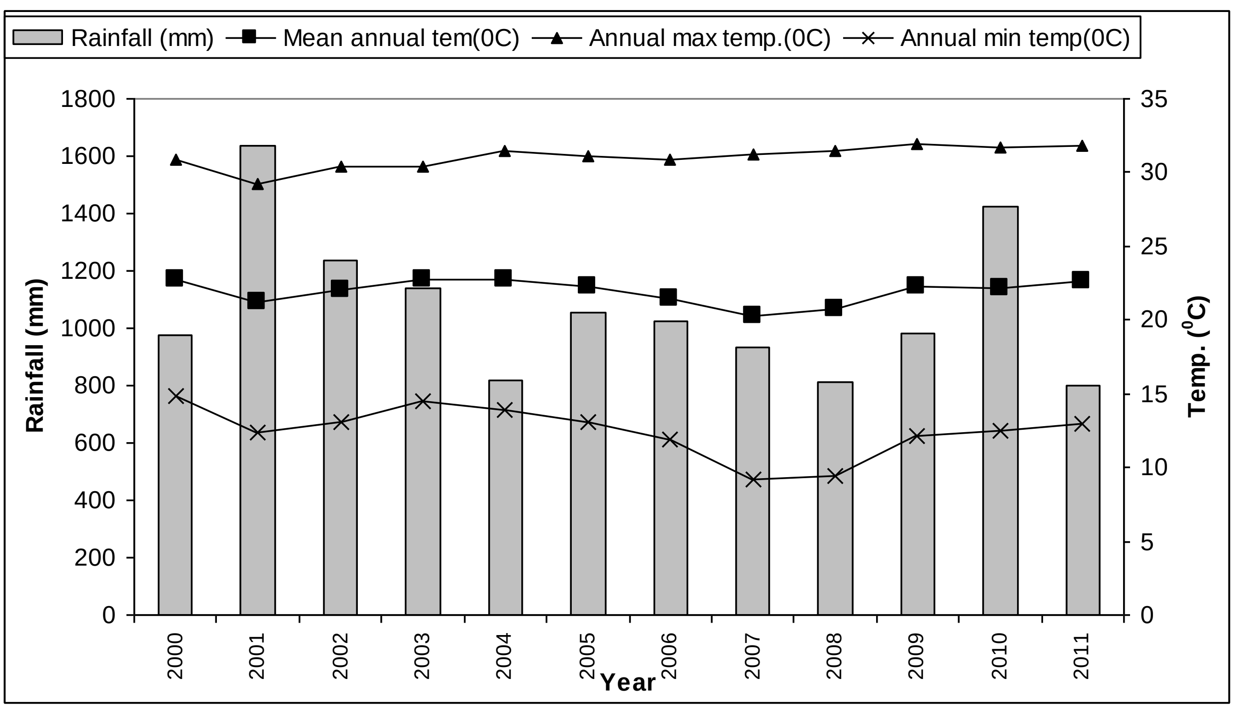


Figure 3. 3. Mean annual temperature and total annual rainfall of the study watershed (2000-2011)

3.1.4. Geology, Soil Types and Drainage

The study watershed is a result of both endogenic and exogenic geological processes. It is mainly covered by volcanic rocks formed during Tertiary period of Cenozoic era. The rocks are composed of Oligo-Miocene Trap basalts and are with faults and fractures (Abbate et al., 2014; Mengesha et al., 1996).

The study area consists of three main soil types: Cambisols, Regosols and Vertisols. Cambisols are the most dominant soil types covering 87.3 % of the area of the watershed, followed by Regosols (12.5 %) and Vertisols (0.2 %). Cambisols generally have relatively a soil profile with a moderate condition and are known for lack of adequate quantities of organic matter, Al and/or Fe compounds and illuviated clay. Regosols are those with poorly developed soil profile and their profile can't be easily differentiated because of slow rate of soil formation and/or young age. Vertisols are soils with a high swelling clay contents. They show deep and wide cracks when they are dried out and also swell when they gain moisture (IUSS Working Group WRB, 2015). The study watershed is part of the Awash River basin. It is mainly drained by Borkena River and also by a smaller stream called Hita.

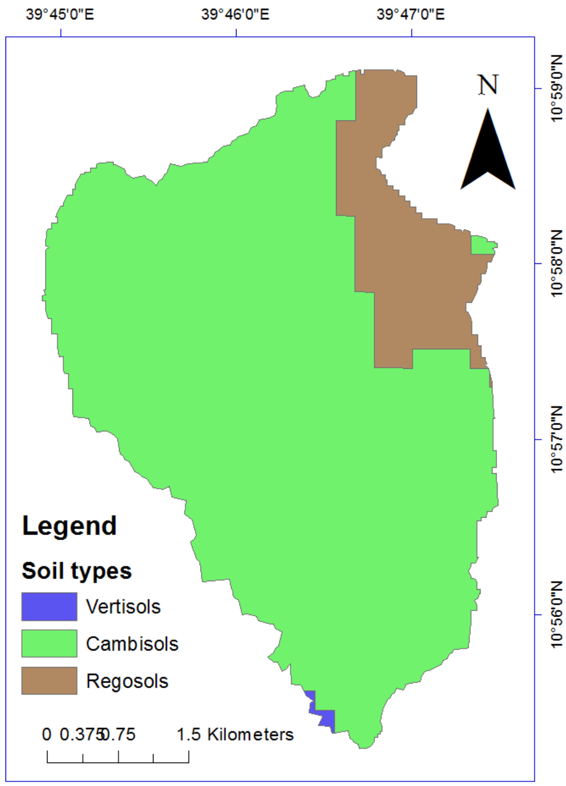


Figure 3. 4. Soil Types of Hita-Borkena watershed, northeastern Ethiopia

3.1.5. Vegetation

Most of the vegetation types of the study watershed are found on the hillsides (in area closure) while some are also located around homesteads, on farm boundaries, grave yards, floors of gorges and on road and river sides. The main vegetation types found in the study area include different acacia species (*Acacia tortilis, Acacia seyal, Acacia brevispica*, and A*cacia nilotica*), *dedeho* (*Euclea racemosa* subsp. *schimperi),* tree euphorbia/*kulkual* (*Euphorbia abyssinica), kitkita* (*Dodonaea viscose*), *agam* (*Carissa spinarum, C. edulis), key bahir zaf* (*Eucalyptus camaldulensis), wanza* (*Cordia Africana), qurqura (Ziziphus spina-christi),* brown olive/*weira (Olea africana),* ironwood/*digita (Cassia siamea),* river bean/*girangire (Sesbania sesban), Grevillea (Grevillea robusta), and* pepper tree/*qundo berbere (Schinus molle).*

Figure 3. 5. Grasses, trees and shrubs in area closure in Hita-Borkena watershed, northeastern Ethiopia

3.1.6. Population and Major Land Cover Types

There are a total of 4578 persons living in the watershed, as estimated from the average population density (218.64 persons/km^2) of Kalu district. The population density of the watershed and the district is much greater than the average for Amhara National Regional State (101.31 persons/km^2) and for Ethiopia (67.05 persons/km^2) (CSA, 2008a and 2008b).

This study identified six major land cover types in the watershed: barelands, croplands, forestlands, grasslands, settlements and shrublands. Croplands cover about 63 % of the area of the watershed while shrublands and grasslands together constitute about 28 %. Currently, due to the closure of hillsides, the area covered by forestlands, shrublands and grasslands in combination on steep slope (> 36 %) is greater than the corresponding value for cropland.

3.1.7. Farming System

Agriculture is the main economic base of the residents of the study watershed. People in the watershed practice a mixed farming system with high emphasis on cereal crops (Gete et al., 2014). The major cereal crops that grow in the area are sorghum, *teff*, maize, *masho* (a local name for a variety of haricot bean), and chickpea. Those fruits and vegetables that commonly grow include orange, mango, papaya, guava, lemon, onion and tomato. Among the livestock, cattle, small ruminants and chickens are the major ones. In addition, some farmers also supplement their income by growing coffee, *chat* and eucalyptus and also by involving in beekeeping.

3.1.8. Natural Resources Management

Because of MERET project, different conservation activities have been implemented in this watershed since 2001/2. Through this project, wastelands are either restored or changed into farmland. In this watershed, there are 'closed areas'. The majority of these 'closed areas' are given for farmers for feeding their livestock using cut-and-carry system, and the remaining area is given for female farmers for undertaking different development activities. The watershed is covered with different SWC measures. The efforts made not only conserved the natural resources but also benefitted the local farmers (Kalu District Agriculture Office, 2013).

3.2. Research Design

Though much emphasis was given to quantitative approach, this study followed a mixed research design. A mixed method allows the researcher to employ both qualitative and quantitative approaches and exploit the advantages of such an empirical study (Creswell, 2009; Denscombe, 2007; Hashemi and Babaii, 2013). It was selected because of the reasons that it does have the following advantages: it is a useful means to converge data obtained from different sources (Creswell, 2009), it improves the accuracy of the study, gives a complete and comprehensive picture of the theme under study, and also facilitates the running of data analysis in a smooth manner since one method is complementing the other even if a researcher is required to be skillful in dealing with the two aforementioned approaches (Denscombe, 2007). Moreover, the philosophical foundation of this study is pragmatism since it employed a mixed research design. Denscombe (2007) noted that pragmatism is often referred to as the appropriate philosophical underpinning for the mixed method research approach. Creswell (2009) also justified that pragmatism gives the room for having different techniques of data collection and analysis in the mixed research design.

Both qualitative and quantitative data were collected, analyzed and interpreted simultaneously. In doing so, a concurrent triangulation design was used for it was important to harmonize, cross-validate and corroborate the results of the study (Creswell, 2009; Hashemi & Babaii, 2013). In order to achieve the objectives of the present study, both primary and secondary data were used. The primary data was obtained by administering household questionnaire, in-depth interview and field survey. The secondary data was accessed from satellite images, Kalu District Agriculture Office and different literatures. The study made use of tables, graphs, descriptive and inferential statistics so as to analyze the collected data quantitatively. Besides, a qualitative data was also analyzed with the help of a qualitative approach.

3.3. Data Sources

The study used both primary and secondary data. The secondary data which was needed for this study include satellite images, toposheets, socio-economic data, data on previous conservation works and climate data. The secondary data was obtained from published and unpublished sources of the governmental and the non-governmental organizations, and from relevant websites.

The primary data was obtained through field survey, laboratory analysis, photographing, in-depth interview and semi-structured questionnaire.

3.4. Target Population, Sample Size and Sampling Technique

3.4.1. Target Population

The study area, Hita-Borkena watershed, was selected purposely. The reason for selecting the watershed was that since it is part of Kalu district, which doesn’t receive sufficient annual rainfall and is severely degraded, the district's agriculture office in collaboration with WFP implemented landscape restoration since 2001. Thus, the study watershed was selected to assess the impact of such restoration on the environment and society. The target populations of the study were those households living in Shehana-Borkena and Tikuro sub-watersheds, both found in the study area.

3.4.2. Sample Size and Sampling Technique

The sampled households were taken from Shehana-Borkena and Tikuro sub-watersheds. The two sub-watersheds were purposefully selected because of the availability of area closure (574 ha in Shehana-Borkena and 163 ha in Tikuro), which is the concern of this study. The total number of household in Shehana-Borkena and Tikuro sub-watersheds were 410 and 343, respectively (Kalu District Agriculture Office, 2013). The sample size was determined following two steps sample calculation procedure: in the first step, sample size was determined for infinite population and in the second step, actual sample size for the study area was determined by applying sample size correction calculator for the known population (CRS, 2012) as indicated hereunder:

$$S = \frac{Z^2 * P * (1-P)}{C^2} \text{-------------------------} (1)$$

Where:

Z is Z-value (1.96) for 95 confidence level

P is percentage picking a choice, expressed as a decimal (0.5)

C is confidence interval expressed as a decimal (0.05 = ±0.05)

Subsequently, actual sample size for the study area was determined as:

$$SS_{kp} = \frac{S}{1 + \frac{S-1}{P_k}} \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (2)$$

Where:

SS_{kp} is sample size for the known population size

S is sample size for unknown population calculated using equation 1

P_k is known population size from which sample size is calculated

Thus, 255 farm households (33.8%) of the study population were selected randomly for household questionnaire survey; 139 from Shehana-Borkena and 116 from Tikuro. Additional data was also gathered from 7 agricultural experts through interview.

Before administering the questionnaire, attempt was made to identify the poor, rich and better-off farmers.

3.5. Research Methods

3.5.1. Studying Land Cover Dynamics

In order to analyze the land cover dynamics of the study watershed, cloud-free three satellite images was downloaded from the website of United States Geological Survey (USGS) named http://glovis.usgs.gov. The three images were Landsat TM (Thematic Mapper) of 1986 with 30 meters resolution, Landsat ETM+ (Enhanced Thematic Mapper Plus) of 2001 with 30 meters resolution, and Landsat ETM+ of 2015 with 30 meters resolution. The three years are selected on the basis of the period of implementation of MERET project in the study area. The year 1986 is selected because it is 15 years before the implementation of the project in the study watershed. The year 2001 is selected because it is the time when the project had begun. The year 2015 is selected because it is 14 years after the implementation of the project. Hence, using these reference years, it is possible to see the impact of the project on the land cover conditions of the study watershed.

The satellite images were clipped to fit the size of the study area. The images were radiometrically and geometrically corrected, and were georeferenced to Transverse Mercator geographic projection using WGS84 as a datum (Belay, 2002: Messay, 2011). Then, unsupervised classification was done to identify major land cover classes depending on their reflectance properties. Field visits and observations were made so as to collect ground truths, i.e. to identify the major land cover classes.

Incorporating data obtained from field visits and observations, supervised classification was made to produce three separate land cover maps for the three reference years. Such process led to the identification of six major land cover classes: forestland, shrubland, grassland, cropland, settlement and bareland. Accuracy assessment (Messay, 2011) was calculated for the 2015 land cover map. The overall accuracy was 86.57 % with a Kappa coefficient of 0.84. Furthermore, the producer's and user's accuracies were also calculated as shown in Chapter 5. The calculations were made using the following formulas taken from Congalton and Green (2009):

Overall accuracy = $\frac{\sum_{i=1}^{K} n_{ii}}{n}$ Producer's accuracy = $\frac{n_{ii}}{n_{+i}}$ User's accuracy = $\frac{n_{ii}}{n_{i+}}$

Where n = total number of points (sample)

k = number of categories (1, 2, 3, …, k)

n_{ii} = correctly mapped point for each land cover type (diagonal values usually bold type)

n_{i+} = number of map data points for each land cover type (row total)

n_{+i} = number of ground data points for each land cover type (column total)

The area covered by each land cover class in each year was determined. The change of each land cover class in the two time intervals: 1986-2001 and 2001-2015 was computed. In doing such analysis, graph and tables were used. These all processes were conducted by integrating ERDAS IMAGINE 9.1 and ArcGIS 10.3 softwares.

In order to analyze the link between land cover dynamics and slope, first a slope map was produced from the DEM of Ethiopia by surface analysis using spatial analyst tool of ArcGIS and then the slope map was classified into three classes based on Aklilu (2006): gentle slope (0-12 %), mid slope (12-36 %) and steep slope (>36 %). The area of each land cover type on each slope class for the three land cover maps was calculated using overlay analysis. To assess the relation between slope and area closure, the area of Forestland, Grassland and Shrubland (F-G-S) was aggregated for each slope class in the reference years. Also, emphasis was made on the improvement of vegetation on mid and steep slopes since area closures are located on such slopes.

3.5.2. Soil Sample Collection Method and Analysis

In order to partly evaluate the impacts of the restoration project, analysis and comparison of the physico-chemical characteristics of soils of restored (with the help of area closure and other SWC measures) and degraded adjacent open grazing areas (which are not treated with any conservation measures) was undertaken. In doing so, the first task was reconnaissance survey. It was carried out to identify representative soil sampling sites.

Since most parts of Hita-Borkena watershed are treated with SWC measures and are excluded from contacts of livestock and human beings, 24 composite soil samples were taken from the 'closed areas' (experimental groups), 15 from Shehana-Borkena sub-watershed and 9 from Tikuro sub-watershed, and 12 composite soil samples were collected from the degraded adjacent open grazing lands (control groups), 6 from Shenana-Borkena and 6 from Tikuro. That is, a total of 36 samples from 180 sampling sites were collected. The samples were taken using auger up to a depth of 20 cm. The samples were taken from four corners and the middle of each plot and were composited. The samples were taken from the three slope positions: upslope, midslope, and footslope. This is because drainage conditions vary along these positions. A total of 36 core soil samples were taken from the center of each plot from the three slope positions for bulk density determination. From these, 24 core soil samples were collected from the 'closed area,' 15 from Shehana-Borkena and 9 from Tikuro. The remaining 12 core soil samples were collected from the degraded adjacent open grazing sites, 6 from Shehana-Borkena and 6 from Tikuro.

The soil samples were kept using plastic bags, coded and were sent to Debrezeit agricultural and nutritional research laboratory for analysis of soil parameters other than bulk density. The bulk density was analyzed in Dessie regional soil laboratory.

The parameters that were analyzed in the laboratory are soil texture, bulk density, soil pH, soil organic carbon (SOC), total nitrogen (TN), available phosphorus (AvP), available potassium (AvK) and Cation Exchange Capacity (CEC). The samples were air dried, crushed and sieved before making analysis.

The soil texture was determined by hydrometer method, pH by 1:2.5 soil/water suspensions, SOC by Walkley and Black method, TN by Kjeldhal method, AvP by Olsen method, AvK and CEC by ammonium acetate extraction method. The core sample was dried by oven at 105^0 to determine bulk density. Soil organic matter (SOM) is derived from soil organic carbon using a simple formula, i.e. SOM = SOC x 1.72 (Landon, 1991). The total porosity (%) values are derived by taking the soil bulk density value measured in the laboratory and the average soil particle density value of 2.65 gcm^{-3}. The formula employed in this case was the one given by Hazelton and Murphy (2007).

$$\text{Total Porosity (\%)} = 1 - \frac{\text{Bulk density}(\text{gcm}^{-3})}{2.65\ \text{gcm}^{-3}} * 100$$

3.5.3. Identifying Environmental Problems, the Role of Area Closure and Methods Used for Restoration

Semi-structured questionnaire were prepared with the intention of identifying environmental problems before landscape restoration, the benefits of area closure in tackling environmental problems and the methods used to restore the area. Sample household heads were asked to respond to both the closed-and-open-ended questions and the well-trained enumerators interviewed the respondents. The questionnaire was administered after pretesting. This pilot study enabled the researcher to modify and discard some questions. The main issues addressed by the questionnaire are soil erosion, soil fertility, overgrazing, illegal cutting of trees, the different methods used to restore the study watershed, and main emphasis was given to area closure as one method for restoring the watershed. Additional data was also generated by interviewing agricultural experts who involve in managing the watershed. The interviews were recorded by cell phone by asking the permission of interviewees. In order to supplement data generated by questionnaire and interview, some sections of the watershed was also photographed by using photo camera.

3.5.4. Investigating Linkages between Landscape Restoration and Household Livelihood

In order to investigate the linkages between landscape restoration and household livelihood, SLF was used. Based on SLF, variables were selected for the sake of undertaking impact assessment. The selected variables were asset base, livelihood activities and livelihood outcomes of sample households. In this case, semi-structured questionnaire was used as a tool for collecting data on the impacts of MERET project on the selected variables (households' asset base, livelihood activities and livelihood outcomes) (Dirwayi, 2010). Here, asset base include house type, house utensils, farm implements and other assets like shop, car, tailor machine, etc. There were three possession statuses of such assets by sampled households: low, medium and high. Livelihood activities refer to on-farm and off-farm activities, whereas livelihood outcomes are those achievements (mainly related with income, food security and the environment) resulted due to the landscape restoration of MERET project. Figure 3.6 indicates the relationships among different variables that were studied in this research.

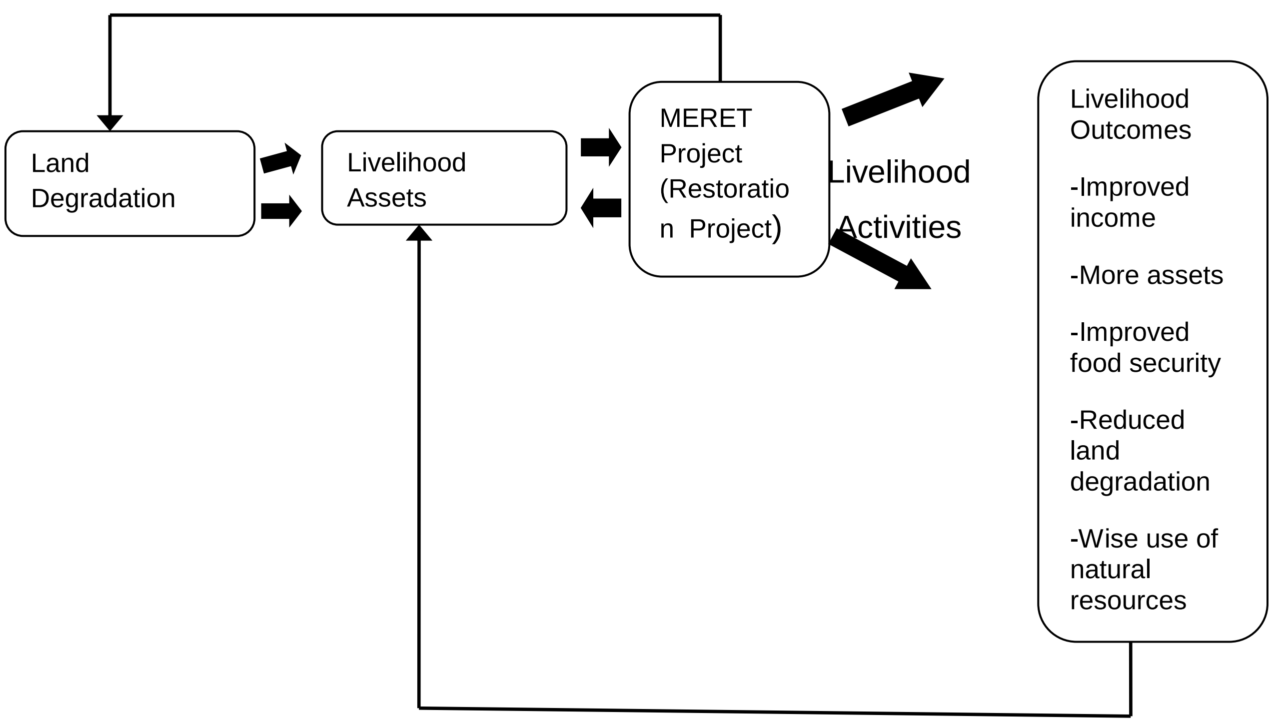


Figure 3. 6. A modified SLF (Adapted from DFID, 2001)

In addition, supplementary data was also generated using in-depth interview. Agricultural experts, who involve in the restoration project, were interviewed. Again, the talks were recorded so as to avoid the missing of valuable information.

3.6. Data Analysis and Presentation

The collected data was analyzed both quantitatively and qualitatively. In qualitative analysis, the responses of farmers and experts were described using qualitative technique. In the case of quantitative analysis, descriptive analysis, inferential statistics and bivariate correlation were used. The quantitative data was analyzed using SPSS (Statistical Package for Social Sciences) version 21 software.

Descriptive statistics: Descriptive statistics such as frequencies, cross tabulation, percentages, means, measures of dispersions, and figures were used.

Inferential statistics: In inferential statistics, Chi-square (X^2) test, one sample, independent samples and paired t-tests, and one-way and two-way analysis of variance (ANOVA) and test of association (r and r_s) were used and required test results were discussed at 0.05, 0.01 or 0.001 level of significances.

Chi-square (X^2) test was used to evaluate the dependence of status of food security on sex of the respondents and livestock possession.

One-sample t-test was computed to assess a statistically significant difference between the mean landholding (ha) of Ethiopia and the mean land holding size of the study watershed. It was also used to test the significant differences of scaled responses (responses that were collected in five-point Likert scale) of respondents from the central response/neutral values. The tested variables and their respective scale are given in the table below:

Table 3. 1.List of variables analyzed by one-sample t-test and their respective scale

Variable	Likert scale				
	1	2	3	4	5
Rate of soil erosion before landscape restoration	very low	Low	neither low nor high	high	very high
Rate of soil erosion after landscape restoration	very low	Low	neither low nor high	high	very high
Rate of existing soil erosion compared to the past	very low	Low	neither low nor high	high	very high
Rate of overgrazing before landscape restoration	very low	Low	neither low nor high	high	very high
Rate of current overgrazing problem compared to the past	very low	Low	neither low nor high	high	very high
Rate of community's benefit due to area closure	none/very small	Small	neither small nor high	high	very high
Rate of the importance of area closure in improving land productivity	very little	Little	neither little nor high	high	very high
Rate of agreement/disagreement with regard to the opinion that "area closure restores degraded land"	strongly disagree	disagree	neither disagree nor agree	agree	strongly agree
Rate of satisfaction/dissatisfaction in the involvement on area closure and other restoration activities	strongly dissatisfied	dissatisfied	neither dissatisfied nor satisfied	satisfied	strongly satisfied
Rate of the effect of the restoration project on farmers' livelihood activities	very negatively	negatively	neither negatively nor positively	positively	very positively
Rate of non-farm income of farmers after the restoration project	decreased very much	decreased	neither decreased nor increased	increased	increased very much
Rate of the number of income sources of farmers after the restoration project	decreased very much	decreased	neither decreased nor increased	increased	increased very much
Rate of farmers' current income as compared with the past 15 years	decreased very much	decreased	neither decreased nor increased	increased	increased very much

Independent samples t-test was employed to test the mean difference of selected physico-chemical soil properties under area closure and open grazing land. It was also used to analyze the statistical difference between food secured and insecured ones in terms of age, household size and landholding size. Here, Levene's test for equality of variances was used to test whether soil properties have the same or different levels of variability between the two land use types or not

One-way ANOVA was used to evaluate the statistical variation between household size and landholding size with that of economic status of sampled households. It was also employed to analyze the effect of slope positions (i.e upslope, midslope, and footslope) on the mean soil physico-chemical properties. For variables which were statistically significant ($p < 0.05$), *post hoc* Tukey Honestly Significant Difference (HSD) test was used to indicate where significant mean difference lies.

Two-way ANOVA was computed to see the impacts of land use type (i.e. area closure and open grazing land) and slope position (i.e. upslope, midslope and footslope) on selected soil physico-chemical properties.

Bivariate Correlation Matrix

Pearson product-moment coefficient of correlation (*r)* was used to assess the association between selected physico-chemical properties. Such association was also evaluated using scatter plots. The Pearson correlation was also used to test the association between income from sorghum and number of ox owned, and landholding size and coffee income.

Spearman rank coefficient of correlation (r_S) was calculated to test the relation between asset possession statuses and selected household characteristics.

Chapter Four

4. Demographic and Socioeconomic Characteristics of the Respondents

This chapter describes the demographic and socioeconomic characteristics of the sampled households of this study. The study area includes two target sub-watersheds found in Hita-Borkena watershed, namely Shehana-Borkena and Tikuro. In this chapter, it is intended to discuss age, sex, household size, marital status, educational status, and landholding size of the respondents. Attempts are also made to identify length of years that the sampled household heads reside in the current place of their residence and reasons responsible for changing previous residence, if any. The data presented in this chapter are assumed to be essential so as to interpret or understand the subsequent chapters of the thesis since landscape restoration and livelihood are the functions of the demographic and socioeconomic characteristics of households.

4.1. Demographic Characteristics

4.1.1. Age and Sex Structure

The data generated from the semi-structured questionnaire of the study depicted that the minimum, mean, median and maximum age of respondents were 22, 49, 49 and 83 years, respectively; with standard deviation of 11.04 (Table 4.1). The average age of household heads of this study is almost close to and between the average age reported by Efrem (2010), i.e., 44 years, and Arega (2013), i.e., 51 years. Almost similar mean age was observed for both male-and female-headed household (i.e., about 49 for male and 50 for female) (Table 4.1).

Table 4. 1. Descriptive statistics of age of respondents by sex of household heads

Sex of household head	Descriptive statistics of age of respondents						
	N	% of Total N	Minimum	Maximum	Mean	Median	Std. Deviation
Male	220	86.3	22	83	49.29	50.00	11.12
Female	35	13.7	30	80	50.20	49.00	10.65
Total	255	100.0	22	83	49.42	49.00	11.04

While the minimum age of the respondents was 22, about 12.6% were aged less than 37, 16.5% were between 37–44, and 70.9% were above 44 and less than 84 years old (Table 4.2). This implies that the majority of the respondents belong to the category of adult population presumably with possession of good knowledge of the problems of the study area.

Table 4. 2. Age of sampled household heads

Number and % of household head	Age of household head								Total
	21-28	29-36	37-44	45-52	53-60	61-68	69-76	77-84	
Number	4	28	42	88	58	20	2	13	255
Percent	1.6	11.0	16.5	34.5	22.7	7.8	0.8	5.1	100

The household survey revealed that 35 of the sampled households (13.73%) were female-headed, whereas 220 of them (86.27 %) were male-headed. Such result is relatively low as compared to 20 % female-headed households incorporated in the study conducted by Efrem (2010), but it is almost similar with the number of female-and male-headed households involved in the study made by Arega (2013). Fourteen and 86 % of the households selected by Arega (2013) were female-and male-headed, respectively.

The total number of household members of the surveyed household heads was 1,272. Of whom, 679 (53.38 %) were males, whilst 593 (46.62%) were females (Figure 4.1). It was found out that 10 out of the total 1272 household members had blood relation with the respective household head or spouse. Furthermore, there were no non-relatives living with the households. This leads to interpret that the majority of the respondents were living with their respective children and spouse and were in turn receiving labor and related supports from them.

Household members aged below 15 and above 64 accounts for 37.74% and 2.64%, respectively, while members between the age of 15 and 64 accounts for 59.62% (Figure 4.1). This implies that about 6 persons out of 10 of the household members were assumed to be economically active. The percentage of the household members below the age of 15 (i.e., 37.74%) was lower than the percentages of the same age population of Ethiopia i.e., 45% (CSA, 2008a and EDHS, 2014) and Amhara region, i.e., 43% (CSA, 2008b). In contrast to the broad-based population pyramid of developing countries in general and Ethiopia in particular, household members under the age of 5 of the study area and Amhara region represented narrow base (Figure 4.1). The number of male and female members of the sampled households in each age group was relatively disproportional unlike the condition in Amhara region where the study area is located and in Ethiopia (Figure 4.1). From Figure 4.1, it is possible to infer that there was relatively lower rate of fertility in the study area and in Amhara region compared to Ethiopia and developing countries.

Hita-Borkena Watershed (2015) Amhara Region (2015) Ethiopia (2015)

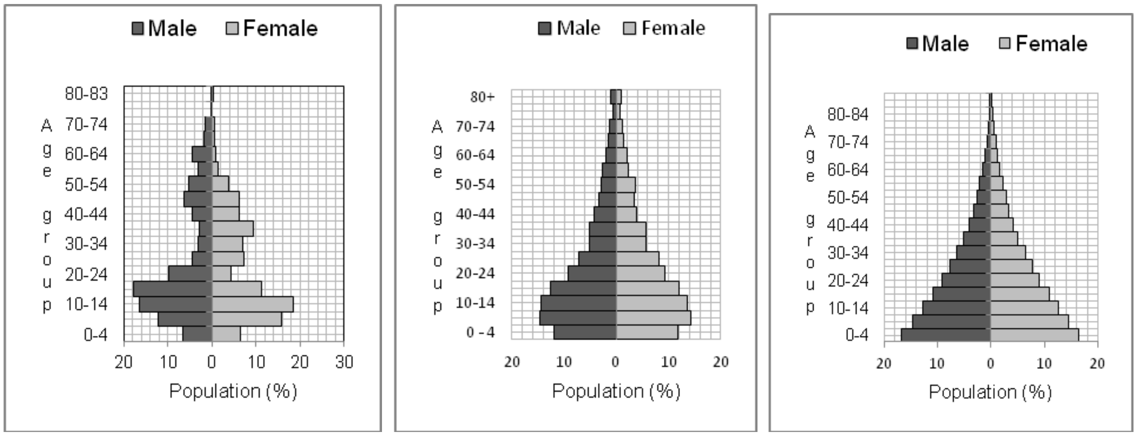


Figure 4.1. Population pyramids of surveyed households of Hita-Borkena watershed, northeastern Ethiopia (left), Amhara Region (middle; ANRS-BoFED, 2016), and Ethiopia (right; United States Census Bureau (USCB), 2016)

4.1.2. Household Size

The mean household size of the respondents was 5, while the standard deviation was 1.6. The minimum and maximum household sizes were 1 and 10, respectively. The distribution of household size is almost normal, i.e. not relatively skewed, and the highest number of respondents did have the household size between 4 and 6 (Figure 4.2.). This is in line with the study conducted by Arega (2013), who revealed that the average family size and the standard deviation of the sampled households are 5.2 and 2, respectively. The same author also found out that the highest number of surveyed households lies between 4 up to 6 family sizes.

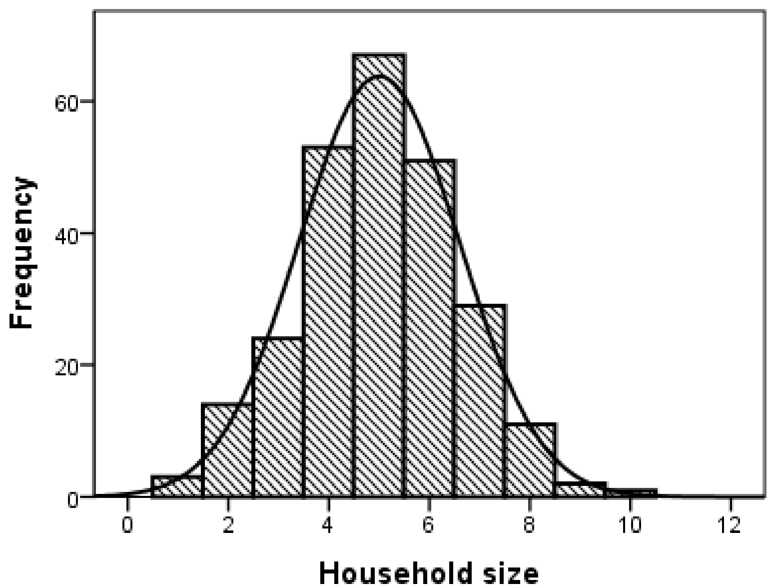


Figure 4.2. Household size of the respondents

About 76% of the informants had household size between 3 and 6. Those with household sizes below 3 and above 6 account for about 7% and 17%, respectively (Figure 4.2). With regard to household size, Tegegne (2014) found out that surveyed households containing members below 3, 3-8, and above 8 constitute 8.6, 69, and 22.4 %, respectively. Dirwayi (2010), on the other hand, indicated that out of the total sampled households, those with size ranging from 1 – 4 , 5 –10 and > 10 account for 57.1, 41.5 and 1.4 %, respectively.

As can be identified from the household survey, the maximum household size was exhibited by male-headed households (Table 4.3). This is due to the reason that the majority of female respondents were widowed. Table 4.6 also shows how household size is related with marriage. The result of this study is in agreement with Arega (2013), who stated that the surveyed households headed by females did have very low family size.

Table 4. 3. Household size by sex of household head

Sex of household head	Household size					Total
	1-2	3-4	5-6	7-8	9-10	
Female	7	17	11	0	0	35
Male	10	60	107	40	3	220
Total	17	77	118	40	3	255

The average number of children living with the sampled households was 3; with the standard deviation of 1.518. The minimum and maximum numbers of children identified in this study were 0 and 8, respectively. About half of the respondents had a number of children between 3 and 4. Those households with a number of children below 3 and above 4 account for around 33 and 17%, respectively (Table 4.4).

Table 4. 4. Number of children of respondents

No. and % of children	Number of children					Total
	Nil	1 – 2	3 - 4	5 – 6	7 - 8	
Number	13	71	128	40	3	255
Percent	5.10	27.84	50.20	15.69	1.18	100

4.1.3. Marital Status

The household survey indicated that 83.53% of the respondents were married whereas 3.14, 10.98, 2.35% were divorced, widowed and widower, respectively (Table 4.5). No single or unmarried respondent was recorded in the survey. Similarly, Arega (2013) and Tegegne (2014) found that the majority of the sampled informants are married. But as opposed to this study, both of the aforementioned researchers noted that there is small number of single respondents in their study.

Table 4. 5. Marital status of surveyed household heads

Number and % of household heads	Marital status					Total
	Single	Married	Divorced	Widowed	Widower	
Number	0	213	8	28	6	255
Percent	0	83.53	3.14	10.98	2.35	100

The variation in the type of marital status has got direct implication on the size and structure of households and families (Tegegne, 2014). Similar to this fact, it was assured using the questionnaire survey that large household size was related with married household heads whereas smaller household size was found to be correlated with divorced, widowed and widower household heads (Table 4.6). This result is in consistent with the general truth because marriage in general is most of the time the base for the increase in number of births.

Table 4. 6. The relationship between marital status and household size

Marital status	Household size					Total	Percent
	1 – 2	3 - 4	5 – 6	7 – 8	9 – 10		
Married	6	58	106	40	3	213	83.53
Divorced	2	4	2	0	0	8	3.14
Widowed	6	13	9	0	0	28	10.98
Widower	3	2	1	0	0	6	2.35
Total	17	77	118	40	3	255	100

The mean household size of married respondents was highest whereas the corresponding size for divorced and widowed ones was almost similar. On the other hand, the least household size was exhibited by widower household heads (Figure 4.3). The mean household size's relation with marital status is presented in the figure below.

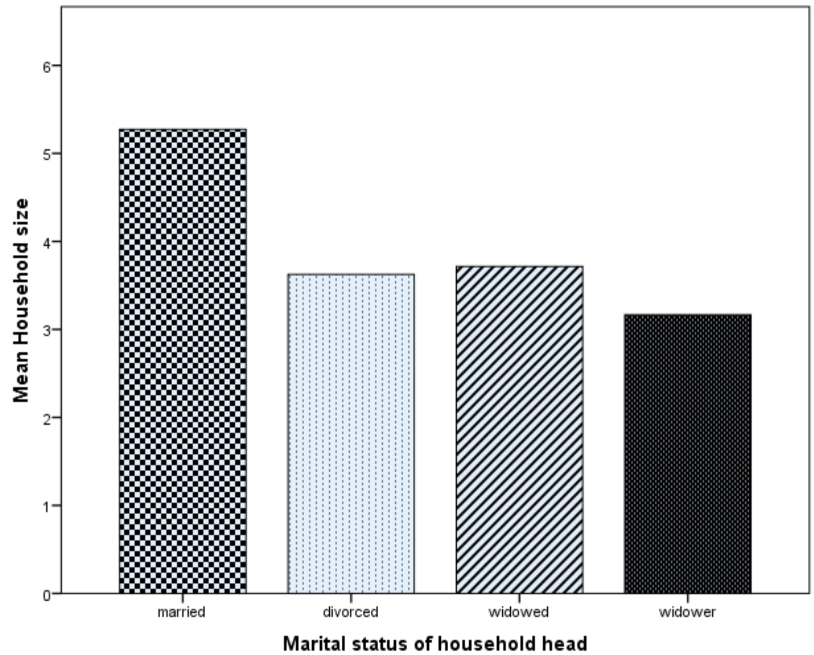


Figure 4.3. Mean household size by marital status

4.1.4. Educational Status

The table given below shows that 44.31% of the surveyed household heads couldn't read and write whereas 42.75% could only read and write. Those who attended formal education account for 12.94%. The result of this study was lower as compared to the one given by Efrem (2010), who found out that out of the total respondents, those who had formal education constitute 46%. From such percentage, according to Efrem (2010), 5% of them had educational background above elementary and junior levels.

The table given below also depicts that there was no respondent whose educational background is high school, preparatory school, technical and vocational college diploma, and BA/BSc.

Table 4. 7. Educational status of the respondents

Name and % of respondents	Educational status				Total
	Illiterate	Read & write only	Elementary 1st cycle (grade 1-4)	Elementary 2nd cycle (grade 5-8)	
Number	113	109	22	11	255
Percent	44.31	42.75	8.63	4.31	100

As can be seen in Figure 4.4, respondents older than 50 years couldn't read and write. On the other hand, the average age of sampled household heads who could only read and write was relatively greater than the average age of informants who attended elementary 1st and 2nd cycle.

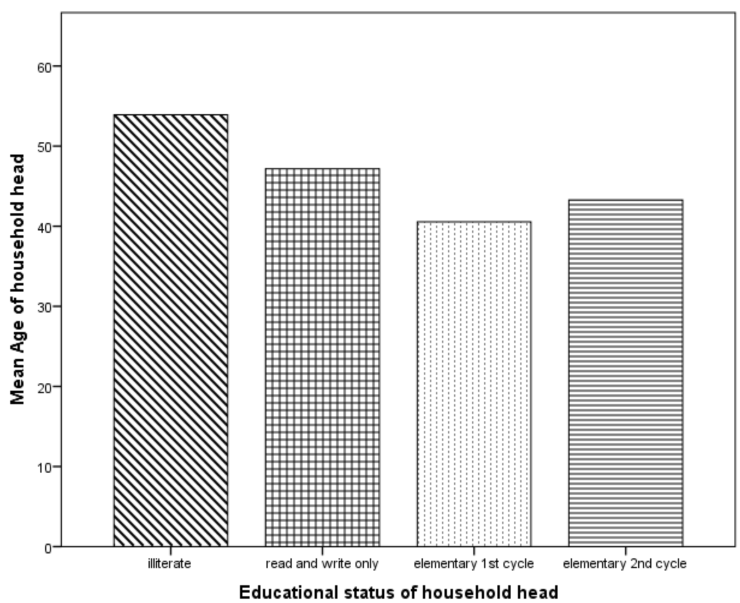


Figure 4. 4. Mean age of household heads by educational status

4.2. Socioeconomic Characteristics

4.2.1. Economic Status

As shown in the table given below, 31.37% of the household heads were poor, 65.49% medium and only 3.14% better-off. This indicates that the majority of the target households were in between poor and better-off. Different from the percentages mentioned earlier, Dereje (2010) investigated that 48.7, 41, and 10.3% of the households involved in the study were poor, medium and rich, respectively.

Table 4. 8. Economic status of sampled household heads

Number and % of household heads	Economic status			Total
	Poor	Medium	Better-off	
Total	80	167	8	255
Percent	31.37	65.49	3.14	100

During the household survey, it was investigated that half of the poor households, 45% of medium households, and 37.5% of better-off respondents had a household size between 5 and 6 (Table 4.9). The same table also reveals that better-off households had no household sizes 1 – 2 and 9 – 10.

Table 4. 9. The relationship between economic status and household size

Economic status	Household size					Total
	1 – 2	3 – 4	5 - 6	7 – 8	9 - 10	
Poor	10	19	40	10	1	80
Medium	7	56	75	27	2	167
Better-off	0	2	3	3	0	8
Total	17	77	118	40	3	255
Percent	6.67	30.2	46.27	15.69	1.18	100

Contrary to Arega (2013) and similar with Efrem (2010), this study using one-way ANOVA found out that there is not statistical variation between household size and economic status of the surveyed households ($p > 0.05$). This implies that there isn't statistically significant difference in household size among the poor, medium and better-off households (Table 4.10).

Table 4. 10. One-way ANOVA test result for economic status of surveyed households (independent variable) and household size (dependent variable)

	Sum of squares	*df*	Mean square	*F*	*p*
Between groups	9.81	2	4.91	1.94	0.145
Within groups	636.19	252	2.53		
Total	646.00	254			

4.2.2. Landholding Size

The mean landholding size of the respondents was 0.57 ha; with the standard deviation of 0.26. The survey made by CSA and WB in 2013 incorporating 3,969 households residing in rural and small towns of Ethiopia indicates that though it varies with place of residence and sex of household head, the mean landholding size of farm households of Ethiopia is 1.37 ha. A one-sample t-test confirmed that the mean landholding size is statistically significantly different for Ethiopia and the study watershed (t = -49.28, $p <$ 0.001).

While three respondents were landless, the land holding size of sampled households who possessed land was between 0.125 ha and 1.750 ha. The landless households produce crops by either renting in land in cash or through crop sharing. In a different circumstance to this, Tegegne (2014) pinpointed that sampled households do have a plot size between 0.25 up to 5 ha.

Table 4.11 shows that 40.48% of the households sampled from Hita-Borkena watershed did have a landholding size between 0.376 and 0.600 ha. About 3/4th of the surveyed households possessed a plot size between 0.376 and 0.750 ha, and those with a plot greater and less than 1 ha constitute about 11 and 89% of the total respondents, respectively. This clearly indicates that the sampled households possessed a very small-sized plot of land that in turn affects their livelihood.

Table 4. 11. Landholding size of the respondents

Number and % of respondents	Landholding size (ha)*					Total
	0.125-0.375	0.376-0.600	0.601-0.750	0.751-1.250	1.251-1.750	
Number	60	102	63	24	3	252
Percent	23.81	40.48	25	9.52	1.19	100

*Respondents replied their landholding size in a local unit of measurement known as *timad*. 1 *timad* = 0.25 ha

The mean landholding size of better-off households was the highest compared with the size of plot owned by medium and poor households (Figure 4.5). This figure also indicates that the mean landholding size of better-off household heads was almost close to 1 ha while the respective size for both medium and poor respondents was less than 1 ha.

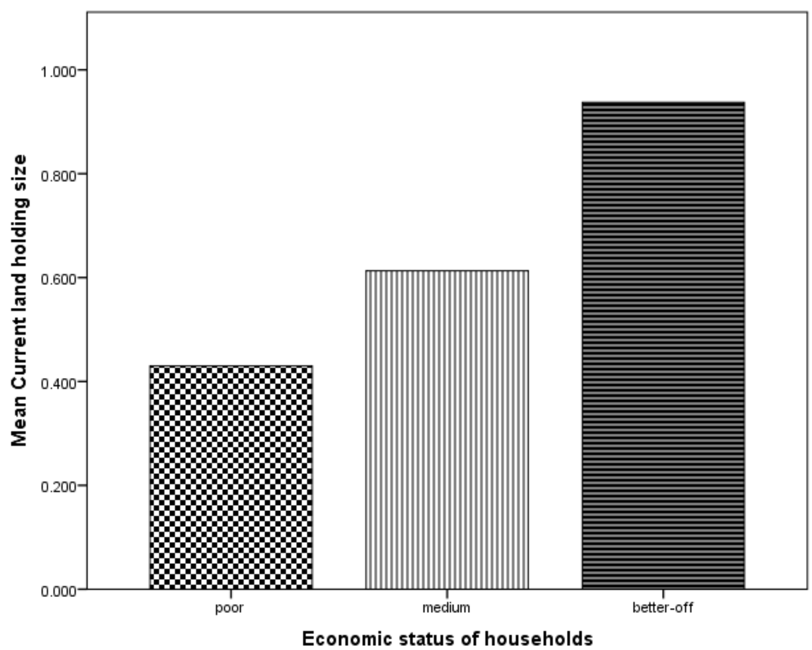


Figure 4.5. Mean landholding size by economic status of households

One-way ANOVA was computed to see the mean difference between landholding size and economic status of households and the result shows that there is statistical difference between the two ($p < 0.05$) (Table 4.12). Multiple comparisons calculated using *post-hoc* Tukey HSD test revealed that the mean landholding size of better-off households was statistically significantly different from those of medium and poor households. Besides, the mean size for medium households was significantly different from the poor ones (Table 4.13). This leads the low income individuals in the study area not to diversify their livelihood.

Table 4. 12. One-way ANOVA test result for landholding size (dependent variable) and economic status (independent variable) of respondents

	Sum of squares	*df*	Mean square	*F*	*p*
Between groups	2.95	2	1.48	26.43	0.000
Within groups	13.92	249	0.06		
Total	16.87	251			

Table 4. 13. Multiple comparisons of landholding size considering a statistically significant difference by economic status of households

Economic status of households	Mean difference	Std. Error	*p*
Poor vs. medium	-0.18	0.03	0.000**
Poor vs. better-off	-0.51	0.09	0.000**
Medium vs. better-off	-0.32	0.09	0.001*

- * and ** significant at the 0.01 and 0.001 level, respectively

As can be inferred from the table below, the mean landholding size of male-headed households (0.57 ha) was slightly greater than the respective size of female-headed households (0.54 ha). The table given below also shows that the maximum landholding size of male- and female-headed households was 1.75 and 1.25 ha, respectively. On the other hand, the minimum landholding size owned by male- and female-respondents was 0.125 and .25 ha, respectively.

Table 4. 14. Descriptive statistics of landholding size by sex of household head

Sex of household head	Descriptive statistics of landholding size (ha)						
	Mean	N	% of Total N	Std. Deviation	Median	Minimum	Maximum
Female	0.54	35	13.89	0.22	0.50	0.25	1.25
Male	0.57	217	86.11	0.27	0.50	0.13	1.75
Total	0.57	252	100	0.26	0.50	0.13	1.75

4.2.3. Reasons for Changing Previous Place of Residence

Almost 57% (i.e. 146) of the surveyed households were permanent residents in the study area. The remaining ones (i.e. 109) come to the study area because of different reasons (Table 4.15). About half of them displaced from their previous place of residence searching for farmland and the next main reason for the displacement of respondents was marriage.

Table 4. 15. Reasons for changing previous place of residence

Number and % of Respondents	Reasons			Total
	Searching for farmland	Marriage	Other	
Number	56	31	22	109
Percent	51.38	28.44	20.18	100

As indicated in Table 4.15, 20.18 % of the respondents mentioned other reasons for changing their previous residence. From such reasons, the main ones as given by the respondents were searching for job and resettlement, respectively (Table 4.16). The aforementioned reasons are in turn causes for the rise in population of the study watershed.

Table 4. 16. Other reasons for changing previous place of residence

Number and % of Respondents	Reasons			Total
	Searching for job	Resettlement	Inheritance of relative's farmland	
Total	13	5	4	22
Percent	59.09	22.73	18.18	100

4.2.4. Marketing Activities

The average distance between respondents' home to the main market place was around 5.08 km; with the standard deviation of 4.76 km. The minimum and maximum distance between respondents' home and the main market place was found to be 0.05 and 20 km, respectively (Table 4.17).

Table 4. 17. Descriptive statistics of distance (km) between respondents' home and main market place

Descriptive statistics						
Mean	Median	Mode	Std. Deviation	Range	Minimum	Maximum
5.08	4.00	4.00	4.76	19.95	0.05	20.00

During the household survey, it was confirmed that most informants make use of more than one type of transport system to transport material to and from the market. Respondents in the study watershed employed donkey back, own carrying, horse/donkey cart and other systems. From these, other system was found to be the most commonly used transport system. Mule back was not employed as a means of transport system by any of the respondents at all (Table 4.18).

Table 4. 18. Transport system employed by the respondents

Number and % of respondents	Transport system					Total*
	Own carrying	Donkey back	Horse/donkey cart	Mule back	Other	
Number	48	30	26	0	177	281
Percent	17.08	10.68	9.25	0	62.99	100

*The total exceeds the sample size, i.e. 255, because of multiple responses.

As shown in the table above, most respondents used other transport systems to transport materials to and from the market. From such transport systems, it was found out that camel back was the dominant transport system in the watershed under study (Table 4.19). This may be due to the fact that Hita-Borkena watershed's climate is favorable for camel.

Table 4. 19. Other transport systems employed by the respondents

Number and % of respondents	Transport system			Total*
	Bajaj	Camel back	Other kind of car	
Number	67	165	30	262
Percent	25.57	62.98	11.45	100

*As shown in table 4.17, 177 respondents employed other transport system. But in this table, the total number of respondents that made use of such means of transport adds up to 262 due to multiple responses.

4.3. Conclusion

This study tried to identify the demographic and socioeconomic characteristics of respondents selected from the two target sub-watersheds found in Hita-Borkena watershed, Kalu district, northeastern Ethiopia. The household survey revealed that the majority of the respondents were adults aged between 37 and 60. The population pyramid of the sampled household members indicated that there was lower rate of fertility in the study watershed unlike the condition in Ethiopia. Household size was found to be influenced by sex of the respondents. Female-headed households were with relatively lower household size compared to the male counterparts due to the reason that most of them were widowed, as household size is correlated with marriage. There was small number of respondents who attended formal education. Sampled farmers possessed a very small plot of land which negatively affects their livelihood. The mean landholding size for better-off households was significantly higher than those of poor and medium ones. The two most important factors for the in-migration of respondents to the study watershed were searching for farmland and marriage. There was no as such far distance between respondents' home and the nearby market place. Most of the respondents didn't carry materials to and from the market, they rather made use of camels and a small vehicle called bajaj.

Chapter Five

5. Land Cover Dynamics in Hita-Borkena Watershed from 1986 to 2015 and its Relation with Area Closure and Slope

In this chapter, it is intended to discuss the accuracy of the land cover classification, the descriptions of the six identified land cover types, the trends of land cover dynamics from 1986 to 2015, the transitions of each land cover type, and the relationship among area closure, slope and land cover dynamics of the Hita-Borkena watershed. The results and discussion given in this chapter are expected to be important because they are some of the ways used to deal with the resource management of a given area.

5.1. Accuracy of the Land Cover Classification

The error matrix (also called confusion matrix) is the most commonly employed technique in assessing the accuracy of land use land cover maps derived from satellite imagery (Congalton, 1991). In the error matrix overall accuracy, kappa coefficient, producer's accuracy and user's accuracy are commonly considered. Table 5.1 shows the error matrix for the 2015 land cover map. From this table, it was calculated that the overall accuracy is 86.57 % with a kappa coefficient of 0.84 (see chapter 3 for the calculations and formulas of overall accuracy and kappa coefficient). These accuracy values indicate that it is possible to undergo analysis since they fulfill the accuracy level demanded from land cover maps, which are derived from satellite imageries (Anderson et al., 1976 cited in Berakhi et al., 2015). Besides, Ganasri and Dwarakish (2015) reported that a kappa coefficient greater than or equal to 0.75 reveals a good degree of agreement between classified and reference data. Table 5.1 also depicts that cropland exhibited the lowest accuracy value, i.e. only 79 % of the area on the map accurately classified. This happened because some areas representing barelands, grasslands, settlements and shrublands were wrongly classified as cropland. Grassland also received low accuracy value, 83 %, due to the fact that some areas of barelands, forestlands, settlements and shrublands were miss-classified as grasslands. With regard to producer's accuracy, from the same table it is possible to recognize that the lowest accuracy score was recorded for forestland, i.e. 78 %. This is because some areas of shrublands and grasslands were inappropriately classified as forestland. Barelands also exhibited the second smallest accuracy as it was bewildered with cropland and grassland.

Table 5. 1. Error Matrix Generated from the 2015 Land Cover Map of the Study Area and the Reference Data

Classified data	Reference data						Row total	User's accuracy*
	Forestland	Shrubland	Grassland	Cropland	Settlement	Bareland		
Forestland	**39**	4	--	--	--	--	43	91
Shrubland	6	**50**	2	--	--	1	59	85
Grass land	5	1	**49**	--	1	3	59	83
Cropland	--	2	7	**77**	6	6	98	79
Settlement	--	--	--	--	**46**	--	46	100
Bareland	--	--	--	3	--	**42**	45	93
Column total	50	57	58	80	53	52	**350**	--
Producer's accuracy**	78	88	84	96	87	81	--	--

Overall accuracy (summation of the diagonal land covers/ summation of column or row totals): 86.57 %, and Kappa coefficient: 0.84 (see chapter 3 for details)

* Diagonal value of a land cover (bold)/row total of the same land cover

** Diagonal value of a land cover (bold)/ column total of the same land cover

5.2. Description of Land Cover Types

Six major land cover types were identified from 1986, 2001, and 2015 satellite images of Hita-Borkena watershed. These include barelands, croplands, forestlands, grasslands, settlements and shrublands. This does mean that these land cover types are the only ones in the watershed. There are rather other types like gullies, Borkena River and smaller streams, and main asphalt road that connect Addis Ababa to Kombolcha-Dessie-Woldia-Mekelle, but their spatial coverage is insignificant compared to the major ones. The description of the major land cover types is given in Table 5.2.

Table 5. 2. Description of Land Cover Types in Hita-Borkena Watershed

Land cover types	Descriptions
Forestlands	Areas devoted for the growth of relatively taller trees that form closed or nearly closed canopy (70 – 100 %) (Alemayehu et al., 2016), are mostly dominated by acacia species.
Shrublands	Areas that contain shrubs and thorny bushes and are less in density than forestlands. They include a bush canopy (> 50 %) which is mixed with some trees and that of grass cover (< 50 %). They are non-herbaceous species whose branches begin from the base of their stem and are usually < 5 meters in height (Alemayehu et al., 2016; Belay, 2002). The dominant plant species in this category in the study area is *Euclea racemosa* (locally called "*Dedeho*")
Grasslands	Non-woody areas dominated by grasses with no or few shrubs (Messay, 2011) and are used for communal grazing by the residents of the watershed.
Croplands	Land used for the growth of seasonal and perennial crops, which are mostly grown by rainfall and sometimes by traditional irrigation means. The source of irrigation water is mostly Borkena river.

Settlements	These are referring to both rural and urban settlements. Those located in rural areas can be of clustered or scattered dwelling units. Urban settlements are those with better road and social service facilities than the rural counterparts.
Barelands	Parcels of land mostly covered with no or little plant cover and contain exposed rocks. They are indicators of high rate of degradation in the given area.

5.3. Trends of Land Cover Dynamics

Forestland

Currently, forestland covers the smallest portion of the study watershed. It occupied 220.6 ha (10.5 %) in 1986, 135.9 ha (6.5 %) in 2001, and 25.6 ha (1.2 %) in 2015 (Table 5.3 and Figure 5.2). The area devoted for such land cover type decreased by 38.4 % (5.65 ha per year) between 1986 and 2001, by 81.2 % (7.88 ha per year) between 2001 and 2015, and by 88.4 % (6.72 ha per year) between 1986 and 2015 (Table 5.4 and Figure 5.3). The available forestland was mainly deforested between 2001 and 2015 that give rise to the clearing of forest that covers 110.3 ha, i.e. 50 % of the forest cover in 1986. Considering a decreasing trend of forestland and increasing trends of cropland and settlement in the study watershed, it is possible to reason out that the aforementioned event happened due to population pressure and lack of focus to afforestation (see also Chapter 4 for population pressure in the study area). The result of this study is in contrary with Woldeamlak (2002) and Berakhi et al. (2015), but it is in conformity with Gete and Hurni (2001); Kebrom and Hedlund (2000); Mohammed (2011); and Tegegne (2014). Woldeamlak (2002) reasoned out that the afforestation program during the *derg* regime (1974 – 1991), protection by the local community and planting of trees at the household level to cope up with the dearth of trees from natural forests were responsible for the increase in coverage of forests in Chemoga watershed between 1957 and 1998.

Table 5. 3. Land Cover Changes in Hita-Borkena Watershed in 1986, 2001 and 2015

Land cover type	Land cover changes					
	1986		2001		2015	
	ha	%	ha	%	Ha	%
Forestland	220.6	10.5	135.9	6.5	25.6	1.2
Shrubland	774.0	37.0	441.8	21.1	285.4	13.6
Grassland	254.4	12.2	234.8	11.2	298.9	14.3
Cropland	766.5	36.6	1143.7	54.6	1315.2	62.8
Settlement	35.7	1.7	59.4	2.8	78.6	3.8
Bareland	42.6	2.0	78.1	3.7	90.0	4.3
Total	2093.8	100	2093.8	100	2093.8	100

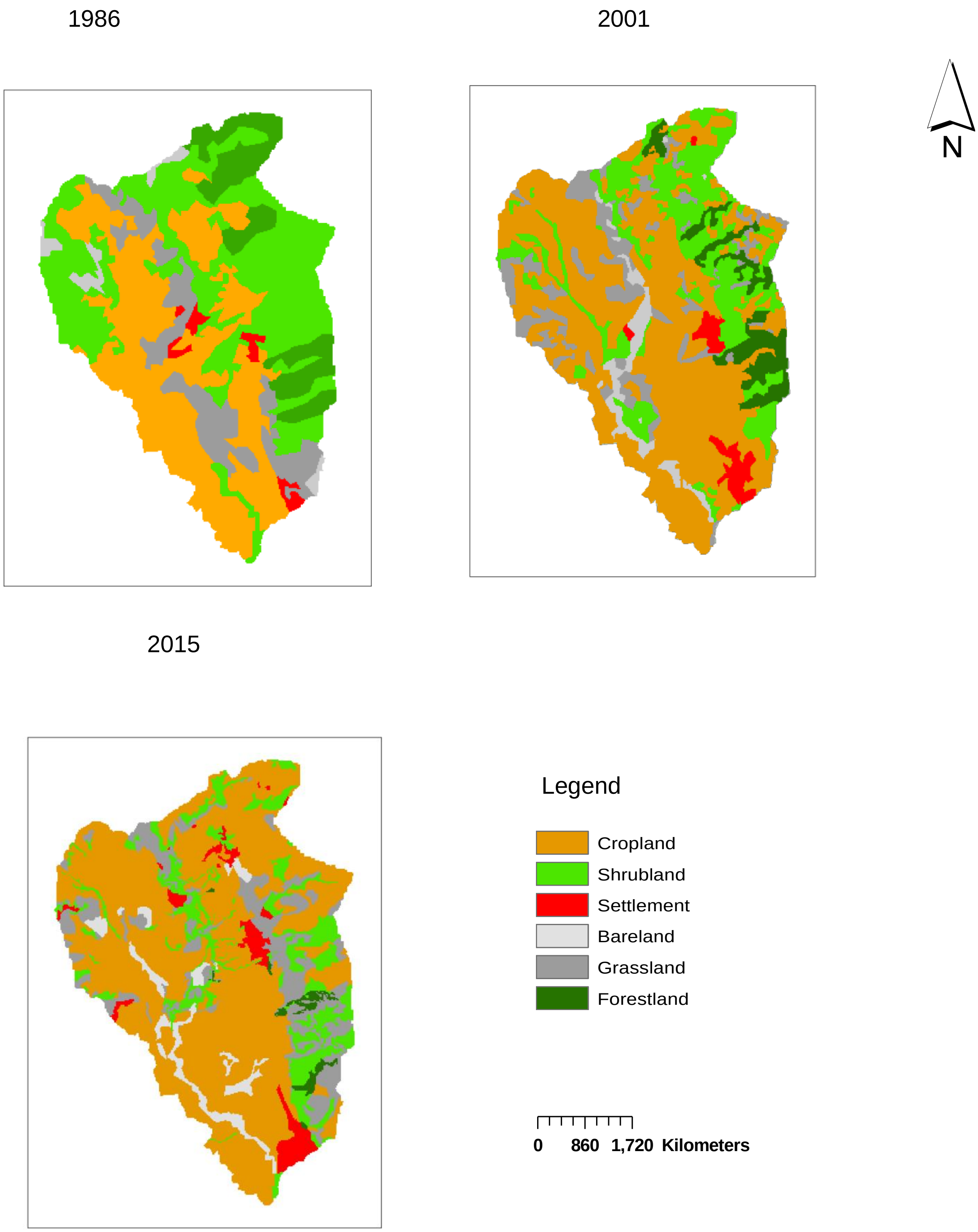


Figure 5.1. Land cover maps of Hita-Borkena watershed, northeastern Ethiopia

Shrubland

At the beginning of the analysis period of this study, shrubland constituted the largest part of the study watershed. It followed, however, a decreasing trend between 1986 and 2015. It covered 774 ha (37 %) in 1986, 441.8 ha (21.1 %) in 2001, and 285.4 ha (13.6 %) in 2015(Table 5.3 and Figure 5.2). It shrank down by 42.9 % (22.15 ha per year) between 1986 and 2001, by 35.4 % (11.17 ha per year) between 2001 and 2015, and by 63.1 % (16.85 ha per year) between 1986 and 2015 (Table 5.4 and Figure 5.3). Contrarily, Gete and Hurni (2001) indicated that shrubland gained 307 ha between 1957 and 1995, whereas Woldeamlak (2002) found that the same land cover type decreased between 1957 and 1982 but increased to some extent between 1982 and 1998. On the other hand, Belay (2002), Kebrom and Hedlund (2000), Mohammed (2011) and Tegegne (2014) depicted the shrinking of shrubland in their respective analysis periods. Collection of wood by the local people for fuel wood and charcoal production were the reasons mentioned by Belay (2002) for the decrement in coverage of shrubland in Derekolli catchment between 1957 and 2000.

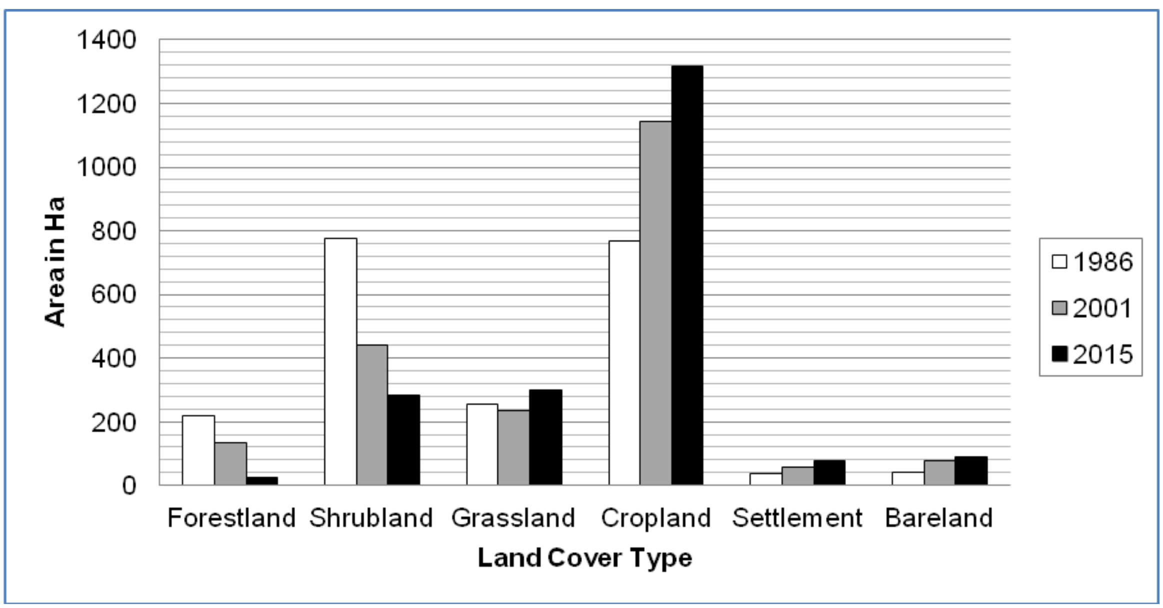


Figure 5.2. Area coverage of each land cover type in Hita-Borkena watershed in 1986, 2001 and 2015

Grassland

Unlike the result given by Mohammed (2011), grassland fairly occupied a good portion of Hita-Borkena watershed during the periods considered. The land under this land cover type accounted for 12.2 % (254.4 ha) in 1986, 11.2 % (234.8 ha) in 2001 and 14.3 % (298.9 ha) in 2015 (Table 5.3 and Figure 5.2). As opposed to other major land cover types, it followed a unique trend, i.e. it decreased by 7.7 % (1.31 ha per year) between 1986 and 2001, increased by 27.3 % (4.58 ha per year) between 2001 and 2015, and increased by 17.5 % (1.53 ha per year) over the 29-analysis period (Table 5.4 and Figure 5.3). This happened due to the fact that cut and carry system has begun to be implemented in the study watershed after 2001. The result of this study is in contrary with Aklilu (2006) that investigated an increasing, a decreasing and an increasing trends of grazing land over the first, second and overall analysis periods, respectively. Gete and Hurni (2001), Messay (2011) and Mohammed (2011), on the other hand, found out that grassland show a decreasing trend over their respective analysis periods. Belay (2002) revealed that grassland followed an increasing trend in Derekolli catchment between 1957 and 2000 due to the shrinking and modification of shrubland.

Table 5. 4. Trends of land cover changes in Hita-Borkena Watershed in different periods

Land cover type	Area dynamics of each land cover type					
	1986 - 2001		2001 – 2015		1986 - 2015	
	ha	%	ha	%	Ha	%
Forestland	-84.7	-38.4	-110.3	-81.2	-195.0	-88.4
Shrubland	-332.2	-42.9	-156.4	-35.4	-488.6	-63.1
Grassland	-19.6	-7.7	64.1	27.3	44.5	17.5
Cropland	377.2	49.2	171.5	15.0	548.7	71.6
Settlement	23.7	66.4	19.2	32.3	42.9	120.2
Bareland	35.5	83.3	11.9	15.2	47.4	111.3
Total	0.0	0.0	0.0	0.0	0.0	0.0

Cropland

Considering area coverage in the watershed, this study like most studies (for example, Aklilu, 2006; Belay, 2002; Gete and Hurni, 2001; Kebrom and Hedlund, 2000; Menale et al., 2016; Messay, 2011 among others) confirmed an increasing trend of cropland between 1986 and 2015. The area under cropland constituted 36.6 % (766.5 ha) in 1986, 54.6 % (1,143.7 ha) in 2001 and 62.8 % (1,315.2 ha) in 2015. It exhibited a remarkable increase throughout the analysis period and is by far the largest land cover type in the study watershed (Table 5.3 and Figure 5.2). It increased by 49.2 % (25.15 ha per year) between 1986 and 2001, by 15 % (12.25 ha per year) between 2001 and 2015 and by 71.6 % (18.92 ha per year) between 1986 and 2015 (Table 5.4 and Figure 5.3). Figure 5.4 also displays the expansion of cropland to the steepy slope in the study watershed. The diminishing of forestland and shrubland and the expanding of cropland, bareland and settlement attributed to the increase in population (see Chapter 4).

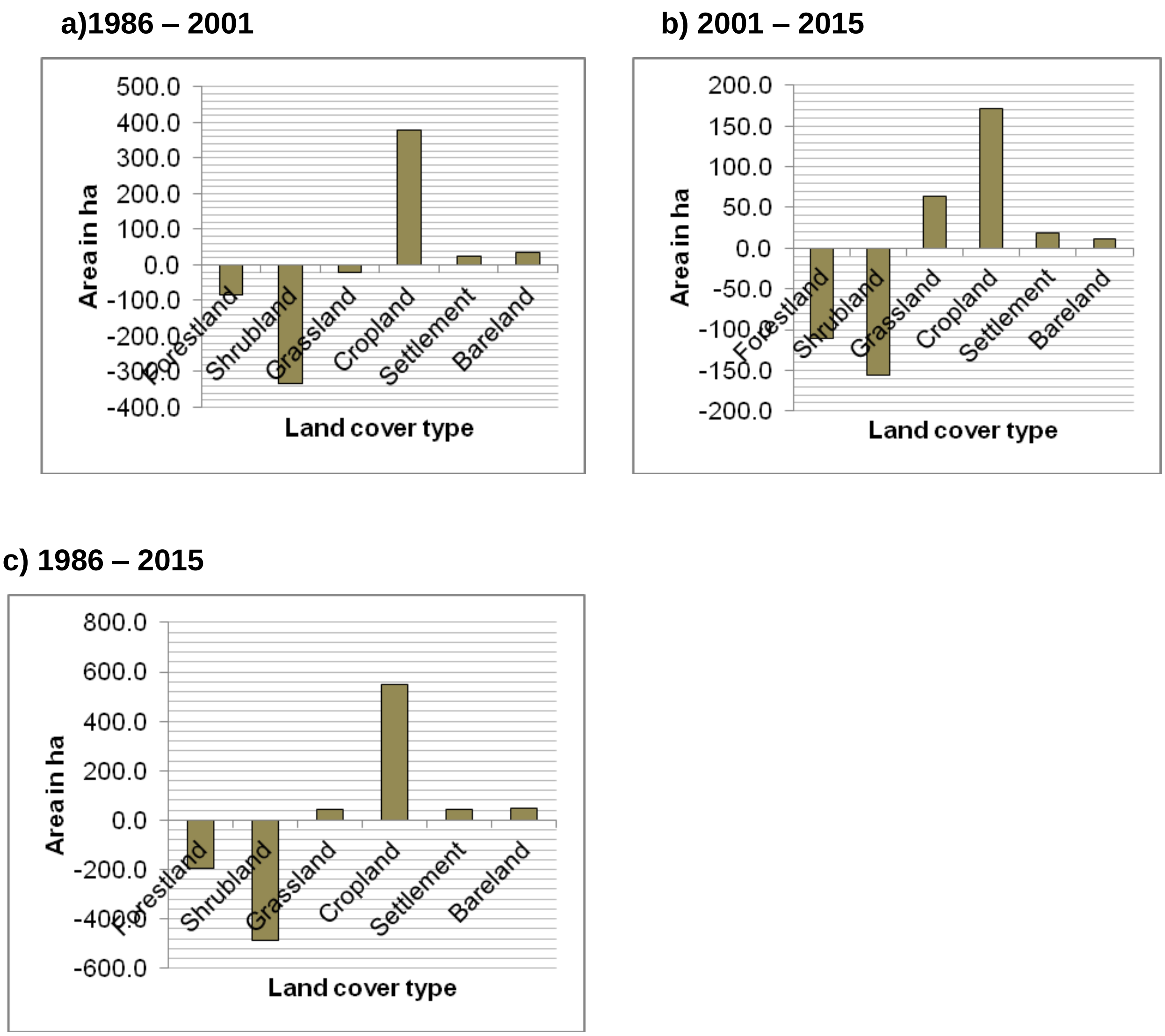


Figure 5.3. Area dynamics of major land cover types in Hita-Borkena watershed in the three periods

Figure 5.4. Expansion of cropland to sloppy bushland in Hita-Borkena watershed, 2015

Settlement

The portion of Hita-Borkena watershed under this land cover type showed an increasing tendency between 1986 and 2015 unlike forestland and shrubland. It constituted 1.7 % (35.7 ha), 2.8 % (59.4 ha) and 3.8 % (78.6 ha) in 1986, 2001 and 2015, respectively (Table 5.3 and Figure 5.2). In a similar fashion with bareland, it increased by 66.4 % (1.58 ha per year) between 1986 and 2001, by 32.3 % (1.37 ha per year) between 2001 and 2015 and by 120.2 % (1.48 ha per year) between 1986 and 2015 (Table 5.4 and Figure 5.3). This with no doubt reveals the presence of population pressure in the study watershed in the years under consideration (see Chapter 4). In line with this study, Aklilu (2006) confirmed that settlement rise by 108 % in Beressa watershed, northeastern Ethiopia between 1957 and 2000. Similarly, Menale et al. (2016) found that number of houses increased from 29 in 1957 to 365 in 2013 in Tara-Gedam watershed, northwestern Ethiopia.

Bareland

It is a badland which is mostly overgrazed and contains rock outcrops (Woldeamlak, 2002). It covered 42.6 ha (2 %) in 1986, 78.1 ha (3.7 %) in 2001 and 90 ha (4.3 %) in 2015 (Table 5.3 and Figure 5.2). It exhibited an increasing trend alarmingly between 1986 and 2015 (Table 5.4 and Figure 5.3). This implies that there has been a threat of land degradation (Gete and Hurni, 2001; Menale et al., 2016) in the study watershed. It increased by 83.3 % (2.37 ha per year) between 1986 and 2001, by 15.2 % (0.85 ha per year) between 2001 and 2015 and by 111.3 % (1.63 ha per year) between 1986 and 2015. Though it recorded a rapid rate since 1986, the rate after the implementation of landscape restoration including area closure (i.e. after 2001) is relatively slower. However, Mr. Ali, who has been working as an agricultural expert in the study area for a long period of time, witnessed that the interest of the community to conserve the watershed relatively declined immediately after MERET project had stopped in 2012 (personal communication, 2015). Now, the researcher observed that more care is being given for hillsides where area closures are found, but some farmers are letting their animals to graze freely at the foot of the hill (Figure 5.5).

Figure 5.5. Overgrazed grassland in Hita-Borkena watershed, 2015

The recent railway construction that connects Wollo to Afar passing through the watershed is disturbing the watershed and is contributing to the increase in area coverage of bareland.

5.4. Transition between Land Cover Types

As mentioned above, forestland declined massively in Hita-Borkena watershed between 1986 and 2015. It was the fourth largest land cover type in terms of area coverage in 1986, preceded by shrubland, cropland and grassland in order of size of coverage. It converted significantly into shrubland, followed by cropland, between 1986 and 2001 and into shrubland, followed by grassland, between 2001 and 2015. Considering the conversion of other land cover types into forestland, the conversion from shrubland into forestland was the most important one during the two periods: 1986 – 2001 and 2001 – 2015 (Table 5.5 and 5.6).

In a similar fashion with forestland, shrubland coverage in the watershed decreased extensively. It stood first in terms of area in the watershed in 1986, followed by cropland. It changed to cropland, followed by grassland in 1986 – 2015 and 2001 – 2015. There was of course conversion of other land cover types into shrubland. The main conversions took place between forestland to shrubland and grassland to shrubland during the aforementioned periods (Table 5.3, 5.4 and 5.5).

In the first year of the analysis period, grassland covered 12.2 % of the total area of the watershed. Due to the prohibition of free grazing, though some violations still exist, its coverage increased to 14.3 % in 2015 unlike other land cover types. It mainly transformed into cropland, followed by shrubland during the periods between 1986 – 2001 and 2001 – 2015. On the other hand, it gained 114.6 and 106.6 ha from shrubland and between 1986 – 2001 and 2001 – 2015, respectively. Larger area of bareland was relatively transformed into grassland during the second period than the first one (Table 5.5 and 5.6).

Cropland has been occupying huge portion of the watershed compared to other land cover types. It changed to shrubland, followed by grassland, between 1986 and 2001 and to grassland, followed by shrubland, between 2001 and 2015. It gained larger area from shrubland and grassland in both periods compared to the area it lost (Table 5.5 and 5.6). This is confirmed by Aklilu (2006). Besides, Mohammed (2011) found out that conversion of grassland, forestland and shrubland gave rise to the expansion of cultivated land.

Bareland gained more area through 1986 – 2015. It expanded at the expense of mainly cropland, grassland and shrubland between 1986 and 2015. It completely lost to cropland, followed by shrubland and grassland, in both periods: 1986 – 2001 and 2001 – 2015 (Table 5.5 and 5.6). As indicated by Aklilu (2006), bareland transformed into cropland, plantations and grazing land during the period between 1957 and 2000.

In response to the increased population in Hita-Borkena watershed, rural and urban settlement greatly expanded through the analysis period. It converted into cropland, followed by bareland, between 1986 and 2001 and into cropland, followed by shrubland, between 2001 and 2015. The area it gained was greater than the corresponding area it lost in the two periods. It gained land from grassland, followed by cropland and from cropland, followed by shrubland, in 1986 – 2001 and 2001 – 2015, respectively (Table 5.5 and 5.6). Similarly, Kebrom and Hedlund (2000) revealed that rural settlements transformed into cultivated areas, remaining open areas, shrublands and other land cover classes in 1958 – 1986. The same authors noted that conversion of other land cover categories into rural settlements constituted more than 50 %.

Table 5. 5. Land cover change matrix in Hita-Borkena watershed between 1986 and 2001

		From land cover type in 1986						
	Land cover type	Forestland	Shrubland	Grassland	Cropland	Bareland	Settlement	Total
		ha	ha	Ha	Ha	Ha	ha	ha
To land cover type in 2001	Forestland	81.1	52.6	0.0	2.2	0.0	0.0	135.9
	Shrubland	86.1	254.7	19.3	73.6	4.8	3.2	441.8
	Grassland	5.4	114.6	45.3	63.0	3.6	2.9	234.8
	Cropland	46.6	328.6	154.1	573.2	34.2	7.0	1143.7
	Settlement	1.1	10.6	17.8	13.6	0.0	16.4	59.4
	Bareland	0.2	12.8	18.0	41.0	0.0	6.2	78.1
	Total	220.6	774.0	254.4	766.5	42.6	35.7	2093.8

Table 5. 6. Land cover change matrix in Hita-Borkena watershed between 2001 and 2015

		From land cover type in 2001						
To land cover type in 2015	Land cover type	Forestland	Shrubland	Grassland	Cropland	Bareland	Settlement	Total
		ha	ha	Ha	Ha	Ha	ha	ha
	Forestland	11.6	6.5	0.1	5.6	0.0	1.8	25.6
	Shrubland	72.5	94.0	32.6	61.9	13.6	10.7	285.4
	Grassland	30.6	106.6	58.3	84.2	10.3	8.9	298.9
	Cropland	20.1	204.0	126.7	920.2	22.7	21.5	1315.2
	Settlement	1.1	19.1	12.5	29.7	0.0	16.2	78.6
	Bareland	0.0	11.6	4.6	42.0	31.5	0.3	90.0
	Total	135.9	441.8	234.8	1143.7	78.1	59.4	2093.8

5.5. Link among Land Cover Dynamics, Slope and Area Closure

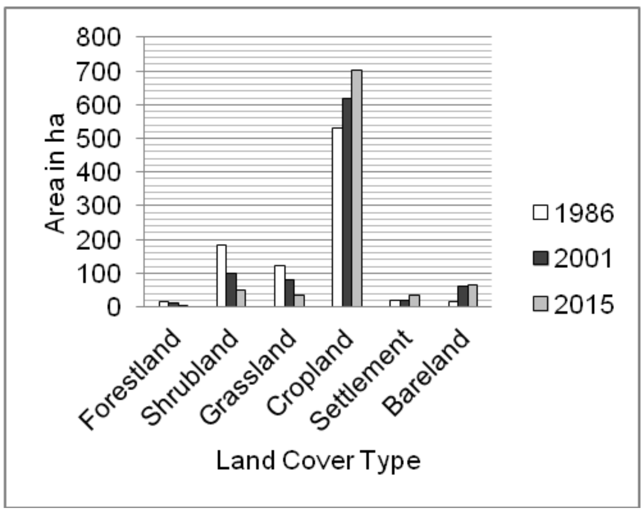
Attempts were made to see the association among land cover dynamics, slope and area closure in Hita-Borkena watershed, northeastern Ethiopia. The study watershed was classified into 3 slope classes, i.e. gentle slope (0 – 12 %), mid slope (12 – 36 %) and steep slope (>36 %), based on Aklilu (2006).

As can be seen in Figure 5.6 a, cropland was the major land cover type on the gentle slopes in the watershed. On the other hand, forestland, grassland and shrubland shrank down on the same slopes through 1986 – 2015.

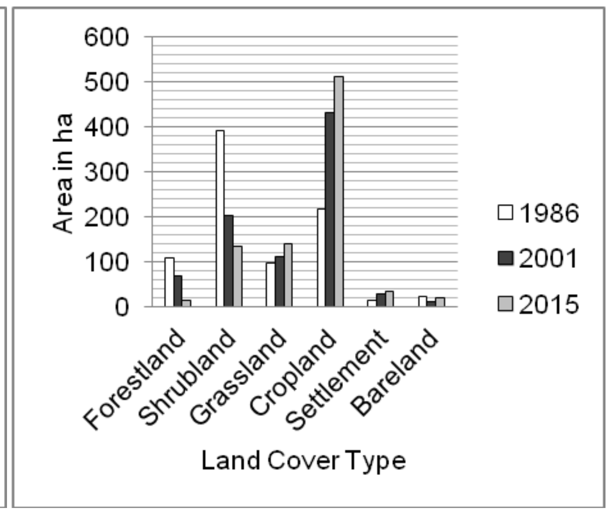
Though the mid slopes in the watershed were dominated by cropland, grassland showed an increasing trend in the analysis period (Figure 5.6 b) mainly due to area closure. However, due emphasis should also have been given to forestland and shrub-land. This is because the watershed could be protected not only by grassland but also by forestland, shrubland and different SWC measures. In relation to grazing land, Aklilu (2006) identified that it is mostly located on gentle and mid slopes of Beressa watershed, Ethiopia.

In 1986 and 2001, unlike gentle and mid slopes, steep slopes in the watershed predominantly contained shrubland. In 2015, three land cover types: cropland, grassland and shrubland, were dominating the watershed (Figure 5.6 c). Grassland's coverage on the steep slopes significantly increased as a result of the presence of area closure in the watershed under consideration, but forestland on the same slope class drastically decreased. This implies that there was negligence of tree planting and high rate of deforestation in the study area. In line with this, Gete and Hurni (2001) noted that 90 % of the forestland on the steep slopes in Dembecha area, northwestern highlands of Ethiopia had deforested between 1957 and 1982.

a) On gentle slope (0 – 12 %)



b) On mid slope (12 – 36 %)



c) On steep slope (> 36 %)

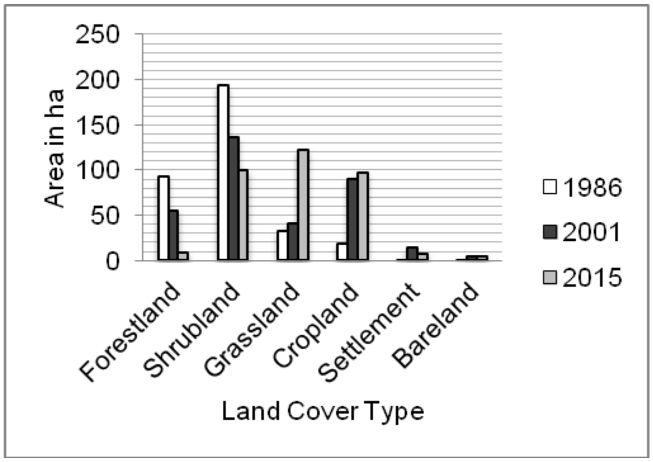


Figure 5.6. Link between land cover dynamics and slope in Hita-Borkena watershed, northeastern Ethiopia in 1986, 2001 and 2015

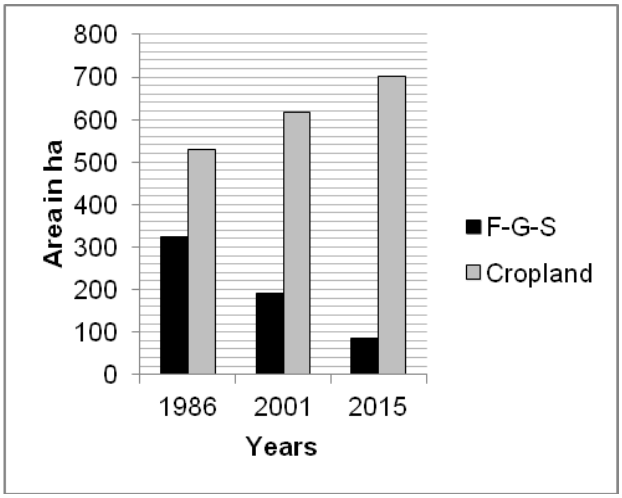
Comparisons were made in order to show how the amount of vegetation including forests, grasses and shrubs in combination and cropland on gentle, mid and steep slopes changed in the watershed between 1986 and 2015.

As revealed in Figure 5.7a, cropland showed a considerable increase in the gentle slope throughout the analysis period for the reason that such slope is favorable for crop production. On the other hand, forestland, grassland and shrubland (F-G-S) in combination exhibited opposite trend.

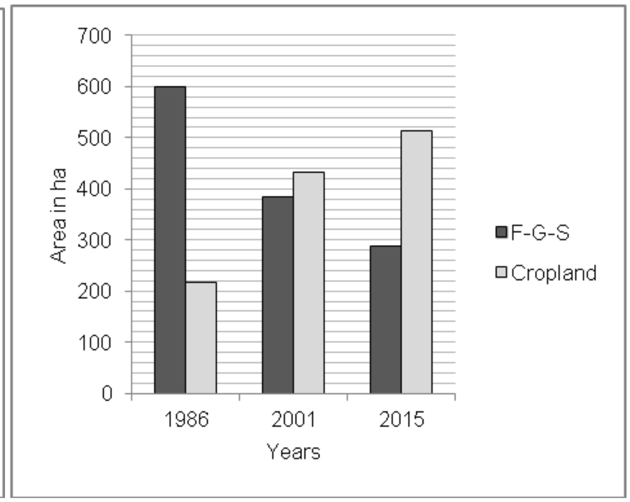
In 1986, F-G-S on mid slopes covered almost 30 % of the area of the watershed while cropland constituted only 11 %. F-G-S on the same slopes declined to 18 and 14 % in 2001 and 2015, respectively, whereas there was the corresponding rise in the size of cropland in the indicated years (Figure 5.7b). Though not possible to resume the vegetation cover in 1986, the present F-G-S has been conserved as a result of the restoration project that incorporates area closure in the study watershed.

Figure 5.7c presents that F-G-S on steep slopes in the watershed had occupied larger area compared to cropland, even though its area coverage in the three considered years was different. Contrarily, Gete and Hurni (2001) found out that forest, bush, grass and bush, and grass in combination on steep slopes in Dembecha area, Gojjam, Ethiopia accounted for 80, 25 and 11 % in 1957, 1982 and 1995, respectively.

a) On gentle slope (0 – 12 %)



b) On mid slope (12 – 36 %)



c) On steep slope (>36 %)

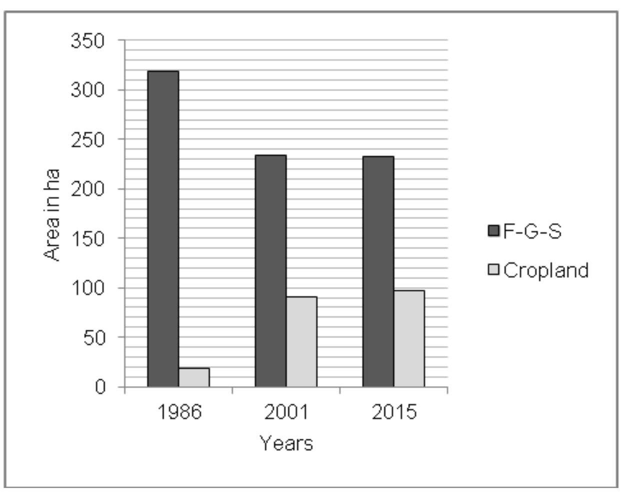


Figure 5.7. Combined vegetation cover (Forestland-Grassland-Shrubland/F-G-S) against cropland on gentle, mid and steep slopes in Hita-Borkena watershed, northeastern Ethiopia in 1986, 2001 and 2015

5.6. Conclusion

In this chapter using GIS and remote sensing technologies, it is confirmed that the major land cover types of the study watershed have undergone changes through 1986 – 2015. One of the vegetation types, i.e. forest, received a significant change throughout the analysis period. It constituted 10.5 %, 6.5 % and 1.2 % of the total area of the watershed in 1986, 2001 and 2015, respectively. This implies that serious deforestation took place in the indicated years. The same trend, though the rate is relatively minimal, is followed by shrubland. This could happen because of the fact that the shrinking of forest leave pressure on shrubs. Grassland relatively followed a unique trend, i.e. a decreasing trend through 1986 – 2001 and an increasing trend through 2001 – 2015. An increasing trend is enjoyed due to MERET project that incorporates area closure and the project was introduced in the watershed in 2001.

The general truth which states that agriculture expands at the expense of vegetation was disproved by the study conducted by Belay (2002) in Derekolli catchment. However, the study made in Hita-Borkena watershed, northeastern Ethiopia confirmed that cropland expanded remarkably between 1986 and 2015 which is in agreement with the aforementioned general truth. Cropland expanded at the expense of mainly shrubland and grassland. Bareland and settlement have also expanded throughout the analysis period, though the rate is different from cropland. The area coverage of bareland was being tackled by MERET project especially after 2001. However, low participation of local people after MERET project, i.e. 2012, and recent railway construction are now mainly contributing to the expansion of bareland. As it is also true in other areas of the world, settlement has got an increasing trend in the study watershed through 1986 – 2015 because of population pressure.

In this study, it is witnessed that cropland was the main land cover type on gentle slope (0 – 12 %) throughout the analysis period. Here, it is mandatory to acknowledge the contribution of area closure for the increasing trend of grassland on both mid (12 – 36 %) and steep (> 36 %) slopes between 2001 and 2015. F-G-S was found to be higher in coverage compared to cropland on steep slope through 1986 – 2015. The overall coverage of F-G-S is, however, decreasing. This calls for the coordinated efforts of local people, local, zonal regional and federal concerned offices, and NGOs to improve the vegetation coverage of the study watershed.

Chapter Six

6. Comparison of Soil Physico-Chemical Properties of Area Closure and Adjacent Open Grazing Land

Soil is one of the essential natural resources that support living organisms including human beings. However, it has been depleting due to the increase in number of both human and animal populations. Thus, conservation and restoration of soil is highly needed (Lal, 2016). One of the soil restoration techniques is the establishment of area closure (Wolde et al., 2016) on degraded hillsides. So, taking into account of this fact, this chapter presents the physico-chemical characteristics of area closure found in the study area. In order to analyze the impact of area closure on soil quality, attempt is also made to compare the selected soil properties (i.e. soil texture, bulk density, soil pH, total nitrogen, soil organic matter, organic carbon, available phosphorus, available potassium, and cation exchange capacity) of area closure and adjacent open grazing land. A total of 36 composite soil samples (24 from area closure and 12 from open grazing land) were collected from both target lands and from three slope positions (i.e. upslope, midslope and footslope) using auger up to a depth of about 20 cm.

6.1. Soil Physical Properties of Area Closure and Open Grazing Land

6.1.1. Soil Texture

Soil texture is one of the crucial physical properties that control soil fertility and productivity. It does have its own impact on different soil properties like bulk density, structure, moisture holding capacity and soil chemistry. It generally plays a major role in regulating the whole soil environment (Osman, 2013).

The soil of Hita-Borkena watershed, in general, contained 22, 28 and 50 % of clay, silt and sand fraction, respectively. Hazelton and Murphy (2007) rated the clay, silt and sand content of such soil as low, moderate and high, respectively. The high level of sand of the soil of the study area is probably related with the past land degradation intensity and presence of dry climate.

Clay Separate (%)

The mean clay contents of the soils of the two land use types considered in this study (i.e. area closure and open grazing land) found under the three slope positions (i.e. upslope, midslope and footslope) is displayed in Table 6.1. As can be seen in the table, the clay fraction of the soil of area closure varied between 21.75 and 24.75 % whereas the corresponding value for open grazing land lied between 20 and 22 %. This implies that the clay content in area closure was relatively higher compared to the respective value in open grazing land.

Table 6.1 also reveals that the mean clay content (22.75 (±1.25 SE)%) of the soil of area closure was slightly greater than the corresponding value of open grazing land (i.e. 21 (±1.25)[1]%). This could be due to the fact that area closure compared to open grazing land minimizes the risk of soil erosion which in turn protects the removal of clay. Similar to the present study, Abiy (2008) found out that clay fraction (in percent) of enclosure is greater than the corresponding fraction of free grazing land. From Table 6.1, it can also be identified that the lowest and highest values of clay fraction (%) were exhibited by open grazing land and area closure, respectively.

Independent samples t-test was computed to identify whether the distribution of mean soil physical properties was the same under area closure and open grazing land or not (Table 6.2). This table shows that there was no statistically significant difference ($p > 0.05$) between the mean clay contents of area closure and open grazing land. Similar to this, Kibret (2008) reported that there was no significant difference between the clay content of enclosure and open grazing land. Dereje and Assefa (2016) also reported that there is no statistically significant difference among the mean clay contents of the four land use types (i.e. forestland, annual cropland, multistory canopy coffee farm, and coffee monoculture) considered in their study.

[1] In this chapter, figures in parenthesis with ± represent standard error of the mean (SE).

Table 6. 1. Minimum (mini), maximum (maxi), mean and standard error (SE) of mean of soil particle distribution, bulk density & total porosity in the 0 – 20 cm soil depth along different slope positions of area closure and open grazing land of Hita-Borkena Watershed, Northeastern Ethiopia

Land use	Slope position	Particle size distribution (%)												Textural class	Bulk density (gcm^{-3})				Total porosity (%)			
		% Clay				% Silt				% Sand												
		Mini	Maxi	Mean	SE	Mini	Maxi	Mean	SE	Mini	Maxi	Mean	SE		Mini	Maxi	Mean	SE	Mini	Maxi	Mean	SE
Area closure (N=24)	Upslope	15.00	31.00	24.75	2.28	27.00	35.00	31.50	0.91	34.00	56.00	43.75	2.52	Loam (L)	0.88	1.40	1.14	0.07	47.17	66.79	57.17	2.57
	Midslope	13.00	29.00	21.75	1.96	19.00	39.00	28.75	2.46	38.00	64.00	49.50	3.27	Loam (L)	0.92	1.44	1.23	0.06	45.66	65.28	53.68	2.11
	Footslope	17.00	37.00	21.75	2.36	19.00	39.00	29.50	2.41	32.00	62.00	48.75	3.72	Loam (L)	0.94	1.69	1.31	0.10	36.23	64.53	50.57	3.65
	Average	15.00	32.33	22.75		21.67	37.67	29.92		34.67	60.67	47.33		Loam (L)	0.91	1.51	1.22		43.02	65.53	53.81	
Open grazing land (N=12)	Upslope	19.00	27.00	21.00	2.00	23.00	27.00	25.00	0.82	46.00	58.00	54.00	2.71	Sandy Clay Loam (SCL)	1.31	1.53	1.45	0.05	42.26	50.57	45.38	1.80
	Midslope	11.00	27.00	20.00	3.70	15.00	31.00	23.00	3.37	44.00	68.00	57.00	6.40	Sandy Clay Loam (SCL)	1.06	1.58	1.33	0.12	40.38	60.00	49.91	4.67
	Footslope	15.00	31.00	22.00	3.70	17.00	31.00	22.50	3.40	38.00	68.00	55.50	6.29	Sandy Clay Loam (SCL)	1.32	1.46	1.38	0.03	44.91	50.19	48.12	1.13
	Average	15.00	28.33	21.00		18.33	29.67	23.50		42.67	64.67	55.50		Sandy Clay Loam (SCL)	1.23	1.52	1.38		42.52	53.59	47.80	

Silt Separate (%)

As shown in Table 6.1, the average percentage of silt under area closure along the three slope positions runs from 28.75 to 31.50 % and the respective value for open grazing land runs from 22.50 to 25 %. This indicates that the silt content under area closure was greater than the corresponding content under open grazing land. Although soil texture is an intrinsic soil property, it is assumed that the change in vegetation cover and accelerated soil erosion are the responsible factors for the difference in silt content under the two considered land use types (Tizita, 2004; Yuan et al., 2012)

Considering only land use type as an independent variable, it was investigated that the mean silt percentage of area closure (i.e. 29.92(±1.16)%) was greater than that of the mean silt percentage of open grazing land (i.e. 23.5(±1.50)%) (Table 6.1). The finding of this study is different from the report of Abiy (2008) that reported silt (%) under open grazing land was greater than the respective percentage under enclosure. Table 6.1 given above also portrays that the minimum silt percentage (i.e. 15 %) was recorded on soils of open grazing land while the maximum (i.e. 39 %) was exhibited on soils of area closure.

Table 6.2 reveals that there was statistically significant difference ($p < 0.05$) between the mean silt content (%) of area closure and open grazing land. This result is opposite to the finding reported by Kibret (2008).

Sand Separate (%)

The mean sand fraction (%) under area closure along the upslope, midslope and footslope positions varied between 43.75 and 49.50 %. On the other hand, the same fraction (%) under open grazing land along the same slope positions varied between 54 and 57 % (Table 6.1). This means that the soils under area closure had lower sand content than the soil under open grazing land.

The mean sand fraction (%) was calculated disregarding slope position and considering land use type (Table 6.1). Similar to the finding of Abiy (2008), this study indicates that the sand content of the soil of area closure (i.e. 47.33(±1.85)%) was smaller than the corresponding content of the soil of open grazing land (i.e. 55.50(±2.85)%). This may be due to the reason that relatively sparse vegetation cover of open grazing land makes the soil susceptible to accelerated soil erosion that in turn paves the way for the removal of clay leaving sand behind. This may also lead to relatively higher and lower percentages of sand and clay, respectively under the soil of open grazing land (Tizita, 2014). The minimum (i.e. 32 %) and the maximum (i.e. 68 %) sand fractions were exhibited in soils of area closure and open grazing land (Table 6.1), respectively.

The mean sand fraction (%) difference between area closure and open grazing land was statistically significant ($p < 0.05$) (Table 6.2). Unlike to the finding of this study, Kibret (2008) noted that there was no significant difference between the sand fraction (%) of the soil of enclosure and open grazing land.

Table 6. 2. Independent samples t-test result for selected soil physical properties and land use type

Soil physical property	Levene's test for equality of variances	t-test for equality of means		
		t	*Df*	*p*
Clay (%)	Equal variances assumed	0.82	34	0.420
Silt (%)	Equal variances assumed	3.28	34	0.002*
Sand (%)	Equal variances assumed	-2.48	34	0.018*
Bulk Density (gcm^{-3})	Equal variances assumed	-2.27	34	0.029*
Total Porosity (%)	Equal variances assumed	2.27	34	0.029*

Notes: - Levene's test for equality of variances was used to test whether soil properties have the same or different levels of variability between the two land use types or not.

- *Significant at $p < 0.05$ (2-tailed)

Soil Textural Class

As can be seen in Table 6.1, the soil textural class of area closure and open grazing land along the three slope positions was loam and sandy clay loam, respectively. This implies that sand and clay fractions dominate (together make up > 75 %) the soil of open grazing land. In comparison, moderate percentages of clay, silt and sand were observed on soils of area closure. Soils with textural class of loam and sandy clay loam can be rated as medium- and fine-textured (Osman, 2013), respectively. Loam soil texture of area closure provides more optimum conditions of infiltration, aeration, water holding capacity, nutrient holding capacity, and workability than sand clay loam soil texture of open grazing land. Tizita (2014) in a different way to the present study investigated that the textural class name of the soil samples taken from three closed areas was clay, whereas the class name of the samples taken from two open grazing lands was sandy loam and for the remaining grazing land was clay.

6.1.2. Bulk Density

Bulk density is one of the soil physical properties that has got close tie with porosity, permeability, soil organic matter content, compaction and activity of soil micro-organisms. It does have direct relationship with only compaction while its relation with the other aforementioned soil behaviors is indirect.

The mean soil bulk density (g cm-^{3}) under area closure along the upslope, midslope and footslope positions varied between 1.14 and 1.31 g cm^{-3}. In comparison, the respective values under open grazing land along the same slope positions run from 1.33 to 1.45 g cm^{-3} (Table 6.1). From this, it can be inferred that area closure had relatively smaller soil bulk density than the corresponding value under open grazing land.

As shown in Table 6.1, both the minimum (i.e. 0.88 g/cm3) and the maximum (i.e. 1.69 g cm^{-3}) bulk density values were recorded in the area closure. The mean bulk density (i.e. 1.22(±0.04) g cm-^{3}) of area closure was smaller than the mean value of the same soil parameter under open grazing land (i.e. 1.38(±0.04) g cm^{-3}). This may lead to interpret that the above mentioned conditions of soil behaviors with the exception of compaction were better under area closure. Abiy (2008), Lemma et al. (2015), Mohammed et al. (2017), Tizita (2014) and Wolde and Veldkamp (2012) reported that relatively higher soil bulk density under open grazing land than soil bulk density of area closure/exclosure.

The mean bulk density difference of the two considered land use types was significant ($p < 0.05$) (Table 6.2). This was consistent with Yuan et al. (2012). They reported that restored grasslands had significantly lower bulk density than control area.

6.1.3. Total Porosity

The total porosity (%) is derived from soil bulk density and particle density values (see chapter 3 for details). The average total porosity of soils of area closure on the slope positions differed between 50.57 and 57.17 while that of open grazing land was between 45.38 and 49.91 (Table 6.1). This implies that area closure had relatively larger total porosity than open grazing land. This could happen due to the reason that the improved organic matter under the former land use type lead soil bulk density to decline that in turn is the cause for the increment in total pore spaces (Osman, 2013).

Regardless of slope positions, the mean total porosity of the soil of area closure (i.e. 53.81(±1.67)) was significantly higher than ($p<0.05$) that of the soil of open grazing land (i.e. 47.80 (±1.64) (Tables 6.1 & 6.2). The relatively better soil organic matter, clay and silt contents, less bulk density value, better litter input and no trampling by livestock led the soil under area closure to have higher total porosity compared with those soil behaviors under open degraded land (Osman, 2013).

The result of the present study was consistent with Tizita, 2014; Yuan et al., 2012. Yuan et al. (2012) found out that restored grasslands had significantly higher values of soil water holding capacity and total porosity than control area.

6.2. Soil Chemical Properties of Area Closure and Open Grazing Land

6.2.1. Soil pH

Soil pH being a chemical property controls the availability, solubility and toxicity of nutrients, and affects soil micro-organisms' activity and population.

The pH values vary between 5.05 and 7.47 in soils of area closure and between 5.71 and 7.65 in soils of open grazing land (Table 6.3). The mean values of soil pH (1:2.5 H_2O) did vary in a smaller rate with both land use type and landscape position (Table

6.3). These values differed between 6.61 and 6.86 and between 6.86 and 7.37 for area closure and open grazing land, respectively. Soil favorable for agricultural practices have pH values ranging from 6 – 7 (Osman, 2013). Hence, most of the aforementioned pH values are good for undertaking agricultural activities and so for plant/vegetation growth (taking into account that other factors are constant).

Table 6. 3. Minimum (mini), maximum (maxi), mean and standard error (SE) of mean of soil pH, OM, Available P, Available K, TN and CEC in the 0 – 20 cm soil depth along different slope positions of area closure and open grazing land of Hita-Borkena Watershed, Northeastern Ethiopia

Land use	Slope position	pH (1:2.5 H_2O)				OM				AvP (ppm)				AvK (ppm)				TN (%)				CEC (meq/100g)			
		Mini	**Maxi**	**Mean**	**SE**	**Mini**	**Maxi**	**Mean**	**SE**	**Mini**	**Maxi**	**Mean**	**SE**	**Mini**	**Maxi**	**Mean**	**SE**	**Mini**	**Maxi**	**Mean**	**SE**	**Mini**	**Maxi**	**Mean**	**SE**
Area closure	Upslope	5.05	7.47	6.61	0.26	2.09	3.75	2.71	0.24	3.14	87.27	21.32	10.01	5.73	27.87	13.92	2.50	0.29	1.05	0.64	0.10	26.12	48.62	39.76	2.52
	Midslope	6.13	7.13	6.77	0.12	1.12	3.77	2.48	0.43	3.25	84.06	40.47	12.26	7.95	14.49	11.17	0.73	0.20	1.28	0.58	0.13	20.64	41.66	33.09	2.18
	Footslope	6.45	7.21	6.86	0.11	0.69	4.66	2.44	0.47	3.83	83.26	39.81	12.08	7.24	24.85	13.82	1.86	0.10	1.28	0.59	0.14	24.98	55.28	39.23	3.97
	Average	5.88	7.27	6.75		1.30	4.06	2.54		3.41	84.86	33.87		6.97	22.40	12.97		0.20	1.20	0.60		23.91	48.52	37.36	
Open grazing	Upslope	6.42	7.47	6.90	0.23	0.80	2.48	1.50	0.35	3.78	57.64	39.57	12.37	13.08	27.56	21.33	3.22	0.19	0.31	0.23	0.03	23.62	42.12	34.30	3.87
	Midslope	7.10	7.65	7.37	0.12	0.53	1.31	0.93	0.16	4.98	77.66	53.08	16.64	16.40	26.96	22.49	2.56	0.14	0.35	0.22	0.05	23.62	37.44	32.06	3.10
	Footslope	5.71	7.41	6.86	0.39	0.34	1.33	0.94	0.21	4.90	84.06	55.47	17.66	18.81	48.69	31.21	6.72	0.15	0.43	0.23	0.07	31.44	40.32	34.24	2.06
	Average	6.41	7.51	7.04		0.56	1.71	1.12		4.55	73.12	49.37		16.00	34.40	25.01		0.16	0.36	0.23		26.23	39.96	33.53	

Note: - OM = Organic Matter, AvP = Available Phosphorus, AvK = Available Potassium, TN = Total Nitrogen, and CEC = Cation Exchange Capacity

Regardless of landscape position, the soil pH of area closure was 6.75(±0.10) while for the open grazing land was 7.04(±0.16) (Table 6.3), and these values can be rated as very slightly acidic and nearly neutral (Osman, 2013), respectively. However, the mean pH difference between these land uses was not statistically significant ($p>0.05$). This test result was in agreement with the test result provided by Kibret (2008). The relatively lower mean pH value under area closure took place probably due to the higher vegetation cover that encourages percolation of soil water and the removal of basic nutrients/cations. This finally may cause the soil to be very slightly acidic in nature (Abiy 2008; Tizita, 2014). The solubility of Ca, Mg, and Mo may increase and that of Fe, Al, Mn, Cu and Zn may decrease due to the relatively higher pH values (Osman, 2013) of open grazing land.

6.2.2. Total Nitrogen

The minimum total nitrogen (%) contents of area closure and open grazing land were 0.10 and 0.14, respectively. On the other hand, the maximum ones for the same land use types were 1.28 and 0.43, respectively (Table 6.3). The mean values of total nitrogen under area closure along with different slope positions ranged between 0.58 and 0.64% while that of open grazing land lied between 0.22 and 0.23% (Table 6.3). The former and the latter values can be rated as high and medium soil nitrogen contents, respectively (Landon, 1991). This implies that soils under area closure showed an improvement in total nitrogen compared to their counterpart in open grazing land may be partly due to the establishment of area closure.

Regardless of slope positions, the mean soil total nitrogen (%) value of area closure was 0.60 (±0.07) was significantly higher than ($p < 0.05$) that of the soil of open grazing land (i.e. 0.23 (±0.03)) (Tables 6.3 and 6.4). The relatively higher value of total nitrogen under area closure compared to the open grazing land counter part could be related with the availability of higher organic matter content and lower rate of soil erosion. This means that soil total nitrogen rises with the increase in amount of soil organic matter, whereas arresting soil erosion through conservation measures like area closure leads to the increment of the same soil parameter (Abiy, 2008; Tizita, 2014). Similarly, Gao et al.

(2011) reported that there was higher total nitrogen in exclosure than in grazing land due to the reason that vegetation rehabilitated, which in turn improved input and quality of litter and that of nutrient cycling.

The result of the present study was in contrary to Kibret (2008), who reported that the mean total nitrogen difference between enclosure and open grazing land was statistically insignificant ($p > 0.05$).

6.2.3. Available Phosphorus

It is customary to assess the level of available phosphorus in the soil since phosphorus is one of the primary nutrients required by plants. In Table 6.3 above, it is shown that the range of the mean available phosphorus (ppm) of area closure along the three landscape positions was between 21.32 and 39.81 while that of open grazing land on the same positions was between 39.57 and 55.47. Here, there is a clear indication of the higher concentration of available phosphorus in open grazing land than in area closure. Fortunately, the aforementioned values, according to Havlin et al. (1999), lie in the rating of high.

In the present study, efforts are also made to identify the variation of the mean values of available phosphorus due to land use type alone. The minimum and maximum soil available phosphorus contents of area closure were 3.14 and 87.27, respectively. Comparatively, the corresponding contents of open grazing land were 3.78 and 84.06, respectively (Table 6.3). The mean values of such parameter of the first and the second land use types were 33.87 (± 6.60) and 49.37 (± 8.48), respectively. However, the mean available phosphorus difference between the two land use types was not statistically significantly different ($p > 0.05$) (Table 6.4). This was in line with Kibret (2008). The relatively lower contents of available phosphorus under area closure could be due to the fact that phosphorus in such land use type exists more in unavailable form. This leads to state that area closure didn't have role in the improvement of the amount of available phosphorus (Abiy, 2008; Tizita, 2014) in the study area. That is, there will be relatively smaller phosphorus in the soil, as under area closure, if the buffering capacity of soil phosphate mineral in a given amount of time is limited (Hazelton and Murphy, 2007).

The other reason might be related with the presence a higher uptaking of such soil nutrient by restored vegetation (Ermias et al., 2017).

Table 6. 4. Independent samples t-test result for selected soil chemical properties and land use type

Soil chemical property	Levene's test for equality of variances	t-test for equality of means		
		t	*Df*	*p*
pH (1:2.5 H_2O)	Equal variances assumed	-1.65	34	0.108
OM (%)	Equal variances not assumed	5.26	33.98	0.000*
AvP (ppm)	Equal variances assumed	-1.40	34	0.172
AvK (ppm)	Equal variances assumed	-4.98	34	0.000*
TN (%)	Equal variances not assumed	5.04	28.57	0.000*
CEC (meq/100g)	Equal variances assumed	1.38	34	0.176

Notes: - Levene's test for equality of variances was used to test whether soil properties have the same or different levels of variability between the two land use types or not.

- *Significant at $p < 0.05$ (2-tailed)

6.2.4. Available Potassium

The mean available potassium (ppm) contents of area closure along the slope positions mentioned above ranged between 11.17 and 13.92 whereas that of open grazing land between 21.33 and 31.21 (Table 6.3). As can be observed from such values, available potassium was found to be relatively higher under open grazing land compared to area closure. Besides, Landon (1991) rated available potassium (ppm) values between 12 and 78 as low. It means that with the exception of the lower limit of the range under area closure, i.e. 11.17, all of them lied under the category of low. This further suggests that effort to improve this essential nutrient of plants using the establishment of area closure needs still more time.

The mean soil available potassium (ppm) exhibited discrepancy between the land use types considered. It differed between 12.97 (±1.05) under area closure and 25.01 (±2.72) under open grazing land. The minimum (i.e. 5.73) and maximum (i.e. 48.69) values of such parameter were recorded by the former and the latter land use types, respectively. This could happen because of the reason that soil potassium in area closure is stored in unavailable form or because more potassium is being extracted by vegetation placed in area closure at the rate higher than the amount that can be consumed by grass species in the open grazing land. The present result was opposite to Abiy 2008; Tizita, 2014. In conformity with these two investigators, Yuan et al. (2012) also found out that the restoration of grasslands increased clay and silt fractions, and amount of nitrogen, phosphorus, potassium and organic matter.

A statistically significant mean difference of available potassium ($p < 0.05$) was found between the land use types (Table 6.4). Mengistu (2011) and Wendwessen (2009) also investigated the same result. The second researcher reported that area closure didn't positively affect soil available potassium, which is similar with the finding of the present study.

6.2.5. Soil Organic Matter

Soil organic matter (%) is a material supplied by both plants and animals, which is then subject to the process of decomposition by microbes. It is a source of different soil nutrients like C, O, H, and of S, N, P, K, Ca and Mg in relatively a smaller amount (FAO, 2005). Its value is expressed in percent and is derived from soil organic carbon (%) value as shown in chapter 3. The average soil organic matter contents of area closure on the upslope, midslope and footslope were 2.71, 2.48 and 2.44, respectively, and that of open grazing land were 1.50, 0.93 and 0.94, respectively (Table 6.3). This leads to suggest that implementation of area closure on degraded hillsides in the study area has raised the amount of soil organic matter. According to Landon (1991), all of the soil organic matter values of these land uses can be rated as very low.

The lowest (i.e. 0.34) and highest (i.e. 4.66) values of soil organic matter were exhibited by open grazing land and area closure, respectively. The average soil organic matter value of area closure (i.e. 2.54 ± 0.22) was statistically significantly greater than ($p < 0.05$) the same value of open grazing land (i.e. 1.12 ± 0.16) (Table 6.3 and 6.4). The present finding was consistent with Abiy, 2008; Kibret, 2008; Lemma, 2015; Mengistu, 2011; Tizita, 2014; Wendwessen, 2009; Wolde, 2013; Yuan et al., 2012. For example, Wolde (2013) witnessed increment of soil organic matter after communal grazing lands are changed into exclosures. Yuan et al. (2012) also stated that increased amount of silt, clay and soil organic matter in the rehabilitated grasslands leads to a decline in bulk density and a rise in water holding capacity of the topsoil.

As opposed to the aforementioned findings, Wolde et al. (2016) didn't find a clear trend of soil organic matter in exclosures and communal grazing lands. The same researchers speculated two main reasons for this unusual incident. Their first reason was due to suitable soil conditions, the accumulation and turnover of soil organic matter improve and then leads to a decline in soil organic matter. The second one was the probable enhancement of soil organic matter content in communal grazing land due to the availability of cow dung in such areas.

A minimum amount of soil organic matter in open grazing land in the study area could be due to three main reasons: a) a decline in biomass production, b) a rise in the rate of decomposition process, and c) a decrease in litter input. Continuous grazing of the open grazing land considered in the present study probably lead to soil compaction and in turn to limited soil aeration. Overgrazing in this area could also reduce the density of vegetation leading the area to be vulnerable to soil erosion and restraining the accumulation of soil nutrients and the carrying capacity of the grazing land (FAO, 2005). When the land is exposed for erosion due to less vegetation cover (like the open grazing land considered in this study), large amounts of soil nutrients including soil organic carbon will be removed. At this time, GHGs (Green House Gases) including CO_2 will be emitted to the atmosphere, i.e. soil carbon in the form of CO_2 will be released to the atmosphere. That is, as opposed to open grazing lands, controlled grazing and SWC measures are important to gain a good carbon budget (Lal, 2016). In connection with the role of exclosures in sequestering CO_2, Wolde et al. (2015) conducted a study in northern Ethiopia in the Nile basin and found out that exclosures sequester CO_2 and thereby partly mitigate climate change. The same authors further noted that the current annual income of the local people in their study area will be increased by 42 % if the sequestered carbon in the aboveground biomass of exclosures is traded.

6.2.6. Cation Exchange Capacity

The mean Cation Exchange Capacity (CEC) (meq/100g) of the soil of area closure and open grazing land taken along the three slope positions as rated by FAO (2006) was high (Table 6.3). It ranged from 33.09 to 39.76 under area closure and from 32.06 to 34.30 under open degraded land. In contrast, better CEC values were recorded in area closure than in open grazing land.

Both the lowest (i.e. 20.64) and the highest (i.e. 55.28) CEC values were exhibited by area closure (Table 6.3). The mean CEC values calculated taking land use type as an independent variable are also shown in the same table. The mean value of such parameter for area closure (i.e. 37.36 ± 1.77) was greater than that of the same value for open grazing land (i.e. 33.53 ± 1.65). This may be due to the fact that area closure contained relatively higher amounts of soil organic matter and clay as compared to open grazing land (Abiy, 2008; FAO, 2006; Tizita, 2014; Woldeamlak, 2003). A relatively lower CEC of open grazing land could be because of higher rate of decomposition or because clay surfaces in the soil system of such land use become inaccessible (FAO, 2006).

There was not statistically significant difference between the mean values of CEC of area closure and open grazing land ($p > 0.05$) (Table 6.4). This was in agreement with Wendwessen, 2009; Wolde et al., 2016, but in opposite to Abiy, 2008; Kibret, 2008; Tizita, 2014; Shimeles et al., 2013; Yuan et al., 2012. As attained by Abiy (2008), the mean CEC values of young enclosure, old enclosure and free grazing land were 32.04, 33.18 and 25.29, respectively, and these values were significantly different at $p = 0.05$. On the other hand, Wolde et al. (2016) found that the mean CEC of exclosures aged 1 – 7 years and communal grazing lands were not significantly different at $p = 0.05$.

6.3. Relationships between Soil Properties and Slope Position

A one-way ANOVA (at $\alpha = 0.05$) was computed to see the effect of slope position (i.e. upslope, midslope and footslope) on selected soil physico-chemical properties. The result was that PH, available phosphorus, available potassium, total nitrogen, CEC, % clay, % silt, % sand, bulk density, organic matter, and total porosity didn't significantly vary along the slope positions at *p* equals 0.462, 0.309, 0.429, 0.946, 0.205, 0.635, 0.582, 0.470, 0.541, 0.696, and 0.627, respectively. This implies that unlike land use type mainly area closure, landscape position alone didn't have significant effect on the soil fertility of the study watershed. In conformity with this, Wolde and Ermias (2011) detected no significant differences ($p > 0.05$) among slope positions in soil parameters (i.e. total nitrogen, available phosphorus, CEC, total nitrogen stock and available phosphorus stock) within exclosures aged 5, 10, 15 and 20 years and the adjacent open grazing lands.

6.4. Effect of Land Use Type and Slope Position on Soil Properties

A two-way ANOVA analysis (at $\alpha = 0.05$) was performed taking land use type (i.e. area closure and open grazing land) and slope position (i.e. upslope, midslope and footslope) as independent or explanatory variables, and selected soil properties as dependent variables (Table 6.5). From the results, one can conclude that the interaction of land use type and slope position didn't significantly affect any of the soil properties considered in this study. However, as shown in sections 6.1 and 6.2 above, land use type did have effects on the variation of different soil properties except available phosphorus, CEC, clay, and PH. This means that probably other factors (other than land use type and slope position) are responsible for affecting the earlier mentioned soil properties.

Table 6. 5. Two-way ANOVA result for the effect of the interaction between land use and slope position on selected soil physico-chemical properties

Soil properties	Land use		Slope position		Interaction between land use & slope position	
	F	*p*	*F*	*p*	*F*	*p*
Clay (%)	0.62	0.439	0.27	0.767	0.27	0.767
Silt (%)	9.94	0.004*	0.58	0.569	0.03	0.969
Sand (%)	5.75	0.023*	0.59	0.559	0.10	0.907
Bulk density (g/cm^3)	5.15	0.031*	0.32	0.730	1.22	0.311
Total porosity (%)	5.15	0.031*	0.32	0.730	1.22	0.311
pH (1:2.5 H_2O)	2.68	0.112	1.07	0.356	0.93	0.404
OM (%)	16.80	0.000*	0.61	0.551	0.09	0.913
AvP (ppm)	1.86	0.183	0.97	0.392	0.02	0.980
AvK (ppm)	26.37	0.000*	2.30	0.117	1.54	0.232
TN (%)	12.21	0.002*	0.04	0.961	0.03	0.974
CEC (meq/100g)	1.90	0.178	1.08	0.354	0.26	0.776

Notes: - * Significant at $p < 0.05$.

- Other p values without asterisk are not significant at $p < 0.05$.

6.5. Relationships between Soil Properties

Soil organic matter showed a significant and positive correlation with total nitrogen (Figure 6.1 (c)), clay (Figure 6.1 (b)) and total porosity (at 0.01 level) and with CEC (Figure 6.1 (d)) (at 0.05 level) (Table 6.6). As revealed in section 6.2.5, the establishment of area closure in the study watershed contributed to the positive correlation between soil organic matter and the aforementioned soil parameters. As predicted, there was strong positive correlation between soil organic matter and total nitrogen, and this result is consistent with Shimelis (2012), and Birhan and Assefa (2017). This happened because organic matter supplies nitrogen to the soil system and this in turn means that as soil organic matter increases, so does soil nitrogen. A significant and negative correlation (at 0.05 level) was recorded between organic matter and available phosphorus (Table 6.6; Figure 6.1 (e)), though organic matter is also a source of phosphorus. This may be due to the reason that soil phosphorus was not stored in available form. Wolde et al. (2007) found a significant and positive correlation between soil organic matter and that of total nitrogen, available phosphorus and CEC.

There was significant and positive correlation (at 0.01 level) between clay and CEC (Table 6.6; Figure 6.1 (f)). This implies the role of clay fraction in supplying available nutrients to plants (Dereje and Assefa, 2016) both in area closure and open grazing land. The result of the present study was also in agreement with Yuan et al. (2012), who revealed that clay has a significant and positive correlation (p < 0.01) with soil water holding capacity, soil organic matter, total nitrogen, total phosphorus, available nitrogen, available phosphorus, available potassium, and CEC. In contrary to the present study and Yuan et al. (2012), Wolde et al. (2007) indicated that there was insignificant and positive correlation (p > 0.05) between CEC and clay.

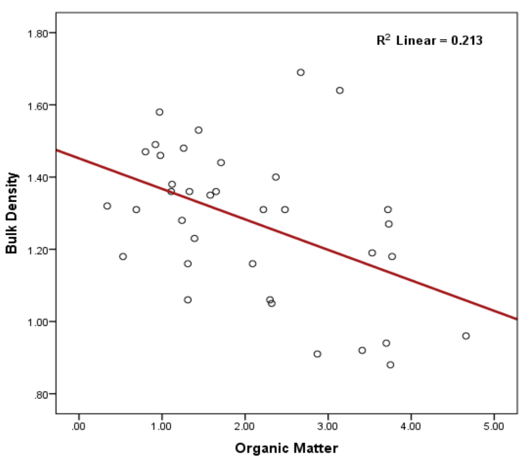
Soil bulk density had a significant and negative correlation (at 0.01 level) with organic matter (Table 6.6; Figure 6.1 (a)), total nitrogen, CEC and total porosity. Similarly, Birhan and Assefa (2017) found out an inverse correlation between bulk density with that of organic matter and clay. The present study, which is consistent with the reality, showed that as soil aeration and porosity decline due to the increment of bulk density, the amount of the aforementioned soil parameters also decline.

Table 6. 6. Pearson correlation coefficients between selected soil properties

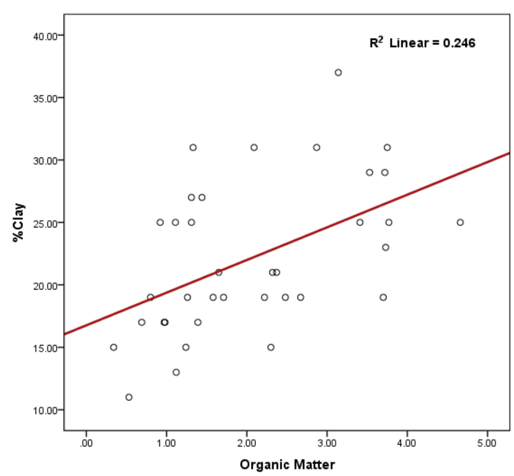
Parameters	PH	AvP	AvK	TN	CEC	Clay	BD	OM
AvP	-0.03							
AvK	0.23	0.05						
TN	-0.08	-0.24	-0.26					
CEC	-0.18	-0.08	-0.08	0.53**				
Clay	-0.19	-0.09	0.18	0.39*	0.48**			
BD	-0.04	0.21	0.14	-0.64**	-0.42**	-0.16		
OM	-0.15	-0.34*	-0.36*	0.77**	0.42**	0.50**	-0.46**	
TP	0.04	-0.21	-0.14	0.64**	0.42**	0.16	-1.00**	0.46**

Note: N = 36, * and ** refer to correlation was significant at the 0.05 and 0.01 level (2-tailed), respectively

a)



b)



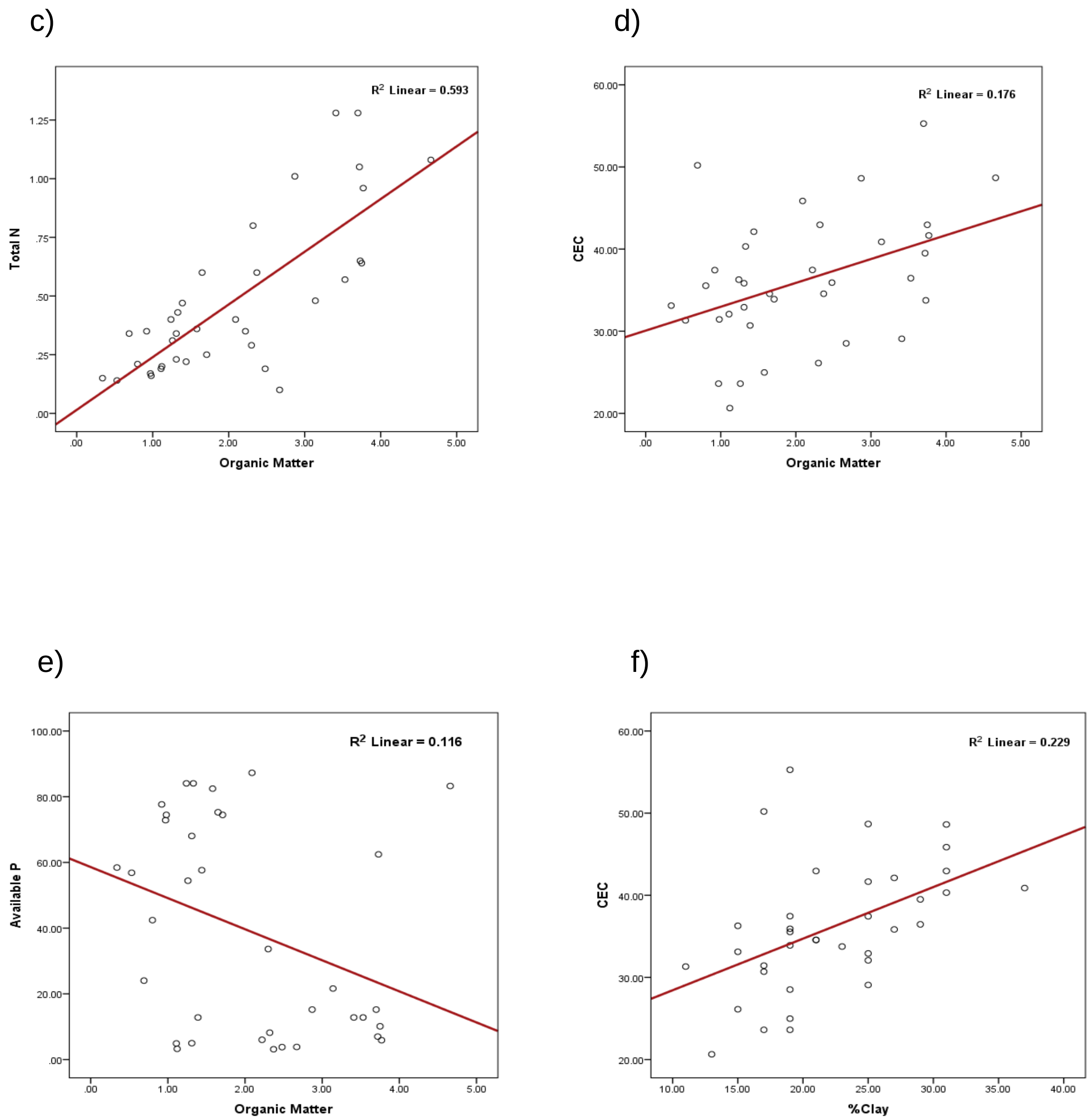


Figure 6.1. Bivariate correlations between OM with selected soil properties, and correlation between clay and CEC

6.6. Conclusion

The impact of area closure as well as slope position on soil properties was evaluated in this study by employing standard soil laboratory analysis procedures and appropriate statistical techniques.

The present study confirms that area closure is a viable land management technique to restore the soil properties/fertility of degraded lands, like Hita-Borkena watershed found in northeastern Ethiopia. This was assured comparing the selected soil properties of area closure and open grazing land. Such result happened because area closure does have relatively better vegetation cover, aboveground biomass and is less exposed to soil erosion than the open grazing land counterpart. It was also found that slope position alone, and the interaction of land use type and slope position didn't considerably affect the selected soil properties.

Here, it is advised to be understood that more is still expected from the existing area closure in the study area in relation to soil fertility. Some soil properties like available potassium, organic matter, and the vegetation cover (aboveground biomass) shall be improved so as to gain more benefits by restoring the degraded lands of the study area.

Chapter Seven

7. Farmers' Perceptions on the benefits of Area Closure and Related Conservation Techniques

Since 2000/2001, landscape restoration activities of the MERET project have been practiced in the study area as a measure of soil erosion control. One of such activities was establishing area closure along the degraded hillsides. In order to check farmers' level of acceptance about the already established area closure and related conservation measures, it is advisable to assess their views on the impacts of the intervention on controlling soil erosion. It is also clear that a watershed cannot only be managed by area closure but also by other conservation techniques. In view of these facts, in this chapter, farmers' views on soil erosion, status of soil fertility, overgrazing, and illegal cutting of trees, in particular, and on area closure in general are treated. Attempts are also made to substantiate farmers' views by agricultural experts' responses. To this end, semi-structured questionnaires and in depth interview were employed to gather data from 255 sampled farmers and 7 experts, respectively. Statistical differences between the central response values of five-point Likert scale and the mean values of the scaled responses of farmers were tested using a one sample t-test.

7.1. Farmers' Perception on the Status of Soil Erosion before and after Landscape Restoration

Soil erosion is a process driven mainly by water and wind agents that removes topsoil and associated organic matter and nutrients. This problem in turn affects soil infiltration and fertility that lead to increased run off (Pimentel, 1993).

The one sample *t*-test statistic of Table 7.1 indicates that farmers rated the status of soil erosion as it was high in the study area before the introduction of MERET project (t = 17.67, P<0.001), with 95% confidence interval of the difference between 0.76 and 0.95.

The one sample t-test of Table 7.1 revealed that the sampled farmers rated soil erosion as it was high in the study area before the introduction of landscape restoration of MERET project (t = 17.67, p<0.001), with 95% confidence interval of the difference between 0.76 and 0.95. This implies that soil erosion in the study area before the said project was relatively severe. As a result, the local people as well as the physical environment were negatively affected. This was the primary reason that provoked Kalu district agriculture office in collaboration with WFP-Ethiopia to launch restoration activities in the name of MERET project in the study area in the year 2000/2001. Regarding farmers' perception toward the severity of soil erosion, Woldeamlak (2011) found out that they rate soil erosion as severe when gullies appear here and there or when crops/seedlings/plants are damaged by torrential rainfall or when applied fertilizers are removed by the same cause.

Table 7. 1. One sample t- statistics on farmers' perception on the rate of soil erosion before landscape restoration, and current status

Status of soil erosion at different period	Test Value = 3					
	t	*df*	Sig. (2-tailed)	Mean Difference	95 % confidence interval of the Difference	
					Lower	Upper
Soil erosion before landscape restoration	17.67	254	0.000	0.86	0.76	0.95
Current soil erosion problem	-15.24	254	0.000	-0.73	-0.82	-0.63
Soil erosion existing now as compared to the past	-9.82	254	0.000	-0.58	-0.70	-0.46

Respondents rated soil erosion after landscape restoration as low (t = -15.24, p<0.001; Table 7.1). In agreement with farmers' perception, interviewed agricultural experts working in the study area also appreciated MERET project's contribution in this respect and noted that soil erosion is now reduced by different conservation measures including area closure. In this regard, one of the experts explained with remorse that both farmers and experts participation at the beginning of the project was magnificent but now declined. Overall, from the views of both farmers and experts, it is possible to notice that soil erosion is relatively reduced compared to the situation before the project. Gebrehaweria et al. (2016) by collecting data from key informants selected from 6 watersheds located in 3 regions (Amhara, Oromiya and Tigray regions) of Ethiopia (2 watershed from each region) concluded that restoration activities or watershed management lead to a reduction of soil erosion by a percent ranging from 35 up to 90. In connection with one of the restoration measure, i.e. exclosures/enclosures/area closures, different researchers (e.g. Abenet et al., 2016; Haile, 2012; Mengistu and Mekuria, 2015; Shimelis, 2012; Tagel and Veen, 2014; Tefera et al., 2005; Tesfay, 2016; Verdoodt et al., 2009; WLRC, 2015; Wolde et al., 2017; Wolde et al., 2007 among others) disclosed that they are important measures to arrest soil erosion. And, by doing so, soil quality has been restored and environmental degradation minimized (Lal, 2015).

Respondents were also asked to compare the existing soil erosion problem with that of before restoration measures of the area, and have responded as it was statistically significantly low (t = -9.82, p<0.001; Table 7.1). Similar with the responses of sampled respondents, interviewed agricultural experts also acknowledged the contribution of restoration activities in combating soil erosion.

7.2. Causes and Consequences of Soil Erosion

Out of the total of 255 respondents, 30 of them rated current soil erosion problem as high and very high. Such farmers were questioned to list the causes and consequences of soil erosion in the study watershed and their responses are given hereunder.

The majority of the above mentioned farmers revealed that overgrazing, steepness of the slope of the watershed, deforestation and improper farming like vertical plowing are the main causes of soil erosion in the study watershed. Some also enunciated failure to plant trees, less vegetation/forest cover and closeness of farmlands to the available river/streams as the causes for the problem of soil erosion in their locality. In addition to these, experts also depicted that soil in the study area is being eroded due to failure to keep and upgrade existing SWC measures, existence of asphalt road that crosses the watershed which causes creation of gullies, failure to restore deep gorges/gullies, abnormal rainfall that falls at unwanted time, availability of some plots in the watershed which are not totally conserved and low awareness of some local people. The causes of soil erosion mentioned earlier are related with land use (Wolde et al., 2007), and with farmers' practices and natural phenomenon. Studies made by Mengistu and Mekuria (2015) and Wolde et al. (2007) confirmed overgrazing, poor land management practices and deforestation as the major causes of soil erosion. Woldeamlak (2007), on the other hand, found out that soil erosion is mostly caused by steep slope, presence of easily erodible soil and too high rainfall. Other causes of soil erosion as shown by Osman (2013) include shifting cultivation, forest fire, burning of crop residue, grasslands and scrub vegetation, absence of crop rotation, and tillage practices that lead a soil to be very fine in texture.

Of the 30 respondents, most of them mentioned decline in soil fertility and productivity, decline in crop yield, removal of fertile topsoil and creation of gullies as the main consequences of soil erosion in the study watershed. A few of them also pinpointed that increase in flooding risk especially in downslope, shortage of fodder for livestock, mudflow and increase in salinity of the soil are the results of soil erosion. Here, the respondents focused on the impacts of soil erosion on the physical environment and on their livestock. However, soil erosion can also be the cause for social crisis like poverty, hunger and out-migration. Besides, it also leads to shortage of farm plots and grazing fields, fertilizers loss, high fertilizer requirements, and subsoil exposure (Woldeamlak, 2011). Another consequence of soil erosion, which is not mentioned so far but is identified by Wolde et al. (2007), is agricultural and grazing lands fragmentation.

7.3. Farm Plots' Fertility before and after the Restoration Project

About 92 % of the sampled farmers (i.e. 235 respondents) confirmed that their respective farmlands found in the study watershed lose their fertility before the implementation of MERET project. The rest, i.e. about 8 % of them, reacted to the above mentioned issue oppositely. This may be related with their level of awareness or for their farm plots are less vulnerable to soil erosion.

The majority of respondents revealed that the current fertility status of their farm plots is relatively better than before. Some believed that their farmlands fertility is improving from year to year. One of the respondents exemplified that he harvested 10 quintals in the past but now harvests 13 quintals. As to a few farmers, some plant species which had disappeared due to severe degradation are now regenerating as a result of soil quality improvement. Some other informants also dictated that the current soil fertility is a little bit better than before, their farm plots don’t show any change in fertility at all, and some even regretted that the fertility of their farm plots in the past was better compared to their present condition. Previous studies (such as Abenet et al., 2016; Gebrehaweria et al., 2016; Wolde et al., 2017) witnessed that area closure/exclosure being integrated with physical and biological conservation measures improve soil fertility by arresting soil erosion and adding litter and increasing above-ground biomass. This, in turn, leads to increase in soil depth and moisture content. Consequently, the productivity of the plot enhances that can also have positive impacts on farmers’ livelihood.

The interviewed agricultural experts also noted that the soil fertility of the study watershed relatively improved compared to its past situation. They added that soil productivity is also increased though this particularly depends on farmers’ courage in controlling diseases, weeds and maintaining existing moisture. Also, one of the experts described the following story:

> *A female farmer dwelling in the study watershed, who owns a quarter of 1 ha of farmland, harvested 6 quintals of sorghum in the past but now harvests 12 ½ quintals of the same crop.*

7.4. Status of Overgrazing and Illegal Cutting of Trees before and after Landscape Restoration

Overgrazing occurs when the pressure on grazing lands rises, i.e. when it becomes beyond its carrying capacity. So, in order to reduce degradation of such land use types, in restoration activities, watersheds especially hillsides are kept away from the interference of humans and livestock.

The majority of respondents showed that the rate of overgrazing before the restoration project was statistically significantly high (t = 21.69, p < 0.001; Table 7.2). From this, one can infer that overgrazing was severe in the past, i.e. farmers were letting their animals to graze freely. Obviously, this causes fodder shortage, forage species loss, expansion in coverage of bushland, prevalence of non-forage species, a decline in regenerative capability of plant species which finally leads to biodiversity loss (Verdoodt et al., 2009).

The sampled farmers rated the current overgrazing problem in comparison with the past as low (t = -15.34, p < 0.001; Table 7.2). In support of this, the interviewees expressed the current situation of overgrazing in the study watershed in different ways as follows:

- It is reduced because of the decrease in the number of livestock and cut-and-carry grazing system.
- It is decreasing from time to time, but especially in the evening some persons involve in doing so.
- It is minimized but not controlled completely.
- The hillsides are not overgrazed, but grazing lands located under the downslope are somewhat overgrazed.

Table 7. 2. One sample t- statistics on farmers' perception on the rate of the current overgrazing problem compared to the past

Overgrazing	Test Value = 3					
	t	*df*	Sig. (2-tailed)	Mean Difference	95 % confidence interval of the Difference	
					Lower	Upper
Overgrazing before the restoration project	21.69	254	0.000	1.01	0.92	1.10
Current overgrazing problem	-15.34	254	0.000	-0.78	-0.88	-0.68

The coverage of grazing land in the study watershed enhanced due to a decline in pressure on such features (see chapter 5). This is, of course, linked with the implementation of cut-and-carry system of feeding livestock, i.e. stall feeding, in the study area. As to Wolde et al. (2017), boosting fodder production, limiting livestock movements, reducing grazing pressure, promoting regeneration of different plant species and protecting any conservation measures from potential damages are the major merits of employing cut-and-carry system. In connection with this, a study by Dereje et al. (2003) recommended that leaving area enclosures non-grazed in the growing season and doing the opposite in the dry season is good for fostering restoration. On the other hand, Abenet et al. (2016) recommended that it is possible to perform cut-and-carry system within a year of closing the area provided that it is properly managed and adequate fodder production is available.

Figure 7.1. Cut-and-carry style of feeding cattle in the study area

Source: Kalu District Agriculture Office, 2013

Almost all respondents believed that illegal cutting of trees was much more pronounced during the time when the restoration project was not put into practice (Table 7.3). This implies that rate of deforestation was much higher before the project. And, one of the very reasons for the establishment of area closure is to restore degraded lands by combating land degradation and controlling deforestation. In this respect, showing the success of the implementation of area closures in Ethiopia, Abenet et al. (2016) indicated that they are now being protected from deforestation by local bylaw, i.e. the one who violates this law will be punished.

The interviewed agricultural experts also revealed their opinions on illegal cutting of trees after MERET project as follows:

- Such illegal practice has decreased very much, but some do so especially in the evening even with the presence of a guard.
- It is decreasing from time to time for farmers become well aware of the use of forest.
- Mostly youngsters cut trees, but older ones are relatively not engaged in doing so.

This decreasing trend of deforestation, as mentioned by farmers and experts, is registered for the fact that (WLRC, 2015) the awareness of farmers about conserving the environment is enhanced. This is, of course, an important measure for escalating above-ground biomass. Also, it promotes sequestration of greenhouse gas, i.e. carbon, which in turn is good for climate change mitigation.

Table 7. 3. Farmers' responses on the time that there was illegal cutting of trees

Presence of illegal cutting of trees	Frequency	Percent
Before the restoration project	245	96.1
After the restoration project	5	2.0
Both before and after the project	5	2.0
Total	255	100

With regard to community's role in tree planting in the study area, most of sampled farmers acknowledged that there is good participation both in tree planting and conservation by the community. There is a campaign of such planting activities, which is organized annually, leading the watershed's vegetation to increase from time to time. Even the community is now conserving those trees grown on farmlands by fencing and constructing SWC measures. A few farmers are not participating as expected. The community is protecting area closure by formulating bylaws and by assigning a guard. However, in chapter 5, it is clearly showed that the watershed's forest cover recorded a decreasing trend from 1986 to 2015. Provided that most members of the community are participating very well in afforestation and conservation, the researcher is optimistic that the watershed's vegetation cover will be improved in the future.

7.5. Methods Used to Restore Hita-Borkena Watershed Together with Area Closure

It is a recommended fact that area closure should be integrated with physical and biological conservation measures to gain a number of benefits, like soil erosion reduction, above-ground biomass augmentation, increased fodder and livestock productions, better income for farmers, enhanced soil fertility and productivity, and better carbon sequestering capability (Wolde et al., 2017). Accordingly, the participants of the present study listed the following conservation measures, which play important roles for the restoration of the study watershed along with area closure. These measures can be classified into three based on the site that they are implemented in the watershed. They include:

A. Those implemented on hillsides
    1. Area closure
    2. Hillside terrace
    3. Water collection trench
    4. Eyebrow basin with pit
    5. Micro-basin
    6. Tree planting
B. Those implemented on farmlands
    1. Farm terrace (bench terrace)
    2. Soil and stone bund
    3. Waterway
    4. Cutoff drain
    5. Agroforestry
C. Those implemented on gullies and downslope
    1. Gully rehabilitation
    2. Sediment storage dam (SS Dam)

3. Checkdam with gabion and stone

Though they are not mentioned by informants, Kalu district agriculture office (2013) disclosed that water harvesting and growing of vetiver grass are also other conservation means, which are employed to restore the watershed. Abenet et al. (2016) justified that construction of physical conservation measures like terracing, tree and grass planting are often the common practices in Ethiopia that are implemented together with area closure. This is good for enhancing both the vegetation cover and the biodiversity. Figure 7.2 given below shows how the integration of conservation measures plays a role in restoring a degraded hillside.

a) Before restoration **b) After restoration**

Notes: a) The hillside before the establishment of area closure but it is with other conservation works mainly contour trench

b) The same area with figure (a) containing area closure plus other conservation works along the hillside

Figure 7.2. A degraded hillside in Hita-Borkena watershed before and after restoration activities

Source: Kalu District Agriculture Office, 2013

7.6. Farmers' Views on Area Closure

7.6.1. Importance of Area Closure

As revealed earlier, area closure is, in general, good for the restoration of ecosystem. It, however, needs the support and/or participation from the community, governmental organizations (GOs) and non-governmental organizations (NGOs) for the management and up scaling of such measure in order to benefit both the community and the environment.

From all sampled household heads, 239 (93.7 %) of them replied that none of their farm plots were taken by the government for the purpose of establishing area closure in the study watershed. The rating of community's benefit because of area closure by those respondents (i.e. they are 16 in number) whose farm plots were taken for the same purpose was not statistically significant (t = 1.07, p>0.05; Table 7.4). It seems that a few farmers did have negative sentiment about area closure, which really requires awareness creation for them by concerned bodies. Regarding this, Betru et al. (2005) emphasized that the community should be clear with the specific benefits that they are going to gain because of the establishment of area closure.

Table 7. 4. One sample t-statistics on farmers' perception on community's benefit and land productivity because of the establishment of area closure

Benefits of area closure	Test Value = 3					
	t	*df*	Sig. (2-tailed)	Mean Difference	95 % confidence interval of the Difference	
					Lower	Upper
Community's benefit because of area closure*	1.07	15	0.30	0.25	-0.25	0.75
Importance of area closure to improve land productivity	25.23	254	0.000	0.94	0.87	1.01

* Total number of respondents doesn't add up to 255 because such question was intended for those, who lost their farmland for the sake of implementing area closure. Thus, this study identified 16 of such persons out of the total of 255 respondents.

With regard to the contribution of area closure for the improvement of the productivity of the formerly degraded land, most of the selected household heads believed that it is high (t = 25.23, p<0.001; Table 7.4). In line with this, Mengistu and Mekuria (2015) indicated that area closures are effective in promoting vegetation cover and reducing soil erosion and thereby enhancing land productivity. Besides, Wolde et al. (2007) witnessed that the majority of respondents involved in their study rated exclosures' role as important. In the same study, such respondents also noted that conserving uplands found above farm plots is important for promoting soil quality through litter addition from shrubs and grasses. This, in turn, is also important for protecting farm plots from soil erosion by reducing run off.

7.6.2. Agreement and Satisfaction Levels toward Area Closure

In accordance with the generally assumed reality, the sampled farmers rated their agreement with the opinion that "area closure restores degraded land" as agree (t = 31.92, p<0.001; Table 7.5). This perception of farmers is confirmed by different studies (for example, Abenet et al., 2016; Betru et al., 2005; Emiru et al., 2007; Gebrehaweria et al., 2016; Haile, 2012; Mengistu & Mekuria, 2015; Tagel & Veen, 2014; Verdoodt et al., 2009; WLRC, 2015: Wolde et al., 2016; Wolde et al., 2007 among others). As estimated by Abenet et al. (2016), it takes 3 – 5 years of closure of the degraded land, which was totally unsuitable for undertaking production, so as to use it again for the same purpose. However, full recovery of such land may take 7 – 10 years, which is determined by the species and vegetation type present in area closure. Factors that are responsible for affecting rate of recovery of degraded land, as shown by Abenet et al., 2016; Betru et al., 2005; WLRC, 2015, are level of degradation of the land and intensity of the management it experiences, climatic condition especially distribution and amount of rainfall, property of the soil, and level of participation of the community.

Table 7. 5. One sample t-statistics on farmers' views on rate of agreement/ disagreement and satisfaction/ dissatisfaction with area closure

Agreement/disagreement and satisfaction/dissatisfaction with area closure	Test Value = 3					
	t	*df*	Sig. (2-tailed)	Mean Difference	95 % confidence interval of the Difference	
					Lower	Upper
Agreement/disagreement with regard to the opinion that "area closure restores degraded land"	31.92	254	0.000	1.14	1.07	1.21
Satisfaction because of the involvement on area closure/landscape restoration	26.34	254	0.000	1.09	1.01	1.18

Farmers rated their satisfaction level because of their involvement on area closure and/or restoration activities as satisfied (t = 26.34, p<0.001; Table 7.5). Such optimistic attitude of the respondents took place for they realize the possible outcomes of engagement in restoration activities (Betru et al., 2005). It also means that they were aware of the big role of area closure and other restoration activities in restoring degraded communal lands (Wolde et al., 2007).

7.6.3. Activities Allowed in Area Closure

Area closure is a land management technique that allows revegetation and/or regeneration, and restores the ecology of a degraded landscape to reduce depletion of natural resources (Abenet et al., 2016). To achieve such target, some activities are allowed in area closures and some are not. As indicated by the majority of the respondents, cut-and-carry of grass, collection of branches of dead trees, and bee keeping are the activities allowed in the area closure of the study watershed (Table 7.6). It seems that most of the respondents were aware of the activities that should be disallowed to gain the earlier mentioned benefits of area closure. The result of the present study is in line with Betru et al. (2005), and Mengistu and Mekuria (2015). A study made by WLRC (2015) revealed that fruit production is an activity allowed in area closure in addition to bee keeping in one of the five watersheds it surveyed. Tefera et al. (2005) have reported that free grazing by oxen during the rainy/farming season was found to be allowed in area closure. Allowing oxen to freely graze while not doing so for goats in area closures lead to a reduction in species richness and grasses, and bush encroachment (Betru et al., 2005).

Table 7. 6. Farmers' views on activities allowed in area closure

Activities	Frequency*	Percent*
Free grazing	10	3.9
Firewood collection	10	3.9
Bee keeping	170	66.7
Cut-and-carry of grass, and collection of branches of dead trees	245	96.1
Other**	5	2.0
Total	----	----

* The frequency doesn't add up to 255 and the percent doesn't add up to 100 because of multiple responses.

** Other include no activity is allowed, grow fodder and feed livestock, and grow vegetables being in association.

Nearly all (about 97 %) of the respondents believed that restriction of humans and livestock from area closure is appropriate. This is in agreement with Mengistu and Mekuria (2015). Verdoodt et al. (2009) found out nonexistence of dung in communal closed areas indicating that there was little interference of cattle for relatively long time. Closing of a degraded area without the interference of humans and animals either to rehabilitate naturally or to restore with the integration of other conservation measures are two ways of implementing area closure (Abenet et al., 2016). Most of the respondents forwarded the following rationales behind closing of an area from human and animal interference:

- Area closure, associated SWC measures and planted seedlings will be damaged.
- It protects deforestation.
- Allowing the entrance of both in area closure lead to soil erosion and to the creation of gullies.
- It increases soil fertility and productivity.
- It prevents migration of wild animals.
- It eases supply of fodder for domestic animals.
- It protects free (over) grazing.
- It is important to restore the degraded hillsides.
- It protects downstream areas not to be eroded and keeps also their fertility.

To put the above mentioned practice into effect, the community shall obey the bylaws to sustain the area closure. The district agricultural experts are also required to involve in creating awareness for farmers about the consequences of freely utilizing the resources found in area closure (WLRC, 2015).

7.6.4. Disadvantages of Area Closure

Most of the sampled household heads pinpointed that area closure doesn't have any disadvantage. However, a few of them mentioned narrowing of farm plots and communal grazing lands, restricting movement of livestock, limiting rearing of animals on a large scale basis, and leading to reduction in fodder for livestock as the demerits of area closure. The result of the present study implies that there is little resistance to adopt and protect the existing area closure in the watershed under consideration. But, the issue of fuelwood shortage (Wolde et al., 2015) as a result of the presence of such closed area is not raised by the respondents. This may be because of the reason that farmers are collecting firewood from trees grown on their farmlands and homesteads.

Degradation of non-closed communal grazing lands and a lot of energy requirement of cut-and-carry system (Descheemaeker et al., 2010; Wolde et al., 2015) are also other disadvantages, which were not listed by the respondents. Wolde et al. (2015) proposed that such stresses of the community shall be addressed by GOs, NGOs, and the communities on a collaborative basis. In contrary to the above result, Wolde et al. (2007) found that no respondent involved in their study mentioned the negative impact of closing a degraded area.

7.6.5. Community's Involvement in Area Closure for the Future

With regard to farmers' participation in keeping the existing area closure, the interviewed agricultural experts of Kalu district disclosed that most of them does have good awareness and are participating very well. However, a few of them fail to take of the grown seedlings. One of the experts informed that to cut a given tree found in area closure, a farmers has to plant at least 5 seedlings, just a year before doing so.

Almost all (about 94 %) of the respondents revealed that they have an intention to continue involving in area closure in particular and in restoration activities in general in the future. Most of them were intending so for area closure:

- Escalates soil fertility and productivity.
- Protects soil erosion and free (over) grazing.
- Reduces runoff or flood.
- Encourages increase in vegetation or forest cover.
- Eases access to fodder by cut-and-carry system.
- Plays a big role in the sustenance of human beings.
- Restores degraded land.
- Impacts the climate of the environment positively.
- Leads the entire environment to be green.
- Leads to the increase in the amount of surface and underground water, and thereby protecting drying up of springs and streams.
- Leads to re-emergence as well as creation of ponds and springs.

Some of the respondents even proposed that not only the current generation but also the coming one shall also continue practicing area closure for it does have multiple benefits. Some also need expansion of this management activity. In general, sampled farmers had positive perceptions toward the effects of area closure, which is an important asset for restoration activities (Wolde et al., 2007) in the study watershed.

7.7. Conclusion

The perceptions of farmers toward statuses of soil erosion, soil fertility, overgrazing and illegal cutting of trees before and after the restoration project, and the role of area closure and associated SWC measures were assessed by administering questionnaire. Besides, agricultural experts working in the study watershed were also interviewed and a document on MERET project prepared by Kalu District Agriculture Office was also consulted.

In this study, it was identified that the majority of farmers perceive that currently soil erosion, overgrazing and illegal cutting of trees are all reduced while soil fertility is improved compared to the situation before the implementation of restoration activities including area closure in the study area. Most farmers had also positive perceptions toward area closure while a few of them resist such perceptions. This implies that the majority of farmers were well aware of area closure in particular and restoration activities in general, which is a base for future sustainability of natural resources and for tackling land degradation in the study watershed. The negative feeling about area closure by a small number of farmers shall be addressed through education by concerned bodies.

To better conserve and reduce pressure on area closure in the study area, farmers shall involve in income generating activities. In this case, it is advisable to integrate area closure with activities like beekeeping, animal fattening, dairy production, planting of fruit trees and also trees used as fuel wood like Acacia decurrens. To further satisfy the fuel wood demand of the community and prevent deforestation, alternative energy sources shall be introduced (Wolde et al., 2017).

Chapter Eight

8. Impact of Landscape Restoration Activities on Farmers' Livelihood

A successful restoration project must give emphasis both for the problems of the ecology and of the people (Zheng and Wang, 2014). MERET project (or in this chapter called landscape restoration (project) or simply restoration (project)), which was expected to address the problems of both the people and the environment, was put into practice in most parts of Ethiopia in early 2000s (Gebrehaweria et al., 2016). This project was implemented with the aim of restoring the degraded environment and improving farmers' livelihood in Hita-Borkena watershed in 2001 (Kalu District Agriculture Office, 2013). Accordingly, area closure and moisture retention management techniques were practiced on hillsides, gullies were rehabilitated and on-farm SWC measures were also implemented.

The environmental aspects of the study watershed are treated in the preceding chapters. In this chapter, employing a modified Sustainable Livelihoods Framework (SLF), an attempt is made to assess the impacts of landscape restoration on the asset base, livelihood activities and outcomes of the respondents.

8.1. Improved Ecosystem Services and Livelihood Diversification

Landscape restoration was implemented in the study watershed for the reason that it was highly degraded and the communities were severely food in secured (Gete et al., 2014; Kalu District Agriculture Office, 2013). The interviewees reported that such activities have increased underground water level, availed irrigation water and enabled harvesting of water even at household level. It became possible to reverse the fertility of the degraded land through restoration. As witnessed by most of the respondents, the fertility of the soils of the study watershed has improved after the implementation of the restoration activities. These respondents also noted that due to the improvement in soil fertility, crop production has also escalated. Besides, farm plots which were formerly unproductive become the opposite due to the aforementioned activities. The majority (i.e. 84.3%) of sampled farmers revealed that the productivity of their farmland is improving from year to year. This is in line with Kassu (2010), who stated that MERET (restoration) project has enhanced the productive capability of degraded lands. The same researcher also added that those abandoned lands, which were once severely degraded, have become productive through restoration.

It is generally believed that because of landscape restoration, maintenance of soil moisture and escalation of soil depth become possible which in turn results for grown crops not to be easily damaged through facilitating absorption of nutrients by crops and reducing loss of nutrients. The majority (i.e. 86.7%) of respondents appreciated the role of landscape restoration in increasing crop yield. The restoration program through practicing different SWC activities restored degraded farmlands in the study area. According to Betru, 2005; Gebrehaweria et al. (2016) and Gete et al. (2014), such attempt can decrease crop failures and improve crop production and productivity.

In the present study, it was also confirmed that the restoration activities implemented in the study watershed allowed communities to grow different crops, fruits, vegetables, livestock fodders and to practice agroforestry. It also enabled farmers to grow fodder at a larger scale and livestock have been restricted to walk. The household survey revealed that most of the respondents approved that livestock production in the study watershed has improved after putting into practice different restoration activities. The respondents also disclosed that the restoration project has created a suitable environment for growing different fruits and vegetables. As a result, according to them, they are now able to grow fruits and vegetables which were formerly impossible to grow them. Moreover, Kalu District Agriculture Office (2013) also displayed that both male and female farmers of the study watershed benefitted from the sales of fruits and vegetables. Gebrehaweria et al. (2016) also investigated that in Abraha-Atsbaha watershed located in Tigray region of Ethiopia, after the restoration of degraded lands and gullies, farmers were able to grow different fruits, vegetables, trees and forages.

As witnessed by most respondents, due to the restoration of the watershed, the numbers of income sources have increased and the current income have also increased compared to the past after the implementation of landscape restoration in the study watershed. They further report to actively engaged in growing and selling of different crops, fruits, vegetables and forages and in raising and selling livestock to diversify their household income. .In line with this finding, Kassu (2010) depicted that MERET project has improved the productive capability of degraded lands, which in turn has led to the diversification of the livelihoods of farm households. Moreover, assessing the impacts of landscape restoration on the livelihoods of farm households, Gete et al. (2014) indicated that the overall income from the sales of crop, livestock, trees and grasses has increased after the restoration of the studied watersheds.

8.2. Impact on Livelihood Activities

In the case of the livelihood of people residing in rural areas, livelihood can be of two types: on-farm and off-farm. On-farm activities include production of different kinds of crops and livestock rearing. On the other hand, off-farm activities comprise pottery, carpentry, trading, wage labor, guard duty in government offices, etc**.**

8.2.1. Occupation

Occupation indicates the amount of time that one invests for a certain kind of livelihood activity (Dirwayi, 2010). The present study revealed that 99.6 % (i.e. 254 out of 255) of the respondents' primary occupation is farming. This implies that the sampled individuals' livelihoods depend mostly on the productions of crops and livestock. Hence, they are agrarian, which means improvement in agriculture can give rise to the betterment in the life of such people. The interviewees also witnessed that farmers are now engaged in different kinds of small businesses like trading, daily labor, pottery, and production of different fruits and vegetables. The study made by Dirwayi (2010) in South Africa shows that 75, 19 and 6 % of the informants' primary occupations were farming, off-farm activity and civil servant, respectively.

It was also investigated that 87.5 % (i.e. 223 out of 255) of the respondents do not have secondary occupation, whereas 12.2 % of them (Table 8.1) supplement the income they generate from agriculture by involving in different activities like livestock selling, guard duty, carpentry, merchandize, wage labor, tailoring, and welding; of which, most of them were found to be engaged in wage labor.

Table 8.1. Secondary occupation of the respondents

Livelihood activity	Frequency	Percent
Farming	1	0.4
No secondary occupation	223	87.5
Off-farm activity	31	12.2
Total	255	100

8.2.2. The Restoration Project and Livelihood Activities

Taking into account of the fact that the study watershed is situated in the district where there is severe land degradation and chronic food insecurity (Kalu District Agriculture Office, 2013; Gete et al., 2014) that in turn affect the livelihood of farmers, the respondents were asked to rate the effect of restoration on their livelihood activities and their responses are given below.

A large number of respondents (i.e. 92.6%) rated the effect of restoration on their household livelihood activities as positive (t = 24, p< 0.001; Table 8.2). In relation to this, Abenet et al. (2016) disclosed that the integration of area closure with other SWC measures leads to the improvement in the livelihoods of local people. Gebrehaweria et al. (2016) further pinpointed that integration of watershed restoration activities, which were introduced in the early 2000s, positively affected not only natural resources, production and productivity of both crops and livestock, but also socio-economic conditions and livelihoods of communities.

The questionnaire survey showed that the restoration project doesn’t bring about change from the type of occupation that respondents were doing prior to the implementation of the project; still are agrarians. However, they reported that their production types is divesified (crops, agroforestry, vegetables, such as tomato and onion, fruits, such as orange, mango, papaya, guava, lemon, perennial crops, such as coffee and *chat*) with increased productivity and income.

Respondents perceived that the restoration project does have positive impact on their livelihood activities because of the reason that it enables the farmlands to get restored compared to their situations prior to the implementation of the project. Most of them also believed that the restoration activities reduce soil erosion and the incidence of flooding, controls overgrazing, and improves both crops and livestock production and hence farmers' livelihood. They added that it also allows farmers to grow a variety of crops and this paves the way to diversify their income sources. In support of such farmers' views, Kassu (2010) noted that MERET project escalates the productivity of the land and diversifies farmers' livelihoods by rehabilitating the ecosystem. This, in turn, permits farmers to adapt problems caused by climate change.

In this study, the respondents, who believed that the restoration project does have negative impact on their livelihood activities, forwarded their reasons as follows: it leads to the narrowing down of farmlands, it reduces the number of livestock, it restricts the movement of livestock and the vegetation cover especially area closure becomes a cause for the prevalence of monkeys that damage grown crops. It seems that such farmers were relating the above negative impacts with the disadvantages of area closure mentioned in chapter 7.

Table 8.2. One sample t-test result for the scaled responses of farmers on the rate of the effect of the restoration project on livelihood activities

Livelihood activities	Test Value = 3					
	T	*df*	Sig. (2-tailed)	Mean Difference	95 % confidence interval of the Difference	
					Lower	Upper
Rate of the effect of the restoration project on livelihood activities	24.00	254	0.000	0.86	0.79	0.93

8.2.3. Non-farm Income and Income Sources after Watershed Restoration

In this study, non-farm income refers to income from the secondary occupation of the respondents mentioned in section 8.2.1 above other than farming. The sampled household heads perceived that non-farm income has increased after the implementation of the restoration project in the study watershed (t = 31.11, p< 0.001; Table 8.3). A study by Efrem (2010) pinpointed that on-farm and non-farm incomes constitute 75 and 25 % of the total household income, respectively. The same researcher further stated that the non-farm income was more earned by the poor farmers followed by medium and better-off ones. The share of non-farm income compared to the total income of the rural population of Ethiopia is 36 % (Reardon, 1997 cited in Degefa, 2005). Betru et al. (2005) warned that the increase in off-farm income (as for example the increase in income from the sale of fuel wood obtained from area closure) can reduce the communal management of resources.

Table 8.3. One sample t-test result for the scaled responses of farmers on the rate of the effect of the restoration project on income

Income	Test Value = 3					
	t	*df*	Sig. (2-tailed)	Mean Difference	95 % confidence interval of the Difference	
					Lower	Upper
Rate of non-farm income after the project	31.11	254	0.000	0.87	0.82	0.93
Rate of the number of income sources of households after the project	30.51	254	0.000	0.87	0.81	0.93
Rate of the comparison between current income and the income in the past 15 years	15.73	254	0.000	0.69	0.61	0.78

The sampled farmers rated the number of income sources to increase after the restoration and it was also statistically significant (t = 30.51, p< 0.001; Table 8.3). This is in agreement with the interviewed agricultural experts' views. That is, the interviewees mentioned that farmers are now engaged in different small businesses and they are growing fruits and vegetables using irrigation water. The experts noted that farmers are practicing irrigation for the streams are not dried unlike the previous time because of the conservation of the upslopes. With regard to this, Gebrehaweria et al. (2016) discovered the emergence of shallow wells in their study areas following watershed restoration, which in turn improved crop yields due to the increase in irrigated area. The same authors also confirmed that in addition to enhancing biophysical conditions, the restoration also diversifies income sources.

8.2.4. Crop Production

Mixed farming system with the dominance of cereal crops production (Gete et al., 2014) is the main livelihood activity of the residents of the study watershed. As can be differentiated from the questionnaire survey, different kinds of crops are produced by the respondents. The crops in descending order in terms of the number of growers include sorghum, *teff*, haricot bean, maize, chickpea and wheat. From these crops, sorghum is the main crop type in terms of yield and income for respondents.

Respondents were asked to indicate the amount of income that they generated from the sale of crops immediately prior to the data collection period of this study, i.e. in 2013/14. It was investigated that sorghum was supplying a good amount of money for the sampled households, followed by *teff* and haricot bean (Table 8.4). It was also showed that the maximum and minimum incomes are generated from the productions of sorghum and maize, respectively.

Table 8.4. Descriptive statistics of households' income from different crops grown in 2014

Descriptive statistics	Income in Ethiopian Birr				
	Sorghum (N = 233)	Maize (N = 21)	*Teff* (N = 109)	Haricot bean (N = 35)	Chick pea (N = 14)
Mean	6305.84	2309.52	3794.31	3597.14	3264.29
Std. Error of the mean	240.86	311.06	228.67	294.27	653.44
Minimum	600.00	500.00	600.00	900.00	600.00
Maximum	18500.00	6000.00	12000.00	8000.00	8000.00

Note: N is different from 255 because of multiple responses, difference in the choice of production of crops, and because of the reason that farmers consumed all or part of the amount they produced.

The increase in crop production and productivity is one of the outcomes of watershed restoration (Betru, 2013; Gebrehaweria et al., 2016; Gete et al., 2014). Among the factors that affect crop production and hence income from such activity is landholding size (Arega, 2013). The study showed that 80 % of the respondents, who earned income from selling of sorghum, possess a land ranging in size from 0.5 – 1.75 ha. The other factor that determines crop income (production) is availability of plowing oxen that in turn affect the effective production of crop (Arega, 2013; Degefa, 2005; Efrem, 2010). Using the questionnaire survey, it was identified that from the total of 176 oxen owners, who were engaged in sorghum production, 63 % (111) of them possessing 2 oxen each benefitted a good amount of money from such crop production compared to those having only one and no ox. The Pearson correlation revealed a significant positive correlation ($r = 0.313$, $p = 0.000$) between income from sorghum production and number of ox owned by the respondents ($p < 0.001$, 2-tailed). Household size was another factor which was found to determine income from crop production. This is because household size can also affect the number of labor force for undertaking such activity.

Regarding the trend of crop production, 88.2% of the respondents replied that there is improvement in crop production in the current time compared to the last 15 years, whereas some said that there is rather decrement, no change and fluctuation in crop yield in the said time. Most of them believed that crop production in the period before 15, 10 and 5 years was low, medium and medium, respectively. Some respondents were, of course, challenged to determine the amount of production in the last 15 years. It seems that there was improvement in crop production in the study watershed after the restoration was implemented in 2001. A study by Gebrehaweria et al. (2016) witnessed that there was sedimentation on down hills including grazing land and farmlands before the restoration took place in one of their study watersheds, i.e. Abraha-Atsbaha watershed that in turn caused poor soil productivity and hence low crop production. The same researchers also found in another watershed called Goho-Cheri improvement in crop production as a result of the expansion of croplands which was exhibited after the reclamation of gullies by the restoration project.

A number of causes for the decline in the production of crop from time to time were mentioned by 15.7% of the respondents. These respondents focused on two main causes for such problem: drought and attack of crops by diseases/pests/weeds. Some of them also indicated exhaustion of farmlands and absence of crop rotation as the causes for the aforementioned problem. Efrem (2010) listed recurrent droughts, low rainfall, poor distribution of rainfall, soil degradation, lack of farm oxen, population growth, deforestation and farmers' poor health condition as the causes for the decline in crop yield in his study area.

8.2.5. Livestock Production

Livestock production is another main livelihood activity in the study watershed. Livestock are crucial for farmers in many ways: they indirectly improve soil fertility, important in cultivating fields, sources of income and food. They are means to challenge shocks that farmers may face (Efrem, 2010). Farmers owning some number of livestock are relatively more secured during the period of emergency and are more capable of coping with shocks than those who own no livestock (Devereux et al., 2003 cited in Arega, 2013).

The survey data revealed that 92.16 % (235) of the respondents were livestock owners. Even without considering those possessing only chickens, it was identified that 91.37 % (233) of them were found to own livestock unlike the result shown by Degefa (2005), i.e. 65 % of the respondents own livestock without taking into account chicken owners.

The total number of livestock (excluding chickens) owned by the respondents was 1558 (Table 8.5). The livestock belonging to the sampled households were consisting of oxen, cows, heifers, bulls, calves, sheep, goats, camels and donkeys. The survey result showed that cattle (54.5 %) were the dominant livestock followed by small ruminants (40.75 %) and camel (4.3 %), whereas donkeys were the least dominant accounting for only 0.45 % of the total livestock. The total number of chickens belonging to 135 households was 854 (Table 8.5). Here, one can notice that the number of cattle (849) and chicken are almost similar unlike the result given by Arega (2013). The same researcher disclosed that cattle and small ruminants are given priority by the studied people for the sake of prestige and for earning better amount of income.

Table 8.5. Ownership of livestock by households in 2014/15

Livestock type	Frequency	Percent	Livestock/sampled households	Number of owners
Oxen	358	22.98	1.40	193
Cows	238	15.28	0.93	180
Bulls	60	3.85	0.24	50
Heifers	3	0.19	0.01	2
Calves	190	12.20	0.75	150
Goats	314	20.15	1.23	83
Sheep	321	20.60	1.26	77
Camels	67	4.30	0.26	61
Donkeys	7	0.45	0.03	7
Total livestock	1558	100	----	-----
Chicken	854		3.35	135

The number of the dominant livestock types, i.e. cattle and small ruminants, is given in Table 8.6. Most of the sampled households (i.e. 74.51 %) possessed 1 – 5 cattle. On the other hand, insignificant number of respondents possessed a livestock greater than 10. Those who didn’t own sheep, goats and cattle accounted for 69.8, 67.45 and 12.55 %, respectively. This implies that large number of households didn’t have sheep and goats compared to those owning cattle.

Table 8.6. Possessions of cattle, goats and sheep by households in 2014/15

No. of livestock	Livestock owners by type					
	Cattle		Goats		Sheep	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
1 – 5	190	74.51	67	26.27	59	23.14
6 – 10	29	11.37	15	5.88	15	5.88
>10	4	1.57	1	0.39	3	1.18
Not owners	32	12.55	172	67.45	178	69.80
Total	255	100	255	100	255	100

The maximum mean in the case of the number of livestock owned by individual farmers was exhibited by sheep (Table 8.7). On the other hand, all livestock types equally showed the minimum number of livestock. Sheep ownership also exhibited the maximum standard deviation which is an indication of a more dispersed distribution of such livestock type compared to others.

Table 8.7. Descriptive statistics of livestock types in 2014/15

Livestock type	Minimum	Maximum	Mean	Std. Error of the mean	Standard deviation
Ox	1	4	1.85	0.05	0.66
Cow	1	8	1.32	0.06	0.76
Bull	1	3	1.20	0.07	0.50
Heifer	1	2	1.50	0.50	0.71
Calf	1	5	1.27	0.05	0.58
Goat	1	11	3.78	0.24	2.20
Sheep	1	15	4.17	0.30	2.64
Camel	1	2	1.10	0.04	0.30
Donkey	1	1	1.00	0.00	0.00

The respondents were asked to indicate the income they generated from the sell of livestock immediately prior to the data collection period of the present study, i.e. in 2013/14. The survey data revealed that 143 (56.08 %) of the respondents were involved in livestock selling. The main sources of income in this respect were selling of ox (46.8 %) followed by selling of camel (12.6 %) and calf (12 %) (Table 8.8). These three sources together make up 71.4 % of the income sources of the respondents from livestock selling. The minimum and maximum incomes were obtained from the sale of camel and goat, respectively. From the total number of sellers, the dominant ones were those involved in small ruminants (83 in number) and oxen (47 in number) selling (Table 8.8).

Table 8.8. Descriptive statistics of the income of the respondents from livestock selling in 2013/14

Livestock type	Number of sellers	Income in Ethiopian Birr						
		Minimum	Maximum	Mean	SE Mean	Std. deviation	Total	% of total
Ox	47	4500	14000	9518.09	333.87	2288.90	447350	46.8
Cow	9	4000	12000	5866.67	824.62	2473.86	52800	5.5
Bull	5	2000	5600	3440.00	598.00	1337.16	17200	1.8
Heifer	5	4000	6000	4860.00	468.61	1047.85	24300	2.5
Calf	33	1500	6000	3478.79	206.83	1188.16	114800	12.0
Goat	43	400	6000	2423.95	265.88	1743.52	104230	10.9
Sheep	40	600	4000	1813.50	144.59	914.49	72540	7.6
Camel	8	130000	16500	15062.5	359.04	1015.5	120500	12.6
Donkey	1	1900	1900	1900.00	-----	-----	1900	0.2
Total	191*						955620	100

Note: *The number of sellers is different from 143 due to multiple responses.

In relation to the trend of livestock production, most respondents relatively agreed that there is improvement in such activity in the current time, before 5 and 10 years. However, they also witnessed that there was low level of such activity before 15 years.

Here, respondents were acknowledging the contribution of the restoration. In support of this, Kalu District Agriculture Office (2013) also depicted that a female farmer's income has improved from time to time for she was involved in oxen fattening, sheep rearing and vegetable growing. The same office further indicated that she was expected to earn about 40,000 Ethiopian Birr from oxen fattening alone. Authors like Gete et al. (2014), Gebrehaweria et al. (2016) and Wolde et al. (2017) noted that watershed restoration is crucial not only for livestock production but also for their productivity.

Those respondents, who believed that livestock production is declining from time to time, mentioned shortage of fodder and grazing land as the main causes of the problem. Some also related the problem with the occurrence of drought and diseases. As opposed to such respondents' views, Wolde et al. (2017) argued that there will be improvement in fodder production, limit in livestock movements which in turn saves their energy, reduction in grazing pressure if livestock are exposed to feeding through the cut-and-carry system.

8.2.6. Perennial Crop Production

Taking into consideration of the number of producers, a small number of producers were relatively found to involve in perennial crops production mainly coffee and *chat* and in perennial cash tree, i.e. eucalyptus growing. From the total number of respondents, 66 (25.9 %) of them identified as perennials growers. The data from the questionnaire survey revealed that from the total growers, 39 (59.09 %) of them earned income in 2013/14. Out of these 39 respondents, 25, 4, 4 and 6 of them earned income from coffee, coffee and *chat*, *chat* and eucalyptus, respectively. The remaining farmers out of 66, i.e. they are 27 in number, were found either using perennials for home consumption or the crop/tree was not ready to be sold in the considered year.

The average incomes from selling coffee, *chat* and logs of eucalyptus in the year 2013/14 were 946.55, 595, 1216.67 Ethiopian Birr, respectively. In comparison with other socioeconomic characteristics of the respondents (i.e. sex, age, household size, educational background, and economic status), landholding size recorded a significant positive correlation (r = 0.638, p = 0.000) with that of coffee income. This implies that keeping other related factors constant, landholding size did have a significant role in coffee growing in the study watershed. Also, a total of 49 (72.24 %) of the respondents, who were involved in growing perennials, possessed a land ranging in size from 0.5 – 1 ha. Both the minimum, i.e. 100 Ethiopian Birr, and the maximum, i.e. 3000 Ethiopian Birr, were obtained from the sale of both coffee and logs of eucalyptus. The corresponding values for *chat* selling were 200 and 1000 Ethiopian Birr, respectively.

During field survey, the writer of the present study observed that eucalyptus trees mainly grow around homesteads, on boundary between area closure and adjacent farmlands, and on degraded land of the watershed (Figure 8.1). A similar observation about the place of growth of eucalyptus trees was also reflected by Arega, 2013, Engdawork, 2012 and Woldeamlak, 2003.

a)

b)

c)

Figure 8.1. Eucalyptus trees in Hita-Borkena watershed, northeastern Ethiopia

Farmers were required to respond to the trend of perennials production before the restoration, i.e. before 20 years and after the project, i.e. in the last 20 years. Most of them (i.e. 84.7%) confirmed that there is improvement in the production of perennials from time to time. i.e. after the restoration. Besides, the majority of them (i.e. 84.3%) revealed that such production before 20 years was relatively low. In line with the present study, Gete et al. (2014) investigated that 97% of the respondents involved in their study rate the impacts of the restoration (MERET) project on the income earned from the sale of horticultural crops as increased. Similarly, Kalu District Agriculture Office (2013) confirmed that a number of farmers are earning good amounts of money by selling coffee and different fruits like orange, mango, papaya and lemon after the project is put in place in the study watershed.

8.2.7. Fruit and Vegetable Productions

These are other main livelihood activities of the respondents next to crop and livestock productions. They are important economic activities helpful in improving farmers' livelihoods and resilience. Out of the total respondents, 84 (32.94 %) of them were growing fruit (s) and vegetable (s) during the survey time, i.e. in 2015.

The respondents generated different amount of income by selling fruits and vegetables in 2013/14 (Table 8.9). The main sources of income in this regard were selling of onion (40.57 %), mango (11.98 %) and orange (11.20 %). These three sources together make up 63.75 % of the income sources of the sampled households from fruits and vegetables selling. The incomes from the sale of onion alone and fruits (i.e orange, mango, banana, papaya and guava) are almost similar.

The maximum and minimum incomes were obtained from the sale of salad and onion, respectively (Table 8.9). Moreover, those income sources that showed maximum dispersed distribution in order include pepper, onion and orange, respectively. Sugarcane exhibited the maximum average income; the dominant source of income was onion with an average of 7465.22 Ethiopian Birr.

Table 8.9. Descriptive statistics of respondents' income from the sale of fruits and vegetables (2013/14)

Fruit & Vegetable type	No of sellers	Income in Ethiopian Birr						
		Minimum	Maximum	Mean	Std. Error of the Mean	Std. Deviation	Total	% of total
Orange	23	100.00	15000.00	2060.87	742.12	3559.08	47400	11.20
Mango	27	100.00	15000.00	1877.78	552.09	2868.74	50700	11.98
Banana	2	200.00	1500.00	850.00	650.00	919.24	1700	0.40
Papaya	21	200.00	5000.00	1754.76	294.79	1350.92	36850	8.71
Guava	14	100.00	4000.00	1167.86	342.17	1280.27	16350	3.86
Lemon	25	100.00	4000.00	962.00	199.32	996.59	24050	5.68
Onion	23	100.00	20000.00	7465.22	1074.97	5155.37	171700	40.57
Salad	1	60.00	60.00	60.00	----	----	60	0.01
Pepper	2	2000.00	10000.00	6000.00	4000.00	5656.85	12000	2.84
Cabbage	2	300.00	1000.00	650.00	350.00	494.97	1300	0.31
Tomato	17	150.00	8000.00	2273.53	455.36	1877.51	38650	9.13
Sugarcane	3	6000.00	9500.00	7500.00	1040.83	1802.78	22500	5.32
Total	160*						423260	100

Note: *N is different from 84 because of multiple responses and for some farmer was growing fruit(s) and/or vegetable(s) but didn't earn income.

As observed during the field survey, farmers were growing onion on farmlands near Borkena River. An interesting story raised by one of the interviewed agricultural experts in relation to the income from fruits and vegetables was that a farmer, who is residing in the study watershed, on a quarter of 1 ha of land, grows lemon, papaya and onion. From a single lemon tree, he earned about 4000 Ethiopian Birr. Totally, he is now earning about 30,000 Ethiopian Birr a year from those three sources of income. This farmer does have no farmland for growing cereal crops.

With regard to the trends of fruit and vegetable productions before 20 years and in the current time, most respondents revealed that there is increment in such productions in the latter time, i.e after the restoration. On the other hand, 75.5% of them witnessed the low levels of productions in the former period, i.e. before the restoration. Kalu District Agriculture Office (2013) also cited a farmer, who is earning about 21000 Ethiopian Birr a year by selling papaya after MERET project. In conformity with this, Gebrehaweria et al. (2016) noted that after watershed restoration, farmers in their study watersheds were found practicing both irrigation and rainfed agriculture leading them to grow different crops and fruits. The same authors also showed that the benefits from the productions of crop and fruits for upstream dwellers was from rainwater harvesting, but the downstream ones did have access to irrigation from wells that enabled them to produce different crops within a year. Gete et al. (2014) also investigated the diversification of both the nutrition and income of farmers following the introduction of different kinds of fruits and vegetables by MERET project.

8.2.8. Apiculture

. This is an alternative means of livelihood for the households living in the study watershed. Its benefits are mainly more pronounced for women, landless youth, unemployed and emerging households (Gebrehaweria et al., 2016; Gete et al., 2014; Wolde et al., 2017). It plays crucial roles in bee forage production and pollination, and also in increasing the vegetation cover of an area (Gebrehaweria et al., 2016). It can also assist farmers to withstand from shocks.

Among the total respondents, 27 (10.6 %) of them were beekeepers implying low participation of sample households in this livelihood activity. According to one of the interviewees, apiculture is being practiced by a small number of farmers in the watershed because of the presence of excess chemicals (i.e. related with pesticides) that negatively affect bees and hence honey production.

Most of the respondents, who were involved in apiculture, had the experience ranging from 3 – 25 years. Of the total beekeepers, 25 of them report to earn an annual total income of 61820 Ethiopian birr in the year 2013/14. The maximum annual income earned from such activity was 5000 Ethiopian Birr, whereas the mean ± Std. error was 2472.80 ± 331.55 Ethiopian Birr.. The maximum income generated fall in the category of 4000 - 4799 (Table 8.10).

Table 8.10. Income generated from apiculture by the respondents in 2013/14

Income in Ethiopian Birr	Frequency	Percent	Total
0 – 799	5	20	1820
800 – 1599	5	20	5300
1600 – 2399	2	8	4000
2400 – 3199	2	8	5700
3200 – 3999	4	16	13800
4000 – 4799	5	20	21200
>4799	2	8	10000
Total	25	100	61820

The majority of experienced beekeepers, who involved in the present study, disclosed that honey production showed a decreasing trend as compared with its situation before 20 years. Like experts' views, farmers also mentioned the issue of chemicals, as a contributing factor for the decrement of honey production in the current time. It seems that the role of landscape restoration in promoting apiculture is overshadowed by the existence of chemical pollution in the study watershed. Assessing the credibility of the factor mentioned by both the farmers and experts is beyond the scope of this study and needs further research. Acknowledging the positive relations between watershed restoration and apiculture, Gete et al. (2014) discovered that such restoration promotes the accessibility of bee forage and water for the bees. Wolde et al. (2017) also proposed the integration of apiculture with exclosure especially in areas where there is enough bee forage. A study by Gebrehaweria et al. (2016) noted the emergence of economic activities like animal fattening, crop production using irrigation and apiculture following watershed restoration. The same authors revealed the improvement in asset base and livelihoods of farmers because of their involvement in the aforementioned activities.

8.3. Impact on Livelihood Outcomes

In this study, livelihood outcomes refer to those achievements made possible as a result of the implementation of the landscape restoration project. The main identified outcomes are related with household income, food security, and the environment (or watershed in this case).

8.3.1. Households' Current vs. Past Income

Farmers were asked to compare their current income and the income after the restoration project, i.e. in the last 15 years. The majority of them (i.e. 76.8%) replied that their current income has increased as compared with the income in the past 15 years (t = 15.73, $p < 0.001$; Table 8.5). This means the restoration has contributed significantly in improving most of the sampled households' income. In support of the views of respondents, TANGO and IDS (2012) cited in Gete et al. (2014) reported that the restoration of watersheds through MERET project significantly increased the incomes of households as a result of improved sales of livestock and crops. Likewise, Gebrehaweria et al. (2016) investigated a 50 % increment of farm incomes after landscape restoration.

8.3.2. Households' Food Security Status

For farm households to be considered as food secured, they must be able to produce, purchase, access food or cash through selling a given item (s), and the variation in the supply of food for home consumption on annual basis or from year to year must be little (Degefa, 2005). Out of the total respondents of the present study, 138 (54.1 %) of them believed that their past household food security status before the restoration was lesser than the current one. This implies that more than half of the respondents were suffering from food shortages in the past. These respondents further forwarded different reasons as to the impact of the landscape restoration on their current food security status. The main listed reasons were:

- The restoration has reduced soil erosion and flooding and also improves soil fertility. This situation in turn improves crop production.

- After landscape restoration, soils have become fertile, which in turn escalate crop production.
- The restoration has also improved livestock production.
- The restoration has enabled farmers even to take care of other expenses of households in addition to food.
- It has also allowed farmers to diversify their livelihood activities and hence their income.

In an attempt to identify the number of food aid beneficiaries even after the implementation of landscape restoration, farmers were asked whether they have been receiving food aid in the past 15 years or not. Those who responded ‘yes’ accounted for 38 % of the total households. This means that the majority of them didn’t receive food aid in the aforementioned time. In connection with this, Efrem (2010) found that some farmers receive food aid to cope up with the periods of shortage of food. The same researcher also noted that the coping mechanisms mostly applied during the times of food insecurity by farmers were charcoal or firewood selling so as to purchase food items, reductions of the frequency of eating and of the amount of food to be eaten at a time.

In line with the expected outcome, the survey result revealed that 195 (76.5 %) of the respondents are currently food secured households. As described in the previous sections, the improved productions of crops, livestock, fruits, vegetables and perennials enabled sampled households to improve and diversify their income sources. This made most of the farmers living in the study watershed food secured. This is also confirmed by the interviewed agricultural experts. Gete et al. (2014) pointed out that the restoration (MERET) project has led to a significant improvement in the food security and livelihoods of beneficiaries. Moreover, Gebrehaweria et al. (2016) discovered that the restoration has improved food security of farm households by about 56 %.

Most of those respondents of the current study, who evaluate their household food security status as being food in secured, reported that they have been suffering from the problem of food shortages for more than 4 years. The main reasons that were identified to cause food insecurity by the respondents include: shortage of farmland, frequent occurrence of pests, diseases and weeds, and absence of sufficient amount of rainfall (which is related with drought). Efrem (2010) related the problem of food insecurity with drought, high population pressure, high erratic rainfall, shortage of fodder and assets, decline in crop production, and deforestation.

Out of the total sampled male and female-headed households, 21.4 and 37.1 % of them were found to be food insecured, respectively. This means that female-headed households were more vulnerable to the problem of food insecurity compared to men headed households in the study watershed. The chi-square test also showed a statistically significant association between sex of household head and food security status (X^2 = 4.178, p = 0.041). In agreement with this, Arega (2013) noted that women are relatively more exposed to food insecurity than the men counterparts for they do have lower access to resources and lower job opportunities.

In the present study, it was found that the mean ages of food secured and insecured household heads were 49.69 and 48.83 years, respectively. However, there was no a statistically significant difference between the former and the latter groups in terms of the mean age (Table 8.11). The opposite result was obtained for the two groups when mean household size and landholding size were considered.

It is clear that asset ownership does have its own effect on the food security status of households. Regarding this, this study found out that 77.4 % of livestock owners were food secured, but there was no a statistically significant association between livestock possession and food security status (X^2 = 1.587, p = 0.208).Contrarily, Efrem (2010) found a significant positive correlation between the two formerly mentioned variables.

Table 8.11. Independent samples t-test result for selected household characteristics and food security status

Household characteristics	Levene's test for equality of variances	t-test for equality of means		
		t	*Df*	*p*
Age	Equal variances assumed	0.71	253	0.480
Household size	Equal variances assumed	2.05	253	0.041*
Landholding size (ha)	Equal variances assumed	3.66	250	0.000**

Notes: - Levene's test for equality of variances was used to test whether household characteristics have the same or different levels of variability between the two food security statuses or not.

- *Significant at $p < 0.05$ (2-tailed)
- ** Significant at $p < 0.001$ (2-tailed)

8.4. Impact on Asset Base

One of the goals of implementing watershed restoration projects is improving the asset base of beneficiary households. To analyze the effect of such restoration on the respondents' asset bases, the basic asset types and number owned were collected through questionnaire.

Based on the real situation prevailing in the rural parts of Ethiopia and on Dirwayi (2010), the asset possession status of the respondents was classified into three as follows:

A. Low asset possession status: Those respondents falling in this category owned only a hut, a few house appliances (like radio and/or mattress and/or traditional shelf) and farm implements(plough, spade and/or sickle).

B. Medium asset possession status: Those who belong to this class owned a mud house with iron sheet roof and average number of house utensils (like radio, chair, table, mattress and/or bed, traditional shelf) and farm implements (like plough, spade, sickle, hoe and/or backhoe).

C. High asset possession status: Respondents of this class owned one or more mud houses with iron sheet roof, modern house utensils (like television, radio, tape player, DVD player, etc)and farm implements (like water pumper and irrigation pipes), and other assets (like shop, tailor machine, bicycle and a car that looks like a motor bike locally called *bajaj*).

Table 8.12. Classification of asset possession status of respondents

Class of asset possession status	Frequency	Percent
Low asset possession	34	13.3
Medium asset possession	192	75.3
High asset possession	29	11.4
Total	255	100

The majority of respondents (about 75 %) fall in the category of medium asset possession status (Table 8.12). From the survey data, it is also found that out of a total of 220 respondents, who owned mud houses with iron sheet roof, 154 (70 %) of them constructed such houses after MERET project is implemented in the study watershed. On the other hand, television owners (22 out of 22), tailor machine owners (3 out of 3), water pumper and irrigation pipes owners (9 out of 9), sofa set owner (1 out of 1) and *bajaj* owner (1 out of 1) established such assets after the aforementioned restoration practice is put into practice. Since the present study also confirmed that the primary occupation of the respondents is farming, it is possible to deduce that the above assets were established because of the improvement in the income generated from agriculture. The interviewed agricultural experts also revealed that farmers are now building good houses by participating in livestock fattening, milk production and selling grass. They also added that because of the improved asset status, some farmers are now able to purchase some modern house utensils (like television and shelf) and farm implements (like water pumper and irrigation pipes). In line with this, Tesfaye (2011) found that households' livelihood improved for they participated in integrated watershed management. As a result, their capabilities to purchase house amenities, agricultural inputs, build better houses, cover medical expenses and send their children to school had improved. Similarly, Gete et al. (2014) investigated that the asset base of the majority of the respondents of their study has enhanced after the implementation of MERET (restoration) project in their locality. Figure 8.2 below shows change of house type due to the positive impact of landscape restoration.

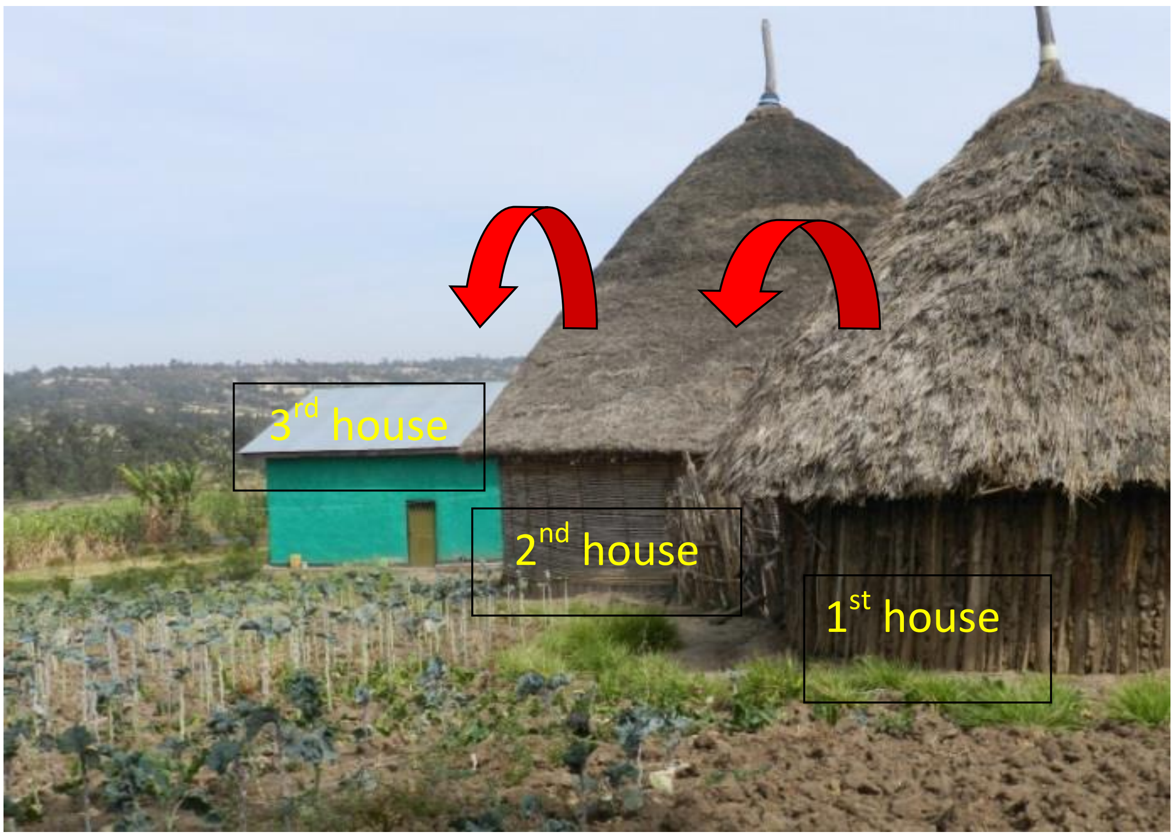


Figure 8.2. Changes in asset base at household level due to MERET in Ana Belesa watershed, Lemu, SNNP Region, Ethiopia (Gete et al., 2014)

The assumption of SLF is that the implementation of a development project (restoration project) in a given area would, keeping other related factors constant, result in the improvement of the livelihood of households and hence their asset base (Dirwayi, 2010). The association between asset possession status and selected factors is described hereunder.

One of the factors that determine agricultural production and livelihood assets (resources) is the landholding size (Degefa, 2005). In the present study, it is also witnessed that there was significant positive correlation between farm plot size and asset possession status of the respondents (r_s= 0.294, N = 252, p< 0.01; Table 8.13).

Acknowledging the contribution of indigenous knowledge and experiences for household livelihood and food security, Degefa (2005) also signified that education and household livelihood do have positive relationships, i.e. in the case of subsistence farming, literate farmers perform better than the illiterate ones. The present study also revealed that there is significant positive correlation between educational status of sampled household heads and their asset possession status (r_s = 0.158, N = 255, p< 0.05; Table 8.13).

In this study, it was confirmed that there is significant positive correlation between economic status of sampled household heads and their asset possession status (r_s = 0.459, N = 255, p< 0.01; Table 8.13). It was also identified that high asset owners are found to dominantly have not only modern equipments (like television and water pumper) but also have large number of fundamental farm equipments (like spade, hoe and sickle) compared to low asset owners. For example, high asset owners did have mostly 3 or 4 sickles, but the low asset owner counterparts did have largely 1 sickle only. The range of the number of sickles owned by the former group runs from 1 – 15, whereas the range for the latter group runs from 1 – 3.

Table 8.13. Spearman's correlation between asset possession status and selected variables

Selected variables	Asset possession status	
	Spearman's (rho) correlation coefficient	Sig. (2-tailed)
Farm plot size	0.294**	0.000
Educational status of household heads	0.158*	0.011
Economic status of household head	0.459**	0.000
Age of household heads	0.105	0.094
Household size	0.059	0.349
Length of time that the household head live in the current place of residence	0.020	0.751
Sex of household head	0.077	0.221

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

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

- N = 255 except for farm plot size, N = 252 because of the reason that 3 respondents were landless (see chapter 4).

As can be seen in Table 8.13 above, other than farm plot size, economic status and educational status of selected respondents, the other variables did not have significant association with asset ownership status. Contrarily, Dirwayi (2010) found out that as individuals grow older, they will have better probability to accumulate assets. The same researcher also pointed out that household size does have positive linkage with that of asset base.

8.5. Conclusion

This study, based on a modified SLF, assessed the impacts of landscape restoration project on the asset base, livelihood activities and outcomes of farm households living in Hita-Borkena watershed, northeastern Ethiopia.

The result of the study showed that there was improvement in the asset base of the majority of respondents after landscape restoration. It was also found that the asset base is also affected by farm size, educational background and economic status of the respondents.

It was identified that there become improvement in the productions of crops, livestock, perennials, fruits and vegetables after the implementation of landscape restoration in the study watershed. In order to address the worry of some respondents, drought resistant variety of crops shall be disseminated, the diseases of both crops and livestock should be addressed by concerned bodies, and the production of fodder at the rate that can satisfy the farmers must be taken into account. The presence of chemical pollution in the watershed is negatively affecting the apiculture sector. This also seeks immediate response from concerned experts and/or from agriculture office.

The landscape restorationhas played significant roles in improving the income and food security of respondents. It has also increased the fertility and productivity of the soil of the study watershed. It has also enabled farmers to diversify their livelihoods. This leads to conclude that implementing similar restoration activities in the degraded lands/watersheds of Ethiopia is a recommended action since the country is still seeking to promote the livelihood of rural people and to restore the degraded environment.

Chapter Nine

9. Conclusions and Recommendations

Landscape restoration has been practiced in Ethiopia in general and in Amhara National Regional State in particular to rehabilitate the severely degraded area and benefit the people. So far some studies have been undertaken in Amhara region focusing on the role of area closure in soil characteristics and vegetation diversity. Thus, the impacts of landscape restoration (including area closure) both on the environment and the community need to be assessed. This study attempted to analyze the land cover dynamics in Hita-Borkena watershed located in Kalu district, Amhara region, northeastern Ethiopia. It was also intended to compare soil characteristics of area closure and adjacent open grazing land, it investigated the environmental problems of the study area before the implementation of landscape restoration, and the impact of the restoration effort on farmers' livelihood was also assessed through SLF approach. The conclusions and recommendations of the study are presented below.

9.1. Conclusions

In order to tackle land degradation problems and to apply resource management in environments like Hita-Borkena watershed, analysis and assessment of land cover conditions is required. The present study revealed that there were shrinkages of forestlands and shrublands through 1986 – 2015 though the extents of shrinkage for the former land cover type were relatively higher than the latter one. It was also identified that grassland shrunk and expanded between 1986 – 2001 and 2001 – 2015, respectively. Expansion of such land cover type was achieved due to the implementation of area closure under MERET project in 2001 in the study area. The study watershed also experienced expansion of croplands throughout the analysis period in the expense of mainly shrublands and grasslands. A recent railway construction that passed through the watershed and the low participation of the local community especially after 2012 are considered to be the two main reasons for the expansion of barelands. Like other parts of the world, the study watershed faced an increasing trend of settlement through 1986 - 2015 mainly due to population pressure.

Due to the contribution of area closure, grasslands exhibited an increasing trend on both mid- and foot-slopes between 2001 and 2015. It is also learnt that the vegetation coverage of the watershed under study still needs improvement.

The coverage of F-G-S on steep slopes (> 36%) was found to be higher compared to that of croplands on the same slope through 1986 – 2015. However, their overall coverage is following a decreasing trend.

This study confirmed that the implementation of landscape restoration in general and area closure in particular do have a profound effect on the soil properties. It is also found that slope position alone and the interaction of slope position and land use type didn’t bring significant change in the soil fertility of the study watershed. This shows that probably other factors are responsible for such change in addition to area closure, which really needs further research.

There was better clay content, significantly higher silt content and total porosity in area closure compared to open grazing land. The sand content and bulk density of the latter land use type was found to be higher than the former one. This could happen due to change in vegetation cover which leads to differences in organic matter content and porosity and due to occurrence of accelerated soil erosion under open grazing land, which selectively removes finer soil particles.

A slightly acidic nature of soils of area closure compared to open grazing land could be due to the presence of vegetation, which leads to the percolation of water and in turn a removal of cations.

Both TN and OM were significantly higher under area closure than under open grazing land. The increased OM content is directly related with vegetation cover (biomass). As shown by FAO (2005), three possible reasons can be cited as the causes for the minimum amount of OM under open grazing land: a) a decline in biomass production, b) an increase in decomposition rate, and c) a decline in litter input.

Both available P and K are found minimum under area closure. This may be due to the reason that such essential plant nutrients exist more in unavailable form in this land use type. The other reason might be more of these nutrients are extracted by the restored vegetation (Ermias et al., 2017). The better CEC content of area closure as compared with open grazing land could be related with its OM and clay contents.

As witnessed by respondents, rates of soil erosion, overgrazing and illegal cutting of trees were relatively higher before the restoration project in general and area closure in particular. Respondents also appreciated the contribution of the restoration in improving the fertility of the soils of the study area. These positive perceptions or optimistic views of farmers about the restoration activities are crucial for the future sustainability of natural resources of the study watershed.

It was learnt that area closure alone didn't restore the watershed rather other related SWC measures are also important. It was also found that there were a few respondents, who did have negative feeling about the existing area closure, need awareness creation/education by concerned bodies. In the future, it is advisable to integrate area closure with activities like apiculture, livestock fattening, dairy production, production of fruits, planting of trees that can be used as fuel wood like Acacia decurrens, and introduction of alternative energy sources so as to reduce pressure on area closure and to better conserve them (Wolde et al., 2017).

Past landscape restoration efforts in Ethiopia were mainly focusing on the physical environment ignoring livelihood of smallholder farmers. This study investigated that the asset base of respondents improved after landscape restoration. The three important characteristics of respondents that were identified to significantly affect the asset possession status are educational background, economic status and landholding size.

It was found that the livelihood of almost all respondents depend on farming. Those few respondents, who supplement their income from farming, are engaged in the following activities: livestock selling, merchandize, guard duty, wage labor, carpentry, tailoring and welding. The dominant activity from the listed ones was wage labor.

This study confirmed the positive contribution of landscape restoration for the productions of crops, livestock, perennials, fruits and vegetables. However, apiculture exhibited a decreasing trend in the last 20 years due to existence of chemical pollution in the study watershed that affects bees and bee forage. This needs immediate attention from local administrative staffs and other concerned bodies.

It was also witnessed that landscape restoration significantly improved respondents' livelihood activities, the number of income sources, non-farm income and current income compared to the past 15 years. It also improved food security of respondents, fertility and productivity of the soils of the study watershed. It also diversified the livelihood of farm households. This leads to conclude that implementation of landscape restoration (MERET) project was not only important to improve the environment, but it was also crucial to promote farmers' livelihood. Hence, similar other projects shall be put into practice in other parts of Ethiopia.

9.2. Recommendations

The recommendations of this study based on the major findings are the following:

1. Though grasslands' coverage improved after area closure, the overall vegetation cover (F-G-S) decreased dramatically. This is partly due to the low participation of local people after 2012, the railway construction passing through the watershed and lack of care of planted seedlings on hillsides. Hence, these problems shall be alleviated in order to escalate the vegetation cover of the study area. Besides, it is advisable to grow indigenous trees that can adapt the local climate.
2. It was observed that there was expansion of croplands even at sloppy bushlands. This aggravates soil erosion in the area and also negatively affects the undergoing restoration activities. This may be the result of population pressure. Hence, family planning programs and education are recommended measures to reduce population pressure and hence expansion of croplands.

3. In order to strengthen the role of area closure in relation to soil fertility, it is suggested to improve the vegetation cover (above ground biomass) of the study watershed. This will definitely increase the litter and biomass inputs in the soil system, which is in turn good for the enhancement of essential plant nutrients.
4. This study found that land use type did have roles in affecting soil fertility, but not slope position alone and the interaction of slope position and land use type. This calls for interested researchers to look for other related factors responsible for affecting soil fertility of the study watershed.
5. There is also a need to raise awareness of a few farmers, who did have negative feeling about area closure through proper education by concerned bodies.
6. To ensure the sustainability of area closure, it is recommended to integrate it with apiculture, livestock fattening, dairy production, planting of fruit trees and also trees used as fuel wood like Acacia decurrens, and introduction of alternative energy resources.
7. In order to react with the growing demand for fodder by farmers, there shall be planting of fast growing grasses along the terrace bunds, farm boundaries, in area closure and around homesteads.
8. To boost crop production in the study watershed, it is suggested to grow drought- and disease-resistant crops. The diseases of livestock that negatively affects the respondents' income shall also be addressed by concerned bodies.
9. The chemicals sprayed on the fields are affecting the apiculture sector. The extent of such problem shall be investigated and the controlling measures shall be immediately undertaken. The credibility of such problem also needs further research.
10. This study strongly recommends the implementation of similar other landscape restoration activities in similar environments in Ethiopia to enhance both the environment and farmers' livelihood.

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Website

http://glovis.usgs.gov/....................The Official website of U.S. Geological Survey.

Appendix I: Household Questionnaire

University of South Africa
College of Agriculture and Environmental Sciences
Geography Department

Household Questionnaire

This questionnaire is prepared for two reasons. These are:

1. In order to collect data for completing PhD study.
2. In order to investigate impacts of landscape restoration in general and area closure in particular on reducing environmental problems, improving local farmers' livelihood and the different measures used to restore the study area.

Taking the above mentioned objectives into account, you are kindly requested to provide appropriate answers for the questions given below. The answers given by you will be kept confidential and will be used only for academic purpose.

Thank You in Advance!

Date____
Name of enumerator______________________________
Household code_________________________________
Name of Kebele_________________________________
Name of Village_________________________________
Name of Sub-watershed___________________________

Part I: Household Characteristics

1. Data on household head

No.	Sex	Age	Educational Status[a]	Marital Status[b]
1				

- [a] 0 = illiterate; 1 = read and write only; 2 = elementary 1st cycle; 3 = elementary 2nd cycle; 4 = high school; 5 = preparatory; 6 = technique school; BA/BSc.;
- [b] 1= single; 2 = married; 3= divorced; 4 = widowed (for female); 5= widower (for male)

2. Data on household members

No.	Sex	Age	Relationship to Household Head[a]
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

- [a] 1= husband; 2 = wife; 3= son; 4 = daughter; 5 = relative; 6 non-relative (supporter)

3. Is your household 1. Female-headed 2. Male-headed
4. For how long that you live at the current place of residence? ________________
5. If you don't live in the current place of residence permanently, what was the main reason for changing your residence?
   A. War/conflict
   B. Searching for farm land
   C. Because of natural disaster
   D. Marriage
   E. Because of the enforcement of local administrators
   F. Other(specify) ____
6. Is your household A. Poor B. Medium C. Better-off
7. Distance of your house to the main market in km is ________________________
8. Which type of transport system do you employ to transport materials to and from the market for goods? (multiple response is possible)
   A. Own Carrying C. Horse/donkey cart E. Other, specify__________
   B. Donkey back D. Mule back

9. Indicate your total landholding size (in hectare or “timad”). _____________

Part II: Environmental Problems and Methods used for Restoration

1. How was the rate of soil erosion before the landscape restoration?

   1 Very low   2 Low   3. Neither low nor high   4.High   5. Very high

2. How do you rate the current soil erosion problem in your farm plot(s)?

   1. Very low   2. low   3. Neither low nor high   4.High   5. Very high

3. If your answer for question no. 2 is ‘high or v. high, what do you think are the main causes for such kind of problem?

   ____
   ____
   ____
   ____

4. If your answer for question no. 2 is ‘high or v. high, what do you think are the main consequences of such kind of problem?

   ____
   ____
   ____
   ____

5. How do you see the current soil erosion problem as compared to the situation before the implementation of landscape restoration?

   1. V.low   2. Low   3. Neither low nor high   4.High   5. Very High

6. Did your farm plot lose its fertility before the introduction of the restoration project?

   1. Yes   2. No

7. If yes, what about now?

   ____
   ____
   ____

8. How was the rate of overgrazing before the landscape restoration?

1. V.low 2. Low 3. Neither low nor high 4.High 5. Very High

9. How do you see the current overgrazing problem as compared to the past?

   1. V.low 2. Low 3. Neither low nor high 4.High 5. Very High

10. At which time that there was or is illegal cutting of trees?

    1. Before the landscape restoration

    2. After the landscape restoration

    3. Both before & after the landscape restoration

11. If your choice is '1', how do you see the effort of the community in conserving the existing trees and in planting other ones?

    ____
    ____
    ____
    ____

12. Mention the methods that you use to restore/rehabilitate the area and also the structures implemented by the government.

    ____
    ____
    ____
    ____

13. Is your farm plot(s) taken by the government for the purpose of area closure?

    1. Yes 2. No

14. If "yes", how do you rate the community's benefit because of the presence of area closure?

    1.None/v.small 2. Small 3. Neither small nor high 4.High 5. V. high

15. How do you rate the importance of area closure to improve land productivity?

    1. V. little 2. Little 3.Neither little nor high 4.High 5.V.high

16. How do you rate your agreement or disagreement with regard to the opinion that "area closure restores degraded land"?

1. Strongly disagree 2. Disagree 3. Neither disagree nor agree
4. Agree 5. Strongly agree

17. How do you rate your satisfaction considering the benefit you have gained so far because of your involvement on area closure in particular and restoration activities in general?

1. Strongly dissatisfied 2. Dissatisfied 3.Neither dissatisfied nor satisfied
4.Satisfied 5.Strongly satisfied

18. What kind(s) of activity (activities) are allowed in closed areas? (multiple response is possible)

1. Free grazing 2. Firewood collection 3. Beekeeping

4. Cut-and-carry of grass and collection of branches of dead trees

5.Other, specify_______________________________________

19. Do you think that restriction of humans and livestock from area closure is appropriate?

1. Yes 2. No

20. If yes, how?

____
____
____
____

21. What are the main disadvantages of area closure?

____
____
____
____

22. Do you have an intention to continue involving in area closure in particular and restoration activities in general?

1. Yes 2. No

23. If yes, why?

Part III: Asset Base

Indicate the type of asset that your household posses.

Type of Asset	Number of Asset	Availability	
		Before 20 years	Current
House Type			
1.Mud house with iron sheet			
2.Hut			
3.Other,specify			
House Utensils			
4.Television			
5.Radio			
6.Tape Player			
7.DVD Player			
8.Table(s)			
9.Chair(s)			
10.Bed(s)			
11.Locker(s)			
12.Sofa set			
13.Mattress			
14.Shelf(ves)			
15.Other, specify			
Farm Implements			
16.Tractor(s)			
17.Spade(s)			
18.Hoe(s)			
19.Water Pumper			
20.Irrigation Pipes			
21." Maresha" /Plough			
22.Wheelbarrow(s)			
23.Sickle			
24.Other, specify			
Other Assets			
25.Car(s)			
26.Bicycle			

27.Motorcycle			
28.Tailor Machine			
29.Shop			
30.Other, specify			

Part IV: Livelihood Activities

1. What is your current primary occupation?

   1. Farming 3. Off-farm activity (specify)_______________

   2. Government employee

2. What is your current secondary occupation?

   1. Farming 3. No secondary occupation

   2. Government employee 4. Off-farm activity (specify) _______________

3. How do you rate the effect of the restoration program on your livelihood activities (negatively or positively)?

   1. V. negatively 2. Negatively 3.Neither negatively nor positively
   4.Positively 5. V. positively

4. If your answer for question no. 3 is "positively (4 or 5)", what was your past occupation?

   1. Farming 3. Off-farm activity (specify)_______________

   2. Government employee

5. If your answer for question no. 3 is "positively (4 or 5)", how?

   ____
   ____
   ____
   ____

6. If your answer for question no. 3 is "negatively (1 or 2)", how?

   ____
   ____
   ____
   ____

7. How do you rate your non-farm income after the restoration of the watershed?

   1. Decreased v. much 2. Decreased 3. Neither decreased nor increased

   4 Increased 5. Increased v. much

8. How do rate the number of income sources of your household after the restoration of the watershed?

   1. Decreased v. much 2. Decreased 3. Neither decreased nor increased

   4 Increased 5. Increased v. much

9. What type of crops that you commonly grow in your farm land (s)?

   ____

10. Indicate the trend of productivity of crops that you grow per hectare

    1. Before 15 years______________________________
    2. Before 10 years______________________________
    3. Before 5 years______________________________
    4. Current time______________________________

11. Indicate the type of crop and the respective income generated last year.

Crop type	Income generated last year

12. If you think that crop production is declining from time to time, what are the main causes?

    ____

    ____

    ____

    ____

13. Do you own livestock? 1. Yes 2. No

14. If your answer for question no. 13 is "yes", mention the types and number of livestock you own?

Livestock type	Number
Ox	
Cow	
Bull	
Heifer	
Calf	
Goat	
Sheep	
Chicken	
Horse	
Camel	
Donkey	
Other (specify)	

15. Indicate the type of livestock and the respective income generated last year.

Livestock type	Income generated last year

16. Indicate the trend of livestock production
    1. Before 15 years____
    2. Before 10 years____
    3. Before 5 years____
    4. Current time____

17. If you think that livestock production is declining from time to time, what are the main causes?

____

____

____

____

18. Do you grow perennial crops? 1. Yes 2. No

19. If yes, mention the kind of perennial crops you grow and the income generated last year.

Perennial crop type	Income generated last year
Coffee	
Chat	
Other	

20. If yes, how do you see the trend of perennial crop production?

    1. Before 20 years____

    2. Current____

21. Do you grow fruits and vegetables? 1. Yes 2. No

22. If yes, mention the kind of fruits and vegetables you grow and the income generated last year?

Fruit and vegetable type	Income generated last year
Orange	
Mango	
Banana	
Papaya	
Guava	
Lemon	
Onion	
Salad	
Pepper	
Carrot	
Cabbage	
Tomato	
Potato	
Other, specify	

23. If yes, how do you see the trends of fruit and vegetable productions?

   1. Before 20 years____

   2. Current____

24. Do you practice bee keeping?   1. Yes   2.No

25. If yes, for how long do you practice bee keeping? ________________________

26. If yes, indicate the income generated last year. ___________________________

27. If you have long time experience in bee keeping, describe the trend.

   1. Before 20 years____

   2. Current____

Part V: Livelihood Outcomes

1. How is your current income as compared to the past 15 years?

   1. Decreased v. much   2. Decreased   3. Neither decreased nor increased
   4 Increased   5. Increased v. much

2. Was the food security status of your household lesser than the current one?

   1. Yes   2. No

3. If the answer for question no. 2 is "A", how do you see the impact of the restoration project?

   ____
   ____
   ____
   ____

4. Did your household receive any food aid in the past 15 years?

   1. Yes   2. No

5. What is the current food security status of your household?

   1. Food Secured   2. Not food secured

6. If the answer for question no. 5 is "2", for how long does such problem last?

   ____

7. If the answer for question no. 5 is "2", what were the possible reasons?

____

____

____

____

8. The role of the current restoration project

   1. For soil fertility ____

   2. For land productivity______________________________________

   3. For crop production_______________________________________

   4. For fruit and vegetable productions _____________________________

   5. For livestock production____________________________________

Appendix II. Interview Guide

University of South Africa
College of Agriculture and Environmental Sciences
Geography Department

Interview for Agricultural Experts

This interview is prepared for two reasons. These are:

3. In order to collect data for completing PhD study.
4. In order to investigate impacts of landscape restoration in general and area closure in particular on reducing environmental problems, improving local farmers' livelihoods, and the different measures used to restore the study area.

Taking the above-mentioned objectives into account, you are kindly requested to provide appropriate answers for the questions given below. The answers given by you will be kept confidential and will be used only for academic purpose.

Thank You in Advance!

Date_______________________________________

Name of Kebele_________________________________

Name of Village__________________________________

1. Educational status_________________________________
2. Job title____
3. For how long do you work in the study area?___________________________
4. Do you think the introduction of MERET project in the study area is essential?

   A. Yes B. No

5. How do you see the status of soil erosion problem after the introduction of the restoration project?

6. What are the causes of soil erosion in the study area?

7. How do you see the status of overgrazing after the introduction of the restoration project?

8. How do you see the problem of illegal cutting of trees after the restoration project?

9. Based on your experience, how do you see the role of the restoration project in

   9.1. Soil fertility____________________

   9.2. Soil productivity____________________

10. How do you see the role of area closure in

    10.1. Soil erosion____________________

    10.2. Overgrazing____________________

11. How do you evaluate farmers' participation in keeping the existing area closure?

____

____

12. What are the methods employed in the study area to restore the watershed?

____

____

13. How do landscape restoration in general and area closure in particular play roles in

13.1. Livelihood assets____

13.2. Livelihood activities____

13.3. Livelihood outcomes____

Appendix III. Supplementary Tables

Farmers' views on rate of soil erosion before landscape restoration

Rate of soil erosion	Frequency	Percent
Very low	7	2.7
Low	14	5.5
Neither low nor high	13	5.1
High	196	76.9
Very high	25	9.8
Total	255	100

Farmers' views on rate of soil erosion after landscape restoration

Rate of soil erosion	Frequency	Percent
Very low	16	6.3
Low	184	72.2
Neither low nor high	25	9.8
High	29	11.4
Very high	1	0.4
Total	255	100

Farmers' responses on rate of existing soil erosion compared to the past

Rate of soil erosion	Frequency	Percent
Very low	19	7.5
Low	170	66.7
Neither low nor high	9	3.5
High	54	21.2
Very high	3	1.2
Total	255	100

Farmers' perception toward rate of overgrazing before landscape restoration

Rate of overgrazing	Frequency	Percent
Very low	3	1.2
Low	17	6.7
Neither low nor high	0	0
High	189	74.1
Very high	46	18.0
Total	255	100

Farmers' perception toward rate of the current overgrazing problem compared to the past

Rate of overgrazing	Frequency	Percent
Very low	18	7.1
Low	202	79.2
Neither low nor high	1	0.4
High	29	11.4
Very high	5	2.0

Farmers' perception toward rate of community's benefit because of the establishment of area closure

Rate of community's benefit	Frequency*	Percent
None/very small	0	0
Small	5	31.3
Neither small nor high	2	12.5
High	9	56.3
Very high	0	0
Total	16	100

* Total number of respondents doesn't add up to 255 because such question was intended for those, who lost their farmland for the sake of implementing area closure. Thus, this study identified 16 of such persons out of the total of 255 respondents.

Farmers' perception toward rate of the importance of area closure in improving land productivity

Rate of the importance of area closure	Frequency	Percent
Very little	1	0.4
Little	14	5.5
Neither little nor high	5	2.0
High	214	83.9
Very high	21	8.2
Total	255	100

Farmers’ views on rate of agreement/disagreement with regard to the opinion that “area closure restores degraded land”

Rate of agreement/disagreement	Frequency	Percent
Strongly disagree	1	0.4
Disagree	5	2.0
Neither disagree nor agree	5	2.0
Agree	191	74.9
Strongly agree	53	20.8
Total	255	100

Farmers’ views on rate of satisfaction/dissatisfaction in the involvement on area closure and other restoration activities

Rate of satisfaction/dissatisfaction	Frequency	Percent
Strongly dissatisfied	1	0.4
Dissatisfied	13	5.1
Neither dissatisfied nor satisfied	0	0.0
Satisfied	188	73.7
Strongly satisfied	53	20.8
Total	255	100

Farmers' responses on the rate of the effect of the restoration project on their livelihood activities

Rate of the effect	Frequency	Percent
Very negatively	3	1.2
Negatively	14	5.5
Neither negatively nor positively	2	0.8
Positively	233	91.4
Very positively	3	1.2
Total	255	100

Farmers' views on rate of non-farm income after the restoration project

Rate of non-farm income	Frequency	Percent
Decreased	3	1.2
Neither decreased nor increased	35	13.7
Increased	209	82.0
Increased very much	8	3.1
Total	255	100

Farmers' perception toward rate of the number of income sources after the restoration project

Rate of the number of income sources	Frequency	Percent
Decreased	5	2.0
Neither decreased nor increased	30	11.8
Increased	213	83.5
Increased very much	7	2.7
Total	255	100

Farmers' perception toward rate of current income as compared with the past 15 years

Rate of current income vs. past income	Frequency	Percent
Decreased very much	2	0.8
Decreased	24	9.4
Neither decreased nor increased	30	11.8
Increased	193	75.7
Increased very much	6	2.4
Total	255	100

Appendix IV: Permission letter from Kalu District Agriculture Office

Kalu Wereda Agriculture Office
Kalu, Ethiopia

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ቃሉ ኢትዮጵያ

ቁጥር 10 24 / 2014
Ref. No.
ቀን Feb. 13, 2014
Date

To University of South Africa
College of Agriculture and Environmental Sciences
Geography Department
Pretoria, South Africa

Subject: Ethics approval

Mr. Alemayehu Assefa Ayele, who is a PhD student at your university, requested our office ethics approval letter. Accordingly, we have observed his research proposal entitled "Impacts of Area Closure for Landscape Restoration in North Central Ethiopia" for human, animal, plant and environmental risks and impacts. We have noticed that the focus of the research is on gathering geographical data. It has little human participation, soil sampling and field observation. As indicated in the proposal consent form, the rights and interests of human participants are protected. From protected area point of view, the field observations and soil samples have little or no impact on the natural resources. In General, we anticipated no ethical risks on Kalu district, if the proposed research takes place.

Therefore, on behalf of our office, I would like to grant permission for Mr. Alemayehu Assefa to undertake the proposed research in Kalu district.

Regards,

Wondwossen Mekonnen

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IMPACTS OF LANDSCAPE RESTORATION ON THE ENVIRONMENT AND FARMERS' LIVELIHOOD IN HITA-BORKENA WATERSHED, NORTHEASTERN ETHIOPIA

by

Alemayehu Assefa Ayele

Submitted in Accordance with the Requirements for the Degree of

Doctor of Philosophy

in Geography to the

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES
DEPARTMENT OF GEOGRAPHY

at the

University of South Africa

Supervisor: Dr. Assefa Abegaz Yimer

Co-supervisor: Prof. Simphiwe E. Mini

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