DYNAMICS OF LAND USE AND LAND COVER CHANGE AND VEGETATION COMPOSITION OF GUASSA COMMUNITY CONSERVATION AREA, AMHARA REGION, ETHIOPIA

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Dynamics of Land Use and Land Cover Change and Vegetation Composition of Guassa Community Conservation Area, Amhara Region, Ethiopia

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This is to certify that the Thesis prepared by Girma Nigussie Asresu, entitled*: Dynamics of Land Use and Land Cover Change and Vegetation Composition of Guassa Community Conservation Area, Amhara Region, Ethiopia* and submitted in partial fulfillment for the requirements for the Degree of Master of Science in Plant Biology and Biodiversity Management complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Dynamics of Land Use and Land Cover Change and Vegetation Composition of Guassa Community Conservation Area, Amhara Region, Ethiopia

Girma Nigussie Asresu, Msc Thesis

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*This study was conducted in Guassa Community Conservation Area, in North Shewa Zone, Amhara regional state, Ethiopia. The Guassa Community Conservation area is very important for the livelihoods of the local communities and the area is managed through local participation. The objectives of the study was to determine the rate of LULCC in the study area, to identify the causes of LULCC in the study area, to document the plant species of GCCA and to identify the species composition differences between plantation and natural vegetation. The LULCC data was gathered by using three LANDSAT satellite images starting from period of 1986, 2003 and 2015. All the available images were classified into different land cover types by applying a maximum likelihood algorithm under supervised classification method and with the support of ArcGIS v.10.1 software. The vegetation data was collected from 70 sample plots (35 from natural vegetation and 35 from plantation site). Each sample had quadrat size of 10m x 10m for trees and shrubs, five quadrats (2m x 2m), one at each corners and one at center for herbaceous species was laid out along a transect at an interval of 200 m between each large quadrat. The LULC maps of the GCCA for three referenced years and statistical summaries of the different LULC types were mapped. The study identified a total of 88 plant species which belongs to 64 genera and 33 plant families. Of the 33 plant families, Asteraceae had the highest number of species (31), the second was Poaceae with nine species. The study was concluded by mapping the LULC changes and documenting a total of 88 plant species with 18 endemic plants to Ethiopia. Finally, developing good mechanism to remove invasive species (*Helichrysum *species) and farther study on market value chain of *Festuca *species (economically valuable grass) are recommended.*

Keywords: Guassa Conserved Area; Land Use and Land Cover; natural vegetation; plantation forest; vegetation composition

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ACRONYMS

ASTER	Advanced Space borne Thermal Emission and Reflection
AVHRR	Advanced Very High Resolution Radiometer
^{0}C	Degree Centigrade
cm	Centimeter
DBH	Diameter at Breast Height
E	East
ERDAS	Earth Resource Data Analysis System
ESRI	Environmental System Research Institute
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
GCCA	Guassa Community Conservation Area
GIS	Geographic Information System
GIS	Geographic Information System
GPS	Global Positioning System
H	Height
ha	Hectare
IUCN	International Union for Conservation of Nature and Natural Resources
km	kilo meter
Land Sat TM+	Land Sat Thematic Mapper
LULCC	Land Use Land Cover Change

m	Meter
m.a.s.l	Meter above sea level
MSS	Multi Spectral Scanner
N	North
NDVI	Normalized Difference Vegetation Index
no	Number
RS	Remote Sensing
sp	Species
TM	Thematic Mapper
USGS	United States of Geological Survey

Chapter one

1. Introduction

1.1 Background

Land cover provides information on the physical and biological coverage of the earth surface. Land cover also shows the activities of human beings on the landscape, revealing the degree to which humans exploit their environment. Land use and land cover dynamics (LULCC) are very important factors that affect ecosystem structure and function (Mary *et al*., 2013). Recently LULCC dynamics have been considerably altering the biophysical cycle of the earth leading to changes in surface atmospheric energy fluxes, alteration of carbon and water cycles, decline in soil quantity and quality, loss of biodiversity, and diminishing the capacity of ecosystems in fulfilling human needs. Therefore, recognizing land use and land cover change (LULCC); analyzing the subsequent trends of change; and understanding the complex dynamics of a social-ecological system are necessary for planning, implementation of natural resource management policies and decision making (Mary *et al*., 2013).

Among many direct and indirect drivers of LULCC some studies suggest demographic dynamics as a primary contributor (Rezaul *et. al*., 2010). Rapid population growth, migration, and accelerated socioeconomic activities have intensified LULCC over the last several centuries. The impacts of these changes on climate have been found in local, regional, and global trends in modern atmospheric temperature records and other relevant climatic change indicators (Rezaul *et. al*., 2010). Large scale environmental phenomena such as land degradation and desertification, biodiversity loss, habitat fragmentation and species migration are consequences of land use changes by converting natural land covers into other land use types (Amare Sewnet, 2014). Understanding the cause and effects of LULCC is very important for good planning, especially for Ethiopia, where the resource base is rapidly declining and there is a need to be improving LULCC in order to feed Ethiopia's rapidly growing population.

Since the early 19th century, there has been rapid increase in the area of crop lands in the northern parts of the Ethiopian high lands. The resultant land cover change has led to a number of variability in the local and regional climate system by changing surface temperature and thermal radiation, evapo-transpiration, wind direction, increasing flood hazards (Rezaul *et. al*., 2010).

Guassa Community Conservation Area (GCCA) is found in Ethiopian high lands. GCCA provides habitat to many important Afro-alpine endemic and rare faunal (like African wolf and Red fox) and floral (like *Festuca* grass) species. The area serves as sources of natural resources for local communities in the area and thus is very important for the livelihoods of the people. Before 1974, the area was managed by a system called "Qero" for many years. "Qero" is an indigenous management system the local communities used to manage and protect the conserved area. However, the system has been changing over the last few decades and it is no longer functioning in its traditional form because of transformed in to locally organized management system now (Zelalem Tefera and Leader, 2003).

Currently the area is managed by an indigenous knowledge based system including livestock grazing, fuel wood collection and harvesting Guassa grass, although fuel wood collection and livestock grazing are not permitted bylaw (Zelalem Tefera *et al*., 2012). The only permitted activity is harvesting Guassa grass (*Festuca* grass land) with an interval of 2-5 years based on the growth rate of the grass. The area is threatened by rapid population growth which will lead to more severe land cover change affecting the people living around GCCA through its effect on the local climate. There is a growing need food production in the area, therefore, leading to expansion of agricultural lands. This when coupled with increasing demand for fire woods, building materials, and charcoal production are expected to exacerbate land cover and land use change in GCCA.

Therefore, identifying causes for land use and land cover change at appropriate scales and in a timely manner is essential to better understand the existing LULCC dynamics in the area and to design a strategy for the future land management system of the area. Therefore, this study was conducted in order to identify the dynamics of LULCC of the GCCA and to predict the future of the GCCA in terms of expected LULCC. In addition, this study will investigate the vegetation composition of both the natural vegetation and the plantation area of GCCA. This part of the study is expected to indicate the importance of protecting the remaining natural vegetation for conservation of floral diversity of the area. Finally, the study is expected to provide insights for prospective conservation and restoration of the GCCA.

1.2 Statement of the problem

The effects of land use and land cover change on climatic and weather conditions ranges from local to global scale. LULCC is now a day a global research agenda due to an increasing understanding of the influence of land surface processes on climate (Otterman, 1974). In 1970 scientists recognized that land-cover changes alter surface albedo and consequently atmospheric energy fluxes affecting regional climate (Charne and Stone, 1975; Sagan *et al.*, 1979). Later on more researches indicated terrestrial ecosystems as sources and sinks of carbon which underscored the impacts of LULCC on global climate through its effects of global carbon cycle (Woodwell *et al.*, 1983; Houghton *et al*, 1985). This indicates that addressing the issues of LULCC will help us decreases the uncertainties surrounding terrestrial sources and sinks of carbon. More recent development is our understanding of the important contribution of local evapo-transpiration on global water cycle, which appears to be a function of land cover change highlighting an additional considerable impact of LULCC spanning from local to global scale (Eltahir and Bras, 1996).

In Ethiopia, particularly in highlands areas of the country, many studies showed that there is a rapid LULCC due to many factors among which are population increase; infrastructure expansion; market driven forces; ineffective policies and climate change (Hussien *et al*.2005; FAO, 2015).Even though LULCC dynamics is often driven by human activities and widespread, they also impact human lives (Hussien *et al*., 2005). For instance, they are altering availability of different biophysical resources including, soil, water, animal feed and vegetation.

In recent past Ethiopia has aimed to wisely manage its natural resources in order to insure food security for its rapidly growing population. Rural populations, like this study area, are rapidly growing, which will be many undesirable effects on the natural resource base in the area. This includes decrease in the area under natural vegetation due to rapid conversion of natural areas into other land use types (Woldeamlak Bewket *et al*., 2005). In order to curb this, resource managers and policy makers will need quantitative research and information on the spatial distribution of land use types, their spatial and temporal dynamics (Abiy Wogderes, 2006). Hence, this study was conducted to investigate the LULCC in GCCA, Amhara Regional State by using modern remote sensing and GIS tools complemented by ground survey of both natural and plantation forest in the study area.

1.3 Research Questions

1. What are the major drivers of LULCC and what is the rate of LULCC inside the GCCA?
2. How does the plant diversity and community composition change between natural vegetation and plantation forest?

1.4 Objective

1.4.1 General objective

The overall objective of the study was to analyze the drivers and rate of LULCC in GCCA and document the floral diversity and vegetation composition in natural vegetation and plantation.

1.4.2 Specific objectives

The specific objectives of the study were the following:

- ✓ To determine the rate of LULCC in the study area
- ✓ To identify the causes of LULCC in the study area
- ✓ To document the plant species diversity of GCCA and
- ✓ To identify the species composition differences between plantation and natural vegetation

Chapter Two

2. Literature Review

2.1 Land use land covers change

Land use and land cover change (LULCC) is increasingly attracting the attention of scientists all over the world. Recognizing this change is important for understanding local to global environmental change and sustainable development issues. FAO (1994) has defined “land” as:“A delineable area of the earth's terrestrial surface, embracing all attributes of the biosphere immediately above or below this surface, including those of the near surface climate, the soil and terrain forms, the surface hydrology including shallow lakes, rivers, marshes and swamps, the near-surface sedimentary layers and associated groundwater and geo-hydrological reserves, the plant and animal populations, the human settlement pattern and physical results of past and present human activity.”

Some people use the terms land cover and land use interchangeably, but there are actually clear distinctions between them. Land cover is defined as a physical description of space or the observed physical cover of the earth's surface (European, 2001). Land use is more complex than land cover because sometimes it coincides with certain land covers. For example, when the land is covered by buildings we can say that land use and land cover are the same. However, land use is usually more complex. The European Commission defines land use by considering two schools of thought; functional basis of land and socio-economic basis of the land. By this definition, land use is a series of operations on the land, carried out by humans, with the intention to obtain products and/or benefits through using land resources (European, 2001). Landscapes changed by humans occur from many different types of human activity. Some changes are by design, such as new housing developments, new roads, or new farm lands. Other anthropogenic changes occur by accident or other means, such as excessive erosion induced by vehicle traffic on thin soils or human caused grass fires (Keith, 2008).

LULCC can be divided in to two forms: conversion and modification (European, 2001). Conversion occurs when a change is made from one land cover or use category to another (e.g. from forest to grassland), and modification is when a change occurs within one land use or land cover category (e.g. from rainfed cultivated area to irrigated cultivated area). Based on land cover and land use change information, certain changes can be retrieved, which might also serve as simple indicators (European, 2001).

2.2 The Relation between Land degradation and LULCC

Land degradation has direct and indirect links with LULCC. Land degradation is defined as any use that decreases the natural potential of the land or that negatively affects biodiversity (Netsanet Demeke, 2007).According to Dudal (1981), land degradation is the qualitative or quantitative loss of land productivity through various processes such as erosion, water logging, depletion of nutrients, deterioration of soil structure and pollution. However, other authors have summarized land degradation as the reduction of the productive potential or capacity of the land in relation to actual uses. Land degradation often leads to food shortage for the animals, plants and people who depend on the land. In Ethiopia, the pressure on the land resource is more severe in the highlands (> 1500 m.a.s.l), which cover about 45% of the country. There are high human and animal populations in the highlands, and 95% of the land is cultivated regularly (FAO 1986). The highland farming population grows rapidly, and correspondingly the demand for crop land is increasing. This rising population places more demand on marginal land for cultivation and grazing and leads to clearing natural vegetation for conversion to cropland. Converting forest and grazing land to cropland creates shortages of fuel wood and animal feed, forcing the rural people to use dung and crop residues as fuel rather than allowing them to remain in the field to assist with soil fertility and soil formation. Combined with many other physical and socio-economic factors, these conditions are leading to degradation of the natural resources.

Many studies conducted in different parts of Ethiopia have reported that forests and bush lands are being converted to croplands and thus the natural vegetation cover is decreasing. For example, study by Gete Zeleke and Hurni (2001), showed a significant conversion of forest land into cultivated land between 1957 and 1995 in the Dembecha area of northwestern Ethiopia. Kebrom Tekle and Hedlund (2000) reported that, there are increasing settlements and decreasing shrub lands and forestlands between 1958 and 1986 in the Kalu area of north-central Ethiopia. The expansion of farmland was reported by Woien (1995) around Debre-Sina in central Ethiopia between 1957 and 1986.

2.2.1 Causes of land degradation

Studies have identified many different causes of land degradation. For some authors, the cause of land degradation involves two dependent complex systems; the natural ecosystem and the human social system (Berry, 2003). The success and failure of resource management is depending on the interaction of these two. Other studies classify the causes of land degradation into (a) biophysical factors such as unsuitable land use (environmentally unsuited for sustainable use), (b) socioeconomic factors such as poor land management practices, land tenure, marketing, institutional support, income and human health, and (c) political factors such as lack of incentives and political instability (Temesgen Gashaw *et al.*, 2014). Essentially, degradation is a biophysical process that is caused by socioeconomic and political problems (Mulugeta L., 2004). Most of Ethiopia's growing population demands increased agricultural land, which is a major reason for land degradation in this country (Gebreyesus and Kirubel, 2009).

2.2.2 Causes of land cover and Land use changes

There are many different factors which can cause or drive LULCC. According to Lambin *et al*. (2000), the following land change was examined as major causes: deforestation (cutting forests for different purpose), rangeland modification (grazing land change in to agriculture or House land), agricultural intensive (expansion of agriculture) and urbanization.

2.2.3 Impacts of land use/land cover change

Human activities have changed or modified the environment for many years. Significant population increase, migration, and accelerated socio-economic activities have intensified these environmental changes over the last several centuries (Rezaul *et al.,* 2010). The major human influence on atmospheric temperature trend is extensive land use and land cover change and its effect on climate (Rezaul *et al.,* 2010). Local LULCC often has severe impacts on local environments, and when these local impacts are aggregated globally, they can significantly affect the functioning of the global ecosystem and thus human livelihoods around the world (Abba *et al*., 2006). According to Abba *et al.* (2006), decreased land productivity, increased food insecurity and poverty, climate change and water scarcity can be the results of LULCC.

Land degradation due to LULCC has multiple and complex impacts on the ecological system through direct and indirect processes affecting a wide range of ecosystem functions and services (GEF 2006). The principal environmental impacts of land degradation include a rapid loss of habitat and biodiversity fragmentation, influencing water flows, and sedimentation of reservoirs and coastal zones (Temesgen Gashaw *et al.*, 2014). Land degradation also interrupts the regulating and provisioning services of ecosystems, in particular nutrient cycling, the global carbon cycle and the hydrological cycle.

Land degradation contributes to persistent poverty due to decreasing ecosystem resilience and provision of ecosystem services (Bossio *et al*., 2004). In addition, environmental resource decline due to land degradation adversely affects the health, well-being and livelihood opportunities of individuals (Vivian *et al.*, 1994). The most serious problem of Ethiopia's land resources is soil erosion caused by land degradation. Every year the country is losing resources in the form of soil, nutrients and agro-biodiversity losses (Paulos, 2001). Land degradation is one of the major causes of low and declining agricultural productivity and continuing food insecurity and rural poverty in Ethiopia (Temesgen Gashaw *et al.*, 2014). Land degradation reduces livestock productivity by reducing grazing land resources and causing the extinction of nutritious plants and grass species (Fitsum Hailu *et al.*, 1999).

Therefore; Local changes in LULC are affecting everything on earth, especially when they aggregated globally they may affect significantly earth's functioning system and human livelihoods (Abba *et al*., 2006). Estimates of the LULCC in areal extent are useful to manage the environment and to predict future impact caused by LULCC. That is why doing this research was very important.

LULCC can be detected by using Remote sensing (RS) and Geographic Information system (GIS). RS and GIS play a major role in how to detect LULCC (Michael *et al.*, 1996). The most commonly used for natural resource management is satellite system, because of which has a twice daily overpass and can be freely downloaded by low-cost ground receiving stations (Andrew *et al.*, 1997). Therefore, the method of this paper was carried out by using remotely sensed data (Satellite system) particularly image processing techniques and the capabilities of GIS technologies.

2.4 Remote sensing for land use and land cover detection

Digital remote sensing has been started after the launch of Landsat1 since 1972, to monitor natural resources and provide input to better manage natural resources (Andrew *et al.*, 1997).

Remote sensing is defined as the science of the measurement or acquisition of information about the earth using instruments which are remote or without intimate contact to the earth's surface, usually from aircraft or satellites (Levin, 1999; Lwin, 2008). The technique uses devices such as the cameras, lasers, and radio frequency receivers, radar systems, sonar, seismographs, gravimeters, magnetometers, and scintillation counters.

Human beings are intimately familiar with remote sensing because we rely on visual perception to provide us with much of the information about our environment (Levin, 1999), which is the basis of remote sensing as well.

Remote sensing has been recognized as an important tool for viewing, analyzing, characterizing, and making decisions about our environment. According to Levin (1999) remote sensing technology has recently upgraded on the three bases: a) from predominantly military uses to a variety of environmental analysis applications that relate to land, ocean, and atmosphere issues; b) from analog or photographic systems to sensors that convert energy from many parts of the electromagnetic spectrum to electronic signals; and c) from aircraft to satellite platforms.

2.4.1 Remote sensing applications in Land use Land Cover

Land use/land cover applications of remote sensing can be used to evaluate natural resource management, wildlife habitat protection, urban resource extraction activities, hazard damage delineation (flooding, volcanic, seismic, fire), legal boundaries for tax and property evaluation, and target detection - identification of landing strips, roads, clearings, bridges, land/water interface (Baumgartner and Apel, 1996).

These days there is a need for updated and accurate information to help decision making (Tilman *et al*., 2002), therefore, remote sensing is being used as a basic component of many studies. It is especially useful in supporting decision-making and identifying effects happening in a land cover (Takao and Priyadi, 2010). For instance, the use of remote sensing by forest managers has increased in large part via better integration with GIS technology and databases. The most important forest information obtained from remotely sensed data can be broadly classified as:

- Assessment of forest structure in support of sustainable forest management
- Broad area monitoring of forest health and natural disturbances, and
- Detailed forest inventory data (Wulder and Franklin, 2012)

Remote sensing (RS) uses sensors that are mounted on satellites as platform (Lillesand *et al.*, 2014). These sensors use magnetic spectrum to capture images of places which are used in observing and analyzing changes. However, the selection of a sensor from where to obtain one's image is very critical (Xie *et al.*, 2008) (**Table1**). Satellites can acquire data depending on method of objects response to the remote sensor. Then, this data can help to differentiate objects by means of capturing, transferring, classification and analysis (Sun *et al.,* 1997). Therefore, it is possible to gather information in a short time. As a result, obtaining terrestrial information is vital use of RS in forest management (Weilin *et al.*, 1999). The most common software's used in remote sensing are ERDAS, ESRI and MapInfo (Gupta *et al*., 2012).

Table 1 Main characteristics and application of different sensors (Xie *et al.*, 2008)

Sensor	**Characteristics**	**Application**
Landsat TM	Use multispectral data Covers an area of 30m x 30 m	Able to map large areas and vegetation at community level
SPOT	Spatial resolution is from 20m to 25m and covers an area of 60 x 60 km at minimum	Useful for monitoring and managing natural resources
AVHRR	Approximate view size 2400 x 2400 km	It is suitable for mapping land cover types
ASTER	It collects image from visible to near infrared bands at different spatial resolutions	Able to map from regional, national and local level

For instance, studies have shown that around 35 % of Ethiopia was covered by forests. Therefore, RS based assessment of forest resources was performed. Then, the result shows that natural high forests were approximately 4.75 % in the 1970's. However, in 1980's only 0.20 % of the country was left. Due to this, these days notable forest ecosystems can only be found in remote areas (Reusing, 2000). As a result, RS can offer the way how to recognize areas of forest degradation and deforestation (Sajjad *et al*., 2015).

2.4.2 Processing of remotely sensed data

Remotely sensed data are recorded in the optical range of the electromagnetic spectrum, and so fundamental physical knowledge concerning the path of radiation from the sun to Earth and to the sensor is necessary. Different processing is needed between passive and active sensor systems such as radar (e.g., Doppler radar, Synthetic Aperture Radar (Baumgartner and Apel, 1996).

The processing scheme includes the procedure of pre-processing (data must be calibrated, normalized and atmospherically Corrected) and processing (spatial data modeling, algorithm development and multi spectral classification) of remote sensing data which are usually summarized in the form of image processing (Baumgartner and Apel, 1996; Lwin, 2008).

2.4.3 GIS in land use and land cover

GIS (Geographic Information system) was developed as a new computer system in 1960's (Lu and Tang, 1998). GIS is a system which is designed to collect, store, update, manage, manipulate, analyze and represent graphical and non-graphical spatial data (Baumgartner and Apel, 1996). It consists of the terms: Geographic, Information and

System. The word geographic deals about spatial features associated with a specific place on the earth. Likewise the term information deals about quantity of data regarding an object. Finally, the word system is used to characterize techniques in describing an object or feature (Gupta *et al.,* 2012). According to Gupta *et al.* (2012), forest management based on GIS can be achieved by two major categories: modeling and analysis, and forest inventory. For instance, inventory activities may include (a) recording available forest resources for different purposes, (b) examining resource alterations that happen over time, and (c) assessing the capability of forest land productivity.

GIS can store numerical as well as geographic structure like forest and connects them to spatial databases. It helps managers to efficiently add both spatial and temporal elements in planning process. For instance, variation in forest resources of Xinjiang in China was studied based on GIS. The results revealed that forests were improving in general, while problems such as imbalanced age structure and mono species composition still occur (Lu and Tang, 1998). Furthermore, GIS can also be used to classify erosion risk in a forest and to predict the amount of sediment from forest road network (Parsakhoo *et al.*, 2014).

- **Monitoring forest dynamic change**

The usual management systems can only show the extent of forest change. However, GIS based systems have analysis function for spatial data. Because, using data derived via remote sensing (RS) and global positioning system (GPS), it is possible to apply relationship analysis to study geographic distribution of forests. This can provide counter measures for decision makers to regulate development plan and increase forest improvement (Weilin *et al*., 1999). As described by Apan (1999), GIS has plenty of applications in forest resource monitoring to identify and map a forest ecosystem. Therefore, the uses of GIS in this regard are:

- Assessment of degradation, deforestation and land use change.
- Monitoring forest ecosystems at different scales, and
- Determining forest types and their successional stages.

➢ **Timber management**

According to Gupta *et al*. (2012), management of timber centers on efforts to offer uninterrupted supply of trees for optimal timber production. Previously, forest professionals were dependent on wood supply models to conduct optimum harvesting, which usually ignore particular spatial locations. However, GIS has now made it achievable to include geographic factors into planning and modeling. Additionally, in each step of management, forest managers can use GIS and RS records to predict population growth and urban spread. Then, forest and timber management can be designed considering future needs of settlements.

➢ **Assists decision making in natural resources**

GIS not only map spatial data, but also plays a role in analysis of results. For instance, it is crucial to apply GIS in planning and designing of forest road network. This is because it can help foresters to find out best distribution plan of forest road network by analysis and calculation depending on different situations (Weilin *et al.*, 1999).

2.4.5 General application of GIS in resource management

In recent years, the relationship between GIS and spatial thinking has attracted much attention (Wakabayashia and Ishikawab, 2011). Additionally, the use of GIS has flooded in many fields offering efficient methods for collecting and analyzing data (Sonti, 2015).

Forests are a dynamic resource, being affected by many factors that interrelate over time and space. Therefore, to understand its dynamics and to forecast future impacts, all basic variables should be included in a single database (Perez *et al.*, 2016). As a result, GIS plays a vital role to include all variables and manage forests sustainably (Sonti, 2015). Generally, GIS is an important application to manage forests as it can answer the following questions: Where it is? Location: identifying position of resources, for example using spatial references such as longitude and latitude.

- ✓ Where is it? Situation: distance of forested areas from river or road.
- ✓ What has altered? Tendency: assists to determine what has shifted inside a given forest over time.
- ✓ What if? Modeling: finding out what will happen if a road network is constructed
- ✓ What kind of pattern exists? Patterns: for example, it helps to find out whether or not landslide occurs in a forest (Sonti, 2015).

Many apparent and realized benefits provided by GIS will help the establishment, sharing and use of spatial databases. Such databases assist to resolve problems related to resource planning and management (Apan, 1999). In this regard, gathering inventory data and examining resource changes are decisive to forest management actions. As a result, GIS can assemble on actions by including models to direct, for instance, forest utilization, fire and silvicultural activities (Wulder and Franklin, 2006).

2.4.5.1 Saving plant species and wildlife

Commercial forestry is an industry which involves long-term planning for regrowth and cutting. Its major component is logging. In this regard, reliable data from satellite images can be used for monitoring and management of activities. In addition, forest ecosystem assessment via GIS should be achieved to evaluate the effect of logging on wildlife species.

Therefore, tree species inventory via GIS and remote sensing can be used to recognize habitats of wildlife species as well as endangered plant species (Gupta *et al*., 2012).

2.4.5.2 Protecting insect outbreaks

An integrated GIS cellular automata (CA) model in order to control insect outbreaks was developed in Canada. The outcome shows that forests subject to thinning are more successful than clear-cutting for minimizing insect epidemic. This is because clear-cuts may raise a spatially identical reaction to insect occurrence. Therefore, GIS are helpful in management of forests since spatial associations among stands and individual trees can be assessed and incorporated into management decisions (Bone *et al.*, 2007).

2.4.5.3 Risk management

These days the world is being affected by different disasters. Several regions are vulnerable to different natural hazard, which includes windstorms, earthquakes and forest fires. However, using GIS and remote sensing as an integrated approach is very important in disaster risk management (van Westen, 2013). In addition, GIS and RS techniques are also crucial for change detection and mapping land use/land cover (Mengistu and Salami, 2007).

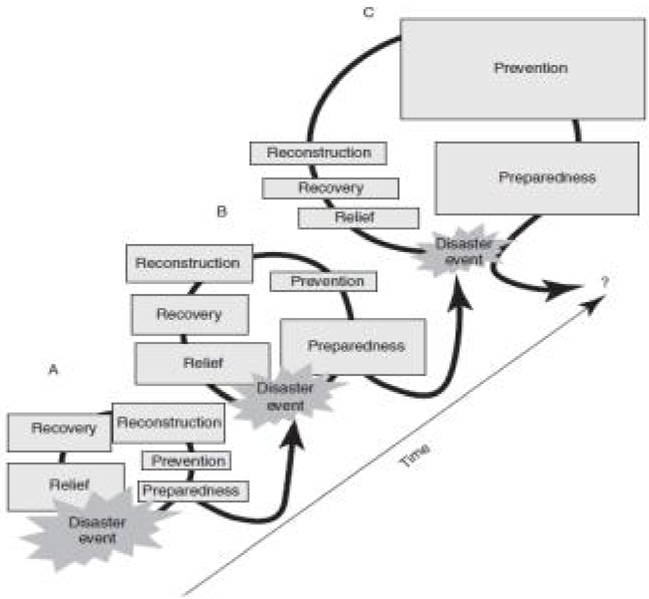

Figure 1 *Development of disaster through time (van Westen, 2013)*

2.4.6 Specific applications of GIS

According to Weilin *et al.* (1999), by collecting, compiling and examining information, GIS can offer a sequence of assistant conveniences for decision makers. Management of forests entails predictions about the future trait of forests. This capability is decisive to many features of forecasting forest management, specifically regarding long term supply of products and services (Kane 1997). Therefore, in GIS information that supports forest management is stored primarily in the form of forest inventory databases. Forest inventory is a survey of location, composition and distribution of forest resources. As the principal sources of forest management, these databases help a wide range of decisions (Wulder *et al.*, 2005).

2.4.7 Challenges in GIS application

The fundamental problem in different applications of GIS is that of understanding an event, which have both temporal and spatial dimension. This means that entity of study has diverse character for different locations (spatial dimension) and also these characteristics change over time (temporal dimension) (Rolf, 2004). Moreover, the complexity of interactions between different variables and scarcity of reliable data lead to difficulty in integrating large scale and local planning systems together. Therefore, generating a spatial model, based on GIS is necessary (Sacchelli *et al*., 2013).

According to Baral (2004), GIS is only a way to recognize and work out problems. Therefore, it requires appropriate planning to achieve its maximum potential. Generally, some of the reasons hampering the use of GIS in management of forests are:

- ✓ Lack of skilled workforce
- ✓ Scarcity of budget
- ✓ Weak ability of spatial database building
- ✓ Limited information access, and
- ✓ Scarcity of applications and data

Chapter Three

3. Materials and Methods

3.1 Description of the study area

3.1.1 Location

Guassa Community Conservation Area lies between altitude of 10^{o} 15' – 10^{o}27′ N and longitude of 39^{o} 45$'$ - 39° 49′ E. It is found at about 295km north-east from Addis Ababa, the capital city of Ethiopia and 165 Km North from Debre-Birhan city, biggest town near the study area. The total land area of Guassa is about 111 km² and its altitude ranges between 3200 to 3700 m.a.s.l (Figure 2). The area is part of the Menz-Gera Administrative District in the North Shoa Administrative Zone of the Amhara Regional state of Ethiopia. The district administrative town called Mehal Meda, which is located at about 35 km from the Guassa Area (Zelalem Tefera *et al*., 2012; Gomje Amessie, 2014).

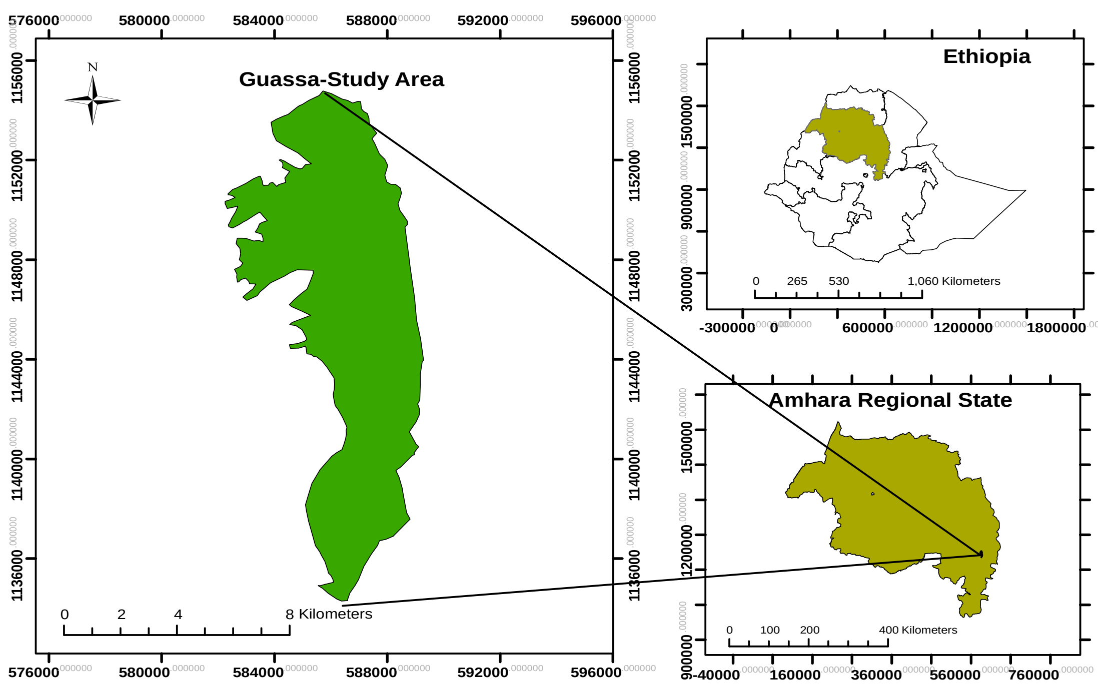

Figure 2 Map of the Guassa Community Conservation Aea (study area)

3.1.2 Population

The population of the Menz-Gera Administrative District including GCCA is about 111,000. The population is predominantly Amhara, which is second largest ethnic group in the country. The people in Amhara Regional State predominantly speak Amharic language (Zelealem Tefera and Williams, 2005).

3.1.3 Soil and Geology

The GCCA is formed by tectonic movement during Oligo-Miocene geological period. Today, the area contains 15-26 million years old Miocene Thyolitites, basalts and 20 - 26 million years old Oligo-Miocene Tarmaber basalts and Phonolites. The central highland consists of black-clay and reddish brown heavy loam soil (Gomje Amessie, 2014).

3.1.4 Climate

At the high altitude, wet season is characterized by a combination of rain fall, frequent fog and occasional snow. Frost is common during dry season. There are two main rainy seasons in Guassa area, which are called locally 'Kiremt' (high rainy season between June and September) and 'Belg' (low rainy season between February and April). The mean annual rain fall of the area is 860mm (Figure 3), while the temperature monthly mean ranges from 5.2 ^{0}C - 19.5 ^{0}C (EMA, 2016).

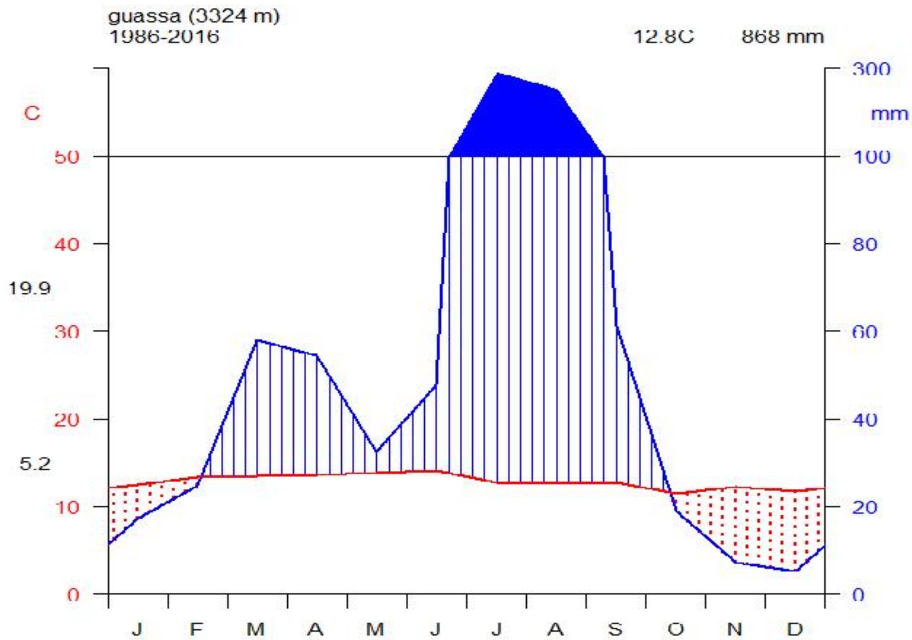

Figure 3 *Climate diagram of GCCA, indication high and low rainfall and mean monthly temperature.*

3.1.6 Vegetation

The GCCA is characterized by a high altitude Afro-alpine vegetation type. The area contains important and endemic plant species including Guassa grass (*Festuca spp*), *giant Lobelia* (*Lobelia rhynchopetalum*), *Helichrysum* and *Alchemilla* species. The Afro-montane vegetation of the Guassa area varies with altitude, and is a key attraction of the area. The other common plant species found in the area include *Carex monostachya*, *Carex fischeri* (Cyperaceae) and *Kniphofia foliosa* in the family *Asphodelaceae*. At higher altitudes, *Euryops* - *Alchemilla* community occurs over 3,200 meters on flat, gentle slopes and well drained areas. The shrubby vegetation of *Euryops pinifolius* (Compositae family) is extensively used as firewood by the communities living adjacent to the Guassa area. As the altitude increases, the vegetation changes to *Helichrysum-Festuca* type of grassland followed by *Erica* moorland. The torch lily or red-hot poker (*Kniphofia spp.*)

covers entire hillsides with its flame-colored flowers between June and November. The palm-like giant lobelia (*Lobelia rhynchopetalum*) is most spectacular and reaches up to 12 meters in height (Zelalem Tefera *et al.*, 2005).

There is plantation area inside GCCA. The plantation was planted by previous government of Ethiopia. The planted trees were found only along the border of east side direction of conserved area. The most plantation area was covered by *Cuperus lustanica* and small area is covered by *Eucalyptus globulus.*

According to Zelalem Tefera and William (2005) and Getachew Simeneh (2010), the area has five Habitat types.

A. *Festuca* grassland - The drainage of this land is good and the soil is deep. It is found on steep to moderately steep slopes up to altitude of 3500 m.a.s.l. The common plant species in *Festuca* Grassland are: *Festuca abyssinica, Festuca simensis*, *Festuca richardii*, *Festuca macrophylla, Andropgon abyssinicus*, *Poa shimperina*, *Alchmilla abyssinicus*, *Senecio vulgaris*, *Thymus schimperi, Helichrysum formosissium,* and *Artemesia* species.

B. *Euryops* - *Alchemilla* shrubland - It is found on flat and gentle slopes and well drained areas, and is located above 3200 m.a.s.l. Common plant species, found in this area include; *Thymus schimperi, Euryops pinifolius, Alchmilla abyssinica, Kniphofia foliosa, Urtica simensis, Anthemis tigreensis*, *Echinops steudneri*, *Ferula communis*, *Hebenstretia dentate*, *Agrostis graclifolia*, *Geranium arabicum*, *Kalanchoe deficiens*, *Senecio gigas, S. vulgaris* and *S. schultz.*

C. *Euryops* - *Festuca* Grassland – Is characterized by mounds. The dominant species of this area are; *Euryops pinifolius, Festuca abyssinica, Festuca richardii, Festuca macrophylla, Festuca simensis, Andropogonamethystinus, Alchemilla abyssinica, Anthemis tigreensis, Thymus schimperi, Rumexabyssinicus* and *Crisium vulgare.*

***D. Helichrysum* - *Festuca* grassland -** This land occurs on hill tops and the soil is poor. The Common plant species in this area are; *Helichrysum splendidum, H. gofense, H. formosissimum, Pinnisetum spp., Alchemilla abyssinica* and *Echnnops spp*.

***E. Erica* Moorland -** *Erica* moorland is commonly found in high altitude areas with shallow and well-drained soil. The common plant species in this habitat are; *Trifolium burchellianum, Erica arborea, Thymus schimperi, Alchemilla abyssinica, Hellichrysum splendidum, Swertia abyssinica, Rubus abyssinicus, R. steudneri, Urtica simensis* and *Kniphofia foliosa.*

F. Swamp Grassland - This habitat is inundated by grasses especially during the wet season. It provides year around green grass for the local cut and carry fodder system. The dominant plant species are; *Carex monostachya, Carex fischeri* and *Alchemilla spp.*

3.1.7 Fauna

GCCA has nine (23%) of the endemic mammals of Ethiopia, including the Ethiopian wolf, the Gelada and the Ethiopian Highland hare. The Ethiopian wolf is legally protected and is the most endangered in the world with a total world population of less than 450. The gelada is the only living member of the once widespread genus *Theropithecus* and it is endemic in the highlands of northern Ethiopia. They live in large groups reaching up to 400 individuals. Other mammals of the area include klipspringers, jackals, leopards, spotted hyenas and civets (ZelealemTefera *et. al*, 2005).

3.1.8 Birds

There are 114 birds recorded in this area, which is 12% of 862 species of birds in Ethiopia. The area is also home to migrant birds of prey and serves as a wintering ground for 38 species of African migratory birds. The endemic birds which found in this area includes; Ankoberserin (*Serinus ankoberensis*),Abyssinian catbird (*Parophasma galinieri*), Abyssinian long-claw (*Macronyx flavicollis*), blue-winged goose (*Cyanochency anoptera*), Ethiopian/black-headed siskin (*Serinus nigriceps*), black-winged lovebird (*Agapornis taranta*), Rouget's rail (*Rougetius rougetii*), spot-breasted plover (*Vanellusmel anocephalus*), thick-billed raven (*Corvus crassirostris*), wattled ibis (*Bostrychiacar unculata*), white-collared pigeon (*Columba albitorques*) and white-winged cliff chat (*Myrmecocichla semirufa*) (Zelealem Tefera *et. al*, 2005). Some part of GCCA captured by digital camera (Figure 4).

Figure 4 *Partial view of Guassa community conservation area; this picture was taken at the middle of conserved area. It represented by Euryops-Festuca Grassland community type. The altitude of this area is about 3400 m a.s.l and the photo was taken by Girma Nigussie in Oct/2016.*

3.2 Methodology for land use/land cover change

The data was collected by using both primary sources (interviewing key informant (**Appendix 5**) and direct field observation) and secondary sources (GIS and Remote sensing data).

3.2.1 GIS and Remote Sensing Method

Three LANDSAT satellite images starting from period of 1986, 2003 and 2015 were used from USGS. LANDSAT images of 30 m resolution for 30 years and GPS points were collected from field and Google earth. A band selection was made in order to obtain the most important information from remotely sensed data through the analyses of reflectance properties of objects or features. Spectral reflectance curve of the different land use types of the area and the histogram behavior of the bands was used for the purpose of image processing of Landsat satellite images. Digital image enhancement and interpretation techniques were used to increase the quality of the work in this study. To increase the visual interpretability of the satellite images and the amount of information that could be visually interpreted from the data, both True Color Composite (TCC) and False Color Composite (FCC) images were produced. Digital image enhancement techniques such as contrast stretching and band ratios were performed (Martin, 2008).

Data Collection: A preliminary field visit was carried out and an overall overview of the study area was captured, the five land use/ land cover types were identified, and the GPS readings were collected from identified features. The second field visit was used to verify the various land-use/land-cover types identified through satellite image manipulation and to consult the local community, district agricultural and rural development office experts. Through these interviews the factors driving the vegetation cover change were identified.

These data were used for designing the final image classification and identifying the sample site, which was used for land cover map validation.

At each land cover type, 30 reference points were randomly taken using GPS for ground truth verifications. In addition to these data, photographs were taken at the site, which helped to support the identification of patterns. All the available images were classified into different land-use/cover types by applying a maximum likelihood algorithm under supervised classification method and with the support of ArcGIS v.10.1 software (Martin, 2008).

Accuracy assessment of LULCC was evaluated by employing accuracy assessment technique using R software in order to assess whether the map reflected reality well. The accuracy percentage has direct relationship with classification system. As the percent of accuracy increased the correctness of classification also increased. In this study accuracy assessment has been done for the period of 2015, which is the only time period for which we have ground truth data. The description of Landsat images of three referenced years are showed in (Table 2).

Table 2 Description of the Landsat images (Source: USGS, 2016)

Sensor	**Path /Row**	**Date of Acquisition**	**Resolution**
LANDSAT 5_TM	168 / 53	27/03/1986	30 m X 30 m
LANDSAT 7_ETM	168 / 53	12/01/2003	30 m X 30 m
LANDSAT 8_OLI_TIRS	168 / 53	06/02/2015	30 m X 30 m

Table 3 Description of Land cover classes

No.	Land cover class	Description
1	Forest	Area covered by planted trees with crown cover greater than 30%. Plantation forest species are *Cupressus lucitanica*, *Eucalyptus globules* and scattered *Hagenia abyssinica.*
2	Shrub land	A Land that dominated with shrubs, which are usually not greater than 5 meters height and crown cover greater than 20%. Dominated by grouped shrubs with better ground cover.
3	Grass land	The land covered by basically grass and other herbaceous species. Grass and other herbs are dominant vegetation type with no or scattered shrubs.
4	Agriculture	A Land that cultivated annual crops with rain fed and infrastructures basically roads (since roads have the same reflectance with agriculture).
5	Bare land	Little or no vegetation cover at all mainly on areas with stony and rocky sites.

The procedure was followed for land use change analysis was presented using the flow chart (**Figure 5**). It shows the steps followed beginning from the acquisition and classification of multi temporal satellite image of the study area to the extraction of the required information both secondary and primary data.

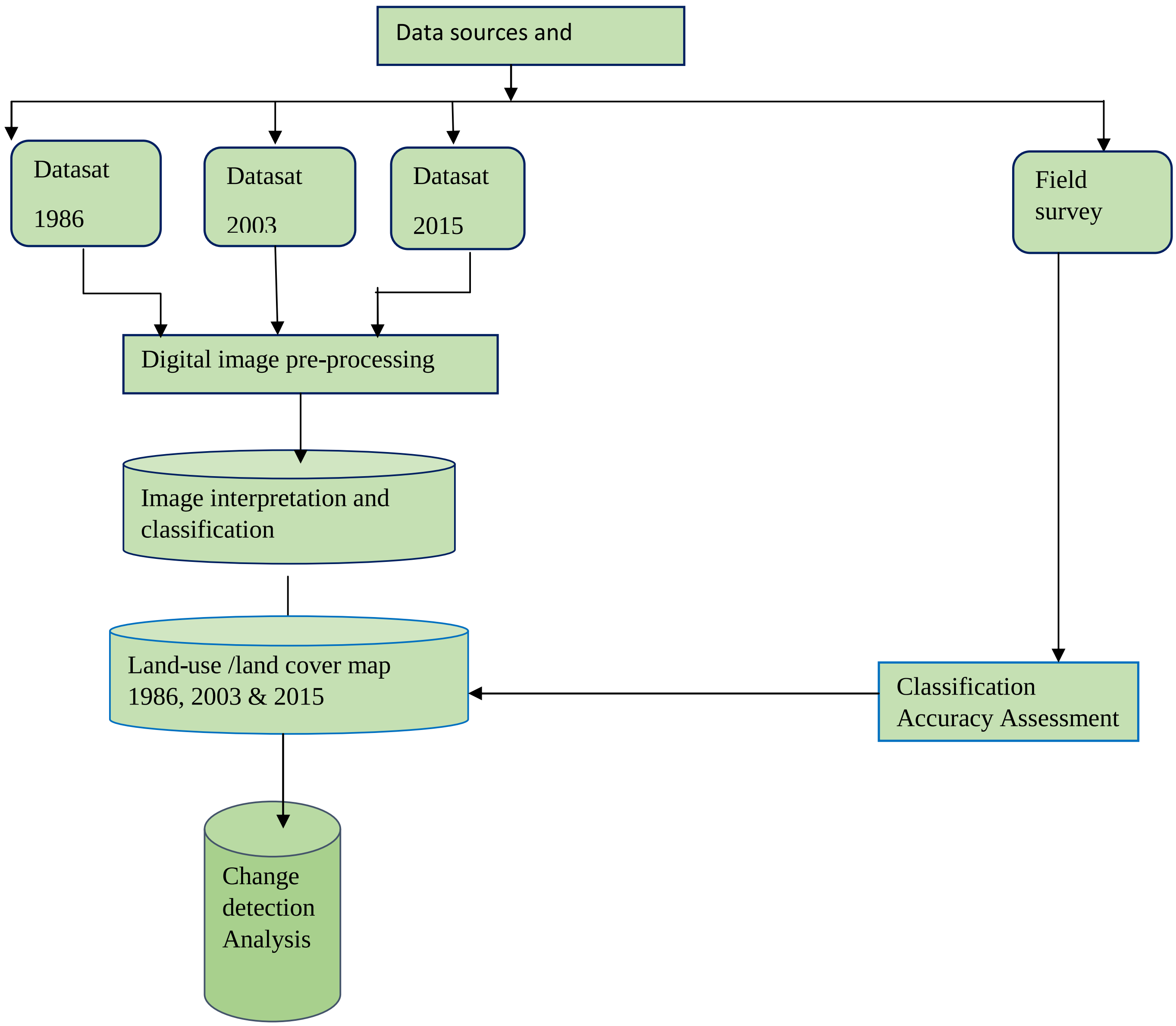

Figure 5 a flow chart showing the procedure

3.2.2 Socio-Economic Survey Method

There are nine kebeles, (equivalent to neighborhood, which is the smallest administrative unit in Ethiopia) who have direct access to use the resource in the conservation area. Of these, five kebeles do not directly border the GCCA but are nearby while the remaining four kebeles share common border with the conservation area. Therefore, in this study the four kebeles that share a border with the conservation area were surveyed. A total of 100 respondents who are above 50 years of age (25 respondents from each kebele) were selected randomly in order to answer questions about the past history of the area (Figure 6). Open ended questionnaires were prepared that could capture a time line of historical events and the interview data were summarized based on “Historical ecology” later on. “Historical ecology is the use of historical knowledge in the management of ecosystems. Historical perspectives increase our understanding of the dynamic nature of landscapes and provide a frame of reference for assessing modern patterns and processes.” (*http://environment-ecology.com/history-of-ecology.html*).

This is helpful to distinguish different causes and consequences of LULCC under different Ethiopian regimes. The timeline was developed in the reference of two governments that governed the country during the study period the Derg regime (1975 to 1991) and the Ethiopian People Democratic Republic Front (EPDRF) (from 1992 to the present). The interviewed data were summarizing to capture major events in the historical ecology of the area.

Figure 6 Picture taken during interview with selected key informant from one of the neighborhoods (kebele) 05. The credit: Abebe Gosim. The photo was taken in December 2016.

3.3 Methods for Vegetation Composition

The data collection was carried out from 24 October2016 to 20 November 2016. Vegetation sampling was conducted in two vegetation areas; natural vegetation and plantation forest. Vegetation data were collected from 70 sampling quadrats (Figure 7) by using purposive sampling system along established transect line. Two line transects were laid (one in plantation and the other is in natural vegetation) at 500 m distance from each other and the distance between quadrats was 200 m starting from South to North direction. Floristic data were collected from both vegetation areas 35 quadrats each (**Appendix 3 and 4**), making the total number of quadrats 70 for this study. Each sampling quadrat had a size of 10m x 10m for trees and shrubs survey and five sub-quadrats (2m x 2m) were laid down for survey of herbaceous vegetation. The five sub-quadrats were laid in the main quadrat by placing one small quadrat at each four corners and one at center of the main quadrat (BLM, 1996).

In order avoid edge effect in plantation forest the line transects were laid down at 10m inside from edge. All the plant species in the quadrat were collected and recorded for the vegetation composition analysis and the plants outside the quadrat but inside the conserved area also recorded as present. The collected plant specimens were pressed properly and brought to the National Herbarium at, Addis Ababa University and the species were identified. The specimens were dried and identified by using authenticated specimens, consulting experts and referring to the Flora of Ethiopia and Eritrea.

Analysis

Vegetation classification: Multivariate analysis by means of hierarchical cluster analysis is very common technique. Cluster analysis used to categorize a set of observations (sampled quadrats) in to group based on their floristic similarities (Kent and Coker, 1992). Therefore for this study the data matrix contained 70 quadrats and 88 plant species were grouped using hierarchical cluster analysis with R. version 3.3.2 (Zerihun Woldu, 2012), identified four plant cluster (community) types. These communities were assigned as I, II, III and IV and they are represented by the dominant species they have. Dominant species were identified by species index value.

Importance value index (IVI): was calculated to detect the dominant or species which had high number of individuals within a community by considering abundance cover (Dufren and Legender, 1997) (**Appendix 2**). Abundance cover is defined as the proportion of an area in quadrat covered by each species. The recorded cover abundance from each species in the quadrat was changed in to modified Braun Blanquet scale values 1-9 (vander Maarel, 1979). As follows:

1. Rare, only one individual
2. Occasional, less than 5% of total cover (0.5%-1.5%)
3. Few individuals, less than 5% of total cover (1.6-2.9%)
4. Very abundant, less than 5% of total cover (3-4%)
5. 5%-12%
6. 12.5%-25%
7. 26%-50%
8. 51%-75%
9. >75%

Diversity index - Diversity index is a quantitative or mathematical measure that shows how many different types of species there are in a given area or a community, and Evenness reflects how evenly the individuals are distributed among those types of species. Species richness indicates the number of different species in the community (Kent and Coker, 1992; Krebs, 1999). Therefore; for this study Shannon-Wiener diversity index, species richness and Shannon's evenness were used to describe species diversity of the natural vegetation and the plantation forest with in conserved area. Shannon - Wiener diversity index is the most popular measure of species diversity because it accounts both for species richness and evenness, and it is not affected by sample size (Kent and Coker, 1992; Krebs, 1999). Shannon-Wiener diversity index was calculated as follows.

$\mathbf{H} = -\sum_{\mathbf{i=1}}^{\mathbf{s}} pi \ln pi$ Where,

- ✓ **H** = Shannon diversity index**,**
- ✓ **S** = the number of species**,**
- ✓ **Pi** = the proportion of individuals and
- ✓ **ln** = logbase_n

Evenness (Equitability) $\mathbf{E=H/H_{max}}$, where:

- ✓ **E**=Evenness,
- ✓ **H** =Shannon-Wiener diversity index
- ✓ $\mathbf{H_{max}}$=$\ln_s$ where s is the number of species

The higher the value of E, the more even the species is in their abundance within the community or the quadrat. Similarly, the higher the value of H, the more diverse the community or the quadrat are. Sorensen's similarity index was used to determine the pattern of species turnover among cluster communities. It is described using the following formula (Kent and Coker, 1992).

Ss = 2C/ (N+P), Where:

- ✓ **Ss** = Sorensen's similarity coefficient
- ✓ **C**= Number of species common to both areas;
- ✓ **N**= Total Number of species in natural area;

P= Total Number of species in plantation area.

The natural vegetation and plantation forest were compared in terms of their vegetation composition and species diversity. ANOVA was used to check whether there is significant difference or not between natural vegetation and plantation area in vegetation composition and diversity.

Plant individuals were categorized as Climber/Lianas, Herb, Shrub and Tree life forms.

Structural analysis: The structure of plantation forest was described by using DBH and Height. The natural vegetation did not consider in structural analysis because of no trees and shrubs more than DBH 2 cm). The DBH was measured by measuring tape (cm) and the height was measured by calibrated stick. In the planted area, the planted species are *Cuperus lustanica*and few individuals of *Eucalyptus glubulus.* Tree density was described as number of individuals per hectare. There are five classes for DBH and Height (H). For DBH (class 1= 10-15 cm, class 2= 16-20cm, class 3= 21-25 cm, class 4=26-30 cm, and class 5>30cm) and for Height (class 1=10-15m, class 2= 16-20 m, class 3=21-25 m, class 4=26-30 m, and class 5>30 m.

Figure 7 Photo taken during data collection: This type of quadrat of size 2m x 2m was laid in natural vegetation at altitude of 3426 m.a.s.l. The picture was taken by Girma Nigussie in Oct/2016.

Chapter Four

4. Result

4.1 The Land Use Land Cover

The LULC maps of the Guassa Community Conservation Area (GCCA) for three referenced years and statistical summaries of the different LULC types were presented (**Figure 8** and **Table 4**). The major LULC categories identified (**Table 2**). Five major LULC types were identified: Forest, Shrub land, grassland, Agriculture and bare land.

Over the three decades of the study, LULCC at different rates of conversion were shown in all cover types except agricultural land (because of no agricultural land in side GCCA).

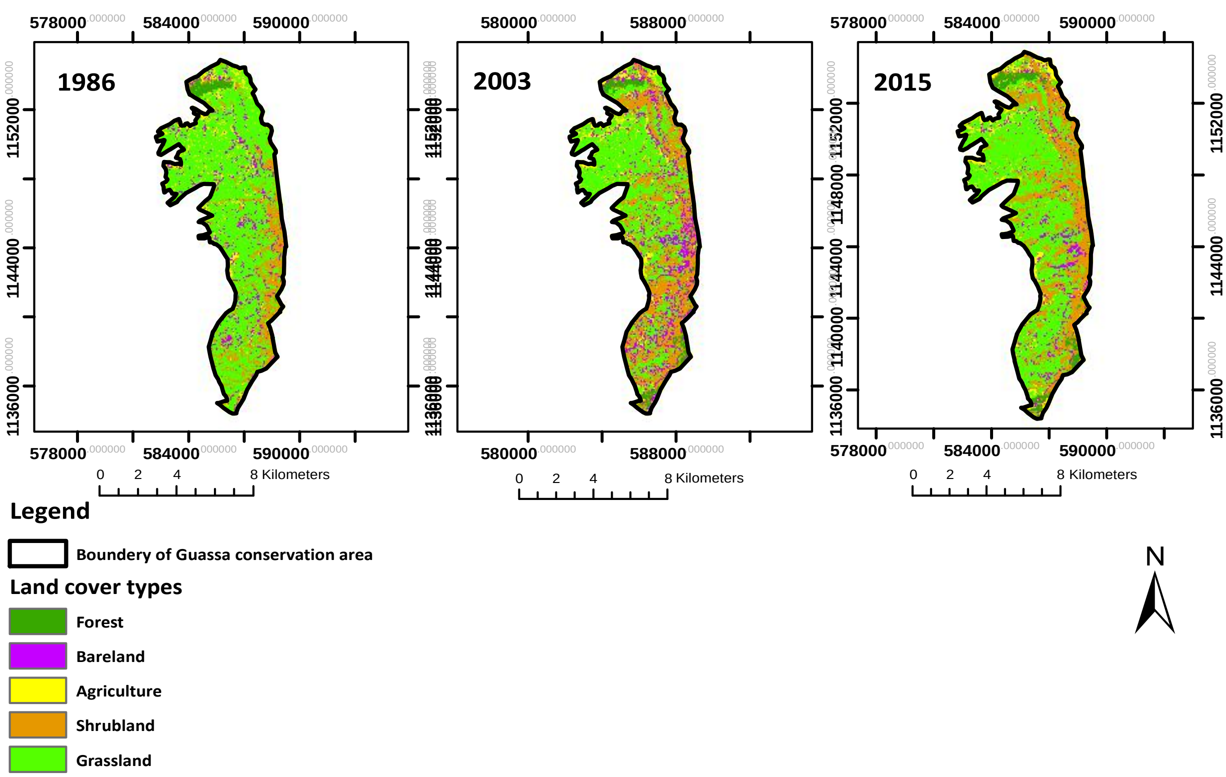

Figure 7 LULC Dynamics map from 1986-2015. The left side map shows the land cover classification in 1986 with scale 1:100,000, the middle map shows land cover classification of 2003 with scale 1:112500 and the right side map shows the 2015 land cover classification with the scale of 1:125000.

Forest: This land cover type constituted 2.12% of the total area of GCCA in 1986 and slightly increased (1.82%) from 1986 to 2003. The forest cover increased from 3.94% in 2003 to 4.3% in 2015.

Bare land: The result showed that bare land increased over the years. It was 8.98% of the total GCCA in 1986 and increased to 14.47% in 2003. From 2003-2015, the bare land decreased significantly, from 14.47% to 6.9%.

Agriculture: The area of agricultural land at the border GCCA in 1986 was 517.4ha (7.2%), and it decreased to 495.09ha (6.9%) in2003.

Shrub land: This LU/LC category covered a total area of 547.9 ha (7.67%) in 1986. It then increased to 2194.47 ha (30.72%) in 2003. From 2003 to 2015 there was very slightly decreasing pattern (**Table 4** and **Figure 9**).

Grass land: The total area of this land was5285.8 ha (73.98%) in 1986. It decreased in to 3135.96 ha (43.89%) in 2003.It increased to 51.77% (3699 ha) in 2015.

Table 4 the area of Land use class in the study site (1986-2015)

Land class	**1986**		**2003**		**2015**		**1986-2015**
	Area(ha)	**%**	**Area(ha)**	**%**	**Area(ha)**	**%**	**Total loss/gain(ha)**
Forest	151.6	2.12	281.7	3.94	306.5	4.3	154.9
Bare land	641.9	8.98	1033.72	14.47	493.1	6.9	-148.81
Agriculture	517.4	7.2	495.09	6.93	540.8	7.57	23.4
Shrub land	547.9	7.67	2194.47	30.72	2105	29.5	1558.1
Grass land	5285.8	73.98	3135.96	43.89	3699	51.77	-1586.8
Total	**7144.6**	**100**	**7144.38**	**100**	**7144.4**	**100**	

(Note: The (Table 4) showed the area coverage of different land cover in different years. The last column showed a total gain or loss in three referenced years (1986-2015). Hence the positive values indicate gain and the negative values indicate total loss of land cover. For example; the grass land has 154.9 ha of total gain and the bare land has 148.81 ha of total loss within 30 years.)

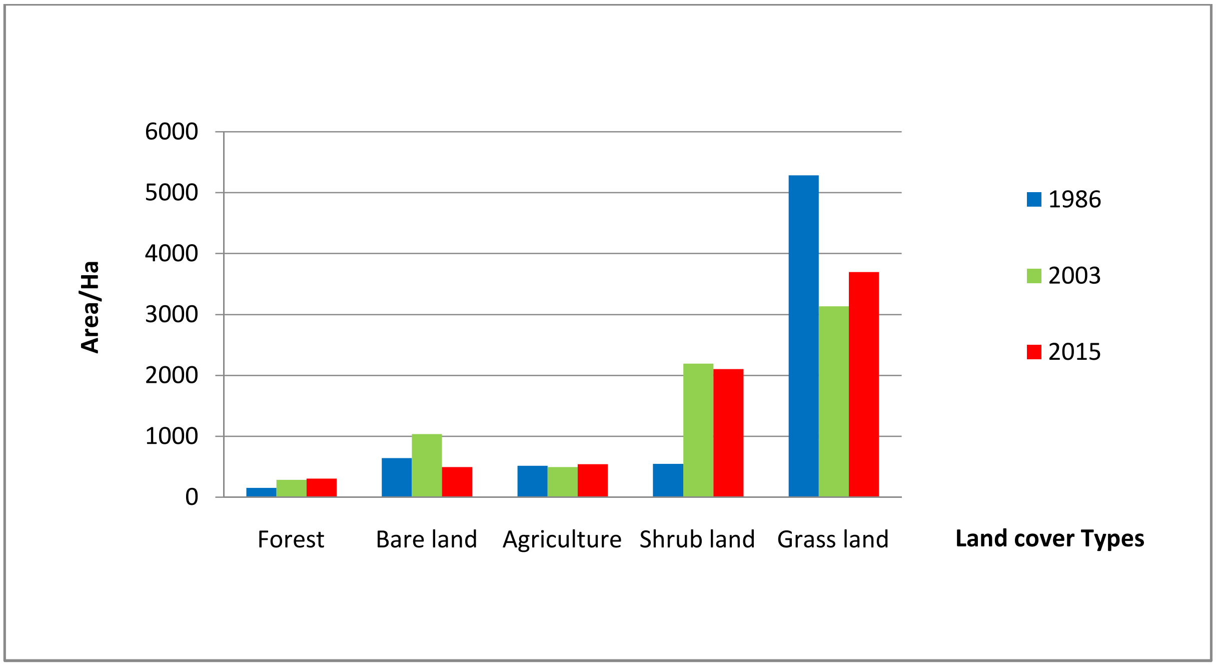

Figure 8 Area of land use class in the three study decades

4.1.1 Accuracy assessment

In (**Table 5**)**,** the bold diagonal numbers refers to the target full points. That means out of 30 random points taken from each land cover type, the indicated number at diagonal are correct. And the other numbers refers to confused points (clashed land cover type). The reason why confusion occurring between different cover types may be because of error trained during supervised classification. Therefore the percent of accuracy assessment in this study is 90.67%.

Table 5 Confusion matrix of accuracy assessment (A year, 2015)

	Forest	Bare land	Agriculture	Shrub land	Grassland
Forest	**28**	0	0	1	1
Bare land	0	**26**	1	2	1
Agriculture	1	0	**26**	2	1
Shrub land	0	0	0	**29**	1
Grassland	0	0	0	3	**27**
Accuracy : 0.9067; Kappa : 0.8833					

4.1.2 Socio-economic activities of the community around the conservation area

The livelihood of the people around the GCCA is mainly dependent on agricultural crops and livestock production. The major crops produced by the community are barley, wheat, sorghum, lentil and bean, while their livestock are comprised on cattle, sheep, equine and goats. Majority of respondents (97%) in our survey stated that they have scarcity of cropland with an ownership of less than one hectare. Therefore, demand for cropland is increasing as a result of increasing human population and lack of alternative employment opportunities. Another challenge faced by the community is declining productivity of their cropland, the main reason for this being nutrient depletion due to the lack of crop rotation.

4.1.3 The importance of conserved area for the community

Guassa grass (*Festuca* species) is very important for the people of the area. The local people state that the area is under conservation for major purpose of growing this grass. This is because the grass is used for multiple purposes from construction materials to cattle feed stock. They harvest the grass legally every two or five years based on the growth rate of the grass. According to the respondents, Guassa grass is their life. Without this grass their life may be impossible. One respondent said that "*Guassa is my shelter (I construct my house from Guassa grass), my food and my cloth (I sell the grass and buy a food and cloth), generally I can say it is my life. Without it I do not think to exist*". They sell the grass with 600 birr/shekim by bringing to the nearest city Mehal Meda (29 km from Guassa) or Meleya (31 km) from GCCA. (Note: "shekim" is local measurement of the grass, which equivalent to 35-40 kg). Another respondent said that "*I consider Guassa area as my mother; because Guassa gives me what I want, like mother gives what* *her child wants"*. In addition to Guassa grass, the people also use 'Asta' (*Erica arborea*) for firewood and charcoal production. Additional but seldom income might be generated from tourists and researchers. There are nine kebeles that use the resource of Guassa conserved area.

For the local people conservation of the area is very important and any threat to *Festuca* grass and Asta population is considered a serious threat to their livelihood. For instance, expansion of *Helichrysum* species considered a conservation threat in the area.

Generally, the conserved area has the following advantages orderly for the community

1. Source of construction materials (Guassa grass);
2. It is main source of drinking water for people and animals;
3. Source of firewood;
4. Source of income (from tourists) and
5. Cut and carry system for livestock fodder

The followings are some disadvantages of the conserved area

- Ethiopian wolf and African wolf are eating their sheep;
- Local crops were eaten by gelada monkey and
- A herb they called Nachillo (*Helichrysum splendidum)* was anti for economic valuable Guassa grass (this Nachillo herb is considered as invasive species for the area and competes with the highly valued grass *Festuca macrophylla*)

4.1.4 Causes of land cover changes in GCCA

According to the local community, the major cause for LULCC is the management system of the conserved area. When the management system was effective, the conserved area is covered by shrubs and herbs. When it was not effective, the conserved area was over grazed; the shrubs were cut down for firewood and charcoal production. Hence the LULCC is driven by over grazing and cutting shrubs for firewood and charcoal production. The management system should be improved to have good conserved area. This result is more or less similar with other works. Even though, they found population growth and expansion of agriculture as main causes, but they also indicated other causes like ineffective management of land, over grazing and cutting trees and shrubs for fuel wood (Amare Sewnet, 2013; and Mengistie Kindu *et al.,* 2015).

4.2 Floristic Composition of the conserved area

A Total of 88 plant species which belong to 64 genera and 33 plant families were recorded from the GCCA in the 70 quadrats. From 88 species, 86 species were recorded within the sampling quadrat and two species were recorded outside of sampling quadrat but inside the conserved area. From the total species, ten (11.4%) were shrubs, 73(83%) were herbs including grasses, ferns and sedges, four (4.5%) were trees; one (1.1%) was climber (Appendix 1).

Of the 33 plant families, Asteraceae had the highest number of species (31), followed by Poaceae with nine species, Rosaceae, Cyperaceae and Polygonaceae represented by four species each. Of these, 59.1% of total species recorded from the area were included under these five families. And there are 15 plant families which were represented by only one species each (**Table 7**).

At genus level the *Helichrysum* (Asteraceae) accounted the highest which contained five species and the second were Festuca (Poaceae) and *Conyza (*Asteraceae*)* with four species each.

4.2.1 Endemism

There are 18 species in the conservation area, which are endemic to Ethiopia (**Table 8**). These are *Alopecurus baptarrhenius, Bidens pachyloma, cineraria abyssinica, Cirsium dender, Cirsium* schimperi, *Conyza flabellate, Euryops pinifolius, Festuca macrophylla, Hypericum peplidifolium, Inula confertiflora, Kniphofia foliosa, Lobelia rhynchopetalum, Phagnalon abyssinicum, Plectocephalus varians, Senecio ochrocarpus, Solanum marginatum, Thymus schimperi* and*Urtica simensis,* whichaccount 20.5% of total species.

From 18 endemic species two species are listed in the IUCN RED lists as vulnerable and threatened conservation status. These are *Euryops pinifolius* as vulnerable and *Inula confertiflora* as near threatened.

Table 6 List of plant families with their number of genera and species

No.	Family	Genera	Species	(%)
1	Asteraceae	18	31	35.2
2	Poaceae	6	9	10.2
3	Cyperaceae	2	4	4.5
4	Polygonaceae	3	4	4.4
5	Rosaceae	3	4	4.5
6	Crassulaceae	2	2	2.3
7	Cupressaceae	2	2	2.3
8	Boraginaceae	1	2	2.3
9	Dipsacaceae	2	2	2.3

10	Ericacae	1	2	2.3
11	Scrophulariaceae	3	3	3.4
12	Guttiferae	1	2	2.3
13	Plantaginaceae	1	2	2.3
14	Lamiaceae	2	2	2.3
15	Caryophyllaceae	2	2	2.3
16	Others	15	15	17.0
Total		**64**	**88**	**100**

Table 7 list of endemic plant species found in GCCA

Family	**Genera**	**Species**
Asteraceae	9	10
Poaceae	2	2
Asphodelaceae	1	1
Guttiferae	1	1
Lobeliaceae	1	1
Solanaceae	1	1
Lamiaceae	1	1
Urticaceae	1	1
Total	**10**	**18**

There are four types of life forms in the GCCA area. The proportion of life forms in the area (Figure 11).

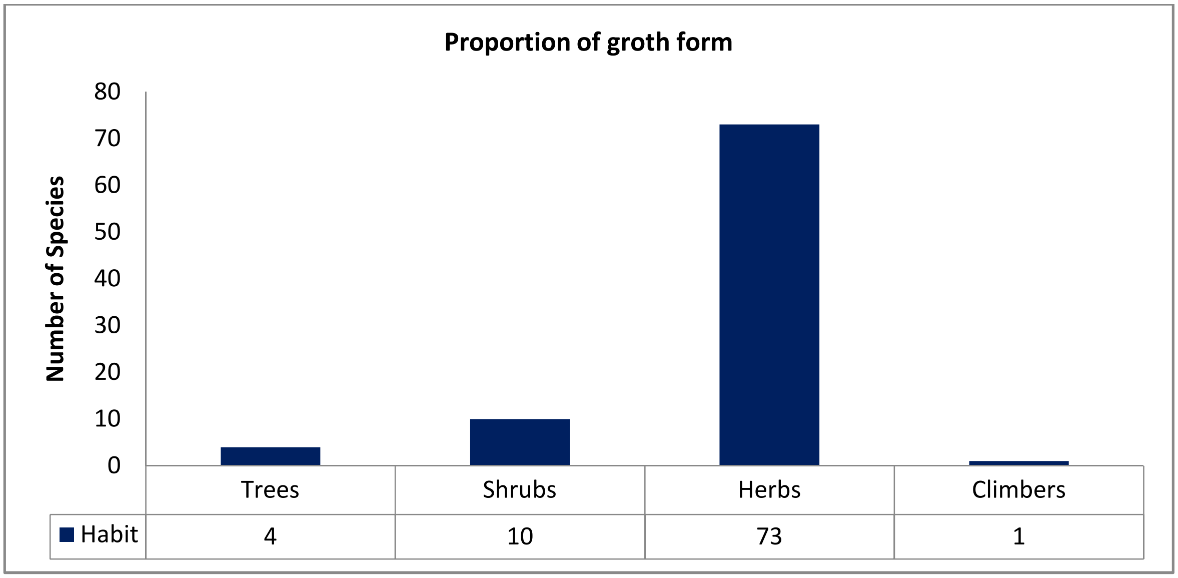

Figure 9 Classification of plant species based on growth habit or form in GCCA

4.2.2 Vegetation Classification

Hierarchical cluster analysis produced four clusters or plant community types. Figures 7 below presents these clusters, designated by roman numbers (I-IV), and descriptions of the community types are given by the dominant species in each clusters and thus the communities named accordingly.

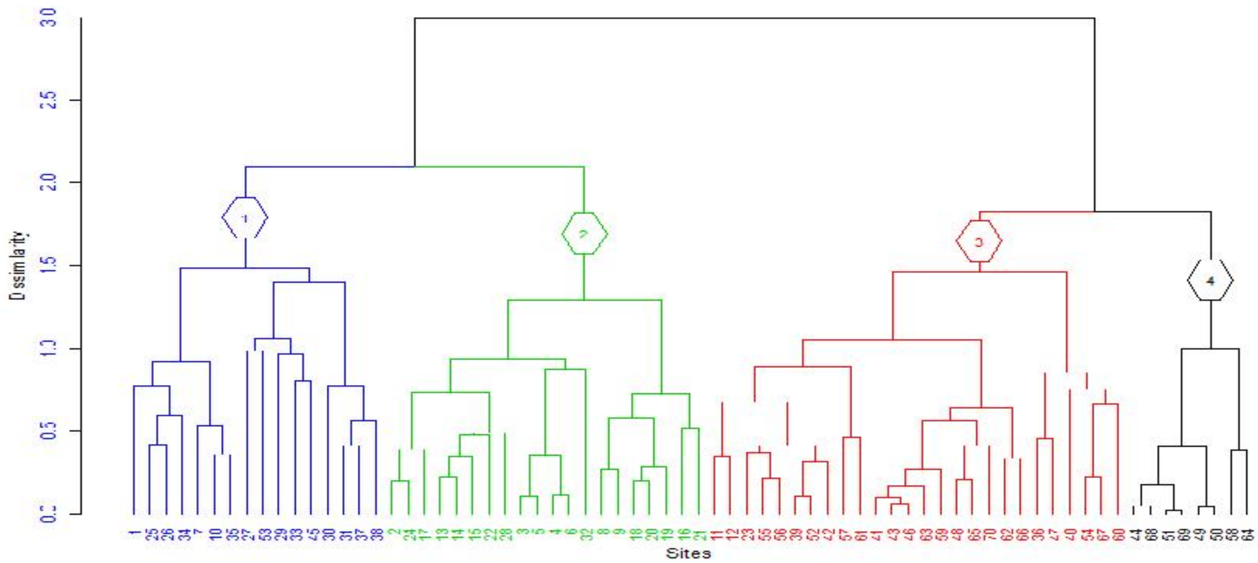

Figure 10 Dendrogram showing the vegetation of GCCA. The dendrogram is produced by Hierarchical cluster analysis using R software version 3.3.2

The quadrats included in each cluster are listed in (**Table 9**) due to may not clearly seen in dendrogram (**Figure 11**).

Table 8 Quadrats included in each cluster

Community	Quadrats	Total
I	1, 7, 10, 25, 26, 27,29,30,31,33,34, 35,37,38,45,53	16
II	2, 3, 4, 5, 6, 8, 9, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 28, 32	20
III	11, 12, 23, 36, 39, 40, 41, 42, 43, 46, 47, 48, 52, 54, 55, 56, 57, 59, 60, 61, 62, 63, 65, 66, 67,70	26
IV	44, 49, 50, 51, 58, 64, 68, 69	8

4.2.3 Species importance value index

A species which had high importance value index is dominant species in the community. The bold numbers in the (**Table 10**) indicate to represent the community types.

Table 9 Importance value of species in each cluster

Species	Communities			
	I	II	III	IV
Euryops pinifolius	**12**	4.8	1.77	0.88
Helichrysum splendidum	**6.5**	14.3	1.31	0
Festuca macrophylla	2.56	**29.5**	4.08	0
Thymus schimperi	3.31	**26.6**	8.81	5
Erica arborea	1.38	7.45	**4.27**	1.38
Kniphofia foliosa	5.25	2.35	**8.85**	2.12
Alchemilla abyssinica	9.94	15.05	52.23	**178**
Andropogon abyssinicus	0.31	3.5	3.96	**27.75**

4.2.3.1 Euryops pinifolius - Helichrysum splendidum Community type (I)

This community was composed of 16 quadrats and 50 species. The community is distributed between the altitudinal ranges of 3399 - 3548 m.a.s.l. This community had six indicator species (*Euryops pinifolius, Helichrysum splendidum, Alchemilla abyssinica, Kniphofia foliosa, Veronica glandulosa, Festuca macrophylla)*.

4.2.3.2 Festuca macrophylla - Thymus schimperi Community type (II)

This community type is composed of 20 qaudrat and 65 species. And it has six indicator (dominant) species (*Festuca macrophylla, Thymus schimperi, Helichrysum splendidum, Festuca richardii, Alchemilla abyssinica, Erica arborea).* Most of these dominant species are herbs and the altitudinal range of this community type is between 3355m-3536 m.a.s.l.

4.2.3.3 Erica arborea - Kniphofia foliosa **Community type (III)**

This community type is composed of 26 plots and 50 species. The indicator species of this community type are (*Alchemilla abyssinica, Festuca abyssinica, Thymus schimperi, Andropogon abyssinicus, Erica arborea, Kniphofia foliosa).* The altitudinal range is between 3355m-3527 m a.s.l.

4.2.3.4 Alchemilla abyssinica - Andropogon abyssinicus **Community type (IV)**

This community type was distributed at altitudinal range between 3330 m - 3342 m.a.s.l. The community was composed of eight quadrats and 30 species. The indicator species of this community were (*Alchemilla abyssinica, Andropogon abyssinicus, Veronica glandulosa* and *Festuca abyssinica).*

4.2.4 Sorensen's Similarity

Community type I and III had relatively the highest coefficient value, therefore these community types were similar. Community type II and IV had the lowest coefficient value and these communities were dissimilar (**Table 11**).

Table 10 Sorensen's Similarity coefficient of the six community types

	C-I	**C-II**	**C-III**	**C-IV**
C-I	1			
C-II	0.63	1		
C-III	0.68	0.61	1	
C-IV	0.61	0.47	0.67	1

4.2.5 Comparison in species Diversity, Richness and Evenness of Natural and plantation area

There were 78 species recorded from natural vegetation area (35 quadrats). Of these 78 species, 38 (43.2% of total species) were recorded exclusively in the natural area. There were 50 species recorded from plantation area (35 quadrats. Of these 50 species, 10 (11.4% of total species) were found only in the plantation area and the remaining 40 species found on both plantation and the natural vegetation. Therefore; the total species in the conserved area were 78 + 50 - 40 = 88 species or 38 +10 + 40 = 88 (Figure 9). Of the 18 endemic species, five were from natural area, four were from plantation area, and nine were found in common. The natural area had mean species richness of 12 species per quadrat. The highest was 18 species per quadrat and the lowest was six species per quadrat. On the other hand, in the plantation area mean species richness per quadrat was 11 with 19 and 3 the highest and the lowest per quadrat respectively. Natural area was represented by community type Two and plantation area was represented by community type four.

The natural area (community type two) had higher diversity index which had average 3.08 index value and 0.79 evenness value than plantation area (community type four) which had 1.31 and 0.39 average index value and evenness value respectively (**Table 12**).

Table 11 Shanon weiner diversity index

Community	Richness	H	Simpson	Shannon_Evenness	Simpson_Evenness
I	50	3.08	15.10	0.79	0.30
II	65	2.73	9.38	0.65	0.14
III	50	2.65	6.07	0.68	0.12
IV	30	1.31	1.94	0.39	0.06

Community two had the highest species richness (65) with 2.73 of diversity index. Community four had the least richness (30) with diversity index 1.31.

Even though, there is slight difference between natural and plantation area in their species composition and diversity, it is not significant (**Table 13**).

Table 12 comparison between natural area and plantation area in Species composition

Species composition of Natural area and Plantation area	Df	Sum Sq	Mean Sq	F value	Pr(>F)
	1	45	45.48	0.257	0.613

The P-value of species composition is 0.6 which is greater than alpha-value (0.05) that means the vegetation composition of natural area and plantation area is not significantly different.

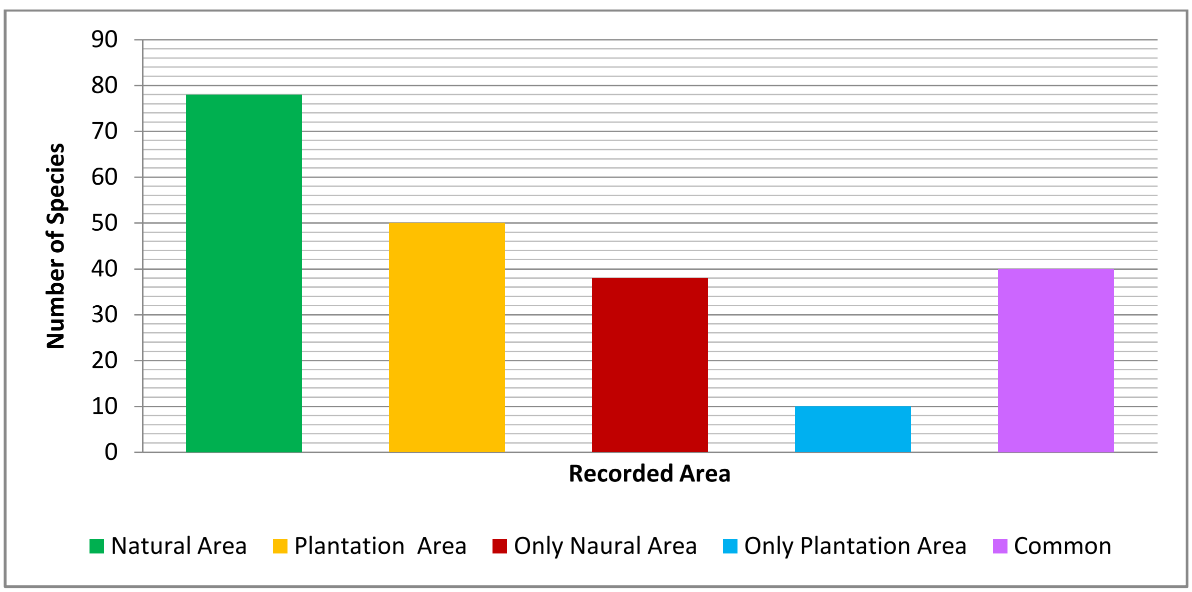

Figure 11 Number of species recorded in natural vegetation and plantation site

4.2.6 Structure and tree density of plantation area

In DBH, the highest number of individuals/ha was recorded in DBH class three (i.e, 21 cm up to 25 cm) which is 188 trees/ha whereas in Height, the highest number of individuals/ha was in height class two (i.e, 16-20 cm) which is 311 trees/ha (**Table 14 and Figure14**).

Table 13 number of individuals/ha

Class	**DBH**	**Height**
	Number of individuals/ha	Number of individuals/ha
1	10	54
2	54	311
3	188	157
4	114	10
5	165	0

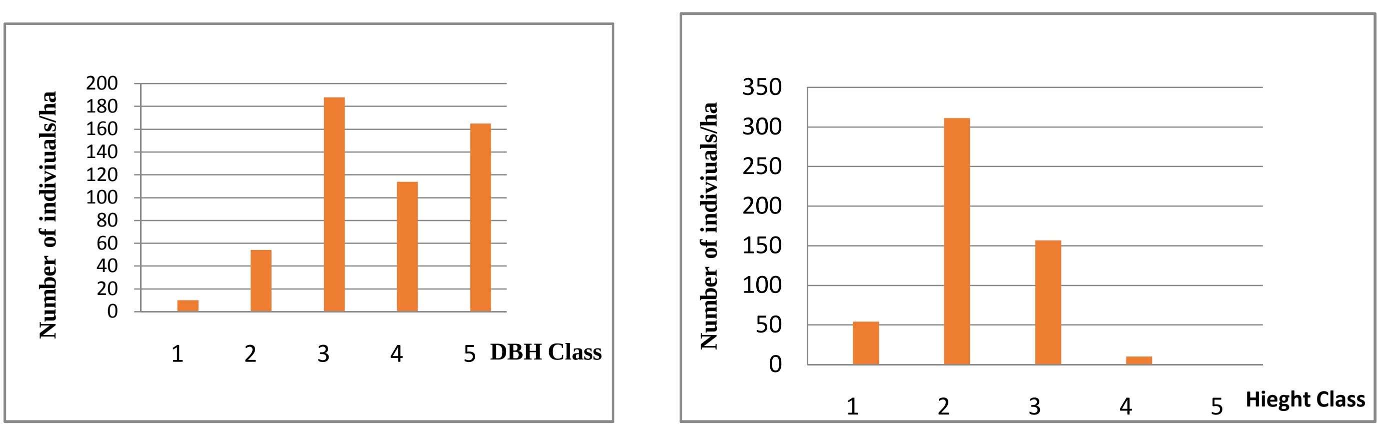

Figure 12 DBH class and Height class

Chapter Five

5. Discussion, Conclusion and Recommendation

5.1 Discussion

5.1.1 The land use and land cover change

The results of land cover and land use change in this study identified five categories of land cover/use types. These are forest; bare land; agricultural land; shrub land and grassland.

Forest as defined by FAO (1997) includes natural forests and forest plantations. It is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. In the study area only plantation forest is found since it is an afroalpine ecosystem. According to Hedberg (1964), Afroalpine belt is characterized by five distinctive life forms: giant rosette plant, tussock grasses, and cushion plants and sclerophyllous shrubs. Therefore, natural forest cannot be formed under the prevailing climatic conditions of the afroalpine belt. However, there exists plantation forest in GCCA planted during the Military Government (Derg regime) in 1985. The result of our LULCC study indicated that the land under plantation forest has slightly increased overtime (1986-2015). Since there was no reported active tree plantation since 1985, the increase in plantation forest cover detected in this study might be related to the following primary reason. Plant growth under afroalpine belt is retarded due to unfavorable climatic and soil conditions, therefore, tree planted in this area grew slowly overtime and thus were missed from satellite image detection during the earlier stage of the study.

Similarly, some studies for instance by Nurelegn Mekuriaw and Amare Sewnet (2014) at Ribb watershed in Amhara Regional state showed decreasing pattern of forest cover overtime. The watershed had lost 57.42% of its forest cover, perhaps because of deforestation and forest land changes in to other land use types (Nurelegn Mekuriaw *et al*., 2014). Their study was conducted for the years 1973, 1987, 1995 and 2011 and over this period of time forest cover decreased. In any scenario, reported timeline decrease of forest cover is not a unique phenomenon to our study area.

Bare land; In this study includes lands with no vegetation that are rocky and have no visible uses**.** This land cover category in GCCA also showed a slight increase between 1986 and 2003. This increase could be related to over grazing and digging roots of *Erica arborea* for the purpose of charcoal production. The observed slight increase in bare land in the study area happened during the earlier stage of study timeline where the traditional management system practiced in the area was weakened as a result of ensued political turmoil during the fall of Derg Regime.

In the later stages, between 2003 and 2015 the bare land cover decreased due to improvement of management system and subsequent ecological succession that happened due to reduction of human interference in the area. Reduction of human interference perhaps because of improved management system or area enclosure create a conducive condition for natural succession to happen thus decreasing bare land cover. Similar results are reported elsewhere in Ethiopia such as the results of Netsanet Demeke (2007) who studied at Harenna forest and surrounding area in Oromia regional state.

Agricultural Land; Showed a decreasing trend from 1986 to 2003. Based on the interviews, during the Derg regime and especially at the transition of government from Derg to EPDRF, farmers who had land at the border of conserved area expanded their farmland in to the conserved area. When the EPDRF government was established and the management system of GCCA was restored, then the farmers were forced to stop ploughing the land inside GCCA. Therefore, leading to reduction in land cover/use type under agriculture, also in other parts of the country, some studies reported decrease in land under agriculture due to improvement of management systems. For instance study by Minale Wondie *et al.* (2011) in Simen Mountain National Park and by Netsanet Demeke (2007) in Harenna forest reported related results.

From2003 to 2015, the land under agriculture increased in GCCA. This could be related to an increasing demand for agricultural land due to market opportunities created because of road infrastructure development during this study period. These results concur with results of Amare Sewnet (2013) reported from Gilgel Abay watershed and Nurelegn Mekuriaw and Amare Sewnet (2014) reported for Ribb watershed in Ethiopia.

Shrub land; This land cover type showed increased from 1986 to 2003. During this period agricultural activity was prohibited in the area and grasslands were converted into shrub land possibly by natural succession. During this period, especially around 1995, the area was strongly protected from expansion of agriculture and collecting fire wood from shrubs thus facilitating natural succession of grassland into shrub land. Between 2003 and 2015, the shrub land showed a slight decrease from 30.72% in 2003 to 29.5% in 2015 meaning there is no change in shrub land cover during this period (2003-2015). This result contradicts with the finding of Netsanet Demeke (2007) from Harenna forest and Worku *et al*., (2014) from Ameleke watershed in Ethiopia.

Grass land; This land cover category was encompasses lands covered by grasses and herbaceous species. This land cover type decreased between 1986 and 2003 may be due to over grazing that converted the grasslands into bare land and because of ineffective management system during this period. The grassland cover increased from 2003 to 2015 perhaps because over grazing reduced. But also there were illegal harvesting of woody shrubs of *Erica arborea* for firewood and charcoal production from in the conserved area during this time. This activity might aid grasses in their competition against shrubs which were selectively cut down by humans. This study agreed with other similar findings in Ethiopia such as Minale Wondie *et al.* (2011), Amare Sewnet (2013), and Worku *et al*. (2014). While other studies reported the opposite of our findings, for instance study by Nurelegn Mekuriaw and Amare Sewnet (2014) in Ribb watershed showed.

5.1.2 Floristic composition and community types

According to the result of this research, the conserved area had a total of 88 plant species, grouped under 64 genera and 33 families. Similar study in this area was conducted by Habtamu Wodaje *et al*, (2016) recorded 82 plant species, 62 genera and 27 families. This difference may be due to the amount of area covered during data sampling or time of data collection.

The richness of herbs in GCCA is 12 species per quadrat. However, it is very poor in regard to the diversity of shrubs. There is only one dominant shrub species in the area, *Erica arborea*. This is because of the nature of the environment; normally the afoalpine vegetation is dominated by herbs. The conserved area is characterized by its Afroalpine vegetation type, and some of the trees found are the planted during the previous regime (the Derg regime).

Among the four community types identified in this study Community type I and Community type III are similar (**Table 11**). This is because these community types were represented from both natural vegetation and plantation area. That means the quadrats in community type I and III were from both natural area and plantation area. The most dissimilar communities were Community type II and Community Type IV. This was due to community II was represented completely only natural area and community IV was completely only plantation area.

Community two was mostly represented by the natural vegetation (**Appendix 3**) and community four represented by the plantations (**Appendix 4**). The study showed presence of highest species diversity in the natural area than the plantation area. The plantation area was lower in species diversity possibly due to the shading effect and low ability of native herbs to compete with planted trees for nutrients (**Table 12**).

Startling the result of this study was similar in species composition between that natural vegetation and plantation forest. There is no significant difference among them (**Table 13**). This is may be due to sparse distribution of the trees in the plantation area, which enabled the growth of herbaceous and typically afro alpine vegetation types under the plantation forest.

Similarly, the structure and tree density of plantation area is monotonous. The number of individuals is concentrated in only two or three class density classes and they not proportionally distributed among all five classes. Height class distribution is concentrated in class two and class three (**Table 14**), because the trees were planted almost at the same season and they have the same age.

The GCCA has high endemicity with the 18 (20%) of the total number species recorded from the area are endemic to Ethiopia. This makes the area among areas of high endemicity in Ethiopia. Also our results showed that two species *(Euryops pinifolius* and *Inula confertiflora)* needs implementation of conservation measures, because they are listed under IUCN Red lists of Ethiopian endemic species. Study Habtamu Wodaje *et al*. (2016) recorded 11 endemic species to Ethiopia from the same area and the present study expanded the list to 18. This actually shows that repeated floristic composition of a given area might be necessary in order to capture the full flora of a given area.

5.2 Conclusion

The land use land cover change of GCCA is mainly depends on the management system of the area. The classified categories were shown different changes in different regimes that governed the country; therefore the policy of government could affect the land use land cover change. To meet the objective of the study remote sensing and GIS techniques were basic tools used in this study. Remotely sensed data for 1986, 2003 and 2015 were used to analyze land use/land cover of the study area. The LULC change during thirty years was evaluated from three Landsat satellite images. Therefore, the extent and trend of Land Use/ Land Cover changes was showed. In order to understand the possible causes of land use/land cover changes of the conserved area, the socio-economic situation and the management system of the conserved area were very important factors. It was found that LULCC mainly happened on grass land and shrub land. Household survey in this study indicated that the local people assume the main cause of land cover change to be over grazing and fire wood collection from conserved area. This implies that the driving force for LULC change in GCCA is driven primarily by human activities in conserved area. Therefore, the management system of the conserved area plays very important role in LULCC.

There is no difference between natural vegetation and plantation area in species composition. Plantation did not affect the species composition of the area. The study was completed with documentation of 88 plant species grouped under 64 genera and 33 families. Asteraceae was found to be the most dominant families followed by Poaceae, Rosaceae, Cyperaceae and Polygonaceae. The other 15 families had also contribution to the overall species composition of the conserved area by representing one species each.

Of the total species recorded, 18 were endemic to Ethiopia. Of these 18 endemic species, three species are listed in the IUCN Red list. This implies that, the conserved area is rich in endemic plants and it needs high priority for conservation. There are 78 species which recorded from natural vegetation area. Of these 78 species 38 were recorded from only natural area. On the other hand, 50 species were recorded from plantation area. Of these 50 species, 10 species were recorded from only plantation area. There are 40 species which present on both plantation area and natural area. The natural area had relatively higher diversity index value and evenness value than plantation area.

5.3 Recommendation

The Guassa community conservation area is not only rich in endemic plant species and other studies also indicated that the area is rich in endemic animals and birds. The area is becoming a famous destination for tourists. However, the GCCA is also faced with a number of anthropogenic and natural. Therefore, to sustain the conserved area, the following recommendations are forwarded.

- During the course of this study, we have observed that the local communities are seriously concerned with the presumable expansion of *Helichrysum spp.* This species assumed to compete with the most important resource for the people of the area, *Festuca spp.* A further research that will look at the environmental or anthropogenic factors that favor *Helichrysum spp*. need to be a priority.
- In line with the above, development of a technology or a mechanism that help remove species such as Nachillo (*Helichrysum splendidum*) will go a long way to address the concern of the community.
- Further study should be conducted on the market value chain and economic importance of Guassa grass (*Festuca macrophylla)*. Because this grass is very valued and marketable grass in the area.
- There is wood electric pole planted along the conserved area to supply electricity for Mehal Meda town. The buried part of pole decomposed and falls down on the grassland causing fire disaster in the area. This happened during the course of our study period (**Figure 16**). Therefore, simple recommendation will be to change the wooden electric poles to concert made hollow poles widely used these days in Ethiopia.

Figure 15 Fire disaster caused by electric pole fall in GCCA. The fire was stopped by the effort of local communities and Menz-Gera werda administration staffs. The photo was captured by Girma Nigussie in Oct/2016.

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Appendices

Appendix 1 Scientific and local name of Plant species recorded from Guassa conserved area

No	Local name	Sci. Name	Family	genus	Habit
1	Yefyel dabo	*Aeonium leucoblepharum* A. Rich	Crassulaceae	*Aeonium*	H
2	Midir koso	*Alchemilla abyssinica* Fresen.	Rosaceae	*Alchemilla*	H
3	Dihanet	*Alchemilla ellenbecki* Engl.	Rosaceae	*Alchemilla*	H
4	Unknown	*Alopecurus baptarrhenius* S.M. Phillips	Poaceae	*Alopecurus*	H
5	gaya sar	*Andropogon abyssinicus* Fresen.	Poaceae	*Andropogon*	H
6	unknown	*Anthemis tigreensis*J.Gray ex A. Rich	Asteraceae	*Anthemis*	H
7	Yayt misir	*Argyrolobium ramosissimum* Bak.	Fabaceae	*Argyrolobium*	H
8	Chqugn	*Artemisia abyssinica* Sch.Bip. ex A. Rich.	Asteraceae	*Artemisia*	H
9	Adey abeba	*Bidens pachyloma* (Oliv. & Hiern) Cufod.	Asteraceae	*Bidens*	H
10	unknown	*Calamagrostis epigejos L.*	Poaceae	*Calamagrostis*	H
11	yahya koshele	*Carduus schimperi* Sch. Bip. ex A. Rich.	Asteraceae	*Carduus*	H
12	Koshele	*Carduus nyassanus* (S. Moore) R.E. Fries	Asteraceae	*Carduus*	H
13	dirf	*Carex monostachya* A. Rich	Cyperaceae	*Carex*	H
14	unknown	*Cineraria abyssinica* Sch. Bip. ex A. Rich	Asteraceae	*cineraria*	H
15	koshele	*Cirsium dender* Friis	Asteraceae	*Cirsium*	H
16	koshele	*Cirsiumschimperi* (Vatke) C. Jeffrey ex Cufod.	Asteraceae	*Cirsium*	H
17	ye azo hareg	*Clematis simensis* Fresen.	Ranunculaceae	*Clematis*	C
18	Qersheshnbo	*Conium maculatum L.*	Apiaceae	*Conium*	H
19	ye bere bakilo	*Conyza flabellate* Mesfin.	Asteraceae	*Conyza*	H
20	unknown	*Conyza hypoleuca* A. Rich	Asteraceae	*Conyza*	S
21	unknown	*Conyza pyrrhoappa* Sch. Bip. ex A. Rich.	Asteraceae	*Conyza*	H
22	unknown	*Conyza stricta* willd.	Asteraceae	*Conyza*	H
23	unknown	*Crassula alba* Forssk.	Crassulaceae	*Crassula*	H
24	unknown	*Crepis carbonaria* Sch. Bip.	Asteraceae	*Crepis*	H
25	yebeg wetet	*Crepis rueppellii* Sch. Bip.	Asteraceae	*Crepis*	H
26	yegib shinkurt	*Crinum abyssinicum* Hochst ex A. Rich.	Amaryllidaceae	Crinum	H
27	yefernj tid	*Cupressus lusitanica* Mill.	Cupressaceae	*Cupressus*	T
28	godelo	*Cynoglossum amplifolium Hochst. ex A.DC. in DC.*	Boraginaceae	*Cynoglossum*	H
29	chigogot	*Cynoglossum coeruleum Hochst. ex A. DC.*	Boraginaceae	*Cynoglossum*	H
30	ketema	*Cyperus elegantulus* Steud.	Cyperaceae	*Cyperus*	H

31	engcha	*Cyperus longus* L.	Cyperaceae	Cyperus	H
32	engcha	*Cyperus rigidifolius* Steud.	Cyperaceae	*Cyperus*	H
33	ye ayt kibe	*Dicrocephala chrysanthemifolia* (Bl.) DC.	Asteraceae	*Dicrocephala*	H
34	akrari	*Dipsacus pinnatifidus* Steud. ex A. Rich.	Dipsacaceae	*Dipsacus*	H
35	enseferis	*Dryopteris athamantica* (Kunze)	Dryopteridaceae	*Dryopteris*	F
36	unknown	*Epilobium stereophyllum* Fresen.	Onagraceae	*Epilobium*	H
37	Asta	*Erica arborea* L.	*Ericacae*	*Erica*	S
38	unknown	*Erica tenuipilosa* Eng. ex Alm Fries.	*Ericacae*	*Erica*	S
39	nech bahr zaf	*Eucalyptus globules* Labill.	Myrtaceae	*Eucalyptus*	T
40	cherenfe	*Euryops pinifolius* A. Rich.	Asteraceae	*Euryops*	H
41	Muasel sar	*Festuca abyssinica* Hochst. ex A. Rich.	Poaceae	Festuca	H
42	guassa	*Festuca macrophylla* Hochst. ex A. Rich.	Poaceae	*Festuca*	H
43	geber guassa	*Festuca richardii* Alexeev.	Poaceae	*Festuca*	H
44	unknown	*Festuca simensis* Hochst. ex A. Rich.	Poaceae	*Festuca*	H
45	Ashkit	*Galium simense* Fresen.	Rubiaceae	*Galium*	H
46	Koso	*Hagenia abyssinica* (Bruce) J.F. Gmelin.	Rosaceae	*Hagenia*	T
47	Gudign	*Haplocarpha rueppelii* (Sch. Bip) Beauv.	Asteraceae	*Haplocarpha*	H
48	Getin	*Haplocarpha schimperi* (Sch. Bip) Beauv.	Asteraceae	*Haplocarpha*	H
49	unknown	*Hebenstretia angolensis* Rolfe.	Scrophulariaceae	*Hebenstretia*	H
50	unknown	*Helichrysum arenarium* (L.) Moench.	Asteraceae	*Helichrysum*	H
51	unknown	*Helichrysum formosissimum* Sch. Bip. ex A. Rich.	Asteraceae	*Helichrysum*	H
52	Nachilo	*Helichrysum forsskahlii* (J.F.) Gmel.	Asteraceae	*Helichrysum*	H
53	Nachlo	*Helichrysum splendidum (*Thunb.) Less.	Asteraceae	*Helichrysum*	H
54	unknown	*Helichrysum stenopterum* DC.	Asteraceae	*Helichrysum*	H
55	unknown	*Hyparrhenia dregeana* (Nees) Stent.	Poaceae	*Hyparrhenia*	H
56	unknown	*Hypericum peplidifolium* A. Rich.	Guttiferae	*Hypericum*	H
57	Ameja	*Hypericum revolutum* Vahl.	Guttiferae	*Hypericum*	S
58	Eja/wenagft	*Inula confertiflora* A. Rich.	Asteraceae	*Inula*	S
59	Yabesha tid	*Juniperus procera* Hochst. ex Endl.	Cupressaceae	*Juniperus*	T
60	Abelbila	*Kniphofia foliosa* Hochst.	Asphodelaceae	*Kniphofia*	H
61	unknown	*Koeleria capensis (Steud.) Nees*	Poaceae	*Koeleria*	H
62	unknown	*Lactuca serriola* L.	asteraceae	*Lactuca*	H
63	Jibra	*Lobelia rhynchopetalum* Hemsl.	Lobeliaceae	*Lobelia*	S
64	Lit	*Malva verticillata* L.	Malvaceae	*Malva*	H
65	Yewof gomen	*Osteospermum vailliantii* (Decne) T.Norl.	Asteraceae	*Osteospermm*	H
66	unknown	*Pellaea quadripinnata* (Forssk.)	Sinopteridaceae	*Pellaea*	F

67	Libasil	*Phagnalon abyssinicum* Sch. Bip. ex A. Rich.	Asteraceae	*Phagnalon*	H
68	unknown	*Plantago lanceolata* L.	Plantaginaceae	*Plantago*	H
69	unknown	*Plantago major* L.	Plantaginaceae	*Plantago*	H
70	unknown	*Plectocephalus varians* (A. Rich) C. Jeffery ex Cufod.	Asteraceae	*Plectocephalus*	H
71	unknown	*Polygala steudneri* Chod.	Polygalaceae	*polygala*	H
72	Enjori	*Rubus volkensii* (Engl.)	Rosaceae	*Rubus*	S
73	Mekmeko	*Rumex abyssinicus* Jacq	Polygonaceae	*Rumex*	H
74	Tult	*Rumex nepalensis* Spreng.	Polygonaceae	*Rumex*	H
75	Embuacho	*Rumex nervosus* Vahl.	Polygonaceae	*Rumex*	S
76	Hulegeb	*Salvia merjamie* Forssk.	Lamiaceae	*Salvia*	H
77	unknown	*Scabiosa columbaria* L.	Dipsacaceae	*Scabiosa*	H
78	unknown	*Senecio ochrocarpus* Oliv. & Hiern	Asteraceae	*Senecio*	H
79	unknown	*Senecio ragazzii* Chiov.	Asteraceae	*Senecio*	H
80	Wegert	*Silene macrosolen* A. Rich.	Caryophyllaceae	*Silene*	H
81	Embuay	*Solanum marginatum* L.f.	Solanaceae	*Solanum*	S
82	unknown	*Stellaria media* (L.) Vill.	Caryophyllaceae	*Stellaria*	H
83	unknown	*Swertia schimperi (*Hochst.) Griseb	Gentianaceae	*Swertia*	H
84	Tosign	*Thymus schimperi* Ron.	Lamiaceae	*Thymus*	H
85	Sama	*Urtica simensis* L.	Urticaceae	*Urtica*	H
86	Ketetina	*Verbascum sinaiticum* Benth	Scrophulariaceae	*Verbascum*	H
87	Girawa	*Vernonia amygdalina* Del.	Asteraceae	*Vernonia*	S
88	unknown	*Veronica glandulosa* Hochst. ex Benth	Scrophulariaceae	*Veronica*	H

(T= Tree, S= shrub, H= Herb, C= Climber, F= Fern)

Appendix 2 Importance value of species

No	**Species**	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
1	*Aeonium leucoblepharum*	0.12	0.05	0	0
2	*Alchemilla abyssinica*	9.94	15.05	52.23	178
3	*Alchemilla ellenbecki*	3.81	0	0	0
4	*Alopecurus baptarrhenius*	0.19	0	0	0
5	*Andropogon abyssinicus*	0.31	3.5	3.96	27.75
6	*Anthemis tigreensis*	0.31	0	0.35	0
7	*Argyrolobium ramosissimum*	0.06	0.35	0	0
8	*Artemisia abyssinica*	0	0.05	0.69	0
9	*Bidens pachyloma*	0	0	0.19	0.12
10	*Calamagrostis epigejos*	0.06	0.1	0.88	0
11	*Carduus* schimperi	0.94	0.15	0	0
12	*Carduus nyassanus*	0	0.1	0	0
13	*Carex monostachya*	2.62	0	0.81	0
14	*cineraria abyssinica*	3.25	0	1.12	1.88
15	*Cirsium dender*	0	0	0.31	0
16	*Cirsium* schimperi	0.06	0.05	0	0
17	*Clematis simensis*	0	0.05	0	0
18	*Conium maculatum*	0.62	0.1	0.04	0.5
19	*Conyza flabellata*	0	0.1	0.04	0
20	*Conyza hypoleuca*	0	0.05	0	0
21	*Conyza pyrrhoappa*	0	0	0.23	0
22	*Conyza stricta wild*	0	0	0.08	0
23	*Crassula alba*	0.25	0.05	0	0
24	*Crepis carbonaria*	0.12	0	0	0.62
25	*Crepis rueppellii*	0	0	0.38	0
26	Crinum abyssinicum	0	0.1	0	0
27	*Cupressus lusitanica*	0.56	0	4.42	5
28	*Cynoglossum amplifolium*	2.38	5.4	4.77	2.75
29	*Cynoglossum coeruleum*	0.94	0.45	2.19	2
30	*Cyperus elegantulus*	0	2.25	0	0
31	Cyperus longus	0	1.75	0.38	0
32	*Cyperus rigidifolius*	0	0.35	0	0
33	*dicrocephala chrysanthemifolia*	1.38	0.65	2.27	1.5
34	*Dipsacus pinnatifidus*	0.75	0	0.54	0
35	*Dryopteris athamantica*	0	0.25	0.12	0
36	*Epilobium stereophyllum*	0	0.1	0	0
37	*Erica arborea*	1.38	7.45	4.27	1.38
38	*Erica tenuipilosa*	0.25	1.4	0.69	0
39	*Eucalyptus globulus*	0.25	0	0.35	0.38

40	*Euryops pinifolius*	12	4.8	1.77	0.88
41	*Festuca abyssinica*	6.94	1.1	11.19	5.88
42	*Festuca macrophylla*	2.56	29.5	4.08	0
43	*Festuca richidii*	7.56	13.4	0.85	0
44	*Festuca semensis*	0.81	2	0.5	0.38
45	*Galium simense*	0.81	0.3	3.38	1.25
46	*Hagenia abyssinica*	0.25	0.25	0.42	0
47	*Haplocarpha rueppelii*	0	0.2	0	0
48	*Haplocarpha schimperi*	0	0.05	0	0
49	*Helichrysum arenarium*	0.5	2.2	0.73	0.12
50	*Helichrysum formosissimum*	0.19	0.6	0.04	0
21	*Helichrysum forsskahlii*	0.06	0.4	0.08	0.25
52	*Helichrysum splendidum*	6.5	14.3	1.31	0
53	*Helichrysum stenopterum*	0	0.2	0	0.25
54	*Hyparrhenia dregeana*	0	0.6	0	0
55	*Hypericum peplidifolium*	0.31	0	2.23	2.5
56	*Hypericum revolutum*	0.44	0.4	0	0
57	*Inula confertiflora*	0	0.1	0	0.38
58	*Juniperus procera*	0.06	0	0	0
59	*Kniphofia foliosa*	5.25	2.35	2.85	2.12
60	*Koeleria capensis*	0.5	0.45	0	0
61	*Lactuca serriola*	0	0	0.15	0.62
62	*Lobelia rhynchopetalum*	1.38	0.05	0	0
63	*Malva verticillata*	0	0.25	0	0
64	*Osteospermum vailliantii*	0	0.2	0	0
65	*Pellaea quadripinnata*	0.19	0.15	0.31	0.12
66	*Phagnalon abyssinicum*	0.06	0	0	0
67	*Plantago lanceolata*	0	0.2	0	0
68	*Plantago major*	0	0	1.77	0.62
69	*Plectocephalus varians*	1.38	2.35	2.58	1
70	*polygala steudneri*	0	0.2	0.23	0
71	*Rubus volkensii*	0.81	0	0	0
72	*Rumex abyssinicus*	0.19	0	0.04	0
73	*Rumex nepalensis*	0	0.1	0	0
74	*Rumex nervosus*	0	0.3	0	0
75	*Salvia merjamie*	0.12	1.15	0.15	0
76	*Scabiosa columbaria*	0.31	0.05	2.96	1.88
77	*Senecio ochrocarpus*	0	0	0	0.12
78	*Senecio ragazzii*	0	0.05	0	0
79	*Silene macrosolen*	0	0.05	0.04	0
80	*Solanum marginatum*	0	0.05	0	0

81	*Stellaria media*	0	0.75	2.65	0
82	*Swertia schimperi*	0	0.15	0.31	0
84	*Thymus schimperi*	3.31	26.6	8.81	5
85	*Urtica simensis*	0	0.25	0	0
86	*Verbascum sinaiticum*	0.06	0.1	0	0
87	*Vernonia amygdalina*	0	0.05	0	0
88	*Veronica glandulosa*	4.19	2.35	7.38	6.38

Appendix 3 Sample plot location in natural vegetation

plot	location		Altitude
	Latitude	Longitude	
1	-	-	
2	$10^o17'34.52''$ N	$39^o47'45.97''$E	3355m
3	$10^o17'39.91''$N	$39^o47'45.17''$E	3377m
4	$10^o17'47.06''$N	39o47'40.13"E	3389m
5	$10^o17'54.47''$N	$39^o47'35.45''$E	3399m
6	$10^o18'1.95''$N	$39^o47'33.81''$E	3403m
7	$10^o18'7.1''$N	$39^o47'41.79''$E	3399m
8	$10^o18'15.1''$N	$39^o47'49.47''$E	3410m
9	$10^o18'21.57''$N	$39^o47'53.26''$E	3421m
10	$10^o18'34.69''$N	$39^o47'50.67''$E	3426m
11	$10^o18'48.37''$N	$39^o47'57.29''$E	3403m
12	$10^o19'2.74''$N	$39^o48'4''$E	3395m
13	$10^o19'19.68''$N	$39^o48'7.69''$E	3429m
14	$10^o19'38.59''$N	$39^o48'27.62''$E	3410m
15	$10^o19'24.87''$N	$39^o48'31.11''$E	3385m
16	$10^o19'22.13''$N	$39^o48'16.38''$E	3413m
17	-		
18	$10^o17'58.07''$N	$39^o47'59.22''$E	3414m
19	$10^o18'10.16''$N	$39^o48'1.06''$E	3434m
20	$10^o18'22.53''$N	$39^o48'5.66''$E	3423m
21	$10^o18'31''$N	$39^o48'9.79''$E	3446m
22	$10^o18'39.69''$N	$39^o48'14.12''$E	3435m
23	$10^o18'48.42''$N	$39^o48'17.43''$E	3453m
24	$10^o18'59.9''$N	$39^o48'24.97''$E	3420m
25	-	-	
26	$10^o20'7.68''$N	$39^o48'27.64''$E	3495m
27	$10^o20'14.77''$N	$39^o48'30.54''$E	3511m
28	$10^o20'20.17''$N	$39^o48'31.03''$E	3506m
29	$10^o20'31.09''$N	$39^o48'34.18''$E	3495m
30	$10^o20'37.27''$N	$39^o48'33.62''$E	3511m
31	$10^o20'45.56''$N	$39^o48'.22''$E	3526m
32	$10^o20'59.28''$N	$39^o48'32.67''$E	3527m
33	$10^o21'30.42''$N	$39^o48'30.43''$E	3536m
34	$10^o21'10.70''$N	$39^o48'25.48''$E	3548m
35	$10^o21'20.59''$N	$39^o48'21.17''$E	3516m

Appendix 4 Sample plot location in plantation site

plot	Location		Altitude
	Latitude	longitude	
1	10^{o}16'31.95"N	39^{o}47'44.14"E	3350m
2	-	-	
3	10^{o}16'49.25"N	39^{o}47'53.85"E	3322m
4	10^{o}16'53.1"N	39^{o}47'57.31"E	3323m
5	10^{o}16'55.33"N	39^{o}47'59.68"E	3324
6	10^{o}16'59.38"N	39^{o}48'2.65"E	3313
7	10^{o}17'4.74"N	39^{o}48'11.48"E	3324
8	10^{o}17'8.75"N	39^{o}48'12.98"E	3343m
9	-	-	
10	10^{o}17'15.75"N	39^{o}48'16.79"E	3337m
11	10^{o}17'19.22"N	39^{o}48'16.68"E	3352m
12	10^{o}17'21.4"N	39^{o}48'18.33"E	3373m
13	10o17'23.84"N	39o48'20.32"E	3383m
14	10^{o}17'29.01"N	39^{o}48'20.31"E	3342m
15	10^{o}17'31.81"N	39^{o}48'28.39"E	3333m
16	10^{o}17'36.78"N	39^{o}48'25.44"E	3310m
17	10^{o}17'42.33"N	39^{o}48'24.31"E	3310m
18	10^{o}17'45.33"N	39^{o}48'22.74"E	3327m
19	10^{o}17'48.97"N	39^{o}48'21.39"E	3352m
20	10^{o}17'51.38"N	39^{o}48'16.01"E	3327m
21	10^{o}17'49.96"N	39^{o}48'12.77’’E	3312m
22	10^{o}17'50.95"N	39^{o}48'13.12" E	3328m
23	10^{o}17'53.71"N	39^{o}48'13.82"E	3335m
24	10^{o}17'56"N	39^{o}48'13.41"E	3350m
25	10^{o}17'57.78"N	39^{o}48'14.09"E	3360m
26	10^{o}17’’59.47"N	39^{o}48'15.44"E	3382m
27	10^{o}18'1.57"N	39^{o}48'15.5"E	3393m
28	10^{o}18'2.03"N	39^{o}48'11.01"E	3387m
29	10^{o}18'4.83"N	39^{o}48'7.38"E	3385m
30	10^{o}18'7.35"N	39^{o}48'7.51"E	3410m
31	10^{o}18'5.16"N	39^{o}48'5.17"E	3392m
32	10^{o}18'0.11"N	39^{o}48'6.64"E	3367m
33	10^{o}17'57.07"N	39^{o}48'6.05"E	3330
34	10^{o}17'50.44"N	39^{o}48'6.56"E	3328m
35	10^{o}17'46.8"N	39^{o}48'6.03"E	3326

Appendix 5 Questionnaire prepared for interview

I. **Demographics**

Region________________ Zone_______________

Wereda______________Kebelle_________

Name of respondent____

1. Gender: a) Female   b) Male

2. Age_______________

3. Birth village/ kebele________________________________

4. Current village/kebele: ____

5. Marital Status__________1) Single   2) Married   3) Divorced

6. Number of children including other dependents___________________________

7. Literacy: a) Read Only   b) Write Only   c) Read and Write only

   d) Literate

8. Education: what is the highest grade you completed? At what age? _______________________________

9. In the last year, did you or any member of the household participate in off-farm activities?

Yes = 1   No = 2

10. If yes, what kind of activities and how much income did they earn?

____

____

____

____

11. Does anyone in your family plan to participate in off-farm activities in the coming year? What kind?

____

____

____

____

12. Is any member of your family currently on the Guassa Council? Who, and for how long?

____

____

13. Has any member of your family previously been on the Guassa Council? Who, and for how long?

____

____

II. <u>Perceptions on Conservation</u>

1. What is your overall attitude towards the Guassa conservation area?

a. Positive b. Negative c. I don't have an opinion d. I don't know/ I am conflicted about it

2. Is the management of the Guassa area effective?

a. Yes b. a little c. No

3. Why or Why not?

____

____

4. Are you actively involved in decisions made about the future of the Guassa area?

a. Yes b. a little c. No

5. What decisions do you make about the Guassa area?

____

____

____

____

6. Are you worried about the future of the Guassa area?

a. Yes b. a little c. No

7. Why or Why not?

____

____

____

____

8. Has the size of the Guassa area changed over the last 30 years?

a. Yes, increased b. Yes, decreased c. No change

9. What environmental problems are common within and around the Guassa area?

____

10. Which of these problems affect you personally, and how?

11. What is the current amount of land held by your household (in hectares)?

12. How much grain did you produce from that land last year? What about the year before that?

13. Did you think your farm land productivity is increasing over the last 15 years to present?

a) Yes b) no c) No change

14. Why or why not?

15. How many sheep/cattle does that land support? How has that number changed over the 30 years?

____

____

16. Is the Guassa area well-protected?

a. Yes   b. a little   c. No

17. What would improve the management of the Guassa Area?

____

____

____

____

____

III. <u>Perceptions on Land Change</u>

1. What kind of changes have you observed in each of these resources over the last 15 years? Why do you think these changes are occurring?

a. Water____

____

____

____

____

____

____

____

b. Grassland____

____

____

____

____

____

c. Cropland

d. Native Forest

e. Plantation Forest

f. Human settlements and infrastructure

Do you have any questions for us?

IV. **Perceptions on the causes of land change**

1. What are the causes for land use/land cover change in your area?

Declaration

I, the undersigned declare that this Thesis is my original work and it has not been presented in other universities, colleges or institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

Name: ___________________________ Signature: _______________ Date: _____________

This work has been done under my supervision.

Name: ____________________Signature: __________________ Date: ___________

__________________________ Signature: __________________ Date: ___________