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GIS And Remote Sensing Based Assessment of the Population Pressure on Land Use/Land Cover Change of Legedadi Catchments Area and Its Impact on the Legedadi Water Reservoir, Central Ethiopia

Dilnesa Mekonnen Mengstu

**A Thesis Submitted to
The Department of Geography and Environmental Studies
Presented in Partial Fulfillment of the Requirements for the Degree of Master
of Arts in Geography and Environmental Studies
(Population, Resources and Development)**

Addis Ababa University

Addis Ababa, Ethiopia

June, 2016

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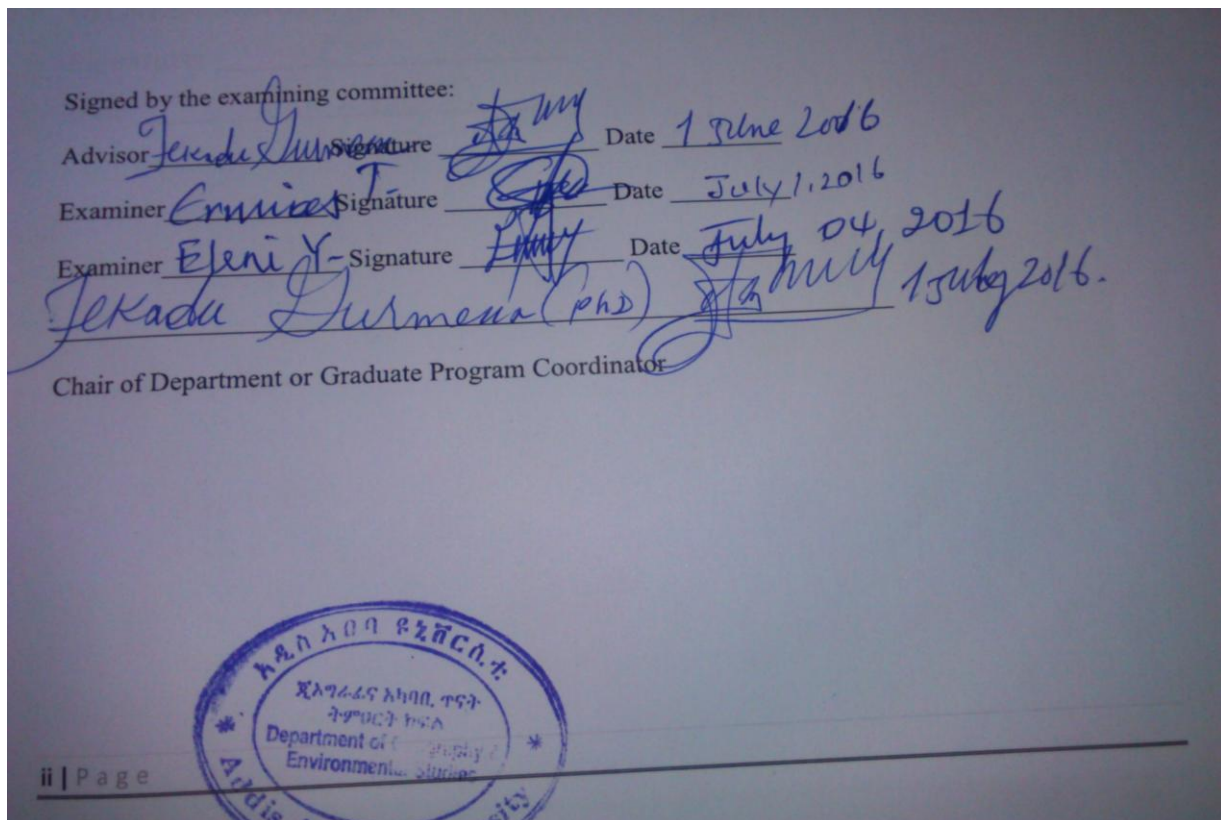
Addis Ababa University

Addis Ababa Ethiopia

June, 2016

Addis Ababa University
School of Graduate Studies

This is to certify that the thesis prepared by Dilnesa Mekonnen entitled *GIS and Remote Sensing based assessment of the population pressure on land use/land cover change of Legedadi Catchments Area and its impact on Legedadi water reservoir, Central Ethiopia* and submitted in partial fulfillment of the requirements for the degree of Master of Arts (Geography and Environmental Studies, specialization: Population, Resource and Development) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.



Declaration

I hereby declare that the thesis entitled. *GIS and Remote Sensing based assessment of the population pressure on land use/land cover change of legedadi catchments area and its impact on Legedadi Water Reservoir, Central Ethiopia* has been carried out by me under the supervision of Dr. FeKadu Gurmessa, Department of Geography and Environmental Studies, Addis Ababa University, Addis Ababa during the year 2015/16 as part of Master of Art in Geography and Environmental studies specialized on population, Recourse and Development. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

DILNESA MEKONNEN

Signature: _____

Date _____

Abstract

GIS and Remote Sensing Based Assessment of Population Pressure on LULC Change of Legedadi Catchment Area and its impact on LWR, Central Ethiopia

Dilnesa Mekonnen Mengstu

Addis Ababa University, 2016

In the last thirty years in LCA which is one of the source of surface water for the city of Addis Ababa, existed population pressure which is responsible for LULCC. The main objective of this study is examine the population pressure on LULC change of LCA and its consequence on LWR. In this thesis, data on population over time were taken from CSA and Bereh *Wereda* during 1984-2014 census result, RS image of 1984, 1999 and 2014 to detect the LULCC using maximum likelihood supervision, AAWSA data to investigate the relationship of LWR and LULCC, questioner, FGD and KII were used to attain the proposed research objectives. The population growth in LCA shows that it is more than double within three decades. The population pressure over the last thirty years in LCA where examined by using PPI and the finding indicates that the population pressure increased from 1984-2014. The GIS and RS analysis results confirms that the LULCC observed, Settlement showed an increase of 134 % and followed by Cultivation by 118.2%. While natural vegetation, eucalyptus, grassland and water body decreased by -25.7%, -28.1,-32% and -10.8% respectively. The correlation result of population growth and LULCC of the study area shows that there was a strong positive relationship between population growth and LULCC. The correlation result of LWR and LULCC also indicates an impact of LULCC on volume of water and the amount of siltation through time. From the analysis of the socio economic situation of households to identify the proximate and underlying causes of the LULCC, the results suggested that LULCC were closely associated with human activities.

Keywords: Population growth, PPI, GIS, Remote Sensing, LULC, TM, ETM+, Correlation

Dedication

This thesis is dedicated to my loving, caring and industrious grandmother who raised me with unlimited love. Words cannot adequately express my deep gratitude to you. Always you are in my heart. Let your Soul rest in peace.

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Special thanks to the Almighty God for his guidance and grace that allowed me to stay until this time and my work come to be successful.

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Abbreviation

AAWSA	:	Addis Ababa Water and Sewerage Authority
CSA	:	Central Statistical Authority
DEM	:	Digital Elevation Mode
EMA	:	Ethiopian Mapping Agency
ERDAS	:	Earth Resource Data analysis System
ETM+	:	Enhanced Thematic Mapper Plus
FGD/s-	:	Focus Group Discussion/s
FDRE	:	Federal Democratic Republic of Ethiopia
GCPs	:	Ground Control Points
GIS	:	Geographic Information System
GPS	:	Geographical Positioning System
KII	:	Key Informant Interview
LANDSAT	:	LAND + SAT(ellite)
LCA	:	Legedadi Catchment Area
LWR	:	Legedadi Water Reservoir
LULC	:	Land Use/Land cover
LULCC	:	Land Use /Land Cover Change
MCM	:	Million Cubic Meter
MSS	:	Multi Spectral Scanner
NMA	:	National Meteorological Agency
PPI	:	Population Pressure Index
RS	:	Remote sensing
TM	:	Thematic Mapper
USGS	:	United States Geological Survey
UN	:	United Nations
UNFPS	:	United Nations Fund for Population Studies

UNHDI : United Nations Human development Index

UTM : Universal Transverse Mercator

CHAPTER I

INTRODUCTION

1.1. Background of the study

World population never exceeded 10 million people for most of human history. The death rate was higher than birth rate for many centuries, and the rate of population growth was scarcely above zero. Population growth began, when humans started to farm and raise animals around 8000 B.C. (Joseph and McFalls, 2003).

There are now 7.2 billion people on the planet, roughly 9 times the 800 million people estimated to have lived in 1750, at the start of the industrial revolution. The world population continues to rise rapidly, by around 75-80 million people per year. Soon enough there will be 8 billion by the 2020s, and perhaps 9 billion by the early 2040s (Population Reference Bureau, 2014).

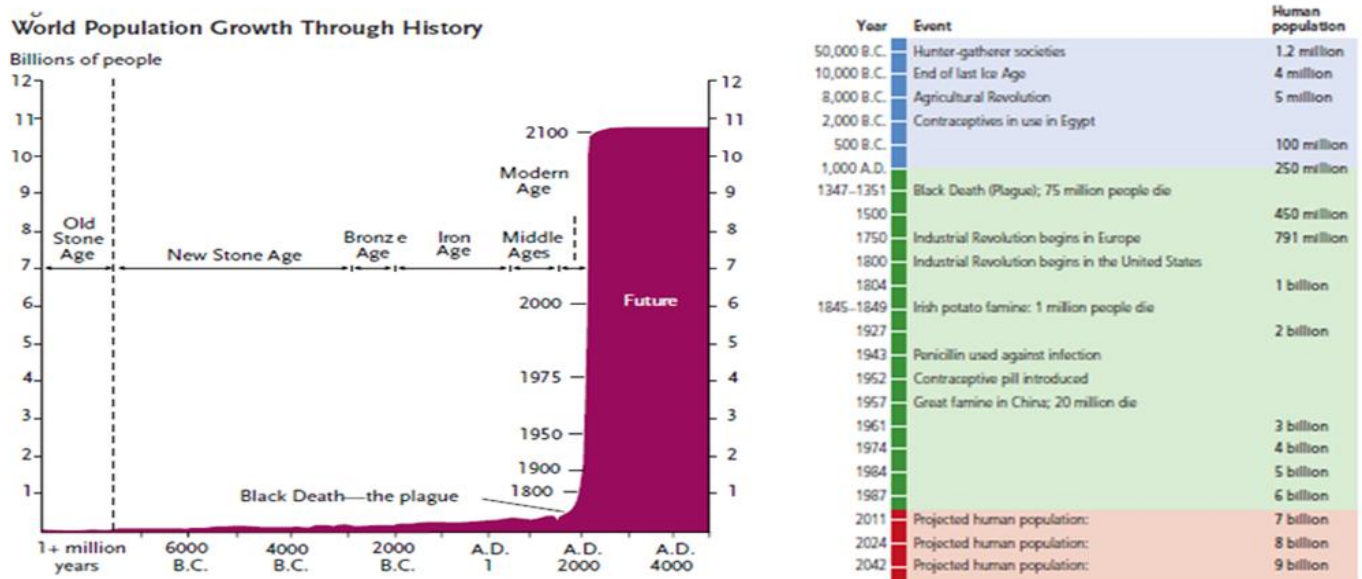


Figure 1 projected global population growth

Source : The population reference bureau, (2014)

One of the poorest regions in the world is Sub Saharan Africa is undergoing a demographic transformation. It is home to around 900 million people, a number that is projected to grow to 1.2 billion by 2025, and 2.4 billion people who will likely be added to the world by 2050 and to almost 2 billion by 2100. The region’s population is growing at a rate of more than 2 percent – the fastest in the world. Thirty-one of the 51 countries in SSA are projected to at least double their population by 2050. (AFIDEP and PAI, 2012).

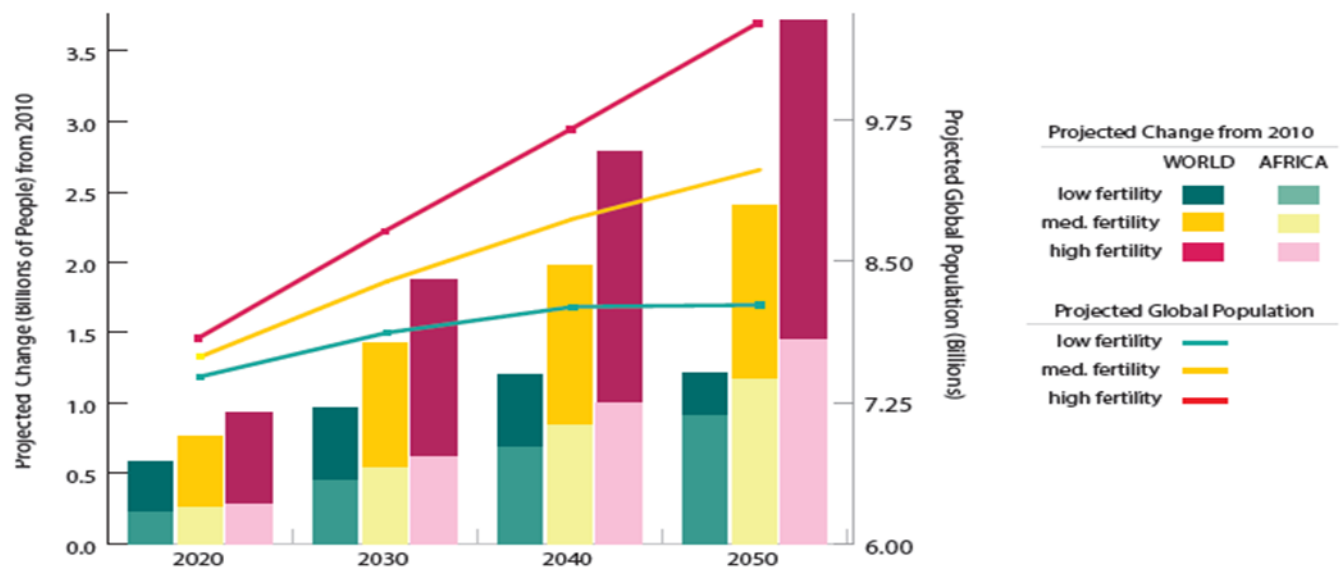


Figure 2 Africa’s projected population

Source:United Nations (UN) Population Division, 2011

Ethiopia has experienced slow population growth for many years (Arowolo, 2010). But from 1984 to 1994 census of population shows increase in population size from 41.2 million in 1985 to 63.5 million in 2000 (CSA, 2004). The projected figures for the year 2015 became 94,000000. The high rate of population growth has declined only marginally over the years, from a peak of 3.0 percent per annum in 1990 to 2.7 percent in 2005, and is projected to decline further to 2.6% (2005-2010) and an average of 2.4% during the period 2010-2015 (Arowolo, 2010).

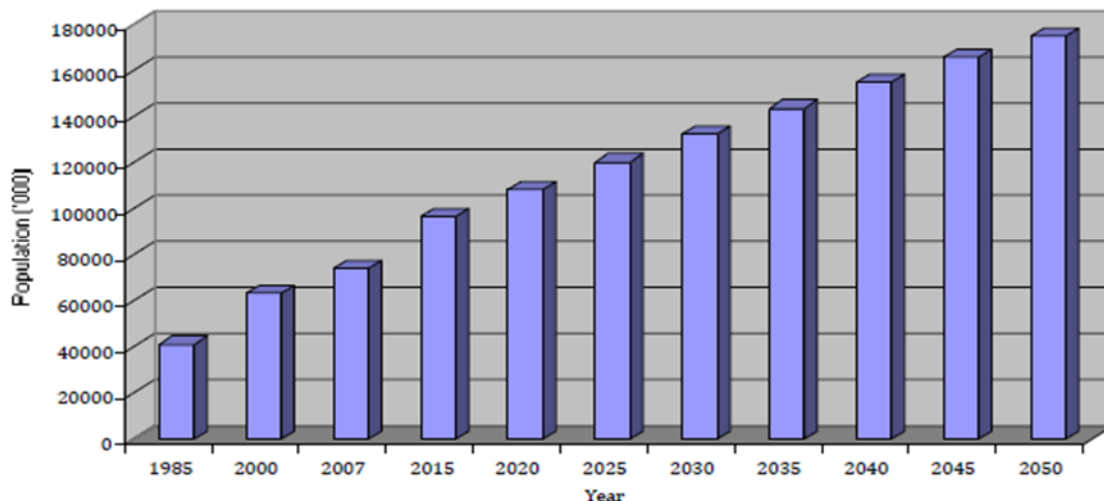


Figure 3 Estimated projected population of Ethiopia

Source: UN, Population Division, 2009

Population pressure has both positive and negative impact on the environment in a given area or in global level. Since environment and population are closely interrelated they cannot be studied separately. Population and environment have a complicated relationship. There are different debates in the interaction of population and environment. The controversy on the population and environmental interrelationships has been between those who consider rapid population growth, increases demand for resource and environmental degradation, and those who emphasize opportunities rather than problems (Markos and Dilnesaw, 1998).

Mulneh (2003: as cited in Sahlu, 2004) stated that high concentration of population in the highland area of Ethiopia is related to altitude, climate, and soil. Around 90 percent of the population lives in areas above 1,500 meters and only 11 percent are living below 1,500 meters (hot climatic zone. This shows population in Ethiopia is growing rapidly and distributed unevenly and it has negative implication to environmental resources.

During pre-historic time, population distribution was so sparse and man-land ratio was very low. But as population growth increased over the centuries the settlement expanded and its density also increased. With rapid population growth the availability of land gradually became less (Markos and Dilnesaw, 1998).

For several thousands of years human beings have modified natural environments to obtain food and other essentials. The status, properties and function of ecosystem today is affected by the rates, extents and intensities of human pressure on land than before (Ellis, 2007).

To satisfy the resource need of a growing population land is the center of agricultural production, basic land-use change is required, expanding food production through forest clearing, to intensify production on already cultivated land and developing infrastructure needed to support increased population (Hunter, 2000).

For environmental and population interaction studies and management, land-use change data can provide input. An understanding of past land use practices, current land use and land cover patterns and projection of future land use and land cover, will determine the effects of land use and land cover change on the earth system and its impact on human distribution, economic development, technology and other factors (Thadiparthi B. and Mekonnen A., 2004).

LULUC which was caused by human population pressure, Climate change, socio-economic and political factors will cause land degradation. Related to LULC change soil erosion is a serious problem in Ethiopian highland areas that increases sedimentation of reservoirs and lakes. (Weldeamlak, 2003; Sonneveld, 2002). Most of the areas which has the pressure are found in the highland areas above 1500m (Weldeamlak, 2003; FAO, 1986).

Therefore, attempt will be made in this study to map out the status of population pressure in land use land cover change the Legedadi catchment area and their impact for LWR for the three decades (from 1984 and 2014) using, population pressure index, remote sensing and GIS, volume of water and amount of siltation and establish the main causes of land use/land cover change through household questionnaire and a focus group discussion.

1.2 Statement of the problem

Population growth is one of the reason for the sever problems of environmental destruction and land use change, that the world is facing today. From 1750 onward population growth accelerated. The world population, which did not reach its first 1,000,000,000 until about 1800, added another 1,000,000,000 persons by 1930. After that, it took a mere fifty years for the population to double again to four billion in the 1970s. And now 2015 it is around 7.2 billion (Population Reference Bureau, 2014).

Ethiopia is the second-largest populous country in Africa, with an estimated population of nearly 94 million and a growth rate of 2.6 percent per year. Ethiopia is a predominantly rural and young society, with 84 percent living mainly in densely populated highland settlements (Arowolo, 2010).

Rapid population growth can create pressure on basic resources such as water, forests and land, as well as biodiversity beyond what is available. These resources must be conserved and enhanced to meet the needs of growing populations without denying the coming generations. Land use in agriculture and forestry must be based on a scientific assessment of land capacity or forest resources must not exceed the rate of regeneration (Daniel , 2008).

Like other developing countries, most of the population in Ethiopia live in rural areas and depend directly on land for their livelihood. This rural population is currently growing rapidly and causing

much impact of on resource and bring changes to land use/land cover in natural vegetation coverage and its conversion causes deforestation, overgrazing, and poor land management (Woldeamlak et al.,2005).

Legedadi Reservoirs is one of the main sources of surface water for the area of Addis Ababa. Presently, Addis Ababa faces a serious deficit in the water supply. Silt deposits in Legedadi reservoir affects its storage capacity, water quality is decreasing because of high population pressure and LULC change in the Legedadi Catchment Area.

Therefore, in this study an attempt has made to investigate the population pressure on the Legedadi Catchment Area (LCA) particularly it's consequence on LULCC using Remote sensing and GIS, asses the relationship between population growth and LULCC in the catchment area, examine the correlation between LULCC and the amount of silt and volume of water change in Legedadi Water Reservoir.

Literature is scarce on the consequences of population pressure on the environment of the study area. However, there are some researches done on Climate change (Endalkachew, 2012) and its impact on the study area and prediction of sediment inflow (Andualem, 2008), The BCEOM 1993 study examined the existing Legedadi and Gafarsa dams and conducted bathometric surveys, (AESL, 1993), justifies its approach which was to estimate the sedimentation that has occurred in past of 13 year and (Tahel, 2003) carried out the bathometric surveys.

1.3. Objective of the study

1.3.1. General objective

The general objective of the study is to examine the population pressure on land use/land cover change of Legedadi catchments area and its consequence on Legedadi Water Reservoir.

1.3.2. Specific objectives

The specific objectives of the research are to

- Describe the population growth and population pressure level of the catchment area.
- Mapping out land-use/cover change in the area over years between 1984—2014.
- Assess the relationship between population growth and LULCC of the catchment area.
- Examine the relationship between LWR volume of water and amount of silt with LULCC
- Identify the causes of LULC changes of the Legedadi Catchment Area.

1.4. Research questions

The purpose of this study is to answer the following questions. The questions are drawn from the objectives stated above.

- How are population growth and population pressure level in the study area?
- How is the pattern of LULCC of the area over the study period?
- What is the correlation between the population growth and the LULCC in LCA?
- What is the relationship between LULCC and LWR volume of water and amount of silt?
- What are the cause of LULC change in the LCA?

1.5. Significance of the study

This study is designed to contribute to the effect of population pressure on LULCC and its impact on LWR. Hopefully, it provides clue on measures to be taken and strategies to manage population pressure and to improve sustainable resource use, support decision making at the *wereda* level for sustainable LULC management. In addition to this, the study may be used as a source of additional material for further study in the relationship between population growth and LULC change and

even became significant for AAWSA to understand the population pressure and LULC in the source of the water area.

Additionally, this scientific information will be invaluable not only to academia but also to formulate appropriately policy interventions, to the catchment area managers, different regional and federal government bodies in Ethiopia to control negative effects of population pressure on LULCC and to manage the catchment areas properly.

1.6. Scope of the study

To assess the effects of population pressure on land use and land cover change and its consequence in LWR, it is important to have an understanding of the population growth trend, land use and land cover patterns of the catchment area and the amount of silt and volume of water of LWR.

The spatial scope of the study is limited to Legedadi catchments area in the upper North Western part of Awash basin whereas the temporal scope is based on the long term CSA and the Bereh *wereda* administration population data, the three decade Landsat image data analyze obtained from EMA since 1980s and the amount of silt and volume of water of LWR from AAWSA. Hopefully, it provides clue on measures to be taken and strategies to be devised to the interaction of population and environment.

1.7. Organization of the Study

This thesis were organized into five chapters. Chapter I introduction, objectives, research questions, scope and organization of the study. Chapter II attempts to review the related works of other academia and research institutions. Chapter III tries to introduce the location, major biophysical and socioeconomic attributes of LCA with the assumption that these have direct relations with the issues under investigation and listing of the detailed description of the way the

data were captured and processed. Chapter IV concentrates on analysis the result and discussions related to the population growth, population pressure level, LULC change, correlation analysis and the socio-economic surveying in LCA. Chapter V deals with conclusions and recommendation for stakeholders so as to mitigate the existing vegetation degradation in the catchment.

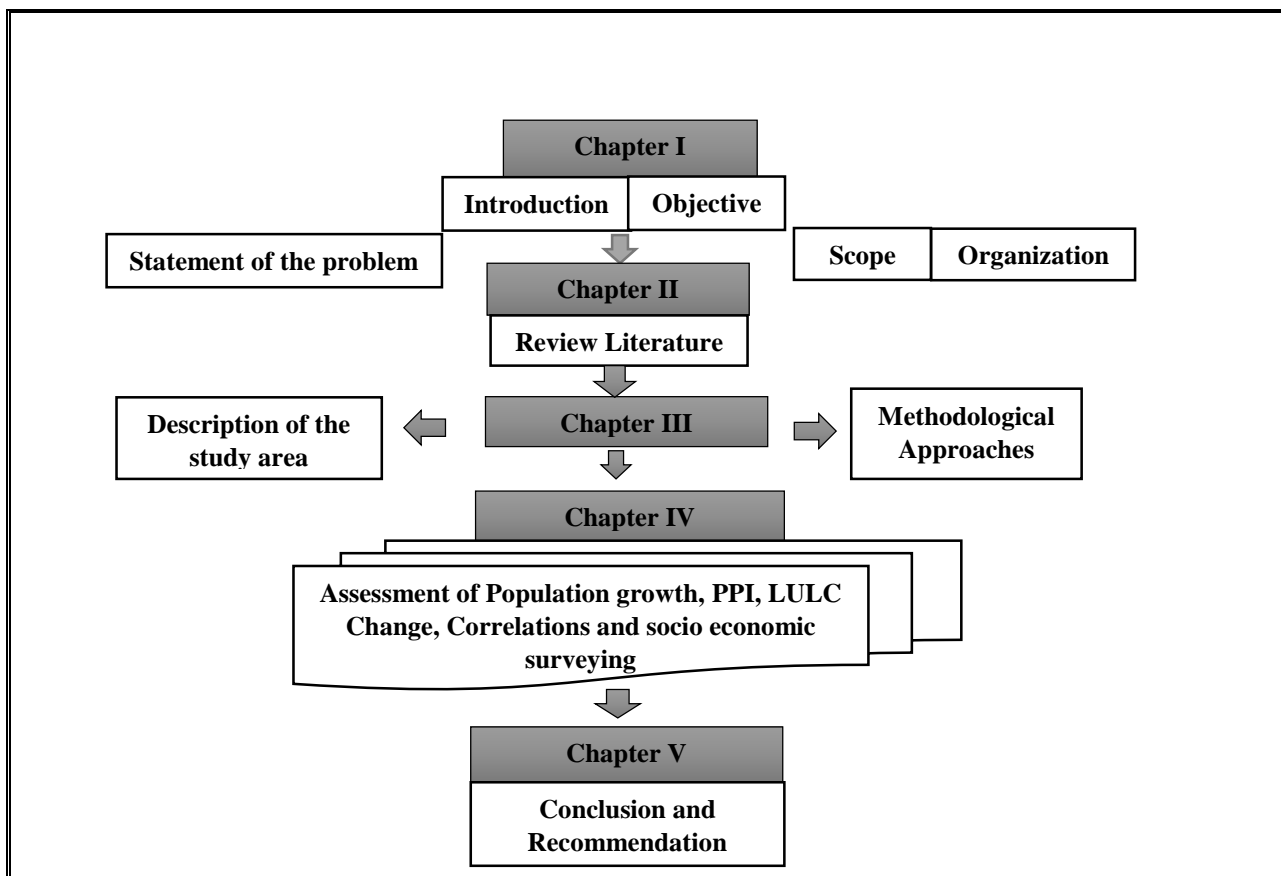


Figure 4 Thesis Structure

CHAPTER II

CONCEPTUAL AND LITERATURE REVIEW

2.1. Conceptual Literature

2.1.1. Population size trends and patterns

Before 1750 population growth was very slow, preceded by a dramatic population increase. The unprecedented growth of world population after this time arose because birthrate outnumbered death rate. For many centuries, the birth rate and the death rate fluctuated. This fluctuation formed the four stages of demographic transition (Joseph and McFalls, 2003).

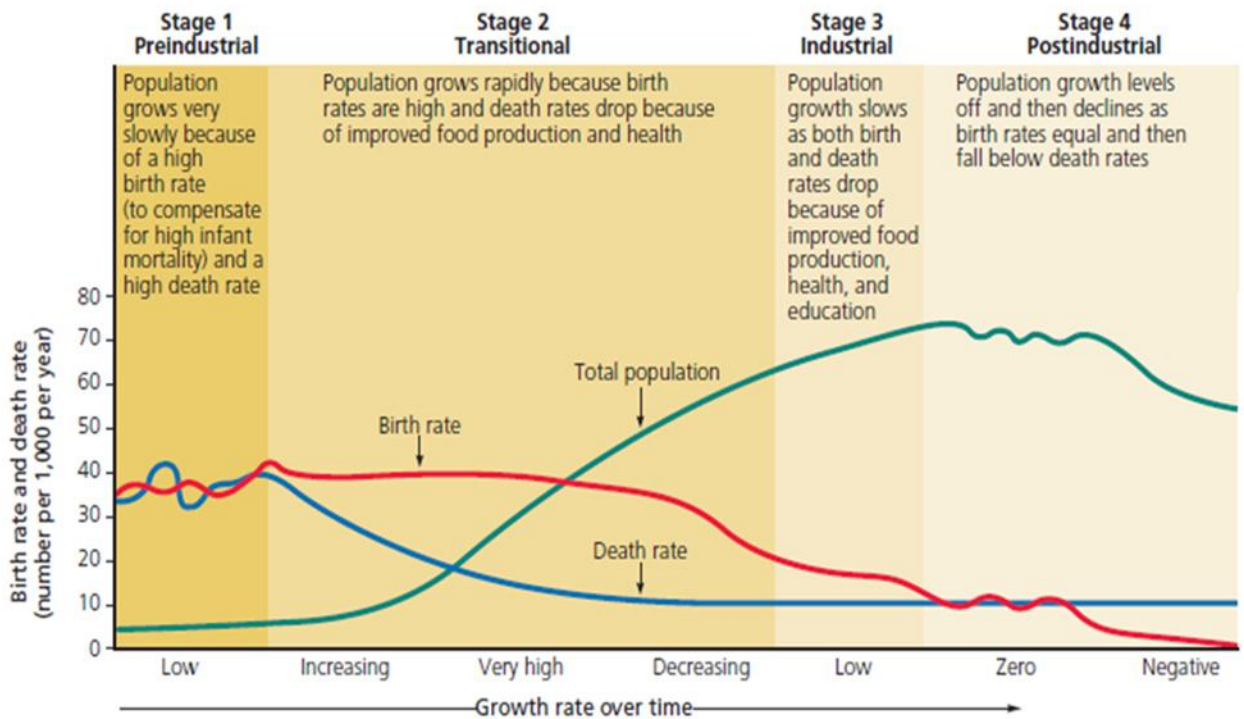


Figure 5 Demographic Transition stages

Source: Wrigley, (1969)

One reason for this change is the industrial revolution in Britain and this caused advance in public health and hygiene brought about by the scientific-technological economic revolution that began

in the mid-eighteenth century particularly altering the course of global population history through dramatic reductions in mortality rate. The population of our planet doubled between 1960 and 1999, increasing from three billion to six billion people. And currently it reaches around 7.2 billion (Population Reference Bureau, 2014).

According to Hunter (2000), population distribution changes are because of variations in natural increase that shift the relative proportions of population across locales and migration. The past 40 years have witnessed remarkable changes in the distribution of humans across the globe. In particular, the increasingly urban concentration of population is a prominent contemporary demographic trend.

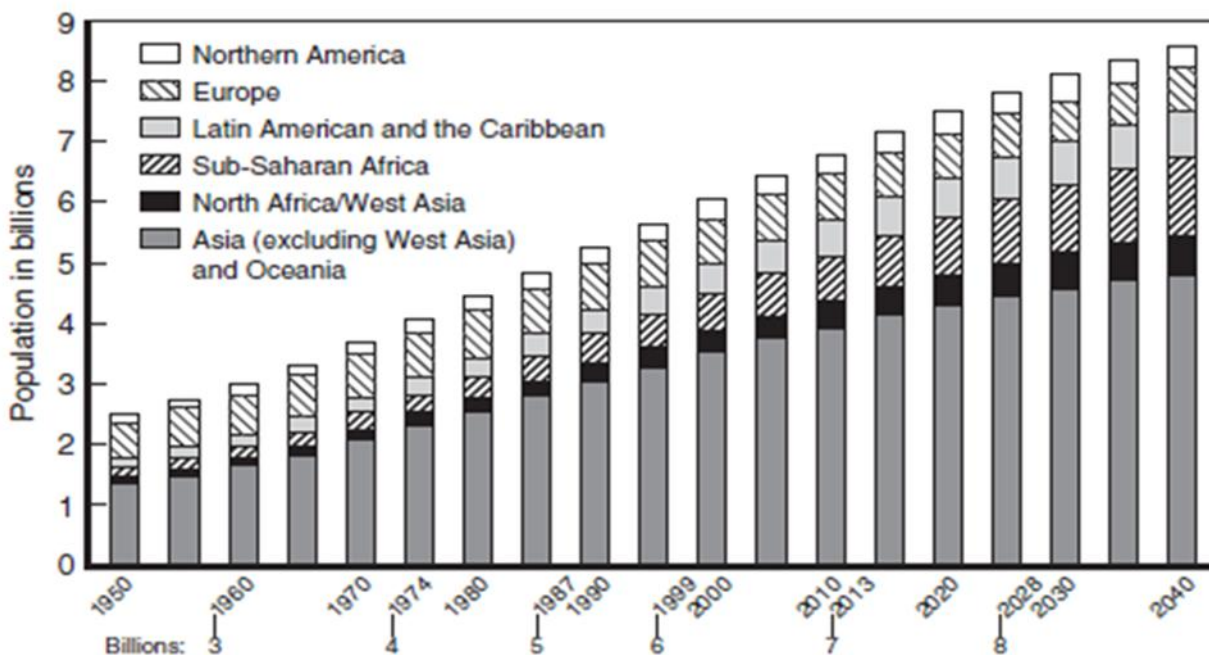


Figure 6 Regional population distribution

Source: U.N. Population division, 1998

This change persuade in the environmental change in unprecedented fashion. These billions of people are struggling to find food, safe water, and shelter they need for survival and unknowingly

they are endangering environmental sustainability. This population growth and environmental degradation has become more important that we deepen our understanding of the role played by human population Change in environmental change (Hunter, 2000).

2.1.2 Population size and environment

Since world population size is permanently connected to land, air, and water environment. Each and every individual uses environmental resources and contributes to environmental degradation. While the scale of resource use and the level of wastes produced vary across individuals and across cultural contexts, the fact remains that land, water, and air are necessary for human survival (Hunter, 2000).

According to Sydenstricker-Neto (2012), “*Population pressure and environment relationships are better understood if conceptualized as being mediated by economic, social, cultural, and institutional factors.*” In addition to this, Hunter, (2000) explained how technological change has impacted the since the pre-historic time to the modern time and how Institutions and policy plays key role in determining the final effect of humans on the environment.

Cultural factors like land tenure arrangements, farming practice and other mismanagement in the forestry sector al are important drivers that mediate population and environment (Geist et al., 2002).

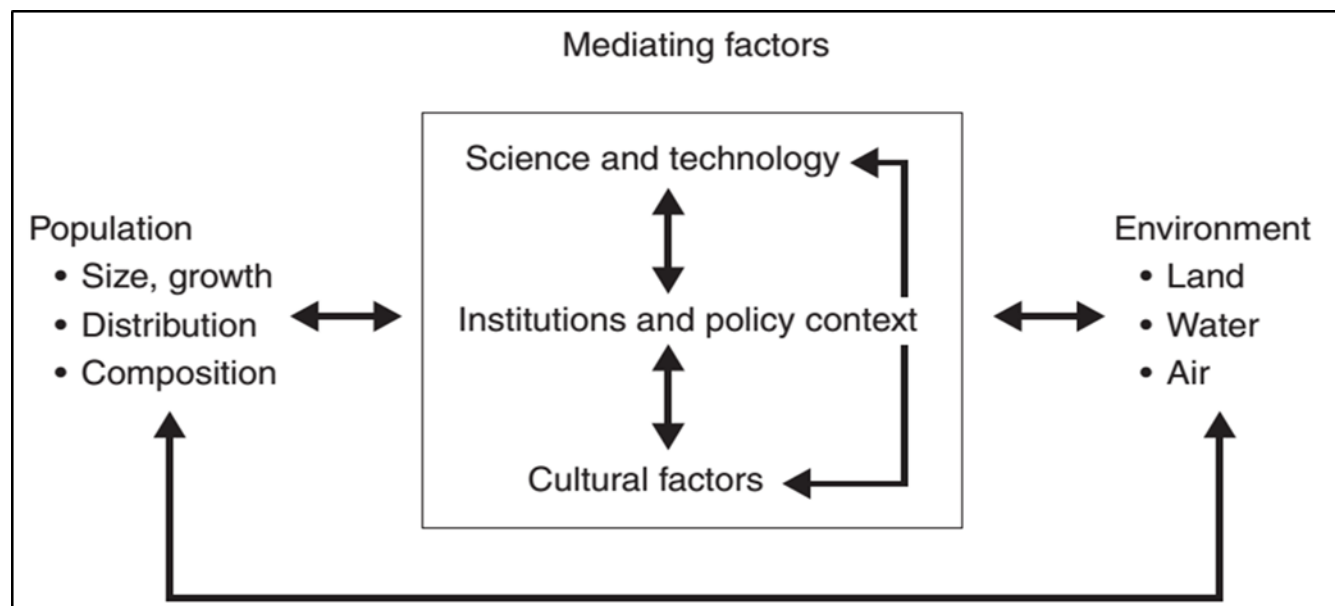


Figure 7 Relationship between population and Environment

Source: MacKellar et al., 1995

2.1.3 Population and Environment Nexus: Theories

Debate about population has been going on at least since Aristotle, who cautioned that populations could outstrip their subsistence base, leading to poverty and social discord (Cohen, 1995). The effects of population size on the environment is not a new idea. British economist Thomas Malthus' essay on the Principle of Population (Malthus T, 1960) that was credited with launching the study of population and resources as a scientific topic of inquiry, warned of the unsustainability of unchecked population growth more than 200 years ago, arguing that human population has a tendency to exceed the ability of the environment to provide subsistence. In particular, Malthus suggested that unrestrained population growth would outstrip the ability of the Earth to provide sufficient food. Although this perspective has been criticized for its simplistic focus on population

size as the sole driving force in resource change, Malthus initiated a debate on carrying capacity and his influence continues today. Many contemporary population-oriented interest groups focus on population size as the determining factor in environmental degradation (Campbell and Martha, 1998).

In the contrary Boserup (1981), argues that technological change as means of innovation under population pressure, suggesting that increasing population density might encourage technological changes that allow food production to keep pace with population growth. Boserupian theory focuses on the relationships between these three factors: population, environment, and technology.

According to Simon J. (1996), historical population growth leads to improvement of the living condition. He suggested that population growth induces sufficient technological change to expand food output faster than population.

Both the Malthusian and Boserupian propositions focus on linear relationships between population and the environment. Boserupian concept of population, like Malthus, refers mainly to land resources and related factors such as climate and soil quality. But neither Boserup nor Malthus specifically address population, environment, and technology with the topics of land use or food production (Amare, 2013).

The second perspective the Multiplicative emphasis how population and its characteristics (size, growth, density and distribution) interacts in a multiplicative way with other factors, such as levels of consumption and technology, to have impact on environment.

According to Carla et al. (2001), The Mediating Perspectives presents that social, cultural and institutional factors play a mediating role in determining population-environment relationships.

The influence of those factors is viewed as multi-level so that layers of mediating variables at the household, community, national and international levels are considered.

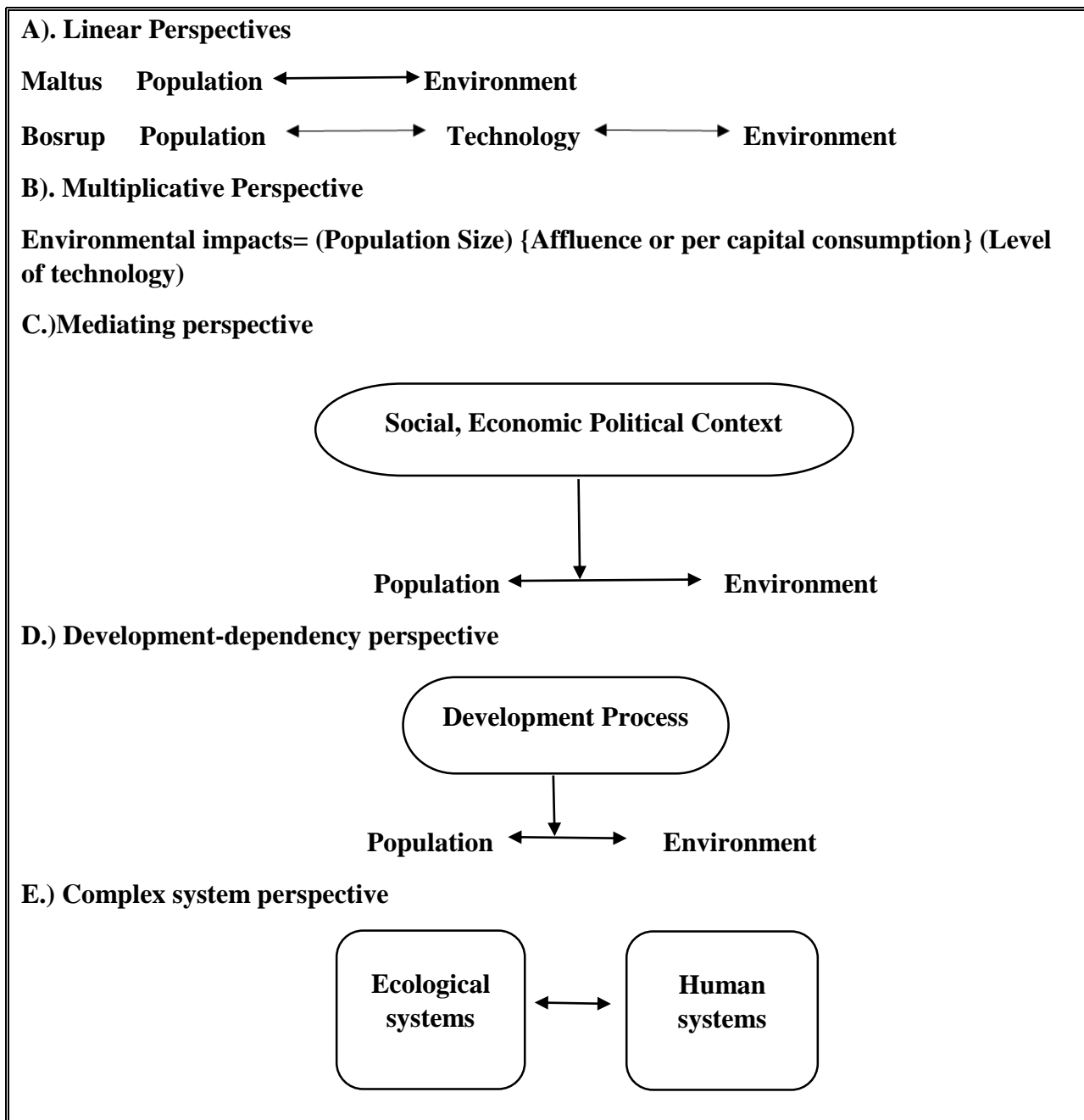


Figure 8 Conceptual approach of Population and Environment

Source Marquette, C. M. and R. Bilborrow, (1994)

2.1.4 Population change and demand for natural resource

According to Markos and Dilnesaw (1998), one of the ancient debate in our world is concerning population pressure and resource. But the unprecedented demographic change of our recent time has brought the issue top of the priority list of worldwide problems that needed international attention. Most of the world countries today have shown tremendous growth both in the economic and development sectors which resulted from using natural resources. Both non-renewable and renewable resources which share the ecosystem with human and on whom humans in turn depend. But the most important renewable resources have been land. It is a resource that can be re-newed and re-used for generations although there are indication that can also have limit.

2.1.5 Population and demand for land use

Land is the earth's terrestrial surface which is full of resources for most human activities and needed for such activities (Daniel, 2008). According to Wolman (1983), land use changes over the past 6,000 years are associated with the growth of human population. For many years, the growth of agricultural production related to the expansion of population, together took place through the expansion of land under cultivation.

Historical records indicate that different population densities and different population growth rates produce different land use patterns and changes over time. More people means more food, which can come only from either expansion of agriculture into new lands, or use of existing agricultural land more intensively (Theodore, 2000).

As Daniel (2008) explained rapid population growth exerts pressure on the existing land resources through increasing the demand for food, wood for fuel and construction purposes, and other

necessities. Farmers convert the remaining patches of forest in to field and fallow their lands for shorter period's thereby increasing soil erosion.

2.1.6 Land use/Land cover change

LULC are defined by many scholars and organizations. e.g., FAO, (2000). Land use is *“the total of all arrangements, activities and inputs that people undertake in a certain land cover type”*. In contrast, Land cover *“is the observed physical and biological cover of the earth's land as vegetation, rocks, water body or man-made features”* (FAO, 2000). Similarly, (Herold et al., 2006) presented the term land cover to observe biophysical cover of the earth's surface (Water surface, soil, rock, vegetation and manmade features) and land use refers to peoples activity on the land cover. In addition to this Quentin et al., (2006), explained it *“Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses”*.

Meyer (1994: Asmamaw cited in, 2013) LULC change can be seen in to two broad groups: conversion and modification. Conversion refers to a change from one cover or use group to another (e.g. from cropland to settlement). Modification, on the other hand represents a change within one land use or land cover group (e.g. from rainfed cultivated area to irrigated cultivated area) due to changes in its physical or functional attributes.

2.1.6.1 Proximate and Underlying Causes of LULC change

LULC changes can be seen as in two broad categories: proximate or direct and underlying or indirect (Geist et al., 2002). Proximate variables are context and region specific while the root causes on the other hand are the result of complex political, economic and social conditions occurring at near and far. As it is clearly indicated in (Fig 9) infrastructural and agricultural expansion, wood extraction and other factors such as soil quality as proximate causes whereas demographic and economic, policy and institutional, and cultural factors as underlying factors.

Proximate factors occur at local or household/farm level whereas underlying factors emanate from regional, country or even global level. As a consequence, proximate variables are context and region specific while the root causes on the other hand are the result of complex political, economic and social conditions occurring at a distance (Geist et al., 2002).

To provide the necessary resource for a growing population fundamental land-use change is required. This includes the expansion of food production through forest clearing, to intensify production on already cultivated land, or to develop the infrastructure necessary to support increasing numbers of human. Indeed, it is the ability of the human race to manipulate the landscape that has allowed for the rapid pace of contemporary population growth (Hunter, 2000).

In whatever way, population and environmental factors (soil characteristics, climate, topography, vegetation and water body etc.) are the determinants of Land use land cover change but also reflect the land's importance as a fundamental factor of production (Hunter, 2000).

There is an important statistical correlation between population pressure and LULC change in most of African, Asian, and Latin American countries (Meyer et al., 1994). Population growth and its connection between land and forest is an important determinant of food demand. Since

agriculture is the only source of food, the type of agricultural land-use change will be determined by fundamental social, economic, and technological factors (Gerhard, 1994). Deforestation also related to agricultural land-use change, as it is often a consequence of agricultural extension (Houghton, 1994).

In general, the factors that affect LULC changes are complex. Therefore, the study of LULC changes need a careful investigation at local, national and global levels.

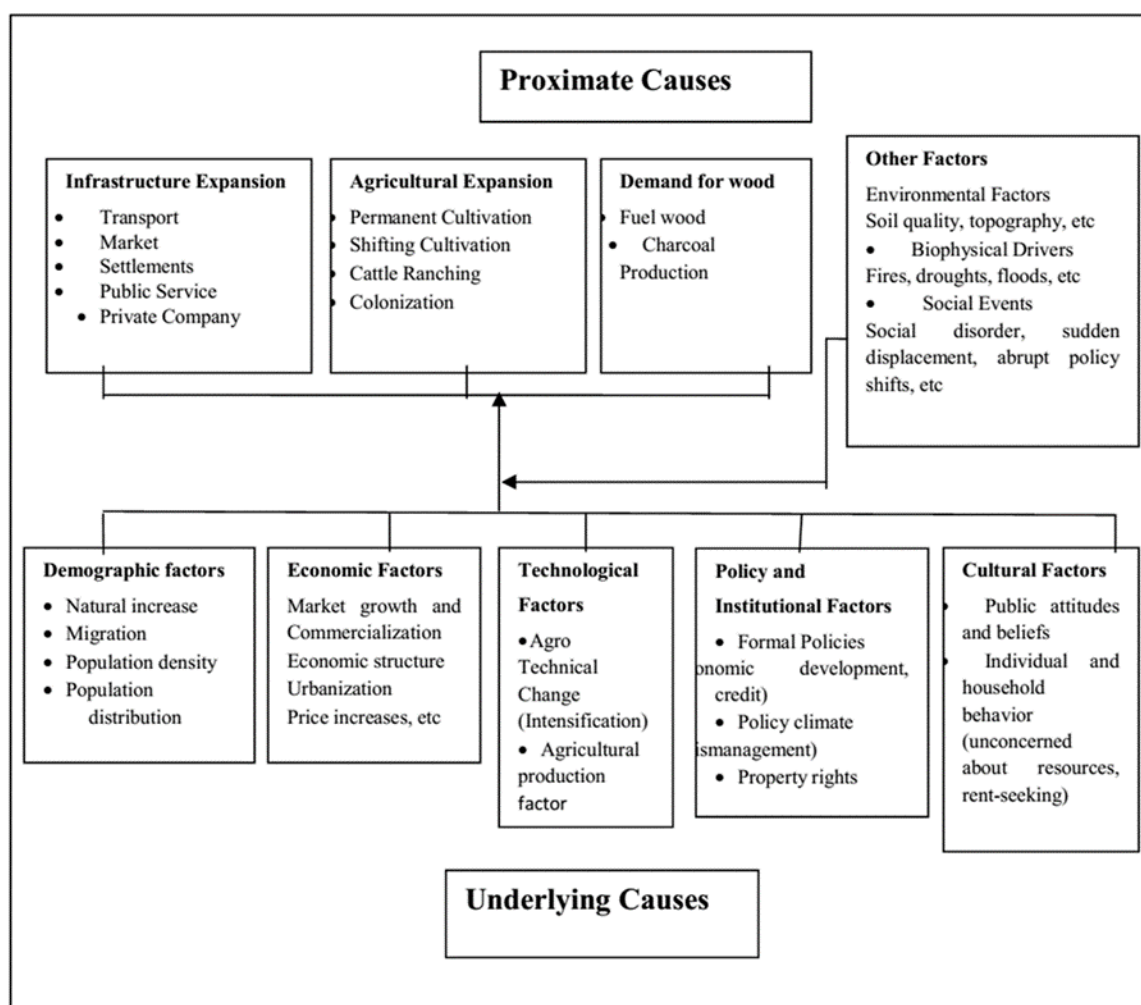


Figure 9 Proximate and underlying Causes of LULC changes

Source: (Geist, H. J. and Lambin, E. F., 2002)

2.1.7 Land use/land cover change influence soil erosion and water balance

One of the most important factors that determine the amount of soil loss because of erosion is land use/ land cover. It influence the power arising out of erosional agent type and the characteristics of the eroding subject Morgan (1995: as cited in Woldemlak, 2005).

LULC change because of agriculture and deforestation has several environmental consequences. Agriculture can lead to soil erosion, in addition overuse of chemical inputs can also degrade soil (Matson et al., 1997). Deforestation also causes soil erosion, lowering the ability of soils to hold water and increasing the frequency and severity of floods (Goudie et al., 1997).

As Woldeamlak et al., (2005) explained LULCC will result in soil degradation, the removal of topsoil, leading to loss of soil fertility, and the depletion of biodiversity, which in turn leads to severe destruction of natural resources.

LULC has an impact for hydrological cycle. Less vegetation covered area is vulnerable for high water runoff and water retention. When runoff increases it will create the removal of sediments from the top hill and accumulates in the downstream and cause water pollution, reservoir siltation and sedimentation. (Woldeamlak, 2005).

2.1.8 Application of remote sensing and GIS for Land use/Land cover analysis

According to Wim et al. (2000), “*Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation.*” The sensor which is an instruments used for measuring electromagnetic radiation, record the reflected radiation from the surface of the earth and will be used for many analyses.

Different techniques are used to classifying remotely sensed data. Image classification is the process of grouping the pixels of an image into a specific number of individual classes based on set criteria (European Commision, 2001). Grouping is primarily based on the spectral patterns and radiance measurements obtained in the various bands of the individual pixels in an image (Wim et al., 2000). There are two main classification namely unsupervised and supervised classification. Supervised classification, requires prior knowledge of the ground cover in the study site. The supervised approach is preferred by most researchers because it generally gives more accurate class definitions and higher accuracy than the unsupervised classification (Prasetyo et al., 2009). The maximum likelihood procedure because of its robustness is used by many researchers as the most commonly applied supervised classification method. In a maximum likelihood supervised classification procedure, each pixel is evaluated for its statistical probability of belonging in each category of the LULC and assigned to class with maximum probability. Castro et al. (2002: as cited in Eleni et al., 2013).

In unsupervised classification, an algorithm is chosen that will take a remotely sensed data set and find a pre-specified number of statistical clusters in multi-spectral or hyper-spectral space (Wim et al.,2000).

Accuracy assessment is an essential and most crucial part of studying image classification and thus LULCC detection in order to understand and estimate the changes accurately. It is important to be able to derive accuracy for individual classification if the resulting data are to be useful in change detection analysis (Wim et al., 2000). The most common accuracy assessment elements include overall accuracy, producer's accuracy, user's accuracy and kappa coefficien (Jensen, 2004).

Following image classification and accuracy assessment the most important part for LULCC is change detection. Change detection is the process of identifying differences in the state of an object

or phenomenon by observing it at different times (Sing, 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Coppin, P. and Bauer, M. (1996) and Sing (1989) developed and summarized different digital change detection techniques. Some of them are:

Table 1 LULC change detection techniques

Techniques	Characteristics	Advantages	Disadvantages	Examples
Image differencing	Subtracts the first date image from a second date image, pixel by pixel	Simple and Straight forward, easy to interpret the results	Cannot provide a detailed change matrix, requires selection of thresholds	Forest defoliation, land-cover Change and irrigated crops monitoring
Image regression	Establishes relationships between bitemporal images, then estimates pixel values of the second-date image by use of a regression function, subtracts the regressed image from the first-date image	Reduces impacts of the atmospheric, sensor and environmental differences between two-date images	Requires to develop accurate regression functions for the selected bands before implementing change detection	Tropical forest change and forest conversion
Image ratioing	Calculates the ratio of registered images of two dates, band by band	Reduces impacts of Sun angle, shadow and topography	Non-normal distribution of the result is often criticized	Land-use Mapping
Post classification comparison	Separately classifies multitemporal images into thematic maps, then implements comparison of the classified images, pixel by pixel	Minimizes impacts of atmospheric, sensor and environmental differences between multitemporal images; provides a complete matrix of change information	Requires a great amount of time and expertise to create classification products. The final accuracy depends on the quality of the classified image of each date	LULC change, wetland change and urban expansion
Spectral-temporal combined analysis	Puts multi-temporal data into a single file, then classifies the combined dataset and identifies and labels the changes	Simple and timesaving in classification	Difficult to identify and label the change classes; cannot provide a complete matrix of change information	Changes in coastal zone environments and forest change

Source: Sing (1989)

2.2 Empirical Literature

2.2.1. Population growth trends in Ethiopia

Although Ethiopia has an estimated area of 1.12 million km² with wide ecological diversity, the spacio-temporal distribution of its population is uneven throughout the country (U.N. Population Division, 1999). At the beginning of the 20th century the population of the country was estimated to be 11.8 million and its growth rate was then only 0.2 percent per year. In 1950, the population size increased to more than 19 million and its growth rate had reached 2.1 percent per year (Arowolo, 2010). The growth of the population followed a slow rate of increase until 1970 and accelerated thereafter. High birth rate and slowly declining mortality rate were the main stakeholders for high population growth (Carla et al., 2001).

Table 2 Population growth; past, present, and projected future

	(population in millions)		
	1950	2000	2050(est.)
Trouble Spots			
Afghanistan	9	23	61
Angola	4	13	37
Dem. Rep. Congo	12	52	160
Iraq	5	20	55
Water scarce			
Ethiopia	18	63	169
Saudi Arabia	3	22	54
Sudan	9	29	59
Yemen	4	18	59
Tropical			
Colombia	13	42	72
Guatemala	3	11	27
Philippines	21	76	131
Tanzania	8	34	81
Giants			
China	555	1278	1478
India	368	1014	1529
Indonesia	80	212	312
Nigeria	31	112	244
Pakistan	40	156	345

Source: U.N. Population Division, 1999

As Amare (2013) explained the Ethiopian population change analysis can be divided before and after census of 1984. Population data before first census (1984) was based on sample surveys which were done in different times. The estimated data shows that the population has increased dramatically between 1900 and 1988. At the beginning of the 20th century the crude birth rate was estimated at 0.2% per annum. The total population in 1900 was estimated at 11.8 million. It took 60 years for this to double to 23.6 million in 1960. It took only 28 years for the population in 1960 to double to 47.3 million in 1988 and growth at 2.9% between 1980 and 1989.

Table 3 Projected population size of Ethiopia

Period	Reconstructed based on the 1984 census			Projected based on the 1994 census			
	Growth Rate (%)	Year	Population (thousands)	Period	Growth Rate (%)	Year	Population (thousands)
1900-1905	0.2	1900	11,754.3	1995-2000	2.92	1995	54,649
1905-1910	0.4	1905	11,871.8	2000-2005	2.73	2000	63,495
1910-1915	0.5	1910	12,121.1	2005-2010	2.62	2005	73,044
1915-1920	0.8	1915	12,424.1	2010-2015	2.44	2010	83,483
1920-1925	1.0	1920	12,933.5	2015-2020	2.26	2015	94,526
1925-1930	1.1	1925	13,606.0	2020-2025	2.05	2020	106,003
1930-1935	1.2	1930	14,367.9	"	"	2021	108,318
1935-1940	1.3	1935	15,258.7	"	"	2022	110,632
1940-1945	1.5	1940	16,281.0	"	"	2023	112,959
1945-1950	1.8	1945	17,534.6	"	"	2024	115,276
1950-1955	2.0	1950	19,182.9	2025-2030	1.85	2025	117,586
1955-1960	2.1	1955	21,197.1	"	"	2026	119,893
1960-1965	2.2	1960	23,550.0	"	"	2027	122,198
1965-1970	2.3	1965	26,281.8	"	"	2028	124,498
1970-1975	2.3	1970	29,488.2	"	"	2029	126,787
1975-1980	2.6	1975	33,085.8	"	"	2030	129,059
1980-1985	2.8	1980	37,684.7				
		1984	42,185.0				

Source: CSA, 1988 and OPHCC, 1999.

Ethiopia now stands as the second most populous country in Sub-Saharan Africa, after Nigeria. It is projected that the population will increase to 96.6 million by 2015, and 175.4 million by 2050 (UN, Population Division, 2009)

2.2.2 Population growth trends in Addis Ababa

As Tamiru et al.(2003, cited in Tekeste, 1990) the number of Addis Ababa’s population was 65,000 in 1912, which grew to 100,000 in 1935 .According to Central Statistic Authority (CSA, 2011), the population of Addis Ababa has grown from 443,728 in 1961 to 683,530 in 1967, 1,167,315 in 1978, 1,423, 111 in 1984, 2,112,737 in 1994, 2,739,551 in 2007, 2,979,000 in 2011 and 4,620,000 in 2015.

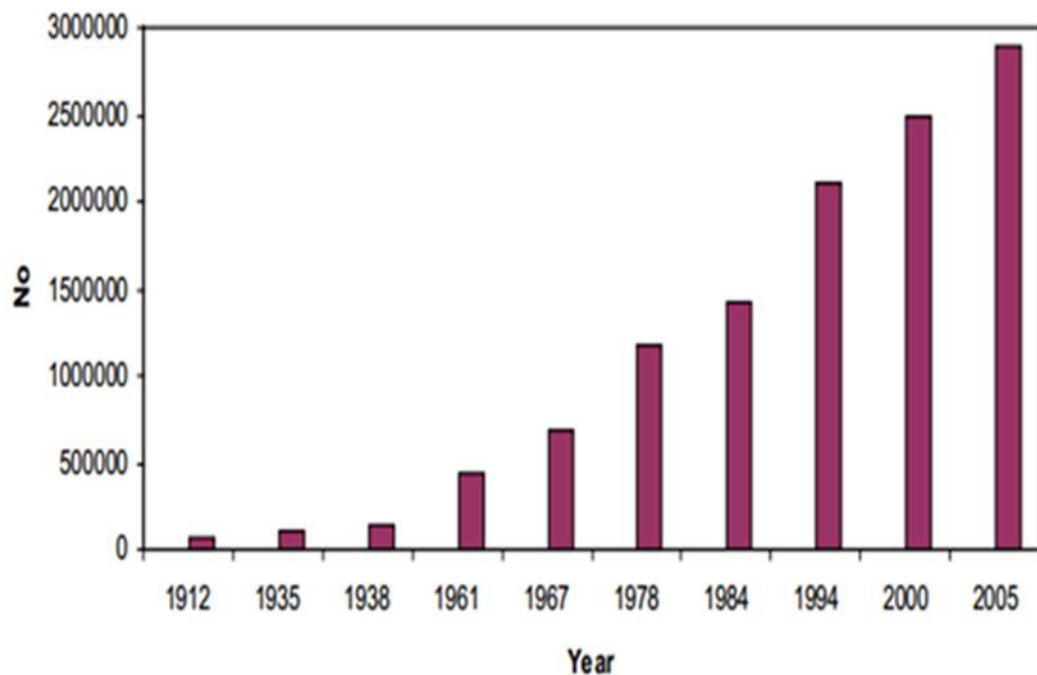


Figure 10 Population growth in Addis Ababa

Source; Tamiru, et al. 2003

According to Addis Ababa Urban Planning Institute (2012), the population density of Addis Ababa is 5271 people per kilometer square and it decreases from inner Weredas to peripheral areas.

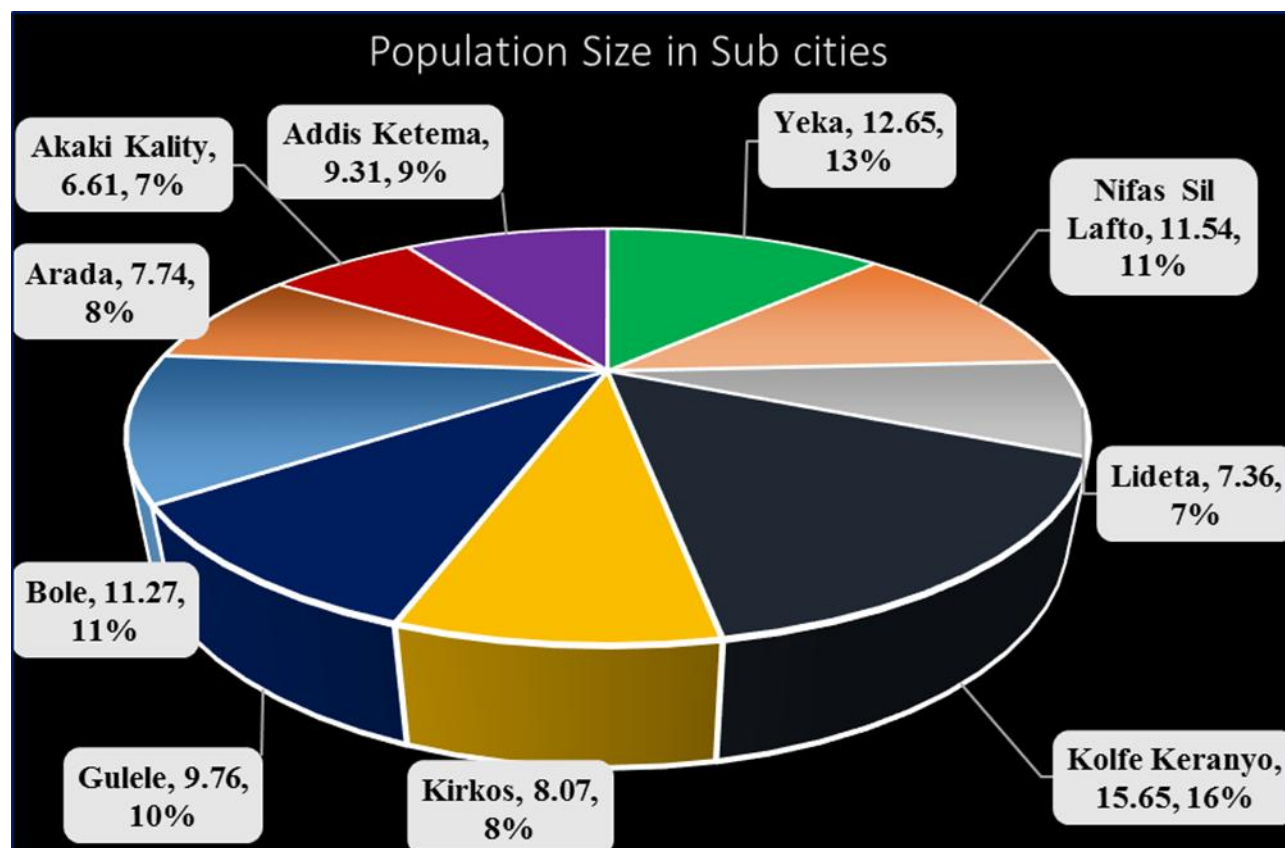


Figure 11 Population size in sub cities

Source: Addis Ababa Urban Planning Institute, 2012

2.2.3 Land use/Land cover change in Ethiopia

According to Messay (2011, as cited in Aklilu, 2006), 88% of the the country's population is located in the 45% of the country's highland, with an altitude of greater than 1500m. Ethiopia has huge diversity in biological resources: forest, woody, and grass lands, shrubs, and varied wildlife. But, it is eliminating.

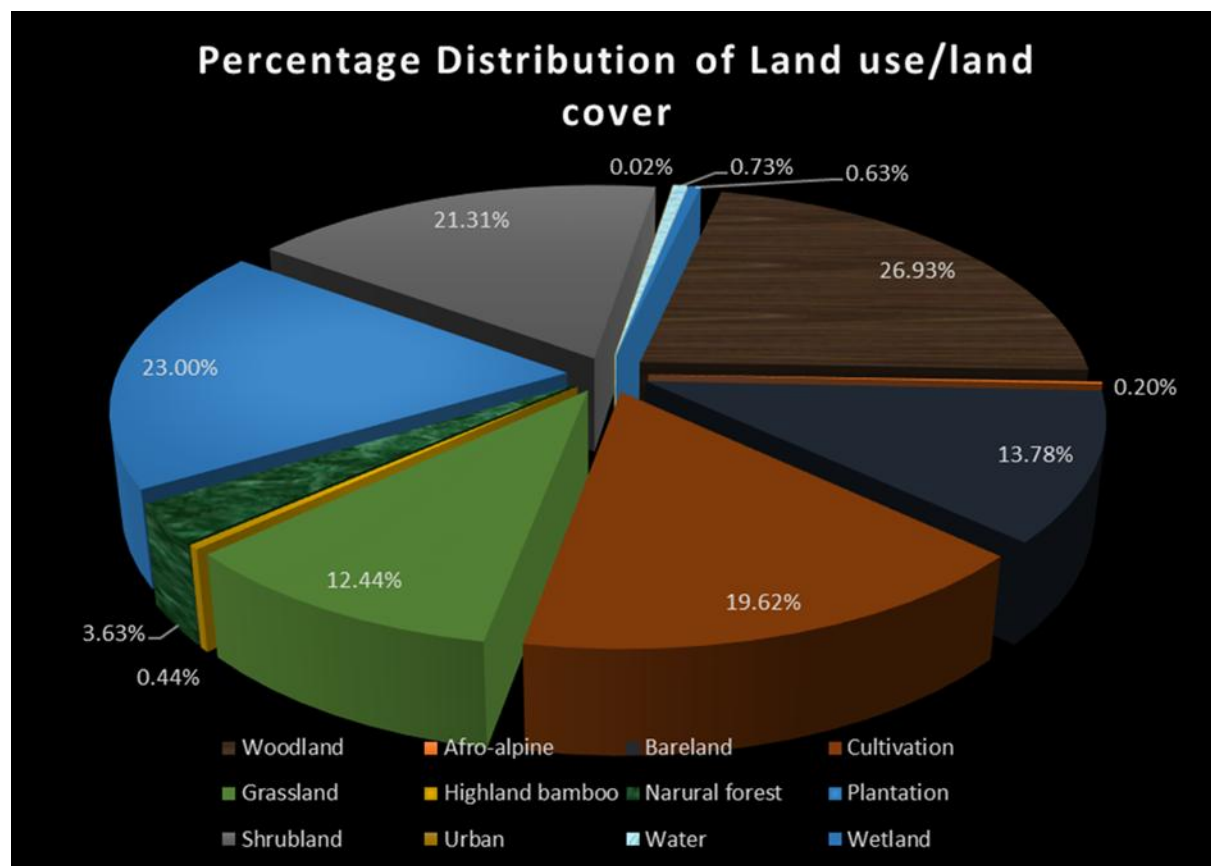


Figure 12 Percentage Distribution of LULC change in Ethiopia

Source Messay (2011)

In addition to this, Ephrem (2010), explained the LULC distribution of Ethiopia based on grazing and browsing (50%) occurs in cultivated areas, in woodlands and forests, bushlands, shrub lands, grasslands and in not usable lands. Cultivation forms (23%) , woodlands cover about 7 percent and bare land(16%) , in the form of exposed rock, salt flats and sand.

According to Hussein (2009), in different parts of Ethiopia, the type of natural resources and their change vary from place to place. The Ethiopian highlands receive between 600 and 2700mm of rainfall annually. Besides high rainfall variability and water shortage is widespread in the highlands. At the beginning of 20th century forest and woodlands coverage of Ethiopia was 40 %

of the total area of the country. But presently this figure is estimated at less than 3% (Badege, 2005).

Most of researches carried out in Ethiopia have shown that there were considerable LULC changes in the second half of 20th century because of deforestation and gradual change of cultivation land beyond expected limits were the major causes of land degradation, particularly in the highland part of the country (Daniel , 2008).

As noted in the Mengistie et al (2013), LULC change is one of the main problem related with agricultural production in Ethiopia. The total area of the country 1,130,000 km² is experiencing huge land use/land cover change in natural vegetation, farming practices and human settlement. The highland part of the country which contributes 44% of the county has severe problem.

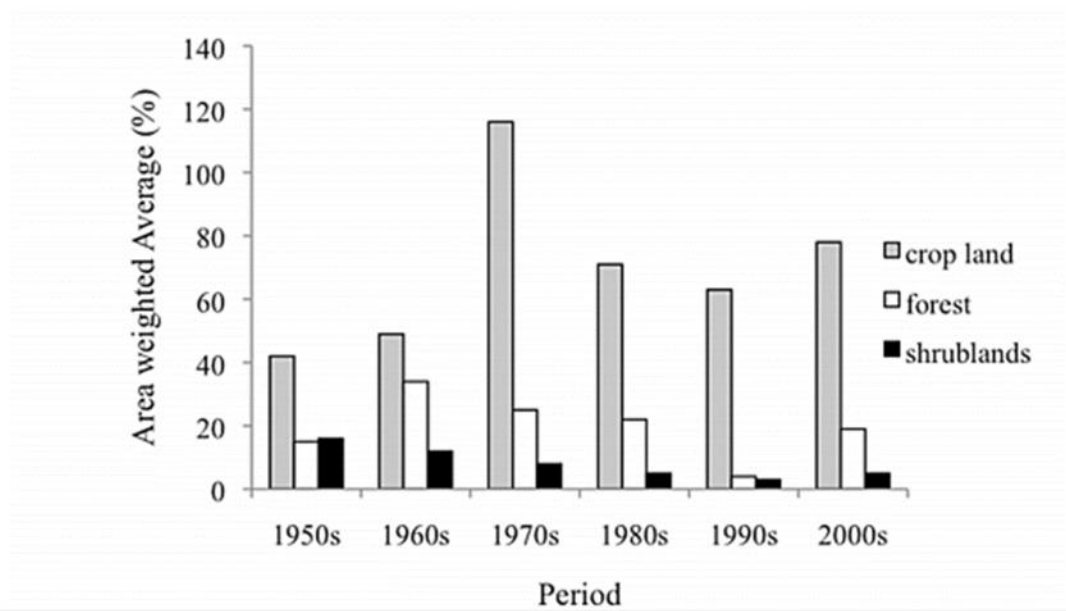


Figure 13 General trend of crop land increment and reduction of shrubs and forest

Source:Alemayehu, 2010

According to Daniel (2008), many reports shown heterogeneity in the changes, type, pattern, direction, and magnitude of LULC in the country and have seen the difficulty of predict the known trends to areas that have not been studied. For instance Messay (2011) in his study, in the district of Nonno, detected both types of changes (conversion and modification) and six major land use types. Girma, (2003) also reported the decline of natural forests and grazing lands due to conversions to croplands in southern Wello. On the contrary (Woldeamlak Bewket, Sterk, G., 2005) found the opposite i.e an increasing trend by 19 % from 1957-1982 and 27% from 1982 - 1998 in Chemoga watershed area.

Most of the rural population is dependent on mixed farming system of crop production and livestock which has high demand on cultivated land and settlement and trees for fuel and construction purposes aggravates the change of LULC. The growing of population is one of the most critical drivers of the observed land cover dynamics because the livelihood of almost the entire rural population depends on it (Gebresamuel et al., 2010).

In Ethiopia and other developing countries population growth has been the main cause of land use and land cover change than other forces (Sage, 1994). Many research in Ethiopia shows the impacts of population pressure on LULC changes. For instance, population pressure has been found to have negative effect on riverine vegetation, scrublands and forests in Kalu district (Tekle, et al., 2000), Riverine trees in Chemoga watershed (Woldeamlak, et al., 2005), and natural forest cover in Dembecha Woreda north-western Ethiopia (Zelege G.and Hurni H., 2001).

Daniel (2008) identified in the 32-years period between 1972 and 2004 shrub-grassland and riverine trees covers had decreased at a rate of 21.5 and 16.3 ha per year respectively. Riverine trees suffered the greatest devastation and by 2004 had been reduced to only 16% of their cover in 1972. In contrast, eucalyptus tree plantations, annual crops and bare land/open grassland cover

increased at a rate of 2.8, 12.5 and 24.8 ha per year, respectively. He concluded that population pressure was an important driver for expansion and intensification of agricultural land in recent periods.

According to Asmamaw (2013), land use and land cover changes and socioeconomic dynamics have a strong relationship. Since when population increases the need for cultivated land, grazing land, fuel wood, settlement areas also increases to meet the growing demand for food and energy, and livestock population.

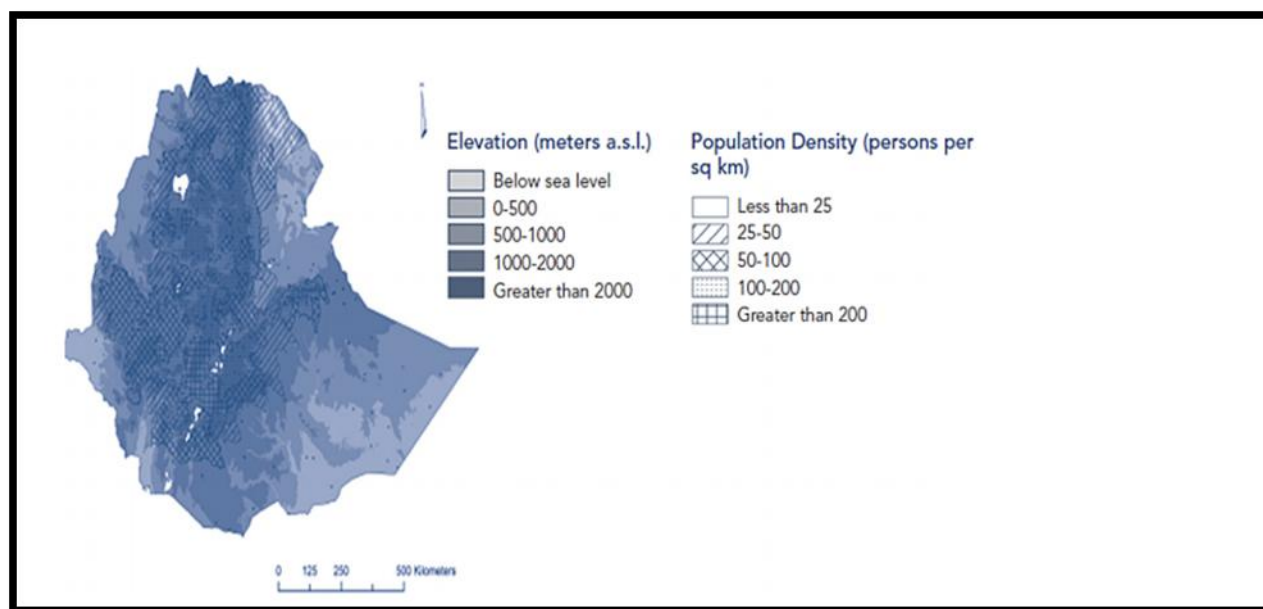


Figure 14 Elevation and population density in Ethiopia

Source (Alemayehu, 2010)

The findings by (Mulugeta, 2004) and Woldeamlak (2003) shown LULC changes have resulted in soil degradation, the removal of topsoil, leading to loss of soil fertility, and the depletion of biodiversity, which in turn leads to difficult in replacing its natural cover. Eleni et al., (2013) also showed a significant decrease of natural woody vegetation of the Koga catchment since 1950 due to deforestation in spite of an increasing trend in eucalyptus tree plantations after the 1980's.

And recently (Ermias, 2015) showed the land use and land cover changes in the Upper Blue Nile (Abay) basin Jedeb watershed since 1957. His findings shows that cultivated land and grassland were the dominant LULC classes, but the cultivation coverage increased through time.

Many of the researches in Ethiopia indicated that LULC change and population change have a strong relationship; as population increases the need for cultivated land, grazing land, fuel wood; settlement areas also increases to meet the growing demand for food and energy, and livestock population. Thus, population pressure, lack of awareness and weak of management are considered as the major causes for the deforestation and degradation of natural resources in Ethiopia.

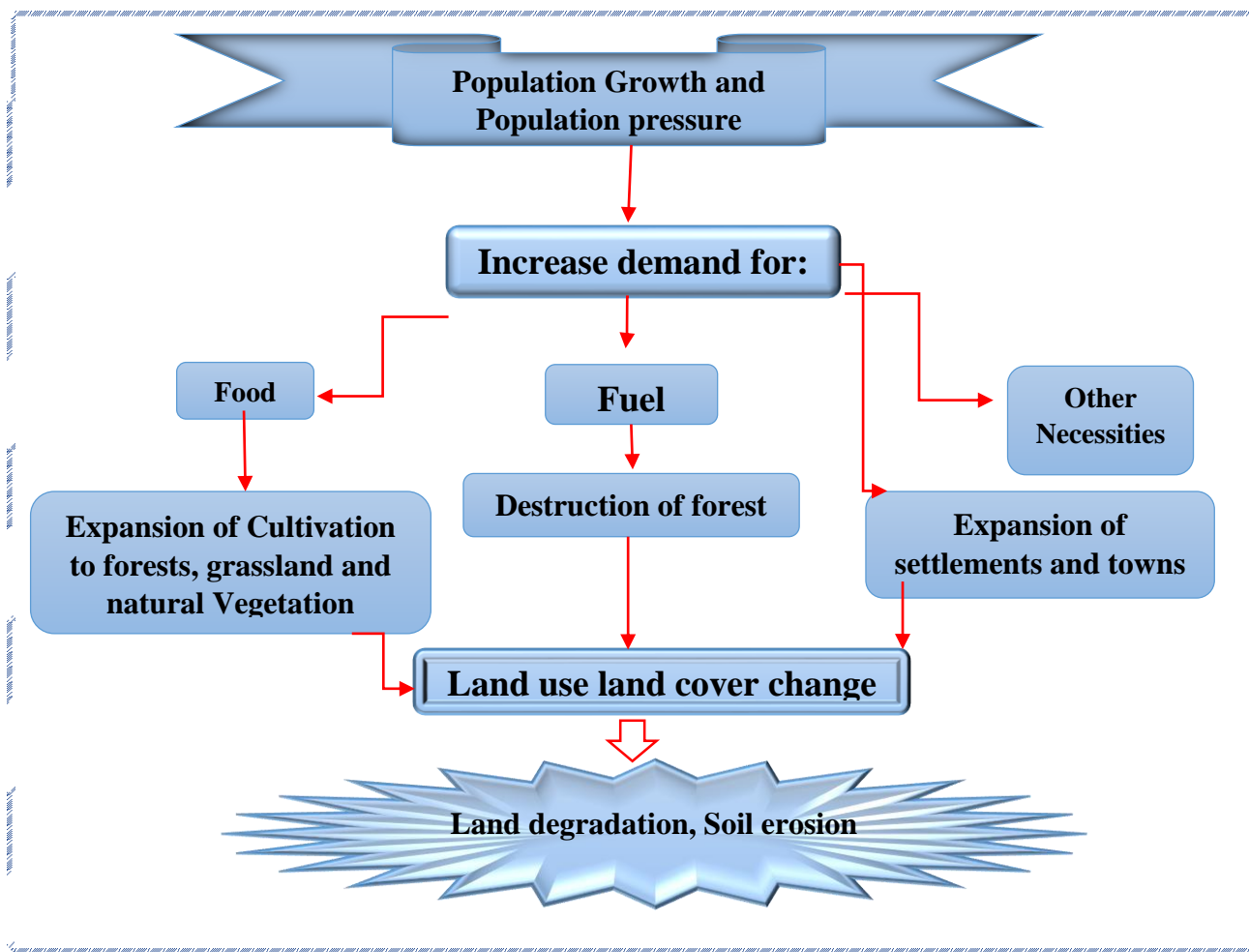


Figure 15 Conceptual framework

Source: Designed based on literature review

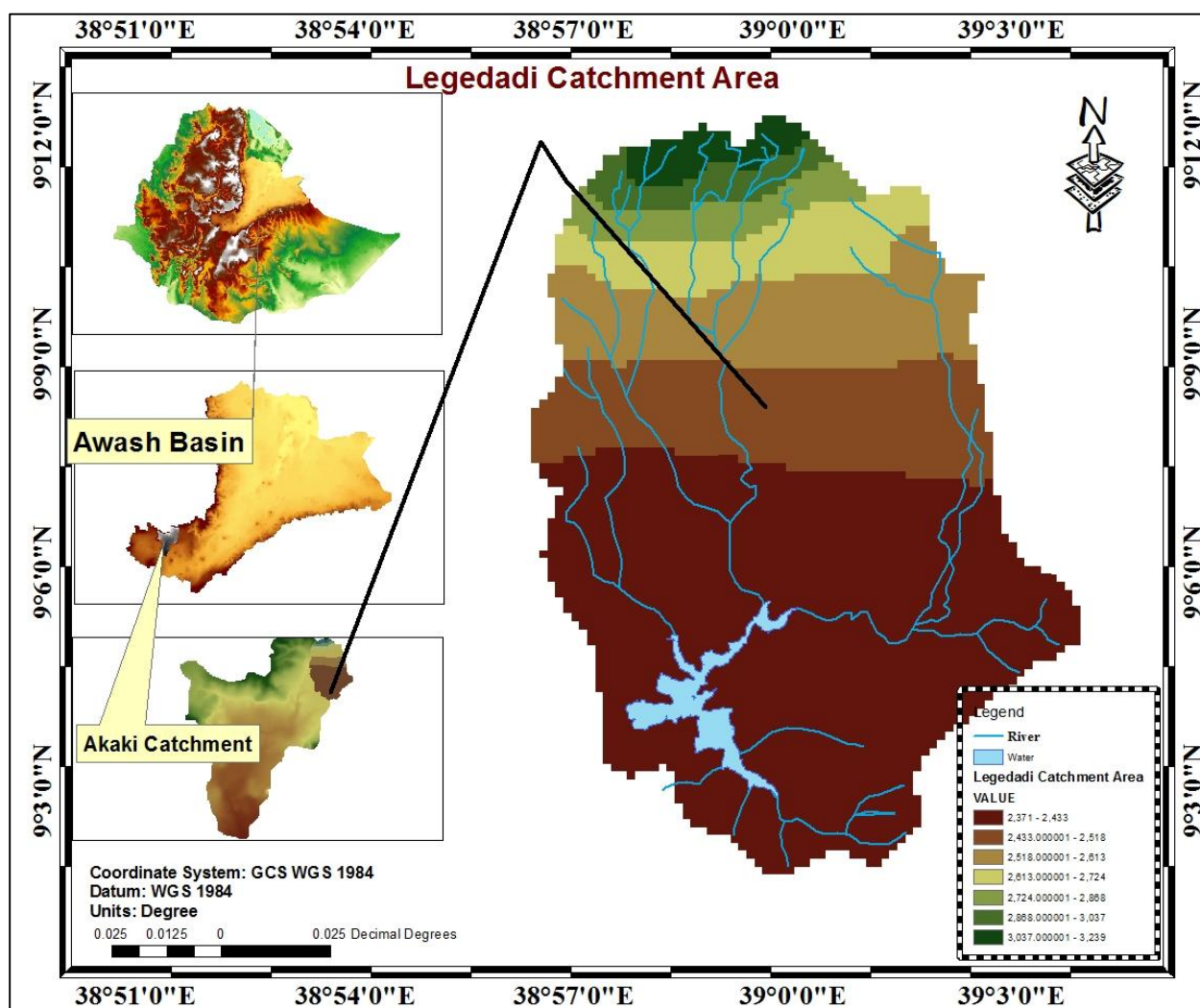
Chapter III

Materials and Methods

3.1 Description of the Study Area

3.1.1 Location and Topography

The study area is located about 25 km from Addis Ababa in the east direction. The Legedadi Catchment Area exists in Awash basin. The catchment is bounded by latitude 9°01' N – 9°13' N and longitude 38°60' E - 39°07' E. In general, the catchment area has a total area of 217 km².



The Legedadi dam, constructed in 1970 to harvest run-off water during the rainy seasons for urban water supply, is the principal source of water for the Addis Ababa Metropolitan Area. The Addis Ababa-Dessie main asphalt road runs west-east across the central part of the reservoir catchment area. Dry weather road crosses the catchment area from South to North (Andualem, 2008).

There are five sub-catchment areas for the legedadi catchment basin and these sub-catchment areas are found in nine kebeles of the Bereh wereda.

- 1) The Lege beri, sub catchment
- 2) The Sekoru-Fule sub catchment
- 3) The Lege bolo sub catchment
- 4) The Sendafa sub catchment
- 5) The south sub catchment

These five sub catchment areas are also divided in to three substream based on their altitude, river flow and location form the LWR. The upper stream areas are the northern part of Lege beri, Sekure-Fule and Lege-Bolo and Sendafa sub catchment areas (Dabe Muda Godo, Girari Reh, Deri-Sokoru *kebeles* and Sendafa town), the Midstream areas are the middle areas of Lege beri, Sekure-Fule and Lege-Bolo and Sendafa sub catchment areas (Lege-beri Lege-bolo and Weligwo *kebeles*) and the downstream area includes the southern catchment area (Lenicho-Choba Sululta and Chebi Sire Guyo *kebeles*). Lege Sekoru and Lege Fule enter Legedadi reservoir via a common course. Lege Bolo and Lege Sendafa also merge several hundred meters before entering Legedadi reservoir (Thael, 2003).

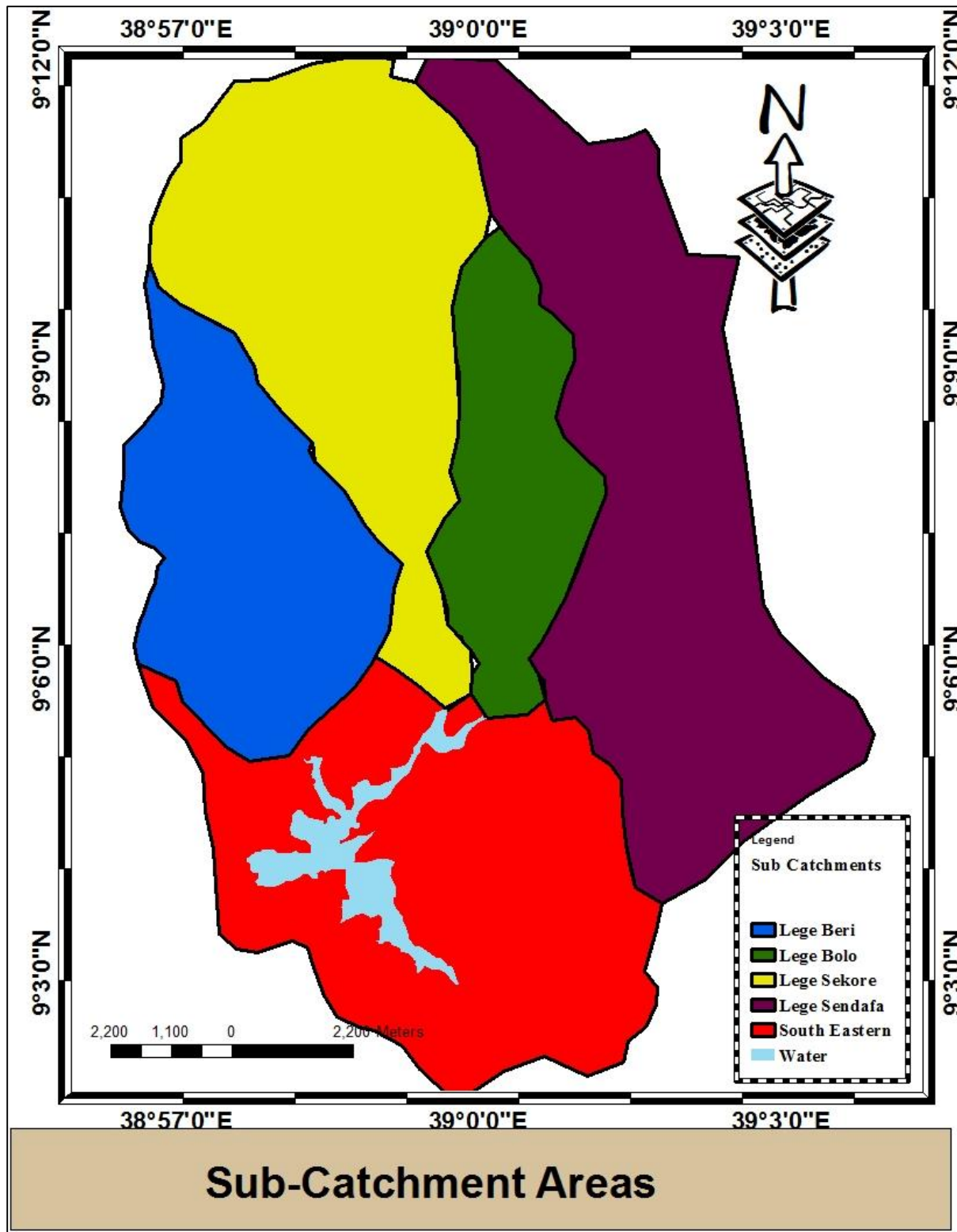


Figure 17 Map of Legedadi Sub Catchment areas

3.1.2 Lededadi Dam and Reservoir

The Legedadi dam was constructed and commissioned in 1970. It is partly constructed of earthen section with a height of 22 m and crest length of 600 m. The other section is of a concrete buttress of height 44 m and length of 400 m. The concrete buttress section has overflow spillway gates (Thael, 2003).

3.1.3 Geology and soil condition of the catchment

The Addis Ababa area is found in the transitional boundary between north western highlands which ranges from Intoto to the western lowlands of Ethiopia and rift valley which is running about 35 km from the city. These areas have basic differences in the types of their rocks. The main rock types in the rift valley are acidic, mainly quaternary rocks, whereas the plateau rocks are basic and belong to older tertiary formations. The area of Addis Ababa city and the Legedadi catchment area lie exactly on the boundary of the main blocks. Therefore, all major rocks found, both on acidic and basic (Bceom, 1993).

There are four soil types, which cover the Addis Ababa and surrounding close region (according to their genetic origin), namely, alluvial, colluvial, residual and lacustrine deposits (Bceom, 1993).

3.1.4 Climate

There are two seasonal weather patterns in the region of Addis Ababa, and these are clearly observed and reflected by the weather observation records. From summer season the weather is relatively cool and wet, mainly from July to September, a strong air current moves from the Gulf of Guinea to the Upper Awash and Abay (Blue Nile) watersheds, but from October to June it has warmer temperatures and less rainfall with easterly winds. The rainfall patterns in the region of

the areas have strong peaks in the summer months and minor rainfalls in the months of March and April (Thael, 2003).

The daily average temperature ranges of the area is between 9.9 to 24.6°C and the mean monthly temperature ranges between 15°C and 18°C (Alema, 2009).

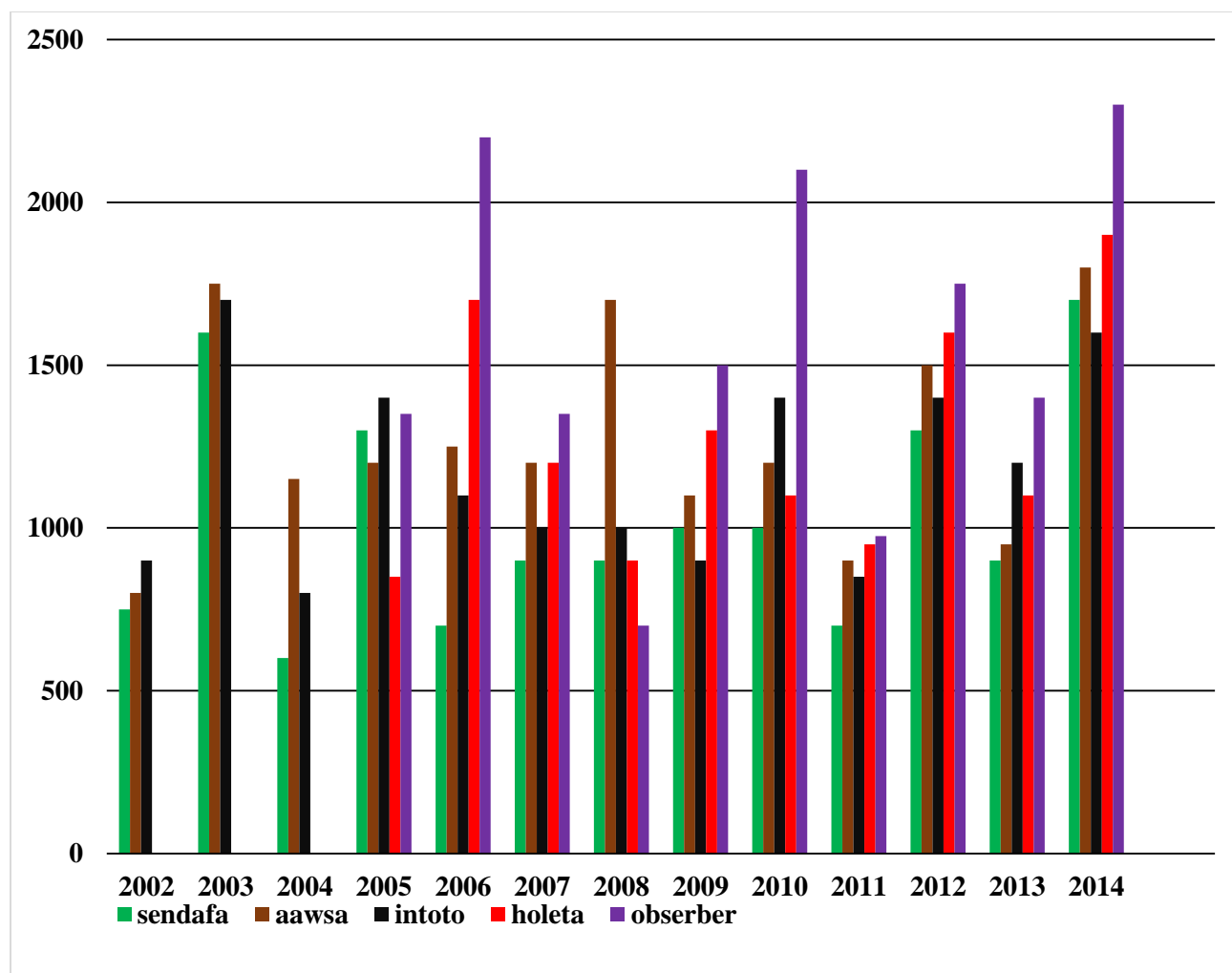


Figure 18 Annual rainfall in different stations around Addis Ababa and LCA

Source: Endalkachew, (2012)

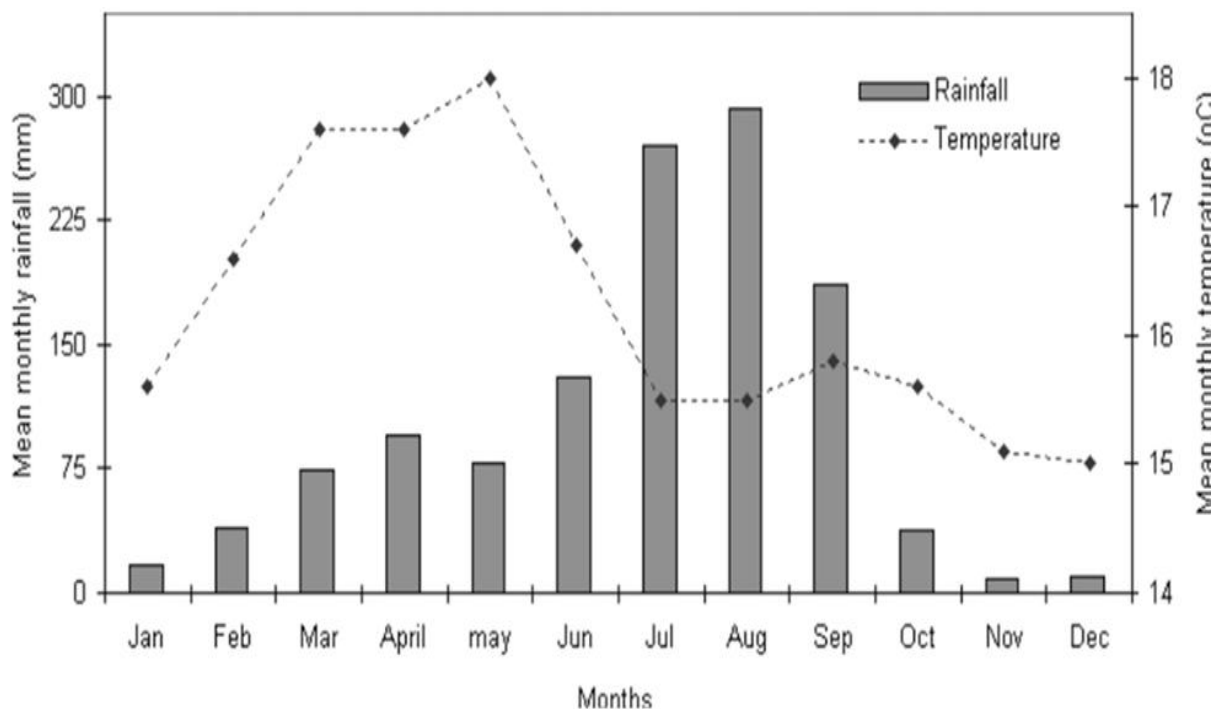


Figure 19. The relationship between rainfall and temperature in the catchment area

Source: (Alema, 2009)

3.1.5. Farming System

Agriculture is the main economic base of Ethiopian economy contributing around 50 percent of the GDP; provide employment and source food for the majority of the rural inhabitant. It dominated by the smallholder farm households and provides more than 70% of the agricultural raw materials (UNHDI, 2014).

In LCA also farming is dominated by more of smallholders and the main crops cultivated are cereals (*wheat, teff and barley*). Beyond these cereals the crop of significance are different kinds of pulses (lentils, vetch, chickpeas, and horse beans). In addition there are small commercial eucalyptus plantations and vegetable fields (onion, garlic and cabbage). All cultivation is rain-fed.

3.1.6 The linkage between Addis Ababa and Legedadi Catchment Area

Since the establishment of Addis Ababa as the capital city and commercial center of Ethiopia in 1886 in the country, the principal sources of water were the numerous springs located at the foot of the Intoto mountain range and hand dug wells located in the lower areas. Continued growth necessitated the construction, in 1938, of a plant at the foot of Intoto to treat water from a number of springs and the nearby Kechene River, and in 1944 the original Gefersa dam located North West of the city was completed. In 1966, the raw water storage capacity in the Gefersa watershed was increased with the construction of another small dam north of the existing dam. This dam was also assumed to assist as a sediment trap (AAWSA, 2015).

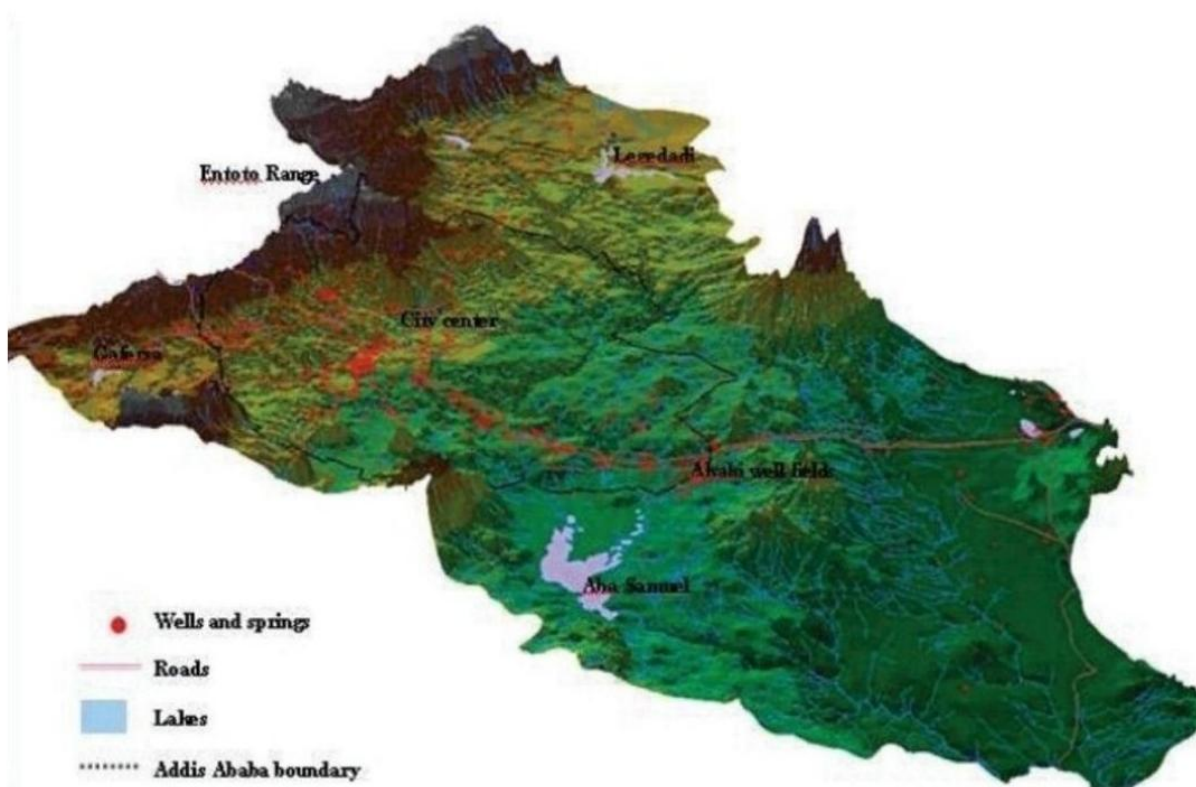


Figure 20 The 3D View of Addis Ababa and the surrounding

Source: (Alema, 2009)

According to Amdework (2012), currently there are three main surface water dams as sources for the surface water supply for Addis Ababa. These are Gefersa, Legedadi and Dire. Legedadi dam is situated 25 km east of Addis Ababa. Legedadi dam (treatment plant) which was 60,276,776m³/year with 61 percent of the total water supply of Addis Ababa. Legedadi subsystem includes supplies from Legedadi water treatment plant to service reservoirs of Kotebe terminal, karalo, Ankorcha, Jan Meda, Gebrial Palace, Teferi Mekonnen, Entoto, AAWSA main office, Belay Zeleke, Police Hospital, Army hospital and Kasa Gebre; and to pumping stations at Ureal and Mexico square.

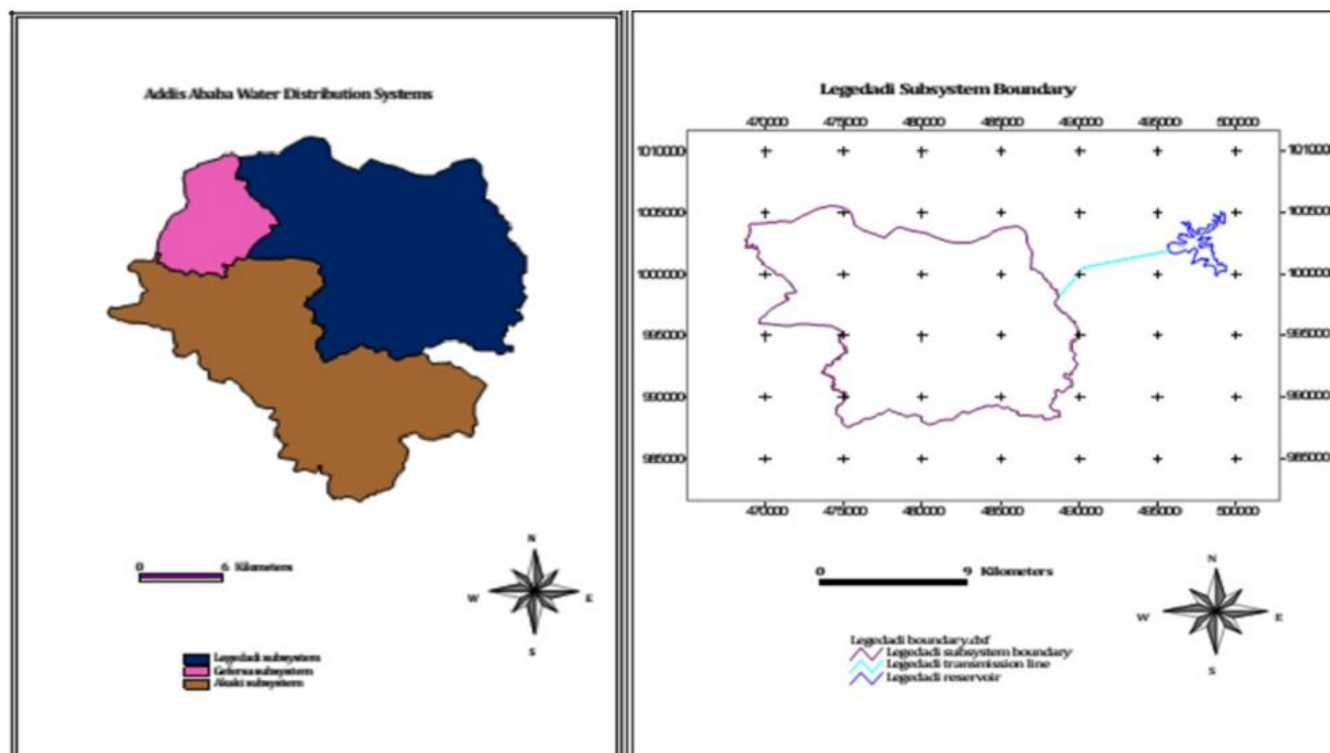


Figure 21 Water supply area and location of LWR

Source: (Amdework, 2012)

3.2 Research Methodology

3.2.1 Data Acquisition

Different kinds of data have been collected from different sources to conduct this study. Satellite images, field data information from local people. The secondary data such as, long-term population data of the study area from CSA and Long – term LWR silt deposition and volume of the reservoir through different time from AAWSA were used to carry out this study and were dealt with in detail.

3.2.2 Long-term population data

To examine the population change in the study area, population data was obtained from different sources: Census, periods (Inter-censal) and from the study area wereda administration.

The first census 1984 data was obtained from Central Statistic Authority (CSA), the 1999 population was calculated based on the geometric growth formula and the 2014 population was obtained from Bereh *wereda* administration.

3.2.3 Image processing

The Landsat program started in 1972 with the Landsat-1 satellite carrying the MSS multispectral sensor. After 1982, the Thematic Mapper (TM) replaced the MSS sensor. Both MSS and TM are whiskbroom scanners. In April 1999 Landsat-7 was launched carrying the ETM+ scanner. And Landsat-8 was launched on February 11, 2013 (Wim et al., 2000).

The three such images used for this study are the Landsat Thematic Mapper of 1984 and 1999, and Landsat Enhanced Thematic Mapper Plus (ETM+) Image of 2014. These images were obtained from Ethiopia Mapping Agency (EMA). All the scenes obtained from the EMA were already

georeferenced to the Universal Transverse Mercator (UTM) map projection (Zone 37), WGS 84 datum.

Images were composed in different ways in order to identify surface features in the study area. True color composite usually known by RGB 321 combination were band 3 reflects red color, band 2 reflects green and band 1 reflects blue color. Another composite called "false color composite" which uses an RGB combination of 432. In this band combination band 4 represents the NIR infrared, band 3 belongs to red and band 2 to green. This combination gives better visualization in identifying vegetation which looks red in 432 combinations.

The local administrative data and topographic map of the study area were obtained from CSA and Ethiopian Mapping Agency (EMA) respectively. And the catchment area boundaries are found from AAWSA previous year works and DEM. These were brought to Universal Transverse Mercator (UTM) projection in zone 37⁰N.

The final LULC classes were classified and mapped. Erdas Imagen 2013 and ArcGIS 10.3 soft wares were used to process both the pre-and post-image processing and quantification works.

Table 4 Landsat image sources and characteristics

No	Data type	Sensor	Date of Data Acquisition	Path/Row	Resolution
1.	Landsat images	TM	December 21, 1984	168/53	30m by 30m
2.	Landsat images	TM	January 15, 1999	168/53	30m by 30m
3.	Landsat images	ETM+	December 21, 2014	168/53	30m by 30m

Source: EMA (2015)

3.2.4 Long-term amounts of silt deposition and volume of Water of the Legedadi Reservoir

Long-term silt deposit and volume of Water of the Legedadi Reservoir records were obtained from Addis Ababa Water Supply and Sewerage (AAWSSA). These were used to analyze the correlation of LULC change and the volume of water and silt deposition.

3.2.5 Socio-economic baseline supplementary data

As indicated earlier the research design that was employed in this paper is concurrent type of mixed approach. Therefore, in addition to the laboratory based data and secondary data, some socio-economic quantitative and qualitative data were generated by using survey questionnaire, focus group discussions and key informant interviews.

3.2.6 Household Questionnaire Survey

This was another vital data acquisition technique in the study. The questionnaire survey enabled the researcher to capture multiple socio-economic and biophysical attributes in the catchment. Emphasis was given to demographics, to identify the variables that determined the crop production per year in quintal, and causes of land-use/cover change.

Selection of sample households for the questionnaire-based survey followed a two-stage sampling design. In the first stage 2 *kebeles* were selected purposively out of the 10 *kebeles* in the catchment area. In the second stage sample households were selected by using systematic random sampling from the list of the households.

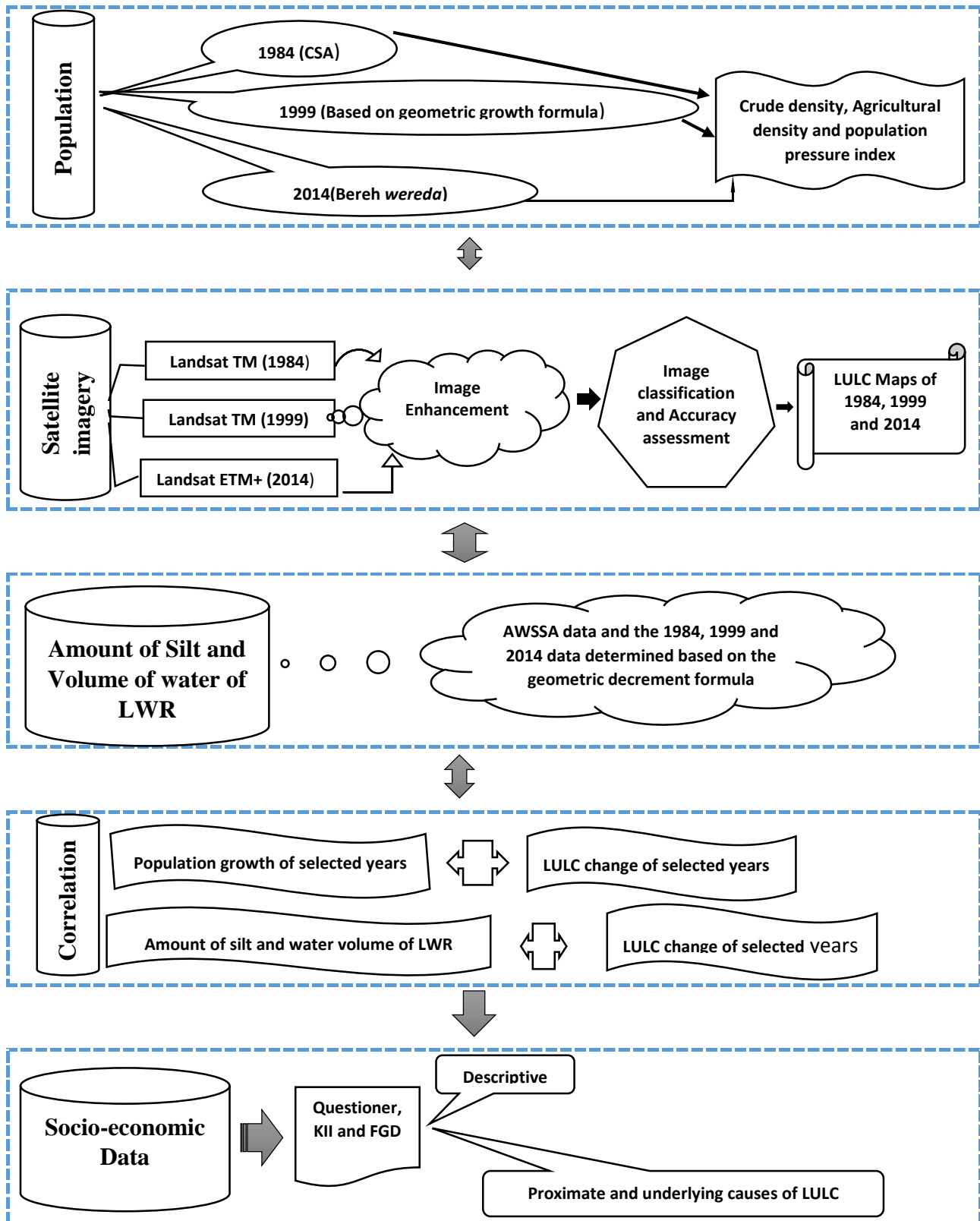
3.2.7 Key Informant Interview

Key informant interviews were carried out with the intention of capturing more firsthand socio-economic and biophysical data for the study. The key informants were the elderly, experts in AAWSA, chairmen and managers of *kebeles*. Each interview were carried out by the researcher with the aim of making further investigations on the basis of the information received from the respondents.

3.2.7 Focus Group Discussion (FGD)

The focus group discussions were carried out with representatives from different economic status (well-off and indigent), education, gender, age group (youth, adult and elderly), and community-based organizations. And this discussion were related to population growth, environmental protections, and causes of LULCC.

Table 5 General methodology and flow of the study



3.2.8 Method of Data Analysis

To achieve the objectives of the study, several statistical techniques were employed. These are described in the sub-sections below.

3.2.9 Analysis of population data

As indicated earlier, the data of population was obtained mainly from, Central Statistical Agency (CSA) 1984, Bereh *wereda* administration (2014) and estimation by the geometric growth formula (1999). These data were used to understand the population pressure of the study area.

Equation 1 Geometric growth of population

$$P_t = p_0 (1 + r/100)^n$$

P_t = the population at time t,

P_0 = population size of the initial census,

n = the time elapsed between the two census periods.

r = growth rate

The population pressure level was determined by using the Population Pressure Index (PPI) method (Soemarwoto, 1985). The index of population pressure is calculated as follows:

Equation 2 Population pressure index

$$PPI = Z(1 - \alpha) \frac{fp_0(1 + r)^t}{L}$$

PPI = Population index at year t

t = time

L = L is the total of agriculture area (KM²)

- Z** = is the minimum agriculture land-hold for proper life of each farmer
P = Population
r = Annual rate of population growth at year
f = is the proportion of farmer in population
 α = is the proportion of non-agricultural income and agricultural income

If the PPI index is less than one, it means there is no population pressure on land and that land can still accommodate agricultural activities (Soemarwoto, 1985).

To show the spacio-temporal population pressure index of 1984 the national agricultural and non-agricultural income from CSA were used. The 2014 population pressure were calculated based on the data which were found from Bereh *wereda* administration.

In addition to this, the crude density and agricultural density were calculated based on the ratio of total population with total area of the study area and the rural population with the cultivated area which was found by the GIS classification of LULC.

3.2.10 Land-use/cover classification and analysis

3.2.11 Image processing

The remotely sensed image data is usually not ready for use directly but need to undergo a series of preprocessing steps. Image processing consists of processes aimed at the geometric and radiometric correction, enhancement or standardization of imagery to improve our ability to interpret qualitatively and improve our ability to interpret qualitatively and quantitatively image components. In order to cover the intended period of study, different types of imageries originating from different types of sensors were used. Hence two different years (1984 and 1999) thematic mapper(TM) and Landsat 8 (2014) for about three decadal time.

Since Ethiopian Mapping Agency collected the satellite images from the United States Geological Survey(USGS), which freely offers the Landsat Orthorectified data collection which consists of a global set of high-quality, relatively cloud-free Orthorectified TM and Landsat 8 imagery therefore there is no need for geometric correction but checking of the position was made using scanned Toposheet of 1:50000.

After the satellite images were georeferenced and radiometrically corrected, color composite, and extracting the catchment area, were carried out, then image interpretation was performed.

3.2.12 Development of classification scheme

Based on the prior knowledge of the study area and additional information from previous research in the study area six different types of land use and land cover have been identified for Legedadi Catchment Area. Accordingly six classes were identified namely cultivation, water, grassland, Eucalyptus forest, Settlement and Natural Vegetation. The descriptions of these land uses and land covers are given as follows:

Table 6 Description LULU types identified

LULC classes	Description
Water	The legedadi water reservoir, the rivers and its main tributaries.
Settlement	Urban areas and Permanent residential areas of varied patterns.
Natural Vegetation	Area with a plant community, characterized by a mixture of shrubs herbs.
Eucalyptus	Land covered with dense Eucalyptus trees.
Grassland	Areas covered with grass used for grazing, as well as bare lands that have little grass or no grass cover.
Cultivation	Areas used for crop cultivation, both annuals and perennials, dispersed rural settlements, and homesteads.

3.2.13 Image Classification

To perform the classification the maximum likelihood supervised classifier were employed. Training areas for all spectral classes were developed composing each information class to be identified by the classifier. Maximum likelihood classifiers, which are a widely used form of supervised classification, assume the training data statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. In a maximum likelihood supervised classification procedure, each pixel is evaluated for its statistical probability of belonging in each category of the LULC classes and assigned to class with maximum probability.

3.2.14 Accuracy Assessment

Accuracy assessment is an important step in the image classification process. Land use/cover classification is not free from errors. Errors may appear from the method of image capturing to the classification technique implemented. Thus, image classification needs accuracy assessment at last. The accuracy assessment were be done by using the first hand data collected by using GPS. From different methods of classification accuracy assessments, the dominant and mostly used classification error matrix or a confusion matrix were produced. The overall classification accuracy and an overall Kappa statistics were calculated. The Kappa coefficient implies the errors that may come with simple random classification and over all classification accuracy reveals that the amount of classification accuracy. In addition, producer and user accuracy were also be attained from the matrix created. Producer's accuracy is calculated as the total numbers of correct pixels in a category divided by the total numbers of pixels of that category as derived from the reference data (i.e. the column total). This accuracy measure indicates, the probability of a reference pixel being

correctly classified. On the other hand, if the total number of correct pixels in a category is divided by the total number of pixels that will be classified in that category, it is said to be user's accuracy or reliability (Congalton, 1991).

Equation 3 kappa statistic formula

$$\text{Kappa} = \frac{N \sum_i^r - \sum_i^r (x_i + x + i)}{N^2 - \sum_i^r (x_i + x + i)}$$

N is the total number of observed pixels

r is the number of rows

x_i is the number of observations in row i and column i,

x_i+ and $x+i$ are the marginal totals of row and column, and

3.2.15 Statistical method to determine Optimum samples for accuracy assessment

Sample size of the accuracy assessment was also determined using a two formula derived from (Cochran, 1977) . The first formula determined desired sample size while the second one the actual size of sample of each classified classes based on the KmX^2 of the study area.

$$n_o = \frac{Z^2 pq}{e^2}$$

n_o = sample size

Z= confidence level (1.96 or 95% confidence)

p= percentage of picking choice (0.5 as there is equal chance of picking)

q = 1-P

e= tolerance error (0.05 for 95 % confidence)

$$\mathbf{n} = \frac{n_o}{1 + \frac{(n_o - 1)}{N}}$$

n = sample size and

N = area size in sq. km.

No= sample size

In the above formula, a total test samples of 138 for image 1984, 1999 and 2014 was randomly selected respectively from the original mosaic images of 1984 and 1999 and 2014. The accuracy assessment was done with the help of GPS and Google earth for the images 2014. In addition for 1984 and 1999 images some of the sample points was supported by the EMA toposheets 0939 D4 and local area elders as “what was there at what time” and for 2014 visual observations was carried out.

3.2.16 Land use/land cover change detection analysis

Post classification image comparison technique was conducted for LULC change detection analysis. According to Lu et al. (2003, as cited in Ashenafi Burqa, 2008). The post classification change detection method was found to be the most preferable for land use/land cover change analysis. This approach is generally considered the most obvious approach to change detection (Liu, H. and Zhou Q., 2004). As Serra et al. (2003), explained post-classification approach requires

the comparison of independently classified images of the same study area acquired over two different time periods.

Post image classification separately classifies multi-temporal images into thematic maps, then implements comparison of the classified images, pixel by pixel. It minimizes impacts of atmospheric, sensor and environmental differences between multitemporal images; provides a complete matrix of change information (Sing, 1989).

The classified images were compared over three decades i.e. 1983-1999, 1999-2014 and 1984-2014. Change statistics were computed by comparing values of area of one data set with the corresponding value of the second data set in each period. The values were presented in terms of kilometer square and percentage. Quantification of the rate of change has been applied to generate information about the land use/land cover dynamics of the study area. The rate of change of each land use and land cover can be calculated using the following formula:

$$\text{Equation 4 Rate of change} \quad \text{Rate of change} = \frac{x-y}{y}$$

, where **X**= recent area of land use land cover

Y= Previous area of land use/land cover

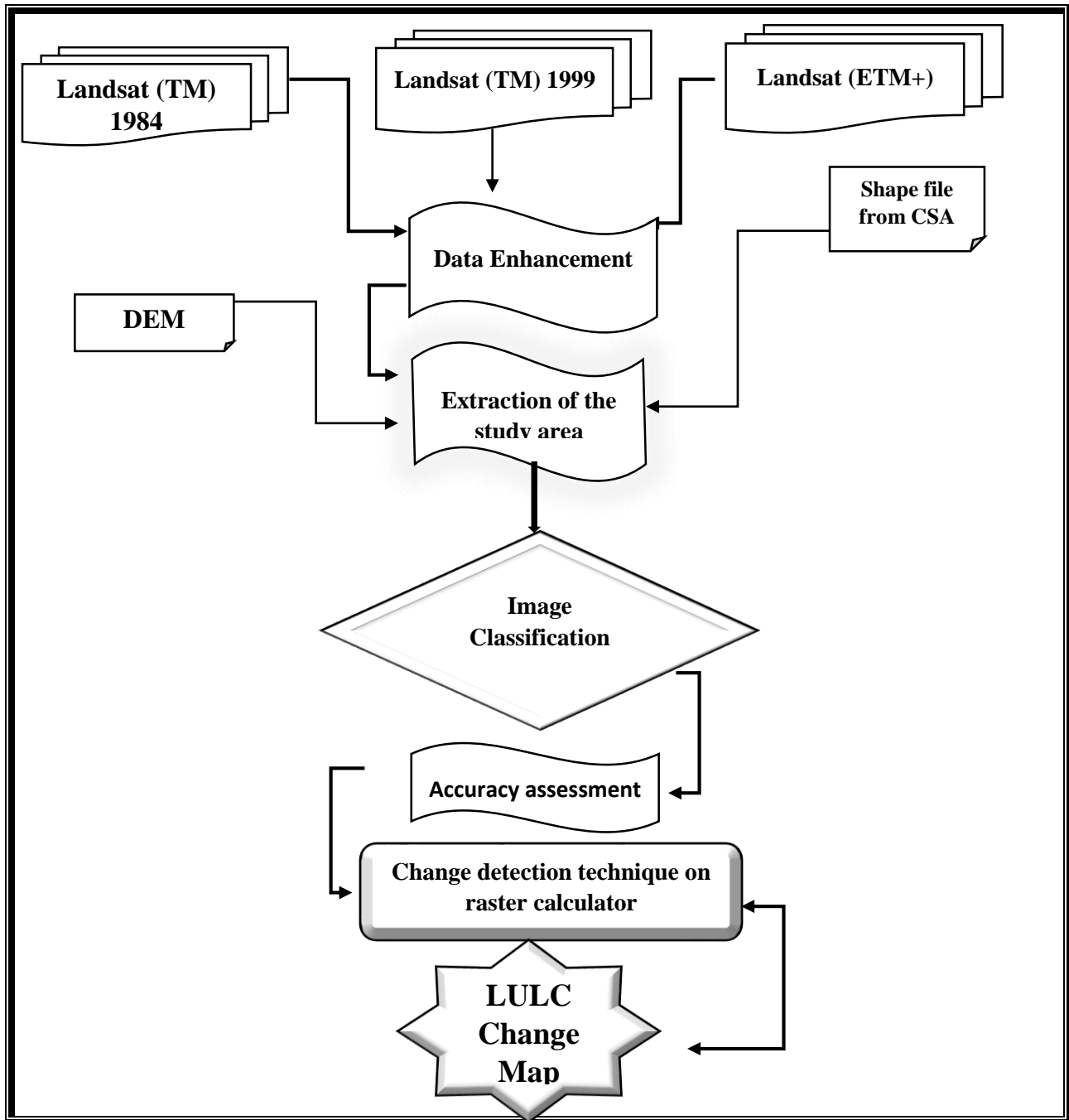


Figure 22 Method of GIS and remote sensing data interpretation

3.2.17 Analysis of the Legedadi water reservoir volume of water and silt deposition

The source for the Legedadi water reservoir volume of water and silt deposition analysis was the work of (AAWSA, 2013). This report has identified the change of volume of water and siltation deposition from 1979-2013 by using different surveying methods. But for this research volume of water and silt deposition amount of 1984, 1999 and 2014 were determined. Using the geometric decrement formula.

Equation 5 Geometric decrement

$$P_t = P_0 (1 - r/100)^n$$

P_t = the population at time t,

P_0 = population size of the initial census,

n = the time elapsed between the two census periods.

r = growth rate

Statistical analysis with Pearson Correlation Coefficient was applied to identify the relationship between land use land cover changes result of GIS and LWR amount of water and siltation change of the last three decades.

3.2.18 Analysis of correlation between population growth, LULC change and the legedadi reservoir volume of water and silt deposition

The correlation analysis was employed to verify whether there is the interaction of the population growth, LULCC and the Legedadi reservoir volume of water and silt deposition for the last three decades (1984-2014) using SPSS. The population data, the major land classes area coverage in km² (settlement water, cultivation, eucalyptus, natural vegetation, grassland) and the reservoir volume of water and silt deposit were compared to show their relationship.

3.2.19 Method of socio economic data analysis

The analytical techniques used in the socio-economic study were the descriptive, quantitative analysis of proximate and underlying causes LULC change. The description statics used to analyze the different variables in the data set to get a comprehensive picture of what the data looks like and assist in identifying patterns in the form of frequency and percent distributions of important variables.

Proximate causes of LULCC causes are grouped into three categories. They are agriculture, infrastructure expansion and wood extraction. Each of these broad groups was further sub divided in to several factors. Underlying causes of LULCC causes were also grouped into four major groups and further sub divided into specific factors. Because of probability that favors multiple counts of response of the response the relative percentage does not sum up100%.

3.2.20 Sampling Design for Household Survey

As Miaoulis et al. (1976), explained three criteria usually will need to be specified to determine the appropriate sample size, In addition to the purpose of the study and population size: the level of precision, the level of confidence or risk, and the degree of variability in the attributes being measured. Based on the location of the Legedadi water reserve and altitude of the catchment area two sample *kebeles* were purposely selected one near the Legedadi water reservoir the low stream (Lege Beri Lege Bolo) and the second *kebele* far-off from the water reservoir (Dabe Muda Guda) from the catchment area high altitude area (high stream). This was done purposely to include the outlook of the society from different altitudinal area and distance from LWR, so that the sample *kebeles* could spatially and sufficiently represent the study area.

Sample size of the house hold survey will be determined using a two formula derived from

(Cochran, 1977). The first formula determined desired sample size while the second one the actual size of sample based on the house hold *kebele*'s which are selected purposefully.

Equation 6 Formula to calculate sample size

$$n_o = \frac{Z^2 pq}{e^2}$$

Where

n_o= sample size

Z= confidence level (1.96 or 95% confidence)

p= percentage of picking choice (0.5 as there is equal chance of picking)

q = 1-P

e= tolerance error (0.05 for 95 % confidence)

Based on equation 6, the desired sample size was determined as 384 and using this value equation 7 was computed to get the actual sample size for the socio economic survey.

The following formula will be used to decide the actual sample size for the survey.

Equation 7 Actual sample size

$$n = \frac{n_o}{1 + \frac{(n_o - 1)}{N}}$$

n = sample size and

N = population size

n_o= sample size

The desired sample size was found to be 384 and to compute the actual sample size for the selected *kebeles* population number data of each *kebele* were prepared based on equation 7 (Table 7).

Table 7 Number and Sample size of selected *kebeles*

No	Name of the <i>kebele</i>	Number of households	Sample size
1	Dabe Muda Guda	131	81
2	Lege Beri Lege Bolo	112	69
	Total	243	150

3.3 Presentation

The result of the analysis were presented in table, graphs and maps. The overall description will be written under each presentation. Photographs and maps of specific areas of the catchment area were appropriately designed related with words.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1. Population Change in the Legedadi Catchment

In Ethiopia census is the recent phenomena and the first national census was conducted in 1984, and the second in 1994 and the third was conducted in 2007. The population of the catchment area has shown a rapid increase over the last 30 years since 1984 (the first census of Ethiopia).

Table 8 Population distribution of LCA in *Kebeles* from 1984-2014

Kebele in the Catchment	Population in 1984			Population in 1999			Population in 2014		
	Male	Female	Both Sex	Male	Female	Both Sex	Male	Female	Both Sex
Lege-beri Legebolo	700	692	1393	1142	1128	2270	1693	1663	3359
Sendafa	3574	3531	7105	5825	5755	11580	8653	8482	17135
Dabe Muda Godo	888	877	1765	1447	1430	2877	2150	2107	4257
Girari Reh	707	698	1405	1152	1138	2290	1711	1677	3388
Deri-Sokoru	911	870	1781	1435	1418	2853	2115	2107	4222
Aba Mela Mugero	688	681	1369	1123	1109	2232	1668	1634	3302
Chebi Sire Guyo	850	840	1690	1400	1382	2782	2079	2037	4116
Lenicho-Choba Sululta	1373	1356	2729	2237	2211	4448	3323	3258	6581
Weligwo	960	940	1900	1524	1492	3016	2311	2264	4575
Total	10656	10444	21100	17263	17043	34306	25723	25212	50935

Source: CSA and Bereh *wereda* administration

Sex is one of the basic characteristics of a population. To determine and decide different discussions sex composition has vital role. Male population is slightly higher at the country level since the 1984 census 50.3% than female population 49.7%. In 1999 it was 50.4% for male and 49.6% female and in 2014 it was 49.4% female and 50.6% male.

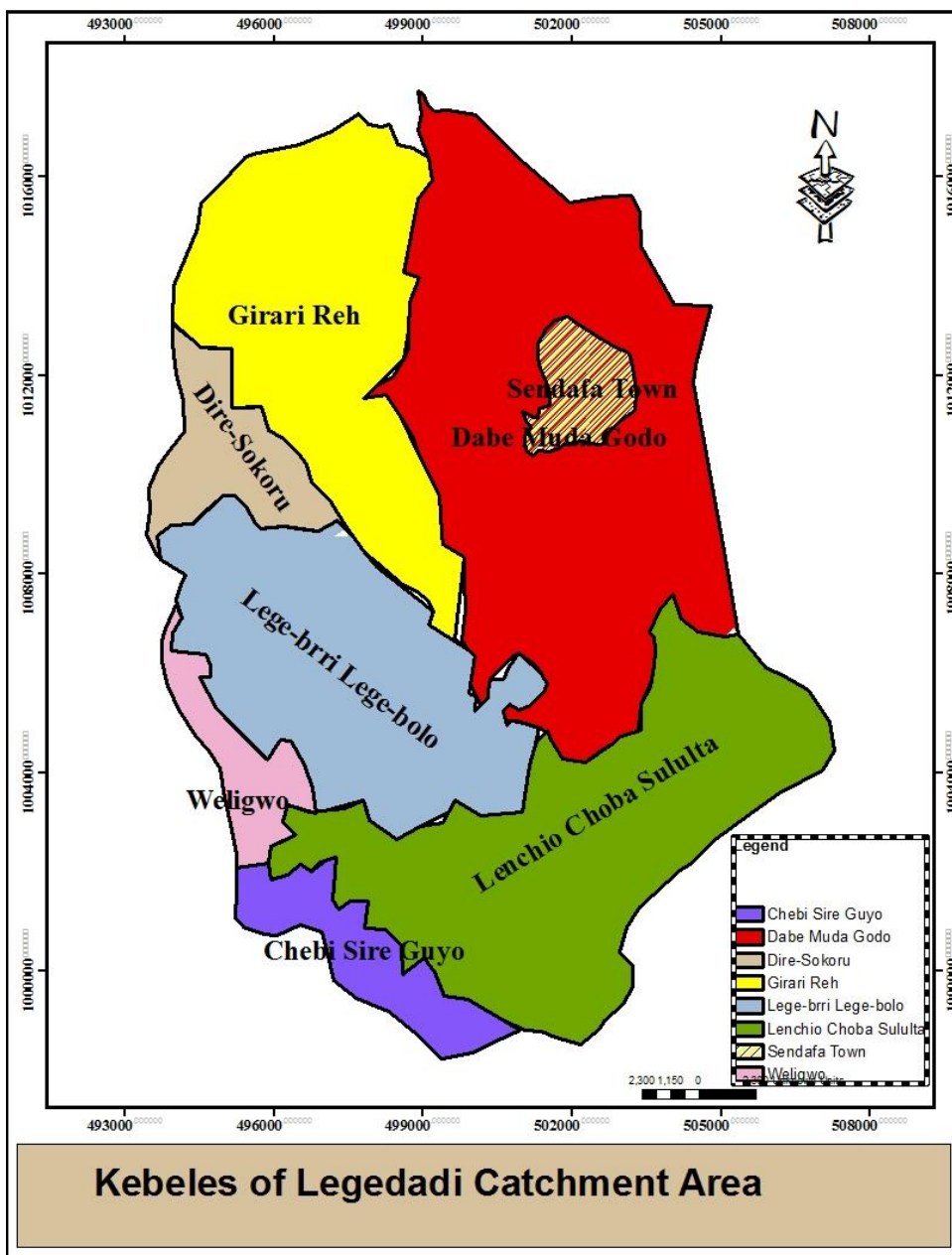


Figure 23 Map o Kebeles in LCA

Table 9 percentage distribution of population by sex and census year

Census Year	Male	Female	Both sex
1984*	10656	10444	21100
1999**	17263	17043	34306
2014***	25723	25212	50935

Source: CSA *, projection by geometric growth formula** and Bereh *wereda* *** administration

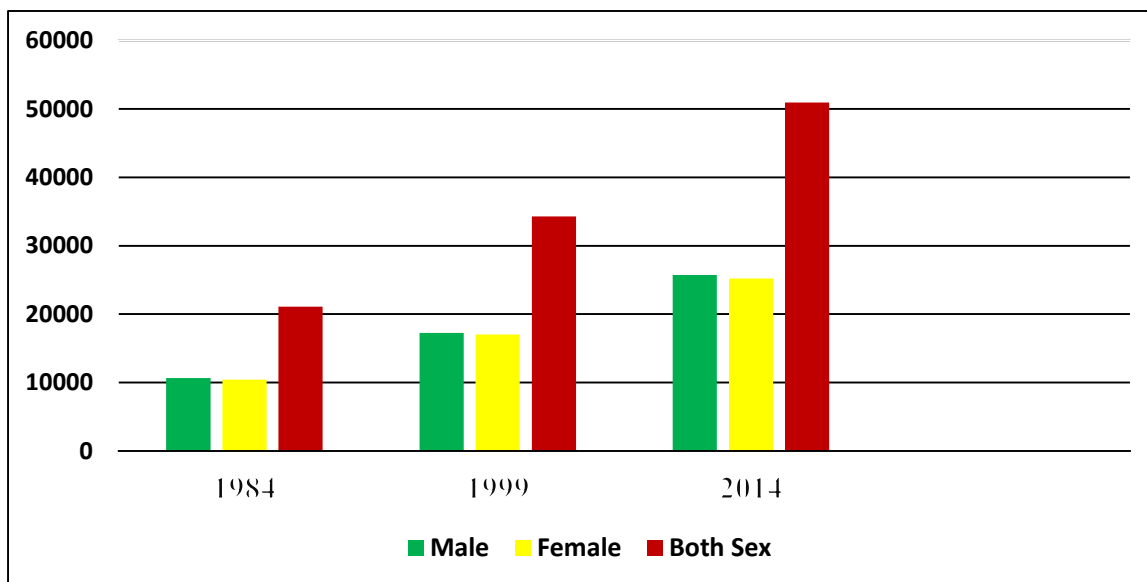


Figure 24 Chart of population distribution of Legedadi Catchment Area

The majority of the population of LCA *kebeles* are rural residents. (The only urban area in this area is Sendafa town). The study area's population pressure has an effect in the rural populations land availability, fragmentation of farm plots, agricultural production and productivity.

4.1.2 Population Density in LCA

The population of the area has become doubled more than double in the last three decades. The implication of this is that there would be increased demand for arable land, land for settlement expansion, forest for fuel and construction and other natural resources. More people in a short period means more pressure on land resources which in turn accelerates degradation and loss of resources.

Table 10 Population density and Agricultural Density of LCA

Year	Total Population	Rural population	Area of the study area in km ²	Cultivated land in km ²	Agricultural density	Crude density
1984	21100	13995	217	31.98	437.6	97.2
1999	34306	22726	217	55.4	410.2	158
2014	50935	33800	217	69.8	484.2	234.7

Source:CSA, Bereh wereda and GIS result

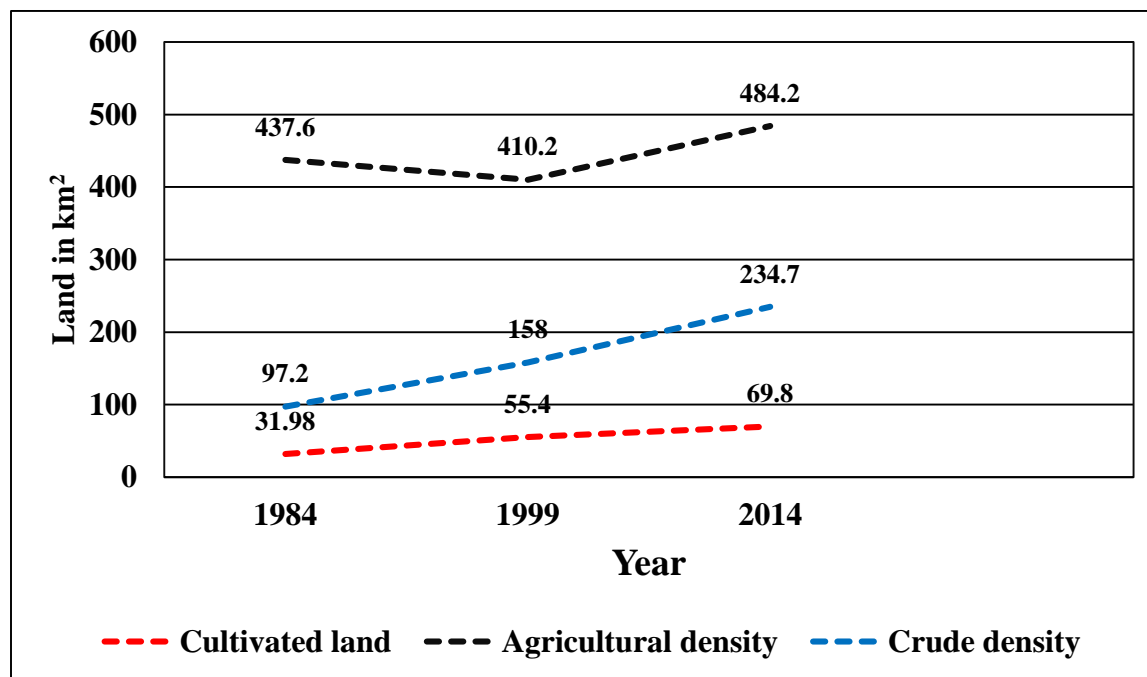


Figure 25 Cultivated land, Agricultural density and Crude density

In order to better understand the population pressure on land, the crude density of population and agricultural density of the year 1984, 1999 and 2014 were examined and summarized in Table 9. The data indicated that the agricultural and crude density of the 1984 was 437.6 people/km² and 97.2 people/km², 410.2 people/km² and 158 people/km² in 1999 and in 2014, 484.2 people/km² and 234.7p/km². Both densities show that there is high population pressure in the study area.

4.1.3 Population pressure in LCA

In order to better understand the population pressure on land, the population pressure index year 1984 and 2014 were examined and summarized in Table 10.

Table 11 Population pressure Level of LCA

Year	T.pop	R.pop	T.area KM ²	C.area KM ²	Agri. Income	N-Agri	Ave.agr KM ²	Level	Category
1984	21100	13995	217	31.98	1500 _{ETB}	281 _{ETB}	0.0023	0.845	No pressure
2014	50935	33800	217	69.8	1250 _{ETB}	28740 _{ETB}	0.0021	1.007	Under pressure

Legend: Total population (T.pop), Rural population (R.Population), Cultivation area (C.area), Agricultural income (Agri. Income), Non-Agricultural income (N-Agri. I), Average of agricultural land area (Ave.agri) and Ethiopian Birr (ETB).

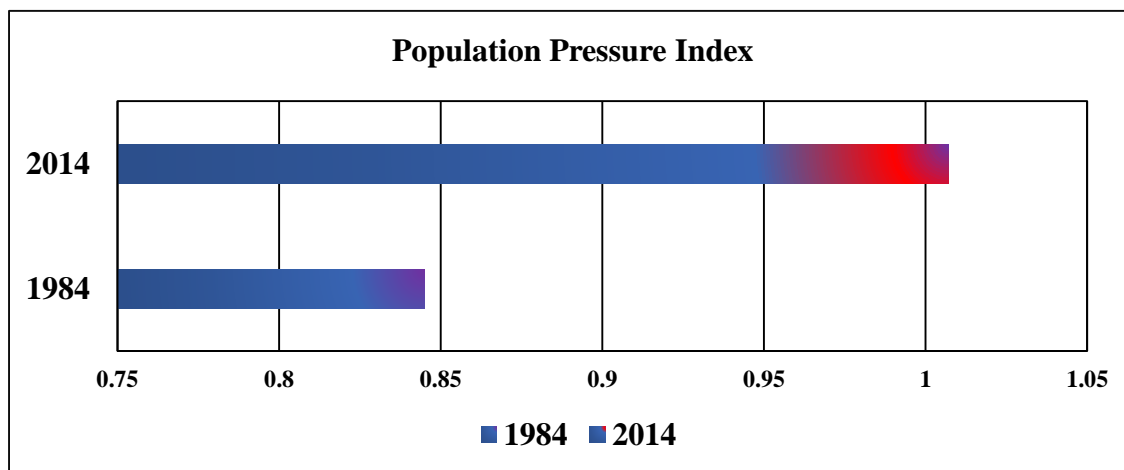


Figure 26 Chart of population pressure index

The data indicated that LCA was in high population pressure in 2014 there was no pressure during 1984. This result means that agricultural carrying capacity of the catchment area could support the

population of 13995 in 1984; on the contrary, it could not accommodate the population of 33800 in 2014.

Furthermore, the findings of this research agreed that the consequent high pressure on resources are feared to have adverse effects on the existing natural resources of the area as the demand for food and other necessities would increase. Among the major causes, demographic factors, especially an increase in local population including household structure and land-hold, play a significant role in LULC change (Geist and Lambin, 2002).

4.2 Land Use and Land Cover Analysis

4.2.1 Land Use and Land Cover Mapping

As indicated in the classification scheme Water, Settlement, Natural Vegetation, Eucalyptus Grassland and Cultivated land are the major LULC classes for the study periods. The classified images were acquired, when crop harvesting had already started, and farmlands appeared bare and grasslands look relatively bright in their color.

4.2.2 1984 LULC

For different applications, band combinations other than true or false color may be used. Land-use categories can often be distinguished quite well by assigning a combination of Landsat TM bands 5–4–3 or 4–5–3 to RGB (Wim et al., 2000).

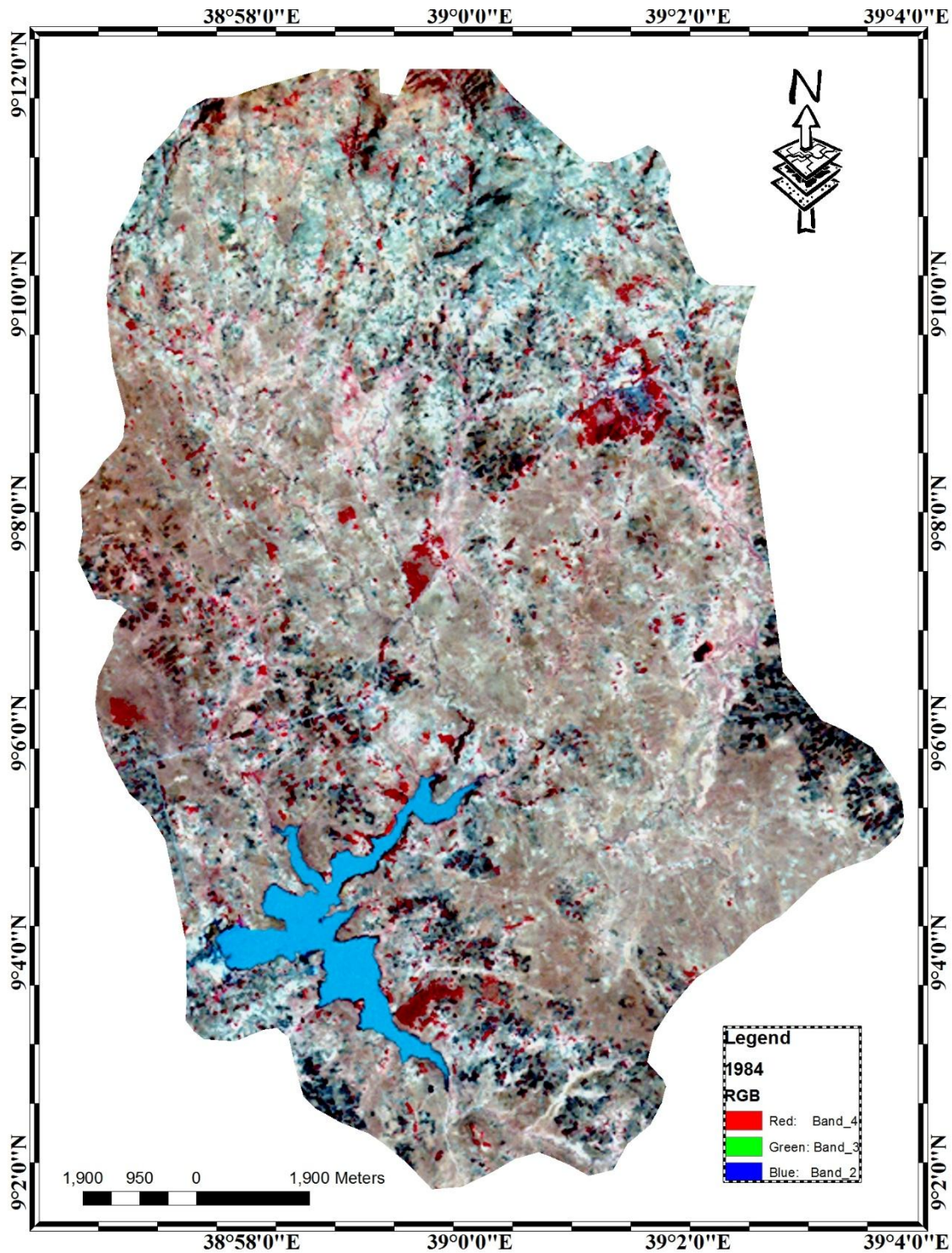


Figure 27 Landsat TM image of 1984

Source: Produced based on unprocessed satellite images obtained from EMA

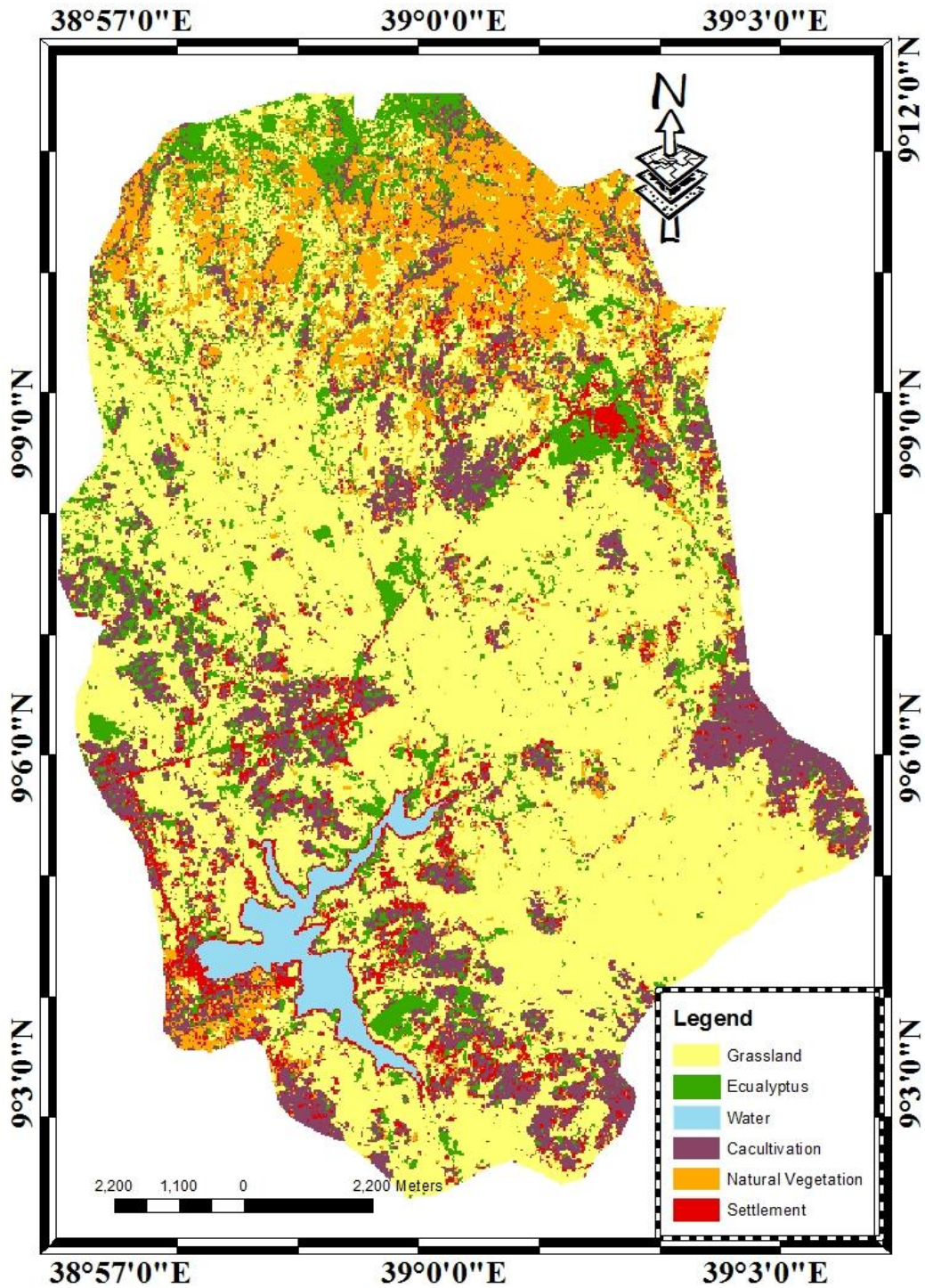


Figure 28 Interpreted result of Landsat TM, 1984

Source: Produced based on unprocessed satellite images obtained from EMA

Table 12 Interpretation result of 1984

LULC classes	Periods	
	1984	
	Area in hectare	Area in Percent
Water	4.6	2.1%
Settlement	11.39	5.2%
Natural Vegetation	24.1	11%
Eucalyptus	23.66	10.8%
Grassland	123.1	56.2%
Cultivation	31.98	14.6%

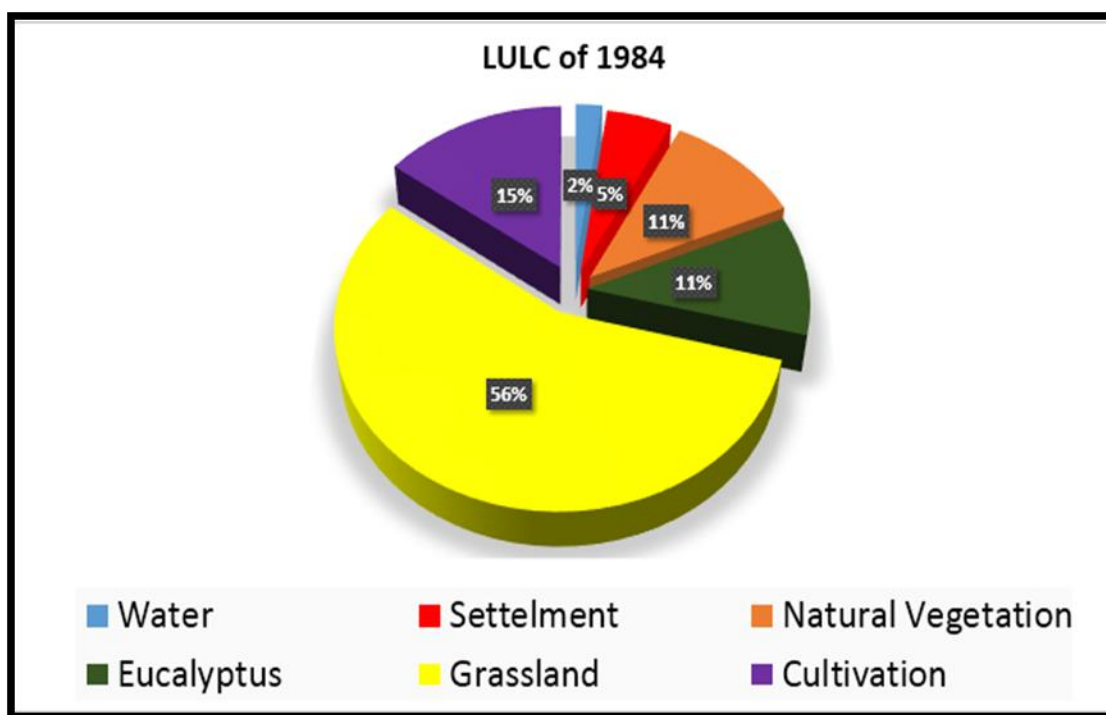


Figure 29 Chart of the LULC of 1984

Source: Based on the GIS analyzed result

As it is indicated in table 7, grassland accounts for about 42.1 % of the total land area of the Catchment area followed by Cultivation, Eucalyptus, Natural Vegetation, Settlement and water body (20.28%, 15.58%, 13.47%, 6.8% and 1.69% respectively)

4.2.3 1999 LULC

As Hussein (2009) explained, the wave length range for the TM sensor ranges from the visible in to the thermal infrared portion of the electromagnetic spectrum and it has a spatial resolution of 30 meter. TM band 4, 3 and 2 were combined to make conventional false color composite images.

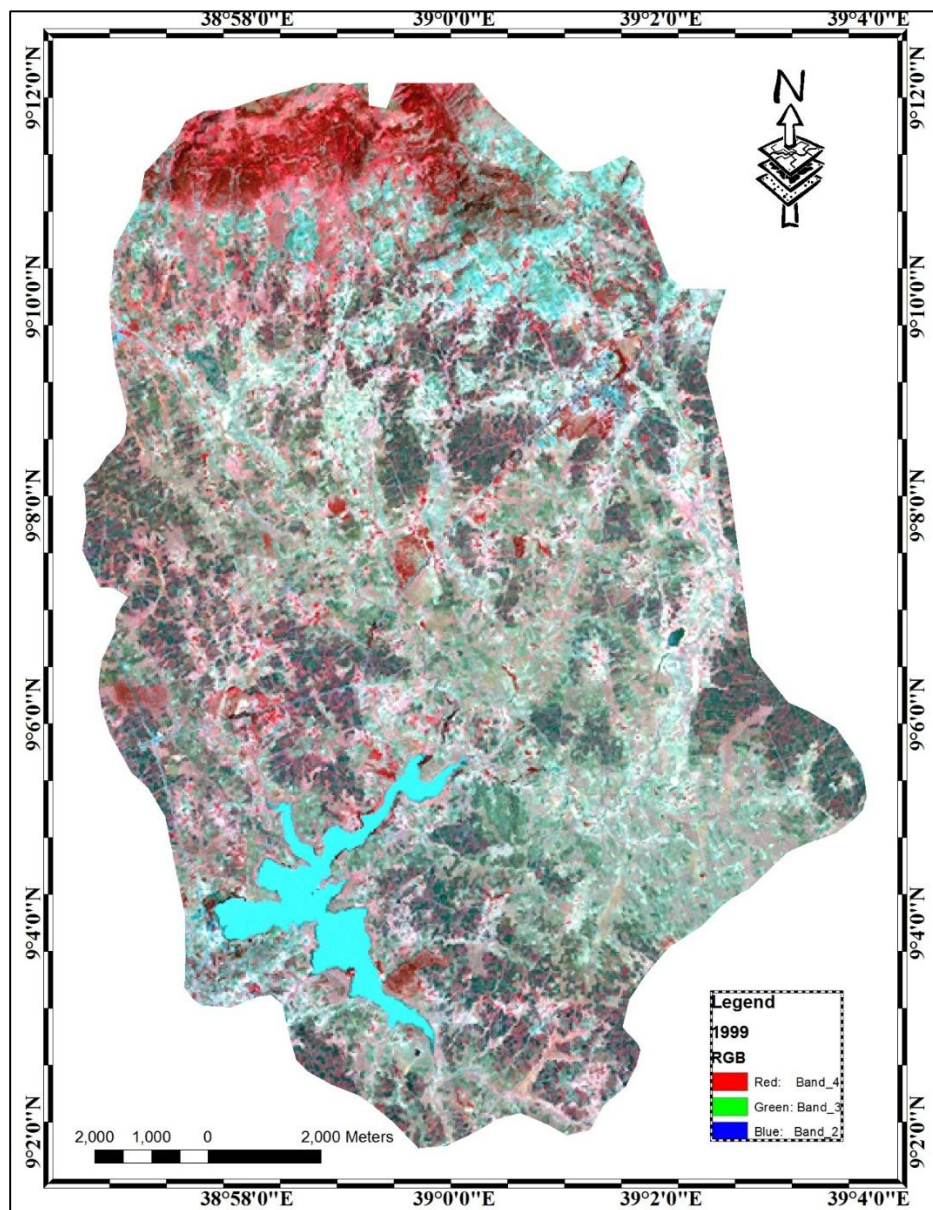


Figure 30 1999 Landsat image

Source: Produced based on unprocessed satellite images obtained from EMA

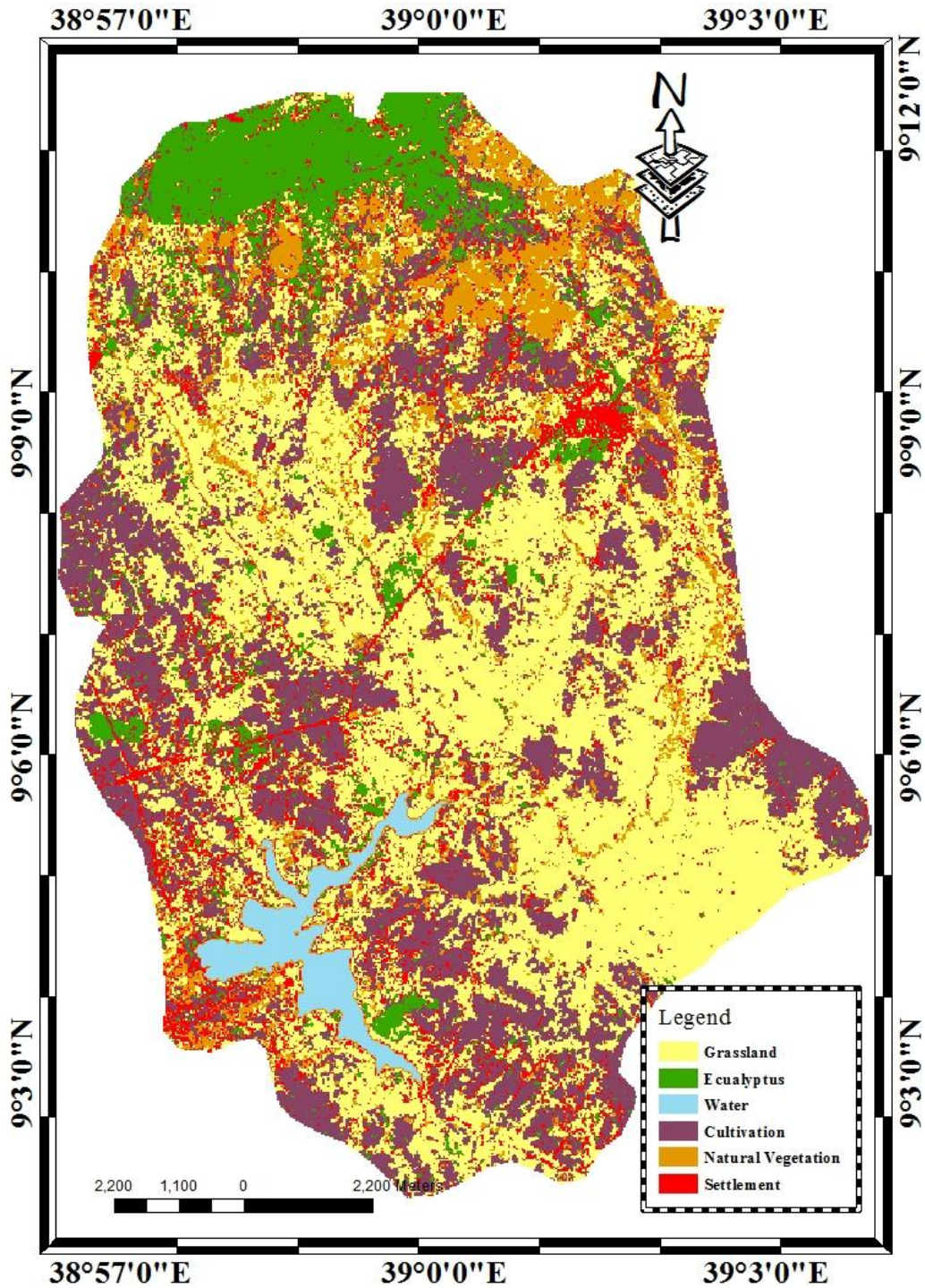


Figure 31 Interpretation result of 1999

Source: Produced based on unprocessed satellite images obtained from EMA

Table 13 Interpretation result of 1999

LULC Classes	Period	
	1999	
	Area in Square km	Area in Percentage
Water	4.8	2.19%
Settlement	23.7	10.47%
Natural Vegetation	19.86	9.07%
Eucalyptus	21	9.63%
Grassland	92.69	42.31%
Cultivation	55.4	25.32%

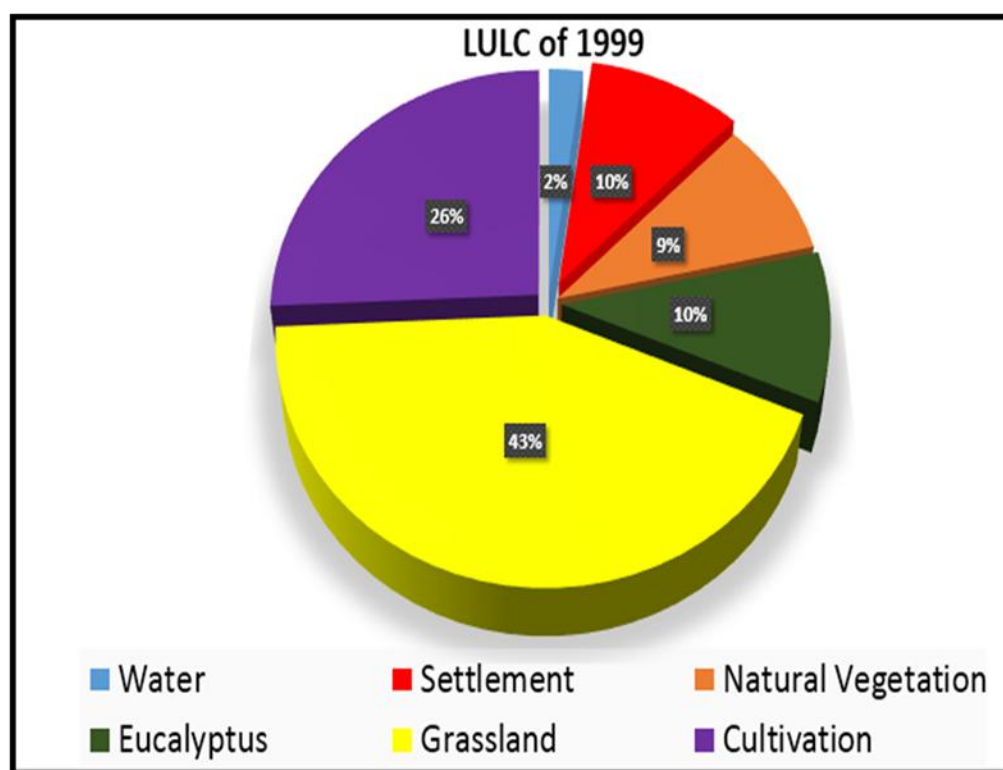


Figure 32 Chart of LULC of 1999

Source: Based on the GIS analyzed data

As it is indicated in table 8, grassland accounts for about 38.22 % of the total land area of the Catchment area followed by Cultivation, Eucalyptus, Natural Vegetation, Settlement and water body (29.65%, 15.58%, 13.39%, 9.89% and 1.72% respectively).

4.2.4 2014 LULC

The Landsat 8 EMT+ image band 5, 4 and 3 were combined to make conventional false color composite images with a spatial resolution of 30 meters (Fig. 32)

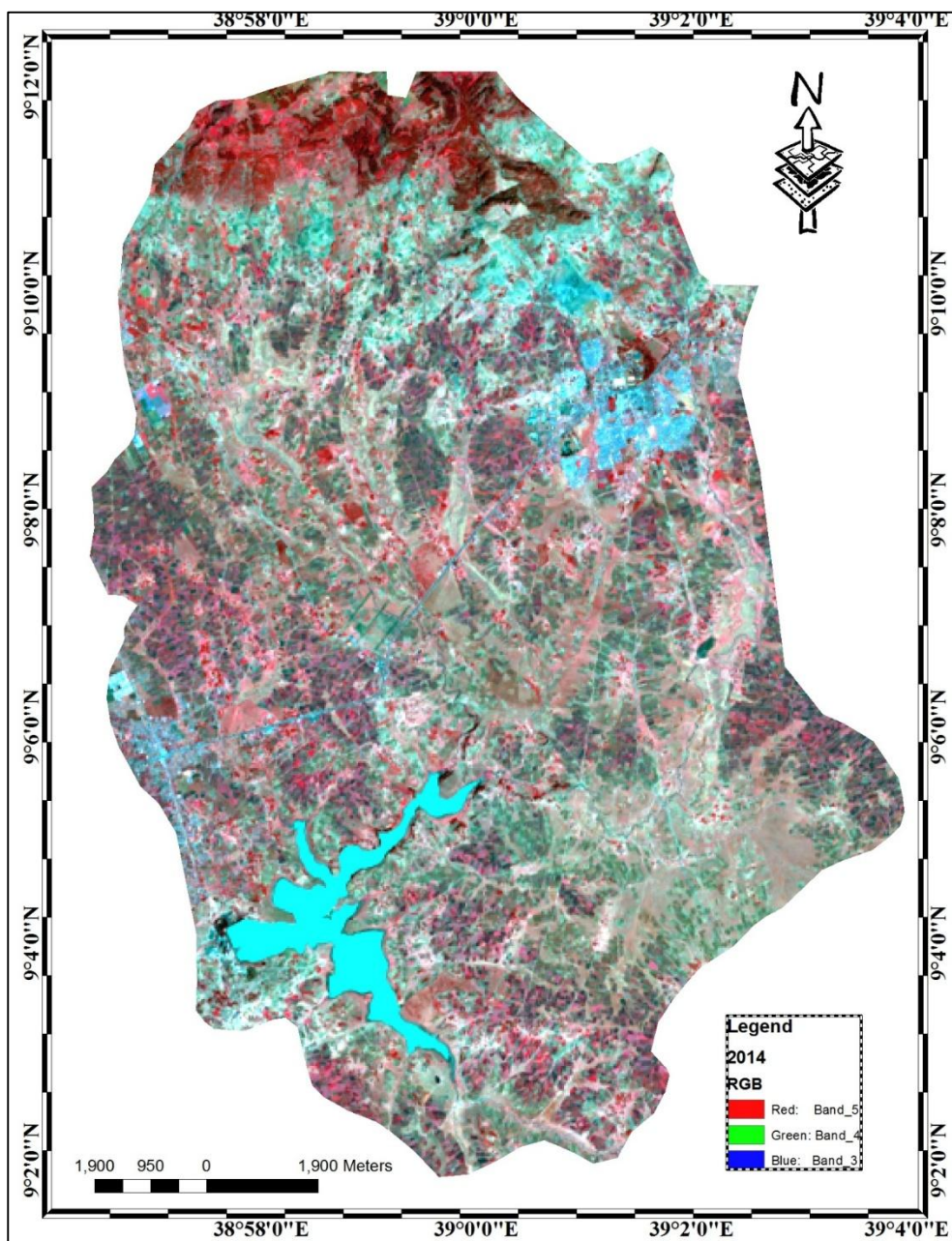


Figure 33 2014 Landsat image

Source: Produced based on unprocessed satellite images obtained from EMA

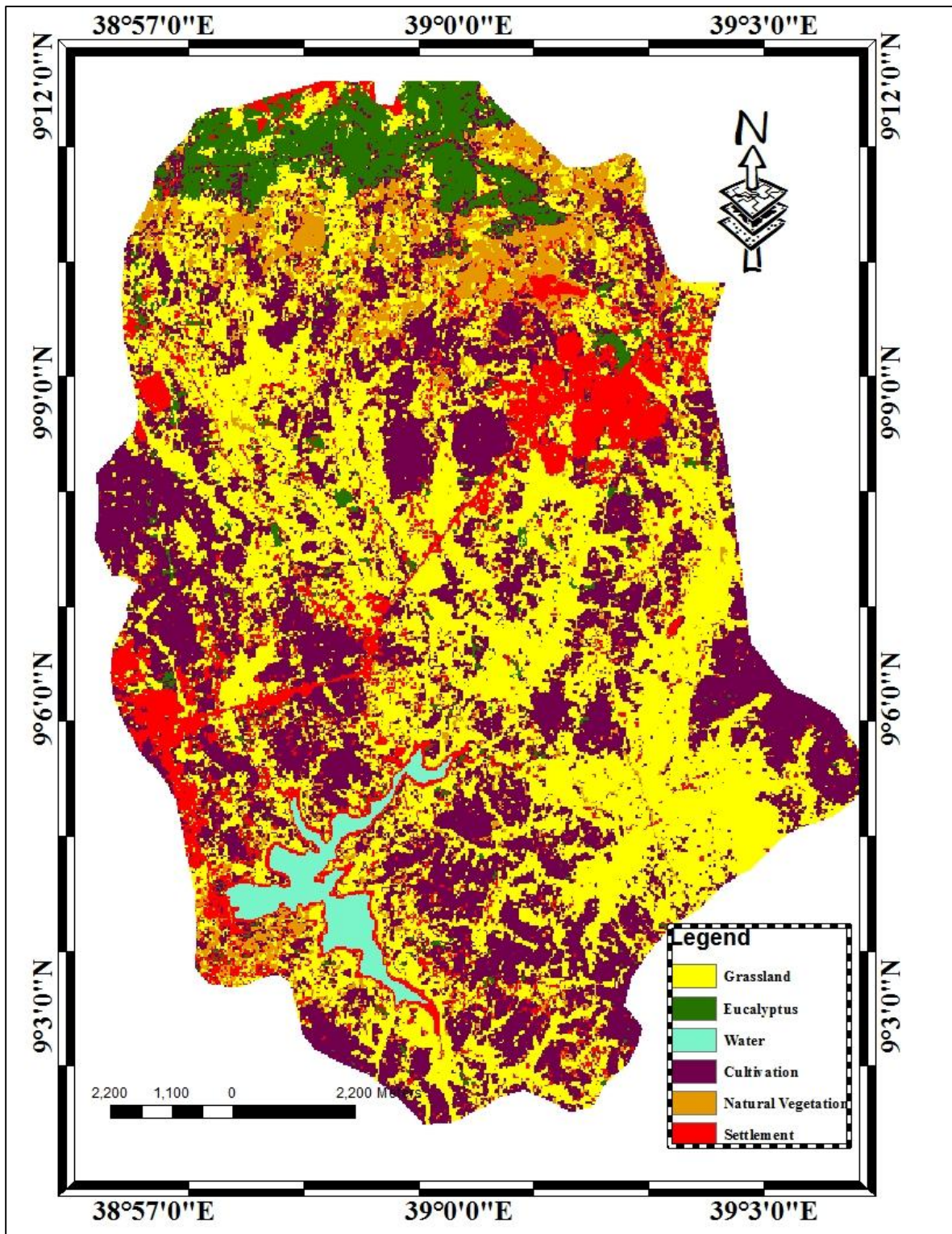


Figure 34 Interpretation result of 2014

Source: Produced based on unprocessed satellite images obtained from EMA

Table 14 Interpretation result of 2014

LULC Classes	Period	
	2014	
	Area in square km	Area in percent
Water	4.1	1.8
Settlement	26.7	12
Natural vegetation	17.9	8.2
Eucalyptus	17	7.7
Grassland	83.8	38.6
Cultivation	69.8	32.1

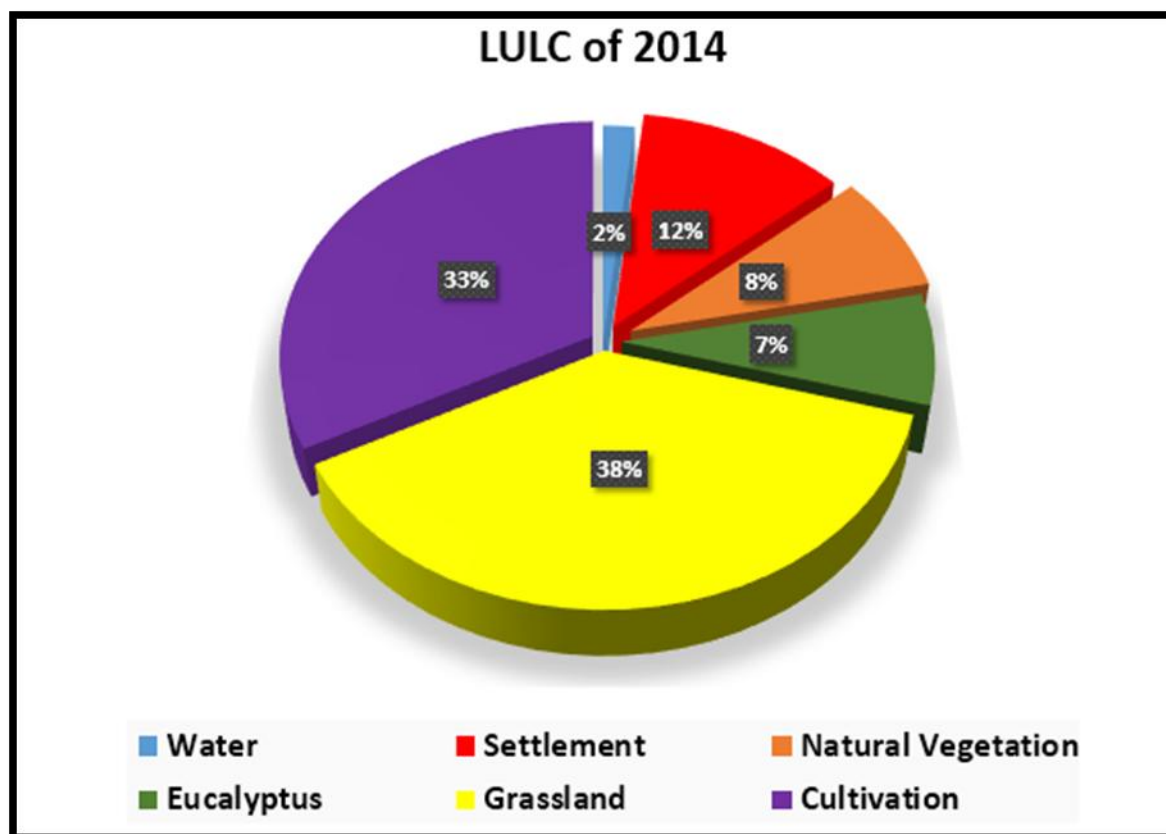


Figure 35 Chart of 1999 LULC change

Source: Based on GIS Analysis

As it is indicated in table 9, cultivation accounts for about 32.1 % of the total land area of the Catchment area. And Grassland, Natural Vegetation, Eucalyptus, Settlement and water body (38.6 %, 8.2%, 7.7%, 12% and 1.8% respectively).

4.2.5. Accuracy Assessment

Land cover accuracy is commonly defined as the degree to which the derived classification agrees with reality and the accuracy of the map in a larger part determines the usefulness of the map (Ashenafi, 2008).

Accuracy assessment was critical for a map generated from any remote sensing data. Error matrix is the most common way to present the accuracy of the classification results overall accuracy, user's and producer's accuracies, and the Kappa statistic were then derived from the error matrices.

4.2.6 Accuracy Assessment of 1984

Table 15 Accuracy assessment of 1984

		Reference Data							
Map data		Water	Settlement	Natural Vegetation	Eucalyptus	Grassland	Cultivation	Total	Users Accuracy
	Water	3	0	0	0	0	0	3	100
	Settlement	0	5	0	1	1	0	7	71.4
	Natural Vegetation	0	1	11	1	1	1	15	73.33
	Eucalyptus	0	1	1	12	0	1	15	80
	Grassland	0	1	1	3	70	3	78	89.7
	Cultivation	0	0	1	1	1	17	20	85
	Total	3	8	14	18	72	21	138	
	Producers Accuracy	100	62.5	78.57	66.66	97.22	76.2		

The overall accuracy and kappa analysis were used to perform a classification accuracy assessment and accordingly over all accuracy of the data is 84.05%.and over all kappa coefficient was

computed which is 0.7785. The Kappa coefficients indicated that the classified images showed moderate classification performance.

4.2.7 Accuracy Assessment of 1999

Table 16 Accuracy assessment of 1999

		Reference Data							
Map Data		Water	Settlement	Natural Vegetation	Eucalyptus	Grassland	Cultivation	Total	Users Accuracy
	Water	3	0	0	0	0	0	3	100
	settlement	0	12	1	1	1	0	15	80
	Natural Vegetation	0	0	11	1	1	0	13	84.6
	Eucalyptus	0	1	1	11	0	0	13	84.6
	Grassland	0	2	2	2	50	3	59	84.74
	Cultivation	0	1	1	1	2	30	35	85.71
	Total	3	16	16	16	54	33	138	
	Producers Accuracy	100	75	68.75	68.75	92.59	90.9		

The overall accuracy and kappa analysis were used to perform a classification accuracy assessment and accordingly over all accuracy of the data is 84.78% and overall. The Kappa coefficients indicated that the classified images showed moderate classification performance agreement which was computed at 0.7935.

4.2.8 Accuracy Assessment of 2014

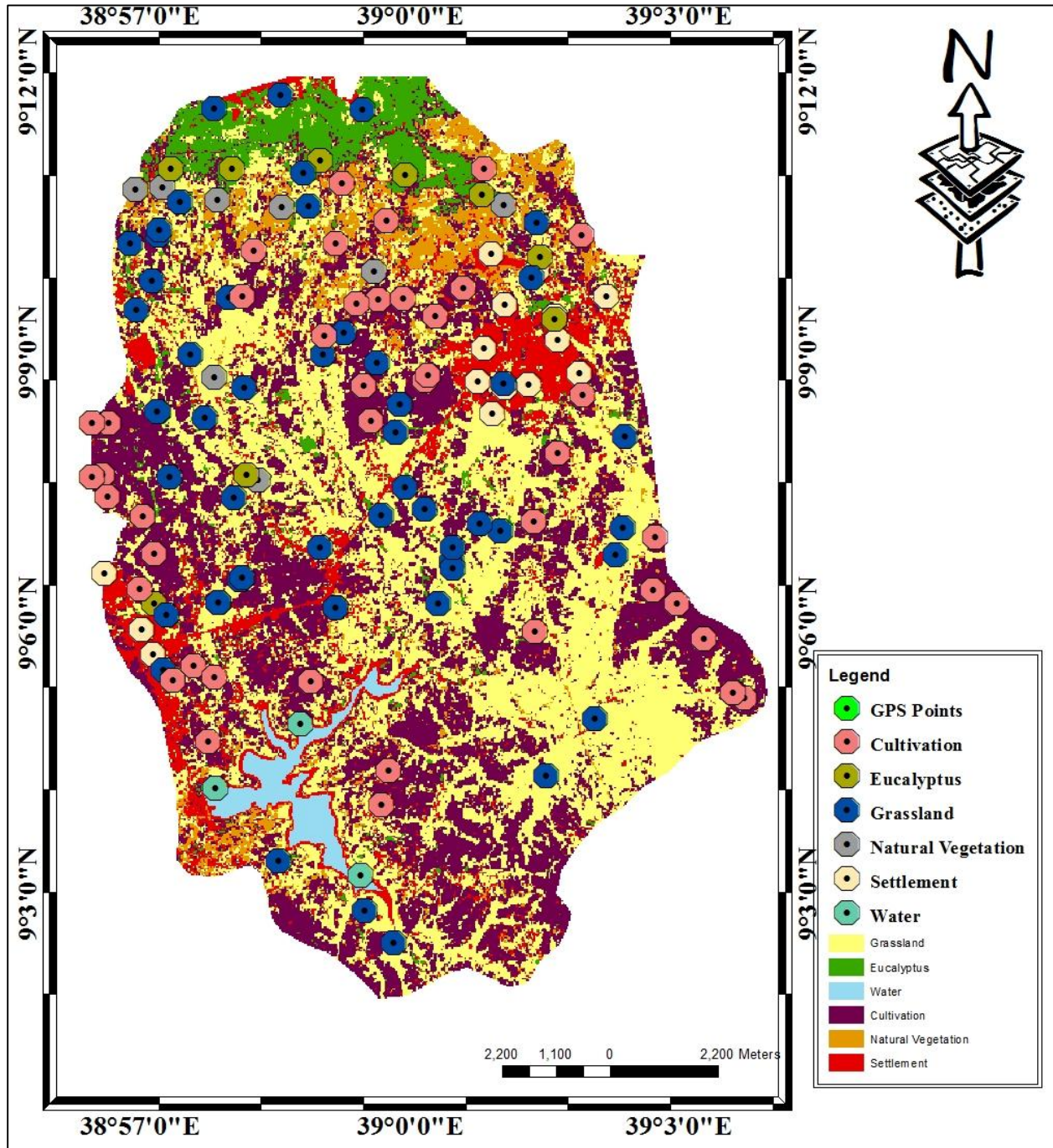


Figure 36 GPS points for ground truth

Table 17 Accuracy assessment of 2014

		Reference Data							
Map Data		Water	Settlement	Natural Vegetation	Eucalyptus	Grassland	Cultivation	Total	Users Accuracy
	Water	3	0	0	0	0	0	3	100
	Settlement	0	13	0	1	1	1	16	81.25
	Natural Vegetation	0	0	7	1	0	1	9	77.77
	Eucalyptus	0	1	1	7	0	0	9	77.77
	Grassland	0	1	2	1	49	2	55	89.09
	Cultivation	0	2	1	1	1	41	46	89.13
	Total	3	17	11	11	51	45	138	
	Producers Accuracy	100	76.47	63.63	63.63	96.07	91.11		

The overall accuracy and kappa analysis were used to perform a classification accuracy assessment and accordingly over all accuracy of the data is 86.9% and over all kappa coefficient was computed which is 0.8404. The Kappa coefficients indicated that the classified images showed moderate classification performance or moderate agreement.

4.2.9. Change Detection Analysis

Change detection analysis was conducted using post classification image comparison technique. Accordingly, change of land use/ land cover between 1984-1999, 1999-2014 and 1984- 2014 were computed using post classification result and it is presented in table17.

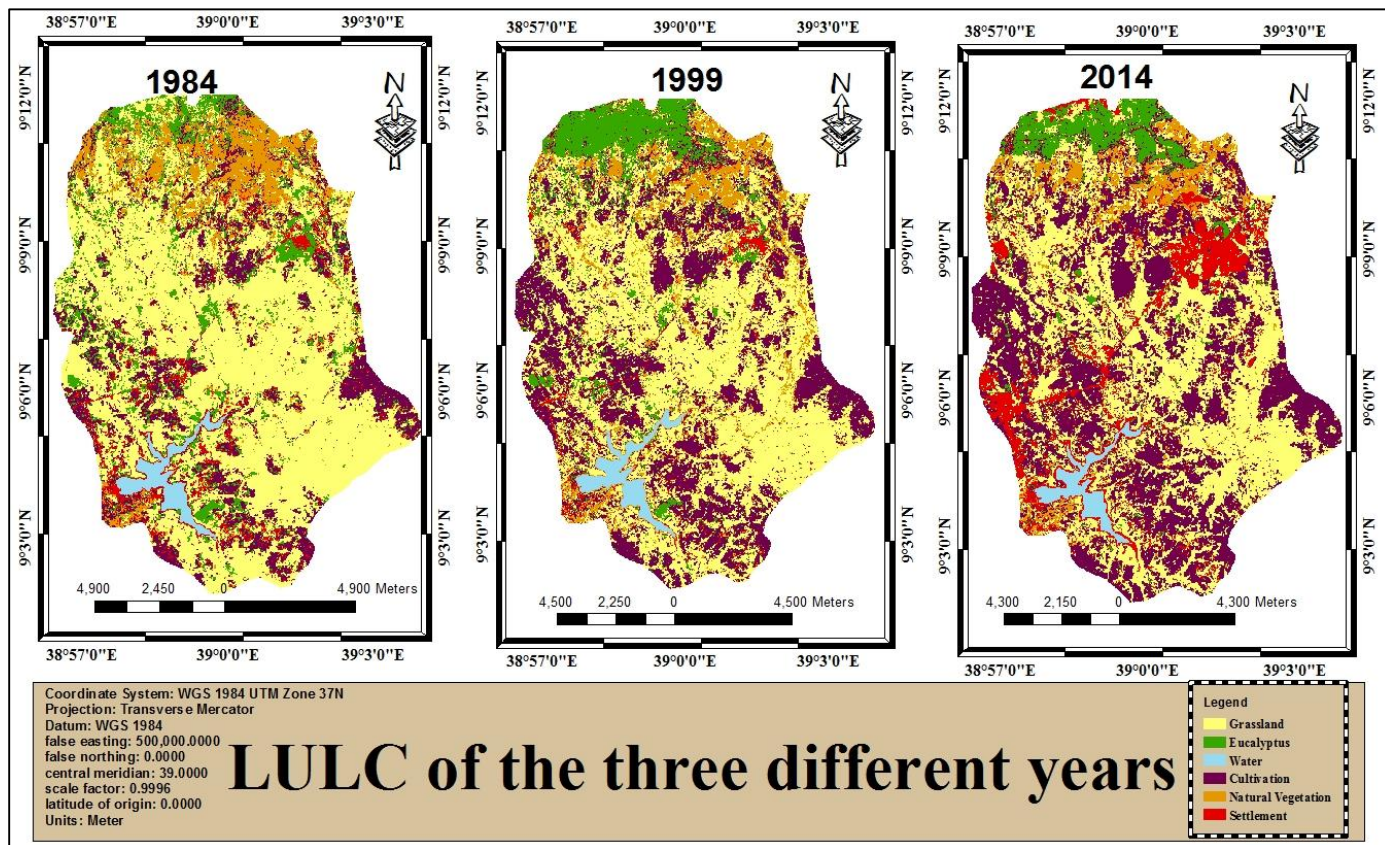


Figure 37 Map of the three years LULC

Source: Produced based on unprocessed satellite images obtained from EMA

Table 18 Change of classes in three time periods.

LULC	PERIODS											
	1984		1999		2014		1984-1999		1999-2014		1984-2014	
	Km ²	%	Km ²	%	Km ²	%	Km ²	%	Km ²	%	Km ²	%
Water	4.6	2.1	4.8	2.19	4.1	1.8	+0.2	4.1	-0.7	-14.5	-0.5	-10.8
Settlement	11.39	5.2	23.7	10.4	26.7	12	+12.3	+107.9	+3	+12.6	+15.3	134
Natural Vegetation	24.1	11	19.86	9.07	17.9	8.2	-4.24	-17.5	-1.96	-9.8	-6.2	-25.7
Eucalyptus	23.66	10.8	21	9.63	17	7.7	-2.66	-11.2	-4	-19	-6.66	-28.1
Grassland	123.1	56.2	92.69	42.31	83.8	38.6	-30.4	-24.7	-8.89	-9.6	-39.3	-32
Cultivation	31.98	14.6	55.4	25.32	69.8	32.1	+23.4	+73.2	+14.4	+26	+37.8	+118.2

Source: GIS analysis result

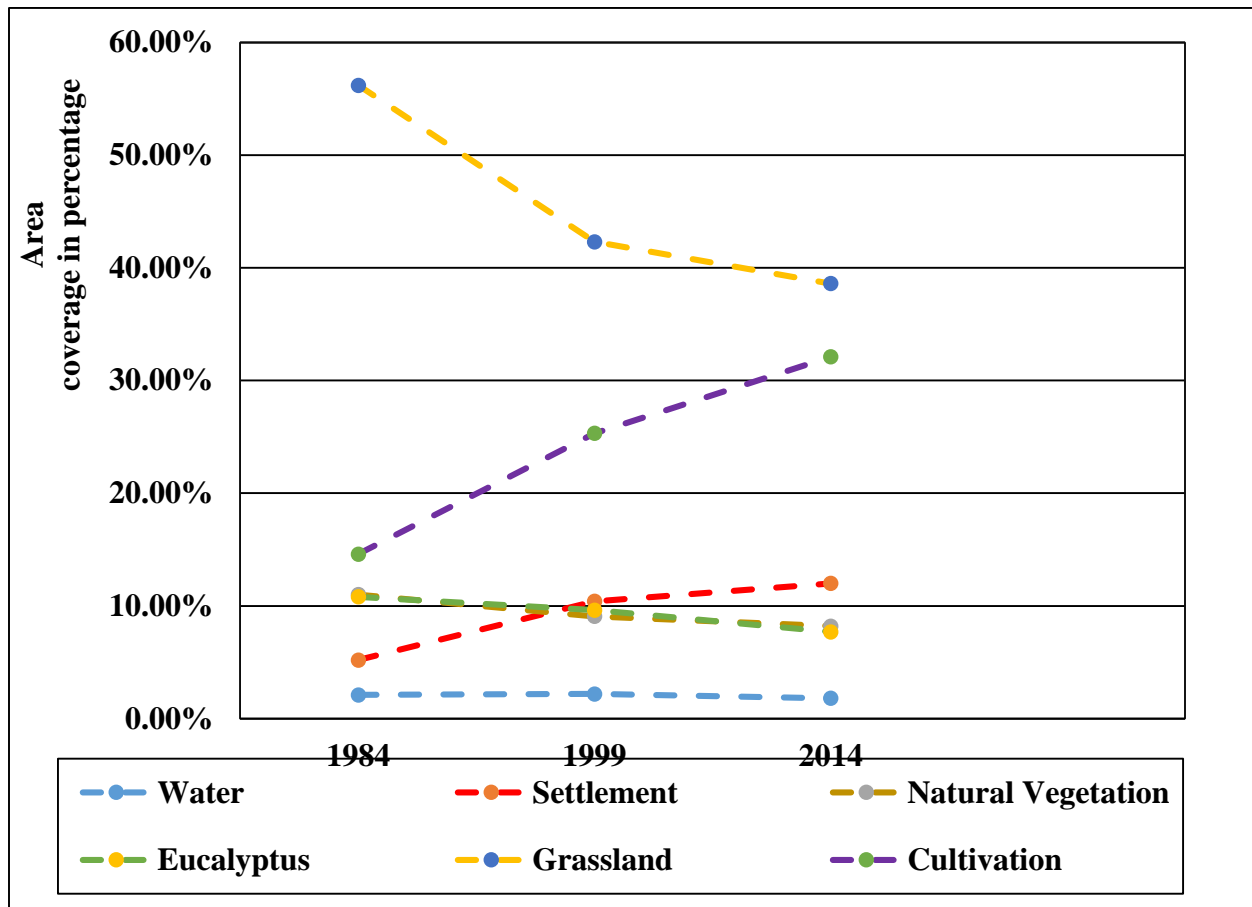


Figure 38 Pattern of LULC change over different decades

Furthermore, the dynamic patterns of LULC change are also represented in Figure 37 It appears that Grassland, Natural vegetation and Eucalyptus has changed into another LULC type. Its change to Settlement and Cultivation area could be the indication of a trend and need of agricultural expansion and population growth.

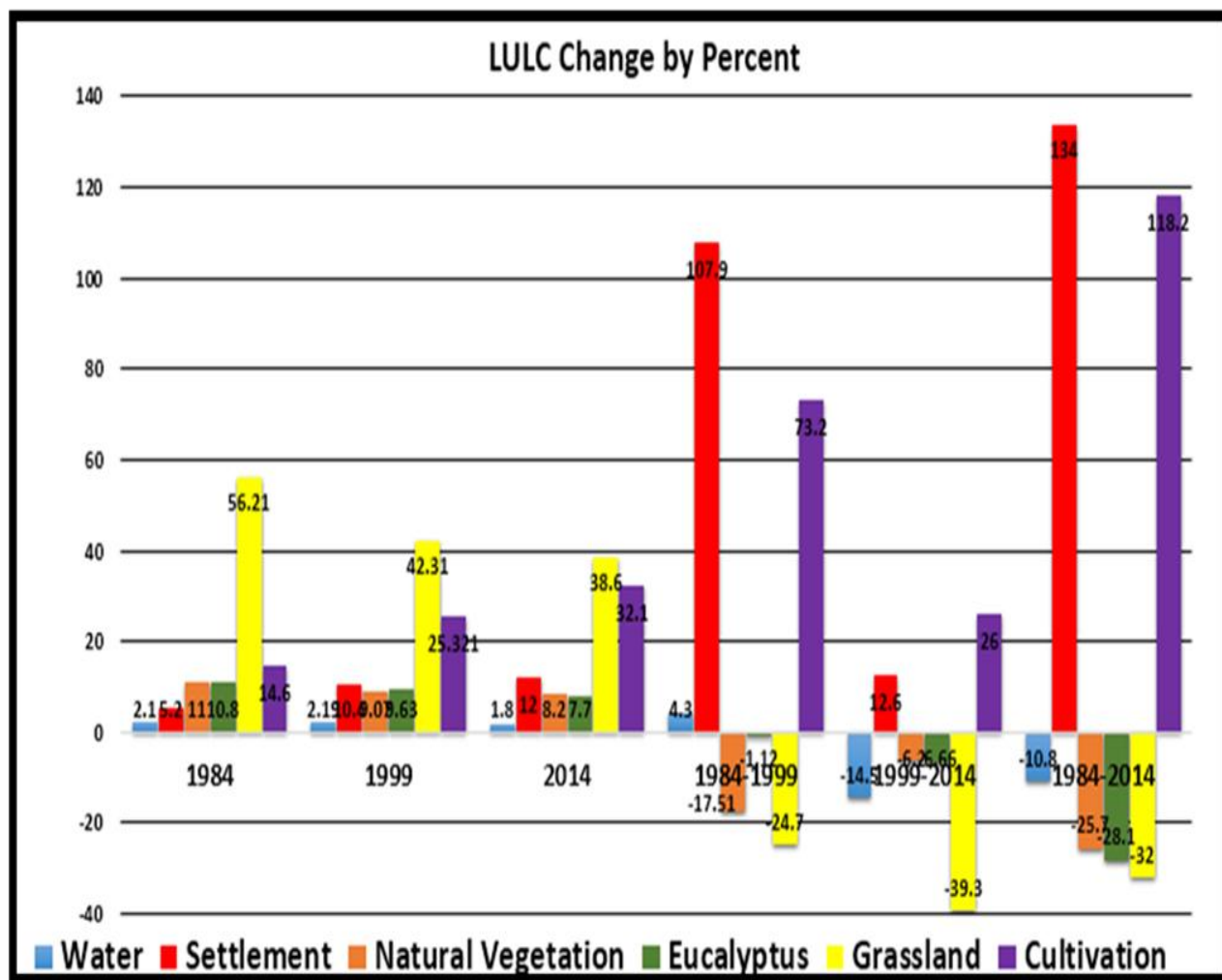


Figure 39 Chart of LULC Change trend by percentage over different time decades

Source: Based on GIS Analysis

The distribution of LULC and its changes for 1984, 1999 and 2014 is summarized in Table 17. The dynamic patterns of LULC change are also represented in Figure 38 and 39. Through the period of study, several LULC categories had increased such as settlement, cultivation land. Grassland accounts for 56.2% of the landscape followed by Cultivation 14.6%, Natural vegetation

11 % Eucalyptus 10.8%, Settlement 5.2% and Water 2.1%. In 1999 LULC map, cultivation ,settlement and water had increased in coverage to 73.2 % ,107.9 % and 4.3% respectively, while grassland, eucalyptus, and natural vegetation declined to -24.7% , -1.12 and -17.5 % respectively. In 2014 LULC, cultivation accounted for about 32.1%, followed by settlement (12 %), grassland (38.6%), natural vegetation 8.2%, eucalyptus 7.7% and water also accounted for about 1.8 %. From 1999-2014 indicated that settlement and cultivation increased by +12.6 and +26 percent respectively and grassland, eucalyptus, natural vegetation and water declined to -9.6%,-19%, -9.8% and -14.5%% respectively. When the change analysis for the last 30 years is observed, Settlement showed an increase of 134 % followed by cultivation showing an increase of 118.2%. Natural vegetation, eucalyptus, grassland and water body decreased by -25.7%, -28.1,-32% and -10.8% respectively.

4.2.10. LULC Change Map

4.2.11 LULC change map from 1984-1999

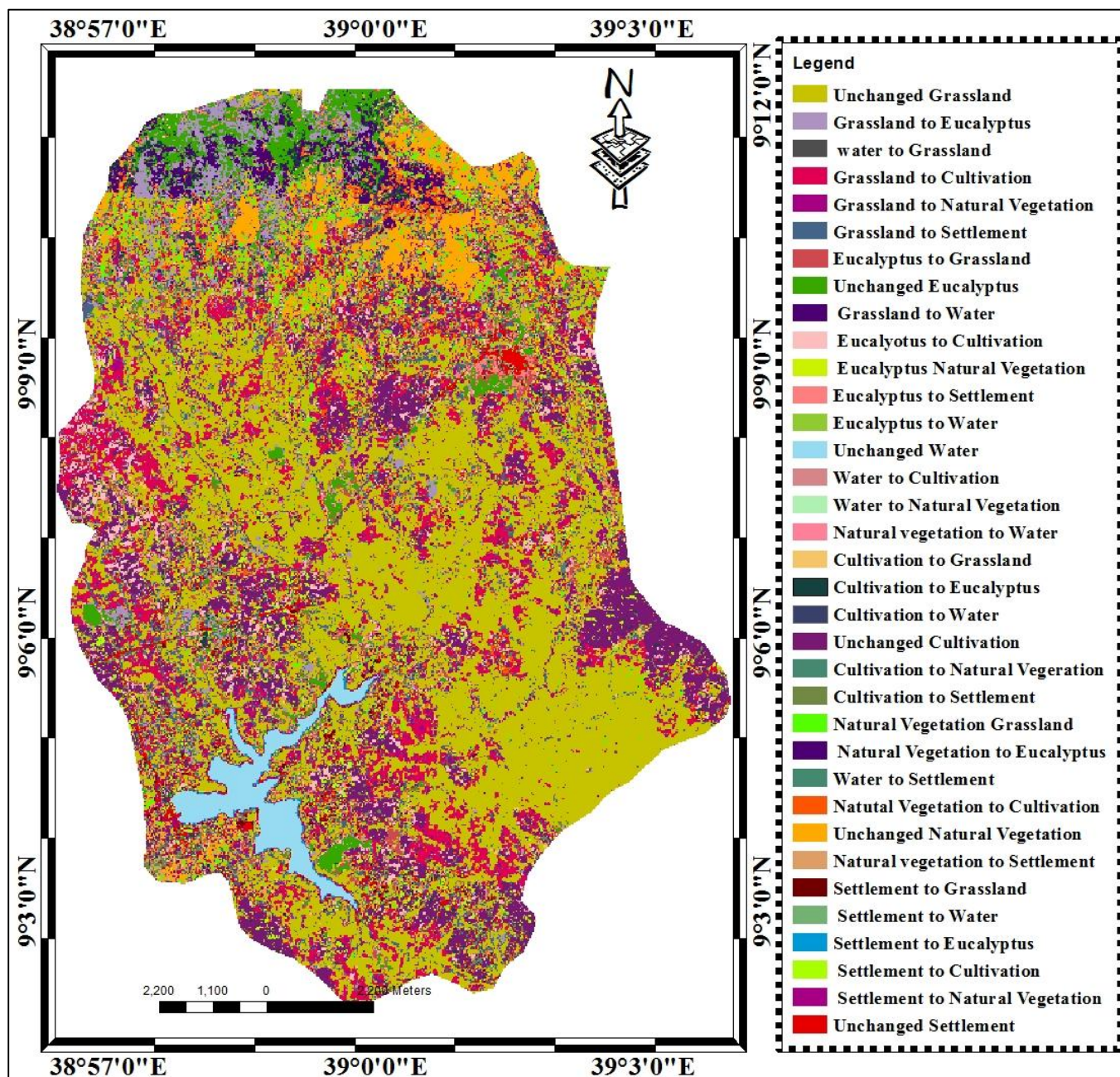


Figure 40 LULC change map of 1984-1999

Table 19 LULC conversion Matrix of 1984-1999

Conversion matrix of 1984-1999		1999					
		Water (km ²)	Settlement (km ²)	Natural Vegetation(km ²)	Eucalyptus (km ²)	Grassland (km ²)	Cultivation (km ²)
1984	Water	(4.47)	0.14	0.11	0	0.002	0.001
	Settlement	0.3	(3.26)	1.79	0.29	2.04	3.76
	Natural vegetation	0.016	12.8	(8.04)	3.63	4.67	4.78
	Eucalyptus	0.002	3.33	0.86	(8.4)	2.24	5.76
	Grassland	0.002	11.7	7.2	6.52	(77.76)	19.98
	Cultivation	0.019	3.96	1.85	2.24	2.76	(21.16)

Through the period of 1984-1999, there were substantial changes in several LULC categories including settlement and cultivation area increased. Cultivation has expanded at the expense of grassland (19.98sq. km), Eucalyptus (5.76sq. km), Natural Vegetation (4.78 sq. km) and Settlement (3.76 sq.km) classes and Settlement has expanded at the expense of Water (0.14sq km), Natural Vegetation (12.8sqkm), Eucalyptus (3.33sq. km.), Grassland (11sq.km.) and Cultivation (3.96 sq. km).

In general, the conversion matrix showed a tendency towards more land being brought under cultivation area and settlement. These given data expressly stated that the increase in cultivated function resulted in deforestation, meaning that some forest areas of eucalyptus tree and the natural vegetation and converted to cultivated areas.

4.2.12 LULC change map from 1999-2014

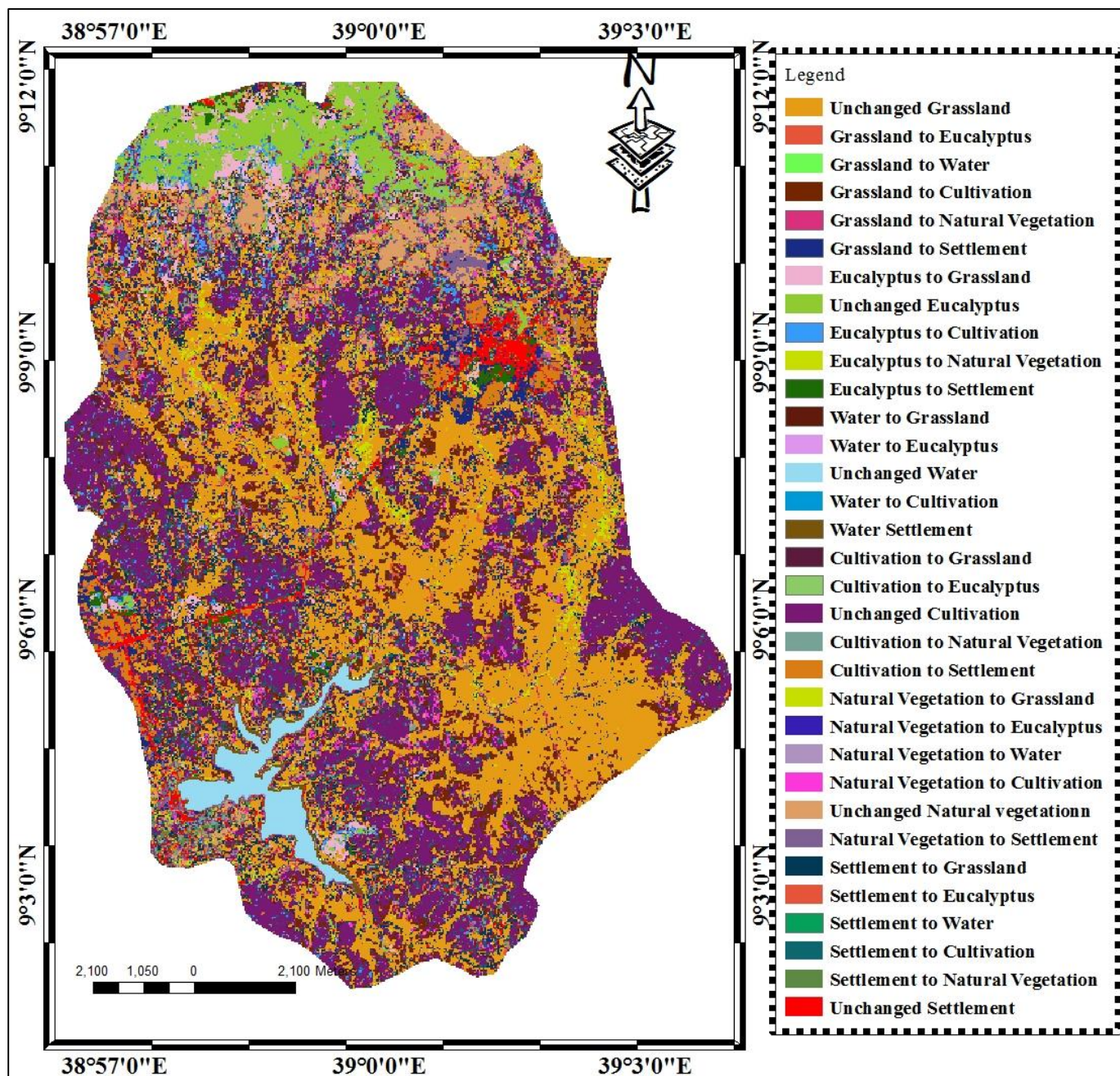


Figure 41 LULC change map from 1999-2014

Table 20 LULC Conversion Matrix of 1999-2014

Conversion matrix of 1999-2014		2014					
		Water (Km ²)	Settlement (km ²)	Natural Vegetation(km ²)	Eucalyptus (km ²)	Grassland (km ²)	Cultivation (km ²)
1999	Water	(3.6)	0.7	0.023	0.001	0.006	0.002
	Settlement	0.005	(5.3)	1.7	0.81	7.9	6.9
	Natural Vegetation	0.05	2.63	(6.27)	0.22	4.9	3.9
	Eucalyptus	0	2.3	0.24	(8.36)	4.68	3.38
	Grassland	0.001	7.49	2.67	1.67	(56.2)	15.4
	Cultivation	0	2.6	6.2	1.23	5.8	(3.9)

According to Table 19 conversion matrix for the year 1999-2014, the change in the land use/ land cover in the study area was by large attributed to expansion of cultivation and settlement area. Cultivation has expanded at the expense of grassland (15.4sq. km), Eucalyptus (3.38sq. km), Natural Vegetation 3.9 sq. km). Settlement (6.9 sq.km) and water (0.002 sq km) classes and Settlement has expanded at the expense of Water (0.7sq km), Natural Vegetation (2.63sqkm), and Eucalyptus (2.3sq. km.), Grassland (7.49sq.km.) and Cultivation (2.6sq.km.). Generally there is decrease of grassland, natural vegetation and eucalyptus cover in this period which goes to cultivation and settlement.

4.2.13 LULC change map from 1984-2014

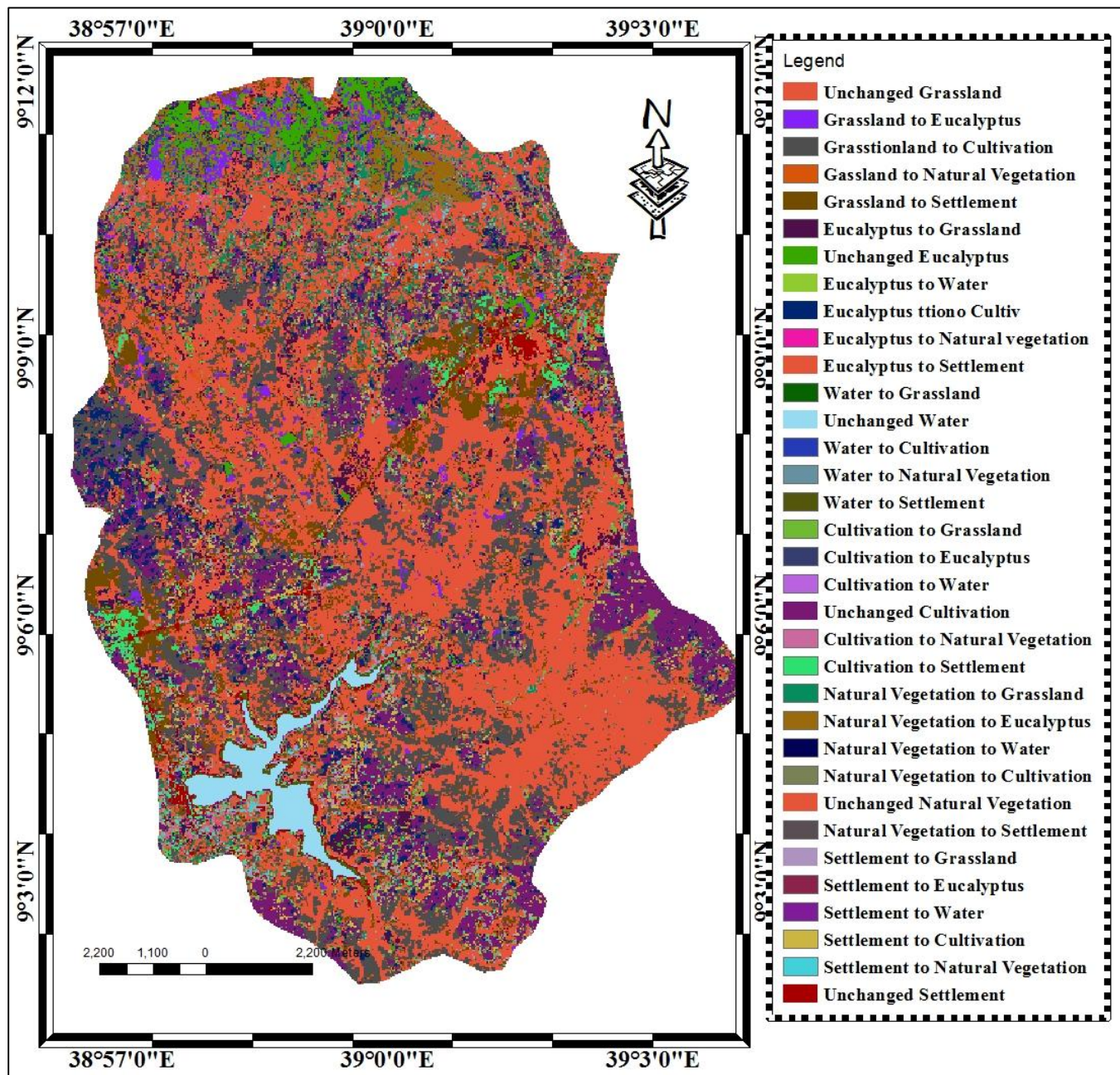


Figure 42 LULC change map from 1984-2014

Table 21 LULC Conversion Matrix of 1984-2014

Conversion matrix of 1984-2014		2014					
		Water (km ²)	Settlement (km ²)	Natural Vegetation(km ²)	Eucalyptus (km ²)	Grassland (km ²)	Cultivation (km ²)
1984	Water	(3.5)	0.59	0.019	0	0.008	0.001
	Settlement	0.12	(3.1)	0.93	0.13	2.2	3.8
	Natural Vegetation	0.004	2.2	(6.79)	2.88	4.69	4.9
	Eucalyptus	0.001	3.7	0.47	(4.2)	6.62	6.4
	Grassland	0	3.65	0.47	3.6	(62.7)	30.8
	Cultivation	0.01	3.2	1.5	1.36	3.2	(19.47)

According to Table 16 conversion matrix for the year 1984-2014, the change in the land use/ land cover in the study area was by large attributed to expansion of cultivation and settlement area. Cultivation has expanded at the expense of grassland (30.8 sq. km), Eucalyptus (6.4sq. km), Natural Vegetation (34.9sq. km). Settlement (3. 8 sq.km) and water (0.1 sq. km) classes and Settlement has expanded at the expense of Water (0.59sq km), Natural Vegetation (2.2sqkm), and Eucalyptus (3.7sq. km.) Grassland (3.65sq.km.) and Cultivation (.32sq.km.). Generally there is a decrease of grassland, natural vegetation and eucalyptus cover in this period which goes to cultivation and settlement.

In general, the last thirty years LULC change patterns showed a tendency towards more land being brought under annual crops and settlement. These given data expressly state that the increase in cultivated function mostly result in deforestation of eucalyptus tree and natural vegetation and converted grassland to cultivated areas.

4.3 Population and Environment Linkages in LCA

The population of catchment area *kebeles* has shown a rapid increase and it doubled in thirty years. The increment of population was very rapid and has implication to the resource base of the catchment. Parallel to this period, in the catchment there was very rapid land cover and use change as stated above in the land use land cover change analysis because of population increase.

Table 22. The population growth and the land use land cover change of the LCA

Year	T pop	Wat	Sett	NV	Euc	Grass	Cult
1984	21100	4.6	1139	24.1	23.66	123.1	31.98
1999	34306	4.8	23.7	19.86	21	92.69	55.4
2014	50935	4.1	26.7	17.9	19	79.5	69.8

Legend: Total population (T.Pop), Water in km² (Wat), Settlement in km² (Sett), Natural Vegetation in km² (NV), Eucalyptus in km² (Euc), Grassland in km² (Grass) and Cultivation in km² (Cult).

Source: CSA, Bereh *wereda* and GIS analysis result.

A correlation matrix among the considered variables was firstly tested employing Pearson's correlation coefficient through bivariate analysis with statistically significance at $p < 0.05$ to identify the relationship between LULCC and population growth over the study periods. In this analysis the land use category served as the independent variable and the rate of population growth as the dependent variable.

Table 23 Correlation of population size and land cover units in LCA

LULC Type	Statistical Indicator	population growth
Water	Pearson Correlation	-.815
Settlement	Pearson Correlation	.881
Natural vegetation	Pearson Correlation	-.997
Eucalyptus	Pearson Correlation	-.972
Grassland	Pearson Correlation	-.962
Cultivation	Pearson Correlation	.959

There was relationship between population size and land cover changes in LCA. The population in LCA and land cover units were correlated (Table 20 and 21). There was strong positive relationship between population size and year change, settlement expansion and Cultivation expansion. This is because there was increase in population size and there was proportional expansion of cultivation and settlement in the catchment. But the relationship between population size and water, natural vegetation coverage, eucalyptus and grassland coverage has shown strong but negative correlations that means as population size increased there was decline of natural vegetation coverage, eucalyptus, grassland coverage and volume of water of the reservoir (Table 21). This implies that population growth in LCA was one of the causes of conversion of water, natural vegetation coverage, eucalyptus coverage and grassland into cultivation and settlement within the stated periods and its final consequence is the disturbance in the ecosystems of the catchment.

4.4 Volume of Water and Sediment accumulation of LWR of different years

4.4.1. Volume of LWR in different years

Table 24 Legedadi Water reservoir Volume of water

No	Years	Volume of water
1	1979	45.9 M CM
2	1998	43.8 M CM
3	2010	42.17 M CM

Source: AAWSA, 2013

A total volume at the maximum water level for the 1979 data of 45.9 MCM was obtained. For the same elevation in 1998 the volume is 43.8 MCM. This indicates a 2.1 MCM reduction and the 2010 survey showed a total reservoir volume 42.17 MCM. This amounts to a volume reduction of 3.72 MCM since 1979 and 1.62 since 1998. (AAWSA, 2013)

4.4.2. Average annual siltation rates

Table 25 Average annual siltation rate of LWR

N0	Years	Annual siltation rates	Average annual volume reduction rate
1	1979 to 1998	110,000 m ³ /year	0.24%/yr
2	1979 to 2010	120,000 m ³ /year	0.31%/yr
3	1998 to 2010	135,000 m ³ /year	0.26%/yr

Source: AAWSA, 2013

An average annual siltation rate of 110000m³/yr from 1979 to 1998 120,000 m³/yr between 1979-2010 and 135,000 m³/yr between 1998-2010. These figures translate to an average annual volume reduction rate of 0.26%/yr for the period 1979-2010 and 0.31%/yr for the period (AAWSA, 2013).

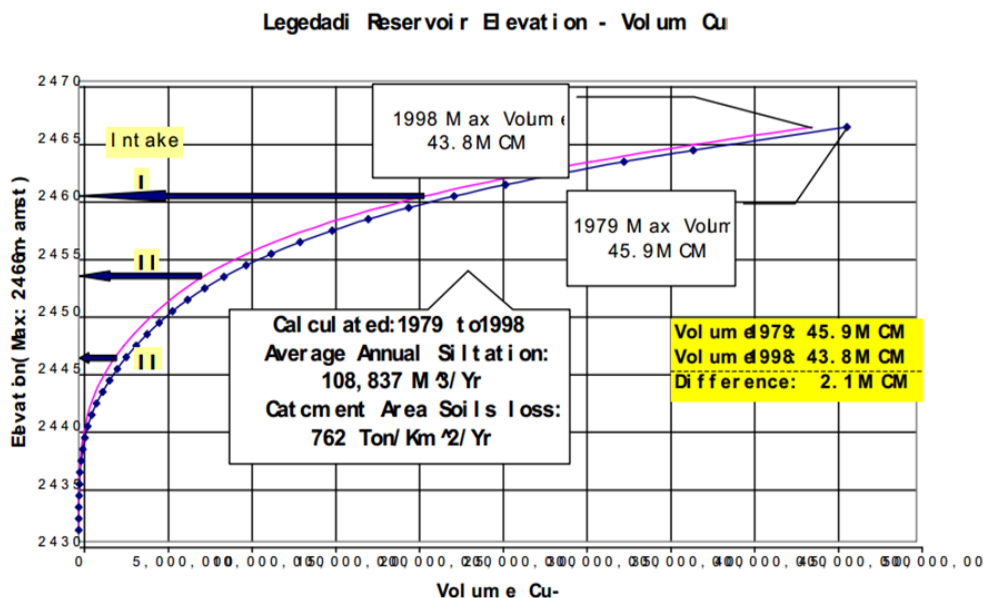


Figure 43 Legedadi Water Reservoir Volume curve

Source:Tahel Consulting Engineering (2003)

Attempt has been made to project the volume of water and silt deposition of the LWR by taking the 1979, 1998 and the 2010 Bathymetric survey result. The growth rates were calculated on the basis of the assumption of geometric decrement formula.

Table 26 Projected Volume of water and amount of silt in LWR

Year	Volume of water	Amount of silt
1984	44.338MCM	575,000m ³
1999	42.615MCM	1270000m ³
2014	41.193MCM	540000M ³ * 1810000M ³ **

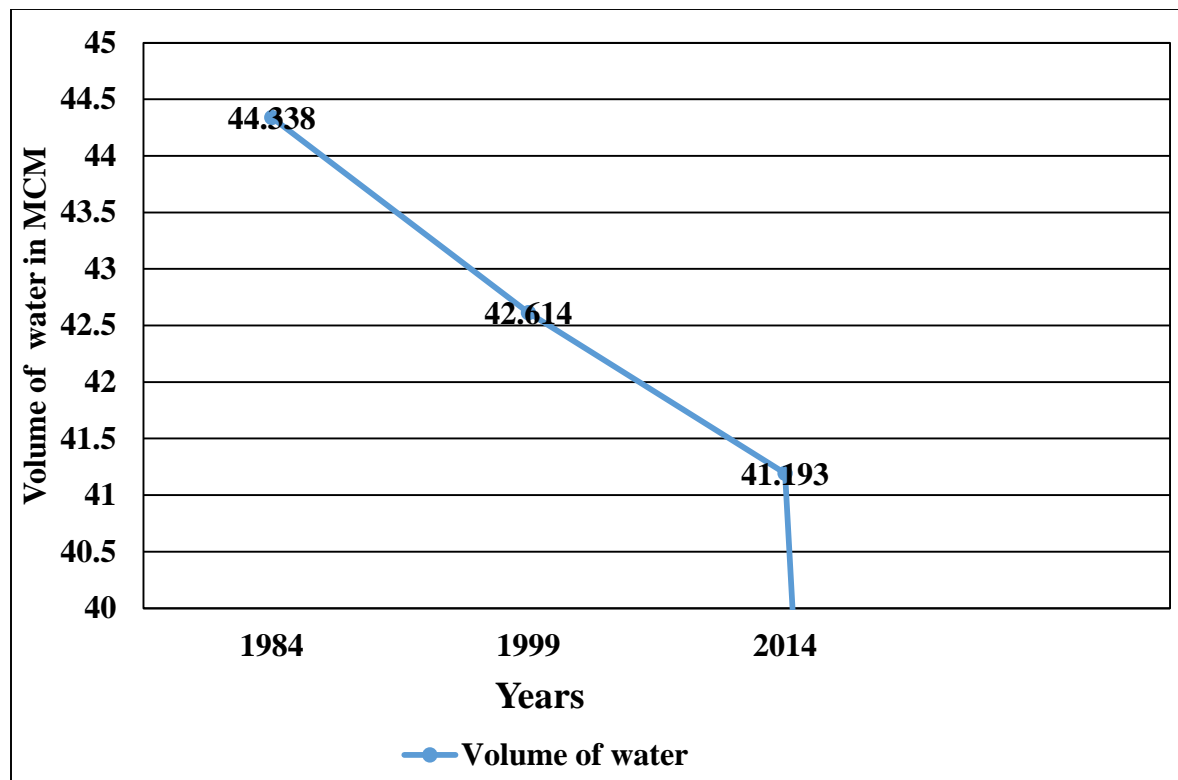


Figure 44 change of volume of water

Source: AAWSA, 2013

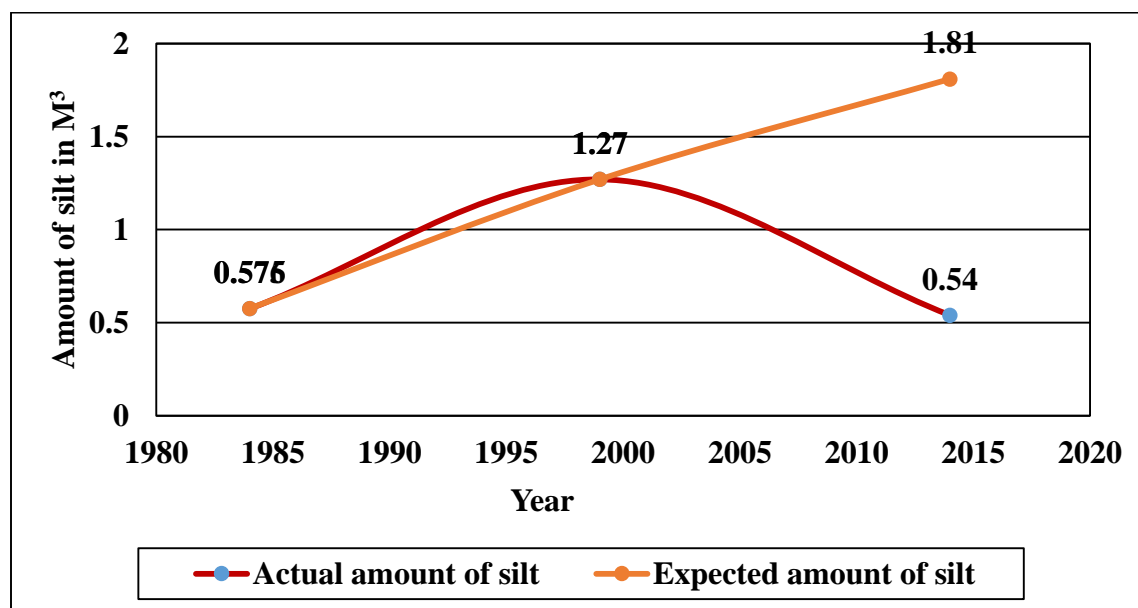


Figure 45 Chart of the amount of silt deposition of LWR

Source: AAWSA, 2013

Engineering works of (AAWSA, 2013), the volume of water in the reservoir decreased from time to time and the amount of silt deposition increased as the result of the amount of erosion in the catchment area. The expected amount of silt in 2014 was 1810000M³ but it decreased to 540000M³ because there was treatment of the reservoir in 2010.

4.4.3 The relationship between land use land cover change and LWR

Statistical analysis with Pearson Correlation coefficient through bivariate analysis with statistically significance at $p < 0.05$ was applied to identify the relationship between LULCC and volume of water and amount of silt in LWR over last thirty years. In this analysis the land use category served as the independent variable and the rate of volume of water and amount of silt of LWR served as the dependent variable.

Table 27 Pearson’s correlation coefficient between LULC and volume of water and the amount of silt

LULC Type	Statistical Indicator	Volume of water	Amount of silt
Water area	Pearson Correlation	.742	-.734
Settlement	Pearson Correlation	-.930	.936
Natural vegetation	Pearson Correlation	.982	-.978
Eucalyptus	Pearson Correlation	.938	-.931
Grassland	Pearson Correlation	.987	-.990
Cultivation	Pearson Correlation	-.986	.988

There was strong positive relationship between volume of water and water area, natural vegetation, eucalyptus grassland coverage and negative correlation with settlement area and cultivation expansion. This shows that there was a significant relationship between volume of water decrement the expansion of settlement and cultivation area.

The amount of silt and settlement increment and the expansion of settlement and cultivation was positively correlated which means the expansion of settlement and cultivation had an impact for the increment of silt in the LWR.

4.5 Analysis of Socio-Economic Survey

According to the Cochran formula the desired sample size was found to be 384 and to compute the actual sample size for the selected *kebeles* population number data of the two *kebeles* were 81 (Dabe Muda Guda) and 69 (Lege Beri Lege Bolo) .

These 150 households were randomly selected from their respective *kebeles* to analyze their response regarding the population growth and underlying causes and effects of land use/land cover change and the variables that determined the production of crops per quintal per year.

4.5.1 Age - Sex Composition

The age - sex structure refers to the composition of the household head according to age and sex.

The age - sex composition of the sampled household is presented in Table 29.

Table 28 Age- Sex composition of the study population

Age group	Sex		
	Male	Female	Total
25-35	16	7	23
36-44	25	9	34
45-53	45	23	68
54-64	9	7	16
>64	5	4	9
Total	99	51	150

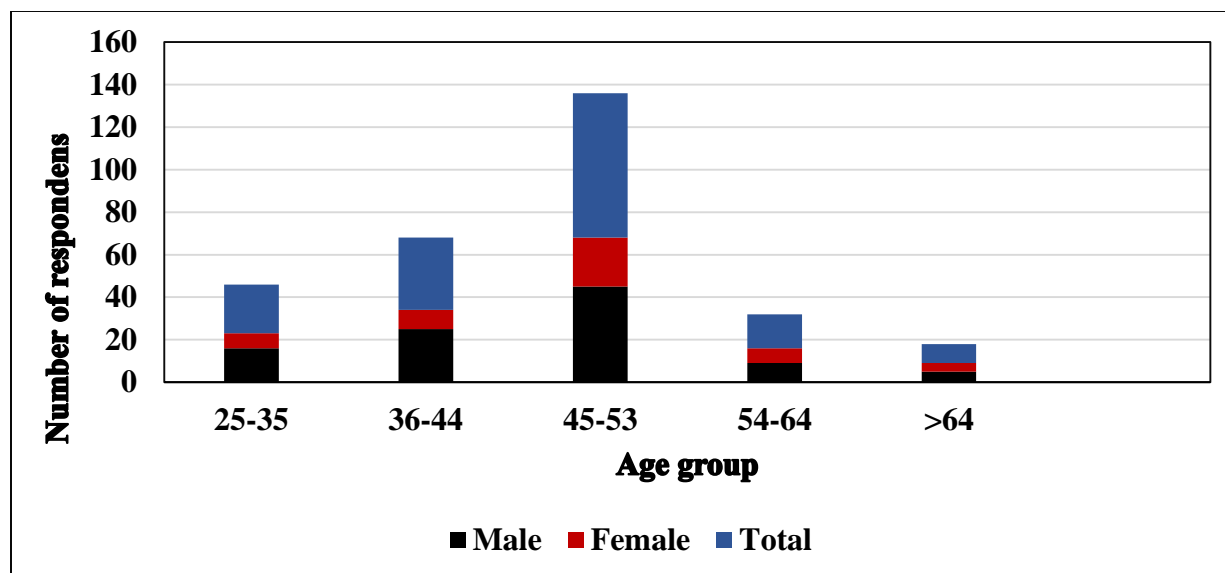


Figure 46 Chart of Age- Sex composition of the study population

The age - sex structure refers to the composition of the household head according to age and sex. The age - sex composition of the sampled household is presented in Table 27. Accordingly, the mean age of the respondent was about 44 years. While the median age was between 45 and 53. Respondents below age 44 constituted nearly 57 per cent of the total and above 44 the remaining 33 per cent. Sex wise the vast majority of the household heads nearly 66 per cent were males whereas females constituted the remaining proportion (34 per cent).

4.5.2 Marital Status

Table 29 Percentage Distribution of Respondents by marital status

Marital Status	Number	Percent
Married	110	73.3
Divorced	25	16.6
Widowed/Widower	15	10
Total	150	100

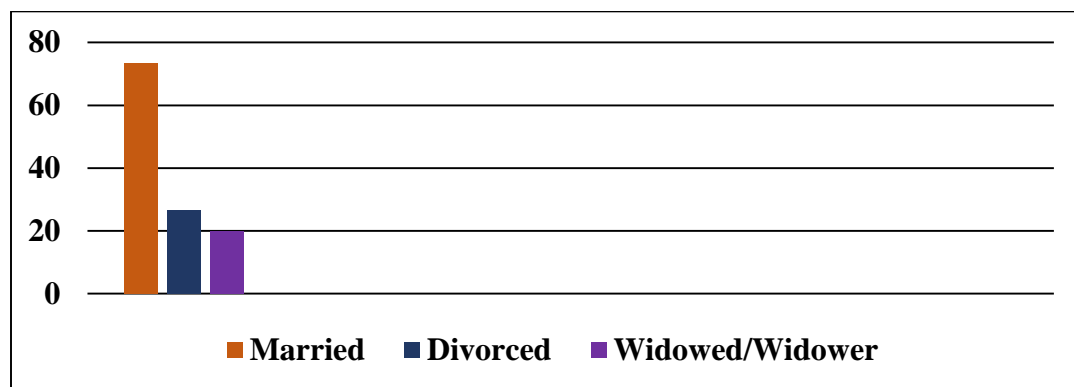


Figure 47 Chart of percentage distribution of respondents by marital status.

Analysis of the data indicated that 73.3 percent of the respondents were currently married while divorced and widowed/widower constituted 16.6 and 10 percent respectively. Table 29 presents data on the marital status of the respondents.

4.5.3 Literacy Status of Respondents

Table 30 Percentage of the respondent's educational level

Education	Number	Percent
Illiterate	120	80
Read only	17	11.33
Read and write	13	8.6

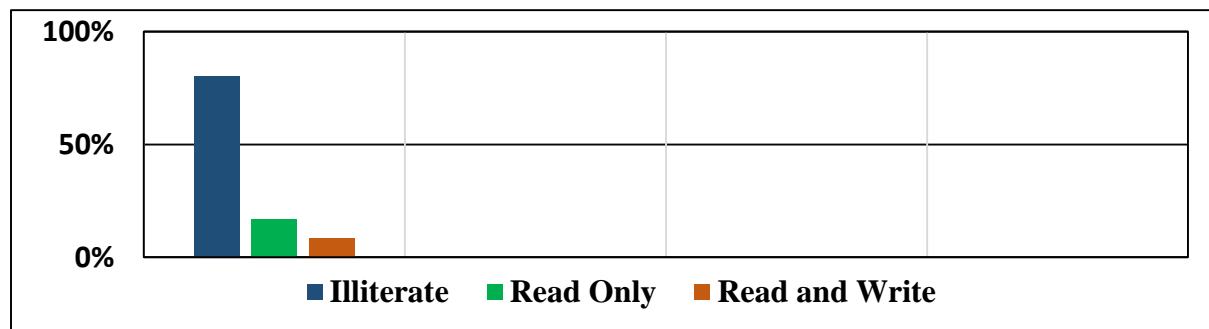


Figure 48 Percentages of the respondent's educational level

The majority of the people make a living from agriculture, 80 percent of the respondents were illiterate, whereas 11.33 and 8.6 percent could read and read and write respectively.

4.5.4 Population growth in the area

Table 31 percentage Distribution of Respondents reason for population growth

Reason for population growth	Number	Percent
Natural increase	110	73.3
Migration	40	26.66
Total	150	100

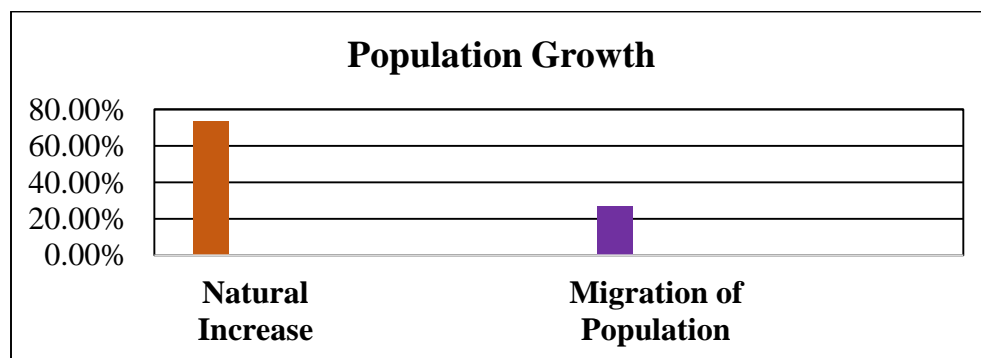


Figure 49 Chart of population Change

As indicated in Table 23 and Fig 49 more than 73% of the respondents stated that there is population growth in the area because of natural increase of the population, whereas 26.66 % agreed that the cause of population growth is because of migration of people from other place.

Regarding this, the FGD discussants and KII participant (held at a place called Dabi Muda *Kebebe* 01/02/2016 Figure 50) witnessed that high population growth in the area resulted by mostly the natural increase.



Figure 50 FGD discussants

Source: From the field work

4.5.5 Off - Farm Income

As it was discussed in PPI, off –farm (non- agricultural) activity is one of the most important factor that determine the population pressure level of the area. During the survey, respondents were asked whether they had participated in off-farm activities or not. The data given in Table 32 show the

percentage distribution of the sample household by off-farm income. Accordingly, 88 percent of the respondents were not involved in off - farm activities while about 12 percent of the respondents had participated in off - farm activities in the last 12 months.

Table 32 Percentage distribution of respondents by their monthly off farm income

Off farm income status	Number	Percent
Participated	18	12
Not participated	132	88
Total	150	100

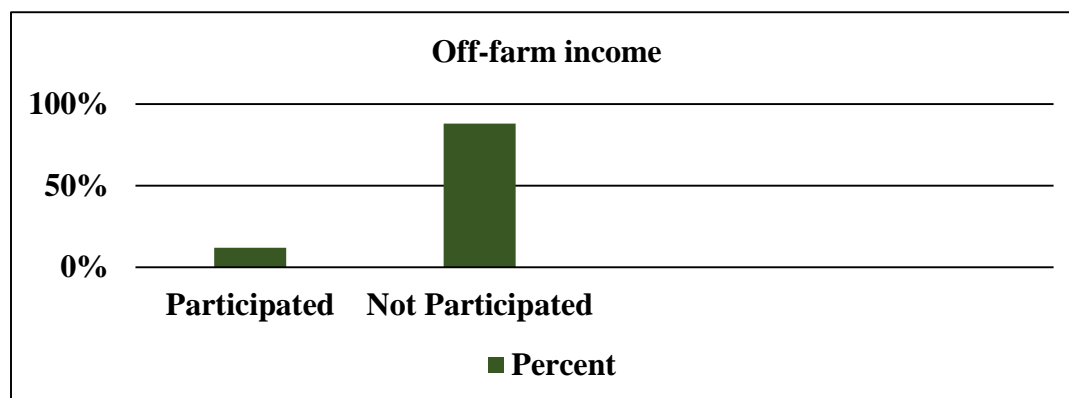


Figure 51 Chart of distribution of respondent by their monthly off-farm income

The result shows that only few people are participating in the off-farm activities. If farmers were to increase their off-farm income, the relative risk for population pressure and its consequence LULC change would not be at large rate.

4.5.6 Proximate causes of Land use land cover change

Table 33 Perception of respondent for the proximate causes of land use land cover change

Proximate Causes	Number	Percent
Agricultural Expansion	10	6.66
Infrastructure Expansion	3	2
Wood Extraction	1	0.6
Two factors		
Agri-Infra	63	42
Agri-Wood	20	13.3
Infra-Wood	13	8.66
Three Factors	40	26.61
Total	150	100

As it's presented in Table 34 the agricultural expansion of agriculture as a single factor represented 6.66%, infrastructure 2% and wood extraction explained .06 % each.

Table 34 Perception of respondent for the specific proximate causes of land use land cover change

Specific Factors	Number	Percent
Agricultural Expansion	133	88.57
✓ Small scale subsistence	105	70
✓ Resettlement	108	72
✓ Commercial cultivation	45	30
✓ Shifting Cultivation	3	2
Infrastructure Expansion	119	79.27
✓ Settlement expansion	98	65.3
✓ Road transport	67	44.66
✓ Duration of houses	24	16
Wood Extraction	74	49.33
✓ Fuel wood	76	50.66
✓ Charcoal production	15	10
✓ Wood for house construction	73	48
✓ Logging	9	6

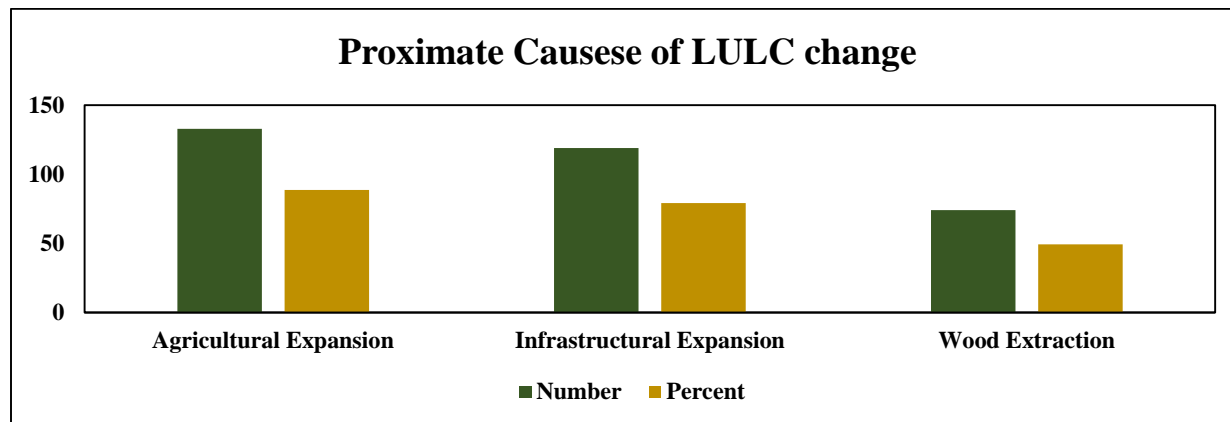


Figure 52 Chart of Proximate causes of LULC change

From the broad division of proximate causes agricultural expansion was the main cause of the LULC change in LCA. Among the specific factors, the share of small farming, resettlement, commercial cultivation and shifting cultivation was 70%, 72%, 30% and 2%.

Agriculture is the dominant proximate change in the study area, as most of the population heavily relies on this sector for food and the main economic activity.

Infrastructural expansion with other approximate causes explains 119 out of 150 respondents of land cover change (79.27%). The specific factors of infrastructural expansion; settlement expansion 65.3%, road transport 44.66% and duration of house 16% contributed for LULC change.

The combined contribution of wood extraction with the other proximate causes was found to lead as confirmed by 74 out of 150 respondents (49.33%). Among the specific causes of wood extraction fuel wood 50%, charcoal production 10%, wood house construction 48% and logging 6% contributed.

4.5.7 Underlying causes of Land use land cover change

Table 35 Percentage of Perception of respondent for the underlying causes of land use land cover change

Underling Driving Forces	Number	Percent
Political	0	0
Demographic	10	6.66
Economic	3	2
Socio-Cultural	3	2
Two Factors		
Pol-Dem	10	6.66
Pol-Eco	9	6
Pol-Socul	2	1.33
Dem-Eco	15	10
Dem-Socul	16	10.66
Eco-Socul	7	4.66
Three Factors		
Pol-Dem-Eco	22	14.66
Pol-Eco-Socul	24	16
Dem-Eco-Socul	20	13.33
Pol-Dem –Socul	9	6
All	35	23.3
Total	150	100

Like proximate causes, the underlying causes of LULC change are also characterized by different single factors. 10.66% of the respondent explained single underlying forces as the causes of LULC change whereas 89.44% of the respondent answered combined causes of LULC change. Demographic factors with other underlying causes (91.33%) was found to be the most dominantly causes to all respondents. Economic factors (90%) was found as the second dominant causes, socio-cultural (77.33%) and political factors (74%).

Table 36 Percentage of Perception of respondents for the specific underlying causes of land use land cover change

Drivers	Number	Percentage
Political	111	74
✓ Corruption	63	42
✓ Weak institutional performance	57	38
✓ Insecure tenure	52	34.66
Demographic	137	91.33
✓ Population increase(natural)	135	90
✓ Population increase (migration)	94	62.66
✓ Population density	129	86
Economic	135	90
✓ Increase access to market	89	59.33
✓ Increase In crop price	77	51.33
✓ Increase in annual income	45	30
Socio –Cultural	116	77.33
✓ Change in public altitude	87	58
✓ Extensification	76	50.66
✓ Religion	33	22

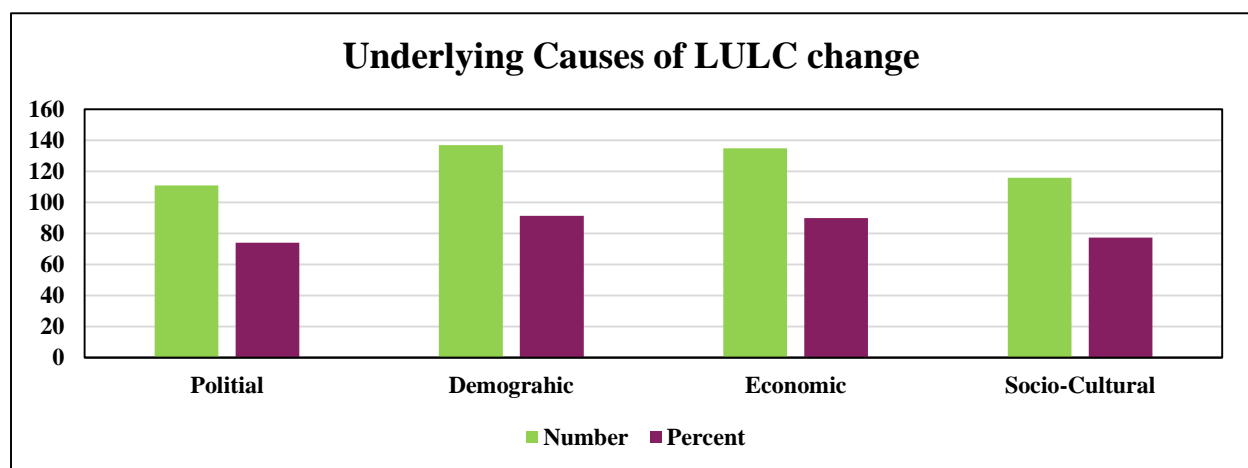


Figure 53 Chart of Underlying Causes of LULC change

Political factors were found to be underlying causes of LULC change accounted for 111 out of 150 (74%) of all respondents. This large category was subdivided in to corruption, weak institutional performance and insecure tenure accounted for 42%, 38% and 34.66% respectively.

The specific factors of demographic factors (91.33%) contributed, the population increase (natural) 90%, population increase (migration) 62.66% and population density 86%.

The economic factors were identified to underlie (90%) of all the respondents of LULC change with 135 out of 150. Among the specific factors, increase access to market 59.33%, increase in crop price 51.33% and increase in annual income 30% contributed.

The last underlying cause of LULC change were the socio-cultural factors, which contributed 77.33% from all the respondents. Among the specific factors change in public attitude is the most frequently cause of LULC change (58%). Extensification, which is the clearing of forests for cultivation contributed 50.66% and lastly religion contributed 22%.

Furthermore, a discussion about the adverse causes of LULC change among FGD participants and KII generated such adverse causes as rise of population pressure, expansion of settlement and cultivated areas.

A reflection on the responses of both FGD participants and KII revealed that there seems to exist a considerable level understanding of the causes of LULC change. This is desirable because it can be thought to imply the greater likelihood of emerging behavioral intentions aimed at mitigating the problems of LULC change. Moreover, a seventy years old household head from Lege Beri Lege Bolo *kebele* when asked about the causes of LULCC said the following;

“I have born and living here in this kebele and saw many LULCC for many years. This may be because of the growth of population which was causing land scarcity for many years up to now.”

The above response from an interviewee demonstrates the impacts of population pressure on LULCC. The respondent assumes that the population growth results in the LULCC and then concludes that the scarcity of land is caused by population growth

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the result indicates that the population growth and the increasing of population pressure level is observed. The growing population pressure and its associated problems, such as the increasing demand for land for agricultural products and the expansion of settlement were identified. Currently, Legedadi Catchment Area, which is the largest source of surface water for Addis Ababa, reflected a critical dynamic change of LULC due population pressure. The correlation of population growth and LULC change over the study periods shown that there was strong linkage between population growth and LULCC.

The results of the study disclosed that the Legedadi Catchment Area had been under continual LULC changes from 1984 to 2014. Cultivation and grassland coverage are the predominant types of LULC, however the earlier has been increased its expansion. Expansion of cultivated area and deforestation of natural vegetation and eucalyptus trees and increasing demand for settlement had imposed a threat of land degradation. The results also showed that the areas were dominated by high levels of land degradation.

LULC types showed a significant relationship with water quality of the LWR. The relationship of the LWR and the LULC types were indicated using correlation model. It was noticed that there was strong correlation between Land use/ Land cover change and the Legedadi Water Reservoir (LWR). Furthermore, it could be concluded that water volume and amount silt of the Legedadi Water Reservoir was associated with LULC, which were generally good predictors of water quality conditions.

On the basis of household survey, the proximate and underlying causes of LULC change were identified. The evidence from this analysis indicated that among the broad group of proximate causes, Agriculture was the main causes of LULC change. And from the underlying causes of LULC change demographic were the main causes of LULC change in Legedadi Catchment Area.

5.2 Recommendations

For recommendation, therefore, lasting solutions to the problem of resources degradation in the watersheds and the country level should be considered, a number of practical measures geared toward improving sustainability of the catchment are identified as follows:

1. Reducing population pressure on the land. Population increase has played a major role on LULCC and there should be strong family planning awareness.
2. Conserving the forest area by strong follow up and by creating reserved area for forest area only.
3. Promoting development of the non-agricultural economy.
4. Upper catchment *kebeles* (Girari Reh, Deri-Sokoru, and Dabe Muda Godo), the most fragile segmentation, can be managed by rehabilitation program for degraded areas with agroforestry system. The middle and downstream area, receiver of environmental impacts, can be managed by developing non-agricultural economic activity.
5. There is an urgent need for community education and information awareness about the social, economic, and physical consequences on the impacts of LULC change and watershed degradation, e.g. forest degradation, water pollution and soil erosion
6. Making the catchment area people more profitable by providing water for the people from the reservoir.

7. Policy review and assessment needs to be undertaken by all concerned stakeholders in managing the water reservoir and the catchment area.

References

- AAWSA. (2013). Master Plan Review, Catchment Rehabilitation and Awareness Creation for Geffersa, Legedadi, and Dire Catchment Areas. *Master Plan Review* (p. 148). Addis Ababa: Urban water supply and sanitation project .
- AAWSA. (2015). *Addis Ababa Water Supply Stage III-A Project*. Addis Ababa: AAWSA.
- Addis Ababa Urban Planning Institute. (2012). *Population distribution in Addis Ababa*. Addis Ababa.
- AESL International Ltd. Consulting engineers. (1993). *Addis Ababa water resources reconnaissance study*. Addis Ababa: AAWSA.
- AFIDEP and PAI. (2012). *Population Dynamics, Climate Change, and Sustainable Development in Africa*. Nairobi, Kenya: Population Action International and African Institute for Development Policy (AFIDEP) and Population Action International (PAI).
- Aguinaldo, P. (2009). Rethinking Validity in Qualitative Research from a Social. *The Qualitative Report*, 125-136.
- Aklilu, A. (2006). Caring for the Land: Best Practices in Soil and Water Conservation in Beressa Watershed, Highlands of Ethiopia. *Tropical Resource Management Papers No.76*.
- Alema, T. (2009). Steady-state groundwater flow and contaminant transport modelling of Akaki wellfield and its surrounding catchment. *Unpublished Thesis*, 150-160.
- Alemayehu, M. (2010). Synthesis of research on LULC dynamics in the Ethiopian highlands. *Unpublished MA thesis*, 50-62.

- Amare, S. M. (2013). Population and Environment Interaction: the case of gilgel abbay catchment, northwestern Ethiopia. *Jornal of Environmental Research and Management*, 153-162.
- Amdework , B. (2012). Hydraulic Network Modeling and Upgrading of Legedadi Water Supply. *Unpublished thesis*, 160-178.
- Andualem, G. (2008). Prediction of sediment inflow to Legedadi reservoir. *Nile basin water Engineering Scientific*, 1.1, 60-74.
- Arowolo, O. O. (2010). *Population Issues in National Development of Ethiopia*. Center for Global Development Working Group on UNFPA's Leadership Transition.
- Ashenafi, B. (2008). Landuse/landcover dynamics in prosopis juliflora invaded area of Metehara and the surrounding districts using remote sensing and GIS techniques. *Unpublished MA Thesis*, 88.
- Asmamaw , G. A. (2013). Assesing the impact of LULC change on Hydrology of Watershed: A Case study on Gilgel–Abbay Watershed, Lake Tana Basin, Ethiopia. *Unpublished phD dissertation*, 60-70.
- Atasoy, M., Biyik, C.,Ayaz, H.,Karsli, F., Dermir, O., Baskent,E.Z. (2006). Monitoring land use changes and determinating the suitability of land for different uses with digital Photogrammetry. In *Remote Sensing and photogrammetry* (pp. 200-250). Cairo, Egypt.
- Badege, B. (2005). Deforestation and Land Degradation in the Ethiopian Highlands. *A Strategy for Physical Recovery*.

- Bceom. (1993). *Water Supply -Project Stage 2 new dams preliminary survey*. Addis Ababa Ethiopia.
- Bereh Woreda Administration. (2015). *The socio-economic condition of the Bereh woreda administration*. Sendafa.
- Boserup, E. (1981). *Population and Technological Chang*. Chicago: University of chicago Press.
- Campbell and Martha. (1998). An Analysis of Interest Groups Influential in International Population Policy. *Population and Environment*, 19, 120-130.
- Carla Bielli, Gezu Berhanu, Amare Isaias, Arianna Orasi. (2001). *Population growth*. Roma,Italy: Institute for population research _National research council (Irp_Cnr).
- Castro, F.; Silva-Forsberg, M.; Wilson, W.; Brondizio, E.; Moran, E. (2002). The use of remotely sensed data in rapid rural assessment. *Field Method.*, 243-269.
- Cochran, W. (1977). *Sampling Techniques*. 440.
- Cohen, J. (1995). *How Many People can the Earth Support?* New York: Norton.
- Colin McEvedy and Richard Jones. (The 1998 Revision). *Atlas of World Population History*. New York: U.N. Secretariat, World Population Prospects.
- Congalton, R. (1991). A Review of assessing the accuracy of classifications of remote sensing data. *Remote Sensi Environ*, 35-45.
- Coppin, P. and Bauer, M. . (1996). Digital Change Detection in Forest Ecosystems with Remote Sensing Imagery. *Remote Sensing Reviews*. Vol. 13. , 200-250.

- Creswell, W. (2003). *Qualitative, Quantitative and Mixed approaches*. London: Sage Publication.
- CSA. (1984 a). *The population and Housing Census of Ethiopia;Result at a Cotntry level*. Addis Ababa: Office of population and housing census commission.
- CSA. (1984 b). *Annual Agricultural Sample Survey*. Addis Ababa: CSA.
- CSA. (1994). *The population and Housing Census of Ethiopia;Result at a country level*. Addis Ababa,Ethiopia: Office of populationand housing commision.
- CSA. (2004). *Statistical Abstract. Federal Democratic Republic of Ethiopia*. Addis Ababa: office of population and housing commision.
- CSA. (2008). *Summary Statistical Draft Report of National Population Statistic*. Addis Ababa, Ethiopia: office of Central Stastitics Authority.
- CSA. (2014). *Shape files of Ethiopia and Regions*. Addis Ababa: CSA.
- Daniel , A. M. (2008). Remote sensing and GIS-based Land use and land cover change detection in the upper Dijo river catchment, Silte zone, southern Ethiopia. *Unpublished MA Thesis*, 37.
- Eleni Yeshaneh, Wagner, W.,Exner-Kittridge, M., DagnachewLegesse and Bloschl, G. (2013). Identifying Land Use/Cover Dynamics in the Koga Catchment, Ethiopia, from Multi-Scale Data, and Implications for Environmental Change. *ISPRS International Journal of Geo-Information*, 302–323.
- Ellis, E. a. (2007). Land use and land cover change. *Encyclopedia of Earth*.

EMA. (1982). *Toposheets 0939 D4*. Addis Ababa: EMA.

EMA. (2015). *Landsat images of the Legedadi Catchment area*. Addis Ababa: EMA .

Endalkachew, G. (2012). Climate Change Impact on Surface Water Sources of Addis Ababa.

Unpublished MA Thesis, 110-120.

Ephrem , G. B. (2010, September). Geospatial Analysis to Study Environmental Change:Climate

Variability and Vegetation Cover Dynamics in Ethiopia and the Horn of Africa.

Unpublished PhD. Dissertation, 105.

Ermias, T. D. (2015). Soil hydrological impacts and climatic controls of land use and land cover

changes in the Upper Blue Nile (Abay) basin. *Ph.D Dissertstion*, 263.

European Commision. (2001). *Manual of concepts on land cover and land use information*

systems. Luxembourg.

FAO. (2000). Classification Concepts and User Manual. In *Land Cover Classification System*

(LCCS). Retrieved from <http://www.fao.org/>

Gebresamuel, G., Singh, B. R. & Dick. (2010). Land-use changes and their impacts on soil

egradation and surface runoff of two catchments of Northern Ethiopia. *Acta Agriculturae*

Scandinavica, Section B – Plant Soil Science, 210-230p.

Geist, H. J. and Lambin, E. F. (2002). Proximate Causes and Underlying Driving Forces of

Tropical Deforestation. *BioScience*, 140-150.

Gerhard, H. (1994). Neglected Dimensions of Global Land-Use Change. *population and*

development review, 20, 830-858.

- Getachew, W. (2013). Rural Livelihoods under Climate Variability: Impacts, Vulnerability. *Unpublished MA Thesis*, 120-125.
- Girma, K. (2003). GIS based analysis of land use and land cover, land degradation and population changes: A study of Boru Metero area of south Wello, Amhara Region. *Unpublished MA thesis*, 100.
- Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report*, 597-605.
- Gomm, R. (2009). Key Concepts in Social Research Methods. *MacMillan Research Review*, 18(1), 200.
- Goudie, Andrew, and Heather Viles. (1997). *An Introduction to Human Impacts on the Environment*. Oxford, U.K.: Blackwell Publisher.
- Herold, M., Latham, J.S., DiGregorio, A. and Schullius, C.C. (2006). Evolving Standard in the land cover characterization. *Journal of land use science*, 157-168.
- Hessen-Biber, S.N. (2010). *Mixed Methods Research: Merging Theory with Practice*. New York: The Guilford press A RAND Program of Policy-Relevant Research Communication.
- Houghton, R. (1994). The Worldwide Extent of Land-Use Change. *Bioscience*, 44, 305-313.
- Hunter, L. M. (2000). *The Environmental Implications of Population Dynamics*. Santa Monica: RAND.

- Hussein, A. O. (2009). Landuse and landcover change, Drivers and its Impact: A comparative Study from Kuhar Michael and Lenche Dima of Blue Nile and Awash Basins of Ethiopia. *Unpublished Msc Thesis, Cornell University ,Bahirdar,Ethiopia*, 140.
- Jensen, J. (2004). *Introductory digital image processing: a remote sensing perspective*. New Jersey: Prentice-Hall.
- Joseph A. and McFalls Jr. (2003). Population: A Lively Introduction, 4th Edition. *Population Bulletin*, 58, No. 4, 44.
- Knapp, T.R. and Mueller, O.R. (2010). Reliability and Validity of Instruments. . *Guide to Quantitative Methods in the Social Sciences*, 337-343.
- Liu, H. and Zhou, Q. (2004). Accuracy Analysis of Remote Sensing Change Detection by Rule Based Rationally Evaluation with Post-classification Comparison. *International Journal of Remote Sensing*, 1000-1050.
- Lu, D., Mausel, P., Brondi'zio, E. and Moran, E. (2003). Change detection techniques. *Remote Sensin*, 2365-2410.
- MacKellar, F. Landis, W. Lutz, C. Prinz, and A. Goujon. (1995). population, Households, and CO2 Emissions. *Population and Development*, 21(4), 850-860.
- Malthus T. (1960). *An Essay on the Principle of Population 1798 and 1803*. New York: Modern Library and Randome House.
- Markos E. and Dilnesaw A. (1998). population, Environment, Resource and Sustainable development in Ethiopia. In ICDR, *Hand book on population and family life education*

for secondary school in Ethiopia (p. 390). Addis Ababa: Institute for Curriculum, Development and Research.

Marquette, C. M. and R. Bilborrow. (1994). A Literature Survey and Bibliography of Recommendations for Future Research. In *Population and Environment in Developing countries* (p. 122). New York: United Nations Population Division.

Matson, P. A., W. J. Parton, A. G. Power, and M. J. Swift. (1997). Agricultural Intensification and Ecosystem Properties. *Science*, 277, 500-510.

Mengistie Kindu, Thomas,S., DemelTeketay, Thomas, K. (2013). Landuse/Landcover change analysis using Object based classification approach in Munesa Shashemene Landscape of the Ethiopian highlands. *Remote Sensing*, 5, 2411-2435.

Messay , M. T. (2011). Land-use/Land-Cover Dynamics in Nonno District, Central Ethiopia. *Journal of Sustainable Development in Africa (Volume 13, No.1, 2011)*, 140.

Meyer, W.B. and Turner, B. L. (1994). *Changes in land use and land cover*. New York: Cambridge University Press.

Miaoulis, George, and R. D. Michener. (1976). *An introduction to Sampling*. Dubuque. Kendall/Hunt Publishing Company.

Mulugeta, L. (2004). Effects of Land Use Changes on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia. *Doctoral dissertation Department of Forest Soils, SLU (Swedish University of Agricultural Sciences)*., 250-260.

Muluneh, W. (2003). Population growth and Environmental Recovery: More people, more trees.

Ethiopian Journal of Social Sciences and Humanities Vol. 1, No.1 ISSN: 1810-4487, 1-33.

Pallant, J. (2007). *Step by step guide to data analysis using SPSS*. Open University.

Population Reference Bureau. (2014). *World population Data Sheet*. Wasington D.C.: The population reference bureau.

Powell, H., Mihalas, S., Onwuegbuzie, A., Suldo, Sh. and Daley, Ch. (2008). Mixed reasearch methods in school psychology. *Mixd method investigation of treand in the literature, 45, 200.*

Prasetyo, L. B., Setiawan, Y., and Nursal, W. (2009). *The analysis of LULC change ffect to soil erosion using spatial modeling and analysis in Telaga Warna Catchment Area*. Bogor.

Quentin, F. B., Jim, C., Julia, C., Carole, H., and Andrew, S. (2006). *Drivers of land use change*. Melbourne,Australia.: Department of Sustainability and Environment and primary industries, Royal Melbourne Institute of Technology. .

Sage, C. (1994). Population and Income. In W. a. Meyer, *Change in land use and land cover* (pp. 280-285). New York: Cambridge university press.

Sahlu H. (2004). Population, Development and Environment in Ethiopia. In *Sustainable Intensification of Agriculture in Ethiopia* (p. 200). Addis Ababa, Ethiopia: Economics Society of Ethiopia.

- Serra, P., Pons, X., and Sauri, D. (2003). Post-classification Change Detection with Data from Different Sensors: Some Accuracy Considerations. . *International Journal of Remote*, 4500-5000.
- Simon J. (1996). *The Ultimate Resource*. . princeton: Princeton University.
- Sing, A. (1989). Digital Change Detection Techniques Using Remotely Sensed Data. *International Journal of Remote Sensing*, 1000-1200.
- Soemarwoto, O. (1985). A quantitative model of population pressure and its potential use in development planning. *Majalah Demografi Indonesia*, 10-15.
- Sydenstricker-Neto. (2012). Population and Deforestation in the Brazilian Amazon: a mediating perspective and a mixed-method analysis. *Journal of Population and Environment*, 120-125.
- Tamiru Alemayehu, Tenalem Ayenew, Dagnachew Legesse, Yirga Tadesse, Solomon Waltenigus, Nuri Mohammed,. (2003). *Ground Water Vulnerability Mapping of the Addis Ababa Water Supply Aquifers, Ethiopia*. Addis Ababa: Addis Ababa Water & Sewerage Authority (AAWSA).
- Taye, A. (2009). The Impact of LULC Change on Catchment Hydrology and Water Quality of Legedadi-Dire catchments, Ethiopia. *Unpublished MA Thesis*, 90.
- Tekeste, A. (1990). *Urban Development and its Impact on the Environment. Conference on National Strategy*. Addis ababa: The National Committee for central planning.
- Tekle, K and Hedlund, L. (2000). Land Cover Changes between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. *Mountain research and development*, 20, 45-5-.

Thadiparthi B. and Mekonnen A. (2004). 2004). Analysis of landcover changes and major driving forces assessment in middle highland tigray, Ethiopia: The case of areas around Laelay Koraro. *Bio.Envnt.1(6)*, 23-30.

Thael, E. C. (2003). *Addis Ababa Water Supply Project III A (AAWSP-III A)*. Addis Ababa, Ethiopia: AAWSA.

The population reference bureau. (2014). *World Population Data Sheet*. Washington D.C.: The population reference bureau.

Theodore, P. (2000). Population and Environmen. *CID Working Paper No. 54*, 66.

U.N. Population division. (1998). *Regional Distribution of Population*. New york: Unired Nations, Department of Economic and Social Affairs, Population Division.

U.N. Population Division. (1999). *Population Growth: Past, Present, and Projected Future*. New York: Department of Economic and Social Affairs, Population Division.

U.N. Population Division. (1999). *World Population Size According to Main Fertility Scenarios, 1950–2050*. New York: Unired Nations, Department of Economic and Social Affairs, Population Division.

UN, Population Division. (2009). *Estimated and projected population of Ethiopia*. New York: United Nations, Department of Economic and Social Affairs, Population Division.

UNHDI. (2014). *United Nations Human development Index*. New York: UN.

United Nations (UN) Population Division. (2011b). *World Contraceptive Use 2010*. New York: United Nations, Department of Economic and Social Affairs, Population Division.

Wim Bakker, Lucas Janssen, Michael Weir, Ben , Christian Pohl, Tsehaie Woldai, John Horn and Colin Reeves. (2000). *Principles of Remote sensing*. (L. L. Janssen, Ed.) Enschede, The Netherlands: The international institute for aerospace and earth science (ITC).

Woldeamlak Bewket, Sterk, G. (2005). Dynamics in landcover and its effect on stream flow in the chemoga watershed Bluenile basin, Ethiopia. *Hydrol. process*, 19, 445-460.

Wolman, M. G. (1983). *Population, Land Use and Environment: A Long History*. Washington: National Academy Press.

Wrigley, E. (1969). *population and History*. New York: McGraw Hill.

Zelege G. and Hurni H. (2001). Implications of Land use and land cover dynamics for mountain resource degradation in the northwestern Ethiopia highlands. *Mountain reasearch elopmentand de*, 21, 184-190.

APPENDIX I. Questionnaires

Dear respondent,

My name is Dilnesa Mekonnen. I am a postgraduate student at Addis Ababa University, in Population, Development and Resource Stream of the Department of Geography and Environmental Studies. Currently, I am writing my thesis on the population pressure on land use/land cover change of Legedadi catchments area and its impact on Legedadi Water Reservoir.

The main aim of this questionnaire is to explore the extent to which human beings, through their socio-demographic characteristics have influenced the land use/land cover in Legedadi catchment area. The study is for academic purpose. If you accept to participate in this research, you will be doing so voluntarily and there will not be any monetary returns. You are also free to refuse to respond to any questions you do not feel comfortable answering or to withdraw from the research all together. Hence, the responses from respondents are confidential.

Thank you in advance for your cooperation.

Questionnaire No. 1: To be completed by household Head

I QUESTIONNAIRE IDENTIFICATION

Date (day/month/year) ____/____/2016

Respondents 'code: _____

Kebele: _____

Sub Catchment: _____

Village: _____

II Household Head General Characteristics

1. Sex _____

A. Male

B. Female

2. Age _____

3. Marital Status

1. Single

2. Married

3. Divorced

4. Widowed/Widower

4. Family size _____

5. Education

1. Illiterate

2. Read Only

3. Write Only

4. Read and Write only

5. Primary (1 - 8)

6. Secondary (9 - 12)

7. Tertiary (12+)

III. Household Income and Business Activities

1. Do you or any member of the household participated in off farm activities?

1. Yes

2. No

1. If yes, please specify the weekly income that you were involved _____

IV. Farm Structure

1. Current total land holding hectare. _____
2. Is the land you hold is large enough for your farm purpose?
3. If your answer for question number 2 is yes, why?
 - A. Land allocation following new comers or sharing among offspring'sa.
 - B. The proportion of fertile land is diminishing
 - C. All are engaged in farming activities as there is no off-farm activities
 - D. The portion of land become waste land because of degradation
 - E. Lands are converted to build up areas
 - F. Other, Specify _____
4. How many years have you been living here?
5. How is your farm produce from your plot over these years?
 - A. Increased
 - B. Decreased
 - C. Remains the same

V. Population growth in the area

1. Do you think that there is population growth in your area?
 1. Yes
 2. No
2. If your answer for question number 1 is yes, why?
 1. Natural increase in the locality
 2. Migration from other areas

VI. Land use/Land cover change

1. Which of the following drivers do you think be the possible causes of LULC change in your locality? Mark “X”

Drivers	“X”
Agricultural expansion ✓ Shifting cultivation ✓ Small scale subsistence farming ✓ Commercial farming ✓ Resettlement	
Wood extraction ✓ Fuel wood extraction ✓ Charcoal production ✓ Wood for construction ✓ Logging	
Infrastructural expansion ✓ Road transport ✓ Settlement expansion ✓ Duration	
Economic factors ✓ Increased access to market ✓ Increased in crop price ✓ Increased in annual income	
Policy and institutional factors ✓ Corruption ✓ Weak institutional performance ✓ Insecure	
Socio-cultural factors ✓ Change in public factors ✓ Extensification ✓ Religion	
Demographic factors ✓ Population growth ✓ In-migration ✓ Population density	

Questionnaire No. 2: To be completed by elderly and focus group participants

Dear respondent,

My name is Dilnesa Mekonnen. I am a postgraduate student at Addis Ababa University, in Population, Development and Resource Stream of the Department of Geography and Environmental Studies. Currently, I am writing my thesis on the the population pressure on land use/land cover change of Legedadi catchments area and its impact on Legedadi Water reservoir.

The main aim of this questionnaire is to explore the extent to which human beings, through their socio-demographic characteristics have influenced the land use/land cover in Legedadi catchment area. The study is for academic purpose. If you accept to participate in this research, you will be doing so voluntarily and there will not be any monetary returns. You are also free to refuse to respond to any questions you do not feel comfortable answering or to withdraw from the research all together. Hence, the responses from respondents are confidential.

Thank you in advance for your cooperation.

1. What is your perception about the impact of population change of the area on the land use pattern? _____

2. What are the major reasons/causes for all these changes?

3. Do you Participate in the off-farm activity

4. Do the individuals or the community actively participating in the conservation activities?

Appendix II: Ground Control Points for Image Interpretation and Classification

NO.	X	Y	LULC
1	497908	10001821	Water
2	4970000	1003962	Water
3	499281	1008609	Water
4	494743	1005265	Settlement
5	494510	1005777	Settlement
6	493741	1006918	Settlement
7	501655	1010176	Settlement
8	501353	1010828	Settlement
9	501492	1011503	Settlement
10	502400	1010758	Settlement
11	503447	1010991	Settlement
12	502982	1011666	Settlement
13	501911	1012387	Settlement
14	501632	1013434	Settlement
15	503983	1012563	Settlement
16	502563	1013085	Settlement
17	500678	10110665	Settlement
18	501911	1010711	Settlement
19	502935	1012154	Settlement
20	501888	1014435	Natural Vegetation
21	50375	1013690	Natural Vegetation
22	499250	1013062	Natural Vegetation
23	497363	1014389	Natural Vegetation
24	496046	1014528	Natural Vegetation

GIS and Remote Sensing Based Assessment of Population Pressure on LULCC of Legedadi Catchment Area and its impact on LWR

25	494929	1014784	Natural Vegetation
26	494370	1014738	Natural Vegetation
27	495976	1010921	Natural Vegetation
28	496884	1008826	Natural Vegetation
31	502935	1012108	Eucalyptus
32	502633	1013365	Eucalyptus
33	501446	1014645	Eucalyptus
34	499886	1015040	Eucalyptus
35	498141	1015343	Eucalyptus
36	496349	1015157	Eucalyptus
37	495092	1015157	Eucalyptus
38	496651	1008919	Eucalyptus
39	494766	1006299	Eucalyptus
40	504169	1007290	Grassland
41	504332	1007849	Grassland
42	504378	1009711	Grassland
43	501888	1010781	Grassland
44	502460	1012946	Grassland
45	502563	1014063	Grassland
46	505559	1063520	Grassland
47	503750	1003939	Grassland
48	502763	1002775	Grassland
49	500561	1006289	Grassland
50	500841	1007150	Grassland
51	500864	1007011	Grassland
52	500864	1007430	Grassland

GIS and Remote Sensing Based Assessment of Population Pressure on LULCC of Legedadi Catchment Area and its impact on LWR

53	501818	1007779	Grassland
54	501409	1007918	Grassland
55	500282	1008221	Grassland
56	499654	999377	Grassland
57	499049	1000028	Grassland
58	497303	1001052	Grassland
59	496069	1006312	Grassland
60	496512	1006778	Grassland
61	496395	1008454	Grassland
62	494836	1010223	Grassland
63	496605	1010711	Grassland
64	499700	1009780	Grassland
65	499770	1010362	Grassland
66	499305	1011200	Grassland
67	498211	1011380	Grassland
68	498630	1011828	Grassland
69	496279	1012550	Grassland
70	496093	101308	Grassland
71	494719	1012876	Grassland
72	497908	1014412	Grassland
73	497815	1015087	Grassland
74	495278	1014488	Grassland
75	494836	1013807	Grassland
76	495976	1016390	Grassland
77	494267	1013644	Grassland
78	494394	1012294	Grassland

GIS and Remote Sensing Based Assessment of Population Pressure on LULCC of Legedadi Catchment Area and its impact on LWR

79	495488	1011386	Grassland
80	495790	1010083	Grassland
81	494859	1013923	Grassland
82	494813	1010223	Grassland
83	495069	1008873	Grassland
84	496558	1006825	Grassland
85	495013	1006056	Grassland
86	494952	1004939	Grassland
87	499886	1008663	Grassland
88	496069	1006312	Grassland
89	498467	1006219	Grassland
90	498467	1006219	Grassland
91	498141	1007430	Grassland
92	499002	1016367	Grassland
93	497349	1016670	Grassland
94	499398	1008105	Grassland
95	493835	1009990	Cultivation
96	493695	1008919	Cultivation
97	494533	1008081	Cultivation
98	494766	1007313	Cultivation
99	494463	1006592	Cultivation
100	495557	1005032	Cultivation
101	495976	1004800	Cultivation
102	497955	1004707	Cultivation
103	499537	1002891	Cultivation
104	499398	1002193	Cultivation

GIS and Remote Sensing Based Assessment of Population Pressure on LULCC of Legedadi Catchment Area and its impact on LWR

105	506799	1004381	Cultivation
106	506566	1004480	Cultivation
107	505984	1005568	Cultivation
108	505426	1006289	Cultivation
109	504937	1006569	Cultivation
110	504983	1007662	Cultivation
111	502516	1005731	Cultivation
112	501609	10055824	Cultivation
113	502510	1007965	Cultivation
114	502982	1009361	Cultivation
115	503494	1010548	Cultivation
116	500282	1010851	Cultivation
117	500352	1010944	Cultivation
118	499188	1010013	Cultivation
119	499025	1010735	Cultivation
120	499328	1012503	Cultivation
121	498234	1011759	Cultivation
122	498886	1012410	Cultivation
123	499840	1012527	Cultivation
124	500492	1012154	Cultivation
125	501073	1012736	Cultivation
126	496558	1012563	Cultivation
127	498467	1013644	Cultivation
128	499491	1014109	Cultivation
127	503471	1013807	Cultivation
130	501492	1015157	Cultivation

GIS and Remote Sensing Based Assessment of Population Pressure on LULCC of Legedadi Catchment Area and its impact on LWR

131	499979	101457	Cultivation
132	496791	1013504	Cultivation
133	498583	1014877	Cultivation
134	493486	1009990	Cultivation
135	493484	1008873	Cultivation
136	493812	1008477	Cultivation
137	495138	1004730	Cultivation
138	495860	1003473	Cultivation

APPENDIX III: Sample pictures from field



Participant of KII



Legedadi Water Reservoir



Siltation in the Legedadi Water Reservoir



Settlement and Cultivation area



Ground truth activity in Sendafa town



Ground truth activity in natural vegetation area