JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCE AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

SCHOOL OF GRADUATE STUDIES

SPATIOTEMPORAL ANALYSIS OF DEFORESTATION IN KUYU WOREDA USING MCE, NORTH SHEWA, OROMIA NATIONAL REGIONAL STATE, ETHIOPIA

BY

GETU LEMI DABA

JUNE, 2017

JIMMA, ETIOPIA

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ATHESIS SUBMITTED TO DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES IN PARTIAL FULFILLMENTS OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCES IN GEOGRAPHY AND ENVIRONMENTAL STUDIES (SPECIALIZATION OF GIS AND RS)

JUNE, 2017

JIMMA, ETHIOPIA

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Approval of Thesis

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As Thesis Research advisor, I hereby certify that I have read and evaluated this Thesis Research prepared, under the guidance, by ____________________ I recommend that it be submitted as fulfilling the Thesis requirement.

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As member of Board of Examination of the MSc, Thesis open defense examination, we certify that we have read, evaluated the Thesis Research prepared by __________________and examined the candidate. We recommended that the Thesis Research be accepted as fulfilling the Thesis requirement for the Degree of Master of science in GIS and remote sensing.

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Chairman, Examination Signature Date

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External Examiner Signature Date

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Internal Examiner Signature Date

Declaration

I hereby declare that this thesis is my original work, has not been presented for a degree in any other university and that all sources of material used for the thesis have been dully acknowledged.

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This thesis have been submitted for examination with my approval as a university advisor Name: Dr. Ajay Babu

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Date: ______________

Acknowledgement

For the success of this work many individuals and institutions have contributed a lot. First and for most, I would like to thank, the ‘Almighty God who made it possible, not only to begin and finish this work successfully, also for his protection and favor in my entire life. Next, greatest thanks goes to my advisor Dr. Ajay Babu for his valuable comments and contributions of ideas as well as sharing of his precious time to read the earlier drafts of this paper. I would also like to express my deepest sense of gratitude and acknowledgement to my co-advisor Dr. Kefelegn Getahun for his constructive criticism and reading, as well as correcting of this research.

I would like to express my deepest sense of gratitude and acknowledgement to Dr. Messay Mulugeta for his immeasurable and priceless support, by giving necessary materials and data as well as constructive criticism and devoting precious time in guiding me.

For various data and information I received; my foremost thanks goes to Ethiopian Metrological Agency, Central Statistical Authority and great thanks also go Administrators, Experts and Staffs of Kuyu *Woreda* Office of Agriculture, Forest Conservation and Protection Branch Mr. Diribsa and Mr. Dereje Amayu and *Kebele* Administrators (Chairmen) and others who assisted me in providing information and facilitated the data collection process. The respondents owe me thanks for their sacrifice of time during the interview. The enumerators also deserve special thanks for the effort they made to collect reliable data.

To my best friends Ashenafi Bekele and Mamo Asfa are also acknowledged for their friendship and cooperation during my stay in data collection.

Last but not least, I would like to thank to my family, who had sent me to school at early time stage of childhood and stood with my side all the time and for their persistent encouragement and moral support throughout my study.

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Acronyms

CIFOR:	Center for International Forestry Research
CSA:	Central statics agency
DEM:	Digital Elevation Model
EPA:	Environmental Protection Authority
ERDAS:	Earth Resource Data Analysis System
FAO:	Food and agricultural organization
FRA:	Forest Resource Assessment
IFAD	International Fund for Agricultural Development
IPCC:	Intergovernmental Panel on Climate Change
MCE	Multi Criteria Evaluation
MOA:	Ministry Of Agriculture
NAPA:	National Adaptation Programme of Action
NDVI:	Normalized Differencing Vegetation Index
NMA:	National Metrological Agency
NEPAD:	New Partnership for Africa's Development
OFEDB:	Oromia Finance Economic Development
PA:	Peasant Association
SCBD:	Secretariat of the Convention on Biological Diversity
SRTM:	Shuttle Radar Topographic Mission
UNEP:	Unite Nation Environmental program
UNRISD:	United Nations Research Institute for Social Development
UTM:	Universal Transverse Mercator
WGS:	World Geodetic System

Abstract

The ever increasing demand of farmland, demand for fuel wood and charcoal coupled with population growth has accelerated the rate of forest reduction in recent years in Ethiopia. At present, an excessive and destructive exploitation of forest resources is a threat that exists at Kuyu Woreda. The overall objective of this study is to investigate the determinants and rate of spatiotemporal dynamics of deforestation in Kuyu Woreda, North Shewa Zone of Oromia National Regional State and gathering socioeconomic data using key informant interview and focus group discussion. The major data for this study were obtained from three series of LANDSAT images (1986 TM, 2000 ETM+ and 2016 ETM+), GPS based ground truth and socioeconomic data. The important activities performed for the study were delineation of study area, land use classification and change detection statistical analysis. The result of change detection analysis revealed that the cropland to be the most expanding land use type in the woreda. It increased from 24.9% (1986) to 47.8% (2016) at the rate of about 724.4ha per year. The area covered by grass land, bare land, forest cover land has been reduced by the annual average rate of 323.2 ha, 239.3ha and 203ha respectively. The problem of deforestation is directly linked with the activity of man such as population pressure, and the socio-economic factors. In order to hold back the problem of forest cover change and its impact, corrective measures had been suggested which can be implemented both in the short term and long term phase.

Keywords: *Land cover, land use, spatiotemporal, Deforestation, GIS, Remote sensing, Kuyu Woreda, Ethiopia.*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Natural resources such as forests and wildlife were abundant on the earth but much concern was not given about its wise use. As human population continues growing rapidly, resources are becoming scares. Obviously, these resources are changed or exhausted unless wisely used. In order to mitigate the scarcity or complete loss, mankind has started to become concerned about conserving natural resources, of which one is forest resource (Workaferahu, 2016).

Developing countries are highly dependent on primary economic activities and direct utilization of natural resources, particularly the forest that are currently under serious threat due to human economic activities (FAO, 2001; Guzman, 2013). As forest ecosystems play very important role in regulating the climate, deforestation and forest degradation exacerbated the climate change problem and other environmental problems. Larger proportions of the forests are deforested and the remaining is severely degraded. The forests are left only at inaccessible areas of steep hills, on non-arable lands and securely protected areas. Even if the degraded forests have lost much of their ecological goods and services they once provided, many of the primary forest tree species and animals are still there and if protected a significant forest ecosystem can be recovered (Milkessa, 2015).

Ethiopia also is noted by severe environmental degradation of which the most notable ones are soil erosion, deforestation, water depletion, and shrinking wetlands. Historical documents show that forest and woodlands once covered over 40% of the total area at the beginning 20th century. Presently, it estimated to be less than 10% (Bane, *et al,* 2008). According to Woldeamlak (2009), the country's annual deforestation rate is estimated to be about 62,000 hectares, attributed primarily to the increased demand for farmland, fuel wood, and settlement sites.

This has resulted in severe soil degradation (about 2 billion tons per year), alteration of hydrologic regimes, disturbance of local and/or regional climates, loss of biodiversity, and expansion of desert ecological conditions. These environmental problems call for an accurate investigation in the status, causes, processes, and rate of land use/cover dynamics in a given area. Such inquiries enable researchers, policy/strategy formulators, environmentalists, and aid providers to have accurate data related to the subject and proceed accordingly (Messay, 2013).

According to Messay (2013), have shown that the land-use/cover has been rapidly changing in Ethiopia, owing to population pressure, resettlement programs, climate change, and other human- and nature-induced driving forces. Particularly, anthropogenic activities are the single most significant factors adversely altering the natural status of the Ethiopian landscape. This resulted in shocking changes in the land-use/cover patterns of the country over time.

It is with this understanding that the researcher is planning to investigate the trends and status of deforestation in Kuyu *Woreda* by using remote sensing and GIS techniques. In this study, attempts were made to map the status of land-use land-cover dynamics between1986 and 2016 with a view of detecting the spatiotemporal (temporal and spatial) forest degradation in the study area.

1.2. Statement of the problem

It is believed that Ethiopia in general and the study area in particular are characterized by severe environmental degradation and loss of bio-diversity at present than ever before. There are still areas that are under severe environmental degradation at present. In some areas people are destroying forest owing to various factors such as expansion of farmlands, firewood and charcoal production, settlement and construction (Messay, 2013). Currently, the country aims to achieve carbon-neutral middle-income status before 2025 by building a climate-resilient green economy with zero net emissions goal. To achieve the goal, environmental resource, particularly natural forest, protection plays crucial role. Protecting and re-establishing forests for their economic and ecosystem services is one of the pillars of green economy strategy to reduce emission and adapt to the climate changes while continuing economic growth (EPA, 2011).

Despite the government's efforts of increasing the forest cover of the country through conservation, restoration, afforestation, rehabilitation, awareness creation etc., the natural forests are being cleared and degraded, particularly forests on privately held lands. Since the land holders highly depend on the forest lands the remaining forest on such lands are highly fragmented and degraded. The left over indigenous natural trees that are capable and usually regenerate are being seasonally cut for different economic activities before they mature (Milkessa, 2015).

Kuyu *Woreda* was covered by dense forest and rich in biodiversity 40 years ago. The areas were rich in indigenous plants species and considerable number of wild animals. Currently there is no significant dense forest. Most of the forest lands are deforested and changed to farm lands and the remaining forests severely degraded and have lost much of their productivity and biodiversity.

According to the Office of Agriculture, Forest Conservation and Protection Branch of the *woreda,* even there is no research properly conducted so far to investigate the status of forest degradation at present by using GIS and RS technology. Nothing is known about the existing and disappeared species of flora and fauna. The study by Milkessa (2015) roughly indicates that out of the total area of the *woreda* (97,400 hectares), only about 9.53% is covered by forests (natural forests, manmade forests, bushes and shrubs in 2013. The latest study by Tenaye (2016) indicates that out of the total area of the *woreda,* only about 8% is covered by forests.

The rate and extent of forest cover change in the *woreda* is not precisely investigated by using appropriate techniques like GIS and RS. However, from available records and field visits, it is evident that forest cover change is very widespread and is continuing at an alarming rate. According to Tilahun (2010) and Milkessa (2015), the process involves the shrinking of forest lands through selective cutting of tree species to complete clearance of forest land into other land cover and land use systems, but they fail to apply GIS and RS tools to show severity of the problem on the map.

Based on the views from agricultural officers of Kuyu *Woreda*, extensive forest covered land have been converted into cultivated land. The forest resources have been deteriorating due to uncontrolled cutting and clearing for the expansion of cultivation and grazing lands, income as well as constructional material and fuel wood supply for the people who are living in and around the study area. Hence, it has become increasingly important to analysis the status of land use land cover change and forest resource degradation in the study area by using GIS and RS, so that a coherent conservation measures possibly were suggested to protect and use the valuable forest resources in a sustainable manner in Kuyu *Woreda*.

1.3. Objectives of the study

1.3.1. General objective

The overall objective of this study is to investigate the determinants and rate of spatiotemporal dynamics of deforestation in Kuyu *Woreda*, North Shewa Zone of Oromia National Regional State

1.3.2. Specific objectives

More specifically, the study aspired to:

- generate land use land cover maps of 1986, 2000 and 2016 of study area
- investigate the trend, rate and spatiotemporal dynamics of deforestation in Kuyu *Woreda*
- generate forest degradation susceptibility map and identify the major causes and impacts of deforestation in the study area

1.4. Research questions

In order to address the stated problem and objectives, the study attempted to answer the following questions:

- What is the areal extent and rate of land use / cover change in Kuyu *Woreda* during 1986, 2000, 2016 time periods?
- What does the spatiotemporal environmental dynamics look like in Kuyu *Woreda*?
- What are the major causes and impacts of forest cover change in the study area?

1.5. Significance of the study

Analysis of GIS-based spatiotemporal land-cover/land use dynamics is one of the most precise techniques to understand how land was used in the past, what types of changes are expected in the future, the forces and processes behind the changes and its implications on livelihoods, environmental degradation and deforestation. Therefore, this study is helpful to enhance the existing methods and techniques in the analysis of remotely sensed data so as to apply it in land-use/cover dynamics, and environmental degradation.

The output of this research is also essential for natural resources managers, development agents, socio-economic development planners and environmentalists in order to have appropriate environmental protection and development interventions. Particularly, local community will be most beneficial as this study may plead with development interventions and emergency works by governmental and non-governmental organizations in the area.

1.6. Scope of the study

Spatially, this study is delimited to Kuyu *Woreda* with the target of concentrated investigation and analyses so as to come up with very perceptive policy inferences. As the core concern of this study is to analysis the determinants and intensity of deforestation and land use land caver change, various bio-physical and socio-economic attributes were investigated.

1.7. Limitation of study

The main limitation of this study was the fact that the resolution of the satellite images used is low i.e. 30m x 30m Landsat images. This happened because of the scarcity and expensiveness of the high resolution satellite images such as SPOT and Quick Bird. Similarly, the structuring and restructuring of offices/bureaus at *woreda* level are believed to have mislaid some crucial data and materials for this study.

1.8. Organization of the study.

The thesis is organized in to five chapters. The first chapter is an introduction part, which comprises background of the study, statement problem and objectives of the study, basic research questions and significance of the study, scope and limitation of the study. Chapter two provides a literature review with an over view of related studies conducted in other parts of the world simultaneously with previous works in Ethiopian context. Background of the study area as well as the various data sets, materials and methodology which are manipulated in this research is presented in chapter three. The results and major finding obtained with the various methods are out lined in chapter four. Finally, the conclusions drawn together with recommendations are presented in chapter five.

1.9. Ethical consideration

One of the main concerns in scientific research, that incorporates human subjects in the study, is ethical considerations for the research subjects. The researcher, cognizant of this was recognizing the ethical principles of scientific research declared in Belmont Report1 of 1979. These principles were shading light on issues like informed consent, beneficence, anonymity and respect for the respondents.

Knowing of this truth the researcher is planned to get the consent of focus group discussants and key informants. They were also informed about the objectives and outcomes of the research quite adequately. Beyond the ethics on human subjects, research ethics also considers acknowledgement of data generated by others and appropriate citations of scholarly research outputs, books, websites, and any other related documents in order to assure intellectual and scientific integrity of the researcher. By recognizing this, the researcher was cited and acknowledge all the information taken from scholarly literatures and data generated by other individuals or organizations.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1 Deforestation: The Concept and Global Overview

Deforestation is defined in different ways. It is the act by which a forest is totally felled and cleared by human activities. It is the removal or damage of vegetation in a forest to the extent that it no longer support to its natural flora and fauna. In other words, deforestation can be defined as the transformation of forest land to non-forest uses where forest land includes land under agro-forestry and shifting cultivation, and not simply closed canopy primary forests (FAO/UNEP, 1997). Deforestation defined broadly can include not only conversion to non-forest, but also degradation that reduces forest quality, density and structure of the trees, the ecological services supplied, the biomass of plants and animals, the species diversity and the genetic diversity (FAO, 2005).

Deforestation is often asserted as “evil” because of the long term environmental implication for sustainable development. It is undeniable that the dependence of millions of people on forests leads to degradation and deforestation. There are numerous benefits accruing from such loss (in the form of livelihoods, income and employment) for the sustenance of indigenous people (Tindan, 2013).

As indicated in Tilahun (2010), United Nations Research Institute for Social development (UNRISD) also defines deforestation as the loss or continual degradation of forest habitat primarily due to human related causes. Agricultural, Urban sprawl, unsustainable forestry practices and mining all contribute to human caused deforestation. In this case the term deforestation used to refer to activities that use the forest, such as fuel wood cutting, commercial logging, as well as activities that cause temporary removal of forest cover such as the slash and burn technique, a component of some shifting cultivation agricultural system or clear cutting. It also used to describe forest clearing for annual crops and forest loss from over grazing.

The definition of forest is also ambiguous like definition of deforestation. According to FAO (2006) forest is a minimum land area of 0.05-1 ha with tree crown cover more than 10-30% and tree height of 2-5m at maturity. FAO (2001) defined a forest as “land with a tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.5 hectare; the trees should be able to reach a minimum height of 5 meter at maturity. In February 2015 Ethiopia adopted a new forest definition as follows: 'Land spanning at least 0.5 ha covered by trees and bamboo), attaining a height of at least 2m and a canopy cover of at least 20% or trees with the potential to reach these thresholds in situ in due course (Anonymous, 2016).

Nowadays, many people are aware of our changing the natural environment and an increasing pressure of mankind on its easily fragile nature. In light of this, human activities have become recognized as major forces in shaping the physical and manmade environment. Accordingly, Berhan (2007) asserted that the action of human beings rather than natural forces is the sources of most contemporary change in the states and flows of this dynamic world.

It is observed the rate and extent of deforestation varies among continents, countries, regional and local boundaries (FAO, 2005). This indicates that global statistics on the rate and extent of deforestation are extrapolations from local, national, and continental findings. As a result the tendency that such global estimate on the extent of deforestation to be misleading is likely due to underestimation or overestimation and general changes of parameters and internal variations within the different locations. A typical example of internal variation is the case of Brazil and Indonesia which had the highest net loss of forests in the 1990s and have significantly reduced their rate of loss in 2000s while at the same time Australia experienced exacerbated forest loss due to internal factors such as; severe drought and forest fires (FAO, 2010).

Global Forest Recourse Assessment (2010) concludes that net deforestation at the global level occurred at the rate of 0.14 percent per year between 2005 and 2010. This compares with estimated net annual global deforestation rates of 0.20 percent between 1990 and 2000, and 0.12 percent between 2000 and 2005. The net rate is calculated by estimating the total forest area converted to other land uses, and adding back the area that is afforested plus any natural expansion of forests, for example on abandoned agricultural land. If the world’s net forest area continues to decline by 5.2 million hectares per year (the average net annual loss between 2000 and 2010), it will take

775 years to lose all of the world's forests. This would seem to provide enough time for actions to slow or stop global deforestation.

In addition FRA (2012), reports make an important distinction between the total forest area lost in a given period and changes in net forest area. Between 2000 and 2010, the world lost about 130 million hectares of forest (about 3.2 percent of the total forest area in 2000), but gained back about 78 million hectares, mainly as planted forests and natural forest expansion. The net loss of forest area was 1.3 percent over the ten-year period.

Globally, land use change and forestry are estimated to account for 18.2% of Greenhouse gases emissions. This amounts to 1.6 billion tons of carbon emissions annually, more than the global emissions from the transport sector, and almost equivalent to the total emissions from US fossil fuel use. Deforestation and degradation have contributed some 90% of total global emissions from land use change since 1950. Following centuries of deforestation and degradation in North America and Europe, these regions have now become net sinks for emissions (Robledo *et al*, 2008)

According to the IPCC (2007), 65% of the mitigation potential in the global forest sector is located in the tropics. While total emissions from least developing countries for all sectors constitute only 5% of global greenhouse gases emissions. Least developing countries are responsible for 20% of the global emissions that stem from land use change and forestry.

Land use change and forestry is thus the only truly significant source of emissions from least developing countries in both global terms and within least developing countries, where 74.4% of emissions derive from this source. The ongoing effects of climate change are, however, expected to impact on forest ecosystems in terms of both the physical metabolism of forests and the functions they provided. Changes in atmospheric carbon content, as well as in rainfall and temperatures, may lead to a number of changes in terms of biomass production, composition of forest species (Robledo *et al*, 2008).

It is therefore important to reiterate the viewpoint by Adams (2009), that research and policy development on deforestation must be location specific. The available evidence from the 1980s and throughout the 1990s indicates the massive loss of tropical forests. Though the rate of loss seems to have reduced in the 2000s, 13 million hectares of forest loss as compared with 16 million hectares during the 1990s, it is imperative to mention tropical deforestation is still a wanton challenge in 2010, because the world had just over 4 billion hectares of forested area, which corresponds to an average of 0.6 forest per capita (FAO, 2010). According to the Global Forest Resources Assessment 2015 the global forest area fell by 129 million hectares (3.1 percent) in the period 1990–2015, to just under 4 billion hectares (FAO, 2015a),

In relative to the Africa, the degree of deforestation has been devastating because between 1990 and 2000, the continent missing about 52 million ha of forest, which accounts for 56 percent of the worldwide reduction in forest cover (FAO, 2003). It is noted the continent experienced an average forest cover loss of 0.8 per cent and this is higher than the world average of 0.2 per cent for the same period (FAO, 2005). 70% of dry lands in Africa, South America and Asia are affected by Land degradation which involves: 30% of irrigated arid lands, 47% of rain-fed cultivation and 73% of vegetation (Utuk and Daniel, 2015), and Africa has the highest net of forest loss recording 2.8 million hectares lost annually (FAO, 2015).

2.2. Causes of deforestation

The causative factors of deforestation have their roots in different sectors (Mahapatra and Kant, 2003) and as a result, the effects produced are also varied across the global, national and local boundaries. These factors may be categorized broadly into anthropogenic and natural. In most cases the anthropogenic causes are often easily identifiable probably because of the increasingly recognition of human footprints on the earth's system (McCarthy, 2009). It is important to note the human drivers of environmental change (deforestation) vary in nature and scope but can be broadly grouped together as economic, conflict and governance, demographic, social and science and technology (UNEP, 2006).

Deforestation and forest degradation over the past 30 years has been the continuation of a process with a long history. The historic loss of forests is closely related to demographic expansion and the conversion of forest land to other uses. Major direct causes of forest degradation brought on by humans include over harvesting of industrial wood, fuel wood and other forest products, and overgrazing. Underlying causes include poverty, population growth, markets and trade in forest products and macroeconomic policies. Forests are also susceptible to natural factors such as insects, pests, diseases, fire and extreme climatic events (UNEP, 2006).

According to FAO (2016), agriculture is still the most significant driver of global deforestation; given the importance to the planet's future of both agriculture and forests. There is an urgent need to promote positive interactions between these two land uses. The challenge of feeding a global population projected to increase from more than 7 billion people today to more than 9 billion by 2050 is made more difficult by the threats of climate change, growing water and land scarcity, and soil and land degradation.

In addition to helping mitigate climate change and protect soils and water, forests hold more than 75 percent of the world's terrestrial biodiversity. It provides many products and services that contribute to socioeconomic development, and are particularly important for hundreds of millions of people in rural areas, including many of the world's poorest people (FAO, 2014a). Poor rural women are especially dependent on forest resources for their subsistence (World Bank, FAO and IFAD, 2009).

Forests clearance and the subsequent agricultural development according to Yasuka and Levins (2007) have a detriment. The *qolla* and *woinadega* parts, on the other hand, are severely cut by running water and are characterized by several gullies, escarpments, cliffs and resistant rocks. It, therefore, undoubtedly belongs to some of the severely eroded parts of the country. The *qolla* parts of the PAs are characterized by extensively barren rocky lands and very steep slopes.

The causes of deforestation are complex and often differ in each forest and country. It may be difficult to determine the cause of deforestation in a particular forest and noted that there are three schools of thought with regards to the causes of deforestation. One is the Impoverishment school, which believes that the major cause of deforestation is "the growing number of poor". This school of thought sees small holders as the principal agents of deforestation. The second school of thought is Neoclassical which believes that the major causes of deforestation are "open-access property rights". They see various agents as the principal agents of deforestation. The third school of thought which believes that the major cause of deforestation is that "capitalist investor's crowd out peasants" is called political-ecology. This school sees capitalist entrepreneurs as the major agents of deforestation (Tilahun, 2010).

2.3. Benefit of sustainable utilization

According to the World Bank (2004), it is estimated that approximately 60 million indigenous people are almost wholly dependent on forests while 350 million people depend on forests for a high degree for subsistence and income, and about 1.2 billion people rely on agro-forestry farming systems .The sustenance of people (human well-being) is core to the sustainable development which is achievable through sustainable livelihoods. Sustainable livelihoods guarantee access and entitlement to a range of assets and opportunities which are essential in achieving human well-being. This is essential for most indigenous people especially in forest fringe communities who often lack the basic necessities to maintain a decent standard of living such as sufficient and nutritious food, adequate shelter, access to health services, energy sources, safe drinking-water, education and a healthy environment (Tindan, 2013).

The trade of wood products is an obvious source of substantial income for national and local governments as well as traditional rulers and individuals. This often comes in the form of export earnings, taxes, royalties and personal income for those engaged either directly or indirectly in the exploitation of these forest products. Export of tropical wood contributes approximately US $ 100 billion annually, about 0.5% of global gross domestic product (Mahapatra and Kant, 2003). The sale and distribution of chainsaw lumber is argued to generate some un-estimated revenue in the form of market tolls, income tax, taxes from waybills and custom duties within national economies. Research by the Center for International Forestry Research and Poverty Environment Network found that income from forest activities makes up about one fifth of total household income for rural households living in or near forests (Manfre and Rubin (2012).

The World Bank *et al* (2009), for instance indicate women in forest communities to derive 50% of their income from forests, while men derive only a third (Tindan, 2013). Though this perspective points to women benefiting substantively in terms of income than their men counterparts, there are no reasons offered to explain the "why and how" of such difference. The contrast is established in the research findings by CIFOR that men contribute more to household income than women because their forest activities are income generating whereas women are more involved in subsistence activities. It is hope that such a finding will contribute greatly to unravel the obstacles that have created this inequality and to find ways to redress the imbalances. Failure to capture the complexity of gender roles and social relations may result in failure to see opportunities for improved forest management and the possibilities of building greater equity (Manfre and Rubin, 2012)

2.4. Negative effects of deforestation

The process of tropical deforestation may produce many negative effects of varied and mixed implications. But conventionally the long-term dangerous environmental consequences such as global warming, biodiversity loss and soil degradation which are often identified (Mahapatra and Kant, 2003). On the part of global warming, it is noted that deforestation and forest degradation in developing countries are held to account for about 18% to 20% of increased emission of greenhouse gases (GHGs) that are responsible for global warming and climate change (Tindan,2013).

There is an established relationship between deforestation and global warming because forests, notably tropical forests are major carbon sinks (Gorte and Sheikh, 2010). The loss of tropical forests in many countries means the collapse of major carbon sinks and generation of more carbon dioxide which is a serious threat to global climate and atmospheric temperature distribution. Though the economic impacts of climate change are uncertain and difficult to quantify, these are evidently visible and are known to affect the poor and their occupations particularly agriculture in the developing countries, as the frequency and severity of drought increases (Chomitz, 1999).

That is, the conversion of forests to grasslands increases surface temperatures above the treeless ground and this also increases the water-holding capacity of the warmer air. As wind moves the hotter, drier air, it tends to exert a drying effect on adjacent forest and agricultural lands. Trees and crops outside the denuded area experience heat and aridity stress which is not normal to their geographical locations (Getis *et al*, 2005). The increased evapotranspiration contributes to increased dryness of the land,

and this may lead to desertification. This is true in Africa where the loss of forest and woodland cover (which is fairly about 650 million hectares or 21.8% of the total land area) has produced tremendous impact on the diverse yet fragile ecological conditions (FAO, 2003).

Apart from the impact on soil nutrients, the close relationship between the soil and lifecycle of the vegetation could affect the soil carbon content. Though this may be critical, Gorte and Sheikh (2010), indicate the impact of deforestation on soils, and the release of soil carbon, depends on the magnitude of soil disturbance and the type of soil. Karkee (2004) also highlights soil erosion as one of the degrading processes likely to arise due to increased deforestation (Beyene, 2011). Its impact cannot be underestimated because it is believed to affect approximately one-third of topsoil and soil nutrients needed to support crops and vegetation growth (Keller, 2005).

The close relationship between deforestation and poverty of rural households is an established policy narrative in the development discourse (Zwane, 2002; Kerr *et al*, 2004; Pfaff *et al*, 2008). This is because increased deforestation means loss of livelihood assets and outcomes. It causes loss of (incomes, employment, food, medicine, and energy) for most of the 500 million to 1.6 billion people in forest fringe communities who directly and indirectly depend on forest resources for their survival (Vermeulen, 2002).

2.5. Deforestation in Ethiopia: Causes and impacts

The estimates of forest resources of Ethiopia vary widely from one source to the other; different literatures indicated that for 35% to 40% of Ethiopia's land area was covered with heavy forests on the basis of the potential climatic climax during the beginning of 20th century. But, one fact all research findings indicated that Ethiopia's forests and woodland resources have continued to decline. The natural forest cover of Ethiopia at the beginning of 20th century was first estimated in the 1960s by Breitenbach (1962), as 41.2 million ha or 37% of the total land of the country. But forest cover change is by no means a unique modern phenomenon for Ethiopia. It has there from time immemorial to meet the growing demand for cultivable land, grazing land, settlement, fuel wood, commercial wood and building materials (Berhan, 2007).

Therefore, Ethiopia is noted by severe environmental degradation of which the most notable ones are soil erosion, deforestation, water depletion, and shrinking wetlands. Historical documents show that forest and woodlands once covered over 40% of the total area of the country. Presently, it is estimated to be less than 10% (Bane, *et al*, 2008). The country's annual deforestation rate is estimated to be about 62,000 hectares, attributed primarily to the increased demand for farmland, fuel wood, and settlement sites (Messay and Tsetargachew, 2013).

By analyzing the records available in the MOA, Demel (2000), provides some facts about the occurrence, extent and risk of fire in Ethiopia during in the early 1980s and between1990 and 2000. In 1984, about 209,913 ha areas of both plantations and natural forest were burnt, the largest impact being on natural forest about 209,913 ha. In the meantime, in the years between 1990 and 2000, about 155,960ha areas of forest were burnt. Only in the year 2000, over 150,000 ha forest resources were destroyed. From this explanation, fire is one of the major contributing factors for forest cover change in Ethiopia.

The progressively growing population pressure and agricultural expansion in Ethiopia will inevitably increase the forest resources utilization (construction and fuel wood, wood, etc.). Hence, different forms of unsustainable forest utilization will take place (fires, encroachment, logging, cultivation, urbanization) in coming decades ultimately leading to the total forest depletion (Fekadu, 2015). Based on the most recent estimates of the rates of deforestation, and assuming that 75 percent of forest losses are attributable to agricultural expansion, it is estimated that over the next 25 years the agriculture sector will require an additional 250 to 300 million hectares of new land to accommodate the demands of commercial farming, subsistence cropping, pasture and range development. Most of this increase in land area will come at the expense of forests lands (Mulugeta and Zenebe, 2011).

On the other hand, the recent data on forest resources of Ethiopia reported in FAO (2010) puts Ethiopia among countries with forest cover of 10-30%. According to this report Ethiopia's forest cover (FAO definition) is 12.2 million ha (11%), clearly underestimated. It further indicated that the forest cover shows a decline from 15.11

million ha in 1990 to 12.2 million ha in 2010, during which 2.65% of the forest cover was deforested.

As indicated in Fekadu (2015), between 1990 and 2005 the country actually lost 14 percent of its forest or 2.1 million hectare, that indicate us deforestation increased by 10.4 percent from 1990-2005. Therefore, because of deforestation the number of wild animals in the country has is becoming less and less overtime. The growing need for fuel wood and agricultural land and overgrazing by livestock, coupled with improper forest and land tenure policies, are believed to be the major causes of forest degradation (Mulugeta and Melaku, 2007). Extensive forest fires have also resulted in further losses.

Therefore, deforestation and forest degradation is one of a serious environmental challenge in Ethiopia, and also the major underlying causes for declining agricultural productivity. Destruction of the natural forests of Ethiopia results directly in the loss of unaccounted plant and animal species as well as in a shortage of fuel wood, timber and other forest products. It also indirectly leads to more aggravated soil erosion, deterioration of the water quality, further drought and flooding, reduction of agricultural productivity, and to an ever-increasing poverty of the rural population. It is obvious that the depletion of forest resources contributes significantly to the climatic and physical changes of the environment (Fekadu, 2015). To sum up, rapid population growth along with the need for farming and grazing land, the need of fuel wood and building materials and forest fire are the major contributing factors for the transformation of forest cover land in to other land use and land cover systems in the country.

2.6. Literature gap

Developing new tools, methods and practices to monitor biodiversity and increase stakeholder participation is become prerequisite currently, to support and improve forest management practices. For example, new technology and mapping systems to guide forest conservation practices and inform policy. However, in Ethiopia, like most developing countries, reliable information on the vegetation resources such as their spatial coverage, distribution, changes over time (deforestation or re growth), growing stock in the standing vegetation, regeneration and recruitment status and other essential information are lacking or difficult to get because it is scattered (Demel, 2010).

According to Workaferahu (2015), besides, previous research works related with forest cover change detection tries to apply only one or two of change detection methods and analysis the result which might raise question on accuracy of the result. And also previously satellite images were bought from concerned institutions such as EMA in imagine format, so, there might be loosing of some most important bands which help for analysis which leads to inaccurate result. Besides, Ground verification was applied to check whether the classification already exist on the ground.

This study tries to consider above all issues and solve problems, and applies digital change detection by post classification approach on forest cover change and checks the accuracy of classification result by collecting GCP points and apply accuracy assessment by using Confusion matrix. And also the researcher tried to apply method called multi criteria evaluation techniques by using various important factor maps indicate areas which was susceptible for forest degradation. As the case may be true in most areas of Ethiopia, deforestation has been one of the serious problems in Kuyu *Woreda*. The farmers used to cut trees indiscriminately in search of settlement places, ample farmland, firewood and charcoal, construction materials and traditional agricultural tools (Messay, 2011).

In Kuyu *Woreda* there was study Carried out by Tilahun (2010) on impacts of deforestation on rural Livelihoods and also other study by Milkessa (2015) on Land Holders Willingness to Accept Compensation to Voluntarily Protect Natural Forest for Regeneration. Their analysis shows that the forested land was declined. However, they failed to show the rate of deforestation by using recent technologies of GIS and remote sensing. Some research works related with forest cover change detection were carried out in different area; however, in case of Kuyu *Woreda* there were no studies that used GIS and remote sensing technique to investigate the Forest cover change or spatiotemporal dynamics of deforestation. With this understanding that the researcher is planning to investigate the trends and status of deforestation in the District by using RS and GIS techniques.

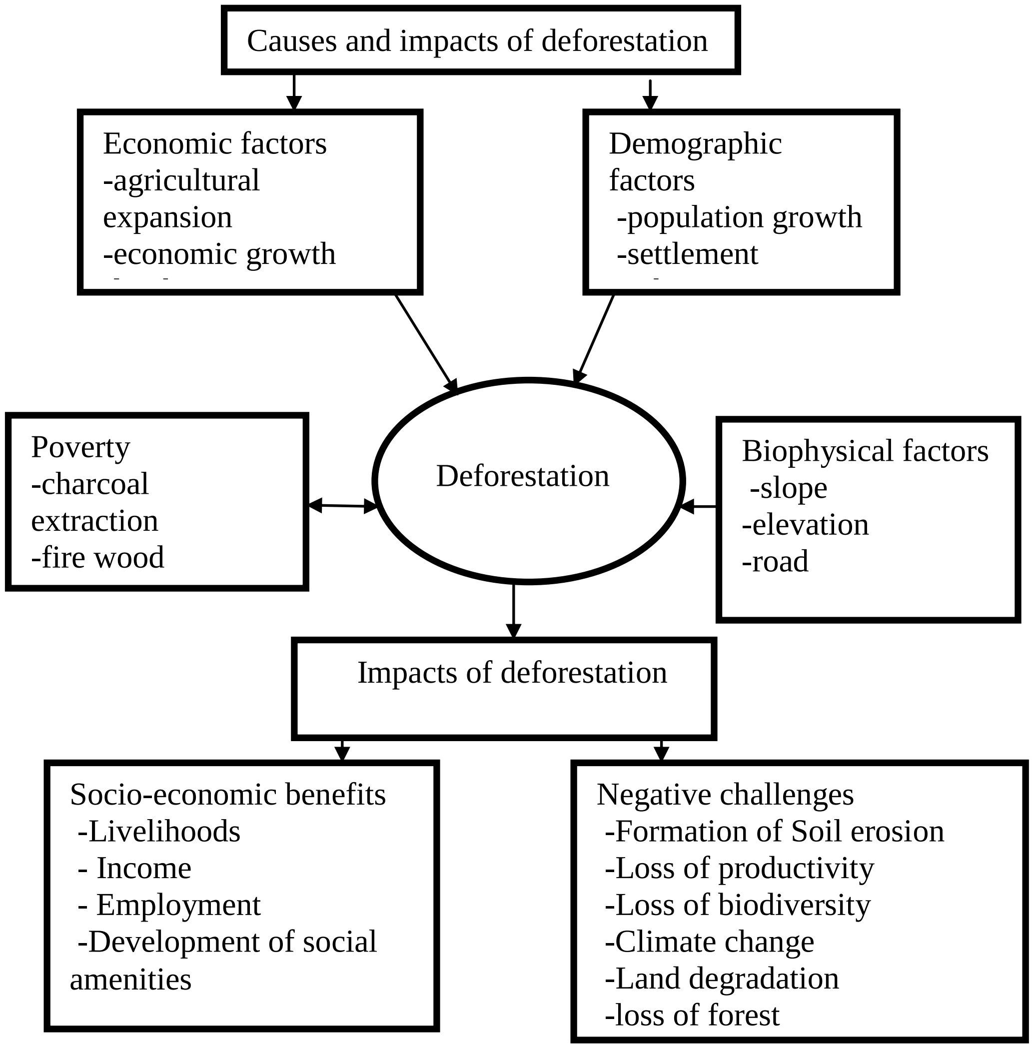

Figure 2.1: Conceptual framework on major causes and impacts of deforestation (source: computed from literature review)

2.7. The Role of remote sensing and geographic information system for assessment of spatiotemporal dynamics of deforestation.

2.7.1. Remote sensing

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 physical contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 2000). This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. Within the frame work of this study, the focus of remote sensing is the measurement of emitted or reflected electromagnetic radiation, or spectral characteristics, from a target object by a multispectral satellite sensor. Remote sensing satellite images are immensely used in natural resources monitoring and management, study the time to time changes due to its repetitive coverage especially in forest resources estimation and monitoring.

2.7.2. Land cover mapping

Land cover mapping is one of the most important and typical applications of remote sensing. Initially, the land cover classification system should be established, which is usually defined as levels and classes. The level and class should be designed in consideration of the purpose of use (national, regional or local), the spatial and spectral resolution of the remote sensing data, user's request and so on Japan Association of Remote Sensing (1996). According to Jensen (1996), there is a fundamental difference between information classes and spectral classes. Information classes are those defined by men while spectral classes are those inherent in the remote sensing data and must be identified and labeled by the analyst. The aim of digital classification is to translate spectral classes into information classes.

2.7.3. Image classification

According to Jensen (1996), digital image classification is the process of assigning or sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. Usually, each pixel is treated as an individual unit composed of values in several spectral bands. By comparing pixels to one another and to pixels of known identity, it is possible to assemble groups of similar pixels into classes that match to the informational categories of interest to users of remotely sensed data. Digital image classification is divided into two supervised and unsupervised classifications.

2.7.4. Change detection methods

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi temporal data sets (Singh, 1989). According to Lillesand, (2004), Change detection involves the use of multi-temporal datasets to discriminate areas of land cover change between dates of imaging; In addition essentially, it involves the ability to quantify temporal effects using multi-temporal data sets.

According to Alelign (2010) also noted that change detection is useful in such diverse applications as land use change analysis, monitoring of shifting cultivation, assessment of deforestation, seasonal changes in pasture production, damage assessment, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes. All digital change detections are affected by spatial, spectral, temporal and thematic constraints. The type of method implemented can profoundly affect the qualitative and quantitative estimates of the disturbance. Many change detection methods have been developed and used for various applications, like post classification comparison, image differencing, image rationing, image regression (Chen, 2000). Generally, they can be broadly divided into two: post classification and spectral change detection approaches.

2.7.5. Post classification approach

Post classification is among the most widely applied techniques for change detection purpose. Numerous studies have been carried out using post classification approach. In post classification change detection approach two images from different dates are classified and labeled. The area of change is then extracted through the direct comparison of the classified results (Lunetta, 1999). This method avoids problems encountered, in image rationing and subtraction, and needs both images to be individually rectified and classified before they can be compare pixel by pixel Jensen (1996). This method provides to and from information and results in a base map that can be used for the subsequent year. It identifies where and how much change has occurred.

2.7.6. Spectral change detection approach

There are a number of techniques in the spectral change identification category. Spectral change detection techniques rely on the principle that land cover changes result in persistent changes in spectral signature of the affected land surface. These techniques involve the transformation of the two original images into a new single band or multiband image, in which the area of spectral change is, highlighted Mather

(1987). Most of the spectral change detection techniques are based on image differencing or image rationing.

2.7.7. Geographic Information System (GIS)

The development of GIS could be viewed differently by different scholars based on the perception of what a GIS is. Because of lack of a single universally accepted definition provided for GIS, different authors defined it from different perspectives. Borrough and Mc Donnel (1986), GIS is a powerful tool for collecting, storing, retrieving, as well as, transforming and displaying spatial data from the real world for a particular set of purpose. According to Hellden (1987), GIS is a multipurpose computer based information system for retrieval, administration, processing, integrated analysis and graphic, cartographic and statistical presentation and combination of data which can be defined in time and space.

Whichever definition is given, most of the definitions relay on the computer based GIS and now, GIS is popular as a result of the rapid access to data, flexibility, easy update opportunity and other features that enable to analyze different databases. In addition, the popularity of GIS has become more pronounced as a result of parallel development with satellite technology and computer science (Burrough and Donnel, 1986). More specifically, GIS technology is important, because it offers an important means of understanding and dealing with some of the most pressing environmental problems, like deforestation, climate change, the need for ecologically sensitive development of global natural resources and rapid urbanization.

Accordingly, Lovett (2000) also concluded that by combining GIS and database management system technology, it is easier to create and maintain compressive information about natural resources. Hence, GIS technology can be used to mimic the behavior of certain aspects of the real world. It is being used to model the present, and predict the future. Therefore, the researcher is planned to investigate the trends and status of deforestation in Kuyu *Wored*a by using remote sensing and GIS technique

CHAPTER THREE

3. METHODS AND MATERIALS

3.1. Description of the study area

Kuyu *Woreda* is one of the eighteen *woredas* in North Shewa Administrative Zone of Oromia National Regional State. It is found in the northwest of Addis Ababa. The *Woreda* is bordered by West Shewa Zone in the West, Ware Jarso *Woreda* in the North, Hidebu Abote *Woreda* in the East, and Dagam *Woreda* in the South. Astronomically, it is located at about 9^{o}36' 34" to 9^{o}56'56" north latitude and 38^{0}05'00" to 38^{o} 34'13" east longitude.

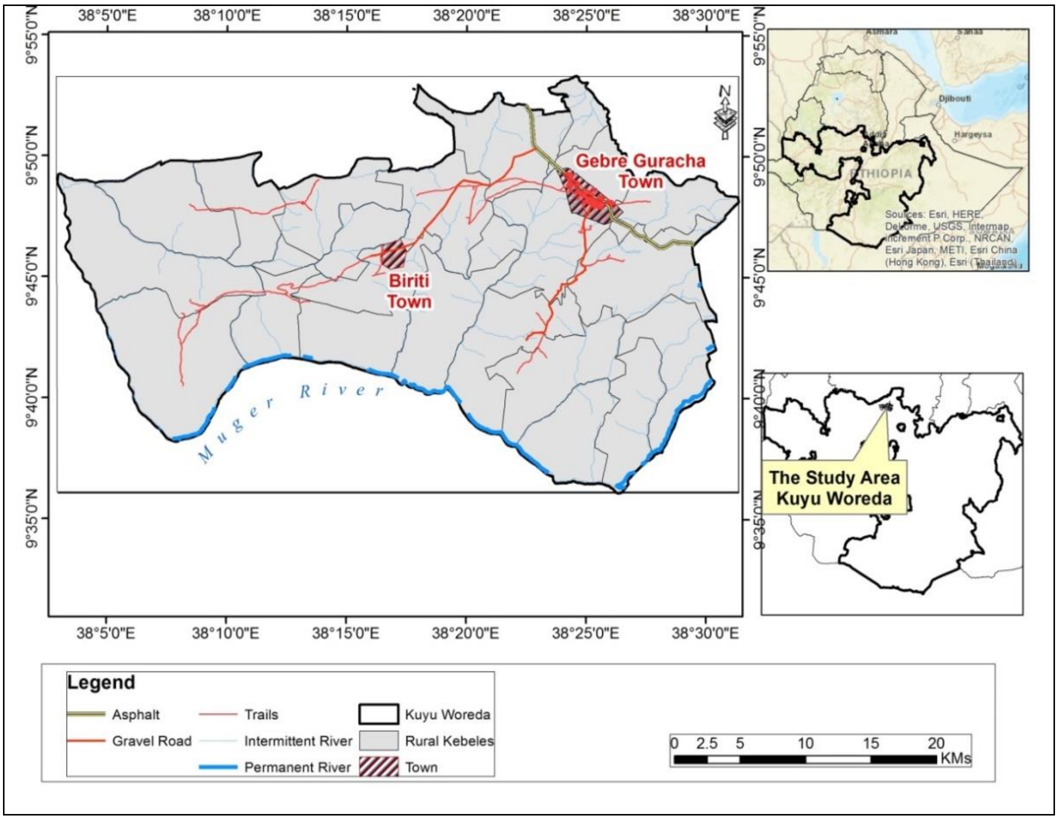

Figure 3.1: Location map of the study area (Source: Computed by the writer)

The total area of the *woreda* is 950.75 square kilometers. It is the fourth largest district in North Shewa Zone of the Oromia Regional State. The *woreda* is divided in to 23 rural and four urban (two *kebeles* in Garba Guracha, one *kebele* of Bucho Town and one *Kebele* of Biriti Town). The *woreda's* current administrative capital town, Garba Guracha, is located about 156 kilometers northwest of Addis Ababa (Messay, 2011; Messay, 2016; Tenaye, 2016).

3.1.1. Relief and drainage

Kuyu *Woreda* found within the central lava highlands of Ethiopia commonly known as Shewan Plateau. The altitude of the district varies between 1200 meters and 2800 meters above mean sea level. Majority of its area (91percent) lies above 1500 meters and belongs to the highland parts of the country. Even most of its areas that are found below 1500 meters are river valleys. Most of the lands in the *dega* (*bada* in afan oromo) agro climatic zone are flat (plateau) and cut by small number and size of streams majority of which are seasonal. The lands in this zone are intensively cultivated and densely settled. The *qolla* (*gammojji* in afaan oromo) and *woinadega* (*badadare* in Afaan Oromo) parts, on the other hand, are severely cut by running water and are characterized by several gullies, escarpments, cliffs and resistant rocks. It, therefore, undoubtedly belongs to some of the severely eroded parts of the country. The *qolla* parts of the PAs are characterized by extensively barren rocky lands and very steep slopes (Tilahun, 2010; Messay, 2011; Mahlet, 2013; Tenaye, 2016).

Sharp drops in elevation from *dega* to *woinadega* and then to *qolla* is common in the study area. As a result, several PAs are found partly in two or three of the agro climatic zones. A typical example to this is Halelu Chari *Kebele* which elevation drops from 2,560 meters on Dayyi Plateau to about 2300 meters at the bottom of the plateau and then 1,500 meters at Qerrensa River Valley. Bonde Gidabo *Kebele* can be another example, which 2,590 meters elevation at Harbu Bose Plateau drops sharply to 2,380 meters at the bottom of the plateau. Several other sharp drops can be observed in Koyye Akale, Jila Qerresa, Jalisa Lutu, Dawicha Qerrensa, Darro Wilincho and Darro Dhaye *Kebeles*. Due to several cliffs, river gorges, and steep slopes, movements' in *qolla* (*gammojji* in Afaan Oromo) parts of the *woreda* is relatively difficult. Hence, the vast majority of the lands in these agro climatic zones are not suitable for ox-drawn harrowing. The peasants prepare most of their plots using hoes unlike the case in *dega* and majority of the *woinadega* settlers (Massay, 2011).

As far as the drainage pattern of the study area is concerned, Mogor is the most important drainage basin which together with its tributaries drains the western, southern and central parts of the area. The important rivers joining Mogor are Qararu, Leman, Liban, Chiraca (alternatively Qerrensa). Leman drains the southeastern part of the area, whereas Qararu and Chiracha rivers drain the southern and central parts. The northeastern part of the *woreda* is drained by Liban River. The northeastern regions are drained by the small streams joining Alaltu River in Hidhabu Abote *Woreda*. Moreover, several other small streams drain different parts of the area. However, very little use is made of these streams and rivers for irrigation at present (Messay, 2011; Mahlet, 2013).

3.1.2. Rainfall and temperature

Like any other parts of the country, the climatic condition of Kuyu *Woreda* is greatly influenced by its altitude. There is seasonal distribution of rainfall in the *woreda*. It is evident that rainfall is unimodal in nature with heavy rains occurring from June to September; where it peaks in July. The total annual rainfall varies from 637.3 to 1759 mm per year. The temperature condition is clearly influenced by the angle of the sun and cloud cover. The mean annual temperature of the region varies from 4.8^{o}c to 28.5^{0}c. The absolute maximum temperature occurs from February to May and the absolute minimum temperature occurs in November, December and January. Rainfall shows considerable fluctuations in amount and periodicity from year to year thereby posing significant implications in agricultural production and productivity.

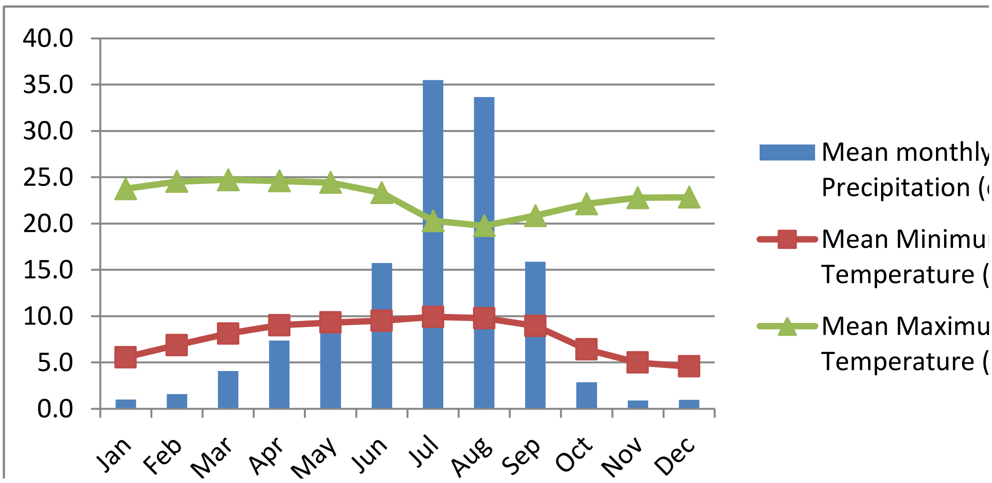

Figure 3.2: Mean monthly rainfall, minimum and maximum temperatures in Garba Guracha Town (1980-2016). (Source: Computed based on the raw data obtained from NMA)

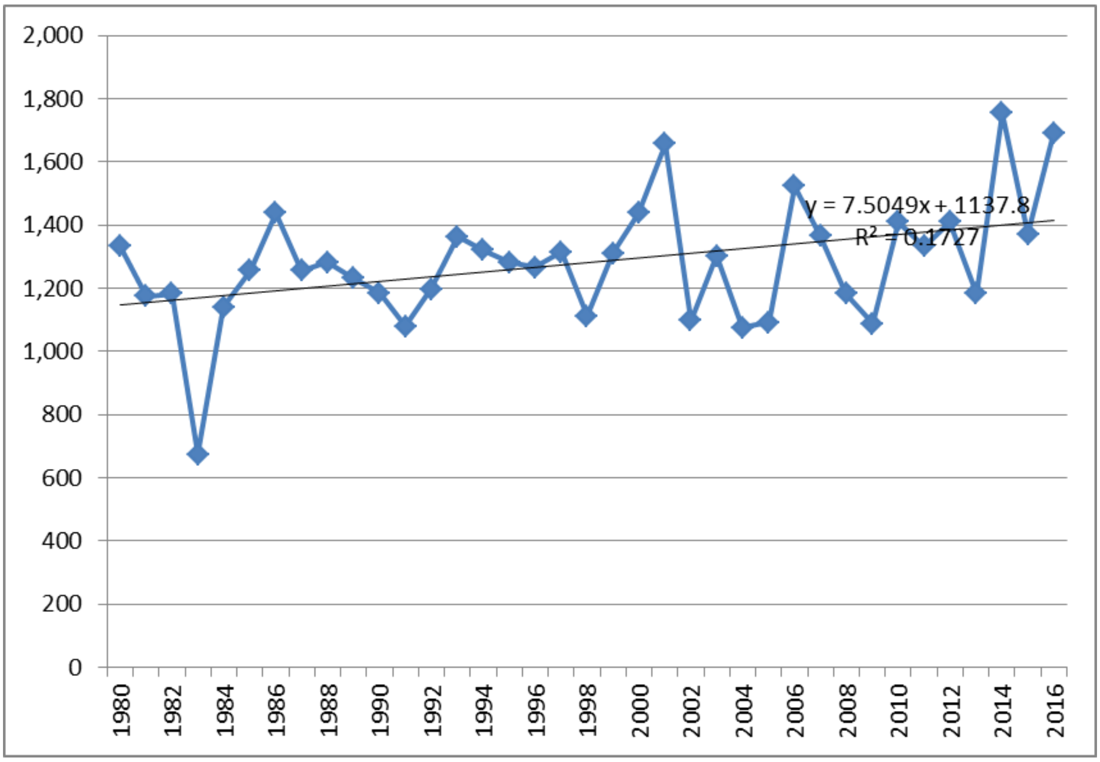

Figure 3.3: Annual total rainfall at Garba Guracha Meteorological Station (Source: Computed based on the raw data obtained from NMA).

As indicated in Figure 3.3, the general trend of rainfall in the area seems increasing over years. The solid blue line in the figure indicates an increasing annual total rainfall between 1980 and 2016. This could be one of the opportunities for the overall agricultural (both crops and livestock sub-sectors) development of the area as water is one of the crucial resources for these sectors. This could be an important input for the existing water resources whether it is underground or surface water. In fact, one can see the increasing trends of rainfall as an adversity as this may amplify the prevailing severe soil erosion in the area. The prospective adverse impacts of the above discussed temporal rainfall conditions in Kuyu *Woreda* may aggravate the existing socio-economic, environmental and livelihoods systems of the community in the area. If the rainfall variability continues deteriorating no doubt it will worsens the overall socio-economic, environmental and livelihoods systems in the area.

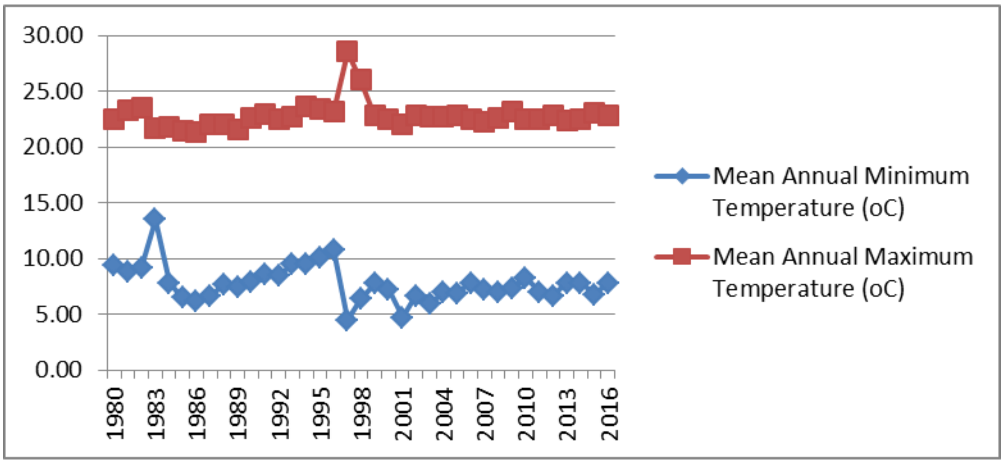

Figure 3.4: Mean annual minimum and maximum temperatures in Garba Guracha Town (1980-2016). (Source: Computed based on the raw data obtained from NMA).

Regarding temperature condition, as an element of weather and climate, there is no significant change of temperature over the last 36 years (1980-2016). The average mean annual temperature seems constant as compared to the variability in rainfall. This may be because the change in temperature within this short period of time is inconspicuous to detect the presence of increasing or decreasing temperature values.

As a result of the wide range of altitude, there are different agro-climatic zones in the *woreda*. Temperate (*bada* in Afan Oromo and *dega* in Amharic) type of climate that accounts for about 50 percent of the *woreda* is found in areas greater than 2,300 meters above sea level. Subtropical (*badadare* in Afan Oromo and *woinadega* in Amharic) climate is found in altitudes ranging from 1,500-2,300 meters above sea level having a share 40 percent; while Tropical (*gamoji* in Afan Oromo and *qola* in Amharic) climate prevails in areas of less than 1,500 meters above sea level covering about 10 percent of the total area of the *woreda.*

3.1.3. Demographic and socio-economic aspects

The total population of Kuyu *Woreda* in the year 2015 was 152,366 of which 75,523 were males and 76,843 were females giving it a sex ratio of 101.6... The *woreda* is a moderately populated area where the population density is about 160 persons per square kilometer. Majority of the households have a household size ranging from 3 to 8 members (CSA, 2015). An overwhelming majority of the population in Kuyu belongs to the Oromo ethnic group and the majority of the inhabitants are adherents of the Ethiopian Orthodox Christianity religious sect. Likewise, majority of the population is in the lower age categories; a manifestation of the high level of fertility and perhaps high levels of mortality and lower life expectancy. Therefore, the *woreda's* population could be labeled as a young population (Messay, 2016)

Kuyu *Woreda* has basically a subsistence agricultural economy where the majority (93.17%) of the *woreda's* population are farmers leading a sedentary way of life. The major means of livelihood of the study area are mixed agricultural practices (crop production and livestock rearing). Land is an important factor of production, human labor is the principal sources of power and livestock are important household assets. The major types of crops cultivated in the study area are cereals and pulses. Irrigation schemes and other water development projects across the *woreda* are at low level. Problems arise from rainfall scarcity and variability, and there is insufficient water supply to the rural community since most of the springs and streams are low yielding and intermittent (Ibid).

3.2. Data source and materials

Three series of LANDSAT images (1986 TM, 2000 ETM+ and 2016 OLI) were acquired. The main purpose of the utilization of the three series images is to investigate the rates and intensity of changes in forest cover in Kuyu Woreda over 30 years. The selected images were all cloud free since they were captured during the dry period. It was give a clear picture of the level and intensity of degradation of vegetated lands. The unprocessed satellite images were undergone both pre and post processing procedures by using ERDAS 2014software.

Table 3.1: List of data source and materials

No	Types of data	sensor	Spatial Resolution	Acquisition date	Source
1	Land sat 7	TM	30x30m	14,January 1986	USGS
2	Land sat 7	ETM+	30x30m	10,January 2000	USGS
3	Landsat8	ETM+	30x30m	21,January 2016	USGS
4	Climate data				NMA
4	*Woreda* and *Kebele* Boundaries from				CSA
5	Roads map				ERTA
6	Slope and elevation				SRTM-30m
	Software used		Application		
1	ARC GIS 10.3		GIS analysis and image processing		
2	ERDAS EMAGINE 2014		Image processing and change detection		
3	IDRSI 32		Weighting factors		

3.2.1. Research design

A research design can be understood as the framework in which data is collected and analyzed (Bryman, 2008). This research is, therefore, a retrospective-cross-sectional study type involving the investigation of a onetime socioeconomic profile of the respondents and climatic (rainfall and temperature) as well as land cover dynamics of the study area over 30 years. For socioeconomic aspect of the study, the cross-sectional design was selected for this study because a onetime data was required in this regard. A critical look at the research questions indicates that a pattern of association between and among the key variables which were required and the cross-sectional design is a good choice in that regard. As stated by Bryman (2008, p.31), the cross-sectional design entails the collection of data on more than one case and at a single point in time in order to collect a body of quantitative or quantifiable data in connection to two or more variables which are examined to detect a pattern of association.

3.3. Method of data collection

The most important data for this study are satellite images, GPS-based ground survey, long-term climatic data (rainfall and temperature) and firsthand socioeconomic data that were obtained. Procedure to collect or access each of data which were used for the study is described below.

3.3.1. Satellite image data

Three series of LANDSAT images (1986 TM, 2000 ETM+ and 2016 ETM+) were acquired. Data is available for free from the United States Geological Survey Website (USGS) (earthexplorer.usgs.gov/). The selected images were all cloud free since they were captured during the dry period. The TM and ETM+ images (multi-temporal Landsat images), it was already geo-referenced were down loaded from 'USGS website' and used. The UTM geographic projection, WGS 1984 spheroid and datum, zone 37 North, were used.

3.3.2. Long-term climatic data

Long-term rainfall and temperature records were obtained from National Meteorological Agency (EMA) of Ethiopia. This was used to analyze temperature conditions, and the trend and variability of rainfall which consequences are assumed to be crucial factors in the theme of the study i.e. land-use/cover dynamics and environmental degradation in the study area.

3.3.3. Socioeconomic baseline supplementary data

The cross-sectional design was employed to collect socioeconomic data. Since the socio-economic data in the study is supplementary, there consider some basic socioeconomic data which could cause the deforestation in the study area. Therefore, these socioeconomic data were generated by using key informant interviews and focus group discussions. A detail procedure for the KII and focus group discussion has been presented hereunder:

Key Informant Interview: Key informant interviews were carried out with the intention of capturing more firsthand socioeconomic and biophysical data for the study. The key informants were the elderly people, experts in the Kuyu *Woreda* agriculture land and environmental protection office, development agents (DAs) and chairmen and managers of *kebeles*. There are 23 *Kebeles* in Kuyu *Woreda* and four *Kebele* were selected purposively such as; Dawicha Kerensa, Dero Wulincho, Wuye Gose and Halelu Chari. At this stage the researcher has taken very great care so that the selected *kebele* was representing the district in terms of socio-economic and physical characteristics sufficiently.

Three Key Informants (one each from *Kebele* elderlies, DAs and *Kebele* Chairmen) were selected purposively from each sampled *kebeles* with the expert's consultation. One Key Informant was selected from *Wereda* agriculture land and environmental protection office experts. Totally, 13 individuals were selected for Key informant interviews. Each interview was carried out by the researcher with the aim of making further investigations on the basis of the information received from the respondents.

Focus Group Discussion (FGD): Four focus group discussions were carried out with representatives from different economic status (well-off and indigent), religion, gender, age group (youth, adult and elderly), and community-based organizations. This technique was used to extract information in a participatory manner so that the perceptions and views of the community were captured and interpreted. Suitable conditions were set for the discussants so that they would able to describe the issues under investigation precisely in their own language, Afan Oromo. The participants were respectfully requested for their time.

3.4. Techniques of data analysis

3.4.1. Land-use/cover analysis and classification.

One of the main objectives of this study is to identify and quantify the spatiotemporal dynamics of deforestation over the last 30 years i.e. from 1986 to 2016 Landsat. The processed images were classified into various land uses based on the supervised classification technique, and this was land-use/cover maps. The Landsat images of 1986, 2000 and 2016 with 30-meter resolution were used.

Furthermore, on the bases of the years 1986,2000 and 2016 multi-temporal Landsat data forest cover change detection analysis were carried out using Post classification change detection comparison methods. In relation to this, the year 2016 land cover and land use classification result was evaluated by employing accuracy assessment technique using ERDAS 2014 software to investigate how the result reflects the reality on the ground. Moreover, the years 1986, 2000 and 2016 forest cover map also independently generated from each land use land cover maps.

To analyze susceptibility to forest degradation based on 2016 forest cover condition, Multi Criteria Evaluation (MCE) analysis was carried out. GIS software such as Idrisi32and ArcGIS10.3 (Spatial Analyst), a model named MCE had been used to facilitate this process.

3.4.2. Image processing

Performing image analysis is an inevitable task to extract meaningful information from remotely sensed data. So, an effort is made to use the remotely sensed data with different level of image pre-processing methods. The methods of image processing techniques used in the current study are: Procurement of best and available different dates of satellite image data is the initial stage for image processing and analysis in this study. In the meantime, multi-temporal Landsat images with path 169 and raw 53 on January 1986, 2000 and 2016 which were already geo-referenced) were down loaded from Earth explorer.USGS.GOV. Landsat satellite images of the year 1986, 2000 and 2016 having a map projection of UTM zone37 and datum WGS84 were re-sampled to UTM zone37, local datum Adindan using ERDAS Imagine2014 software in order to well-suited the image with other map layers.

The 1986 image has seven bands with a spatial resolution of 30m. This image was used detailed land use land cover classification using 4-3-2 false color band combination of RGB (Red, Green and Blue) order and also the 2000 satellite image of Landsat 7 ETM+ is used which has eight bands with a spatial resolution of 30 meter. This image used for land use/land cover classification using 4-3-2 false color band combinations in RGB order. Furthermore, the 2016 satellite image of Landsat-8 (OLI) is used for most of the analysis and mapping activities in the present study since it is the recent available satellite image. This image was already geo-referenced and its quality was found to be very good during field work, having spatial resolution of 30m was used. Besides, this image was used for land use/land cover classification using 5-4-3 false color band combinations in RGB order.

3.4.3. Image classification

The principle of image classification is that a pixel is assigned to a class based on its feature by comparing it to predefined clusters in the feature space. In this study, supervised image classifications was carried out for the three images of (1986, 2000 and 2016) based on different false color composites of 4, 3, 2 and 5, 4, 3. Then the change detection analysis was carried out by visual comparison of features and detailed quantitative approaches. In addition to this, maximum likelihood image classification algorithm was utilized.

Using the application of image classification methods, land cover and land use types are identified in order to perform forest cover change detection and to determine forest degradation susceptibility analysis. Therefore, in this study the forest cover types play a much more important role than other types of land cover/land use found in the district. Based on the characteristics of Landsat satellite image of the year 1986, 2000 and 2016, the District’s major land cover and land use types were classified with the support of ERDAS Imagine 2014 Software.

3.4.4. Climatic data analysis

As indicated in source of data above, the unprocessed long-term climatic data (amounts of rainfall and temperature) for this study were obtained from National Meteorological Agency (NMA) of Ethiopia. The target of this analysis was to look into the nature and magnitude of climate-induced biophysical problems that might have resulted in fast land-use/cover in the area. Graphs and descriptive statistic (mean values) was used to analyze the long-term climatic conditions of the area.

3.4.5. Socioeconomic data analysis

Socioeconomic data were generated by using key informant interviews and focus group discution from the *woreda*. Hence, the data is qualitative, the methodologies employed to analyze the collected data is descriptive statistics.

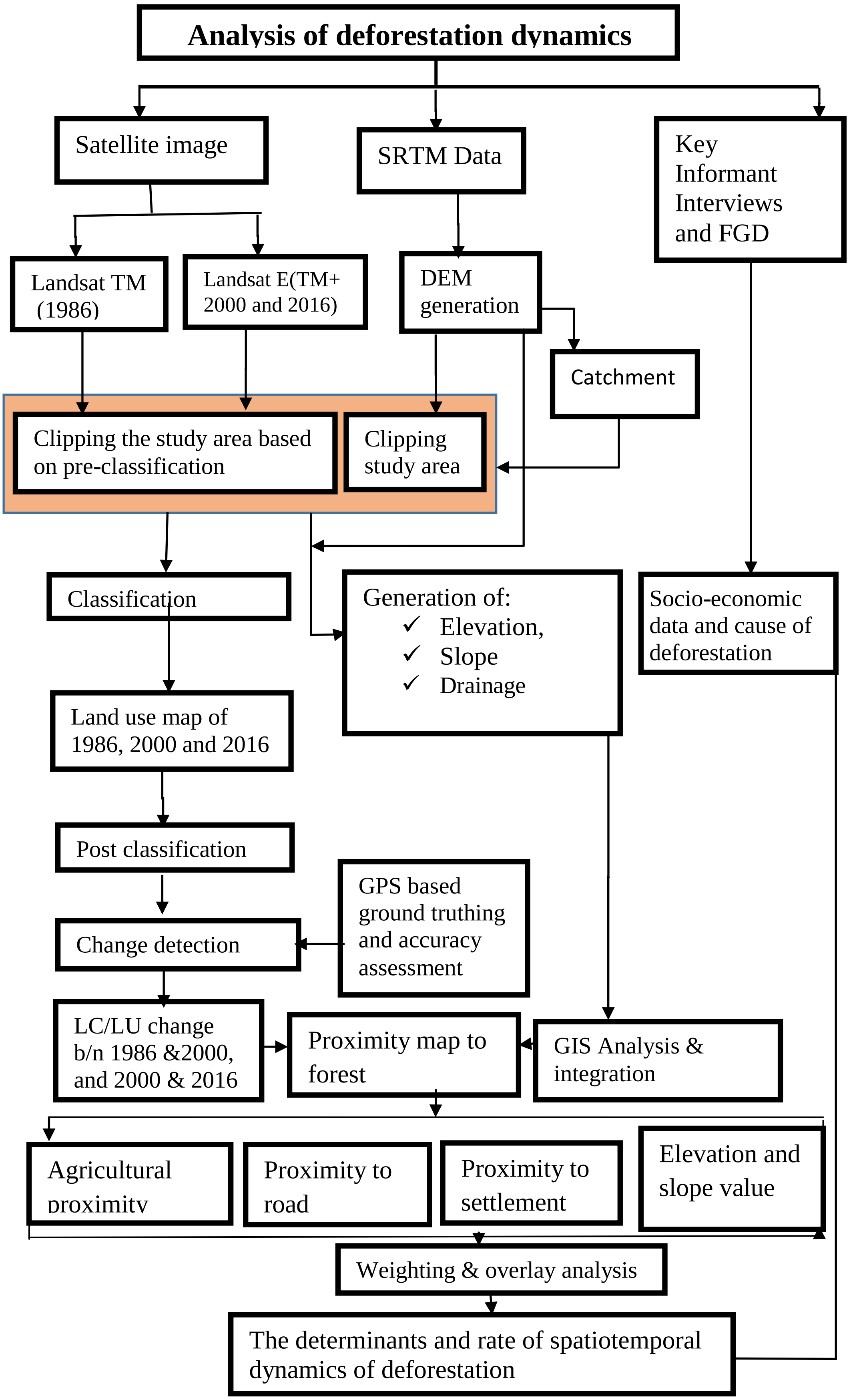

Figure 3.5: General methodological flow of the stud

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Land cover mapping of Kuyu *Woreda*

Using the application of image classification methods, six major land use and land cover types were identified. These include forest, shrub or bush, grass, agricultural (crop land), bare land and settlement based on the characteristics of Landsat satellite images of the year 1986, 2000 and 2016 with the support of ERDAS Imagine 2014 Software and described as follows:

Table 4.1: Description of each land use land cover type

Crop land	Areas allotted to rain fed crop production, mostly of cereals in subsistence farming (https://www.merriamwebster.com/dictionary/cropland)
Forests	Areas covered by trees forming closed or nearly closed canopies; predominant species like Juniperus procera (Alelign 2010)
Shrub land	Land supporting an assemblage of small trees and shrubs (Berhan, 2007)
Grass land	Grasslands are non-woody areas where the vegetation is dominated by grasses and herbs with nil or little proportion of shrubs (Messay, 2011)
Bare Land	Parts of the land surface which is mainly covered by bare soil and rock out crops (Alelign, 2010)
Built up Area	A built-up area is an area such as a town or city which has a lot of buildings in it (https://www.collinsdictionary.com/dictionary/english/built-up)

4.1.1. Land use/land cover map of Kuyu *Woreda* in 1986

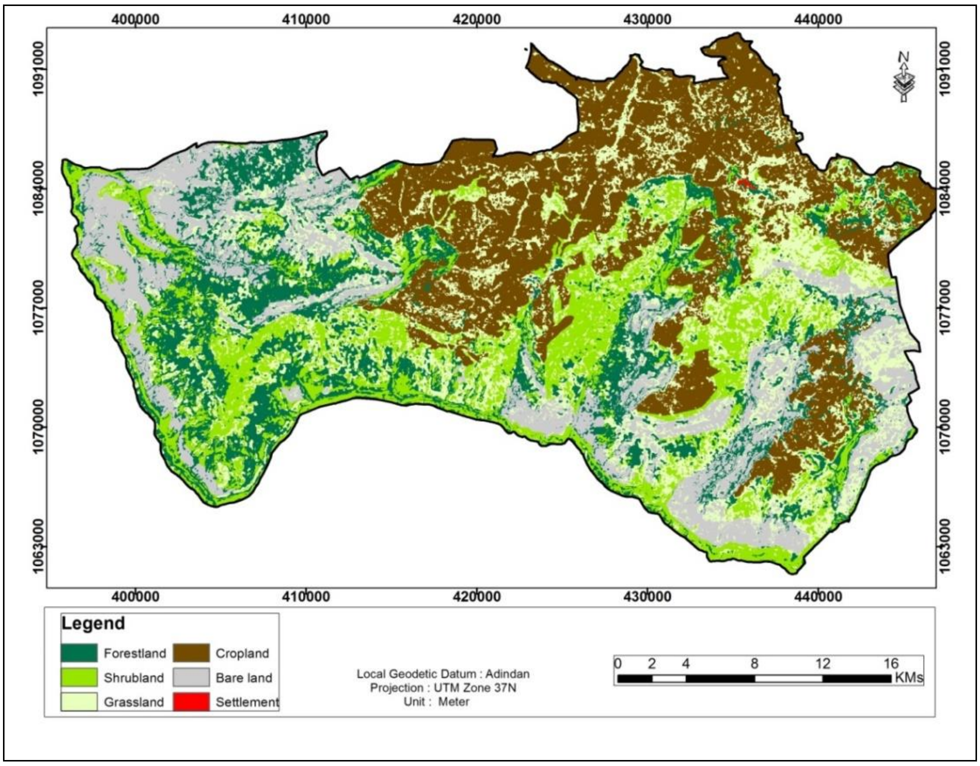

Figure 4.1: Land use/land cover map of Kuyu *Woreda* in 1986 (Source: computed from +1986 satellite image interpretation).

The major land use/land cover classes of 1986 include crop land, grassland land, Shrub or bush land, forest, bare land and built up area. As indicated in (Figure 4.1) the greatest share of land use/land cover from all classes is crop land, which covers an area of 23534.9 ha, which contributes, 24.9 % of the total area. Similar study in Dandi district by Berhan (2007) and in Borena District by Alelign (2010), also indicted that cropland was the greatest share of land use land cover change. Another Grass land, shrub and forest land cover an aerial size of 20420 ha (21.6 %), 17793.5 ha (18.8 %) and 17139.2 ha (18.1) respectively, whereas the aerial coverage of bare land and settlement is 15694.3 ha (16.6%) and 26.3 ha (0.03) from the total area of the wereda. This shows that 58.5% of the total area of the district was covered by shrub, forest and grassland in 1986 and the remaining 41.5% was covered by agricultural, bare land and settlement, which indicates that much of the area was covered by green vegetation in 1986.

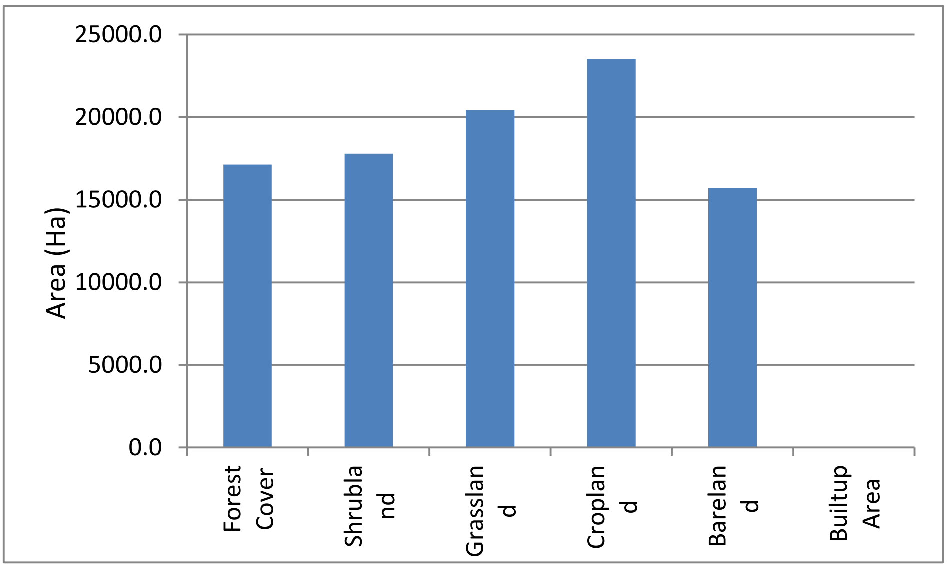

Figure 4.2: Pattern of land use/land cover distribution in Kuyu *Woreda* in 1986 (source: computed from table 4.2).

4.1.2. Land use /land cover map of Kuyu *Woreda* in 2000

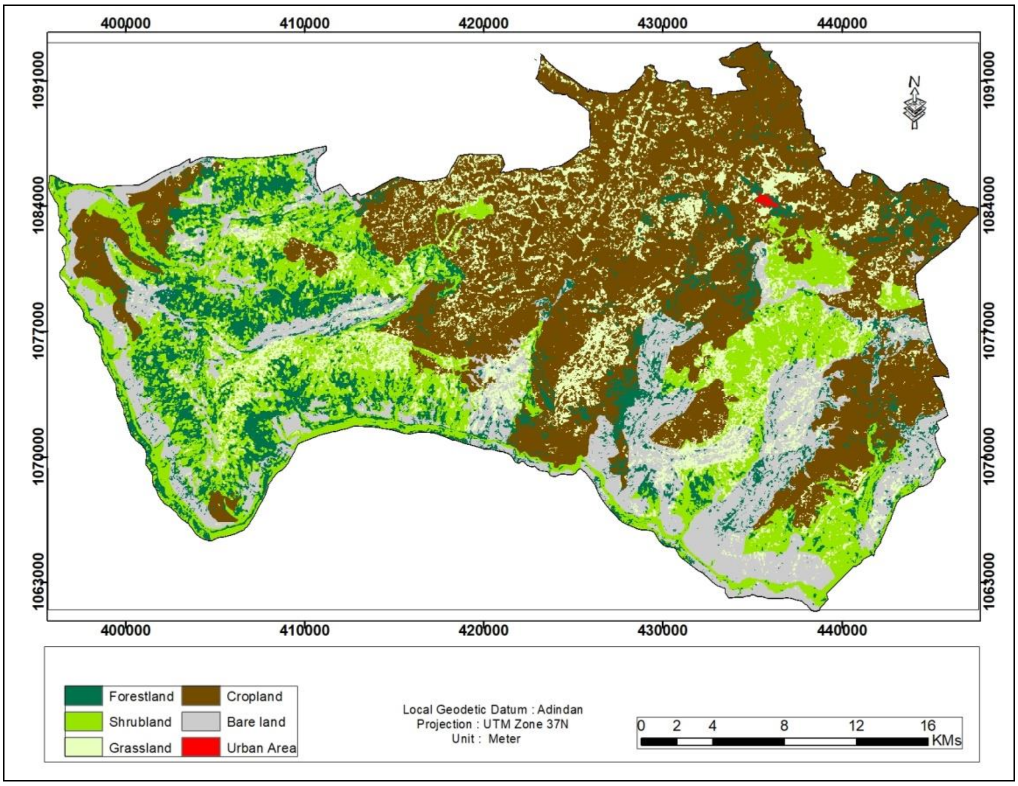

Figure 4.3: Land use/ land cover map of Kuyu *Woreda* in 2000 (Source: computed from 2000 satellite image interpretation).

Where as in the case of 2000 the major land use/land covers classes were crop land, grass land, shrub or bush land, forest, bare land and urban area. As indicated in (Figure 4.3) shows the Greatest share of land use/land cover from all classes is crop land, which covers an area of 34907.5 ha (36.9 %). Shrub land and bare land cover an aerial size of 19796.5ha (20.9 %) and 15212.7 ha (16.1%) respectively. The least aerial coverage is still forest, grass land and urban area, which has only 12369.4 ha (13.1 %) and 12270.5 ha (13%) and 51.8 (0.1%) respectively from the total area of the wereda. As shown in (Table 4.2), 36.9 % of the area is covered by cropland land due to the conversion of forest, bare land and grass land to agricultural land because of rapid population growth in the study area. In addition to this there was expansion of shrub land from 17793.5ha (18.8%) in 1986 to 19796.5ha (20.9%) in 2000 because of conversion of forest land to shrub land in the *woreda.*

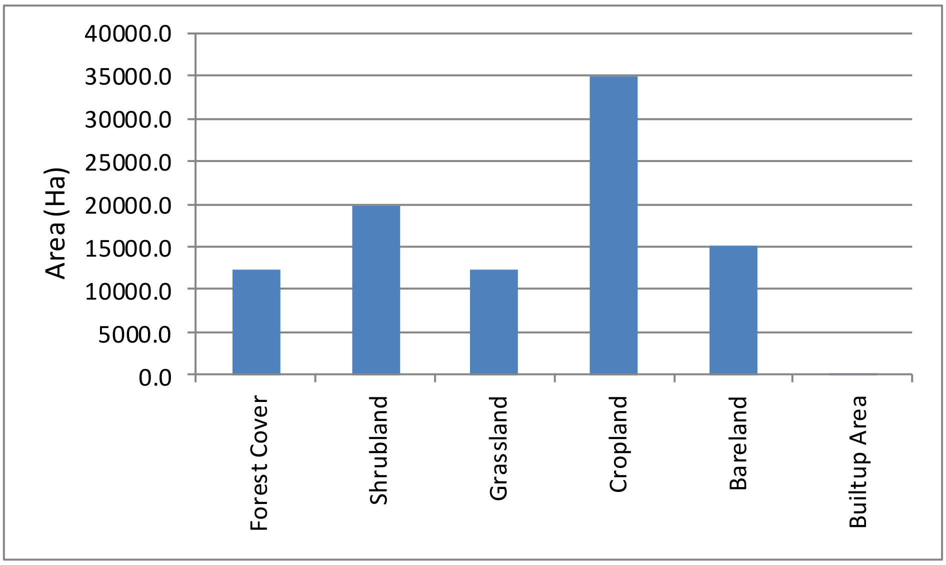

Figure 4.4: Pattern of land use/land cover distribution in Kuyu *Woreda* 2000 (source: computed from table 4.2).

4.1.3. Land use/ land cover map of Kuyu *Woreda* in 2016

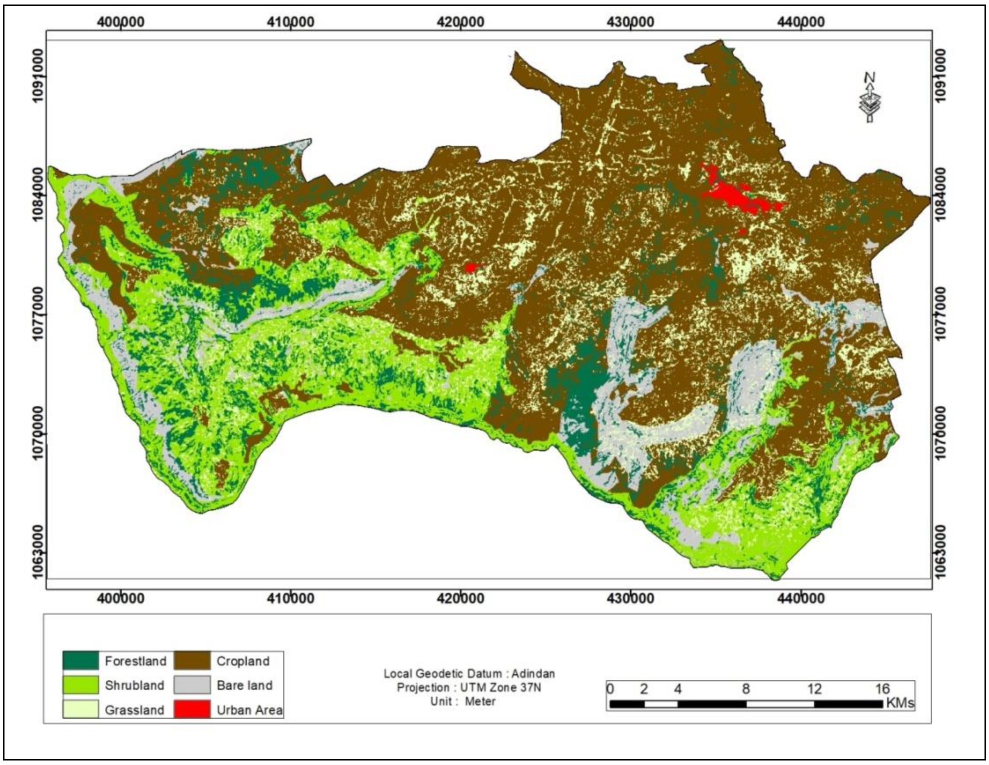

Figure 4.5: Land use land cover map of Kuyu *Woreda* in 2016 (Source: computed from 2016 satellite image interpretation).

During 2016 the major land use/land cover classes include crop land, grass land, Shrub or bush land, forest, bare land and urban area but all the land use classes have different aerial coverage from the previous time. As indicated in (Table 4.5) the greatest share of land use/land cover from all classes is cultivated land, which covers 45265.4 ha (47.8 %) almost half of the total area of the district. Shrub or bush land covers decreased from 20.9% to 19.7% because of some shrub land change to crop land. There was no great change on shrub land due to forest changes shrub. The least area is covered by forest, grass land and bare land and urban land which is 11022.8 ha (11.7%) 10725.8 ha (11.3%), 8514.7 (9%) and 4361.5 (0.5%) from the total size of the *wereda* respectively. Still cropland covers the largest area in 2016 which shows conversion of other land cover classes to cultivated land. However, urban area was increases continuously from 1986 to 2016 specifically from 2000 to 2016 because of migration of rural population to urban to get job opportunities.

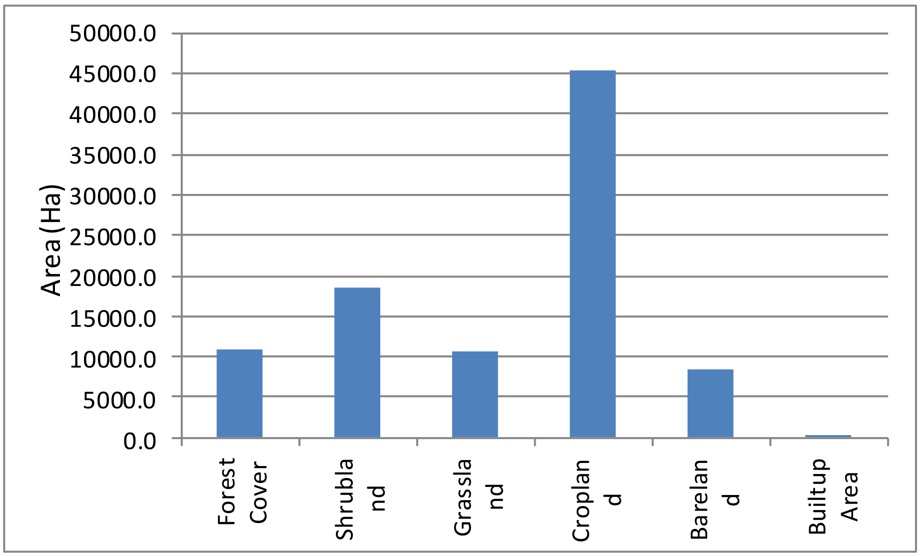

Figure 4.6: Pattern of land use/land cover unit in Kuyu *Woreda* in 2016 (source: computed from table 4.2).

Moreover, to have a clear understanding about the cover change and its pattern's in the study area, figure 4.7 had been generated based on the1986, 2000 and 2016 satellite image interpretations. It indicates that cropland was found to be the most expanding land use type in study area. However, the area covered by forest, grass and bare land has been reduced continuously, but shrub land was increased in 2000 because of some forestland change to shrub land and decreased 2016 doe to shrub land changed to other land use. In addition to crop land urban area also shows the continuous increments in the study area.

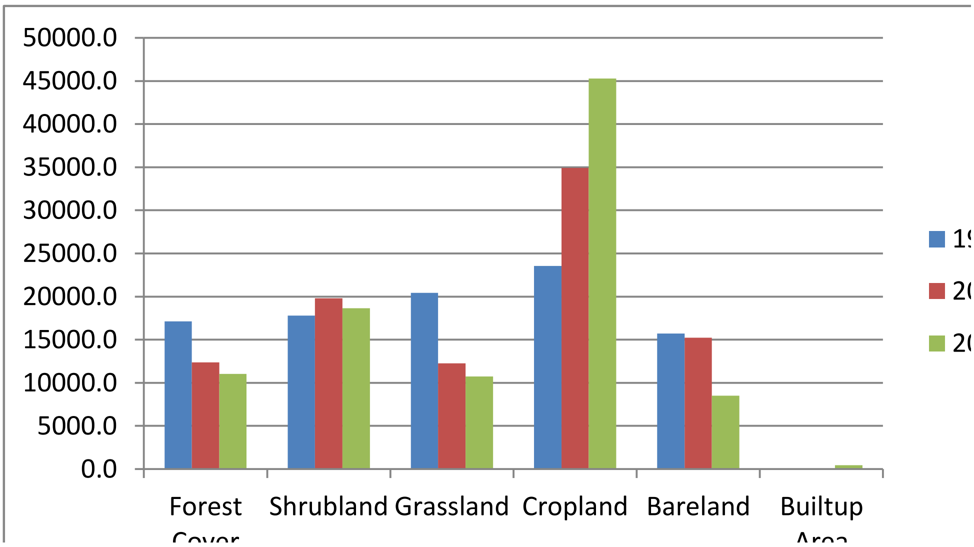

Figure 4.7: Patterns of land cover /land use units of Kuyu *Woreda* in 1986, 2000 and 2016 (Source: computed from Table 4.2)

Table 4.2: Summary statistics of land cover/ land use units of Kuyu Woreda in 1986, 2000 and 2016

LU/LC type	1986		2000		2016	
	Ha.	%	Ha.	%	Ha.	%
Forest Cover	17139.2	18.1	12369.4	13.1	11022.8	11.7
Shrub land	17793.5	18.8	19796.5	20.9	18643.7	19.7
Grassland	20420.3	21.6	12270.5	13.0	10725.8	11.3
Cropland	23534.9	24.9	34907.5	36.9	45265.4	47.8
Bare land	15694.3	16.6	15212.7	16.1	8514.7	9.0
Built up area	26.3	0.0	51.8	0.1	436.1	0.5
Total 1986	94608	100.0	94608	100.0	94608	100.0

Source: Computed from Satellite Image Interpretation of 1986, 2000, 2016.

4.2. Land cover change detection in Kuyu *Woreda*

4.2.1. Land cover change obtained from post classification change detection

An important aspect of change detection is to determine what is actually changing to what i.e. which land use class is changing to the other. This information will also serve as a vital tool in management decisions. This process involves a pixel to pixel comparison of the study year images through overlay analysis. The land use land cover change matrix depicts the direction of change and the land use type that remains as it is at the end of the day. For the land use land cover change matrix shown in (Table 4.3, 4.4 and 4.5) the columns represent the older land cover categories and the rows represent the newer categories.

To analyze and extract information from these land cover/land use change matrix, the following points should be taken in to considerations:

I. the land covers /use value is presented in hectare.

II. Each column values give the cover and use type in the previous years

III. Each row values indicate the cover and use types for the recent years.

Finally, in the change matrix the value above and below the diagonal lines represent change in land cover/use. The value along the diagonal line represent where no change has occurred.

4.2.2. Change between 1986 and 2000

This period shows decrease huge amount of forest than 2000 to 2016 period. The major changes observed in this period were decrease in the overall area of forest from 17139.2 ha in 1986 to 12369.4 ha (by 4769.8 ha) in 2000 and an increase in the areas of cropland from 23534.9 ha in 1986 to 34907.5 ha in 2000 (by 11372.6 ha) and increments of shrub land from 17793.5 ha in 1986 to 19796.5 ha in 2000 (by 2003 ha) (see table 4.3). According to Fekadu (2015), Based on the most recent estimates of the rates of deforestation, and assuming that 75 per cent of forest losses are attributable to agricultural expansion, it is estimated that over the next 25 years the agriculture sector will require an additional 250 to 300 million hectares of new land to accommodate the demands of commercial farming and subsistence cropping.

As indicated by Tilahun (2010), the destruction of the forest resources of the study was factual after the fall of the Dergue Regime in the early 1990s indicates the fact that rural development in general and forestry activities in particular could not succeed without the unserved participation of the rural population. During derg regime the forests are belonging to the government. The *woreda* officials attempt conserve the resource by restricting the inhabitants from using forest resources through punishment on them. Thus, farmers feel that they are not beneficiaries and claim to use the resource. They also believe that it is not their own as possessed by *woreda* agricultural offices. Therefore, the farmers are destructing the resources without any feeling of ownership after the fall of the Derg regime.

Table 4.3: Land use land cover change matrix of Kuyu *Woreda* (1986 to 2000).

		Land use/Land cover types 1986						
	LU/LC type	Forest land	Shrub land	Grass Land	Crop Land	Bare land	Built up area	Total
		Ha.	Ha.	Ha.	Ha.	Ha.	Ha.	Ha.
Land use/Land cover types 2000	Forest Land	**7451.0**	1915.7	1347.5	272.1	1382.8	0.4	12369.4
	Shrub Land	5026.3	**7507.4**	5811.9	109.4	1341.5	0.0	19796.5
	Grass Land	734.7	3669.1	**3720.2**	2881.5	1265.0	0.0	12270.5
	Crop Land	1524.9	3018.6	6653.1	**20140.9**	3570.0	0.0	34907.5
	Bare Land	2390.0	1677.6	2884.6	125.6	**8135.0**	0.0	15212.7
	Built up area	12.3	5.0	3.1	5.5	0.0	**25.9**	51.8
	Total	17139.2	17793.5	20420.3	23534.9	15694	26.3	94608.5

4.2.3. Changes between 2000 and 2016

The major Land cover changes observed during this period had been the reduction in the area of forests, shrub land, grass land as well as bare land by 1346.6, 1152.8, 1545.7 and 6698.28 ha respectively. A considerable increase in the overall areas of cropland by 10357.9 ha has been registered (see table 4.4). During this period the rate of deforestation was declined. This result is consistent with what have been currently reported by the Ethiopian government regarding vegetation cover all over the country (Tigabu, 2016). In fact, the improvement in these time periods could be due to the effects of massive tree planting (afforestation and reforestation) since the last three decades.

Table 4.4: Land use land cover change matrix of Kuyu *Woreda* (2000 to 2016).

		Land use/Land cover types 2000						
	LU/LC type	Forest land	Shrub land	Grass Land	Crop Land	Bare land	Built up Area	Total
		Ha.	Ha.	Ha.	Ha.	Ha.	Ha.	Ha.
Land use/Land cover types 2016	Forestland	**5159.9**	2674.1	475.4	1194.8	1518.4	0.2	11022.8
	Shrub Land	3633.5	**8949.7**	1919.7	108.4	4032.5	0	18643.7
	Grass Land	430.8	2570.7	**3595.6**	3019.1	1109.5	0	10725.8
	Crop Land	2247.9	5232.8	5476.1	**30346.3**	1962.4	0	45265.4
	Bare Land	818.3	359.9	746.55	0.0	**6590**	0	8514.72
	Built up area	79.0	9.4	57.24	238.9	0	**51.66**	436.14
	Total	12369.4	19796.5	12271	34907.5	15213	51.84	94608.5

4.2.4. Change between 1986 and 2016

While considering the whole range of time under consideration, the reduction in the area covered by forest types were remarkable, despite this crop land expansion observed in the second time period due to high shift of forest land, shrub land, grass land and bare land to crop land. Image differencing of the two extreme times, 1986 and 2016 indicated that forest cover reduced from 17139.2 to 11022 ha respectively. There were Considerable increment on cropland and urban area by 21730.5 ha and 409.86 ha respectively (see table 4.5).

Table 4.5: Land use land cover change matrix of Kuyu *Woreda* (1986 to 2016).

		Land use/Land cover types 1986						
	LU/LC type	Forest land	Shrub land	Grass land	Cropland	Bare land	Built up area	Total
		Ha.	Ha.	Ha.	Ha.	Ha.	Ha.	Ha.
Land use/Land cover types 2016	Forest land	**5822.8**	2052.4	1262.0	274.5	1611.1	0.0	11022.8
	Shrub Land	5375.1	**7332.6**	3889.9	0.5	2045.7	0	18643.7
	Grass land	864.8	2451.1	**4617**	1807.4	985.5	0	10725.8
	Crop Land	3399.1	5510.9	9046.2	**21314.3**	5994.9	0	45265.4
	Bare Land	1614.8	423.0	1419.8	0.0	**5057.1**	0	8514.72
	Built up area	62.6	23.7	185.4	138.2	0	**26.28**	436.14
	Total	17139.2	17793.5	20420	23534.9	15694	26.28	94608.5

4.1. Accuracy assessment

Land cover maps derived from remote sensing always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture. In order to wisely use the land cover maps which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy. Fieldwork was conducted according with the schedule to collect ground information, gather necessary information through official view of the current land cover change. Sufficient numbers of randomly distributed sample plots was selected for ground observation. The error matrix and kappa method was used to assess the mapping accuracy. The overall accuracy only considers the correction of diagonal elements in the matrix, while the kappa method takes the other element in the matrix into account, which can compensate the disadvantage of error matrix method.

In this study, an error matrix was generated based on the year 2016 forest cover classification and area of interest data (Table 4.6). The accuracy is essentially a measure of how many ground truth pixels were classified correctly. The kappa value is a measure of the agreement between classification and reference data with the agreement due to chance removed. As it is shown in (Table 4.6) the overall accuracy and kappa coefficient is 85.14% and 0.82 respectively. This shows 85.14% of the land use land cover classes are correctly classified.

Table 4.6: Confusion matrix of 2016 land use land cover classification of Kuyu *Woreda*

		Land use/Land cover (office interpreted)						Total
		Bare land	Crop land	Forest	Grass land	Shrub land	Urban Area	
		No.	No.	No.	No.	No.	No.	No.
Land use/ Land cover (Field Observed)	Bare land	9	0	0	0	0	0	9
	Crop land	1	16	0	1	0	0	18
	Forest cover	0	0	10	0	1	0	11
	Grass land	0	1	0	12	1	0	14
	Shrub land	0	1	2	1	6	0	10
	Urban Area	1	1	0	0	0	10	12
Total		11	19	12	14	8	10	74

Overall accuracy=85.14   kappa coefficient= 0.82

4.2. Rate of land use land cover changes in Kuyu *Woreda*

The rate of change was calculated for each land use land cover using the following formula:

Rate of change (ha/year) = (A-B)/C

Where A = Recent area of land use/ cover in ha.

B = Previous area of land use/ cover in ha.

C = Time interval between A and B in years

Table 4.7: Land use land cover classes and rate of change in Kuyu *Woreda* (1986 to 2016)

Land use land cover	Years			Rate of change (hectare/year)		
	1986	2000	2016	1986 to 2000	2000 to 2016	1986 to 2016
Forest cover	17139.2	12369.4	11022.8	-340.7	-84.2	-203.9
Shrub land	17793.5	19796.5	18643.7	143.07	-72	28.34
Grassland	20420.3	12270.5	10725.8	-582.1	-96.5	-323.2
Cropland	23534.9	34907.5	45265.4	874.8	647.3	724.4
Bare land	15694.3	15212.7	8514.7	-34.4	-418.6	-239.3
Urban area	26.3	51.8	436.1	1.82	32	13.7

As shown in table 4.7, between 1986 to 2000 crop land increased with a rate of 874 ha/year and further increased in 2016 with accelerated rate of change 647.3 ha/ year . From 1986 to 2016 crop land increased with a rate of 724.4. The expansion of agricultural land was by the outflow of bush/shrub land, forest land and grass land as it is explained in the change matrix of (Table 4.3, 4.4 and 4.5). From (1986 to 2000) 1524.9, 3018, 6653.1 and 3570 ha of forest, shrub land, grass land and bare land had been changed to agricultural land respectively. While “between” 2000 to 2016, 2247.9, 5232.8, 5476.1 and 1962.4 ha of forest, shrub grass land and bare land had been changed to agricultural land respectively. This shows that there was a dramatic expansion of agricultural land within the specified time period because of population pressure and poor land administration. The expansion of agricultural land between 1986 and 2016 in the *woreda* in general could be directly related to rapid population growth.

On the other hand, forest land, grass land and bare land had decreased from 1986 to 2000 with 340.7, 582.1 and 34.4 ha/year rate of change and also decreased in 2016 with rate of 72, 96.5 and 418.6 ha/year respectively. The change was induced by the transfer of forest land, grass land and bare land to agricultural land from 1986 to 2000 and 2000 to 2016. From 1986 to 2000 shrub land was increased with the rate of 143.07 ha/year because of forest land changes to shrub land but decreased with the rate of 72 ha/year in 2016 due to shrub land change to crop land. The massive reduction of vegetation particularly in between 1986 to 2000 was because of lack of administration especially during the transition period Tilahun (2010). Whereas urban land was continuously increased "between" 1986 to 2000 with a rate of 1.2 ha/year and then further increased with a rate of 32 ha/year in 2016. The rate of increment is very high "between" 2000 to 2016 because of migration of rural population to urban area in Kuyu *Woreda.*

4.3. Areal extent and rate of forest cover change in Kuyu *Woreda*

Assessment of forest cover change was done using remote sensing and GIS techniques with the integration of field observation, interviews and focus group discussion. In this study, three Landsat satellite images were used to monitor the areal extent and rate of forest cover change with in time sequence. According to Ethiopia's Forest Reference Level Submission to the UNFCCC (2016), the adjusted area estimate for forest loss is 1.1 million ha +/- 0.91 million ha and for forest gain is 0.4 million ha +/- [RS experts to fill] over the period 2000-2013 which corresponds to an annual forest loss of approximately 70,000 ha/yr. and annual forest gain of approximately 30,000 ha/yr. During the analysis stage, digital image interpretation of forest cover in study area for each year was performed and total area of the forest cover in terms of ha and its percentage from each date of satellite interpretations were computed and summarized. Figure 4.11 and table 4.10 revealed that the pattern of forest cover changes between 1986 and 2016 in Kuyu *Woreda.*

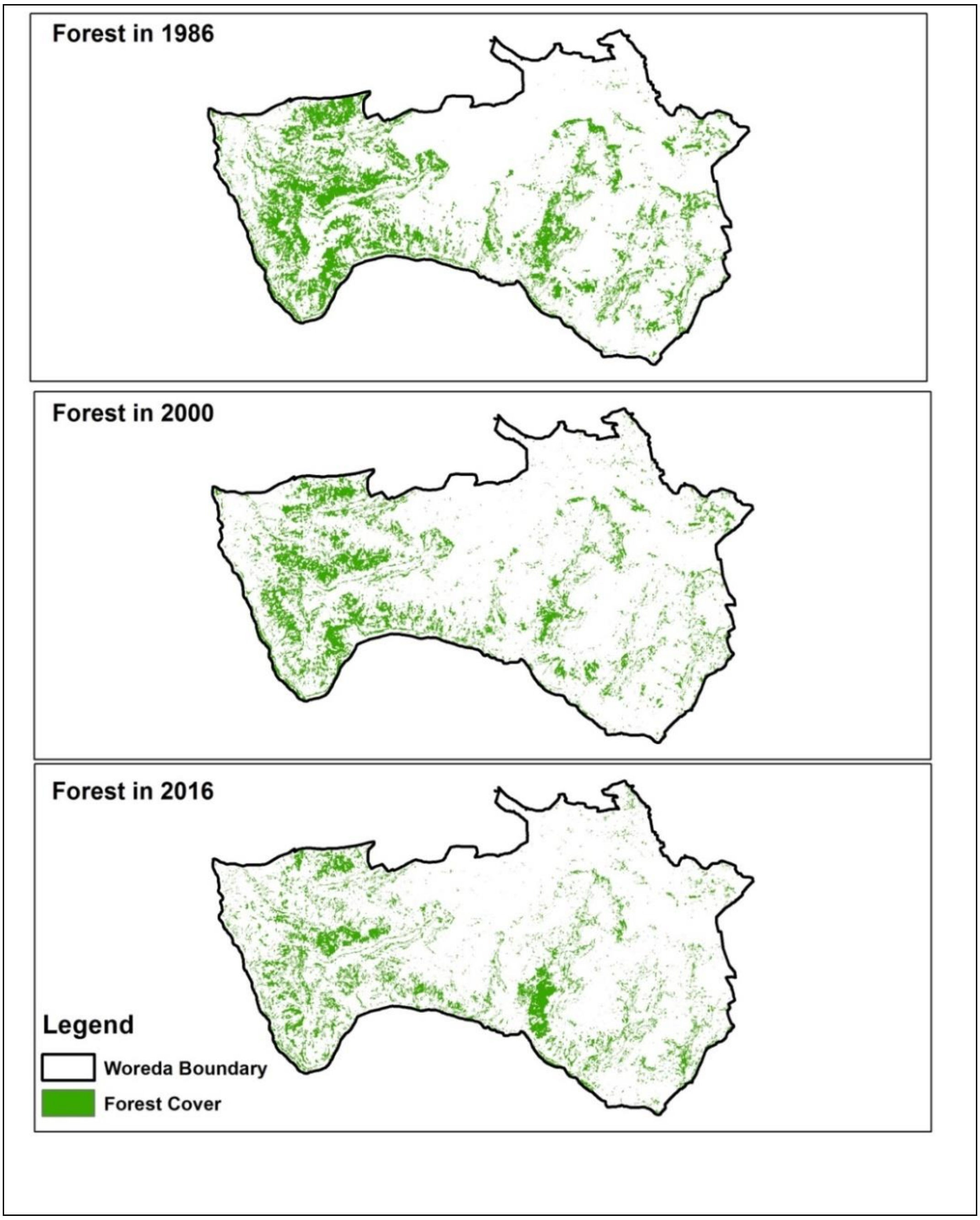

Figure 4.8: Forest cover map of Kuyu *Woreda*, 1986, 2000 and 2016

Source: Derived from 1986, 2000 and 2016 land cover /land use map

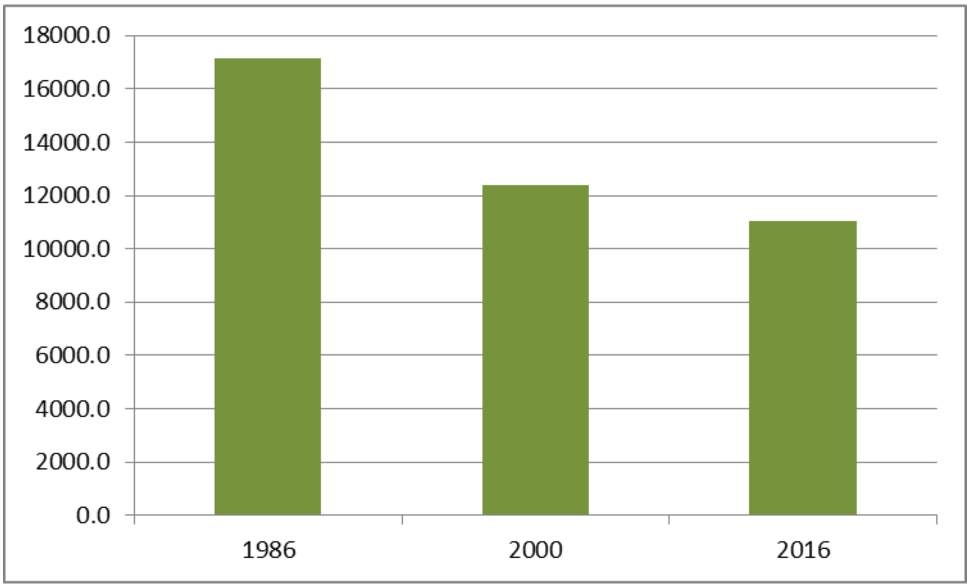

Figure 4.9: Pattern of forest cover in hectare value in Kuyu *Woreda*; 1986, 2000 &2016 (source: computed from table 4.1).

In the year 1986, 18.1 % of the *woreda* was covered with forest resources while from the total area of the *woreda* about 13.1 % was covered with forest resources in 2000. In the meantime, this figure turned down in to 11.7% in the year 2016.

4.4. Susceptibility to forest degradation analysis

The rate of forest degradation is very high from 1986 to 2016, the total area of forest coverage was 17139.2 ha (18.1%) and 12369.4 ha (13.1%) in 1986 and 2000 respectively. But in 2016 it was decreased to 11022.8 ha (11.7%), from 1986 to 2016 the forest coverage is almost decreased by 6116.4 ha. Since forest is disappearing at alarming rate, therefore preparing forest degradation susceptibility map is necessary for protecting it from further degradation and for management purposes.

In order to monitor forest degradation and generate susceptibility to forest degradation map of the *woreda*, the year 2016 forest cover map was considered to be the base line for this analysis. This map is generated from the land cover/ land use map of the year 2016 satellite image classification, which is the only available recent satellite image data source. According to Berhan (2007) and Alelign (2010), Susceptibility to forest degradation is understood that the forest resources can be influenced or degraded by human activities. In reality, forest resources are degraded not only by human activities but also due to other natural factors too. However, in this research human activities were taken in to consideration, because the unplanned actions such as illegal logging, exploitation of forest resources for fuel wood and charcoal production as well as expansion of agricultural lands are the main factors that cause forest degradation in Kuyu *Woreda*. To carry out susceptibility to forest degradation mapping, MCE analysis was used. The procedures which were designed to run MCE analysis in the present study listed below:

4.4.1. Preparing input datasets (factor maps)

The first step to run MCE is deciding, analyzing and generating proximity to forest cover data stets or factor maps which are responsible for forest degradation (Alelign, 2010). Accessibility to forest resource is used as how easily the local people can go to or penetrating the forest areas to extract different types of forest products for the purpose of house hold consumption and income generation as well as expansion of agricultural lands along the borders of forest areas. The selected datasets are settlement proximity, road proximity, slope and elevation value of the *woreda* and Proximity to agricultural land.

To begin with, slope is considered to be one of the contributing factors that aggravate the susceptibility to forest resource degradation in Kuyu *Woreda.* As indicated in Alelign (2010), the underlying assumption is that; if the existing forest resource is found in relatively gentle slope gradient, there is a possibility of easily degradation to this resource. This argument is also strongly supported by the *Woreda* agricultural officers, foresters and even by local dwellers. According to their views, if the physiographic region of the area lies with relatively gentle slope gradient, there is a positive correlation for the expansion of agricultural and grazing land as well as rural settlement at the expense of forest cover; shrub land and grass cover areas. According to Alelign (2010), on the contrary said, Steep slope areas are the natural forest cover keepers.

Secondly, the expansion of agricultural land is the major triggering factor for the depletion of forest resources in Ethiopia. According to Fekadu (2015), based on the most recent estimates of the rates of deforestation, and assuming that 75 per cent of forest losses are attributable to agricultural expansion. When the forest area is encroached by agricultural lands, there is a probability of these resources to be degraded as well as deforested in order to secure sufficient cultivated and grazing lands. As indicated in the change detection result part, the encroachments of cultivated lands at the expense of forest cover units is the major factor for the conversion of forest cover land in the study area. Due to this, proximity to cultivated land is considered to be one of the decisive factors for future susceptibility to forest resource degradation.

Likewise, urban growth in particular and rural settlement expansion in general are the most important factors for the destruction of forest resources in Ethiopia. This is because most of the population is dependent on forest resources found in and around their residential areas in order to secure the demand of constructional material as well as fuel wood supply. In addition to this, most people (especially women and jobless youths) are used the forest resources found in the nearby urban areas as income generation means for them. But in the case of this study since there is one well-known urban center called Garba Guracha and both small towns and villages which have assumed to be highly populated are selected for the analysis.

Besides, road is one of the crucial factor that provide access for natural resource exploitation, areas with no accessible roads are less likely to get disturbed by human intervention as it would be difficult to over pass natural barriers. The same is true for vegetation exploitation. As indicated in Workaferahuw (2015), the vegetation resource nearby access to roads is more likely to be exploited than the less accessible ones. In this forest susceptibility degradation exemplary, the graveled roads radiating across all over the *woreda* were considered to be the input criterion which contributes for the problem of forest degradation. The principal assumption is that, the proximity of the forest cover area to the road networks facilitates the movement of various types of forest products from the source to market centers.

Finally elevation data set was used, according to the traditional climatic classification most of the *woredas* area is found in the "*woina dega'* and *dega* (between 1500m and 2898m a.m.s.l) climatic zone. Most of the rural populations of the study area are agglomerated in this agro-ecological zone due to its suitability for the practice of different types of agricultural activities. As a result, the presence of high population concentration and the expansion of agricultural activity within the stated altitude range create a great pressure on the forest resources. Mainly, the forest cover land with low elevation is given higher value in terms of forest resource accessibility because local people can easily access the forest areas found in this particular region.

4.4.2. Driving and standardizing datasets

Susceptibility to forest degradation mapping of the study area is one of the major objectives of this study. As indicated previously to analyze forest degradation susceptibility, MCE with the techniques of weighted overlay and combination procedure was performed. Then, the derived raster data sets are reclassified and masked with a raster forest layer of 2016. Masking layer identifies those cells within the analysis extent that will be considered when running analysis tool.

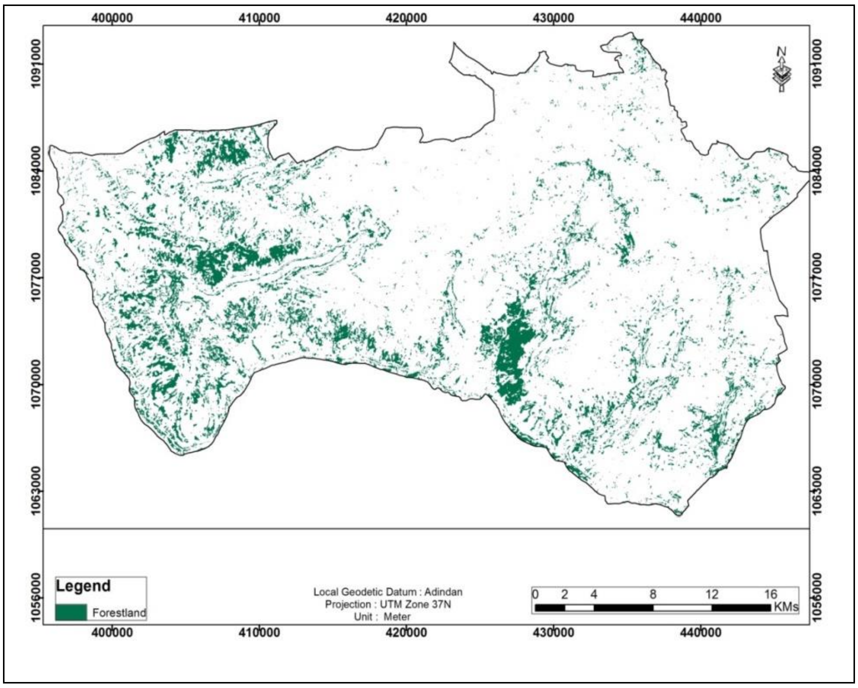

Figure 4.10: Forest cover map of year 2016 (Source: Derived from 2016 land cover /land use map)

4.4.3. Slope value dataset

The slope nature of the area is considered to be one of the factors affecting the susceptibility to forest resource degradation. Generally, forest degradation decreases away from relatively gentle slope gradient to steep slope (Berhan, 2007 and Alelign, 2010). The output slope dataset of high values (25.1^0-88.9^0), shaded with red color on the map represents steep slope areas. On the contrary, green and the yellow color shading areas depicts those areas having relatively gentle gradient less than 15^{o} as shown in (Figure 4.11).

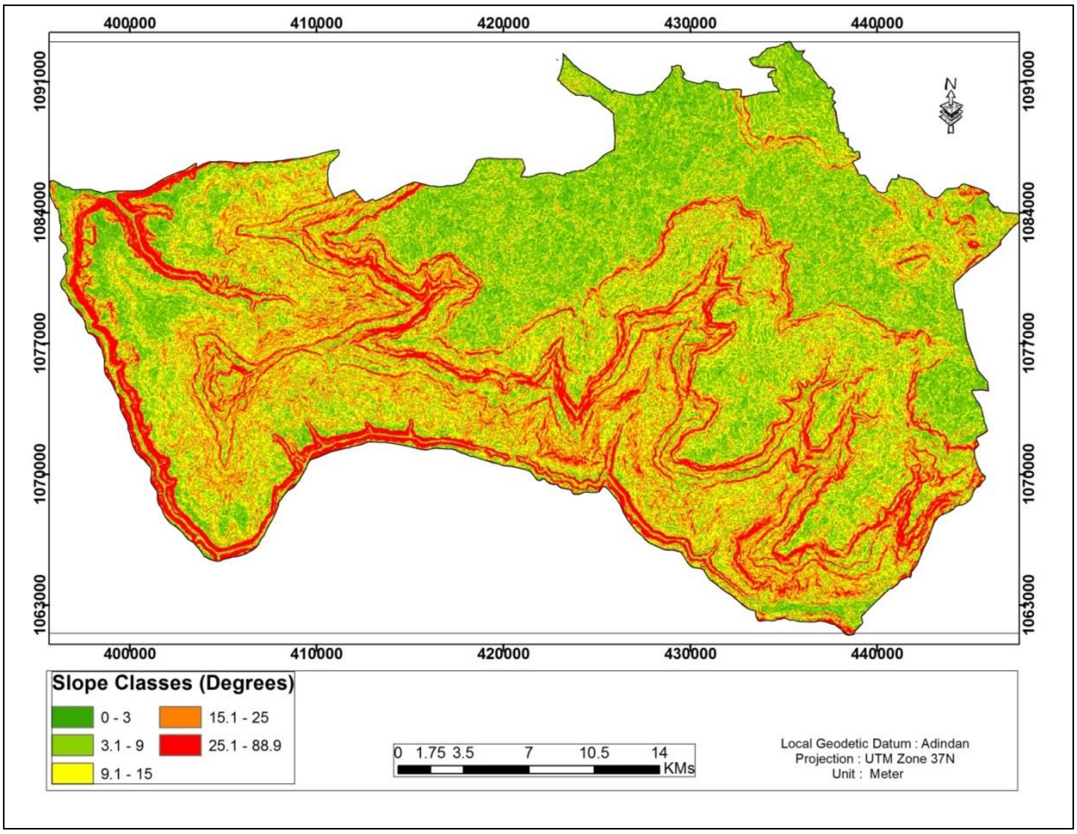

Figure 4.11: Slope value of the study area (Source: Prepared from digital elevation model

The slope has been set in to five classes. These classes have then been reclassified by assigning values ranging from 1 to 5 using year 2016 forest cover as analysis masking layer. Areas with lower slope steepness have been given higher values. To the contrary, areas with higher slope steepness have been given lower values as shown in (Figure 4.12) and these areas are relatively difficult to intervene.

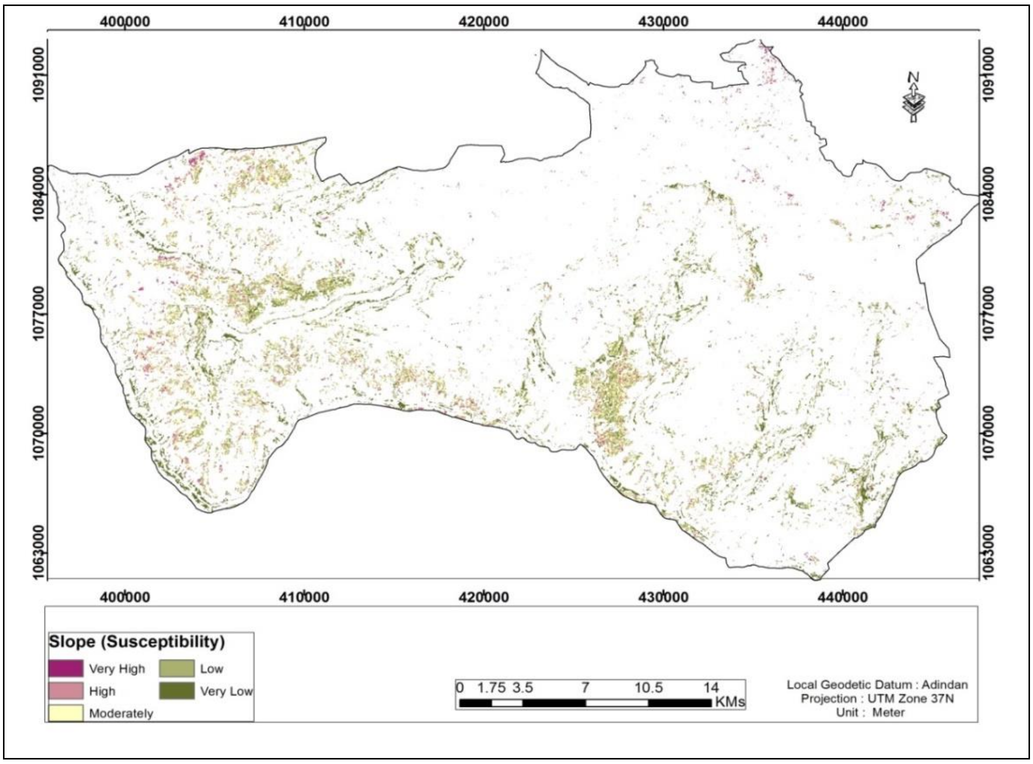

Figure 4.12: Reclassified slope factor using forest cover.

4.4.4. Cultivated land proximity dataset

The Cultivated land category map was generated independently from the year 2016 land use/ land cover map and finally merged together to consider as independent dataset for susceptibility to forest resource degradation analysis. Then this data is standardized and reclassified to run MCE. And then, the cultivated land raster data layer is reclassified using forest raster dataset as analysis masking layer and straight line distance is calculated to characterize susceptibility to forest degradation.

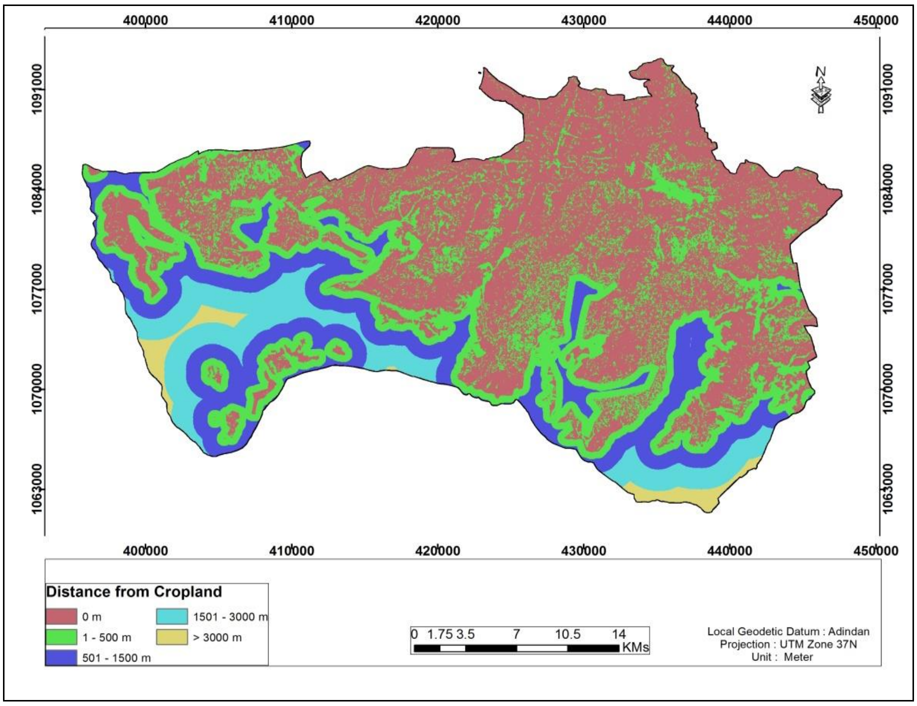

Figure 4.13: Proximity to crop land in meter (source: computed from 2016 image interpretation)

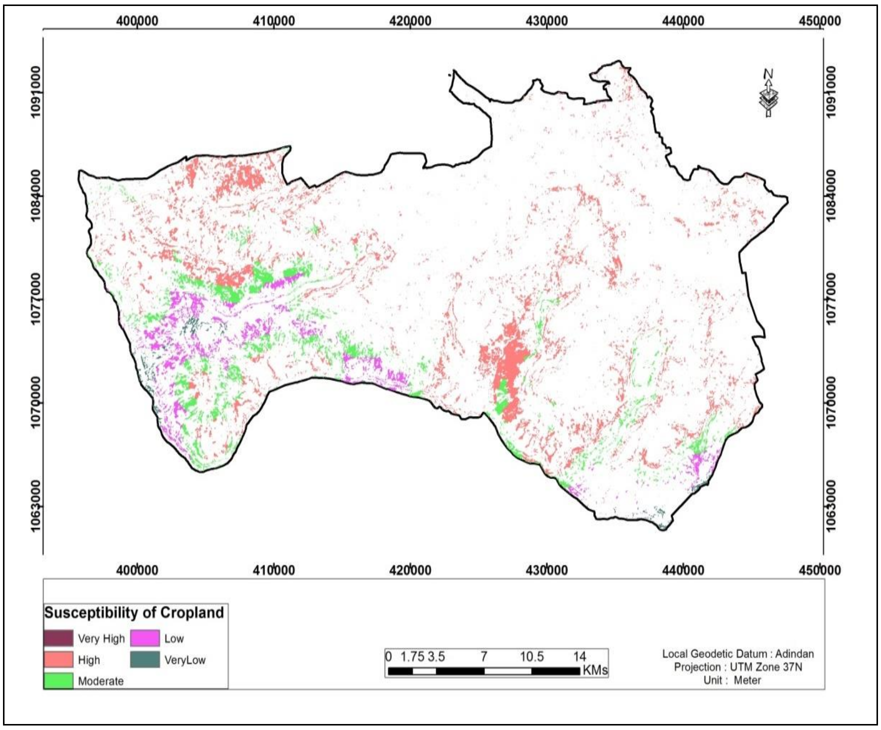

Figure 4.14: Reclassified crop land factor using forest cover

4.4.5. Settlement proximity dataset

Vegetation nearby a settlement whether it is urban or rural is most likely to be overexploited, like most parts of Ethiopia, people living in Kuyu *Woreda* are heavily dependent upon vegetation for energy, building materials, source of income, and cultural values. About three towns which are found within the study area and twenty one rural settlements or villages have been considered to influence the vegetation. The straight line distance from the towns and villages has been produced as shown in (Figure 4.15).

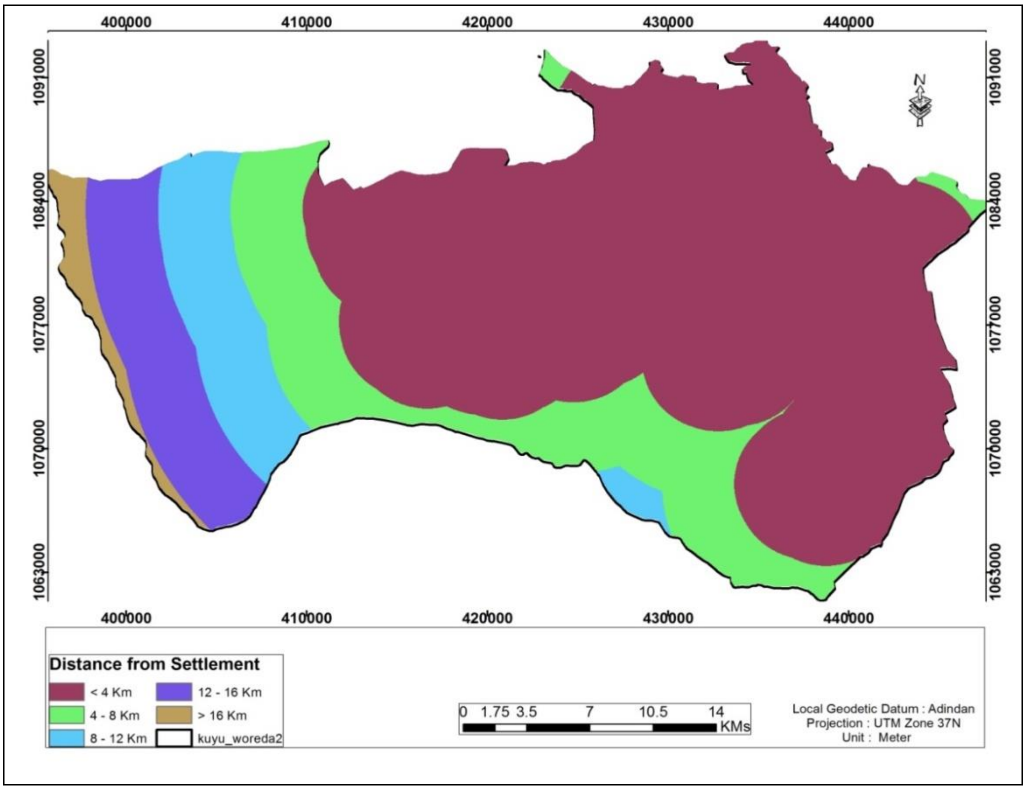

Figure 4.15: Buffer map of Proximity to settlement in km (source: Digitized from Google Earth)

The data set has then been reclassified using forest cover as analysis masking layer to a common scale ranging from 1 to 5 in accordance with their contribution to the vegetation vulnerability as presented in (Figure 4.19) and from this reclassified and masked settlement proximity dataset, the forest cover land near to settlement is highly susceptible to degradation than the forest cover found far away from settlement location. Proximity to settlement dataset also rasterized and standardized in order to reclassify and to distinguish the future forest disturbance problem in the study area. Around the major settlement centers crop lands were expanding at the expense of natural forest. The above idea was also supported by (USEPA, 2004) forwards that the forests nearer to rural settlement or residential sites (to the minimum 2-2.5 Km) are more prone for human disturbance. For this reason, proximity to rural settlement has been considered as one of the major factor in the forest disturbance analysis. The reclassified settlement proximity raster map with respect to forest cover was presented in (Figure 4.16). The forest cover land shaded with red color is highly prone to disturbance than the forest cover found far away from settlement.

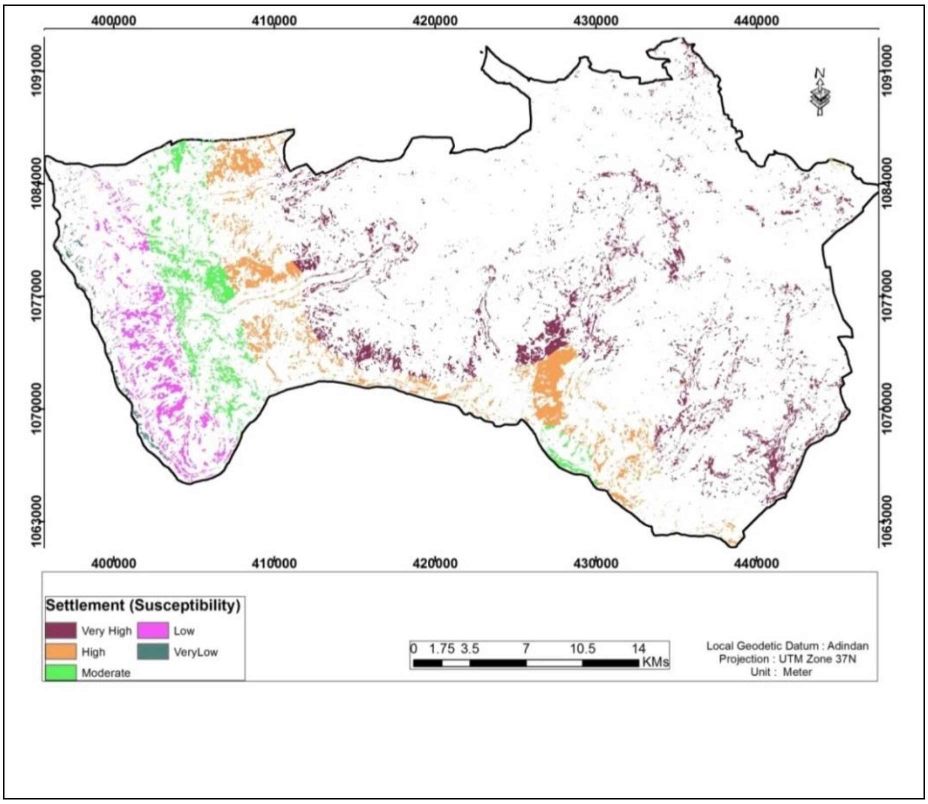

Figure 4.16: Reclassified settlement factor using forest cover.

4.4.6. Road proximity dataset

It is essential to characterize the forest cover condition of the district and its future susceptibility in relation to road proximity. Then, road distance raster dataset is derived (Figure 4.17). Consequently, the road raster data layer is reclassified using forest cover as analysis masking layer to analyze and determine the degree of susceptibility to forest degradation in relation with road proximity.

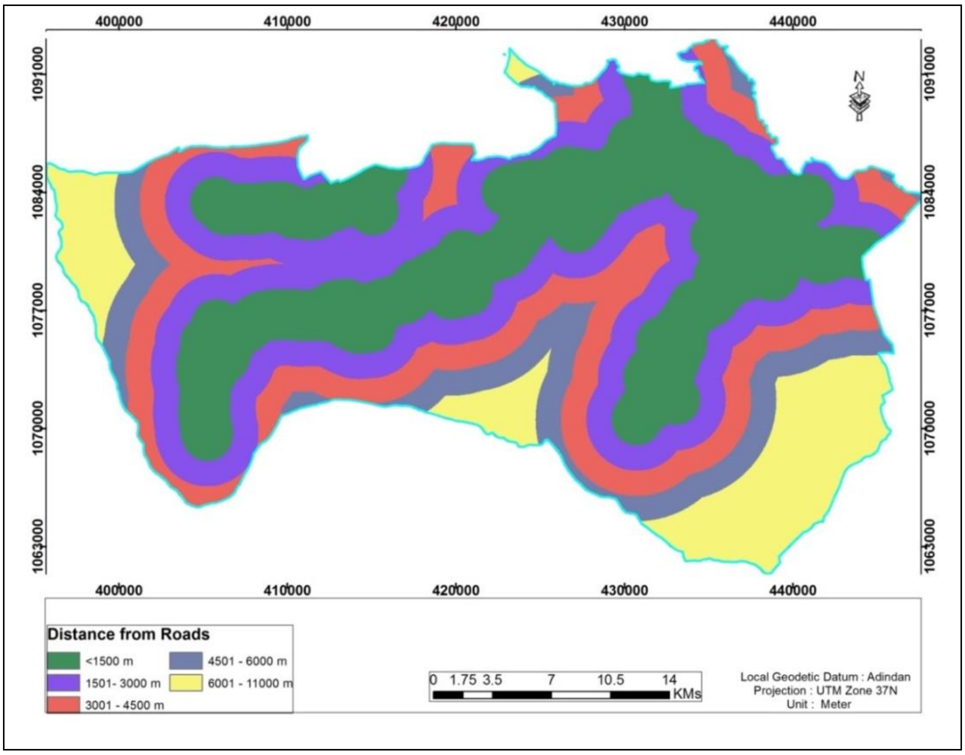

Figure 4.17: Proximity to roads in mater

From the reclassified road proximity dataset (Figure 4.18), forest cover areas having low distance value from road network location are highly susceptible to degradation than those located far away from road networks. According to Workaferahu (2015), people prefer to settle around the major roads for various reasons mainly its access for transportation. But, legally or culturally protected environment such as dense forest, parks and areas which found around spring water must far from any disturbing human related and investment activity in a distance of at least above 0.5 km and not more than 3-5km. So, major settlements in the study area were strong co-correlation with major road. And rural settlements were expanding at the expense of natural forest following road network.

For this reason, proximity to Roads has been considered as one of the major factor in the forest disturbance analysis. The reclassified road proximity raster map with respect to forest cover was presented in (Figure 4.18). The forest cover land shaded with red color is highly prone to disturbance than the forest cover found far away from road.

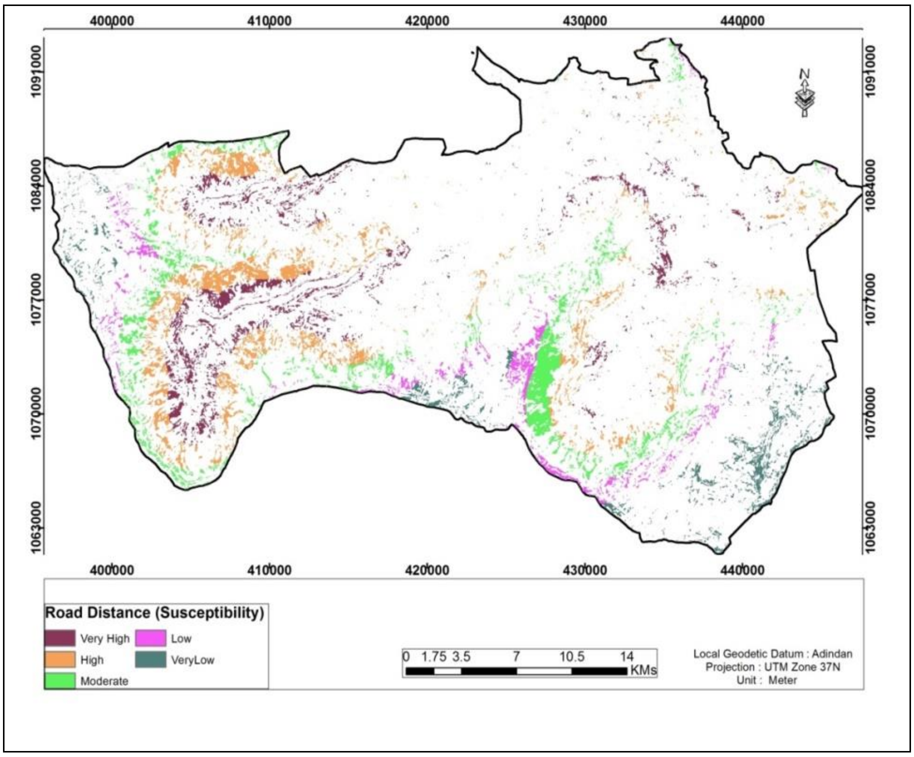

Figure: 4.18: Reclassified road proximity factor using forest cover.

4.4.7. Elevation value dataset

The elevation criterion dataset is rasterized and standardized to evaluate the degree of susceptibility to forest cover change. Later on, the rasterized dataset is reclassified by using forest cover raster data layer to correlate the existing forest cover with the future forest susceptibility to degradation. Then, from the reclassified elevation dataset, the forest cover areas found at relatively higher elevation are very highly susceptible than those forest cover areas found at lower altitude.

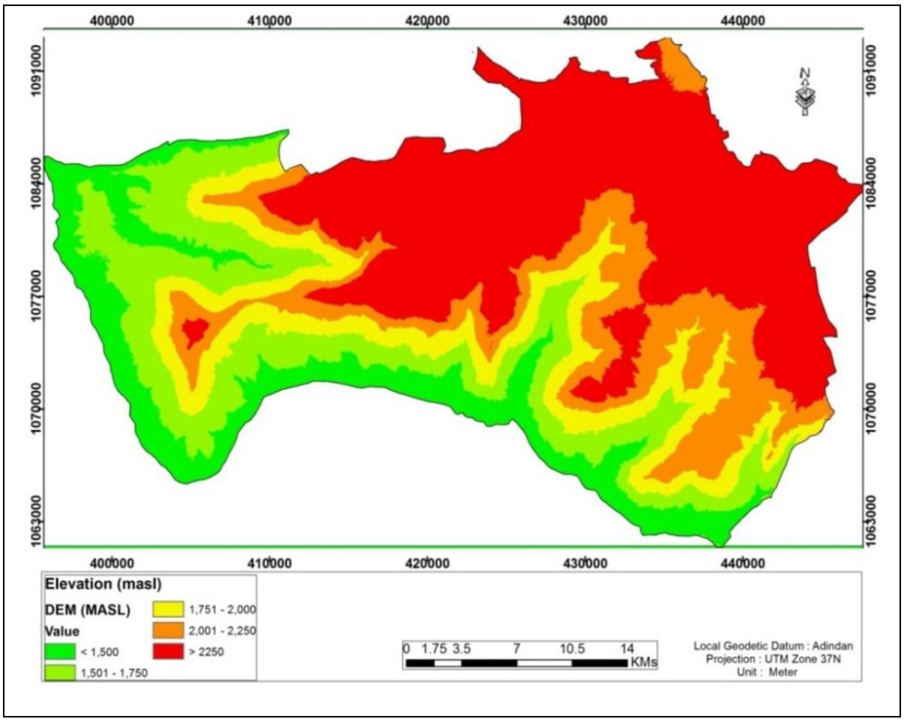

Figure 4.19: Map of elevation value in meter (Source: Prepared from Digital elevation model)

After settling and standardizing altitude dataset, the output reclassified altitude dataset map (Figure 4.20) was prepared based on MCE (multi criteria evaluation) techniques. The forest cover areas shaded with red colors were more prone to disturbance than forest cover areas shaded with other colors.

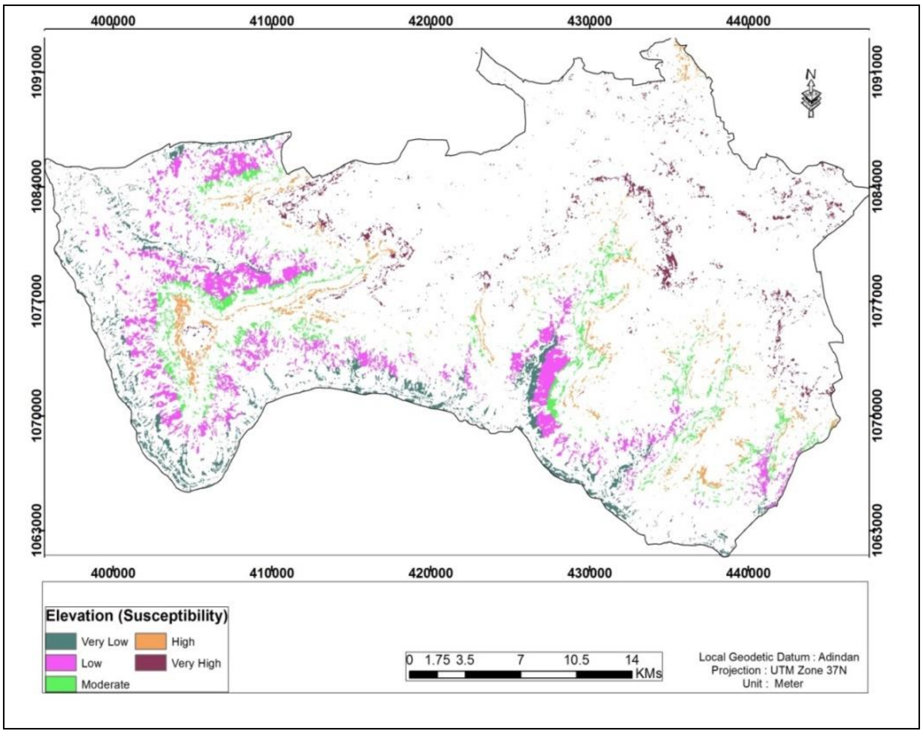

Figure 4.20: Reclassified elevation value factor using forest cover

According with the above table areas that found 2000-2898 meter elevation intervals encompass about 2621.4 ha land are more prone to human disturbance risk. Because, researcher witnessed that majority of rural settlement and agricultural activity practiced elevated areas of the study this also supported by World Bank (2011). So, it was more preferable for settlement and agricultural activity.

4.5. Weight of factor maps

Assigning weights for each datasets and combining together based on their weight is the subsequent procedure for conducting MCE in the present study. Weighting is used to express the relative importance of each factor relative to other factor. The larger the weight the more important is the factor in overall usefulness. The various comparisons indicated that highest weight is for the crop land dataset followed by the settlement, road proximity, elevation value and slope dataset. The final combined result gives susceptibility to forest degradation maps of the study area. Based on the pairwise Comparison method, the Eigen vector ratio matrix of the weight is calculated for all layers (Table 4.8 and 4.9). The consistency ratio was also calculated (Table 4.9) that shows if the given pair-wise weights are accepted.

Table 4.8: pairwise comparison 9 point continuous rating scale

1/9	1/7	1/5	1/3	1	3	5	7	
extremely	Very strongly	Strongly	Moderately	equally	moderately	strongly	Very strongly	Extremely
More important					Less important			

Table 4.9: Weight of factors that aggravates forest degradation process in the study area

	Crop land	Settlement	Road	Slope	Elevation
Crop land	1	2	4	5	4
Settlement	1/2	1	2	3	3
Road	1/4	½	1	2	3
slope	1/5	1/3	1/2	1	2
Elevation	1/4	1/3	1/3	½	1

Table 4.10: Eigenvector ratio matrix that gives weight for each factor

Factor map	The eigenvector of weight
Crop land	0.4426
Settlement	0.2439
Road	0.1512
Slope	0.0928
Elevation	0.0696

Consistency ratio = 0.03, consistency is acceptable.

4.6. Multi-criteria evaluation

After the input raster datasets are reclassified to a common measurement scale using the Reclassify tool a scale, of 1 to 5 (1 being least susceptible and 5 being highly susceptible) and an evaluation scale of 1 to 5 by 1 entered for the evaluation scale in the Weighted Overlay dialog box, MCE analysis is employed.

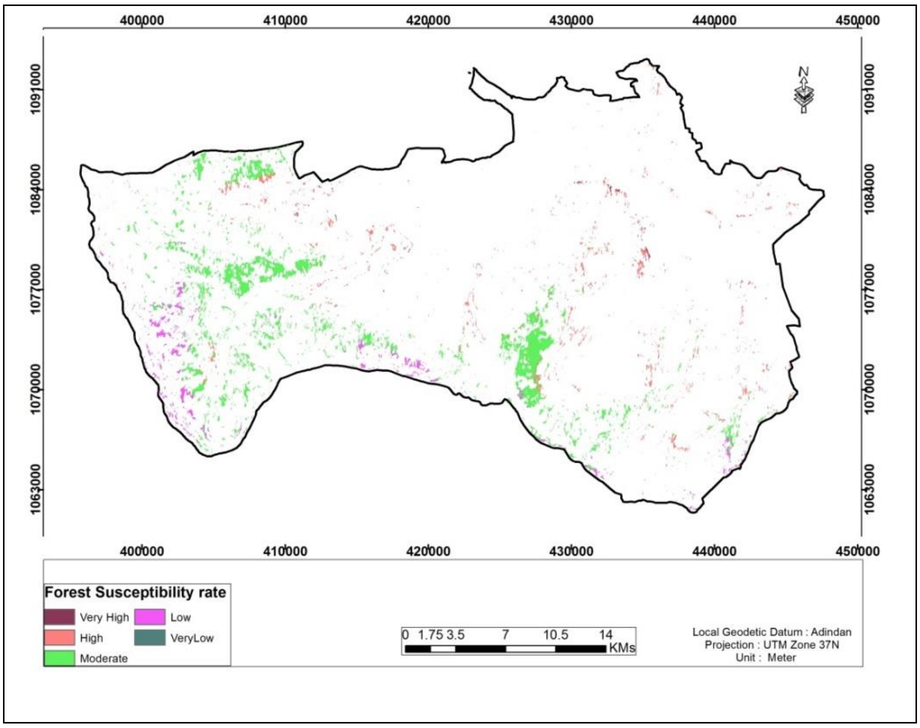

Figure 4.21: Map showing susceptibility an area to forest degradation

Table: 4.11. Forest Area under Different Elevation Susceptibility Level

Susceptibility Level	COUNT	Area(HA)	% Area
No Forest	888601	83450.2	88.3
Very Low (< 1500m)	23349	2192.7	2.3
Low (1500 - 1750m)	46315	4349.5	4.6
Moderate (1750 - 2000m)	20080	1885.8	2.0
High (2000 - 2250m)	13799	1295.9	1.4
Very High (> 2250m)	14114	1325.5	1.4
Total		94499.6	100.0

To sum up, based on the total forest cover areas of the year 2016 of Kuyu *Woreda* about 1325.5 and 1295.9 ha of forest cover land is categorized under very high and high susceptible to degradation respectively. On the other hand, 2192.7 ha, 4349.5 ha and 1885.8 ha forest cover lands are considered to be very low, low and moderate susceptible to forest degradation respectively. According with the above table areas that found 2000-2898 meter elevation intervals encompass about 2621.4 ha land are more prone to human disturbance risk. Because, researcher witnessed that majority of rural settlement and agricultural activity practiced elevated areas of the study this also supported by World Bank (2011). So, it was more preferable for settlement and agricultural activity.

4.7. Causes and impact of deforestation in Kuyu *Woreda*

4.7.1. Causes of deforestation in Kuyu *Woreda*

According to Tilahun (2010), Deforestation is activated by various factors that undermine the forest cover potential and its productivity which leads to irreversible deterioration. Besides, forest cover change is the direct reflection of the dynamics of socio-economic activities. Likewise, several factors stimulated by the activity of man are responsible for massive conversion of forest cover land into other land cover and land use units in Kuyu *Woreda*. In the study area, especially in the highland part of the district, forest resources were completely cleared. Only bush and shrubs types of vegetation are found. But in the low land part of the study area, forest resources are found along river valleys, gorge and on other in accessible areas which is not suitable for agricultural purposes. The cause for forest destruction of the study area is complex and many in numbers. Some of them are discussed as follows:

Agricultural land expansion

The agro ecological condition of the district is convenient for agriculture. The farmers in the study area are extending the farm lands to the fragile forest ecosystem in an attempt to meet the increasing demand for food. As indicated in Fekadu (2015), based on the most recent estimates of the rates of deforestation, and assuming that 75 per cent of forest losses are attributable to agricultural expansion, the one uncontrolled population growth and subsequent increase in demand for food to support the surplus population could contribute to further deforestation. According to the informants of the *woreda*, the vegetation area of the study area started to change into agricultural land since 40 years ago. This is because of decline of soil fertility, population growth and food insecurity. They also respond that the low productivity of traditional method of farming demands extensive lands. On the other hand, the amount of land required to feed the growing population is steadily increasing. Agricultural productivity lagging far behind population growth rates and the gap between the availability and the demand for agricultural land continues to grow from year to year. This led to severe land use conflicts among crop farming, animal grazing and forestry.

Therefore, the presence of peasants with their various types of agricultural activities (both crop production and livestock rearing) inside and along the margin of the *woreda* forest cover land is considered to be the major factor for forest cover change in the study area. At the present time, some farmers are clearing the forest to obtain additional agricultural land. The following figure shows the land previously under forest and ready to use for farming purpose.

Figure 4.22: Clearance of vegetation for agricultural purposes in study area (Photo taken by Getu Lemi March 2016)

Fuel wood and construction materials

The inevitably rising demand for fuel wood, particularly in and near urban areas is the most important cause of forest depletion in the study area. The demand for fuel wood is much higher than the capacity of forest to provide it. As indicated in Tigabu (2016), the increasing demand for construction materials, industrial use, fuel wood and charcoal were the main factor of deforestation. In the rural areas fire wood (collected from the nearby forest areas) and cow dung are the two most important sources of energy (Tilahun, 2010). According to the informants over the recent years fire wood is commercialized as its demand has increased particularly in those areas which are devoid of trees and in the urban areas of the *woreda*. Moreover, as the agricultural officers identified fire wood and charcoal productions are the major causes of forest cover change.

Hence, the increasing demand of forest products, in the form of fire wood and charcoal within and outside the *woreda* has been causes of deforestation in in Kuyu *Woreda*. Much of the fuel wood collected is used for cooking food. In the study areas some fuel wood is used for heating houses during cold period. However, the devices used for the purpose of cooking are so poor that much of the energy generated is wasted. That means that the stoves used are extremely in efficient. This is one of the reasons contributing to the fast disappearance of the natural forest of the *woreda*. The local community freely cut tree for charcoal and fire wood and supply for the market. They considered this activity as the easiest means of making quickest return**.**

According to Tilahun (2010), as the study area is close to town like Garba Guracha, Fitche and Addis Ababa, the area serves as the major source of fuel wood supply. According to interviews with charcoal merchants in the town of Garba Guracha, charcoal selling is more profitable than other forest products. There are over ten merchants in the town who transport hundreds sucks of charcoal to Addis Ababa per day by track.

These forests products for construction purposes are obtained from either by collecting or commercially depending on the accessibility. All the ingredients of most building are of forest origin except in few cases. The introduction of two man's saw has accelerated an ease exploitation of forests especially in timber production. This over exploitation of the distributed forest ecosystem for local construction purpose and commercialization of it has induced substantial pressure on the forest resource of the area.

Figure: 4.23. Timber and charcoal production in study area (Source: Photo taken by Getu Lemi March 2016).

4.7.2. Impact of deforestation in Kuyu *Woreda*

Currently people depend on forests more than ever, especially for their socio-economic, environmental and aesthetic value. These precious resources have a variety of products and services. They provide raw materials for housing and they are traditional sources of fuel wood. Besides, they are the best biological conservation structure for the soil resources. Despite of all these importance, this resource is miss-treated and deforested unwisely. The increasing demands for fuel wood, constructional timber, and cultivated as well as grazing land to support the growing population aggravate the rate of Deforestation with no shadows of doubt. Likewise the major environmental problems in the study area, which are resulted from forest cover change such as increased land degradation, soil erosion and flooding as well as deteriorating of bio-diversity, some of them are discussed here under in the following paragraphs.

Land degradation with severe soil erosion

The term land degradation is a process, which resulted in a radical change in the complete character of the land due to the loss of plant nutrients and organic matter, the breakdown of soil structure and destruction of vegetation cover (Berhan, 2007). Land degradation is the decrease in biological productivity of land use resulted from unsustainable land uses such as over cultivation, deforestation, overgrazing, poor management and poor cultivation. It is a process, which results in an absolute change of the complete characteristics of the land due to the loss of minerals and disappearance of the organic matter. One can argue that unrestricted removal of vegetation cover from the land is the most important factor encouraging land degradation.

Soil erosion in one way or another is resulted from the cumulative effect of human activity in the study area. This in turn has a great effect on the economies of the local people. This is because of the fact that most of these people in the area depend heavily on their natural resource base. The farmers in the study area are subsistence oriented expanding their plots on sloping and marginal lands highly eroded. According to Tilahun (2010), about 3000 quintals of soils is lost from farmlands per annum. This is mainly because the vast proportion of the land is uncovered by vegetation and steep slopes. Generally, those mentioned factors coupled with expansion of frontier of agricultural activity contribute to forest and marginal land degradation. The peasants also constitute the poorest and largest segment of the population in the study area. Their livelihoods thus directly depend on the exploitation of the natural resources enhancing the overall degradation.

Figure: 4.24. Land degradation in Halelu Chari *Kebele (*Photo taken by Getu Lemi in March 2016)

Declining of biodiversity

Deforestation in turns brings about the loss of biodiversity both flora and fauna. A number of plant species are being threatened owing to the increasing pressure. According to experienced respondents in the area, before disappearance of local forests there were a large number of wild animal species were found in forest such as tiger, lion, monkey, etc. which are disappeared know from the area.. But at the present they could not see such type of wild animals. Decline of vegetation area was associated with subsequent decline of wild life through death and migration. Thus, the situation is treating both forest bared floras and fauna species in the study area. The study areas wild life population has been declining concurrently with the decline of its natural vegetation cover.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Forest cover change in the form of degradation as well as deforestation is a major environmental problem manifested at Kuyu *Woreda*. The case study as presented in the current research is a vivid example of how rapidly the forests are disappearing in the *woreda*. Now a days, the situation at Kuyu *Woreda* shows that extensive areas of forest land have been completely deforested while some areas of the forest cover land has been considerably degraded. Many of the forestland areas have been converted into cultivated land or grassland with a few scattered trees and shrubs.

From the analyzed results, the magnitude of land use and land cover in general and forest cover change in particular was drastically changed between 1986 and 2016 at Kuyu *Woreda*. Particularly, expansion of cultivated land and urban area and decline of forest cover, shrub land, grass land and bare land and grass land were observed. In relation to this, currently, the overall condition of the forest cover land of Kuyu *Woreda* is strongly disturbed. Besides, the areal extent of forest cover land is reduced from time to time. As empirical findings indicated that from the total area of the district about 17139.2 ha of land was covered with forest in 1986. But, this figure is declined to 11022.8 ha in the year 2016. On top of this, considering the annual rate of forest cover change between1986 and 2016, the computed result indicated that about 203.9 ha of forest land is changed in to other land use land cover annually.

Finally, both quantifiable and non-quantifiable socio-economic data were identified as major causes of deforestation and impacts in Kuyu *Woreda*. This resource has been utilized in unsustainable manner due to population growth (with other variables) such as demand of forest products for construction, fire wood and Charcoal production, income generation and expansion of various types of agricultural activities in the areas. This circumstances leads to further depletion of forest resources in the study area. As a result, the problem of forest degradation as well as deforestation with other related factors has aggravated land degradation with soil erosion and deterioration of biodiversity in Kuyu *Woreda*. Hence, this type of data is very useful for the concerned bodies in protecting the remaining forest resources from distraction.

5.2. Recommendations

It has already been indicated that the scope of this research is limited to Kuyu *Woreda*. However, the findings of the study could be used to suggest a number of policy measures that can be used to minimize the deforestation problems and brings about sustainable forest resource conservation in study area, the following feasible suggestion are recommended:

- Today the technology of remote sensing and GIS techniques are progressing in both increased data acquisitions and processing capabilities. The training of man power with the use of Remote sensing techniques, GIS and major application areas should be given a due consideration by Administrative Office of the *woreda.*

- To protect the forest resources from further destruction, to realize the impact of deforestation as well as how to use this precious resource with a sustainable manner, awareness creation campaigns by the *Woreda* Forest Conservation and Protection Brach especially for the farmers who are dwelling along the margin and inside the forest areas should be an indispensable incident.

- Jobless youths and Women Fuel Wood Carriers who are engaged in illegal tree cutting and harvesting activities should be educated by Kuyu *Woreda* Office of Agriculture, about the economic and ecological value of the forests as well as the consequences of deforestation. Besides, organizing them in to a legally recognized group that operates small-scale economic enterprise will enable to attain self-sufficiency.

- Furthermore, to conserve and increase the biodiversity of the study area, Forest Conservation and Protection Branch of the *woreda* should be plan to planting various types of indigenous vegetation and plantation tree by participating local community of each *kebeles.*

- Urban inhabitants are also play a major role in forest degradation through depending on charcoal and wood as source of energy. Therefore, Administrative Office of Garba Guracha Town should be making Urban Area to adopt the culture of using electricity by facilitating electric power.

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Appendix 1

Interview Question

1. Do you think that, deforestation is the major problem in your locality?
2. How do you relate the impact of population growth on forest resources of the area?
2. How do you see today's forest cover compared to the conditions before 1986?

   A. Declined B. Increased C. No change

3. If your answer is (A) for question number two what are the major causes for deforestation?

A. Cultivated land expansion _________ B. Cutting trees for fire wood _____

C. For charcoal production____________ D. for additional grazing lands ___

E. Cutting of trees for house and fens construction------ F .Income generation_______

4. What are the major impacts of deforestation?
5. Are there species of "trees" and wild animals endangered for extinction due to forest cover change?
6. What do you think about the possible solution to alleviate the current problem of deforestation and to use forest resources in a sustainable manner?
7. Rank the following factors which play a major role for the susceptibility to forest Degradation in level of ordering?

A, Cultivated land Proximity_______________ D. Rod proximity _____________

B. Elevation value_______________ E. Settlement proximity____________

C, Slope Value________________

8. Which cover types have been changes to other type's very commonly?

Appendix 2

Ground control point

Point	LU/LC_type	x	y
1	Forest	437621	1082705
2	Forest	439262	1082493
3	Forest	441452	1083357
4	Forest	436343	1084265
5	Forest	436307	1084336
6	Forest	436700	1084594
7	Forest	436434	1083848
8	Forest	435528	1082585
9	Forest	435524	1082569
10	Forest	434629	1081922
11	Forest	435728	1081888
12	Forest	435947	1081877
13	Forest	438921	1082716
14	Grassland	435300	1082508
15	Grassland	434643	1081817
16	Grassland	435487	1081862
17	Grassland	436407	1082047
18	Grassland	436606	1082242
19	Grassland	437159	1082029
20	Grassland	437300	1082035
21	Grassland	437627	1082277
22	Grassland	438553	10822814
23	Grassland	440244	1082565
24	Grassland	439007	1083342
25	Cropland	435577	1082752
26	Cropland	435328	1082503
27	Cropland	435379	1082066
28	Cropland	435644	1081904
29	Cropland	436123	1082065

30	Cropland	436662	1082261
31	Cropland	437232	1082055
32	Cropland	437433	1082195
33	Cropland	439663	1082531
34	Cropland	439440	1083354
35	Cropland	438618	1083468
36	Cropland	437932	1083588
37	Cropland	436266	1084381
38	Cropland	436208	1084601
39	Cropland	436351	1082843
40	Cropland	436061	1082866
41	Cropland	435857	1083052
42	Urban Area	435528	1082585
43	Urban Area	435524	1082569
44	Urban Area	436739	1084169
45	Urban Area	437717	1082900
46	Urban Area	436773	1083252
47	Urban Area	436196	1083731
48	Urban Area	437100	1083183
49	Urban Area	437523	1083457
50	Urban Area	436453	1083432
51	Urban Area	436172	1083754
52	Urban Area	436639	1083621
53	Urban Area	436317	1083677
54	Urban Area	436378	1083738
55	Bare land	436474	1083482
56	Bare land	435207	1082258
57	Bare land	434851	1082048
58	Bare land	441171	1083364
59	Bare land	434895	1081942
60	Bare land	440998	1083373
61	Bare land	434834	1081884

62	Bare land	434732	1081825
63	Bare land	434698	1081802
64	Bare land	449414	1083321
65	Bare land	441210	1083374
66	Shrub land	434936	1082015
67	Shrub land	434878	1082045
68	Shrub land	434795	1082015
69	Shrub land	439428	1082550
70	Shrub land	439615	1082530
71	Shrub land	439923	1082543
72	Shrub land	439955	1082543
73	Shrub land	440013	1082546
74	Shrub land	440568	1082468