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**ADDIS ABABA UNIVERSITY FACULTY OF SCIENCE SCHOOL OF
GRADUATE STUDIES**

**LAND USE LAND COVER CHANGE DETECTION AND VULNERABILITY
TO FOREST DEGRADATION USING REMOTE SENSING AND GIS: A
CASE OF BORENA DISTRICT IN NORTH CENTRAL ETHIOPIA**



By Alelign Dessalew

Advisor: Dr. Mohammed Umer

JUNE, 2009

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Table of contents

Contents	Page
ACKNOWLEDGMENT.....	IV
TABLE OF CONTENTS.....	V
LIST OF FIGURES.....	VIII
LIST F TABLES.....	IX
LIST OF ANNEX.....	IX
LIST OF ACRONYMS.....	X
ABSTRACT.....	XI
CHAPTER ONE.....	1
1. INTRODUCTION.....	1
1.1 STATEMENT OF THE PROBLEM.....	3
1.2 OBJECTIVES.....	4
1.2.1 General objectives.....	4
1.2.2 Specific objectives.....	4
1.3 RESEARCH QUESTIONS.....	4
1.4. MATERIALS AND METHODS.....	5
1.4.1 Materials and sources.....	5
1.5 SIGNIFICANCE OF THE STUDY.....	7
2.1 LAND USE/ LAND COVER CHANGE DETECTION.....	8
2.1.1. Land use/ cover and land degradation in the north central highlands of Ethiopia.....	9
2.1.2. Human induced land use/cover changes and land degradation in the North central highlands of Wello.....	10
2.1.3 Consequences of Land use/ Land cover changes and land degradation in the North central high lands of Wello.....	12
2.2. TRENDS OF FOREST COVER CHANGE ON THE HIGHLANDS OF ETHIOPIA.....	13
2.2.1 Causes of forest cover change in Ethiopia.....	13
2.2.2 Impacts of forest cover change in Ethiopia.....	14
2.3. THE ROLE OF REMOTE SENSING AND GIS.....	15

2.3.1 Remote Sensing.....	15
2.3.1.1 Land cover mapping.....	16
2.3.1.2 Image classification.....	16
2.3.1.3 Change detection methods	17
2.3.1.3.1 Post classification approach	17
2.3.1.3.2 Spectral change detection approach	17
2.3.1.4 Factors affecting comparability of images.....	18
2.3.1.5 Accuracy Assessment	18
2.3.2 Geographic Information System (GIS).....	19
2.3.2.1 Multi criteria evaluation.....	19
CHAPTER THREE	21
3. GENERAL DISCRPTION OF THE STUDY AREA	21
3.1 GEOGRAPHICAL LOCATION.....	21
3.2 TOPOGRAPHY AND DRAINAGE	21
3.3 SOILS.....	22
3.4 CLIMATIC CHARACTERISTICS	22
3.4.1 RAINFALL AND TEMPERATURE	22
3.5 VEGETATION	23
3.6 POPULATION.....	24
3.7 SOCIO-ECONOMIC CONDITIONS.....	24
CHAPTER FOUR.....	25
4. RESULTS AND INTERPRETATION	25
4.1 INTRODUCTION	25
4.2 LAND COVER MAPPING	25
4.2.1 Land use/land cover map of 1972	26
4.2.2 Land use/land cover map of 1985	27
4.2.3 Land use/land cover map of 2003	28
4.3 NDVI IMAGE COMPARISON	29
4.4 LAND COVER CHANGE DETECTION.....	31
4.5 ACCURACY ASSESSMENT	33
4.6 RATE OF LAND USE LAND COVER CHANGES	34
4.7 SUSCEPTIBILITY TO FOREST DEGRADATION ANALYSIS.....	35

4.7.1 Preparing input datasets (factor maps).....	36
4.7.2 Driving and standardizing datasets	39
4.7.2.1 Slope value dataset.....	39
4.7.2.2 Cultivated land proximity dataset	41
4.7.2.3 Settlement proximity dataset.....	41
4.7.2.4 Road proximity dataset	43
4.7.2.5 Elevation value dataset.....	44
4.7.3 Weight of factor maps.....	45
4.7.4 Multi criteria evaluation.....	46
4.8 CAUSES AND IMPACTS OF FOREST COVER CHANGE IN BORENA DISTRICT.....	47
4.8.1 Causes of forest cover change.....	47
4.8.1.1 Agricultural land expansion	47
4.8.1.2 Fire wood and charcoal production.....	48
4.8.1.3 Cutting trees for constructional materials	48
4.8.1.4 Income generation.....	49
4.8.2 Impacts of forest cover change in Borena district.....	49
4.8.2.1 Land degradation with soil erosion	49
4.8.2.2 Declining bio diversity.....	50
CHAPTER FIVE.....	51
5. CONCLUSION AND RECOMMENDATION	51
5.1 CONCLUSION	51
5.2 RECOMMENDATION	53
REFERENCES.....	54
ANNEX	58

List of Figures

Figure 1.1: Flow chart showing the general methodology -----	6
Figure 3.1: Map shows location of the study area -----	21
Figure 3.2: Rainfall trends of Borena district from 1989 to 2005-----	22
Figure 3.3: Temperature graph of Borena district from 1988 to 2005 -----	23
Figure 4.1: Land use/land cover map of 1972 -----	26
Figure 4.2: Depicts aerial coverage and percentage of each land use type of 1972 -----	26
Figure 4.3: Land use/land cover map of 1985 -----	27
Figure 4.4: Depicts aerial coverage and percentage of each land use type of 1985 -----	27
Figure 4.5: Land use land cover map of 2003 -----	28
Figure 4.6: Depicts aerial coverage and percentage of each land use type of 2003--	28
Figure 4.7: Land use land cover classes of the three periods (1972, 1985 and 2003) -----	29
Figure 4.8: NDVI map of 1972-----	30
Figure 4.9: NDVI map of 1985-----	30
Figure 4.10: NDVI map of 2003 -----	31
Figure 4.11: LU/LC change between 1972 to 1985-----	32
Figure 4.12: LU/LC change between 1985 to 2003-----	33
Figure 4.13: Forest Cover map of year 2003 -----	39
Figure 4.14: Slope value of the study area -----	40
Figure 4.15: Reclassified slope factor using forest cover -----	40
Figure 4.16: Reclassified land use land cover factor map-----	41
Figure 4.17: Proximity to settlement map-----	42
Figure 4.18: Reclassified settlement proximity factor using forest cover -----	42
Figure 4.19: Proximity to roads -----	43
Figure 4.20: Reclassified road proximity factor using forest cover-----	43
Figure 4.21: Elevation value in meter -----	44
Figure 4.22: Reclassified elevation value factor using forest cover -----	44
Figure 4.23: Weight of factors that aggravates forest degradation process in the study area -----	45
Figure 4.24: Map shows susceptibility to sorest degradation-----	46

Figure 4.25: depicts aerial and percentage coverage of susceptibility to forest degradation-----	46
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List f Tables

Table 1.1: Shows materials and their sources-----	5
Table 1.2: Software used -----	5
Table 4.1 Shows description of each land use land cover type-----	25
Table 4.2: Depicts NDVI value of the three periods-----	31
Table 4.3: Land use land cover change matrix between (1972 to 1985) -----	32
Table 4.4: Land use land cover change matrix between (1985 to2003)-----	33
Table 4.5: Confusion matrix of 2003 land use land cover classification -----	34
Table 4.6: Land use land cover classes and rate of change (1972 to 2003)-----	34
Table 4.7: Area and percentage coverage of forests from (1972 to 2003) -----	36
Table 4.8: Eigenvector ratio matrix that gives weight for each factor-----	45

List of Annex

Plate1: Photograph taken from Denkoro state forest in the northern part of Borena district -----	24
Plate 2: Photo graph shows agricultural land expansion towards the forest area -----	48
Plate 3: Photograph Shows remnants of indigenous forest in steep slope areas-----	50

List of Acronyms

a.m.s.l	above mean sea level
CSA:	Central Statistical Authority
DEM:	Digital Elevation Model
ENVI:	Environment for Visualizing Image
ERDAS:	Earth Resource Data Analysis System
ETM+:	Enhanced Thematic Mapper Plus
FAO:	Food and Agricultural Organization
FWCDA:	Forestry and Wild life Conservation and Development Authority
GIS:	Geographic Information System
GPS:	Global Position System
Ha:	Hectare
Km:	Kilometer
Km ² :	Square kilometer
LC/LU:	Land Cover/ Land use
M:	Meter
MCE:	Multi Criteria Evaluation
MSS:	Multi Spectral Scanner
NDVI:	Normalized Differencing Vegetation Index
NGO:	Non Governmental Organizations
RS:	Remote Sensing
SIDA:	Swedish International Development Agency
SRTM:	Shuttle Radar Topographic Mission
TM:	Thematic Mapper
UNDP:	United Nation Development Program
UTM:	Universal Transfer Mercator
WGS:	World Geodetic System

Abstract

Land use/ land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. Hence, information about it is essential for the selection, planning and implementation of land use schemes. The aim of this study is to detect the magnitude and rate of land use land cover change for the last 31 years from three different time satellite images of 1972, 1985, and 2003, and generating susceptibility to forest degradation map using GIS techniques in Borena district. NDVI image comparison and post-classification change detection methods were employed, hence the result of multi_temporal imagery has depicted that the study area has undergone a series of land us land cover dynamics, shrub and grass lands had decreased whereas, cultivated and bare lands had increased. In addition to this, susceptibility to forest degradation was done by considering factors such as cultivated land, settlement, road, slope and elevation value. And then, four levels of susceptibility to forest degradation map was generated. Based on the forest cover map of the year 2003 (6087 ha) of Borena district, about (20%), (28%) and (32%) of forest cover land are categorized under less, moderately, and highly susceptible to degradation respectively and the remaining (20%) of forest cover is very highly susceptible to degradation. The problem of forest cover change is directly linked with the activity of man such as expansion of agricultural land, demand of fuel wood and constructional materials as well as using this resource as income generating means's. Besides, due to the problem of forest cover change; land degradation in the form of soil erosion, as well as declining of biodiversity seems to have reached a critical stage. 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.

Key words: Land use/Land cover change, Forest degradation Susceptibility, GIS and remote sensing,

CHAPTER ONE

1. INTRODUCTION

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental change. Since the late 1960's, the rapid development of the concept of vegetation mapping has led to increased studies of land use and land cover change worldwide. Providing an accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources has become an important priority. Land use/land cover change is an endlessly changing process taking place on the surface of our planet (Bottomley, 1998).

The land use/land cover pattern of a region is an outcome of natural and socioeconomic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population (Moshen A, 1999).

To better understand the impact of land use change on terrestrial ecosystems, the factors affecting land use must be more fully examined. Growing human populations exert increasing pressure on the landscape as demands multiply for resources such as food, water, shelter, and fuel. These socioeconomic factors often dictate how land is used regionally. Land use practices generally develop over a long period under different environmental, political, demographic, and social conditions. These conditions often vary yet have a direct impact on land use and land cover (Ojima, 1994). The interaction of nature and society and their implications on land use and land cover is a very complex phenomenon that encompasses a wide range of social and natural processes.

As human beings modify the landscape, resource agencies find it increasingly important to monitor and assess these alterations. Changes in land use affect vegetation this in turn would affect wildlife habitat, aesthetic and historical values and ambient air quality.

Viewing the Earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. In situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from Earth sensing satellites has become vital in mapping the Earth's features, managing natural resources and studying environmental changes.

Therefore, Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth system function, patterning, and changes at local, regional and global scales over time and space; such data also provide an important link between rigorous, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996).

Finally an attempt will be made in this study to map the status of land use land cover dynamics of Borena district in South Wello Zone of north central Ethiopia between 1972 to 2003 with a view of detecting the temporal and spatial analysis of land use land cover changes and forest degradation vulnerability mapping using remote sensing and Geographic Information System (GIS) techniques.

1.1 Statement of the problem

Ethiopia is a country well endowed with diversified natural resources. Regarding this Ermias (1994) noted that Ethiopia's outstanding natural resource endowments are its soil, climate, water, wild animals, rich livestock population as well as big reservoir of vegetation. However, what continuously to be highly visible and increasing concern is the ever accelerating rate of resource degradation. The country has faced quite a number of environmental problems such as severe deforestation, land degradation, soil erosion, expanding desertification, recurrent drought, as well as decline of biodiversity.

Among the various natural resources in Ethiopia, forest resource is perhaps the one most affected by human activities. Whatever the extent of the land surface that might have been covered by forests, today most of the forest resources (mainly the indigenous forests) in Ethiopia have been disappearing. Research findings revealed that almost all the forests in Ethiopia have been cut in the last 40 years and only less than 3% of the entire country is now covered with trees, prompting fears of a threatening environmental disaster if the problem is going to get worse (*Burton, 1994*)

As a result of this, today only few scattered and relatively small areas of forest remain largely confined to inaccessible steep slopes, escarpments, monasteries, dissected and deep river valleys, and mountains far from road networks (Markos and Dilnesaw, 1998). Hence the most critical problem stated in this study would be the dynamics of land use land cover change in general and the problem of forest degradation in Borena district of South Wollo Zone in particular.

The rate and extent of forest cover change in the district is not determined till date objectively by modern techniques. However, from available records and field visits, it is evident that forest cover change is very widespread and is continuing at an alarming rate. 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. Based on the views from agricultural officers, 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 generation

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 assess and monitor the status of land use land cover change and forest resource degradation in the study area, so that a coherent conservation measures could be suggested and implemented immediately to protect and use the valuable forest resources in a sustainable manner.

1.2 Objectives

1.2.1 General objectives

The major objective of this study is to produce land use land cover map of Borena district at different times in order to detect the changes that have been taken place and to identify areas vulnerable to forest degradation.

1.2.2 Specific objectives

- To generate the year 1972, 1985 and 2003 land use land cover map.
- To assess the aerial extent, rate and the pattern of land use land cover change status.
- To generate forest degradation susceptibility map and identify the major causes and impacts of forest cover change in the study area.

1.3 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 Borena district during different time periods?
- ❖ What are the factors responsible in determining susceptibility to forest degradations in Borena district?
- ❖ Where are zones of different susceptibility to forest degradation in Borena district?
- ❖ What are the major causes and impacts of land use/ cover change in the study area?

1.4. Materials and methods

1.4.1 Materials and sources

To meet the objectives of the research multi-temporal satellite imagery, global positioning system for ground verification, digital camera, and topographical maps of scale 1:50,000 has been used as it is summarized in (Table 1.1).

Table 1.1: Materials and their Sources

No	Image	Sensor	Resolution or Scale	Date of acquisition	Source
1	Landsat1	MSS	57x79m	12/12/1972	GLCF
2	Landsat5	TM	30x30m	1/1/1985	GLCF
3	Landsat7	ETM +	30 x30m	12/2/2003	GLCF
4	Topo Sheet		1:50,000		EMA
5	Shape Files and population data				CSA
6	Statistical data				Wereda agricultural Office
7	Soil Data		1:250.000	3/4/1997	FAO
8	SRTM Data		90m		GLCF

Table 1.2: Software used

Software	Application
ARCGIS 9.2	GIS analysis and image processing
ERDAS EMAGINE 9.1	Image processing
IDRSI 32	Weighting factors
ENVI 4.3	Change detection
MS EXCEL	Charts, graphs
MS WORD	Word processing
3DEM	For SRTM data Processing

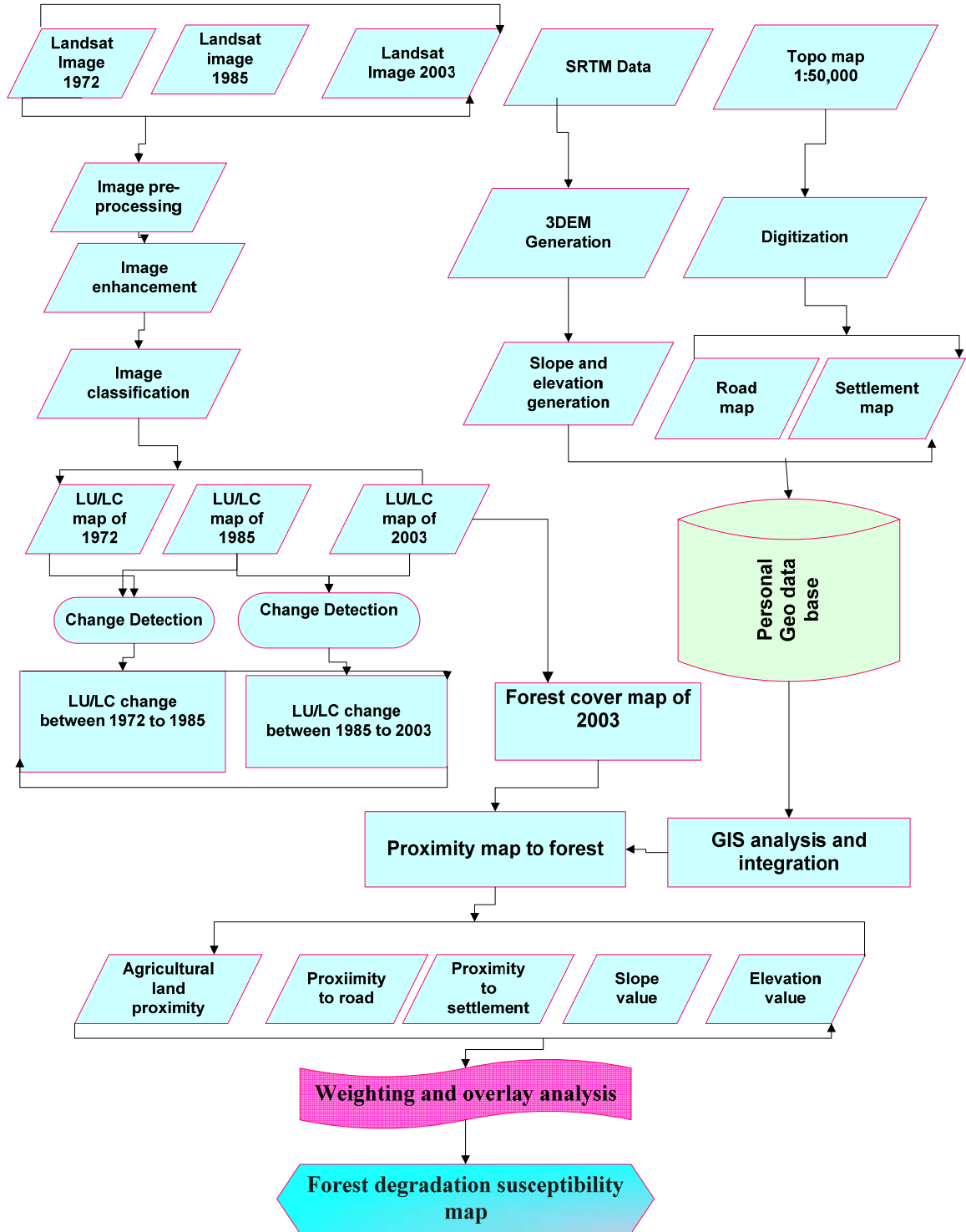


Figure 1.1: Flow chart showing the general methodology

1.5 Significance of the study

At present, one of the challenges facing Ethiopia is the alarming rate of land degradation specially soil erosion and deforestation which is mostly experienced in many parts of the country. Yet the rates and extent of the problem are still debatable due to limitations of reliable data and the processes involved are not clearly understood. This study is considered to be an important step in producing information about the land use and land cover change and vulnerability to forest degradation, which fills the information gap about cover changes at district level. Specifically, the result of the study is expected to have the following contributions:-

- May provide an insight towards an understanding of the dynamics of land use land cover change processes in Borena district for agricultural officers, land use planners, forestry experts, other concerned government bodies, NGOs and local dwellers so as to have appropriate interventions on the issue.
- Provide achievable solutions for those who are responsible and interested for taking measures to mitigate the problem.
- Generate first hand information on the problem of forest cover change in the study area for those who are interested to conduct further research on the issue

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1 Land use/ land cover change detection

Every parcel of land on the Earth's surface is unique in the cover it possesses. According to FAO (2000), "Land cover is the observed biophysical cover on the earth's surface". The same document also defines land use as the arrangements, activities and inputs that people under take on a certain land cover type. According to this definition, land cover corresponds to the physical condition of the ground surface, like forest, grassland, concrete pavement, while land use reflects human activities such as the use of the land such as industrial zones, residential zones, and agricultural fields.

Forces other than anthropogenic can alter land cover. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover. Globally, today land cover is altered principally by direct human use: by agriculture and livestock rearing, forest harvesting, urban and suburban construction (Meyer, 1995).

An increasingly common application of remotely sensed data is important for quantifying and identifying the continuous land use land cover dynamics. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times for different applications (Bottomley, 1998).

Change detection is an important process in monitoring and managing natural resources and urban development. Change detection is useful in such diverse applications as land use change analysis, monitoring shifting cultivation, assessment of deforestation, and study of changes in vegetation conditions, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring (Bottomley, 1998). The basic premise in using remote sensing data for change detection is that changes in land cover result in changes in radiance values, which can be remotely sensed.

2.1.1. Land use/ cover and land degradation in the north central highlands of Ethiopia

The term land degradation is the reduction in the capability of the land to produce benefits from a particular land use under a specific form of land management (Douglas, 1994). Land degradation has a broader concept which comprises the degradation of soil, water, climate, fauna and flora (Ofori, 1993).

Generally land degradation is divided into three, namely biological, chemical, and physical. Physical land degradation includes degradation of soil structure, crusting, compaction, and erosion. Chemical degradation includes acidification, salinization, and nutrient fertility depletion where as biological includes reduction in soil carbon and soil biodiversity processes (Ofori, 1993).

In Ethiopia the 1500 meter contour line is generally accepted to divide the total area of the country in to highlands and lowlands. Thus the areas which are categorized under highlands are chronically affected by land degradation specially deforestation and soil erosion problems than the rest of the country.

The high lands covering nearly 44% of the total area are characterized by favorable climatic condition and provide an excellent human habitat (Hurni, 1988). These highlands have been settled for millennia and agriculture is the predominant economy, which is until today the major cause of natural resource degradation. The highlands are the most significant areas in economic terms as they support over 80% of the country's population and 75% of the livestock populations which generates more than 90% of the country's agricultural output FAO (1986) cited on (Solomon, 1994). The high concentration of population, coupled with many other physical, socio-economic and political factors, has led to serious degradation of natural vegetation of the Ethiopian highlands.

Due to this fact, the Ethiopian high lands presently constitute one of the most degraded lands in Africa. Estimates by the Ethiopian highland reclamation study (EHRS) shows that, around 52% of the area in the highlands are affected by various degrees of land degradation. Various studies also show that soil erosion in the Ethiopian highlands is

initiated and aggravated in particular by deforestation, over cultivation, overgrazing, over population as well as rural development policies (Solomon, 1994).

As many researchers point out, the shortage of cropland has pushed people into clearing the vegetation and exposed the cropland on to ever steeper slopes in the northern highlands. Once the land is devoid of its vegetation cover, soil erosion becomes rampant, a process in turn accentuated by the rugged topography. Due to the shortage of land, croplands are also continuously utilized year after year without fallowing, thus, leading to fertility depletion and giving diminishing yield.

Centuries of exploitation, degradation and neglect have not only enormously reduced the productive capacity of the northern highlands, but have also diminished the ability of the land to withstand climatic inconstancy. A slight decline in rainfall becomes a period of famine. A slight increase in rainfall over and above results in severe flooding and hundreds of thousands of tons of fertile topsoil that took thousands of years to build, are easily eroded and carried away by runoff (Markos, 1998).

2.1.2. Human induced land use/cover changes and land degradation in the North central highlands of Wello

In the North central highlands, where the study area is located, various factors, such as population growth, frequent land tenure, economic policy changes, and unstable institutional setup, are considered to be the major driving forces for the observed land use and land cover changes and the expansion of cultivated land towards marginal areas (Gete, 2000).

As Belay (2002) stated in his study based on aerial photographs, in all the periods considered, cultivated land constituted the predominant type of land cover in the Derekolli catchment of southern Wello particularly in Bati area, of the total catchment area, the cropland accounted for 65.1, 69.7 and 70.6 per cents in the years 1957, 1986 and 2000, respectively (Belay, 2002). This is not surprising as all historical records suggest that almost all the currently cultivated land in the Wello highlands was already under cultivation at least as far back as the 1930s. Population pressure is one of the most

frequently cited factor of land use land cover change and land degradation in the highlands of Wello (Belay , 1995).

According to Girmay, a study conducted in Southern Wello of Boru district, the population concentration analyzed from the stated aerial photos shows that, a population density of 175 persons/km² in 1965, 216 persons/km² in 1986 and 317 persons /km² in 1994. The result of agricultural density also shows that, 389.93 person /km², 572.52persons/km² and 637.99 persons/km² of cultivated land in 1965, 1986 and 1994 respectively. Such huge concentration of rural population has no other alternatives except to use all the resources of the land and land degradation due to population pressure is severe in the area (Girmay, 2003).

According to Belay (2002), a group of interacting variables are responsible for the drastic decline of the shrub land and forests despite the generally expected overgrazing by livestock and subsequent bush encroachment. The first of these is the extensive use of the woody vegetation for charcoal production and firewood. The study very well confirms the fact that the major cause for the extensive destruction of the shrub land in the Derekolli catchment is firewood collection and charcoal production for the surrounding markets. It should be noted that charcoal, which causes more destruction of woody biomass than fuel wood, is produced primarily for markets in the surrounding towns.

Interviews conducted with farmers by Sebsebe (1997) around Kallu area in Southern Wello also revealed that the sale of firewood and charcoal shows considerable increase during the drought years that encourages destruction of woody biomass in the region. One should also keep in mind that once shrubs and trees are cut, their regeneration is constrained by dry condition of the region (i.e. low erratic rainfall and the high evapotranspiration rate); this encourages a more rapid expansion of the grassland at the expense of woody vegetation. Shortage of cultivated land has also forced farmers to increasingly rely on selling firewood and charcoal for supplementary income, and this has also contributed to the extensive destruction of the woody biomass and shrub land.

2.1.3 Consequences of Land use/ Land cover changes and land degradation in the North central high lands of Wello

It is well known that land degradation is widespread and serious in the high lands of Ethiopia, but until the Ethiopian high land reclamation study, there were only general and usually qualitative estimates of its extent, severity and geographic distribution. The (EHRS) maintains that, the increasing high land population over the country has resulted in more and more soil erosion as a result of deforestation which brings areas with steep slopes under cultivation. In Wello, as in many other parts of the country, it is customary to burn animal dung when wood is scarce. Recent reports show that, throughout the country, the burning of dung for fuel rather than using it to regain soil fertility results in reduction of grain production by about 550, 000 tons annually (Markos, 1998).

According to Kebrom and Hedlund (2000) in Southern Wello Zone of Kallu district about land use and land cover change using aerial photographs from 1958 to 1986, especially during the transition period of 1991 most of the shrub lands and forests under hillside closures disappeared in the area. This results in runoff, soil erosion and flooding in the adjacent lowlands of the study area.

The general loss of vegetation cover and its possible implication in ecological disturbances in the study area in particular, and in the country in general, have already led to problems and may also lead to further destructive scenarios in the future where as the 1973 famine in Wello was associated with activities such as deforestation and clearing of areas for cultivation (Markos, 1998).

One of the immediate impacts of the thinning and destruction of the shrub land is shortage of fuel wood and construction materials for the farming community. This condition forces farmers not only to travel very long distances to collect wood, but also to increasingly burn crop residues and organic manure for cooking and heating. The latter has momentous consequences for the fertility and productivity of the cropland as the action leads to depletion of the organic matter in the cultivated soils. The reduced possibility for cropland expansion and severe shortage of land has also its own impact. The shortage of land has compelled farmers to practice continuous cropping and completely abandon even seasonal

fallowing. Such continuous cultivation in a situation where little organic matter returns to the soils leads to severe soil erosion and land degradation (Belay, 2002).

2.2. Trends of forest cover change on the highlands of Ethiopia

The Ethiopian highlands were almost completely covered with more or less dense forests in ancient times. But forest cover change at present is not greater than 3% of the total area of the country, because of different factors to meet the growing demand for cultivable land, grazing land, settlement, fuel wood, commercial wood and building materials (Breitenbach, 1962).

Although, estimates of forest resources of Ethiopia vary widely from one source to the other, different literatures indicated that from 35% to 40% of the total area of the country 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 (Breitenbach, 1962).

According to Waber (1999) based on the recent satellite imagery analysis, indicated that about 2.35% of the area of the country is covered with forests and this forest resources can be seen only in some parts of the country. It includes localized areas in the western and south western parts of Ethiopia, which is found far away from human settlements such as along stream banks, near the tops of steep hills and in most valleys, safe from fire as well as human disturbance.

The estimated rate of forest cover change in Ethiopia by the late 1980 was 1000 km² per year (Davidson, 1988). Later on, some findings indicated that the rate of deforestation in Ethiopia varies between 1500km² to 2000km² per year and this situation threatens to eliminate the remaining both natural and plantation forests within a short period of time (Desta, 2001).

2.2.1 Causes of forest cover change in Ethiopia

The causes of deforestation are complex, Markos and Delenessaw (1998) confirmed that the rapid rate at which the population increased over the decades is the major factor contributing to the accelerated rate of deforestation in Ethiopia. The immediate causes are

the need for farming and grazing land, the demand for fuel wood and construction materials, repeated fire out breaks, and movement of political center (Desta, 2001).

Now a day's much more damages have been done on the forest resources of Ethiopia. With their axes a group of people can destroy dense forests so as to get fresh farm and grazing lands (Zemedie, 1997). According to Kassahun (1999) the problem of deforestation is very common for the rural people to clear vegetation cover for cultivable land expansion and procuring essential forest products such as constructional materials and fuel wood. In his findings Bekure (1996) stated that the increasing demand for croplands, grazing land, constructional poles and fuel wood including charcoal Production are the main reason for the uncovering of the lands of Ethiopia. In addition, forests are cleared to acquire constructional materials, to provide source of energy, to make space for grazing, farming, building and layout infrastructures networks and to supplement raw materials such as an input for agricultural production and livestock grazing (Mesfin, 1990).

In addition, the shifting of political center from place to place in the past and the introduction of sawmill industry and their uncontrolled activity is to a large extent responsible for the massive destruction of forest resources and large areas were selectively exploited without reforestations (FWCD, 1982).

To sum up, rapid population growth along with the need for farming and grazing land, movement of political capital in the country for a long period of time, the need of fuel wood and building materials, forest fire and the introduction of sawmill industry are the major contributing factors for the transformation of forest cover land in to other land use and land cover systems in the country.

2.2.2 Impacts of forest cover change in Ethiopia

In many areas of Asia and Africa peasants search for wood possess a major effort. Where wood cannot be found, dried cattle dung serves as a substitute fuel. Besides, the immediate human suffering from lack of wood, the depletion of forest resources is associated with increased erosion, siltation, and flooding, climatic change and declining of biodiversity. Being a developing country, the same is true for the impact of forest cover change in

Ethiopia. Regarding this, some of the major identified impact of this senseless destruction of forest resources beyond its regenerative capacity in Ethiopia is land degradation, soil erosion mainly by water, frequently happening drought, declining of biodiversity, shortage of fuel wood and constructional materials and unbelievable high cost of fire wood products (Davidson, 1988).

2.3. The Role of Remote sensing and GIS

2.3.1 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.

Multispectral sensor acquires multiple images of the same target object at different wavelengths bands Mather (1987). Hence, multiple band images can be used to identify different features as each band measures unique spectral characteristics about the target. A spectral band is a data set collected by the sensor with information from discrete portions of the electromagnetic spectrum which ranging from cosmic waves to radio waves.

In relation to this, spectral reflectance characteristics of common earth surface features are located within the visible and near to mid-infrared range. The reflectance of different features on the earth surface varies with the wave length of the interacting radiation. The reflectance of vegetation, soil and water, which are the three major features on the earth surface, shows different spectral reflectance characteristics. The spectral reflectance curve of the vegetation is of immense use to study the forest resources and there condition in an area.

2.3.1.1 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.

2.3.1.2 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 classification.

I. Unsupervised classification

Unsupervised classification uses statistical clustering techniques to combine pixels into groups (classes) according to the degree of similarity of their brightness value in each spectral band. The analyst then combines spectral classes into real land cover type using maps and field based knowledge. The analyst should understand the spectral characteristics of the terrain in the area of interest well enough to properly label certain clusters into a specific information class (land cover type). In this process many spectral classes can be assigned to a few land cover types (Jensen, 1996).

II. Supervised classification

Supervised classification is the process of grouping pixels using a known identity of specific sites (through a combination of fieldwork, analysis of aerial photography, maps and personal experience) in the remotely sensed data, which represent homogenous

examples of land cover types to classify the remainder of the image. These areas are commonly referred to as training sites (Jensen, 1996).

2.3.1.3 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). Many change detection methods have been developed and used for various applications, like post classification comparison, image differencing, image rationing, image regression (Chen, 2000). But generally, they can be broadly divided into two: post classification and spectral change detection approaches (Singh, 1989).

2.3.1.3.1 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 compared 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.

2.3.1.3.2 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.

Among spectral change detection methods, NDVI image differencing and comparison is the most widely used method. NDVI is a measure derived by dividing the difference between near infrared and red reflectance measurements by their sum (Hay, 2001): $NDVI = (NIR - R) / (NIR + R)$, high positive values of NDVI correspond to dense vegetation cover, whereas negative values are usually associated with bare soil, snow, water, clouds or non vegetated surfaces. Most of the studies came to the common conclusion that NDVI image differencing method yields highest accuracy. Studies by Lyon (1998) reported that NDVI differencing was the best method for vegetation change detection in biologically complex ecosystem and it is least affected by topographic factors, but here in this study only NDVI image comparison is used for visual change detection.

2.3.1.4 Factors affecting comparability of images

A number of complicated factors should be taken into account when performing change detection analysis Yuan (1999) spatial resolution and spectral band pass between images acquired with two different sensors. Phenological variations in vegetation result in large changes in the reflectance patterns of the land surface. Spectral differences in vegetation between wet and dry years can also be quite pronounced even if image dates are more closely matched. Cloud cover, differences in the radiometric performance between sensors, variations in solar irradiance, solar zenith angle, and solar azimuth (affects scene brightness, levels and location of shadows) scene to scene variation in atmospheric effects (scattering and absorption) spatial miss registration of images. This tends to reduce the accuracy of any digital change detection effort. Therefore, these factors should be carefully considered during change detection analysis.

2.3.1.5 Accuracy Assessment

When the satellite images are classified, they intend to produce information that describes reality. This way, systems that allow us to verify to what extent the produced classification is compatible with what actually exists are fundamental. It involves the production of references or facts that evaluate the produced classification. These references may be produced from maps, aerial photos or visits to the field with the help of GPS and may be represented by points or areas. These references should necessarily be georeferenced, allowing them to be superimposed to the produced classification and compared to the value of facts from the field and the value of the classified map. This comparison produces an error matrix that is the basis for the accuracy verification process (Weber, 1999).`

2.3.2 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 Mc 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.

2.3.2.1 Multi criteria evaluation

In decision theory, multi criteria evaluation is the process of applying a decision rule to a set of alternatives. A decision rule is a procedure by which criteria are combined to arrive at a particular evaluation, and by which evaluations are compared and acted upon. A decision is a choice between alternatives. The basis for a decision is known as a criterion

(these are factors and constraints). Factors are generally continuous in nature (such as the slope gradient or road proximity); they indicate the relative suitability of certain areas. Constraints are always Boolean in character (such as the reserved lands). They serve to exclude certain areas from consideration. Factors and constraints can be combined in the MCE module using one of three methods (Boolean intersection, Weighted Linear Combination and Ordered Weighted Average). Therefore in multi criteria evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective and combining them to form a single suitability map from which the final choice will be made (Eastman 2001).

CHAPTER THREE

3. GENERAL DISCRIPTION OF THE STUDY AREA

3.1 Geographical location

Borena district is found in Amhara regional state of South Wello Zone, which is located South West of Dessie town at a distance of 180 km and 600 km from Addis Ababa. The Wereda shares boundaries with East Gojam Zone in the West, Saynt Wereda in the North, Legambo Wereda in the North East and Wogidi Wereda in the South East. The geographic location extends from 10°33'20" to 10°55'50" North latitude and 38°27'50" to 38°54'30" East longitude with an elevation ranges from 1200 meter to 3700 meter above mean sea level, and has a total area of 937.3km² as shown in (Figure 3.1).

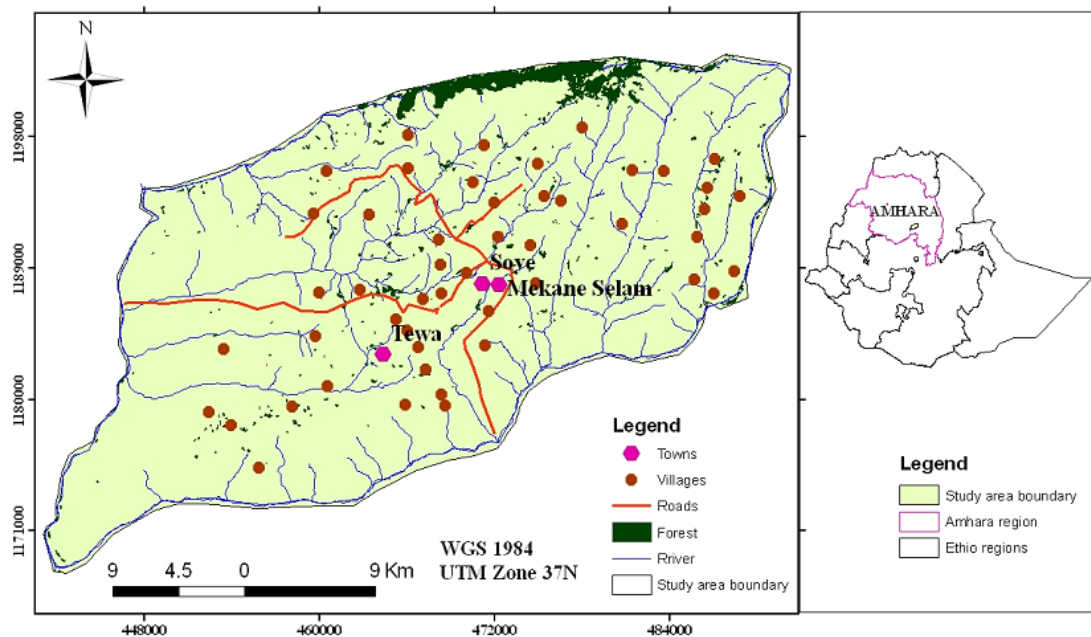


Figure 3.1: Location of the study area.

3.2 Topography and drainage

Since the district is surrounded and dissected by tributaries of Abay river, it has very steep and rugged terrain of mountain, mountain scarps, valley and minor valleys. Generally the area comprises mountainous terrain in its northern and north western parts, where as it has a deeply dissected topography in the North Eastern, Eastern, South Western and rolling plain in the centre of the district. Moreover, the Northern part of the study area (on which

the existing dense natural Denkoro forest is located) is the main source of many rivers which drain to the Blue Nile (Abay) basin in the South Western part. As a result, the terrain is intersected by rivers flowing from the North and North Eastern to the South and finally joined to Blue Nile. The drainage pattern in the study area is dendritic or trellis in nature with high drainage density.

3.3 Soils

According to FAO (1997) soil classification, there are six major types of soils in the area: these are Arenosols, Cambisols, Lithosols, Rendizians, Vertisols and rock surface. From these soil types Cambic and Lithosols are the dominant soil types.

3.4 Climatic characteristics

3.4.1 Rainfall and temperature

The major agro climatic zones of the wereda are kolla, woina dega, dega and wurch. The total annual rainfall varies from 700 to 1500 mm per year. The highest rainfall falls during summer, which starts in June and ends in September and short rainy season is in spring which encompass March, April and May.

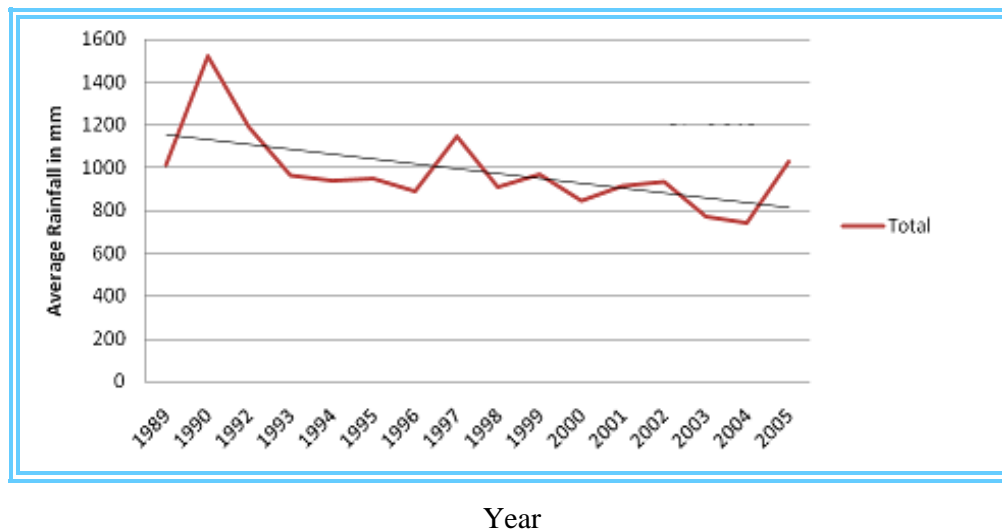


Figure 3.2: Rainfall trends of Borena district from 1989 to 2005.

Source: Ethiopian metrological Agency (EMA)

The mean annual temperature of the region varies from 9.5⁰c to 28.5⁰c. The absolute maximum temperature occurs from March to May and the absolute minimum temperature occurs in December, July and August. The upper North Western part of the wereda is known for its minimum temperature which results in the prevalence of wurch type of climate while the South Western part of the wereda, has the highest temperature, characterized by kolla climate.

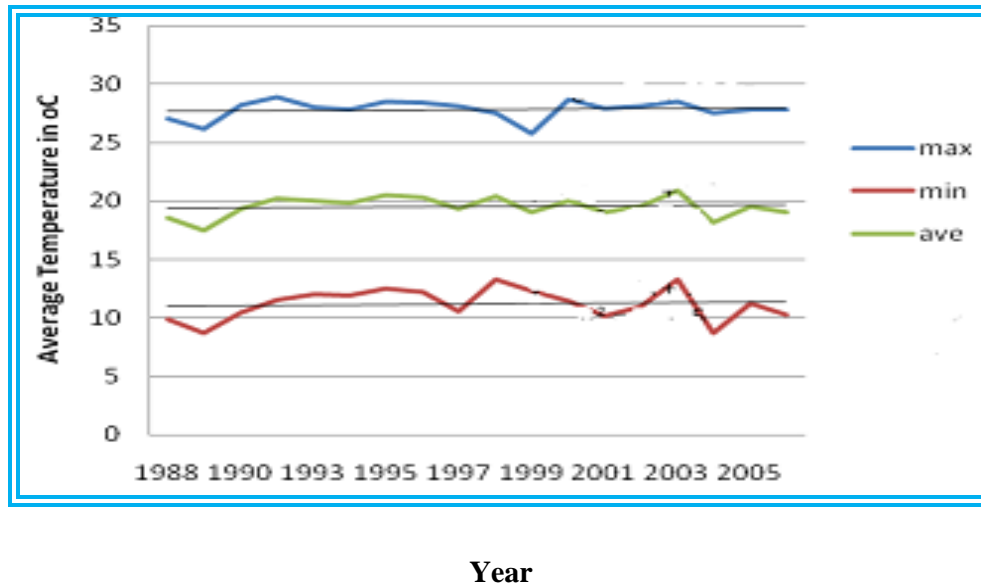


Figure 3.3: Temperature graph of Borena district from 1988 to 2005.
Source: Ethiopian metrological agency (EMA).

3.5 Vegetation

The entire area of the district was covered once with dense forest resources, but now only the Denkoro state forest in the Northern part, very scattered vegetations in steep slope areas and gallery forests with various types of vegetations such as higher trees, riverine trees, small trees, shrubs and ground cover grasses are the remnant vegetations. The forest, which is found around Denkoro River, is one of the few remnant forests of the district. The major tree species in the canopy are Junipers procera, podocarpus falcatus, olea-europaea, hagenia abssinica, and eucalyptus as shown in (Plate1.)



Plate1: Photograph taken from Denkoro state forest in the northern part of Borena district.

Source: Photo taken by the researcher.

3.6 Population

Based on the 1994 and 2007 CSA population and housing census report, the total population of Borena district was 125,126 and 158,920. The high population growth is attributed to the favorable climatic conditions for both crops and livestock production, which attract a lot of people from outside the district. The district is inhabited by around 10000 urban dwellers and densely populated areas have been observed particularly in the central and north eastern parts of the district around Mekane Selam and Soye towns.

3.7 Socio-economic conditions

Presently, 95% of the population is engaged in agriculture (Wereda's agricultural office report, 2008). Since agro-climatic zone of the district is conducive for crop production, various types of crops such as barely, wheat, teff, maize, sorghum, beans, chickpeas etc. are the major crops grown in the district. Furthermore, cattle breeding is very common in the area. In addition sale of forest products is also the major household income sources of the forest surrounding community.

CHAPTER FOUR

4. RESULTS AND INTERPRETATION

4.1 INTRODUCTION

The interpretation and analysis of remote sensing imagery involves the identification and measurement of various targets in images in order to extract information. In this study image classification was carried out in such a way that first unsupervised classified color prints of year 2003 Landsat image was prepared and taken to the field. In the field it was cross referenced using GPS to ground features. After fieldwork, supervised classification was carried out for the three images of (1972, 1985 and 2003) based on different false color composites of 4, 3, 2 and 6, 4, 2. Then the change detection analysis was carried out by visual comparison of features and detailed quantitative approaches.

4.2 Land cover mapping

Using the application of image classification methods, five major land use and land cover types were identified. These include forest, shrub or bush, grass, agricultural and bare land, based on the characteristics of Landsat satellite images of the year 1972, 1985 and 2003.

Table 4.1 shows description of each land use land cover type.

Land cover classes	Description of each land use class
Agricultural Land	Areas allotted to rain fed crop production, mostly of cereals in subsistence farming
Forests	Areas covered by trees forming closed or nearly closed canopies; predominant species like <i>Juniperus procera</i> .
Shrub land	Land covered by small trees, bushes, and shrubs, in some cases mixed with grasses; less dense than forests
Grass land	Are those lands where small grasses are the predominant natural vegetation. It also includes land with scattered or patches of trees and it is used for grazing and browsing
Bare Land	Are parts of the land surface which is mainly covered by bare soil and rock out crops.

4.2.1 Land use/land cover map of 1972

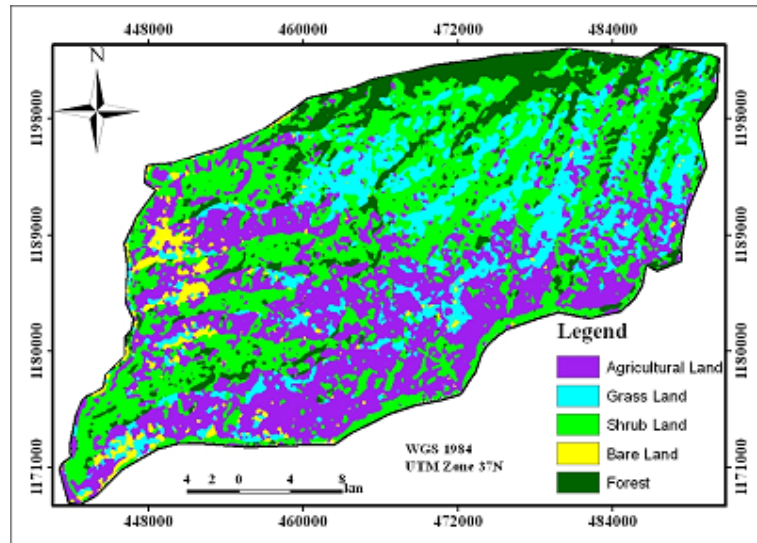


Figure 4.1: Land use/land cover map of 1972.

The major land use/land cover classes of 1972 include cultivated land, grassland land, shrub or bush land, forest and bare land. As indicated in (Figure 4.2) the greatest share of land use/land cover from all classes is shrub land, which covers an area of 36239 ha, contributes 35% of the total area. Agricultural land and grass land cover an aerial size of 32750 ha (32 %) and 16535 ha (16 %) respectively. Whereas the aerial coverage of forest and bare land is 13599 ha (13%) and 4790 ha (5%) from the total area of the wereda. This shows that 64% of the total area of the district was covered by shrub , forest and grass land in 1972 and the remaining 36% was covered by agricultural and bare land, which indicates that much of the area was covered by green vegetation in 1972.

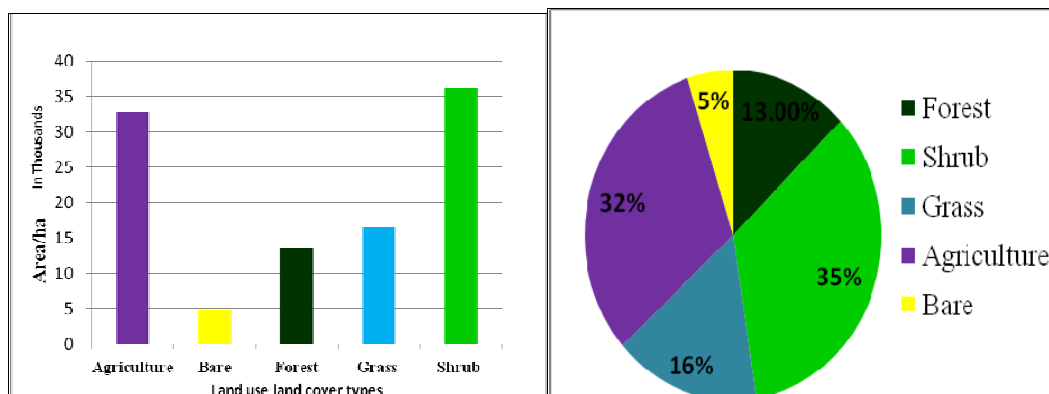


Figure 4.2: depicts aerial coverage and percentage of each land use type of 1972.

4.2.2 Land use/land cover map of 1985

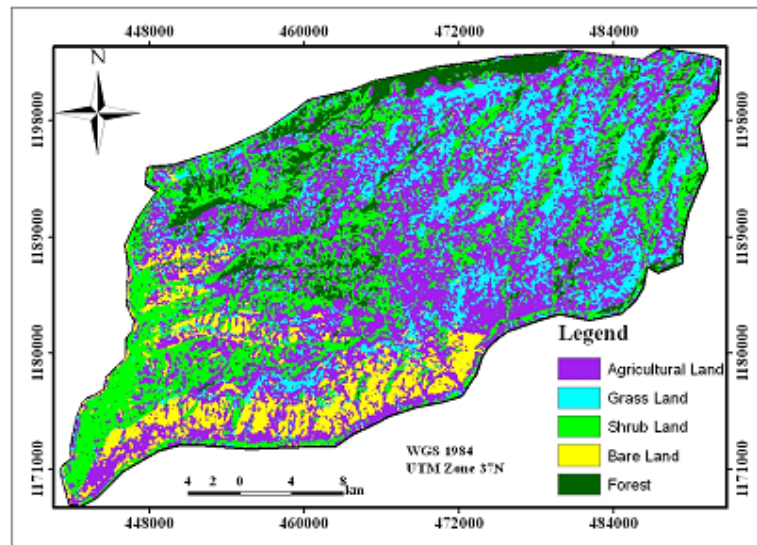


Figure 4.3: Land use/land cover map of 1985.

Where as in the case of 1985 the major land use/land cover classes were cultivated land, grass land, shrub or bush land, forest and bare land. As indicated in (Figure 4.4) the greatest share of land use/land cover from all classes is cultivated land, which covers an area of 45735 ha (44 %). Shrub or bush land and grass land cover an aerial size of 25020 ha (24 %) and 15580 ha (15 %) respectively. The least aerial coverage is still forest and bare land, which has only 9795 ha (10 %) and 8117 ha (8%) respectively from the total area of the wereda. As shown in (Figure 4.4), 44% of the area is covered by cultivated land due to the conversion of forest, shrub and grass land to agricultural land because of rapid population growth in the study area. In addition to this there was expansion of bare land from 5% in 1972 to 8% in 1985 because of severity of drought in 1985 in Wello area.

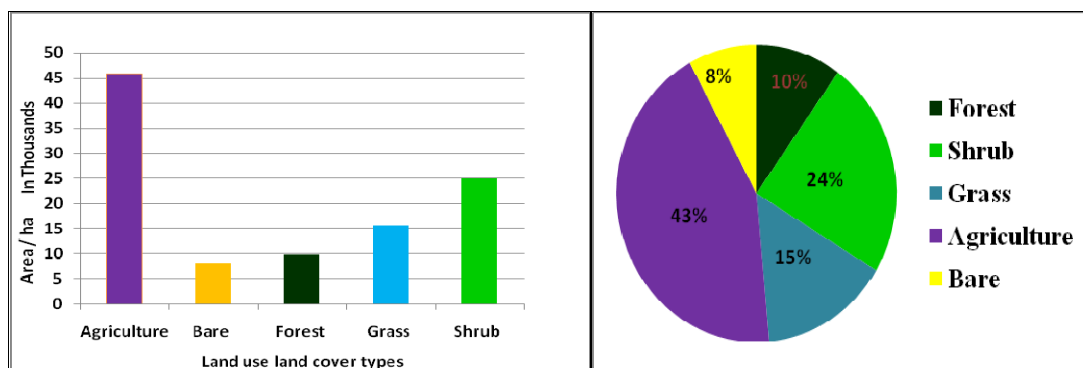


Figure 4.4: depicts aerial coverage and percentage of each land use type of 1985.

4.2.3 Land use/land cover map of 2003

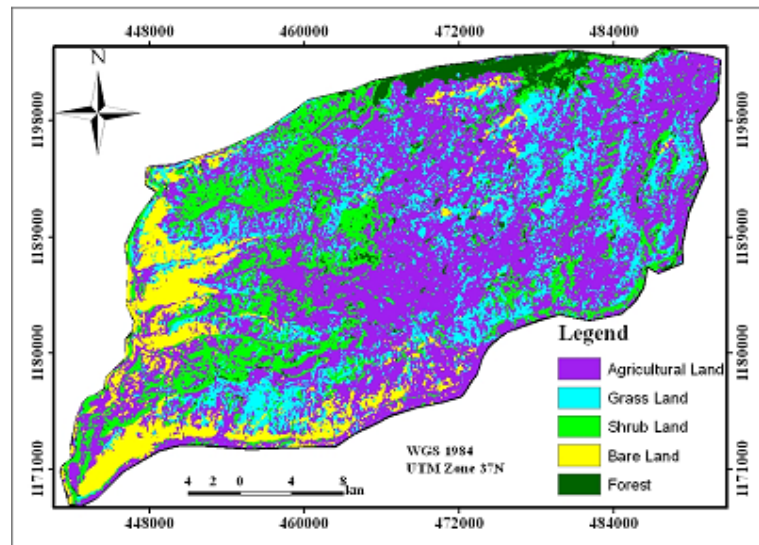


Figure 4.5: Land Use Land Cover Map of 2003.

During 2003 the major land use/land cover classes include cultivated land, grass land, shrub or bush land, forest and bare land but all the land use classes have different aerial coverage from the previous time. As indicated in (Figure4.6) the greatest share of land use/land cover from all classes is cultivated land, which covers 51842 ha (49 %) almost half of the total area of the district. Shrub or bush land and grass land covers 18186 ha (17 %) and 19604 ha (19 %) respectively. The least area is covered by forest and bare land, which is 6087 ha (6%) and 9076 ha (9%) from the total size of the wereda. Still agriculture covers the largest area in 2003 which depicts conversion of other land cover classes to cultivated land.

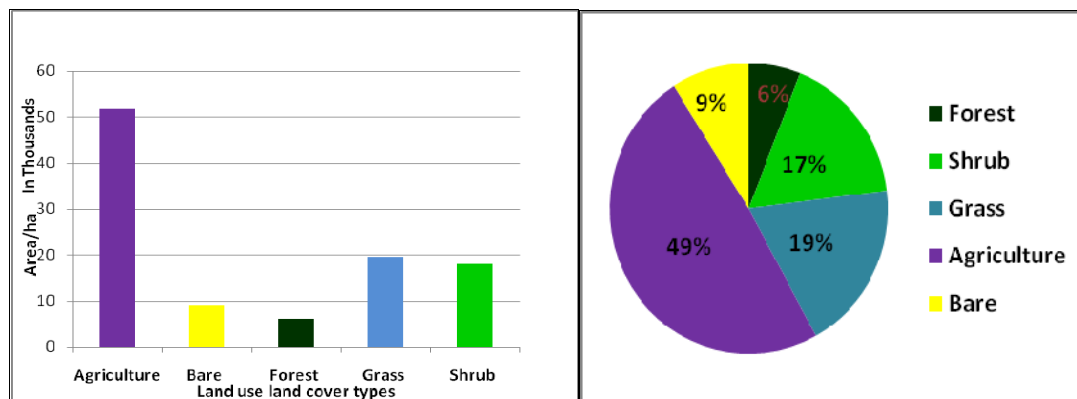


Figure 4.6: depicts aerial coverage and percentage of each land use type of 2003.

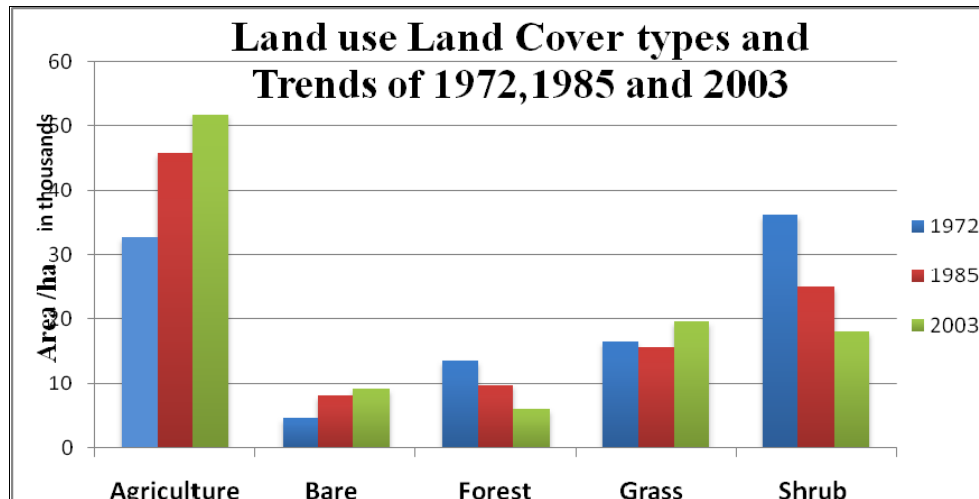


Figure 4.7: Land use land cover classes of the three periods (1972, 1985 and 2003).

4.3 NDVI image comparison

One of the most common vegetation indices is the normalized differencing vegetation index (NDVI). This technique was developed for identifying the health and dynamism of vegetation and for estimating green biomass (Hayes, 2001). The value of the result will be between negative one and positive one. NDVI is calculated using the following equation:

$$NDVI = (NIR - RED) / (NIR + RED),$$

Where NIR = the near infrared band

RED = the red band

In this research NDVI was used to get an over view of the vegetation biomass change over the three periods, which is important for land cover identification. The results of NDVI values for different time periods of 1972, 1985 and 2003 are shown in (Figure4.8, 4.9 and 4.10). And the statistics of NDVI images are shown in (Table 4.2).

As it is shown in (Figure 4.8) NDVI value ranges from -0.48 to 0.72 in the year 1972, this indicates that the northern part of the area is characterized by high NDVI values which have a strong correlation with thick vegetation cover at that time period. On the other hand the southern and south eastern part is characterized by low NDVI values with low vegetation cover.

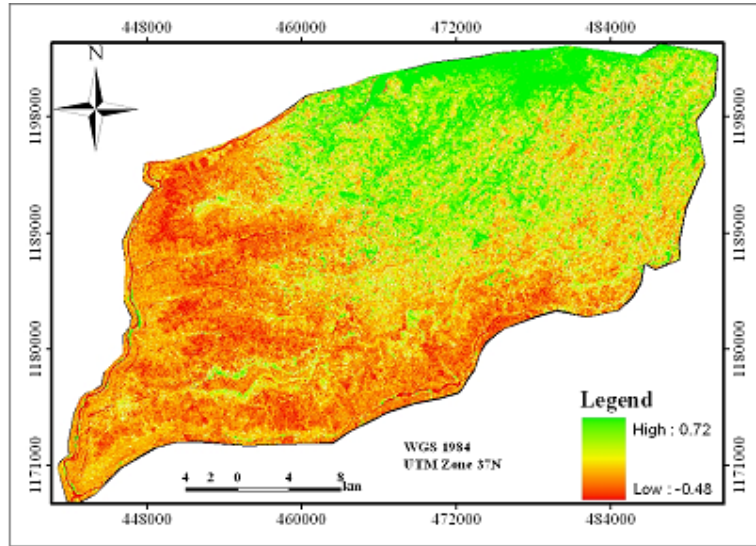


Figure 4.8: NDVI map of 1972.

In 1985 there was a reduction of NDVI value from 0.72 in 1972 to 0.63 in 1985 accompanied by loss of vegetation cover especially by the 1985 severe drought in Wello area.

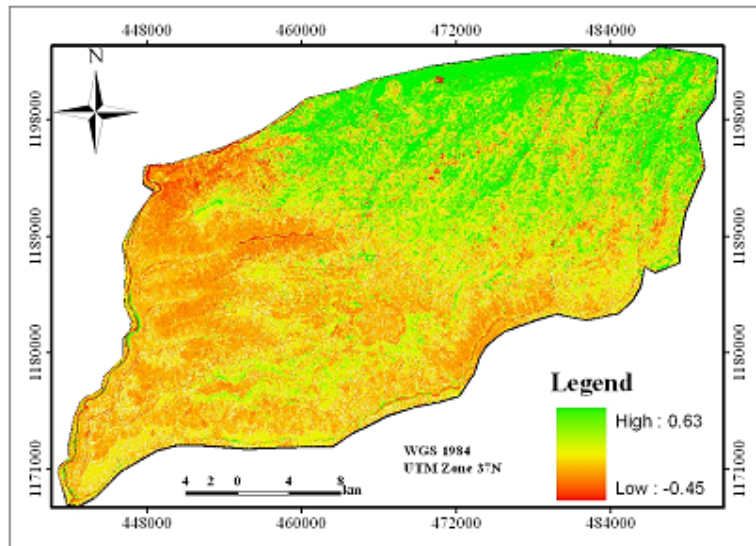


Figure 4.9: NDVI map of 1985.

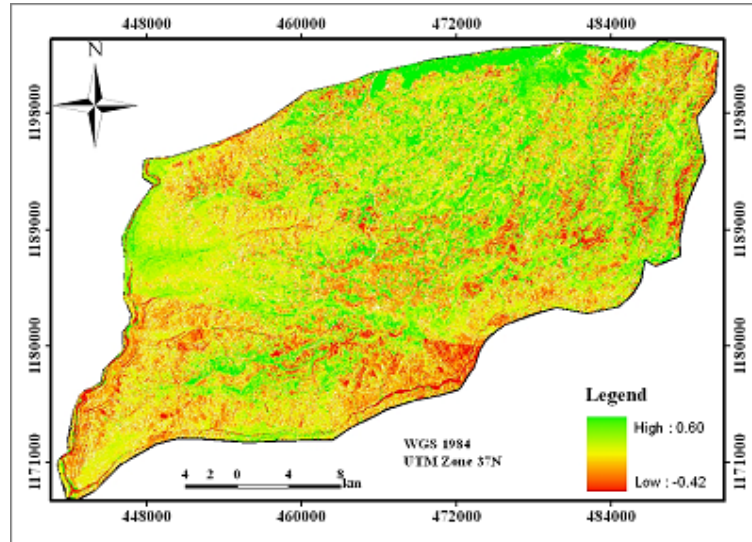


Figure 4.10: NDVI map of 2003.

Generally NDVI value was used for visual comparison and to aid classification. The statistics and visual observation of the NDVI images over the subsequent periods show reduction in vegetation biomass. This shows how vegetation biomass has degraded severely. The following table depicts NDVI statistics of the three periods.

Table 4.2: depicts NDVI value of the three periods.

NDVI Statistics	Year		
	1972	1985	2003
Maximum	0.72	0.63	0.60
Minimum	-0.48	-0.45	-0.42
Mean	-0.006	0.027	0.019
Standard Dev.	0.0860	0.090	0.067

4.4 Land cover change detection

4.4.1 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 and 4.4) the columns represent the older land cover categories and the rows represent the newer categories

Table 4.3: Land use land cover change matrix between (1972 to 1985)

Land use land cover type of 1985	Land use land cover type of 1972					
	Agricultural land	Forest	Bare Land	Shrub Land	Grass Land	Class Total
Agricultural land	27953	1221	0	11432	5205	45811
Forest	0	7665	0	2130	0	9795
Bare Land	4797	0	4747	11	3359	8117
Shrub land	0	4562	0	20458	0	25020
Grass Land	0	151	43	5352	7971	15517
Class Total	32750	13599	4790	36239	16535	0

As shown in (Figure 4.11) between (1972 to 1985), there was a dramatic increase of agricultural land followed by bare land but shrub land, forest land and grass land shows a reduction in aerial coverage.

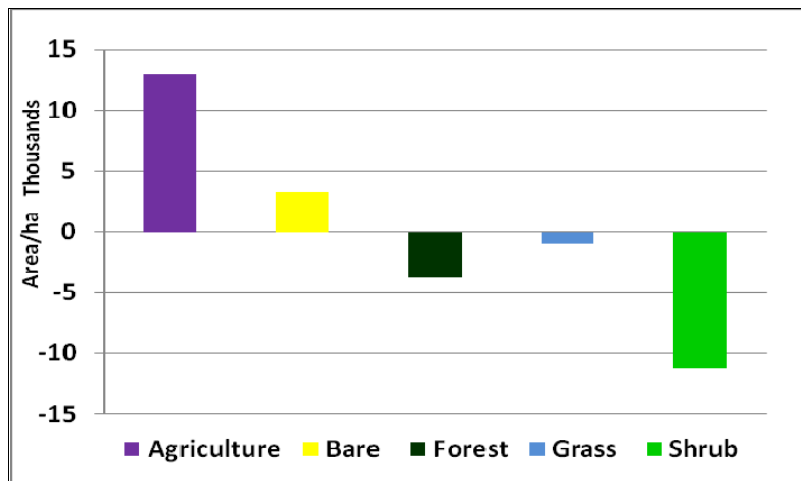


Figure 4.11: LU/LC change between (1972 to 1985).

On the other hand between 1985 to 2003 the same is true for agricultural land, bare land, shrub land and forest land but grass land shows a slight increase in the aerial coverage due to the conversion of forest and shrub land to grass land and it is clearly shown in (Figure 4.12).

Table 4.4: Land use land cover change matrix between (1985 to 2003).

Land use land cover type of 2003	Land use land cover type of 1985					
	Agricultural land	Forest	Bare Land	Shrub land	Grass Land	Class Total
Agricultural Land	40711	2688	0	7896	547	51842
Forest	0	5399	0	688	0	6087
Bare Land	2500	0	6576	0	0	9076
Shrub Land	1017	1247	141	15082	699	18186
Grass Land	1507	461	1400	1354	14882	19604
Class Total	45735	9795	8117	25020	15580	0

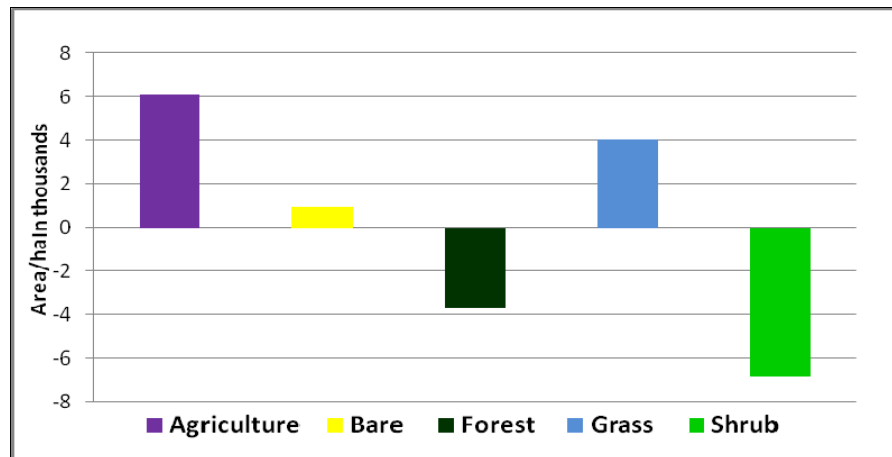


Figure 4.12: LU/LC change between (1985 to 2003).

4.5 Accuracy Assessment

To assess the classification accuracy, confusion matrix was used. Confusion matrix indicates the nature of the classification error and used in many other research works, as it is shown in (Table 4.5) the overall accuracy and kappa coefficient is 86.11% and 0.8312 respectively. This shows 86.11% of the land use land cover classes are correctly classified.

Table 4.5: Confusion matrix of 2003 land use land cover classification.

Land Use Type	Bare Land	Forest	Shrub Land	Grass Land	Agriculture
Bare Land	95.9	0.08	2.05	4	6.24
Forest	0	94.91	5.96	0.69	0
Shrub Land	0.57	2.31	80.43	8.09	6.55
Grass Land	1.4	2.57	8.11	80.22	8.12
Agriculture	3.58	0.13	3.45	7	79.09
Total	100	100	100	100	100

Overall Accuracy = 86.11% with a Kappa Coefficient of = 0.8312

4.6 Rate of land use land cover changes

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

$$\text{Rate of change (ha/year)} = (A-B)/C$$

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 4.6: Land use land cover classes and rate of change between (1972 to 2003)

Land use land cover	Years			Rate of change (hectare/year)	
	1972	1985	2003	1972 to 1985	1985 to 2003
Agricultural land	32750	45735	51842	998.85	339.28
Forest	13599	9795	6087	-292.62	-206
Bare Land	4790	8117	9076	255.92	53.28
Shrub land	36239	25020	18186	-863	-379.67
Grassland	16535	15580	19604	-73.46	223.56

Between 1972 to 1985 agricultural land increased with a rate of 999 ha/year and further increased in 2003 with accelerated rate of change 339 ha/ year. 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 4.2 and 4.3). From (1972 to 1985) 1221, 11432

and 5205 ha of forest, shrub and grass land had been changed to agricultural land respectively. While between 1985 to 2003, 2688, 7896 and 547 ha of forest, shrub and grass 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 1972 and 2003 in the district in general, could be directly related to rapid population growth.

On the contrary, shrub or bush land and forest land had decreased from 1972 to 1985 with 863 and 293 ha/year rate of change and further decreased in 2003 with rate of 380 and 206 ha/year. The change was induced by the transfer of shrub and forest land to agricultural land between 1972 to 1985 and to grass land and agricultural land between 1985 to 2003 and even to bare land, rural and urban settlements. The massive reduction of vegetation particularly in between 1972 to 1985 was because of lack of administration especially during the transition period and land re distribution.

Similarly, grass land was reduced in size between 1972 to 1985 with rate of 73 ha/year. But it increases between 1985 to 2003 with a rate of 223 ha/year. This is because of the degraded forest and shrub lands especially during the drought years and the transition period were changed to grass lands. Whereas bare land was continuously increased between 1972 to 1985 with a rate of 256 ha/year and then further increased with a rate of 53 ha/year, the rate of increasment is very high between 1972 to 1985 because of severity of drought in 1985 in Wello area which kills thousands of animal and human life and a huge of loss of vegetation biomass. And now 9% of the study area is covered by bare land particularly areas which are found at the south western part of the wereda around Abay river.

4.7 Susceptibility to forest degradation analysis

The rate of forest degradation is very high from 1972 to 2003, the total area of forest coverage was 13599 ha (13%) and 9795 ha (10%) in 1972 and 1985 respectively. But in 2003 it was decreased to 6087 ha (6%), from 1972 to 1985 the forest coverage is almost decreased by half. Since forest is disappearing at a fastest rate, therefore preparing forest

degradation susceptibility map is necessary for protecting it from further degradation and for management purposes.

Table 4.7: Area and percentage coverage of forests from 1972 to 2003.

Year	Area in (ha)	Percent
1972	13599	13
1985	9795	10
2003	6087	6
Total		100

In order to monitor forest degradation and generate susceptibility to forest degradation map of the district, the year 2003 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 2003 satellite image classification, which is the only available recent satellite image data source. 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 Borena district. 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:

4.7.1 Preparing input datasets (factor maps)

The first step to run MCE is deciding, analyzing and generating proximity to forest cover data sets or factor maps which are responsible for forest degradation. 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 selected settlement proximity, road proximity, slope and elevation value of the district 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 Borena district. 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 district's 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. On the contrary, they 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. 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 no well known urban center, 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. The vegetation resource nearby access to roads is more likely to

be exploited than the less accessible ones. In this forest susceptibility degradation model, the graveled roads radiating across all over the district 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 (Zelalem, 2007).

Finally elevation data set was used, according to the traditional climatic classification most of the district's area is found in the "woina dega' and dega (between 1500m and 3300m a.m.s.l) climatic zone. Most of the rural populations of the district 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.

Basically, the level of susceptibility to forest degradation is affected by all of the selected factors above. However, their influence is different with each other. That is why quantifying the importance level (weight) of the selected factors are an important task before running MCE. Accordingly, after analyzing the influence of each factor with forest resource degradation based on literature review, the view of professionals and local dwellers, the weights of all the factors involved were ranked and calculated by using Pair Wise Comparison methods with the support of Idrisi32 software.

For the assessment of susceptibility to forest degradation in Borena district, the selected and weighted five factor maps were evaluated under the principle of weighted overlay analysis with the help of ArcGIS9.2 software spatial analyst raster calculator extension and finally, the weighted overlay combination result is derived and mapped by using the following equation. Weighted over lay and combination result = ((factor 1* weight 1) + (factor 2* weight 2) + (factor 3* weight 3) + (factor 4* weight 4) + (factor 5* weight 5).

4.7.2 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 2003. Masking layer identifies those cells within the analysis extent that will be considered when running analysis tool.

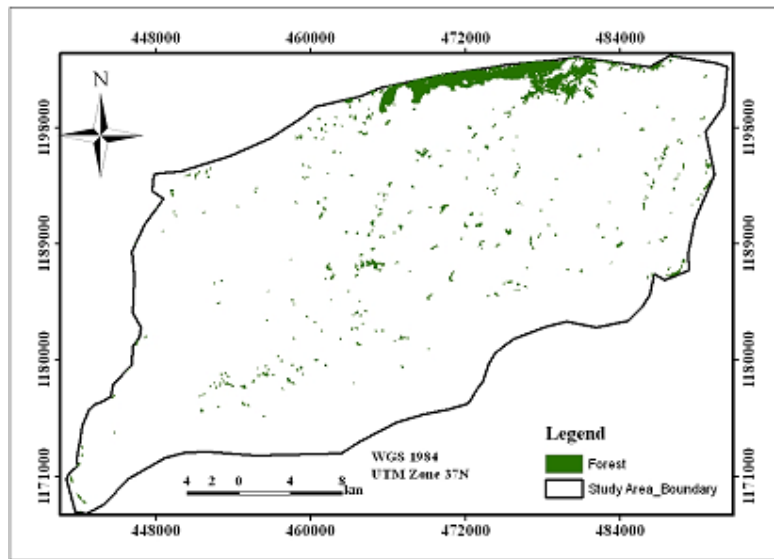


Figure 4.13: Forest cover map of year 2003.

4.7.2.1 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. The output slope dataset of high values ($30-67^{\circ}$), shaded with red color on the map represents steep slope areas. On the contrary, the yellow color shading areas depicts those areas having relatively gentle gradient less than 10° as shown in (Figure 4.14).

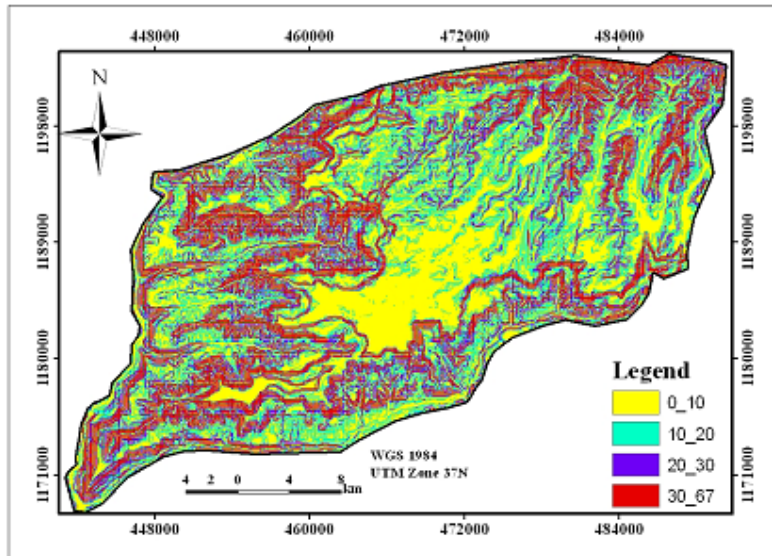


Figure 4.14: Slope value of the study area

The slope has been set in to four classes .These classes have then been reclassified by assigning values ranging from 1 to 4 using year 2003 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 4.15) and these areas are relatively difficult to intervene.

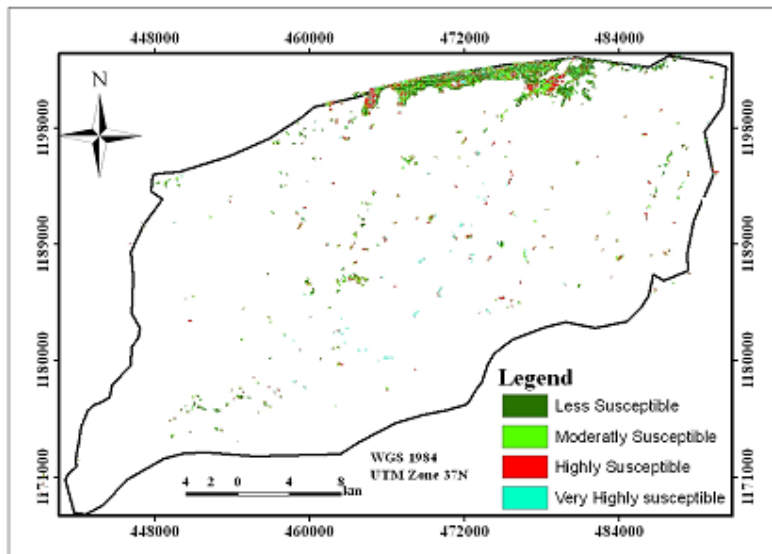


Figure 4.15: Reclassified slope factor using forest cover.

4.7.2.2 Cultivated land proximity dataset

The Cultivated land category map was generated independently from the year 2003 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.

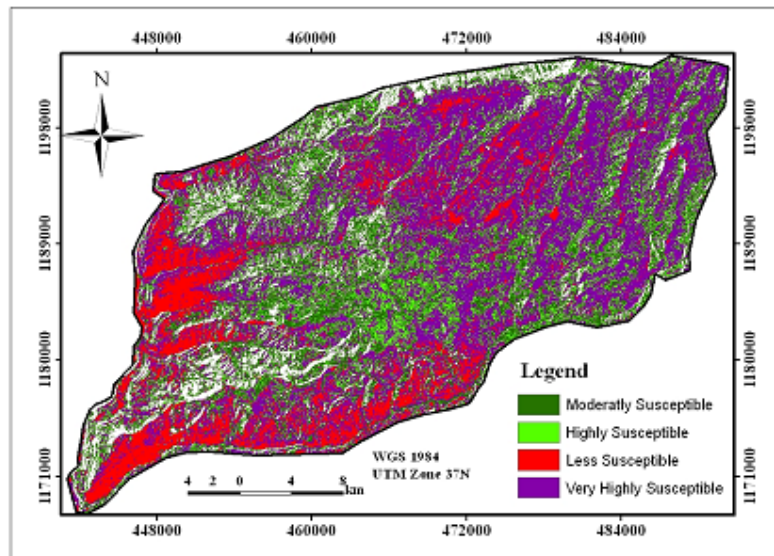


Figure 4.16: Reclassified cultivated land factor using forest cover

4.7.2.3 Settlement proximity dataset

Vegetation nearby a settlement whether it is urban or rural is most likely to be over exploited, like most parts of Ethiopia, people living in Borena district 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 forty five 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 4.17).

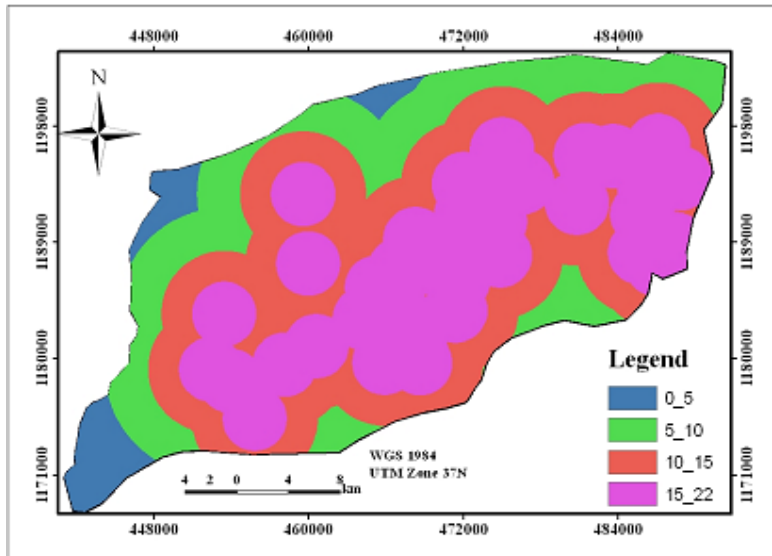


Figure 4.17: Proximity to settlement in km.

The data set has then been reclassified using forest cover as analysis masking layer to a common scale ranging from 1 to 4 in accordance with their contribution to the vegetation vulnerability as presented in (Figure 4.18) 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.

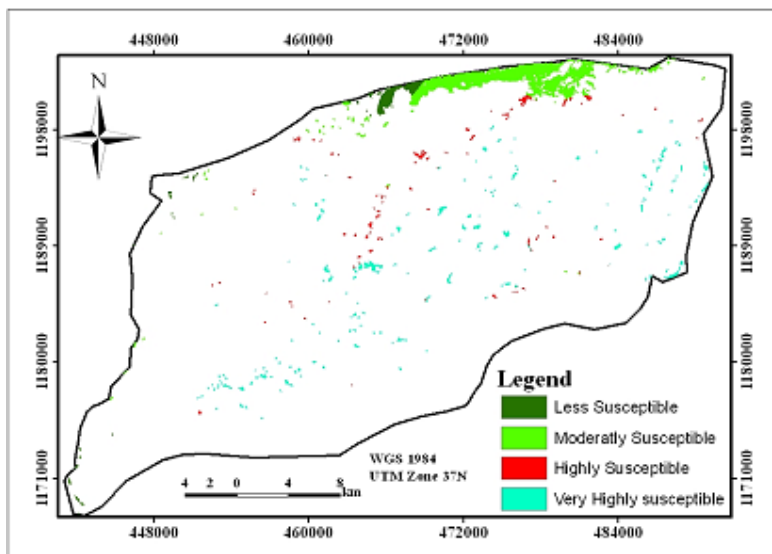


Figure 4.18: Reclassified settlement factor using forest cover.

4.7.2.4 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 4.19). 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.

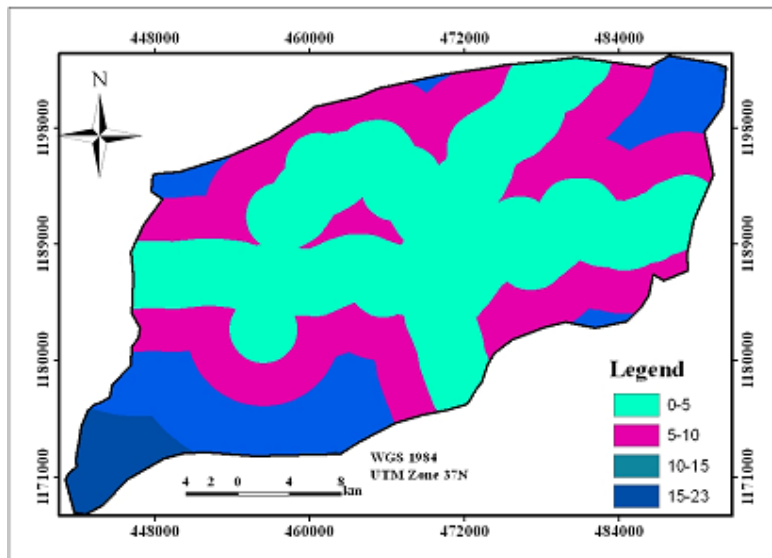


Figure 4.19: Proximity to roads in (Km).

From the reclassified road proximity dataset (Figure 4.20), forest cover areas having low distance value from road network location are highly susceptible to degradation than those located far away from road networks.

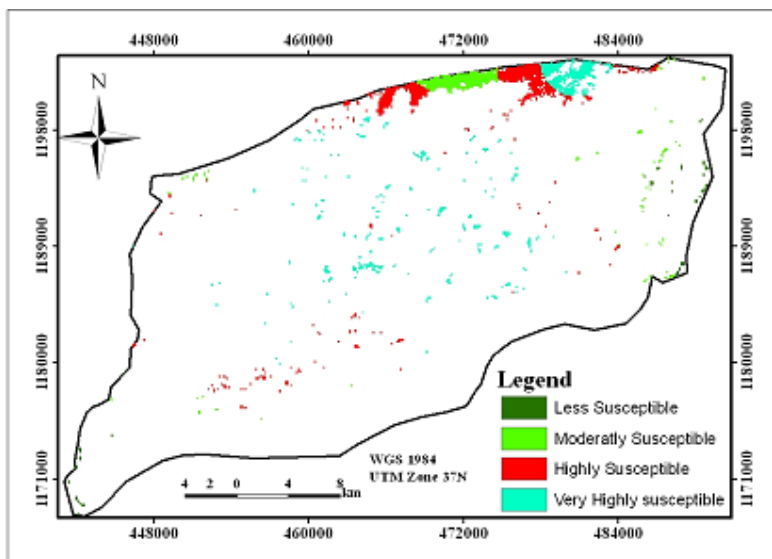


Figure4.20: Reclassified road proximity factor using forest cover.

4.7.2.5 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 lower elevation are very highly susceptible than those forest cover areas found at higher altitude.

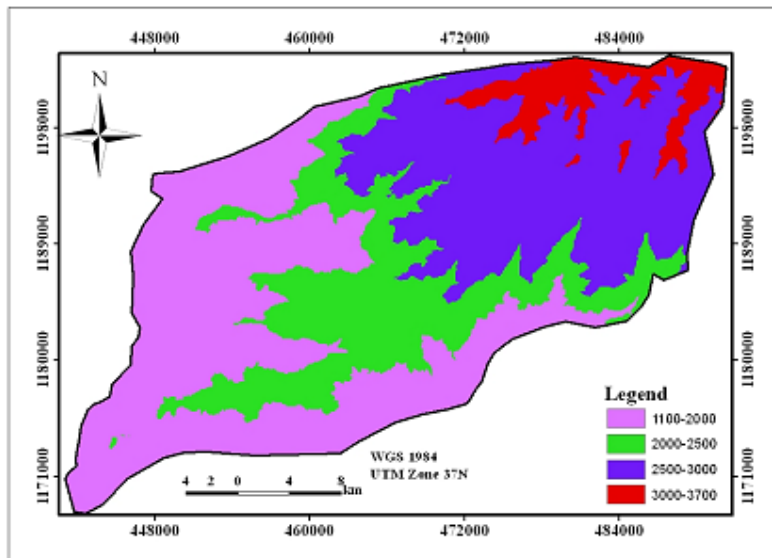


Figure 4.21: Reclassified elevation value in meter.

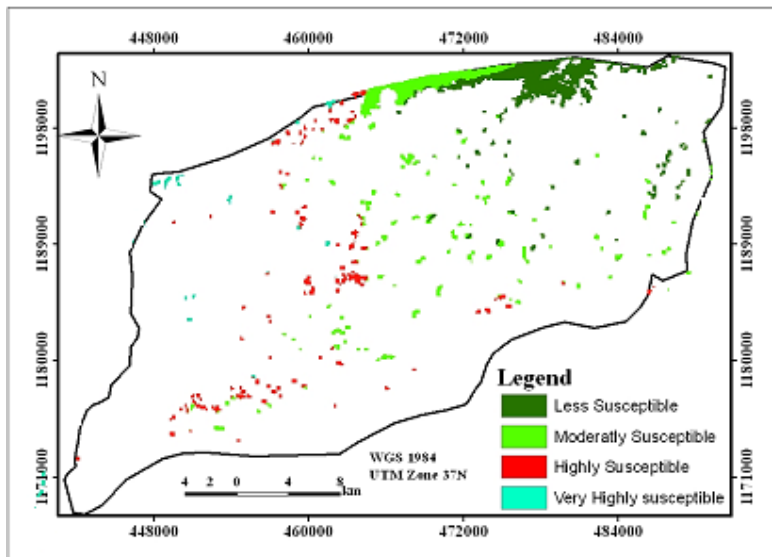


Figure 4.22: Reclassified elevation value factor using forest cover.

4.7.3 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 the other factor. The larger the weight the more important is the factor in overall usefulness. The various comparisons indicated that highest weight is given to proximity to agricultural land) followed by Settlement proximity, road proximity, and slope and elevation value dataset. The final combined result gives susceptibility to forest degradation maps of the study area. Based on the pair wise comparison method, the Eigen vector ratio matrix of the weight is calculated for all layers as shown in (Figure 4.23).

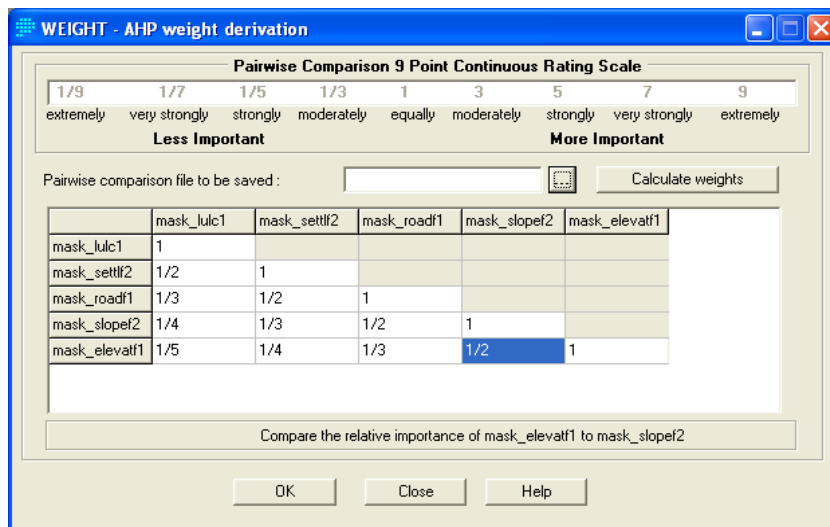


Figure 4.23: Weight of factors that aggravates forest degradation process in the study area.

Table 4.8: Eigenvector ratio matrix that gives weight for each factor.

Factor Maps	The eigenvector of weights
Land use Management	0.4185
Settlement	0.2625
Roads	0.1599
Slope	0.0973
Elevation	0.0618
Total	100

4.7.4 Multi criteria evaluation

After over laying and combining the entire reclassified and weighted maps, the weighted over lay analysis technique was processed and forest compartment with four level of susceptibility to degradation map was generated. The four categories are very highly susceptible, highly susceptible, moderately susceptible and less susceptible as shown in (Figure 4.24).

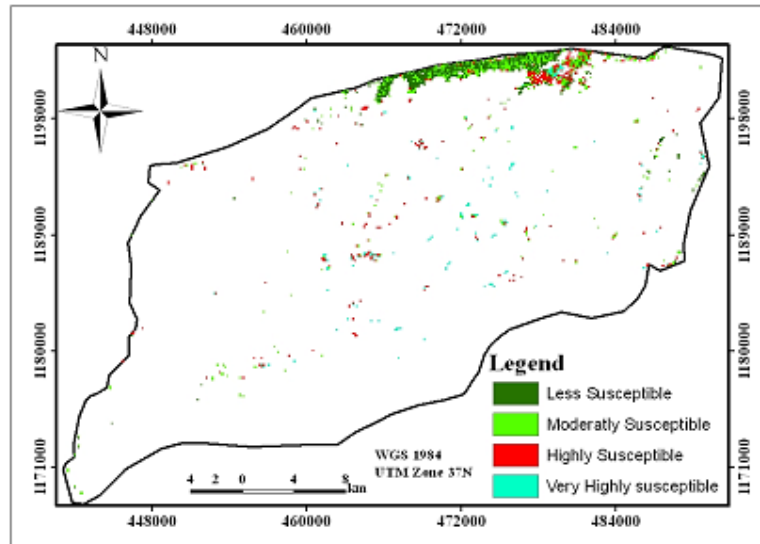


Figure 4.24: Map shows susceptibility to forest degradation

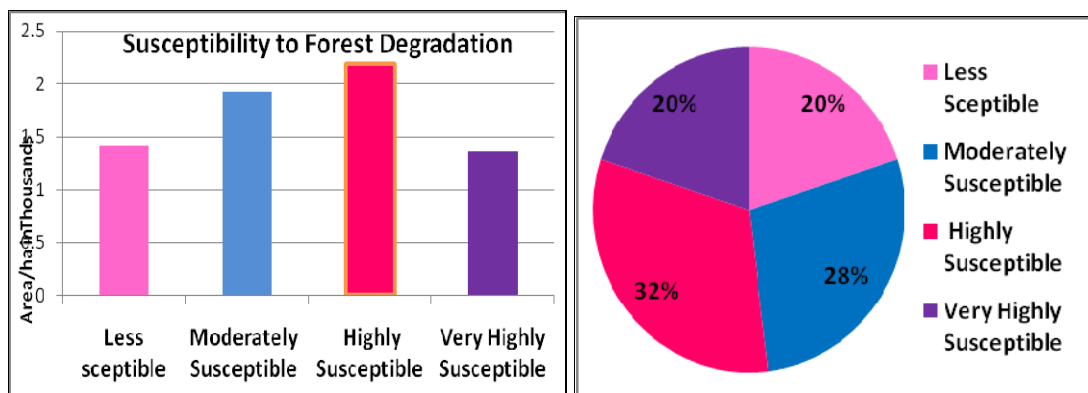


Figure 4.25: depicts aerial and percentage coverage of susceptibility to forest degradation.

As shown in the table above 1413 ha (20%) of the total forest is less Susceptible which is far from population, on the other hand 1931 ha (28%) and 2191 ha (32%) are moderately and highly susceptible, and the rest 1362 ha 20% is very highly susceptible to degradation.

4.8 Causes and impacts of forest cover change in Borena district

4.8.1 Causes of forest cover change

Forest cover change is triggered 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 development. 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 Borena district. All the factors of deforestation such as the prevalence of various types of agricultural activities, fire wood and charcoal production, cutting trees to fulfill the demand of constructional materials, settlement expansion and income generation are directly or indirectly related to population growth. As it has been explained in chapter three, the population of Borena district is almost enlarged from 125,126 in (1994) to 158,920 in (2007) and results in severe deforestation in the study area.

4.8.1.1 Agricultural land expansion

As discussed in the previous sections, the agro ecological condition of the district is convenient for agriculture. Due to this, crop production and livestock rearing is the basic economic activity in the district. Most of the farmers rear livestock and want to maintain large number with little care for their quality. According to the informants, the larger number of cattle population in a given family is both a source of wealth and status. Indeed, this mental attitude is not limited to the study area and is prevalent throughout Ethiopia.

Table 4 .5 indicated that there is an increasing trend of cultivated land from 1972 to 2003. The implication of increased cultivated land in terms of aerial coverage means other land cover/land use units have been converted into cultivated lands. For instance, between 1972 and 1985, about 3,804 ha forest cover land is drastically changed into agricultural lands. In addition to this, according to the views of respondents, the expansion of various types of agricultural activities is the major sources of forest cover change in the study area. 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 districts forest cover land is considered to be the major factor for forest cover change in the study area.



Plate 2: Photo graph shows agricultural land expansion towards the forest area

Source: Photo graph taken by the researcher

4.8.1.2 Fire wood and charcoal production

In the rural areas fire wood (collected from the nearby forest areas) and cow dung are the two most important sources of energy. 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 district. 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 district has been causes of deforestation in Borena district.

4.8.1.3 Cutting trees for constructional materials

The demand of forest products for the construction of house and fence has been aggravated the destruction of forest in Borena district .From the respondent's point of view, it was evident that cutting trees to fulfill the demand of constructional material is considered to be the causes of deforestation in the district. Field observation data also indicated that woody biomass was found to be the most important house construction material in the district specially for making doors and windows.

4.8.1.4 Income generation

According to the view of agricultural officers most of the population of the district are poor and exposed for lack of adequate access to basic needs (such as food, clothing and shelter). Therefore selling of wood and wood products are means of income for the poorest people such as jobless youths and women fuel wood carriers who are living in the district. Referring to this, agricultural officers and forestry experts argue that these groups of people illegally cut down trees from the forest area so as to supply large quantity of forest products for urban and rural dwellers through the nearby small markets.

4.8.2 Impacts of forest cover change in Borena district

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 means for soil resources. Despite of all this importance, this resource is deforested unwisely, which results in land degradation, soil erosion, drying up of surface water mainly rivers and deteriorating of bio diversity are the major consequences of deforestation.

4.8.2.1 Land degradation with 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 (Markos and Delnessaw, 1998). 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.

As it has been stated in the previous chapter, the relief feature of Borena district is rugged with wide range of altitudinal variation (ranges from 1200 to 3700m) and it is dissected by many tributaries of Abay river .This rugged nature of topography coupled with removal of vegetations and high amount of summer rain fall results in greater soil erosion.

4.8.2.2 Declining bio diversity

As it has been stated previously, the geographical setting of Borena district has a diverse and conducive ecological condition due to its wide range of altitude and relatively high amount of rain fall. As a result of this, the district was originally the land of many indigenous tree and animal species such as *Juniperus procera*, *Acacia abyssinica*, *Hagenia abyssinica* and different animals like semen fox chilada baboon etc. However, many of the indigenous tree species, are over exploited due to selective cutting, agricultural land expansion and currently confined only in few inaccessible areas like very steep slope and protected areas as shown in (Plate 3.).



Plate 3: Shows remnants of indigenous forest in steep slope areas

Source: photograph taken by the researcher

This clearly shows that the exploitation of indigenous forests through different types of activities greatly affects the biological diversity of Borena district. In Addition, according to the interview made with elders various types of wild animals like semen fox and chilada baboon have been disappeared.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study assessed land use/ land cover change detection and vulnerability to forest degradation of Borena district in the north central highlands of Ethiopia by integrating GIS and remote sensing techniques. The basis of this research comprises multi-temporal classification of Landsat satellite imageries to detect, delineate, and map land cover change between 1972 to 1985 and 1985 to 2003.

Based on the analysis of the Landsat images as an input data, generally about five land use land cover classes were identified. These include agricultural land, forest land, shrub or bush land, grass land and bare land.

The shrub land and forest land which apparently constituted the climax vegetation of the region, and accounted for 35% and 13% of the District in 1972, declined to 24% and 10% in 1985 and further dropped to 17% and 6% in the year 2003 respectively. These figures suggest that shrub land and forest land were disappearing at the rate of 863 and 380 ha per year between 1972 to 1985, and 292 and 206 ha per year from 1985 to 2003, respectively, thus resulting in severe degradation of the natural vegetation cover of the area. The extensive destruction of the shrub land and forest land is attributed to the expansion of agricultural land and increased demand for fuel wood in the study area. Whereas agricultural land and bare land accounted for 32% and 5% of the study area in 1972, and increased to 44% and 8% in 1985 and further increased to 49% and 9% in 2003 with a rate of 999 and 256 ha from 1972 to 1985 and 339 and 53 ha between 1985 to 2003. But grass land decreased from 16% in 1972 to 15% in 1985 at a rate of 74 ha and then increased from 15% to 19% with a rate of 223 ha at the expense of shrub land and forest land.

Based on Post classification comparisons, All Vegetation type covers are generally decreased with accelerated rate of change except grass land cover between 1985 and 2003 and results in a dramatic increase of agricultural land as the expense of vegetation degradation particularly shrub lands and forests in all the periods from 1972 to 2003 with a

dramatic expansion of agricultural land between 1972 to 1985 particularly during the transition period.

In the mean time, forest cover compartment with four levels of susceptibility to forest degradation was generated based on the year 2003 forest cover map. The computed quantitative data revealed that from the total forest cover condition of the year 2003 (6087 ha) about 1413 ha (20%) of forest cover land is categorized under less susceptible to degradation. On the other hand, 1931 ha (28%), 2191 ha (32%) and 1362 ha (20%) of forest cover lands are considered to be moderately, highly and very highly susceptible to degradation respectively.

Finally, non quantifiable socio economic data were identified about the major causes and consequences of forest cover change in Borena district. 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 and built up areas along the margin and even inside the forest areas. As a result, the problem of forest degradation with other related factors has aggravated land degradation with soil erosion and deterioration of biodiversity in Borena district.

In general, findings of this study show that the study area has been under continual land use /land cover changes since 1972. Deforestation due to population growth and the associated expansion of farming and increasing demand for resources are imposing threat on the biodiversity of the area. The findings of the land use land cover analysis can have a paramount importance in natural resource management and land use planning in the context of resource allocation decisions.

5.2 Recommendation

Remote sensing images are very important for land use land cover classification and generation of up to date information about the earth's features. Therefore, it should be used in natural resource management (NRM) as they are powerful tools that provide managers and policy makers with technical support to planning and decision making.

- ✚ Creating awareness among the society concerning optimum use of natural resources, conservation systems and their benefits by policy makers and NGOs could play significant role in rehabilitation of the environment.
- ✚ Continuing the current efforts of introducing family planning to make the people aware of consequences of population pressure should be carried out intensively.
- ✚ Jobless youths and women fuel wood carriers who are engaged in illegal tree cutting and harvesting activities should be educated about the economic and ecological value of the forests as well as the consequences of deforestation.
- ✚ Controlling agricultural expansion through appropriate legislation such as land use plan.
- ✚ Core areas should be identified and protected with special management emphasis.
- ✚ Reforestation of trees in the degraded areas should be facilitated in order to rehabilitate the environment.
- ✚ The vegetation vulnerability map can assist in policy decisions during a land use planning as it shows the environmental risk zone of vegetation degradation, therefore local planners and policy makers should make use of risk zone model outputs as a decision support.

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Annex 1: Ground control points

LU/LC Types	X	Y
Agricultural Land	466870	1183311
Agricultural Land	465467	1185651
Agricultural Land	468809	1185918
Agricultural Land	458648	1185985
Agricultural Land	462375	1179768
Agricultural Land	468784	1198284
Agricultural Land	470747	1189996
Agricultural Land	465600	1197750
Agricultural Land	461122	1193739
Agricultural Land	481643	1191065
Forest Land	468413	1201093
Forest Land	469996	1201821
Forest Land	473504	1202120
Forest Land	475857	1202420
Forest Land	477825	1202805
Forest Land	480221	1201008
Forest Land	465064	1187351
Forest Land	470268	1191732
Forest Land	475409	1189918
Forest Land	472921	1190514
Shrub Land	479953	1202836
Shrub Land	483752	1202699
Shrub Land	466605	1200235
Shrub Land	469970	1190686
Shrub Land	463046	1190138
Shrub Land	479440	1185364
Shrub Land	456872	1183926
Shrub Land	458139	1187691
Shrub Land	452670	1119166

Shrub Land	457830	1179283
Grass Land	477703	1199617
Grass Land	477292	1199275
Grass Land	477771	1196058
Grass Land	480441	1195270
Grass Land	478935	1191471
Grass Land	473870	1191061
Grass Land	473664	1193730
Grass Land	469147	1189315
Grass Land	456137	1176682
Grass Land	455827	1175926
Bare Land	449118	1184520
Bare Land	450590	1184349
Bare Land	450575	1185889
Bare Land	452712	1187703
Bare Land	447031	1172644
Bare Land	452541	1173842
Bare Land	465855	1176682
Bare Land	470975	1190954
Bare Land	475766	1198039
Bare Land	473576	1190954

Annex 2: Interview Questions

1. Do you think that, deforestation is the major problem in your locality?
2. How do you see today's forest cover compared to the conditions before 1973?
A. Declined B. Increased C. No change
3. If your answer is (A) for question number two what are the major causes for deforestation?
4. What are the major consequences 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, Slope Value_____ B. Elevation value_____
- C. Road proximity _____ D. Settlement proximity_____
- E. Cultivated land Proximity_____

DECLARATION

I, the undersigned, declare that this thesis is my original work and has not been presented for any degree in any university and all the sources of materials used for the thesis have been duly acknowledged.

Name: Alelign Dessalew Faris

Signature: _____

This thesis has been submitted for examination with their approval as University advisors.

Name: Dr. Mohammed Umer

Signature _____

Date and place of submission; Department of Earth science

Addis Ababa University

JUNE, 2009