DEPARTMENT OF EARTH SCIENCES
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REMOTE SENSING AND GIS TECHNIQUES IN LAND USE LAND COVER MAPPING AND CHANGE DETECTION IN THE MAIN ETHIOPIAN RIFT (MER) BETWEEN KOKA AND ZIWAY

BY

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A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in GIS and Remote Sensing.

JULY 2005.

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MSS .... Multi Spectral Scanner

NGO ...... Non Governmental Organization

PA.......... Peasant Association

PCA .... Principal Component Analysis

RGB....... Red Green Blue

RMS....... Root Mean Square

ROI .... Region of Interest

TM .... Thematic Mapped

URL .... Uniform Resource Locator

UTM ...... Universal Transverse Mercator

Names of organization

CSA .... Central Statistics Authority

EMA ...... Ethiopian Mapping Authority

NMSA.... National Meteorological Services Agency

OBPED........ Oromiya Bureau of Planning and Economic Development

ABSTRACT

Land use/land cover change investigation of the study area between 1973 and 2002/5 was conducted using remote sensing and geographic information system (GIS) controlled by ground truthing. The study area is about 560km^2 located in the main Ethiopian rift (MER) with in the Orommia Regional Government state and can represent mountain degradation of the rift valley of Ethiopian

The research was conducted with the objective of creation of historical and the current LULC maps and LULC change map of 1973-2002/5. The maps were derived utilizing standardized digital remote sensing classification techniques using three multitemporal Landsat scenes acquired on Jan 30, 1973(MSS), Jan 21, 1986 (TM), and Feb 30, 2002 (ETM+). Classification accuracy was determined to be sufficient by means of employing standardized accuracy assessment measures.

According to the statistics calculated from the land use and land cover change data between the 1973 and 2002/5, the intensively cultivated and Urban lands have been expanded by 18710 ha and 555 ha which is 128.43% and 411.11% increase respectively. On the other hand, the wooded cultivated/grass land, the shrub grass land, the wet land and water bodies show decrease by 14779 ha (58.86%), 4478 ha (64.46%), 432 ha (7.98%), 229 ha (6.05%) respectively. The degraded shrub Grass Land also showed an increase by 518 ha (386.57%) between 1986 and 2002/5.

The population growth was certainly the most important factor causing the observed land cover change because of the increase of demand of land for cultivation, settlement and trees for fuel and construction purpose. As a result, large areas, which were once under wood and shrub cover, are now exposed and affected by sheet and rill erosion which in turn resulted in formation of big gullies and hence loss of farmlands.

If current trends are allowed to continue damage to the natural resource base will continue and land lost due sheet and gully erosion will increase. The increase in run off and low water retention due to low land cover further intensify the sheet erosion and rill and gullies to

widen and deepen which therefore degrade the agricultural land more than the present condition. The sediments removed are channeled to the lakes and cause sedimentation and pollution. The increase in the length and depth of the gullies associated with the rugged topography, nature of the soil , low vegetation cover of the area, together with the rainfall that come after a long dry period might cause serious land slide which is observed by soil fall occurring in the area.

Introducing alternative energy sources such as biogas should be encouraged to reduce dependency on natural vegetation for fuel. On the other hand, Planting of trees individually or in group in the mountainous areas and in the areas which are degraded so that out of usage for agriculture will add to the rehabilitation process and also satisfy need of wood for fuel, construction and could compensate for low coverage of woodland and at the same time reduce erosion currently affecting the environment.

Educating the society concerning optimum use of natural recourses, conservation systems and their benefits and continuing the current efforts of introducing family planning to make the people aware of consequences of population pressure should be carried out intensively.

CHAPTER ONE

INTRODUCTION

1.1. Background Information

There are few landscapes left behind on the Earth's surface that have not been extensively altered or are not being altered by humans in some manner. Presence of human being on the Earth and his adjustment of the landscape have had a profound effect upon the natural environment. These influences on changing patterns of land use are a primary component of many current environmental concerns as land use and land cover change is gaining recognition as a key driver of environmental degradation. Changes in land use and land cover are pervasive, increasingly rapid, and can have adverse impacts and implications at local, regional and global scales. But effects are felt in the developing countries than developed countries because of high population growth rate and associated raped depletion of natural recourses (Wilson, 1992).

Ethiopia is one of the most environmentally troubled countries in the Shale belt. The principal environmental problem in Ethiopia is land degradation in the form of soil erosion, gully formation, soil fertility loss and severe soil moisture stress, which is partly the result of loss in soil depth and organic matter. (Fitsum Hagos, et al. 2002)

Currently, little of the natural vegetation remains in the highlands, existing in only small patches in the southern and south-western parts of the country. In Ethiopia, annual loss of natural forest cover, mainly for agriculture, has been estimated at 150,000 to 200,000 hectares per year. (EFAP,1993)

Oromiya region's topography consists of a high and rugged central plateau and the peripheral lowlands. Elevations in the region range from less than 500 to over 4300 meters above sea level (masl). The highlands (>1500 masl) constitute about 48% of the region's total area while areas between 1000 to 1500 masl constitute 38% (OBPED 1997a). The highlands are home to more than 80% of the total human population and

70% of the livestock population of the region and account for over 90% of the cropland. Almost 90% of the region's economic activities are concentrated in the highlands.

Berhanu (1998a) has indicated that, Oromiya region has predominantly an agrarian economy where agriculture accounts for about 70% regional GDP and 92.2% of employment. The region accounts for about 51% of the total major crop production in Ethiopia and is considered the source of the country's agricultural surplus. In addition, Bezuayehu Tefera et al. (2002) has indicated that the soil degradation in the northern highlands forced the people to move southwards, particularly to the Oromiya highlands. This situation is still putting pressure on the highlands of the region. Increased demand for trees/forests for construction and fuel, and expansion of farmlands to steep and marginal areas.

The conversion of woodlands and shrub lands into croplands has resulted in loss of the natural vegetation cover and has caused severe soil erosion (Mc Dougall et al., 1975; and Virgo and Munro, 1977). Feoli (2002) recommended that the state of the resource base of the Ethiopian rural system should be examined in relation to population pressure by integrating environmental protection strategies with development strategies and their implementation.

Land needs to be used to fulfill the day to day demand of the population by increasing production. On the other hand, environment, biodiversity, and local climate systems should not be affected and changed to a situation that may not be recovered. Therefore, both conditions should be satisfied with one of them not affecting the other. As a result, having detailed and in-depth knowledge of the potentials and limitations of the present land uses and their impact on the environment is unquestionable. That is why availability of reliable land cover and land use data for sustainable management of the earth's natural resources was emphasized at the UN conference, known as the "Earth Summit", which took place in Rio de Janeiro in 1992 and Johannesburg in 2002.

The management and rehabilitation of natural resources needs sufficient data collection and detail analysis to identify the factors and propos appropriate methodologies that

5. In addition, it seems that the area is undergoing climatic changes and affected by expansion of desert.

Therefore, this research will address relevant issues on Land Use and Land Cover changes and its impacts and try to provide recommendations which may contribute to the rehabilitation of the environments.

1.3. Objectives of the Research

By utilizing remote sensing technologies and implementing GIS mapping techniques, land use and land cover change of designated areas can be monitored and mapped. The dynamics of conversion of wooded cultivated/grass and shrub grass lands to intensively cultivated land as well as its spatial distribution and patterns are the primary focus of this research. The principal objective is to detect, delineate, and map areas that have experienced land use and land cover change in the specified area over the three decade time period of 1973 - 2005 utilizing multi-temporal Landsat satellite imagery.

1.3.1. General Objectives

- Creation of land use and land cover maps for the years 1973, 1986 and 2005 as well as a land use and land cover change map(1973 – 2005)

1.3.2. Specific Objectives

- To produce digital land use / land cover map, creating spatial data base which will be part of future regional/national land cover database.
- Land cover change detection over the past 30 years in the specified area (1973 -2005) and quantifying the change and rate of change.
- Recommend appropriate land use rehabilitation that has to be made in the study area.

1.4. Expected Outputs of the Research

- Quantify the extent of Land Use and Land Cover change for the study area.

- The Final output data will be available as digital map and associated spatial data base that will be part of the future national and/or regional Land cover data base and can bee used for governmental and/or Non-governmental organizations engaged in practical implementation and/or further scientific research work.
- Industrial framings currently growing in the area can get land management information and availability of recourses.
- Predict what will happen in the future if current land use systems and population trends continue for the study area
- The research will add considerable Contribution to the benefit of the region in the natural resource development and rehabilitation.

1.5. Methodology and Materials

This research addresses land use and land cover changes over 30 year period, between 1973 & 2005. The dynamics of conversion of wooded cultivated/grass and shrub grass lands to intensively cultivated land as well as its spatial distribution and patterns are the primary focus of this research.

To meet the objectives of the research three sets of satellite images described below are collected.

No.	Sensor	Path-Row		Date of Acquisition
1	MSS	180-54	Landsat 1	1/30/73
2	MSS	181-54	Ladsat 1	1/30/73
3	TM	168-54	Landsat 5	1/21/86
4	ETM+	168-54	Landsat 7	2/26/02

Table 1. Description of Satellite Images used in this study.

Other ancillary data considered important for this research were, topological map, soil map, human and livestock population data, meteorological data (monthly mean Min and Max temperature, and monthly total rain fall) and arial photographs were collected form governmental and non governmental organizations.

Four topological maps of scale 1:50,000 and 42 Arial photographs of the area were collected from Ethiopian Map Authority (EMA). Human and Livestock population reports of the two weredas (Ziway Dugda and Dugda Bora) and the meteorological data were collected from Central Statistics Authority (CSA) and the National Meteorological Services Agency (NMSA) respectively. In addition, human and livestock data applicable at wereda level were obtained from a project called woody biomass. Soil map of 1:250 ,000 scales is obtained from Addis Ababa University department of Earth sciences.

The topographic map is used to obtain layers of roads, drainage pattern, water bodies, study area boundary etc and the soil map is used to obtain layer of soil map by digitizing using digitizing table. In addition ground control points (GCPs) used for geo-referencing of satellite image was obtained from the topographic maps. The software employed for digitizing is Cartalinx version 1.04. All the above data were attributed and exported to ArcView GIS 3.2 for further analysis. The population and metrological data, collected in hardcopies, were entered to personal computer using the spreadsheet software, Excel 2000. In addition, literatures were reviewed and discussed with concerned peoples.

The other component of the methodology is ground truthing. It is done using Global Positioning System (GPS). The following flow charts will describe the methodology and materials involved and the procedures followed during the Land Use and Land Cover map production, change detection analysis and finally to come up with land use/cover change map.

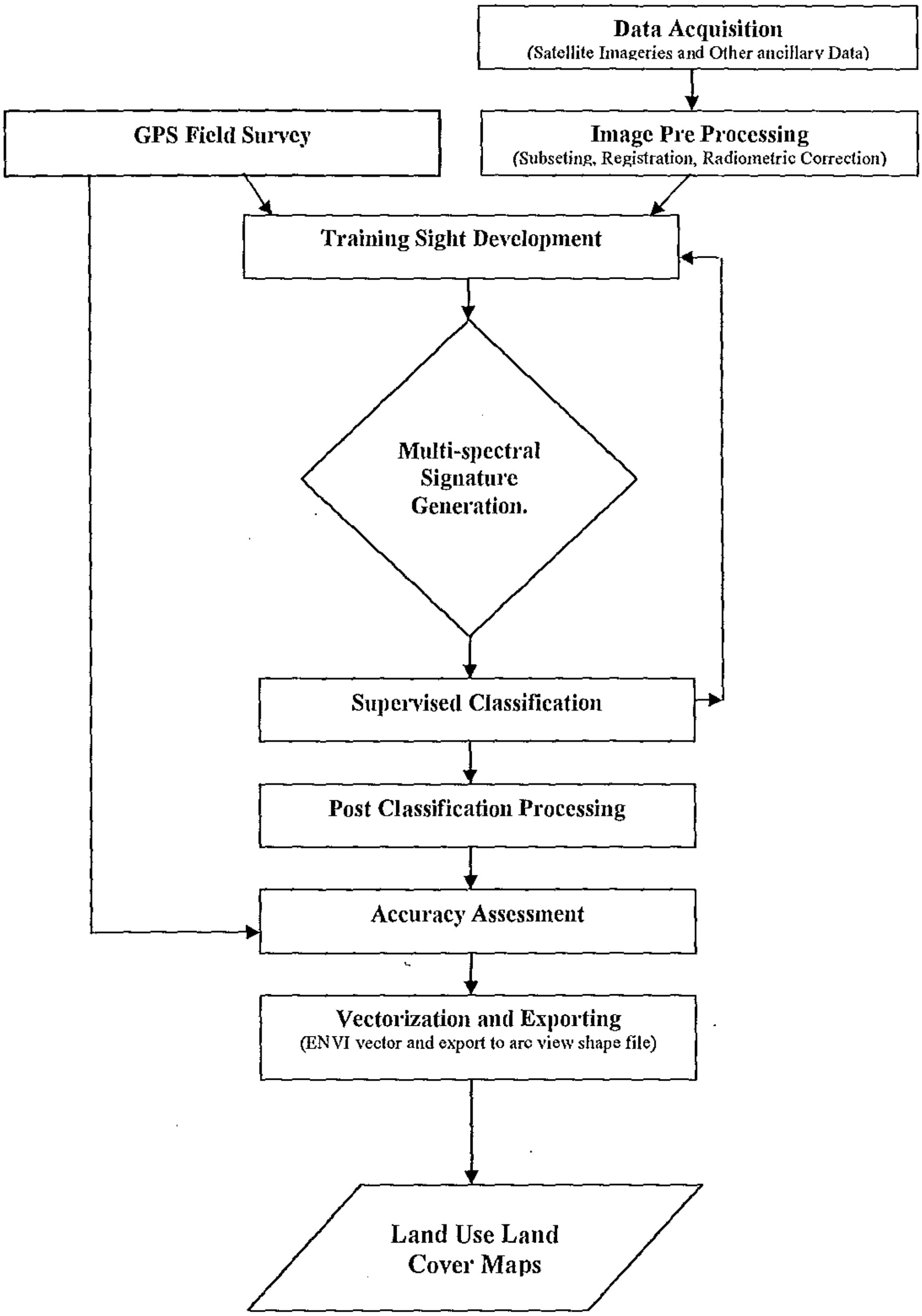


Figure 1. Land Use / Land Cover Map production Procedural Flow Chart

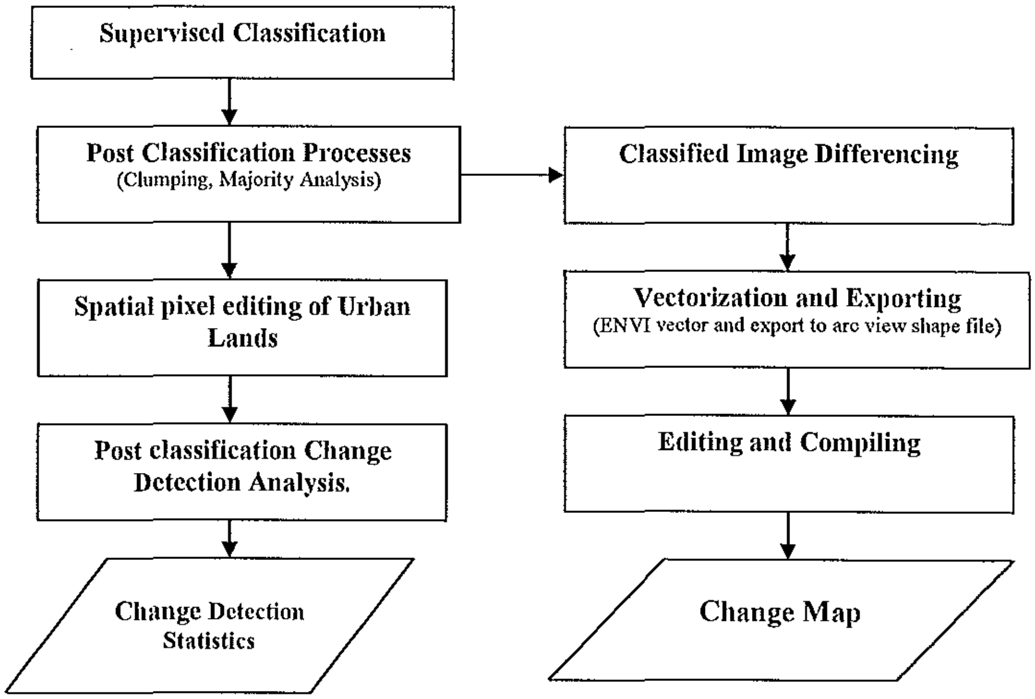


Figure 2. Land Use / Land Cover Change analysis and change map production Procedural Flow Chart

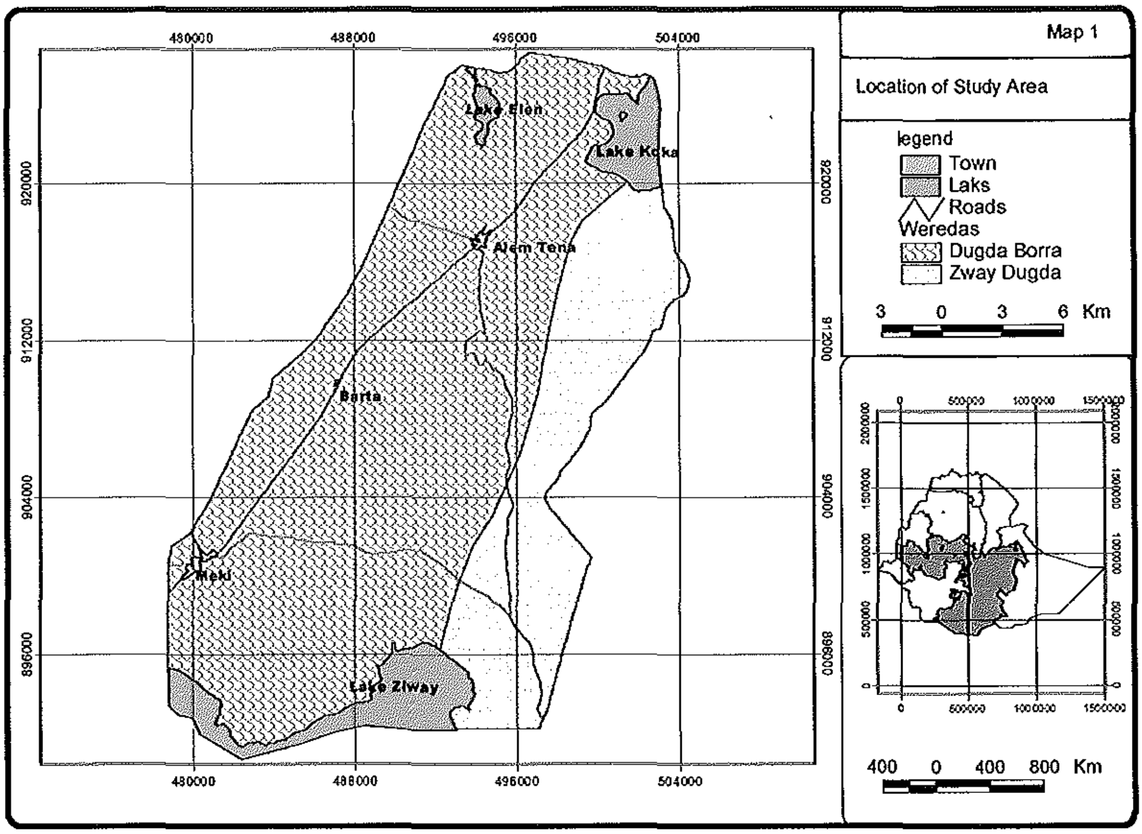
CHAPTER TWO

THE STUDY AREA

2.1. Description of the Study Area

2.1.1. Location

The study area is about 560km^2 located in the maim Ethiopian rift (MER) with in the Orommia Regional Government state 80km to 150km south of Addis Ababa. It falls in two weredas of the region namely Ziway Dugda in the East and Dggda Bora in west part located with in Arsi and East Shewa zones respectively.(Map. 1)



Map 1. **Location of the Study Area**

2.1.2. Topography, Geology and Soil

The topography of the central part of the rift is characterized by intensively faulted blocks with steep scarps forming local graben structure. Long and relatively narrow(1-5m) extension fractures(Tesfaye Korme et al.,1997) Breceaited lava flows, Lava domes, cinder cones, craters and calderas are the most notable features. The wide belts stretching from the north rift margin to the lakes in the valley bottom, the Fault scarps are connected by gentle slop. The altitude ranges between 1600m to 2280m above sea level (amsl) where the peak is Mount Bora. (2280m amsl).

Except the narrow belts around the lakes which are covered by lacustrine deposits the entire area is covered by quaternary volcanic rocks (Tuffs, Ash, ignimbrites, and lava flow) susceptible to land degradation processes and desertification risk and the area is characterized by the soil types such as vertisol, Andosol, Cambisol, Fluvisol and Liptosol, which are broadly related to their parent material and eco-climatic zones within which the soils are most commonly found.

2.1.3. Climate

Inter-tropical Convergence Zone (ITCZ), the northeast trade winds, and the southwest monsoons are the main air mass circulations that cause different seasons in Ethiopia. The inter-annual oscillation of the surface position of the ITCZ causes variations in the wind flow patterns in Ethiopia. In its oscillation to the north and south of equator, the ITCZ passes over Ethiopia twice a year and this migration alternatively causes the onset and withdrawals of winds from north and south. As it drifts towards the north, equatorial jet streams from the south and southwest invade most parts of Ethiopia while the Trade Winds retreat. Its southward drift marks the onset of Trade Winds from the north and causes the equatorial monsoons to retreat. This periodical anomaly of winds causes rainfall to be variable and seasonal in Ethiopia. (EMA, 1981).

The weather data reported here is based on information from National Meteorological Services Agency (NMSA) taken from the nearest stations around the study area.

Rainfall shows large seasonal variability. Small rain occurs from March to May and the main rain season is from June to September. (Figure.3)

The study area presents semiarid climate with mean annual precipitation ranging between 600-800 mm. The major rainy season extends from June to September when the ITCZ is to the north of Ethiopia, and covers all parts of the study area. Reliability of rainfall is important in the area because the livelihood for the population is mainly based on rain-fed agriculture.

Even though there are two seasons of rain, it is the main rain season (June to September) used for crop production. The other rain season (March to May) is not used for crop production but important to grow grasses and preparation of the land for the next farming.

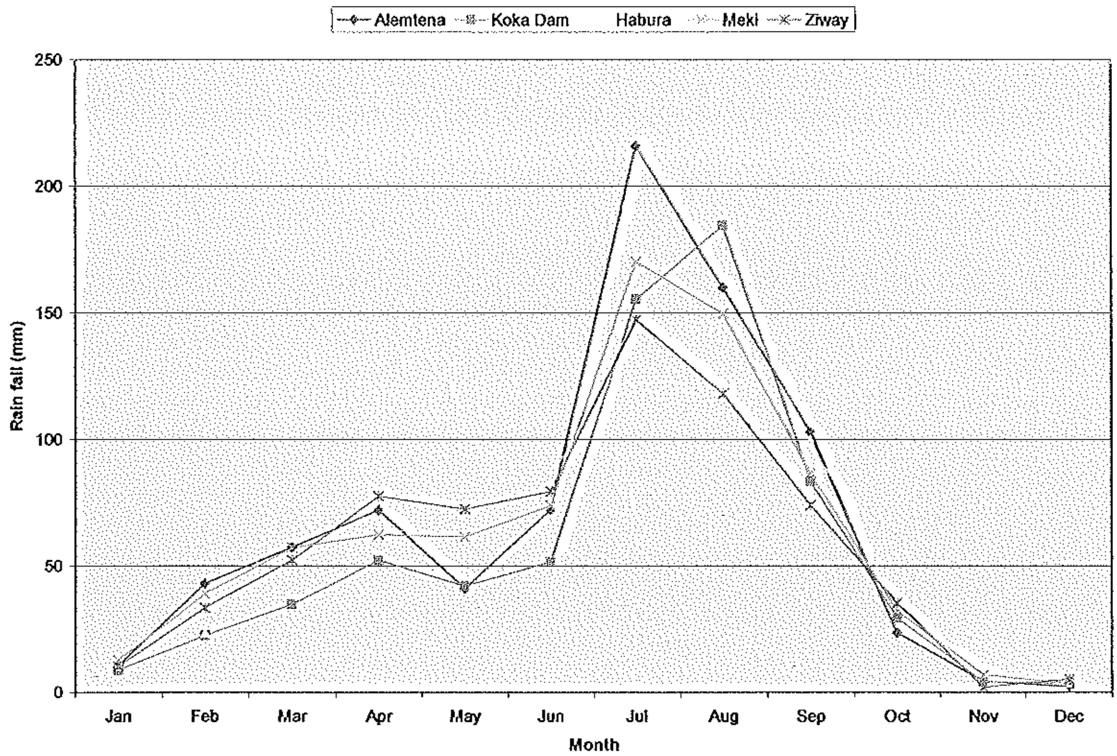


Figure 3. Seasonality Analysis of Rain in the Study Area (1965-2003)

The long-term (1970-2003) yearly average mean monthly minimum and maximum temperature over four different stations within and around the study area indicate that both the yearly average mean monthly minimum and yearly average mean monthly maximum temperature are increasing. (Figure. 4 & 5) while the rain fall is variable.

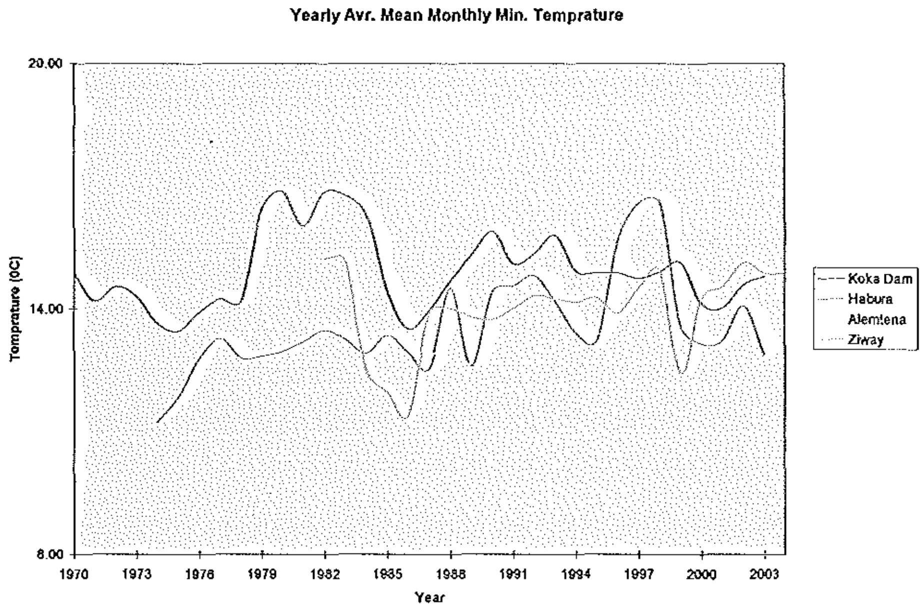


Figure 4. **Year Wise Monthly Mean Minimum Temperature Record of Stations.**

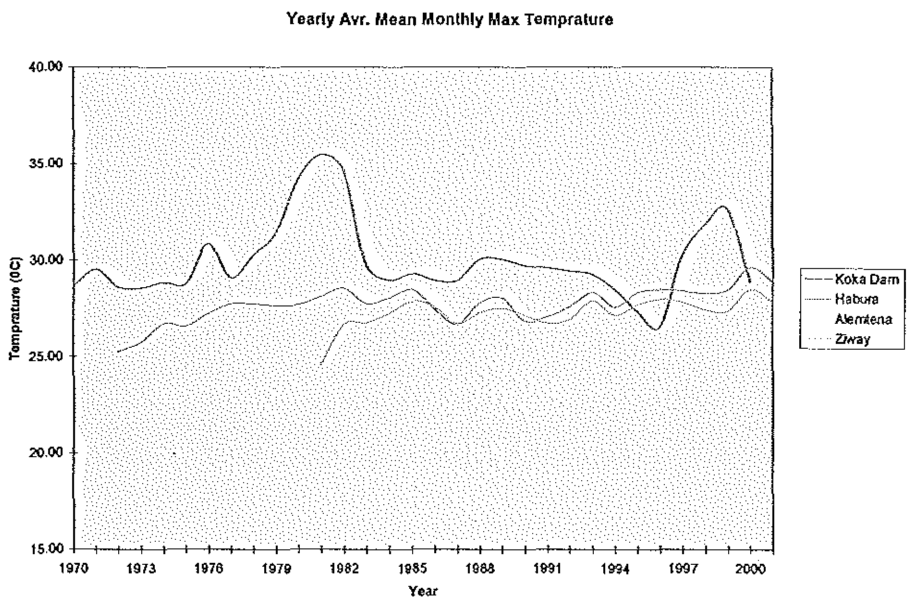


Figure 5. Year Wise Monthly Mean Maximum Temperature Record of Stations.

2.1.4. *Water Resources*

The drainage system of the study area fall with in the two national basins namely Awash and Zeway-Shala containing number of perennial and intermittent streams. In addition, it contains many known lakes of the rift valley including Lake Ziway, Lake Koka, and Lake Elen. There are also Seasonal water bodies in different part the study area that drains water from the high land during the rainy season and used as source of water for livestock and even as drinking water of local peoples. Awash and Meki rivers are the two important rivers that fall in the study area. The area also characterized by high ground water Potential (M J Makin et al. 1976, Bezuayehu Tefera et al., 2002). The above mentioned lakes and river are important source of irrigation water that many farmers depend on for growing different vegetables.

2.1.5. *Socio Economic Activities*

The socioeconomic activities of an area play an important role on the land use land cover type of the area. In relation to this, economy of the study area is based on primary productions such as crop farming and animal husbandry, which indicate the agrarian background. According to Berhanu et al. (1998a), it is included under the mixed crop–livestock farming system of production. The mixed crop–livestock farming system can be further divided into four sub production systems among which the mixed cereal–livestock production subsystem is the characteristic of the study area and have implications for how the land resource is used and the resulting effects on Land cover change.

Concerning rural infrastructure, all the towns are accessible by the asphalt road from Addis Ababa to Awasa and there are several all weather and dry weather roads as well as numerous interconnected footpaths for easy access during field visiting activities

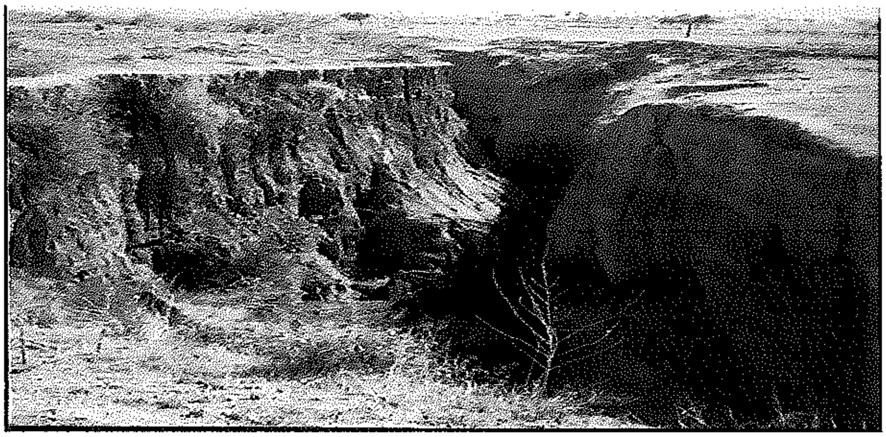
As it is observed during ground truthing, other social services such as health centers, clinics, schools etc are growing in many urban and rural settlement areas but modern industrialization and establishing of factories is vary much limited.

2.2. *Soil Erosion*

The eastern part of the study area which its most part is with in Dugra Bora wereda, is high lands (altitude reaching 2280m amsl-Mount Bora and 2252m amsl mount Baricha) characterized by rugged topography, and poor vegetative cover. During rainy seasons, large amount of water is carried down the slope towards the lakes (Lake Ziway and Lake Koka) and seasonal water bodies eroding the less vegetated highlands, the cultivated land and the surrounding as sheet and rill erosion and then forming vary long, large and deep gullies (2-50 m t width, 3-20 m depth) toward the mouth where they join the lakes and/or seasonal water bodies. (Figure 6 & 7)

Oromiya region's topography consists of high altitudes and rugged landscapes, as described earlier. The rugged topography and steep slopes affect soil erosion rate through its morphological characteristics. Two of these, namely gradient and slope length, are essential components in quantitative relationships for estimating soil loss (Wischmeier and Smith 1978).Erosion increases dramatically because the increased angle facilitates water flow and soil movement. It is not surprising, therefore, that areas like the Charchar highlands in Hararghe, MartiJaju areas in Arsi, central Shewa etc. suffer some of the region's highest erosion rates.

(a)



(b)

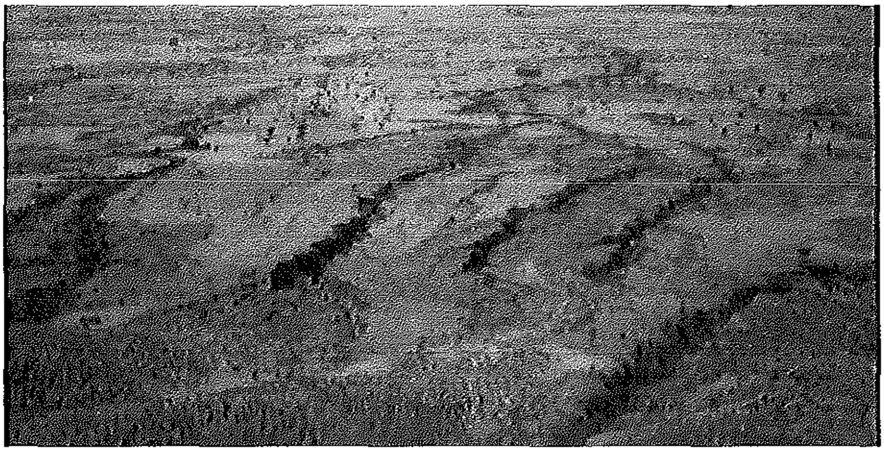


Figure 6. (a) A Gully (b) Net-work of Gullies taken from top a mountain with intensively cultivated land in between (b)

In addition to damaging the cultivated lands and affecting productivity, ease of access to many of the Peasant associations (PA) namely; Suti, Tubi Ilala and Babey, is extremely difficult because of the extended, vary large and deep valleys formed by gully erosion. As peasants of the area say, this problem is more severe in the rainy season. As this is because the gullies become full of floodwater and break accessibility to the villages.

There are gullies of width reaching 50m and depth of 20m. Because of the nature and structure of the soil around these areas there is occurrence of minor land sliding on both sides of the deep gullies destroying the agricultural land and even trail that people use to move from one place to another. And the detached soil particles from the soil mass will be ready to be easily transported by the energetic water during rainy season. (figure.7)

Soils vary in their resistance to erosion partly based on texture and amount of organic matter. The resistance also depends on soil condition and depth. Soils high silt and low in clay content and sand are highly erodable (Nill et al. 1996).

The characteristic soils in the location highly affected by gully erosion are vertisol, cambisol, liptosol, Andosol, and their combination. Andosols are young volcanic soils and have high water absorbing capacity, which create high water pressure in pore spaces. Vertisols are characterized by their extensive cracking.

The gentle slope area that covers about 75% of study area is not affected by gulley. But sheet and rill erosion are wide spread. It is intensively cultivated (Figure.8) by completely clearing the shrub and wooded-grass land except in some location. The frequency, number, width and depth of the gullies decrease toward south.

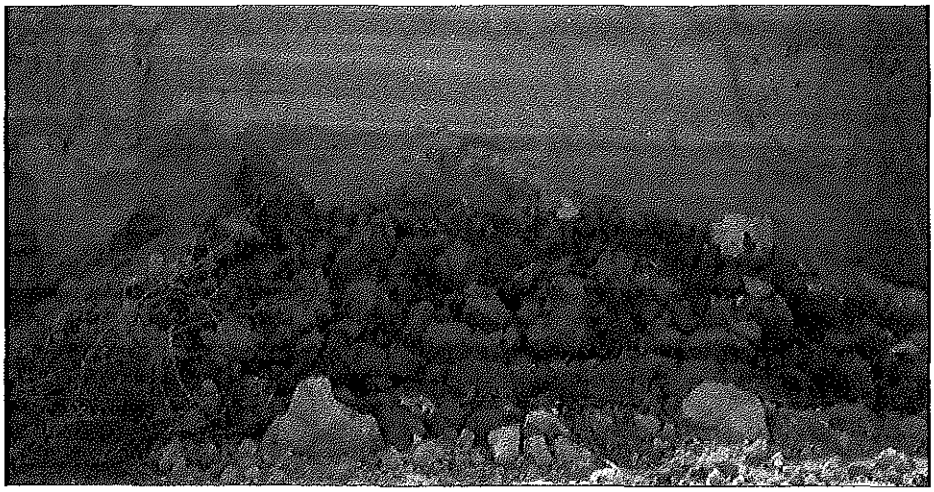


Figure 7. **Soil fall occurring in Gullies**

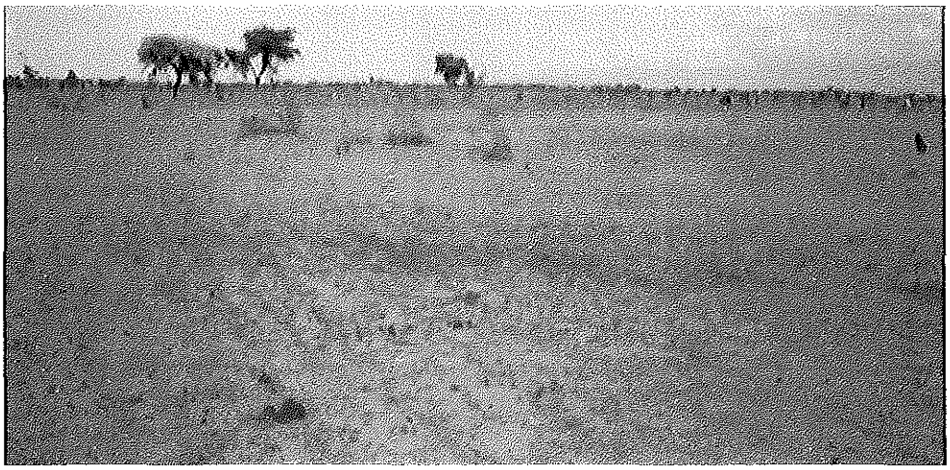


Figure 8. **Intensively Cultivated Land exposed to sheet erosion.**

2.3. *Land Management*

Clearing vegetation for expansion of agricultural land is common on the remaining small wooded-grass land of the area and is done with out any control. For example, in the place called "shebogibi" in Ziway Dugda woreda of Arsi Zone, there was burning of number of hectares of wooded-grass land for expansion of agricultural land in Feb.2005. As the information collected from the local people the land was previously owned and protected by government and the fire was put purposely to burn part of the compound (shibogibi) for expansion of agricultural land. But due to the windy condition of the time, the fire was out of control and as the result large part of the wooded-grass land was burned, all wiled life (tiger, hyena, fox etc) in side the compound were affected seriously. The peoples in the area also informed that this practice is common especially on grazing lands in the mountainous area for the purpose of removing old grass (Figure.9)

Figure 9 **Wooded Grass land affected by Burning.**

Clearing of vegetation for fire wood, charcoal production and other day to day activities of the population in the rural and urban is common and is done with out replacement. Cultivation on steep lands is common and is not properly managed.

Croplands and pastures are susceptible to erosion but croplands are more vulnerable because the soil is repeatedly tilled and left without a protective cover of vegetation. The socio-economic situation in rural areas often leads people to use their environment inappropriately which induce land degradation. In many areas the type of land use affects the level of soil protective cover and consequently the rate of erosion and erodibility. Deforestation and the removal from the fields of dung and crop residues for fuel and feed causes a steady reduction in the organic matter content of highland soils, rendering them less productive and more easily erodible. Bezuayehu et al. (2002).

CHAPTER THREE

LITERATURE REVIEW

3.1. *Land Use & Land Cover*

Every parcel of land on the Earth's surface is unique in the cover it possesses. Land use and land cover are distinct yet closely linked characteristics of the Earth's surface. Land use is the manner in which human beings employ the land and its resources. Examples of land use include agriculture, urban development, grazing, logging, and mining. In contrast, land cover describes the physical state of the land surface. Land cover categories include cropland, forests, wetlands, pasture, roads, and urban areas. The term land cover originally referred to the kind and state of vegetation, such as forest or grass cover, but it has broadened in subsequent usage to include human structures such as buildings or pavement and other aspects of the natural environment, such as soil type, biodiversity, and surface and groundwater (Meyer, 1995).

3.2. *Land Use/Land Cover Change*

Globally, land cover today is altered principally by direct human use. This includes clearing vegetation for expanding farming land, cut forests and trees for fuel wood and charcoal and overgrazing, forest harvesting and management, and urban and suburban construction and development which all are anthropogenic effects. On the contrary, Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cove.

Even though, natural processes may also contribute to changes in land cover, the major driving force is human induced land uses (Allen and Barnes, 1985). Changes in land use and land cover are pervasive, increasingly rapid, and can have adverse impacts and implications at local, regional and global scales. But effects are felt in the developing countries than developed countries because of high population growth rate and associated raped depletion of natural recourses (Wilson, 1992).

In Ethiopia, deforestation, sedentary agriculture, soil erosion and overgrazing have changed the land cover. Given the low level economic development, the pressure exerted by population growths exerted pressure for change of the environment. Conversion of woodlands and shrub-lands into croplands has resulted in loss of the natural vegetation cover and has caused severe soil erosion (Mc Dougall et. Al., 1975; Virgo and munro, 1977)

According to Robinove, (1981) the use of remotely sensed data for mapping land use and land cover has become an essential component of modern land use studies and can be used as substitute data of landscape features. The utilization of remotely sensed data enables substitute mapping due to the impracticality of direct measurement of the landscape.

In addition, the impotency of the availability of reliable land cover and land use data for sustainable management of the earth's natural resources was emphasized at the UN conference, known as the "Earth Summit", which took place in Rio de Janeiro in 1992 and Johannesburg in 2002. The earth summit recommended the use of remote sensing and GIS technologies for coordinated, systematic and harmonized collection and assessment of data on land cover and environmental degradation. (Johannesburg, 2002)

3.3. Studies Done on LULC change in Ethiopia.

Different studies of land use and land cover change has been made in different location of Ethiopia. In general, all have reached to the conclusion that the crop land, urban areas and rural areas as well as open lands expanded in large amount in the expense of natural vegetations including forest, wooded land, and shrub land. Berhanu et al. (1998a) has reported that 3.1% of the natural forests is lost annually due to shifting cultivation, commercial agriculture, fuel wood collection, urbanization, forest fires, poor utilization and logging.

Studies made in Bura Adele, Berisa and Daneba Peasant Associations of Adaba and Dodola district, in Bale zone, shows that the annual rate of deforestation was 1.6, 9.4 and 5.6%, respectively, during the period 1993–97 (Abdurahiman 1998). Another study on the Belete and Gera forests of Jimma zone shows that the annual rate of deforestation was 9.5 and 4.7%, respectively, during 1996–98 (MOA 1998).

In addition, Different studies, made using remotely sensed data, for some parts of the country, indicate that croplands have expanded at the expense of natural vegetation, including forests and shrub lands (Selamyihun Kidanu, 2004; Girmay Kassa, 2003; Belay Tegene, 2002) For Example, by a study made in wello in the area called kalu by Kebrom Tekle and Hedlund (2000), with in the last 28 years, open area, urban and rural lands showed an expansion by 333%, 195%, and 75 %.respectively at the expense of shrub land and forest.

Similarly, Devendra et al. (1998) has reported that, the mixed broad-leafed forests in the Oromiya region that provide almost all the lumber marketed in the whole of Ethiopia have shrunken in size while others have degraded in terms of quality or have been converted to other land use types. In addition this report showed that between 1989 and 1998, plantation forest areas declined by 93% in the Jalo-Muktar forest in east Hararghe and 32% in the Gara Gada forest in West Wellega. The density of Syzygium guincense has declined drastically in West Wellega and Cordia africanum and Anenjeria adolfi-friedrici, the species very good for timber, have become endangered in the western zones of the region because of uncontrolled logging.

3.4. Causes of LULC change and its impact in Ethiopia

Keeping all other factors such as increased per capita income, governmental policies, technological change etc constant, increase in population can impose pressure on land use hence cause LULC change. The impact of population growth is increase of demand of the basic needs of the population. For example, increase in demand of food due to population increase will in turn lead to produce more that force peoples to use more lands for agriculture therefore result in LULC change.

Many researchers agrees that the main cause of LULC change and related impacts in Ethiopia are anthropogenic in origin even though natural processes may also contribute to change. The pressure exerted by population growths is taken as the main factor. Given the low level economic development, increase in population exerted pressure on change of the environment by the conversion of woodlands and shrub-lands into croplands that resulted in loss of the natural vegetation cover. (Mc Dougall et. al., 1975; Virgo and munro, 1977)

According to Bezuayehu et al. (2002), the increase in the human population has reduced land holding per capita and created pressure on limited land for agricultural production. In addition, those who cannot produce enough cut forests and trees for fuel, wood and charcoal to earn a living. For example, 22% and 33% of households in Melkedera Peasant Association in Ambo woreda depend occasionally and regularly, respectively, on nearby forests for their livelihood. Also, the removal or destruction of vegetation cover through overgrazing and bush burning etc.

This is what is happening in the study area. The increase in population with little or no change in technology, and the different land policies in the past and the poor land management practices have resulted in the change of the land cover and causing serious land degradation in the area. The study area falls in two weredas of the Orommia Regional Government state namely Dggda Bora and Ziway Dugda and located with in East shewa and Arsi zones respectively even though it do not cover the whole area of the two weredas. The population census data made by central statistics authority (CSA) of Ethiopia in 1984 and 1994 of the two weredas showed an increase by 29.8% and 34.9% respectively. The projections of population for July 2005 of the two weredas are 190,375 and 117,035 respectively which is 83.8% and 82.1% increase as compared to the 1984 population.

The other factors that contributed to the LULC change are property rights. Private ownership protected forests to some extent during the imperial reign (Adugna et al. 1996). The ownership right was passed to the Peasant Association during the Derg regime for management as a community resource. These forests were not only poorly managed but they were sometimes exposed to accidental fire and even repeatedly set on fire deliberately which then allowed free grazing rights and free cutting of fuel wood after burning. Such practices have a negative effect on proper management of forest resources and ultimately the land is easily degraded (Asefa 1994).

The author of this paper also has the same attitude with the above statement for what he practically seen on the occasion happened in the first field survey before two month (Feb, 2005). The place is the so called "shebogibi" in Ziway Dugrad woreda of Arsi Zone. The location was previously protected by government for long period of time but now privatized. As the information collected from the local people the fire was put purposely to burn part of the compound (shibogibi) for expansion of agricultural land. But due to the windy condition of the time, the fire was out of control and as the result large part of the wooded-grass land was burned, all wiled life in side the compound were affected and so on. (Figure. 8)

Land degradation is the most series impact of LULC changes happened in Ethiopia. According to (Agray-Menash 1985), Land degradation, which in generally is decreasing of potential of productivity of land is caused by different processes including soil erosion and nutrient depletion and so on. These processes are interrelated and could occur due to natural causes but they are invariably accelerated by human intervention in the natural environment. Inappropriate institutional and policy applications e.g. land tenure, input supply and forest regulation policies. Poorly designed and constructed roads, defective conservation measures, cattle tracks and footpaths are also some of the human induced factors causing visible degradation.

A study made by Bezuayehu et al. (2002),) in Oromiya administrative region, has indicated that the increased demand for trees/forests for construction and fuel, and expansion of farmlands to steep and marginal areas have contributed to degradation. The present extent of soil degradation which is over a very large area of the Hararghe highlands, North and East Shewa, and Wellega, Arsi and other zones is evidence of the unabated spread of soil degradation in the region.

According to the above study in Oroniya region, Overgrazing in some parts of the region has changed grassland from a high cover perennial species to a low cover annual species and from more palatable to less palatable species. Expansion of farmlands has not only led to forest or bush clearing and burning, but also restricted the area for overgrazing. Due to the shortage of grazing lands in many areas of the region, croplands are usually used for uncontrolled grazing immediately after crop harvesting. Livestock roam, feeding on weeds and grasses and creating stresses on agricultural lands. Although this practice is not entirely new or recent, the intensity and the duration of such common access grazing have apparently increased in recent times due to a feed shortage for an increasing livestock population. This kind of livestock grazing and the resulting traffic causes soil crusting and reduced infiltration which makes the vulnerable to erosion.

In addition, Solomon (1994) has reported that Overstocking and overgrazing including grazing of leftover residues on cropland after harvesting cause soil compaction due to heavy and continuous trampling by livestock. Watering points and cattle routes are particularly vulnerable to soil compaction, which leads to excessive runoff and reduced water infiltration. Revegetation in these areas is therefore impeded. Unimpeded water flowing down slopes causes rills and gullies. The bulk density of grazing land in Illubabor area was measured to be 1.34 g/cc. This is a high figure compared to 0.83, 0.79 and 1.12 g/cc for a coffee forest, unglazed grass fallow, and crop land, respectively.

Thomas (1991) reported that of all the visible erosion incidents in harerge area, 81% were caused by human induced factors while the rest were by natural factors. The most common human-induced factors that cause accelerated erosion include deforestation, inappropriate agricultural practices such as over cultivation and overgrazing.

Once forest land is converted to agriculture, erosion rates increase because of vegetation removal, over-grazing, and tilling. Vegetation cover reduces erosion. Living and dead plant biomass reduces soil erosion by intercepting and dissipating raindrops and wind energy. Above-ground foliage slows the velocity of water running over the soil decreasing the volume of water and soil lost in surface runoff. Plant roots physically bind particles, thus stabilizing the soil and increasing its resistance to erosion. Plant roots also enhance water conservation by creating pores in the soil surface that enable water to enter easily into the soil matrix. The uptake of water by plant roots also depletes the soil water content and thereby further increases infiltration rates.

Hurni (1990) has shown that erosion is greatest on cultivated land especially currently unproductive but formerly cultivated lands which are now have low vegetation cover. (Table.2.)

Land Cover	Area Country (%)	Estimated Soil Loss Tons/Ha/Yr	Total Soil Loss Million tons/year	% of Total
Annual Crop	13.1	42	672	45
Perennial Crops	1.7	8	17	1
Grazing And Brows	51.1	5	312	21
Forests	3.6	1	4	-
Wood and Bush land	8.1	5	49	3
Currently Un Productive	3.8	70	325	22
Currently Uncultivated	18.7	5	114	8
Total			1,493	100

Source: Hurni (1990)

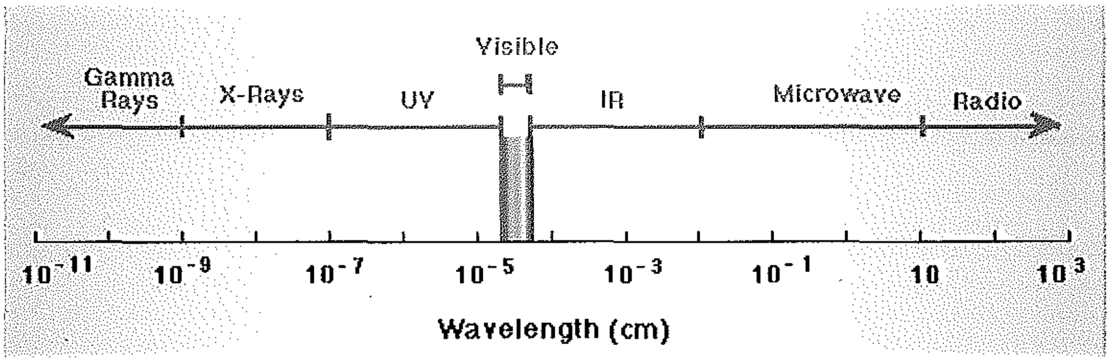
Table 2. **Estimated rate of soil loss in Ethiopia.**

In addition to soil loss impact, LULC change is also accompanied with nutrient loss by erosion. Generally nutrients are lost through erosion in runoff and in the eroded sediment. Finer soil fractions are the most vulnerable to erosion. Nutrients, being abundant in these finer soil fractions, are also lost to erosion. According to Tamirie (1997) loss of nutrient associated with soil erosion ranged from 15-1000kg/ha/year.

Similarly, Shibru Daba et al. (2003) reported the effect of land use land cover change in causing major gullies. In addition, Selamyihun Kefanu (2004) also reported that increases in surface area of gullies from 16.6 to 36.2 ha, (from 1957 to 1994) in the central highlands of Ethiopia.

3.5. *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 contact with object, area, or phenomenon under investigation using electro magnetic (EM) radiation as media. The EM Spectrum is a range of electromagnetic radiation ranging from cosmic waves to radio waves. (Figure.9)



Source: http://www.maic.jmu.edu/

Figure 10. *The Electromagnetic Spectrum.*

Spectral reflectance characteristics of common earth surface materials are located within the visible and near to mid-infrared range. Two basic processes are involved in EM remote sensing; data acquisition and data analysis. The elements involved in data acquisition process are energy sources, propagation of the energy through the atmosphere, interactions of energy with earth surface features, retransmission of energy through the atmosphere, airborne and/or space borne sensors, the generation of sensor data in pictorial and/or digital form.

The data analysis involves examining the data using various viewing and interpretation devices to analyze pictorial data and/or a computer to analyze digital sensor data. Reference data about the resources being studied are used where available to assist in the data analysis which could help the analyst to extract information about the type, extent, location, and condition of the various resources over which the sensor data were collected. This information is then compiled in the form of hard copy maps and tables or as computer files that can be merged with other layers of information in GIS.

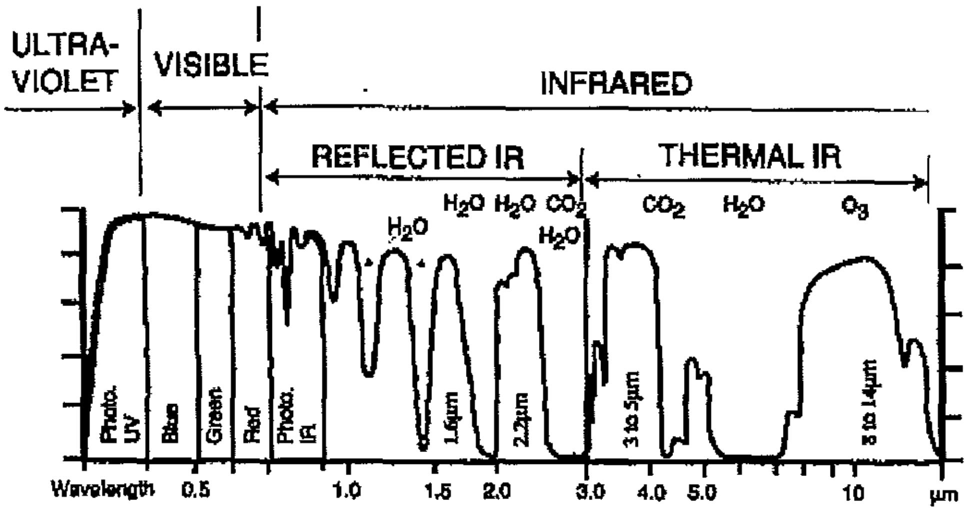
The principal advantages of remote sensing are speed at which data can be acquired from large areas of the earth's surface, and the fact that comparatively inaccessible areas may be investigated. Its ability for the purpose of monitoring changes over time is also very significant. It can be applied in almost all fields and is getting wider acceptance as processing procedures are advanced and accuracy of results increased with time.

Further more, Remote sensing image data of the Earth's surface acquired by spacecraft platforms is readily available in a digital format. Digital remote sensing systems convert electromagnetic energy to a digital form. Spatially, the data is composed of discrete picture elements, or pixels, and radiometrically it is quantized into discrete brightness levels (ERDAS field guide, 2002). The advantage of having data available in digital format is that it can be processed by computer either for machine assisted information extraction or for the enhancement by an image analyst.

Remote sensing systems can be active or passive .Those systems that supply their own source of energy to illuminate feature of interest and record the reflection of that energy from the earth surface are active systems where as those systems that sense naturally occurring (emitted or reflected) radiation are Passive systems.

For this study, the focus of remote sensing is the measurement of emitted or reflected electromagnetic radiation, or spectral characteristics, from a target object by multi-spectral satellite sensors which are passive.

Multi-spectral sensors sense simultaneously through multiple, narrow wavelength ranges located at various points in electromagnetic (EM) spectrum. Some types of electromagnetic radiation easily pass through the atmosphere, while other types do not depending on the wavelength or type of the radiation. This is because of gases that comprise the atmosphere that absorb radiation in certain wavelengths while allowing radiation with differing wavelengths to pass through. The areas of the EM spectrum that are absorbed by atmospheric gases such as water vapor, carbon dioxide, and ozone are known as absorption bands while atmospheric windows are wave length ranges in which the atmosphere is particularly transmissive of EM radiation. (Figure.10). Remote sensors on space platforms are programmed to operate in these windows and make measurements using detectors tuned to these specific wavelength frequencies which pass through the atmosphere. 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 EM spectrum.

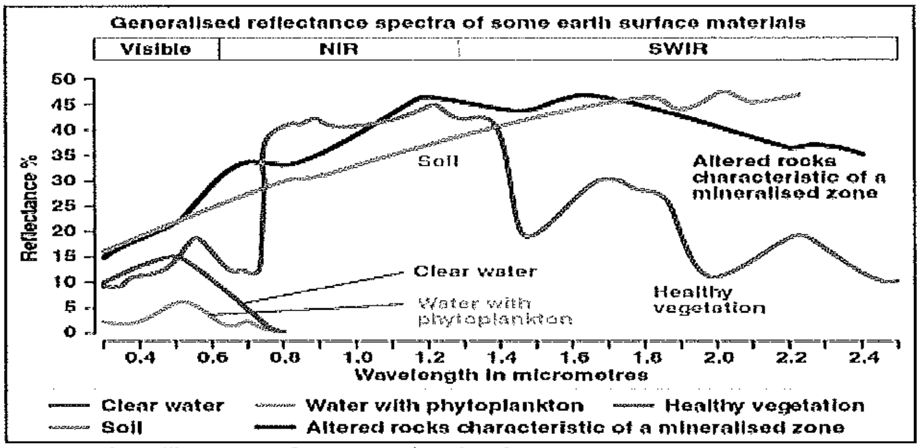


Source: http://imagers.gsfc.nasa.gov/teachersite

Figure 11. ***Atmospheric window and gasses responsible for blocking EM Radiation at different wave lengths.***

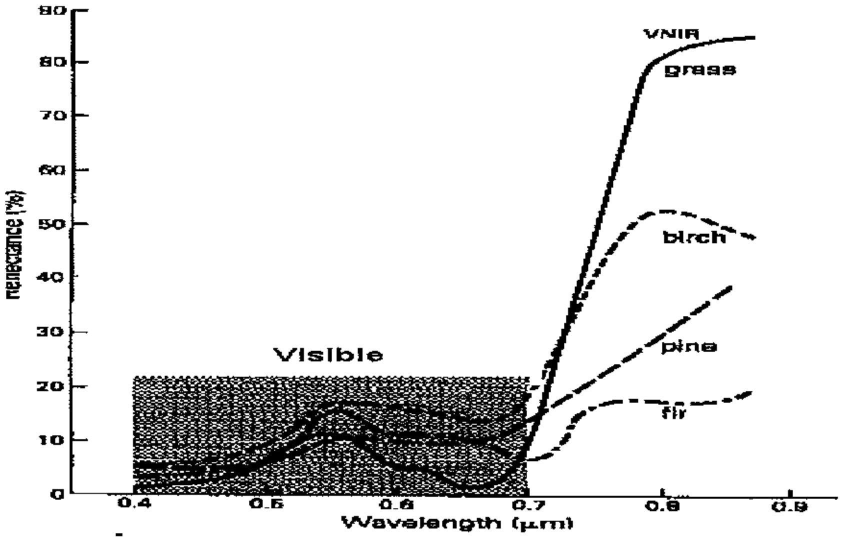
EM energy reaching the earth surface can be reflected, absorbed or transmitted. It is the amount spectral distribution of the reflected energy used in remote sensing to infer the nature of the reflecting surface. The basic principles are: First, individual targets (soil of different type, water with varying degree of impurity, rocks of different lithology, vegetation of various species and so on) have an individual and characteristic manner of interacting with the incident radiation which is described by spectral response of each target. (Figure .9)

Secondly, two features which are indistinguishable in one spectral range can be very different in the other wave length band. This is what is called wave length dependency (Figure. 10)



Source: http://imagers.gsfc.nasa.gov/teachersite

Figure 12. Spectral reflectance curve of some earth materials



Source: http://imagers.gsfc.nasa.gov/teachersite

Figure 13. Wavelength Dependency.

3.6. *Resolution*

Resolution is an important term commonly used to describe remotely sensed imagery. There are four distinct types of resolution; spatial, spectral, radiometric, and temporal. These resolution characteristics help to describe the functionality of both remote sensing sensors and remotely sensed data. (ERDAS Field Guide, 2002)

Spatial resolution is the measure of the smallest object that can be resolved by the sensor or the smallest area on the ground represented by each pixel. It tells the degree of detail of the earth surface feature recorded by the sensor. The finer the spatial resolution in remote sensing refers to imagery in which each pixel represents a small area on the ground and the de tail the recorder. Small scale refers to imagery in which each pixel represents a large area on the ground.

Spectral resolution refers to the specific wave length intervals in EM spectrum sensor can record. Wide intervals in the electromagnetic spectrum are referred to as coarse spectral resolution, and narrow intervals are referred to as fine spectral resolution.

Radiometric resolution refers to the dynamic range, or number of possible data files value in each band. This is referred to by the number of bits into which the recorded energy is divided. The total intensity of the energy, from 0 to the maximum amount, the sensor measures is broken down, for example, into 256 brightness values for 8-bit data. The data file values range from 0, for no energy return, to 255, for maximum return, for each pixel.

Temporal resolution is a measure of how often a given sensor system obtains imagery of a particular area, or how often an area can be revisited or the frequency at which satellite data is recorded about an earth surface feature. Temporal resolution is an important factor to consider in change detection studies.

3.7. *Image processing*

Image processing is a mathematical manipulation and interpretation applied on the pixel value and/or its geometry. Is broadly classified in to preprocessing and post-processing.

Pre-processing operations, which are also called image restoration and rectification are essential prior to image classification and change detection. It involves correction of sensor- and platform-specific radiometric and geometric distortions of data. Radiometric corrections removes errors related with variation of illumination and viewing geometry, atmospheric conditions, and sensor noise and response. Geometric distortions can be caused by several factors, including: the perspective of the sensor optics; the motion of the scanning system; the motion of the platform; the platform altitude and velocity; the terrain relief; and, the curvature and rotation of the Earth. Geometric corrections are intended to compensate for these distortions so that the geometric representation of the imagery will be as close as possible to the real world.

Registration/Georeferencing: The Image registration process, one of the pre-processing, involves identifying the GCPs in the distorted image and matching them to their true positions in ground coordinates. Ground coordinates can be obtained from map or georeferenced image for image-to-map or Image to-image registration respectively. Once several well-distributed GCP pairs have been identified, the coordinate information is processed by computer to determine the proper transformation equations to apply to the original image coordinates to map them into their true ground coordinates.

Radiometric correction: Other things being equal, the radiance measured by any givens system over a given object is influenced by such factors as changes in scene illumination, atmospheric condition, viewing geometry, instrument characters etc. Radiometric preprocessing influences the brightness values of an image to correct for sensor malfunction or to adjust the value to compensate for atmospheric degradation.

Absolute radiometric calibration techniques require ground reflectance data and information about the sensor and atmosphere for the date of image acquisition, which are often difficult or impossible to obtain. William et al. (1997)

The atmosphere degrades the true DN value of earth feature by introducing additional brightness from its components by scattering. The preprocessing operation to correct atmospheric degradation; haze correction or dark subtract, is used to compensate this error.

Image enhancement: is the process of making an image more interpretable for particular application. Common problem in remote sensing is that the range of brightness collected by sensor that most of the time do not match with capabilities the image medium. Contrast enhancement is used to compensate for this problem. It matches the range of the values in the image to take full advantage of the capabilities of the display. Using of the full capability of the display will add more tonal information as the result interpretability will increase.

3.8. Subsettig and Mosaicing

Subsetting refers to breaking out a portion of large file in to one or more files and Mosaicing is combining images to create one large file. Subsetting is important in case when the image contain area much larger than the study area. In this case, it is helpful to reduce the size of the image file to include the area of interest (AOI) or Region of Interest (ROI). Subsetting not only eliminates unwanted data in the file but also it speeds up processing.

3.9. Image Classification

Classification is the process of sorting pixels in to a finite number of individual classes or categories of data, based on their data values. (ERDAS Field Guide, 2002) The classification process involves translating the pixel values in a satellite image into meaningful categories. Within the scope of the study, image classification is defined as the extraction of distinct classes or land use and land cover classification categories, from satellite imagery. There are two primary methods of image classification utilized by image analysts, unsupervised and supervised classification.

According to (ERDAS Field Guide, 2002) Unsupervised image classification is a method in which the image interpreting software separates the pixels in an image based upon their reflectance values into classes or clusters with no direction from the analyst. Once this process is completed, the image analyst determines the land cover type for each class based on image interpretation, ground truth information, maps, field reports, etc and assigns each class to a specified category by aggregation. In unsupervised classification, there may not be prior knowledge of the area, no opportunity of human error and the classes are often uniform but they may not necessarily correspond the informational categories that are of interest and the analyst has vary limited control. In addition, since spectral properties of the specific information change with time the relation between information classes and spectral classes are not constant.

Supervised image classification is a method in which the analyst defines small areas, called training areas, on the image which are representative of each desired land cover category. Training is a process of defining the criteria by which patterns are recognized. The image analyst then trains the software to recognize spectral values or signatures associated with the training area. After the signatures for each land cover category have been defined, the software then uses those signatures to classify the remaining pixels using classification decision rule. The decision rule is a mathematical algorithm that, using the data contained in the signature, performs the actual sporting of pixels into distinct class values. Amongst the different decision rule employed in supervised classification, maximum likelihood, quantitatively evaluate both the variance and covariance of category spectral response patterns when classifying an unknown pixel based on the assumption that the distribution of the cloud of points forming the category training data is normally distributed. A drawback of this classification is the large number of computation required to classify each pixel which is time taking. But the writer of this paper beliefs that with the present and advancing technology of computer this may not be taken as problem.

In addition, Manual and hybrid approaches are also the other classification methods. Manual, or visual, classification of remotely sensed data is an effective method of classifying land cover especially when the analyst is familiar with the area being classified. This method uses skills that were originally developed for interpreting aerial photographs. The drawback of manual interpretation is that it tends to be tedious and slow when compared with automated classification and because it relies solely on a human interpreter it is more subjective. A hybrid approach combines the advantages of the automated and manual methods to produce a land cover map that is better than if just a single method was used. One hybrid approach is to use one of the automated classification methods to do an initial classification and then use manual methods to refine the classification and correct obvious errors with advantages quickly classification with the automated approach and then use manual methods to refine the classes that did not get labeled correctly.

3.10. Change Detection technique

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different time. (Singh, 1989) There are several methods of land cover change detection. For example there is post-classification comparison, Multi-date composite classification, Image math (difference, ratio), and so on.

Post classification change detection is likely the most common and intuitive change detection method. In this method, a land cover map is produced for each of the two dates and then these two land cover maps are compared, using simple image math, to determine the land cover change. With Multi-date composite classification approach the images from the two dates are combined into one multi-temporal image. This multi-temporal image is then classified using the automated classification method of choice, such as supervised or unsupervised. In the case of image math, single- band images from the two dates are compared by subtracting or differencing or rationing them, and then the resulting image is analyzed to determine the range of values that represent a change in land cover from one date to the next. (Remote sensing Guide, 2004)

Post-classification comparison is used for change detection in this research. As indicated above this is the most obvious method of change detection that needs comparison of the classification maps which are independently produced. An algorism simply compares the two classification images utilizing class pairs specified by the analyst and generates a map indicating areas of change.

3.11. Global Positioning Systems (GPS)

The Global Positioning System links ground-based, usually hand-held data receivers with a network of earth-orbiting satellites to provide very precise measurements of an object's physical location on the planet's surface. GPS thus provides a way of ground-truthing or verifying remote sensing data as well as of providing original location data. Combined with high resolution remote sensing and GIS for land use studies, GPS can provide high accuracy ground-truth data for training-site development.

3.12. Geographic Information System (GIS)

Today, GIS is a unique system designed to input, store, retrieve, manipulate, and analyze layers of geographic data to produce interpretable information. A GIS should also be able to create reports and maps (Marble, 1990). The GIS database may include computer images, hardcopy maps, statistical data, or any other data that is needed in a study. Although the term GIS is commonly used to describe software packages, a true GIS includes knowledgeable staff, a training program, budgets, marketing, hardware, data, and software (Walker and miller, 1990) GIS technology can be used in almost any geography-related discipline, from Landscape Architecture to natural resource management to transportation routing.

With the increasingly widespread, combined implementation of remote sensing and GIS technology, more natural resource professionals have been provided with efficient and accurate tools for mapping and maintaining management information on forests and other natural resources in regional areas. GIS technology is expanding, allowing for greater integration of remote sensing with digital cartography, thus providing the means to produce more accurate land use and land cover maps.

In general, remote sensing and Geographic Information Systems (GIS) are providing new tools for advanced environmental management. The collection of remotely sensed data facilitates the synoptic analyses of earth-system function, patterning, and change at local, regional, and global scales over time. Other factors such as rainfall intensity (erosivity), soil erodibility and slope gradient and length can also be identified and analyzed by GIS techniques. There fore, the integration of GIS and remote sensing provides exciting capability to analyze the dynamics of land-use change.

CHAPTER FOUR

RESULT AND DISCUSSION

In this Study, process of mapping land use and land cover change over time begins with mapping the recent (2002/5 satellite imagery), then looking back in time to map the past (1986 and 1973 satellite imageries) to evaluate for change detection. All land use and land cover map were derived utilizing standardized digital remote sensing techniques.

4.1. Subsettig and Mosaicing

In order to extract the ROI from the three images, a vector file defining the boundary of the study area and having the same projection as the images was imported into ENVI and overlaid as region of interest on each of the scenes and the subsetting is made via the region of interest. In the case of the MSS image, since the ROI fall in two adjacent scenes mosaicing was made before subsetting.

4.2. GPS Ground Truth Data Acquisition

After the pre-processing the recent satellite imagery (Registration, radiometric correction) a 1:50,000 map of the study area was prepared and extensive field survey was made throughout the study area using Global Positioning System (GPS).

The first field survey was performed in order to obtain accurate location point data for each land use and land cover class for the creation of training sites and signature generation. In addition, data of distribution of gullies over the study area is collected using GPS. The field survey was carried out over a two week period. Further, GPS has been used for ground truthing of land use land cover map developed by supervised classification in the seconded field survey carried out over a one week period

4.3. Geometric Registration/ Georeferencing

The ETM+ image was registered to the Universal Transverse Mercator (UTM) projection Zone 37 N, with Adinden datum, based upon 53 ground control points (GCP) collected from topographic maps of the study area obtained from EMA (image to map registration). The other two images (MSS and TM) were registered to the ETM+ image using 22 and 26 GCPs with Root Mean Square (RMS) Listed in (Table 3.) (image to image registration). All imageries were re-sampled to a 28.5 m pixel size using first order polynomial transformation and nearest neighborhood resampling technique. This is because, first order transformation provided sufficient accuracy and reduced potential introduction of unwanted geometric distortions in areas with no ground control points. Nearest neighborhood resampling maintains original pixel values and it offers advantage of computational simplicity.

No	Image	GCP Number	RMS	Type Of Registration
1	ETM+(2002)	53	0.0221	Image to Map
2	TM(1986)	22	0.0029	Image to Image
3	MSS (1973)	26	0.0023	Image to Image

Table 3. Root Mean Square of Georeferenced Images

4.4. Radiometric correction

Other things being equal, the radiance measured by any givens system over a given object is influenced by such factors as changes in scene illumination, atmospheric condition, viewing geometry, instrument characters etc. Radiometric preprocessing influences the brightness values of an image to correct for sensor malfunction or to adjust the value to compensate for atmospheric degradation.

Absolute radiometric calibration techniques require ground reflectance data and information about the sensor and atmosphere for the date of image acquisition, which are often difficult or impossible to obtain. William et al. (1997)

The atmosphere degrades the true digital number value of earth feature by introducing additional brightness from its components by scattering. The preprocessing operation to correct atmospheric degradation; haze correction or dark subtract, is used to compensate this error and the only radiometric correction applied on the imageries prior to enhancement.

4.5. Image Enhancement

Image enhancement is the process of making an image more interpretable for particular application. According to ERDAS field guide (2002) classifying enhanced data with principal component, Image algebra etc can produce vary specific and meaningful result. However, it is recommended that the original, remotely sensed data be classified

Common problem in remote sensing is the range of brightness collected by sensor that most of the time does not match with capabilities the image medium. Contrast enhancement is used to compensate for this problem. It matches the range of the values in the image to take full advantage of the capabilities of the display. Using of the full capability of the display will add more tonal information as the result interpretability will increase. Hence, linear contrast starching is applied on the dark subtracted imageries prior to image classification.

4.6. Image Classification

Within the scope of the study, image classification is defined as the extraction of distinct classes or land use and land cover classification categories, from satellite imagery.

Usually, Land use and land cover information are presented on separate maps. For this study the terms land use and land cover have been combined as one entity for the description of the landscape within the area of study.

Based on Knowledge of the study area, visual interpretations of imagery and Aerial photos and detailed reconnaissance field survey, different LULC categories were distinguished, so that it will be possible to investigate changes that occurred since 1973. Therefore, the land use/cover classes analyzed for changes were: Intensively cultivated land, Shrub-grasslands, degraded shrub-grassland, Wooded Cultivated-Grassland, wetland land, water body and urban land. The description of these land use/ cover categories is given in table.5.

Training Sites were developed from the ground truth data obtained by GPS (for ETM+ image) and visual interpretation of Arial photographs taken before 1973 (to generate training areas for the MSS image) by on screen digitizing of selected areas for each land cover class using color composite, bands 7, 4, 2 (RGB) and 4, 1, 3 (RGB) respectively.

ROI separability was determined to be good for all land categories of each image except the separability value of the degraded shrub grass land and intensively cultivated land of the MSS image which was below the agreement. Separability was calculated employing both the Jeffries-Matusita and Transformed divergence separability measures. These values range from 0 to 2.0 and indicate how well the selected ROI pairs are statistically separate. Values greater than 1.9 indicate that the ROI pairs have high separability. (ENVI User Guide, 2001) The minimum calculated separability between the signatures generated in this research was 1.921.The maximum calculated separability was 2.0 (Table. 4)

No	Image	Minimum Separability	Maximum Separability
1	ETM+	1.942	2.0
2	TM	1.921	2.0
3	MSS	1.932	2.0

Table 4. Region of Interest Separability

Once separation of the training sites was determined, a supervised maximum likelihood classification was processed. The classification included all bands of the MSS, Band 1, 2, 3,4,5, and &7 of the TM image and Bands 1,2,3,4,5,6 of ETM+. The TM's Band 6 was Excluded from the classification process because it was assumed to contain thermal information rather than land cover.

Land Use/ Land Cover	Description
Urban land	Is comprised of areas with much of the land is residential land. In addition contains areas of commercial and services, utilities communications and transportation.
Shrub-Grass Land	Open or closed shrubs and grass land. If present trees are small in size and scattered. Presently restricted to highlands of the area.
Degraded Shrub Grass Land	Areas under degraded shrub-grasslands.
Wooded Cultivated /Grass land	An open stand of trees forming crown. The adjacent trees are often in contact and the ground is covered either by grass and small plants or is cultivated.
Wet Land	Areas where the water table is at, near, or above the land surface for a significant part of most years. Most of the land could be used for crop production in dry seasons. In some locations especially in river banks and near the lakes, it may contain big trees (wooded).
Water Body	Areas completely covered by water such as lake Ziway, Lake Koka and Lake Elene.
Intensively Cultivated Land	Areas of land ploughed prepared for growing rain feed or irrigated crops. This category includes areas currently under crop, fallow and land under preparation. Characterized by no trees or if present extremely scattered. The class may include small inter-field cover types (e.g., grass strips, small windbreaks, small villages etc.)

Table 5. Land Use Land Cover Classes

Once separation of the training sites was determined, a supervised maximum likelihood classification was processed. The classification included all bands of the MSS, Band 1, 2, 3,4,5, and &7 of the TM image and Bands 1,2,3,4,5,6 of ETM+. The TM's Band 6 was Excluded from the classification process because it was assumed to contain thermal information rather than land cover.

Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. (ENVI User Guide, 2001) It is considered to give very accurate results since it takes most variables in to consideration but use an extensive equation that takes a long time to compute and relies heavily on the normal distributions of the data in each input band. (ERDAS field Guide, 2002)

The first classification output was good with the two exceptions that lowered the classification accuracy. Firstly, misclassification of some parts of the urban areas into degraded shrub-grass land and dry vegetation (Older vegetation) of the wet land as shrub-grass land. Secondly, the effect of shadowing on same parts of the mountainous part of the study area has forced the shrub grass land to be classified as wet land.

In the beginning, it was intended to classify urban areas as one class of the classification. But it was found that some of the urban lands were classified as degraded shrub land. This is because, Urban areas have similarly bright reflectance values as the degraded shrub grass and in TM and ETM+. As a result, urban areas were not included in the Maximum Likelihood Classification. Urban areas were excluded from the classification by masking using ROI generated by on screen digitizing of false colure composite images of scenes of each date. Visual interpretation has played the role of identifying the boundary of the urban areas.

The first attempt made to resolve the misclassification of the wet land and the effect of shadow is to enhance the imageries of each date before classification using saturation stretching, Principal component Analysis (PCA) and decorelation stretching. All this methods have brought some meaningful improvement on the classification but haven't completely solved the problem.

The other effort made is to reclassify the images by developing two separate training areas for the older and young vegetations of the wet land. This classification procedure dramatically reduced many of the misclassifications of the wet land and shrub grass land including the misclassification due to shadowing except in vary small areas which are finally correctly classified by post classification majority analysis and clumping applied on the classified imageries. Finally, the two subclasses of wetland created by the above process were combined to create one class.

4.7. Land Use and land cover

As described earlier, for this study the terms land use and land cover have been combined as one entity for the description of the landscape within the area of study. Based on Knowledge of the study area, visual interpretations of imagery and Aerial photos and detailed reconnaissance field survey, different LULC categories were distinguished, so that it will be possible to investigate changes that occurred since 1973 (Table 5.)

The analysis for the MSS image was made using all bands (Band 1, 2, 3 & 4) shows that the area was dominated by wooded cultivated/Grass land, 25108 ha (44.87%) and the next was the intensively cultivated land which was 14568 ha (26.04%) where as the shrub grass land, the wet land, the water bodies, and the Urban land were 6947 ha (12.42%), 5412 ha (9.67%), 3785 ha (6.76%) and 135 ha (0.24%) respectively. (Map 2.)

Even thought not quantified, the report by M J Makin et al. (1976) is in line with the current result. It indicated that before the establishment of the farm land the areas around Ziway and Meki were under Acacia wood and bush land (Acacia tortilis, Acacia /sporobulus, Acacia albda/ Croton mascrostachys) with the ground cover dominated by hyparrhenia grasses which were rapidly being converted to farm land.

The degraded shrub grass land classified as one class in the ETM+ and TM imageries have vary low (<1) separability value with the intensively cultivated land of that time in the MSS image. This is may be because of the relatively coarse spectral resolution and small number of bands used in MSS imagery and/or effect of resampling applied on the image during georefernsing. On the other hand, the degraded shrub grass land was smaller in size and dominated by the vegetation canopy of the time.

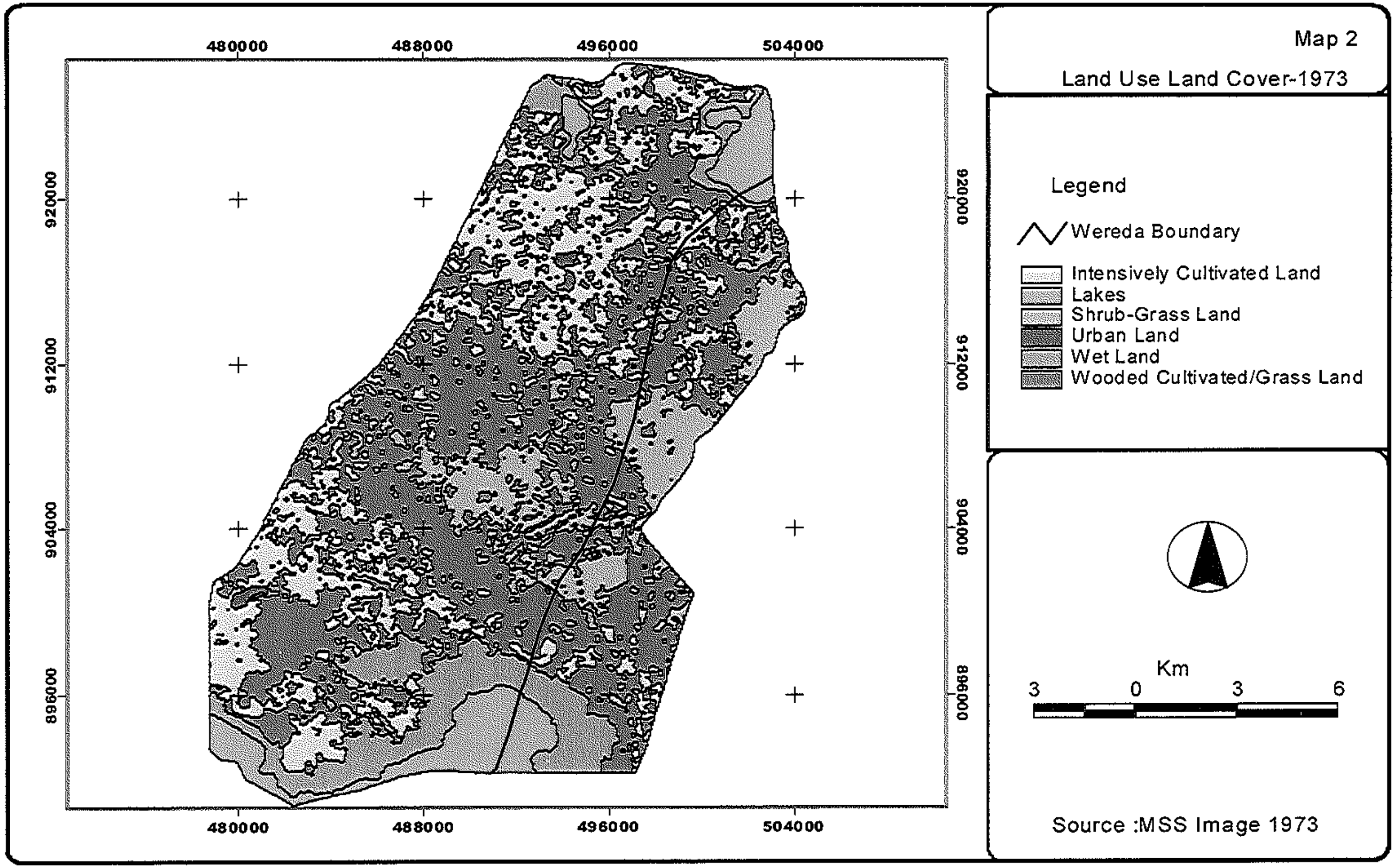
Since the TM's Band 6 was assumed to contain thermal information rather than land cove was excluded from the classification process and intensively cultivated land was the dominant land cover amounted to 28137 ha(50.29 %) and the is the wooded cultivated grass land which was 14713 ha (26.29%).The wet land, water bodies, shrub grass land, urban land and degraded shrub grass land each amounted to 4922 ha (8.80%), 4230 ha (7.56%), 3514 ha (6.28%), 305 ha (0.55%) and 134 ha (0.24%) respectively. (Map 3.)

For ETN+ image all bands were used in the classification and the result shows that the intensively cultivated land 59.47% (33278 ha) and , the wooded cultivated/grass land, wet land, water Bodies, shrub Grass Land, urban Land and degraded shrub-grass land amounted 18.46%(10329 ha), 8.95(4980 ha), 6.36%(3556 ha), 4.41%(3469 ha), 1.23%(690ha) and 1.17%(652ha) respectively. (Map 4.)

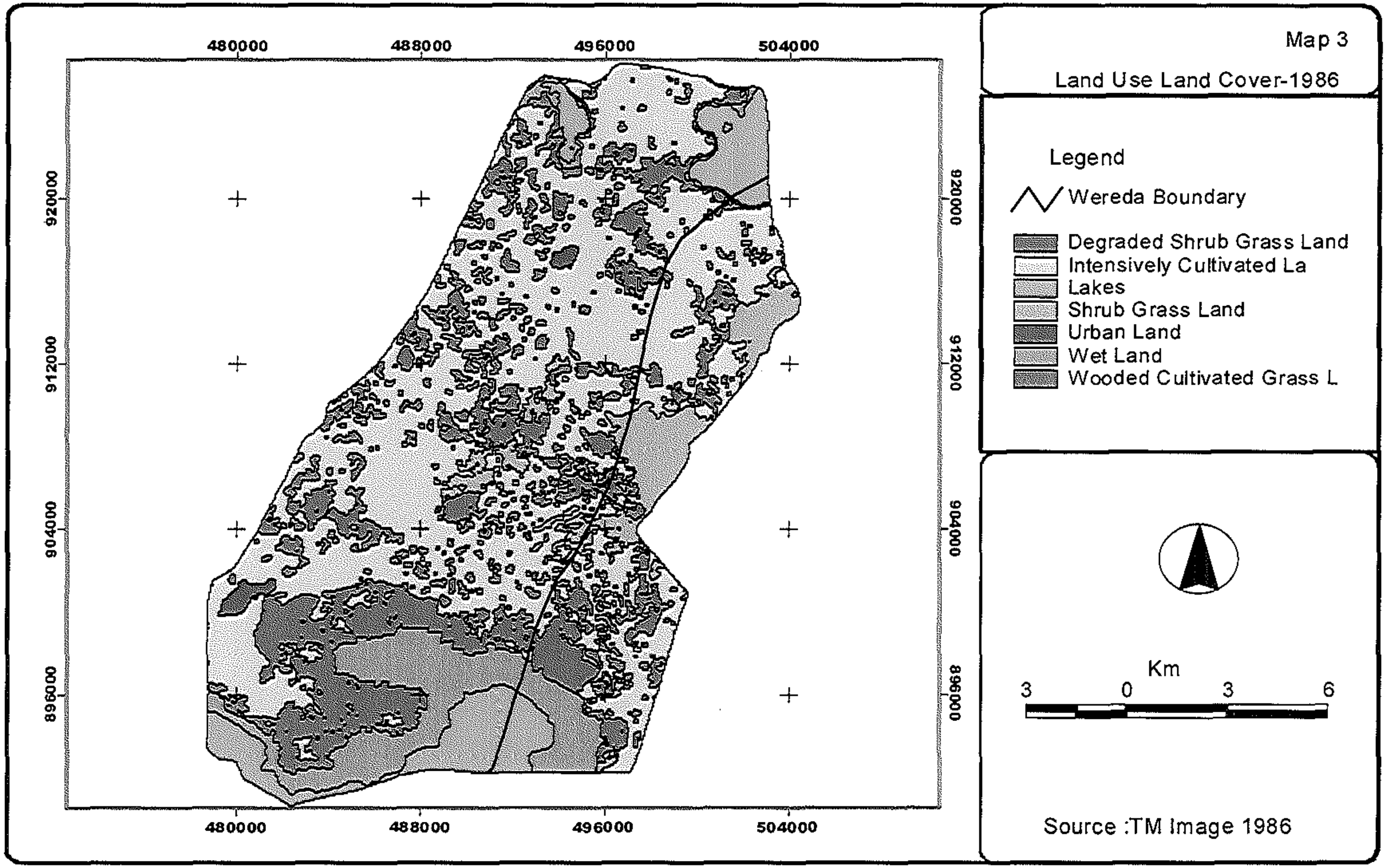
4.8. Land Use & Land Cover Map Accuracy Assessment

Confusion matrix is a square array of numbers organized in rows and columns which express the number of Pixels of the ROI assigned to a particular category relative to the actual category as indicated by reference data. The ground truth ROI data were utilized in the maximum likelihood report as the independent data set from which the classification accuracy was compared. The accuracy is essentially a measure of how many ground truth region of interests (ROIs) pixels were classified correctly.

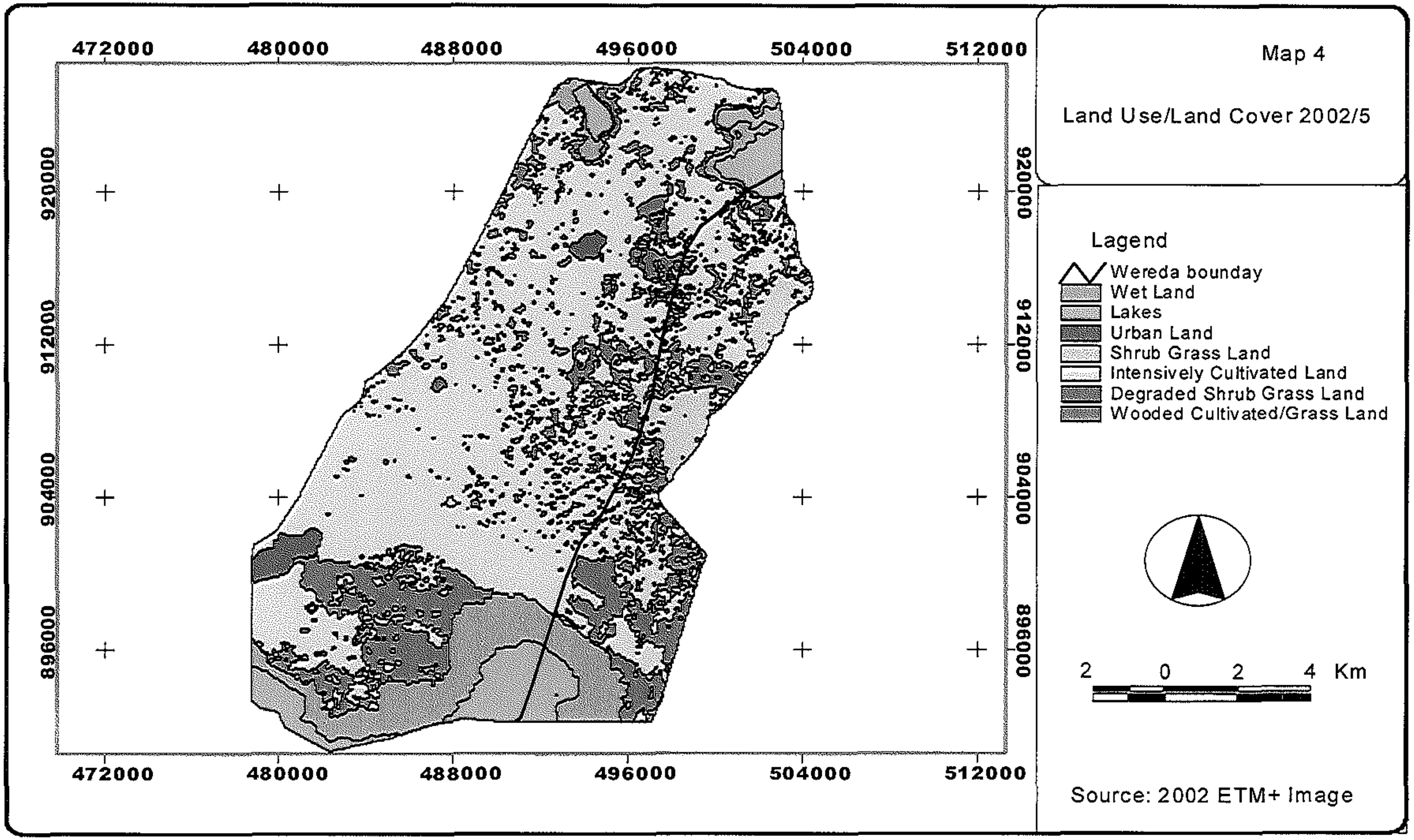
Items calculated includes; overall accuracy, kappa coefficient, confusion matrix, errors of commission, errors of omission and producer accuracy. Only the first three are reported here. The overall accuracy is calculated by summing the number of pixels classified correctly and dividing by the total number of pixels and is more accurate estimate of accuracy.



Map 2. Land use Land Cover, 1973



Map 3. **Land use & land cover, 1986**



Map 4. **Land use & land cover, 2002/5**

The kappa coefficient expresses the proportionate reduction of in error generated by classification process compared with the error of a completely random classification. (ERDAS filed guide, 2002) for example, a value of 0.82 implies that the classification process is avoiding 82 percent the errors that a completely random classification generates. Therefore, it is possible to test if a land use and land cover map is significantly better than if the map had been generated by randomly assigning labels to areas. It is widely used because not just the main diagonal but also all elements in the classification confusion matrix, contribute to its calculation.

The Kappa coefficient lies typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy. Kappa values are also characterized into 3 groupings: a value greater than 0.80 (80%) represents strong agreement, a value between 0.40 and 0.80 (40 to 80%) represents moderate agreement, and a value below 0.40 (40%) represents poor agreement (Congalton, 1996).

4.8.1. Accuracy Assessment of ETM+

In the beginning, an overall accuracy of 87.1032% was achieved with a Kappa coefficient of 0.8443. Thus, the overall accuracy is a more accurate estimate of accuracy. The classification output was also good. But it had misclassification of some parts of the urban areas into degraded shrub-grass and dry vegetation (Older vegetation) of the wet land as shrub-grass land. Secondly, the effect of shadowing on same parts of the mountainous part of the study area has forced the shrub grass land to be classified as wet land.

After applying mask on urban land and regrouping the wet land in to two separate subclasses (Wet and Marsh) an additional confusion matrix was generated with improved results. The overall accuracy reported was 94.8691%, Kappa coefficient of 0.9361. Even though overall accuracy of 94.8891% and a Kappa coefficient of 0.9361 is enough, further, the wet and marsh land subclasses were combined and then 5 by 5 majority analyses and a 3 by 3 clumping were applied to spurious pixels within a large single class and to clump adjacent similar classified areas together respectively. The final accuracy achieved for the ETM+ of the study area was with an overall accuracy of 96.7539% and a Kappa coefficient of 0.9594. (Table. 6)

4.8.2. Accuracy Assessment of TM and MSS

In this Study, process of mapping land use and land cover change over time begins with mapping the recent (2002 satellite imagery), then looking back in time to map the past (1986 and 1973 satellite imageries) to evaluate for change detection. Therefore, the next step was to classify the other imageries. All the processes used in the classification of the ETM+ were employed. In addition, further subdividing of the wet and shrub grass lands into number of distinct subclasses and then recombining after the classification was necessary during the classification of the MSS imagery to achieve the target of this study.

The degraded shrub grass land classes in the ETM+ and TM imageries have vary low (<1) separability value with the intensively cultivated land of that time in the MSS imagery. This is may be because of the relatively coarse spectral resolution and small number of bands used in MSS imagery or they were vary small in size and dominated by the reflectance of vegetation canopy of the time. The classification accuracy reports are given in table 7 & 8

4.9. Change Detection Technique

As sighted by William K. et al. (1997), several general classes of algorithms have been used to detect land use and land cover change, including, image differencing, image rationing, PCA, change vector analysis, post classification change detection and so on.

Post classification change detection is likely the most commonly used change detection method. Post classification change detection allows areas of no change to be identified and in case where a change has occurred, the nature of the change can be determined (Philip J. et al., 1981).

Class	Ground Truth (Pixels) Water Bodies	Intensively C	Degraded Shru	Wet Land	Shrub GrassL	Wooded Cultiv	Total
Unclassified	0	0	0	0	0	0	0
Water Bodies	112	0	0	0	0	0	112
Intensively C	0	228	5	0	0	8	241
Degraded Shru	0	0	53	0	0	2	55
Wet Land	0	2	0	99	0	0	101
Shrub Grass L	0	0	0	0	225	1	226
Wooded Cultiv	0	0	0	4	9	207	220
Total	112	230	58	103	234	218	955

Overall Accuracy = (924/955) 96.7539%
Kappa Coefficient = 0.9594

Table 6. **Confusion Matrix of ETM+**

Class	Ground Truth (Pixels) Intensively C	Shrub G	Water Bodies	Degreded Shru	Wooded Cultiv	Wet Land	Total
Unclassified	0	0	0	0	0	0	0
Intensively C	163	0	0	3	1	0	169
Shrub G	0	204	0	0	1	0	205
Water Bodies	0	0	190	0	0	0	190
Degreded Shru	0	0	0	25	0	0	25
Wooded Cultiv	0	0	0	0	119	0	119
Wet Land	0	0	0	0	0	87	87
Total	163	204	190	28	121	87	825

Overall Accuracy = (818/825) 99.1515%
Kappa Coefficient = 0.9895

Table 7. **Confusion Matrix of TM**

Class	Ground Truth (Pixels) wet Land	shrub Grass L	water Bodies	Intensively C	Wooded C	Total
Unclassified	0	0	0	0	0	0
Wet Land	48	0	0	0	0	48
Shrub Grass L	0	857	0	0	0	857
Water Bodies	0	0	900	0	0	900
Intensively C	0	0	0	980	0	980
Wooded Cultiv	0	0	0	20	140	160
Total	48	857	900	1000	140	2945

Overall Accuracy = (2925/2945) 99.3209%
Kappa Coefficient = 0.9904

Table 8. **Confusion Matrix of MSS**

For is analysis the images were initially co-registered. Independent supervised classification was made for each date. Then using spatial pixel editor utility of ENVI the individual pixel values (0) of unclassified urban lands were given constant (<>0) values prior to land cover change detection analysis. Post classification change detection was applied and change statistics and change map were derived.

4.10. Quantitative Change Detection & Analysis

The extent of the LULC change is analyzed based on the change detection statistics between the LULC categories. The statistical LULC change for study area was computed from the loss and gain of land use category between 1973 & 1986, 1973 & 2002 and 1986 & 2002. That is, for each initial state class the analysis identifies the classes in to which those pixels changed in the final state image.

Table.9, 10, 11 shows overlap of areas of LULC classes between base and final images and their changes.

From 1972 to 2002/5 the intensively cultivated land has expanded by 128.43% mainly in the expense of the areas which were previously wooded-grass and/or shrub-grass land and the areas where the slop is steeper. For example, out of the 14568 ha intensively cultivated land of 1973, 14065 ha was restricted to areas where the slope is between 0% and 8%. The remaining 494 ha and 7ha were with in 8% to 30% and >30% slop range respectively. On the other hand in 2002/5, the distribution of intensively cultivated land in the indicated slope ranges is changed to 31532ha, 1715 ha and 31ha respectively.

Wooded cultivated/grass land has changed from 25108 ha (44.87%) in 1973 to 10329 (18.48%) in 2002/5. The rate of change which was -743.5 ha/year between 1973 and 1986 showed a decrease to -219 ha/year between 1986 and 2002/5. (Table12.)This decrees of rate of clearance of trees is not because of some measures taken by the peoples to not cut trees but instead the major land clearance was made between the former two years and there are only vary small patches of lands with scattered trees remnant this days.

The shrub-grass lands that covered central gentle slope and the mountains of the study area and were 6947ha in 1973 now are 2469 ha restricted to the high land area only which is decrease by 58.86%. Since it is these areas that remained, are source of fire wood and other local consumption and as the result its density is decreasing. This in turn is putting pressure on the acceleration of rate of degradation of the mountainous area by erosion.

The urban land which was 135 ha in 1973 is changed to 690 ha in 2002. The average rate of expansion between 1973-1986 and 1986-2002 are 12.14 ha/year and 19.25 ha/year respectively which is increasing. Generally the urban land has expanded by 410.37 % between 9173 and 2002/5 which is again in the expense the wooded-cultivated/grass and intensively cultivated Land that contributed 155 ha and 399 ha respectively.

Even though it is difficult to know the amount of degraded shrub-grass land present in 1973 by the reason indicated in the previous section, from change detection analysis made between 1986 and 2002 imageries, the degraded shrub-grass land which was 134 ha in 1986 was expanded to 652 ha in 2002/5 which is an increase by 387.31%.

As the change matrixes indicate there are wet, shrub, and intensively cultivated lands converted in to wooded cultivated/grass land between 1973 and 2002/5 even though they haven't brought change towards increase of the total wooded cultivated/grass land of the area because of higher rate of removal of trees.

The wet lands of the area are situated around the two lakes (Koka and Ziway), river banks, deltas of Awash and Meki rivers and their tributaries favorable for the grow of trees (Acacia tortilis, Acacia /sporobulus, Acacia albda/ Croton mascrostachys).These areas, due to over flow of rivers, the branching structure of the deltas of the rivers and expansion of the lakes etc become wet for long/short period of the years and some times dry also. Spatially, the wet lands around delta of Meki river in 1973 and 1986 has regretted towered Lake Ziway and the wet areas are converted to wooded cultivated/grass land. In the dry condition the reflectance of the vegetation canopy will dominate and forced them to be grouped as wooded cultivated/grass land while on an other time wet land. The conversion of intensively cultivated land in to wooded cultivated/grass land may be the regeneration of the cleared woods that forming canopy. The visual observation of the classified images indicates that the conversion of shrub grass land to wooded cultivated grass land is generally observed in the central part of the study area. Based on the knowledge of the area it is true that theses areas were not totally covered by shrub but contain scattered wooded plants which their reflectance was dominated by the shrub in the base image not on the resent one.

4.11. Land use and Land cover change Map

Change matrix can clearly show that change has taken place in the environment .But there is no way of determining, however, where the change haves take place. Change map is the solution for this problem.

Change map is derived by image differencing. That is, the base classified image (1973) was subtracted from the final (2002/5) classified image. Then, the out put was vectorized and exported to ArcView GIS shape file for farther editing and came up with Land use land Cover change map between 1973 and 2002.(Map 5.)

4.12. Socio Economic characteristics of the study area

4.12.1. Human Population

Land cover change is caused by a number of natural and human driving forces. Whereas natural effects such as climate change are felt only over a long period of time, the effects of human activities are immediate and often drastic. As most researchers agree with, Population growth is the most important factor in Ethiopia.

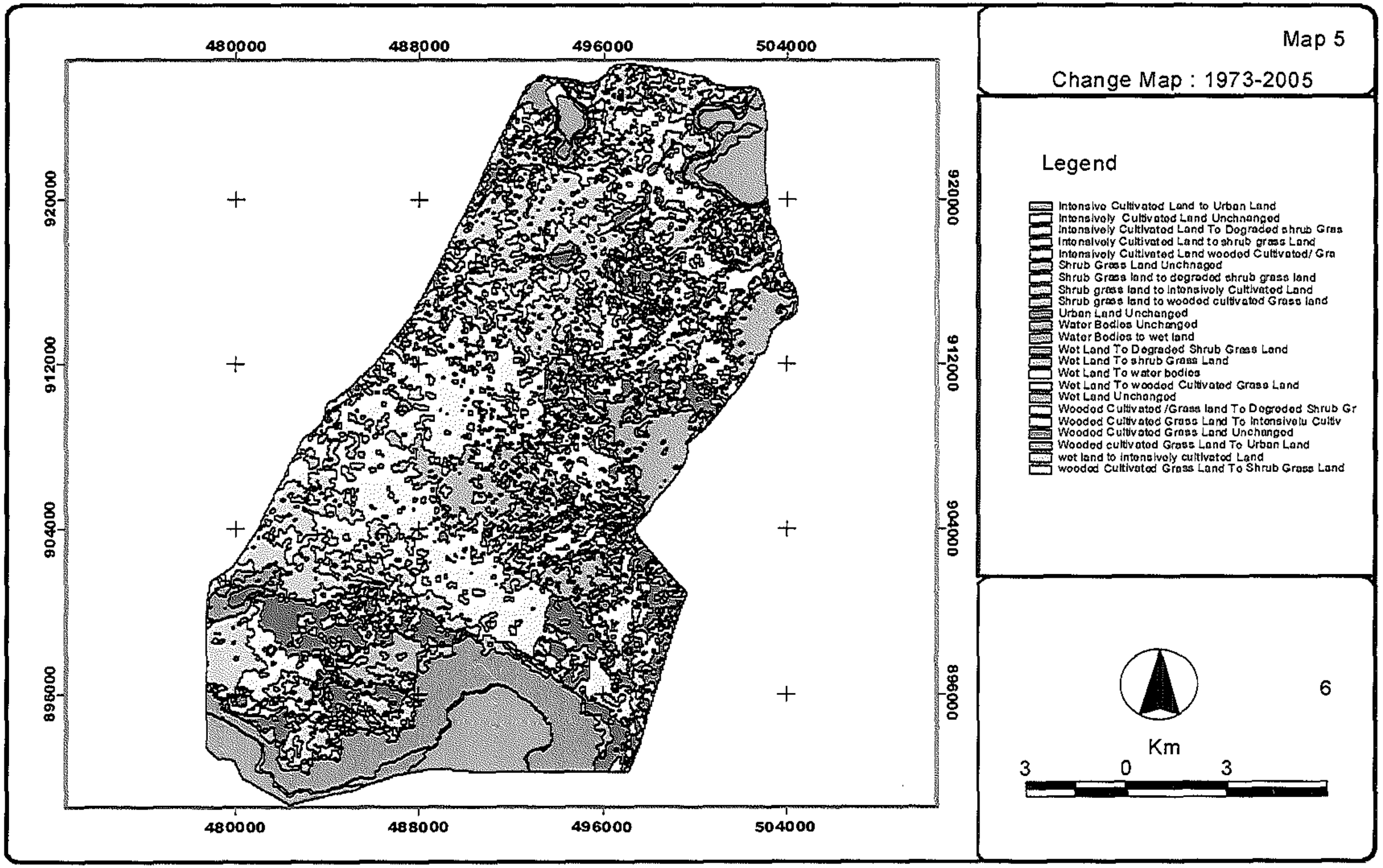
Even though it is not possible to obtain demographic data for specific study area, the data collected from CSA applicable at wereda level shows a tremendous increase in population in the two weredas, Zeyay Dugda and Dugda Bora, in to which the study area is situated.

Area (Ha)	LULC Classes 1973					
LULC Classes 1986	Water Bodies	Wet Land	Intensively Cultivated Land	Shrub Grass Land	Wooded Cultivated /Grass Land	Urban Land
Water Bodies	3690	539	0	0	0	0
Degraded Shrub Grass Land	0	0	10	56	68	0
Wooded Cultivated / Grass Land	0	563	4164	1121	8865	0
Wet Land	95	4234	167	7	419	0
Shrub Grass Land	0	9	17	2775	713	0
Urban Land	0	0	130	0	40	135
Intensively Cultivated Land	0	67	10080	2987	15003	0

Table 9. Change Matrix indicating area of LULC classes overlap between 1973 and 1986

Area (ha)	LULC Classes 1986						
LULC Classes 2002	Water Bodies	Intensively Cultivated Land	Wet Land	Shrub Grass Land	Degraded Shrub Grass Land	Wooded Cultivated / Grass Land	Urban
Unclassified	0	0	0	0	0	0	0
Water Bodies	3531	0	25	0	0	0	0
Intensively Cultivated Land	0	23899	237	952	41	8149	0
Degraded Shrub-Grass Land	0	482	6	1	65	98	0
Wet Land	699	28	3740	2	0	511	0
Shrub Grass Land	0	515	16	1759	1	178	0
Wooded Cultivated/Grass Land	0	2847	897	800	27	5757	0
Urban	0	366	0	0	0	19	305

Table 10. Change Matrix indicating area of LULC classes overlap between 1986 and 2002



Map 5. Land Use Land /Land cover Change Map: 1973-2002/5

The population census report made by Central Statistics Authority (CSA) of Ethiopia in 1984 and 1994, show that the population in the two weredas (Ziway Dugda & Dugda Bora) increased by 29.8% and 34.9% respectively between the two years. Similarly, the projections of population for July 2005 of the two weredas shows 84.25% and 82.1% increase as compared to the 1984 population. (Annex 2)

4.12.2. Livestock Population

The data obtained from CSA is applicable only at zone level so is not possible to present it on this paper. But, since agriculture is the source of livelihood for farmers in the area, livestock play an important role and is the major assets. The data obtained from the project called woody Biomass, from the project's household survey in Oromiya region; show that the two werdas have high livestock population. Especially, Ziway Dugda wereda carries more than the capacity of the land. (Annex 3)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The basis of this research comprises the multitemporal classification of Landsat satellite imageries to detect, delineate, and map land cover change, 1973 – 2002/5. This time period was chosen based upon the availability of current and compatible satellite imagery for classification and change detection as well as a means to provide current land use and land cover trends. This period also coincides with a period of substantial increases in agricultural activity. Thus, the objective of this research was to produce both current and past land use and land cover maps of the area from recent and historic satellite imageries and quantify the change between land use land cover classes.

All land use and land cover map were derived utilizing standardized digital remote sensing classification techniques. The classification employed three multitemporal Landsat scenes dated, Jan 30, 1973(MSS), Jan 21,1986 (TM), and Feb 30, 2002 (ETM+). Classification accuracy was determined to be enough by means of employing standardized accuracy assessment measures, the error matrix and the kappa coefficient of agreement. Overall accuracies of 99.3209%, 99.1515% and 96.7539% and a Kappa coefficient 0.9904, 0.9895 and 0.9594 respectively were achieved by comparison with ground truth data obtained from extensive GPS field surveys.

The change detection method employed was post classification change detection. The land use and land cover change map, 1973 – 2002/5, was contains changed and unchanged classes. It was determined by image differencing of classified image, rasterizing to ArcView GIS for farther editing and compiling.

5.1. Conclusion from the Analysis and observation

According to the statistics calculated from the land use and land cover change data between the 1973 and 2002/5, there were a lot of land cover changes occurred in the study area. In general, the intensively cultivated land and Urban lands have expanded by 18710 ha and 555 ha which is increase by 128.43% and 411.11% respectively. On the other hand, the wooded cultivated/grass land, the shrub grass land, the wet land and water bodies show decrease by 14779 ha (58.86%), 4478 ha (64.46%), 432 ha (7.98%), 229 ha (6.05%) respectively. The degraded shrub Grass Land also showed an increase by 518 ha (386.57%) between 1986 and 2002/5.

The average expansion rate of the intensively cultivated land between 1973 and 1986 was average rate +969.21 ha/year which show a decrease to +257.05 ha/year in the date between 1986 and 2002/5.On the other hand the rate of expansion of the urban land between 1973 and 1986 was 12.14ha/year and shows increase to 19.25 ha/year in the day between 1986 and 2002/5.On the contrary, the rate of change of wooded cultivated/grass land, the shrub grass land and the wet land was -742.50 ha/ year, -245.21ha/year, -35.00 ha/year respectively in the day between 1973 and 1986 and it was -219.2 ha/year, -52.25ha/year, 2.9 ha/year respectively.

The population growth was certainly the most important factor causing the observed land cover change because of the increase of demand of land for cultivation, settlement and trees for fuel and construction purpose. In other word, the increase in the human population has reduced land holding per capita and created pressure on limited land for agricultural production. This in-turn has forced farmers to expand their farming land to areas previously covered by vegetation including the steep and marginal areas.

The society cut trees for fuel, wood and charcoal to subsidize their life. Cutting of trees for fuel, wood and charcoal and construction was without replacement. As a result, large areas, which were once under wood and shrub cover, are now exposed. In addition, removal or destruction of vegetation cover through overgrazing and burning etc. has played its own role for the land cover change.

The loss of the vegetative cover of both the highland and the gentle area next to the highlands has affected by sheet and rill erosion which in turn resulted in formation of big gullies and hence loss of farmlands.

As indicated on the long term meteorological data analysis, the yearly average mean minimum and yearly average mean maximum temperature of the area are increasing and size of the water bodies (the lakes) is lower by 229 ha (6.05%) as compared to the size of the lake water in the base image. This could be impact of the temperature increase in the area that increased evaporation and/or due to increase of consumption of water for irrigation in the area nearby the lakes.

5.2. *Recommendation*

If current trends are allowed to continue damage to the natural resource base will continue and land lost due to sheet and gully erosion will increase. The increase in run off and low water retention due to low land cover further intensify the sheet erosion and rill and gullies to widen and deepen. The sediments removed are channeled to the lakes and cause sedimentation and pollution. The increase in the length and depth of the gullies, the rugged topography, nature of the soil , low vegetation cover of the area together with the rainfall that come after a long dry period might cause serious land slide which is indicated by soil fall occurring in the area south of Lake Koka which are highly affected by gullies.

There fore, the community, decision makers, planners and NGOs and other concerned national and international groups are expected to work for the rehabilitation of the environment.

Introducing alternative energy sources such as biogas should be encouraged to reduce dependency on natural vegetation for fuel. On the other hand, Planting of trees individually or in group in the mountainous areas and in the areas which are degraded so that out of usage for agriculture will add to the rehabilitation process and also satisfy need of wood for fuel, construction and could compensate for low coverage of woodland and at the same time reduce erosion currently affecting the environment.

Creating awareness among the society concerning optimum use of natural recourses, conservation systems and their benefits by policy makers and NGOs could play significant role in rehabilitation of the environment. In addition, since most important factor for the land cover change in the in Ethiopia in particular in the study area is the increase in population, continuing the current efforts of introducing family planning to make the people aware of consequences of population pressure should be carried out intensively.

The management and rehabilitation of natural resources needs sufficient data collection and detail analysis to identify the factors and propos appropriate methodologies that enable decision makers to make appropriate decision. In this regard, having of updated Land use and land cover information is crucial. For that matter, application of remote sensing and GIS was found helpful in quantifying past and present condition so that appropriate planning could be made for the future. It is therefore hopped that future development activities will exploit these resources more.

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Annex 1. Monthly mean minimum and maximum and monthly total rainfall of stations in the study area.

Alemtena Monthly Mean Maximum Temperature (^0C)													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly avg. Monthly mean Max Temperature
1987	25.0	27.3	30.2	28.3	32.7	30.1	27.6	26.9	27.5	28.1	27.9	27.1	28.2
1988	26.3	28.6	30.4	30.8	32.5	28.5	24.2	25.0	25.8	26.3	26.3	26.4	27.6
1989	25.3	26.0	28.7	27.1	29.8	19.6	25.4	25.0	26.1	26.0	26.8	26.1	26.0
1990	27.0	27.0	27.3	28.1	30.8	29.7	26.0	25.1	25.9	26.5	27.4	27.4	27.4
1991	28.0	28.7	29.1	29.8	31.0	30.5	24.5	25.3	25.6	27.1	27.6	27.4	27.9
1992	28.1	28.6	29.5	30.0	30.8	29.8	25.4	25.3	26.0	27.2	27.6	27.3	28.0
1993	28.3	28.5	30.0	30.2	30.5	29.2	26.2	25.4	26.3	27.3	27.7	27.3	28.1
1994	28.5	28.2	30.8	30.6	30.0	27.8	25.1	25.0	25.4	27.0	26.0	25.2	27.5
1995	26.7	29.4	29.3	29.9	31.4	30.8	26.2	25.3	26.3	28.2	27.8	28.2	28.3
1996	26.5	29.5	29.7	29.7	28.6	26.2	25.3	25.3	26.8	27.8	27.7	26.7	27.5
1997	27.2	28.5	30.9	28.6	30.9	28.7	25.5	26.7	27.9	27.8	27.1	26.7	28.0
1998	28.0	29.4	30.1	31.6	31.3	30.6	26.6	25.6	27.6	26.7	26.2	27.0	28.4
1999	28.7	29.9	30.0	32.7	29.0	30.3	25.0	26.7	28.1	26.9	26.3	26.1	28.3
2000	27.4	29.1	30.9	30.2	29.7	29.2	25.0	25.3	27.2	27.3	26.8	27.1	27.9
2001	26.8	28.6	29.2	30.3	30.2	27.5	26.5	26.3	27.5	28.9	29.1	28.1	28.3
2002	27.3	30.0	30.2	31.0	32.2	30.0	28.3	27.1	28.1	28.8	28.9	28.0	29.2
2003	27.6	30.0	33.5	29.5	31.8	32.3	29.1	28.0	27.8	29.8	30.3	27.1	29.7

Alemtena Station Monthly Total Rainfall (mm)													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Total Rain fall (mm)
1987	22.1	92.6	63.2	87.5	181.2	0.9	119.3	172.9	123.0	1.3	0.0	0.0	864.0
1988	11.5	36.8	43.5	47.0	5.7	85.7	161.8	200.1	171.7	19.4	0.0	1.7	784.9
1989	0.9	143.9	129.7	92.7	0.0	123.1	105.6	185.1	136.8	11.6	0.0	2.5	931.9
1990	0.0	166.9	21.1	132.4	11.9	26.3	206.2	170.9	157.6	0.0	0.0	0.0	893.3
1991	1.2	32.3	90.4	29.5	16.0	45.1	205.7	166.8	164.5	2.1	0.0	0.0	753.6
1992	13.8	49.6	45.2	94.2	27.7	52.5	259.0	162.7	88.0	4.2	0.0	0.0	796.7
1993	26.3	66.8	0.0	158.9	39.3	59.8	312.3	185.2	78.9	23.6	0.0	0.4	951.5
1994	0.0	0.0	8.6	25.3	17.2	117.1	206.1	126.5	84.0	14.4	16.0	13.2	628.4
1995	0.0	44.8	87.8	47.5	31.5	29.9	159.8	135.6	89.0	5.2	0.0	0.0	631.1
1996	65.4	0.0	100.0	31.1	63.0	113.4	197.6	153.5	92.5	0.8	0.0	0.0	817.3
1997	10.7	0.0	32.3	92.0	9.3	158.4	194.6	151.2	70.7	48.0	6.0	0.0	773.2
1998	7.1	21.8	36.3	102.6	33.1	49.8	216.4	190.7	52.0	98.4	0.0	0.0	808.2
1999	2.4	0.0	19.7	6.8	19.2	81.1	227.5	165.6	72.1	119.9	0.0	0.0	714.3
2000	0.0	0.0	0.0	127.1	89.0	51.7	207.8	142.0	155.8	52.7	54.0	0.0	880.1
2001	0.0	24.6	157.7	15.7	113.8	104.2	200.2	155.5	73.1	0.0	0.0	0.0	844.8
2002	1.5	35.4	24.3	82.9	11.3	45.0	296.4	150.7	45.6	0.5	0.0	0.0	693.6
2003	19.0	16.4	116.9	54.0	29.4	84.6	392.5	105.4	96.5	0.0	0.0	21.7	936.4

Koka DAM Monthly Mean Minimum temperature in 0c													Yearly Avg. Mean Monthly Min T
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1970	14.70	14.60	16.00	16.50	17.20	17.40	15.90	15.70	15.40	14.40	10.60	10.20	14.88
1971	11.80	12.40	14.10	15.60	16.00	15.60	15.10	14.90	15.50	14.10	13.00	12.20	14.19
1972	12.10	13.60	14.40	18.30	16.60	15.85	15.20	15.20	15.10	13.30	12.00	12.90	14.55
1973	12.10	13.00	15.90	17.30	16.20	16.10	14.90	15.20	15.20	13.60	12.30	9.90	14.31
1974	12.30	13.40	14.60	15.00	15.50	15.30	14.80	15.50	15.00	12.00	9.90	10.60	13.66
1975	9.80	13.00	15.30	15.60	15.80	14.60	14.10	14.90	14.20	12.80	11.20	10.20	13.46
1976	11.80	13.90	14.30	15.50	15.70	15.60	14.80	14.10	14.30	13.30	12.50	11.30	13.93
1977	13.70	12.90	14.20	14.60	15.00	15.30	15.10	15.30	15.10	14.30	11.80	13.60	14.24
1978	12.10	12.90	15.00	15.50	15.60	15.60	15.30	15.30	14.70	13.70	12.00	12.50	14.18
1979	13.40	15.20	16.30	17.70	17.30	17.00	16.50	17.40	17.60	19.00	15.20	14.40	16.42
1980	14.90	15.80	18.40	17.60	17.80	17.90	17.50	15.80	18.30	17.50	15.80	15.30	16.88
1981	13.60	14.40	15.60	16.20	16.70	17.50	16.35	*16.35	17.15	16.75	16.00	15.80	16.03
1982	17.90	15.70	18.40	18.50	18.00	17.10	15.20	16.90	16.00	16.00	16.20	16.30	16.85
1983	16.20	16.60	17.80	17.50	16.90	17.30	17.20	16.20	16.00	16.60	16.60	16.50	16.78
1984	15.80	16.20	16.70	17.20	17.70	16.90	16.50	16.50	16.40	15.30	15.30	15.30	16.32
1985	15.60	14.00	15.30	15.10	15.70	16.20	14.00	14.00	14.00	13.50	13.20	12.70	14.44
1986	11.90	13.70	13.50	14.40	14.10	13.80	13.70	13.90	13.80	13.20	13.50	12.70	13.52
1987	13.90	13.50	14.30	14.30	14.30	14.50	14.20	14.30	14.80	14.60	12.80	12.00	13.96
1988	14.40	16.20	15.60	14.50	14.10	16.30	16.00	14.80	15.70	14.40	11.90	12.30	14.68

* Interpolated Missing Data by linear /Neighbor hood Interpolation

KOKA DAM Monthly Mean Minimum temperature in 0c													Yearly Avg. Mean Monthly Min Temperature
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1989	13.00	14.20	15.20	15.90	16.00	16.70	15.80	16.00	16.10	16.00	15.20	13.70	15.32
1990	14.70	15.10	15.20	16.70	17.40	17.00	16.30	16.50	16.00	16.80	14.90	14.00	15.88
1991	15.70	14.60	14.80	15.50	16.00	14.60	16.90	14.00	*15.65	14.20	14.98	14.25	15.10
1992	14.95	14.65	17.00	18.10	18.00	14.20	15.60	15.20	15.30	11.60	15.05	14.50	15.35
1993	14.20	14.70	19.20	16.80	16.10	15.80	15.40	15.30	16.70	15.10	15.20	15.00	15.79
1994	11.10	10.40	13.50	17.50	16.40	15.80	15.45	15.70	16.60	16.30	15.35	15.00	14.93
1995	16.70	15.40	14.66	17.79	16.21	15.80	15.50	16.10	16.50	17.50	15.50	14.25	14.88
1996	12.79	14.20	15.82	17.16	17.29	16.12	15.36	16.07	16.48	15.45	13.58	11.12	14.88
1997	14.10	13.00	15.73	16.81	16.98	16.43	15.23	16.04	16.45	13.40	11.65	11.12	14.75
1998	13.80	14.50	15.20	16.10	16.30	16.30	14.20	16.00	15.70	15.20	12.80	12.80	14.91
1999	11.60	14.50	16.60	16.30	16.80	16.40	16.70	16.10	17.20	14.50	13.00	11.85	15.13
2000	11.10	12.50	14.90	16.00	16.40	15.00	15.00	15.30	15.30	13.80	13.20	10.90	14.12
2001	9.90	13.60	15.20	15.40	15.50	15.10	15.40	15.30	15.30	11.60	11.80	14.10	14.02
2002	12.80	14.70	15.50	15.20	15.00	14.70	14.70	15.30	14.80	14.50	13.50	14.40	14.59
2003	14.90	14.90	15.20	14.40	15.40	15.40	15.30	15.60	15.50	12.40	14.90	13.67	14.80

* Interpolated Missing Data by linear /Neighbor hood Interpolation

KOKA DAM Monthely Rain Fall (mm)													Yearlt Total RainFall
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1972	0.0	0.0	0.0	7.7	16.0	43.5	169.5	95.2	36.4	204.0	0.0	0.0	572.3
1973	0.0	0.0	0.0	0.1	46.3	11.4	42.3	52.4	76.9	24.9	0.0	0.0	254.3
1974	0.0	2.0	57.6	0.0	13.8	43.7	96.0	61.9	103.0	0.0	0.0	0.0	378.0
1975	0.0	2.1	0.0	85.3	26.7	69.5	199.6	48.7	40.9	0.0	0.0	0.0	472.8
1976	0.0	0.0	5.7	25.0	26.8	24.9	67.9	89.1	48.9	0.1	17.7	0.0	306.1
1977	15.9	0.0	10.1	33.4	37.3	23.7	46.9	57.3	13.0	62.5	11.6	0.0	311.7
1978	0.0	25.0	8.8	0.0	11.0	41.9	54.7	86.4	28.5	0.0	0.0	0.0	256.3
1979	31.9	5.2	22.2	1.5	29.6	58.4	53.8	45.8	42.1	4.4	0.0	10.3	305.2
1980	25.9	0.0	1.9	30.5	9.7	41.4	65.5	102.8	2.8	18.8	2.8	0.0	302.1
1981	0.0	30.0	17.2	32.1	0.0	0.0	46.2	50.5	81.1	2.9	0.0	0.0	260.0
1982	15.6	9.9	10.3	17.2	70.1	13.9	26.9	10.6	41.1	46.0	12.6	44.0	318.2
1983	0.0	29.6	2.2	53.0	29.9	0.0	25.1	134.4	90.3	17.1	0.0	4.4	386.0
1984	0.0	0.0	2.0	0.0	36.6	21.2	61.2	34.4	13.5	0.0	0.0	0.0	168.9
1985	0.0	0.0	0.0	19.1	89.5	0.0	127.0	129.2	26.0	0.0	0.0	0.0	390.8
1986	0.0	10.8	11.7	3.2	6.5	26.8	72.8	24.6	12.9	0.0	0.0	0.0	169.3
1987	0.0	0.0	17.9	16.6	103.8	14.3	70.7	76.7	6.4	0.0	0.0	0.0	306.4
1988	0.0	21.2	15.0	64.0	8.5	48.7	237.0	244.8	132.4	29.9	0.0	1.0	802.5
1989	0.5	22.8	64.9	185.9	2.7	55.2	106.1	283.7	104.7	14.0	0.0	0.5	841.0
1990	0.0	152.8	292.0	151.2	0.5	5.0	225.1	213.4	168.4	0.0	0.0	0.0	1208.4
1991	0.0	9.3	43.7	0.0	0.0	0.0	164.4	220.9	289.5	0.0	0.0	0.0	727.8
1992	0.0	71.2	55.9	151.3	90.4	249.1	499.7	666.8	410.6	0.0	0.0	0.0	2194.9
1993	47.0	133.0	68.0	293.0	143.0	75.0	289.4	698.4	182.4	36.8	0.0	6.2	1972.2

KOKA DAM Monthly Rain Fall (mm)													Yearly Total Rainfall
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1995	0.0	29.2	38.8	48.4	10.6	9.2	441.2	88.2	9.5	0.0	0.0	0.0	675.1
1996	3.5	14.6	27.4	40.1	10.2	39.0	116.2	260.6	49.3	0.0	0.0	0.0	560.9
1997	25.7	0.0	41.5	39.3	10.7	145.4	210.9	259.2	51.5	66.6	0.0	0.0	850.8
1998	31.0	37.6	17.9	27.2	130.3	65.8	245.9	399.1	71.5	167.9	0.0	0.0	1194.2
1999	15.6	0.0	4.1	0.0	10.0	110.2	219.3	211.4	67.0	177.6	0.0	0.0	815.2
2000	0.0	0.0	1.6	57.9	122.7	90.6	337.0	264.3	212.1	0.0	67.8	0.0	1154.0
2001	0.0	16.2	141.2	40.9	154.7	178.3	50.1	436.0	119.0	13.3	5.9	21.7	1177.3
2002	19.8	32.3	13.1	58.3	8.9	13.0	217.0	175.6	63.1	0.6	0.0	13.9	615.6
2003	46.1	65.6	104.2	22.0	0.0	121.3	274.7	273.4	33.2	0.0	3.8	0.0	944.3

Meki Monthly Rainfall													Yearly Total Rain Fall
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1965	43.1	70.2	81.9	47.1	87.6	111.6	203.8	168.9	53.9	45.1	4.5	0.0	917.5
1966	38.1	111.0	36.1	29.1	38.5	43.0	154.1	280.4	135.2	36.1	0.0	0.0	901.6
1967	0.0	1.2	91.4	21.9	54.9	83.5	253.3	70.3	95.5	67.7	117.3	0.0	857.0
1968	0.0	50.1	27.2	147.1	8.6	95.8	122.6	138.7	118.3	3.2	1.6	0.0	713.2
1969	9.5	84.6	55.0	30.8	22.9	34.2	161.9	105.6	79.9	3.8	0.0	0.0	588.2
1970	118.5	31.0	49.6	4.9	59.4	20.2	117.3	155.5	120.4	15.7	0.0	0.0	692.5
1971	0.4	0.0	21.8	21.2	57.8	129.6	100.8	195.6	119.8	0.0	11.3	7.0	665.3
1972	30.8	30.7	42.3	167.3	37.4	116.5	116.6	159.3	60.0	0.0	0.0	0.0	760.9
1973	53.0	24.7	97.7	83.7	88.3	98.5	169.3	158.6	132.8	2.3	0.0	0.0	908.8
1974	0.0	18.7	153.1	0.1	139.2	80.4	222.0	157.9	205.6	4.5	0.0	0.0	981.5
1975	2.4	7.3	12.7	69.0	61.0	118.4	321.1	61.8	83.3	5.8	0.0	0.0	742.8
1976	0.5	1.0	104.0	40.5	86.3	56.4	180.8	136.5	73.7	4.2	22.6	0.0	706.5
1977	4.5	74.0	19.1	78.1	22.5	132.1	253.6	91.6	95.0	223.7	38.9	0.0	1033.1
1978	8.5	147.0	53.6	46.9	19.3	229.3	83.2	243.5	102.8	35.4	1.1	0.0	970.6
1979	68.9	14.8	139.9	37.7	60.0	135.5	155.1	63.7	83.8	71.6	0.0	0.3	831.3
1980	20.4	7.2	0.6	57.0	39.9	98.3	153.3	133.9	52.9	23.0	0.0	0.0	586.5

Meki Monthly Rainfall													Yearly Total Rain Fall
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1982	18.1	18.1	6.5	67.8	65.9	3.1	98.1	122.3	117.0	65.5	9.9	2.7	595.0
1983	0.0	13.4	55.2	132.6	245.7	87.4	195.8	183.6	95.4	19.8	0.0	0.0	1028.9
1984	0.0	8.6	1.8	7.7	153.0	57.3	193.0	230.7	68.0	0.0	0.0	0.0	720.1
1985	0.0	0.0	6.3	58.4	86.2	8.9	225.9	195.4	115.3	0.0	0.0	0.0	696.4
1986	0.0	167.6	31.1	58.2	101.2	157.9	211.2	67.1	105.7	38.0	0.0	0.0	938.0
1987	0.0	13.9	116.5	66.1	231.2	27.2	111.9	167.6	67.3	2.3	0.0	0.0	804.0
1988	0.7	51.0	16.0	83.2	20.3	129.1	142.4	134.6	99.9	51.6	0.0	0.0	728.8
1989	3.0	36.9	112.5	84.8	14.5	122.7	122.7	173.7	109.9	35.1	0.0	0.0	815.8
1990	0.0	257.5	7.7	83.0	13.6	17.2	215.8	211.8	79.9	18.6	0.0	0.0	905.1
1991	0.0	49.2	173.5	0.1	11.6	2.8	66.8	43.9	21.0	7.6	0.0	11.7	388.2
1992	18.3	54.7	2.2	68.6	56.3	47.9	290.8	243.3	76.2	59.8	0.0	16.5	934.6
1993	31.4	30.4	1.4	120.2	61.4	65.0	188.2	147.4	46.1	56.9	0.4	0.0	748.8
1994	0.0	0.0	29.1	14.1	68.1	127.0	248.2	97.9	44.3	0.0	5.1	0.0	633.8
1995	0.0	0.7	34.6	80.6	49.8	19.0	90.9	46.6	8.4	0.0	0.0	0.0	330.6
1996	0.0	9.5	60.0	5.5	63.8	74.4	150.1	191.2	82.3	44.2	0.0	0.0	681.0
1997	0.0	1.0	59.6	21.5	58.1	69.6	152.4	181.8	80.6	51.0	0.0	0.0	675.8
1998	0.0	50.4	37.3	54.1	37.8	50.3	141.2	183.3	88.8	90.7	0.0	0.0	733.9
1999	0.0	44.0	78.0	71.0	8.3	68.2	196.2	123.6	59.4	154.3	0.0	0.0	803.0
2000	0.0	0.0	0.0	77.4	63.3	56.6	112.7	181.4	138.3	18.1	63.0	19.2	730.0
2001	0.0	44.1	147.7	15.3	113.6	50.3	180.5	154.8	47.6	0.0	0.0	0.0	753.9
2002	0.0	8.6	42.1	72.3	12.7	65.1	121.7	145.6	29.3	0.0	0.0	24.2	521.6
2003	31.3	27.2	86.5	166.5	9.7	44.5	269.4	94.5	15.7	0.0	0.0	55.5	800.8
2004	7.8	0.0	13.6	141.4	0.0	18.7	111.4	127.1	138.7	0.0	0.0	0.0	558.7

OGOLCHO/Habura Station Monthly Minimum Temperature													Yearly average mean monthly MIN Temperature
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1974	12.4	12.1	12.5	11.8	10.8	10.9	12.8	14.6	13.2	9.9	8.2	6.9	11.2
1975	6.2	10.7	11.9	12.9	12.4	12.4	13.6	14.3	13.0	11.5	9.7	8.2	11.9
1976	9.7	11.6	12.8	13.9	13.9	13.9	14.4	13.9	12.8	13.1	11.2	9.5	12.8
1977	13.2	12.5	13.7	14.3	14.5	14.7	14.0	14.1	13.5	13.9	11.7	9.1	13.3
1978	9.2	13.4	13.3	13.1	13.5	14.0	14.7	13.7	12.9	12.5	10.1	9.6	12.8
1979	11.2	13.3	13.2	13.2	14.4	13.9	13.9	14.1	13.4	12.9	9.7	9.6	12.8
1980	11.8	12.5	13.4	14.3	15.3	13.7	13.1	14.4	13.9	13.3	9.2	9.5	13.0
1981	10.2	11.8	14.6	14.9	14.8	14.9	14.5	14.8	13.7	12.9	8.8	9.6	13.2
1982	11.0	12.3	13.8	14.7	14.9	13.9	14.5	14.4	13.5	12.5	12.9	10.9	13.5
1983	10.5	12.9	13.0	14.7	15.1	14.2	14.3	14.2	13.3	12.1	11.6	10.6	13.3
1984	10.0	13.6	12.1	14.7	15.3	14.4	14.1	14.1	13.2	10.2	10.2	10.3	12.9
1985	11.3	13.2	14.2	14.8	15.3	15.1	13.9	13.7	13.1	12.3	10.5	10.8	13.4
1986	9.8	12.9	14.4	15.3	14.8	15.1	14.2	12.3	10.6	9.6	11.5	11.6	12.9
1987	11.7	12.5	15.2	13.9	15.1	15.1	14.4	10.8	8.0	8.9	11.8	12.5	12.6
1988	13.1	12.2	16.5	16.0	15.3	15.4	15.0	14.8	14.7	14.5	12.6	12.7	14.5
1989	12.5	13.2	13.8	13.1	13.5	14.1	14.0	4.4	13.8	12.9	12.6	13.2	12.6
1990	13.3	15.0	14.2	14.8	15.1	15.0	13.5	13.3	14.7	14.5	14.2	14.4	14.4
1991	14.4	14.4	14.6	14.4	14.4	15.1	14.4	13.7	14.2	14.8	15.4	14.8	14.6

OGOLCHO/Habura Station Monthly Minimum Temperature													Yearly average mean monthly MIN T
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1992	15.8	14.4	14.5	15.2	14.9	15.5	13.6	14.2	14.2	15.9	15.4	15.2	14.8
1993	14.4	14.5	14.9	14.2	14.2	13.7	13.4	14.0	13.6	13.6	15.4	14.7	14.2
1994	16.3	13.3	12.2	13.2	11.7	12.6	12.4	11.9	13.8	13.6	15.7	17.3	13.4
1995	16.0	13.0	12.2	12.0	12.3	12.6	12.0	12.2	14.1	13.7	16.0	15.4	13.2
1996	14.8	12.6	11.6	13.4	13.3	14.9	16.5	17.5	18.0	19.8	19.0	15.0	15.6
1997	17.6	12.1	17.0	16.9	17.1	17.2	17.0	17.4	17.7	16.9	17.1	16.1	16.6
1998	18.3	18.0	16.6	16.3	14.9	15.8	16.0	16.1	16.9	16.9	17.9	17.2	16.6
1999	14.1	14.7	15.1	15.6	14.8	14.6	14.6	14.0	13.4	12.2	10.9	9.7	13.6
2000	9.9	11.3	13.4	14.8	14.6	14.2	14.6	14.3	13.6	12.6	11.7	9.6	13.2
2001	11.0	11.4	13.7	14.2	14.5	14.2	14.3	14.0	12.7	13.4	11.5	11.5	13.2
2002	12.8	12.1	14.6	15.0	14.9	15.4	15.2	13.5	12.8	13.4	13.2	14.7	14.1
2003	13.2	12.8	12.7	12.1	12.2	14.7	14.7	14.3	13.6	12.1	12.4	10.3	12.9

OGELCHO/Habura Station Monthly Mean Max Temperature													Yearly Avg. Mean monthly Max. Temprature
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1974	28.3	28.0	28.1	28.9	27.6	25.6	25.0	22.9	20.3	23.4	22.4	22.8	25.3
1975	26.0	23.8	26.4	24.7	26.5	26.5	24.9	24.3	26.3	25.8	26.2	27.7	25.8
1976	25.9	25.1	27.6	29.1	27.4	27.4	24.7	24.7	26.3	28.2	26.6	27.6	26.7
1977	26.0	26.4	28.7	28.9	28.3	26.6	24.6	24.1	25.3	27.0	26.1	27.1	26.6
1978	27.4	27.1	28.1	30.7	29.8	28.4	24.4	25.0	25.8	26.3	26.9	27.2	27.3
1979	26.8	28.7	29.8	30.8	29.3	28.5	24.3	25.4	27.8	24.4	28.3	28.9	27.7
1980	27.5	29.1	29.1	29.2	28.8	29.1	26.2	25.2	26.1	26.0	28.2	28.4	27.7
1981	29.3	29.5	27.3	27.5	30.2	29.8	25.6	25.0	24.3	27.5	28.1	27.8	27.7
1982	28.5	29.8	30.1	28.8	29.3	29.2	26.1	24.6	25.9	26.3	26.7	27.2	27.7

OGELCHO/Habura Station Monthly Mean Max Temperature													Yearly Avg. Mean monthly Max. Tempretature
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1983	28.9	29.7	30.3	30.7	28.9	27.5	26.0	25.3	26.4	27.5	28.4	28.1	28.1
1984	29.3	29.6	30.4	32.5	28.5	25.8	25.8	26.0	26.9	28.8	30.1	28.9	28.6
1985	29.0	29.0	27.4	28.4	28.2	28.6	25.4	25.1	26.2	28.7	28.7	28.4	27.8
1986	28.3	28.1	27.9	28.6	30.4	27.6	25.4	27.2	27.0	28.2	29.6	28.4	28.1
1987	28.3	29.8	29.5	29.1	27.9	27.5	27.2	26.6	28.0	29.7	29.3	28.9	28.5
1988	28.3	29.0	31.5	30.7	30.1	26.8	24.4	24.4	25.2	26.0	26.9	26.4	27.5
1989	27.1	26.8	28.4	25.9	28.9	26.1	24.6	24.6	25.6	27.2	27.0	27.9	26.7
1990	27.9	28.2	28.4	28.9	31.3	28.8	26.1	25.2	25.3	27.2	28.5	27.8	27.8
1991	28.2	27.9	28.4	28.6	29.4	29.1	27.6	26.8	27.0	27.8	28.3	27.6	28.1
1992	27.1	27.5	26.7	26.7	28.1	28.1	26.2	24.7	25.7	27.2	27.5	27.1	26.9
1993	27.3	27.3	29.0	27.7	27.1	27.0	26.9	26.2	26.2	26.1	26.5	27.6	27.1
1994	28.3	30.1	29.4	30.5	29.3	27.0	24.8	23.0	25.7	28.5	27.6	27.0	27.6
1995	28.2	30.7	29.4	28.7	28.5	29.8	25.8	25.3	26.7	29.0	29.3	28.4	28.3
1996	27.4	30.6	27.8	29.8	27.9	25.9	25.0	24.8	26.7	28.6	28.2	28.3	27.6
1997	27.6	29.6	30.5	28.0	29.9	28.0	26.5	26.4	28.6	28.3	28.1	28.6	28.3
1998	28.6	29.9	30.4	32.1	30.7	29.7	25.2	25.4	26.3	26.8	28.6	28.4	28.5
1999	29.4	31.0	29.8	32.1	30.8	28.8	25.0	26.3	26.7	25.9	27.4	28.0	28.4
2000	29.3	30.9	31.8	30.5	29.2	28.2	25.6	24.9	26.0	27.3	27.5	28.2	28.3
2001	28.3	30.6	28.5	30.4	29.0	27.4	25.7	25.8	27.6	30.1	29.4	29.1	28.5
2002	28.7	31.1	30.8	31.4	32.1	28.9	28.1	26.1	28.9	31.0	30.0	28.6	29.6
2003	29.3	30.5	29.5	29.6	31.8	29.5	24.9	26.0	27.0	30.6	30.0	28.0	28.9

Ogelcho/ Habura Station Monthly Rain Fall													Yearly Total Rain Fall
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1974	15.3	0.0	96.6	8.7	49.0	159.0	126.8	94.5	132.0	11.7	0.0	0.0	693.6
1975	20.8	5.2	45.7	111.7	112.8	113.8	131.2	92.5	91.7	8.9	0.0	0.0	734.2
1976	26.3	10.4	14.5	18.5	50.0	68.6	135.6	90.5	51.4	6.1	48.0	0.0	519.9
1977	37.3	3.5	69.3	66.9	134.5	105.2	187.6	100.5	99.1	37.0	0.0	0.0	840.9
1978	0.0	64.2	64.9	11.1	5.9	60.6	101.6	116.2	123.9	52.4	26.8	0.0	627.6
1979	12.2	10.1	81.3	31.4	92.4	93.5	94.5	95.5	133.0	12.7	0.0	0.0	656.6
1980	12.0	37.6	83.7	55.8	96.3	92.8	139.5	99.0	130.3	26.6	0.0	0.0	773.5
1981	0.0	0.0	177.2	80.3	0.4	3.7	184.5	102.4	127.5	40.5	0.0	0.0	716.5
1982	0.0	34.4	39.6	53.3	59.0	26.7	132.5	105.9	60.4	43.2	18.7	2.6	576.3
1983	0.0	28.4	35.4	29.2	99.9	90.8	123.5	99.0	89.7	38.7	0.0	0.0	634.5
1984	0.0	15.7	31.2	5.0	140.7	154.8	114.5	92.2	119.0	34.2	0.0	0.0	707.3
1985	9.2	3.0	82.5	70.6	45.5	34.5	159.7	106.8	73.9	1.5	0.0	0.0	587.2
1986	0.0	72.4	220.6	31.2	104.1	87.6	75.6	63.6	99.3	33.6	0.0	0.0	788.0
1987	0.0	11.8	91.0	32.2	134.3	22.3	52.6	55.9	36.6	2.4	0.2	0.0	439.3
1988	0.0	49.2	8.9	171.2	49.3	192.6	189.7	186.7	260.7	96.3	0.0	0.5	1205.1
1989	0.0	45.1	117.9	91.4	11.1	181.7	177.5	135.9	134.1	27.7	0.0	0.0	922.4
1990	0.0	50.9	95.6	75.0	29.2	27.4	293.9	71.0	88.8	66.8	0.9	2.5	802.0
1991	3.1	56.7	73.3	89.9	43.6	37.4	198.4	55.5	55.5	9.7	0.0	9.1	632.2
1992	29.2	17.9	26.8	40.1	48.0	28.6	195.1	135.6	189.2	14.5	0.0	8.1	733.1
1993	30.0	27.2	32.0	170.0	136.9	21.0	206.1	132.0	90.8	87.4	0.0	0.4	933.8

Ogelcho/ Habura Station Monthly Rain Fall													Yearly Total Rain Fall
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1994	0.0	0.9	29.8	61.4	35.5	173.0	156.9	91.1	42.1	0.5	6.7	0.0	597.9
1995	0.0	33.5	63.4	161.9	93.8	59.3	106.0	116.6	67.7	31.5	0.0	31.6	765.3
1996	70.8	0.7	72.8	30.8	128.4	130.2	113.9	159.7	106.4	5.1	8.1	0.0	826.9
1997	19.8	0.0	152.7	105.2	29.6	62.5	159.2	64.1	97.0	59.1	4.5	0.0	753.7
1998	18.3	22.4	40.4	58.3	80.9	62.3	142.8	147.6	121.8	76.4	8.2	0.0	779.4
1999	0.0	6.3	21.5	2.8	35.0	91.0	125.0	94.9	70.2	174.2	0.0	0.0	620.9
2000	0.0	0.0	0.0	50.4	75.0	69.5	160.7	88.7	141.5	20.9	112.0	0.0	718.7
2001	0.0	4.0	123.4	10.7	100.3	90.6	155.4	157.8	45.1	12.3	0.0	4.1	703.7
2002	0.8	41.5	26.1	44.2	33.7	79.7	133.9	189.3	39.6	2.0	0.0	13.8	604.6
2003	6.1	58.1	90.8	86.5	33.4	92.6	176.6	95.8	91.5	3.4	0.2	38.5	773.5

Ziway Station mean Monthly Maximum Temperature(^{0}C)													Yearly Avg. mean monthly Max Temperature
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1983	25.0	25.6	27.1	25.5	24.7	25.8	23.6	22.8	22.8	24.1	24.4	23.5	24.6
1984	23.6	24.4	26.9	30.4	28.0	26.7	26.7	25.3	26.1	27.3	27.7	27.0	26.7
1985	27.5	27.9	29.3	27.4	27.8	28.2	24.8	24.3	25.0	26.6	26.6	25.8	26.8
1986	26.2	27.2	28.8	28.3	28.9	26.2	25.0	26.6	26.6	28.1	28.0	27.2	27.3
1987	26.4	28.7	28.5	28.8	27.5	27.6	27.4	27.2	28.5	28.7	27.4	27.8	27.9
1988	27.4	28.9	30.9	29.8	30.4	27.9	24.2	25.6	26.1	26.6	26.8	26.4	27.6
1989	26.0	27.0	28.3	26.0	28.1	27.1	24.7	25.7	26.0	27.2	27.7	26.7	26.7
1990	27.5	26.4	27.7	28.6	30.0	28.3	25.3	24.8	26.4	27.7	28.0	26.8	27.3
1991	28.6	27.9	28.2	28.7	30.4	29.0	23.9	24.6	26.6	27.9	27.5	26.9	27.5
1992	26.3	27.1	30.7	29.9	29.8	28.0	24.8	24.2	25.8	26.6	26.3	26.5	27.2
1993	26.0	25.9	29.7	28.0	29.1	27.5	24.5	24.6	25.9	27.4	26.4	26.2	26.8
1994	26.6	27.3	29.3	28.1	29.5	27.0	24.2	24.9	25.9	28.1	26.5	25.9	26.9
1995	27.1	28.7	28.8	28.1	29.8	29.7	25.7	25.9	26.8	28.6	28.0	27.6	27.9
1996	26.6	29.8	29.3	28.8	27.8	25.8	25.0	25.1	26.3	28.0	26.9	26.7	27.2
1997	26.7	28.4	30.0	27.5	29.5	28.2	25.5	26.3	28.5	27.4	27.3	27.2	27.7
1998	27.6	29.3	30.0	31.5	30.5	29.2	25.5	25.0	26.8	26.8	27.0	26.7	28.0
1999	27.5	30.2	28.9	31.1	30.4	28.2	25.5	26.4	27.6	25.7	26.3	26.2	27.8
2000	27.4	28.9	30.2	29.7	28.6	28.1	25.3	25.1	26.6	26.6	26.5	26.3	27.4
2001	26.3	28.5	27.6	29.9	28.2	26.5	25.9	25.4	26.8	29.0	27.3	27.2	27.4
2002	26.6	28.9	29.3	30.2	30.5	28.8	28.1	26.8	27.7	29.4	28.5	27.2	28.5
2003	27.6	30.0	29.8	28.8	31.0	28.4	24.4	25.2	26.8	28.6	27.7	25.9	27.9

Zeway station Monthly Mean Minimum Temperature (^0C)													Yearly Avg. Mean Monthly MIN Temperature
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	15.2
1982	14.8	15.5	15.4	15.6	15.8	15.7	15.4	15.5	14.6	14.5	14.7	15.3	15.2
1983	14.0	17.2	18.4	17.6	17.7	15.5	15.1	15.5	14.6	12.6	11.9	11.9	12.5
1984	11.3	11.5	13.8	13.6	14.5	13.6	13.0	13.3	12.4	10.4	12.0	10.5	12.0
1985	10.9	11.7	13.0	13.8	13.8	13.7	12.9	12.5	12.3	10.6	10.0	8.4	11.4
1986	8.2	12.6	12.4	13.5	13.2	12.5	12.0	11.6	11.7	10.6	8.8	9.8	13.9
1987	11.8	12.7	16.0	14.8	15.8	15.2	14.7	14.8	14.0	13.9	11.6	11.6	14.0
1988	13.0	14.9	14.6	15.5	15.6	15.5	15.3	15.1	14.9	13.0	9.7	11.0	13.8
1989	11.2	13.7	15.0	15.1	14.1	15.1	15.0	14.6	14.4	11.8	11.8	13.8	13.7
1990	11.8	15.4	14.2	14.9	15.6	15.0	14.4	14.4	14.9	11.9	11.9	10.5	14.0
1991	13.3	14.6	15.3	15.0	15.5	16.2	15.2	15.0	13.9	11.7	10.9	11.5	14.3
1992	13.4	15.0	15.6	16.2	15.8	15.6	14.8	15.2	13.4	12.7	11.5	12.7	14.3
1993	12.9	14.9	15.6	16.2	15.8	15.7	15.1	15.2	13.8	12.7	11.8	11.6	14.2
1994	12.4	14.9	15.6	16.2	15.8	15.8	15.3	15.1	14.1	12.6	12.1	10.4	14.3
1995	11.3	14.7	15.5	16.1	15.8	16.0	15.5	15.1	13.7	13.2	11.3	13.1	13.9
1996	14.4	13.2	15.9	15.9	15.4	15.4	15.0	14.6	14.2	11.1	11.4	10.3	14.5
1997	13.5	11.8	15.3	15.5	15.3	15.4	15.4	14.8	14.8	15.1	14.9	12.4	14.9
1998	15.3	16.2	16.4	16.9	17.2	16.6	15.7	15.4	15.2	14.4	10.4	9.4	12.4
1999	11.0	12.5	15.2	12.9	11.6	11.2	13.4	13.6	12.8	14.1	10.6	10.4	14.3
2000	10.9	11.9	14.6	16.5	16.4	16.0	15.7	15.7	15.0	13.8	13.1	11.6	14.5
2001	12.5	13.6	15.5	16.0	16.7	15.8	15.3	15.8	14.8	14.6	12.1	11.7	15.1
2002	13.2	13.3	16.0	16.0	17.4	16.3	15.6	15.7	15.0	14.6	13.2	15.3	14.9
2003	13.5	14.5	15.9	16.7	17.0	16.6	15.7	15.7	15.2	13.0	13.4	11.3	14.9

Ziway Station Monthly Total Rainfall													Yearly total Rainfall
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1983	34.4	56.3	85.9	100.6	152.1	43.3	153.2	146.5	64.6	27.2	0.0	0.0	864.1
1984	0.0	0.0	10.6	103.0	90.6	57.5	213.0	116.2	63.5	0.0	0.0	0.0	654.4
1985	0.4	0.0	30.6	105.4	118.6	40.0	155.7	138.2	69.0	1.3	0.0	0.0	659.2
1986	0.0	53.0	19.7	53.7	110.3	88.2	70.5	54.0	65.8	22.2	0.0	0.6	538.0
1987	0.0	29.8	56.3	47.6	219.6	16.2	67.5	54.1	44.7	17.1	0.0	0.0	552.9
1988	3.2	20.9	1.8	49.8	13.0	118.9	138.2	92.9	162.3	99.4	0.0	0.2	700.6
1989	4.7	50.3	195.7	129.9	2.9	101.9	114.6	150.5	133.5	11.7	0.0	39.6	935.3
1990	0.0	140.8	16.6	52.1	37.8	49.0	162.2	141.6	88.8	0.5	0.0	0.0	689.4
1991	1.7	122.8	141.0	12.8	26.2	114.0	171.9	144.3	47.0	10.7	0.0	9.2	801.6
1992	20.3	21.8	6.2	58.8	75.2	99.4	208.5	153.6	27.5	116.5	1.5	4.9	794.2
1993	42.1	127.4	0.4	100.2	128.5	68.5	223.7	147.5	49.4	71.0	0.0	0.2	958.9
1994	0.0	0.0	24.1	9.0	49.1	145.6	126.4	92.9	65.6	0.0	4.6	0.0	517.3
1995	0.0	28.8	68.0	141.3	21.6	49.5	79.9	131.7	28.5	3.1	0.0	11.6	564.0
1996	47.5	8.2	53.9	110.4	127.1	128.4	125.4	162.0	106.4	0.0	32.8	0.0	902.1
1997	20.0	0.0	70.4	229.5	4.7	150.4	161.7	57.4	45.8	108.4	0.3	0.0	848.6
1998	6.1	22.3	43.4	48.7	57.7	44.9	166.5	177.8	98.0	90.8	0.0	0.0	756.2
1999	5.5	0.0	28.5	2.4	44.2	110.3	85.0	63.8	72.0	133.8	0.0	0.0	545.5
2000	0.0	0.0	3.0	65.2	97.3	34.0	215.5	95.7	106.9	31.1	1.2	24.2	674.1
2001	0.0	0.0	107.8	28.2	74.2	78.3	137.4	130.6	54.6	0.1	0.0	1.8	613.0
2002	12.0	21.8	37.9	55.6	51.1	48.0	94.6	73.6	61.7	0.0	0.0	1.3	457.6
2003	21.2	0.3	98.0	127.1	21.3	82.9	221.7	156.7	101.0	0.0	3.2	17.4	850.8

Annex 2. [1]Human Population Data

Population by wereda : 1984					
Wereda	Rural		Urban		Total
	Female	male	female	male	
Dugda Bora	43788	41750	8432	9386	103356
Zeway Dugeda	30624	31361	1158	1158	64301

Counted Plus Estimated Population Size Of Weredas By Sex, Urban And Rural: 1994									
Wereda	Urban + Rural			Urban area			Rural		
	Both sexes	Male	Female	Both Sex	Male	Female	Both Sex	Male	Female
Dugda Bora	134,451	68,105	66,346	28,030	13,573	14,457	107,114	54,532	51,892
Ziway Dugda	86,691	43,103	43,588	2,424	1,204	1,220	84,267	41,899	42,368

[2]Population Size By Sex, Area And Density At Wereda Level: July 2005.					
Wereda	Population Size			Area	Person/Km^2
	Male	Female	Total		
Duguda Bora	96,469	93,906	190,375	1,459.53	130
Ziway Dugda	57,895	59,140	117,035	1,269	92

[1] Source : CSA

[2] Projected Population Size

Annex 3. Livestock Data

Wereda	Carrying capacity (TLU's)	Stocking Rate TLU'S	Stocking Rate/CC %	TLUs/HA	TLUs/Family	Oxen/Family
Ziway Dugda	90089	147732	164%	1.28	8	2.24
Dugda Bora	131006	96602	74%	0.72	4	1.14

Source: **Woody Biomass**