ADDIS ABABA UNIVERSITY
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DEPARTMENT OF EARTH SCIENCE

Landuse/Landcover Dynamics and Land Degradation Susceptibility Analyses in Kutaber Wereda using Geospatial Tools

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Abbreviations

DSS	Decision Support System
FAO	Food and Agricultural Organization
RS	Remote Sensing
GIS	Geographic Information System
GPS	Global Positioning System
MSS	Multi Spectral Scanner
TM	Thematic Mapper
ETM +	Enhanced Thematic Mapper Plus.
UTM	Universal Transverse Mercator
RDBMS	Relational Database Management System
DEM	Digital Elevation Model
SRTM	Shuttle Radar Topographic Mapping
WLC	Weighted Linear Combination
NASA	National Aeronautics and Space Administration
MCDE	Multi Criteria Decision Evaluation
Amsl	Above mean sea level
^{0}C	Degree centigrade
DN	Digital number
GCP	Ground control points
Km2	Square Kilometer
NGO	Non Governmental Organization
RGB	Red Green Blue
KWARDO	Kutaber wereda agricultural and rural development office

Abstract

LandUse/landCover changes occurred from 1973 to 2010 and land degradation susceptibility analyses were investigated in Kutaber wereda of South Wollo Zone; Amhara regional state, on an area of 719.92 km^2 which was monitored using geospatial tools together with field verifications. In addition to these, different metrological and other ancillary data were used for the study. The study area is a reflection of the Ethiopian highland degradation in many ways because of land degradation, deforestation, land fragmentation, steep slope cultivation are also common features in the study area. These problems have been the driving forces to Landuse/landcover changes in many parts of Ethiopia. The objective of this study is to understand and analyze the long term dynamics of Landuse/landcover change and developing the susceptibility of land degradation map. Results from landcover change dynamics show an increase in agricultural land from 21.59% in 1973 to 51.76% in 2010, with mainly at the expense of grass land, forest land and Shrub land respectively. On the contrary, forest land, shrub land and grass land decreased from 15.21%, 27.58% and 20.6% in 1973 to1.2%, 21.78% and 4.05% in 2010 respectively. Due to the rapid expansion of urban and rural settlement in the second period (1986 – 2010) shows that 8.65% of settlement existed in 2010, with mainly at the expense of grass land. Rate of landcover change and landcover conversion matrix clearly showed that the dynamics of different landcover classes over the study periods. Land degradation susceptibility map of the study area have been produced using multi criteria decision evaluation. Five model parameters: slope, landuse classes, soil type, population and Rain fall intensity have been used to run the susceptibility model. The result of land degradation susceptibility analyses showed that 12.92% the area is very highly susceptible, 23.74% highly susceptible, 24.34% susceptible, 25.08% less susceptible and 13.92% very less susceptible to land degradation. The majority of the area falls on susceptible, highly susceptible and very highly susceptible to land degradation (61%). The resultant land degradation susceptibility map along with the Landuse/landcover can serve local planners and researchers as a primary source of information for NRM of the study area.

Key words: Landuse/Landcover, land degradation susceptibility model, Dynamics.

CHAPTER ONE

1. Introduction

1.1 Background and Justification

Studies have shown that there remain only few landscapes on the Earth that is still in their natural state. Due to anthropogenic activities, the Earth surface is being significantly altered in some manner and man's presence on the Earth and his use of land has had a profound effect upon the natural environment thus resulting into an observable pattern in the landuse/landcover over time.

The landuse/landcover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on Landuse/landcover and possibilities for their optimal use is essential for the selection, planning, implementation and monitoring of landuse schemes to meet the increasing demands for basic human needs and welfare.

In Africa, Ethiopia is the third largest country having an area of over one million km^2 .The country possesses a variety of agro-ecological zones ranging from Arid to Wurch. The Ethiopian highlands acquire altitude above 1500m, which covers about 500,000km^2 amounting for 45% of the total land area (Mohamed saleem, 1995). These area are shelter for about 88% of the population; more than two third of the livestock population; 95% of the cropped land areas and 90% of economic activities in the country (Constable, 1984). Majority of the Ethiopian highland system appears to be well adjusted to environmental conditions that allowed permanent cultivation. The early human settlement and development of several agricultural systems in this agro-ecological zone were favorable climatic and ecological conditions, sufficient rainfall, moderate temperature, and well developed soils in these areas. For these reason, the highlands have been preferable settlement area for many years and known for a similar long-standing agricultural history (McCann, 1995). The complex and long history of settlement and high population pressure in the highlands of Ethiopia brought significant burden to the agricultural land. Due to this reason agriculture land has gradually expanded from gentle sloping to the steeper slopes of the neighboring mountains. This leads to change in landuse/landcover of the area.

The motor of landuse/landcover changes are countless. Some act slowly and some others trigger the event quickly and visibly. To better understand the impact of land use change on terrestrial ecosystems, the factors affecting land use must be more fully examined. Growing human populations exert increasing pressure on the landscape as increasing demands for resources such as food, water, shelter, and fuel.

Change in landuse/landcover such as, conversion of forest lands, wood lands and shrub lands in to agricultural lands has resulted in rapid decrement of the natural vegetation cover and severe land degradation (McDougall et al., 1975; and Virgo and Munro, 1977) as cited in (Feoli *et al*., 2002). A well developed Knowledge about the distribution and type of Landuse/landcover is strongly believed to be the most important indicator for resource base analysis (Solomon Abate, 1994). The influence could be examined by the changes in distribution and type of landuse/landcover in the past, and also those future predictions will be possible. Therefore, the state of the resource base of the Ethiopian highland should be examined in relation to population pressure by integrating environmental protection strategies with sustainable development strategies and their implementation (Feoli *et al*., 2002).

Remote sensing and Geographic Information Systems (GIS) are providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the general view analyses of earth-system function, patterning, and change at local, regional, and global scales over time; such data also provide a vital link between intensive, localized ecological research and the regional, national, and international conservation and management of biological diversity (Wilkie and Finn, 1996). By utilizing remote sensing technologies and implementing GIS mapping techniques, landuse and landcover change and land degradation analysis of designated areas can be monitored and mapped for specific research.

1.2. Statement of the problem

The wereda is highly susceptible to land degradation due to natural and man-made factors such as fast population growth, over-exploitation of resources and generally being a fragile environment. Fast population growth together with the scarcity of land and unmanaged agricultural practices leads to areas having steeper slope to be cultivated, forest land, wood land and shrub lands are converted to agricultural lands and settlement. This change in landuse/landcover has brought sever land degradation in the study area.

This sever land degradation in the study area has resulted in decrement of soil fertility, crop production and productivity. This made the area one of the food insecure weredas in the region.

1.3 Significance of the study.

The need for land degradation susceptibility analyses and landuse/landcover dynamics information become a focus in the current strategies for effective utilization and management of natural resources and in monitoring the rapid environmental change. The expanding geospatial technologies through GIS and Remote sensing system provides the capability to acquire, analyze, interoperate landuse/landcover dynamics on various scales, time and cost effectively.

Therefore, this study will address relevant issues on Landuse/landcover changes and land degradation susceptibility modeling for the study area and try to provide recommendations which may contribute to the sustainability of the environment and for the betterment of the livelihoods of the farming communities of the study area.

1.4. Objectives

1.4.1 General objective

The general objective of the study is to investigate the landuse/landcover dynamics and land degradation susceptibility analysis for a better design of decision support system (DSS) in sustainable natural resource management of the area.

1.4.2 Specific objectives

- To analyze long-term landuse/landcover changes over the past 37 years
- To analyze the impact of Landuse/landcover change on land degradation
- To develop land degradation susceptibility map

1.5. Limitation of the study

The study has some limitations of its own and attempts are made to figure out some of them. It was not possible to get landsat images of the same acquisition date, which are important for classification purpose. The other limitation was that for land degradation susceptibility modelling, soil map was lacking. Since the study used FAO SEA 1997 soil classification map and it was produced with 1:1,000,000 scale.

1.6. Materials and Methods

1.6.1. Data and Materials used

The Software and materials used in this research are described (Table 1.1)

Table1.1Materials used

No	Types	Name and Description
1	Software's	ArcGIS 9.3, ERDAS IMAGIN 9.1, IDIRSI, Global mapper 8, Glovis and ENVI 4.3
2	Topo-map	1:50,000 scale
3	Materials	GPS Magellan
4	Other data	Digital soil map, Digital geology map, population data, Rainfall data and SRTM 30 meter resolution

Table1.2 Satellite images used

Landuse type	Path and Row	Date of acquisition	Spatial resolution (m)
Landsat - MSS	181-052	Jan. 31, 1973	80 x 80
Landsat - TM	168-052	Jan. 05,1986	28.5 x 28.5
Landsat – ETM+	168-052	Jan. 15,2010	1.5 x 28.5

1.6.2. Methodology

1.6.2.1. Landcover Dynamics

Multi-temporal (Landsat MSS 1973, Landsat TM 1986 and Landsat ETM+ 2010) remote sensing data of the area was used to generate landuse/landcover dynamics of the study area. Image enhancement, rectification and classification were applied on the raw images. This has allowed the extraction of information on landcover condition and quantification of changes and its rate over the past 37 years using GIS and Remote sensing analysis (Figure1.1). The landcover conditions of three different periods have been spatially compared and the rate and quality of change have been calculated.

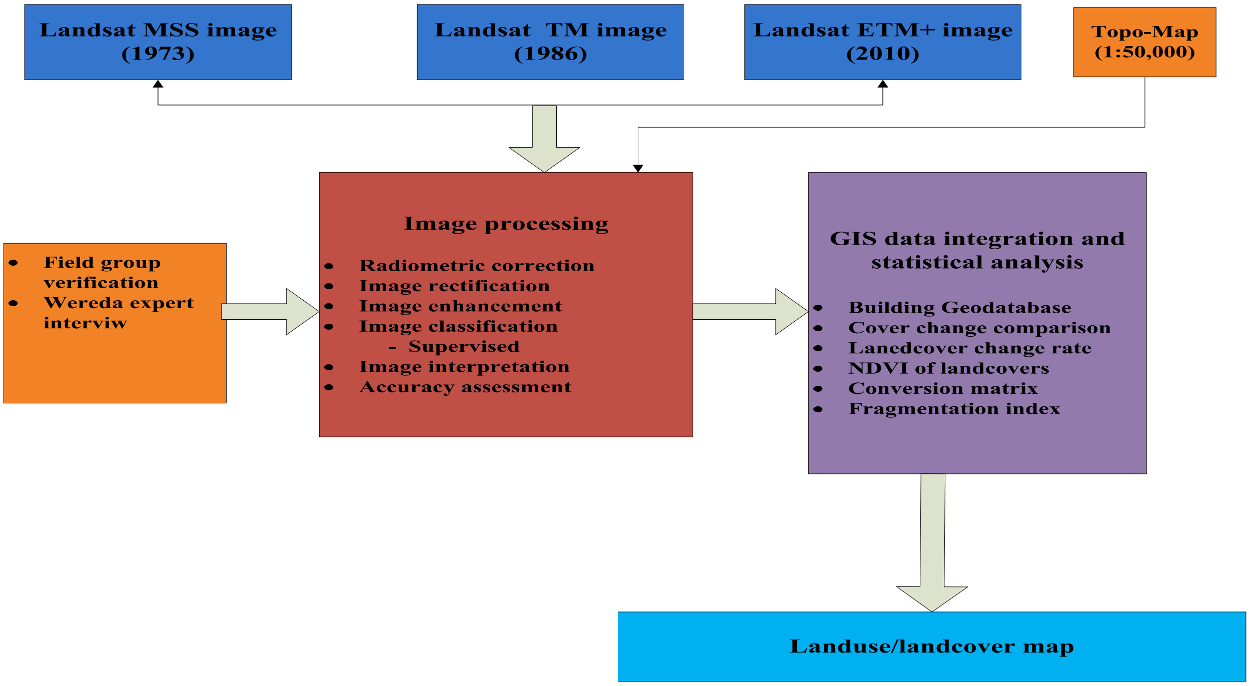


Figure 1. 1Methodology Flow chart

1.6.2.2. Land degradation Susceptibility Modeling

Conceptual land degradation susceptibility model (Figure1.2.) provides the procedures undertaken while running the model. In running the susceptibility model five parameters have been used.

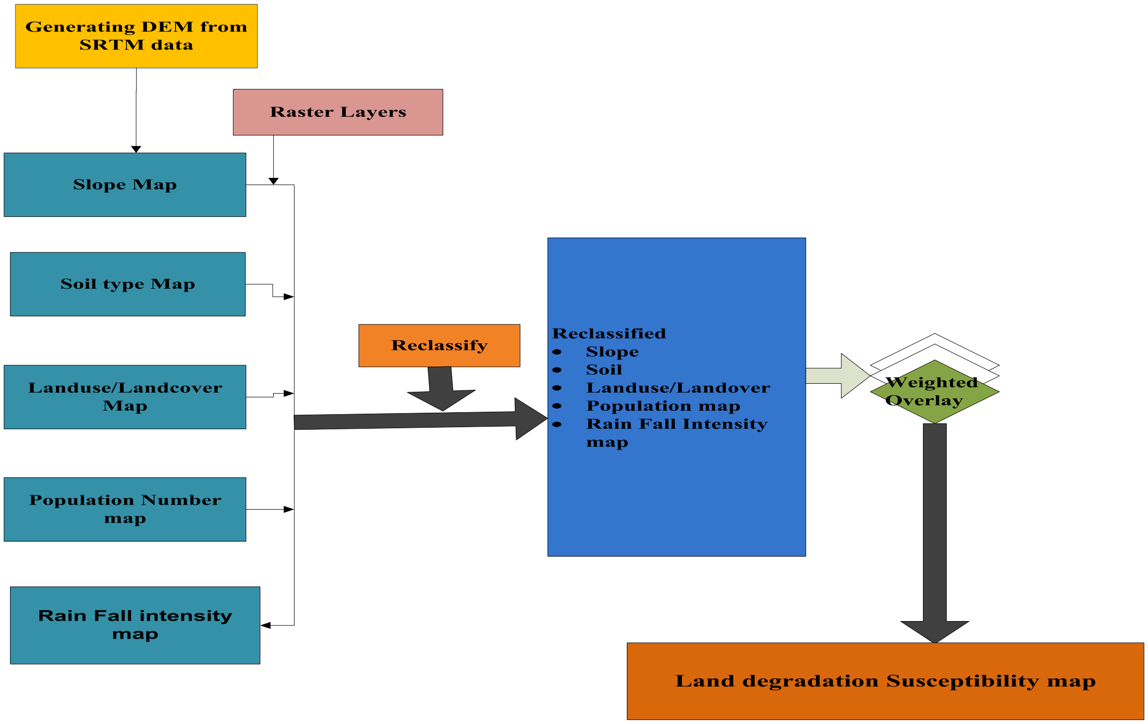


Figure 1. 2Methodology flow chart

Slope gradient, landuse/ landcover, soil type, rainfall intensity and population number was used as a parameters for land degradation susceptibility analysis. These model parameters were given weights based on their respective percent of influence to land degradation susceptibility by comparing each other. The weighted model parameters have been overlaid to come up with land degradation susceptibility model result.

1.6.2.3. Data Collection

A). Reconnaissance Survey

A combination of fieldwork and remote-sensing data was assembled as part of research work to determine the patterns and processes of landscape change over time on Kutaber wereda. Fieldwork was carried out in March. Brief, unstructured interviews were conducted with elder persons who have been familiar with resource-use and landcover histories in the study area over longer period of time and with the relevant experts from wereda agricultural and rural development office. The few interviews that were able to conduct were supported with a collection of historical documents. The different patterns of directional change observed from the pre filed visual interpretation of multi-temporal satellite images (1973, 1986 and 2010) and interviews conducted with informants who interact with the area over which the change is observed.

Information from the interviews and documents allowed us to describe the environmental history of this area from the three decades to present and also GPS has been used in the collection of ground control points for training samples used for image classification. More than 210 sample training sites have been collected

B). Satellite image and Top Map

Along with the above mentioned methods of data gathering the concern of this research data were extracted from the satellite images and from the top sheet which are relevant for the study. Appropriate satellite images and classification routines are selected depending on the targets of the study. For better spatial resolution of 2010 image classification panchromatic band of the image were merged to the other bands, so that the output colored image will have a spatial resolution of 15m x 15m from the panchromatic image.

1.6.2.4. Database Design, Creation, and Processing

A geodatabase is a relational database that contains geographic information. Geodatabase can contain feature classes, feature datasets, tables, and toolboxes. Feature classes can be organized into a feature dataset, or they can exist independently in the geodatabase. A geodatabase is a geographic information model to organize a GIS data and provides a generic framework for geographic information. This framework can be used to define and work with a wide variety of different user- or application-specific models. The model allows defining relationships between objects and rules for maintaining referential and topological integrity between objects. There are two types of geodatabase architecture; personal and multi-user. Personal geodatabase is a geodatabase that stores data in a single-user relational database management system, RDBMS. A personal geodatabase can be read simultaneously by several users, but only one user at a time can write data into it. Multi-user geodatabase is a geodatabase in an RDBMS served to client applications—for example, ArcMap—by ArcSDE. Multi-user geodatabase can be very large and support multiple concurrent editors. They are supported on a variety of commercial RDBMSs including Oracle, Microsoft SQL Server, IBM DB2, and Informix. In this study personal geodatabase has been used as the project database. The figure below illustrates the steps used in the creation of personal geodatabase.

The project database has been created using ArcGIS 9.3 software. The first steep is to design the geodatabase. The kind of data needed have been identified and new feature dataset have been created. The spatial reference and spatial reference and spatial domain have been set. The projection has been set to WGS 84 UTM zone as convenient projected coordinate system for the project. All data have been converted to a usable format. The personal geodatabase architecture has been built as can be seen in the figure.

CHAPTER TWO

2. Literature Review

2.1. History of Landuse/landcover study over the last century

Beginning with the eighteenth and nineteenth centuries, a different approach for determining changes in landuse is possible. Data can be obtained directly from land statistics compiled at administrative districts of varying scales. Croplands are relatively well documented in census records worldwide (Richards, 1990).
Areas of pasture or grazing land are more problematic, but they can be estimated from records of livestock and stocking densities. Based on Historical data and assumptions, approximately 28% of the forest area in Latin America was lost between 1850 and1985 (Houghton,1991).

For most of the tropics, rates have been increasing, with the last few decades showing the most dramatic increase (Figure 2.2). Before 1960 crop lands were expanding more rapidly in regions outside the tropics. In North America, Europe, the former Soviet Union, and China, the largest changes in landuse occurred earlier (Houghton and Skole, 1990 and Williams, 1990).

In the last two decades, a new approach for determining changes in landuse has appeared. With the launch of landsat in 1972, direct measurement of areas of different types of land cover and changes of these covers has become possible (Richards, 1999).

In Africa and Latin America most of the land used in Agriculture was derived from grasslands or shrub lands, where as in tropical Asia most was derived from forests and woodlands (Anderson, 1998).

2.2. Landuse/landcover Change Detection

An increasingly common application of remotely sensed data is for change detection. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Bottomley, 1998). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Change detection is useful in such diverse applications as land use change analysis, monitoring shifting cultivation, assessment of deforestation, and study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes (Bottomley, 1998). The basic premise in using remote sensing data for change detection is that changes in land cover result in changes in radiance values, which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computing power

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).

Landuse affects landcover and changes in landcover affect landuse. A change in either, however, is not necessarily the product of the other. Changes in land cover by land use do not necessarily imply a degradation of the land. However, many shifting land use patterns, driven by a variety of social causes, result in land cover changes that affect biodiversity, water and radiation budgets, trace gas emissions and other processes that, cumulatively, affect global climate and biosphere (Riebsame *et al*., 1994).

Forces other than anthropogenic can alter Land cover. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover. Globally, land cover today is altered principally by direct human use: by agriculture and livestock raising, forest harvesting and management, and urban and suburban construction and development. There are also incidental impacts on land cover from other human activities such as forests and lakes damaged by acid rain from fossil fuel combustion and crops near cities damaged by tropospheric ozone resulting from automobile exhaust (Meyer, 1995).

Changes in land cover driven by land use can be categorized into two types: modification and conversion. Modification is a change of condition within a cover type; for example, unmanaged forest modified to a forest managed by selective cutting. Significant modifications of land cover can occur within these patterns of land cover change. Conversion is a change from one cover type to another, such as deforestation to create cropland or pasture. Conversion land cover changes such as deforestation have been the focus of many global change research agendas (Riebsame *et al.,* 1994).

The loss of rainforests throughout the tropical regions of the world as a result of deforestation for timber resources and conversion to agricultural lands has become a topic of global attention with the aid of widespread media coverage. Research specialists such as (Skole & Tucker, 1993), (Skole *et al.*, 1994), and (Kummer & Turner, 1994) perform extensive studies in an attempt to bring further attention to this situation by focusing on the social implications and the environmental degradation associated with tropical deforestation in the Amazon of South America and in Southeast Asia. Yet, with all the research, awareness, and attention of the world, this potentially devastating phenomenon continues. It is an unfortunate, but fact of life that deforestation occurs on numerous expanses and at varying scales around the globe.

2.3. Environmental consequences of landuse/landcover change

Each category of landcover change is associated with a number of secondary environmental consequences: wet land drainage, for instance, can affect biodiversity, trace gas emissions, soil, and hydrological balance (Crosson, 1990). In economic terms, these effects often represent the externalities of land cover changes the costs and benefits passed on to others by the land user (Arnold, 1998).

2.3.1. Impact of landuse/landcover change on Hydrology

Hydrological (surface and ground water) impacts of landcover and landuse changes include changes in water quality and in water flows. Water pollution due directly to landcover changes stems from cultivation (Principally application of fertilizers and pesticides) and settlement or urban sewage (McCarthy, 1997). Changes in water quality and flow associated with land alteration result both from deliberate withdrawals and from land cover changes such as deforestation (Anderson, 1990).

2.3.2. Impact of landuse/landcover change on forest /Tree cover

Changes in the world's forest /Tree cover are of two kinds: clearance and conversion to another land cover like cultivation, grassland or settlement. The world's current area of closed forest, based on FAO data, is estimated to be around 29x106 km^2, or 21% of the world's land area (Bailey, 1998). Estimation shows that an original 62x106 km^2 of forest and wood land has been reduced by 9x106 km^2 of which 7x106 represent loss of closed forest (Adebyo, 1999). Goals and proximate sources of forest change differ considerably across the world (Anderson, 1998) clearance for cultivation, is probably the most common and widespread cause of deforestation.

2.3.3. Impact of landuse/landcover change on Atmosphere and climate

Much of human contribution to atmospheric trace species occurs through the process of industrial metabolism, but landcover changes significantly contribute to increase in a number of important components (Harvey, 1988). Several of the green house gases implicated in global climatic changes are mainly increased by land-cover change: CO_2 from forest clearance and soil carbon oxidation as well as from fossil fuel burning, methane from rice paddies, biomass burning, and N_2O from soils, fertilizers and biomass burning (Houghton, 1991). With regard to climate, various microclimatic changes as a result of land cover changes are clear; deforestation may affect global temperature through alb Edo change (Henderson-sellers, 1998).

The urban heat effect is the best climatic consequence of settlement expansion. Global warming is the regional impact of landcover charge on climate though the emission of industrial gases plays their own parts (Houghton, 1991). Deforestation would significantly lesson rain fall and increase temperature. Possible regional effect on temperature and precipitation of vegetation loss through over grazing is also the other impact of LUCC on climate (Graetz, 1999).

2.4. The Linkage between landuse/cover change and land degradation

Land degradation means a reduction or loss, in arid and dry sub humid areas of biological or economic productivity, complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and wood lands resulting from landuses or combination of processes. These processes includes those which arising from human activities and habitation patterns, such as soil erosion caused by wind or water, deterioration of the physical, chemical and biological properties of soils as well as lost of natural vegetation and biodiversity (Turner *et al*., 1994). Over the last ten years, a lot of attention has been drawn on the issue of landuse and land cover changes and the direct or indirect relationship that the changes might have with the observed land degradation (Brandt and Thrones, 1996).Such changes are the result of practices such as the relocation of people to the coastal border, farm and grazing abandonment, and the intensification of agriculture, among other landuses. For example, overgrazing, leads to compacting of the soil which reduces the infiltration and thus Increases the amount that leaves as runoff and later land degradation.

Deforestation also leads to increase over land flow since it removes the vegetation which probably affects rates of run off more than any other single factor. The rate of runoff is therefore a useful indicator of land degradation and desertification process which results from landuse practices (Brandt, 1985). Worldwide, soil loss and degradation and sediment transport have undoubtedly been increased greatly as a consequence of landcover change (Anderson, 1990).

2.5. Land Degradation

Land degradation can be related to both natural and human induced processes. Land degradation an outcome of human activity and their interaction with natural environment. They distinguished three types of degradation namely, biological, chemical, and physical. Physical land degradation includes degradation of soil structure, crusting, compaction, and erosion. Chemical degradation includes acidification, salinization, and nutrient and fertility depletion.

Biological includes reduction of soil carbon and soil biodiversity processes (Lal &Greenland, 1979). Accelerated land degradation is a biophysical process driven by socioeconomic and political causes. High population density is not necessarily related to soil degradation but what people do to the land determines the extent of degradation. Causes of land degradation are the agents that determine the rate of degradation. These are biophysical (land use and land management, including deforestation and tillage methods), socioeconomic (e.g. land tenure, marketing, institutional support, income and human health), and political (e.g. incentives, political stability) forces that influence the effectiveness of processes and factors of land degradation (Eswaran *et al.,* 2001).

Land degradation, a decline in land quality caused by human activities, has been a major global issue in the world. The importance of land degradation among global issues is enhanced because of its impact on world food security and quality of the environment (Eswaran *et al.,* 2001). Environmental degradation from human pressure and landuse has become a major problem worldwide but the effects are felt more in the developing countries than in the developed countries because of the high population growth rate and the associated rapid depletion of natural resources (Erlich, 1988).

2.5.1. Land degradation on climate change

Land-surface properties and the way they change in response to land degradation are the primary means whereby climate change may occur. Climatic response was not uniform, but parts of the globe especially affected include northern Africa with a far longer year-round drought. Soils subject to land degradation tend to become lighter in colour and more erodible. The driver of change appears to be the decrease in surface temperatures over most desert areas because of reduced absorption of short-wave radiation by the brighter surface. Additionally, carbon in soils is depleted, for which the links with climate change are well established (Schlesinger, 1991).

2.5.2. Land degradation on biodiversity

Processes of land degradation not only make soils lighter in colour because of selective removal of organic matter and colloids, they also reduce the biological life, or soil biodiversity. Soil erosion reduces productivity (Stocking, 2003), and productivity is closely related to biological processes dependent on both the variety and number of above-ground and below-ground living organisms (Stocking, 1987). Further, a degraded soil is less able to support vegetation biomass and the environmental conditions that would allow support of many sensitive and vulnerable species. So, the loss of habitat through land degradation in, for example, the conversion of forest lands to grassland results in the local extinction of plant and animal species (Sala *et al*., 2000). Conversely, sustainable land use and forestry are increasingly being financed as one legitimate way to enhance what is called 'collateral biodiversity' (Koziell, 2002) or the unplanned but deliberate increase in biodiversity through actions other than those directly related to species.

2.6. Land Degradation in Ethiopia

The occurrence of recurrent drought in Ethiopia has been attributed partly due to land degradation. Soil loss through water erosion is superabundant. Ethiopia loses an estimated 1.3 billion metric tons of fertile soil every year and the degradation of land through soil erosion is increasing at a tremendous rate. Land degradation in Ethiopia with its extent and impact, Ethiopia is one of among the poorest countries and poverty and land degradation appear to feed off each other (Berry, 2003). The paradox is that Ethiopia is a country with high biodiversity and distinctive ecosystems and the natural resource base is critical to the economy and the livelihood of a high percentage of the population Agriculture accounts for 50 percent of GDP, 85 percent of foreign exchange earnings and supports, albeit insufficiently, 85 percent of the workforce. Estimates vary considerably but direct losses of productivity from land degradation are minimally 3 percent of agriculture GDP.

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. Ethiopia is very much affected by soil erosion processes, among them gullies play a very important role and the amount of soil loss due to gulling has become a very serious problem in recent decade as it was associated to remarkable depletion of cultivated land. The development of gullies has many negative impacts as it normally involves the loss and (in some cases) the deposition of a great amount of soil. In many countries, the loss of large soil masses by gully erosion often stands for the depletion of a basic natural resource. Gullies affect large areas with different morphological, pedological and climatic characteristics and once gullies are formed, they tend to develop further and this process is seldom inverted or halted naturally (Billi and Dramis, 2003).

Several studies have been taken about land degradation issues at the national level in Ethiopia. These include the Highlands Reclamation Study: The conclusions from the researches indicate that in mid 1980's 27 million ha or almost 50% of the highland area was significantly eroded, 14 million ha seriously eroded and over 2 million ha beyond reclamation and erosion rates were estimated at 130 tons/ha/yr for cropland and 35 tons/ha/yr averages for all land in the high lands. Forests in general have shrunk from covering 65% of the country and 90% of the highlands to 2.2% and 5.6% respectively (Berry 2003).

2.8. GIS in Land degradation susceptible Modelling

A model is a representation of reality. Due to the inherent complexity of the world and the interaction in it, models are created as a simplified, manageable view of reality. Models help to understand, to describe, or to predict how things work in the real world. There are two types of models; those that represent the objects in the landscape, representation models and those that attempt to simulate processes in the landscape process models. Representation models try to describe the objects in the landscape, such as buildings, streams, or forests. Process models attempt to describe the interaction of the objects that are modeled in the representation model.

2.8.1. Susceptible Modeling Using Multi Criteria Decision Evaluation

Decision theory is concerned with the logic by which one arrives at a choice between alternatives. What those alternatives are varies from problem to problem. They might be alternative actions, alternative hypotheses about a phenomenon, alternative objects to include in a set and so on. Resource allocation decisions are also prime candidates for analysis with a GIS. Indeed, land evaluation and allocation is one of the most fundamental activities of resource development (FAO, 1976).

To meet a specific objective, it is frequently the cause that several criteria will need to be evaluated. Such a procedure is called Multi-Criteria Evaluation (Voogd, 1983). Multi-criteria evaluation (MCE) is the most commonly archived by one of the two procedures. The first involves Boolean overlay whereby all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (AND) and union (OR). The second is known as weighted linear combination (WLC) where in continuous criteria (factors) are standardized to a common numeric range, and then combined by means of a weighted average. Such a procedure is essentially risk-avers, and selects locations based on the most cautions strategy possible location succeeds in being chosen only if its worst quality (and therefore all qualities) passes the test.

A pairwise comparison method has been used for the development of weights of the factors in the land degradation susceptible analyses. Here breaking the information down into simple pairwise comparison in which only two criteria need be considered at a time can greatly facilitate the weighting process, and will likely produce a more robust set of criteria weights. A pairwise comparison method has the added advantages of providing an organized structure for group discussions, and helping the decision making group hone in one area of agreement and disagreement in setting criterion weights. The technique described here and implemented in IDRISI is that of pairwise comparison developed by (Saaty, 1977) in the context of decision making process known as the Analytical Hierarchy process (AHP). The first introduction of this technique to a GIS application was that of (Rao *et al.*, 1991) although the procedure was developed outside the GIS software using a variety of analytical resources.

CHAPTER THREE

3. Description of the Study Area

3.1.1. Geographical Location

Kutaber Wereda is found in Amhara regional state in south wollo zone of north central part of Ethiopia. The Woreda is 495 km far from the regional capital city Bahir Dar, 419 km far from Addis Ababa, and 18 km far from Dessie. The woreda is enclosed by Dessie zuria and Legambo on the south, Tenta on the west, Ambassel on the north, and Tehulederie on the east. The geographic location extends from 39^{0}18’ to 39^{0}38’ east Latitude and 11^{0}8’ to 11^{0}29’ north Longitude. Kutaber Woreda has an area of 719.92 km^{2}. The average elevation of the wereda is 2501m.asl. Major rivers, which drain in the Woreda, include Gerado, Beshlo, and Teleyayen (Figure 3.1).

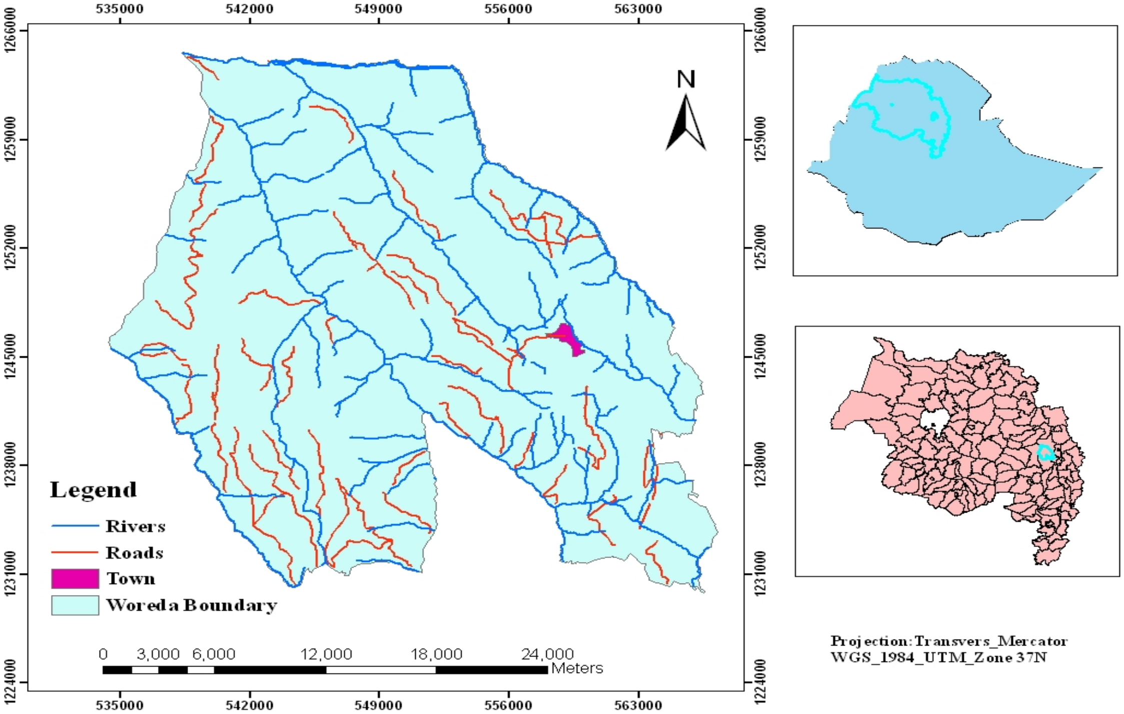


Figure3. 1Location map of the study area

3.1.2. Climate

The agro climatic zone of the Woreda varies from Kolla, Woina Dega and Dega. The average annual rainfall of the Woreda is 1110.57 mm per year. The Woreda high rainfall season is during Kiremt that starts in June and ends in September and short rain season is in Belg in January and ends in February. Temperature is the major determinant factor for Climate in Ethiopian. The mean minimum temperature for the Woreda is 6.56^0c during October and November to mean maximum temperature of 23.13^0c during may.

3.1.3. Geology

The geology of the study area is mainly characterized by Basic rocks (Basalt) and Pyroclastic rocks, unconsolidated Pyroclastics (eg. Ashes, Pumices, and Scoriae) and consolidated pyroclastics (eg. Tuffs, ignimbrites) and also few parts of the study area is characterized by undifferentiated unconsolidated sediments (FAO SEA, 1997).

3.1.4. Soil

The soils for the study area are predominantly Lithic Leptosols and Eutric Vertisols. The general slope ranges on from 0 to 79.85 % in which these soils occur. The area is usually found in landscapes of mountain and major scraps, uplands and bottomlands, and minor valleys (FAO SEA, 1997).

3.1.5. Topography

The topography of the study area is rugged, highly mountainous and altitude ranges from about 1728m in the west to 3466 m asl on the east part of the area. Because of the topographical features of the study area experiences of heavy soil erosion and gully formation on the highly slope areas and bottomlands is common phenomenon.

3.1.6. Basin

In the study area more than 92 seasonal rivers and springs are used for irrigation with a potential to irrigate 2416 ha of land (Kutaber woreda Agricultural and Rural Development Office). In some kebeles of the woreda, however, water for both human and livestock is not easily available. In most cases, farmers use water from small springs and hand dugwells which were constracted by governmental and non-governmental organizations. In few cases, farmers use water from rivers for drinking as well as for cleaning purpose.

3.1.4. Population and Socio-economic Conditions

According to kutaber woreda Agricultural and Rural Development Office (KWARDO), the total population of the woreda is estimated to 126,805 from this urban population is 2849 and rural population is 123,956, with a total household of 24,011. Kutaber woreda has an estimated population density of 184.5 persons per square kilometer and average family size is 5-6.

The woreda is totally inhabited by Amhara people and the people are predominantly followers of the Orthodox Christians and Muslim faith. The most important social and economic problems are the pervasive poverty and the high population growth rate with declining agricultural production.

The economic bases of the community in the wereda are the rain fed farming practices and free range livestock rearing. Mixed agriculture remains to be the main livelihood activity. The major cultivated crops include Teff, Barley, Wheat, Bean, Field peas, Maize, Chickpeas, and sorghum. Average land holding size is 0.75 hectare per household. In general, activities other than agriculture seem to be very limited. Agriculture is an important household resource that plays significant role to household food security, income generation. Cattle, sheep, goat, pack animals and poultry are the most common domestic animals raised in the rural area.

3.1.5 Landuse/landcover around Kutaber Wereda

The following major landuse types were identified from the study area during the field visit. These include agricultural land (a), forest land (b), shrub land (c) and degraded land (d). Figure 3.2 give a good impression of the area.

a b

c d

Figure3. 2Agricultural land, forest land, shrub land and degraded land of the area.

3.2. Data Analysis

3.2.1. GPS Ground Truth Data Acquisition

Extensive field survey was made throughout the study area using Global Positioning System (GPS). The field survey was performed in order to obtain accurate location point data for each landuse and landcover class for the creation of training sites and signature generation. In addition, data of degraded lands and gullies over the study area is collected using GPS. The field survey was carried out over three week's period.

3.2.2. Radiometric correction

The radiance measured by any givens system over a given object is influenced by a number of factors such as changes in scene illumination, atmospheric condition, viewing geometry, instrument characters etc (Lillesand and Kiefer, 1994). Radiometric pre-processing influences the brightness values of an image to correct for sensor malfunction or adjust the value to compensate for atmospheric effect.

Absolute radiometric calibration techniques require ground reflectance data and information about the sensor and atmosphere condition 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 pre-processing operation to correct atmospheric degradation; haze correction or dark subtract, is used to compensate this error.

3.2.3. Image Enhancement

Image enhancement is the process of making an image more interpretable for particular application. Common problem in remote sensing is the range of brightness collected by sensor that most of the time does not match with the capabilities of 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 stretching is applied on the dark subtracted imageries prior to image classification.

3.2.4. Preparing Landsat ETM+ 2010 Image.

Orthorectified Landsat ETM+ SLC-off image acquired on January 15, 2010 were downloaded from GloVis under the Landsat Archive collection. It was difficult to use the image directly due to a hardware failure that resulted in 22 percent of the data missing from each scene. To fill the gap a model was used, “off-to-off” product, which took the Landsat ETM+ SLC-off image and Landsat ETM+ scene acquired on December 5, 2001. By using model-maker in ERDAS IMAGINE 9.1 each band in Image 1 added to the corresponding band in Image 2 using the following statement, where image 1 > 0, use Image 1 data, otherwise, use Image 2.

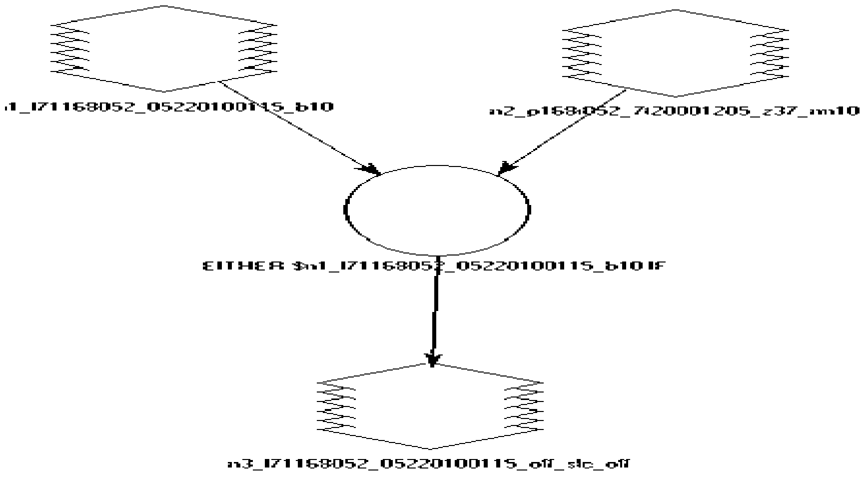


Figure3. 3Sample model for off-to-off image gap fill method

The Image 2 data fill the gaps in Image 1. Mosaic; feathering, overlapped, histogram matching, color correction and radiometrical matching applied to the output image for more complete coverage. Image enhancement, rectification, mosaicing were applied on the raw images (Figure 3.3 and 3.4).

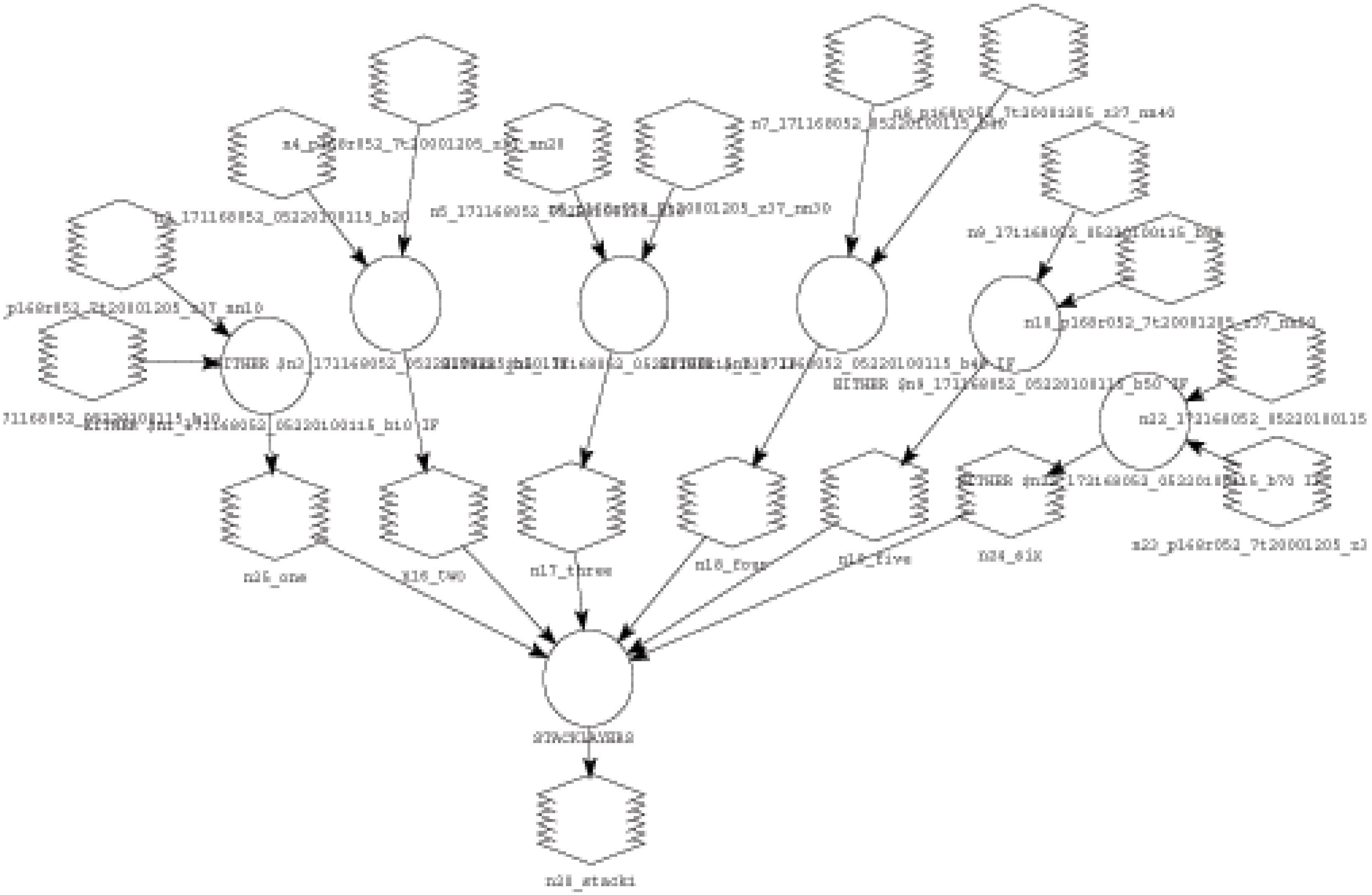


Figure3. 4The six band to band gap fill

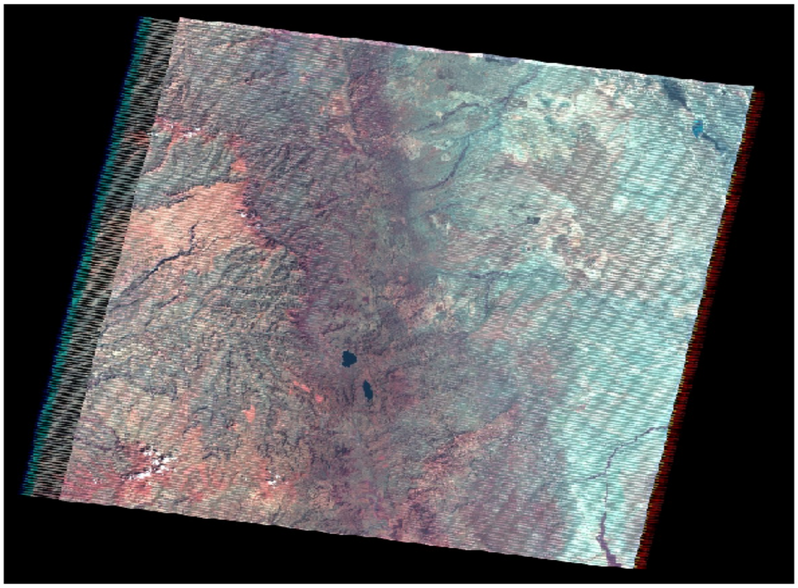


Figure3. 5Landsat ETM+ 2010 SLC-off image

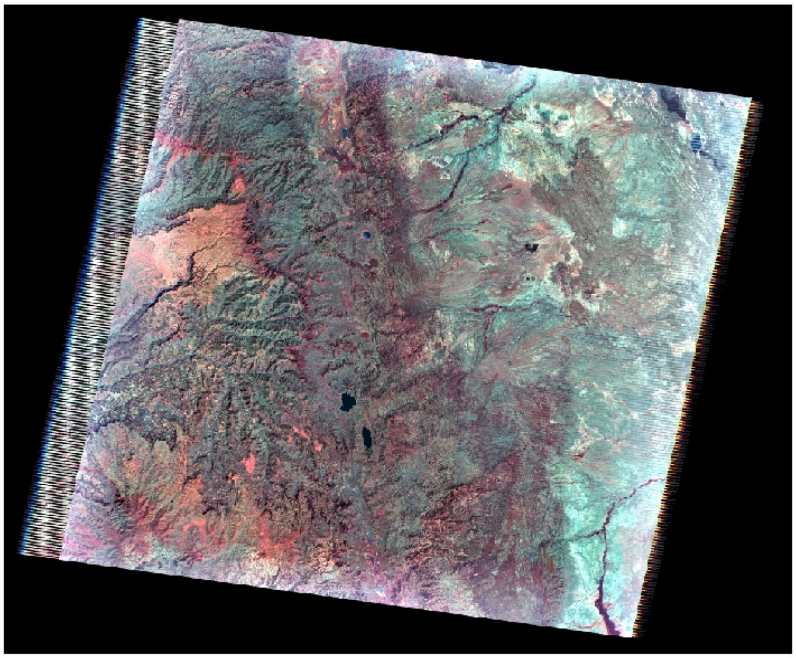


Figure3. 6Landsat ETM+ 2010 off -SLC- off image

3.2.5. Satellite Images Spectral Band selection

Landsat imagery was acquired in a very precise manner. Some of the parameters of this precision involve a scene's radiometry, providing distinct characteristics to components of the image scene. The image radiometric characteristic helps to determine which band combinations are good for different landuse/landcover identification in the image. For example, Bands 1, 2 and 3 are used together to approximate how the real world appears. Vegetation conditions can be clearly identified in FCC (band 4, 3 and 2). Basic information that were used for image interpretation and band combinations for landsat images as referred from GLCF site is provided (Table 3.1).

Table3.1 Landsat image spectral bands and their applications

Band	Band Name	Application
0.45 -0.56	Blue	- Soil and vegetation discrimination
0.52 – 0.66	Green	- Green vegetation mapping and cultural/urban features
0.63 – 0.69	Red	- Vegetated and non-vegetated mapping
0.76 – 0.90	NIR	- Delineation of water body - Soil moisture discrimination
1.55 – 1.75	MIR	- Vegetation moisture discrimination - Soil moisture discrimination
10.4 – 12.5	TIR	- Vegetation and soil moisture analyses - Thermal mapping
2.08 – 2.35	NIR	- Discrimination of minerals and rocks - Vegetation moisture analyses

3.2.6. True and False Color Composite Image Preparation

To enhance the visualization interpretation of image for landuse/landcover classification various false color composite were used. Various combinations of bands for different feature identification were used according to the information provided in table 3.1. These band combinations of both TCC and FCC are used to select the training sites for supervised classification. According to the information extracted, the spectral response for different features and landcover types are analyzed. The spectral profile graph shows the response of each landcover for different spectral bands (Figure 3.7).

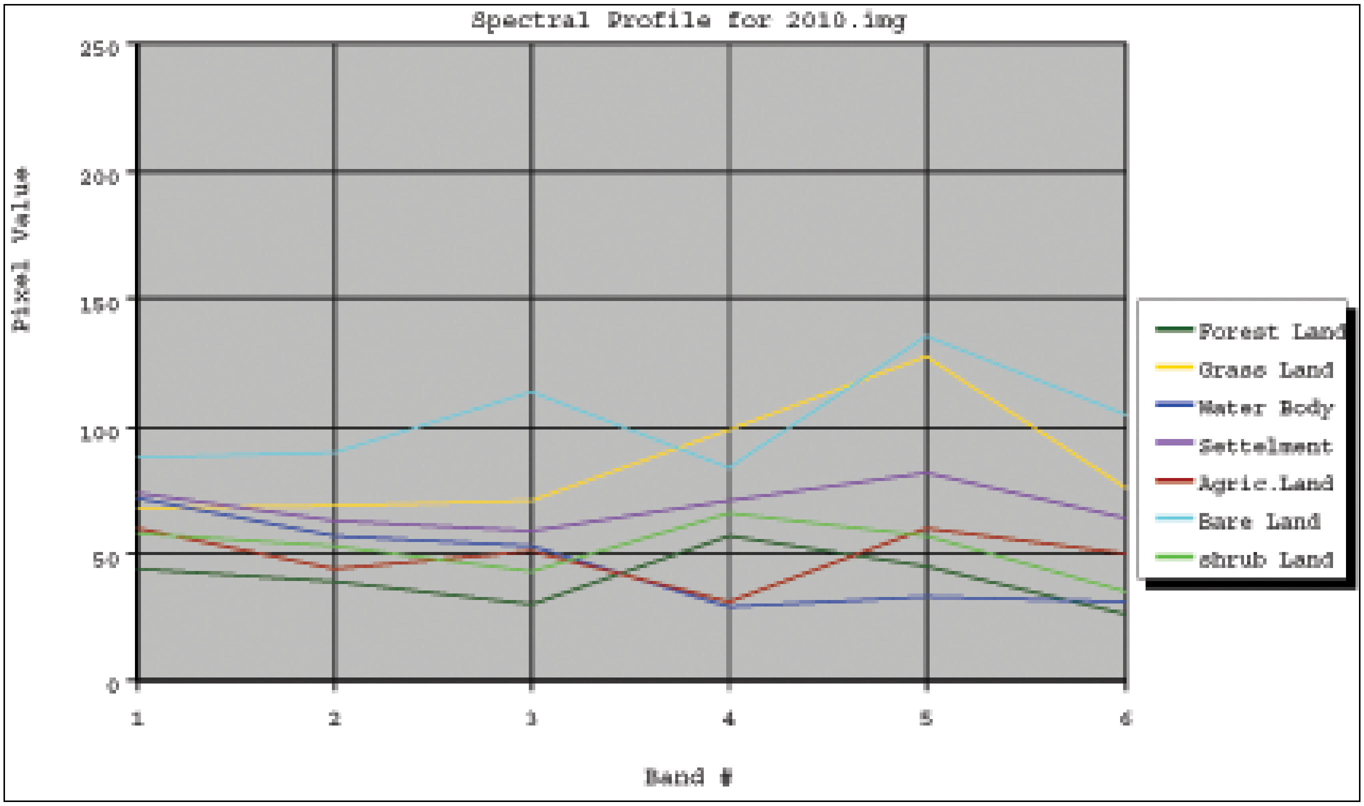
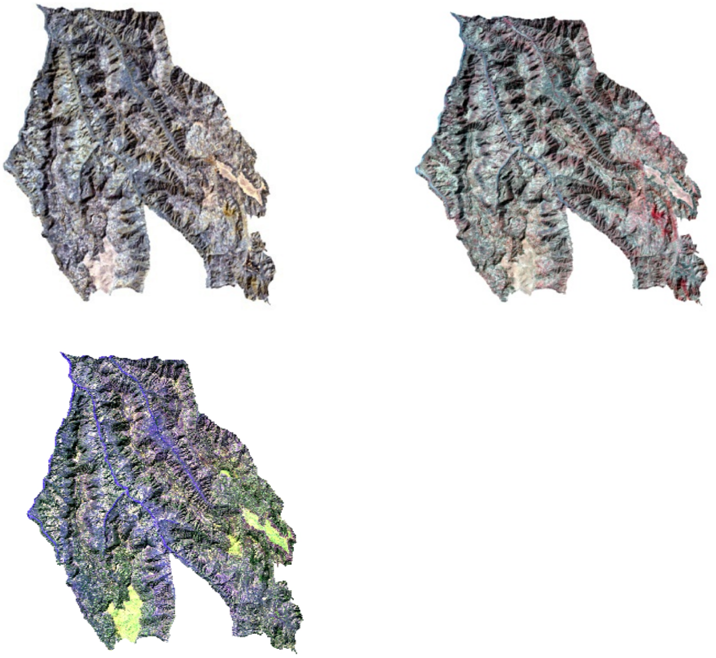


Figure3. 7Spectral reflectance graph of different landcover classes

In this research three TCC and three FCC for all (Landsat MSS, TM and ETM+) images were prepared for the process of identifying the different landcover classes in the study area (Figures 3.8).

FCC of 1973 3-2-1 FCC of 1986 3-2-1 FCC of 2010 3-2-1



TCC of 1973 4-3-2 TCC of 1986 4-3-2 TCC of 2010 6-4-1

Figure3. 8Different band combinations of Landsat ETM+ 2010

3.2.7. Image interpretation and Image Classification

In this paper image classification was used only for the extraction of distinct classes or landuse/landcover categories from satellite imagery. For this study the terms landuse/landcover were combined as one entity for the description of the landscape within the study area.

Based on Knowledge of the study area, visual interpretations of imagery and detailed reconnaissance field survey, different LULC categories were distinguished. The land use/cover classes that were identified for change analysis are: Agricultural land, Grass land, forest land, water body, bare land, shrub land and settlement.

Supervised image classification was done on each of the satellite images using the image processing software ERDAS IMAGINE 9.1. The maximum likelihood classification were applied for the image classification after selecting 18, 20 and 22 training areas on the 1973, 1986 and 2010 landsat images respectively. The selection of training sites were made based on the information obtained from field data, inter band comparison, ancillary maps (LU/LC maps), and that of the image interpretation of different TCC and FCC images.

3.2.8. Normalized Difference Vegetation Index (NDVI)

One of the most common vegetation indices is the normalized differencing vegetation index (NDVI). This technique was developed for identifying the health and vigor of vegetation and for estimating green biomass (Hayes and Sader, 2001). The absolute value of the result will be between zero and one. The greater the amount of photosynthesizing vegetation present, the brighter the pixel will be (Jenson, 1996). NDVI is calculated using the following equation:

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

Where NIR = the near infrared band response for a given pixel,

RED = the red response

3.3.10. Accuracy Assessment

To validate and crosscheck the result of the Landsat classification with known ground truth data accuracy assessment was checked for the signature values of classified images calculating the error matrix in ERDAS IMAGIN 9.1 software. The confusion matrix is a table with the columns representing the observed classes, and the row representing classified (mapped) classes (Rossiter, 2001). Kappa statistics represents the agreement between the classified Landuse/landcover and the observed landuse/landcover. The kappa statistics is a powerful technique in its ability to provide information about single matrixes well as to statistically compared matrices.

CHAPTER FOUR

4. Result and Discussion

4.1. Landuse/Landcover

4.1.1. Landcover classification of multi-temporal images.

To derive Landuse/landcover information for the year 1973 and 1986 images, six Landuse/landcover classes were selected for image classification. These classes were categorized as; Agricultural land, grass land, shrub land, forest land, bare land and water body. Seven Landuse/landcover classes for the year 2010 image classification and these were agricultural land, grass land, shrub land, forest land, bare land, settlement and water body. The absence of settlement in image classification for the year 1973 and 1986 was, most of the people lived in the rural area were living under cottage and the urban settlement of the wereda was too small and scattered. These made the classification difficult to categorize settlement as one distinct class in the year of 1973 and 1986, since the spectral reflectance of agricultural land and cottage and spectral reflectance of those scattered urban settlement and bare land are similar.

The major landcover classes of the study area for the year 1973, 1986 and 2010 were quantitatively analyzed. Generally there was a continuous landcover change taken place for most landcover types in the past 37 years. The landcover classes for Kutaber wereda as shown in table 4.1, figure 4.1 and 4.2 helps to compare each value for the major changes takes places. The comparison of the landcover change area values and area percentage for the three periods including 1973, 1986 and 2010 were summarized.

Table4.1 Result of the classification for the three periods

Landcover classes	**1973**		**1986**		**2010**	
	Area (km^2)	**Area (%)**	**Area (km^2)**	**Area (%)**	**Area (km^2)**	**Area (%)**
Settlement	-	-	-	-	62.272	8.65
Agricultural Land	155.419	21.59	355.235	49.34	372.624	51.76
Forest Land	109.51	15.21	65.511	9.1	8.64	1.2
Grass Land	148.314	20.60	39.4339	5.48	29.133	4.05
Water Body	70.7372	9.83	19.0854	2.65	22.7227	3.16
Shrub Land	198.583	27.58	183.208	25.45	156.823	21.78
Bare Land	37.3278	5.19	57.3879	7.97	67.6734	9.4
Total	*719.891*	*100*	*719.868*	*100*	*719.888*	*100*

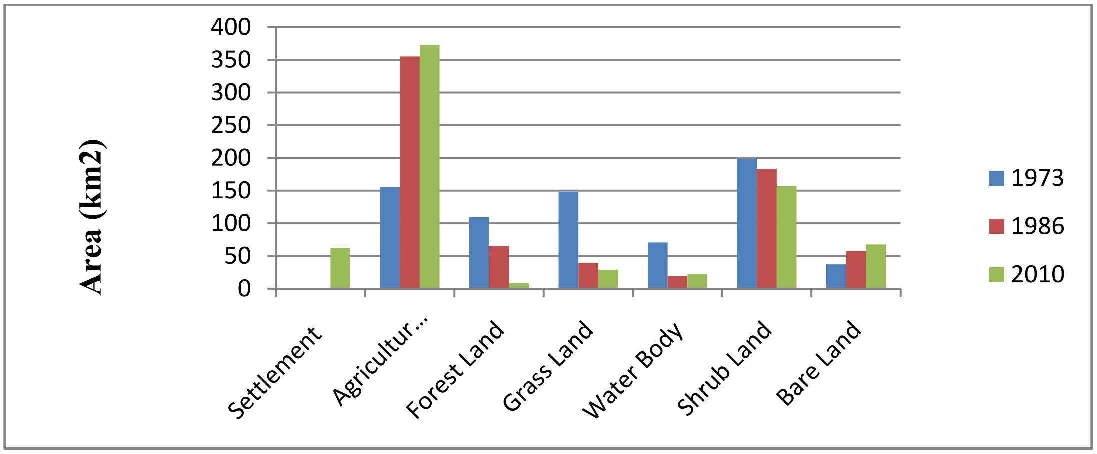


Figure4. 1Landuse/landcover classes of the three periods

The analysis for the 1973 MSS image, (Figure 4.2 and 4.3) shows that the area was dominated by forest land, agricultural land, shrub land and grass land which was 109.51km^2 (15.21%), 155.419km^2 (21.59 %), 198.583km^2 (27.58%) and 148.314km^2 (20.6%) respectively. Whereas, the land covered by water body and bare land was 70.7392 km^2 (9.83 %) and 37.3278 km^2 (5.19%) respectively. The grass land, which contain mainly grass species were found mostly in Alasha, Mariamweha and Guasa meda area of the Kutaber wereda. As Kutaber wereda agriculture and rural development office documented and the elders of the area indicated that, most of the mountainous area and rugged topography of the wereda was covered by indigenous tree specious of mainly *Juniperus procera* and the low land part of the area was covered by *Cordia africana* and *Podocarpus falcatus.*

The landcover classes for 1986, (Figure 4.4 and 4.5) showed that the highest share for agricultural land covered by 355.235 km^2 (49.34%), followed by shrub land which dominates low land, mountainous and rugged topography of the wereda covered by 183.208 km^2 (25.45 %), next to these forest land had 65.511 km^2 (9.1%), bare land 57.3879 km^2 (7.97%), grass land 39.434 km^2 (5.48%) and water body covers the minimum area coverage than any other landcover classes which accounts 19.0754 km^2 (2.65%) of the total area coverage of the study area. At this time three landcover classes showed radical change, these were agricultural land, grass land and shrub land.

The landcover classes for 2010, (Figure 4.7 and 4.8) shows the highest share for agricultural land covering 372.624 km^2 (51.76%), followed by shrub land which dominates low land, mountainous and rugged topography of the wereda covering 156.823 km^2 (21.78 %), settlement 62.272km^2 (8.65%), bare land 67.67km^2 (9.4%), grass land 29.13km^2 (4.05%), water body 22.72 km^2 (3.16%) and forest land covers the minimum area coverage than any other landcover classes which accounts 8.64km^2 (1.2%) of the total area coverage of the wereda. (Figure 4.3 to 4.8) show the landcover distribution and percentile value of the different landcover classes of 1973, 1986 and 2010 for the Kutaber wereda.

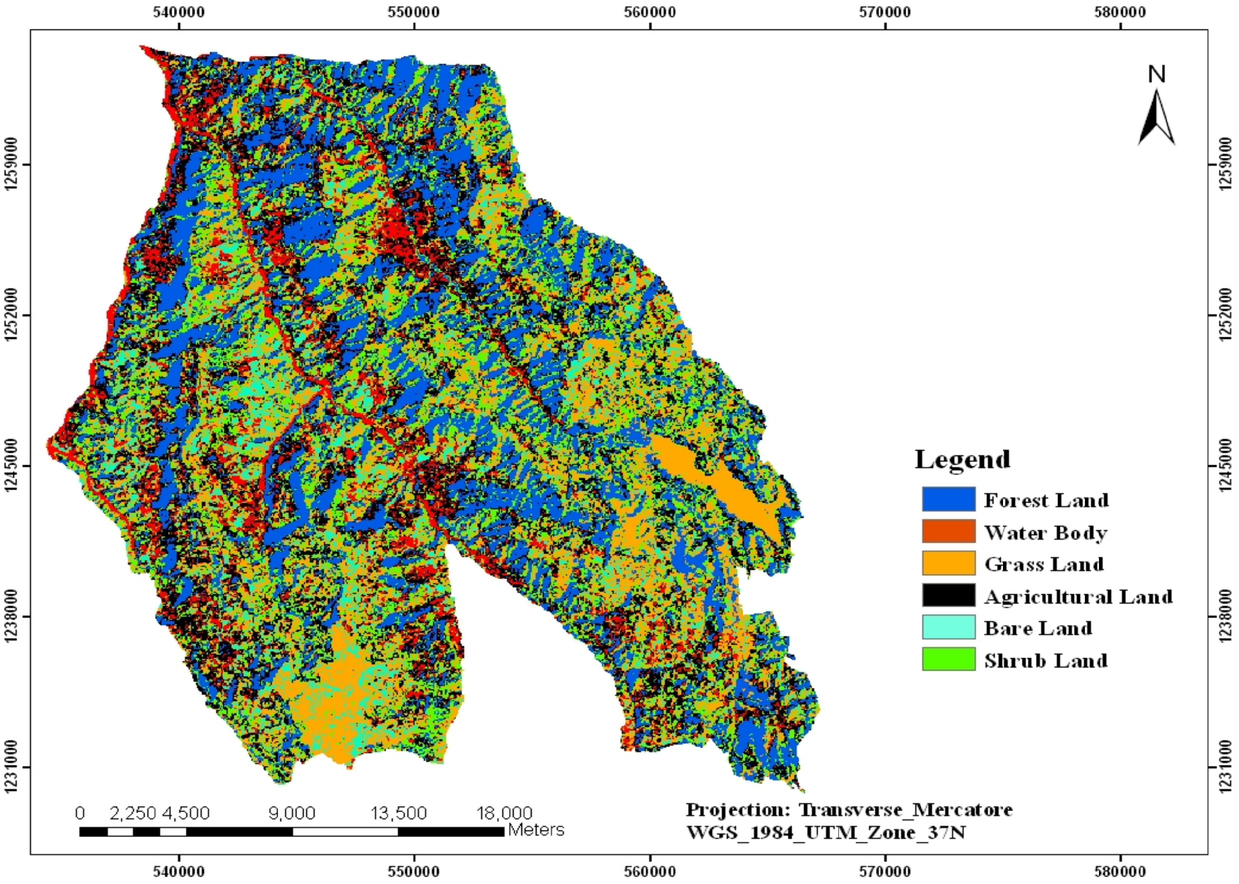


Figure4. 2Landcover classes for 1973

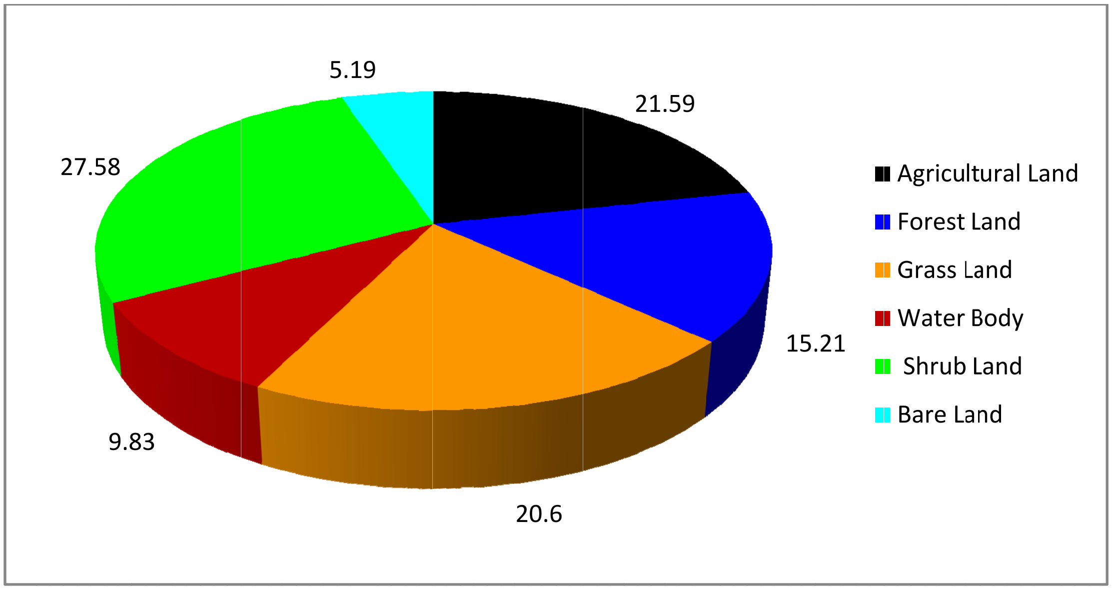


Figure4. 3Percentile values for 1973 Landcover

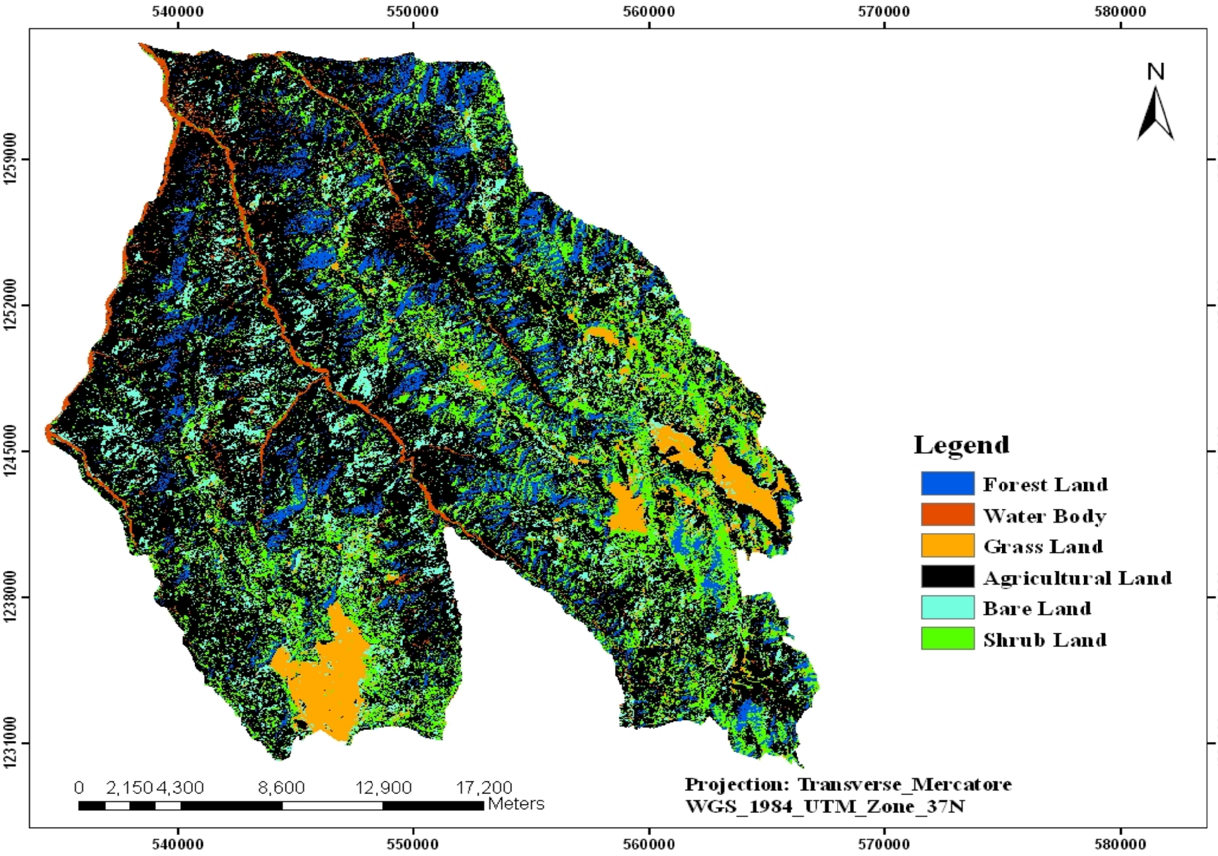


Figure4. 4Landcover classes for 1986

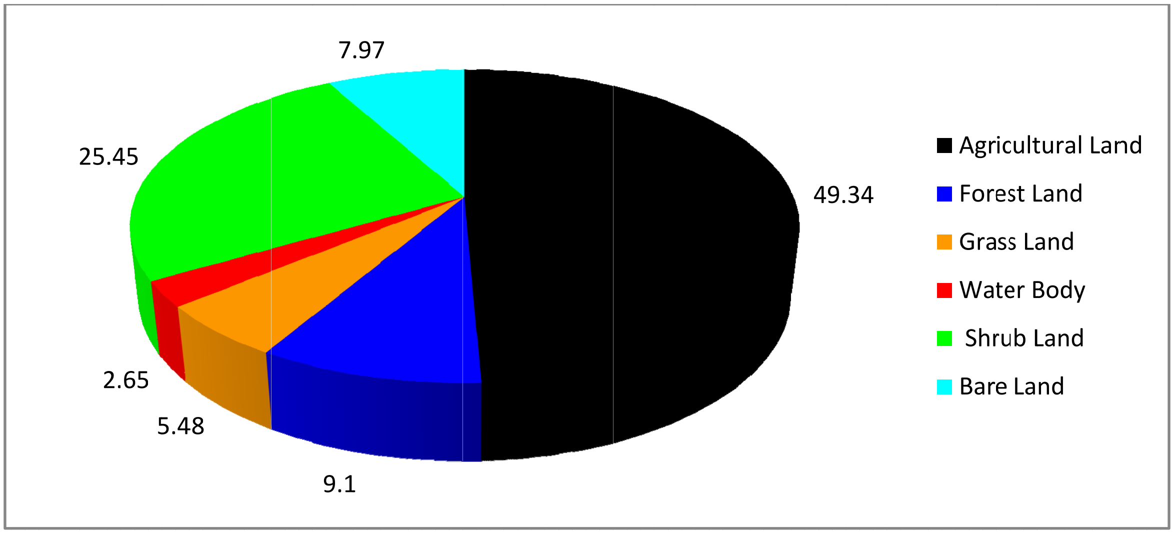


Figure4. 5percentile values for 1986 Landcover

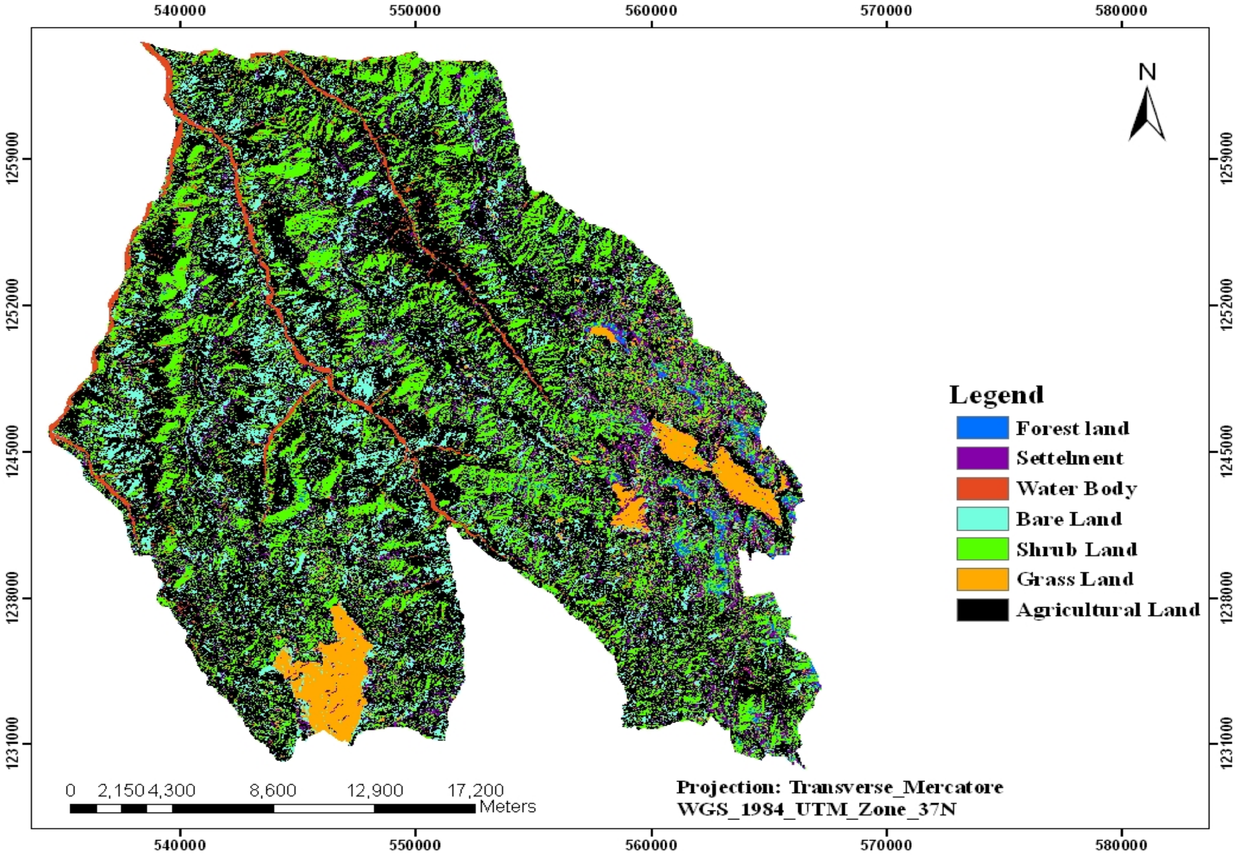


Figure4. 6Landcover classes for 2010

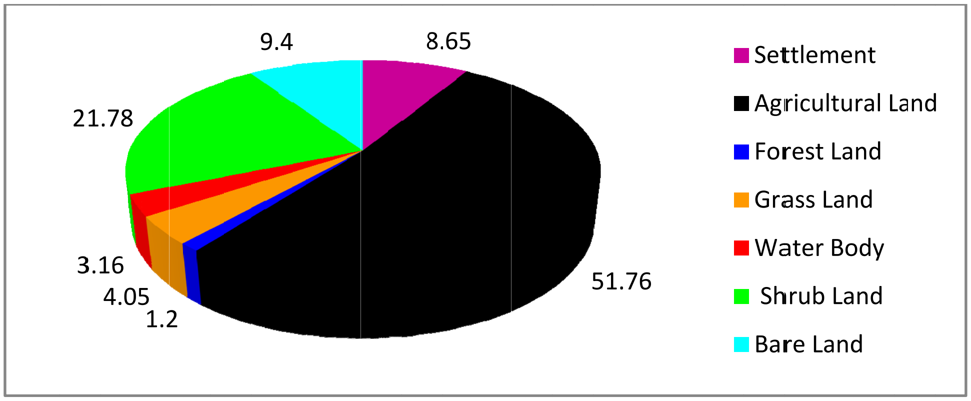


Figure4. 7Percentile values for 2010 Landcover

4.1.2. NDVI Image Comparisons

In this research the NDVI was used to get an over view of the vegetation biomass change over the past 37 years as it indicates the amount of green vegetation in each images which is important for landcover identification. The NDVI is calculated by using the model maker in ERDAS IMAGIN 9.1 software and the model used to calculate the

NDVI values of each year was shown in figure 4.8. The result obtained ranges between -0.7 to 0.84. After generating the three different NDVI images as presented on (fig 4.10, 4.11 and 4.12), then statistics of each of the NDVI images were calculated (Table 4.2).

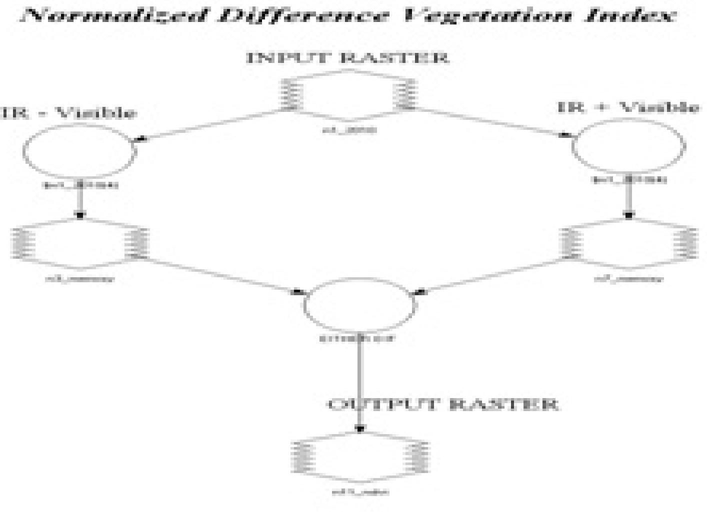


Figure4. 8Model used to calculate NDVI value for each year

The statistics and visual observation of the NDVI images over the periods show decrements in vegetation biomass. The NDVI value response of the different landcover types for the year 1973, 1986, and 2010 images clearly show highest value for forest cover as 0.84, 0.64 and 0.63 respectively. The NDVI was used only for visual comparison and to aid classification. The spatial distribution of NDVI values for the different landcover class shows different pattern due to the continuous change of forest land and shrub land.

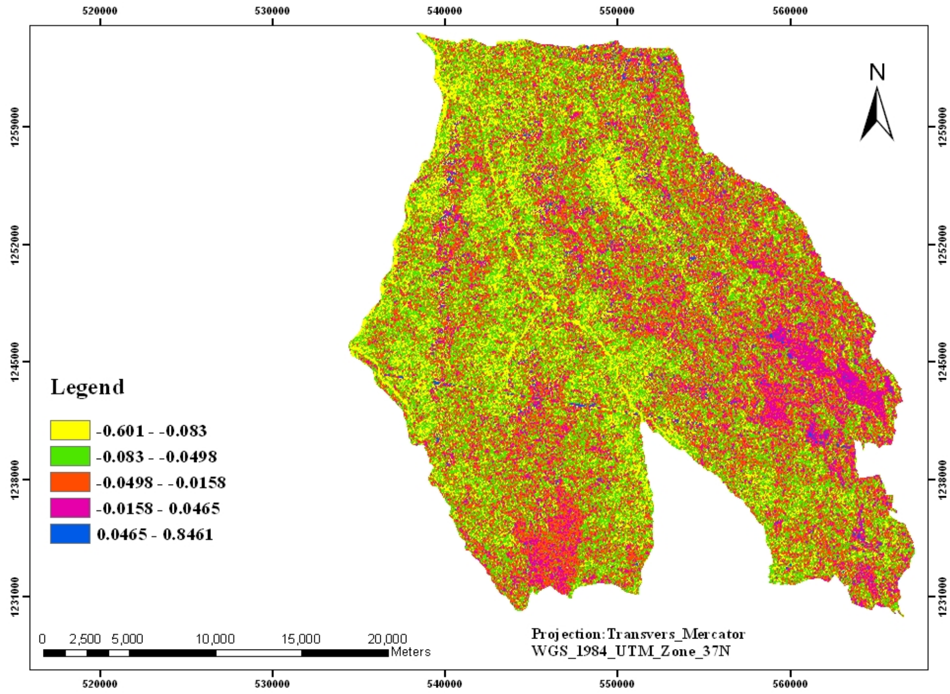


Figure4. 9NDVI map for 1973

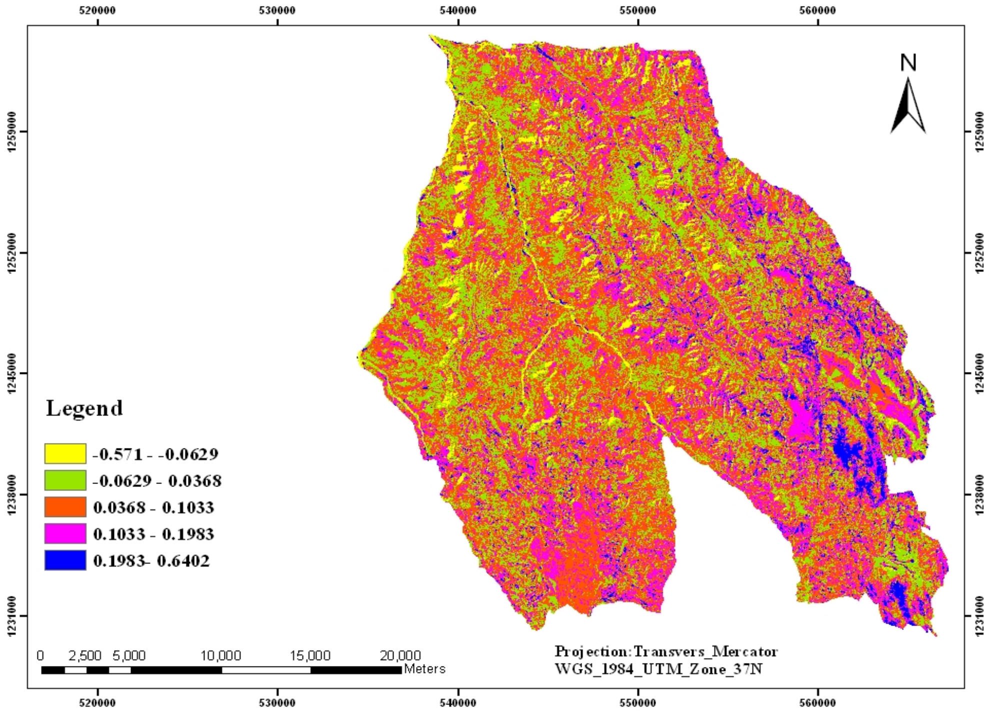


Figure4. 10NDVI map for 1986

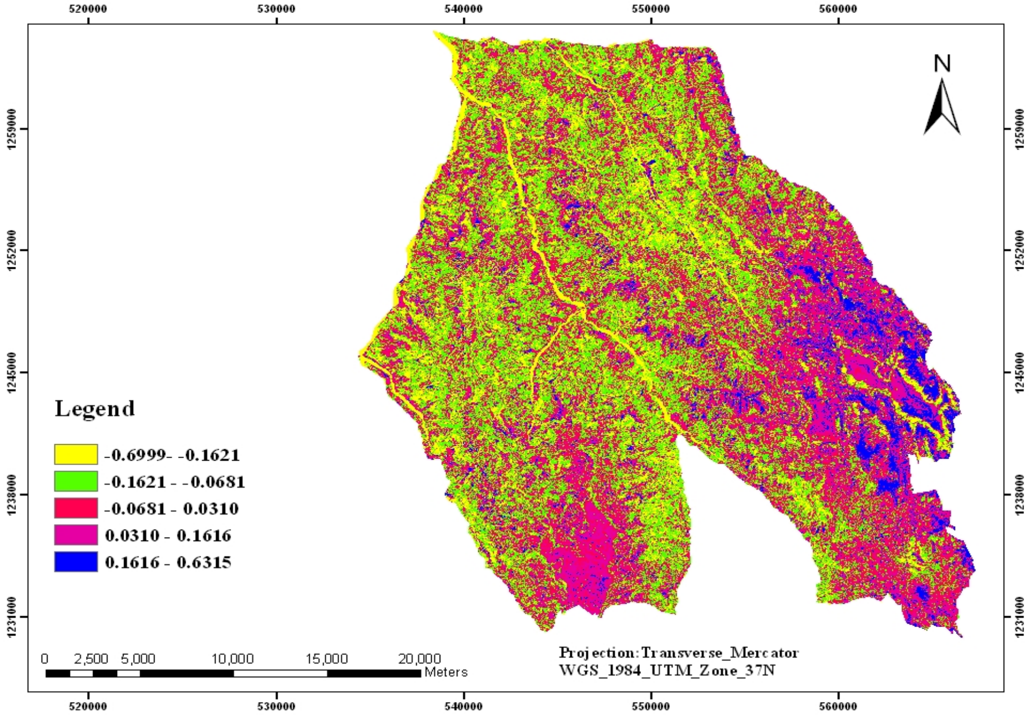


Figure4. 11NDVI map for 2010

Table4.2 NDVI Statistics value for the three years

NDVI Statistics	**Year**		
	1973	**1986**	**2010**
Maximum	0.84	0.64	0.63
Minimum	-0.60	-0.57	-0.70
Mean	0.12	0.03	-0.04
Standard Dev.	0.42	0.35	0.39

4.1.3 Landcover Dynamics and Cover Change Structure

4.1.3.1 Rate of Landuse/landcover changes

The landcover dynamics of the past 37 years which are discussed in the above thematic landcover maps of section 4.1.1 and 4.1.2 are discussed below in table 4.3 and figure 4.13 and 4.14 with various statistical analyses and cover change comparison factors. The first period has 13 year difference (i.e from 1973 to 1986) and the second period has 24 year difference (i.e from 1986 to 2010).

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

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

Where A = Recent area of Landuse/landcover in km^2.

B = Previous area of Landuse/landcover in km^2.

C = interval between A and B in years

The landcover dynamics discusses the rate of landcover change from 1973 to 1986 and 1986 to 2010 (Table 4.3).

Table.4.3 Rate of landcover changes for the two periods

Landover classes	**1973 to 1986**		**1986 to 2010**	
	Area change (km^2)	**Rate of change (km^2/yr)**	**Area change (km^2)**	**Rate of change (km^2/yr)**
Settlement	0	0	62.27	2.59
Agricultural Land	199.816	15.37	17.438	0.72
Forest Land	-43.99	-3.38	-56.871	-2.37
Grass Land	-108.88	-8.37	-10.3	-0.43
Water Body	-51.65	-3.97	3.633	0.15
Shrub Land	-15.375	-1.18	-26.385	-1.1
Bare Land	20.06	1.54	10.28	0.43

Analyses from the rate of landcover changes for the past 37 years clearly shows that agricultural land and grass land shows great change as compared to the other landcover classes between 1973 and 1986 time serious, (i.e Agricultural land shows the highest positive change and Grass land shows the highest negative change) where as forest land, water body, shrub land and bare land show little change in the same period. In the time serious of 1986 to 2010, settlement and forest land show the highest change, (i.e Settlement shows the highest positive change and Forest land shows the highest negative change) where as the other classes show little change as compared as settlement and forest land. Normally, the landcover class settlement was absent on the time serious of 1973 to 1986; due to the reason mentioned in section 4.1.1.

For the time serious of 1973 to 1986, it shows 199.816km^2 and 20.061km^2 area increments by agricultural land and bare land respectively. Agricultural land shows the highest positive rate of change for the time serious of 1973 to 1986 by 15.37km^2/yr and grass land shows the heights negative rate of change for the same period by -8.37km^2/yr. For the time serious of 1986 to 2010, there is 93.584km^2 total area increment by settlement, agricultural land, water body and bare land, from which settlement accounts the highest positive rate of change and it accounts 2.59km^2/yr where as agricultural land accounts 0.72km^2/yr, water body 0.15km^2/yr and bare land 0.43km^2/yr and there was a total area decrease of 93.556km^2 from which forest land shows the highest negative rate of change by -2.37km^2/yr.

Finally, as the rate of landcover change analyses indicates, there is a continuous expansion of agricultural land for the two periods at a rate of 15.37km^2/yr and 0.72km^2/yr from 1973 to 1986 and from 1986 to 2010 respectively and there was a continuous decrement of grass land, forest land and shrub land for the two periods at a rate of – 8.37km^2/yr and – 0.43km^2/yr, -3.38km^2/yr and -2.37km^2/yr and -1.18km^2/yr and -1.1km^2/yr from 1973 to 1986 and from 1986 to 2010 respectively. This shows that the agricultural land and settlement expand with the expense of grass land, shrub land and forest land.

The following graphs helps for clear comparison of rate of landcover change and landcover dynamics for the two periods, from 1973 to 1986 and 1986 to 2010(Figure 4.13 and 4.14).

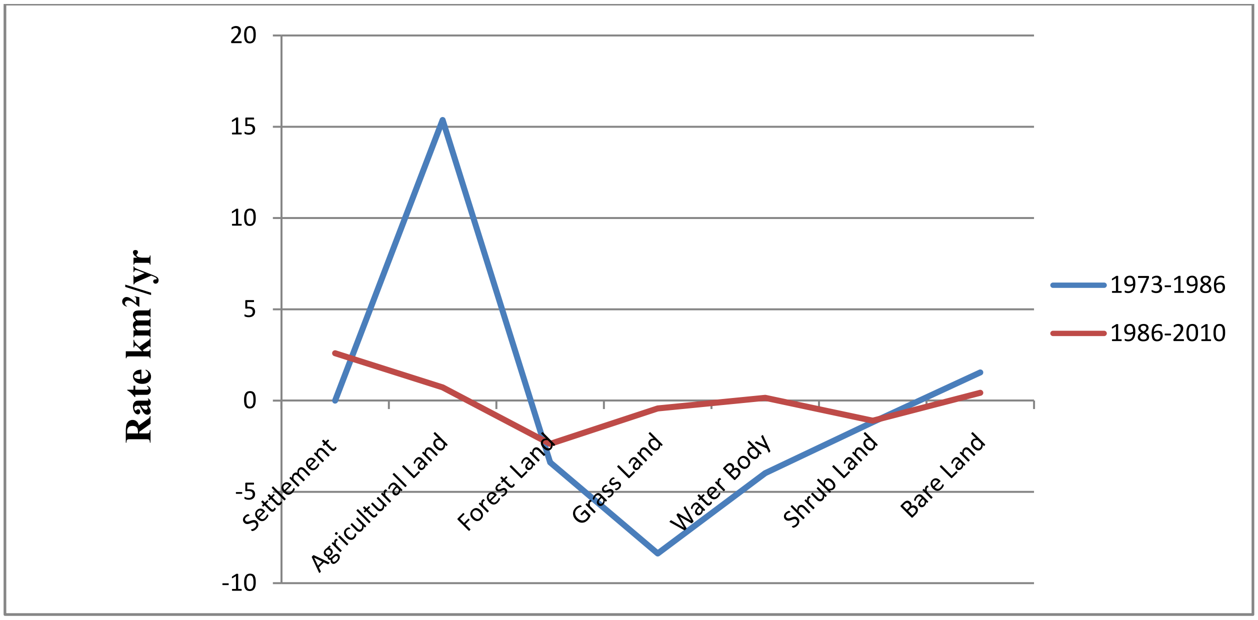


Figure4. 12The rate of change between 1973 – 1986 and 1986 - 2010

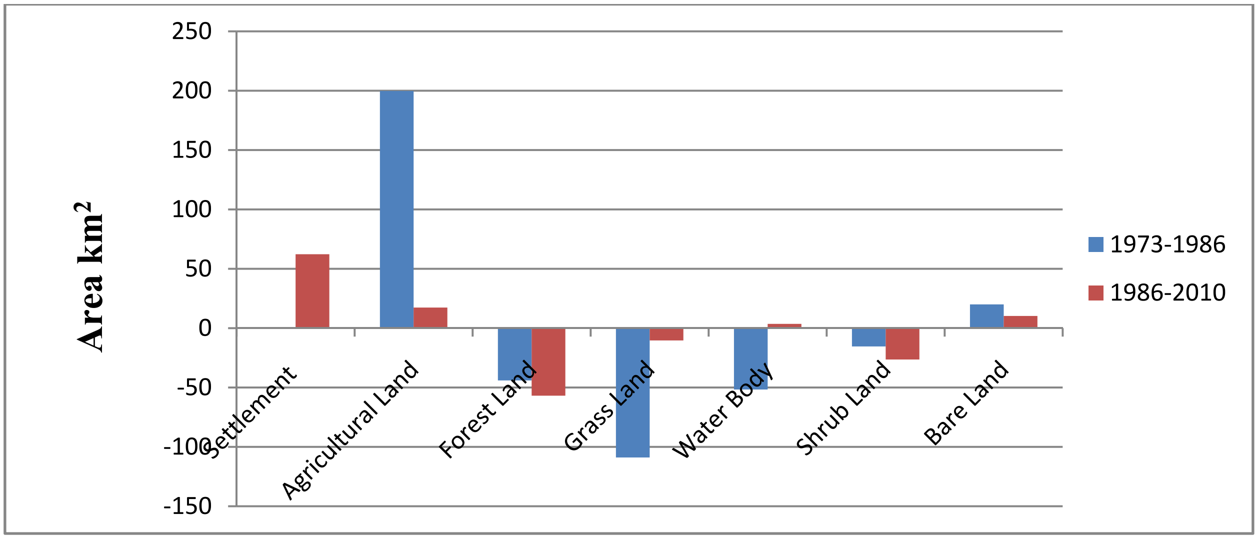


Figure4. 13Landcover dynamics for two periods

4.1.3.2 Landcover Change Matrix

4.1.3.2.1. Change Matrix for 1973 and 1986

Landcover change comparison gives the general information of the major changes of the landcover classes analyzed for the two periods. These cover comparison screen detail information such as which landcover type converted to which landcover type. Thus, to clearly understand the major landcover change source and destination of the landcover classes, change conversion matrix for each period was analyzed (Table 4.4). The rows in the table represent the initial stage (1973) and the columns represent the final stage (1986).

Table4.4 Conversion matrix value for 1973 and 1986

	1973							**Raw Total**
	Landcover classes For 1973/1986	**Bare land**	**Shrub Land**	**Forest land**	**Water Body**	**Agricultural land**	**Grass land**	
1986	**Forest Land**	0.0097	3.16	54.42	0.19	4.57	0.45	65.51
	Water Body	0	0.25	0.55	9.73	2.1	6.224	19.1
	Grass Land	4.27	4.05	1.65	0.37	1.25	28.15	39.43
	Agricultural Land	**11.31**	**114.43**	**24**	**49.56**	**98.1**	**59.67**	355.24
	Bare Land	17.93	5.89	0.69	5.79	4.36	23.23	57.37
	Shrub Land	3.73	70.8	28.2	4.85	45	30.54	183.21
	Column Total	37.33	198.58	109.51	70.74	155.42	148.31	

According to the results obtained from the landcover conversion matrix the landcover classes from 1973 to 1986 was clearly shown in the matrix (Table 4.4 and Figure 4.15), the changes of most landcover classes goes mostly to agricultural land. For instance the majority of forest land converted mostly to agricultural land and shrub land. Again majority of the shrub land converted to agricultural land. The highest converted landcover was forest land to agricultural land and next shrub land to agricultural land and also grass land converted to agricultural land next to forest and shrub land. Figure 4.15 shows the graphical representation of landcover conversion matrix for 1973 and 1986.

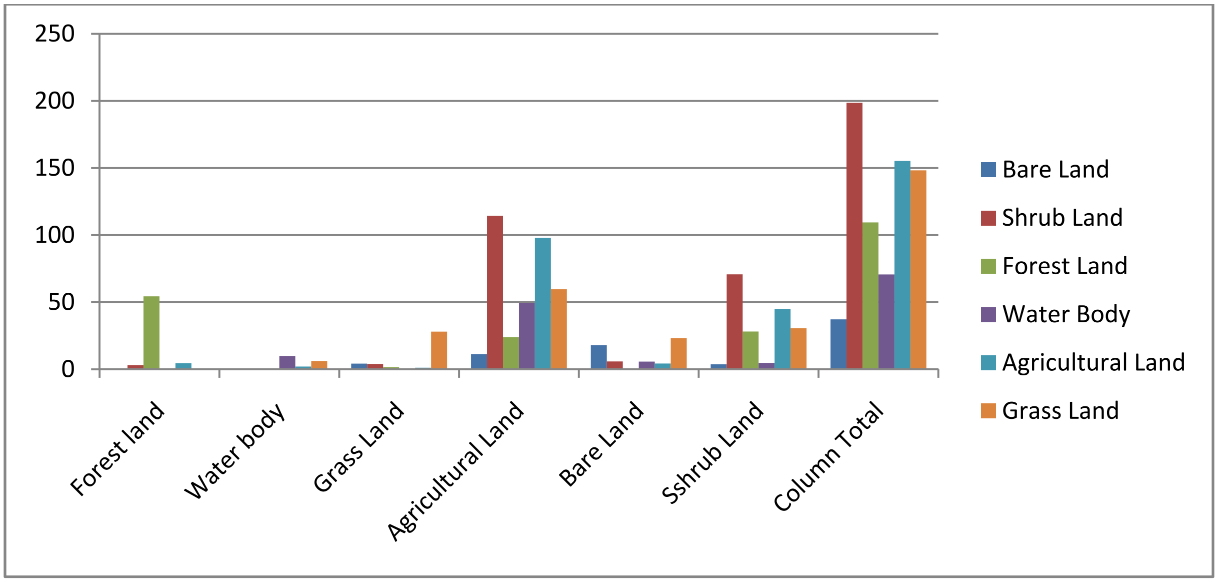


Figure4. 14Landcovers conversation matrix value for 1986 and 2010

4.1.3.2.2. Change Matrix for 1986 and 2010

The landcover conversion matrix from 1986 to 2010 in the second period gives result which shows the pressure on forest land and shrub land of the area for the past 24 years (Table 4.5 and Figure 4.16). In the same fashion as described in table 4.4 and figure 4.14 most of the landcover classes go to agricultural land. The majority of forest land converted mostly to shrub land and agricultural land. Again majority of the agricultural land converted shrub land, bare land and settlement. The highest converted landcover is agricultural land to shrub land. And also, with almost similar extent shrub land is converted to agricultural land and forest land converted to shrub land.

Table4.5 Conversion matrix value for 1986 and 2010

	1986							**Raw total**
	LC Classes1973/1986	Forest Land	Water body	Grass Land	Agricultural Land	Bare land	Shrub land	
2010	Forest Land	5.1	0.0032	0.165	0.094	0.004	3.17	**8.64**
	Settlement	2.5	0.054	4.39	24.88	3.53	26.84	**62.26**
	Water Body	2.4	9.97	0.0016	6.28	0.24	0.89	**22.7**
	Bar e Land	0.07	1.42	4.89	24.52	27.54	9.23	**67.67**
	Shrub Land	**49.32**	0.96	1.67	**70.03**	3.48	31.36	**156.82**
	Grass Land	0.0097	0.0016	23.47	1.24	2.23	2.3	**29.14**
	Agricultural Land	**9.34**	**6.67**	**4.86**	**221.44**	**20.77**	**109.52**	**372.63**
Column Total		**65.51**	**19.08**	**39.43**	**355.24**	**57.38**	**183.21**	

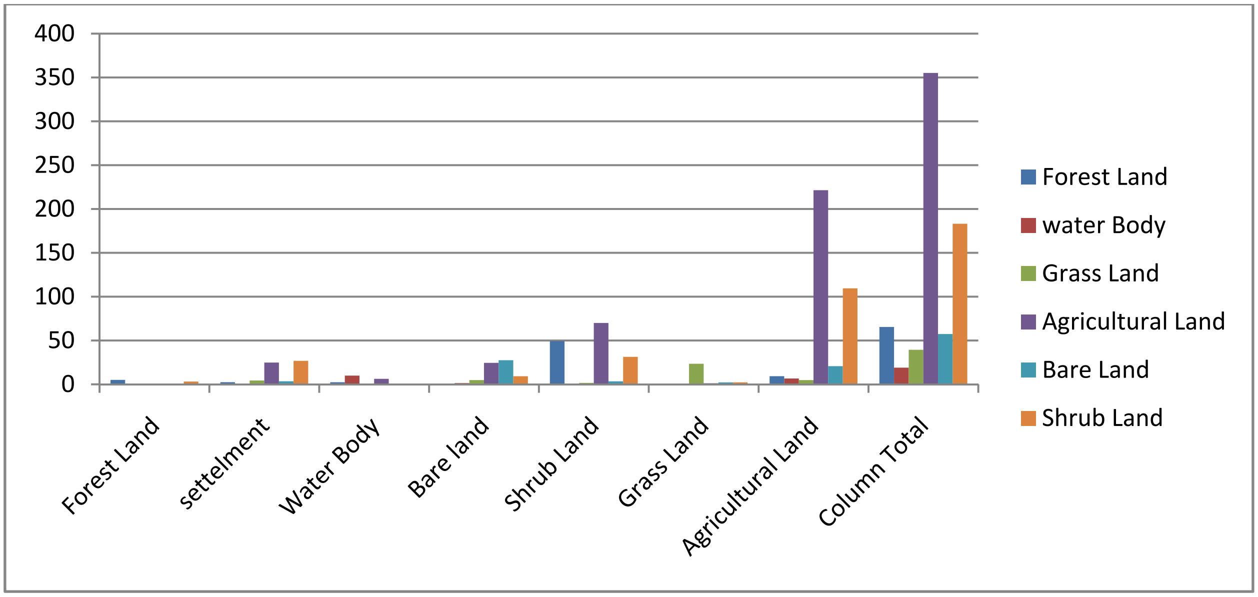


Figure4. 15Landcover conversion matrix value for 1986 and 2010

4.1.3. Accuracy Assessment

The fact that accuracy assessment is so important that it tells us to what extent the truth on the ground is represented on the corresponding classified image, it has been here done for 2010 landuse /landcover classification based on the ground truth taken for each category. In order to perform classification accuracy assessment, it is necessary to compare two source of information that is the remote sensing driven classification map and what we call reference test information (Jensen, 1996). To assess the classification accuracy, confusion matrix was used. Confusion matrix is strong in that it indicates the nature of classification error (ITC, 2001). Confusion matrix (Table 4.6) was generated by crossing the two maps generated using the training sets and the independent data.

Table4.6 Confusion matrix of 2010 landuse classification of the study area

Confusion/Error Matrix

Reference data/Ground truth data

Classified data	Grass Land	Agricultural land	Water Body	Bare Land	Forest Land	Shrub Land	Settlement	Row Total
Grass Land	12203	0	0	0	7	0	0	**12210**
Agricultural Land	0	7441	17	0	121	30	1	**7610**
Water Body	0	63	1043	1	1	0	0	**1108**
Bare Land	6	0	4	280	1	0	0	**291**
Forest Lan	4	88	0	0	4867	10	3	**4972**
Wood and S	0	461	4	0	172	586	3	**1226**
Settlement	1	116	6	0	200	46	25	**394**
Column Total	**12214**	**8169**	**1074**	**281**	**5369**	**672**	**32**	**27811**

Over all classification accuracy 95.08827442%

Over all Kappa statistics 0.928771273

4.1.4 Landuse structural change

Fragmentation index (Pa)

Fragmentation index is the mean area of the landuse type i. It is a measure of the degree to what extent a landscape is fragmented during the course of a change. The bigger Pa, the more fragmented the land type i,

Fragmentation index Pa = Ai/n

Where, Ai is the total area of the land use type i

n is the number of patches of the land use type i

The fragmentation index value for the three landcover maps within 37 years including 1973, 1986 and 2010, except the Pa value for settlement the rest of the landcover classes show a decrease in Pa value, means the number of patches for each landcover class increase and this does not show good ecological and resource stability where as the value for settlement shows an increment. Forest land is the most fragmented, decreased the Pa value from 3.57 to 0.162. Agricultural land and grass land show in common that their Pa value decreased from 1973 to 1986 and increased from 1986 to 2010 and bare land shrub land Pa value decreased from 1973 to 2010 (Table 4.7).

Table 4.7.Fragmentation index of the three years

Class Name	**1973**			**1986**			**2010**		
	Area(km2)	**No of Patch**	**Pa**	**Area(km2)**	**No of Patch**	**Pa**	**Area(km2)**	**No of Patch**	**Pa**
Settlement	0	0	0	0	0	0	62	254.61	0.243
Bare Land	37.32	12.76	2.92	57.79	47.43	1.218	75.2	308.86	0.2434
Water body	70.73	21.77	3.24	19.12	21.41	0.89	23	47.92	0.4795
Forest Land	171.79	48.07	3.57	62.96	86.13	0.73	7.79	47.99	0.162
Shrub Land	136.29	29.96	4.54	124.82	80.88	1.543	179.181	122.55	1.462
Agricultural Land	155.41	29.89	5.19	355.52	323.73	1.054	343.3	43.092	7.9666
Grass Land	148.313	25.36	5.84	39.5	40.485	0.975	29.2	14.41	2.0257

Generally, the landcover classes of the study area are getting fragmented from 1973 to 2010. This shows that the site is undergone dynamic change and this is because of an increment of pressure on the existing natural resources for the past 37 years.

4.2. Land Degradation Susceptibility Modelling

Land degradation susceptibility modeling is a methodology or a set of analytical procedures that simulate real world condition within a GIS using their spatial relationship of geographic features to locate areas that are sensitive to erosion. In this study, five different model parameters have been used in the land degradation susceptibility modeling.

4.2.1. Model parameters

The five model parameters that were used to run the land degradation susceptibility model are slop gradient, landuse management, soil type, rain fall intensity and population density. Before the model parameters were merged in weighted overlay analyses, all the input parameters were made to be uniformly scaled. In addition all the parameters have been classified in to five susceptibility classes ranging from 1 – 5 in accordance with their influence to the land degradation susceptibility. In the susceptibility range 1 implies the least susceptible influence, where as 5 implies the most susceptible influence. All the parameters have been reclassified to a similar scale values. Weighted linear combinations (WLC) where continuous criteria (Factors) were standardized to a common numeric range and then combined by means of a weighted average have been used as a multi criteria decision rule.

4.2.1.1. Digital Elevation Model (DEM)

Digital elevation model of the study area have been clipped from SRTM of NASSA satellite of 30 meters resolution using a masking layer of Kutaber wereda boundary. The DEM of the study area shows (Figure 4.17) an elevation that ranges from 1728 meters to 3466 meters above sea level.

Generally, most of the study area has highly rugged topography which is difficult for agricultural activity, where as little part of the study area shows flat area having little variation in altitude and most of these areas were covered with grass land.

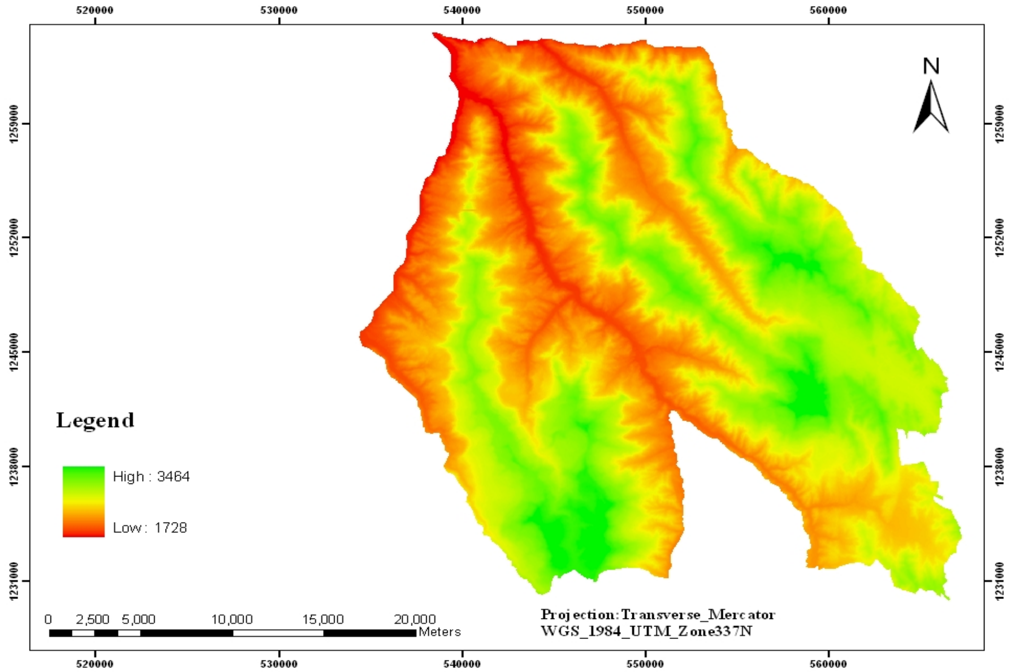


Figure4. 16Digital elevation map

4.2.1.2. Slope gradient

Slope gradient of the study area have been derived from the DEM by using surface analyses in ArcGIS 9.3. The slope steepness of the area ranges from 0^0 to 80^0 (Figure 4.17). Slope has been considered as one of the model parameters for land degradation susceptibility analyses due to the fact that, the steeper the slope of the area, the more it can be faced for soil erosion to downhill side of the area.

Slope of the study area has been reclassified based on susceptibility to erosion (Figure 4.18). The slope values (degree) classified in to five classes based on literature review and have value from $0\text{-}7^0$, $7\text{-}14^0$, $14\text{-}21^0$, $21\text{-}28^0$ and $28\text{-}80^0$ in order to correspond to very less susceptibility, less susceptibility, moderately susceptible, susceptible and highly susceptible to erosion respectively. The reclassified value 1 to

5 represents the above slope classification values respectively. Majority of the study area lies on slope greater than 14^0 and categorized from moderately to highly susceptible class of erosion susceptibility.

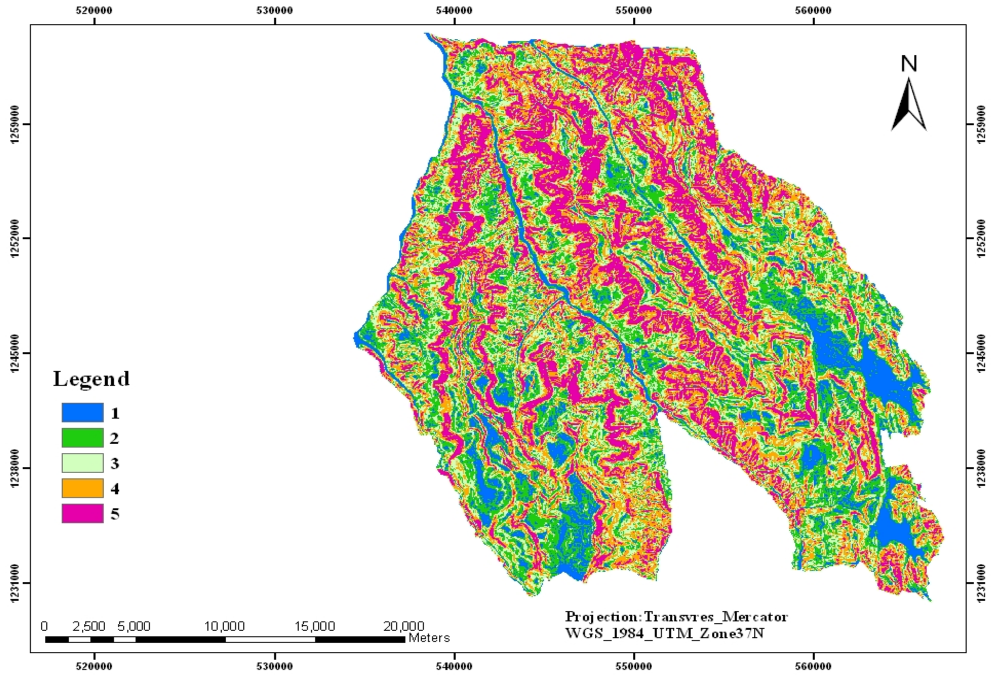


Figure4. 17Reclassified slope map

4.2.1.3. Soil Type

There were two major soil types in the study area, namely Lithic Leptosols and Eutric vertisols as clipped from soil map of Ethiopia; however, there were three types of other classes under Lithic Leptosols which varies according to the Landscape, Geology, vegetation type and slope of the area (FAO, 1997). These three types of classes under Lithic Leptosols are Lithic Leptosols (LPq/LPe.cm4-af) characterized by mountainous, major scraps, Basic- Ultrabasic rocks, bush land/cultivated area and slope greater than 30%, Lithic Leptosols (LPq/LPe.cm5-bf) characterized by mountainous, major scraps, Basic- Ultrabasic rocks, bush land/cultivated area and slope of 30%,%, Lithic Leptosols (LPq/LPe.cm4-4df) characterized by valleys or minor valleys, Basic- Ultrabasic rocks, bush land/Grass land area and slope of 30%.

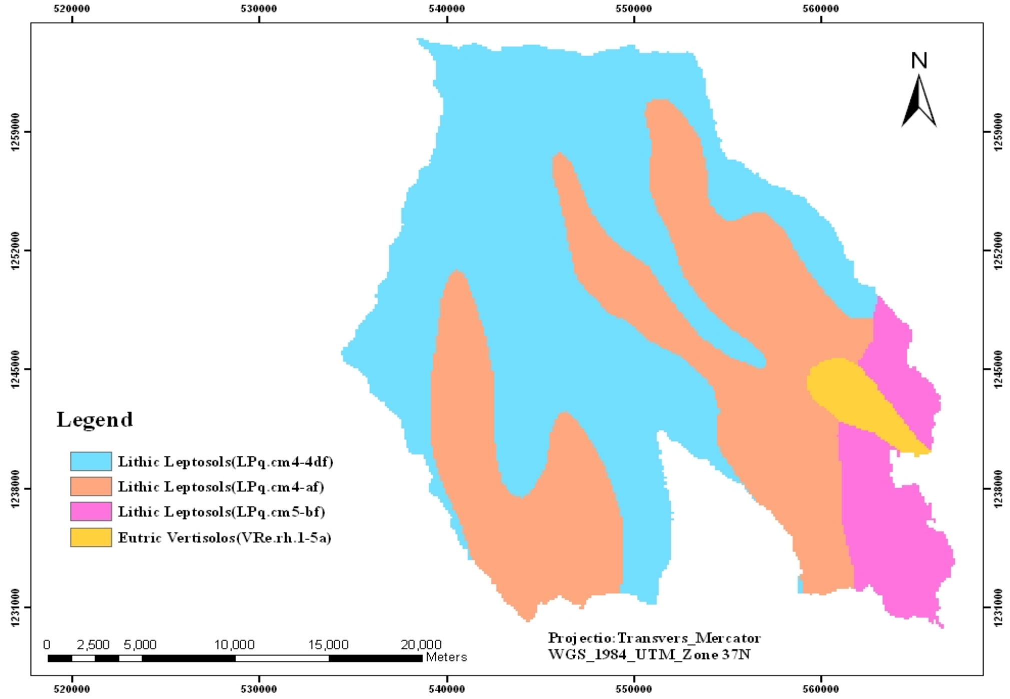


Figure4. 18Soil map

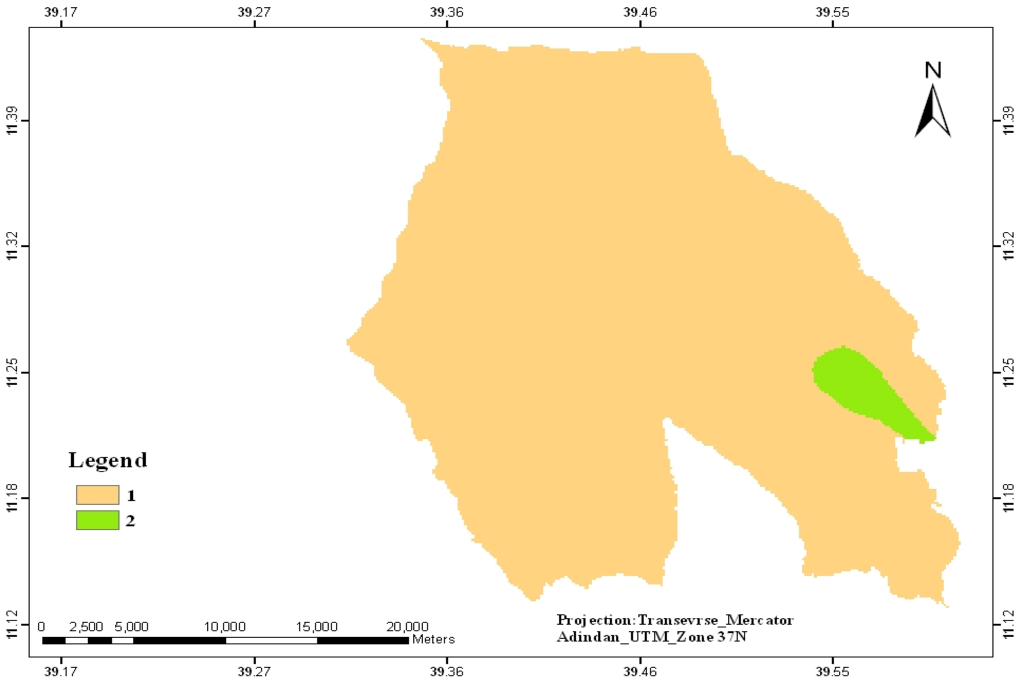


Figure4. 19Reclassified soil type map

The vector soil map of the study area first converted to raster format in order to reclassify in to the level susceptibility for soil erosion (Figure 4.19). Lithic Leptosols is the most dominant soil of the study area. The other type of soil found in the study area is Eutric Vertisols characterized by imperfect to poor drainage capacity, dark gray soils, formed on flat to almost flat plains.

4.2.1.4. Landuse/landcover

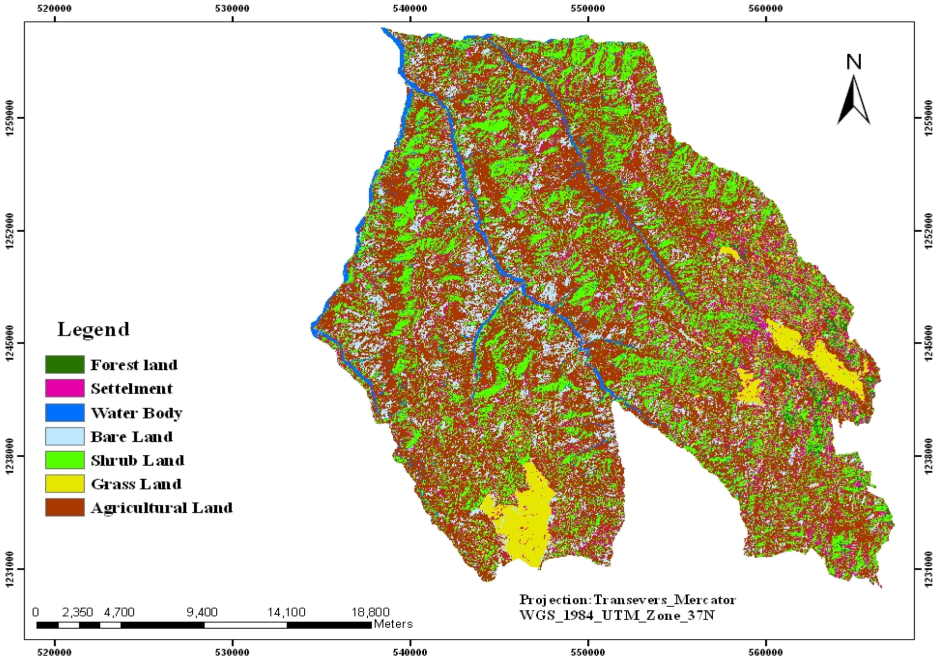


Figure4. 20 Rasterized Landuse/landcover map of 2010

For 2010, Landuse/landcover (Figure 4.21) seven landuse classes were identified, and those are forest land, shrub land, grass land, agricultural land, bare land, settlement and water body. These landuse classes then reclassified based on the degree of susceptibility to land degradation. The landuse categorized as forest land is considered as very less susceptible, shrub land as less susceptible, grass land as moderately susceptible, agricultural land and settlement as susceptible and bare land as highly susceptible and water body considered as constraint. According to the reclassified Landuse/landcover map, classes have values 1 to 5 in which 1(very less susceptible) is for forest land and 5(highly susceptible) for bare land (Figure 4.22).

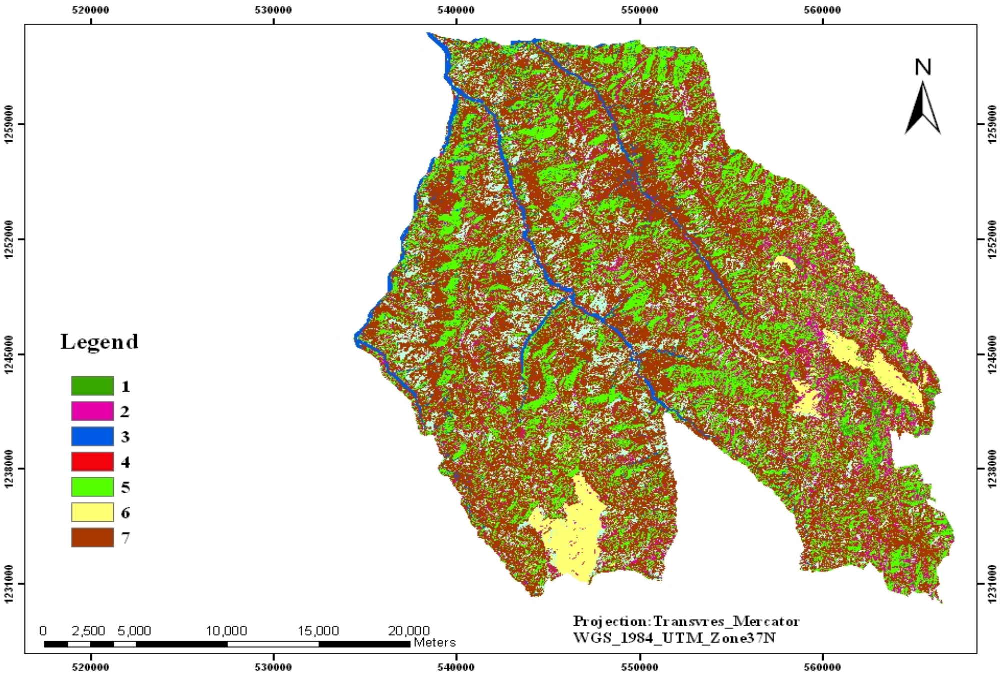


Figure4. 21Reclassfied Landuse/landcover map of 2010

4.2.1.5. Population

Landuse/landcover change and land degradation were 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. For the study area the population map has been produced based on the data obtained from the wereda agriculture and rural development office report. The study area was sub-divided in to twenty rural kebles and one urban kebele. After having the twenty-one kebeles population figure, it has been related and joined to the appropriate kebeles of the study area (Figure 4.23). The result shows that the population ranges from 9080 to 3592 people/kebele. Majority of the people are living on the mountainous and rugged topography of the wereda, which is more susceptible to land degradation.

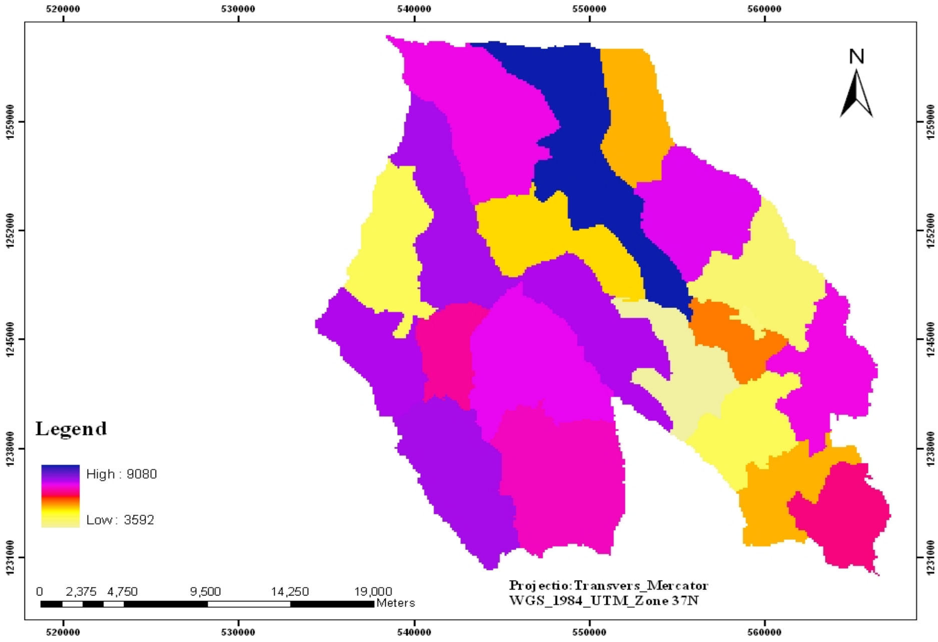


Figure4. 22Rasterized population map

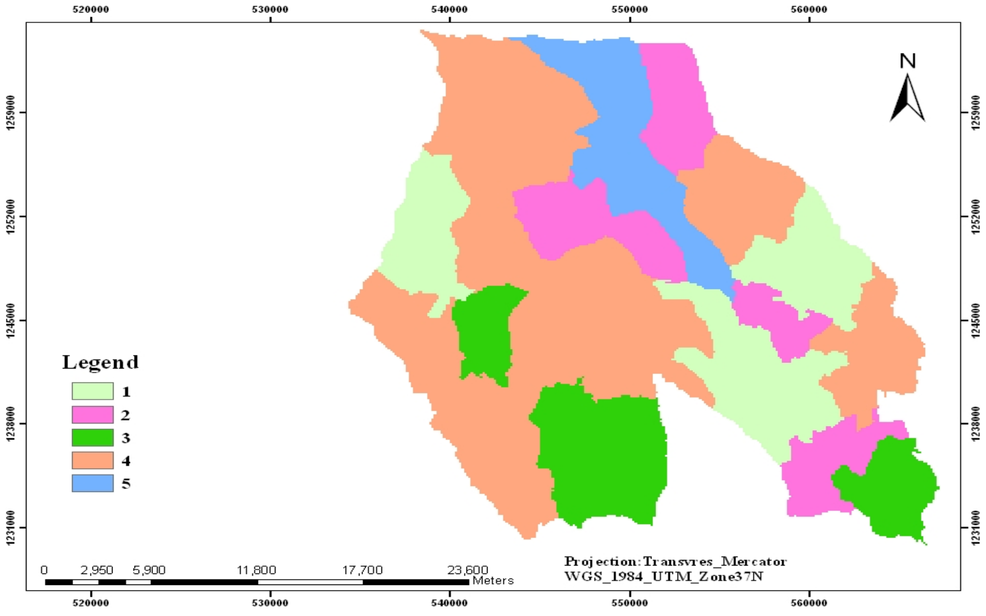


Figure4. 23Reclassified population map

4.2.1.6 Rain fall intensity

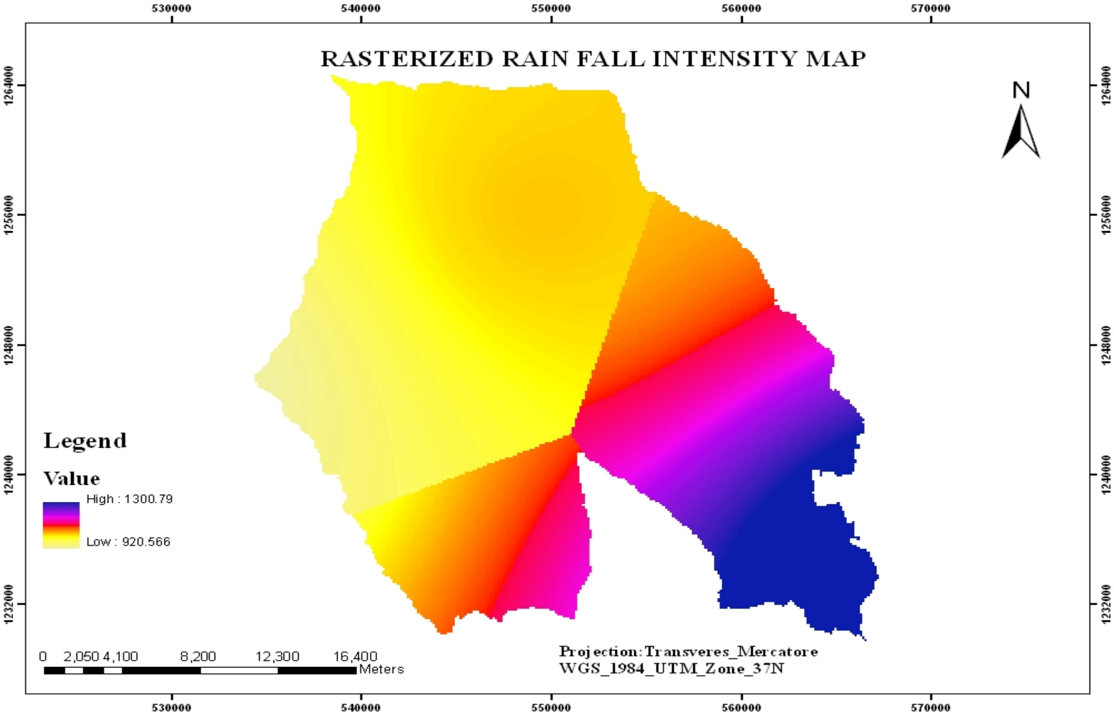


Figure4. 24Rasterized rain fall intensity map

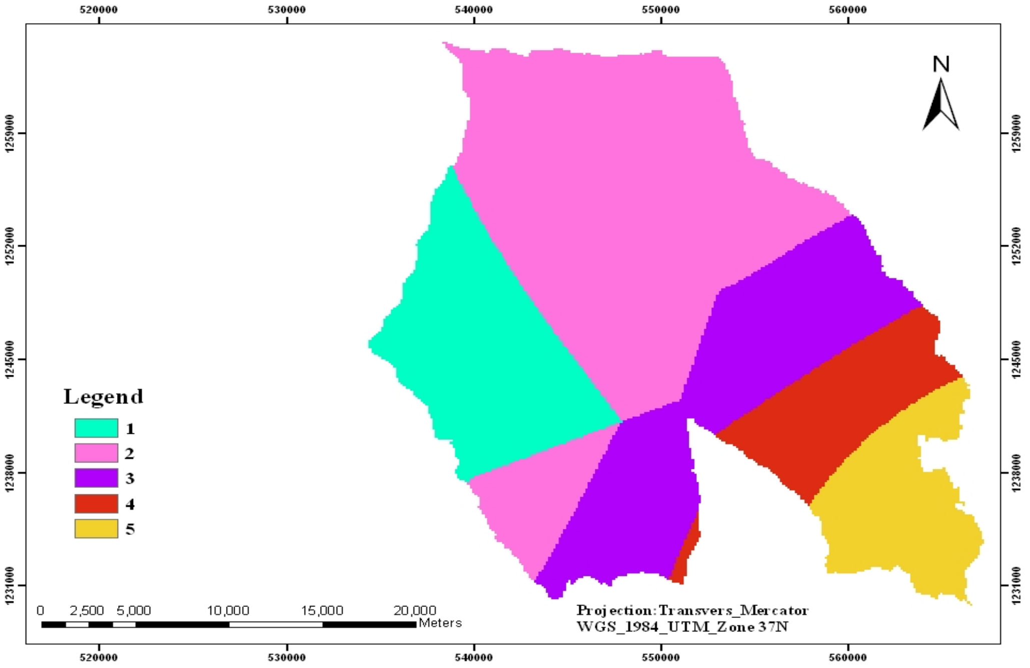


Figure4. 25Reclassified rain fall intensity map

The study area experiences a bimodal rainfall distribution, which was characterized by "Kolla, Woina Dega and Dega" agro-climatic ecology. During January and February the area posses "small" rain, and the principal rainy season occurs between mid - June to September. The rain fall intensity of the study area has been interpolated from five metrological stations using IDW method. The result obtained from the metrological stations ranges from 920.566mm/month to 1300.79mm/month. The minimum value of 920.566mm/month existed on the north west and western part of the study area which was dominated by mountainous, rugged topography with less vegetation cover while, the maximum value of 1300.79mm/month existed on the south west part of the study area particularly on forest shrub and grass exist. The north east and south west part of the area attends a moderate intensity value. The higher rain fall intensity is related to the presence of natural and plantation forest and shrub lands, whereas, the lesser rain fall intensity was related with bare land agricultural land types (Figure 4.25).

4.2.2. Multi Criteria Decision Making

In the procedure for Multi-Criteria Evaluation using a weighted linear combination it is necessary that the weights sum to one. In Saaty's (1977), technique, weights of this nature can be derived by taking the principal eigenvector of a square reciprocal matrix of pairwise comparisons between the criteria. The comparisons concern the relative importance of the two criteria involved in determining vegetation vulnerability of the study area. Ratings are provided on a 9-point continuous scale (Table 4.7).

Table4.7 The Continuous Rating Scale

Extreme	Very strongly	Strongly	Moderately	Equally	Moderately	strongly	Very strongly	Extreme
1/9	1/7	1/5	1/3	1	3	5	7	9

In developing the weights, every possible pairing has been compared and the ratings have been recorded into a pair wise comparison matrix (Table 4.8).Since the matrix is symmetrical, only the lower triangular half actually needs to be filled in. The remaining cells are then simply the reciprocals of the lower triangular half.

Table4.8 Pair Wise Comparison Matrix

	Slope	Landuse	Population	Rainfall Intensity	Soil Type
Slope	1				
Landuse	1/3	1			
Population	1/3	1/3	1		
Rain fall intensity	1/5	1/5	1/3	1	
Soil Type	1/7	1/5	1/5	1/3	1

The Eigenvector of weights are:-
Slope--------- 0.453
Landuse----- 0.2766
Population--- 0.15554
Rain fall------- 0.0742
Soil type------ 0.0408
Consistency ration is 0.07, which is acceptable.

Accordingly, slope has a weight of 0.453, which means that it has 45.3% influences to the land degradation susceptibility of the study area. Landuse, population, rain fall and soil type have percentage influence of 27.66%, 15.554%, 7.42% and 4.08% respective

In running the model using weighted sum analysis, the cell values of each input parameters are multiplied by the computed weight .The resulting cell values were added to produce the final output raster model. At this junction, higher raster values indicate areas that are more susceptible to land degradation, whereas lower raster values indicate are that are less susceptible to land degradation.

The output raster of the land degradation susceptibly model is reclassified in to five classes ranging from 1 to 5. 1 implies the least land degradation susceptible areas whereas, 5 implies highest land degradation susceptible areas.

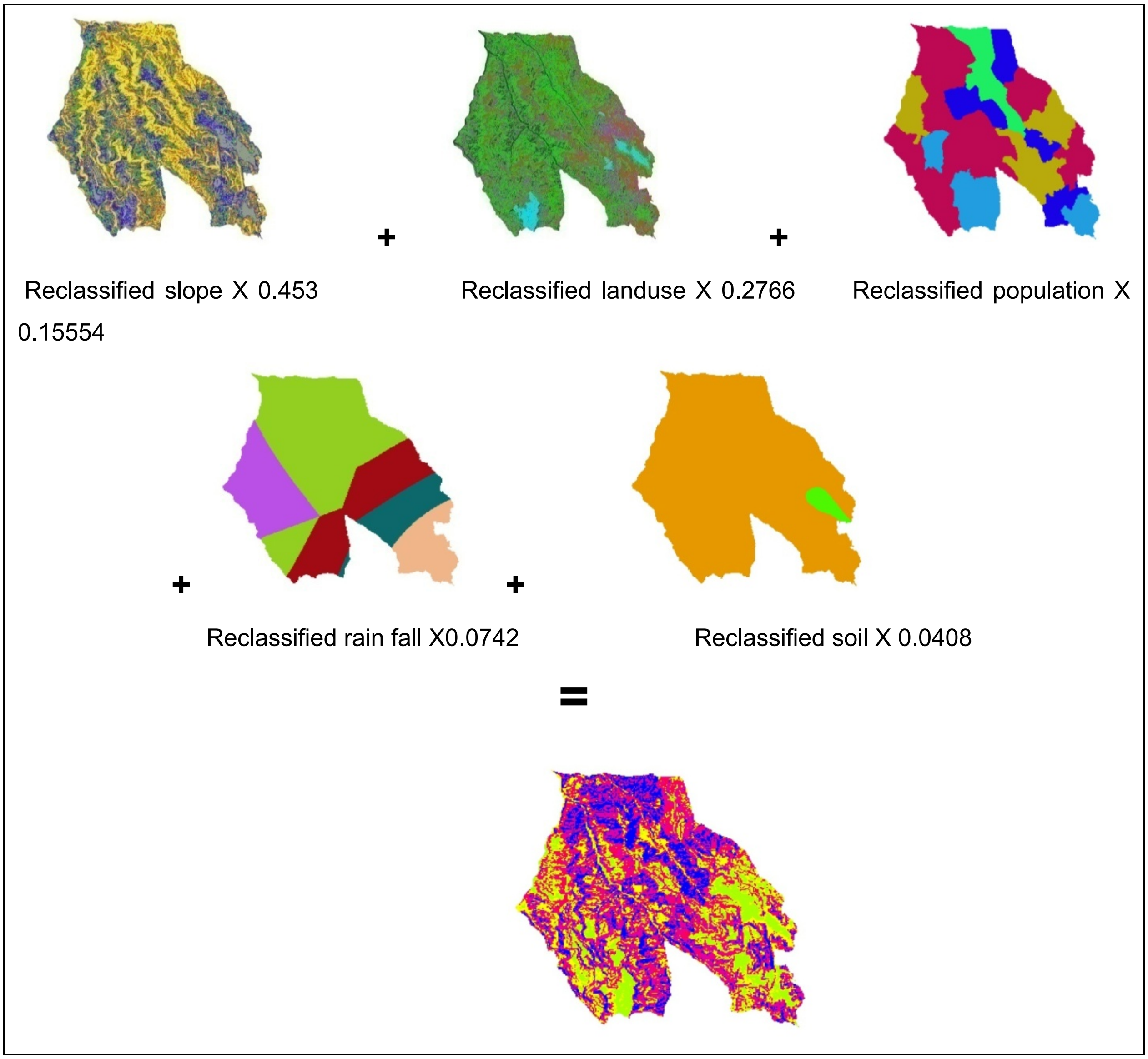


Figure4. 26weight sum overlay of factor layers

According to the land degradation susceptibility model result, five classes were identified based on the degree of susceptibility (Figure 4.27). The result shows that areas which are characterized by high slope, agriculture and bare landuse, high population, high rain fall intensity and Eutric vertisols soil type have been identified as the most areas susceptible to land degradation whereas, those areas having gentle slopes, with forest and plantation landuse, low population, low rain fall intensity and Lithic Leptosols soil type have been identified as the least areas susceptible to land degradation.

The land degradation susceptibility result map depicts that southwest, central, northern and western peripheries of the study area are highly susceptible to land degradation. On the other hand the highland of south western part and the western periphery of the study area are the least susceptible to land degradation.

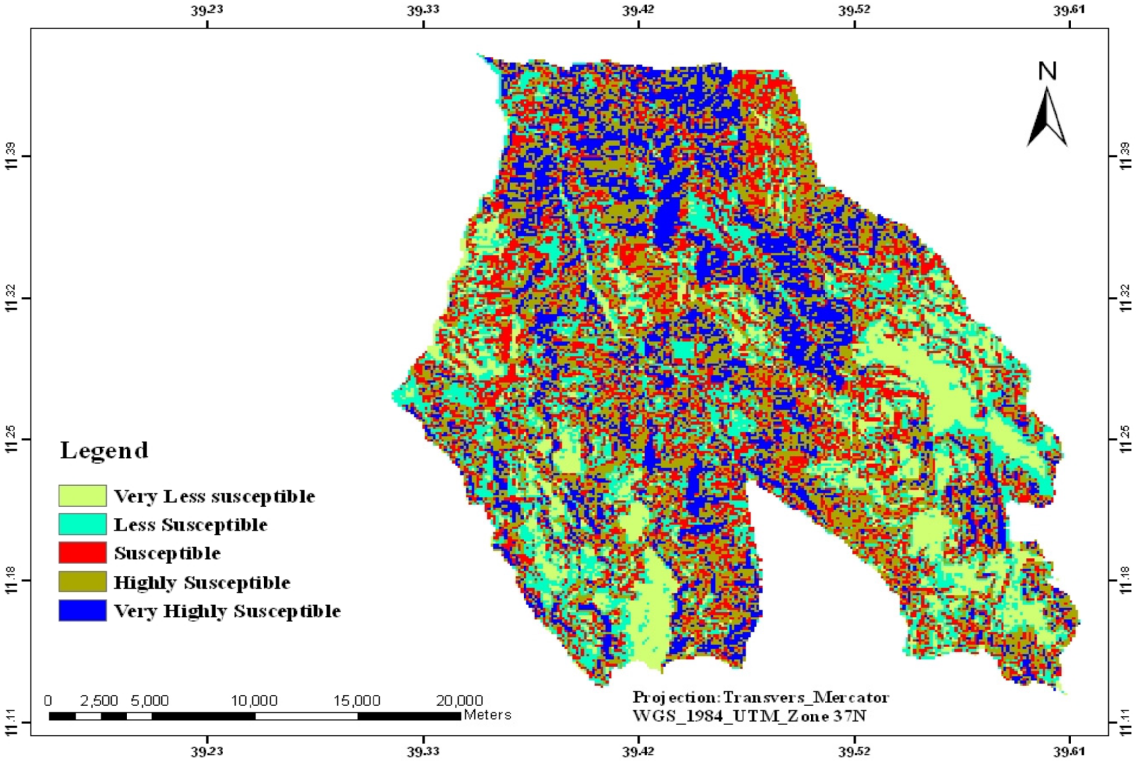


Figure4. 27Land degradation susceptibility map for 2010

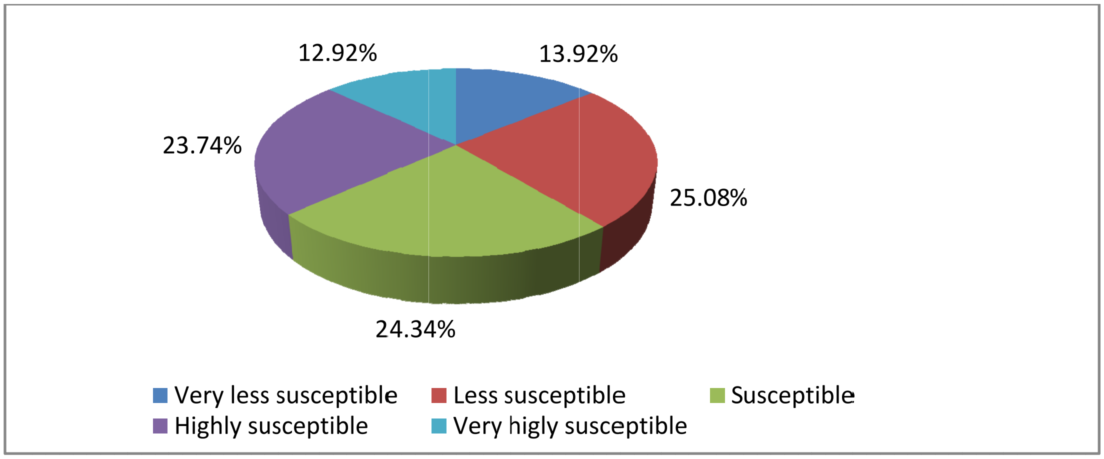


Figure4. 28Percentage value of Land degradation susceptibility map

Table4.9 Summarized value of land degradation susceptibility map of 2010

Degree of susceptibility	Area coverage (km^2)	Percentage value (%)
Very less susceptible	99.4841	13.92
Less susceptible	179.325	25.08
Susceptible	174.006	24.34
Highly susceptible	169.73	23.74
Very highly susceptible	92.3396	12.92

The summarized result (Table 4.9) shows that very highly susceptible area has 92.3396 km^2 (12.92%), highly susceptible area has 169.73 km^2 (23.74%), susceptible area occupies 174.006 km^2 (24.34%), less susceptible area is 179.325 km^2 (25.08%) and very less susceptible area is 99.4841km^2 (13.92%) for 2010 Landuse/landcover of the study area.

The 2010 land degradation map (Figure 4.27) shows that, areas that are susceptible for land degradation are highly dominated by areas that have slope greater than 21 degree. In addition to this the susceptible, highly susceptible and very highly susceptible areas overlap mainly with the existing agricultural land, bare land and highly populated areas.

From the land degradation susceptibility map of the wereda, the purple and blue are the highly and very highly susceptible areas for land degradation respectively but the light apple and yellow are the very less susceptible and less susceptible ones respectively.

CHAPTER FIVE

5. Conclusion and Recommendation

5.1. Conclusion

Findings of the study disclose that the study area has been under continual Landuse/landcover changes since 1973. Deforestation due to population growth and the associated expansion of farming and increasing demand for resources are imposing threat on the biodiversity of the area .The findings of the Landuse/landcover changes and land degradation susceptibility analysis can have a paramount importance in natural resource management and land use planning in the context of resource allocation decisions. This study used an integrated approach to understand the past, present and future conditions of the study area, by fully utilized remote sensing and GIS tools, field work and review different literatures. The study comes up with the following major findings;

- Generating the thematic landcover maps for change detection and comparisons using landsat images
- Analyses of lndcover dynamic factors such as rate of landcover change, conversion matrix and landscape fragmentation index
- Land degradation susceptibility analyses and producing land degradation susceptibility map
- Investigate the different landuse structural change using basic statistical indicators and indices for a better design of decision support system (DSS) in sustainable natural resource management of the study area

The post-classification analysis for the dynamics of Landuse/landcover changes using satellite data together with GIS indicates the increased Landuse/landcover changes due to rapid population growth of the study area between 1973 and 2010. Landcover post classification change analyses for the sub periods (1973 – 1986 and 1986 – 2010) revealed that dynamism for all landcover classes. The analyses conducted for

1973 – 1986 have revealed that the agricultural land has expanded significantly leading to removal of shrub land, forest land and grass land and also for 1986 – 2010 sub period the result revealed that the extent of agricultural land and settlement have increased at the expense of mainly grass land and forest land .

The result of land degradation susceptibility analyses shows that very highly susceptible, highly susceptible and susceptible are mainly related with the agricultural practices on the steeper slope area and the presence of high population in which the very highly susceptible occupies 92.3396 km^2 (12.92%), highly susceptible occupies 169.73 km^2 (23.74%), susceptible ones occupies 174.006 km^2 (24.34%), less susceptible ones occupies 179.325 km^2 (25.08%) and very less susceptible ones occupies 99.4841 km^2 (13.92%) respectively.

5.2. Recommendations

- Resource allocation is indispensable for sustainable land use management planning. The landcover dynamics of paramount importance as it is the most important base line data in resource allocation and therefore should be used as a main input during landuse planning.
- The land degradation map can assist in policy decisions during a landuse planning as it shows the environmental risk zone of land degradation. Therefore local planners and policy makers should make use of risk zone model out puts as a decision support.

- From the land degradation susceptibility map, areas categorized as susceptible, highly susceptible and very highly susceptible ones should be given a serious attention and priority when implementing natural resource conservation activity.

- Improve literacy level of the society: In the study area, level of literacy is low. Therefore, farmers should be thought and encouraged to use different land degradation prevention mechanisms, such as, stop plowing on mountainous and highly steep slope areas, terracing in steep slope area, planting forage trees on the terracing side of the farm land, keeping animals from over grazing. Moreover, farmers who use animal dung instead of fertilizer should be encouraged and motivated. So that the cumulated effect of these all will help to minimize land degradation. In addition, since one of the most important factor for the landcover change in the study area is the rapid growth of population, so it very important in continuing the current efforts of introducing family planning to make people aware of the consequences of population pressure on natural resource should be carried out intensively.

Remote sensing images are very popular for land use land cover classification and land use land cover are most fundamental key factors that reflect the environmental risk and main input for the land use planning. GIS has been used in establishing technical support to planning and decision making through use of comparable, integrated maps and related data types. Therefore the use of RS and GIS in decision support system in the realm of resource allocation and policy decisions is of paramount importance for natural resource management. Managers and decision makers should make use of the information from RS and GIS, as a decision support for a better design of natural resource management.

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ANNEX 1

Long Year monthly rainfall data in mm for Five Stations

Region:	WELLO											
Station:	AKESTA											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982		5.9	91.1									
1992							177.7	239.4	63.1	17.7	20.5	13.4
1993	37.2	60.6	34.9	217.7	49.5	35.1	229.4	118.9	61.2	15.7	0.0	0.0
1994	0.0	25.1	207.2	43.3	3.8	17.2	343.5	236.2	83.8	5.1	5.2	7.0
1995	0.0	17.5	55.8	106.2	63.5	17.8	232.3	151.3	28.3	0.1	0.8	43.5
1996	125.5	12.7	111.0	79.3	130.8	52.8	178.1	249.1	18.5	0.0	40.7	6.9
1997	50.8	0.0	73.3	67.0	5.0	89.1	231.3	237.5	5.6	40.0	52.2	7.1
1998	32.7	65.9	133.0	48.6	100.5	24.1	456.7	244.4	48.4	41.0	0.0	0.0
1999	25.1	0.0	4.1	0.0	0.9	18.7	423.1	342.6	63.5	20.5	0.0	5.6
2000	0.0	0.0	17.0	104.8	42.4	27.1	343.5	246.7	48.5	12.6	41.6	x
2001	0.1	115.5	159.8	20.6	63.6	32.3	432.0	293.1	29.8	12.6	0.0	29.7
2002	78.5	7.9	85.9	50.8	20.4	18.7	354.3	201.7	40.9	0.0	0.0	21.3
2003	9.8	59.2	180.7	72.3	16.7	35.1	208.5	158.8	36.2	0.0	11.5	24.4
2004	7.8	9.5	54.5	88.6	2.0	75.0	307.1	292.4	14.0	0.5	5.0	37.4
2005	42.7	0.0	74.1	56.4	x	76.0	298.9	166.3	11.1	0.0	1.8	0.0
2006	8.9	39.9	132.9	134.7	64.8	2.9	232.7	344.5	72.8	15.3	36.7	x
2007				93.6	1.0							

Region:	WELLO											
Station:	KABE											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	X	x	x	x	35.8	190.3	237.3	152.8	78.3	11.8		19.1
1987	0.0	41.7	180.7	81.9	130.1	x	0.0	75.3	31.1	21.0	0.0	4.6
1988	16.7	x	1.3	256.9	x	x	254.0	266.1	95.5	7.1	0.0	0.0
1989	0.0	x	54.3	116.1	7.0	53.0	260.9	x	x	x	x	x
1992	X	9.5	34.9	18.3	14.8	16.9	197.1	278.6	67.9	6.7	17.6	6.4
1993	11.5	63.0	37.5	103.2	41.5	2.3	x	x	x	0.0	0.0	0.0
1994	0.0		68.8	37.2	14.6	x	x	x	x	x	x	x
1995	1.6	17.2	32.0	94.5	35.2	25.6	339.1	244.4	58.4	1.5	0.0	31.8
1996	59.0	4.1	77.5	10.9	117.4	28.9	263.4	332.5	40.7	2.7	8.8	4.3
1997	49.7	0.0	46.1	37.7	4.9	97.8	222.1	x	x	x	x	0.3
1998	15.5		70.1	1.1	39.9	2.9	373.4	371.4	49.3	18.2	0.0	0.0
1999	X	x	x	x	x	x	354.3	349.1	77.5	43.4	0.0	4.1
2000	0.0	0.0	3.5	93.5	17.7	37.5	405.9	282.8	75.3	29.7	19.9	0.4
2001	0.0	6.5	106.3	3.2	51.8	49.0	455.1	289.8	48.1	4.6	0.0	0.0
2002	67.0	15.0	59.5	71.2	5.9	11.9	235.2	257.8	85.3	3.7	2.5	16.3
2003	13.6	24.3	15.6	75.3	13.6	45.1	282.6	283.3	82.1	0.0	0.0	19.1

Region:	WELO											
Station:	WEREILU											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994	0.0	0.0	47.8	41.5	0.0	25.4	442.3	307.4	45.4	0.0	0.9	0.0
1995	0.0	37.6	23.5	49.9	26.5	26.7	316.8	203.0	77.5	0.0	0.0	29.5
1996	31.1	0.0	60.3	13.9	62.9	6.0	114.2	143.5	39.8	0.0	28.3	0.0
1997	35.3	0.0	56.8	44.8	6.8	99.8	328.7	180.4	12.9	38.5	4.6	0.0
1998	45.2	4.5	88.2	23.3	38.5	9.1	426.4	375.3	51.3	12.7	0.0	0.0
1999	13.7	0.0	23.1	12.4	0.0	11.3	568.0	426.9	71.3	0.0	38.0	3.0
2000	0.0	0.0	12.1	59.4	47.6	47.0	479.4	369.1	97.1	9.5		13.4
2001	0	6.2	123.4	12.1	43.6	26	601.8	301.1	23.8	0	0	10.7
2002	63.4	13.2	51.5	28.8	3.9	43.4	242.1	322.7	32.4	5.7	0	15.6
2003	21.9	21.8	43.4	56.6	3.2	56.5	306.5	250.2	74.4	0	2.2	38
2004	13.3	15.9	46.9	50.8	2.9	42.3	229	225.8	50.4	4	7.9	0
2005	38.6										2	
2006							263.1					
2007			12.6	73.5	2.4							

Region:	WELLO											
Station:	MEKANE SELAM											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	X	4.6	35.1	205.3	53.3	98.3	x	x	146.7	x	10.4	0
1994	0	21.9	63.8	44.5	41.9	69.4	192.2	97.5	74.2	8.1	19	0
1995	0	26.4	58	101.7	98.6	18.7	320.1	226.1	55.4	0.4	0	24.5
1996	32.8	1.6	63.8	102.6	83.1	135	243.6	194.5	78.2	0.2	23.3	6.5
1997	48.9	2.2	62.5	73.9	49.4	94.7	201.7	137.9	43	110.2	100.2	17
1998	23.2	3.7	102.8	48	70.2	70.9	319	264.7	123.7	118.1	19.3	0
1999		0	2.4	63.9	24	33.1	265.1	220.2	80.7	90.1		9.8
2000	0	0	12.5	127.8	43.8	84.1	286.1	185	111.3	74.7	36.5	9
2001	0.4	27.3	133.9	55.1	58.4	104.8	319.2	168.7	45.2	62.2	0.9	20.8
2002	55.3	14.8	60.3	38.6	41.5	57.1	276.6	212.5	91	0	7.1	28.1
2003	15.2	47.1	77.8	55	8.8	80.2	245.1	150.6		0	4	9.3
2004	0.8	0.9	29.4	44.6	21.3	95.9	184.2	181.5	51.7	41	3.4	0
2005	12.2	0	61	55.2	86.3	60.2	207.1	150.9	122.4	32.9	5	0
2006								251.5				
2007			0	58.1	79.8							

Region:Wollo												
Station:	DESSIE											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	0	57.6	61.3	275.1	95.5	64.8	303.5	253.9	100	70	0	53
1996	42.6	35.4	138.3	82.8	144.2	58.7	214.2	413.3	80.2	2.2	104.3	4.5
1997	50.6	0	116.3	57.7	29.5	116.9	234.5	278.2	60.9	172.5	131.5	0
1998	80.9	62.6	55.1	38.9	79.8	0	555	407.2	114.7	92.1	0	0
1999	44	0	40.1	0	11.4	15.3	469.6	444.3	223	122	0	9.1
2000	0	0	5	75.9	57.6	50	425.7	329.3	210.8	102	63.9	55.1
2001	1.3	0	136.4	35.2	106.8	43.7	416.9	309.9	148	40.7	0	9.2
2002	34.3	16.8	90.1	132.4	21.8	6	334.8	389.4	164.8	21.7	0	42.4
2003	42.8	35.8	42.9	187.1	9.3	58.5	177.3	352.6	180.2	2.3	10	77.8
2004	2.3	14.9	11.5	70.6	5.1	46.3	283.6	264.9	92.6	97	50.9	7.6
2005	16	18.9	124.3	116.5	120.3	47.7	355.2	398.3	79.4	37.5	5.8	0
2006	2.3	3	116.4	56.9	102.2	30.6	530.8	418.3	218.7	65.8	x	x

DECLARATION

I here by declare that the dissertation entitled “Landuse/Landcover Dynamics and Land Degradation susceptibility Analyses in kutaber wereda using Geospatial Tools” has been carried out by me under the supervision of Dr. K. V. Suryabhagavan, Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2009-2010 as a part of Master of Science programm in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa

Date: June 2010

(Merkebu Kassaw)