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**Land use land cover Dynamics in Post-Resettlement Areas using  
Cellular Automata model: The case of Gubalafto Woreda**

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## **Abstract**

*Land use land cover 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. In this study the land use land cover dynamics and modelling in post-resettlement areas of Gubalfto Woreda have been undertaken. This study aims to examine and analyze the spatial and temporal variations of land use land cover conditions and model trends of change using cellular automata model by assessing the historical patterns of land use land cover in past 32 years and determining the trend, nature, rate, location and magnitudes of the changes. The study also looks the future land use land cover change. To serve these objectives, field survey, field data collection, 1973 MSS, 1986 TM and 2006 image, topographic maps and Aerial photo were used. In addition slope, proximity to road, altitude, rain fall, population density, settlement, water body, and forest parameters were used to run the CA-Markov model and to predict the future land use land cover changes. The result of the work shows a reduction by 2 % in settlement and by 4 % in agriculture between 1973 and 1986. While the periods between 1986 and 2005 shows an increase in agriculture by 62.5% and settlement by 46%. The trend and rate by which land use land cover has changed also shows that there are reduction in agriculture and settlement between 1973 and 1986 by 2.6 km<sup>2</sup> and 1.5 km<sup>2</sup> per year, respectively. This was because of the 1984/85 resettlement program large number of people leaves their settlement and agricultural land. Whereas, between 1986 and 2005 agriculture and settlement increased by 3.29 km<sup>2</sup> and 2.41 km<sup>2</sup> per year than the other classes. This change is because the settlers returned to their origin after resettlement program has passed. Therefore, agriculture and settlements are the main drivers of land use land cover change, which are in turn direct consequences of population growth. It was also observed that the predicted land use classes by 2020 may likely follow the same trend as that of 1986/2005, which means there is an increase in agriculture by 23.5% and settlement by 92% from 2005 but the forest coverage increase by 146 %. The rate of change in 2020 will be increased in agriculture and settlement by 5.4 km<sup>2</sup> and by 5 km<sup>2</sup> per year and bush land will decrease by 10 km<sup>2</sup> per year. Hence, resettlement has a direct relation with land use land cover change and dynamics.*

**Key words:** *Land use /land cover, Resettlement, CA\_Markov model, MCE.*

# Table of contents

<b>Acknowledgements</b> .....	ii
<b>Abstract</b> .....	iii
<b>Table of contents</b> .....	iv
<b>List of Figures</b> .....	<a href="#">vii</a>
<b>List of Tables</b> .....	<a href="#">viii</a>
<b>List of Appendices</b> .....	vii
<b>List of Plate</b> .....	vii
<b>Acronym</b> .....	<a href="#">viii</a>
<b>1. Introduction</b> .....	1
1.1 Background and justification .....	1
1.2 Statement of the problem .....	2
1.3 Objectives of the study .....	3
1.4 Structure of the thesis .....	4
1.5 Limitations .....	4
<b>2. Literature review</b> .....	5
2.1 Resettlement in Ethiopia.....	5
2.1.1 General description .....	5
2.1.2 Resettlement and land use land cover change .....	6
2.2 Land use land cover dynamics.....	7
2.2.1 Land use land cover .....	7
2.2.2 Change detection.....	8
2.3 Land use land cover change modeling.....	10
2.3.1 Land use change models .....	10
2.3.2 Cellular automata model (CA).....	11
2.4 Image analysis and classification using remote sensing and GIS.....	14
2.4.1. Spatial data and processing.....	14
2.4.2 Image classification and validation.....	15
<b>3. Materials and Methods</b> .....	16
3.1 Description of the study area .....	16
3.1.1 Location .....	16
3.1.2 Climate and Rainfall Distribution.....	17
3.1.3 Geology and Soil .....	17

3.1.4 Agro-ecological zones .....	19
3.1.5 Socio-Economic and Physical Characteristics.....	19
3.1.6 Land Use Pattern.....	20
3.1.7 Population .....	20
3.1.8 Nature of Rural Settlement .....	20
3.2 Site selection and field survey .....	21
3.3 Materials .....	23
3.4 Pre-processing.....	23
3.5 Methods .....	25
3.5.1 Land use land covers change analysis .....	25
3.5.2 Land use land covers change modeling .....	25
<b>4. Spatial Data Analysis and parameterizations .....</b>	<b>28</b>
4.1 Land Use Land Cover Dynamics.....	28
4.2. Land use land cover change modeling.....	30
4.2.1 Model description .....	30
4.2.2 Model parameter .....	31
4.2.3 Land use land cover modeling calibration.....	38
4.2.4 Model implementation and validation .....	42
<b>5. Result and Discussion .....</b>	<b>47</b>
5.1 Land use land cover change.....	47
5.2 Trend and Rate of land use land cover change .....	50
5.3 Land use land cover dynamics.....	52
5.4 Land use land cover prediction for the year 2020 .....	57
<b>6. Conclusion and Recommendations .....</b>	<b>60</b>
6.1-Conclusion.....	60
6.2 Recommendations.....	61
<b>References.....</b>	<b>62</b>
<b>Appendices.....</b>	<b>64</b>

## List of Figures

Figure 2.1 place of settlers' origin and destination in 1984/1985 resettlement programme. ....	6
Figure 2.2 Cells and Neighborhood.....	12
Figure 3.1 Study area Map.....	16
Figure 3.2 Yearly Rain fall Distribution for the last three Decades .....	17
Figure 3.3 Geology map .....	18
Figure 3.4 Soil map.....	18
Figure 3.5 Altitude Map.....	19
Figure 3.6 selected kebeles and sample sites.....	22
Figure 3.7 Land use land cover mapping Framework .....	25
Figure 3.8 Conceptualization Model of land cover change using CA-Markov model.....	26
Figure 4.1 Proximity to road.....	35
Figure 4.2 Slope class Map.....	35
Figure 4.3 Proximity to water bodies.....	36
Figure 4.4 Proximity to settlement areas .....	37
Figure 4.5 Map of rain fall.....	37
Figure 4.6 Map of population density.....	38
Figure 4.7 Pair wise comparison of factors .....	41
Figure 4.8 Suitability Map .....	42
Figure 4.9 Processed CA_Markov Change predictions Model .....	44
Figure 4.10. The actual and predicted land use land cover map of 2005 .....	44
Figure 4.11 Kappa index agreement of actual and predicted map of 2005 .....	46
Figure 5.1 Land use map of 1973 .....	48
Figure 5.2 Land use map of 1986 .....	49
Figure 5.3 Land use map of 2005 .....	49
Figure 5.4 Land use land cover change rate from the year 1973 to 2005.....	51
Figure 5.5 The predicted land use map of 2020 .....	58

## List of Tables

Table 3.1 selection of Woreda .....	21
Table 3.2 Materials and data types .....	23
Table 4.1 Description of change drivers (factors) and their types.....	33
Table 4.2 Level of suitability for each factor types .....	34
Table 4.3 1973_1986 transition probability matrix .....	39
Table 4.4 Fuzzy Module standardization of variables .....	40
Table 5.1 Land use lands cover of 1976, 1986 and 2005 .....	47
Table 5.2 Trend and Rate of Land use land cover change.....	50
Table 5.3 Land use land cover dynamics from 1973 to 1986.....	52
Table 5.4 Land use land cover dynamics from 1986 to 2005.....	54
Table 5.5 Unchanged percentages of 1973 cover and 1986 cover .....	55
Table 5.6 Transitions as percentage of 1973 cover and 1986 cover.....	55
Table 5.7 Projected Land use land cover change by 2020 and actual area of 2005 .....	58

## List of Appendices

Appendix 1 Classification accuracy assessment report of 1973, 1986, 2005.....	64
Appendix 1a. Classification accuracy assessment report of 1973 .....	64
Appendix 1b. Classification accuracy assessment report of 1986.....	64
Appendix 1c. Classification accuracy assessment report of 2005 .....	65
Appendix 2 Partial view of degraded lands in the study area.....	66
Appendix 3 Number of settlers, Rural Population Changes by Awraja, due to the 1984/85 Resettlement Programme .....	67

## List of Plate

Plate 3.1 A farmer explaining about the history of land use land cover during field visit .....	23
Plate 5.1 Partial views of agricultural lands. ....	56
Plate 5.2 Partial view of settlement expansion .....	57

# Acronym

AHP	Analytical Hierarchy Process
ANN	Artificial Neural Network Model
CA	Cellular Automata
CA_Markov	Cellular Automata Markov
CR	Consistency Ratio
CSA	Centre Statistics Agency
DEM	Digital Elevation Model
DN	Digital Number
FAO	Food Agricultural Organization
GIS	Geographic Information System
GPS	Global Positioning System
IDR	Institute of Development Research
LULC	Land Use Land Covers
MCE	Multi Criteria Evaluation
MSS	Multi Spectral Scanner
RRC	Relief and Rehabilitation Commission
SRTM	Shuttle Radar Thematic Mapper
TM	Thematic Mapper
TYPP	Ten Year Perspective Plan
WADU	Wollaita Agricultural Development Unit
WEPLAUO	Woreda Environmental Protection Land Administration and Use Office
WLC	Weighted Linear Combination

# 1. Introduction

## 1.1 Background and justification

Mankind's presence on the Earth and his modification of the landscape has had a profound effect upon the natural environment. These anthropogenic influences on shifting patterns of land use are a primary component of many current environmental concerns as land use and land cover change is gaining recognition as key drivers of Environmental change (Zelalem, 2007). Changes in land use and land cover are increasingly rapid, and can have adverse impacts and implications at local, regional and global scales. To better understand the impact of land use change on terrestrial ecosystems, the factors affecting land use must be more fully examined. Growing human populations exert increasing pressure on the landscape as demands multiply for resources such as food, water, shelter, and fuel. With rapid increases in population and continuing expectations of growth in the standard of living, pressures on natural resource use have become intense. For the resource manager, the task of effective resource allocation has thus become especially difficult (Eastman, 2001).

The problem of ecological degradation in the northern part of Ethiopia was the subject of a massive study undertaken in 1983/1984 by the FAO and ministry of agriculture. The study entitled "The Ethiopian highlands Reclamation study" showed among other things that of the 5.9 million hectares of land in the highlands, about 2.7 million are highly eroded, 1.4 million seriously eroded and 0.2 million are already lost to agriculture which, under cultivation loses about 100 tones of soil per ha every year(RRC,1984).

In response to these facts, which have been known since the early seventies though not quantified, the ten year prospective plan drawn for the period 1983/1984 -1993/1994 has given the resettlement of people from the degraded north to the more fertile south west a prominent place in the socio economic development of the country because the western and south western parts of the country have a considerable amount of land currently under utilized, which are suitable for farm activities. The areas have scarcely populated and have a free space to resettle people. In a period of 14 months (Nov., 1984- Jan., 1985) 594,190 people have been resettled, of these, 63 % came from Wollo, 18 % from Shewa, 15.5 % from Tigray, and the remaining 3.8 % from Gondar and Gojjam administrative region (IDR,

1987). Therefore, the study area Gubalafto Woreda was one of the parts of Wollo that dispatch the highest number of settlers to the destination area.

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

Recent advancement in GIS and remote sensing tools and methods also enable researchers to model and predict land use land cover more efficiently than the traditional approaches. Several modeling approaches have also been developed to model and forecast the dynamics of land use land cover classes. One of the approaches is the Cellular Automata (CA). CA is a dynamical discrete system in space and time that operates on a uniform grid-based space by certain local rules (Alkheder and Shan, 2005 cited in Yikalo, 2009).

The CA is consisting of cells and transition rules are applied to determine the state of a particular cell. Its ability to represent complex systems with spatial-temporal behavior from a small set of simple rules and states made it very interesting for urban studies. In this study an integrated approach of GIS, remote sensing and modeling has been applied to identify and analyze the patterns of land use land cover changes and provide quantitative and spatial information on land use land cover.

## **1.2 Statement of the problem**

In the study area as human and livestock populations increase, their demand for space and resources also increases. There are expansions of human habitations and agriculture at the expense of wild areas. The consequences of an ever-increasing pressure of human development are resulted in changes of land and vegetation cover in the area, or depletion, degradation and fragmentation of habitats, loss of corridors and an increased human–wild life conflict.

The main reason for food insecurity are land degradation, drought, high population pressure, low input subsistence agriculture, small farm size and landless. The highlands of Wollo in general and Gubalafto Woreda in particular have suffered from ecological degradation and their carrying capacity of people and livestock has been seriously undermined. The resettlement of people from these drought prone areas to more fertile areas in the south west of the country is considered as a necessary step to improve food production (IDR, 1987).

The area has been one of the origins where resettlers were relocated to the south west as a result of land degradation and drought. Thus, this study is intended to study the change in land use land cover before and after the relocation of people. Therefore, attempts were made in this study to map out the status of land use land cover change of settler's origin from 1973 to 2005 and model possible changes that might take place by considering a certain parameters using geographic information system and cellular automata model.

### **1.3 Objectives of the study**

#### **➤ General objective**

The general objective is to assess if resettlement has brought any change in the land use land cover in the area and to predict the future land use land cover changes using cellular automata model.

#### **➤ Specific objective**

- To study the land use land cover change and dynamics in the past 32 year before and after resettlement.
- To determine the trend, nature, rate, location and magnitude of land use land cover change.
- To identify the major land use land cover drivers.
- To predict and assess the future land use land cover changes.

## **1.4 Structure of the thesis**

This research work is explained in six chapters. Chapter 1 dealt with introduction, statement of the problem, objective of the research. Chapter 2 makes the survey of some literature related to this work along with a brief explanation of land use land cover, classification, change detection, resettlement, modeling land use land cover change and a brief explanation of remote sensing. Chapter 3 shows the methods and materials used, the selected study area description. It also gives an explanation about the data used for this work. Chapter 4 illustrates in detail Land use land cover change analysis and modeling. Chapter 5 also illustrates result and discussion part of the study. Chapter 6 concludes the research work with some recommendations for future line of work in this field.

## **1.5 Limitations**

There was a major limitation as a result of resolution difference. Landsat image of 1973 was acquired with the multi - spectral scanner (MSS) which has a spatial resolution of 80 meters, whilst the images of 1986 and 2005 were acquired with Thematic Mapper <sup>TM</sup> and Enhanced Thematic Mapper (ETM) respectively. These both have a spatial resolution of 30 meters. Although this limitation was corrected through image thinning, it still prevented its use for projecting into the future so as to have a consistent result. Apart from this, accuracy of image classification, number of parameter, suitability map production and the level of generalization applied affect the future land use land cover prediction.

## **2. Literature review**

### **2.1 Resettlement in Ethiopia**

#### **2.1.1 General description**

The population of Ethiopia, especially those in the northern part had lived with poverty and recurrent famines for generation. Although famine has been a major phenomenon in the history of each and every nation, in recent years, especially after the famine of 1974, for much of the world, unfortunately Ethiopia has become synonymous with draught and famine. However, as any body can observe Ethiopia has a great potential for reducing future famine.

Certainly some of the Ethiopian high lands are over grazed, over cultivated and have a heavy concentration of people while some of the Ethiopian lowlands are scarcely populated, largely fertile, and virgin lands and remain badly under cultivated. This condition makes resettlement a very attractive, reasonable and visible response to famine and drought in the northern part of Ethiopia.

Rural resettlement is generally defined as the planned or spontaneous movement of people to areas of under utilized agricultural potential (Tenassie, 1988). Usually the factors that initiate the resettlement of the people: Sevier pressure on land due to over crowding, rehabilitation of famine victims, and the accommodation of the rural land less and the urban unemployed. Resettlement most often takes place in virgin lands, but sometimes it include land used by nomadic herd men shifting cultivators which, with better management and infrastructure, can support more intensive agricultural productions.

In 1984 the Ethiopian government planned resettlement which had an eight year history, and which was expected to expand during the ten year plan periods. Due to the devastating famine of that year, which at one point affected some ten, million peasants, planned resettlement was quickly replaced with emergency resettlement and a large number of famine victims were relocated in Metema in Gonder province, Metekel, Assosa in Wellega and Gambella in Illubabor. Assosa were settlement areas quickly opened up during the famine itself and all three are located in the western lowlands of the country. Emergency resettlement was not so much a full-fledged policy as a quick response to a national crisis. (Desalegn, 1988)

According to the new program reported by Desalegn(1988), some 300,000 peasant house holds (i.e. about 1.5 million persons) were to be moved to new resettlement site, and of these 1.25 million were destined for the four major centers noted above plus several areas in Keffa province. Of the total to be resettled 50% were to be from Wollo and 33% from Tigray provinces. Mettekel was set to receive 250,000 which were more than the entire population of the Awraja. The study area Gubalafto Woreda is also one of the Woreda's of North Wollo, the previous Yeju Awraja that dispatch a number of settlers during the 1984 resettlement (see Annex, 3 and Figure 2.1). The red color on the map shows the area of destination, whereas the yellow and violet colors indicate the area of resettlers origin.

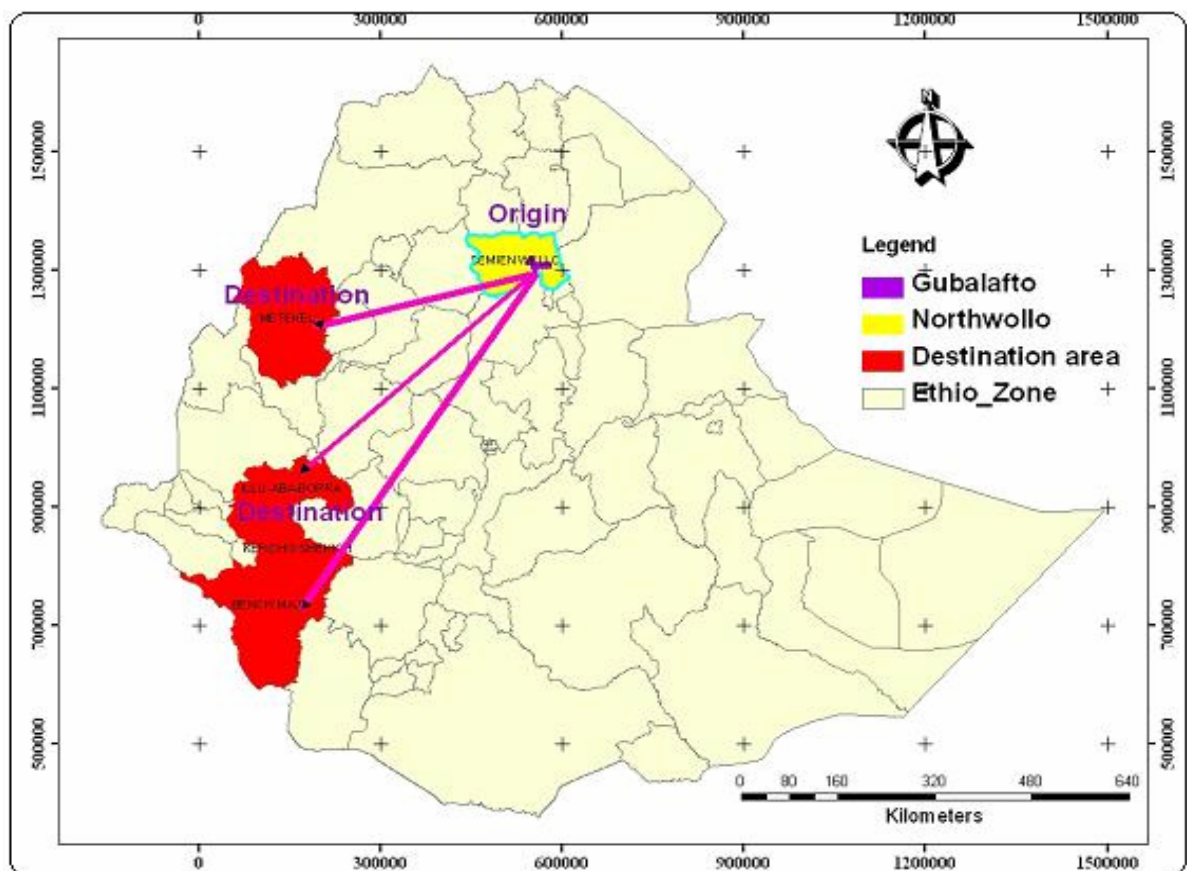


Figure 2.1 place of settlers' origin and destination in 1984/1985 resettlement programme.

### 2.1.2 Resettlement and land use land cover change

As a consequence of prolonged droughts and natural disasters, sporadic movement and migration of people in search of land and other resources have been long-time phenomena in Ethiopia (Alemneh, 1990; cited in Mekuria, 2005). These movements of people usually are from Wollo, Tigray, and Shewa highlands to the south western highlands.

As discussed in section 2.1.1 resettlement takes as an option to solve the problem of drought and saving the life of people. Apart from the objective of saving life, resettlement was considered a viable policy alternative to relax the environmental stress and to bring about a lasting solution to the impact of recurring droughts by reducing the population from the already degraded areas (Mekuria, 2005).

Different studies were undertaken on the areas of resettlers' destination about the land use land cover changes, whereas in the areas of origin no more works have been done except the socioeconomic aspects. But as a result of continuing demographic changes, the pre-1960 trend was characterized by the conversion of increasing areas under bush and forest into cultivated lands (Solomon, 1994). A continuous increment in population growth pushes the public to look for additional agricultural land and land for settlement. Therefore, in the resettlers' origin due to the higher demand for land and the occurrence of repeated drought the land use land cover conversion or change increased.

In 1984/85 the government takes a resettlement program to resist drought and famine problem. The resettlement program was expected to reduce the pressure on land use land cover in addition to saving life by relocating settlers to other less populated areas. Therefore this study also looks for the relation between resettlement and land use land cover change in the resettlers' origin.

## **2.2 Land use land cover dynamics**

### **2.2.1 Land use land cover**

The terms land cover and land uses are often used interchangeably, their actual meanings are quite distinct. Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps. Land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture (Lillesand and Kiefer, 2004).

Every parcel of land on the Earth's surface is unique in the cover it possesses (Meyer, 1995 cited in Zubair, 2006). Land use and land cover are distinct yet closely linked characteristics of the Earth's surface. The use to which we put land could be grazing, agriculture, urban

development, logging, and mining among many others. While land cover categories could be cropland, forest, wetland, pasture, roads, urban areas among others.

In addition to the above two definition (Gebreyohannes, 2008) “Land cover is the observed bio-physical cover on the earth’s surface”; the same document also defines land use as the arrangements, activities and inputs that people under-take on a certain land cover type. According to these definitions, land cover corresponds to the physical condition of the ground surface, e.g., forest, grassland, concrete pavement, while land use reflects human activities such as the use of the land like industrial zones, residential zones, and agricultural fields. The above definitions establish a direct link between land cover and the actions of people in their environment i.e. land use may lead to land cover change. Generally, land cover does not coincide with land use. A land use class is composed of several land covers. Changes in the nature of land use activities often results in land cover changes.

### **2.2.2 Change detection**

A remote sensing device records response which is based on many characteristics of the land surface, including natural and artificial cover. An interpreter uses the element of tone, texture, pattern, shape, size, shadow, site and association to derive information about land cover. The generation of remotely sensed data/images by various types of sensor flown aboard different platforms at varying heights above the terrain and at different times of the day and the year does not lead to a simple classification system. It is often believed that no single classification could be used with all types of imagery and all scales. Other classification schemes available for use with remotely sensed data are basically modification of the above classification scheme.

Change detection is the process of identifying difference in the state of an object or phenomenon by observing it at different times (Divyani, 2006). In remote sensing, change detection and monitoring involves the use of multi-date images to evaluate differences and quantitatively analyze the temporal effects of the phenomenon between acquisition data of images. Change detection is used for numerous functions, example; land use and land cover change; forest and vegetations change; forest mortality, defoliation and damage assessment; deforestation, regeneration and selective logging; wetland change; forest fire; landscape change; urban change and environmental change.

Change detection is an important process in monitoring and managing natural resources because it provides quantitative analysis of the spatial distribution of the population of interest. According to Macleod and Congation (1998) cited in Zubair (2006) list four aspects of change detection which are important when monitoring natural resources:

- I. Detecting the changes that have occurred
- II. Identifying the nature of the change
- III. Measuring the area extent of the change
- IV. Assessing the spatial pattern of the change

The basis of 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 computer power. A wide variety of digital change detection techniques have been developed over the last two decades. Singh (1989) cited in Zubair (2006) summarize 11 different change detection algorithms that were found to be documented in the literature by 1995. These include:

1. Mono-temporal change delineation.
2. Delta or post classification comparisons.
3. Multi-dimensional temporal feature space analysis.
4. Composite analysis.
5. Image differencing.
6. Multi-temporal linear data transformation.
7. Change vector analysis.
8. Image regression.
9. Multi-temporal biomass index
10. Background subtraction.
11. Image rationing.

Therefore, the selection of an appropriate change detection algorithm is very important. Change detection algorithms have a direct impact on the type of classification to be performed and it will dictate whether important “from-to” information can be extracted from the imagery. Also, the selection of the most suitable method is dependent on the analyst’s knowledge of the method, the image used and the characteristics of the study area. A large number of change detection methods have been developed and tested but there is no single method that fits all cases. In aid of identifying an appropriate method in practice different change detection techniques are often executed and compared for a study area, and a selection is made based on which method provides the best result according to the accuracy assessment

or qualitative assessment. Combination of two change detection techniques could improve the change detection results.

Image differencing is one of the widely used change detection approaches and is based on the subtraction of images acquired in two different times. This is performed on a pixel by pixel or band by band level to create the image difference. In the process, the digital number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date (Singh, 1989; Yikalo, 2009). Hence image differencing was the appropriate and selected techniques used in this research work.

## **2.3 Land use land cover change modeling**

### **2.3.1 Land use change models**

The term “model” has been used in different context and in a number of application areas. It is broadly defined as abstraction or approximation of reality achieved by simplification of complex real world relations to the point that they are understandable and analytically manageable. Land use land cover change model can be used for different purposes. These models can be categorized according to the amount of information they contain. These are the whole landscape models, distributional landscape models, or spatial scape models Baker (1989) cited in Anuj (2003). Land use land cover change is influenced by natural and human activity process. Therefore, spatial modeling has more relevance than other methods of modeling in research.

Modeling land use change has a significant role for understanding the impacts of the changes. These would also help for effective environmental management, sustainable development resource use, development plans (use plans) and decision making. In practical situation (e.g. land use land cover studies), models are used to predict the future state of land use patterns considering various physical and socioeconomic elements. In order to achieve all, these numbers of modeling approaches have come to exist. To name a few models based on approaches: Cellular automata models, artificial neural models, Multi-agent models, statistical models and Fractal models (Anuj, 2003). Therefore, due to its simplicity and applicability to GIS environment cellular automata model was selected and applied to this research work.

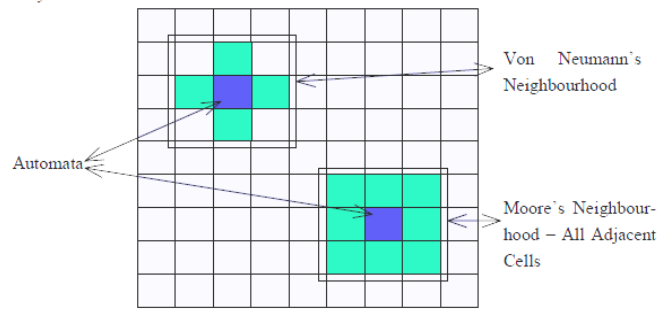
### 2.3.2 Cellular automata model (CA)

Cellular automata model was developed by Ulam in the 1940's (Anuj, 2003; Sudhira *et al.*, 2005) and soon used by Von Neumann to investigate the logical nature of self reproducible system. CA is defined as a dynamic discrete system in space and time that operates on a uniform grid based space (Yikalo, 2009). The approach in this model is "bottom up". The final global structure emerges from purely local interactions among the cells. CA not only offers a new way of thinking for dynamic process modeling it also provides a laboratory for testing the decisions making process (Anuj, 2003).

Cellular Automata (CA) get their name from the fact that they consists of cells, like the cells on the check board, and that cell states may evolve according to a simple transition rule, the automaton. Cellular automata are dynamic model that inherently integrate spatial and temporal dimension. Cellular automata are composed of five elements as described below:

**Cell space:** The cell space is composed of individual cell. Theoretically these cells may be in any geometric shape. Yet most CA's adopt regular grids to represent such a space, which make CA very similar to a raster GIS. **Cell states;** the states of each cell may represent any spatial variable, e.g. the various types of land use. **Time steps:** a cell will evolve at a sequence of discrete time steps. At each step, the cells will be updated simultaneously based on transition rules. **Transition rules:** These rules are the heart of the CA that guides its dynamic evolution. A transition rules normally specifies the state of cell before and after updating based on its neighborhood conditions. **Neighborhood ;** Each cell has two neighbors in one dimensional cellular automata, where as in two dimensional cellular automata model there are two ways to define it.

Von Neumann has considered four neighboring cells as neighbors. Moore considers eight neighboring cells. As shown in Figure 2.2 the green color cells are neighbors to the center cell which is in blue color.



Source (Sudhira *et al.*, 2005)

**Figure 2.2 Cells and Neighborhood**

### **Modeling in Idrisi**

Idrisi is the industry leader in raster analytical functionality covering the full spectrum of GIS and remote sensing needs (Eastman, 2001). Some of the functionalities included in the package are image analysis, change and time series analysis, spatial modeling, decision support system etc. Some of the modeling techniques embedded in Idrisi Andes is logistic regression, stochastic, GEOMOD and CA-Markov chain analysis.

As mentioned above, CA operates on a grid based cells and transition rules are applied to determine the state of cell. Markov chain analysis on the other hand, is a system in which the future state of the system is modeled on the basis of the immediate preceding state. Markov chain analysis is named after Andry Markov, who was a Russian mathematician and best known for his work on the theory of stochastic process. It is based on the principle that gives the present state and future state is independent of the past state.

Many CA models have been developed so far especially in urban growth process studies. Depending up on their transition rules, and calibration methods they differ from each other. Some of the CA models are: Macro and micro integrated CA model (RIKS models), SLUTH model, ANN CA model, Fuzzy CA model, MCE CA model, Multi-CA model, Statistic CA model and Stochastic CA model (Anuj, 2003).

### **MCE-CA model**

The transition rules have been defined by various ways. The combination of three elements GIS, CA, and MCE, as claimed by the author has several advantages; visualization of decision making, easier access to spatial information and the more realistic definition of transition rule in CA. In order to explore land use dynamics, this study employed CA-Markov chain analysis integrated with raster based remote sensing. The CA-Markov chain analysis

uses a MCE to generate the decision rules in the form of suitability maps. The transition rule was based on the factors that have impacts on land use land cover changes. These include agriculture; Market, Road, settlement, population density, slope, etc and other reserved areas (e.g. water bodies, settlement and forest). The effect of these factors were first evaluated using MCE( criteria development) transition rules and resulted in generating potential “suitable “or “susceptible” areas for land use land cover change.

Therefore, MCE is most commonly achieved by one or two procedures. The first involves Boolean overlay where by 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 (Zelalem, 2007).

Hence Markov Chain Analysis is a convenient tool for modeling land use change when changes and processes in the landscape are difficult to describe. A Markovian process is one in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markovian chain analysis will describe land use change from one period to another and use this as the basis to project future changes. This is achieved by developing a transition probability matrix of land use change from time one to time two, which shows the nature of change while still serving as the basis for projecting to a later time period. The transition probability may be accurate on a per category basis, but there is no knowledge of the spatial distribution of occurrences within each land use category. Hence, Cellular Automata (CA) was used to add spatial character to the model.

CA-Markov uses the output from the Markov Chain Analysis particularly Transition Area file to apply a contiguity filter to “grow out” land use from time two to a later time period. In essence, the CA will develop a spatially explicit weighting more heavily areas that proximate to existing land uses. This will ensure that land use change occurs proximate to existing like land use classes, and not wholly random. Overlay operations which is the last method of the three, identifies the actual location and magnitude of change although this was limited to the built-up land. Boolean logic was applied to the result through the re-class module of idrisi32 which assisted in mapping out separately areas of change for which magnitude was later calculated for (Zubair, 2006).

## **2.4 Image analysis and classification using remote sensing and GIS**

GIS and RS are land-related and therefore are very useful in the formulation, implementation and monitoring of land use land cover change analysis and modeling. GIS is a systematic process of spatial data collection and processing. It can be used to study the environment by observing and assessing the changes and forecasting the future based on the existing situation. RS, on the other hand, is the process of data acquisition through space or air borne sensors without having any contact with the target objects. It allows the acquisition of multi-spectral, multi-resolution and multi-temporal data for the land use change analysis and modeling. Both remote sensing and GIS tools have been applied in a number of land use land cover change studies to detect, monitor and simulate land changes (Lillesand and Kiefer, 2004).

Because of their cost effectiveness and temporal frequency, remote sensing approaches are widely used for change detection analysis. However, computer assisted production of spatially detailed and thematically accurate LULC information from satellite image continues to be a challenge for the remote sensing research community. This is due to the heterogeneous nature of land use land cover environment, which makes discriminating land cover classes difficult. It could also be due to the absence of appropriate classification techniques. However, recent advances in GIS and remote sensing tools and methods have enabled researchers to analyze and detect the dynamic nature of land use land cover features in a more efficient way. Some recent researches have also been directed toward quantitatively describing the spatial structure of land use land cover environments and characterizing patterns of land cover land use structure through the use of remotely sensed data (Lillesand and Kiefer, 2004).

### **2.4.1. Spatial data and processing**

Satellite data are the bases for various environmental studies and have been used in different application areas (e.g. mapping and detecting of land use changes). However, consideration must be given to the impacts of the sun's inclination, season of image acquisition and cloud cover. This is because these factors would affect the quantitative analysis of the changes. The impact of the differences of sun's angle may partially be reduced by selecting data belonging to the same time of the year. The availability of multi temporal data to produce land cover changes is also useful because it solves the problems associated with single dated land cover information.

### **2.4.2 Image classification and validation**

Accuracy assessment is a process used to estimate the accuracy of image classification by comparing the classified map with a reference map (Caetano *et al.*, 2005 cited in Yikalo, 2009). It is critical for a map generated from any remote sensing data. Although accuracy assessment is important for traditional photographic remote sensing techniques, with the start of more advanced digital satellite remote sensing the necessity and possibility of performing advanced accuracy assessment have received new interest. Currently, accuracy assessment is considered as an integral part of any image classification. This is because image classification using different classification algorithms may classify pixels or group of pixels to wrong classes. The most obvious types of error that occurs in image classifications are errors of omission or commission.

The common way to represent classification accuracy is in the form of an error matrix. An error matrix is a square array of rows and columns and presents the relationship between the classes in the classified and reference maps. Using error matrix to represent accuracy is recommended and adopted as the standard reporting convention (Congalton, 1991 cited in Anuj, 2003).

## 3. Materials and Methods

### 3.1 Description of the study area

#### 3.1.1 Location

North Wollo Administrative Zone is one of the eleven zones of the Amhara National Regional State. The administrative Zone has eight Woredas, namely; Gubalafto, Habru, Kobo, Delanta, Meket, Wadla, Bugna and Gidan. The study was conducted in Gubalafto Woreda. Geographically the area is located between  $39^{\circ}12'9''$  and  $39^{\circ}45'58''$  East and  $11^{\circ}34'54''$  and  $11^{\circ}58'59''$  North. The Woreda covers an area of  $877.85 \text{ km}^2$ , and is bordered by DelantnaWadela Woreda in the west, Gidanenakobo Woreda in the North, Habru Woreda, in the south and in the east. Woldia town is the administrative center of the Woreda. Which is located within the two symmetrical hills named Gabriel Hill On the northwest and Qaro Hill On the south eastern part and relatively elongated from northeast to the southwest. A look at its topographic feature indicate that the town has undulating landscape, surrounded by hills With average elevation of about 1,900 m.a.s.l. measured from the center of the town. Figure 3.1 indicates the map of Gubalafto Woreda.

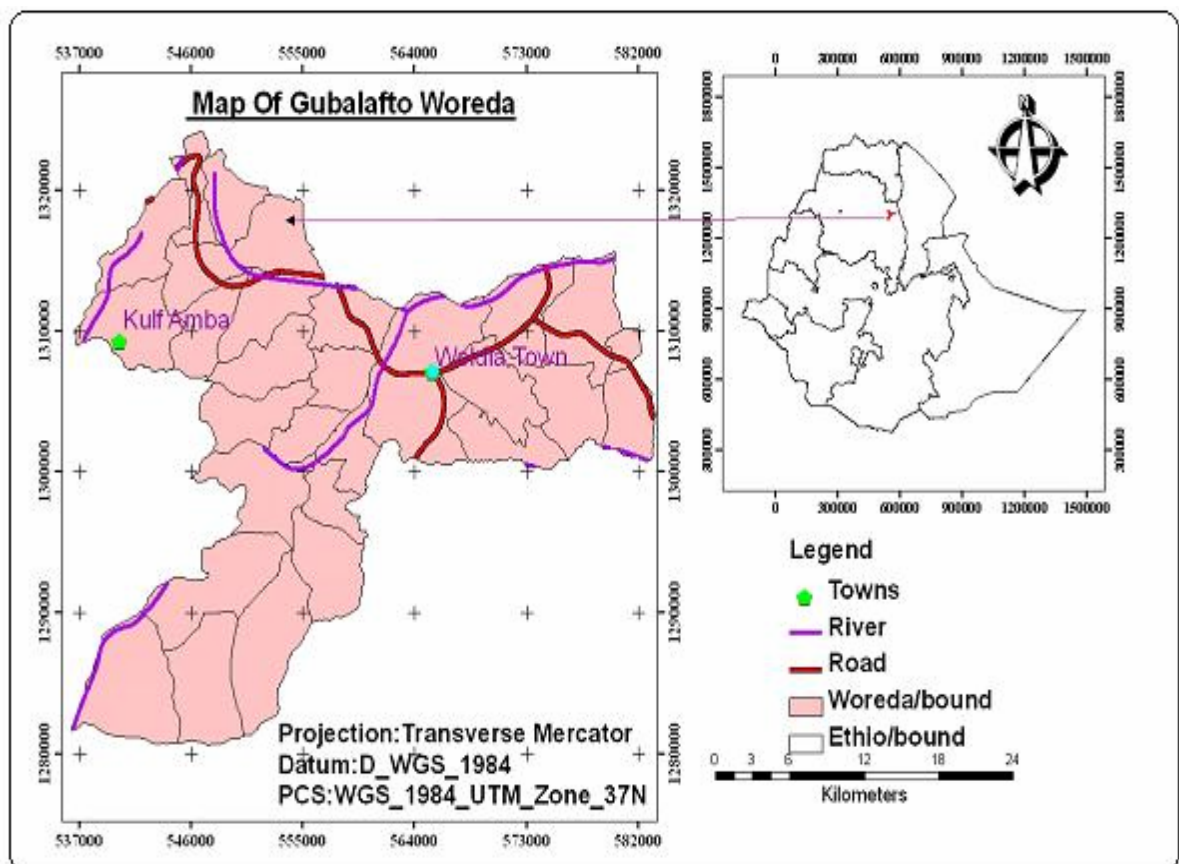


Figure 3.1 Study area Map

### 3.1.2 Climate and Rainfall Distribution

According to the daily air temperature data collected from Sirinka Agriculture Research Center (located about 10km south of Woldya), the mean monthly temperature at Sirinka ranges between 21<sup>0</sup>c to 25<sup>0</sup>c. A bi-modal nature characterizes rainfall in most parts of Gubalafto Woreda: the short rainy season (Belg), which occurs between February and April and long rainy season (Meher), which occurs between June and September. In most cases, the highland areas (Dega) are mainly dependent on Belg rain whereas, the Woinadega and Kolla areas are Meher rain dependent for crop production.

The principal feature of rainfall in most parts of Gubalafto Woreda is its seasonal character, poor distribution and variability from year to year. For the past three decades, an erratic distribution of rainfall has been the major climatic factor affecting crop yields in the area. Figure 3.2 also indicates the past three decade annual rain fall and hence the highest amount of rainfall was recorded during the year 1995 and the least rain fall was recorded in the year 1977/78 and 1998/1999. Due to this less amount of rain fall the people in the area were highly exposed to drought and famine during those years.

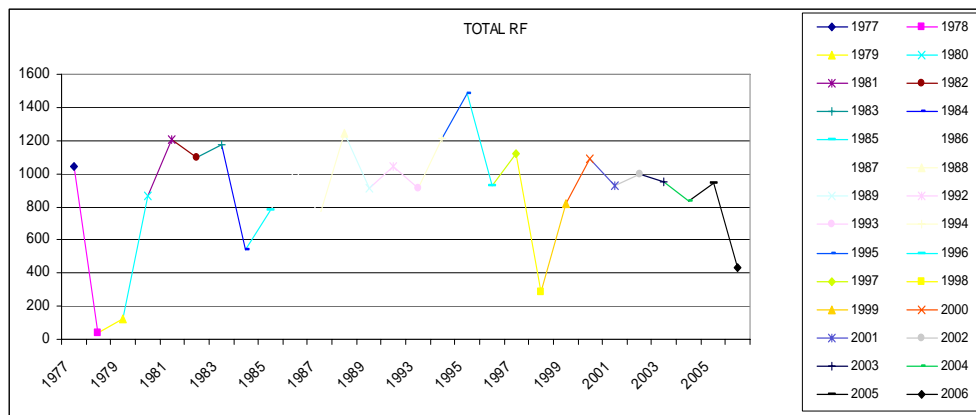
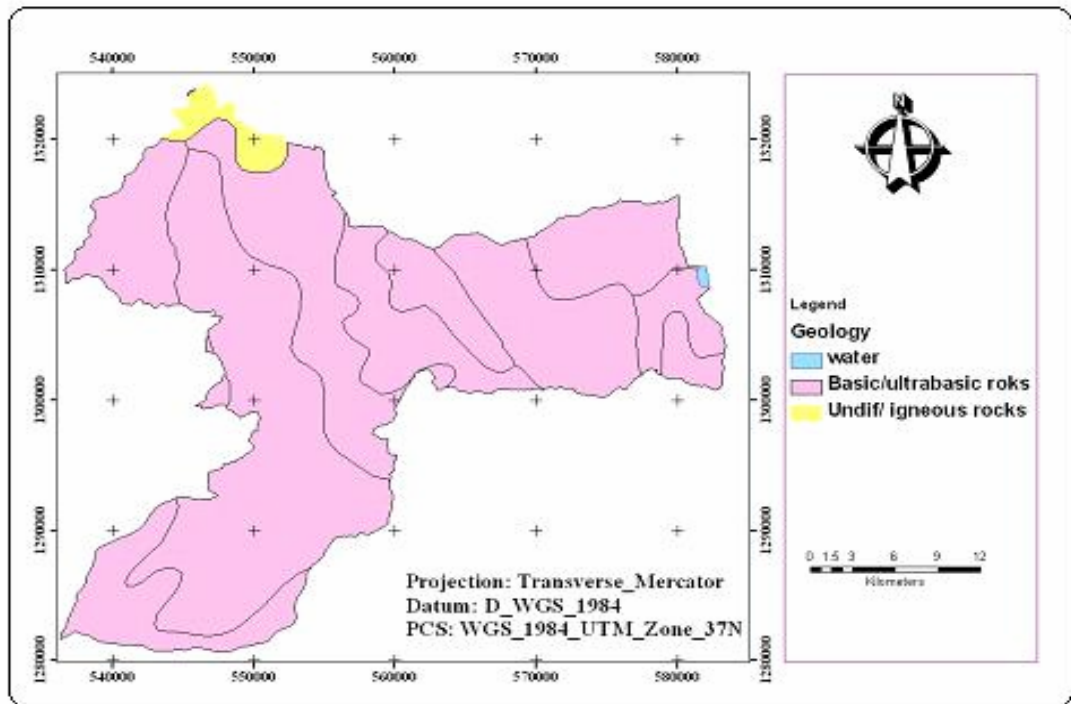


Figure 3.2 Yearly Rain fall Distribution for the last three Decades

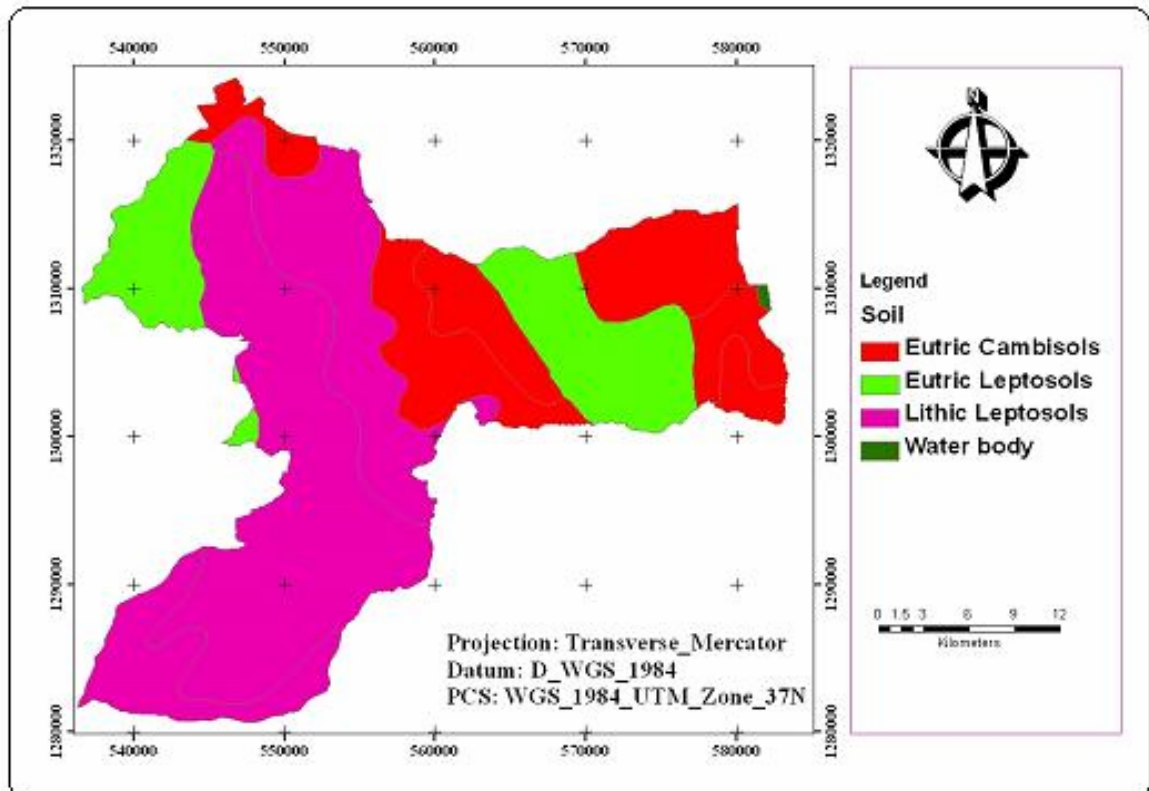
### 3.1.3 Geology and Soil

The study area dominantly covered with basic and ultra basic rocks (example basalt, gabbro, and pyroxenite etc) and Pyroclastic rocks like, ashes, tuffs and ignimbrites and with a small portion of undifferentiated igneous rock (Figure 3.3). In the soil map (Figure 3.4) the area is dominated with 92.2% Lithic Leptosols, 3.9% Eutric Cambisols and the remaining 3.5% were Eutric Leptosols (FAO, 1997).



Data source: (FAO, 1997)

Figure 3.3 Geology map



Data source: (FAO, 1997)

Figure 3.4 Soil map

### 3.1.4 Agro-ecological zones

The Woreda is found in the northwest part of the Amhara region. The topography of the area is characterized by 20% flat, 30% undulating, 35% mountainous and 15% gorges or Valleys. The altitude of the zone varies from 1379 to 3809 meter above sea level (m.a.s.l) (Figure 3.5). Gubalafto Woreda has four agro-ecological zones, namely, lowland (Kolla) 1379-1500 m a.s.l, Mid-altitude (Woinadega) 1500-2300 m a.s.l, Highland (Dega) 2300-3200 m a.s.l, and Wurch >3200 m a.s.l.(Gubalafto Woreda agricultural office).

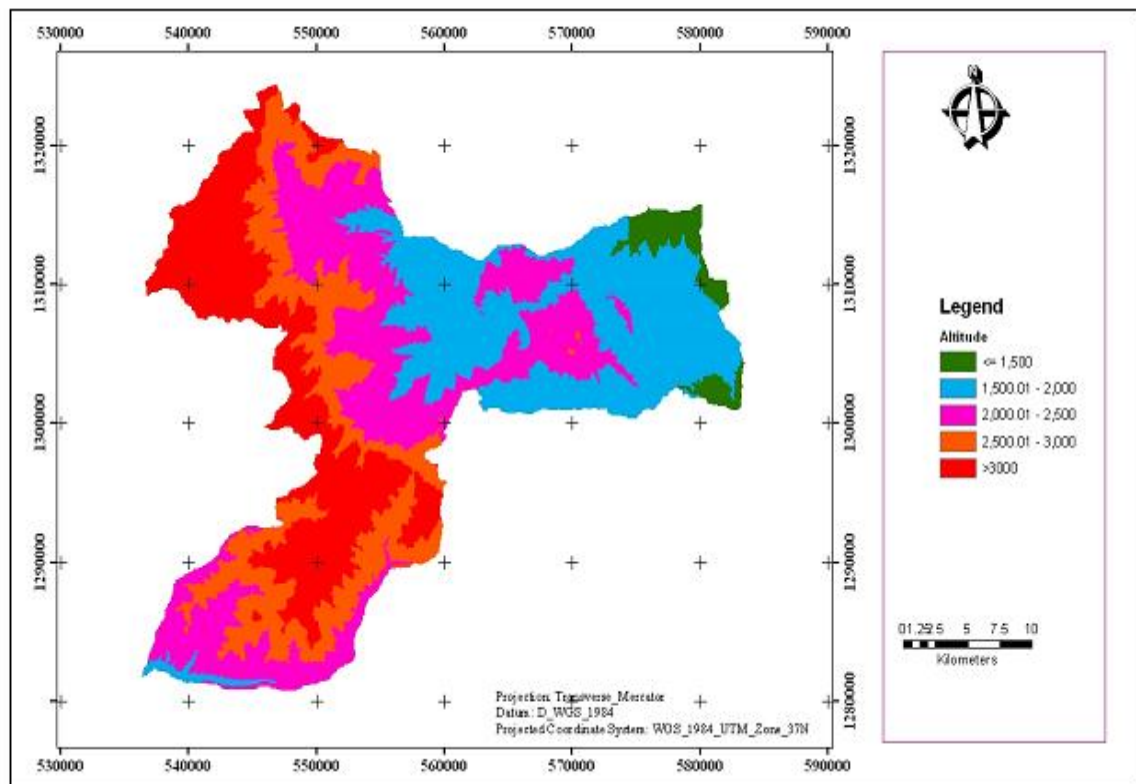


Figure 3.5 Altitude Map

### 3.1.5 Socio-Economic and Physical Characteristics

In Gubalafto Woreda, as in most parts of Amhara Woreda's, subsistence agriculture is the main occupation of the rural population. It is one of the Woreda in the region, which during the past few decades, has been stricken by drought, unreliable rainfall and consequently to miserable poverty and acute food shortage. Furthermore, soil fertility has dramatically declined due to erosion phenomena caused by deforestation and increase population pressure. Due to both man made and natural disaster, the rural community in the Woreda has not been able to produce sufficiently to feed its population.

With regards to crop production, the Woreda is dependent on both the Belg and Meher seasons. According to the Department of Agriculture, the major crops cultivated during the short rain (Belg) season, in order of importance are Barely, Teff and Lentils, while during the main rain (Meher) season the most important cultivated crops are Sorghum, Teff, Maize, Wheat, Barely, Chick peas, Faba beans and lentils. In addition there are about 104,439 cattle, 121,780 goat and sheep, 18,714 donkeys, horses and camels based on 2009 local livestock enumeration by the Woreda agricultural office.

### **3.1.6 Land Use Pattern**

The available data with regards to land use in Gubalafto Woreda vary considerably; however, based up on the data from Gubalafto Woreda environmental protection, land administration and use office, most of the land is mountainous and characterized by steep slopes, unsuitable for agricultural purpose thus; the agricultural land is limited to 36.42 per cent of the total area (Woreda environmental protection and land administration, 2001).

This has the direct implication that intensified methods of production are the sole means of increasing crop production in the Woreda. The nature of the land coupled with that of population pressure has resulted in individual households farming very small areas. At the Woreda level, the average land holding size for a farmer has been estimated to be 0.78 hectare ranging from 0.4 hectare in the highland areas to 1.93 hectare in the Kolla (lowland) areas of the Woreda (Woreda Environmental protection, land administration and use office, (WEPLAUO).

### **3.1.7 Population**

The total populations of the Woreda in 2007 was 195,362 of which, 96,814 were males and 98,548 were females. Of which the urban population of the Woreda was 1732 male and 1803 females and the rural population of the Woreda was 95,082 male and 96,745 females (CSA, 2007). According to the Woreda agricultural office the total rural households are estimated to be 50,461 with an average family size of 3.8 people.

### **3.1.8 Nature of Rural Settlement**

People in rural areas belong to Kebeles that ranges from 2242 (Hara) to 9586 (Zewer Gotera) persons. The Kebele or peasant associations as they were commonly known were established in the mid seventies for the purpose of executing the land reform programme of the Derg

regime (Seid, 2002). They still comprise the lowest level of the administrative structure of the Woreda (country) but have acquired responsibilities in the areas of law enforcement, distribution of relief food and socioeconomic development. The Kebeles are divided in to smaller units, known as Gotts, which consist of a number of families under the leadership of development team (Yelimat Buden). The settlement pattern in the Woreda is highly scattered. People live in small groups of dwellings that contain an extended family as near as possible to the land they cultivate.

### 3.2 Site selection and field survey

This study concerns mainly on the impacts of resettlement on land use land cover before and after 1984/85 resettlement program. Hence, it is necessary to select an appropriate study area for this resettlement issues. As discussed in the previous literature section Ethiopia in general and Wollo in particular has been repeatedly attacked by drought and famine, due to this the government takes resettlement program to reduce the problem. Therefore, this study concerns on the parts of Wollo area.

The study area was selected based on the source of information that were collected from different government offices like; North Wollo zone administration office, zone agricultural office, zone environmental protection and land administration office and zone food security and disaster prevention office. The selection takes place mainly based on the number of settlers that leave from an area and hence the combined selection of each office was ranked. The following Table 3.1 indicates the name of Woreda's that are found in north Wollo zone which dispatch large number of settlers during 1984/85 resettlement program.

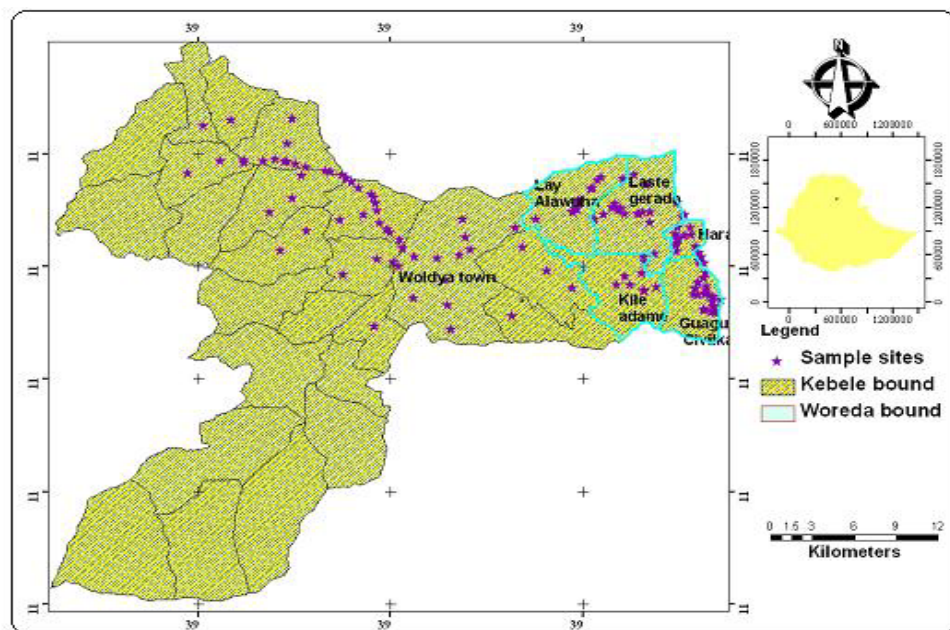
**Table 3.1 selection of Woreda**

R/N	Name of Woreda	Rank
1	Gubalafto	1
2	Habru	2
3	Kobo	3
4	Delantadawnt	4
5	Bugna	5

Based on Table 3.1 the highest rank had given to Gubalafto Woreda that dispatch large number of people to the south west Ethiopia. Therefore, Gubalafto Woreda was selected for this study.

On the other hand after selecting the Woreda by the zonal officials the researcher tries to identify the selected Kebele by following the same procedure together with the concerned Woreda government officials and the residential. Based on the rank given in Table 3.1 the first and second ranked Woreda's were visited and compared which one is more sensible about the resettlement and by contacting both resettled and un-resettled individuals to check the reality. Even though resettlers have been taken from all kebeles of the Woreda based on the number of resttlers, finally five kebeles were selected from Gubalafto Woreda, namely; Hara, Layalawuha, Lastegerado, Kileadame and Gaugurcivilkai.

As indicated in Figure 3.6 from the total of 29 kebeles, the five Kebeles boundaries were highlighted and listed their names on the map because these kebeles dispatch large number of settlers during the 1984/85 resettlement program. According to the Woreda and kebele administration, these Kebeles dispatch almost more than 75% of their residents as compared to the rest of the Woreda's Kebele. Therefore, this study gives more attention on resettlement based on these five selected kebeles.



**Figure 3.6 selected kebeles and sample sites**

In addition the surveys conducted within the study area were used to determine the major types of land use land cover classes. The collected data were used for two purposes of mapping land use land cover classes. Firstly it aid in land use and land cover classification, by associating the ground features of a specific type of land use and land cover with the relevant imaging and spectral characteristics. Secondly, ground data were used for accuracy assessment of the developed land use and land cover maps. GPS has been used in the

collection of GPS points for training samples for image classification. More than 100 sample training sites have been collected. Samples for model verification have also been used. The spatial locations of sample sites have been illustrated in Figure 3.6. Digital camera has been used for taking sample photograph of the site Plate 3.1.



**Plate 3.1** A farmer explaining about the history of land use land cover during field visit

### 3.3 Materials

**Table 3.2** Materials and data types

S/N	Data Type	Date of production	Resolution	Row and Path	Source
1	MSS	1973	80m	181/52	AAU ftp sever
2	Landsat Image	1986	30m	168/52	AAU ftp sever
3	Landsat Image	2005	30m	168/52	GLCF
4	SRTM		90m		AAU ftp sever
5	SPOT	2006	20m		EMA
6	Ethio_GIS Data	Vector data			AAU ftp sever
7	Top map	1994	1:50,000		EMA
8	Arial Photo	1986			EMA
9	Meteorological data	1977-2005			NMA
10	Population and agricultural data	1977_2007			ESA

### 3.4 Pre-processing

In this study, multi resolution and multi temporal time series including historical satellite imagery, aerial photographs and other vector datasets were used to determine LULC changes over the study period between 1973 and 2005. In order to analyze the time series dataset and

generated surface information, different approaches were employed. Except its poor resolution of each image it doesn't have any strip on them and therefore, no correcting mechanisms were taken.

The satellite images and other maps used were projected to a common coordinate system. Using ERDAS IMAGINE software satellite images were, rectified, and enhanced by contrast stretching for better visual interpretation. Then, unsupervised and supervised image classifications were carried out. The sample points collected during fieldwork were used for validating classification results. ENVI and IDRISI soft wares are used for Change detection analysis and for factor weighting, scoring using MCE and modeling using CA-markov chain analysis, respectively. The ArcGIS software was used for analysis and integration of thematic maps.

Satellite images were identified and acquired to represent the land cover use status in the 1973, 1986 and 2005. One major concern over the use of satellite images in the Ethiopian highland is the existence of cloud cover, even during the dry seasons. Such a condition may limit the amount of information that may be extracted from these images, and would create information gaps and loss of valuable data. One would expect that this problem would further be compounded when dealing with change detection as images from different dates are used to identify the extent and type of changes in the land use land cover of an area.

Analysis and interpretation of satellite data were done by digital image processing as indicated in Figure 3.8. The process generally includes three major steps:

1. Image pre-processing, this operation involves the correction of distortion, degradation and noise introduced during the image processing;
2. Image enhancement, this procedure were applied to the image in order to increase the amount of information that can be displayed interactively;
3. Image classification, the objective of this operation is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene.

### 3.5 Methods

#### 3.5.1 Land use land covers change analysis

Land use land cover mapping requires a careful assessment and monitoring to provide planners with information on the tendency of land use land cover change in the future. In order to examine the land use changes, a post classification change analysis (image differencing) was employed and the changes were quantified. Land use land cover measurement was also studied to examine the change in the study area. Figure 3.7. Describes the methods applied to detect changes and analyze the dynamics.

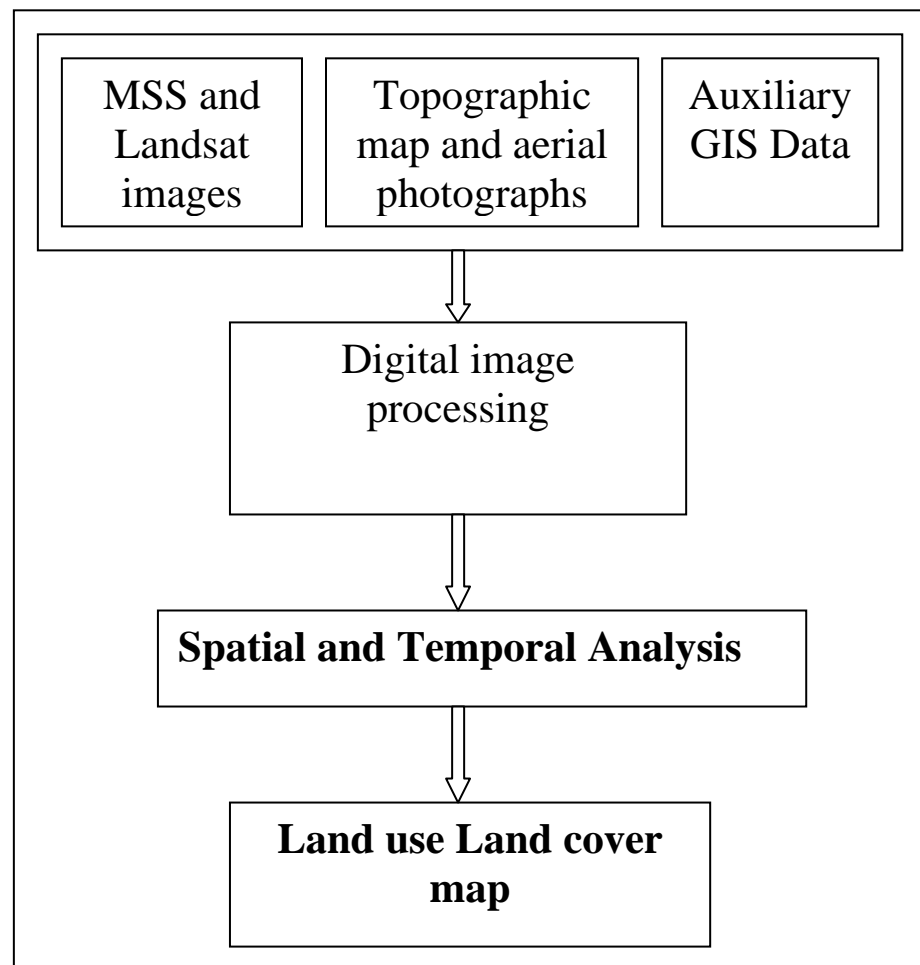


Figure 3.7 land use land cover mapping Framework

#### 3.5.2 Land use land covers change modeling

In order to build the transition rules for the dynamics of land use land cover, the change in the study area was analysed. The overall conceptualisation of the CA model is as shown in Figure 3.8. The land use land cover change in the area was initially quantified for the years 1973, 1986 and 2005, so as to analyse the change and the rate of growth. With the quantification of the land use land cover change from 1973 to 2005, modelling studies were undertaken by

considering the key driving factors responsible for the change. This model was used to predict the change for subsequent years, thereby setting the land use land cover for the CA transition rules for allocating different land cover classes into different land use land cover categories in the subsequent years.

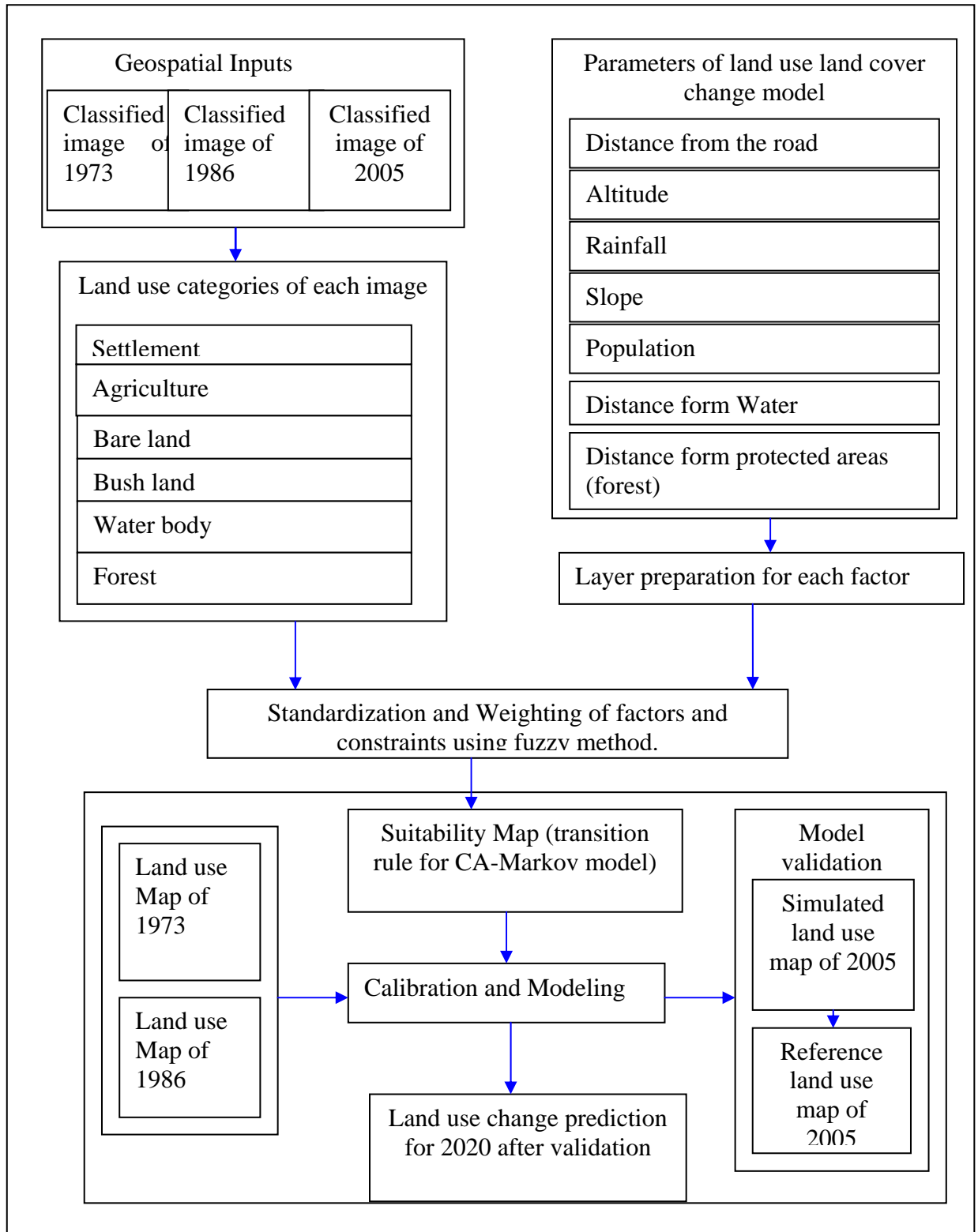


Figure 3.8 Conceptualization Model of land cover change using CA-Markov model

The cumulative transition rule for allocating land was based on the demand set by the regression model and the suitability of the cells established by the multi-criteria evaluation and the neighbourhoods defined by the proximity of the cells to the existing settlement and the road. The foregoing section discusses in detail on the analysis of land use land cover change, subsequent modelling and establishing the suitability of the cells using the multi-criteria evaluation and the definition of neighbourhoods and constraints.

## **4. Spatial Data Analysis and parameterizations**

### **4.1 Land Use Land Cover Dynamics**

Satellite image classification has been performed using ERDAS 9.1 software. Multispectral classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, the pixel is assigned to the class that corresponds to those criteria depending on the type of information required to extract from the original data, classes may be associated with known features on the ground.

The reference data used for accuracy assessment are usually obtained from aerial photographs, high resolution images, Google Earth, and field observations (e.g. GPS data, and photo). In this case, the assessment was carried out using high resolution (25cm) aerial photograph, GPS data, Google Earth and field survey as a reference. A set of reference points has to be generated to assess accuracy and stratified random points were generated for each derived maps. These points were verified and labeled against the reference data. Error matrices were then designed to assess the quality of the classification accuracy of all the maps.

In this study both types of classification was under taken. Unsupervised classification was performed on the images .This is useful for generating a basic set of classes, then supervised classification has been undertaken for further definition of the classes. In the Supervised training pixels that represent patterns or land cover features have been selected based on the Knowledge of the data, and of the classes desired. In this process, the ground truth data which had been collected in the field have been used in selecting training samples. The result of training is a set of signatures that defines a training sample or cluster. Each signature corresponds to a class, and is used with a decision rule to assign the pixels in the image file to a class. After the signatures are defined, the pixels of the image are sorted into classes based on the signatures by use of a classification decision rule.

After classification the result has been evaluated using accuracy assessment cell array.

Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process. In

this study a total of 100 randomly generated reference points (pixels) were used for the assessment. Usually, the assumed-true data are derived from ground truth data. It is usually not practical to ground truth or otherwise test every pixel of a classified image. Therefore, a set of reference pixels is usually used. Reference pixels are points on the classified image for which actual data are known. The reference pixels are randomly selected (Congalton, 1991; Cited in Yikalo, 2009).

In this paper, overall, producer's and user's accuracy were considered for analysis. The Kappa coefficient, which is one of the most popular measures in addressing the difference between the actual agreement and change agreement, was also calculated. The Kappa statistics is a discrete multivariate technique used in accuracy assessment. The report derived from the accuracy assessment cell array shows that the classification has resulted in more than 89% total accuracy which is the percentage of accuracy, based upon the results of the error matrix. The generated report has also resulted in Kappa coefficient of more than 0.84 for each classified image. Kappa coefficient expresses the proportionate reduction in error generated by the classification process compared with the error of completely random classification. The overall classification accuracy is expressed as the ratio of the sum of correct classifications (diagonals) and the total randomly generated reference pixels (points) used for the assessment (Annex 1).

The 1973 MSS image of the study area have been used as one of the inputs in the land use land cover dynamics. The image classification has resulted in 90% total accuracy and 0.85 kappa coefficient. TM image of 1986 is another input for the land use land cover dynamics it also resulted with 92% total accuracy and .88 kappa coefficient where as the 2005 image classification accuracy assessment resulted with 87% total accuracy and 0.81 kappa coefficients (Annex 1).

Land use conversion matrix has been used to study the land use source and destination of change using ENVI 4.3 software. Conversion matrixes for the years 1973 to 1986 and 1986 to 2005 have been produced to investigate the sources and destinations of the land use land cover changes during these time intervals. The annual rate of change between those years also calculated to know how many kilometer square of land each year reduced or added to the given land use land cover classes. Which means Annual rate of change is calculated by

dividing the change of the given land use land cover type by the number of years between the two years.

## **4.2. Land use land cover change modeling**

The purpose of this chapter was to simulate land use change in the future time period and assess the impact of the changes in the surrounding ecosystem. The model applied in this study, CA\_Markov, allows us to predict and project the study area land use change. The Markov chain analysis predicts the future land use pattern only on the basis of the known land use patterns of the past. It is also supplemented by the CA approach and a number of change drivers to better understand the change.

### **4.2.1 Model description**

CA provides a powerful tool for modeling the dynamic nature of land use and is a commonly used method to take spatial interaction into consideration. There are many different CA models in various software platforms and are different options to implement: using an existing model or developing a new model. The later requires extensive and advanced programming knowledge. This study is based on the existing modeling technique “CA\_Markov”. The CA\_Markov integrates two techniques: Markov Chain Analysis and Cellular Automata Analysis. The Markov Chain Analysis describes the probability of land use change from one period to another by developing a transition probability matrix between t1 (1973) and t2 (1986). The probabilities may be accurate on a per category basis but there is no knowledge of the spatial distribution of occurrences within each land use classes (Eastman, 2001). This is the inherent problem of the Markov Analysis. In order to add the spatial character to the model, therefore, Cellular Automata (CA) is integrated to the approach. In the CA analysis, the land use was treated as a dynamic system in which space, time and the states of the system were treated discretely. The Cellular Automata component of the CA\_Markov model allows the transition probabilities of one pixel to be a function of neighboring.

**Cellular automata can be represented as quadruple as follows:**

$$(U, S, N, T)$$

Where U is universe (cell space or lattice) S is set of all possible states which a cell can attain, N is neighborhood of a cell, and T is a set of transition rules. We can represent a state of a cell at time t+1 as a function of its state at time t, its neighborhood and transition rule as follows:

$$S_{t+1} = f(S_t, N, T)$$

$$S_c = S_u + N$$

Where  $S_{t+1}$  is state of a cell at time (t+1),  $S_t$  is a state of a cell at time t, N is neighborhood and T is a set of transition rules followed by the cells. Where  $S_c$  is final score of a cell,  $S_u$  is suitability score and N is neighborhood influence. Suitability again can be divided into two parts. First is due to some inherent geo-physical properties like slope, aspect, etc and other are due to distance from some center such as distance from settlement, distance from road etc. Therefore,  $S_u$  becomes  $S_u = S_u$  (physical factors) +  $S_u$  (proximity factors). Based on this formulation the most selective change drivers (parameters) were selected and quantified for this research.

**4.2.2 Model parameter**

**4.2.2.1 Selection of Causalities (factors):**

It is not possible to incorporate the entire variable. Therefore, optimal variables were chosen with the help of expert knowledge and data availability. For expert knowledge different stake holders have been consulted. If more variables are taken the result can be better, but the methodology here will be the same.

For a good model it is very important to have accurate demand of the cell for a particular class. This can be achieved only if the relationship can be defined between the change in causalities and change in the land use types. Therefore, the first step was to generate demand for land for each class. Since every model is only an abstraction of reality, it has to go through some simplifications. In general, it can be defined as change in land use land cover as a function of various factors. Mathematically it can be defined as:

$$L = L_1 + L_2 + L_3 + \dots$$

Where: L is total change in land use type.  $L_1, L_2, L_3$ , etc are changes in different land use types. For example  $L_1$  may represent change in settlement area,  $L_2$  may represent change in agriculture area, and  $L_3$  may represent change in forest area, and so on. If only two kinds of land classes have been studied then only two components of the series can be taken. Theoretically it can happen that just shifting takes place i.e. one or more land use type can

shift the places without changing the magnitude (area). Each land use type change can be the function of different factors. For example

$$L_1 = F(x_1, x_2, x_3, \dots)$$

Where  $L_1$  is change in land use type (say) settlement.  $x_1, x_2, x_3$ , etc. are factors (like population growth, proximity to main road, climatic factor, land use type, etc.) responsible for change.  $F$  is a function of various factors  $x_1, x_2, x_3$ , etc. these factors can influence the other land use type change also. For example; population growth can force settlement area to increase, and it can also increase the demand for agricultural land because of the need to get enough crop production to feed the over all populations.

Also, these factors can influence each other for example due to population growth, state policy may change etc. Not only this, the factors itself may be representing the processes; for an example population growth which can have their own drivers. Due to these reasons land use land cover change becomes more complex and challenging phenomenon.

The next step is to transform these factors functions i.e.  $f(x_1), f(x_2)$ , etc into land requirement. This can be called as quantifying of causalities, example population growth. These can be very much location and time based. Population growth at one place can be entirely different from the population growth at the other place or this growth can be different at different times even for same region. Therefore for the simplification it was felt that for a particular region the processes could be seen at regional scale.

#### **4.2.2.2 Quantifying causalities and factors (change drivers)**

Based on the above formulation the aforementioned classes were considered but the two most important land use land cover change factors agriculture and settlement are competitor classes for the given cells. Therefore, both land use types were evaluated based on the following causalities.

##### **A. Constraint**

There are many factors responsible for land use land cover change like factors which explained above. In spite of this, there are some constraints for land use land cover change. The most obvious constraints are settlement, water bodies and protected areas like forestry. Constraints are the Boolean criteria that limit land use land cover change (for example; it

limits the expansion of agriculture and settlement). They are characterized by their “hard” rule of 0 and 1 and are criticized for not considering the degree of suitability of the transitions potential.

### **B. Factors**

Unlike the constraints, factors define some degree of suitability and provide alternatives in terms of a continuous measure of suitability. These criteria do not absolutely constrain land use land cover change, but enhance the relative suitability of an area for land use land cover change (Eastman, 2001). The criteria are often obtained or selected in collaborations with Gubalafto Woreda agriculturalist, administrators and environmentalist based on the ability of the factors to change land use land cover in the future. In order to develop the criteria for MCE and implement the CA\_Markov model, the factors affecting land use land cover changes were first identified. Each change drivers were classified in to five types based on their suitability; which means, Very highly suitable, highly suitable, moderately suitable, suitable and poorly suitable for future land use land cover change prediction. The factors considered are listed and described in (Table 4.1). Table 4.2 also indicates the suitability types of each land use land cover change drivers.

**Table 4.1 Description of change drivers (factors) and their types**

Factors	Type1	Type2	Type3	Type4	Type5
Slope	<15 <sup>0</sup>	15_55 <sup>0</sup>	55_65 <sup>0</sup>	65-85 <sup>0</sup>	>85 <sup>0</sup>
Altitude	<1500m	1500-2000m	2000-2500m	2500-3000m	>3000m
Rainfall	<500 mm	500-1000 mm	1000-1200 mm	1200-1400mm	>1400mm
Population Density	<75	76-130	131-200	201-300	>300
Land use	Bare land and bush	Agriculture	Forest	Water body	Settlement
Road	<1km	1-2km	2-2.5km	2.5-5km	>5km

**Table 4.2 Level of suitability for each factor types**

Factors	very highly suitable	Highly suitable	Moderately suitable	Suitable	Poorly suitable
Slope	Type1	Type2	Type3	Type4	Type5
Altitude	Type3	Type4	Type2	Type1	Type5
Rainfall	Type5	Type4	Type3	Type2	Type1
Population Density	Type5	Type4	Type3	Type2	Type1
Land use	Type1	Type2	Type3	Type4	Type5
Road	Type1	Type2	Type3	Type4	Type5

This land use land cover prediction were made by assuming that slope and altitude were not changed through out the prediction period, where as rain fall were assumed to be similar to that of the past 32 years annual average rainfall, population growth were taken by using the 1994 population census medium level growth rate and land use land cover were taken as it is. Finally the road factor was taken as it is, because this study considers only the main road, but there may be additional road expansion within the study area.

#### **Land use factor**

This determines the location and spatial extent of the amount of settlement, agricultural land and other land use types that are available for development. This is based on the land use maps obtained from the images of 1973, 1986 and 2005.

#### **Distance from main road networks**

The major road axis obtained from the Ethio\_GIS data was used and its effects are determined by the distance function. The influence of road network is measured in terms of accessibility and areas close to road access have greater probability to be changed into settlement and agriculture. This is because most Ethiopian settlements and agriculture were situated along the main road to get easy access, to reduce transport cost and to make them selves nearer to other infrastructure and towns. Figure 4.1 indicates the classes of road buffer in kilometer (distance from the existing road in all direction).

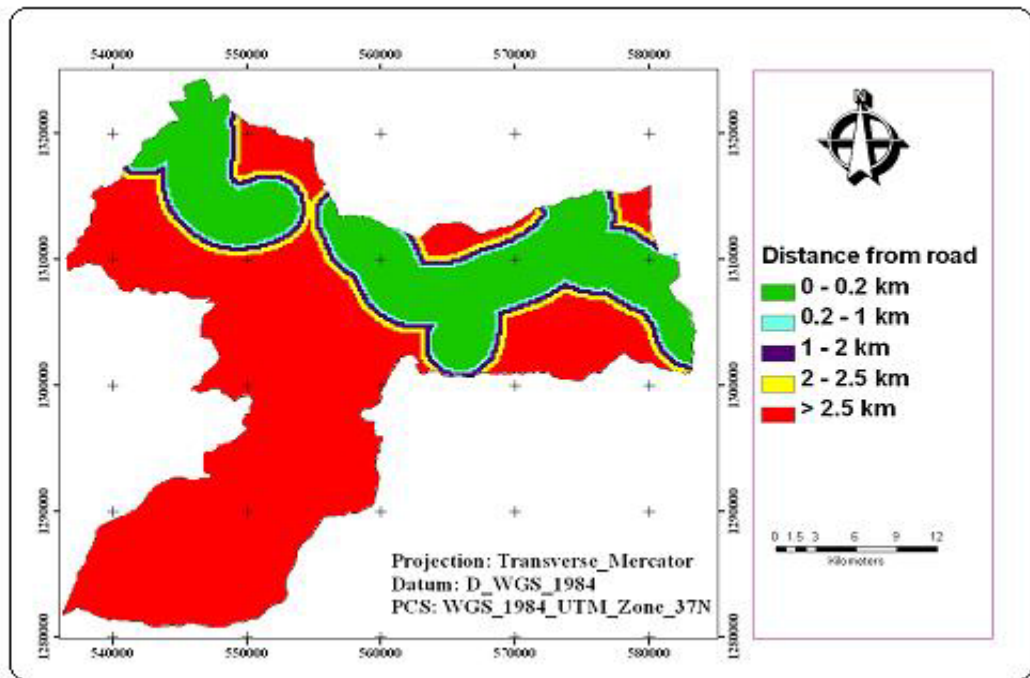


Figure 4.1 Proximity to main road

 **Slope:**

Most often land use land cover change undergoes in a relatively flat areas than hilly areas. Slope is represented in terms of percent or degree, in this research case it is represented in degree (0 represents flat land while cells with a value of  $>85^{\circ}$  represent steep sided). The slope factor was extracted from DEM and obtained by “surface” module in ArcGIS. Figure 4.2 indicates the slope factor classes.

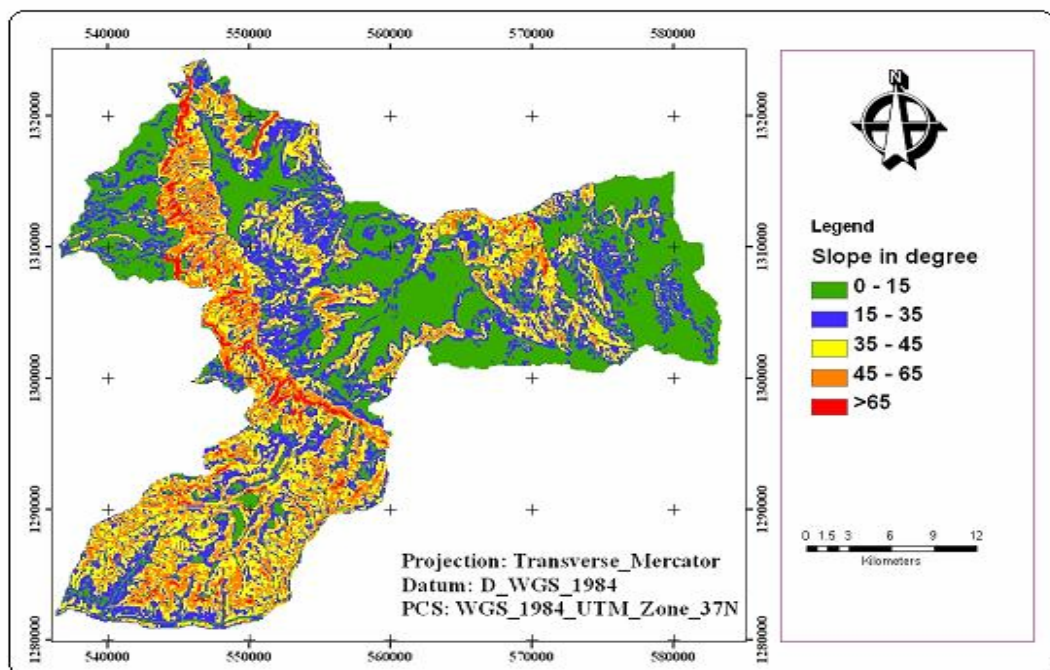
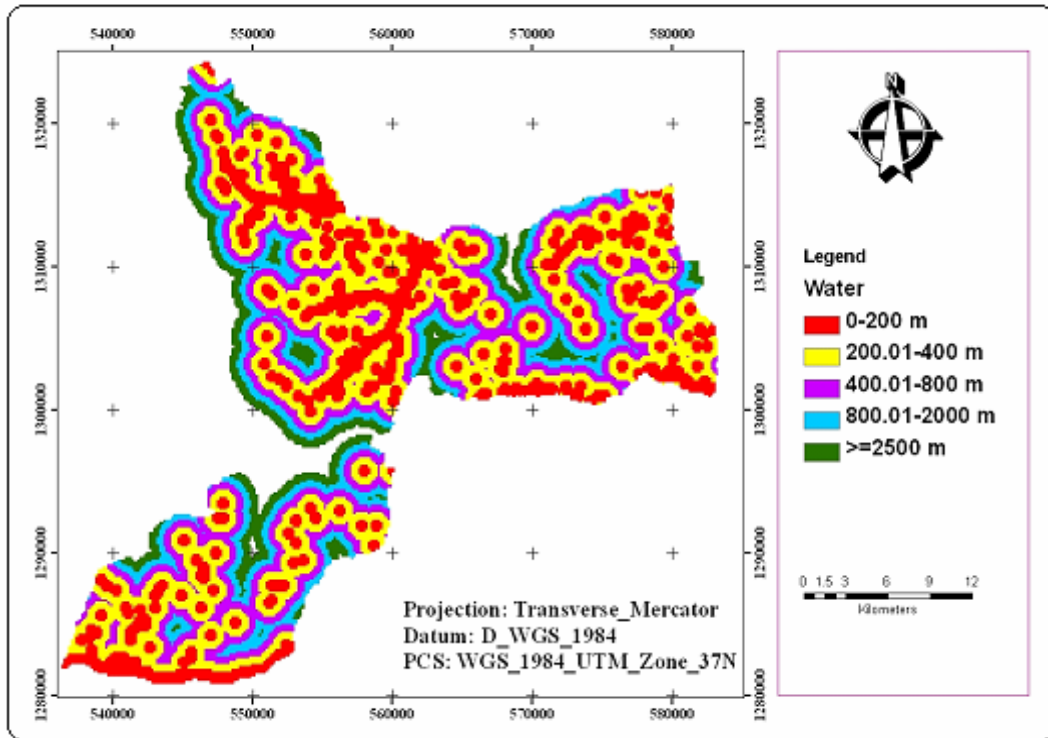


Figure 4.2 Slope class Map

### **Distance from water bodies**

This describes the more the cells close to the preserved areas or water bodies; the less is the probability of change into different land use types. This was also calculated by the distance function in ArcGIS and standardized by Idrisi software's. The proximity of water bodies classes were indicated in Figure 4.3. Even though water bodies were classified in to five classes it was taken as constraints, which means the area covered with water body may not be changed to other land use land cover types.



**Figure 4.3 Proximity to water bodies**

### **Distance from existing settlement areas:**

This also shows that settlement takes places adjacent to developed or vacant areas (i.e. cells close to the developed surface have high probability of being changed to settlement). Distance function had been applied to derive this factor. That means the free space closer to the settlement have higher probability to change than the farther. Figure 4.4 indicates the classes of proximity to settlement in meter.

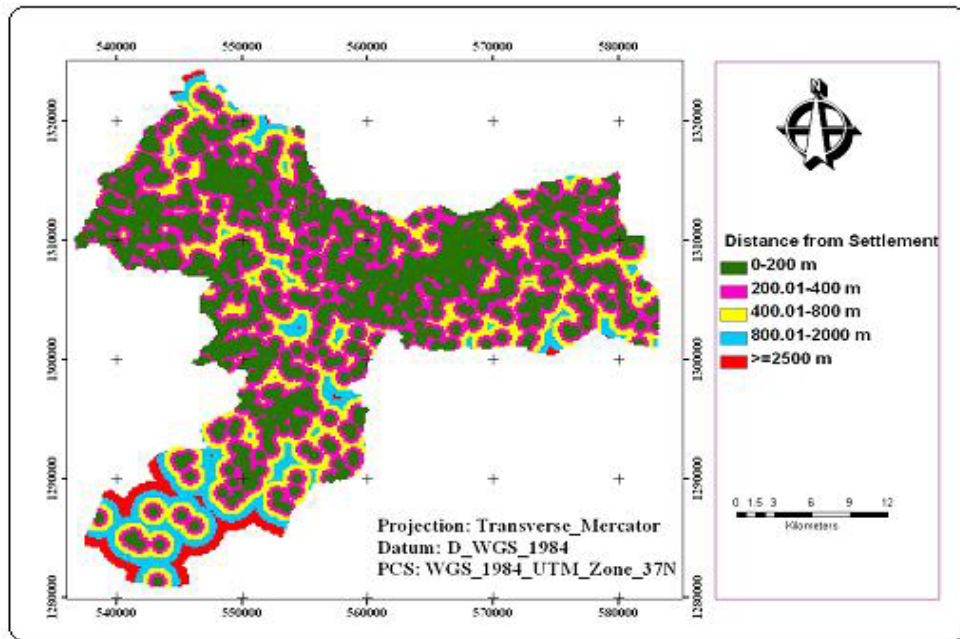


Figure 4.4 Proximity to settlement areas

**Rainfall:**

This determines the optimum amount of total rain fall received from the nearest meteorological stations. In this study five closer meteorological stations are used to obtain the nearest amount of rain fall for the given localities. This shows that areas which have better rain fall amount were more suitable for land use land cover change (example agriculture) than the rest and it is calculated using raster interpolation in ArcGIS software. Figure 4.5 rainfall classes in mm per year.

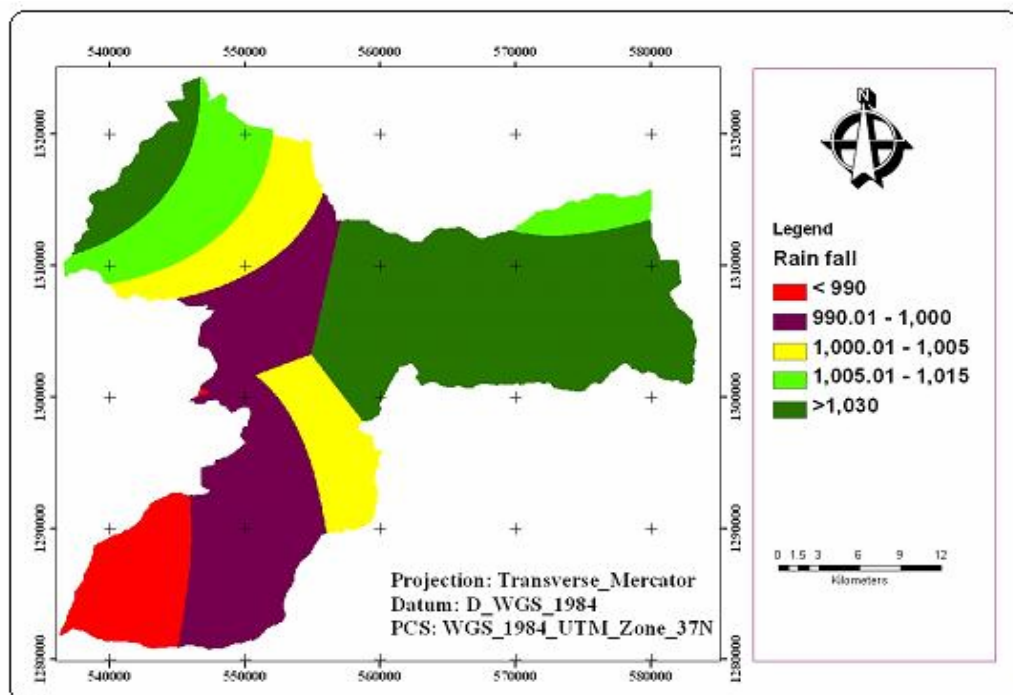
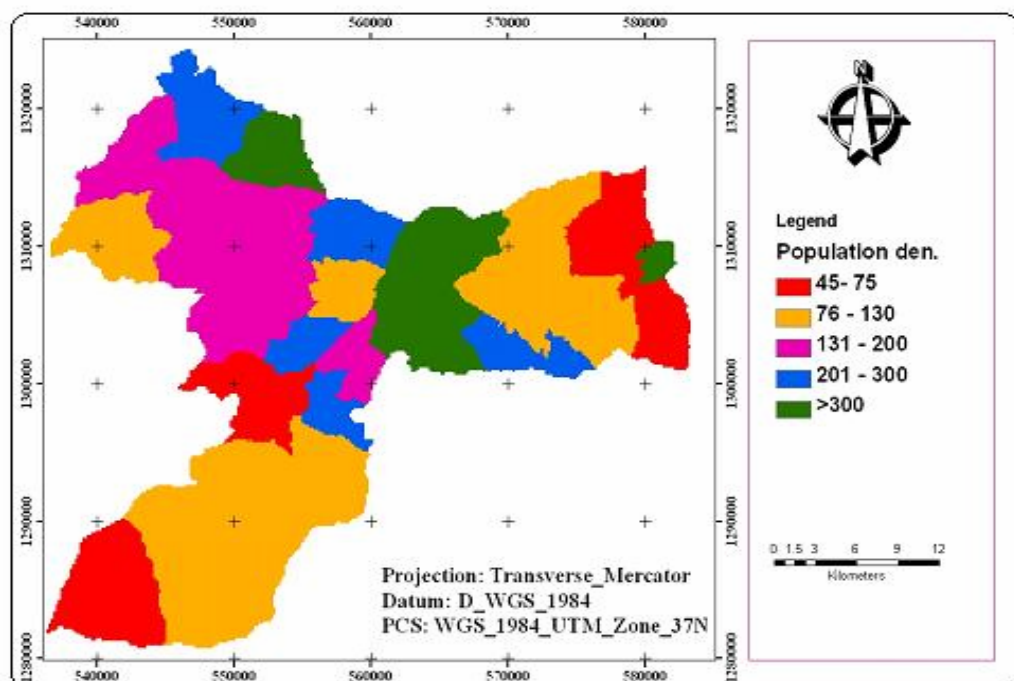


Figure 4.5 Map of rain fall

### **Population Density (population growth)**

Population growth was also the main factor for land use land cover change; it is because of the demand for land for agriculture and settlement. The higher the number of the population the higher the pressure on the given area for land use land covers change. This is calculated based on the population density of year 2005 of the study area locality or Kebele and the future population is calculated based on 1994 Ethiopian national population and housing census medium level growth rate i.e. 3.16 per year. Figure 4.6 shows the classes of population density. Population density calculated as number of population divided by area in kilometer square.



**Figure 4.6 Map of population density**

### **Altitude**

For land use land cover change in the future time, altitude was one of the factors that play an important role. It is calculated from DEM and the two extreme values of altitude had less impact on the land use land cover change as compared to the medium level altitude. The map of altitude was shown in chapter three (Figure3.5)

## **4.2.3 Land use land cover modeling calibration**

The first step in CA\_Markov analysis is to develop a transition probability matrix using the Markov module in Idrisi. The transition probability matrix (Table 4.3) for each land cover classes was developed between 1973 and 1986 and hence used as input for projecting land use

change. A transition probability matrix records the probability that each land cover category will change to every other Category. The off-diagonal elements indicate the number of cells that are expected to change from each existing land use class in 1973 to each new class in 1986.

**Table 4.3 1973\_1986 transition probability matrix**

<b>Land categories</b>	<b>Class1</b>	<b>class 2</b>	<b>class3</b>	<b>class4</b>	<b>Class5</b>	<b>Class6</b>
<b>Class1</b>	<b>1979</b>	<b>43</b>	<b>10</b>	<b>49</b>	<b>225</b>	<b>173</b>
<b>Class2</b>	<b>17</b>	<b>10954</b>	<b>42</b>	<b>1382</b>	<b>963</b>	<b>920</b>
<b>Class3</b>	<b>11</b>	<b>36</b>	<b>3536</b>	<b>711</b>	<b>87</b>	<b>205</b>
<b>Class4</b>	<b>59</b>	<b>3119</b>	<b>711</b>	<b>90736</b>	<b>4664</b>	<b>10823</b>
<b>Class5</b>	<b>338</b>	<b>2010</b>	<b>87</b>	<b>4604</b>	<b>83632</b>	<b>11534</b>
<b>Class6</b>	<b>227</b>	<b>1593</b>	<b>4664</b>	<b>9256</b>	<b>9472</b>	<b>90539</b>

Based on Table 4.3, 1973\_1986 transition area matrix and the given suitability land cover map for the year 2005 was generated for validating the model output. Using the outputs from the Markov Chain Analysis, specifically the Transitions Area matrix, CA\_Markov applies a contiguity filter and suitability drivers to examine the land use change.

#### **4.2.3.1 MCE standardization of factors**

In order to overcome the “hard” rule of Boolean approach, a “soft” or “fuzzy” approach has been applied. In this case, all the criteria were standardized to a continuous scale of suitability from 0 (the least suitable) to 255 (the most suitable). The constraints, however, retained their “hard” Boolean character because these are considered completely unsuitable for further development. The fuzzy membership function in Idrisi is provided for the standardization of factors using a whole range of fuzzy set membership functions. The higher the value of the standardized scale, the higher is the suitability of the land. The fuzzy module embedded in Idrisi Andes, which provides the function of standardization of continuous variable, is applied. Three fuzzy scaling approaches: Sigmoid, J-shaped and linear functions are also employed in setting the critical points for the set of membership function. The selection of the parameters for standardization (membership function type and shape as well as control points) is subjective and depends on analyst knowledge and experiences. In this step all the criteria

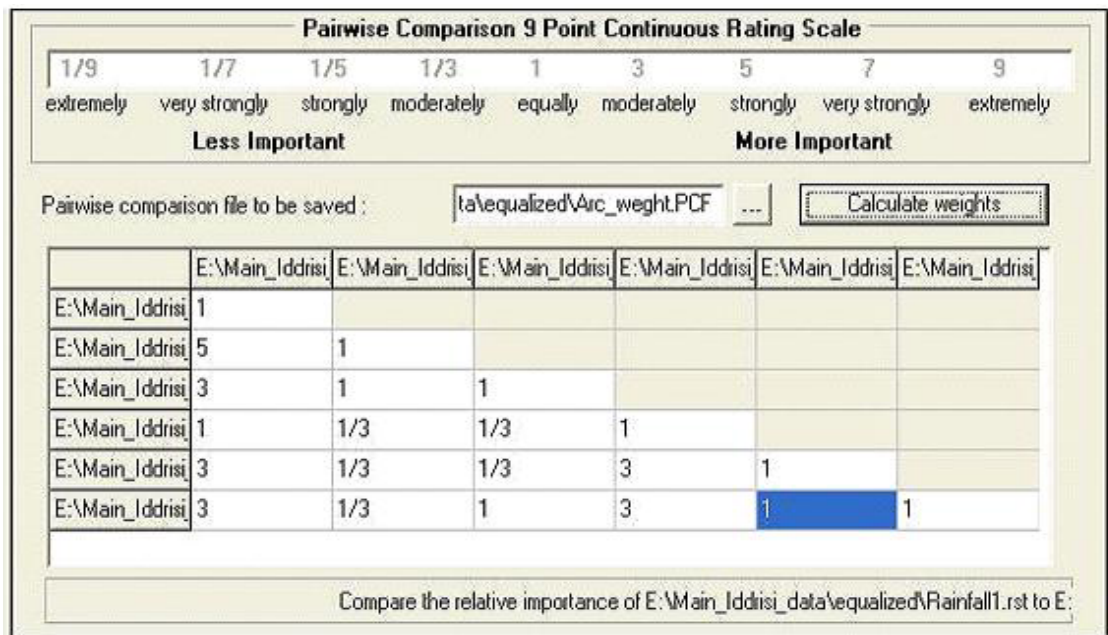
maps were developed and prepared for suitability mapping after weighting each factors. Table 4.4 indicates the standardization of each variables or factors.

**Table 4.4 Fuzzy Module standardization of variables**

Factors	Membership function types/shape	Control point	Descriptions or observations
Distance from the major road	J-shaped decreasing	0.2/5km	The nearest distance to the road has more suitable than the further one.
Distance from water body	Linear increment	200/2500m	The nearest is less suitable than the further one. But it takes as a constraint.
Distance from forest area	Linear increment	200/2500m	The nearest is less suitable than the further one.
Slope	Sigmoidal decreasing	0/15 <sup>0</sup>	Slope greater than 0 is suitable but not more than 15 <sup>0</sup> . If it is greater than 15 <sup>0</sup> it is not suitable.
Altitude	Sigmoidal decreasing	900/2500m	Altitude greater than 900 is suitable but not more than 2500. If it is greater than 2500m it is not suitable.
Rainfall	Linear increasing	750/1200mm	Rain fall value less than 750mm is less suitable than 1200mm per annum. That means the two extremes are not suitable.
Population Density	Linear increasing	46/600	With the increasing growth of population the effects increases with the increments of population.
Land use	Linear decreasing		Based on the type of land use categories it varies but Bush, bare and agricultural lands are the highest suitable area for land use change.

#### 4.2.3.2 Weighting factors

The next step was to establish a set of weights for each of the factors studied and the analyst has to fill out the pair wise comparison matrix using the Weight module in Idrisi. The pair wise comparison was developed by (Saaty, 1977 cited in Eastman, 2001) in the context of a decision making process known as the Analytical Hierarchy Process (AHP). This module uses a pair-by-pair technique to compare the relative importance of one factor (e.g. road) against another factor (e.g. slope). The rating ranges from “extremely less important” (1/9) to “extremely more important” (9). The rating is subjective and entirely depends on the analyst. In this study the researcher compares every pair and assigns the rating into the matrix as shown in Figure 4.7.



**Figure 4.7 Pair wise comparison of factors**

The weights derived from the pair wise comparison matrix and assigned to each of the suitability variables discussed above are summarized in Table 4.5.

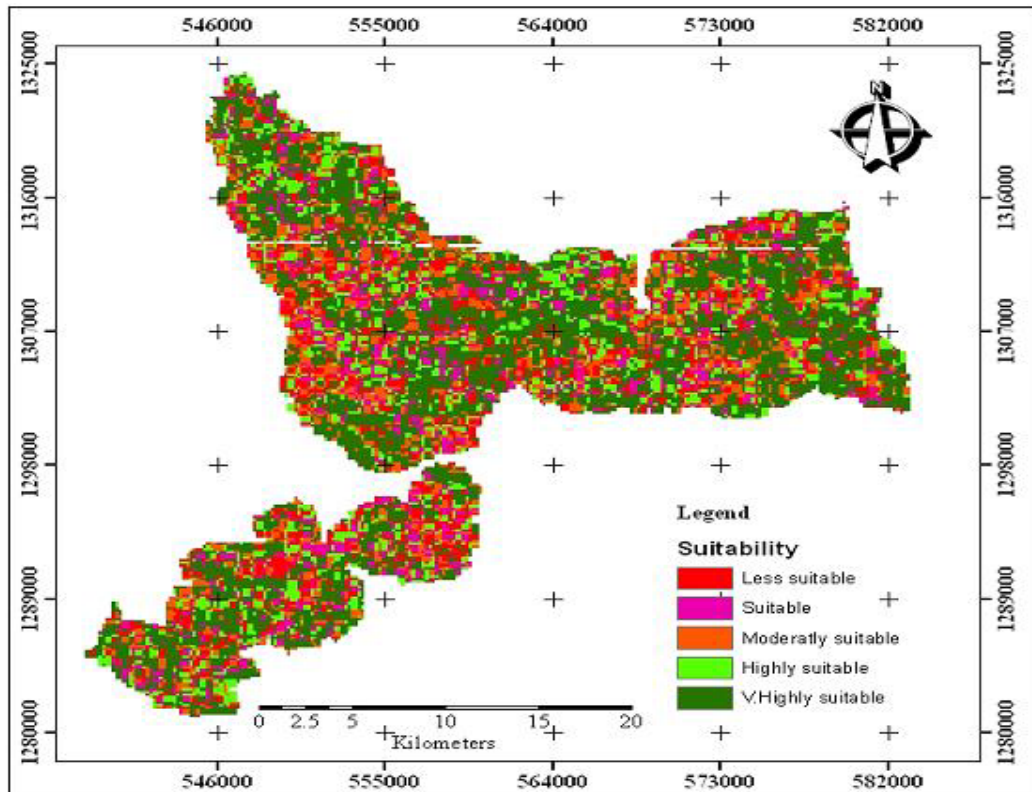
**Table 4.5 Weights assigned to the variables**

<b>Driving force type(Parameters)</b>	<b>Weight</b>
Altitude	0.0602
Slope	0.0670
Land use	0.2462
Distance form road	0.1407
Rain fall	0.1670
Population density	0.3190

Consistency ratio = 0.04  
 Consistency is acceptable.

Once the pair wise comparison was filled, a consistency ratio (CR) was calculated to identify inconsistencies and develop the best fit weights in the complete pair wise comparison matrix. CR is the procedure by which an index of consistency can be produced. It is argued that, a consistency ratio greater than 0.1 should be re-evaluated (Saaty, 1977 cited in Eastman, 2001). In this case, the CR was calculated to be 0.04. Once the criteria maps and weights have been developed and established, respectively, the module MCE in the form of a weighted linear combination (WLC) was applied to combine the standardized factors and constrains. With a WLC, each standardized factor image is multiplied by its weight, then the results are summed and then multiplied by the product of the constraints (i.e. Boolean constrain maps

were applied to limit areas under consideration in the final analysis). The result of the suitability map derived using the MCE is presented in Figure 4.8. This suitability map is a map that indicates the susceptible area for land use land cover change.



**Figure 4.8 Suitability Map**

## 4.2.4 Model implementation and validation

### 4.2.4.1 Model implementation

The Cellular automata Markov analysis is accomplished using the CA\_Markov module in Idrisi Andes. The module uses the following elements to determine the location of changes:

- ✚ Base land cover image (land use map of 1986):

In this study the base land cover image for predicting the 2005 land use map is the 1986 land use map. But for predicting the 2020 prediction land use map the 2005 actual image is used as the base land cover image.

- ✚ The transition areas matrix:

The transition area matrix is used to predict the future land cover change probabilities and therefore the transition area matrix of 1973\_1986 was used to predict the 2005 prediction land

use categories. On the other hand the 1986\_2005 transition area matrix was used for predicting the 2020 land use land cover.

 Transition suitability collections:

This is a raster group file created using the six suitability maps using the collection editor module. The module is used to create the collection or define members of a raster group file collection. This suitability map is used as a transition rule in cellular automata model and it is developed from each standardized parameters.

 A contiguity filter:

The rule state a pixel that is near one land use category (e.g. Agriculture) is more likely to become an agriculture pixel than pixel that is farther. The definition of nearby is determined by a spatial filter that the user specifies. In this study, the default contiguity filter in Idrisi “5\*5” was applied. The 5\*5 contiguity filter considers the predicted land use change to be within two pixels of the edge including the diagonal. Based on these inputs, the module determines the location of change, the number of pixels that must undergo each transition and selects the pixels according to the largest suitability for a particular transition. The initial analysis used the 1973 and 1986 land cover maps to “predict” for the year 2005. Water bodies and marsh areas, settlement and protected areas were considered as a constraint. These were created from the land use map of the year 1986 and 2005, which were used as a base for simulation. After fulfilling the above important inputs the CA\_Markov model were applied and then the following results were obtained (Figure 4.9 and Figure 4.10).

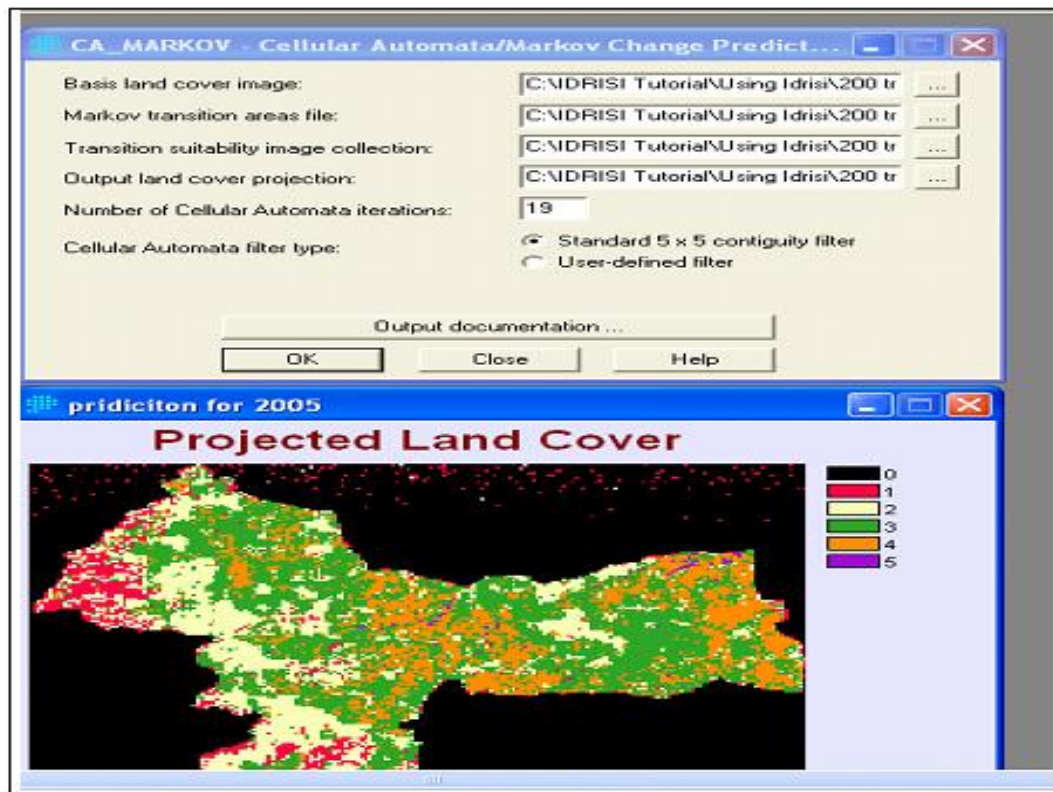


Figure 4.9 Processed CA\_Markov Change predictions Model

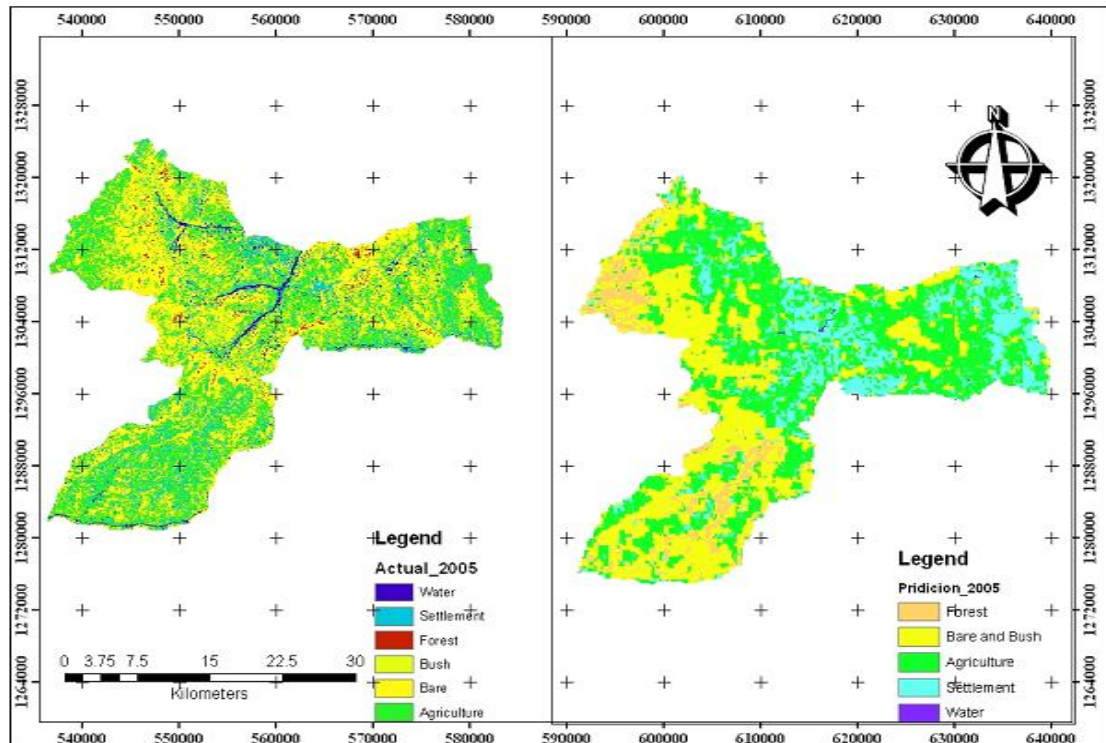


Figure 4.10. The actual and predicted land use land cover map of 2005

On the map of the simulated land use land cover types bare and bush land were mixed, this is because during classifying the change drivers for prediction purpose both are assigned at type one in the land use land cover factors. Therefore, bare and bush lands were produced as in one and hence the simulated and the actual land use land cover map of 2005 were not correspondence to each other.

#### **4.2.4.2 Model validation**

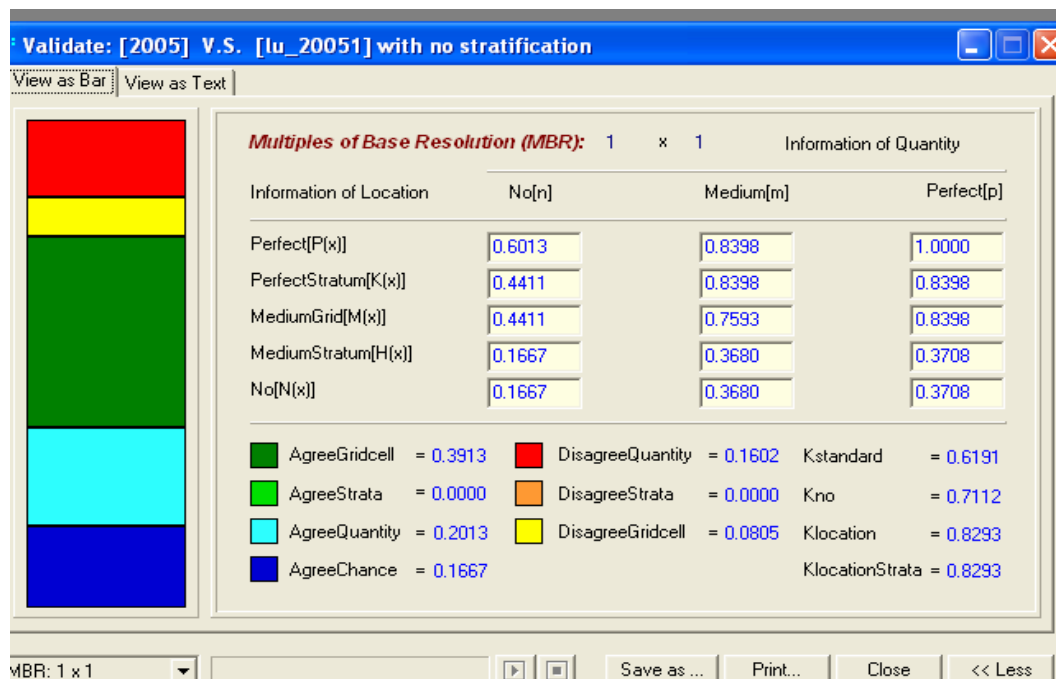
It should be noted that validating the projected land use is an important step in the modeling process because results of the simulation would give a misleading result. Validating land use land cover modeling is a difficult step, because there is no agreed criterion to assess the performance of different land use models (Pontius,2000).Therefore, it is not easy to come out with an accurate and precise evaluation of land use models. The only way to quantify the predictive power of the model is to compare the result of the prediction for (2005) to a reference map of (2005).

The land use land cover for the year 2005 were simulated to compare the result of the “prediction” with the actual land use land cover in that year’ so that further land use prediction can be carried out for the year 2020 after comparing and validating. Visual analysis of the results reveals that the simulated maps are not much close to the “actual” map for the year 2005. However, a more detailed analysis can be carried out based on the Kappa analysis which was found in Idrisi software. The Validate module in Idrisi is thus applied to calculate the Kappa index of agreement: Kno, Klocation and Kquantity in order to compare the 2005 “prediction” with the “actual” land use land cover of 2005 more effectively. The kappa index agreement: Kno, Klocation and Kquantity were methods of evaluating the prediction result, i.e.

**Kno:** The Kno indicates the proportion classified correctly relative to the expected proportion classified correctly by a simulation with no ability to specify accurately quantity or location (Pontius, 2000). It is therefore a variation of the standard Kappa index of agreement that gives the overall accuracy of a simulation. In this case, the resulted Kno is **0.7112**.

**Klocation:** The Klocation indicates the success due to the simulation’s ability to specify location divided by the maximum possible success due to a simulation’s ability to specify location perfectly (Pontius, 2000). It validates the simulations ability to predict location and the Klocation was **0.8293**.

**Kquantity:** It is the success due to the simulation's ability to specify quantity divided by the maximum possible success due to a simulation's ability to specify quantity perfectly (Pontius, 2000). It is a measure of validation of the simulations to predict quantity and the Kquantity was **0.6190**. After putting the two images in to the validate module the following result were under taken Figure 4.11 shows kappa index agreement of the predicted and actual land use land cover of 2005.



**Figure 4.11 Kappa index agreement of actual and predicted map of 2005**

Visual interpretation of the simulation and result of the validation (Kno, Klocation and Kquantity) produced a satisfactory level of accuracy. According to Pontius the Kno, Klocation and Kquantity were accurate if the result were greater than 0.80 for each kappa index agreement. In this research the validation results listed in Figure 4.11 was almost closer to the standard, but the minor difference appears due to two reasons. one of the reason is the use of low resolution image that reduce the accuracy during classification and model development and secondly the suitability map accuracy reduction this is because the number of parameters used in this research were only six parameters but if more number of parameters were participated the suitability map accuracy or validity may increase. Even if the results of the validation had a minor difference from the standards it is possible to predict the future land use land cover change by indicating the limitation (Pontius, 2000). Therefore, the researcher tries to see the results of the future land use land cover change by extending the prediction for 15 years (from 2005 to 2020).

## 5. Result and Discussion

### 5.1 Land use land cover change

Based on the data analysis undertaken in section 4.1 the following results were obtained.

The land use land cover percentage and the area coverage of each land category for each study year were derived from the three satellite images. Image classification of (1973, 1986 and 2005) has resulted six land use land cover classes: Agriculture, settlement, Forest, Bare, Bush and water body. In Figure 5.1 and Table 5.1 of 1973 image result, 3.04% of the study area has covered with water body. About 34.25% and 16.31% of the study area were covered by bush and bare land, respectively.

**Table 5.1 Land use lands cover of 1976, 1986 and 2005**

Land use land cover categories	1973		1986		2005	
	Area (Km <sup>2</sup> .)	Area (%)	Area (Km <sup>2</sup> .)	Area (%)	Area (Km <sup>2</sup> .)	Area (%)
Agriculture	<b>317.79</b>	<b>36</b>	<b>283.54</b>	<b>32.3</b>	<b>346.02</b>	<b>39.4</b>
Settlement	<b>55.17</b>	<b>6.3</b>	<b>36.33</b>	<b>4</b>	<b>82.19</b>	<b>9.4</b>
Bare land	<b>143.19</b>	<b>16.3</b>	<b>259.02</b>	<b>29.5</b>	<b>257.24</b>	<b>29.3</b>
Bush land	<b>300.63</b>	<b>34.3</b>	<b>281.15</b>	<b>32</b>	<b>161.6</b>	<b>18.4</b>
Water body	<b>26.67</b>	<b>3</b>	<b>6.23</b>	<b>0.7</b>	<b>22.29</b>	<b>2.5</b>
Forest	<b>34.4</b>	<b>4</b>	<b>11.58</b>	<b>1.3</b>	<b>8.51</b>	<b>1</b>
Total	<b>877.85</b>	<b>100.00</b>	<b>877.85</b>	<b>100.00</b>	<b>877.85</b>	<b>100.00</b>

Agriculture is mainly practiced through out the study area and it covers 36.20% in 1973. 6.3 % and 4 % of the study area were also covered with scattered settlement and Forest, respectively. Generally, in the 1970's as indicated in Table 5.1 the area was mostly covered with agriculture and bush lands where as forest land and water bodies covered the smallest area.

As discussed in the literature review section after 1970's especially 1973/1974 and 1984/85 due to the occurrence of drought and famine the coverage of agriculture, bush, forest, settlement and water bodies were decreased. Therefore in 1986 Agricultural land had reduced

to 32.30% from 36.2% of the 1973 (Table 5.1). Bush and settlement area were reduced to 32 % and 4 % in 1986 from 34 % and 6.3 % of the 1973 respectively. The water body has covered 0.7 % and forest has covered with 1.3 % and in 1986 but bare land had increased from 16 % in 1973 to 30 % in 1986.

In 1986 bare land cover's the largest portion of area, it is because most of the other land use land cover classes were reduced and changed to bare land due to problem of drought and famine during 1984/85 periods. Therefore the productive lands become infertile (bare) and the people become exposed to hunger and hence the government takes the 1984/85 resettlement program in the study area. Figure 5.1 shows the 1986 land use land cover classes of the study area.

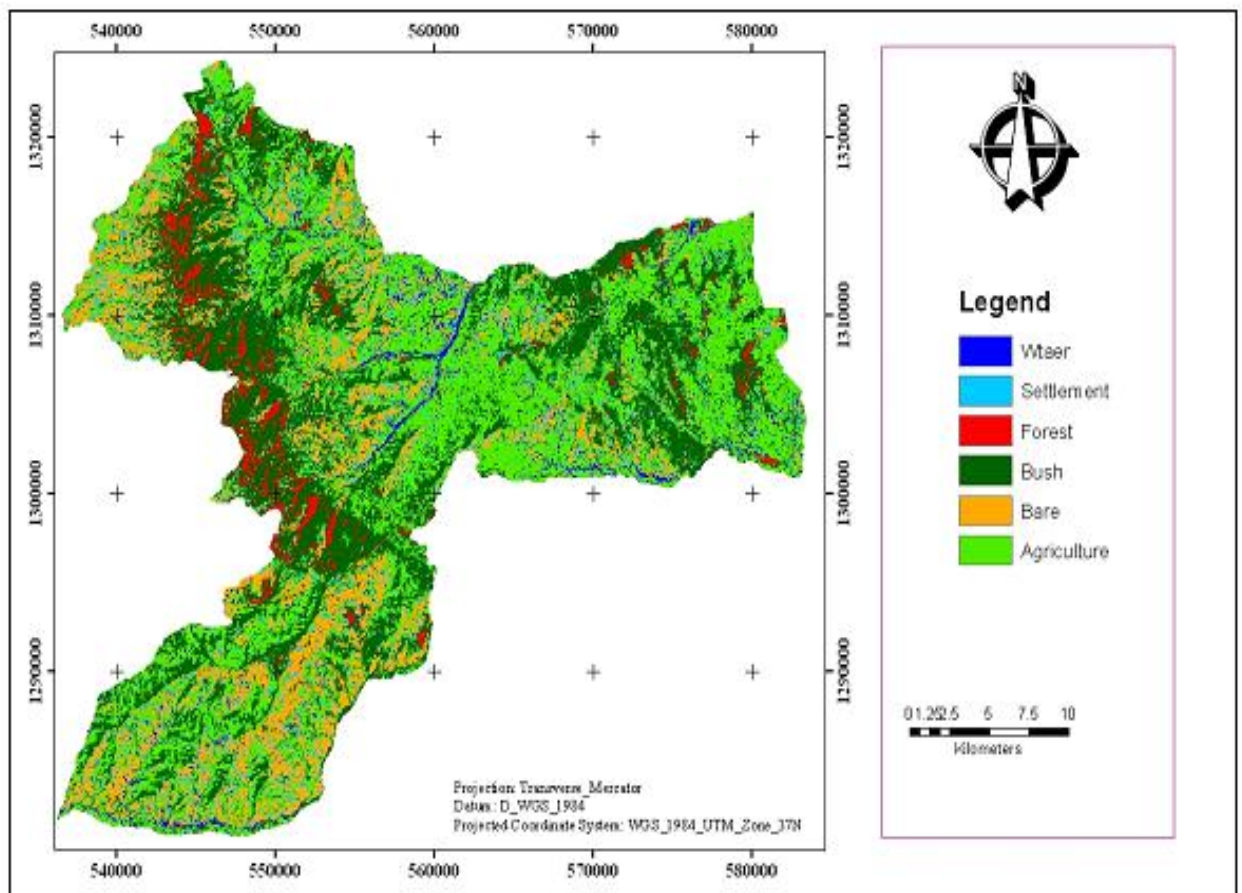
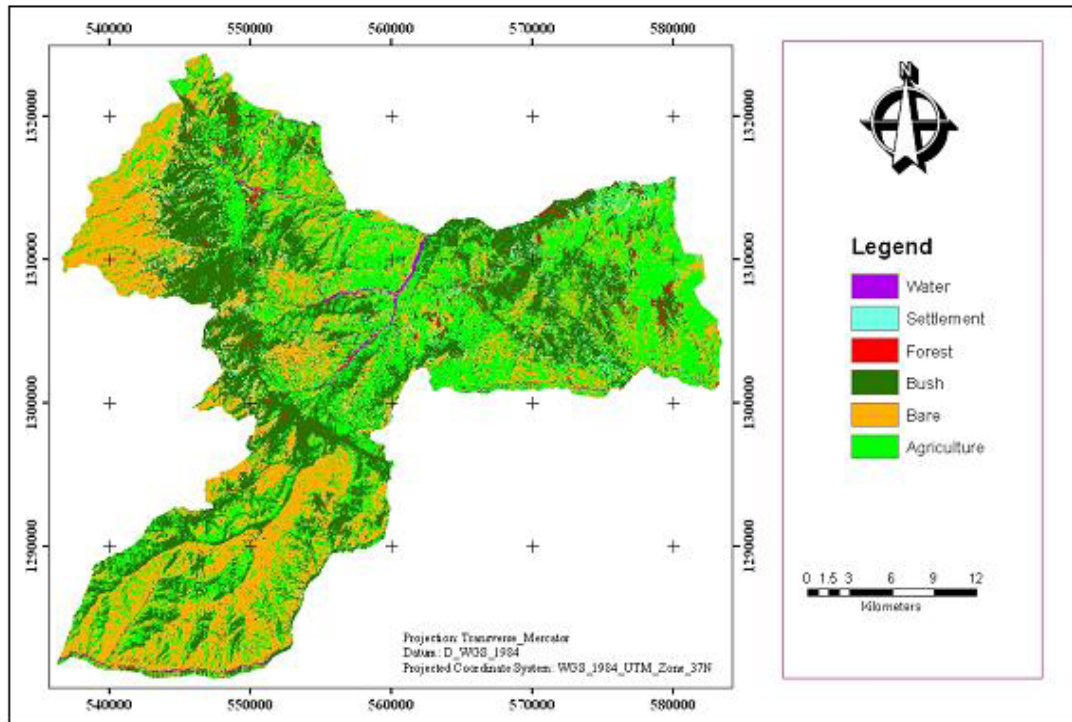
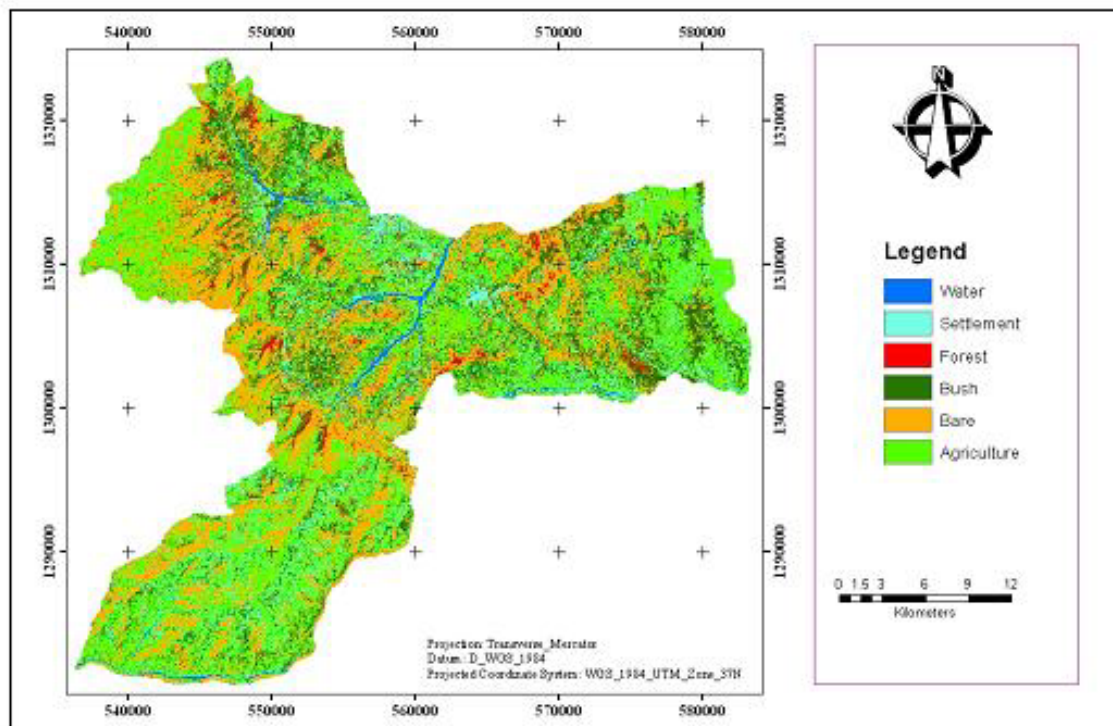


Figure 5.1 Land use map of 1973



**Figure 5.2 Land use map of 1986**

The result of landsat 2005 image could clearly be indicated that the water body, the forest resources and the bush land has tremendously been degraded (Figure 5.3 and Table 5.1). The forest and bush land found in the study area were reached to 1% and 18.4 %, whereas agriculture, scattered settlement has increased up to 39.4 % and 9.4 % respectively.



**Figure 5.3 Land use map of 2005**

The water body has increased to 2.5 %, this is because the drought period during 2005 becomes reduced and the water body replenish well. On the other hand the area of the bare land is almost equal to that of the 1986, which means 29.30%.

## 5.2 Trend and Rate of land use land cover change

Table 5.2 shows the trend and rate the selected resettlers origin land use land cover change from 1973 up to 2005 before and after relocating the area.

**Table 5.2 Trend and Rate of Land use land cover change**

Land categories	1986-1973		2005-1986		Annual rate of change	
	Km <sup>2</sup>	%	Km <sup>2</sup>	%	1986-1973	2005-1986
<b>Agriculture</b>	-34.25	-4	62.48	7	-2.63	3.29
<b>Settlement</b>	-18.84	-2	45.86	5.2	-1.45	2.41
<b>Bare land</b>	115.83	13.2	-1.78	-0.2	8.91	-0.09
<b>Bush</b>	-19.48	-2.2	-119.55	-13.6	-1.50	-6.29
<b>Water</b>	-20.44	-2.3	16.06	1.8	-1.57	0.85
<b>Forest</b>	-22.82	-2.6	-3.07	-0.4	-1.76	-0.16

In Table 5.2, there was a negative change in agriculture by 4 % which means a reduction in farm land between 1973 and 1986 by 4 %. This is because of the agricultural land of settlers became changed to bare and bush except the most fertile and the closer agricultural land to the settlement area. Subsequently, settlement also decreased by 2.15% because of the resettlement program in 1983/84 the settler's leave from their localities (settlements). Therefore the settlement areas become changed to other land use classes like agriculture and bare land. While bare land tremendously increased by 13.2 % because all the other factors; bush, agriculture, forest and water bodies reduced and changed to bare land due to the occurrence of the repeated drought and therefore coverage of the bare land becomes increase. Due to the expansion of bare land the production of the area becomes reduced and it leads to the

starvation of the people and this finally looks a new option to sustain the problem, which is known as resettlement.

Furthermore, water body, bush land and forest were decreased by 2.3%, 2.2% and 2.6% respectively, though there are great differences in the total land use land cover between these periods in all types of land categories.

On the other hand in 1986 and 2005 there was an increment in agriculture, settlement, and water bodies by 7 %, 5.2 %, and 1.8 % respectively. The reason for this increment in Agriculture and settlement were that the people of the area coming back from the resettlement area and occupy new settlements and agricultural area. In addition in 1996 due to the higher demand for agriculture and settlement from the public especially from the youngster the government under take land redistribution. A large number of youngsters and women have got agricultural land and settlement areas with a distribution rule of highly fertile, moderately fertile and less fertile lands (Gubalafto Woreda agricultural office). In this case the less fertile lands are lands that were not previously occupied and used for agriculture. And hence it was a new land that was added to agriculture and settlement comes from free lands like bare and bush lands. On the other hand bush land and bare land decreases by 13.6 % and 0.2 % respectively, this is because of the above mentioned reason.

The annual rate of change in most land use land cover categories reduced by more than one kilometer square per year between the year 1973 and 1986 except bare land which increased by 8.91km<sup>2</sup> per year (Figure 5.4). In the year between 1986 and 2005 the annual rate of change in agriculture and settlement increased by more than 2km<sup>2</sup> per year but the remaining land use types decreased by less than one kilometer square except bush land which decreased by 6.29 km<sup>2</sup> per year.

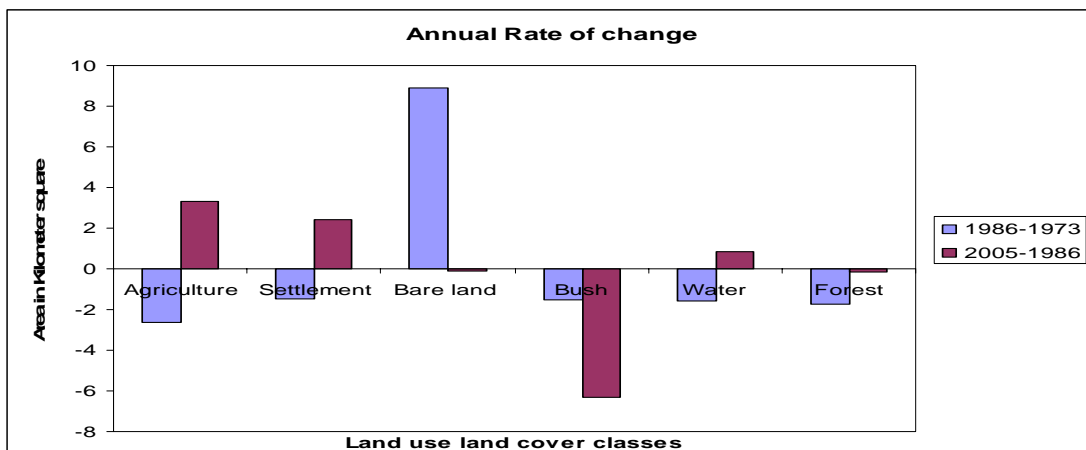


Figure 5.4 Land use land cover change rate from the year 1973 to 2005

Generally the trend and rate of land use land cover between the 1973 to 1986 shows that a reduction in agriculture, bush, settlement, forest and water bodies, whereas bare lands highly increased from 1973 to 1986 due to this reason the settlers were relocated from their area to the south west Ethiopia. Land use land cover trend and rate between 1986 to 2005; agriculture, settlement and water bodies had increased, whereas bush land, forest land and bare land had decreased as compared to the previous years because the drought and famine period during these time were reduced and the settlers return back to their areas and expand the utilization of bush, forest and bare land for settlement and agriculture and therefore the coverage of agriculture and settlement increases whereas the coverage of bush, bare and forest land decrease.

### 5.3 Land use land cover dynamics

An important aspect of change detection is to determine what is actually changing to what which means, which land use class is changing to the other. This information will tell both the desirable and undesirable changes and classes that are “relatively” stable overtime. This information will also serve as a vital tool in management decisions. Table 5.3 and 5.4 expresses about the nature and location of change in the study area land use land cover categories form 1973 to 2005.

**Table 5.3 Land use land cover dynamics from 1973 to 1986**

		Form 1973 “Initial state”							Row Total	Class Total
		Agriculture	Bare	Forest	Bush	Water	Settlement			
To 1986 “Final state”	Land use category									
	Agriculture	166.65	23.81	2.55	63.76	10.77	15.19	282.73	283.87	
	Bare	75.74	97.61	4.61	42.45	10.23	28.79	259.44	260.18	
	Forest	2.97	2.97	1.81	5.32	0.19	0.44	11.36	11.38	
	Bush	60.02	14.82	21.88	174.28	1.79	8.15	280.94	281.91	
	Water	2.58	0.28	0.02	0.4	2.72	0.19	6.19	6.19	
	Settlement	9.83	6.05	2.66	14.42	0.97	2.41	36.35	36.42	
	Class Total	320	143.98	33.81	302.54	26.87	55.46	0	0	
	Class Changes	153.35	46.37	31.99	128.27	24.14	53.05	0	0	
Image Difference	-36.13	116.2	-22.43	-20.63	20.67	-19.04	0	0		

In Table 5.3 shows the land use land cover dynamics between 1973 and 1986. In Table 5.3 the highlighted diagonal indicates the stable land classes’ which were not changed to

other classes between 1973 and 1986 this is true for 1986 and 2005 land use land cover dynamics. But the off diagonal areas of each class indicate the changes of one class to the other by losing or gaining from the initial state. The column total of the table indicates the total area of that particular land use land cover class of the initial state (1973); whereas the row total indicates the area of that particular land use land cover class of the final state (1986).

Thus, by giving a greater emphasis for agriculture and settlement between 1973 and 1986, agriculture has a loss of 153.35 km<sup>2</sup> from 1973 and it is changed to 75.74 km<sup>2</sup> bare, 60.02 km<sup>2</sup> bush and 9.83 km<sup>2</sup> settlement in 1986. On the other hand agriculture gain 117.22 km<sup>2</sup> in 1986 from the land use land cover classes of 1973; 63.76 km<sup>2</sup> from bush, 23.81 km<sup>2</sup> from bare land, 15.19 km<sup>2</sup> from settlement and 10.77 km<sup>2</sup> water. 166.65 km<sup>2</sup> of the area of agriculture remains stable, which means it doesn't change to other land use land cover types. Settlement losses 53.03 km<sup>2</sup> from 1973 and changed to 28.79 km<sup>2</sup> bare, 15.19 km<sup>2</sup> agriculture and 8.15 km<sup>2</sup> bush. It also gain 31.04 km<sup>2</sup> in 1986 from 1973 land use land cover classes: 14.42 km<sup>2</sup> Bush, 9.83 km<sup>2</sup> agriculture and 6.05 km<sup>2</sup> bare land and the rest from forest and water body.

The reason for losing, gaining or changing of agriculture and settlement to other land use land covers were the occurrences of repeated drought (low rain fall amount) and population growth made bare land and bush lands to be highly utilized for agricultural purposes but also left the highly degraded agricultural lands as fallow because of less productivity especially the highlands of the study area. In addition these two years indicate the happenings of the land use land cover change or dynamics before and during resettlement and hence before resettlement there were a wide coverage of agriculture and settlement in 1973 but during resettlement the coverage of agriculture and settlement were reduced and changed to other land use land cover classes. Therefore the resettlement program reduces the pressure of population and due to this reason large number of settlement and agriculture become changed largely to bush and bare land.

**Table 5.4 Land use land cover dynamics from 1986 to 2005**

	Form 1986 “Initial state”								
	Land use land cover class	Agriculture	Bare	Forest	Bush	Water	Settlement	Row Total	Class Total
To 2005 “Final state”	Agriculture	137.38	141.37	2.5	52.19	1.46	11.12	346.02	346.63
	Bare	51.56	40.4	2.36	150.85	0.08	11.99	257.24	257.93
	Forest	0.22	0.06	0.74	7.37	0	0.12	8.52	8.52
	Bush	51.22	43.43	4.77	51.99	0.23	9.96	161.6	161.78
	Water	7.24	3.34	0.36	7.19	3.39	0.77	22.3	22.33
	Settlement	35.92	30.42	0.85	11.56	1.07	2.37	82.19	82.32
	Class Total	284.22	259.69	11.61	281.75	6.23	36.44	0	0
	Class Changes	146.85	219.28	10.87	229.76	2.84	34.07	0	0
	Image Difference	62.41	-1.76	-3.09	-119.97	16.1	45.88	0	0

Table 5.4 shows the land use land cover dynamics from 1986 to 2005. Based on this, the land use land cover dynamics of each class were discussed. Agriculture losses 147.85 km<sup>2</sup> from 1986 and changed to : 51.56 km<sup>2</sup> bare land, 51.22 km<sup>2</sup> bush land, 35.92 km<sup>2</sup> settlement, 7.24 km<sup>2</sup> forest and 0.22 km<sup>2</sup> water in 2005. On the other hand it gains 209.25 km<sup>2</sup> from 141.37 km<sup>2</sup> bare, 52.19 km<sup>2</sup> bush, 11.12 km<sup>2</sup> settlement, 2.5 km<sup>2</sup> forest and 1.46 km<sup>2</sup> water of 1986. Whereas settlement losses 45.88 km<sup>2</sup> from 1986 changed to 11.12 km<sup>2</sup> agriculture, 11.99 km<sup>2</sup>, bare land, 9.96 km<sup>2</sup> bush, 0.77 km<sup>2</sup> water bodies and 0.12 km<sup>2</sup> forests in 2005. It also gain 79.82 km<sup>2</sup> from 35.92 km<sup>2</sup> agriculture, 30.42 km<sup>2</sup> bare land, 11.56 km<sup>2</sup> bush, 1.07 km<sup>2</sup> water bodies and 0.85 km<sup>2</sup> forest of 1986. only 137.38 km<sup>2</sup> agriculture and 2.37 km<sup>2</sup> settlement were stable.

As discussed in the above paragraph the exchange of land use land cover classes during the 1986 to 2005 were occurred after the 1984/85 resettlement program. That means large number of population returned back and occupies large area of agricultural land and settlement. Therefore the coverage of agriculture and settlement were increased, on the other side bare and bush land were reduced. This shows that agriculture and settlement are the main drivers of the land use land cover change. Population and the rain fall fluctuation were also land use land cover change drivers.

### Transitions between vegetation and non vegetation

The land use land cover transition between vegetation and non vegetation also derived to determine the land use land cover change drivers between 1973, 1986 and 2005. Table 5.5 and Table 5.6 were derived from the land use land cover dynamics of Table 5.3 and Table 5.4. Vegetation include bush land and forest lands, whereas non vegetation includes agricultural and, settlement, water bodies and bare land.

**Table 5.5 Unchanged percentages of 1973 cover and 1986 cover**

Land use land cover	Percentage of 1973 cover (1973-1986)	Percentage of 1986 cover (1986-2005)
Vegetation	52	18
Non-vegetation	66	31
Total unchanged	50	27

The percentage of unchanged land use land cover in Table 5.5 indicates that 52 % of the vegetation cover doesn't change in to other land use land cover from 1973 to 1986. Where as 18 % of the vegetation remains stable in the 1986 to 2005 land use land cover dynamics, which means there were a great transition from vegetation to other land use land cover from 1986 to 2005. Non-vegetation land use land cover types were also stable (66%) in the 1973 to 1986 than 1986 to 2005 which was 31%. This indicates that there were high land use land cover transitions in 1986 to 2005 than 1973 to 1986.

**Table 5.6 Transitions as percentage of 1973 cover and 1986 cover**

Land use land cover	Percentage of 1973 cover (1973-1986)	Percentage of 1986 cover (1986-2005)
Vegetation to Non-vegetation	15	26
Non-vegetation to vegetation	10	12
Vegetation to vegetation	3	1.4

Table 5.6 indicates the transition between the land use land cover classes within the 1973 to 1986 and 1986 to 2005 land use land cover dynamics. In both cases the transition percentage of vegetation to non-vegetation was higher than that of non-vegetation to vegetation. Which means the percentage of vegetation to non-vegetation were 15 % and the percentage of non-

vegetation to vegetation results 10 % in 1973 to 1986. This shows that during the resettlement time large coverage of vegetation has been changed to non vegetation due to the problem of drought the vegetated part of the area were dried and changed to bare land. In 1986 to 2005 land use land cover dynamics the percent of transition follows similar trend but the transition cases were not the same. During this transition period vegetated land use land cover were changed to agriculture and settlement than bare land plate 5.1 and 5.2 shows some conversions of he study area land use land cover types. Therefore the overall results of the transition indicate that agriculture and settlements has been the main change drivers for land use land cover change.



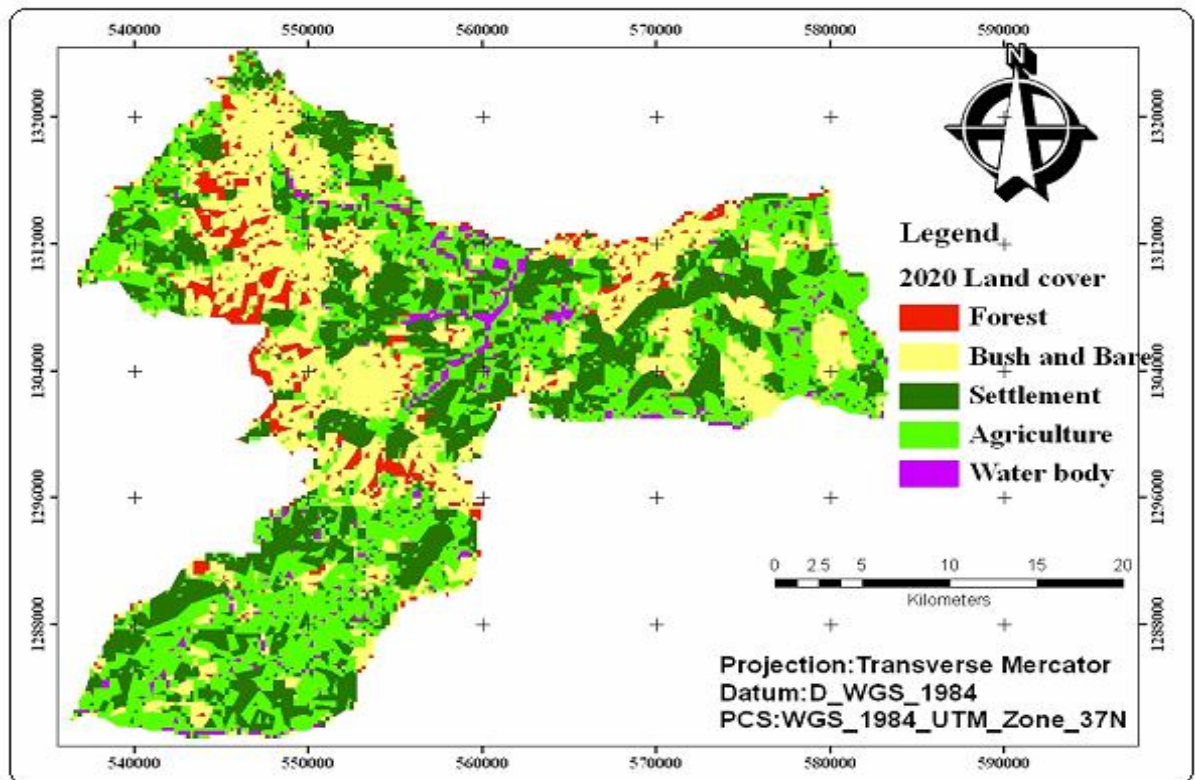
**Plate 5.1 Partial views of agricultural lands.**



**Plate 5.2 Partial view of settlement expansion**

#### **5.4 Land use land cover prediction for the year 2020**

After calibrating the model and assessing its validity, it was interesting to examine the pattern and tendency of the change for the future. Therefore, prediction for the year 2020 was carried out in the same way by considering land use land cover maps of the year 1986 and 2005, the transition area matrix, a contiguity filter and the transition suitability collection. Based on these the predicted land use land cover map of 2020 was produced (Figure5.5).



**Figure 5.5 The predicted land use map of 2020**

Visual analysis of the simulated result indicates that settlement and agriculture areas will occur at very high rate of growth (Table 5.7).

**Table 5.7 Projected Land use land cover change by 2020 and actual area of 2005**

Land use categories	Area in Km <sup>2</sup> (2020)	Area in%	Area of (2005) in Km <sup>2</sup>	Difference in		Annual rate of change 2020-2005 in Km <sup>2</sup>
				Km <sup>2</sup>	%	
Agriculture	427.23	49	346.02	81.21	23.5	5.4
Settlement	157.71	18	82.19	75.52	92	5
Bare and bush land	267.29	30.5	418.84	-151.5	-36	-10.1
Forest land	20.95	2	8.51	12.44	146	0.83
Water bodies	4.24	0.5	22.29	-18	-79	-1.2

Table 5.7 above shows the area of land use land cover projection by 2020 and the actual area of 2005. Comparing to the percentage representations Table 5.7, some similarities exist in the observed land use land cover change between projected 2020 and 2005. This may tend to suggest no change in the class types between 2005 and 2020, but a careful look at the area coverage between these two years shows a change. Thus in Table 5.7, the projected 2020 agriculture maintains the highest position in the class, 49 %, bare and bush land takes up the

next position in common, 30.5%, followed by settlement, 18 %, forest land, 2.4% and finally water body takes the least position, 0.53%. Forest land was increased by 146 % from 2005 because during model development forest and settlement considers as constraint, that means what ever the case may be the two class may not be changed to other classes rather they increases. Also agriculture and settlement increases by 23.5 % and 92 % respectively from the initial 2005. But water bodies decreased by 79 % and bare and bush in common decreased by 36 %.

The rate and trend of agriculture and settlement also shows the highest increment from 2005 to 2020 as shown in Table 5.7 both agriculture and settlement increases by 5 Km<sup>2</sup> annually, which is the maximum increment than the other. Bare and bush land in common decreased by 10.1 km<sup>2</sup> per year from 2005 to 2020. This also shows that agriculture and settlement had been the main drivers of the future land use land cover change.

The results of the simulation indicate that there will be a significant land use changes in the future. As discussed in the actual land use land cover change analysis, settlement and agriculture were the main driving forces for land use land cover change. On the other hand the expansion of infrastructure around the main land use land cover type also aggravates land use land cover changes. Accessibility to main road, rain fall distribution, slope, population density and altitude were also been other driving forces for land use land cover change in the future.

To reduce the pressure of changing most land use land cover of the area to agriculture and settlement may increase the ecological disturbance of the area as well as increase land degradation due to plowing of steep slope areas and protected areas due to the growth of the population. Therefore resettlement may take us an option for protecting the ecology (the land use land cover) of an area in the future.

Furthermore, it should be noted that the result of the simulation might be affected by a number of factors: the resolution of the image, suitability maps, and accuracy of the image classification and the level of generalization applied. Specifically, the suitability maps and the resolution of the image had a great influence on the land use predictions, because the suitability map acted as the transition rules for the CA model.

## 6. Conclusions and Recommendations

### 6.1-Conclusions

The main causes of LULC change and dynamics linked to different policy issues, physical factor (slope, altitude and other), proximity factor (nearest road, settlement and other infrastructure) and other socioeconomic factors that have direct impacts on population and local level resource use patterns. The land use land cover before resettlement shows that there are higher coverages in agriculture, settlement and bush than bare land, forest and water bodies. But during the resettlement (1986) the result shows a reduction in agriculture, settlement and bush land, whereas bare land increases. In 2005 after resettlement agriculture and settlement increased in its coverage than the coverage before and during resettlement. But there are reductions in bush and forest coverage, with no change in the coverage of bare land. The trend and rate land use land cover change also shows that there are reductions in agriculture and settlement between 1973 and 1986 by 2.63 km<sup>2</sup> and 1.45 km<sup>2</sup> per year respectively. Whereas, between 1986 and 2005 agriculture and settlement increased by 3.28 km<sup>2</sup> and 2.41 km<sup>2</sup> per year respectively. Therefore agriculture and settlements are the main drivers of land use land cover change, which are in turn direct consequences of population growth.

The land use land cover dynamics also indicates that vegetation land use types were highly converted or changed to non vegetation, than vegetation to vegetation. That means bush and forest classes were changed to agriculture, settlement bare land. On the other hand the conversion or transitions from non-vegetation to vegetation were very less in both 1973 to 1986 and 1986 to 2005. But the transition between 1986 and 2005 was higher than 1973 and 1986.

The future land use land cover change prediction indicates that there will be an increase in agriculture and settlement by 5.4 km<sup>2</sup> and 5 km<sup>2</sup> per year respectively. The prediction result shows a direct link between the year 2005 land use land cover change. Which means the result of the 2005 shows an increase in agriculture and settlement than the other classes, the same is true for the result of 2020 predicted land use land cover change. Therefore, reducing the pressure of population on land use land cover may the better way to reduce the change and dynamics of land use land cover classes. Hence resettlement can act as an option to reduce the land use land cover change

## **6.2 Recommendations**

Increasing population density accelerates land use land cover change and dynamics, so as to reduce the pressure of population on land use land cover change and dynamics resettlement will have a significant impact.

The result of land use land cover dynamics indicates that vegetation to non-vegetation increases, this implies that there will be a continuous reduction in vegetation cover in the future, unless better remedies were under taken.

Land use land cover prediction of the study indicates there will be an increase in the area of agriculture and settlement; this is because of the continuous growth of population, infrastructure development and physical factors. Therefore, concerned body will prepare proper land use plan to reduce the expansion of settlement and agriculture, to protect forest and water bodies.

Predictions of future land use land cover change will be very useful to land use planners for planning and implementing socio-economic development programs.

Increasing the awareness among peoples will be an important issue to utilize lands intensively than using extensively.

Finally further research should be made to achieve better land use land cover prediction in the same method by adding the necessary information, applicable data and by filling the above mentioned limitations.

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# Appendices

## Appendix 1. Classification accuracy assessment report of 1973, 1986, 2005

### Appendix 1a. Classification accuracy assessment report of 1973

Classified Data	Unclassified	Bush	Forest	Bare	Water	Agriculture	Settlement	Row Total
Unclassified	0	0	0	0	0	0	0	0
Bush	0	38	2	0	0	0	1	41
Forest	0	0	5	0	0	0	0	5
Bare	0	1	0	14	0	2	0	17
Water	0	0	0	0	2	0	0	2
Agriculture	0	2	0	0	0	31	1	34
Settlement	0	0	0	0	0	1	0	1
Column Total	0	41	7	14	2	34	2	100

Class Name	Reference data	Classified total	Number correct	Producer accuracy	Users accuracy
Bush	41	41	38	92.68%	92.68%
Forest	7	5	5	71.43%	100.00%
Bare	14	17	14	100.00%	82.35%
Water	2	2	2	100.00%	100.00%
Agriculture	34	34	31	91.18%	91.18%
Settlement	2	1	0	0.00%	0.00%
Totals	100	100	90		

Overall Classification Accuracy = 90.00%

Overall Kappa Statistics = 0.8547

### Appendix 1b. Classification accuracy assessment report of 1986

Classified Data	Unclassified	Agriculture	Forest	Bare	Bush	Water	Settlement	Row Total
Unclassified	0	0	0	0	0	0	0	0
Agriculture	0	28	0	1	1	0	1	31
Forest	0	0	1	0	0	0	0	1
Bare	0	1	1	29	1	0	0	32
Bush	0	0	0	2	31	0	0	33
Water	0	0	0	0	0	2	0	2
Settlement	0	0	0	0	0	0	1	1
Column Total	0	29	2	32	33	2	2	100

#### ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Agriculture	29	31	28	96.55%	90.32%
Forest	2	1	1	50.00%	100.00%
Bare	32	32	29	90.63%	90.63%
Bush	33	33	31	93.94%	93.94%
Water	2	2	2	100.00%	100.00%
Settlement	2	1	1	50.00%	100.00%
Totals	100	100	92		

Overall Classification Accuracy = 92.00%

Overall Kappa Statistics = 0.8854

**Appendix 1c Classification accuracy assessment report of 2005**

Classified Data	Unclassified	Bush	Settlement	Bare	Agriculture	Forest	Water	Row Total
Unclassified	0	0	0	0	0	0	0	0
Bush	0	18	0	0	1	0	1	20
Settlement	0	0	3	0	0	0	0	3
Bare	0	0	2	23	1	1	0	27
Agriculture	0	2	0	3	41	1	0	47
Forest	0	0	0	0	0	0	0	0
Water	0	0	0	0	1	0	2	3
Column Total	0	20	5	26	44	2	3	100

**ACCURACY TOTALS**

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Bush	20	20	18	90.00%	90.00%
Settlement	5	3	3	60.00%	100.00%
Bare	26	27	23	88.46%	85.19%
Agriculture	44	47	41	93.18%	87.23%
Forest	2	0	0	---	---
Water	3	3	2	66.67%	66.67%
Totals	100	100	87		

Overall Classification Accuracy =  
87.00%

Overall Kappa Statistics =  
0.8090

**Appendix 2 Partial view of degraded lands in the study area**



**Appendix 3. Number of settlers, Rural Population Changes by Awraja, due to the 1984/85 Resettlement Programme**

Awraja Sending Settlers, by Region				Awraja Receiving Settlers, by Region			
Awraja	Rural Population Density (pop./K m <sup>2</sup> )	No. of Settlers	Settlers as % of Rural Population	Awraja	Rural Population Density (pop./K m <sup>2</sup> )	No. of Settlers	Settlers as % of Rural Population
<b>TIGRAY:</b>				<b>WOLLEGA:</b>			
1. Raya & Azebo	18	32400	24.8	1. Assossa	15	59807	27.0
2. Enderta	17	28000	7.9	2. Horo Gudro	19	78421	17.4
3. Hulet Awlalo	16	8200	3.1	3. Kelem	42	72339	16.2
4. Agame	71	6800	2.0	4. Nekemte	51	18884	5.4
5. Adwa	127	5000	1.0	5. Arjo	47	8453	4.4
6. Axsum	90	3000	1.0	6. Ghimbi	48	29341	4.2
7. Shire	39	1400	0.5	<b>ILLUBABOR:</b>			
8. Tembien	70	1400	0.5	7. Gambela	3	38971	55.5
<b>WELLO:</b>				8. Gore	29	28803	24.6
9. Dessie Zuria	191	69775	22.9	9. Sore & Geba	63	31331	12.6
10. Raya & Kobo	22	26279	18.0	10. Motcha	18	9777	8.3
11. Kalu	79	61333	16.9	11. Buno Bedele	54	20229	4.9
12. Yeju	45	42712	16.7	<b>GOJAM:</b>			
13. Wadla Delanta	100	36516	15.0	12. Metekel	8	67055	29.3
14. Ambassel	147	49111	13.7	<b>KEFFA:</b>			
15. Wag	29	18817	9.0	13. Gimira	18	17675	13.4
16. Werehimenu	107	24065	6.8	14. Keffa	47	15576	3.0
17. Lasta	66	17897	4.9	15. Limu	64	10430	2.1
18. Borena	84	13887	3.0	16. Jimma	110	11007	1.3
19. Wereilu	93	6115	2.9	<b>GONDER:</b>			
<b>SHEWA:</b>				17. Chilga	20	6387	1.9
20. Kembata/Hadiya	239	67227	5.4	<b>SHEWA:</b>			
21. Men & Gishe, Yifat & Timuga and Merahbete	72 49 78	41017	4.8	18. Chebo & Gurage	131	6149	0.5
<b>GOJAM:</b>							
22. Mota and Bichena	93 105	16425	2.3				
<b>GONDAR:</b>							
23. Libo and Gayint	56 80	6387	1.9				

Source: settler migration, cause, patterns of movement and some demographic impacts, 1988.