ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF ENGINEERING

ANALYSIS OF URBAN EXPANSION AND MODELLING OF LAND USE/LAND COVER CHANGES IN ADAMA CITY USING REMOTE SENSING AND GIS

THESIS

SUMMITED TO THE SCHOOL OF ENGINERING IN PARTIAL FULFILMENTS OFTHE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN GEODESY AND GEOMATICS ENGINERING

BY

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GEODESY AND GEOMATICS ENGINERING DEPARTMENT

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled "**Analysis of urban expansion and Modeling of Land use/Land cover Changes in Adama City Using Remote Sensing and GIS"** Submitted to School of Engineering in partial fulfillments of the requirements for the award of the degree of master of science in Geodesy and Geometics Engineering authentic record of my own work carried out from October to may,2014 under supervision of Dr. Messay Mulugeta(main advisor) and Dani'el Alemayew (co-advisor).

The matter embodied in this thesis has not submitted by me for the award of any other degree or diploma. All relevant sources of information used in this thesis have been duly acknowledged.

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This is to certify that the above statement made by the candidate is correct the best of our knowledge and believe. And this has been submitted for the examination with our approval.

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Main advisor	signature	date
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Co-advisor	signature	date

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Approved by board of examiners

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ABSTRACT

Adama City has undergone radical changes in its physical form, not only in its vast territorial expansion, but also through internal physical transformations over the last decades. Therefore, understanding and quantifying the spatiotemporal dynamics of urban land use and land cover changes and its driving factors is essential to put forward the right policies and monitoring mechanisms on urban growth for decision making. Thus, the objective of this study was to analyze land use and land cover changes that have been taken place over 37 years, to predict and analyze the future urban growth of Adama City by applying geospatial and land use change modeling tools. In order to achieve this, satellite data of Landsat 1973,2000 and 2010 have been obtained and preprocessed using ArcGIS 10, Erdass 9.2 and Idrisi 32.A supervised classification method has been applied to prepare the base maps with six land cover classes has been used to generate land use and land cover maps. The generated land cover maps have been cross tabulated for quantifying land use and land cover changes, to examine land use transitions between land cover classes, to identify gain and losses of built up areas in relation to other land cover classes and to asses spatial trend of built up areas. Finally, Markov Chain analysis and CA-Markov have been run to model land use and land cover changes in Adama area and to predict future urban land use changes. This model was checked by Kappa statistics values and also by implementing other model validation techniques. Generally, the results of this study have shown that there was an increased expansion of built up areas in the last 37 years from 2%in 1973, 10% in 2000, 23% in2010 and 60.27% in predicted of 2040 after 30 years.

Key words: *Spatiotemporal, Remote Sensing, land use Land Cover, Markov Chain, Cellular Automata, Change Detection, Geographic Information System, Image classification, Land use land cover change, Land change modeling.*

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Acronyms and Abbreviation

AHP:	Analytical Hierarchy Analysis
CA:	Cellular Automata
CA_Markov:	Cellular Automata Markov Model
CORINE:	Co-ordination of Information on the Environment
ECSA:	Ethiopian Central Statistical Authority
EEA:	European Environment Agency
EMA:	Ethiopian Mapping Agency
ETM:	Enhanced Thematic Mapper
FAO:	Food and Agriculture Organization
GCP:	Ground Control Point
GIS:	Geographic Information System
GLCF:	Global Land Cover Facility
GPS:	Global Positioning System
LC:	Land Cover
LULC:	Land use/land cover Change
MCE:	Multi Criteria Evaluation
PRB:	Population Reference Bureau
RS:	Remote Sensing
SPOT:	Systemic Pour l'Observation de la Terre (French remote sensing Satellite)
TM:	Thematic Mapper
UN:	United Nation
UTM:	Universal Transverse Mercator
WGS:	World Geodetic System
WLC:	Weighed Linear Combination

CHAPTER ONE: INTRODUCTION

1.1. Background

Urbanization is a significant global phenomenon and it becomes a great concern for many parts of the world. Population increment and land demand for settlement, commercial and industrial expansion and its impact on environment have also been largely raising issues in many discussions. According to the United Nations (UN) and Population Reference Bureau- PRB (2000), the world has experienced a tremendous urban growth and population increment. For the first time in history, more than half of its human population, 3.3 billion people has been living in urban areas. By 2030, this is expected to swell to almost 5 billion. While the world's urban population grew very rapidly (from 220 million to 2.8 billion) over the 20th century, the next few decades will see an unprecedented scale of urban growth in the developing world (Mesfin, 2009). This will be particularly notable in Africa and Asia where the urban population will double between 2000 and 2030: that is, the accumulated urban growth of these two regions during the whole span of history will be duplicated in a single generation. By 2030, the towns and cities of the developing world will make up 81% of urban population (Mesfin, 2009). Most of the nations with the fastest growing populations are now in Africa, although this is a relatively recent phenomenon. But looking more properly at the urban population, in the period 1950-2000, in Africa the growth rate was the fastest in the world (4.4 percent a year), even though the urban percentage in 1950 was the lowest (15 percent) (Antonio, 2000). Nevertheless the present situation is that Africa, together with Asia, still has, among continents, the lowest percentage of urban population (38 %) (Antonio, 2000).

Ethiopia is largely under-urbanized, even, considering Africa standards (Haregeweyn et al, 2012). The slow speed of urbanization continued until the middle of 1930s, while it was more rapid during and after the Italian occupation of 1936-41(Antonio,2000). Urbanization accelerated between 1950 and1965, when the average growth rate was between 5.4 and 5.6 per cent a year, a rate, which implies a doubling of population in only 13 years. Again, urban population growth in the last fifteen years of the last century was very fast with rates over 5 per cent and a peak in the quinquennium 1985 1990, when the annual rate of change reached 5.93 percent (which implies a doubling time of only 12 years) (Mesev, 2008). The most rapid growth of the urban population is associated with the highest values of the difference between urban and rural rates and massive rural-to-urban migration up to 1975, Whereas, the 1975 land reform program provided incentives and opportunities for peasants and other potential migrants to stay in rural areas (Antonio,2000). It is widely and increasingly accepted that population growth and urbanization are an inevitable phenomenon. In the developed countries of Europe and North America, urbanization has been a consequence of industrialization and has been associated with economic development. By contrast, in the developing countries of Latin America, Africa, and Asia, urbanization has occurred as a result of high natural urban population increase and massive rural-to-urban migration (Mesfin, 2009).

Associated with the rapid expansion of urbanization, a lot of land has been converted from rural to urban (Haregeweyn et al, 2012). Ethiopia, having the second largest population in Africa has a total of over 80 million populations. It has a 2.3% of annual growth rate and having 4.6% average annual urban growth rate (Haregeweyn et al, 2012).

Despite the economic benefits, the rapid rates of urbanization and unplanned expansion of cities have resulted in several negative consequences (Zubair 2006). Most cities in developing countries are expanding horizontally following the routes of roads and railway networks, the urban sprawl is moving to unsettled peripheries at the expense of agricultural lands and areas of natural beauty and other surrounding ecosystems (Mesev, 2008). Such dynamism in urban land cover can be caused by demographic, economic or industrial factors. Currently, these are the major environmental concerns that have to be analyzed and monitored carefully for effective land use management and planning. Furthermore, the rapid urban growth and the associated urban land cover changes attracted many researchers to study and monitor the changes (Mesfin, 2009). An unplanned urbanization process is now a major problem, especially in the developing countries where there is lack of consistent and reliable data including spatial data. In order to understand the evolution of various land use systems, to analyze dramatic changes of land use/land cover at global, continental and local levels, and further to explore the extent of future changes, the current geospatial information on patterns and trends in land use/land cover are already playing an important role(Mesfin, 2009).

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Zubair 2006). Besides, there are no extensive studies conducted related to urban growth and their impacts using remote sensing, GIS and spatial modeling tools. Hence, urban planners and decision makers should consider the potential of geospatial tools to detect, monitor and evaluate the urban land cover changes in the country. In order to analyze land use change and development in the Adama City, a change detection analysis was performed to determine the extent and rate of land cover change and prediction over time and space. The results quantify the land cover change patterns in the city and demonstrate the potential satellite data to provide an accurate, economical means to map and analyze changes in land cover in a spatiotemporal framework that can be used as inputs to land type for management and policy decisions with regard to varied themes that has link with land cover such as urban areas, crop land, forest lands and so on.

1.2. Statement of the Problem

Due to bio- physical process of the nature and socio economic determinants of Adama City and its surrounding has experienced land use and land cover changes. Similarly Adama City has showed remarkable expansion growth developmental activities such as construction of building roads and other anthropogenic activities. Due to effects of continuous growth and expansion of the city productive farmlands and the farming population in the neighbor hoods and rural communities residing in the outlying areas have been subjected to increasing eviction and adverse effects such as pollution, environmental ,social and cultural disturbance(APO,2004). This would have significant impact on the surrounding ecosystem: loss of crop land, destruction of forestland, grassland and on the benefits generated from the land. Because of this rapid growth on the urban-rural fringe, planners and policy makers lack accurate, timely and cost effective urban land use data which is most essential to make decision concerning land resource management. Therefore examining changes in land use and land cover and modeling of it for future time is, therefore, important for monitoring and resolving the negative consequences and increases the benefits for Adama City. This could be useful for better land use management and environmental development in the study area. Besides, urban land use change studies are important for planning and decision making to mitigate the impacts of urban expansion and attain sustainable urban development.

1.3. Objective of the Study

1.3.1. General Objective

The general objective of this study is to detect and analyze land use and land cover dynamics in Adama City by integrating remote sensing techniques and Land Change Modeler.

1.3.2. Specific Objectives

More specifically, the study aspires to:

- Mapping of the urban Land use Land cover of the study areas at selected periods(1973,2000 and 2010);
- Quantify the area of the defined land classes of the acquired maps ;
- Spatial and temporal analysis among the urban expansion during the three study time periods(1973,2000 and 2010);
- Examining the land use transitions of the land classes and identify the gains and losses of the land classes, net changes and characterize impacts of urban land use change on the other land classes ;
- Evaluating the predictive power of the Land Change Modeler in simulating and predicting of urban land use in Adama City.

1.4. Research Questions

This study is designed test the accuracy of determining urban land use land cover changes using remotely sensed satellite by employing advanced geo statistical modes-Markov chain analysis and CA-Markov. In order to assist the analysis, the following research questions were posed:

- Which techniques are available for analyzing the change detection of land cover types of Adama City?
- What is the extent and rate of land use/land cover changes that have occurred in the in Adama City between 1973, 2000 and 2010?
- What is the spatial and temporal land use/land cover change?
- How was the contribution of land cover classes for the growth of built up areas?
- Had the model been satisfactory in predicting and simulating the changes?
- What will be the future land use land cover map of Adama City based on the analysis and simulation of past trends?

1.5. Significance of the Study.

This study quantifies and analyzes the changes between 1973 and 2010 to contribute in the developments of urban land and monitoring of environmental management and monitoring plan of the areas. Therefore, it is expected to provide basic information on the status and dynamics of the urban land cover of the area and the potential of Remote sensing data for such purpose. It is also expected to identify the rate of urban growth and urban land cover changes in different times and provide greater importance to the research community, urban planners, stake holders as well as decision making groups in terms of understanding the impacts of land use land cover changes in Adama City.

The results of this study could provide better information about the changes in urban land use quantified through integrated application of GIS, remote sensing and land change modeler. In addition, it also provides the opportunity to understand the trends of changes in built up areas as a result of driving variables and the findings of this thesis will be an initial input for future research direction for interested groups.

1.6. Limitations of the Research

To perform this type of spatiotemporal analysis, it is important to select the satellite images of the same time interval. Again the spatial resolution of the images is important. For this research purpose, Landsat satellite images have been chosen that are only commercially available but can be found in free public-domain. The main problem of working with Landsat images is low resolution. The spatial resolution of Landsat Image is 30 meter (U.S. Geological Survey). IKONOS, Quick Bird, SPOT or other satellite images with higher resolution can be better option, but those images are expensive. Therefore due to limitations of resources, only free public-domain data have been used for this research.

Another important point, while selecting satellite images, is seasonal variation. The change in Urban land, forest land, crop land, bare land and others land cover types are evident due to different seasons. Therefore, in an ideal situation, satellite images of the same season are selected for this kind of research.

1.7. Scope and Justification of the Study

Analyzing urban spatiotemporal and predicting urban land use change is important if city planners are to provide, even at minimum standard, to manage urban land use land cover changes. Forecasting where and how urban change will manifest itself, however, is a challenge for any city and its planners. Thus, it is envisaged that if the growth process of urban changes is better understood it can be modeled and applied in real situations for the prediction of growth under likely future scenarios. Spatially explicit modeling can be used to conduct experiments that test our understanding of key processes and for describing them in quantitative. The result of the study helped identify urban spatiotemporal pattern of Adama City in order to make adequate future planning for proper provision land use land covers changes of study area.

1.8. Structure of the Thesis

Chapter two concentrates on theoretical literature review and related work for this study. This section presents brief understanding of land use and land cover changes, land use change models, the use of remote sensing in land use and land cover change, image classification, change detection methods and accuracy assessments of land cover maps generated in the classification and land use change models. The third chapter focuses on the general methodology followed and data sets used in this study and detail explanation of the study area. This chapter highlights all the procedures and techniques applied for image classification and land use modeling including the tools such as ArcGIS, ERADASS and IDRISI software. The results and discussions is the fourth chapter which presents the quantified results from image classification and land use change modeling. Moreover, change analysis using markov chain analysis, spatial trends and simulation of land cover maps has been performed. Validation of the accuracy and reliability of the map, by comparing model performance. The last chapter presents conclusions and recommendations. In this section, key findings and critical points that need further treatment has been forwarded as a recommendation for future work.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

In order to write this thesis of analyzing spatiotemporal change land use land cover changes in Adama City, it is important to review historical background and concepts and related works done literature focusing on GIS, Remote Sensing, land cover modeling tools and their applications for spatiotemporal land use/cover studies.

2.1 Theoretical over View

Two basic terms were used throughout this research. These are Remote Sensing (RS) and Geographic Information System (GIS). RS and GIS mean different things to different users. To some, it is a tool that allows the generation of custom maps. To some, it is kind of software that helps in analyzing different aspects of geographic data. To some, it helps in finding out one self or knowing the current position of someone with the help of a detailed digital map. Though it is a hectic task to define RS and GIS in an easy manner, the general definitions of these two terms, along with the definition of Land, land use/land cover was described in this section.

2.1.1. Remote Sensing (RS)

According to Lambin (2004), the definition of Remote Sensing (RS) is as follows: “Remote sensing is the science and art of obtaining information about the Earth's surface through the analysis of data acquired by a device which is at a distance from the surface”. The broad definition of RS may include fields like vision, astronomy, medical imaging, and Earth observation and so on. But for this research purpose, RS only refers to the Earth Observation. In this kind of RS analysis, aerial photographs and images from Earth observing satellites are most commonly used.

2.1.2. Geographic Information System (GIS)

Geographic information means information about the earth. More specifically it refers to earth’s surface information (Good child, 2009). Geographic Information Systems (GISs) are defined as software systems and their relationships to other activities connected with geographic information. (Good child, 2001).Chrisman (1999) has defined GIS as: “Organized activity by which people measure and represent geographic information phenomena then transforms. The representation into other forms while interacting with social structures”

According to Maguire (1991), some people believe GIS as the system of hardware and software while others believe GIS as applications or information processing. In general, GIS support any operation on geographic information: acquisition, editing, manipulation, analysis, modeling, visualization, publication, and storage. GIS has four basic subsystems: input, storage, analysis and output. All these things act like a perfect system. Finally these entities work in a body to get the final result. RS and GIS techniques are comprehensively used for analytical purposes in numerous fields' like-urban planning, geography, earth science transportation planning, environmental planning and disaster management and so on.

2.1.3. Land Use/Land Cover changes

In order to get a notion of land cover dynamics, it is useful to review on the concepts of the terms. The definition of land use and land cover has been used interchangeably in the land use research community because of the availability of many existing information systems. However, these two terms explain two different issues and meanings. Land cover refers to the observed biophysical cover on the earth's surface including vegetation, bare soil, hard surfaces and water bodies. Whereas land use is the utilization of land cover type by human activities for the purpose of agriculture, forestry, settlement and pasture by altering land surface processes including biogeochemistry, hydrology and biodiversity (Di Gregorio and Jansen, 2000). Although humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of land use /land cover change are far greater than ever in human history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. Today, land use /land cover changes encompass the greatest environmental concerns of human population including climate change, biodiversity depletion and pollution of water, soil and air. Currently, monitoring and mediating the adverse consequences of Land use /land cover change while sustaining the production of essential resources has become a major priority of researchers and policy makers around the world. In studying the land use/land cover dynamics, it is quite useful to have an overview of the concepts and working definition of these terms. Hence, land cover refers to the "physical and biological cover over the surface of earth, including water, vegetation, bare soil, and/or artificial structures". Land use is a more complicated term that can be defined in terms of disorders of human activities on the natural environment such as agriculture, forestry and building construction. These activities alter land surface processes including biogeochemistry, hydrology and biodiversity processes (Addis, 2009).

2.2. Empirical Literature

RS and GIS techniques are being widely used to assess natural resources and monitor environmental changes. It is possible to analyze land use/ land cover change dynamics using time series of remotely sensed data and linking it with socio-economic or bio- physical data using GIS. The incorporation of GIS and RS can help analyzing this kind of research in variety of ways like land cover mapping, detecting and monitoring land cover change over time, identifying land use attributes and land cover change hot spots etc (Lambin, 2001). With the advancement of technology, reduction in data cost, availability of historic spatiotemporal data and high resolution satellite images, GIS and RS techniques are now very useful for conducting researches like land cover change detection analysis and predicting the future scenario (Das, 2009). Many researchers have conducted number of researches to detect the land use/ land cover change pattern over time and predict the future growth of urban areas. They have introduced and applied different new or existing techniques and methods to achieve the research objectives. Some examples are as follows.

2.2.1. Trends of Urban Growth

The world is undergoing the largest wave of urban growth in history. According to the United Nations Population Fund (UNFPA, 2013), rapid population growth has been concentrated in towns and cities of the world. The report also projected that by the year 2030 the vast majority of this growth will be observed in the developing world of Africa and Asia where urban growth is highly concentrated. Because cities offer a lot of opportunities such as jobs and sources of income than the corresponding rural areas, they attracted a lot of people. Following the rapid increase of population in urban areas, the growth of the world's rural population has shown a slowly decreasing pattern as indicated in figure below.

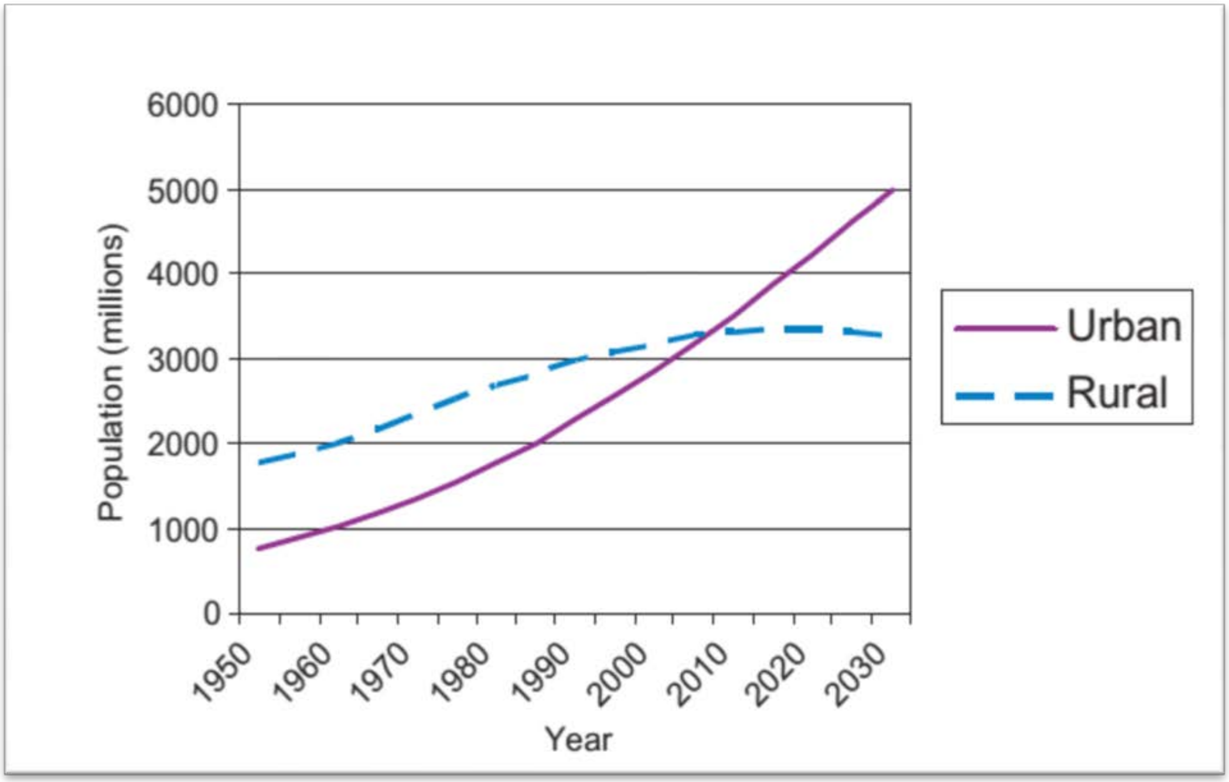


Figure 2.1: World's urban and rural population size estimated and projected, 1950–2030, (Source: Cohen, 2006).

It is clearly shown in figure above that when the world's urban population increased four-fold between 1950 and 2003, the world's rural population less than doubled going from 1.8 billion in 1950 to 3.2 billion in 2000 (Cohen, 2006). Regarding to projection of population growth, the world's urban population is expected to increase by almost 2 billion over the next 30 years, whereas the world's rural population is actually expected to decline slightly falling from 3.3 billion in 2003 to 3.2 billion in 2030.

Ethiopia is one of the second largest populated countries in Africa with a total population of over 80 million and having an annual growth rate of 3.02%. The country is experiencing an average annual urban growth rate of 4.6%, which is a high rate by world standard (Cohen, 2004). Even though urbanization rates differ depending on the methodologies applied, Ethiopia's urbanization is low relative to other Sub-Saharan African (SSA) countries. Since the majority of the population (85%) is living in the rural areas, where agriculture is the backbone of the country's economy, it is evident that urban growth to be low. The self-sufficiency of agriculture also contributed to reinforcing of the rural peasant life from their territory. According to Central Statistical Agency of Ethiopia (CSA), it is only 16% of the population lived in urban areas. Among these are in small cities and towns (Schmidt and Kedir, 2011). Adama ity, where this study is conducted, is located in the south eastern part of Ethiopia. It is one of the fastest growing cities in the country.

2.2.2. Forces Shaping Urban Expansion

The expansion of urban areas is determined by the interaction of the three broad types of phenomena. These are the physical or geographic factors, the demand for land by the households or firms who inhabit the city and the policy constraints that govern land use and spatial interactions in the city (Seto et al, 2003). More specifically, aspects of the natural environment that may affect urban expansion include those of climate, slope, mountain barriers, and the existence of drillable water aquifers. Demographic effects may include rural migration and natural population growth in the city, the level of urbanization and the rank of the city in the country's urban hierarchy.

Aspects of the economy that can affect the urban expansion include the level of economic development, difference in household incomes, exposure to globalization, the level of foreign direct investment, the degree of employment decentralization, the level of real estate finance markets, the level and effectiveness of property taxation and the presence of high inflation and acute shortage of housing (Angel et al 2005). The expansion of urban to the periphery largely depends on the second factor from the three mentioned above. These two conspicuous factors are urban development and urban population increase. The demand for land by various firms who inhabit the city can intensify economic development projects, which could be one cause for urban expansion to the periphery.

Space is needed for various economic and social infrastructures, cultural, and other purposes. Redevelopment and organization of inner cities again cause displacement of citizens. This in turn requires space, which invites extension of urban settlements to the rural territories (Cernea, 1995). Natural population growth is a major element in urban growth for all countries, but rural urban migration contributes more in many developing countries (Gugler, 1996). Migration contributes fast growth of urban population due to the relative economic development that attracts people to urban nuclei for commerce, employment, and education. Many believe that cities are expanding very rapidly and are growing for non productive reasons specifically; some scholars believe that new policies and regulations on land acquisitions and illegal land markets might have encouraged the extensive shifts of cultivated area in to built up area (Yeh et al 2003). A number of observers also suggest that housing price have risen unreasonably high in many cities of the developing countries and are inducing developers and investors to invest in more housing stock than would be rational in a purely market driven economy (Wu,F.2000). In short, scholars believe that there are economic and non-economic factors that are encouraging the expansion of urban to non urban areas.

2.2.3. Forms of Urban Expansion

Urban expansion takes place substantially in different forms. In any city, new urban expansion can take place with the same densities (person per square kilometers) as those prevailing in existing built up areas, with increased densities or with reduced densities. It can take place through the redevelopment of built up areas at high densities through infill of the remaining open spaces in already built up areas or through new “green field” development in areas previously in non- urban use. New green field development can either be contiguous with the existing built up areas or can leapfrog away from them, leaving swaths of undeveloped land that separate it from the existing built up areas. It can encroach upon wetlands, watersheds, forests, and other sensitive environments that need to be protected (Angel et al, 2005). Expansion may take place along corridors resulting in a star shaped or elongated city, or in areas closest to the city center, resulting in a more or less circular or compact shaped city. The form of urban expansion can be orderly, properly laid out in simple geometric forms and it can be disorderly. It may leave adequate space for roads or other necessary infrastructure, or it may leave too little or too much space for roads. The infrastructure accompanying urban expansion may be of a varying quality, reflecting very different levels of investment, maintenance, and repair. New land development can be largely legally sanctioned, conforming to strict zoning and building codes. There are others who favor neither compaction nor expansion of cities. They are advocating for selecting elements from both outlooks. Their argument promotes urban regulation strategies and new intra urban environmental initiatives and it goes in line with the compact city argument that favors controlled direction of inevitable expansion to the periphery to support a full range of facilities and to the sites that causes the least environmental damage (Isaac et al, 2000).

2.2.4. Consequences of Urban Expansion

As the World Bank Transport and Urban Development Department indicated, even though, the available evidences are spotty, controversial and not necessarily applicable to developing country cities, suggest that the above mentioned differences in the growth and expansion of cities are associated with both positive and adverse outcomes that affect the welfare and well being of the citizens. The available literature concerning urban expansion is rife with blame for its inappropriate and unnecessarily costly for developing world cities. Most blame is directed at expensive leapfrogging green filed development. It is claimed that such development reduces both access and view of open space. It encroaches on sensitive environments and on scarce farmlands. It requires long journeys to work; it leads to higher levels of car use and therefore, to higher levels of air pollution, energy use, and the production of green house gases; it increases dependence on vehicles; it makes public transport less attractive and less efficient. It also requires longer and more costly extensions of public infrastructure networks and it imposes additional costs on residents of new expansion sites. It also diverts construction away from the central parts of the cities that needs to be redeveloped. As a result of urban expansion social interaction between people reduces and urban lifestyle becomes less exciting resulting in alienation, social fragmentation, and both economic and social segregation and unplanned changed of farming land into urban land (Durlauf, et al,1995).

2.2.5. Use of Remote Sensing and GIS for Land use Land cover Change

Remote sensing is defined as the use of electromagnetic radiation sensor to record images of the environment which can be interpreted to yield useful information . Remote sensing and GIS are being increasingly used in combination spatial analysis. GIS databases are used to improve the extraction of relevant information from remote sensing imagery, whereas remote sensing data provide periodic pictures of geometric and thematic characteristics of terrain objects, improving our ability to detect changes and update GIS databases. Both remote sensing (RS) and geographic information systems (GIS) have been widely applied and recognized as powerful and effective tools in detecting the spatiotemporal dynamics of land use and land cover (LULC). RS can provide researchers with valuable multi temporal data for monitoring land-use patterns and processes and GIS techniques make possible the analysis and mapping of these patterns (Netsanet, 2007).

2.2.6. Urban Land use/Land Cover Dynamics

Due to several reasons, most of the urban centers expand to the surrounding environment. The outskirts of urban areas, usually referred to as rural-urban-fringe, are characterized by farming land/irrigated fields, forest cover and source of water supply. The trend of urban growth towards the urban-rural-fringe has an impact on the surrounding ecosystem. One of the major impacts of urban land cover change is diminish in surrounding forest and agricultural land. It is also likely that large amounts of valuable agricultural or irrigated lands are converted to non-agricultural areas (e.g. built up areas). Urban land cover change is a very important phenomenon, which characterizes the nature of the cities and their surrounding areas (Mesfin, 2009).The expansion of urban sprawl is mainly caused by the high rate of population growth, and the accompanying loss of agricultural lands, forests and wetlands, escalating infrastructure cost, increases in traffic congestion, and degraded environments, becoming the major concern to citizens and public agencies responsible for planning and managing urban growth and development (Bauer *et al*., 2003). Understanding urban dynamics is one of the most complex tasks in planning sustainable urban development while also conserving natural resources. Despite these difficulties, urban growth and urbanization are major environmental concerns that need consideration and careful assessment and monitoring (George, 2005).

2.2.7. Application of Remote Sensing on Urban Dynamics Study

As mentioned in Addis, (2009), for decades the visual interpretation of aerial photography of urban areas has been based on the hierarchical relationships of basic image elements. A number of urban remote sensing applications to date have shown the potential to map and monitor urban land use and infrastructure and to help estimate a variety of socio-economic data (Jenson and Cowen, 1999). However, much of the expert knowledge of the human image interpreter was lost in the transition from air photo interpretations to digital analysis of satellite imagery.

It is well known that the great strength of remote sensing is that it can provide spatially consistent data sets that cover large areas with both high detail and high temporal frequency, including historical time series. This has been becoming more effective with the emerging sensors that provide high spectral, spatial and temporal resolution data to researchers. Meanwhile, mapping of urban areas has been accomplished at different spatial scales, e.g. with different spatial resolutions, varying coverage or extent of mapping area and varying definitions of thematic mapping objects. Global and regional scale studies are often focused on mapping just the extent of urban areas. A basic difficulty of these efforts encounter relates to the indistinct demarcation between urban and rural areas on the edges of cities. Remote sensing provides an additional source of information that more closely respect the actual physical extent of a city based on land cover characteristics (Weber, 2001). However, the definition of urban extent still remains problematic and individual studies must determine their own rules for differentiating urban rural land (Herold, et al., 2003).

Considering the recent improvements in spatial, spectral and temporal resolution, remote sensing technology can provide special advantages on studying growth and land use/land cover change processes and analysis of the growth pattern and their fragmentations. Remote sensing and spatial datasets obtained through remote sensing are consistent over great areas and over time. They provide information at a greater variety of geographic scales with a greater degree of detail. The information derived from remote sensing can help describe and model the urban environment, leading to an improved understanding that benefits applied urban planning and management (Longley and Mesev, 2000; Longley, et al., 2001).

2.2.8. Image Classification Techniques

In order to examine and asses' environmental and socioeconomic applications such as: urban change detection and socioeconomic variables, image classification results with better accuracy are mandatory. Image classification refers to the extraction of differentiated classes or themes, usually land cover and land use categories, from raw remotely sensed digital satellite data (Weng, 2012). Image classification using remote sensing techniques has attracted the attention of research community as the results of classification are the backbone of environmental, social and economic applications (Lu and Weng, 2007). Because image classification is generated using a remotely sensed data, there are many factors that cause difficulty to achieve a more accurate result. Some of the factors are: The characteristics of a study area, availability of high resolution remotely sensed data, ancillary and ground reference data, suitable classification algorithms and the analyst's experience, and Time constraint.

These factors highly determine the type of classification algorithm to be used for image classification. There are various image classification methods that can be applied to extract land cover information from remotely sensed images (Lu and Weng, 2007). However, their application depends on the methodology and type of data to be used. Some of these methods are: artificial neural networks, fuzzy-sets and expert systems. In a more specified way, image classification approaches can be categorized as supervised and unsupervised, or parametric and nonparametric, or hard and soft (fuzzy) classification, or per-pixel, sub-pixel and per-field. Some of the most commonly used image classification methods are discussed below.(Lu and Weng, 2007)

2.2.8.1. Object-Oriented Image Classification Methods

This method of image classification is based on identifying image objects, or segments with similar texture, color and tone of spatially contiguous pixels (Gao and Mas, 2008; Weng, 2012). This approach allows for consideration of shape, size, and context as well as spectral content (MacLean and Congalton, 2012). The classification stage starts by grouping the neighboring pixels into meaningful areas. Qian et al (2007) noted that in object oriented classification approach, single pixels cannot be classified rather homogenous image objects are extracted during segmentation step. Image analysis in object-oriented is based on contiguous, homogeneous image regions that are generated by initial image segmentation.

2.2.8.2. Pixel-Based Image Classification Methods

A pixel-based classification method automatically categorizes all pixels in an image into land cover classes fundamentally based on spectral similarities (Qian et al, 2007; Weng, 2012). These types of classifiers develop a signature by summing up all pixels. Thus, the developed signature contains the necessary things found in the training pixels but does not contain the influence of mixed pixels (Weng, 2012). According to Tadesse et al (2003), there are two primary types of pixel-based classification algorithms applied to remotely sensed data: unsupervised and supervised.

Unsupervised image classification algorithms are based on categorizing each pixel to unknown cluster centers and then moving from one cluster center to another in a way that the Supervised Spatial Encoder (SSE) measure of the preceding section is reduced data. Whereas in the case of supervised image classification the analyst has previous knowledge about pixels to generate representative parameters for each land cover class of interest. The Maximum Likelihood classification, under the category of supervised classification, which is the most widely, used per-pixel method by taking in to account spectral information of land cover classes (Qian et al, 2007). Although pixel based classification methods have been widely accepted and applicable, however, there are limitations in including spatial pattern during classification. This happened especially in Maximum Likelihood classification methods where they consider only spectral information by neglecting contextual and texture information (Zhou and Robson, 2001; Dean and Smith, 2003).

2.2.8.3. Contextual Image Classification Approaches

In the case of maximum likelihood classification technique the pixels are assigned to represent classes taken in to consideration and this is done through observing of each pixel. However, there could be misclassification errors especially during the presence of random noise which causes different classes to be appeared similar (Sharma and Sarkar, 1998). To avoid such problems, contextual classification techniques have been chosen which exploits spatial information among neighboring pixels. These techniques are based on the assumption that the response and class of two spatially neighboring pixels are highly related. The advantage of using contextual techniques will improve image classification results by reducing error rates related to spectral properties (Weng, 2012).

2.2.9. Land use Change Detection Analysis

Change detection can be defined as the process of identifying differences in the state of object or phenomena by observing them at different times by using remote sensing techniques (Singh, 1989). Essentially, it also involves the ability to quantify temporal effects using multi-temporal data sets. Because of repetitive spatial coverage at short time intervals and consistent image quality, change detection is considered as one of the major applications of remotely-sensed data obtained from Earth-orbiting satellites (Singh, 1989).

Change detection has a wide range of applications in different disciplines such as land use change analysis, forest management, vegetation phonology, seasonal changes in pasture production, risk assessment and other environmental changes (Singh, 1989). The main objective of change detection is to compare spatial representation of two points in time frame by controlling all the variances due to differences in non target variables and to quantify the changes due to differences in the variables of interest (Lu et al, 2004). A change detection research to be good, it should provide the following vital information: area change and rate of changes, spatial distribution of changed types, change trajectories of land-cover types and accuracy assessment of change detection results.

Quantifying land use and land cover changes and applying suitable change detection methods highly depend on the type of changes that happened in landscapes and how those changes are noticeable in images. The changes could be continuous or categorical. According to Abuelgasim et al (1999), change detection in continuous land cover changes focuses on measuring the degree of changes in amount or concentration through time. However, in the case of categorical land cover changes, the goal of change detection is to identify new land cover classes and changes between classes through time.

2.2.10. Change Detection Techniques using a remotely Sensed Data

The selection of suitable method or algorithm for change detection is important in producing a more accurate change detection result since constraints such as spatial, spectral, thematic and temporal properties affect digital change detection. Some techniques such as image differencing can only provide change or non-change information, while some techniques such as post classification comparison can provide a complete matrix of change directions. According to Bekalo (2009), different change detection methods could produce different changes of maps depending on the algorithm they followed. Although there are many change detection methods in remote sensing of image classification, recently researchers divided in to image ratio, image regression, image differencing and the method of change detection after classification (post classification method) (Xu et al, 2009; Bekalo, 2009). The classification of methods mainly depend on data transformation procedures if exists and analysis techniques applied. So, based on these conditions the current common methods of change detection are discussed below:

2.2.10.1. Image Regression Method

In image regression method of change detection, pixels from time t1 are assumed to be a linear function of the time t2 pixels (Singh, 1989). Under this assumption, it is possible to find an estimate of image obtained from t2 by using least-squares regression. According to Abuelgasim et al (1999), image regression technique takes in to account differences in the mean and variance between pixel values for different dates. This consideration minimizes the influence of differences in atmospheric conditions. In detecting changes of urban areas the regression procedure has more advantage than image differencing technique.

2.2.10.2. Image Ratio Method

In image ratio method, images must be registered beforehand and rationed band by band. The results of image ratio are interpreted with a threshold of values. If the ratio of the two images is 1, it means that there is no change in the land cover classes where as a ratio value of greater or less than 1 indicates a change in land cover classes (Singh, 1989; Bekalo, 2009). This method rapidly identifies areas of changes in relative terms.

2.2.10.3. Image Differencing Method

Image differencing is one of the most extensively applied change detection method. It can be applied to a wide variety of images and geographical environment. In this technique, images of the same area, obtained from times t1 and t2, are subtracted pixel wise. It is generally conducted on the basis of gray scale which used to show the spatial extent of changes in the two images. A threshold value is required for the gray of difference image in order to examine the changed and unchanged regions (Xu et al, 2009).

2.2.10.4. Post Classification Method

This method is the most simple and obvious change detection based on the comparison of independently classified images (Singh, 1989). Maps of changes can be produced by the researcher which shows a complete matrix of changes from times t1 to time t2. Based on this matrix, if the corresponding pixels have the same category label, the pixel has not been changed, or else the pixel has been changed (Xu et al, 2009).

2.2.11. Modeling Urban Growth Patterns

In general, modeling means the process of creating a representation of reality; it could be a map, graph, picture, or mathematical representation. The focus of this thesis is on spatial modeling, and it discusses on the data used, data processing for modeling, methodology followed, modeling results and validation and, lastly, the discussion about the model results. “A model is an abstraction of an object, system or process that permits knowledge to be gained about reality by conducting experiments on the model” Clark (2003). In this study, land use and land cover change modeling is defined as the process of creating maps based on the history of Land use land cover, existing information and assumptions of the future.

Modeling of land use land cover plays a significant role to understand impacts of the changes that occur through time. This would help for effective environmental management, sustainable resources utilization, development plans and decision making. This has become more efficient with the advancement of geospatial tools which provide us the capability to integrate and processed spatial data and various other modeling factors. A number of authors in the field of urban studies have stated several modeling advantages. Pontius et al., (2006) have mentioned that, in the field of urban planning, modeling can be used for analyzing, evaluating, forecasting and simulating urban systems to support decision making. Urban land use land cover detection, analysis and modeling plays vital role in planning a healthy growth of urban ecosystem. Ineffectively planned urban growth ends up breaking the equilibrium of environmentally sensitive areas. Scientific models addressing location and quantity of urban expansion in space and time are essential in providing scientists and policy makers with empirical/statistical support for their decisions toward an environmentally sustainable future (Lee et al. 1999).

2.2.12 Urban land use modeling

A number of land use land cover models have been developed; however, it is difficult to compare which one gives more accurate representation (Wu and Webster 2000; Chang, 2006). Among the numbers of land use modeling tools and techniques, the commonly used models are the modeling techniques embedded in Idrisi. These are Land Change Modeler (LCM), Cellular Automata (CA), Markov Chain, CA_Markov, GEOMOD, and STCHOICE (Eastman, 2006). CA operates on a grid based cells and transition rules that are applied to determine the state of a cell. Whereas, Markov Chain analyzes two qualitative land cover images from different dates and produces a transition matrix, a transition areas matrix, and a set of conditional probability images. The CA_Markov is a combination of both CA and Markov chain. These two are termed as the geosimulation techniques used to produce land use predictions (Sun et al. 2007). As stated by Eastman (2006), the geosimulation refers to the process of land use change between two points in time and extrapolating this change into the future. CA_Markov can be used to project with any number of land use classes. Whereas, GEOMOD is relatively easy land use change simulation model that predicts, forward or backward, the locations of grid cells that change over time. It runs only with two numbers of classes e.g. Built up and non-built up. STCHOICE (Stochastic Choice) creates a stochastic land cover map by evaluating the conditional probabilities that each land cover can exist at each pixel location against a rectilinear random distribution of probabilities.

2.2.13. Literature Review Summary

The impact of urbanization on environment and livelihoods can be seen in two ways: positive and negative. According to Alaci (2010) well planned and managed urban growth and development can serve as a positive development factor. The benefits could be seen in terms of high demand on agricultural produces, access to developed extension services, and opportunities to non-farm employment (Satterthwaite and Tacoli, 2003). However, unguided urbanization, like in most developing countries, negatively affects the natural environment and livelihoods of urban areas (UN-HABITAT, 2010). This could be attributed to changes occurring in land use, water resources management, waste dumping, and increasing competition between agricultural and residential use of natural resources (Bah *et al*., 2003).

Kibrom seyoum (2011) has done the thesis entitled "Assessment of land use land cover change detection using Geographic Information System and Remote Sensing technique in a case of Adama City. He uses landsat TM 1984, landsat ETM^+ 2000, SPOT image 2007 somewhat similar with this thesis. But there are some difference such as methodology and additional knowledge. Kibrom have done only the statistics of land use land cover distributions by area (ha) and percentage and he had not clipped the study area. But this thesis includes : The statistics of the land cover classes by area(ha) and percentage and additional new knowledge such as: Gain and loss of between land cover classes, Transition between land cover classes; Modeling of land use land cover classes, Simulation of 2010 land cover map and prediction of 2040 land cover maps. The other is methodological gap, how to do transition between land cover classes, simulation and prediction for the feature.

Eskindir Ayele(2010) has done the thesis entitled “ Land use land cover change detection using Multi-Temporal Remote Sensing and GIS: In case of Bonga town and its surrounding, Kefa *Zone* using landsat TM 1987, ETM 2001, ETM 2006 and he predict the map 2016 for Bonga town. Similarly Atalel Getu (2014) has done the thesis entitled “Analysis of Urban Land use and Land cover Changes: A case Study in Bahir Dar, Ethiopia”. He used satellite data of Landsat TM for 1986, ETM for 2001, ETM 2020 and he tried to predict land cover map for 2019. But its validation and kappa statistics were not accepted.

CHAPTER THREE: DESCRIPTIONS OF THE STUDY AREA

3.1. Description of study area

3.1.1. Location

Adama is one of the cities in Ethiopia which started as a small railway station along Ethio-Djibouti railway line (Messay, 2010). It is located in the central part of Ethiopia only at abuot 100km south-east of Addis Ababa. In the existing regional road network of the country, Adama is located at the point of intersection of the Addis Ababa-Harrar route and located at 8 degrees 30’ latitude and 39 degrees 12’ longitude and at an altitude of 1620m. Adama and its surrounding are classified under sub-humid tropical zone with an average mean annual temperature of 21 deg. Celsius (Messay, 2010). It is hot and dry for the greater part of the winter, and warm and sunny in summer which has made it an attractive resort center in its own right. (Messay, 2010).

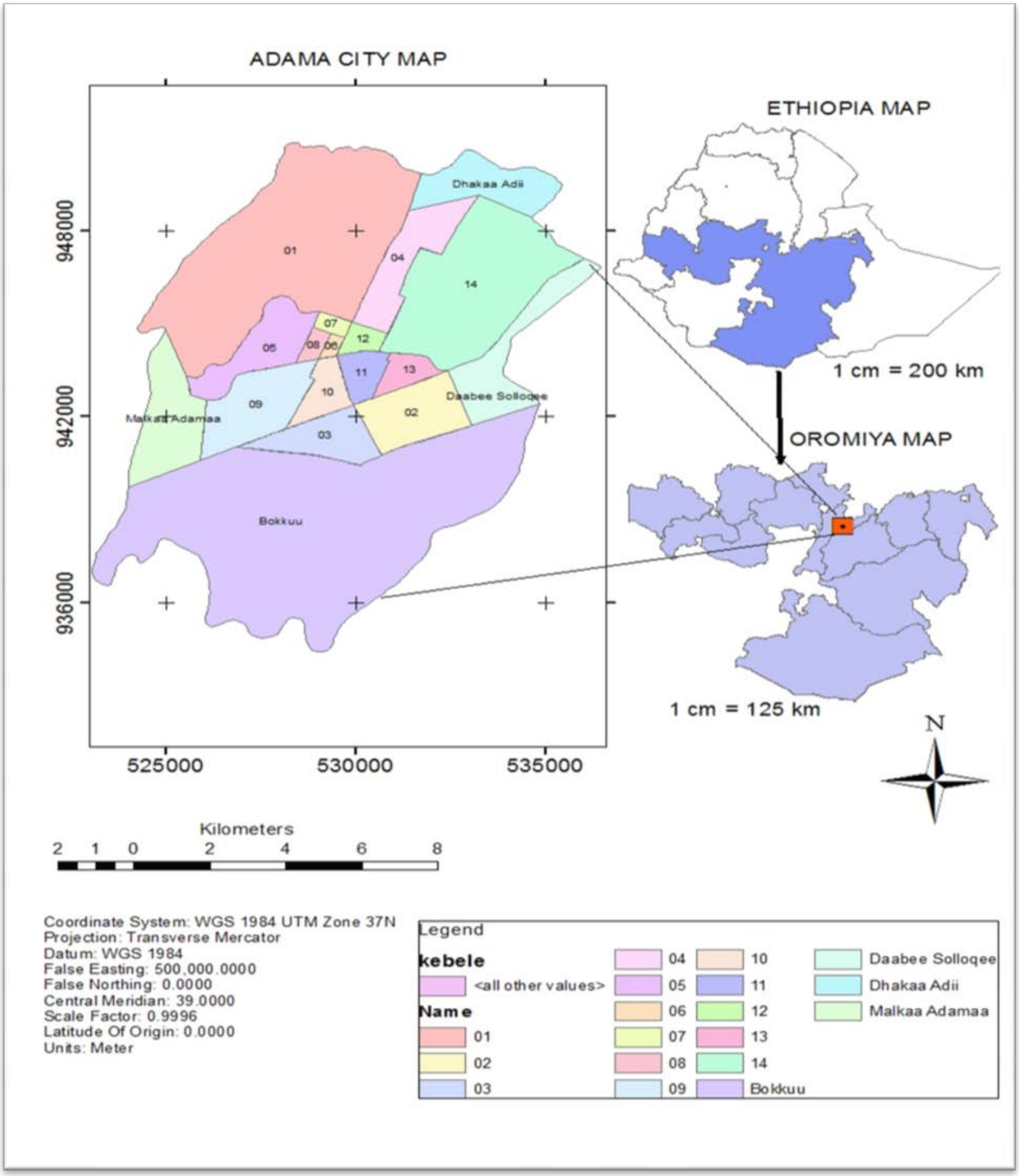


Figure 3.1: Location map of study area

3.1.2. Topography

Adama City is located within the Main Ethiopian Rift valley made of volcanic rocks that extends from the southern Afar Rift to the Konso highland in the southern Ethiopia. The city lies on plain land that formed by geodynamic movement. These conditions have made the City susceptible for earthquake. The topography is characterized by flat land that is surrounded by ridges. The plain land is covered by lacustrine sediments and reworked volcanic while the ridges are made of volcanic rocks. The nature of topography has created three drainage sub catchments. One that drains to Awash River and the other two are closed basins. Absence of appropriate drainage network, lack of natural outlet and unplanned human intervention has made the city vulnerable to flooding (APO,2004).

The first settlers of Adama were employees of the railway station. The first structures were the railway station and a handful of houses constructed by the railway company. Later on, farmers from the surrounding region started to settle near the station in search of the station's water supply and other facilities. The first major transformation of Adama took place during the Italian occupation (1936-41). The Italians had contributed greatly to the city’s development and growth. They built the city with a new plan connecting it with many of their provincial centers by telephone, telegraph and radio networks. Newly developed roads also connected it with Addis Ababa and other regional states. Even after their withdrawal the Italians have continued to contribute to the growth and stability of Adama. Thus, as a compensation for their atrocities during their occupation, they built the Awash Hydro Electric Power Plant which provided electricity to Adama as well as other parts of the region. There was no piped water supply at the time. People used to fetch water from Awash River which is about17kms to the south, traveling on foot. The Italians helped to provide piped water from this river. The municipal office of Adama was also first established by the Italians. After the Italian period, Adama continued to play an important role in the administrative and economic life of the country. It became the administrative center for Yererna Kereyu Awraja. The City became a hub of a number of courts, public offices as well as security and armed forces. Adama, which was the original name of the City, was changed, in 1944/45, to Nazareth by Emperor Haile Sillassie I marking an increasing attention it started to get from the rulers of the time. However, it got its original name back after the 1991 change in government (APO, 2004).

3.1.3. Socio-economic Aspects

Adama is a city of migrants, who came following the trade route in search of jobs and livelihood. As a result, it is composed of people of different ethnic origin. According to citizens who lived in the area for more than 50 years, most of the migrants are from the agriculturally rich regions of Shoa (especially Minjar), Arsi, and Harrar. Thus, Gurages, Amharas and Oromos constitute the major ethnic groups in the city. Some of them settled and became traders. Others come periodically to trade their agricultural products. There were also Arabs and Indians who must have come following the beginning of export of agricultural products to Yemen and the Middle East countries via the railway station. In additions there were also Italians, who settled during the Italian Occupation. The Arabs used to do cereal export and retailing imported items, while most of the Indians were in textile trade. Italians involved in auto mechanics and restaurants and hotels. Even though most of these foreigners are no longer there, there are still a few two and three generations of them in the city. Economically, Adama has been serving as a major focal point for trade and small scale industries.

The City is an important center of distribution of goods that are manufactured locally by the various industries in the City and its suburbs. It still is a relay point for goods produced and manufactured in the country and imported from abroad to the small towns and rural areas in the region. Adama also serves as the loading center for some Ethiopian export goods, particularly cereals. As a result it is characterized by lots and lots of warehouses. Even before the 1960s there were 40 to 50 warehouses in La Gare area. This number has been growing ever since. Due to its location en route to the Sodore hot water spring resort, and its strategic importance as an intersection point between economically important regions, Adama has always been full of travelers. Thus there are a lot of hotels – big and small, restaurants, bars and cafes and the majority of the population gets its livelihood from sundry commercial activities and services. There are also factory and office workers whose number is increasing lately.

3.1.4. Nature of the Soil

Sediments of alluvial and lacustrine origin cover the catchments of the Adama basin. The laboratory analyses made on the soil samples taken at the bed and bank of the main canal that drain the western catchments indicated that the bed of the channel is covered by sandy soil (6% silt and 94% sand) while the bank is covered sandy loam soil **(**38% silt and 64%sand)(AP0,2004)

3.1.5. Precipitation and Temperature Conditions

The information indicated in Adama City Master Plan (1995) reveals that the mean annual precipitation depth recorded for Adama is 82.25cm for the period of 39 years, 1952 to 1991. The mean annual rainfall for the period of 1998 to 2006 was computed to be 72.67mm. Rainfall in this area is erratic in nature. There is a significant seasonal variation in the amount of rainfall. More than 67% of the mean annual rainfall occurs in the four rainy months: June, July, August and September. Some additional rains (about 23%) occur in the remaining dry months with mean monthly values of rainfall as low as zero millimeters.

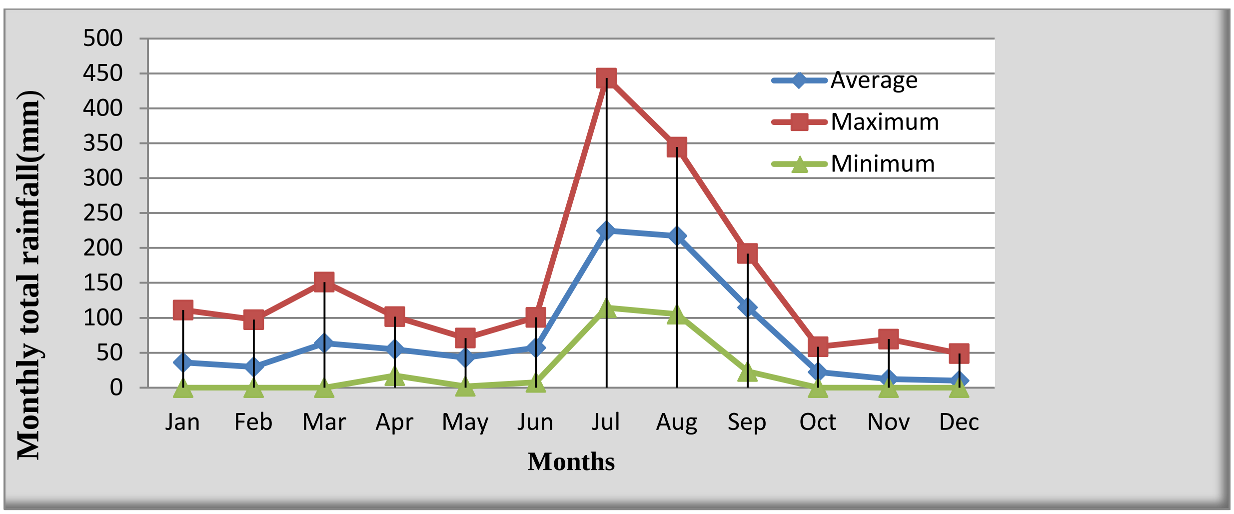


Figure3.2: Monthly total rainfalls (mm) (2004-2013). (Source: Computed based on data obtained from Metrological Agency, Adama Branch)

From above figure the highest monthly total average of rain fall was July that is 224.73 mm. And the highest maximum and minimum average rain fall was also July that is 443.2 (mm) and 114.4 (mm) respectively. The lowest monthly total average and maximum rainfall was

December by value of 9.92(mm) and 48.8(mm). Lastly the lowest monthly average minimums were January, February, March, October, November and December because they have the value of 0(mm). Monthly average minimum temperature the highest average was June 18.253(ºC) and the lowest was December 13.016(ºC). The highest maximum monthly average minimum temperature was June 23.8(ºC) and the lowest was January 14.8(ºC) the highest minimum monthly average minimum temperature was June 16.8(ºC) and the lowest was December 11.6(ºC).

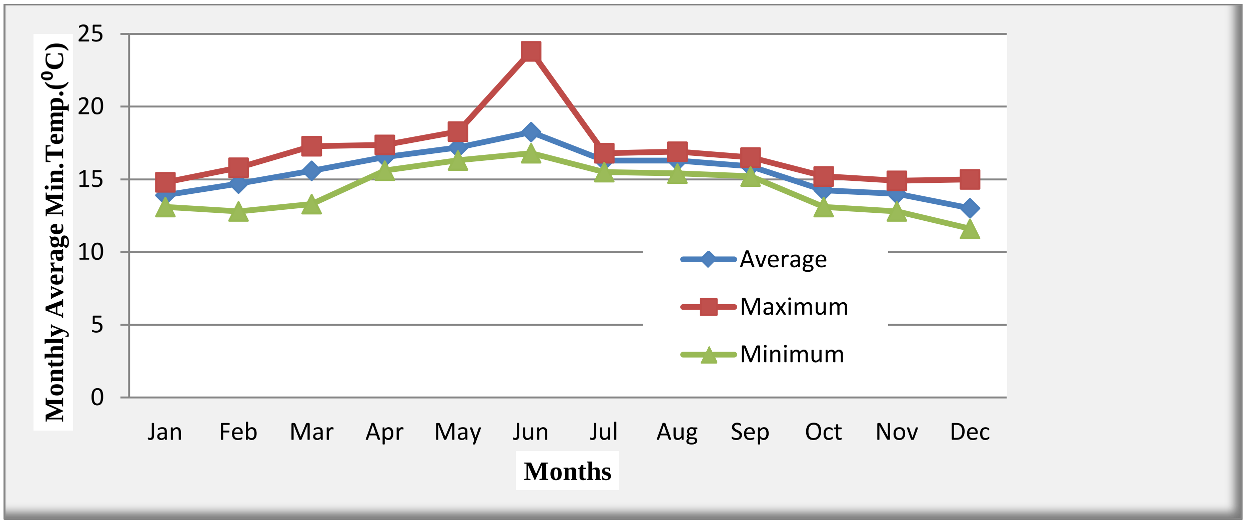


Figure 3.3: Monthly average minimum temperatures. (ºC) (2004-2013). (Source: Computed based on data obtained from Metrological Agency, Adama Branch)

Monthly average Maximum temperature the highest average was May 30.6 (ºC) and the lowest were august and December 25.8(ºC). The highest maximum monthly average maximum temperature was May 31.8(ºC) and the lowest was December 26.7 (ºC). The highest minimum monthly average Maximum temperature was May 29.1(ºC) and the lowest was August 24.5(ºC).

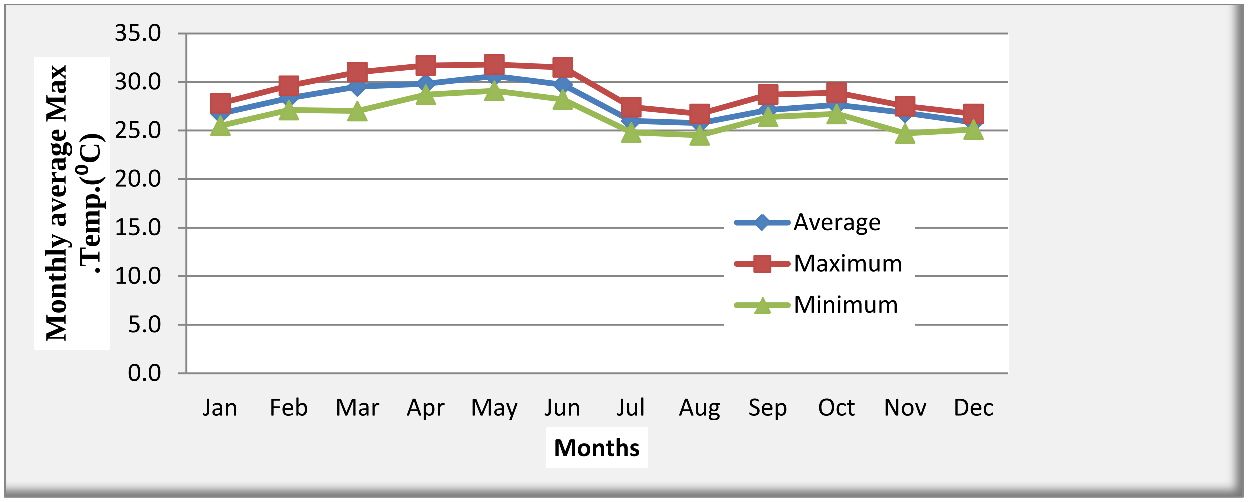


Figure.3.4: Monthly average maximum temperatures. (^{o}C) (2004-2013)

(Source: Computed based on data obtained from Metrological Agency, Adama Branch)

3.1.6. Population

Based on CSA's 1994 Population and Housing Census and 1999 National Labour Force Survey (NLFS), indicate that there were about 187,000 people living in Adama City in 2004. Nevertheless, the 2002/3 estimates of the City Administration reveals that the City population is known to be well over 200,000. The proportion of male to female during the period was about 48.5 to 51.5 percent revealing further that the sex ratio was 94.0 percent, which implies little excess of women over the men (about 100 females for each 94 males). Furthermore, according to the CSA's 1994 census, about 33.6 percent of Adama residents were below the age of 15. Similarly, the data further reveals that populations within the working age group (15-64) and above 64 years of age were 63.5 and 2.9 percent, respectively. Form the figures it could be noted that the conventional dependency ratio for the City at the time was 57.5 percent, implying that every 100 people in the working age group supports about 58 additional people within the dependent age group in every aspect providing shelter, food etc. This was quite very low and largely differs from what the CSA has for the national (102) and regional levels (109). In general, it is rarely possible to observe such discrepancies within same character population unless there are exceptions, which explain the status quo of the area.

As a result, various studies [CSA, 1984, 1994, 1999 and Adama Project Office's (APO) socio-economic surveys, 2004] point that Adama has been one of the areas both in the region and the country that receives heavy influx of migrants each year. For instance, the 1984 Census indicates that 53.7 percent of the City populations were migrants. Similarly, after a decade, in 1994 the second census showed that the extent of migrants were 53.6 percent. The finding of the 1999 NLFS neither contradicts with the above mentioned two census outcomes. According to the results of the NLFS, hence, 52.1 percent of the populations of Adama City were contributed from migrants in 1999. The findings of many socio-economic surveys undertaken by APO in 2003-2004 too, confirm that in-migration stand out as one of the major issues in Adama City. In the Poverty and Socio-economic Problem survey undertaken in Adama, about 68.0 percent of the poor households were migrants. Similarly, in the same study it was found that about 83.0 percent and 87.0 percent of the commercial sex workers and street occupants were migrants respectively (APO, 2004). The census data further points that Adama households were estimated to have about 4.8 persons on the average. From this it could be possible to estimate that about 39.0 thousand households were residing in the city in July 2004.

Table 3.1: Population of Adama City (2002-2011)

Year	Male	Female	Total	Total Area Km^2	Population/Density (p/km^2)
2002	99307	99206	198513	29.86	6648.12
2003	104,051	104,065	208,116	29.86	6969.73
2006	107811	107714	215,525	29.86	7217.84
2007	108872	111340	220212	29.86	7374.81
2009	120,072	123047	243,119	29.86	8142.4
2011	128,832	131,775	260,607	29.86	8,728.1

Source: computed based on data obtained from Central Statistical Agency, Adama Branch

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this city has a total population of 220,212, an increase of 72.25% over the population recorded in the 1994 census, of whom 108,872 are men and 111,340 women. With an area of 29.86 square kilometers, Adama has a population density of 7,374.82; all are urban inhabitants. A total of

60,174 households were counted in this city, which results in an average of 3.66 persons to a household, and 59,431 housing units. The four largest ethnic groups reported in Adama were the Oromo (39.02%), the Amhara (34.53%), the Gurage (11.98%) and the Silte (5.02%); all other ethnic groups made up 9.45% of the population. Amharic was spoken as a first language by 59.25%, 26.25% spoke Oromiffa and 6.28% spoke Guragiegna; the remaining 8.22% spoke all other primary languages reported. The majority of the inhabitants said they practiced Ethiopian Orthodox Christianity, with 63.62% of the population reporting they observed this belief, while 24.7% of the population was Muslim, and 10.57% were Protestant(APO,2004)

Table. 3.2: Population distributions of Adama City by *kebele* in 2007

***Kebele* Name**	**Male**	**Female**	**Total**
01	9112	9706	18818
02	6685	6758	13443
03	9844	9794	19638
04	9505	10523	20028
05	9814	9094	18908
06	3355	3612	6967
07	5902	5591	11493
08	5556	5296	10852
09	10711	11073	21784
10	8473	9161	17634
11	9054	9475	18529
12	4960	5636	10596
13	5405	5361	10766
14	10496	10260	20756

Source: Central Statistical Agency: Adama Branch

CHAPTER FOUR: RESEACH METHODS AND MATERIALS

4.1. Methodology

The following flow diagram (Fig.4.1 summarizes the overall methods, techniques, approaches and materials used to carried out this study, so as to figure out the urban land cover changes and describe the urban spatial patterns changes and future prediction in the study areas.

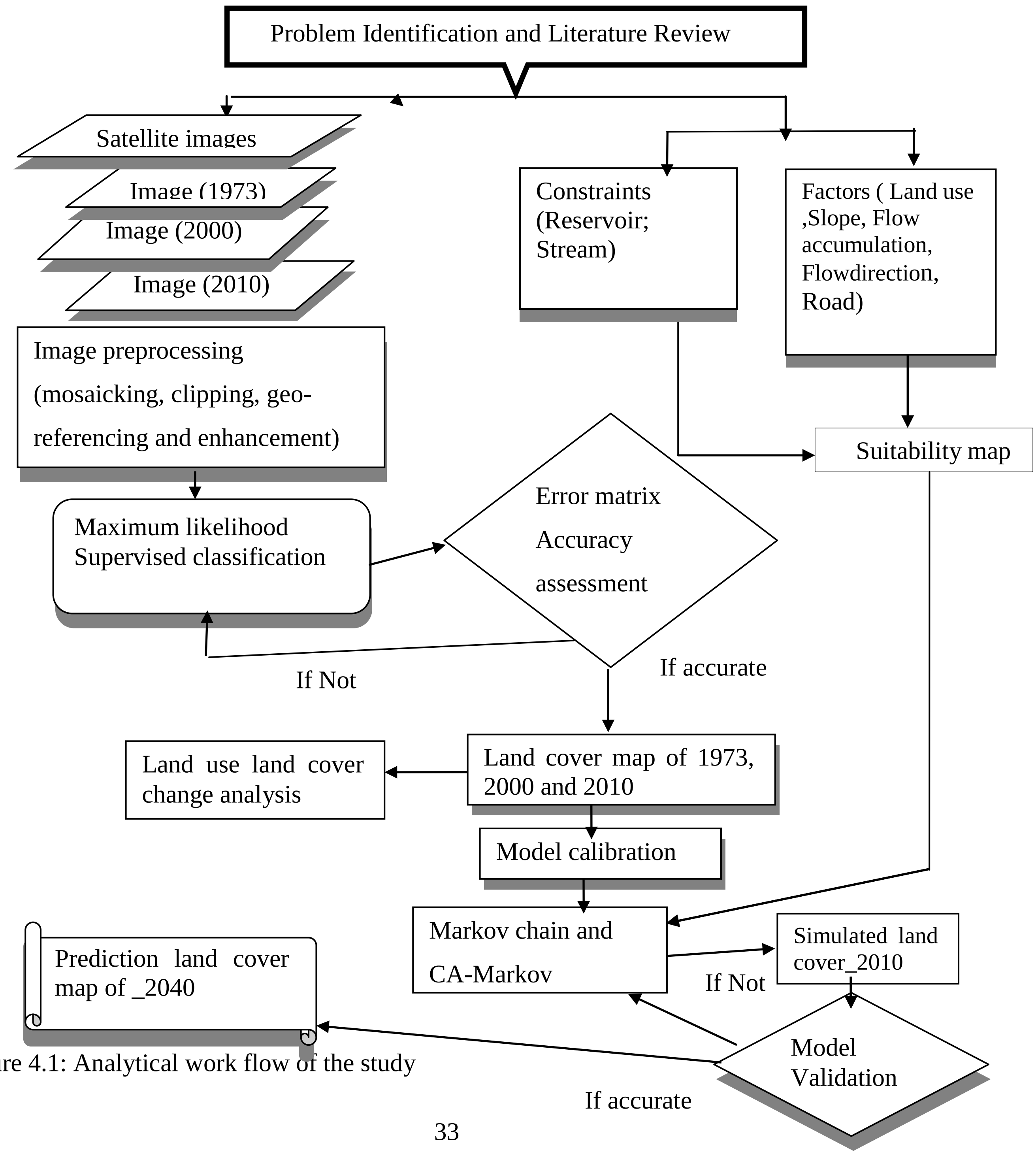


Figure 4.1: Analytical work flow of the study

4.2. Data Source and Processing.

There are a number of different kinds of methods, strategies and techniques to process input data so as to generate the required output in an efficient and sufficient way with desired quality. In fact, the choices of general methodology and specific technical arrangements are largely guided by the availability of the desired input data, the quality of available information, the strength of logistic support including the software employed, researcher's experience and skill to manipulate as well as the necessary fund allocated for the task. The methodology integrated in this study comprises remote sensing tools as well as land use land cover modeling techniques using IDRISI software. The GIS and remote sensing tools were used to classify the satellite data and detect urban changes in different time frame, and to analyze the pattern and the trend of changes. IDRISI software is used to quantify the changes and compare the results and predict for the future. Due to diverse application of remotely sensed data, satellite images have been used for different environmental studies (e.g. Bio diversity and ecological monitoring, agricultural and early warning purpose, change in surface water, global and climate change as well as mapping and detection of urban land cover changes). Data from satellite imageries are nearly perfect to provide information on different geospatial phenomenon on the surface of the earth. However, the consideration has to be given for the level of resolution, level of correctness of an image during processing, impacts of the sun's inclination and season of image acquisition, classification techniques applied etc.   It is also important to use a cloud-free scene. This is because seasonal variation and non-cloud free images could affect the quantitative analysis of the changes (Singh, 1998).

The availability of multi temporal data to produce land cover changes is useful because it solves the problems associated with single dated land cover information. It also provides diverse changes occurred on the surface on different land use classes. Therefore, it is recommended to use multiple dated data type to detect the dynamism of the features. However, it is not easy to have multi-date data of the same time of the year (Mas, 1999). In order to detect the change and patterns of geospatial phenomenon and land use classes accurately, the researcher has to be sure of the availability of images acquired in the same season. For this study the three data types 2000 & 2010 employed, were exactly acquired in the same season and the same level of resolution.. Thus, it was conducive for comparison of changes and patterns occurred in the time under discussion. In orders to avoid the impact of seasonal variation, the images used are predominantly cloud free and are selected from the same season (dry season). Satellite image, MSS, ETM+ and ETM+satellite data are usually used for their multi-spectral and environmental value, because one of the intended uses was to observe land cover character as an environmental backdrop to the urban growth pattern (Gluch, 2002).

Table 4.1: Characteristics of satellite data used in this study

Sensor	Spatial Resolution	Acquisition time	Producer
MSS	57m	January 1973	EMA
ETM	30m	January 2000	EMA
ETM	30m	January 2010	EMA

In order to substantiate the findings and detect the changes on the surface, it is necessary to use additional data including other high resolution imageries, topographic maps, socio economic and environmental data, physiographic and climate data.. The pre-processing and post image processing and analysis were carried out to enhance the quality of the images and the readability of the features using ERDASS software. All scanned aerial photo, Google earth and Landsat geo referenced by Universal Transverse Mercator (UTM) projection system, zone 37 using GIS software. The spheroid and datum was referenced to WGS84. All the images were geometrically co-registered to each other using ground control points into UTM projection. The Ground Control Points (GCPs) collected from known ground points whose positions can be accurately located on the digital imagery. Such features include road intersections, corners of open field or lawns. A sufficient number of such points are used to solve the transformation coefficient.

4.3. Tools

Ground Controls Points (GCPs) was collected by Global Positioning System (GPS). In order to store, analyze and display information, software from ERDAS, GIS, IDRISI 32 was employed. Hence, both Arc Map 10, ERDAS Imagine 9.2 and IDRISI 32 were used to extract land use/land cover information and further analysis of relationships, land use modeling and prediction approach. Besides, IBM SPSS statistics 20 and Microsoft Excel windows accessories for tabulations and graphical representations was used to present describe and analyze land use/land cover dynamics and trends of changes that were undertaken during study periods.

4.4. Land Cover Nomenclatures

In order to make sample collection and classification easy, land cover nomenclatures are required to create and define the possible land cover classes first. Although the focus of the paper is on built-up areas, land cover map of the study areas was first generated using land cover classes presented in table3.3.The land cover classes applied in this paper were adopted from the classification used by European Environment Agency (EEA), **C**o-ordination of Information on the Environment (CORINE) , which describes land cover (and partly land use) according to a nomenclature of 44 classes organized hierarchically in different levels (EUROPA,2008). Moreover, due to the geographical location of the study area in Tropics, the CORINE land classes adopted was not entirely applied. It is a land cover class which is more applicable for Temperate and cold Polar Regions. In order to solve this challenge, AFRICOVER land cover classification system which is widely applied at East African Countries (AFRICOVER, 2002) was integrated. For the sake of simplicity, the researcher modified the descriptions of some of the land cover classes considering the land cover diversity of the study area. Six major land cover nomenclatures (forest land, grass land, bare land, crop land, rural settlement and urban areas) were used to produce the final land cover map of the study area.

Table 4.2: Nomenclature of land use land covers classes.

Land classes	Land cover types	Description
C1	Forest land	Natural and manmade forests, Woodland shrubs, sparsely planted trees.
C2	Grass land	Grasses, shrubs, bushes
C3	Bare land	Open spaces with little or no vegetation, beaches, dunes sands, bare rocks, sparsely vegetated areas
C4	Crop land	crop land with permanent crops, farming and fallow fields
C5	Rural settlement	Permanent residential areas of varied patterns and scale occupied by backyards, compounds, and individual buildings
C6	Urban and associated areas	Continuous and discontinuous urban fabric, Residential, industrial and commercial units, road and other associated lands.

4.5. Image Classification

Image classification is defined as the extraction of differentiated classes or themes, land use and land cover categories, from raw remotely sensed digital satellite data. It is a technique to identify different features such as urban land cover, vegetation types, anthropogenic structures, mineral resources, or changes in any of these properties from the satellite image.

Image classification is a complex and time consuming process. In order to improve the classification accuracy, selection of appropriate classification method is required. This would also enable analyst to detect changes successfully (Elnazir et al, 2004). There are different types of image classification techniques. However, in most cases the researchers categorized them in to 3 major modes: Supervised, unsupervised and hybrid. For this study, the Supervised Classification type was applied. It is a type of classification which is based on the prior knowledge of the researcher to the study area. It requires the manual identification of Point of Interest areas as reference (Ground truth) within the images, to determine the spectral signature of identified features. It is one of the most common types of classification techniques in which all pixels with similar spectral value are automatically categorized into land cover classes or themes.

In this work, Pixel based-supervised classification approach was used and passed through the steps such as: select training samples which are typical representative for the land cover classes;

perform classification using Maximum Likelihood Algorithm and finally assess the accuracy of the classified image through randomly generated training samples and analysis of a Confusion Matrix. The overall classification process was carried out in software “Arc GIS version 10.0. It has the capabilities to import images from different data format, generate training samples, classify and mapping. It also supports different methods to train the algorithm and build up resource and pixel based image classification.

Classification and post-classification overlay was carried out and thematic land-cover maps for the year 1973, 2000 and 2010 produced for the study area by supervised classifications. Six major land cover classes: urban areas, rural settlement, cropland, bareland, grassland and forestland areas were performed to detect possible details, change trajectory of post classification comparison was used to map the patterns and extents of land use and land cover in the study area as well as to determine the magnitude of changes between the years of interest 1973, 2000, 2010and predicted map of 2040 respectively.

4.6. Training Site Collection

Once the classification scheme and segmentation is adopted, the image analyst selects training sites in the image that are representative of the land-cover or land-use of interest. The analyst would locate sites that have similar characteristics to the known land-cover types. These areas are known as training sites because the known characteristics of these sites are used to train the classification algorithm for eventual land-cover mapping of the remainder of the image. To see which features show up better in which band, examine the Landsat images shown in the following table3.8. The individual band images appear as gray scale images - like old-fashioned black-and-white photographs. However, they can be combined to form composite images, with each gray scale image each adding a different color (typically a red-green-blue, or RGB combination). There are many band-color combinations that tell useful stories (Mussie, 2011). Three different and often used composites are summarized below. In this study, firstly, the optimal band mixing; secondly, an image object with appropriate segmentation algorithm (that is multi resolution) was done.

Table 4. 3: Appearance of various surface features in different composite images.

Features	True Color RGB321	False Color RGB432	SWIR (GeoCover) RGB742
Trees and bushes	Olive Green Red	Olive Green Red	Shades of green
Crops	Medium to light green	Pink to red	Shades of green
Wetland Vegetation	Dark green to black	Dark red	Shades of green
Water	Shades of blue and green	Shades of blue	Black to dark blue
Urban areas	White to light blue	Blue to gray	Lavender
Bare soil	White to light gray	Blue to gray	Magenta, Lavender, or pale pink
Clouds	White	White	White-pink-lavender
Snow/Ice	White	Light green-blue	Medium blue

4.7. Accuracy Assessment

Land cover maps derived from classification of images usually contain some sort of errors due to several factors that range from classification techniques to methods of satellite data capture. Hence, evaluation of classification results is an important process in the classification procedure. In so doing among the common measures used for measuring the accuracy of thematic maps derived from multispectral imagery, error/confusion matrix was used (Congalton and Green, 1999). An error matrix is a square assortment of numbers defined in rows and columns that represent the number of sample units assigned to a particular category relative to the actual category as confirmed on the ground. The rows in the matrix represent the remote sensing derived land use map, while the columns represent the reference data that were collected from field work. These tables produce many statistical measures of thematic accuracy including overall classification accuracy, percentage of omission and commission error and kappa coefficient-an index that estimates in the influence of chance (Congalton and Green, 1999).

Error of omission is the percentage of pixels that should have been put into a given class but were not. Error of commission indicates pixels that were placed in a given class when they actually belong to another. These values are based on a sample of error checking pixels of known land cover that are compared to classification on the map. Error of commission and omission can be expressed in terms of user’s accuracy and producer’s accuracy. User’s accuracy represents the probability that a given pixel will appear on the ground as it is classed, while producer’s accuracy represents the percentage of a given class that is correctly identified on the map. On the other hand, Kappa coefficient is a measure of the interpreter agreement. The Kappa statistics incorporates the off-diagonal elements of the error matrices (i.e., classification errors) and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance. One of the problems with the confusion matrix and the kappa coefficient is that it does not provide a spatial distribution of errors (Foody, 2002).The land cover classification accuracy assessment was based on number stratified random sampling points, comparison between each classified images, and comparison with a aerial photo, Google Earth Imageries and existing land cover maps.

4.8. Change Analysis of land use land cover modeling

The change analysis panel provides a rapid quantitative assessment of changes, allowing the researcher to generate evaluations of gains and losses, net change, persistence and specific transitions graphical form. It also provides a means of generalizing the pattern of trend between two land cover map transitions (Eastman, 2006). In this study, land use and land cover maps of the study area obtained from image classification for the periods of 1973, 2000, and 2010 were used for the analysis. Based on the principle of land change analysis, graphs of gains and losses, contributions to net change, transitions of land cover classes between different categories and spatial trend analysis were examined.

4.8.1. Transition Sub-Models

This panel lists all transitions that exist between the two land cover maps of time 1 and time 2. The researcher should specify which transitions to be considered for producing the transition potentials (Eastman, 2012). In the case of this study area, transitions from all land cover classes to urban area areas between 1973 and 2000 were considered as the aim of the study focus on urban areas. Moreover, major transitions between other land cover classes have been incorporated since it has a great role in the dynamism of the study area. Based on this principle, transitions such as; transition from all land cover classes to urban areas, to crop land areas, forest lands, grass land, bare land and rural settlement areas were considered in this study.

4.8.2. Model Variables Development

After analyzing the land use and land cover changes between 1973 and 2000 in Adama and identifying the major transitions, modeling of these transitions have been performed with selected variables. In Markov analysis, model running is performed twice: in this study, the first run was to generate a map of transition potential after the selected variables were incorporated. In the second time, the model has been run for generating a prediction map based on the produced maps of transition potential.

Steiner et al (2000) mentioned that for the purpose of modeling the selected transitions, variables or suitability maps should be created for accurate and desirable direction of future development in built up areas. Suitability analysis techniques incorporate three different factors of an area: location, development activities, and environmental processes and these are important for decision-making (Al-Shalabi et al, 2006). A criterion is some basis for a decision that can be measured and evaluated. It is the evidence upon which an individual can be assigned to a decision set. The suitability range is the decision rule that restricts or allows particular land uses to grow up or transform among each other. Criteria can be of two kinds: factors and constraints (Eastman, 2012). There are many factors responsible for urban growth such as increasing of population and rapid urbanization. However, there are also inhibiting constraints for urban development growth such as topography, water bodies.

4.8.2.1. Constraints

Constraints are variables which restricted or limit the growth of development such as urban land use. They are expressed in the form of a Boolean (logical) map: areas excluded from consideration being assigned a value of 0 (unsuitable) where as those considered ones with a value of being 1 (suitable) (Eastman, 2012). The constraints considered in this study were reservoir and stream. The shape file data for reservoir and stream was digitized from aerial photo of 2014.

4.8.2.2. Factors

Factors are criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. They are not reduced to simple Boolean constraints. It is therefore most commonly measured on a continuous scale (Eastman, 2012). Because of the different scales upon which criteria are measured, it is important to standardize the factors to a continuous scale of suitability. In IDRISI, the FUZZY module is provided for the standardization of factors using a whole range of fuzzy set membership functions. Because the Multi Criteria Evaluation (MCE) module has been optimized for speed using a 0-255 byte level of standardization, it is recommended to standardize the factors in this scale (Eastman, 2012). MCE is a decision support tool for Multi-Criteria Evaluation. A decision is a choice between alternatives (such as alternative actions, land allocations, etc.). The basis for a decision is known as a criterion. In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective. For example, a decision may need to be made about what areas are the most suitable for industrial development. Criteria might include proximity to roads, slope gradient, exclusion of reserved lands, and so on. Through a Multi-Criteria Evaluation, these criteria images representing suitability may be combined to form a single suitability map from which the final choice will be made. Based on the potential behavior of the local population towards land-use development four factors were selected in this study; distance from major roads, distance from existing built up areas and slope,flow accumulation and flow direction were collected. These data was collected; the road digitized from aerial photo of 2014, slope, flow accumulation, flow directions are obtained from DEM (30x 30 resolutions) of Adama city.

Araya and Cabral (2010) described three fuzzy standardization functions in order to design criteria for factors to be used in a decision rule. These were sigmoid, J-shaped, linear functions and user defined with adjustable settings. Based on this principle, factors in this study were standardized and categorized and user defined fuzzy was selected. The following table describes the membership functions used for standardizing the variables.

Table 4.4: Fuzzy Module and Criteria standardization of variables

Factors	Control point
Distance from built up area	0 and 9036m

Distance from road	0and 7939m
Distance from stream	30 and 1000m
Slope	0 to 20 degree
Distance from channel	100 to 500m

4.9. Calibration

Calibration is used to adjust the overall numeric characteristics of an image to match an external standard. This is often used to reduce the effects of sensor differences when comparing images from two dates. Three options are provided to adjust the image to match the character of a reference image; adjust the image using user-defined offset and gain values or adjust the image to have user-defined mean and standard deviation values. Firstly, six calibration periods, *i.e.* 1973-2000, 1973-2010 and 2000-2010, were considered and correspondent simulation results were pre-analyzed in terms of goodness of fit. Results showed that the period 1973-2000 was more capable to simulate the future changes of land. Therefore, in this study, calibration data over the period 1973-2000 was used to extract transition probability matrix.

4.10. Change Prediction and Validation

Markov chain models are relatively simple and more powerful to model complex processes and changes in land use for planning purposes. They provide better information for analyzing time series of system evolution (Levinson and Chen, 2005). A Markovian process is one in which the state of a system at time t2 can be predicted by the state of the system at time t1given a matrix of transition probabilities from each cover class to every other cover class. A stationary property is one of the importance's of these models since it integrates a transition probability matrix. This property is critical to Markov chain model especially for future predictions of land use. The stationary of the transition matrix in turn helps to inspect the validity of the model (Iacono et al, 2012). The MARKOV module in IDRISI can be used to create such a transition probability matrix (Eastman, 2012).

A random process, $X(t)$, is a Markov process if for any moment in time, $t1 < t2 < \cdots < tn < tn + 1$ (St.Petersburg, 1907). The random process satisfies where: tn is the present time so that $tn + 1$ represents some points in the future and $t1$, $t2$, ·….. , $tn - 1$ represent various points in the past.

Based on the present data, future is independent of the past. In other words, future of random process depends neither only on where it is now nor on how it got there (S. L. Miller and D. Childers,2004) If $X[k]$ is a Markov chain with the states $\{x1, x2, x3, \cdots\}$, then probability of transition from the state *i* to the state *j* in one time instant is, $P_{i\,j=}$ pr(x[k+1]=j/x[k]=i)(Eastman, 2003).CA-Markov in IDRISI program involves two techniques, *i.e.* Markov chain analysis and cellular automata. Cellular automata underlie dynamics of the change events based on proximity concept so that the regions closer to existing areas of the same class are more probable to change to a different class. A cellular automaton is a cellular entity that independently varies its condition based on its previous state (according to a Markov transition rule) and adjacent neighbors (Eastman, 2003).

At this last stage, the model is run for change prediction to a specified future date for the allocation of land cover changes (Eastman, 2006). The default procedure, Markov Chain analysis, has been run for this study to determine the amount of change using two land cover maps (1973 and 2000) along with the date specified. The procedure determines exactly how much land would be expected to transition from the later date (1973) to the prediction date (2010) based on a projection of the transition potentials into the future and creates a transition probabilities file.

In the Change Allocation panel, which used to predict future scenarios, there are two basic models of change are provided. These are a hard prediction model and a soft prediction model. Because the soft prediction yields a map of vulnerability to change for the selected set of transitions, it is preferred to be used in this study. Thus, a map for 2010 of study area has been simulated in order to compare with the ‘actual’ land cover map of 2010. Finally, the validation panel which allows determining the quality of the prediction land use map in relation to a map of reality. It has been evaluated by running a 3-way cross tabulation between the later land cover map (a map of 1973), the prediction map (simulated map of 2010), and a map of reality (actual map for 2010). Pinto et al (2009) showed that the overall quality of land cover maps generated from model simulations should be evaluated using kappa statistics parameter. Modeling of land use and land cover changes for future time is important to know the possible scenarios. In the case of Adama Area, in order to model for future time the following assumptions were set. The modeling process for the year 2040 was depending on the assumption that the nature and developments in Adama city stayed similar to the transitions of land use and land cover changes between 1973 and 2010.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1. Classification Results and Validation

The land cover maps generated after running supervised classification as well as a post classification algorithm are presented in Figure 5.1-5.3 below. Land use land cover maps derived from classification of images usually contain some sort of errors due to several factors that range from classification techniques to methods of satellite data capture. Hence, validation of classification results is an important process in the classification procedure. It allows users to evaluate the utility of a thematic map for their intended applications.

Because classified land cover maps from remotely sensed images contain various types of errors, it is the responsibility of the researcher to find out those errors so as to make the produced land cover maps become reliable and easily interpretable by users. Once the classified image is integrated into a GIS, to become an information source for urban planners and researchers, accuracy assessment should be processed as it limits the classification results of a remotely sensed imagery data. To do so, the accuracy of a classified map has to be assessed and compared with a referenced data using an error matrix. The accuracy assessment in this study was made using the original mosaic image for 1973, 2000 and 2010.

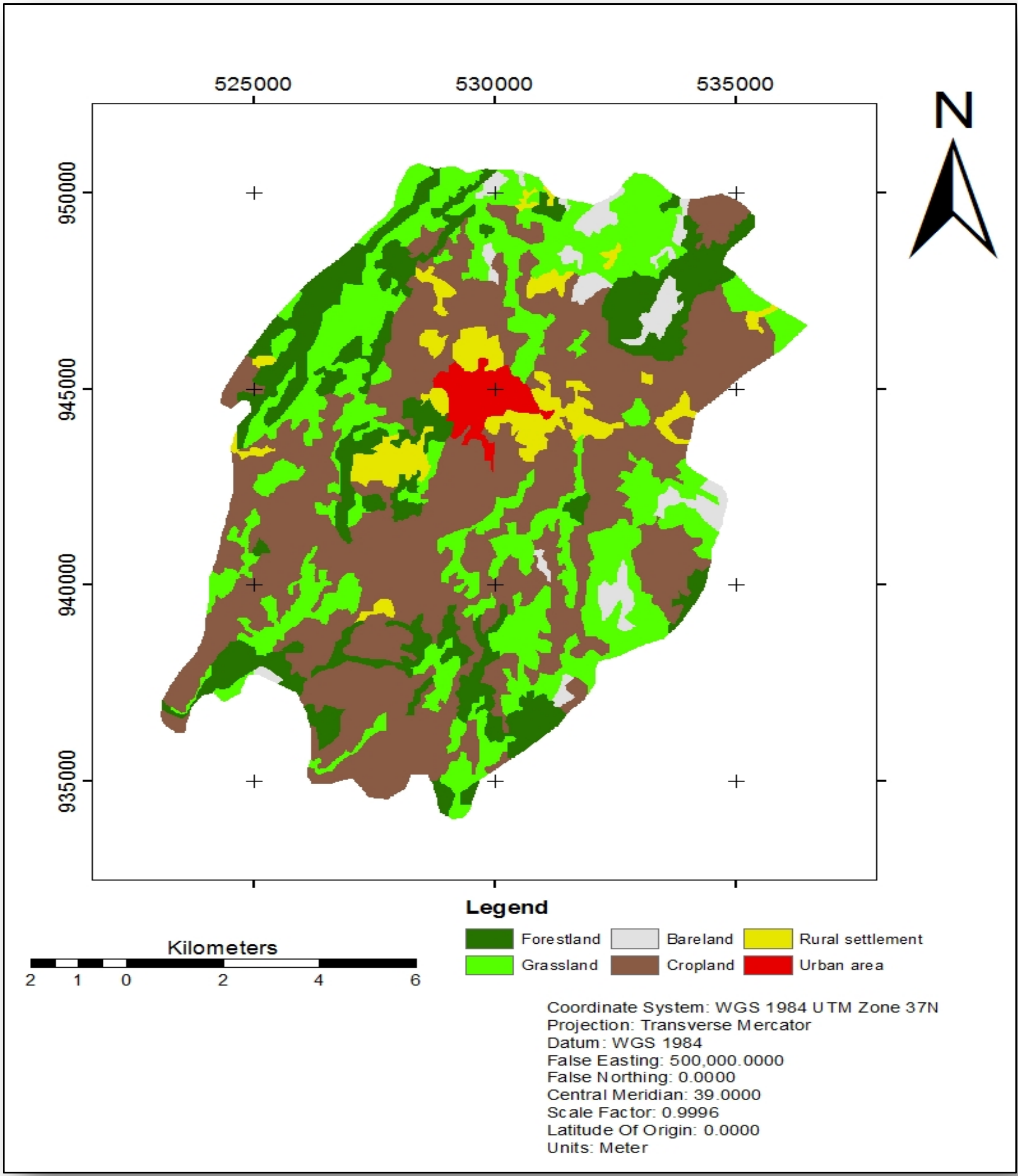


Figure 5.1: Land cover map of study area in 1973

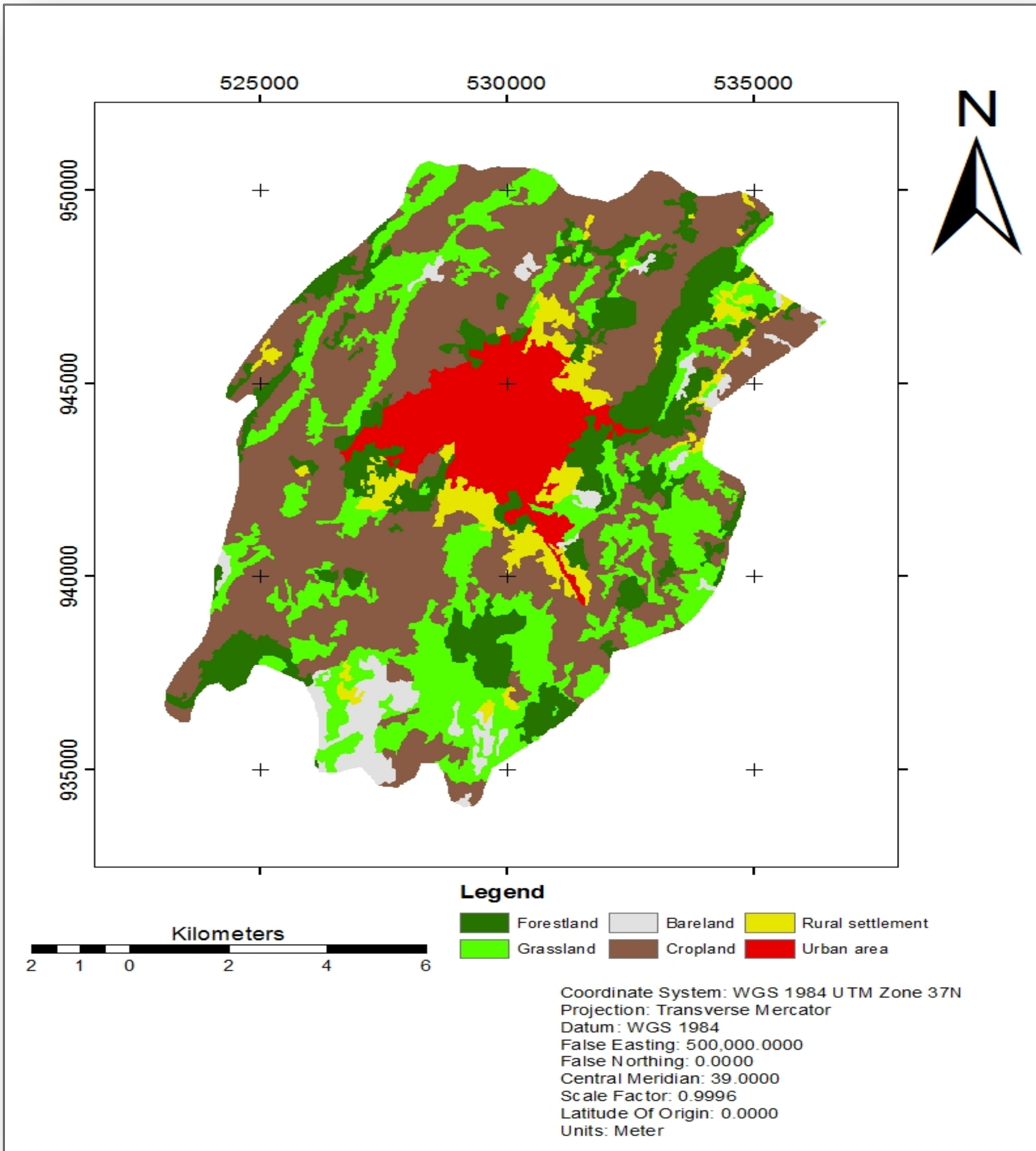


Figure 5.2: Land cover map of study area in 2000

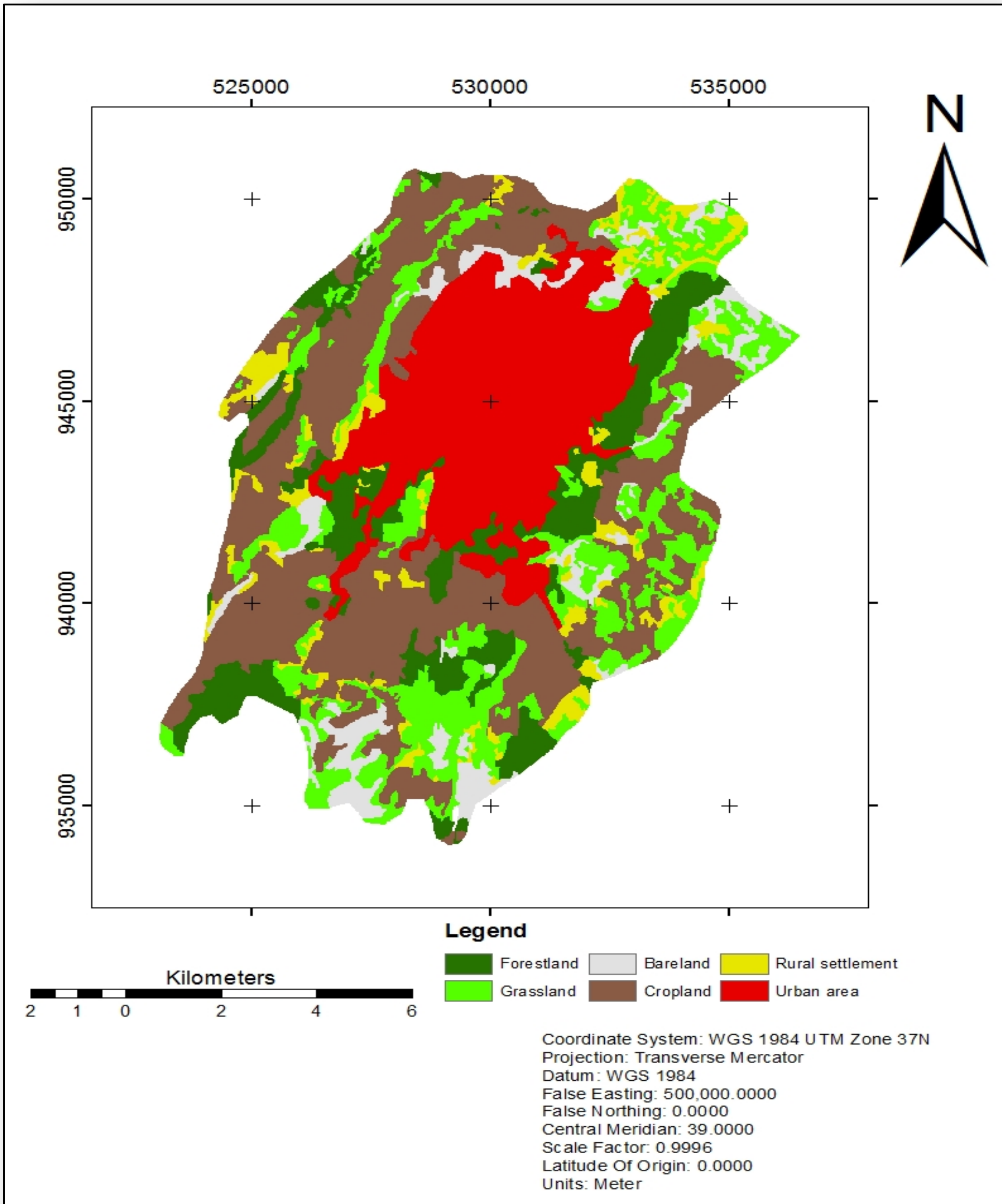


Figure 5.3: Land cover map of study area in 2010

5.1.1. User's Accuracy

Users accuracy refers to the number of correctly classified pixels in each class (category) divided by the total number of pixels that were classified in that category of the classified image (row total). It represents the probability that a pixel classified into a given category actually represents that category on the ground. Results of user's accuracy in this study showed that in 1973 the maximum class accuracy was 96%, which were forestland and bareland where correctly classified and the minimum was grassland class with an accuracy of 68.42% as presented in table 5.1 below. In 2000, the class accuracies range from 76.47% to 94.2% where as in the period 2010, it ranges from 82.35% to 95.5%.

The lowest values of class accuracies were misclassified due to spectral property similarities among other land cover classes. As shown from tables 5.1, 5.2 and 5. 3, the user's accuracy was lowest for grassland in the period of 1973 (68%), for the periods of 2000 and 2010, rural settlement was the lowest by 76.47% and 82.35% respectively. Moreover, the time of image acquisition has a great role for such misclassification problems. In addition to this, the spatial resolution of Landsat data could have an influence on the image classification. According to Zhou et al (2009) for detailed urban land cover mapping at very fine scales, high spatial resolution imagery from satellite sensors such as IKONOS and Quick Bird become more accurate.

5.1.2. Producer's Accuracy

Producer's accuracy refers to the number of correctly classified pixels in each class (category) divided by the total number of pixels in the reference data to be of that category (column total). This value represents how well reference pixels of the ground cover type are classified. As showed in the following highest values were in table 5.1, cropland 93% and in table 5.2, in table ural settlement were 100%.

Table 5.1: Confusion matrix for land cover map of 1973

	Land cover classes	Reference Map							
		Forest land	Grass land	Bare land	Crop land	Rural settlement	Urban area	Total	User's accuracy
Classified Map	Forest land	24	1	0	0	0	0	25	96%
	Grass Land	5	13	0	0	1	0	19	68.42%
	Bare land	0	0	27	0	1	0	28	96.4%
	Crop land	0	0	3	62	1	8	74	83.78%
	Rural settlement	0	0	0	2	14	0	16	87.5%
	Urban areas	0	0	0	3	0	45	48	93.75%
	Total	29	14	30	67	17	53	210	
	Producer's accuracy	82.2%	92.8%	90%	93%	82.35%	84.9%		
	Over all accuracy:					**88.09%**			

Table 5.2: Confusion matrix for land cover map of 2000

	Land cover classes	**Referenced Map**							
		Forest land	Grass land	Bare land	Crop land	Rural settlement	Urban area	Total	User's accuracy
Classified Map	Forest land	26	3	0	0	0	0	29	89.6%
	Grass land	1	13	0	0	0	0	14	92.8%
	Bare land	0	0	27	3	0	0	30	90%
	Crop land	0	0	0	63	0	4	67	94.2%
	Rural settlement	0	1	2	1	13	0	17	76.47%
	Urban area	0	0	0	7	0	46	53	86.79%
	Total	27	17	29	74	13	50	210	
	Producer's accuracy	96.2%	76.4%	93.1	85.1%	100%	92%		
	Over all accuracy:					**89.52%**			

Table 5.3: Confusion matrix for land cover map of 2010

Classified map	Land Cover classes	Referenced Map							
		Forest land	Grass land	Bare land	Crop land	Rural settlement	Urban area	Total	User's accuracy
	Forest land	27	2	0	0	0	0	29	93.1%
	Grass land	1	12	1	0	0	0	14	85.7%
	Bare land	0	0	26	4	0	0	30	86.67%
	Crop land	0	0	0	64	0	3	67	95.5%
	Rural settlement	0	1	2	0	14	0	17	82.35%
	Urban land	0	0	0	5	0	48	53	90.5%
	Total	28	15	29	73	14	51	210	
	Producer's accuracy	96.45%	80%	89.6%	87.67%	100%	94.1%		
	Over all accuracy :					**90.95%**			

5.1.3. Overall Accuracy

It is computed by dividing the total number of correctly classified pixels (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels. It shows overall results of the tabular error matrix. The overall accuracies performed in this study period 1973 were 88.09% (table 5.1), in 2001 was 89.52% (table 5.2) and during 2010 it was 90.95 % (table 5.3). As mentioned by Anderson et al (1976) for a reliable land cover classification, the minimum overall accuracy value computed from an error matrix should be 85%. However, Foody (2002) showed that this baseline makes no sense to be a universal standard for accuracy under practical applications. This is because a universal standard is not exactly related to any specific study area. Foody (2002) also noted that Anderson et al (1976) do not explain in detail about the criteria of map evaluation for universal applications. Moreover, Lu et al (2004) noted that the accuracies of change detection results highly depend on many factors, such as: availability and quality of ground truth data, the complexity of landscape of the study area, the change detection methods or algorithms used as well as classification and change detection schemes. So, the overall accuracies for all maps were above 85% based on Anderson's criteria.

5.2. Land use land covers changes and its descriptive statistical analysis

The classified images were quantified and the results are presented in table 5.4, for the three study periods. The change in hectares and in percentage of individual class area is also presented. As shown from figure, there has been an increase of built up areas with values 2% of the study area in 1973 to 9.6% in 2000 to 23% in 2010. Bare land has been increased between study periods as shown in the table. It increases 3.4% in 1973 to 3.8 % in 2000 to 6.7% in 2010and rural settlement 5.3% 1973 to 5.2 % 2000 (decreased), 5.2% 2000 to 6% 2010 and 6%2010. As shown below crop land decreases from 1973-2010, 3% 1973 to 2000, 9.8 % 2000 to 2010. Forest land and grass lands were decreases between the study periods. This shows that the increasing of built up area. Forest lands decreases 16.1% in 1973 to 15.3 % in 2000, 15.3% in 2000 to 12.8% in 2010 and also grass land, 26.8% to 22.7% to17.9% between 1973 -2010.

Table 5.4: Percentages of land use/land cover in Adama City (1973-2010)

	1973		2000		2010	
LU/LC type	Ha.	%	Ha.	%	Ha.	%
Forestland	2188.9	16.05	2086.6	15.3	1747.9	12.81
Grassland	3658.1	26.83	3091.44	22.67	2438.9	17.89
Bareland	465.24	3.41	521.2	3.82	916.84	6.72
Cropland	6332.3	46.44	5917.9	43.4	4575.5	33.56
Rural Settlement	718.9	5.27	710.2	5.21	816.3	6
Urban area	271.8	2.00	1307.9	9.6	3139.8	23.02
Total	13635.24	100	13635.24	100	13635.24	100

5.3. Land cover changes of Built up areas

The increment in infrastructure development of Adama City from time to time has played a major influence for the expansion of built up areas. The main focus of this study was assessing and examining the spatial extents of built up areas within the four study periods. To achieve this, a reclassification was made to generate land use and land cover maps of built up and non built up areas as shown in figure 5.4, 5.5 and 5.6 below. As clearly seen in table 5.4, the proportion of built up areas in 1973 was 2% of the entire study area. In 2000 the percentage of the built up area is 10% the entire area a, which is 8% more than before. For the periods of 2010 was 23% of area coverage.

Table 5.5: Built and non built-up areas (1973- 2010)

Land cover classes	1973		2000		2010	
	Area(ha)	%	Area(ha)	%	Area(ha)	%
Built up area	271.84	2%	1307.88	10%	3139.77	23%
Non built-up area	13363.4	98%	12327.36	90%	10495.47	77%
Total	13635.24	100	13635.24	100	13635.24	100

The study area has experienced spatial increase of different land use and land cover classes such as; built up areas, due to the corresponding horizontal expansion as well as conversion of land cover classes during the distinct study periods. The reclassified images in figure below (5.4, 5.5, and 5.6) showed that there had been a rapid land cover change from non built up areas to built up areas. In this study periods, crop land areas were the most dynamic classes which contributed to the increase of built up areas. There was a huge increase of built up areas from 1973 to 2010(2% - 23% of study area).

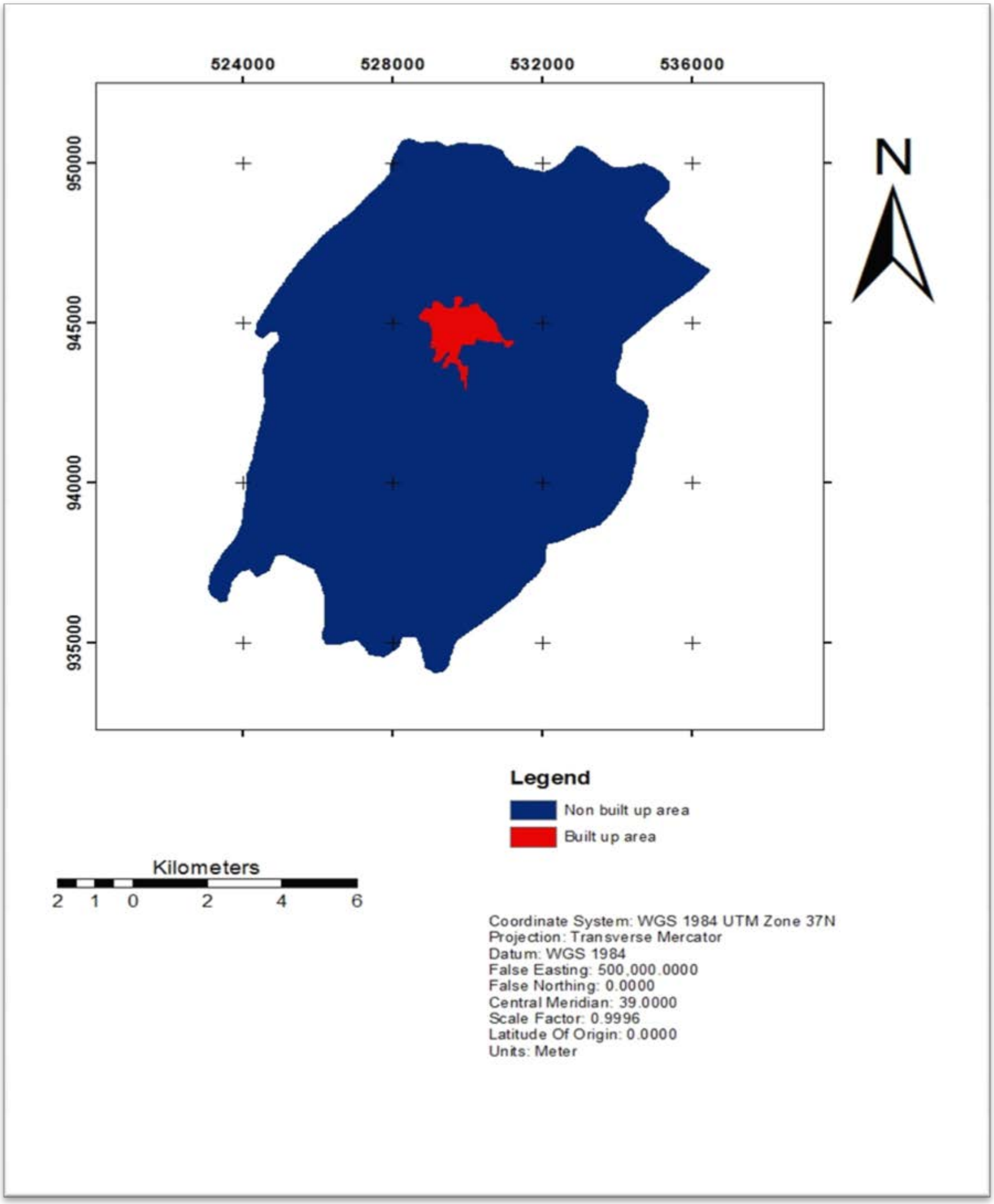


Figure5.4: Built up and Non built Landcover Map of Adama City(1973)

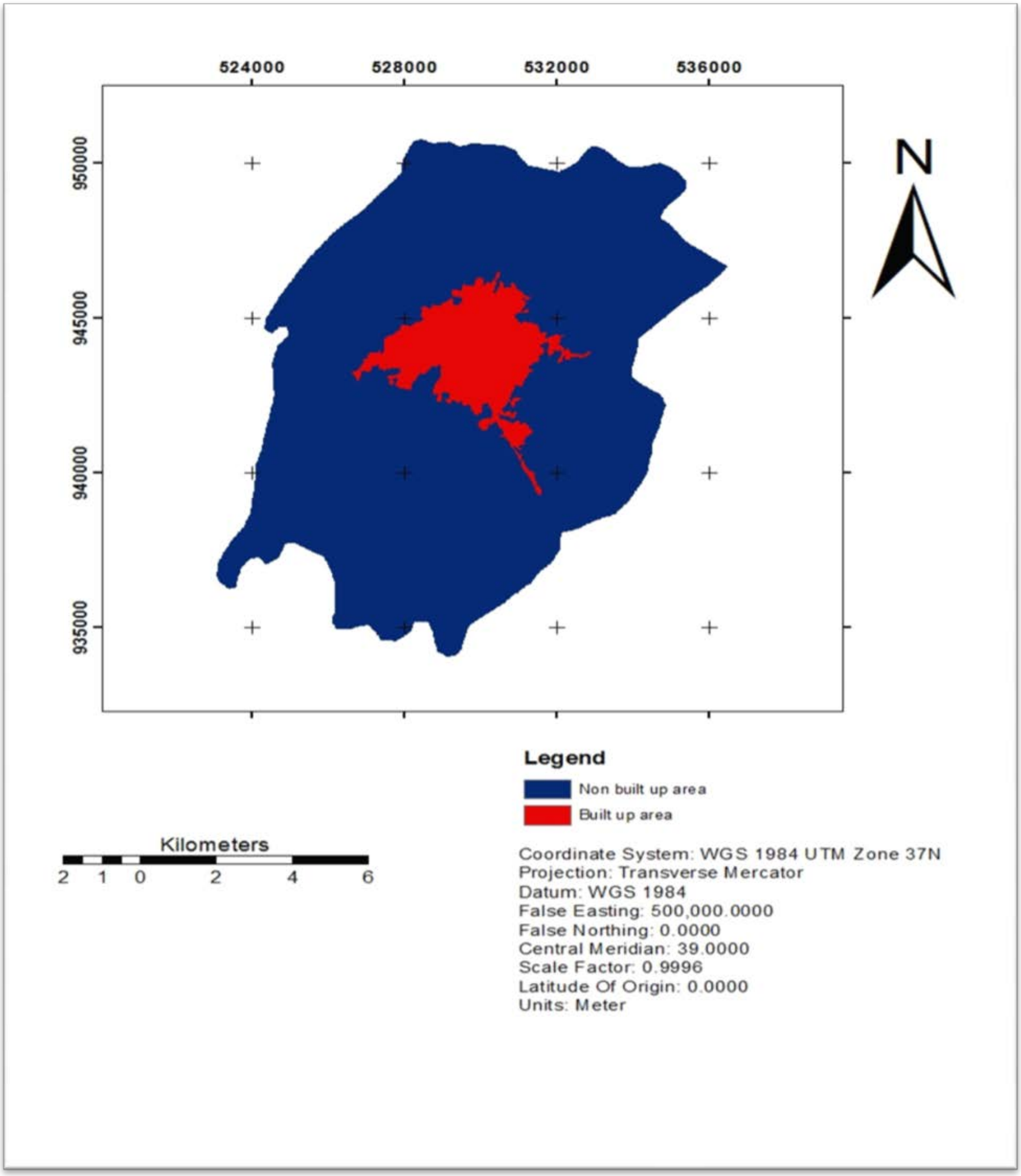


Figure 5.5: Built up and Non built Landcover Map of Adama City (2000)

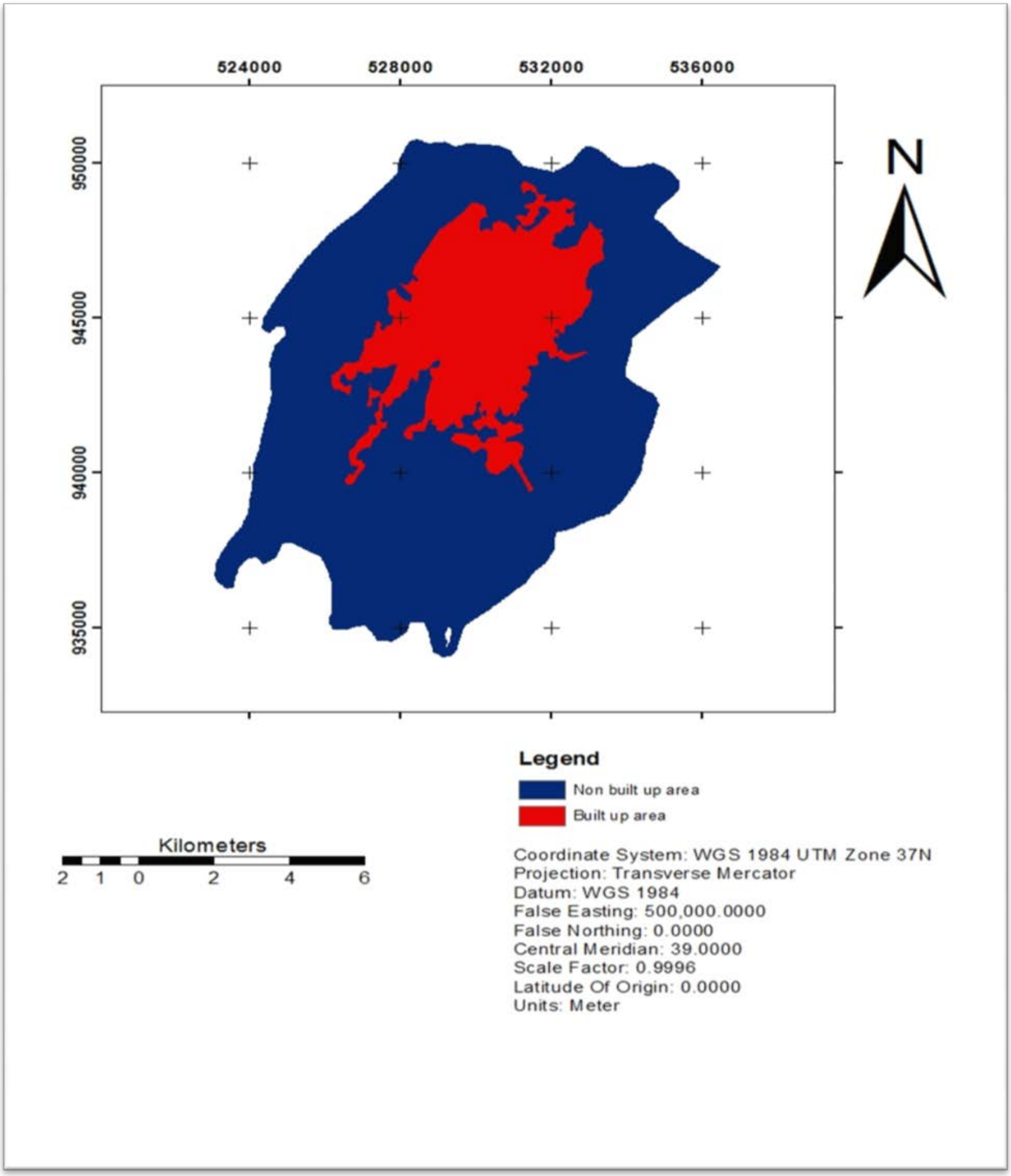


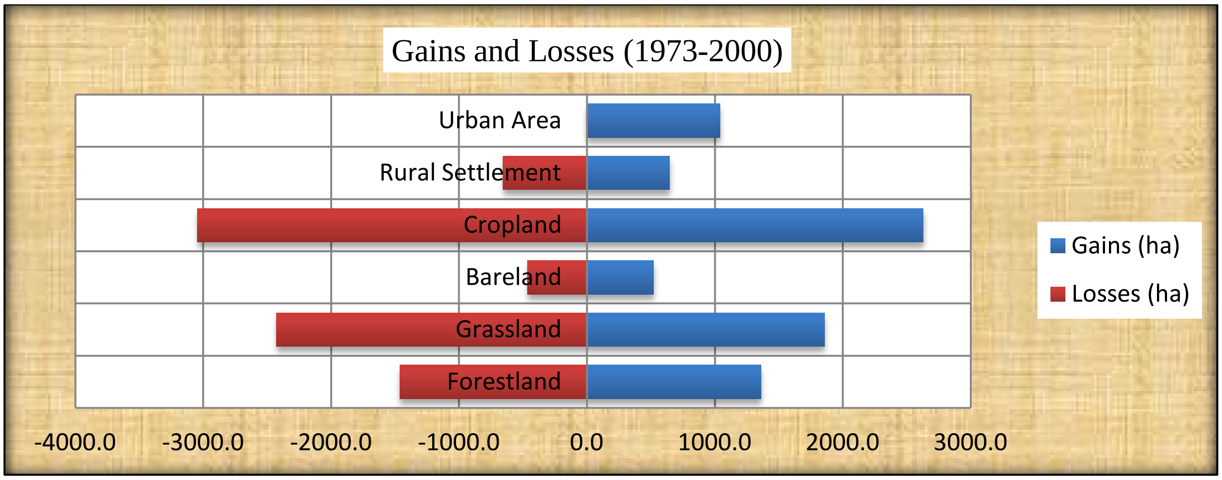
Figure 5.6: Built up and Non built Landcover Map of Adama City(2010)

5.4. Land Use Land Cover Change Analysis by Gains and losses

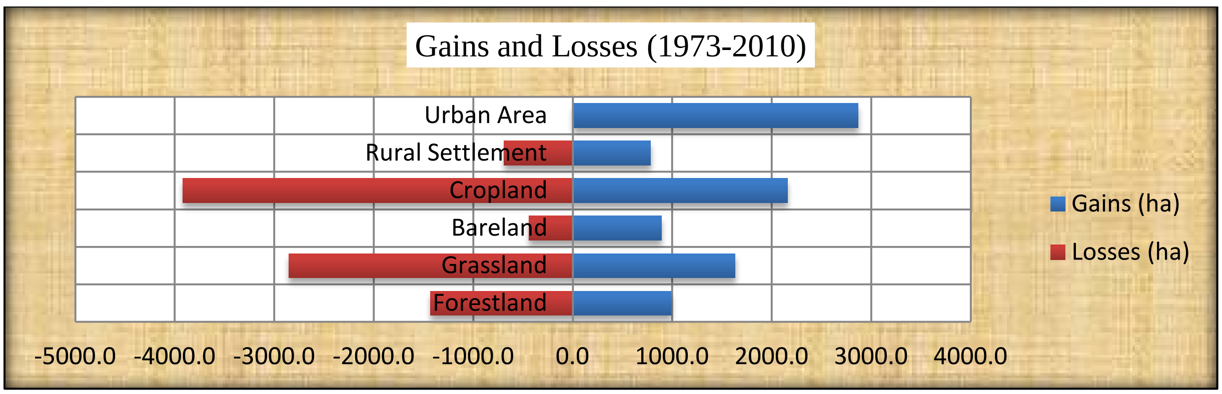
The results of the cross-tabulation comparison of both land use and land cover maps in figure 5.7 below showed that there have been marked changes in all land use and land cover classes between 1973, 2000 and 2010. During the period 1973 - 2000 the total built up areas increased by 1040.3ha gains (representing an increase of 7.63 % of the total study area) and lost 4.2 ha (0.03 % of the study area) and net change 1036 ha (7.60 %), While rural settlement decreased 654.4 ha (4.79% of the total study area) and gained 645.8 ha with a net loss of 8.6 ha. Similarly cropland lost 3043.4 ha (22.32%) and gained 2629 ha (19.28%). Bareland increases by 521ha (increasing of 3.82%), loss of 465.1 ha (decreasing of 3.411%) and net change 55.9 ha increasing of 0.4%. Forestland decreases by loss of 1462.7 ha (10.72%) and gain 1360.4 ha (9.977%). Similarly grassland decreases by loss of 2425.1 ha (17.78%) and gain 1858.5 ha (13.63%).

The built up areas have also continued to increase with a gain of 1876.4 ha (13.76% of study area) and loss of 44.5 ha (0.33%) and net change of in the period 2000-2010 shown in figure 5.7c. Cropland decreased by loss of 3034.9 ha (22.26%), gains1276.2 ha (9.24%) and net change loss of 1758.7 ha (12.89%). Similarly the consistent increase of rural settlements and bareland areas has been also seen in this time with a gain of 756.5ha (5.548%) and 668.5 ha (4.90%) respectively. But forestland and grassland decreases by loss of 1168.4ha (8.57 %) and 2430ha (17.82%) respectively.

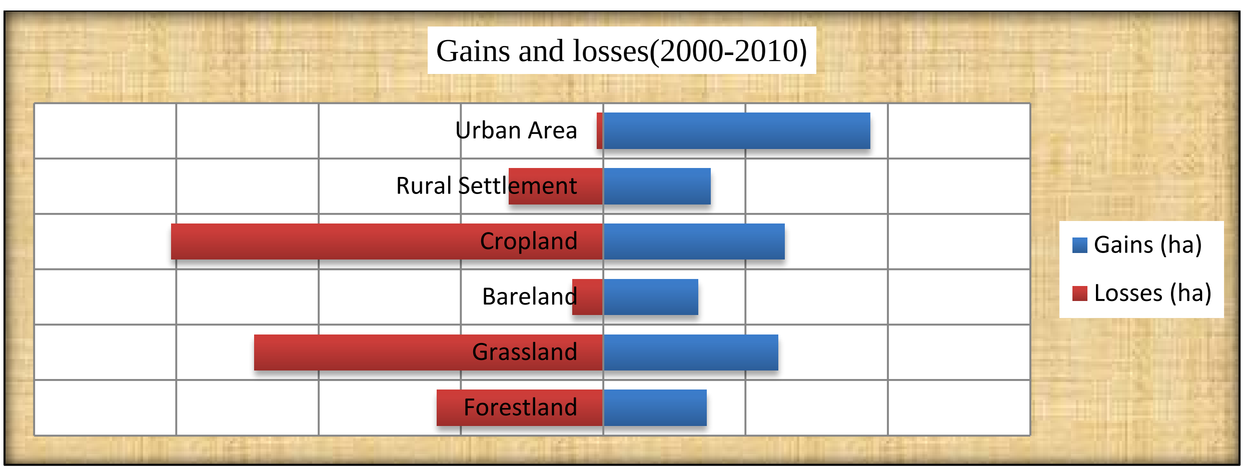
From figure 5.7, the overall changes occurred for the last 37 years in built up areas have shown an increase by gains 7.63 % to 13.76% to 11.59% without loss, whereas cropland areas have lost of 22.32% to 22.26% and gain 20.45%. Bareland increases by gains of 3.82% to 4.90% to 11.59% without loss. Rural settlement have loss of 4.79% to gains (5.548%) to gains 5.41%, forestland have loss of 10.72% to 8.57 %) to 9.56% without gains and grassland decreased by losses 17.78% to 9.56% to 17.34% without gains.



a)



b)



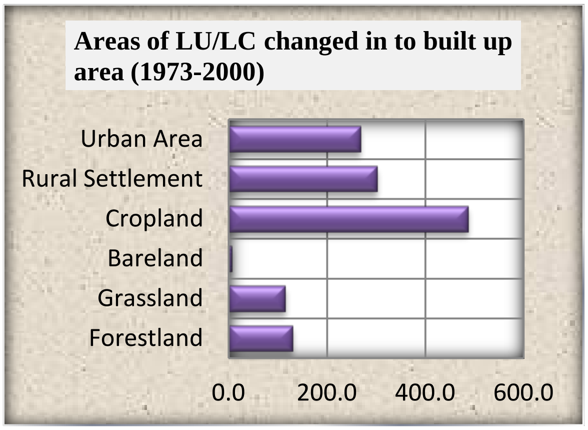
C

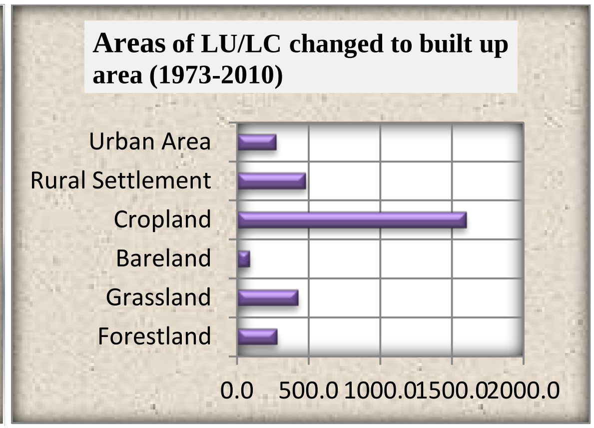
Figure 5.7 Gains and losses between1973-2010

5.5. Contribution of Land use Land Covers Classes to Urban Area

The land cover changes between the study periods were quantified by using differences from the late periods to early study periods. Table 5.8 below shows the changes that have been seen in the past three distinct study years.

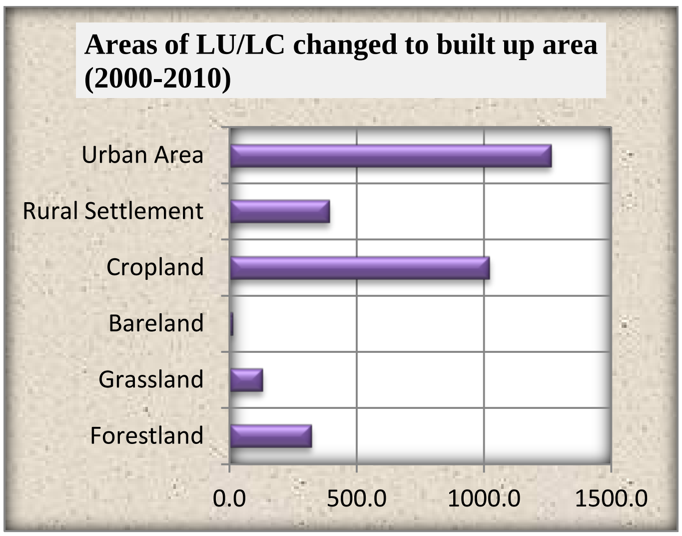
The contributions of other LU/LC to urban areas are presented in figure 5.8 below. It has been clearly shown that cropland areas contribute the majority of the total increase in built up areas (486.7 ha), which represents about 37.2% of the entire urban area in 1973-2000 as indicated in figure 5.8 a. Next to cropland areas, rural settlements take the second contribution to total increase in built up areas by about 301.8 ha (23.1% of the urban area). Next to rural settlement, forestland takes the third contribution to urban area by 129.6 ha (9.9% of the urban area). At the last grassland contribute 115.2 ha (8.8% of the Urban area) and bareland contribute only 7ha (0.5% of the Urban area). As indicated in figure 5.8C (2000-2010) cropland areas were also continued contributing a majority of about 1021.4ha (32.53% of Urban area), rural settlement has the second contribution by 391.72ha (12.48% of Urban area), forestland has the third contribution by 321.36ha (10.23%). Finally grassland and bareland have the less contribution by 130.04ha (4.14%) and 11.92ha (0.38%) respectively.





a) 1973-2000

b) 1973-2010



C 2000-2010

Figure.5.8: Land use land cover changed to built up areas.

5.6. Net Changes of Land Use land Cover of 1973-2010

Net change is the percentage of the difference of gain and loss to total study area. From the table 5.10: urban areas increased through all study periods 7.6% (1973-2000) and13.44% (2000-2010) Crop land which highly contribute to urban area decrease in net change of loss of 3.03% (1973-2000) and 12.89% (2000-2010). Bare land increase 0.4%(1973-2000) to 3.3%(2000-2010) to, grassland decrease from 4.15%(1973-2000) to 8.94%(2000-2010) to, forestland decreases from 0.75%(1973-2000) to 3.23%(2000-2010) and rural settlement has net change loss 0.06% (1973-2000) to net gain 0.69% (2000-2010).

Table 5.6: Net changes of land use/land cover change in Adama Area (1973 – 2010)

Land cover classes	Change 1973-2000		Change 2000-2010	
	Area (ha)	%	Area (ha)	%
Forestland	-102.3	-0.75	-441.5	-3.23
Grassland	-2322.8	-17.3	-1219	-8.94
Bareland	55.9	0.40	451.5	3.3
Cropland	-414.4	-3.03	-1758.7	-12.898
Rural Settlement	-8.7	-0.06	94.3	0.69
Urban Area	1036.	7.79	1831.9	13.43

5.7. Markovian Conditional Probability Land Covers Prediction

In Markovian processes the future state of a system in time t_2 can be modeled/predicted based on the immediate preceding state; time t_1. Therefore, the future state can be predicted not based on the past but rather the present. Here the past and future are independent [Eastman, 2009]. Firstly, two calibration periods, *i.e.* 1973-2000 and 2000-2010 were considered and correspondent simulation results were pre-analyzed in terms of goodness of fit. Results showed that the period 1973-2000 was more capable to simulate the future changes of land. Therefore, in this study, calibration data over the period 1973-2000 was used to extract transition probability matrix. Then two types of criteria (constraints and factors) were developed to determine which lands are suitable for future development. Analytic Hierarchy Process (AHP) was used to determine the weights of driving factors. AHP is a measurement theory founded on expert judgment to drive priority scales using pair wise comparisons (Saaty, 1980). Markov chain produces a transition matrix (Table 4.8), a transition areas matrix (Table 4.9) and a set of conditional probability images by analyzing two qualitative land cover images (Figure 5.9) from two different periods (1973 and 2000).

The matrix of transition probabilities (Table 5.7) shows the probability that each land cover category will change to other categories in 2010. Table 5.8 represents the number of cells/pixels (30 m × 30 m) that will be transformed over time from one land cover type to other types. Markov Chain Analysis also produces related conditional probability images (Figure 5.9) with the help of transition probability matrices. These images are called conditional because the probability is conditional to the current state. These maps/images, which have been projected from the two previous land cover images, are useful for future prediction of land cover change. Each conditional probability image shows the possibility of transitioning to another land cover class.

Table 5.7: Markov probability of changing among land cover types

Land cover classes	Forest land	Grass land	Bare land	Crop land	Rural settlement	Urban area
Forest land	0.373	0.2981	0.0161	0.2557	0.0170	0.0488
Grass land	0.1449	0.3663	0.0210	0.4197	0.0505	0.1176
Bare land	0.2643	0.1089	0.0200	0.4295	0.1066	0.0107
Crop land	0.0820	0.1746	0.0663	0.5437	0.0753	0.4591
Rural settlement	0.2215	0.0108	0.0159	0.2404	0.1185	0.4038
Urban area	0.0168	0.0064	0.0060	0.0558	0.0100	0.9734

Table 5.8: Cells Expected to Transition to Different Classes

Land cover classes	Forest land	Grass land	Bare land	Crop land	Rural settlement	Urban area
Forest land	19538	15557	840	13346	366	2657
Grass land	11429	28322	1625	32456	3135	1358
Bare land	3418	1431	7	8215	76	12
Crop land	12134	25841	9667	80471	11241	8751
Rural settlement	3816	192	282	4269	1926	7280
Urban area	233	0	2	192	3	33246

After analyzing table 5.7, it is clear that most areas will convert into built up areas. The Markovian conditional probability of being built up area ranges up to 0.9734 which is the highest among all the land cover types. This probabilistic prediction is dependent upon the past trend of the last 10 years (1973-2000). From change detection analysis, it is found that most areas are being converted to builtup areas whereas the Markovian conditional probability images are also showing the same trend.

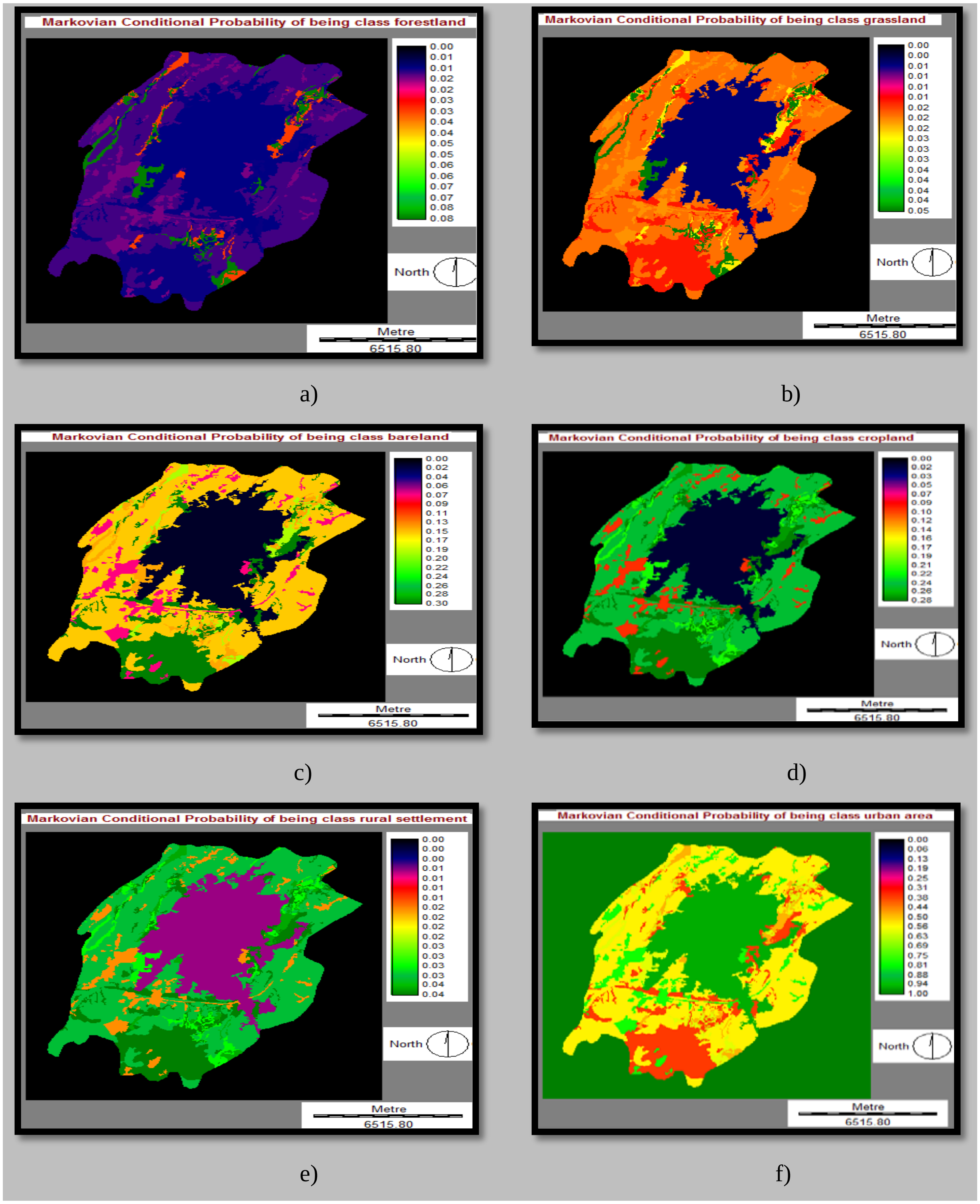


Figure 5.9: Transition maps of land cover classes to forestland (a), to grassland (b), to bareland (c), to cropland (d), to rural settlement (e) and to urban area (f) respectively.

5.8. Model Simulations and Validations

Results from Markov chain model simulations are based on a transition probability matrix of land use changes from time-1(1973) to time-2 (2000). This has become the basis for projection to another time period (2010). Figures 5.10c and 5.10d indicated the actual and simulated land cover maps of Adama City for the year 2010 respectively which showed visible differences. This had been expected as the historical change processes from 1973 -2000 and 2000-2010 cannot be the same in Markov chain analysis. In addition, constraints and driver variables (factors) created for defining the rules highly affected the simulation results as they are sensitive to small changes.

As shown in figure 5.10C much of crop land have been converted in to build up areas. Although there had been much expansion of built up areas, however, the conversion between other land cover classes was limited. For validation, the model's output is compared to a map of land use prediction with actual land use map of 2010. Thus, a three map comparison is required with two reference times and a simulated time. In this case the land cover maps considered were reference time 1 (1973), reference time 2 (2000) and the simulated map (2010). This helped to observe the changes between the years 2000, 2010 and to compare with the simulated map of 2010 with actual map of 2010 to distinguish whether the changes have been predicted correctly or not. Figure 5.10 below was created for showing a comparison of observed changes with predicted changes which identified four types of correctness and error which are; correct due to observed persistence. From figure below legends 1 stands for forest land, 2 for grass land, 3 for bare land,4 for crop land, 5 for rural settlement, 6 for urban area with the layer properties of reference system plane, reference units meters and integer data types because IDRISI 32 software accepts only integer type.

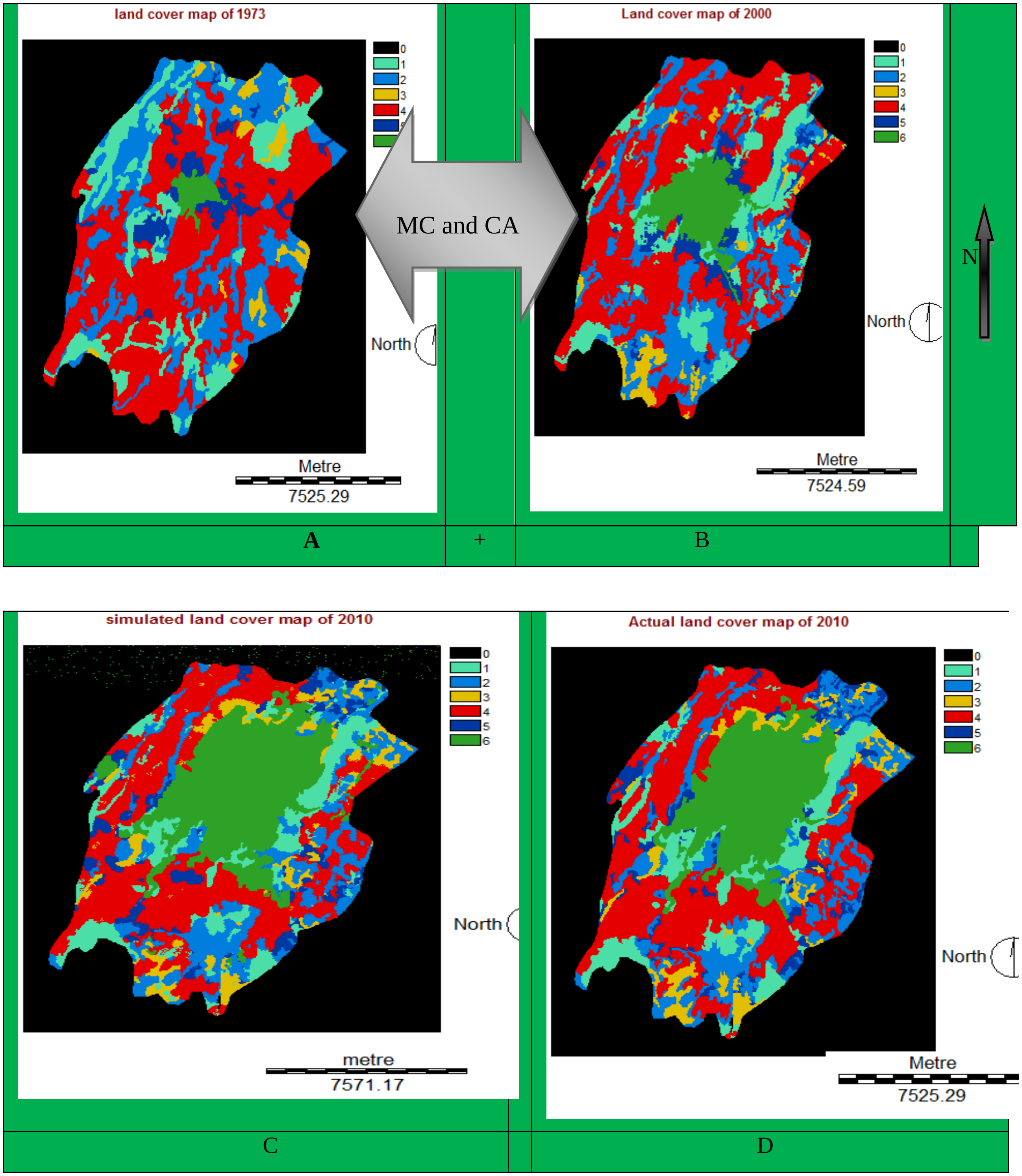


Figure 5.10: Land covers maps for 2010 actual (left) and simulated (right)

Table 5.9: Area percentages of actual and simulated map of 2010

Category	**Actual map of 2010**		**Simulated map of 2010**		Change in Area (%)
	Area(ha)	%	Area(ha)	%	
Forest land	1747.9	12.81	1648.1	12.11098	-0.7
Grass land	2438.9	17.89	2438	17.04345	0.7
Bare land	916.84	6.72	915	6.789489	-0
Crop land	4575.5	33.56	4580	31.56929	-0.1
Rural settlement	816.3	6	825	6.42249	0.0
Urban Area	3139.8	23.02	3151	26.0643	0.0
Total	13635.24	100	13624	100	0

Table 5.9 shows the per category change in area between the two maps. In the most ideal case, the change in area should be 0. The more the deviation, the less sophisticated is the model. In terms of area, it is clear that urban area, rural settlement, cropland and bareland a almost the same. But forest land has decreased, while grass land has increased. It meansforest land and grass land show unexpected results in case of quantitative analysis. This occurs because of time variations, especially in case of land use applications this is difficult to manage due to uneven temporal availability of satellite data. So in this study there was a 27 year gap between the first image acquisitions (1973-2000), however, due to unavailability of imagery data of similar period, the gap between the last two images was only 10 years (2000-2010). From this point it is evident that simulation results could have limitations as changes 1973-2000 and 2010-2010 may not proceeded in similar pattern.

The statistics given in the validation output allow the user to separate quantification error versus location error. Quantification error occurs when the quantity of cells of a category in one map is different than the quantity of cells of that category in the other map. Location error occurs where the location of a category in one map is different than the location of that category in the other map. Both the percent correct and the standard Kappa index of agreement confound these two types of errors. Thus, in addition to calculating the conventional standard Kappa index of agreement (KIA, also denoted Kstandard, in crosstab), Validate offers more statistics: Kappa for no information (Kno), Kappa for location (Klocation), Kappa for quantity (Kquantity), Value of perfect information of location (VPIL), and Value of perfect information of quantity (VPIQ).

All of these statistics are linear functions of the nine points given in the validate output (Pontius, 2000). Based on the above proposed suggestions, a cross-tabulation matrix and validation was computed by comparing the actual and simulated land use map of 2010 as shown below.

Table 5.10: Cross tabulation of actual land cover and simulated land cover map of 2010

Categories	KIA(When Actual land cover map was reference)	KIA(when simulated map was reference)
Forest land	0.2643	0.3392
Grass land	0.2947	0.506
Bare land	0.8842	0.8925
Crop land	0.8416	0.8891
Rural settlement	0.6409	0.5766
Urban Area	0.994	0.8870
	Overall Kappa	**0.884**

The result of KIA was very good for overall kappa for urban area, crop land and bare land moderate for rural settlement, fair for forest land and grass land. This variation occurs due to the temporal variations of satellite data. Kappa value < 0.2 is poor, 0.21-0.4 is fair, 0.41-0.6 is moderate, 0.61-0.8 is good and 0.81-1 is very good (Landis and Koch, 1977). In comparing the map of reality to the alternative map: Kno indicates the overall agreement. Klocation indicates the extent to which the two maps agree in terms of location of each category, given the specified quantities. Kquantity indicates the extent to which the two maps agree in terms of quantity of each category, given the specified locations. VPIL indicates the additional percent correct obtainable if the alternative map were to have perfect location given no change in its quantities of each category. VPIQ indicates the additional percent correct obtainable if the alternative map were to have perfect quantities given no change in its ability to specify location (Pontius, 2000).

Table 5:11 Validation of reference and simulated land cover map of 2010

Category	RefProp	SimProp	Klocation	VPIL
Forest land	0.0222	0.1189	0.3492	0.0322
Grass land	0.0442	0.0100	0.4056	0.0258
Bare land	0.0796	0.6698	0.7942	0.0068
Crop land	0.2597	0.2804	0.8891	0.0282
Rural settlement	0.3318	0.0347	0.3309	0.2113
Urban area	0.3288	0.1541	0.999	0.0003

Correct Chance	0.1429	Perfect Chance	0.1429
Correct Quantity	0.1918	Perfect Location	0.6641
Correct Location	0.5924	Perfect Quantity	0.1830
Error Location	0.0545	K no	0.9249
Error Quantity	0.0184	K location	0.9337
VPIL	0.0545	K quantity	0.9633
VPIQ	0.0169	K standard	0.884

The kappa coefficients of per category are showing high values from above results. This proves that the agreement between the two maps is substantial. Only forest land and grass land are showing less value than the average of the other categories.

5.8. Future Prediction

Using Markov chain analysis it is possible to determine the weights of the transitions that will be included in the matrix of probabilities of Markov Chain for future prediction. The transition probabilities are shown in Table 5.12. The input images are land cover map of 2000 and 2010 with the time difference of 10 years and 30 years.

Table 5:12 Markov Probability of Changing among Land Cover Types.

Land cover classes	**Forest land**	**Grass land**	**Bare land**	**Crop land**	**Rural settlement**	**Urban area**
Forestland	0.0116	0.0064	0.1406	0.2191	0.0318	0.5904

Grassland	0.0111	0.0071	0.1906	0.2685	0.0376	0.4850
Bareland	0.0107	0.0076	0.2970	0.2766	0.0391	0.3690
Cropland	0.0107	0.0064	0.1511	0.2470	0.0348	0.5501
Rural settlement	0.0102	0.0036	0.0744	0.0990	0.0177	0.7950
Urban area	0.0097	0.0018	0.0121	0.0150	0.0078	0.9536

Table 5.13: Cells Expected to Transition to Different Classes.

Land cover classes	**Forest land**	**Grass land**	**Bare land**	**Crop land**	**Rural settlement**	**Urban area**
Forestland	177	98	2142	3338	485	8995
Grassland	110	71	1891	2665	373	4813
Bareland	523	371	14506	13510	1910	18028
Cropland	1646	983	23310	38100	5369	84857
Rural settlement	228	80	1660	2209	395	17731
Urban area	881	163	1096	1356	705	86252

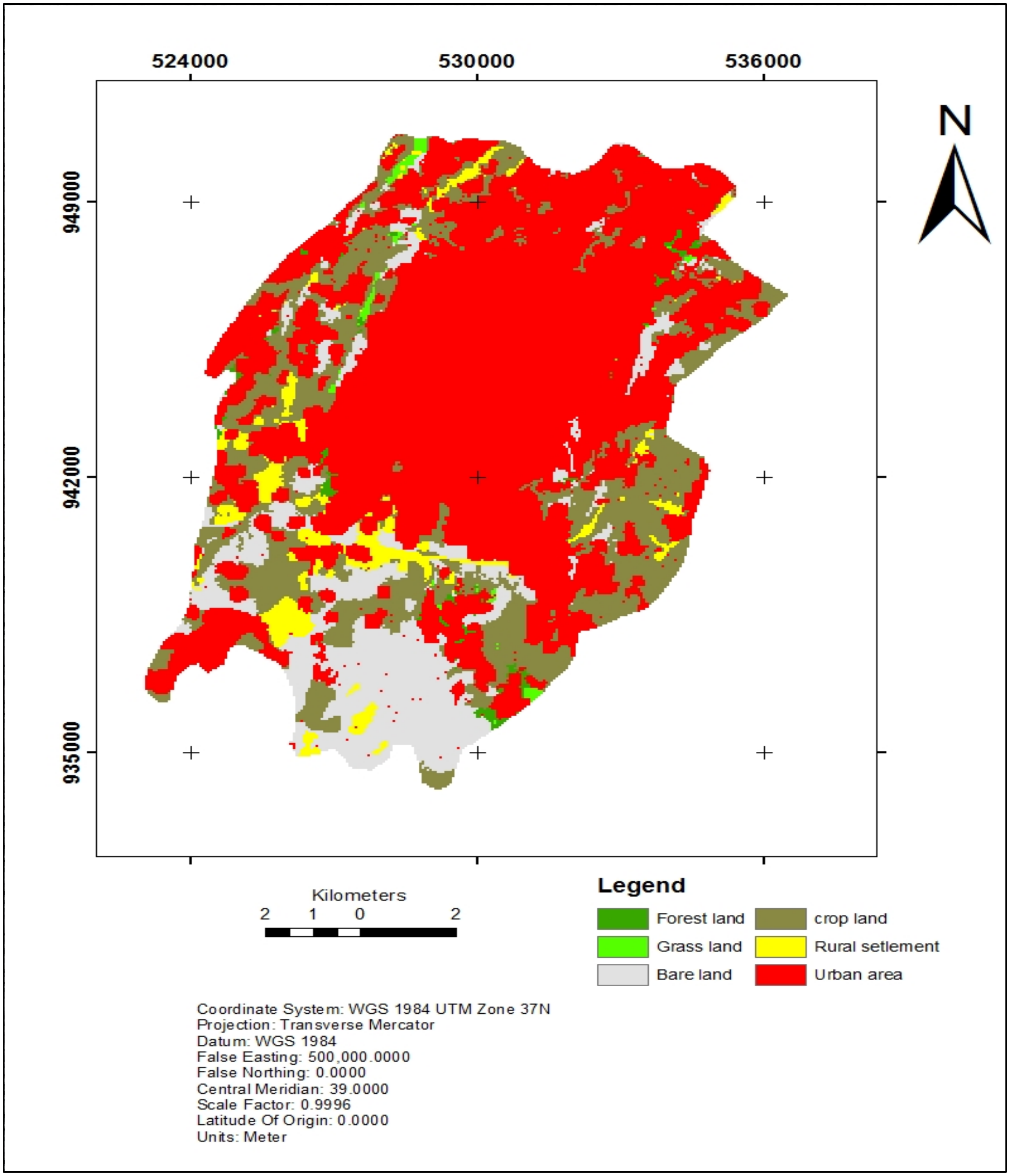


Figure 5.11: Predicted land cover map Adama City 2040

Table 5.14: Percentages of land use Land Cover Changes of actual map of 2010 and predicted map of 2040.

Land cover classes	**Actual map of 2010**		**Predicted map of 2040**		Change in Area (%)
	Area(ha)	%	Area(ha)	%	
Forest land	1747.9	12.81	104.44	0.77	-3.7
Grass land	2438.9	17.89	74.30	0.55	-2.36
Bare land	916.84	6.72	1804.30	13.23	-1.08
Crop land	4575.5	33.56	2875.4	21.09	-24.16
Rural settlement	816.3	6	554.8	4.07	-2.47
Urban Area	3139.8	23.02	8222.0	60.29	33.77
Total	13635.24	100	13635.24	100	0

As clearly seen in table5.14, the proportion of built up areas in 2010 was 23% of the entire study area. In 2040 the percentage of built up areas showed more than double increase and it was 60.27% of area coverage. Almost all land cover decreases from 2010 to 2040, especially crop land decreases 24.16% and forest land decreased by 3.7%, grass land and rural settlement decreased by almost the same ratio (2.36% and 2.47%) respectively and lastly bare land rarely decrease by 1.08% of the area coverage.

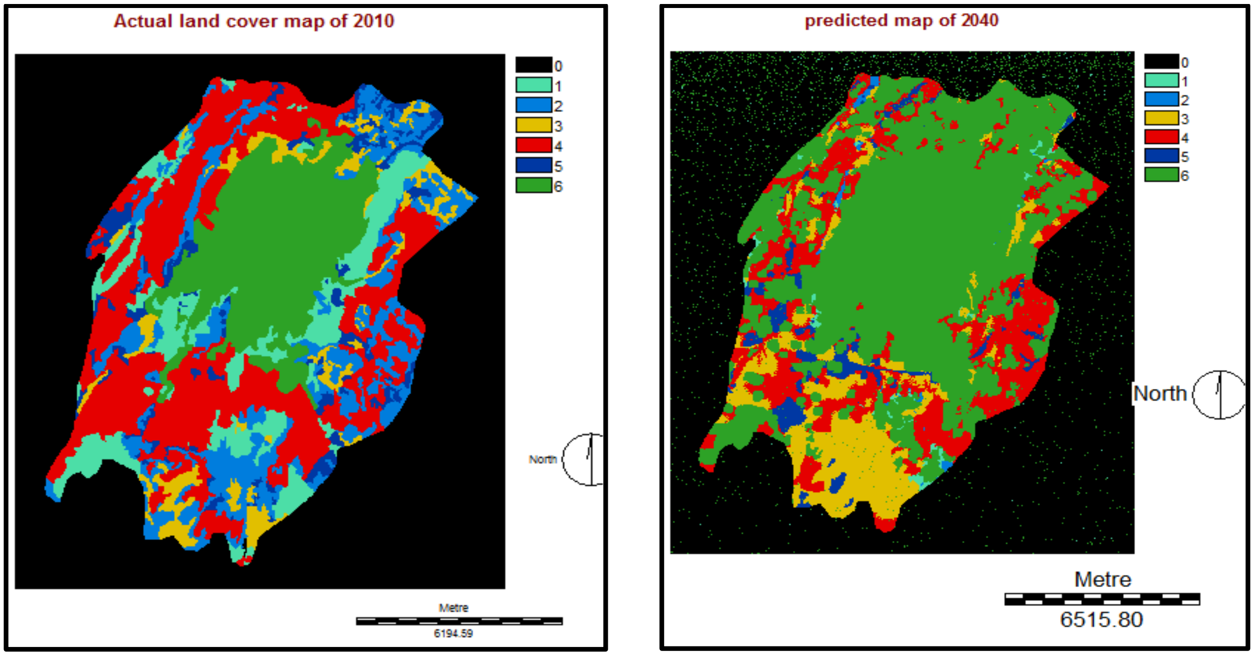


Figure 5.12 Land covers maps of 2010 actual (left) and predicted map of 2040 (right)

5.10. Gains and Losses by Land Use Land Cover Changes

Built-up area has increased over the years while there is slight loss in this category. It means some parts of the previously existed built-up areas have converted to some other land cover classes, while vast new area has transformed into built-up area from other classes. The results of the cross-tabulation comparison of both land use and land cover maps in table 5.15 below showed that there have been marked changes in all land use and land cover classes 2010 - 2040.

Table 5.15: Gains, losses and persistence (2010-2040)

	Persistence		Gains		Losses		Net Change	
Lu/Lc Type	ha	%	Area (ha)	%	Area (ha)	%	ha	%
Forestland	90.5	5.2	13.7	0.26	-519.0	-9.8	-532.7	-3.91
Grassland	71.0	2.9	3.88	0.07	-326.6	-6.1	-322.7	-2.37
Bareland	1420.9	155.0	388.64	7.32	-533.1	-10.0	921.7	6.76
Cropland	2687.7	58.8	186.70	3.52	-3482.9	-65.6	-3296.2	-24.17
Rural Settlement	445.5	54.8	111.32	2.1	-446.6	-8.4	-335.2	-2.46
Urban Area	3618	118.6	4604.26	86.7	-0.5	0.0	4604.8	33.77
Total	8333	61.09	5309	100	-5308.7	-100	-0.1	0.0

5.11. Transition of Land covers Classes

The transitions of one land cover state to another as shown below was generated from all land cover classes to build up areas in order to visualize and interpreted the changes happened between 2010 and 2040. Because the main focus of this study was on built up areas, the transition has been made to this specific land cover class (built up areas). It has been clearly shown in the figure 4.19 that crop land explained the majority of the total increase in built up areas (3100 ha), which represents about 34.96 %(2874.4ha) of the entire study area in 2010-2040. Next to crop land bare land takes the second contribution to total increase in built up areas by about 13.26%(1809.6ha) and rural settlement takes the third contribution to total urban area by about 556.8 ha(5.27% of the area). Lastly forest land and grass land takes the fourth and fifth by 104.2ha (1.27% the area) and 74.9ha (0.91% the area)

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Urban growth and the concentration of people in urban areas are growing steadily specially in the developing countries. Urban Land use and land cover changes have wide range of consequences at all spatial and temporal scales. Because of these effects and influences it has become one of the major problems for environmental change as well as natural resource management. Identifying the complex interaction between changes and its drivers over space and time is important to predict future developments, set decision making mechanisms and construct alternative scenarios.

This study has been conducted by integrating GIS, remote sensing and spatial modeling tools. In order to detect and analyze changes in land cover classes, these techniques were implemented. In this study satellite data for the study periods of 1973, 2000 and 2010 and remote sensing techniques were applied to generate land cover maps through a supervised classification method. The accuracy assessment and change detection processes has also been done. The overall accuracy of land use and land cover maps generated in this study had got an acceptable value. The result of overall accuracy was 88.09% in 1973, 89.52% in 2000 and 90.95% in 2010. The information from image classification accuracy became important to the modeling procedure. In the last section, land use modeling was applied to analyze dynamic changes in built up areas as a result of different driving factors.

The change analysis results from cross tabulation also showed that built up areas gained 1040 ha (1973-2000), 1876.4ha (2000-2010) and 4604.26 ha(2010-2040) and it shows rapidly changing of 2% in 1973 to 10% in 2000 to 23% in2010 to 60.27% in predicted map 2040. Crop land areas explained the majority of the total increase in built up areas (486.7 ha), which represents about 37.2% of the entire study area in 1973-2000. Rural settlements take the second contribution to total increase in built up areas by about 301.8 ha (23.1% of urban area). Next to rural settlement, forest land takes the third contribution to urban area by 129.6 ha (9.9% of urban area). At the last grass land contribute 115.2 ha (8.8% of urban area) and bare land contribute only 7 ha (7% of the urban area). In 2000-2010 crop land areas were also continued contributing a majority of about 102.4 ha (32.53%). Next rural settlement and forestland contribute 391.72 ha (12.47%) and 321ha (10%) of the entire study area respectively. Grassland 130ha (4%) and bareland 11.9ha (0.39%) were less contributed. The conversion of crop land to build up areas could be related to increment of population and faster economic development in Adama City. Urban areas increased through all study periods 7.6% (1973-2000) and 13.44% (2000-2010). Crop land which highly contributes to urban area decrease in net change of loss of 3.03% (1973-2000) and 12.89% (2000-2010) at this period forestland contribute to urban area. Bareland increase 0.4%(1973-2000) to 3.3%(2000-2010), grassland decrease from 4.15%(1973-2000) to 8.94%(2000-2010) to, forestland decreases from 0.75%(1973-2000) to 3.23%(2000-2010) and rural settlement has net change loss 0.06% (1973-2000) to net gain 0.69% (2000-2010).

The statistics given in the validation output allow the user to separate quantification error versus location error. The kappa coefficients of per category are showing high values from above results (KIA=Kstandard=0.884). This proves that the agreement between the two maps is substantial. Only forest land and grass land are showing less value than the average of the other categories. Based on the Markov chain model simulation, it has been found that 60.27% of the total study area will be converted into built-up area cover type in 2040.

6.2. Recommendations

The results of this specific study have shown that remote sensing, GIS and land use models are important tools in land use and land cover change studies. Therefore, based on the findings of this study, the following are recommended as future research directions:

- The use of high resolution imageries such as IKONOS and Quick Bird are important in generating good quality of land cover maps. Because urban areas have complex and heterogonous features, a high resolution imagery provide better information by mapping these areas. Moreover, the use of ancillary data as ground truth helps for better accuracy of an image classification.
- Consistent multi-temporal Landsat satellite data for each year provides detail comparison of images, change analysis and modeling. Especially for Markov chain model, it is a requirement of equal interval of images acquisition although there have been uneven temporal availability of data. .
- Further studies can be conducted, to find out whether these kinds of model are suitable for future prediction, in areas where urban growth is not higher like Adama city. This would be an interesting analysis to discover which model is best-suited for particular research problems.
- Only simulating the future land cover map is not fruitful, until further steps are taken. Some more important research works can be recommended like- trying to compare the predicted map with the existing Master plans of the city. If there any conflicts exist, then it should be taken into special consideration.
- Incorporating socio-economic data, land policy, biophysical and human factors (population density, technology, political) could improve the performance of land use models for future predictions. Hence, it is important to the planners, decision makers and stakeholders for efficient utilization of land.

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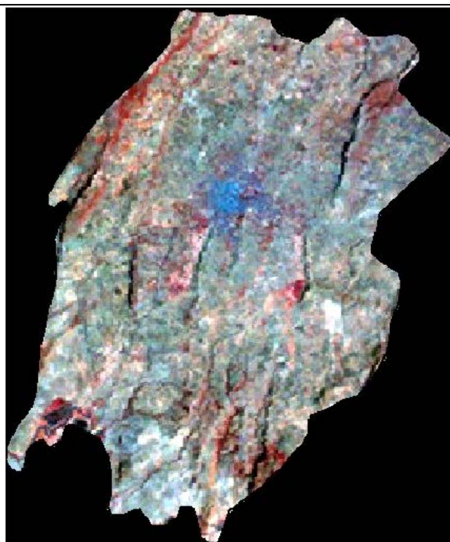
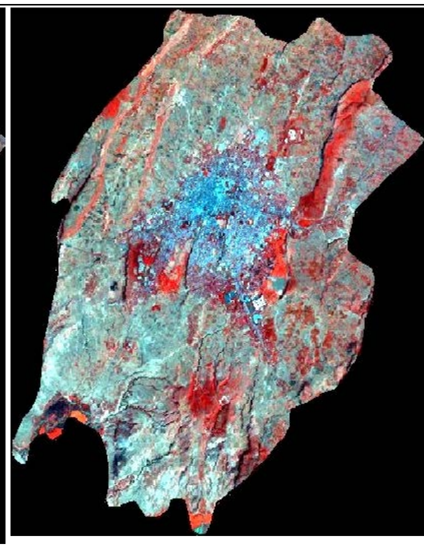
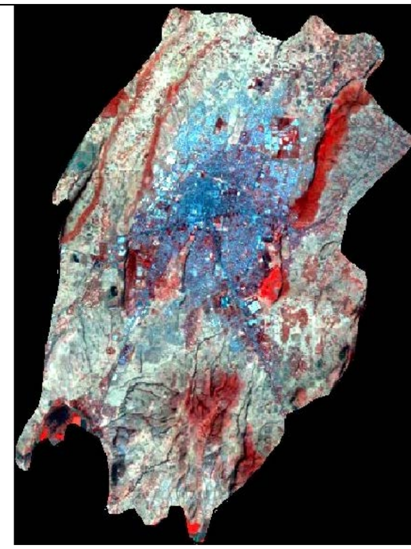
Appendix

Satellite data used

		
MSS 1973	ETM^{+} 2000	ETM^{+} 2010