SPATIAL METRICS AND LANDSAT DATA FOR URBAN LANDUSE CHANGE DETECTION IN ADDIS ABABA, ETHIOPIA

MESFIN TADESSE BEKALO

Dissertation submitted in partial fulfilment of the requirements for the Degree of Master of Science in Geospatial Technologies
SPATIAL METRICS AND LANDSAT DATA FOR URBAN LANDUSE CHANGE DETECTION IN ADDIS ABABA, ETHIOPIA

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Masters Program in

Geospatial Technologies

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ABSTRACT

The rapid development of urbanization coupled with fast demographic change and high demand for land resource requires landuse information for management and planning activities of urban regions. The advent of geospatial tools has great potential to long term monitoring and assessment of urban growth and its associated problems in surrounding landcover. This study analyzes urban landuse/landcover change of Addis Ababa, Ethiopia, using landsat TM and ETM+ acquired, respectively, in 1986 and 2000. The landcover maps with four classes were generated using the Maximum Likelihood Algorithm of Supervised Classification. Overall classification accuracy was tested by Confusion Metrics and Kappa Coefficient. The landcover dynamics in pattern and quantities were analyzed using selected Spatial Metrics units. It has been found that tremendous changes in landcover occurred over the study period. The results indicated that the built-up area expanded to 49% with annual growth rate around 3.5% with significant fragmentation and contagion of small and isolated urban patches. Managers and planners could use this data as a decision-support tool for urban and environment management.
KEYWORDS

Remote Sensing
Spatial Metrics
Landuse/landcover map
Image classification
ACRONYMS

CSA- Central Statistical Authority.

CORINE- Co-ordination of Information on the Environment

EEA- European Environment Agency

ETM- Enhanced Thematic Mapper

GIS- Geographic Information System(Science)

LC- Landcover

LULCC- Landuse/Landcover Change

LU- Landuse

TM- Thematic Mapper
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Chapter One

Introduction

1. Introduction

1.1. Study Background

It is a hot topic in most summits to talk about population explosion, environmental degradation, climate change and other socio-economic challenges. 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. 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 (UNFPA, 2008).

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 (Brunn and Williams, 1983).

Urbanization is often associated with economies of agglomeration and cities are essential to development. They are centers of production, employment and innovation. In developing countries, cities contribute significantly to economic growth. The
The economic importance of cities is rapidly increasing and the future economic growth will become dependent upon the ability of urban centers to perform crucial service and production functions (Cheema, 1993).

Despite the economic benefits, the rapid rates of urbanization and unplanned expansion of cities have resulted in several negative consequences. 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 (Lowton, 1997). Such dynamism in urban landcover 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 landuse management and planning. Furthermore, the rapid urban growth and the associated urban landcover changes attracted many researchers to study and monitor the changes.

1.1.1. Landuse/Landcover change and Geospatial tools

The landuse/landcover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on landuse/landcover and possibilities for their optimal use is essential for the selection, planning and implementation of landuse schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population (Mesev, 2008).

Viewing the Earth from space is now crucial to the understanding of the influence of man’s activities on his natural resource base over time. In situations of rapid and often unrecorded land use change, observations of the Earth from space provide objective information of human utilization of the landscape. Over the past years, data from Earth observatory satellites has become vital in mapping the surface features and infrastructures, managing natural resources and studying environmental change (Mesev, 2008).
A substantial amount of data of the Earth’s surface are collected using remote sensing tools. Remote sensing provides an excellent source of data from which updated landuse/landcover (LULC) information and changes can be extracted and analyzed efficiently (Bauer et al., 2003).

Since the launch of the first remote sensing satellite (1972), multitemporal and multiresolution satellite data are available in various data archives. These have been used as a base for various environmental studies including urban change analysis. Besides, landsat imageries that have been recorded in the last 30 years using TM, MSS and ETM sensors along with data from new sensors (e.g. ASTER) present a reliable database for long term change detection (Moeller, et al., 2004). The advent of high spatial resolution satellite imagery (e.g. IKONOS and QUICKBIRD) also enables researchers to detect, analyze and monitor detailed changes in an urban environment more efficiently (Jensen and Im, 2007). Some recent research has also been directed towards quantitatively describing the spatial structure of urban environments and characterizing patterns of urban structure through the use of remotely sensed data and spatial metrics (Herold et al., 2002).

Addis Ababa has experienced fastest expansion and changes in landcover. There is very limited information on the extent and pattern of changes occurred over time. Besides, there are no extensive studies conducted related to urban growth and their impacts using remote sensing and spatial metrics. Hence, urban planners and decision makers should consider the potential of geospatial tools to detect, monitor and evaluate the urban landcover changes in the country. In this work, remote sensing and spatial metrics are applied to detect and analyze the urban landcover changes of Addis Ababa between 1986 and 2000. The main objective was to investigate the spatial extent of urban landcover changes and compare the rate of changes using selected spatial metrics.

1.2. Statement of the problem

Land resource is the source of all human’s basic needs (e.g. agriculture and water supply) and is depleted by various agents. Urban growth and urbanization are considered as one of the major factors responsible for depletion of land resources and
landcover dynamics. As compared with other types of landcover such as agricultural land, urban land has smaller area coverage but its impact to the surrounding environment is higher than any other landuse classes. Thus, special consideration and careful assessment are required for monitoring and planning urban development and decision making.

Ethiopia is one of the least urbanized countries in the world. Even for African standards, the level of urbanization is low. According to the Population Reference Bureau’s World Population Data Sheet (2002), while the average level of urbanization for Africa in general was 33% in 2002, Ethiopia had only 15% of its population living in urban areas. Despite of the low level of urbanization and the fact that the country is predominantly rural, there is a rapid rate of urban growth, which is currently estimated at 5.1% per year. The urban population of Ethiopia is concentrated in few urban centers and the urban system of the country is dominated by Addis Ababa, the capital, with 28.4% of the total urban population of the country (CSA, 1998). Therefore, the city has experienced rapid physical expansion to the periphery at the expense of other landcover classes, though this has not been properly controlled by appropriate planning intervention. Almost none of the plans prepared at different times have been done using information from Geospatial data and tools of GIS (ORAAMP, 1999).

In addition to low level of geo-information to figure out the extent and pattern of the change in the study area, there is also still serious shortage of geospatial information to predict the future growth and dynamics of the city. This in turn can negatively affect the decision making process of urban, regional and environmental planners. Therefore, the purpose of the study was to detect, analyze and compare the relative urban landcover changes of Addis Ababa, Ethiopia.

1.3. Objectives of the study

Motivated by the serious challenge of the study area as stated above, an attempt has been made to acquire reliable and timely spatio-temporal information for better management of urban landcover dynamics. Therefore, the general objective of the study was using remote sensing and spatial metrics that facilitate generation of continuous, reliable and accurate urban landuse change map with effective spatial
information, which can be used for management of urban landcover and other environmentally sensitive non built up areas around the city. The following were also some of the specific objectives of this work:

- Identifying the landcover/landuse change and examining the change dynamics at different spatial and temporal scales;
- to produce a landuse/landcover map of the study area;
- to identify the trend, nature, rate, location and magnitude of landuse/landcover change;
- to quantify and investigate the characteristics of urban landcover over the study area based on the analysis of landsat TM and landsat ETM+;
- to analyze and examine the changes using spatial metrics;
- to compare the dynamics of urban environment considering different time frame;
- to assess the accuracy of the classification techniques using Error Matrix (Confusion Matrix) and Kappa statistics and
- to put forward a recommendation or set of recommendations that may form the basis for a sound solution for decision makers.

1.4: Research hypothesis and questions

This study was based on the hypothesis that there have been considerable urban landcover changes in the study areas. It was also based on the hypothesis that the rate of the change is particularly high since 1986 which marked as a landmark for high population growth of the city. With regardless of any other land cover classes, the city has been expanded to all directions particularly horizontal expansion to all major road networks at the periphery. In order to assist the analysis, the following research questions were also posed:

- Whether there have been major changes in the urban environment of the study areas or not.
- What was the spatial extent of the landcover change and where was the highest rate of changes?
- How was the pattern of urban growth?
1.5: Significance of the study

This study tried to quantify and analyze the changes between 1986 and 2000 to contribute in the urban land, environmental management and monitoring plan of the areas. Therefore, it is expected to:

- Provide basic information on the status and dynamics of the urban landcover of the area and the potential of satellite imageries for such purpose. It is also expected to identify the rate of urban growth and urban landcover changes in different times.
- Present basic spatial metrics and remote sensing methodologies to detect and analyze urban landcover changes and present the potential of these tools for extracting land related information in the country.
- Assist environmentalists, regional and urban planners to consider the potential of geospatial tools for monitoring and planning urban environment.
- Provide elements for long term bench-mark monitoring and observation relating to resource dynamics.
- Provide a base line for eventual research follow up, by identifying specific and important topics that should be looked in greater detail for those who are interested in the area.

1.6. Study Area

Addis Ababa, the capital of Ethiopia, is located in the central part of the country within a surface area of 530.14 km². The city is located at 9°02′N 38°44′E/ 9.03, 38.74. From its lowest point, around Bole International Airport, at 2,326 metres (7,630 ft) above sea level in the southern periphery, the city rises to over 3,000 metres (9,800 ft) in the Entoto Mountains to the north.
Fig.1.1. Map of the study area

It is known that fast growth of population has been observed in 20\textsuperscript{th} century. Today, Addis Ababa is a rapidly expanding city. Especially the creation of new housing and industrial areas makes Addis Ababa one of the largest cities in sub-Saharan Africa (Ignis, 2008). With the headquarters of the African Union and the United Nations Economic Committee for Africa both based in this capital, it is of unique importance for African diplomacy. The regional headquarters of UNDP, UNICEF, UNHCR are also based in Addis Ababa.

The population of Addis Ababa increases annually by about 6%. This can partly be attributed to the natural population growth of around 2.4% due to high migration from villages to the city. In 2005, the population in the capital itself already counts approx. 3.7 million people. Because of demographic uncertainties, such as high net migration, and natural population increment, the exact number of inhabitants is not really known. However, until 2015 Addis Ababa is expected to host 6-7 million inhabitants (Ignis, 2008).
Addis Ababa is not only the largest city in Ethiopia but also a textbook example of a primate city, as it is at least 14 times as large as Dire Dawa, the second largest city in the country. However, this primacy has been on the decline in the recent past, partly because of increased capital expenditure flows to regional capitals and other major cities of the country. As a result, Addis Ababa’s share of the total urban population has dropped from 30 percent in 1984 to 26 percent in 2000 (Ignis, 2008).

As shown in Table 1.1, Addis Ababa’s population growth pattern has been irregular during the greater part of its history, largely due to changes in the country’s social, economic and political conditions. As official statistics show that the city today is experiencing one of its slowest-ever growth rates, just slightly below three percent per annum. Even with this low growth rate, the capital continues to attract 90,000 to 120,000 new residents every year. In general, it appears that much of this growth (probably up to 70 percent of the total), takes place in the slums and squatter settlements at the periphery of the city (ORAAMP, 1999).

It is worth highlighting that the greater part of this growth is due more to net in-migration (1.69 percent per annum) than to natural increase (1.21 percent per annum). It is not clear why, unlike most other major cities in the developing world, Addis Ababa has such a low rate of natural increase (UNHSP, 2007).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Population</th>
<th>Average annual Growth Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>65000</td>
<td>-</td>
</tr>
<tr>
<td>1935</td>
<td>100,000</td>
<td>1.72</td>
</tr>
<tr>
<td>1952</td>
<td>317,925</td>
<td>6.8</td>
</tr>
<tr>
<td>1961</td>
<td>443,728</td>
<td>3.7</td>
</tr>
<tr>
<td>1970</td>
<td>750,530</td>
<td>5.84</td>
</tr>
<tr>
<td>1976</td>
<td>1,099,851</td>
<td>6.37</td>
</tr>
<tr>
<td>1984</td>
<td>1,423,111</td>
<td>3.22</td>
</tr>
<tr>
<td>1994</td>
<td>2,112,737</td>
<td>3.95</td>
</tr>
<tr>
<td>2000</td>
<td>2,495,000</td>
<td>2.77</td>
</tr>
<tr>
<td>2004</td>
<td>2,805,000</td>
<td>2.93</td>
</tr>
</tbody>
</table>

*Table 1.1. Total population of Addis Ababa between 1910-2004*  
(Source: ORAAMP, 1999)
1.6.1. Physical Expansion Trend in Addis Ababa

The rapid growth of population of the city has put great pressure on the demand for urban spaces. In response to this demand, efforts are being made by the city government to incorporate the peripheral areas of the city, which is resulting in hastening the expansion of the built-up area of the city. Accordingly, Addis Ababa has experienced rapid physical expansion (Table 1.2).

<table>
<thead>
<tr>
<th>Period</th>
<th>Average covered area (hectars)</th>
<th>Total-built-up area (hectars)</th>
<th>Annual growth rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1886-1936</td>
<td>1863.13</td>
<td>1863.13</td>
<td>-</td>
</tr>
<tr>
<td>1937-1975</td>
<td>4186.87</td>
<td>6050</td>
<td>3.1</td>
</tr>
<tr>
<td>1976-1985</td>
<td>4788</td>
<td>10,838</td>
<td>6.0</td>
</tr>
<tr>
<td>1986-1995</td>
<td>2925.3</td>
<td>13,763.3</td>
<td>2.4</td>
</tr>
<tr>
<td>1996-2000</td>
<td>909.4</td>
<td>14,672.7</td>
<td>1.6</td>
</tr>
</tbody>
</table>

*Table 1.2. Physical Growth of Addis Ababa City Built-up area (1886-2000)*

The early development of the city from 1886 to 1936 was characterized by fragmented settlements. Following Italian occupation in 1937, the process of physical development of Addis Ababa was characterized by infill development and consolidation of the former fragmented settlements (ORAAMP, 1999:6). The physical expansion of the built-up area of the city during the period 1937 to 1975 was characterized by a compact type of development. From 1976 to 1985, the built-up area increased by 4788 hectares, thus increasing the cumulative total to 10,838 hectares.

The next period of physical expansion of the city was between 1986 and 1995, when the built-up area expanded by 2925.3 hectares, increasing the cumulative total to 13,763.3 hectares. Simultaneously, horizontal expansion took place in all peripheral areas of the city, where both legal and squatter settlements were established. Out of the total 94,135 housing units built in the city between 1984 and 1994, 15.7% (14,794 housing units) were built by squatters (ORAAMP, 2001:6).
During the most recent period of physical expansion, between 1996 and 2000, the physical built-up area of Addis Ababa increased by 909.4 hectares, reaching a cumulative total of 14,672.7 hectares. Expansion of the city was characterized by the development of scattered and fragmented settlements in the peripheral areas of the city, with both legal residents and squatters. In 2000, Addis Ababa had an estimated total of 60,000 housing units with squatter settlements. This figure accounted for 20% of the total housing stock of the city and the total area occupied by squatter settlements was estimated at 13.6% of the total built-up area (Minwuyelet, 2005).

1.6.2. Physiographic nature of the study area.

Climate
The climate in Addis Ababa is subjected to low pressure, also called Inter Tropical Convergence Zone, which is moving across the equator seasonally northward and Southward on the African Continent (Dirk, 2001)

Temperature
The average maximum temperature varies from 24.3°C in May to 20.3°C in August; the average minimum temperature varies from 11.8°C in May to 7.7°C in December. (Dirk, 2001)

Rainfall
The average annual rainfall in Addis Ababa amounts to 1178 mm. The main wet season takes place from June to September, causing about 70% of annual rainfall with the highest peak in August. Another small peak of rainfall is observed in April (Dirk, 2001)

Geology
The largest part of Addis Ababa is covered with volcanic material. The hill chain (Intoto) in the northern part of Addis Ababa is composed of basalts, called Intoto Cilcic and it is covered with volcanic topsoil materials of about one to two meters thick. The urban area is composed of youngest basalts called “Addis Ababa basalts” which are also covered with volcanic topsoil materials. The western part belongs to the younger age stratum; the northern part is mainly composed of Trachey basalts. In the Bole area, a kind of basalt, called Ignimbrites, is partly found. The topsoil
Vegetation
The catchment areas of the rivers crossing Addis Ababa are on the one-hand characterized by the large urban area of Addis Ababa. On the other-hand, cultivated area, woodland and grassland are found at the banks of the rivers. The eastern part (Hanku river basin) is mostly covered with grassland. The northern part (Little Akaki, Kechene and Kebena river basins) is more or less covered with woodland but a certain part is intensively cultivated land and the urbanization is closed to the basin boundary and expands further. Since the turn of the century, shortly after foundation of the town, a number of eucalyptus plantations were founded in Addis Ababa and on the hills around (Intoto) in order to cover the demand of wood of the city. Due to enormous population growth, deforestation became a serious problem in the last two decades. In addition, mismanagement of the forest resources and failure in reforestation programs resulted in deforested hills in the mountainous region of the Intoto (Dirk, 2001)

Topography
Addis Ababa extends to the central Ethiopian highland. The city is located on a plateau with an elevation ranging from 2326 to 3000 meters. The mountain ridge in the north and east of the city is called Intoto ridge. The elevation of this ridge ranges from 2600 to 3200 meters. The urbanized area of the city is deeply dissected by numerous valleys formed by the five major river systems crossing the city from north to east.

1.7. Organisation of the Dissertation

The first chapter highlights the problem statements by introducing the opportunities and constraints of using remote sensing and spatial metrics for landuse/landcover change in general and urban dynamics monitoring in particular. The main objectives and sub-objectives that facilitate the task of achieving the higher goal are also described in this chapter. The physical and socio-economical state of the study area is
described in words and portrayed graphically. Spatial details ranging from location to
the sizes of important features as well as the biological, topographical and climatic
attributes of the study area are explained in the same chapter.

The Second chapter is describing all theoretical and related review literatures for this
study. Here most of the reviewed materials present the land cover and change analysis
using remote sensing and descriptive statistical landscape metrics.

The third chapter is devoted to the description of the state of the art of the study, the
major methodologies followed for landcover classification and landcover change
detection, multitemoral data sources, landcover classes and training activities. The
steps followed for pixel-based classification in supervised classification technique
using the Maximum Likelihood algorithm of ArcGis software has been stated.

In the fourth chapter, the result and data analysis technique using spatial metrics has
been explained and the accuracy techniques of the landcover classifications have been
stated with some statistical methods.

The last chapter tries to convey the major contents and concepts in the previous
chapters and the basic research question posed in the introduction. To this effect,
conclusions with indications for future research are detailed there.
CHAPTER TWO
LITERATURE REVIEW

2. INTRODUCTION

For centuries, humans have been altering the Earth’s surface for agricultural activities and settlement. Nearly a third of the earth’s land surface is composed of croplands and pastures and over half of the cultivated areas have been cleared in the last century (Houghton, 1994). In the last few decades, conversion of grassland, woodland and forest into cropland, pasture and urban settlement has risen dramatically. This acceleration has drawn the attention about the role of landuse change in driving losses in biodiversity, soils and their fertility, water quality and air quality. These concerns have spawned a flurry of research on the causes and consequences of landuse/land cover change (Penner 1994).

The importance of mapping landuse classes and monitoring their changes with time has been widely recognized in the scientific community. Studying changes in landuse pattern using remotely sensed data is based on the comparison of time-sequential data. Change detection using satellite data allows for timely and consistent estimates of changes in landuse trends over large areas (Prakash and Gupta, 1998). In this chapter, various related works which support this study have been stated and substantiated the finding and the objectives of this work.

2.1. History and application of Remote Sensing

Remote sensing defined as a science of obtaining Information about objects and phenomena with out being in direct contact with the object (Colwell 1983, Lillesand et al.2004). Different kinds of airborne platforms of Earth observation have hundred and fifty years of old history. However, most innovations and scientific developments took place in the past three decades. In 19860's the first Balloon for Earth observation was launched, so this period is considered as an important mile stone in the history of remote sensing (Lillesand et al. 2004). Since then various scientific evolutions have been occurring in such away that platforms have developed to space stations, sophisticated development of the sensor digital cameras for scanning and integration of specialized cartographic work to all rounded disciplines. The first civilian remote sensing satellite of 1972 opened the new history for the progress of modern remote

Progresses and availability of the multispectral data from various sensors have been used to understand the extent, pattern, diversity, and the state of surface features including crops, forest, urban sprawl, land degradation and climate. Soon after the launch and the availability of landsat images, some shocking realities about the damage of environmental resources were disclosed. As an excellent example, the deplorable deforestation and biodiversity loss in Amazonian forest began to be detected by remote sensors (Peres et al. 1995). This event not only triggered the alarm on global deforestation but also opened the door for wide acceptance and application of remote sensing for natural resources conservation and environmental monitoring.

The ever increasing demand of the applications of remote sensing for natural resource management and other environmental monitoring was observed in the 80’s (Tucker 1980, Guyot 1990). The increasing availability of expertise, super computers with high speed and capability for huge data storage and processing and the advancement in GIS have further allowed and facilitated a number of sectors to explore the use of remotely sensed data. Early warning, disaster monitoring, agriculture, forestry, health care and other wide varieties of fields have quickly adapted the opportunity that remote sensing has brought about. It is also remarkable to mention the 1990's
logarithmic increment of the use of remote sensing for landuse management, biodiversity research, greenhouse effect monitoring, and other research areas. It also paved the way for applied geospatial research that links with multi disciplines (Csaplovics, 1992). From 1980 to 1990 alone the use of remote sensing data for tropical deforestation monitoring grew almost seven fold (Rudel et al. 2000). Increment in applied Geospatial research areas, wide acceptance and interdisciplinary approach of the remote sensing has also provided an opportunity for feedback for the improvement of radiometric sensitivity, spatial, temporal and spectral resolutions. Nowadays, the emergence of very high resolution images such as QUICKBIRD, IKONOS and SPOT are integrated in various application areas and research centers, so as to provide reliable, efficient and accurate geospatial Information (Bergen et al. 1999).

Due to the advancement in remote sensing technology and techniques in various application areas, in 2001 the US Government, through NASA and USGS, formally announced to provide a significant amount of archived historical satellite data to UN for further distribution and use by the international community. The Landsat data sets of more than 23,000 images, with coverage of the entire Earth surface are an important source of baseline information to document and quantify the present changes to the environment (USGS/UNE P/UNOOSA 2004). Currently, there are several online and ‘on request’ remotely sensed data, products and service suppliers. Some of the selected ones are:

1. **The Earth Science Data Interface (ESDI) at the Global Land Cover Facility.**
   This source is globally providing an archived data free of charge for downloading or very low handling and shipping costs. It provides landsat imageries which are orthorectified, composite MODIS images, and products such as NDVI vegetation index. It is funded by NASA and hosted at the University of Maryland in the USA. (GLCF, 2008).

2. **Tropical Rain Forest Information Center (TRFIC).**
   The centre is providing data, products and information services to the science, resource management, policy and education communities. It provides Landsat and other high-resolution satellite remote sensing data as well as digital deforestation
maps and databases to a range of users through web-based Geographic Information Systems (TRFIC, 2008).

3. **EPHA (Data Exchange Platform for Horn of Africa) supported by the UN**
   It delivers data and information such as maps, databases, and technical documents that are useful to humanitarian and development communities as a whole for the Horn of Africa region. In addition to developing these products, it also provides low-cost data and information management services (DEPHA, 2008).

4. **FEWS (Famine Early Warning Systems).**
   Through the representatives of FEWS in Africa and Asia, it delivers some higher spatial resolution landsat images for countries or localities in question through these institutions.

5. **ARTEMIS (The Africa Real Time Environmental Monitoring Information System).**
   FAO set the ARTEMIS as a support to its applied satellite remote sensing that is trying to enhance capabilities in the surveillance and forecasting of its Global Information and Early Warning System (GIEWS). Since 1988, the ARTEMIS system has been delivering low resolution, 10-day composite NDVI products as well as other weather and climate data.

6. **Earth Observing System Data Gateway.**
   Land, water and atmosphere data products from NASA and affiliated centres can be queried from the Earth Observing System Data Gateway (EOS). There are very useful high qualities satellite products available free of charge or with affordable handling costs. Famous satellite products including AVHRR, MODIS and ASTER can also be obtained.

7. **UNOSAT**
   UNOSAT is a United Nations programme created to provide the international community and developing countries with enhanced access to satellite imagery and Geographic Information System (GIS) services. The goal of UNOSAT is to make satellite imagery and geographic information easily accessible to the humanitarian
community and to experts worldwide working to reduce disasters and plan sustainable development (UNOSAT, 2008).

8. SPOT Vegetation
Under certain conditions the SPOT Vegetation programme supplies 1 km ground resolution SPOT 5 products for users. Standard 10-day synthesis products older than three months are normally available free of charge for the public. However, primary and recent products are commercial except for approved scientist who can receive them, after paying only the processing and shipping costs.

2.2. Land use and land cover
In most cases, the terms landuse and landcover are used interchangeably. Land cover describes the physical material at the surface of the Earth. It comprises various Landcover types such as trees, bare soil, grass, water etc. Whereas land use is a description of how people utilize the land and socio-economic activity such as urban land, agricultural land, forest land, water land, grazing land etc (Wikipedia, 2008).

The effect of landcover change can directly or indirectly affect the way how human uses the land. Dynamics of landcover do not necessarily mean degradation of land or environment and the vice versa too. However, there are numerous natural and man made driving forces that can alter the coverage and use of land, biodiversity, and other physical and human environments (George, 2005). Alteration in landuse or landcover is principally due to the interaction of humans with their environment and its missuse.

Thus, it is important to think about how to monitor and sustain the environment from climate change, biodiversity and the ecosystem. Hence, in order to manage the changes in landcover and use, it is necessary to have the information on existing and future landuse/landcover (George, 2005).

2.3. Application of Remote Sensing on Land Use/Landcover Change
The traditional method of landuse mapping is labour intensive, time consuming and difficult to update on a timely basis (Herold et al, 2003). Due to ever changing
physical and human environments, maps become outdated with the passage of time. Advancement in remote sensing techniques and GIS have proved to be of immense value for preparing accurate landuse/landcover maps and monitoring changes at regular time intervals (George, 2005). Earth observation sensors capture the spectral electromagnetic value of light from various surface features and an interpreter uses the element of color, texture, pattern, shape, size, shadow, site and association to derive information about landcover.

William et al (1991) noted that information about landuse/cover change, which is extracted from remotely sensed data, is vital for updating landcover maps and the management of natural resources and monitoring phenomena on the surface. Moshen (1999), also noted that landuse data has a great importance to planners in monitoring the consequences of the change on the area, plan and to assess the pattern and extent of the change, to modeling and predicting the future level of change, and to analyze the driving forces of changes.

It is worth mentioning some of the related works done in various parts of the world due to the progress in Earth Observations technology and techniques. Since the launch of the first remote sensing satellite (Landsat-1) in 1972, landuse and landcover studies were carried out in various local, regional and global levels. For instance, using landsat multi-spectral scanner data, Indian National Remote Sensing Agency carried out waste land mapping. In 1985, the U.S Geological Survey carried out a research program to produce 1:250,000 scale landcover maps for Alaska using Landsat MSS data (Fitz et al 1987). The State of Maryland Health Resources Planning Commission also used Landsat TM data to create a landcover data set for inclusion in their Maryland Geographic Information database. All seven TM bands were used to produce a 21 – class land cover map (EOSAT, 1992). In 1992 similar work was also done by the Georgia Department of Natural Resources in mapping the entire State to identify and quantify wetlands and other landcover types using Landsat Thematic Mapper™ data (ERDAS, 1992).

It has been noted over time through series of studies that Landsat Thematic Mapper is efficient for large area coverage. As a result, this reduces the need for expensive and time consuming ground surveys conducted for validation of data (Gossensse, et al,
Generally, satellite imagery is able to provide more frequent data collection on a regular basis unlike aerial photographs which although may provide more geometrically accurate maps, are limited in their extent of coverage. Shoshany (1994), also investigated the comparative advantages of remote sensing techniques in relation to traditional field surveys in providing a regional description of landcover. The results of their research were used to produce four vegetation cover maps of Hangana State in India that provided new information on spatial and temporal distributions of vegetation.

Dimyati (1995) also figured out the role of remote sensing data and techniques of superimposition (overlaying) and Image Differencing which used the subtraction of images of two different time periods of the same location to evaluate the change pattern in different temporal levels. This was done to analyze the pattern of change in the area, which was rather difficult with the traditional method of surveying.

2.4. Urban landuse/landcover 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 landcover 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 landcover change is a very important phenomenon, which characterizes the nature of the cities and their surrounding areas (George, 2005).

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 (Lavalle et al.,
Despite these difficulties, urban growth and urbanization are major environmental concerns that need consideration and careful assessment and monitoring (George, 2005).

2.5. GIS and Remote Sensing for urban change detection and monitoring

The emergence and development of geospatial tools has opened the way for collecting, storing, processing, analyzing and displaying spatial data for various environmental applications. GIS is an information system that integrates, stores, edits, analyzes, shares, and displays geographic information. It can be used in inventorying the environment, observing and assessing the changes as well as forecasting the changes based on the existing situation (Ramachandra and Kumar, 2004). Remote sensing on the other hand is the process of data acquisition through satellite and other airborne sensors without having any physical contact to the objects. It allows the acquisition of multispectral, multi-resolution and multi-temporal data for various purposes. Both remote sensing and GIS tools are applied in a wide variety of application areas including detecting and monitoring environmental changes, location and extent of urban growth, environmental impact assessment (EIA).

According to Herold et al., (2002), remote sensing technology has great potential for acquisition of detailed and accurate landuse information for management and planning of urban regions. The traditional method of surveying for landuse mapping and change detection is time consuming and difficult to update timely. Because of their cost effectiveness, temporal frequency and extensibility, remote sensing approaches are widely used for change detection analysis (Jensen and Im, 2007). In addition, image processing techniques assists in classifying, analyzing and monitoring changes associated with the earth’s surface(Yeh and Li, 1997).

The emergence of different change analysis techniques and various image classification schemes facilitated to provide accurate and efficient location based information for different areas of application. Change detection using analysis of remotely sensed data (e.g. image classification) have been performed using different geospatial tools. Pixel-based classification, for example, is the most commonly applied approach. However, recent studies have indicated that an alternative object-oriented approach produces better and effective results. In summary, integration of
GIS and remote sensing for urban landcover change analysis requires acquisition of
data set, classification of images using efficient algorithm and analysis of the change
undergone which are the major steps in most change detection related works (Herold
et al, 2003).

2.6. Remote sensing of urban areas

Aerial photo has been providing a visual interpretation of urban areas based on the
colour of the objects. The interpretation is quite difficult due to the complexity of size,
shape, pattern of urban landuse/landcover. To alleviate this challenge, a number of
urban remote sensing applications have shown the potential to map and monitor urban
landuse and infrastructure (Barnsley et al, 1993). The combined approach of remotely
sensed data with other socio-economic data also helps the researchers to detect and
model the future trend of the urban sprawl (Herold et al 2003).

As compared with another data sources, the strength of remote sensing is that it can
provide spatially consistent and historically reliable series of data sets with high
degree of resolution and temporal details. Remote sensing provides an additional
source of information that more closely respects the actual physical extent of a city
based on landcover characteristics (Weber, 2001). Nevertheless, in urban remote
sensing the challenging task is the distinct boundary between urban and rural or built
up and non built up. Thus, the problem of urban limit still remains as a challenge, so
the writers used their own rule and criteria for differentiating urban from rural land
(Herold et al 2003).

Due to the complexity and heterogeneous nature of urban landuse, several studies
have shown that high spatial resolution imageries are required to acquire all necessary
landcover classes in the urban environment. It is an asset for urban landuse/cover
researchers that since 2000, data from a very high spatial resolution space born
satellite data have been available for various applications. Particularly, the beginning
and emergence of IKONOS and QUICKBIRD paved the way for the application of
urban studies (Herold et al 2002)
There are different arguments regarding urban landuse analysis based on per-pixel basis and discrete object-based. The pixel-based approach only provides landcover characterization rather than urban landuse information. In order to include detailed mapping of urban landuse and socio-economic characteristics of the area, image pattern and context, as well as texture can be used, which are used to describe the morphology of urban areas. This option shows the socio-economic and landuse characteristics in remotely sensed data using structural, textural and contextual image information derived during image classification. The post classification technique is also used to estimate the urban landuse information from classified landcover map. In most image classification techniques, the analysts use it to show the landuse pattern of the study. Another newly emerged type of approach (Object-based) which is using the discrete landcover objects(segments) to describe the morphology and the spatial relationship of urban land use mapping (Herold et al, 2002).

Various authors e.g. Longley et al (2001), pointed out that the application of remote sensing, the technical aspect of data assembly and the physical image classification should be improved by more interdisciplinary and application-oriented approaches. They noted that research should focus on the description and analysis of spatial and temporal distributions and dynamics of urban phenomena, in particular urban landuse changes. However, there are serious arguments among social scientists and geospatial analysts against urban remote sensing (Rindfuss and et al, 1998). One of the arguments is the limitation of remote sensing to visualize the social phenomena “Pixelizing the social environment”. Remote sensing is only focuses on the physical aspects of urban areas and ignores the social issues. The socio-economic variables are not directly visible in remote sensing detection of the area. Secondly, most social sciences excluding planning and geography are more concerned with why things happen rather than where they happen; thus, most social scientist underestimate the data obtained from remote sensing. They also do not appreciate that the remotely sensed data can provide quantified information on social phenomenon in certain geographical extent.

However, it is not denied that, remote sensing has a potential as a source of information to link landuse and infrastructure change with a varieties of socio-economic and demographic processes (Rindfuss & Stern, 1998). It is also believed
that remote sensing can also provide excellent information for urban growth pattern and landuse/change processes. Remotely sensed data is consistent in large area coverages and can also provide information on a great variety of geographic scales. It can also help to describe and model the level of dynamics, leading to updated information for planning and decision making (Longley et al. 2001).

2.7. Image Classification Techniques

Image classification approaches and techniques in remote sensing have gained the attention of most researchers in the field; because the efficient, accurate, and reliable information on the surface feature is the base for many application areas (Lu and Weng, 2007). In addition, valuable land information extraction and analysis is well performed using image classification. Image classification is the process of assigning pixel images to predefined landcover classes. Information extraction using image classification is a complex and time consuming process. Thus, it might require the consideration of the following factors:

- Availability and proper selection of appropriate software for required classification techniques and algorithms;
- The level of resolution and selection of remotely sensed data (it depends on the availability of the required images);
- Suitability of classification techniques;
- Prior knowledge by the analysts of the study areas (sometimes not required), sufficient number of training samples, and analyst knowledge and skills;
- Appropriateness of change detection techniques e.g. post-classification process
- The performance of the classification accuracy.

In remote sensing, there are different image classification techniques. Their appropriateness depends on the purpose of landcover maps produced for and the analyst’s knowledge of the algorithms he/she is using (Fig.2.2). Classification methods can also be viewed as pixel-based, object-oriented, fuzzy classification, etc. Selection of appropriate classification methods and efficient use of multisource remotely sensed data are useful for minimizing the classification errors and improve the accuracy (Lu and Weng, 2007).
2.7.1. Pixel-Based Image Classification

It is the most commonly and widely used classification method, in which each pixel is classified based on the spatial arrangement of edge features in its local neighborhood (IM et al., 2007). Image classification at pixel level could be supervised or unsupervised. In the supervised classification method (e.g. Maximum Likelihood), the analyst is responsible to train the algorithm. In the unsupervised method, input from the analyst is very limited i.e. in specifying number of clusters and labeling the classes. According to Santos et al (2006), the statistical properties of training datasets from ground reference data are typically used to estimate the probability density functions of the classes. Each unknown pixel is then assigned to the class with the highest probability at the pixel location. However, information extraction at pixel level is associated with mixed pixel problems, although it is the most commonly used technique (fig 2.3).
2.7.2. Object-Oriented Image Classification

Classification based on contextual information or object-based is suggested to avoid the mixed pixel problems. The advent of object-oriented image classification provides a tool for mapping detailed landuse (Mori et al 2004). This approach considers the groups of pixels and geometric properties of image objects. Object-oriented processing techniques segments the images into homogenous regions based on neighboring pixel’s spectral and spatial properties. As shown in the Fig 2.4, the same classes are grouped in the same category.

2.7.3. Advanced Classification approaches

It is always a basic question which type of classification algorithm can satisfies the user. Thus, recently, various advanced classification approaches have been widely
used for image classification (Lu and Weng, 2007). These include artificial neural networks, fuzzy-set theory, decision tree classifier, knowledge and expert based, etc. The pixel-based classification is referred to as hard classification approach in which each pixel is forced to show membership only to a single class. Thus, soft classification approach has been developed as an alternative because of its ability to deal with mixed pixels problem. According to Jensen (2005), soft classification provides more information and potentially a more accurate result.

2.8. Change Detection and analysis techniques

2.8.1. Change detection: conceptual framework

Change detection is the process used in remote sensing to determine changes in the landcover properties between different time periods. It is also viewed as the process of identifying differences in the state of an object by observing it at different times (Singh, 1989). According to Ramachandra and et al (2004) it is the change in information that can guide to more tangible insights into underlying process involving LULC changes than information obtained from continuous change. It is also viewed as the process for monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution in the area of interest (Tardie and Congalton, 2002).

2.8.2. Applications and approaches of change detection

Change detection can be applied in many areas. According to Jensen and Im (2007), the application of change detection may range from monitoring general landcover change using multitemporal imageries to anomaly detection on hazardous waste sites. One of the most common application areas for change detection is agricultural, urban, forest, water land cover/use. Detection analysis using Vegetation Index Differencing (NDVI), for example, is applied to identify the status of vegetation cover in different time period. It is also useful to assess the urban growth and assessment of coastal environmental changes. Change analysis in urban growth assist urban planners and decision makers to implement sound solution for environmental management.

There are varieties of ways to assess and quantify changes in landscapes and their components (Blaschke, 2005). For effective change detection analysis, accurate
registration of the satellite input data is required so that a pixel represents the same location in different images. Therefore, selecting appropriate remotely sensed data and change detection techniques are very essential. Most recent change detection approaches are based on expert systems, artificial networks, fuzzy sets and object-oriented approaches (Jensen and Im, 2007). Change analysis using remotely sensed data involves different procedures such as, identifying the nature of the change detection problem, identifying the nature of remote sensing and environmental consideration, image processing to extract the changes and evaluation of the detection output (Jensen, 2005).

2.8.3. Landuse change detection techniques

Through the development of remote sensing techniques, various types of change detection algorithms have been emerging and applied in different application areas so as to determine the spatial extent and pattern of changes occurred in different time scale. It is well known that different methods of change detection produce different change maps. Thus, selection of an appropriate technique requires knowledge of the algorithms, characteristic features of the study area and nature of the data. Post classification Comparison is one of the most commonly used classification technique (Blaschke, 2005). Based on data transformation procedures and analysis applied, researchers attempted to classify change detection methods as Pre and post classification techniques (Jensen and Im, 2007, Belaid, 2003, Mas, 1998, Singh, 1989, Berkova, 2007). As noted by Singh (1989), there are two basic digital change detection approaches: comparative analysis of independently produced classifications and simultaneous analysis of multitemporal data.

The following section attempted to review some of the techniques applied in different researches and are available in various software platforms. Each of this technique falls into one of the above discussed approaches.

- **Image differencing:**

  Image differencing is based on subtraction of images of two different time periods of the same location and is widely used for change detection. This is performed on a pixel by pixel or band by band to create the difference image. In the process, the digital number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date (Tardie and Congalton 2002, Singh 1989).
Image ratioing:
In this method, geo-corrected images of different data are rationed pixel by pixel (band by band). According to Eastman (2001), image differencing looks at the absolute difference between images whereas image ratioing focuses on the relative differences. When the result of the ratio is equal to one, it reveals that there is no change in the landcover classes. Ratio value greater or less than one reflects landcover changes.

Vegetation index differencing:
This method is applied to analyze the amount of change in vegetation versus non vegetation by computing NDVI. NDVI is one of the most common vegetation indexing method and is calculated by;

\[
NDVI = \frac{(NIR - RED)}{(NIR + RED)}
\]

Where,
NIR- is the near infrared band response for a given pixel
RED- is the red response.

Post classification comparison:
This is the most obvious, common and suitable method for landcover change detection. This method requires the comparison of independently classified images \(T_1\) and \(T_2\), the analyst can produce change maps that show a complete matrix of changes (Singh, 1989).

2.8.4. Landcover/Landuse change analysis techniques

In order to quantify and model the changes occurred in landuse classes, Herold et al (2002) recommended to use spatial metrics. A change in urban landuse structures can be well described using information from spatial or landscape metrics. Spatial metrics are quantitative indices used to describe structures and patterns of landscape (Herold et al., 2002). It is based on the digitally classified images of the area (patches or classes). In some of the literature reviewed (e.g. Herold, et al., 2003 and Cabral et al., 2006) spatial metrics were employed to analyze and model urban growth and landscape changes.
2.9. Spatial metrics for urban landcover change analysis

Spatial metrics sometimes termed as landscape metrics, is useful tool in quantifying an extent of changes occurred in certain geographic area. It is widely applied in areas related to Landscape Ecology. Having a fast development in geospatial tools and its interdisciplinary approach, interest of spatial metrics in remote sensing has also been increasing from time to time. It is an excellent tool to quantify the changes in urban environment. It helps to bring out the spatial components in urban structure and dynamics of change and growth process (Alberti & Waddell, 2000). Herold et al (2002) also pointed out that an integrated approach of spatial metrics with remote sensing is an excellent method to provide spatially consistent and detailed information on urban structure.

Spatial metrics is based on the categorical, patch based representation of a landscape. Patches are defined as homogeneous regions for a specific landscape property e.g. “Industrial land”, “farm land”, “residential zone” etc are categorized patches which can be presented in the form of polygon. Thus, spatial metrics used to quantify the distinct spatial heterogeneity of individual patches with common class with similar spatial properties. Common patch-based indices in spatial metrics are size, shape, edge, length, patch density etc (Gustafson, 1998).

From geospatial point of view, landscape metrics defined as descriptive measurements derived from the digital analysis of thematic categorical maps resenting spatial heterogeneity at a specific scale and resolution (Herold et al 2003). According to Cabral et al (2006), the definition of spatial metrics emphasizes on the quantitative aspects of the mapped features of the landscape (patches, patch classes, or the whole map). Furthermore, Spatial Metrics always represents the spatial heterogeneity in specific extent, resolution and pattern at a given point in time. Most of the quantitative measures of spatial metrics such as size, shape length and density are calculated by FRAGSTATS statistical package.

Since the emergence of spatial metrics in late 1980’s, the interest to apply in landcover change detection and modeling studies has been increasing. Thus, different researchers recommended its application in urban remote sensing (Parker et al.
Spatial metrics is also used to link the economic process and pattern of urban landuse. Parker and et al (2001) investigated an agent-based economic landuse decision making in specific landuse patterns. They also proposed the spatial metrics for modeling complex spatial pattern of urban landuse/landcover. It allows the representation of heterogeneous characteristics of urban areas, and of the impact of urban development on its environs. In general, an integrated approach of spatial metrics with remote sensing for change detection and modeling the urban environment is recommended (Parker and et al (2001).

To summarize, like in any other developing countries, the most obvious problem associated with urban growth in Addis Ababa is encroachment towards agricultural lands and natural resources. A spatio-temporal analysis of growth patterns is essential to develop sufficient infrastructure to support urban growth assessment. Landsat data and spatial metrics are integrated in this research, so as to identify the extent and pattern of the city in different period of time. Hence, urban planners and decision makers should consider the potential of geospatial tools to detect, monitor and evaluate the urban landcover changes in the country.
CHAPTER 3
RESEARCH METHODOLOGY

3. Introduction
The flow diagram (Fig 3.1) summarizes the overall methods, techniques, approaches and materials used to carried out this study, so as to figure out the urban landcover changes and describe the urban spatial patterns changes in the study areas.

![Flow Diagram of Methodologies](image)

3.2. Data source and Type
3.2.1. Data
There are a number of different kinds of methods, strategies and techniques to process input data so as to generate the required research 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 spatial and temporal analysis techniques using landscape metrics. 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. Landscape metrics were also employed to quantify the changes and compare the results.

Due to diverse application of remotely sensed data, satellite images have been used for different environmental studies (e.g. biodiversity and ecological monitoring, agricultural and early warning purpose, change in surface water, global and climate change as well as mapping and detecting urban landcover 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 multitemporal data to produce landcover changes is useful because it solves the problems associated with single dated landcover information. It also provides diverse changes occurred on the surface on different landuse 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, particularly in tropical regions where cloud cover is common (Mas, 1999). In order to detect the change and patterns of geospatial phenomenon and landuse classes accurately, the researcher has to be sure of the availability of images acquired in the same season. For this study the two data types (TM &ETM) 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.
The satellite imageries with acquisition period of 1986-01-21 and 2000-12-05 respectively were downloaded from Global Land Cover Facility of the University of Maryland (GLCF, 2008). Two remote sensing images from Landsat were used and processed for identifying urban landcover change patterns of the study area. In order to avoid the impact of seasonal variation, the images used are predominantly cloud free and are selected from the same season (dry season). The satellite data used are landsat TM and ETM+ acquired in 1986 and 2000, respectively. The resolution of the images is 30 meters. The TM and ETM+ satellite data are usually used for their multispectral and environmental value, because one of the intended uses was to observe landcover character as an environmental backdrop to the urban growth pattern (Gluch, 2002). Characteristics of the satellite data used in this study are summarized in the table 3.1.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Spatial resolution</th>
<th>Spectral resolution</th>
<th>Acquisition time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat TM</td>
<td>30 M, 190 m thm.</td>
<td>6 ms, 1 thermal</td>
<td>1986</td>
</tr>
<tr>
<td>Landsat ETM+</td>
<td>15 m pan, 30 m ms, 120 m thm.</td>
<td>6 ms, 2 thermal, 1 pan</td>
<td>2000</td>
</tr>
<tr>
<td>IKONOS</td>
<td>1 m pan, 4 m ms</td>
<td>4 ms, 1 pan</td>
<td>2000</td>
</tr>
</tbody>
</table>

*Table 3.1. Characteristics of satellite data used*

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. For this study, as an ancillary data, high resolution images (IKONOS) and existing landcover maps of the area, Google maps and Google Earth, and population data were integrated. The ancillary dataset both IKONOS images and existing landcover maps were mostly used to identify surface features, support image classification and landcover change analysis. The dataset were geometrically referenced to the UTM zone 37 projection systems. It was also important to know the characteristic features of each band of the landsat image.

In this study various bands were composed to visualize the colour scene of the features on the image. True Color Composite images were created by combining the
ETM spectral bands that most closely resemble the true color of the features. A true-color composite uses the visible red (band 3), visible green (band 2), and visible blue (band 1) channels to create an image that is very close to what a person would expect to see in a photograph of the same scene. Another band composition employed for this study was Near Infrared Composit (432), which eliminates the visible blue band and uses a Near Infrared (NIR) band to produce the image. The resulting composite does not resemble what the “True Color” looks like. Thus the study comprised band 1, 2, 3, and 4 to detect landuse changes of the study area. Other supporting data i.e. population dataset for the census years of 1976, 1984, 1994 and 2000 were also used to describe, compare and analyze the pattern of urban growth. This was because demographic characteristics of the area could affect an acceleration of urban sprawl.

3.2. Landcover Nomenclatures

In order to make sample collection and classification easy, landcover nomenclatures are required to create and define the possible landcover classes first. Although the focus of the paper was on built-up areas, landcover map of the study areas were first generated using landcover classes presented in table 3.2.

The landcover classes applied in this paper are adopted from the classification used by European Environment Agency (EEA), Co-ordination of Information on the Environment (CORINE), which describes landcover (and partly landuse) 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 landcover class which is more applicable for Temperate and cold Polar Regions. In order to solve this challenge, AFRICOVER landcover 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 landcover classes considering the landcover diversity of the study area. Four major landcover nomenclatures (Urban and associated areas, Agricultural land, Vegetated areas and Water and Wet lands) were used to produce the final landcover map of the study area (Table 3.2).
<table>
<thead>
<tr>
<th>LCC</th>
<th>Landcover Types</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Urban and associated areas</td>
<td>Continuous and discontinuous urban fabric, Residential, industrial and commercial units, road and railway networks and other associated lands.</td>
</tr>
<tr>
<td>C2</td>
<td>Agricultural Land</td>
<td>Irrigated and rain fed arable lands, crop land with permanent crops, farming and fallow fields</td>
</tr>
<tr>
<td>C3</td>
<td>Vegetated Areas</td>
<td>Natural and man made forests, natural grasslands, woodland shrubs, sparsely planted trees.</td>
</tr>
<tr>
<td>C4</td>
<td>Water and Wet Lands</td>
<td>All water bodies, marshes, swamps, artificial lakes and ponds.</td>
</tr>
</tbody>
</table>

Table 3.2. Landcover classes

Because of the major objective of this study, these nomenclatures were further merged and regrouped as built and non built-up classes (Table 3.3). This helped the analyst to discuss and analyze the extent and pattern of urban sprawl. This helped to categorize the heterogeneous nature of different classes under certain major category. However, it was not an easy task to distinguish similar spectral values of the features in urban centers; it was an unavoidable factor which could distort the accuracy of classification.

<table>
<thead>
<tr>
<th>CLASSES ID</th>
<th>CLASSES</th>
<th>DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Buit-up Areas</td>
<td>Comprises commercial, residential, road and impervious features, Continuous and discontinuous urban fabric, Residential, industrial and commercial units, road and railway networks and other associated lands, Airports, Dump sites, construction sites, Sport and Leisure facilities etc.</td>
</tr>
<tr>
<td>C2</td>
<td>Non-Built-up Areas</td>
<td>Irrigated and rain fed arable lands, crop land with permanent crops, farming and fallow fields, Natural and man made forests, natural grasslands, woodland shrubs, sparsely planted trees, marshes, swamps, artificial lakes and ponds and others.</td>
</tr>
</tbody>
</table>

Table 3.3. Regrouped Landcover classes
3.3. Image classification

Image classification is defined as the extraction of differentiated classes or themes, landuse and landcover categories, from raw remotely sensed digital satellite data. It is a technique to identify different features such as urban landcover, vegetation types, anthropogenic structures, mineral resources, or changes in any of these properties from the satellite image. Additionally, the classified raster image can be converted to vector features (e.g. polygons) in order to compare with other data sets or to calculate spatial attributes (e.g. area, perimeter) using different statistical methods including landscape metrics.

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 landcover 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 “ArcGis version 9.2”. 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.
3.4. Training site collection

Training areas/sample objects which are typical representatives of the classes were collected using high resolution images; existing landcover maps, analyst’s personal experiences and knowledge of the physiographical nature of the area. In addition, image enhancement and composition were applied for better discriminating the landcover classes. Using these approaches around 579 sample objects were collected from each image (1986 and 2000).

3.5. Urban landcover change analysis techniques

The pattern or direction of urban expansion and the rate of urban development occurs in a variety of ways depending on the physiographical nature of the area, distance from accessibility (e.g. market areas or roads), and distance from city center, slope, etc. These and other related factors prompt for the development of continuous or discontinuous urban structures. Urban area (built areas) may also occur spatially in isolated or fragmented mode in space. Therefore, it is imperative to quantify and analyze spatial and temporal dynamics of urban landcover and pattern of urban growth. The differences in representation of a space have led to a wide variety of spatial metrics for the description of spatial structure and pattern (Herold et al., 2003). The spatial metrics are algorithms used to quantify spatial characteristics of patches, class areas and the entire landscape (Cabral et al., 2006). They enable analyst to quantify the spatial heterogeneity of classes and identify the changes in the pattern of urban growth.

In this study, spatial metrics were calculated based on thematic maps representing built and non-built spatial patches for both study time. With the growth of urban features (e.g. construction of buildings or other infrastructures), urban structures or landscapes would also change. The changes in urban landscape (e.g. development of discontinuous urban areas or urban fragmentation) are measured and analyzed using FRAGSTATS tool. It is a public domain spatial metrics program, was developed in the mid 1990s and has been continuously improved since (McGarigal et al., 2002). However, landcover change analysis for such fragmented areas may be affected by generalizations of small polygons of urban areas into a large non-built area polygon.
A number of metrics have been developed to describe and quantify elements of patch shape complexity and spatial configuration relative to other patch types; however, it is not clear which will prove to be the most informative and interpretable over large areas (Loveland, 2004). In this work, six spatial metrics (class area-CA, Number of patches – NP, Edge Density – ED, Largest Patch Index – LPI, Euclidian Mean Nearest Neighbour Distance – EMN, Area Weighted Mean Patch Fractal Dimension-FRAC_AM) which have been adopted and used for analyzing the urban landcover changes (Table 3.4).

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA/TA Class Area</td>
<td>CA measures total areas of built and non built areas in the landscape</td>
</tr>
<tr>
<td>NP Number of Patches</td>
<td>It is the number of built and non built up patches in the landscape</td>
</tr>
<tr>
<td>ED-Edge Density</td>
<td>ED equals the sum of the lengths (m) of all edge segments involving the patch type, divided by the total landscape area (m2)</td>
</tr>
<tr>
<td>LPI-Largest-Patch Index</td>
<td>LPI percentage of the landscape comprised by the largest patch</td>
</tr>
<tr>
<td>MNN-MN Euclidian Mean Nearest Neighbo</td>
<td>MNN equals the distance (m) mean value over all patches to the nearest neighbouring patch, based on shortest edge to edge distance from cell center.</td>
</tr>
<tr>
<td>FRAC_AM Area weighted mean patch fractal dimension</td>
<td>Area weighted mean value of the fractal dimension values of all urban patches, the fractal dimension of a patch equals two times the logarithm of patch area (m2), the perimeter is adjusted to correct for the raster bias in perimeter</td>
</tr>
</tbody>
</table>

Table 3.4 Spatial metrics adopted and used (Herold et al., 2003)

### 3.7. Accuracy Assessment

Assessment of classification accuracy is critical for a map generated from any remote sensing data. Although accuracy assessment is important for traditional remote sensing techniques, with the advent of more advanced digital satellite remote sensing the necessity of performing an accuracy assessment has received new interest (Congalton, 1991). Currently, accuracy assessment is considered as an integral part of any image classification. This is because image classification using different classification methods or algorithms may classify or assign some pixels or group of pixels to wrong classes. In order to wisely use the landcover maps which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy. The most common types of error that occurs in image classifications are omission or commission errors.
The widely used method to represent classification accuracy is in the form of an Error Matrix sometimes referred as Confusion Matrix. Using Error Matrix to represent accuracy is recommended and adopted as the standard reporting convention (Congalton, 1991). It presents the relationship between the classes in the classified and reference maps. The technique provides some statistical and analytical approaches to explain the accuracy of the classification. In this study, overall, producer’s and user’s accuracy were considered for analysis. Kappa Coefficient, which is one of the most popular measures in addressing the difference between the actual agreement and change agreement, was also calculated. The kappa was a discrete multivariate’s technique used in accuracy assessment (Fan et al., 2007).

The reference data used for accuracy assessment are usually obtained from aerial photographs, high resolution images (e.g. IKONOS and QUICKBIRD), and field observations. In this study, the assessment was carried out using IKONOS images and existing landcover maps as a reference. A set of reference points has to be generated; thus, three hundred (300) randomly allocated training points were generated for accuracy assessment. These points were verified and labelled against reference data. Error matrices were designed to assess the quality of the classification accuracy of the newly generated landcover map. The error matrix can then be used as a starting point for a series of descriptive and analytical statistical techniques (Congalton, 1991). Overall accuracy, user’s and producer’s accuracies, and the Kappa statistic were then derived from the error matrices.
CHAPTER FOUR
RESULTS AND ANALYSIS

4. Introduction
GIS and remote sensing are excellent tools to map different land cover classes in different spatio-temporal scales. The availability of high and low resolution satellite data specially landsat along with geospatial tools has been providing an opportunity to generate landcover maps of certain geographical area, to observe different changes in different time and modeling the future characteristics. As already mentioned on the methodology part, different image classification techniques and procedures were employed to derive the land cover map of the study area, Addis Ababa (Fig. 4.1), which enable detection and quantification of the changes that occurred in the years 1986 to 2000. This would also play an important role in understanding the nature of change, where major changes are occurring, projecting possible future change and planning future urban development.

4.1. Landcover map
The data revealed that the landcover in two different times showed significant changes. Urban coverage was drastically changed from 34% in 1986 to 51% in 2000. It expanded to all directions particularly to the south, east and North West side. Urban centre grew 49% in 14 years and it was around 3.5% per year (Tab.4.1). It was suggested that the expansion of the urban area to the surrounding environment had an impact on the decrement of agricultural, pastoral, forest, grassland and herbaceous fields. Thus, agricultural land, which constituted 51% of the total area in 1986, diminished to 34% in 2000.

Thus, by the expense of agricultural land and vegetated areas including natural and man made forest, sparse forest, shrub wood land, natural grassland and mixed forest, the built up areas including continuous and discontinuous urban fabrics, industrial, commercial and residential units with other associated urban facilities dynamically increased in the period under discussion. This might be due to high acceleration of population increment with high demand for land and urban provisions, land allocation policy of the government and unplanned (slum) urban sprawl at the periphery of the conurbation.
Dandena (1995) pointed out that the demographic, social and policy issues are major cause for landcove change of the area. The rapid population increase of the study area has been mainly attributable to natural urban population increase and internal migration. According to the country’s 1994 population and housing census, out of the total population of the city, 46.7% were migrants from rural and other urban areas in Ethiopia (CSA, 1999). Thus, the population increment requires additional space for settlement and construction.

<table>
<thead>
<tr>
<th>LUC</th>
<th>1986 Area(ha)</th>
<th>1986 Area (%)</th>
<th>2000 Area (ha)</th>
<th>2000 Area (%)</th>
<th>Change (ha)</th>
<th>Change in Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban and associated</td>
<td>7721</td>
<td>34%</td>
<td>11461</td>
<td>51%</td>
<td>3740</td>
<td>49%</td>
</tr>
<tr>
<td>Agricultural areas</td>
<td>11506</td>
<td>51%</td>
<td>7776</td>
<td>34%</td>
<td>-3730</td>
<td>-32%</td>
</tr>
<tr>
<td>Vegetated areas</td>
<td>3258</td>
<td>14%</td>
<td>2519</td>
<td>11%</td>
<td>-739</td>
<td>-23%</td>
</tr>
<tr>
<td>Water and Wetlands</td>
<td>128</td>
<td>1%</td>
<td>128</td>
<td>1%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22613</strong></td>
<td><strong>100%</strong></td>
<td><strong>22613</strong></td>
<td><strong>100%</strong></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Table 4.1. Areas of Land Use classes and change occurred.*
As the main theme of this study was to investigate the urban landcover dynamics; thus, more attention was given to analyze the extent of built-up areas in comparison with other land cover classes. Thus, in order to examine the nature and spatial extent of the built-up areas, the maps (Fig.4.1) were reclassified into two broad classes as built and non built-up (Fig.4.2). This graphic presentation enables a direct visual comparison of urban landcover changes in different time limits.

**Fig 4.2: Built and non built-up areas in 1986 and 2000 respectively.**

### 4.2: Change detection and reclassification comparison

In remote sensing, the change detection analysis can be employed using a set of multi-spectral and multi-temporal images of the same site but in different time periods. Different techniques, for example, image differencing, image regression and image ratioing can be mentioned as a technique for change detections. The selection of an appropriate technique, however, depends on the knowledge of the algorithms and characteristic features of the study area (Elnazir *et al.*, 2004).
In this study, the most straightforward technique for detecting changes (comparison of independently produced landcover maps from two dates) has been applied. The maps of 1986 and 2000 which considered as “earlier image” and “later image”, respectively were reclassified, overlaid up on each other and analyzed. Both images were initially classified into different thematic landcover classes (Fig.4.1) and were reclassified into built and non-built areas (Fig.4.2). The early image was overlaid to the later one in order to visualize the changes in built up areas (Fig.4.4). Image reclassification and post-classification techniques are iterative and require further refinement in order to produce more accurate change detection results (Fan et al., 2007).

As mentioned above, there are different kinds of approaches to characterize landuse/cover dynamics, and none of them are absolute i.e. each has a set of strengths and weaknesses (Loveland, 2004). In the literature reviewed e.g. Shalaby and Tateishi, 2007, it was noted that successful landcover change detection using landsat images depends on the nature of the changes involved and the success of image pre-processing and classification. In this study, a classified map with 4 major landcover
classes reclassified to two classes (built and non-built up) and overlaid each other to visualize the changed areas (Fig.4.4).

Addis Ababa is the capital and metropolis of the country with around 3.8 million populations, with high demand for commercial, industrial, residential and recreational lands uses. Thus, the dominant landuse class is an urban (built-up) and associated areas. It occupies the highest proportion of the study area. The urban landcover maps derived from remote sensing data also presents the changes from non-built to built-up areas. The expansion of the built-up area is predominantly at the expense of agricultural area and forest cover in the surroundings. Preliminary results from the multi-date visual change detection image indicate that a considerable urban landcover change took place in the study areas.

As depicted on Table 4.2, the built up land cover class has experienced a remarkable growth (3845ha) between 1986 and 2000. Most of the changes in landcover occurred in the peripheries of the urban in accordance with the landuse policies adopted by the government for various development programs. The city government has been allocating the land in the peripheries of the city for cooperatives and real estate
developers for the construction of high density condominiums in different parts of the city. According to ORAAMP (2001), for the implementation of the housing and other urban development projects in the expansion areas, there are no clear policies and administrative orders that regulate the rate of change of agricultural and cultivated land to other uses.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area(ha)</td>
<td>Area (%)</td>
<td>Area ha)</td>
</tr>
<tr>
<td>Built up</td>
<td>7801</td>
<td>34%</td>
<td>11646</td>
</tr>
<tr>
<td>Non-Bu</td>
<td>15057</td>
<td>66%</td>
<td>11240</td>
</tr>
<tr>
<td>Total</td>
<td>22858</td>
<td>100</td>
<td>22858</td>
</tr>
</tbody>
</table>

*Table 4.2. Built and non built-up areas and changes in between 1986 and 2000*

According to the visual analyses of the reclassified maps (Fig 4.3), the built up area of 1986 was smaller than in the year 2000. Some of the observed types of change realized in the study were urban expansion and densification (later discussed under spatial metrics). Besides, the results of the image classifications, change map could provide an estimate of the extent; pattern and direction of urban landcover changes in both study periods.

As already mentioned above, within the study time frame, large area of land changed from agricultural and forest land to urban activities at the periphery of the city. According to the researcher’s prior knowledge, the multi-temporal landcover classification used and ORAMP report (2001), the city has been expanding to all directions. Major and significant scales of land conversion to urban functions can be visualized as:

- The highest is along the Debrezeit road (Gelan and Dukem areas)
- The second is along the Jimma road (Sebeta and Alem-gena area)
- The third one along the Dessie road (Sendafa area)
- The fourth one along the Gojam road (Sululta area)
From an Urban geography point of view, most urban centers in developing countries have emerged along the routes of transport, mining centers, ports, and productive and fertile land areas. So, the pattern of the cities is more or less horizontal to the vicinity of roads, railways and other industrial sites. As any other cities in less developed countries, the growing pattern of Addis Ababa has also been influenced by main road developments which are radiating to various provinces of the country. As newly generated landcover maps of the area have indicated, along the major route of transportation, the urban sprawl has been agglomerated with distinct patterns (Fig 4.5). The clear patterns of the city have mainly been observed along Jimma to the west, Dessie to the East, Debrezeit to the South and Gojam (to the North) roads (highways) outlet to the regional provinces in the country.

Another observable determinant factor of the pattern of the built up area of the study site was the topographic nature, in which the northern most part of the city could not
expand due to the highest mountain which ranges 3000m. It is very rugged and unfavorable for human settlement. So, as shown on the classified map of the study area (Fig.4.3), the dominant land cover class at northern side of the city is vegetated areas and agricultural land classes.

**4.3. Urban landcover change analysis using spatial metrics**

In all geographical researches, the analysis of spatial phenomenon, spatial structures and spatial patterns are central themes which make the research “Geographical”. The major spatial components such as location, distance, direction, orientation, linkage, and pattern have been discussed as general spatial concepts in most researches of geography (Golledge, 1995). In this study these basic spatial concepts and the analysis of spatial structure and pattern were approached from the perspective of spatial metrics on urban landuse/landcover change detection analysis. As none other landuse, urban built ups are very dynamic, complex and mixed with heterogeneous landuse categories. Thus, according to Herold et al, (2003) landscape metrics are important tools to quantify the spatial heterogeneity of individual patches, of all patches belonging to a common class, and of the landscape as a collection of patches.

A supervised type of image classification approach using the Maximum Likelihood Algorithm allowed extracting of pixels with the same and almost similar spectral value but extraction of similar pixels with different representation is not easy. This is because spectral responses of some features (e.g. built areas and bare land; built areas and harvested agricultural land; irrigated land and closed trees; water and shadow, water and wet land etc) are similar. With relatively low level of resolution of the landsat image it was also not easy to describe the situation of urban landcover changes. Large geographical extent of the study area with quite heterogeneous landuse classes was also another challenging factor. Nevertheless, spatial metrics as quantitative measures of spatial structures and patterns was applied to describe the urban features. The changes in landscape diversity and fragmentation as a function of time from 1986 to 2000 using the spatial metrics were investigated. Relatively speaking, the landscape diversity has remained stable in the areas using the landcover map as a reference. However, there was a relative change in the fragmentation or spatial patterns of the study areas.
FRAGSTAT is a spatial pattern analysis program for categorical maps which simply quantifies the areal extent and spatial configuration of patches within a landscape. Table 4.3, contains a summary of statistics from the spatial metrics of the changes obtained using FRAGSTATS. The main interest of this work was the built up landcover class. Therefore, landcover maps with 4 classes (fig.4.3) were reclassified in to built and non built, so as to to analyse the changes occurred and patterns observed. There has been a tremendous growth in the built-up areas and spatial pattern of the study area. Due to the improvements in infrastructures, high value of land at the center of the city, housing policy and program, development of new industrial and recreational zones and population explosion, the rate of urban growth has expanded into the rural-urban fringe. Analysis of the spatial metrics indicated that the urban landcover of Addis Ababa has increased by 3845ha. This value was the differences between the CA (Total area, Class Area) of the two time periods.

**4.3.1: Class Area (CA)**

The Class Area sometimes referred as Total Area, is an excellent mechanism to analyze and compare the development and change extent of built and non built-up
lands (J. Im 2007). CA, in this context, refers to the spatial extent of the built-up areas (urban landuse) obtained using the metrics. According to the CA calculated, urban landuse has greatly changed over the study period. Large extent of landuse change during the study period was characterized by replacement of agricultural areas, vegetated land including forest and scattered tree plantation, wet and water lands with urban areas. The extent of built areas was 7801ha in 1986 and increased into 11646 ha in 2000. This reflects that the urban landcover has increased by approximately 3845ha in a 14 years study period.

The result of the growth is likely to be affected by the season of image acquisition. This is because harvested farming land, other than bare land, may have the same reflectance with built up features during dry season. Hence, built areas, bare land and harvested lands might have been considered as a homogeneous region during classification. The result could also be affected by the generalization applied.

4.3.2: Number of Patches (NP)

The number of patches (NP) metric quantifies the number of individual urban or built area patch. The number of urban patches in 1986 was 324 and has increased into 367 in 2000. This indicates that there has been a development and emergence of a small number of fragmented built up areas. The reason for the fragmentation in the areas could be mainly due to the development of discontinuous urban areas and other artificial or impervious surface features. According to the researcher’s knowledge of the study area, discontinuation of urban sprawl was mainly due to rugged terrain, river and valley barrier, forest and swampy wet landcover. This also implies that there was emergence of new urban centers which were of course part and parcel of the main city but for some reason disconnected from the urban core. Long *et al* (2006) has also supported this analysis stating that the accelerating urbanization process may cause an increase in the degree of fragmentation and structural changes.

4.3.3: Largest Patch Index (LPI)

According to Herold *et al* (2002), LPI (in %) equals the area (m²) of the largest patch of the corresponding patch type divided by total area covered by urban multiplied by 100. The LPI has increased from 26.6 to 43.2. This was related to the contagion of small and isolated urban patches into the largest patch and development of other urban
areas around the existing largest patch. In other word it means that most of the small isolated and fragmented urban sprawl and associated built ups were connected with the core and main urban.

4.3.4: Edge Density (ED)

Another indicator in the expansion level of built up areas is the computation of ED. It is a measure of the total length of the edge of the urban patches, in other words, the length of the urban boundary divided by the total landscape area. The total length of the edge of the landuse patches (urban patch) increases with an increase in the land use fragmentation; the increment in number of patches can surely lead to the increment of Edge Density. In this study, the ED has increased from 29.9 in 1986 to 47.4 in 2000. This implies that the study area has a significant development of urban sprawl and emergence of numerous disconnected or fragmented urban centers.

4.3.5: Area Weighted Mean Patch Fractal Dimension (AWMPFD)

According to McGarigal et al., (2002), it is necessary to measure and calculate the level of crumbling (fragmentation) and complication of patches to the area so as to understand the degree of complexity of a polygon. The Fractal Dimension describes the complexity and fragmentation of a patch by a perimeter–area proportion. Fractal Dimension values range between 1 and 2. Low values are derived when a patch has a compact rectangular form with a relatively small perimeter relative to the area. If the patches are more complex and fragmented, the perimeter increases and yields a higher fractal dimension (Herold et al., 2002). The Fractal Dimension can be applied as a derived metric called area weighted mean patch fractal dimension (AWMPFD). It is derived using the following formula in FRAGSTATS.

\[
AWMPFD = \sum_{i=1}^{m} \sum_{j=1}^{n} \left( \frac{21n(0.25 P_{ij})}{ln a_{ij}} \right) \left( \frac{a_{ij}}{A} \right)
\]

m- Number of patch types (classes)

n- Number of patches of a class

\(P_{ij}\)- perimeter of patch ij

\(a_{ij}\)- area of patch ij

A- Total landscape area

The study area, particularly the built-up class, is relatively compact in shape as compared to other classes. The level of compactness of the polygons was relatively
higher in 1986 than in 2000. This implied that the urban expansion to the periphery
landuse was relatively lower and less fragmentation during early period (1986) than
late periods. The value Fractal Dimension calculated in FRAGSTAT(1.23 and 1.3 in
1986 and 2000 respectively) shows that there was very slight difference in the
complexity of the polygons in two study times. According to Cabral et al, 2006,
values greater than 1 in a fractal dimension indicate an increase in shape complexity.
Relatively little change has been recognized in AWMFD of two time frames. This
reflects that an effect of an increment in CA, LPI and ED, in this context, has just
slightly affected complexity of the shape.

4.3.6: Euclidean Mean Nearest Neighbour (ENN_MN)

In order to examine the changes occurred between different time periods, it is crucial
to analyze the minimum distances between the classes. In this case, the FRAGSTAT
manipulated the ENN_MN distance which represents the average minimum distance
between the individual built areas (urban) patch. Literature reviewed (Herold et al,
2003) also revealed that, ENN_MN considered as a measure of the open space
between urbanized areas. Thus, a decrease in ENN_MN from 249.2 in 1986 to 210.3
in 2000 indicated a decrease in the distance between the built up patches. This was
probably because of the contagion of small and isolated patches into largest patch and
emergence of new settlements around the existing urban patches. In other word it
means that most of the small isolated and fragmented urban sprawl and associated
built ups were connected with the core and main urban. This in turn affects the
increment of Largest Patch Index of the class.

Addis Ababa, the capital, is dominant city of the country. As a result, the “rural-urban
interface” of the areas is highly influenced with the pattern of urban growth. This is
particularly evident from the new residential, industrial, and recreational areas
constructed in the periphery. The results of the spatial metrics of the city was analyzed
and interpreted taking reclassified landcover maps of the area, prior knowledge of the
researcher, environmental, demographic and other socio economic parameters in to
consideration. These helped analysts to compare that the changes, pattern and
development have occurred in Addis Ababa. Analysis of the metrics revealed that the
built up area of the study area has experienced substantial changes in extent, trend and
pattern. Based on the two time series analysis, urban growth in study areas has
occurred in almost all directions of the city. This might be due to the road system design for full integration of expansion areas with the metropolitan core.

4.4: Accuracy Assessment

Evaluating the level of classification accuracy has to be a mandatory work in remotely sensed data. The accuracy and precision of an image can be affected by many variables, including the spatial and spectral resolution of the sensor, processing statistics used, types of classification scheme chosen, limits of detection of different surface materials, suitability of reference spectra used for image analysis training, the type and amount of ground truth data acquisition, and type of atmospheric correction algorithm applied to the imagery. Thus, landcover map derived from remote sensing data contain some sort of errors. Many of them are impossible to avoid; however, it is necessary to show and quantify errors occurred during classification. This might help users and readers to understand some level of inaccuracy and imprecision during image classification. Hence, an accuracy assessment was carried out to assess the quality of the landcover maps. One of the commonly used methods to assess the accuracy of classified image is the Confusion Matrix, a technique that provides some statistical and analytical approaches to explain the accuracy of the classification. In this study Confusion Matrix was applied with some quality measures like user’s and producer’s accuracy; overall accuracy and Kappa analysis.

<table>
<thead>
<tr>
<th>Reference Map</th>
<th>Urban, other built - ups</th>
<th>Agricultural Land</th>
<th>Vegetated Area</th>
<th>Water &amp; Wet land</th>
<th>Grand Total</th>
<th>User’s Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban &amp; Ass.</td>
<td>38</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>95%</td>
</tr>
<tr>
<td>Agricultural Land</td>
<td>30</td>
<td>116</td>
<td>6</td>
<td>-</td>
<td>152</td>
<td>76.3%</td>
</tr>
<tr>
<td>Vegetated Land</td>
<td>3</td>
<td>3</td>
<td>93</td>
<td>-</td>
<td>99</td>
<td>93.9%</td>
</tr>
<tr>
<td>Water &amp; Wet Lands</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>100%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>71</td>
<td>121</td>
<td>99</td>
<td>4</td>
<td>295</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classified Map</th>
<th>Urban, other built - ups</th>
<th>Agricultural Land</th>
<th>Vegetated Area</th>
<th>Water &amp; Wet land</th>
<th>Grand Total</th>
<th>Producer’s Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban &amp; Ass.</td>
<td>38</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>95.5%</td>
</tr>
<tr>
<td>Agricultural Land</td>
<td>30</td>
<td>116</td>
<td>6</td>
<td>-</td>
<td>152</td>
<td>95.9%</td>
</tr>
<tr>
<td>Vegetated Land</td>
<td>3</td>
<td>3</td>
<td>93</td>
<td>-</td>
<td>99</td>
<td>93.9%</td>
</tr>
<tr>
<td>Water &amp; Wet Lands</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>100%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>71</td>
<td>121</td>
<td>99</td>
<td>4</td>
<td>295</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 4.4. Confussion Matrix for Landcover map of 1986
Table 4.5. Confusion Matrix for Landcover map of 2000

### 4.4.1: Overall accuracy

This provides an overall result for the error matrix. The overall accuracies for the Landcover map of the study area in 1986 and 2000 were 85% and 87.6%, respectively. It is computed by dividing the total correctly classified number of pixels (i.e. summation of the diagonal) to the total number of pixels in the matrix (grand total). The potential question here is how much is an overall accuracy for the best classification, and how much is for bad classification, how much is the minimum and maximum, how much is the threshold? Anderson *et al*, 1976, empirical studies, they noted that a minimum accuracy value for reliable landcover classification is 85%. However, other authors (eg. Bedru, 2006), pointed out that the expected accuracy threshold is usually determined by the users themselves depending on the type of application the map product will be used later. Depending up on the purpose of the landcover map, different people use different accuracy levels. As figured above (Tab.4.6), in both landcover maps of the study area, an overall accuracy level was more than Anderson’s level of criteria.
<table>
<thead>
<tr>
<th>Classes</th>
<th>Landcover Map- 1986</th>
<th>Landcover Map-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Producer’s Accuracy</td>
<td>User’s Accuracy</td>
</tr>
<tr>
<td>Urban</td>
<td>53.5%</td>
<td>95%</td>
</tr>
<tr>
<td>Agri.</td>
<td>95.9%</td>
<td>76.3%</td>
</tr>
<tr>
<td>Vege.</td>
<td>93.9%</td>
<td>93.9%</td>
</tr>
<tr>
<td>Water.</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 4.6. Overall accuracies of 1986 and 2000 Landcover map

4.4.2: Producer’s accuracy

It was obtained by dividing the number of correctly classified pixels in the category by the total number of pixels of the category (class) in the reference data. Producer’s accuracy is sometimes termed as an Omission Error, which is the probability of a reference pixels being classified correctly. This accuracy only gives the proportion of the correctly classified pixels. The result of this work revealed that the value of Producer’s accuracy in 1986 landcover map ranged from the lowest 53.5% to the highest 100%, while in 2000 landcover map it ranged from 76% to 100%. The lowest values were misclassified due to similar spectral value of different landcover classes. For instance, similarity in the spectral property of bare soil, urban and farm somehow affected the level of accuracy of classification.

4.4.3: User’s accuracy

It was obtained by dividing the total number of correctly classified pixels in the category by the total number of pixels on the classified image. This method explains the probability that the pixel’s in the classified map or image represents that class on the ground. User’s accuracy of individual classes ranged from 76.3% to 100% for in 1986 landcover map and 77% to 100% for 2000. In both maps, agricultural land and urban and associated lands were largely misclassified. It was because of the season of image acquisition (December), well known “plough season” in the Ethiopia in which most farm land spectral value could appear as urban and vice versa.
4.5: Kappa coefficient

The kappa coefficient, which is a measure of agreement, can also be used to assess the classification accuracy. It expresses the ratio in error generated by a classification process compared with the error of a completely random classification (Congalton, 1991). The Kappa statistic 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. The Kappa coefficient is calculated using the following formula given by Congalton (1991).

\[
K = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{ir} \times X_{ir})}{N^2 - \sum_{i=1}^{r} (X_{ir} \times X_{ri})}
\]

\( r \) = the number of rows in the error matrix
\( X_{ii} \) = the number of observations in row \( i \) column \( i \) (along the diagonal)
\( X_{ir} \) = is the marginal total of row \( i \) (right of the matrix)
\( X_{ri} \) = the marginal total of column \( i \) (bottom of the matrix)
\( N \) = the total number of observations included in the matrix

The value of \( K \) is always less than or equal to 1. One is the highest value and the results very close to 1 imply almost perfect agreement (Table 4.7) In some exceptional situations the value of \( K \) can be negative. This implies that the two observers agreed less than would be expected just by chance. It is very rare to figure out perfect agreement in \( K \). Various people have different interpretation on what good level of agreement should be. Some authors (e.g. Landis et al, 1977) tried to formulate universal standard for \( K \) value interpretation (Table 4.7). The level of accuracy was calculated to be 0.77 and 0.82 in 1986 and 2000 landcover maps respectively, which was considered to be an excellent result.

<table>
<thead>
<tr>
<th>K</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0</td>
<td>No agreement</td>
</tr>
<tr>
<td>0.0 — 0.20</td>
<td>Slight agreement</td>
</tr>
<tr>
<td>0.21 — 0.40</td>
<td>Fair agreement</td>
</tr>
<tr>
<td>0.41 — 0.60</td>
<td>Moderate agreement</td>
</tr>
<tr>
<td>0.61 — 0.80</td>
<td>Substantial agreement</td>
</tr>
<tr>
<td>0.81 — 1.00</td>
<td>Almost perfect agreement</td>
</tr>
</tbody>
</table>

Table 4.7. Kappa Interpretation. Adopted from Childrensmercy, (2008)
4.6: Demographic, Urban Expansion and development trends of Addis Ababa: Overview

Demographic change can affect social, economic, environmental and other factors in negative or positive ways. More specifically, land is a base for all developments. So, change in population growth accelerates the demand for land and the dynamics in landcover change. In this study, the research was curious about the relationship between population growth and urban sprawl. Thus, all discussion and interpretation of data was considered the density, migration, natural increase and other demographic elements. According to the reports obtained from UNHSP (2007), population size in the study area steadily raised up from 1910 to 2004 (Fig 4.6). This factor triggers the ever-growing demand for urban services: demand of land for residence, economic and industrial activities and other public services.

![Fig. 4.6. Total population of Addis Abeba between 1910-2004. Source: UNHSP(2007)](image)

The 1986 Addis Ababa Master plan had proposed compact urban expansion in the three major directions: East (Kotebe), South (Akaki-Kality and Mekanissa-Kotary), and West (Keranio) (Fig. 4.7). The same plan had put general development guide lines for the proposed expansion areas. In this regard, the strategy was to develop land for housing in the expansion area with parallel provision of services and infrastructure. The main goal that was pursued in the expansion areas was that of fostering new and
well-designed integrated development in a restricted number of vacant sites, situated at the peripheral areas of the city with appropriate residential typologies.

Fig.4.7. Structure of Land Use Plan of Addis Ababa and Expansion Areas (Source ORAMP Report 2001)

However, the physical built-up area of the city shows that the city was not following compact type of expansion trend, except during the period 1937-1975, where the entire city has shown compact form (Dandena, 1995). But the development pattern of the urban sprawl could not keep the compactness of the shape of the city. Rather, the city has been expanding to all directions.
The city has shown linear development along four regional outlets excluding the Gojjam road. The expansion along Debrezeit road is the most elongated one with more of an industrial land use, while the expansion into the Kotebe area is intensive, dense and more of residential in function. Further westward, expansions along Jimma road is characterized by informal residential developments.

Nowadays, it has been attracting many social science researchers to identify what was the real cause of such expansion and agglomeration of the sprawl and associated problems in Addis Ababa. According to UNHSP (2007), major causes of the expansion of the city to the fringe areas were:

- The presence of adequate infrastructure along the regional outlets as compared to other parts of the city;
- The growth of small urban centers that were established formerly along the outlet roads like Kotebe, Akaki, Kality, Repi and Burayou;
Lack of follow-up and control of illegal construction activities;

Poor planning and plan implementation practices before the approval of the 1986 master plan of Addis Ababa;

Uncoordinated effort of the city government to implement large scale housing development in different directions of the city after the approval of the 1986 master plan.

Dandena (1995) also figured out major and overall expansion trend of the city as follows;

- Except for the residential expansion in areas like Bole-Megenagna, Old airport and Gergi-Yerber, elongated development along the main outlet roads is the dominant type and the base of the urban pattern of the city;
- Juxtaposition of planned and unplanned developments is another scene of the city;
- The general structure of the city is loose which gave the city a sense of over expansion and sprawl.

Finally, Dandena(1995) summed up that the current expansion trends of the city show that infrastructure; especially roads have the most important contribution to the sprawled development. With no mechanism to stop such developments, the city will continue to extend further into the fringe along the regional outlet roads. The writer also described characteristics of the expansion of the city in all directions as follows;

- Pressure on agricultural activities due to excessive land consumption
- Low densities at periphery areas compared to older city centers
- Formation of fragmented open spaces, and wide gaps between new planned developments that attract informal settlements
- Separation of urban functions into distinct areas, that are isolated residential or industrial estates and
- Lack of public spaces and play grounds

Having this background from various literatures reviewed on the expansion of urban land, its trend, pattern and dynamics, the researcher further applied the techniques of remote sensing and spatial metrics to detect the changes of urban landuse in the year between 1986 ands 2000 and concluded the result and findings in the next chapter.
Chapter Five
Conclusions

Landuse/landcover change over time is the response of combined effect of the social, economic, demographic and environmental variables. Understanding the characteristics, extent and pattern of change in landuse is vital element for efficient planning, managing and decision making activities. In the absence of basic information about the current landuse and landcover, it would be difficult to determine future improvements. This leads to suggest the need to provide up-to-date information about land-related resources to help planners in decision-making.

An integrated approach of GIS, remote sensing and Spatial Metrics are excellent tools to map different land cover classes in different spatio-temporal scales and to quantify the extent and pattern of the changes. The availability of high and low resolution satellite data specially landsat along with geospatial tools has been providing an opportunity to generate land cover maps of certain geographical area, to observe different changes in different time and modeling the future characteristics. As already mentioned on the methodology part, different image classification techniques and procedures were employed to derive the land cover map of the study area, Addis Ababa, Ethiopia, and Spatial Metrics enabled to quantify the changes occurred in the year 1986 to 2000. This would also play an important role in understanding the nature of change, where major changes were occurring, projecting possible future change and planning future urban development.

This study has demonstrated the role of satellite remote sensing and Spatial Metrics in producing accurate LU/LC maps and change statistics of the Addis Ababa for the past 14 years between 1986 and 2000. In the study area, similar study has not been carried out to quantify and detects the changes and patterns of the urban growth. It is worth mentioning that Dandena(1995) tried to examine the major causes and consequences of the expansion of Addis Ababa using the population, infrastructure, and housing data. This work was different in approaches and techniques to test the role of geospatial tools in the urban landcover change detection of Addis Ababa. In summary, the following conclusions can be drawn;
The study shows that the land cover in between two different times showed significant change. Urban coverage was drastically changed from 34% in 1986 to 51% in 2000, with annual growth of 3.5%. It was suggested that the expansion of the urban area to the surrounding environment had an impact on the decrement of agricultural, pastoral, forest, grassland and herbaceous fields. Thus, agricultural land which constituted 51% of the total area in 1986 diminished to 34% in 2000. Thus, by the expense of agricultural land and vegetated areas including natural and man made forest, and sparse forest, the built up areas including continuous and discontinuous urban fabrics, industrial, commercial and residential units with other associated urban facilities dynamically increased in the period under discussion. This might be due to high acceleration of population increment with high demand for land and urban provisions, land allocation policy of the government and unplanned (slum) urban sprawl at the periphery of the conurbation.

The Built up land cover class of the study are showed remarkable growth between 1986 and 2000, the built up area has been changed in 3845 hectares (7801ha of urban land of 1986 has been grew up to 11646ha in 2000) Most of the changes in landcover occurred in the peripheries of the urban sprawl.

Spatial Metrics was the best quantifier and indicator of the level of growth and pattern of the built up areas. Its result can be summarized as follows;

1. ED (Edge Density) has increased from 29.9 in 1986 to 47.4 in 2000. This implies that the study area has a significant development of urban sprawl and emergence of numerous disconnected or fragmented urban centers.

2. As PA (Patches Area) indicates, the number of urban patches in 1986 was 324 and has increased into 367 in 2000. This indicates that there has been a development and emergence of small number of fragmented built up areas.

3. As LPI (Largest Patches Index) indicates that LPI has increased from 26.6 to 43.2. This was related to the contagion of small and isolated urban patches into the largest patch and development of other urban areas around the existing largest patch. Thus, in the study area most of
the small isolated and fragmented urban sprawl and associated built ups were connected with the core and main urban.

4. Area Weighted Mean Patch Fractal Dimension indicated that the level of compactness of the polygons was relatively higher in 1986 than 2000. This implied that the urban expansion to the periphery landuse was relatively lower and less fragmentation during early period (1986) than late periods. This means the urban sprawl has radiated irregularly in to different directions. According to the researchers prior knowledge and the multi temporal land cover classification used and literatures reviewed, the city has been expanding to all directions. Major and significant scale of land conversion to urban functions can be visualized along the Debrezeit road (Gelen and Dukem areas), Jimma road (Sebeta and Alem-gena area), Dessie road (Sendafa area) and along the Gojam road (Sululta area). Thus, the city expansion is not in compact polygon.

5. As Euclidean Mean Nearest Neighbour (ENN_MN) revealed that the measure of the open space between urbanized areas. Thus, there was decrement in ENN_MN from 249.2 in 1986 to 210.3 in 2000 indicated a decrease in the distance between the built up patches. This was probably because of the contagion of small and isolated patches into largest patch and construction of settlements around the existing urban patches. In other word it means that most of the small isolated and fragmented urban sprawl and associated built ups were connected with the core and main urban. Thus, city has shown a tremendous growth in the time under discussion.


[Childrensmercy](http://www.childrensmercy.org/stats/definitions/kappa.htm) (Reviewed, Jan 2009)


UNOMAHA, 2008) http://maps.unomaha.edu/Peterson/gis/notes/RS2.htm (last visit, Dec 2008)


SPATIAL METRICS AND LANDSAT DATA FOR URBAN LANDUSE CHANGE DETECTION IN ADDIS ABABA, ETHIOPIA

MESFIN TADESSE BEKALO

Dissertation submitted in partial fulfilment of the requirements for the Degree of Master of Science in Geospatial Technologies
SPATIAL METRICS AND LANDSAT DATA FOR URBAN LANDUSE CHANGE DETECTION IN ADDIS ABABA, ETHIOPIA