SPATIO-TEMPORAL ANALYSIS FOR MONITORING URBAN GROWTH USING GEOSPATIAL TOOLS: A CASE STUDY OF ADAMA CITY, ETHIOPIA

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDISABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN REMOTE SENSING AND GEOINFORMATICS.

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This is to certify the thesis prepared by Gugsa Dejene entitled as "Spatio-temporal analysis for monitoring urban growth using geospatial tools: A case study of Adama city, Ethiopia" is submitted in partial fulfillment of the requirements for the Degree of Master of Science in Remote Sensing and Geo-informatics compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

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List of Acronyms

ACA	Adama City Administration
CSA	Central Statistical Agency
OECD	Organization for Economic Cooperation and Development
ERDAS	Earth Resources Data Analysis System
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization
LULC	Land use/Land Cover
GIS	Geographic Information System
GPS	Global Positioning System
MUDH	Ministry of Urban Development and Housing
RS	Remote Sensing
QGIS	Quantum GIS
OLI	Operational Land Imager
TM	Thematic Mapper
UN	United Nations
UNDESA	United Nation Department of Economic and Social Affair
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

Abstract

Spatio-temporal analysis for monitoring urban growth using geospatial tools: A case study of Adama city, Ethiopia.

GugsaDejene, MSc. Thesis
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Rapid and unprecedented urban growth is becoming the characteristics of cities in developing countries. Hence, it is normal to assess and monitor urban growth changes using necessary to quantify urban sprawl that provide paramount information for, policy makers, resource managers and urban planners. This study was conducted in Adama city to examine and quantify spatio-temporal trends and patterns of urban growth during 1994–2017. Landsat5 TM image for 1994 and aerial photos of 2004 and 2017 were used for this study. Three different land-cover maps produced at different intervals between 1994 and 2017 were used to evaluate and analyze urban growth visually and quantitatively. The satellite images were classified and land-use/land-cover maps were produced using maximum likelihood supervised classification method. The classification process was checked by producer's, user's, overall accuracy and Kappa statistic accuracy assessments from confusion metrics. Results show acceptable agreement between the classified maps and reference data with a producer's accuracy value >70.6%, and user's accuracy >80%. Post classification change detection analysis and selected spatial metric indices calculation were made to detect, assess and monitor urban growth and the quantify LU/LC changes in the study area. Change detection analysis indicated that Adama is growing rapidly with an average growth rate of 7.3% per year during1944–2017. The built-up area was 45.26 km^2, 74.4 $km^2$and 153.67km^2, respectively in 1994, 2004 and 2017, with annual growth rates of 6.4% and 8.1% in the two study phases. The areas had annual spatial expansion indices of 6.4% and 8.19%, respectively during the periods 1994−2004 and 2004−2017.From spatial metrics analysis, combined number of built-up area patches was 345, 473and 717 for the years 1994, 2004 and 2017. The increase in the number of patches all through the study periods shows the rapid urban growth process in the study area. Therefore, it is time for policy makers, city managers and urban planners to plan and cope up with the pace of Adama urban growth depending on with proper implementation.

Keywords: Change detection, spatial metrics, urban growth, Land-use/land-cover change

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

According to Clark (1982), urban growth is a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. It occurs when people move from villages to towns and cities in expectation of better living conditions, and employment opportunities (Bhatta, 2012). Due to this, population distribution changes from being largely hamlet and village based to predominantly town and city dwelling (Clark, 1982). This movement is the primary cause of urban growth, which is the increase in the physical size of urban areas and being land- use/land-cover change phenomena from a non-urban category to an urban category, a dynamic and complex phenomenon revealing economic development all over the world (Monica and Moses, 2017). Despite their regional economic importance, urban growth has considerable impacts on the surrounding ecosystems (Yuan et al., 2005). It is generating a lot of problems and challenges economically, socially and environmentally (Monica et al., 2017). A direct consequence of urban growth can be observed as increase in built-up areas (Bhatta, 2012).

Most often, the trend of urban growth towards the urban-rural-fringe, where there is less built-up area, and access to irrigation and other water management systems, involves the abandonment of forest and agricultural lands, and these leads to conversion into urban areas, which results in substantial impacts on ecosystems (Genemo Berisa,2012). Many cities are rapidly growing into their periphery, overwhelming former villages and precious farmlands and transforming them into urban expansion because of rapid and uncontrolled urban growth. In fact, urbanization is a contribution to human society if it is controlled, coordinated and planned. Unplanned urban growth and expansions have had serious impacts on the urban ecosystem and on the sustenance of natural resources. Unplanned rapid urbanization with high population density often face severe crisis due to inadequate infrastructure and lack of basic amenities(Kumar et al. , 2014).

The world is rapidly urbanizing and cities are experiencing the dynamic processes of urbanization and globalization (Monica et al., 2017). In the developed world, urbanization has been a consequence of industrialization associated with economic development. In contrast, in developing countries, urbanization occurred because of highly natural urban population increase and massive rural-to-urban migration (Brunn, 1983). While the world experiencing rapid urbanization combined with urban sprawl, expansion of urban-built up area is occurring, i.e., urbanization and urban expansion referred to as spatial growth. Therefore, for the purpose of this study, urban growth is considered as spatial growth and related concepts of urbanization and urban expansion.

Globally, more people live in urban areas than in rural areas (UNDESA, 2014), with 54% of the world's population residing in urban areas in 2014 and it is expected that about 60% (4.9 billion) by 2030 (Kumar, 2014). In contrast, the rural population of the world has grown slowly since 1950 and is expecting to reach its peak in a few years. The global rural population is now close to 3.4 billion and expected to decline to 3.2 billion by 2050 (UN et al., 2014).

The urban population of Ethiopia is also increasing rapidly even if it is at the lowest in the world. In 2012, the urban population of Ethiopia was estimated at 17.3% (15.2 million) and projects to be 42.3 million by 2037 with a growth rate 3.8% a year. This indicates that the rate of urbanization will be even faster, at about 5.4% a year. That means a tripling of the urban population even earlier by 2034, with 30% of the country's people living in urban areas by 2028. The trend is the same for Adama city. According to Central the Statics Agency (CSA, 2007) report, it had a population of about 127,842 and 220,212 in 1994 and 2007 respectively, and it is projected to 555,966 by 2027, with an average growth rate of 4.2% per year.

Understanding the urban patterns, dynamic processes, and their relationships is a primary objective in the urban research agenda with a wide consensus among scientists, resource administrators, and planners, because future development and management of urban areas require detailed information about ongoing processes and patterns. In order to achieve proper management of urban areas, measurement, mapping and monitoring of urban growth are crucial (Kumar et al., 2014). Monitoring these changes and planning urban development can be successfully achieved using multi-temporal remotely sensed data, spatial metrics, and modeling. Effective analysis and monitoring of land cover changes require a large amount of data about the Earth's surface. This is most widely achieved using remote sensing tools.

According to Monica and Moses (2017), application of remote sensing techniques and consequent analyses by means of spatial metrics present effective tools for monitoring temporal and spatial changes of landscapes. This technology has emerged as a popular viable substitute due to its cost effectiveness and technological soundness and that presents permanent and reliable record of spatial patterns. The Repetitive data acquisition, synoptic view and formats processed by computers have made remotely sensed products suitable for change detection application.

Adama city has experienced fast expansion and changes in land-cover. There is very limited information on the extent and patterns of changes occurred in Adama over time. Besides, there are no extensive studies conducted related to urban growth and its impacts. Urban planners and decision makers should consider the potential of geospatial tools to detect, monitor and evaluate urban land-cover changes. During present thesis, remote sensing and spatial-metrics were used to detect and analyze the urban land-cover changes of Adama city during 1994 to 2017. The main objective was to investigate the spatial extent of urban land-cover changes and compare the rate of changes using selected spatial- metrics.

1.2 Statement of the problem

Urbanization and urban growth are complex systems concerning social, economic, technological and political forces interacting together. According to Global Risk Report (2019), the world is experiencing an unprecedented transition from predominantly rural to urban living. By 2050, the world urban population is expected to nearly double, making urbanization one of the 21st century's most transformative trends (UN-Habitat III, 2016). This is mainly due to uncontrolled population growth resulting in serious problems, like scarcity of food, informal settlements, environmental pollution, destruction of ecological structures and unemployment (Maktav and Erber, 2005). This kind of uncontrolled, haphazard, human settlements will lead to urban sprawl. Urban sprawl, which is characterized by haphazard patches of development leads to an improper development in any city usually, happens due to land-use/land-cover conversion in which the growth rate of urbanized land significantly exceeds the rate of population growth over a specified time, with a dominance of low-density impervious surfaces (Barnes et al., 2000).

While the benefits of organized and efficient cities are profound social instability, risks to critical infrastructure, potential water crises and the spread of disease. Nowadays, there are a number of issues concerning urban growth that should be addressed by nations and cites' governments. Climate change, increasing energy costs due to sprawl, loss of agricultural lands, urban sprawl, environmental degradation, and associated impacts, increased residency in urban slums and informal settlements are challenges of urbanization (Besussi et al., 2010; UN-Habitat, 2011; UN-Habitat, 2016).

According to the US Environmental Protection Agency (2001), unplanned urban growth brings long lasting and irreversible impacts such as degradation, loss and fragmentation of habitat, loss of water resource, heat island effect, air quality degradation, greenhouse gas emission and climate change. The Rapid urbanization will increase its pace in developing countries in the coming 30 years while their level of economy remains the lowest. Hence, cities and towns in developing countries will face toughest challenges in the years to come.

Adama city expands rapidly because of population growth, political changes and economic growth. In Adama city, according to Yanit Mekonnen (2017), major land-use increased in Adama area is urban area. During the last 30 years, area under urban land has increased by 31.73% (42.66 ha) due to construction and infrastructure development, while area under agricultural land is decreased by 24.53% (32.98 ha) due to expansion of urban construction. Transformation in agricultural lands in to urban areas has greatly affected the land components and the environment. In Adam city, urban expansion rose dramatically in the last two decades and it is continuing to grow. The city faces rapid urbanization challenges. This poses need for reliable data for efficient planning and information, which can be obtained using remote sensing techniques to examine accurately urban growth in the study area. The outcome of this study will assist policy makers to inform future urbanization policies and this research is worth of studying. The outcome of the study will be helpful in acknowledging town planners with the significance of using advance technological facilities in monitoring urban growth.

1.3. Objectives of the study

The present study takes Adama city as a case study to measure urban sprawl and urban growth change detection during 1994, 2004 and 2017. These years were selected at ten-year interval to address the changes efficiently and each of these years is selected based on availability of data.

1.3.1. General Objective

The general objective of this study was to examine and quantify the spatio-temporal trends and patterns of urban growth of Adama city since 1994 to 2017 using satellite image analysis and calculating spatial-metrics.

1.3.2 Specific Objectives

To achieve the general objective, the following specific objectives of this study:

- Identifying the land-use/land-cover changes and examining the change dynamics at different
- spatial and temporal scales;
- To identify the trend, nature, rate, location and magnitude of land-use/ land-cover changes in Adama city during the study period;
- To map and quantify the urban growth of Adama city during the past 23 years.
- To estimate urban expansion of the Adama city by 2030
- To compare the rate of population growth with the rate of urban growths of Adama city.

1.4. Research Questions

Due to various activities that cause urban growth in the city, it is believed that there would be considerable urban land-cover changes in the study areas in the recent times. Therefore, the research is intended to answer the following questions:

- What was the urban status of Adama before last two decades?
- Where did urban growth occur in the study area during 1994 and 2017?
- Did the urban growth meet the growth rate of population in Adama?
- At what rate and how much land was converted for urban-land cover the study periods in Adama?
- How does spatial-metrics technologies us to understand and present urban growth in Adama?

1.5. Scope of the study

This study deals with Adama city in the Oromia Regional State, Ethiopia. It includes the already developed and expanded areas of the city. It aims to conduct the study in Adama city boundary - the continuous urban development through times. Although urbanization and urban growth are at its lowest levels in Ethiopia, there have been a number of changes with respect to urban expansion in the study area in the past ever few decades. Therefore, the main scope of the study is to monitor urban growth using various change detection techniques and temporal satellite images of 1994 to 2017, and measure urban sprawl using spatial metrics methods.

1.6. Significance of the study

This study tried to quantify and analyze the changes between 1994 and 2017 in Adama city to contribute in the urban land, environmental management and monitoring plan of the areas. Therefore, it is expected to:

i. Provide basic information on the status and dynamics of the urban land-cover 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 land-cover changes in different times, area as well as other concerned body for their decision making processes related to how land-use/land -cover changes the time

ii. It could be used as an input for government policy makers, urban managers, and urban planners for optimum urban analysis in urban planning how land-use and land-cover changes through time.

iii. Present basic spatial metrics and remote sensing methodologies to detect and analyze urban land-cover changes and present the potential of these tools for extracting land related information in the country.

iv. In addition to this, this data can form a reference material and as an input for future researchers.

1.7. Limitations of the study

The present study was an attempt with all possible efforts to attain required inputs in the form of primary and ancillary data collection, interpretation and analysis. However, the study has encountered the following limitations:

- Time constraint
- Financial constraint
- Data availability and quality constraint

1.8. Organization of the Thesis

This thesis is organized into five chapters. The first chapter is the introduction part, which includes background, statement of problem, objectives of the study, research questions, and significance and limitations of the study. This part highlights the global status, prospects and problems of urban growth. The second chapter deals with literature review with different approaches, methods and mechanisms of urban growth studies, which have assisted the researcher to produce different arguments on the selected topic. Here the concept, global and national trends, causes and impacts of uncontrolled urban growth have been stated in brief. The application of GIS and remote sensing techniques in spatial monitoring of urban growth is also presented in this chapter. The third chapter deals with the description of the study area, followed by the methods employed including data types and sources, software and instruments utilized to carry out this research. In this chapter, image classification algorithms and data analysis techniques are briefly described. The forth chapter is dedicated to the results component of the study. Results from the analyses of LU/LC change, Shannon's entropy index, demographic changes and area's susceptibility to urban expansion are included in this part. The fifth chapter is the discussion, which focuses on interpretation of results obtained with this existing theories and practices to highlight the present finding. The conclusion and recommendations are providing as the sixth chapter of this thesis.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

In developing countries, population growth is rapid in urban areas (Jamal Jokar, 2012). Rapid urbanization is extending to farming areas. Metropolitan populations outside cities have increased faster than downtown areas in many regions, indicating a tendency of the outward extension of urban areas. Many cities are growing at their fringes, swallowing rural areas and farmlands and converting into dense commercial and industrial areas (Huang et al., 2009). This chapter reviews literatures regarding urbanization and urban growth, land-use/land-cover changes, advances in remote sensing technology in analyzing urban growth, classification methods, spatial-metrics and their application in monitoring urban growth pattern and driving forces of urban growth and urban modeling techniques.

2.2. Urbanization

2.2.1. Definition of Urbanization and Urban Growth

Urbanization refers to the growth of towns and cities, often at the expense of rural areas, as people move in to urban centers in search of jobs with the expectation of a better life, enabling cities and towns to grow. It can also be termed as the progressive increase of the number of people living in towns and cities. It is highly influenced by the notion that cities and towns have achieved better economic, political, and social mileages compared to the rural areas (Bhatta et al., 2010).

Urban growth is a spatial and demographic process as that refers to the increased importance of towns and cities as a concentration of people with in a particular economy and society (Bhatta et al., 2010). There are at least three different and widely studied concepts of urban growth in the urban and regional planning literature, related to population change, economic performance and the spatial expansion of urban areas (Reis et al., 2015). The socio-demographic dimension of urban growth focuses on demographic trends and migration. The first includes the natural population growth rate, depending mainly on fertility and mortality rates, while the second depends on the capacity of a city to attract residents from other cities or rural settlements (Turok and Mykhnenko, 2007; Rieniets, 2009).

Urban economic growth normally considers a city's economic performance. It takes into a consideration a set of economic variables, such as growth or employment opportunities, income levels, GDP or housing prices (Glaeser and Gottlieb,2006; Cheshire and Magrini, 2009); while, spatial growth concerns changes on the geographic space occupied by built-up structures and human activities, and are often associated to terms such as "urbanization" and "urban expansion"(Clifton et al., 2008).

2.2. 2. Trends of Global Urbanization

The world is rapidly urbanizing and cities are experiencing the dynamic processes of urbanization and globalization (Monica et al., 2017). According to Xing Quan (2015), prior to 1950, global urbanization trends were calculated based on the transformations that took place in Organization for Economic Cooperation and Development (OECD) countries. The proportion of the world's population, which is urban, has been growing rapidly and currently a larger fraction of the total population lives within cities (UN, 2007). According to United Nations world Urbanization Prospect (UNWUP, 2014) the percentage of urban population in 1950 was 30% , which was increased to 54% in 2014, and estimated to be 66% by 2030 (Fig 1). Urbanization is not merely a modern phenomenon, but a rapid and historic transformation of human social roots on a global scale, whereby predominantly rural culture is being rapidly replaced by urban culture (Pawan, 2016).

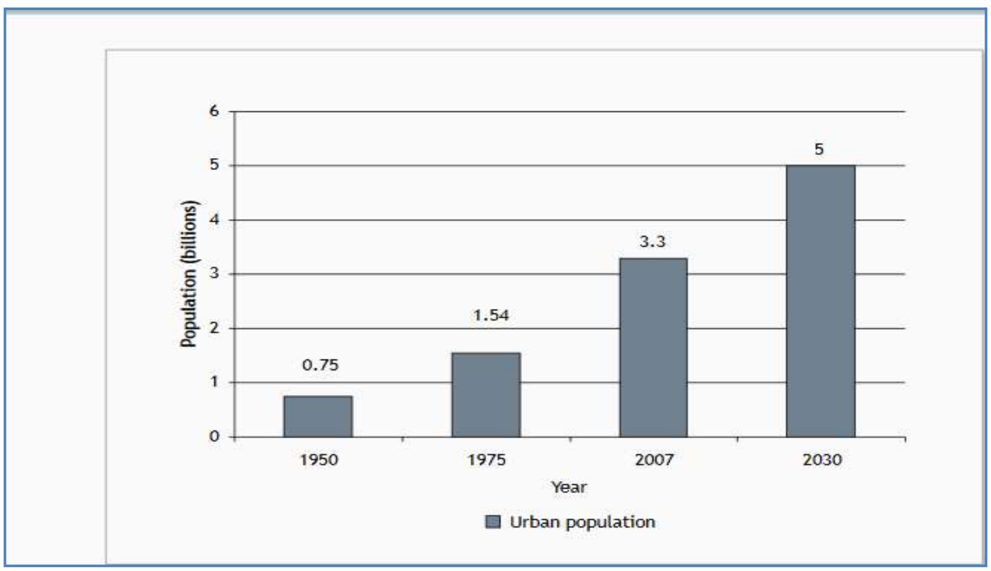


Figure 1. World population in urban area (1950–2030).

(Source: UN (2014)

If well managed, cities offer opportunities for economic and social developments. Cities have always been focal points for economic growth, innovation, and employment (Barney, 2005). If managed proactively, monitoring its growth and expansion in well planned and coordinated manner, cities can provide huge opportunities to shift the structure and location of economic activity from rural agricultural based economy to the larger and more diversified urban industrial and service sectors.

In contrast, if not managed proactively, the growth and expansion of cities poses challenges and managing them becomes increasingly complex. Because a natural expansion of urban centers without monitoring and management, leads to haphazard or unplanned growth, undesirable land-use patterns, i.e. continuous low-density, strip/ribbon, scattered, and leapfrog development (McKee and Smith, 1972; Popenoe, 1977; Heikkila and Peiser, 1992; Ewing, 2008). Of particular concern are the risks to the immediate and surrounding environment, to natural resources, to health condition, to social cohesions, and to individual rights (Cohen, 2005).

2.2.3. Urbanization in Africa

According to Omoakin Jelil (2012), Africa used to be, and perhaps is still, the least urbanized continent, with growth rates of cites close to, if not the fastest in the world. But, today, in virtually every part of the continent, new cities have been emerged, while the old ones have drastically expanded, some of which have become mega-cities. By 2030, for the first time in the history, more of the continent's people will be living in urban areas than in rural regions, and by 2050 an estimated 1.23 billion people, or 60% of all Africans will be city dwellers (Fig 2). Currently, even if the level of urbanization in Africa is low, the rate of urbanization is high due to the population growth, which is one of the most important driving forces of changes in any urban system. If urban population swells, the city must expand upward or outward. Along with economic development and technologies (mainly transport and communication) revolution, rapid urban growth can be characterized by the development of suburban expansion and redevelopment in city centres (Rui, 2013).

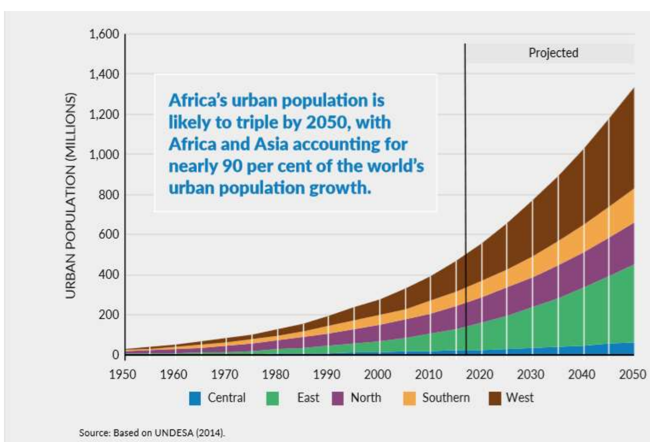


Figure 2. Urban populations by African Sub region, 1950–2050
(Source: UNDESA, 2014)

According to UNECA economic report on Africa (2017), Africa's urban growth is both opportunities and challenges. History and experience demonstrate that urbanization is closely linked to economic growth and the transformation of economies towards productive sectors, namely industry and services. Available evidences suggest urban and industrial developments in Africa are disconnected, resulting in lost opportunities for job creation and improved well-being of people. It is also not surprising that Africa's cities are crippled by severe infrastructure and service gaps and unable to generate employment at the level and scale required to meet ever-increasing demands, especially for youth. Freire et al. (2014) indicated that Africa's urbanization faces four major challenges:

1. Inadequate infrastructure and services, housing shortage, traffic and transport management problems, violence and other social crisis are highly pronounced,
2. Weakness in administration, institutions and overall planning capacity,
3. Urban sprawl with encroaching upon environmental sensitive areas, major agricultural areas and areas which are not suitable for development,
4. Rapid population growth with low-level of economic activities based on inadequate capital.

If well managed, cities offer important opportunities for economic and social developments. Cities have always been focal points for economic growth, innovation and employment (Barney, 2001).

2.2.4. Urbanization in Ethiopia

Although urbanization processes took place prior to the 20th century in Ethiopia, most of the Ethiopian towns originated due to geographical, political and economic factors (NUPI, 1997). However, it is one of the least urbanized countries in the world, well below the Sub-Saharan Africa average of 37 percent. According Ministry of Urban Development and Housing State Report (MUDH, 2015), the level of urbanization in Ethiopia remained low until recent decades that saw expansion of roads and telecommunications infrastructure and the country's multi-faceted participation in the global arena. The country's level of urbanization was about 5% in the 1950s, and only reached 10% in the 1970s. However, by 1984, when the first census was conducted, the level of urbanization was increase to 13%. The level of urbanization was estimated at 19% in 2014, having grown by 6% between 1984 and 2014, reflecting an average increase of 2% in the level of urbanization per decade (Fig 3). However, this is set to change dramatically (MUDH, 2015).

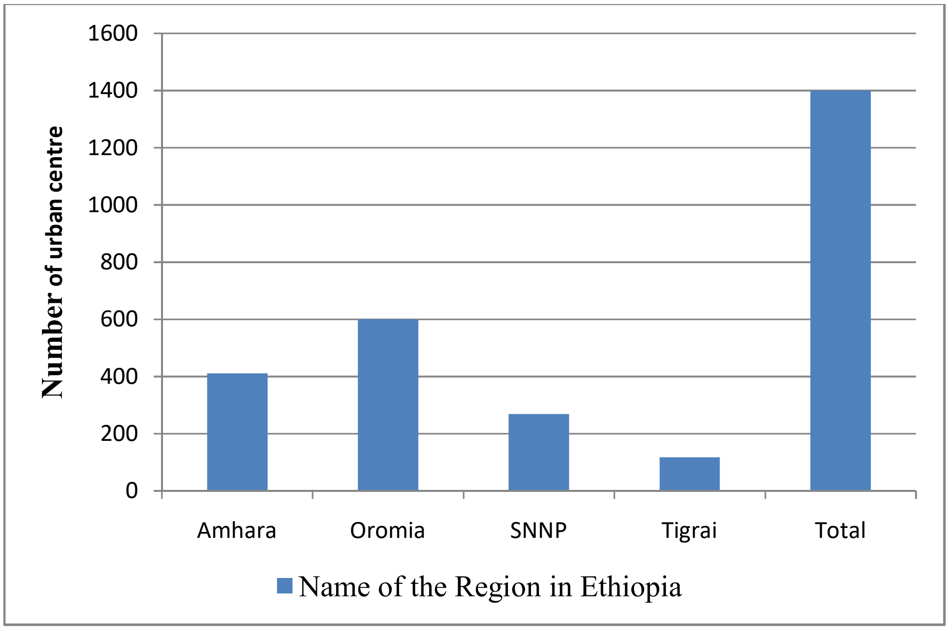


Figure 3.Ethiopian Urban Centres in 2014, (Source: MUDH, 2015)

In Ethiopia, rapid urbanization results in a steady increase in the urban population. According to official figures from the Ethiopian Central Statistics Agency (CSA), the urban population is projected nearly triple from 17.2 million in 2012 to 42.3 million in 2037, growing at 3.8 percent a year (CSA, 2013) (Table 1). Analysis for this report indicates that the rate of urbanization will be even faster, at about 5.4 percent a year. That would mean a tripling of the urban population even earlier by 2034, with 30 percent of the country's people living in urban areas by 2028 (World Bank Group, 2013).

Table 1:National, Urban and Rural Population Size Trend in Ethiopia (1984 – 2014).

YEAR	URBAN	RURAL	TOTAL	RURAL%	URBAN%
1984	4,505,14	35,363,424	39,868,572	88.7	11.3
1994	7,323,207	46,154,058	53,477,265	86.3	13.7
2007	11,862,821	61,888,111	73,750,932	83.9	16.1
2012	14,502,555	69,818,432	84,320,987	82.8	17.2
2014	16,734,000	71,218,000	87,952,000	81.0	19.0

(Source: CSA, 1991, 1998, 2008, 2012 and 2013).

While the share of urban population has increased from 11.3% in 1984 to 19.0% in 2014, the proportion of the rural population declined from 88.7% to 81.0% during the same period. According to the World Bank Group (WBG, 2013) report, Ethiopia has one of the fastest growing urban populations in the world; with the number of people living in cities expected to nearly triple in the next two decades. This demographic dividend presents a real opportunity to change the structure and location of economic activity from rural agriculture to more diversified and much larger urban industrial and service sectors. However, the central challenge for the Ethiopian Government is to make sure that cities are attractive places to work and live, while fostering urbanization. Infrastructure and service delivery have already undermined by the growing urban extent and by stretched municipal budgets, while formal labor markets are failing to keep up with the demand for jobs. As a result, Ethiopian cities run the risk of becoming less attractive places for people and economic activities.

Formal and informal settlements are stretching out horizontally from central cities in all directions on precious farmland and in environmentally sensitive areas without proper planning and management. Land is ineffectively used; new developments are planning on virgin land usually leapfrogging from cores. Generally, as pointed out by Haregewoin (2005), sprawl and misuse of land in Ethiopia is the result of population pressure (both from natural births and migration), poor land policies, lease system, planning and regional imbalances. Action is therefore needed to provide immediate needs of the population while trying for solutions to overcome mismanagement of land and further horizontal expansion with minimum financial expenditure (Haregewoin, 2005).

2.2.4.1. Urban expansion and growth of Adama city

The construction of the Addis Ababa-Djibouti railway at the start of the 20th century had given impetus to the establishment of several urban centers (such as Adama, Dire Dawa, and Hursso) that started as transport outposts. Adama city is one of the railway urban centers, founded as a railway depot in 1916 (Fig 4). According to state of Ethiopian cities report provided by Ministry of Urban Development and Housing (MUDH, 2015) based on 2007 census, the CSA officially had recognized 973 urban centres in Ethiopia. A key feature of the country’s urban system is the primacy of Addis Ababa, which was population wise more than ten times larger than the second largest urban centre, Adama in 2014.

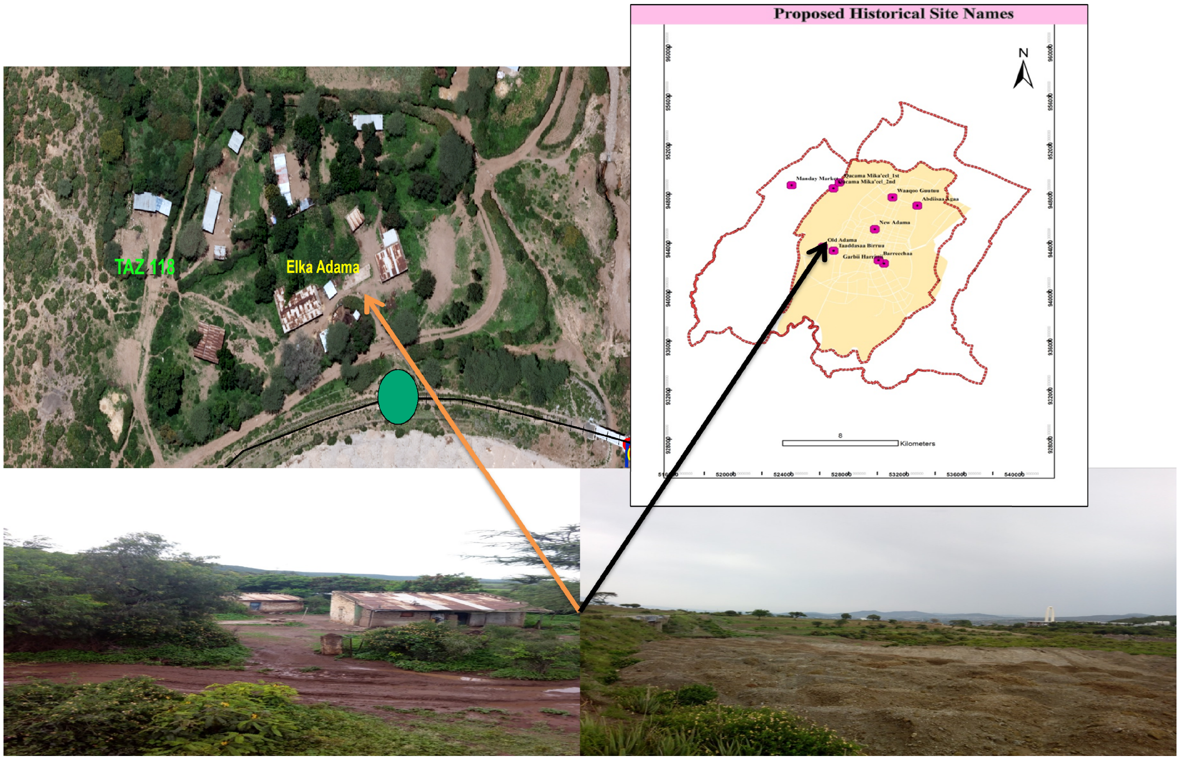


Figure 4. Place of Adama City Emerge

Increase in urban population undoubtedly requires investments to address the ever increasing demand for jobs, housing and other kinds of urban-based services, infrastructure and facilities. Failure to meet these requirements would result in unemployment, housing shortage and congestion, proliferation of informal settlements, environmental degradation, and inadequate basic social services and incidence of crime that would compromise the productivity and livability of cities.

2.2.4.2. Previous Studies on Adama City

Adma city is rapidly putting pressure on the surrounding environment. Most of the studies on urban growth of Adma city (Addis Mebratu, 2007; Seid Yhdego, 2007; Yanit Mekonnen, 2017). They have focused on spatial expansion of the city and its impact on environment in relation to population growth. Therefore, they have not quantified urban growth, sprawl and its fragmentation. Yanit Mekonnen (2017) indicated that geospatial techniques are important technologies for identifying growth of the urban region and conversion of land types.

Therefore, this study is to show those changes happened in the past 23 years and to fill the gap with detailed emphasis on quantifying spatial pattern of landscape changes , quantifying urban growth and patterns of developments. The study is also intended to show how the recent expansion, pattern and composition of Adama city look like and how much of agricultural, open space and green areas are incorporated in to the built-up area of Adama city.

2.3. Urban Sprawl

Although accurate definition of urban sprawl is debated, a consensus is that urban sprawl is characterized by unplanned and uneven pattern of growth, driven by multitude of processes leading to inefficient resource utilization (Bhatta, 2010). Urban sprawl is characterized by haphazard patchwork of developments lead to an improper development in any city. Usually, it happens due to land-use/land-cover conversion in which the growth rate of urbanized land significantly exceeds the rate of population growth over a specified time, with a dominance of low-density impervious surfaces (Barnes et al., 2000). This phenomenon affects the majority of worlds' metropolitan areas and is associated to the replacement and fragmentation of natural habitats and agricultural lands by infrastructures, residential and commercial developments (Pedro et al., 2005). To prevent this kind of sprawl in future, it is necessary to monitor the growth of the city. Hence, an attempt has been made in the present study to monitor the urban growth over a period of time by employing Remote Sensing and Geographic Information System techniques in conjunction with spatial-metrics (Antony et al., 2007).

2.3.1. Causes of urban sprawl

The causes of urban sprawl are quite similar with those of urban growth. In most of the instances, they cannot be discriminated, as urban growth and sprawl are highly interlinked. However, it is important to realise that urban growth may be observed without the occurrence of sprawl, but sprawl must induce growth in urban area (Bhatta, 2010). The causes and catalysts of urban growth and sprawl, as discussed by several researchers (Harvey and Clark, 1965; Squires, 2002; Handy, 2003; Batty, 2004; Burchfield et al., 2006; Torrens, 2006; Bhatta, 2010; EPA, 2013), are summarized below.

- Population growth is one of the most important driving factors behind the urban sprawl. It contributes to sprawl through absolute growth, increased urbanization (the percentage of the population living in urban areas is growing), and the restructuring of household demography (household sizes decrease and housing units increase).
- The increased use of cars is considering as a root cause of urban sprawl. At the same time, highways and other transportation systems have grown quickly. Due to these two reasons, people can choose to live in suburbs. In order to follow labor forces and pursue cheap land, industry and business move from the city to sub-urban by accessing an expanding highway

network. Intersections of sub-urban highways have become sub-centers of new urbanization.

2.3.2. Consequences of urban sprawl

Direct implication of sprawl is change in land-use/land-cover of the region as sprawl induces increase inbuilt-up and paved areas (Sudhria and Ramachandra, 2007). According to Basudeb Bhatta(2010), urban sprawl is responsible for changes in the physical environment, and in the form and spatial structure of cities. The consequences and significance of sprawl, good or ill, are evaluated based on its socio-economic and environmental impacts. Major consequences of urban sprawl can be summarized as follows:

- Loss of farmland: urbanization in general, and sprawl in particular, contribute to loss of farmlands and open spaces (Berry and Plaut, 1978; Fischel, 1982; Nelson, 1990; Zhang et al., 2007). The loss of agricultural land to urban sprawl means not only the loss of fresh local food sources but also the loss of habitat and species diversity, as farms include plant and animal habitat in woodlots and hedgerows. The presence of farms on the landscape provides benefits such as green space, rural economic stability, and conservation of the traditional rural lifestyle (Bhatta, 2010).
- Inflated infrastructure and public service cost: sprawl requires more infrastructures, as it takes more roads, pipes, cables and wires to service these low-density areas compared to developments that are more compact with the same number of households (Cora, 2017).
- Energy inefficiency: urban sprawl causes more travel from the suburbia to the central city and thus more fuel consumption. Furthermore, it also causes traffic congestion. More cars on the roads driving greater distances are a recipe for traffic gridlock resulting in more fuel consumption (Bhatta, 2010).
- Impacts on ecosystem and wildlife: developments associated with sprawl not only decreases the amount of forest area (Macie and Moll, 1989; MacDonald and Rudel, 2005), farmland (Harvey and Clark, 1965), woodland (Hedblom and Soderstrom, 2008), and open space. Also breaks up what is left into small chunks that disrupt ecosystems and fragment habitats (McArthur and Wilson 1967; O'Connor et al., 1990; Lassila, 1999).
- Impacts on Water Quality and Quantity: Sprawl also have serious impacts on water quality and quantity. Urban growth and sprawl lead to an increasing imperviousness, which in turn induces more total runoff volume. So urban areas located in flood-prone areas are exposed to

increased flood hazard, including inundation and erosion (Jacquin et al., 2008).

Generally, several scholars have criticized this phenomenon for the loss of open space, environmental damage, loss of surface water, depletion in groundwater, loss of biodiversity and increased congestion. The unplanned urban growth and expansion has had serious impacts on the urban ecosystem and on the sustenance of natural resources (Manish et al., 2014).

2.4. Monitoring urban sprawl and applications of spatial metrics, GIS and RS

2.4.1. Remote sensing and urban sprawl

According to many scientists, resource managers, and urban planners, the future development and management of urban areas require comprehensive knowledge about on-going processes and patterns. As a result, understanding urban growth patterns, dynamics processes, and their relationships and interactions are key objectives in the present-day urban studies (e.g. Bhatta, 2009; 2010; Degn et al., 2009). In order to achieve proper management of urban growth and sprawling, the measurement, mapping and monitoring of urban growth and sprawl are crucial for government officials and planners in any region. Reliable and updated information on Spatio-temporal pattern of urban sprawl is a perquisite (Manish et al., 2014).

Detailed spatial and temporal information of urban morphology, infrastructure, land-cover/land-use patterns, population distributions, and drivers behind urban dynamics are essential to be observed and understood. Urban remote sensing has attempted to provide such information (Bhatta, 2010). Remote sensing is a helpful tool to better understand the spatiotemporal trends of urbanization and monitor the spatial pattern of urban landscape compared to traditional socio-economic indicators such as population growth and employment shift (Gezahegn Aweke, 2013). However, it cannot provide full description of the underlying processes that are responsible for the changing patterns of urban land-use/land-cover. To bridge this gap spatial-metrics tools are applied. The thematic LC maps obtained from analysis of Landsat images will be used to further quantify and describe urban landscape pattern changes.

2.4.2. Spatial Metrics in Urban Growth Analysis

Spatial-metrics are numeric measurements that quantify spatial patterning of land-cover patches, land-cover classes, or entire landscape mosaics of geographic area (McGarigal and Marks, 1995). It is an expedient tool for quantifying spatial heterogeneity to have better insight on how spatial structures impact the system interaction in heterogeneous landscape. Heterogeneous landscape or spatial heterogeneity refers to the complexity and unevenness of a system property in time and space, spatial heterogeneity is considering synonymous of spatial pattern (Gezahegn Aweke, 2013). Several case studies have been conducted confirming the efficacy of this approach (Rutledge, 2003; Weijers, 2012; Gezahegn Aweke, 2013; Meeli, 2013; Ramachandra, 2014; Megahed, 2015; Reis et al, 2015; Sewunet Shiferaw, 2016) in urban areas to assess the patterns of growth and to quantify urban sprawl.Spatial-metrics have found important applications in quantifying urban growth, sprawl, and fragmentation (Hardin et al., 2007).

Spatial metrics can provide numerical description of the landscape structure according to the level of heterogeneity at patch, patch classes or the whole landscape level (Herold et al., 2003). At the class and landscape level, some of the metrics quantify landscape composition, while others quantify landscape configuration. A patch is relatively homogenous area that differs from its surrounding (McGarigal and Marks, 1995).

Thus, spatial metrics are 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, and patch density (Gustafson, 1998). Spatial metrics combination with spatial metrics techniques provides an accurate and detailed mapping of the data useful in urban application (Akintude et al., 2016).

2.4.3. Change Detection

Change detection analyses describe and quantify differences between images of the same scene at different times (Ibrahim et al., 2015). There is quite a number of change detection methods applied for various purposes. Lu et al. (2004) lists seven methods of change detection techniques, such as (1) algebra, (2) transformation, (3) classification, (4) advanced models, (5) geographic information system, (6) visual analysis, and (7) other approaches. Each category has its own advantages and disadvantages. The categories are in order of their complexity and there are a number of subclasses under each main category. The classification category includes supervised and unsupervised change detection, post classification comparison, spectral-temporal combined analysis, expectation-maximization algorithm (EM) change detection, hybrid change detection, and Artificial Neural Networks (ANN) (Lu et al., 2004). The supervised classification and post-classification comparison method are applied for this study.

CHAPTER THREE

3. MATERIALS AND METHODS

This chapter deals with the study area, presents the accessible data, methods, techniques, approaches and materials used to attain the research objectives. It explains the data sources and types, methods of field data collection, reference data identification of driving forces of urban growth, image classification techniques employed, and change detection methods used, accuracy assessment, selection of spatial metrics and list of software packages used in this research.

3.1. Description of the study area

3.1.1. Location

The Adama City Administration, situated in the Oromia National Regional Stat of Ethiopia (Fig 5), in the Southeastern direction of Addis Ababa, approximately at 100km, along the main railway from Addis Ababa to Djibouti, is the country's most important conference, recreational, industrial, and commercial center. It enjoys urban primacy in the national urban system and serves as a node of the national urban system. It's geographically located in from 8° 35' 00"–8° 36' 00" N Latitude and 39° 11' 57"–39° 21' 15" E longitude. The elevation/altitude ranges from 1,444 to 2054 meters above sea level (m.a.s.l) with a total area of 310 km^2.

Adama city lies in the Great Ethiopian Rift Valley on a nodal location along the main national and regional transport lines from the capital city, Addis Ababa, to other important cities and towns like Dire-Dawa, Harar, Semara , Jijiga and to Djibouti . It is also situated close to natural recreational sites such as 'Sodare and Boku' hot springs.

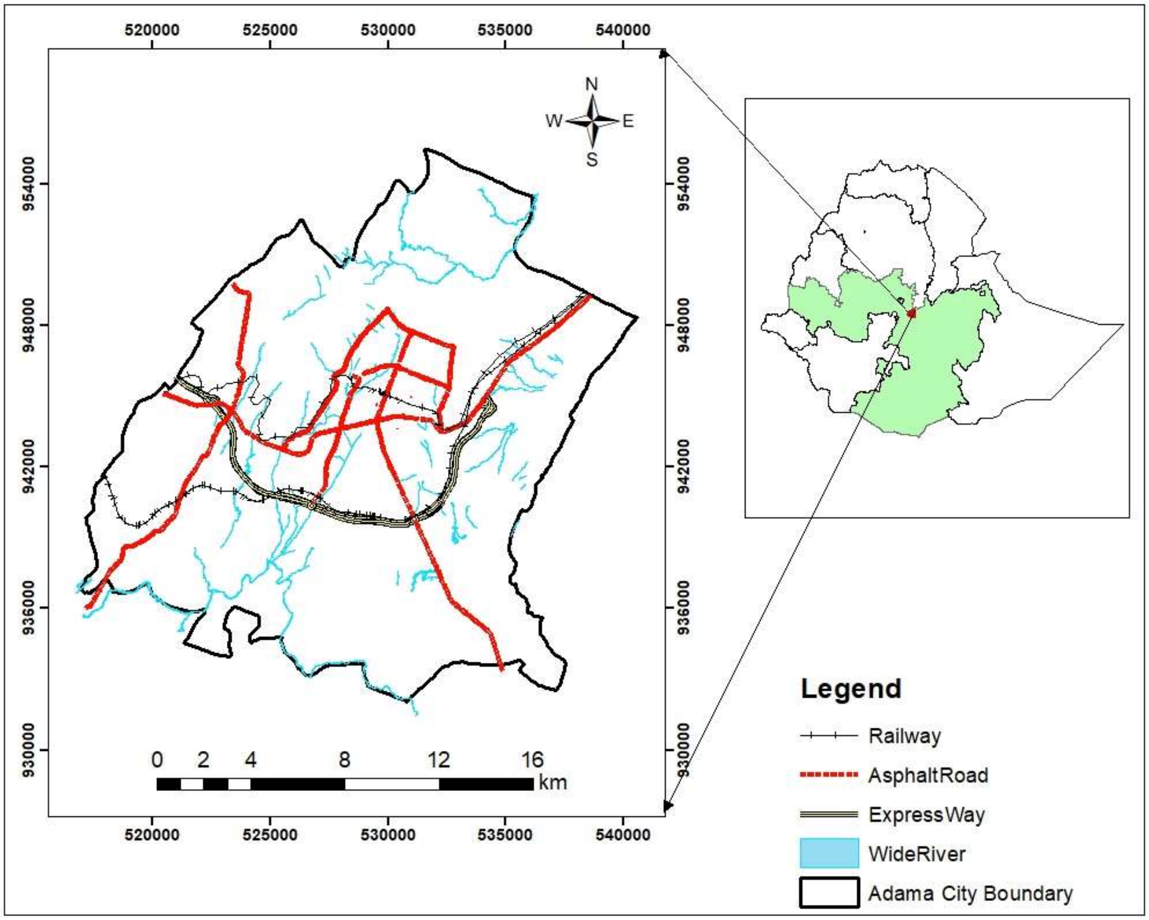
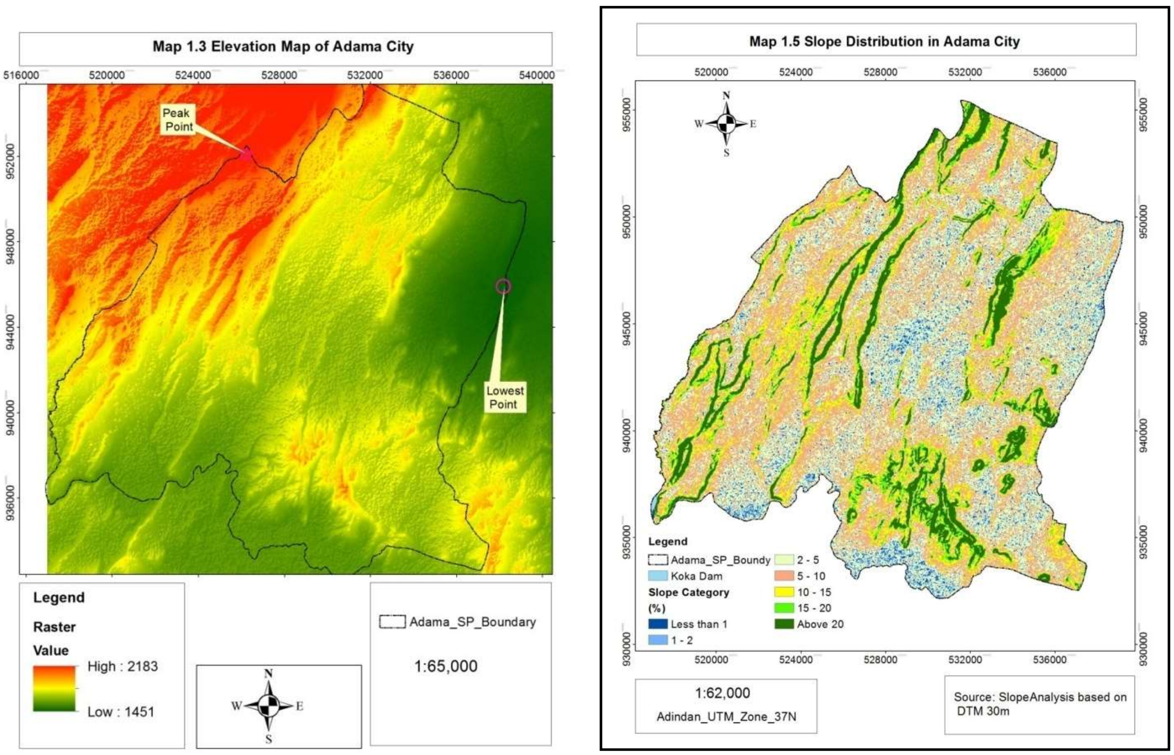


Figure 5. Location map of the study area

3.1.2. Topography

The existing built up area of Adama city, is in 'Kechema' and 'Boriticha' uplands, with a flat topography. This topography generally rolls down from north (Dhaka Adi) to south direction up to the expressway that runs from Addis Ababa to Metehara. The western and eastern parts of the built-up areas that are adjacent to Kechema and Borticha uplands are affecting by flood from the dissected uplands during the rainy season. Adama city lies in the Great Ethiopian Rift Valley. Within this major landform, there are plateau and plain landscapes. Within these landscapes, there are also smaller, wider, shallower and deeper gullies (Fig. 6 a). The elevation ranges from 1,444 to 2054 m above sea level. The lowest and highest points are located at the extreme east and northwest part of the expansion areas, respectively (Fig. 6a).

The mean slope in Adama city is 8.7 %. Slope category less than 1% covers 7.2787 km^2 of the total area (2.3%) is excessively plains.19.8 km^2 of the total area (6.3%) is between 1 and 2º slope, 96.3 km^2 of the total area (30.8%) is between 2 and 5º slope, that is generally flat area, 104.9 km^2 of the total area (33.5%)is between 5 and 10º , that is generally gently rolling area, 39.034 km^2 of the area (12.5%) is between 10 and 15 º, that is mild slopes, 17 km^2 of the total area (5.4%) is between 15 and 20º , that is steep slopes and 28.7 km^2 of the total area (9.2%) of the city area is harsh, steep slope. The slope of the area is indicated in (Fig.6 b).



(a) (b)

Figure 6. (a) Elevation and (b) Slope map of the Study area .

3.1.3. Climate and Vegetation

A. Rainfall

Rainfall record from 1995 to 2016 at the Adama Meteorological Station shows that Adama city falls within summer maximum rainfall region of the country. The mean annual rainfall of Adama city was 923 mm and the maximum monthly average rainfall was 246.53 mm in the month of July (Fig.7).The two months that acquire maximum rainfall are July and August, whereas the minimum rainfall

acquired was during November–February. The warmest month is May and coolest month is July.

Among all months, the driest month is December. Therefore, it is necessary to practice appropriate watershed management on the upper stream and flood control mechanisms downstream.

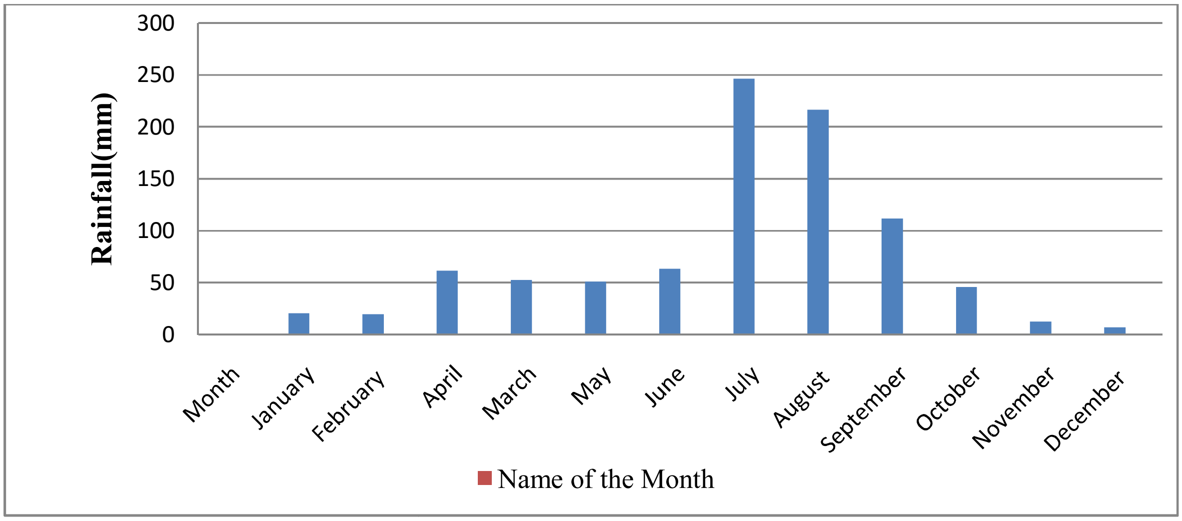


Figure 7. Monthly average rainfall distribution of the Study Area

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The average rainfall recorded between 1995 and 2016 was 709.9 mm, while 1999 and 2010; it was 833.24 mm and 745 for the years between 2010 and 2016. The distribution of annual rainfall from 1995–2016 is presented in (Fig 8).

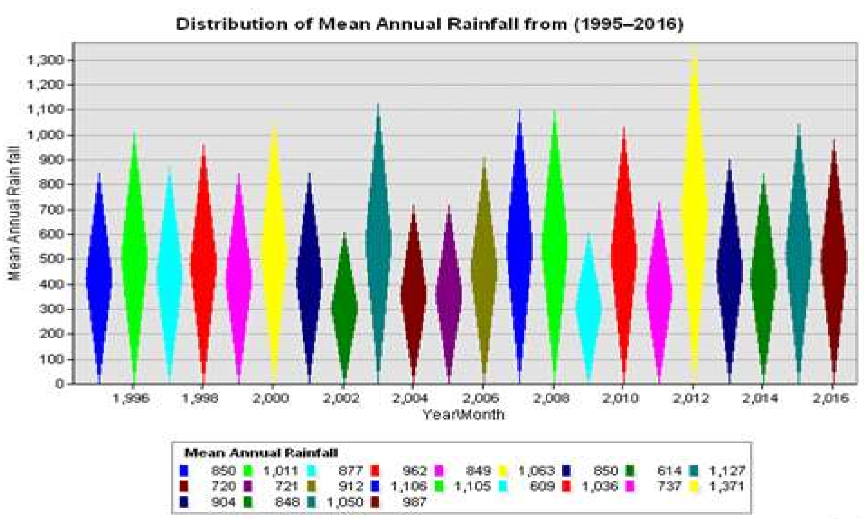

Figure 8: World population in urban area (1950–2030).

B. Temperature

According to the Ethiopian Meteorology Agency, Adama station data (1995–2016), the mean annual temperature of the city is 21.7°C. It is classified as semi-humid to semi-arid climate, which characterizes the altitude range between 1300 to 1800 m a.s.l. In Adama, the hottest month with the maximum mean temperature of 31°C was May (Table 2). The monthly minimum mean temperature was November and December with the temperature 11.5°C. The maximum temperature varies between 21.9°C and 30.7°C while the minimum monthly humidity varies between 16.7°C and 21.7°C. At Adama, the heavy truck movements could contribute to the increase of temperature due to carbon dioxide (Co_2) input into the air (NMSA, 2002).

Table 2: Monthly minimum, mean and maximum temperature of Adama from 1995–2016.

Year\Month	Temp–Min °C	Mean Monthly Temp °C	Temp–Max °C
January	18	19.95	21.9
February	20.4	21.8	23.2
March	21.2	25.95	30.7
April	21.6	22.95	24.3
May	21.7	23.6	25.5
June	21.6	23.3	25
July	20.1	21.8	23.5
August	20.3	21.3	22.3
September	19.8	21.2	22.6
October	19.4	21.45	23.5
November	17.7	19.85	22
December	16.7	19.95	21.2

(Source: Ethiopian Meteorology Agency)

3.1.4. Population

Demographic change can affect social, economic, environmental and other factors negatively or positively. More specifically, land is a base for all developments. Therefore, change in population growth accelerates the demand for land and the dynamics in land-use/land-cover changes.

This presented deals with the relationship between population growth and urban sprawl. Thus, all discussion and interpretation of data could consider density, migration, natural increase and other demographic elements. According to the reports obtained from CSA (2013) and OUPI (2017), population size in the study area steadily raised up from 1984 to 2017. Adama city population was increasing by an average of 4,978.2 persons per year during the period between the first and second censuses conducted in 1984 and 1994 (Fig 9). The annual increase grew to about 9311.1 between the second and the third censuses. Since 1984, the study area population grew from 77,319.000 to 427,302.000 in 2017. This factor triggers the ever-growing demands for urban services such as land for residence, economic and industrial activities and public services.

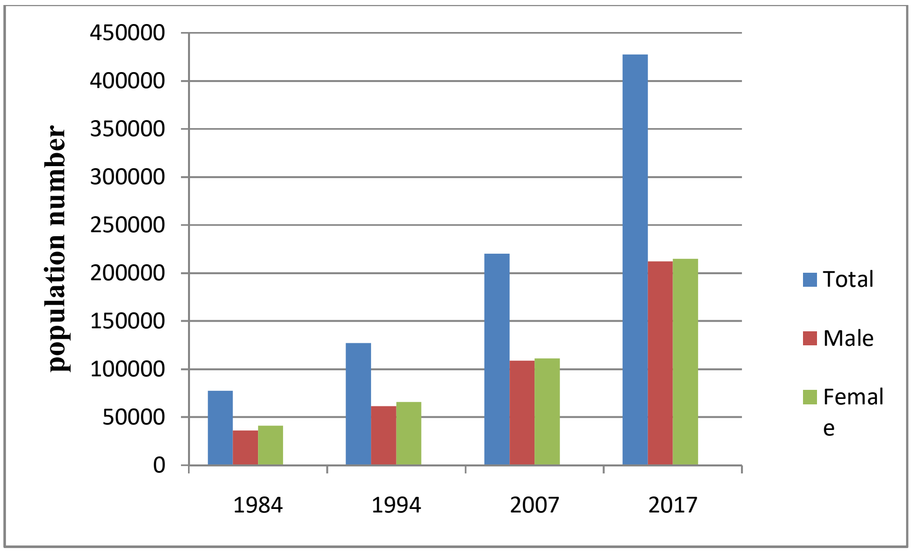

Figure 9. World population in urban area (1950–2030).

(Source: CSA, 2013; OUPI, 2017)

3.2. Data and software used for this present study

Understanding the dynamic, such as urban growth/sprawl, requires land-use/land-cover change analysis, urban sprawl pattern identification and computation of landscape metrics. For this propose, different remote sensing data and software programs were used mainly satellite imagery, and ERDAS Imagine 15, FRAGSTATS 4.2 and ArcGIS 10.2 software programs. ERDAS Imagine is important software for image preprocessing, enhancement, transformation, classification and accuracy assessment activities. FRAGSTATS calculates several spatial metric statistics in landscape environment to measure urban sprawl. Other material, such as Garmin GPS 78 and digital camera were used for ground data collection for accuracy assessment of classified images. Data used for this research comprise both primary and secondary (Ancillary). The most important source was the primary data (satellite data). Ancillary source of data were collected from governmental and non-governmental organization and published information.

Due to lack of Aerial photo or resolution image for 1994, apply landsat5 with fusing it with aerial photo to improve its resolutions. Aerial photographs were used to analyze urban growth trends and patterns for the years of 2004 and 2017. All images acquired geometrically, raiometrically corrected and geo-referenced to Adindan, UTM zone 37N projection systems. Characteristics of the satellite data used in this study are summarized in the (Table 3).

Table 3:Satellite imageries data used for the present study.

Projection	Datum	Satellite	Earth Pixel size(m)	Sensors	Date
UTM_Zone_37N	Adindan	Landsat 5	30	TM	1994
UTM_Zone_37N	Adindan	Aerial photos	0.15		2004
UTM_Zone_37N	Adindan	Aerial photos	0.5		2017

Additionally, the secondary data, such as those published and unpublished documents from various websites and organizations were used in order to prove the findings and detect the changes on the surface (Table 4).

Table 4:Satellite imageries data used for the present study..

Secondary Data	DATA SOURCES
Population Data.	Central Statistical Authority (CSA),
Adama city structure plan	Oromia Urban Planning Institute
Unpublished And Published Documents	Different websites and Library
Topo-sheet	Ethiopian Mapping Agency(EMA)
FACILITY AND SOFTWARES	
ArcGIS 10.2 & Quantum GIS	
ERDAS Imagine 2015	
FRAGSTATS 4.2	
Microsoft office	
GPS	
Digital camera	

3.3. Methodology

For this study, standard image processing techniques such as image extraction, rectification, restoration, classification, categorical map generation, accuracy assessment, reclassification, parameterization, change detection, spatial-metrics selection and annual urban expansion index analysis were used for the analysis of three satellite images (1994, 2004 and 2017). ERDAS imagine software was used for image analysis. Atmospheric correction was applied using improved dark object subtraction method to bring all the images at a common reference spectral characteristic. Images were further geo-referenced and geometrically corrected corresponding to Adindan UTM Zone 37N projection system using the EMA topo-sheets and city plan map obtained from Oromia Urban Planning Institute. The flowchart methodology applied in this study is presented in (Fig. 10).

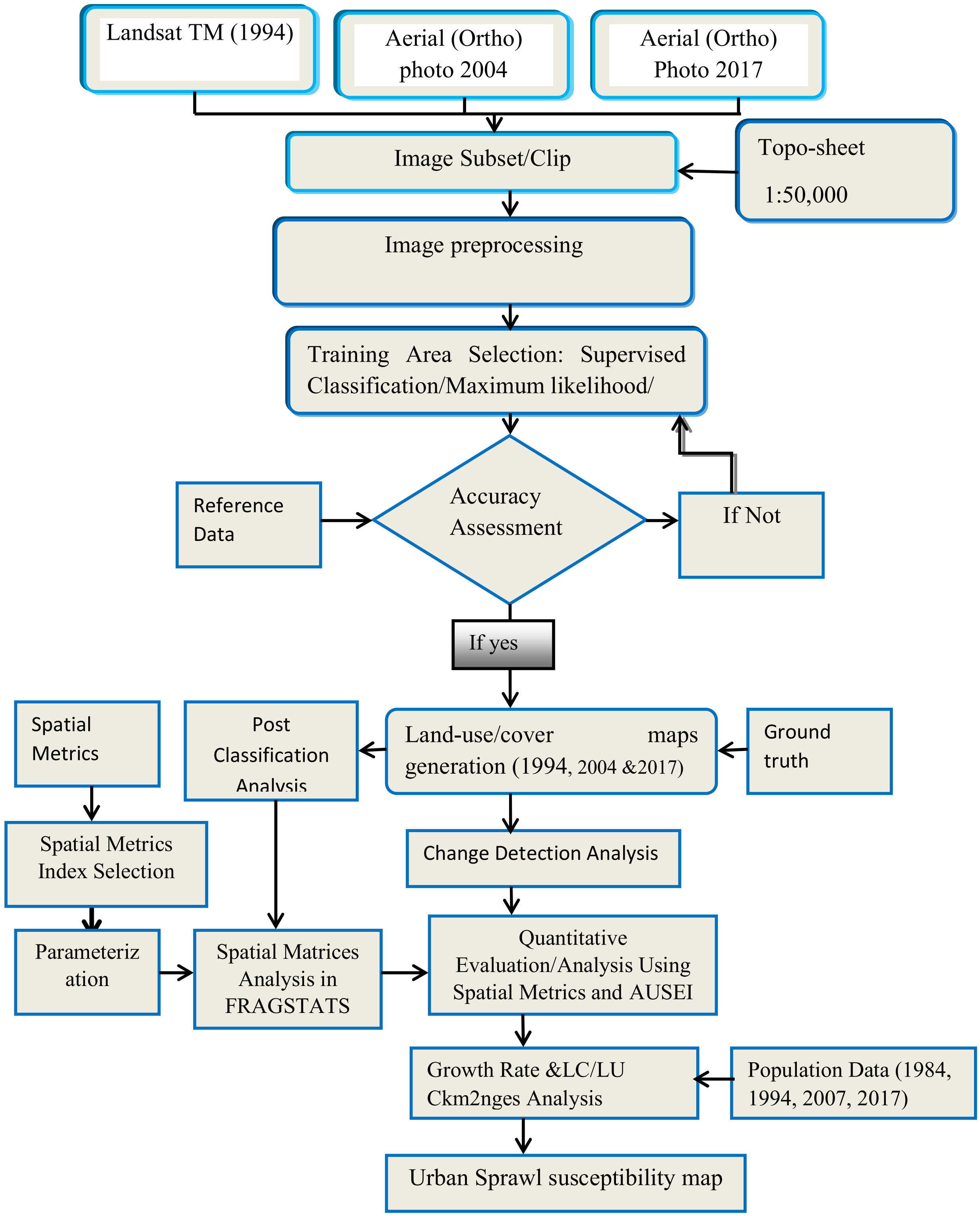

Figure 10. Flow chart of the methodology

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3.3.1. Preprocessing

Image preprocessing activity was necessary to provide a data set to be used to extract spatial information, as satellite images were subject to geometric and radiometric distortions. It was including mosaic construction, sub-setting of the image based on the boundary of study area and re-projection were performed for all images in order to be ready for use. Radiometric correction includes the process of haze reduction, removal of atmospheric noise, brightness inversion and histogram equalization to make more representatives of the ground truth conditions based on the sensors. These activities were done to produce a corrected image as close to possible, both geometrically and raiometrically to the radiant energy characteristics of the original scene and to improve visible interpretability of image by increasing apparent distinction between the features in the scene.

3.3.2. Image Classification

After the pre-processing activities, image classification was done, which was the basis for change detection activity. Land-use and land-cover classes were mapped from digital remotely sensed data through supervised classification method (training process), based on the field knowledge to perform the classification.

In this study, 200 polygons for Landsat5 TM, 1994 and 160 polygons for Arial photo 2004 and 2017 were randomly selected to identify features. Based on selected training polygons, drive signatures, were subsequently classified with the supervised classification type, and used to maximum-likelihood classification algorithm in ERDAS IMAGINE 2015 software environment. Supervised classification involves the selection of training sites to get accurate classification output based on the prior knowledge of the researcher to determine the spectral signature development of identified features and classification. It is based on the quality and quantity of training samples to produce good quality classification results. Accordingly, the images were classified in to different land-cover/land-use classes that finally ended up producing three different years LU/LC maps of the study area. As the main objective of the study was change detection and measuring urban sprawl, LU/LC maps were composed of five major land-cover classes such as built up, agricultural land, vegetated area, barren land/open space and water body (Table 5). In order to increase the overall accuracy the LU/LC mapping and ancillary data were integrated with the classification results. In this way, LU/LC was documented for 1994, 2004 and 2017.

Table 5: Land-cover/land-use feature classes

S/N	Land_ cover Types	Description
1	Built-up Area	Includes all developed areas, roads and transport infrastructures, buildings, housing units, commercial and residential areas and under construction areas
2	Agricultural Land	Irrigated and rain-fed arable lands, crop land with permanent crops, farming and fallow fields,
3	Vegetated Areas	Trees, shrubs-lands and semi natural vegetation, deciduous, mixed forest, palms, woods, herbs, climbers, gardens, inner-city recreational areas, parks and playgrounds, grassland and vegetable lands.
4	Barren land	For this study, it mainly refers to open spaces without any function, bare soils, rocky areas, quarries, gravel pits, grazing land, open areas inside vegetation and residential areas; might be covered by grasses.
5	Water body	Consists of areas with surface water seized in the form river, lake or pound, may be permanent or seasonal.

3.3.3. Accuracy Assessment

Accuracy assessments determine reliability of the classified images based on pixel groupings, to assess how well a classification worked. In this study, the accuracy of the classification results for years 2004 and 2017 were assessed using 160 randomly sampled ground truths with GPS points obtained from the field and topographical maps of 1:50,000 produced from aerial photography acquired in 2017. The accuracy of the classification results for the year 1994 was assessed using the city structure plan and previous work done by Seid Yhdego (2007) by selecting randomly 200 points. These points were verified and labeled against reference data and error matrix (confusion tables) were designed to assess the quality of the classification accuracy of the newly generated land-cover map. The error-matrix (confusion-metrics) is an array of values assigned to a particular category in the reference data and the classified map to be evaluated, and a square array of numbers organized in rows and columns that express the number of sample units (i.e., pixels, clusters of pixels, or polygons) assigned to a particular category relative to the actual category as indicated by the reference data. Error matrices across tabulation of the mapped class *vs*. the reference class were used to assess classification accuracy. Columns typically represent the reference data and rows indicate the map generated from the remotely sensed data. Reference data will be obtained from existing maps, aerial photos (images), field survey (ground observation), and ground or field measurements. Most commonly applied methods of accuracy assessment include overall accuracy, producer's accuracy, user's accuracy and Kappa coefficient (Lu et al., 2004). The technique provides some statistical and analytical approaches to explain the accuracy of the classification. In this study, overall, producer and user's accuracy were considering for analysis.

Producer's Accuracy measures the percentage of correctly classified pixels from a sample data or indirectly indicates errors of omission for a particular class. The number of correct sample units in a category was divided by the total number of sample units of that category from the reference data (i.e., the column total).

Producer's Accuracy = $$\left(\frac{Ci}{Ct}\right)*100 \quad \text{(Eq-1)}$$

Where, Ci = correctly classified sample locations of the reference data or column and

Ct = total number of sample locations of the column.

User's Accuracy measures the total number of correct sample units in a category is divided by the total number of sample units that were classified into that category on the map (i.e., the row total). This result is a measure of commission error. It is calculated as:

User's Accuracy = $$\left(\frac{Ri}{Rt}\right)*100 \quad \text{(Eq-2)}$$

Where, Ri = correctly classified samples in the row and Rt = total number of samples in the row.

Overall Accuracy was computed by dividing the total correctly (i.e., the sum of the correctly classified sample units) by the total number of sample units in the error matrix. This value is the most commonly reported accuracy assessment statistic.

Overall Accuracy = $(\frac{Sd}{n})*100$ (Eq-3)

Where, S_d = sum of values along diagonal and,

n = total number of sample.

Kappa Statistics can be used as another measure of agreement or accuracy. Kappa was used to measure the agreement or accuracy between the remote sensing derived classification map and the reference data as indicated by the major diagonals and the chance agreement. This was indicated by the row and column, totals (Jensen 2003). Kappa values can range from +1 to –1. However, as there should be a positive correlation between the remotely sensed classification and the reference data, positive values were expected. Landis and Koch (1977) lumped the possible ranges for Kappa into three groups: a value greater than 0.80 (i.e., 80% and above) represent strong agreement; a value between 0.40 and 0.80 (i.e., 40%–80%) represents moderate agreement; and a value 0.40 (i.e., 40% and below) represents poor agreement.

Accuracy assessments of the classified images of all years (1994, 2004, and 2017) were conducted in ERDAS Imagine 2015. In this study, the accuracy of classification results for the year 2004 and 2017 were assessed using 160 randomly sampled ground truths collected from fieldwork and base map prepared by OUPI (2017). However, accuracy of classification results for the year 1994 was assessed using Seid Yhdego (2007), and structure plan prepared by Adama city structural plan revision office with PACE engineering consulting (1994).

3.4. Change Detection

Post- classification comparison approach was employed for detection of land-use/land-cover changes by comparing independently produced thematic maps for 1994, 2004 and 2017. Then, the classified land-use/land-cover maps were compared to show the changes between each year, i.e., 1994–2004, 2004–2017 and 1994–2017 for the study area. It was also possible to calculate the amount of increase and/or decrease of each category of land-use and see the changes in percentage in each year using the following formula (Lambin et al., 2001).

Percentage change = $(\frac{\text{observed change}}{\text{total area}})*100$ (Eq-4)

Where, observed change is earlier point of time at T1 is subtracted from the later or recent point of time (T2) in the series.

Land Change Intensity: Land-use change intensity analysis was done to examine the extent and rate of urban land changes in the study area (ULC; i.e., a land change from non-built to build- up) across the two time intervals (i.e., 1994–2004 and 2004–2017). First, the annual change intensity (ACI) was calculated for each time interval (1994–2004 and 2004–2017; Equation (1). Then, compared each ACI to the uniform intensity (UI), which was the rate of change relative to the entire time extent of the land-change analysis the first study (Equation (2). If the ACI in a particular time interval (e.g., t1–t2) was less than the UI, then the ACI intensity of that particular time interval was considered slow; but if it was greater than the UI, it was considered fast.

$$ACI(\%) = \left(\frac{LC/LA}{TE}\right)*100 \qquad (Eq\text{-}5)$$

Where, ACI is the annual change intensity for a given time interval (e.g., t1–t2),

LC is the area of land change from non-built to built for a given time interval,

LA is the area of the entire landscape, and

TE is the duration of a given time interval.

$$UI(\%) = \frac{[(LCTI1+LCTI2)]/LA}{TETI1+TETI2})*100 \qquad (Eq\text{-}6)$$

Where, LCTI1 and LCTI2, respectively, were the land change from non-built to built during time interval 1 and time interval 2. TETI1 and TETI2 were the durations of time intervals 1 and 2.

3.1.1. Reclassification

This is a process appropriate for spatial metric system to measure LU/LC changes in FRAGSTATS. It is necessary to reclassify the class values of categorical maps into positive integer and the background value into negative integer in ArcGIS spatial analyst tool. This is particularly important to calculate spatial metric indices of built up area in FRAGSTATS. Unless the class value of background is changed into negative integer, FRAGSTATS computes the background cells with the focal classes and the result will be different. In other words, FRAGSTATS recognizes cells with positive class values as inside and cells with negative class values as outside. For this reason, the background in all maps was assigned with -999 to exclude it from calculation and other class categories were assigned integers from one (1) to four (4). New categorized maps were used as inputs in FRAGSTATS to calculate spatial metric indices.

3.1.2. Spatial Metrics Calculation

Urban pattern characterization involves its detection and quantification. Spatial metrics were used in this study to obtain information about the urban growth in Adama city. This is including the shape of urban settlement, urban settlement density (aggregated or fragmented) and the distribution of different urban characteristics. Therefore, spatial metrics were algorithms used for quantifying spatial characteristics of patches, classes of pattern, or entire landscape mosaics (McGarigal et al., 2002). For the purpose of this study, spatial metrics were calculated based on thematic maps representing built and non-built spatial patches for the study time (i.e., between 1994–2004 and 2004–2017). 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) were measured and analyzed using FRAGSTATS tool. It is a foremost fragmentation program currently available and a spatial pattern analysis software program for quantifying the structure of landscape i.e., composition and configuration of landscape (Maclean and Congalton, 2013; McGarigal, 2015,).

3.1.2.1. Spatial Metrics Index Selection

A number of approaches in representing spatial concepts have resulted in the development of various spatial metrics, or metrics categories as descriptive statistical measurements of spatial structures and patterns. The most commonly used metrics for urban studies are landscape-level metrics and class-level metrics to examine landscape fragmentation and connectivity as well as to quantify landscape configuration at patch level. These metrics were found to be sufficient to analyses and extract quantitative information of the dynamic spatial pattern of urban growth including the shape irregularity, fragmentation and the relative distribution of different urban characteristics.

The landscape-level metrics refers to spatial metrics calculated to describe the entire landscape or all classes in the landscape. Landscape level metrics quantify the spatial relationship of patches in the landscape, i.e., spatial composition and configuration (Laurent, 2006). The landscape-level metrics included the contagion index (CONTAG), the landscape shape index (LSI), and Shannon's diversity index (SHDI).

The class-level metrics include the percentage of landscape (PLAND), path density (PD), mean patch size (Area_MN), area-weighted mean patch fractal dimension (Frac_AM), and mean Euclidean nearest neighbor distance (ENN_MN). All these metrics were calculated using the FRAGSTATS 4.2 software, employing the 8-cell neighbor rule, which were adopted and used for analyzing the urban land-use/land-cover changes (Table 6).

Table 6: Spatial metrics adopted and used (Herold et al., 2003)

Metrics	Descriptions
CA/TA Class Area	CA measures total areas of built-up and non built-up areas in the landscape. It was calculated as the sum of the areas (in meter square) of all patches of a corresponding patch type divided by 10,000, CA= $\sum_{j=1}^{n} aij(\frac{1}{10,000})$ is, total class area. Where, aij = area (m2) of patch ij.
NP Number of Patches	It was the number of built and none built up patches in the landscape. An increase in number of patches in time series study, indicate an in increase in fragmentation, expansion of urban area (Rutledge, 2003). NP= N where N is total number of Patches.
LPI-Largest-Patch Index	LPI percentage of the landscape comprised by the largest patch LPI= Max(aij)/A(100) Where, aij = area (m2) of larges patch ij. A= total landscape area (m2).
percentage of landscape -PLAND	PLAND_ was calculated as the sum of the areas (m^2) of all patches of the focal class, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage). PLAND(P_i)= $\sum_{j=1}^{n} \frac{aij}{A}(100)$ Where, Pi = proportion of the landscape occupied by patch type (class) i, aij = area (m^2) of patchij. A = total landscape area (m2). The result ranges between 0 and 100

mean patch size Area_MN	Area_MN_ provide a measure of central tendency in the corresponding patch characteristic across the entire landscape, but describe the patch structure of the landscape as that of the average patch characteristic.
annual urban spatial expansion index-AUSEI	AUSEI- was used to determine temporal changes in urban area and growth rates,

Generally, the selected metrics was supposed to describe the configuration and composition of the landscape pattern and were computed for each land-cover maps at the patch of classes and mosaic level. All metrics were computed using public domain software FRAGSTATS 4.2 to answer questions such as where did urban growth occur in the study area between 1994 and 2004, at what rate and how much land was converted to urban land-cover within the study period; and which urban growth theory explains the expansion. These questions were answered with the aid of spatial metrics (total area-TA, class area-CA, number of patches-NP, patch density-PD, largest patch-LP, largest patch index-LPI, mean patch size-MPS), urban growth indicators (annual urban spatial expansion index-AUSEI) and through visual interpretation of the resultant urban land-cover maps. Spatial metrics are numerical indices to describe structure and patterns of a landscape. They quantify and describe the underlying structure and patterns of urban landscape from geospatial data.

The other indicator of urban growth was AUSEI. The urban spatial expansion index is imperative in describing the temporal changes of an urban area, in terms of its annual urban growth rate and annual growth area (Tian et al., 2005; Fan et al., 2009). The annual urban spatial expansion index (AUSEI) was adopted to discuss the temporal urban spatial growth of Adama city as defined below:

$$AUSEIt = \frac{(Ut - Ut-1)/Ut}{(Nt_{Nt}-1)} * 100 \qquad \text{(Eq-6)}$$

Where, AUSEIt (%/year) is the annual urban spatial expansion index;

Ut and Ut-1 are the total urban areas of the study area in km^2 at time t (current year),

time t-1 (former year); and

N is the total number of years from time t (current year) to time t-1 (former year).

3.1.2.2. Parameterization

Parameterization refers to the study factor and input layer preparation to run FRAGSTATS in order to calculate spatial metric indices. This includes categorical map formatting and setting analysis parameters. For this study, classified maps with ERDAS Imagine grid (.img) formats was used as an input. All input maps were integer grids, i.e., each cell assigned an integer value corresponding to its class membership or patch type with the measurement units in meters, but can convert to other measurement units depending on the condition. Regarding neighborhood rule, there were two options, the four cell and eight cell neighborhood rules to determine patch membership. The eight-cell rule was selected because, two cells of the same class diagonally touching were considered as part of same patches. There were five sampling options to calculate sub-landscapes, but as the study area was a single landscape, the conventional approach was selected. In the analysis of edge length and edge density, there were three options to specify the percentage of the background. 'None', 'All', 'Partial' and none was selected to exclude the background from calculation so that the measurement of these indices will not be exaggerated. All other settings were kept by the default and the desired metrics were selected using check boxes from each tabbed page straightforward.

3.1.2.3. Spatial Metrics Analysis in FRAGSTATS

All the above-mentioned indices on section 3.3.6.2 were calculated through FRAGSTATS 4.2 software program at class and landscape level to measure the composition and configuration of urban growth in the study area. These indices were calculated for the years 1994, 2004 and 2017, generated land-use maps with the same parameterization and specification so that comparison between time series results was possible. Outputs of all indices from FRAGSTATS were compared against each other for each year to find out changes in fragmentation, compactness and/or sprawl of the urban landscape in the study area and results were presented in maps, tables and graphs at class and landscape levels.

CHAPTER FOUR

4. RESULTS

4.1. Classification

In this study, 200 polygons for Landsat 5 TM, 1994; 160 polygons for aerial photo, 2004 and 2017 were randomly selected to identify features and assess classification accuracy. Table 7, 8 and 9 below present the accuracy of classified images for 1994, 2004 and 2017, respectively

Table 7: Accuracy assessment for classified images (1994)

Accuracy assessment for classified images (1994)

Land-use class	Reference total	Classified total	Number Classified correctly	Number Classified wrongly	Producer's accuracy (%)	User's accuracy (%)
1	100	89	88	12	97.7	85
2	30	36	27	3	75	90
3	30	31	26	4	83.8	86.7
4	20	24	18	2	75	90
5	20	19	16	4	84.2	80
Total	200	200	175	25		

Table 8:Accuracy assessment for classified images (2004).

Land-use class	Reference total	Classified total	Number Classified correctly	Number Classified wrongly	Producer's accuracy (%)	User's accuracy (%)
1	70	66	64	6	97	91.4
2	35	37	32	3	86.5	91.4
3	30	28	16	5	89.3	83.3
4	15	18	16	3	70.6	80
5	10	11	8	2	72.7	80
Total	160	160	141	19		

Table 9:Accuracy assessment of classified images (2017).

LU/LC class	Reference total	Classified total	Number Classified correctly	Number Classified wrongly	Producer's accuracy (%)	User's accuracy (%)
1	60	60	55	5	88.7	91.7
2	50	48	46	4	95.8	92
3	20	19	17	3	89.5	85
4	20	22	18	2	81.8	90
5	10	11	9	1	81.8	90
Total	160	160	145	15		

Figure 11 shows that the land-use/land-cover types distribution for the three the year's temporal dates (1994, 2004 and 2017), which are important evidences of urban extents and growth patterns.

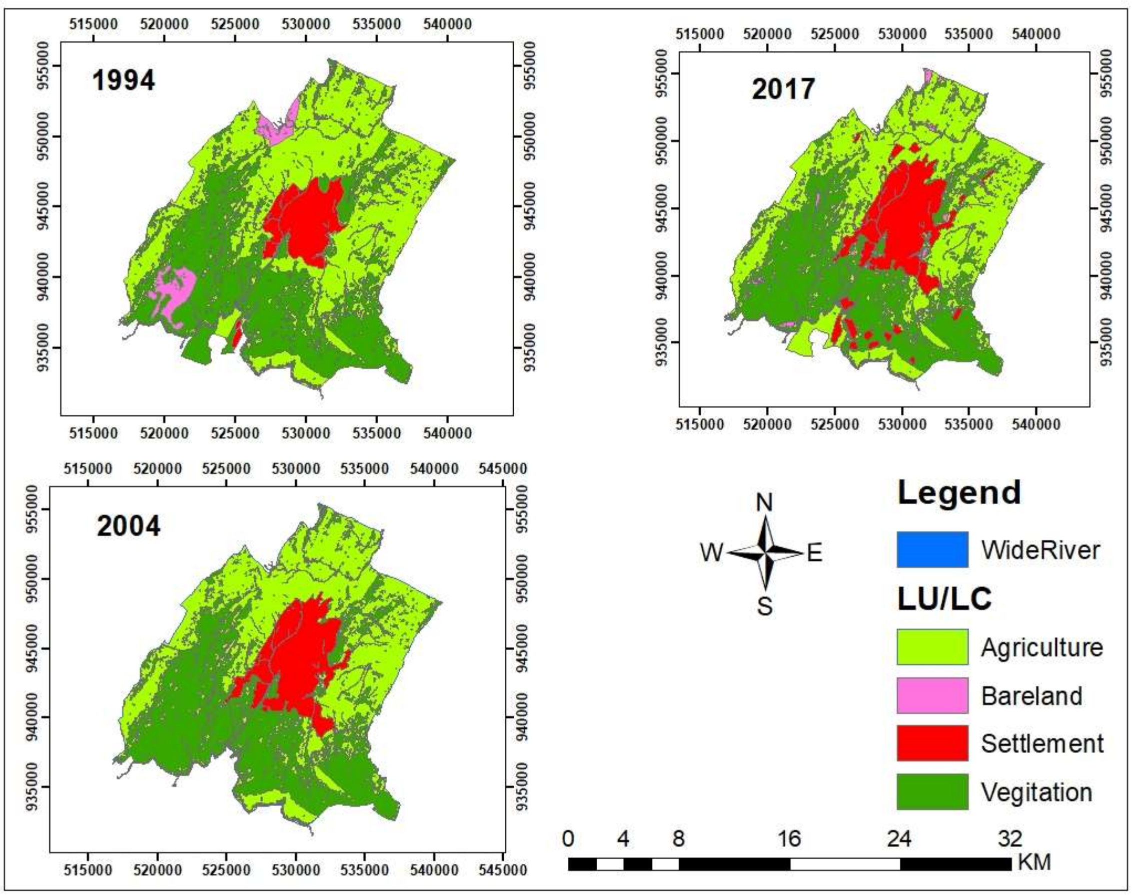

Figure 11. . Land-use and land-cover maps for the years 1994, 2004 and 2017

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The classification results for 1994, 2004 and 2017 are summarized in Table 11. The results shown the land-cover/ land-use distributions in Adama city from 1994 to 2017, indicating major decline with respect to area coverage observed in agriculture and vegetation classes. The areas of built-up, barren-land and water-body classes were increased since 1994 to 2017. The extent of agriculture-land was reduced from 48.7% in 1994 to 22.8% in 2017 of total area. The vegetation land class was reduced from 30.3% in 1994 to 15% in 2017 of the total area. The share of built-up area was 14.6% in 1994 of the total area, which was increased to 54.2% in 2017. The barren-land class was increased from 4.1% in 1994 to 4.5% in 2017, while the extent of water body was increased from 3.2% in 1994 to 3.5% in 2017. In general, the exactly built-up areas increased significantly with enhanced urbanization while the non-built-up areas decreased with the losing of agricultural and vegetated areas.

Figure 10 shows the spatio-temporal urban growth pattern in the study area demonstrating a clear pattern of increased urban expansion extending from the inner (core) part to adjoining fringe especially following roadsides. The other class that faced a percentage increase in the total area during the study period was barren-land. This increase in barren-land happened due to rapid deforestation and erosion of the fertile agricultural land. The classification result of vegetation class supporting the above truth that the vegetation area decreased over the past 23 years by 14.7% from total area of the study area. Figure 12 also provides the land-use/land-cover change map that can show the trend and process of urban growth in the study area during the study period with overlaying classified images, showing the built-up areas of Adama city.

4.2. Accuracy Assessment

To work out the land-use/land-cover classification, supervised classification method with maximum likelihood algorithm was applied. The error matrix or confusion metrics employed to assess classification accuracies and the results are given in (Tables 7–9) using maximum likelihood classifier as the classification methods. The rows characterize the categories of classified map while columns characterize for the categories of reference data in the error matrix. The values along diagonally represent the number of correctly classified points, otherwise the number of points that agree with reference data. The overall accuracy (OA) of all images exceeds 85 % (Table 10), which is considered as good results for remote sensing image based analysis.

Producer's Accuracy

Producer Accuracy measures the percentage of correctly classified pixels calculated using Eq-1. The number of correct sample units in a category was divided by the total number of sample units of that category from the reference data (i.e., the column total). The minimum producer's accuracy reports for the three years ranged from 70% to 97.7% (Tables 7–9), which indicates that the classification performances were reliable and the results are acceptable. The accuracy assessment for built-up area category was exceptionally more than 90% in all accuracy assessment results. However, producers accuracy for barren-land category in the year 2004 was a little bit lower (70.6%). As found during fieldwork, this was mainly because some of barren-area samples were classified as agricultural area and built-up area due to the similarity of pixels.

User's Accuracy

An accuracy assessment evaluation results for user's accuracy range from 80–90 % for 1994, 80–91.4% for 2004, and 85–92% for 2017. Therefore, the results in both producer's and user's accuracy showed that the performance of classification was performed very well and the error margins were within acceptable accuracy (Tables 7–9).

Overall Accuracy

The overall accuracy (OA) of the classification methods for 1994, 2004, and 2017 ranged from 87.5% to 90.6% with Kappa coefficients from 85 % to 96% (Tables 7–9). The overall accuracy of all images exceeds 85% (Table 10), which is a good result for remote sensing image based analysis. Therefore, the classification is reliable.

Overall Kappa coefficient

Kappa coefficient results were less than one (1) and results approaching to one (1) indicated excellent agreement between the classified map and reference data. Overall kappa statistics result for the data were 0.82 for 1994, 0.84 for 2004 and 0.89 for 2017 classification maps. There was there a positive correlation between the remotely sensed classification and the reference data (Table 10).

Table 10: Overall Confusion matrix and Kappa Coefficient for land-cover classification for Adama City from 1994, 2004 and 2017

Accuracy Assessment	Years		
	1994	2004	2017
Overall accuracy	87.5	88.13	90.6
Kappa coefficient	0.82	0.84	0.89

4.3. Change Detection analysis

For the purpose of this study, 23 years time span and three periods change detection study shows change from 1994 to 2017 (Table 11) period between 1994–2017. First period, 1994 to 2004, second 2004 to 2017, and the third period from 1994–2017 (from initial to final years) was moderately enough to show long history of urban growth relative to land use and land-cover changes. The LU/LC change detection was assessed using post-classification by comparing independently produced thematic maps for 1994, 2004 and 2017 (Fig10).

It can be seen that the total investigated area was determined by 310 km^2. The classification results show that in the year 1994, the built-up area covered 45.26 km^2, while the agricultural land covered 153.67 km^2. In the 2004, urbanized area (built-up) covered 74.4 km^2 resulting in additional urbanized area of 29.14 km^2 as 7.8 % of the total area, while the agricultural land was decreased to 90 km^2. In the year of 2017, the urban area was increased up to 168.02 km^2, which means the extra area of 93.62 km^2 as 30.2% of the total area was changed from non-built-up to built-up areas, while the extent of agriculture land was decreased to 59.83 km^2. Table 11 shows the extent of land-use land cover change.

Table 11:Land cover change pattern of classified images (1994–2017).

	LU/LC class	Years/Area (km^2)					
		1994		2004		2017	
		Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Built-up	45.26	14.6	74.4	24	163.67	54.2
2	Agriculture land	136.09	43.9	90	29.03	44.08	14.22
3	Vegetated areas	93.93	30.3	86.7	27.97	35.5	
4	Barren land	24.8	8	43.4	14	45.7	14.7
5	Water-bodies	9.92	3.2	15.5	5	16.7	7
Total		310	100	310	100	310	100

4.4. Description of Urban land-use/land-cover change

Figure 11 shows the LU/LC changes during 1994–2017 in Adama city area. The land-cover/land-use of the study area classified as built-up, vegetation, agricultural land, barren-land and water body. The analysis of LU/LC changes based on post-classification change detection and landscape metrics has discovered that in the first period, from 1994 to 2004, 2004 to 2017 and 1994 to 2017. The built-up area has increased from 14.6% in 1994 to 54.2% in the year of 2017 (Table 11). In other words, it could be observed from Table 11 that in 1994 the built-up area was 45.26 km^2, (14.6%) of the study area while the agriculture land covered 123.38 km^2 (47.8%) of the study area. The land cover map of 2004 shows that the built-up area was 74.4 km^2 (24%) of the study area, and an increase of 9.4% was seen in the extent compared to 1994 (Table 11). The agriculture land had reduced to 90 km^2 (10.77%) (Table 11). In contrary to agriculture land, the areas of barren-land was increased tremendously, from 24.8 km^2 in 1994 to 43.4 km^2 in 2004 and the water body also increased from 9.92 km^2 in 1994 to , 15.5 km^2 in 2017 (Table 11).

During the second study period, 2004 to 2017, the built up area kept the pace of growth and the extent was increased to 93.62 km^2 (Table 15). The extent of agriculture land decreased by about 9.7% and became 59.83 km^2. The extent of vegetation area also decreased by 15.3% to 46.5 km^2 in 2017 year (Table 15). In contrary to agriculture land, the extent of barren-land and water body have increased by 17% and 7%, respectively, and grew to 52.7 km^2 and 21.7 km^2 from 24.8 $km^{2,}$ and 9.92 km^2 in 2017, respectively (Table 11).

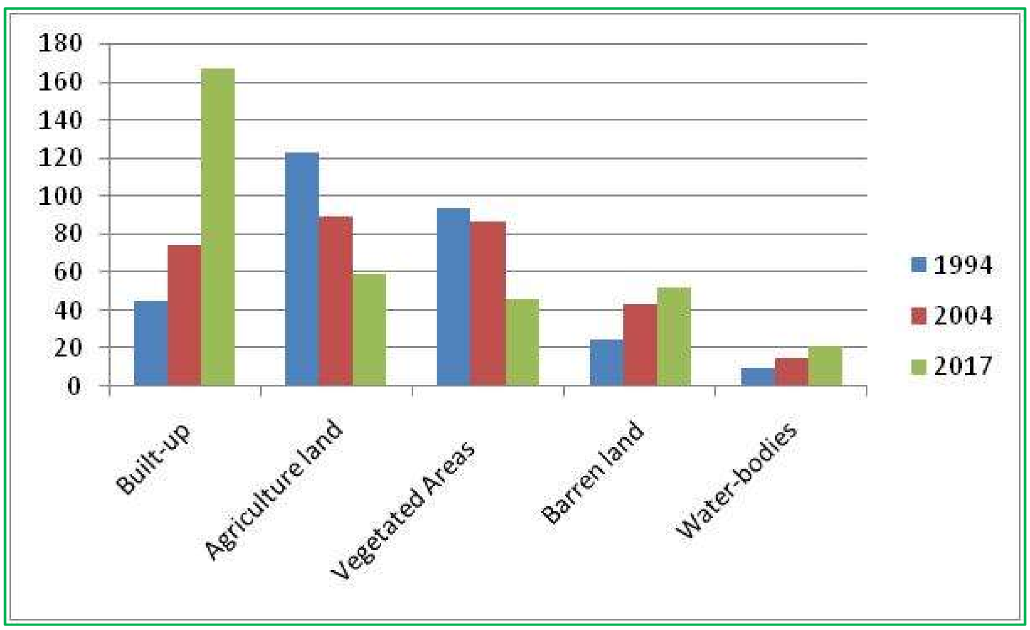

Figure 12.Spatio-temporal changes of different LU/LC classes of Adama City from 1994 to 2017

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4.4.1. Built-up Area

In 1994, Adama city Administration built-up land had an area of 45.2 6km^2, which was increased to 74.4 km^2 in 2004 and to 168.02 km^2 in 2017. This shows that the Adama city built-up land has increased by approximately 39.6% during 1994–2017 by encroaching on non built-up land-cover/land-use (Fig. 13). On the other hand, other land-use types particularly agricultural areas and vegetation land have decreased during 2004–2017 than it was in the previous years, indicating its highest contribution to built-up areas (Table 14 and Fig 12).

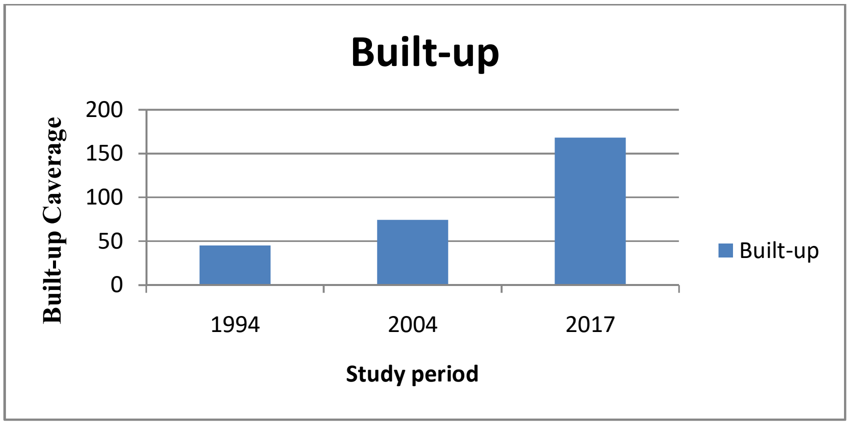


Figure 13. Adama City built up land cover between 1994 and 2017.

During the 1994s, built-up area accounted for 14.6% of the entire landscape, while during the 2004s, built-up area accounted for 24% (Figure 13). The urban land change (from non-built-up to built-up) intensity analysis discovered that the ACI during the first time phase (1994–2004) was 0.93%, while during the second phase (2004–2017) ACI was 2.32%.

However, the result of uniform intensity was 1.72%. Therefore, the rate of annual change intensity at first time phase was less than uniform intensity. Then, the ACI at first phase (between 1994 and 2004) was considered as slow. During the second phase (between 2004 and 2017), the annual change intensity was 2.32%, is greater than uniform intensity (1.72%). Therefore, the rate of convert from non built-up to built-up area during the second study phase interval was considered as faster than during first study phases.

4.4.2. Agricultural area

From the total land of the study area, 123.38 km^2 was categorized as agricultural land in 1994, which was including irrigated and rain-fed arable lands, cropland with permanent crops, farming, and fallow fields. However, by 2004, 33.38 km^2 of land was converted to built-up areas and decreased to

90 km^2. In 2017, the agricultural-land covered only 59.83 km^2. This shows that since 1994, 20.5% of agricultural land was converted to others kinds of land-use types (Table 15). The loss of farmland due to urban growth can also lead to not only the loss of fresh local food sources, but also the loss of habitat and species diversity as well as the causative factors for different kinds of land degradation.

4.4.3. Vegetated area

In 1994, out of the total area of 93.93 km^2 was covered by vegetation. However, in 2004, the extent of the area covered by vegetation was decreased to 86.7 km^2. In 2017, it was decreased to 40.2 km^2 from 2004 and the area covered by different kinds decreased to 46.5 km^2 (Table 15). Table 15 indicates between 1994 to 2017, 15.3% (from total area) of the vegetated area converted to others kind of land-cover/land-use, it is deforested.

4.4.4. Barren land

In 1994, Adama city had an extent of 24.8km^2 as a barren land, which was increased to 43.4km^2 in 2004 and to 52.7km^2 in 2017, while the agricultural and vegetation land decreased. This shows that the Adama city barren-land has increased by approximately 9% in the during 1994–2017, at a rate of 1.21 km^2 per year (Table 15). On the other hand, other land-use type's particularly agricultural areas and vegetation land were decreased during 2004–2017, indicating its highest contribution to built-up land as well as deforestation due to different factors (Table 15).

4.4.5. Water bodies

The analysis for the period of 1994 to 2004 showed that the area classified as water body was increased by 5.58%, where as the area of agricultural-land and vegetation-area decreased by 10.77% and 2.33%, respectively. A similar analysis for the study period of 2004 and 2017 revealed that the coverage of water body area increased by 2% (Table 15).

Table 12: Land-use/Land-cover change detection Adama city area during 1994 to 2017

LU/LC Class	Area			Change area					
	1994	2004	2017	1994–2004		2004–2017		1994–2017	
	km^2	km^2	km^2	km^2	%	km^2	%	km^2	%
Built-up	45.26	74.4	168.02	+28.34	+9.14	+93.62	+30.2	+122.76	+39.6
Agriculture-land	123.38	90	59.83	-33.38	-10.77	-30.17	-9.7	-63.55	-20.5
Vegetated Areas	93.93	86.7	46.5	-7.23	-2.33	-40.2	-12.97	-47.43	-15.3
Barren land	24.8	43.4	52.7	+18.6	+6	+9.3	+3	+27.9	+9
Water Body	9.92	15.5	21.7	+ 5.58	+1.8	6.2	+2	+11.78	+3.8
Total	310	310	310						

Table 13: Post classification matrix of study area showing land encroachment (in km2) 1994 to 2004:

		1994					
	Land use/cover Classes	Built-up	Agriculture land	Vegetated Areas	Barren land	Water Body	Total
2004	Built-up	45.26	22.31	6.83	0	0	74.4
	Agriculture land	0	57.19	28.29	4.52	0	90
	Vegetated Areas	0	40.04	44.11	2.55	0	86.7
	Barren land	0	9.55	14.70	12.15	7	43.40
	Water Body	0	7	0	5.58	2.92	15.5
	Total	45.26	136.09	93.93	24.8	9.92	310

Table 14: Post classification matrix of study area from 2004 to 2017.

Post classification matrix of study area from 2004 to 2017.

	Land-use/cover class	2004					
		Built-up	Agriculture land	Vegetated Areas	Barren land	Water Body	Total
2017	Built-up	74.4	17.37	45.12	16.78	0	153.67
	Agriculture land	0	38.91	7.59	0	0	46.5
	Vegetated Areas	0	12.70	22.80	0	0	35.5
	Barren land	0	21	11.19	13.97	6.54	52.7
	Water Body	0	0	0	12.65	8.96	21.7
	Total	74.4	90	86.7	43.4	15.5	310

4.5. Post-classification matrix

The classified land-use/land-cover maps of the study area compared to show the changes between each of the phase of the analysis, i.e., 1994 to 2004 and 2004 to 2017, with cross-tabulation approach in ARC GIS 10.2 software (Tables 16 and 17). The classified images were compared in two periods, i.e. 1994 to 2004 and 2004 to 2017.

a). About 22.31 km^2 and 6.83km^2 area of agriculture and vegetation, respectively was converted into built-up area.

b). About 40.04 km^2 vegetated-area and 2.55 km^2 barren-land was converted in to agricultural-land in the first period of study.

c). About 0.9.55 km^2, 14.70 km^2 and 7 km^2 area of agriculture, vegetation and water cover was converted into barren-land.

d). About 7 km^2 area of agriculture and 5.58 km^2 area of barren-land was converted into water-cover land.

2. The post classification matrix revealed during 2004 to 2017 are shown in Table 17.

a). About 17.37 km^2,14.12 km^2 and 16.78 km^2 area of agriculture, vegetation and barren-land, respectively was converted into built-up area.

b). About 12.70 km^2 area of agricultural-land was converted into vegetation- area, c). About 7.59 km^2 and 11.19 km^2 area of vegetation has been converted into agricultural and barren-land, respectively, as well as 12.65 km^2 of barren-land was converted to water body.

4.6. Spatio-temporal analysis of urban growth pattern using spatial metrics

Table 15: Spatial metrics calculation of classified images (1994–2017).

Year/ Metrics	LULC	TA	NP	LPI	MPS	AWMPFD
1994	Built-up	4526	351	2.6	12.89	1.19
2004	Built-up	7440	473	7.19	15.72	1.15
2017	Built-up	15367	717	11.12	21.43	1.21

Note: LULC – Land-use and land-cover, TA – Total area, NP – Number of patches, LPI – Largest patch index, MPS – Mean patch size, AWMPFD – Area Weighted Mean Patch Fragmental Dimension.

4.6.1. Built-up area class

According to the results obtained from FRAGSTATS, the built-up area was considerably changed over time in the study area (Table 17). The outcomes presented in Table 19 show that total built-up area grew from 4526 hac (1994) to 7440 hac (2004) and to 15367 hac (2017). It is indicating that, during 1994 to 2017, 10841 hac (108.41 km^2) of non- built-up, area was converted to built-up areas with an average 4.34% per year. The highest rate of urban growth was observed during the second period of urbanization (2004–2017) when the built-up area was increased by 7924 hac (79.27 km^2) within 13 years. These results point out that a more rapid urban growth (urbanization) was occurring in the study area during the period of 2004 to 2017, compare to the other periods. This indicate that large extent of land-use change during the study period characterized by replacement of agricultural areas, vegetated land including forest and scattered tree plantation and barren and water lands with urban areas.

Table 16:Built-up area expansion based on total area metrics

Study-period	Change(hac)	Change %	Time span	Growth rate/year
1994–2004	2914	64.38	10	6.4
2004–2017	7924	106.55	13	8.19

The second period of urbanization covers the longest time span compared to the first period of urbanization. In terms of total land-cover/land-use change in the second period of urbanization (2004 to 2017) continues with the highest witnessing the conversion 7924 hac of none built-up to built-up (urban) land. In contrast to the percentage change, the first study-period comes second with 2914 hac (29.14 km^2) land changed to built-up area. Totally 10841 hac (108.41 km^2) of non-built up land was converted to built-up land over the period 1994 to 2017. As the statistics obtained from the area metrics computation confirms, the built-up area has increased at an average annual growth rate of 6.4% and 8.13% during the period's 1994 to 2004 and 2004 to 2017, and respectively, in the study area (Fig.13 built-up area growth rate (7.3%) per annum per study period).

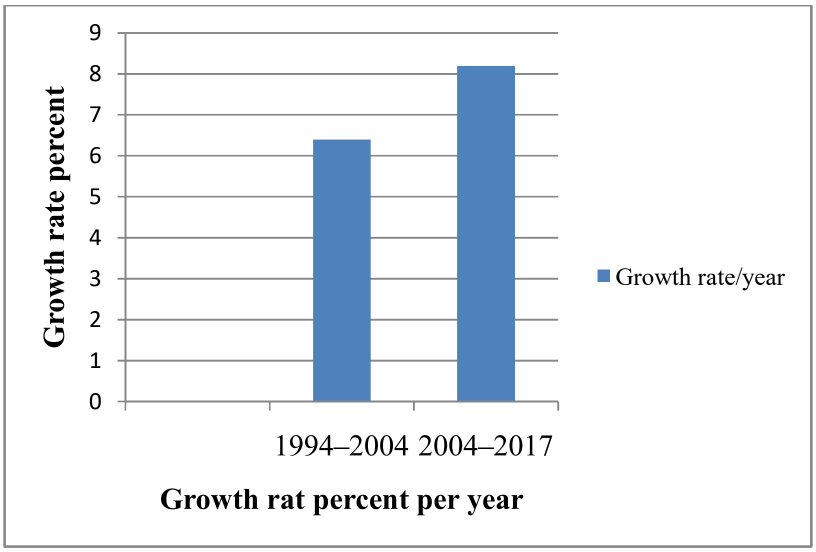


Figure 14. Built up area growth rate (%) per year per study period

4.6.2. Number of patches

The number of patches (NP) metric quantifies the number of individual urban or built area patch and shows how the landscape particularly the built-up area was subdivided into patches or smaller pieces. Continuous increase of the NP in the landscape all through the study periods shows the rapid urban growth process in the study area. In 1994, NP in the study area was 351, and this was increased to 473 in 2004, and the increased to 717 in 2017 possibly from fragment, and various processes of urban growth took place in the study area. During 2004–2017 period viewed extensive changes in NP reaching its peak in 2017, signifying continuous development of fragmented and scattered urban patches. This condition can be ascribed to the development of small and irregular built-up patches around the periphery of the study area following major routes. It could understand from the slop of the two graphs (Fig. 14) that the TA was increasing in much faster rate than NP. The slope of TA between 1994 and 2017 was steeper than the slope of NP in the same study period as indicated on the graph.

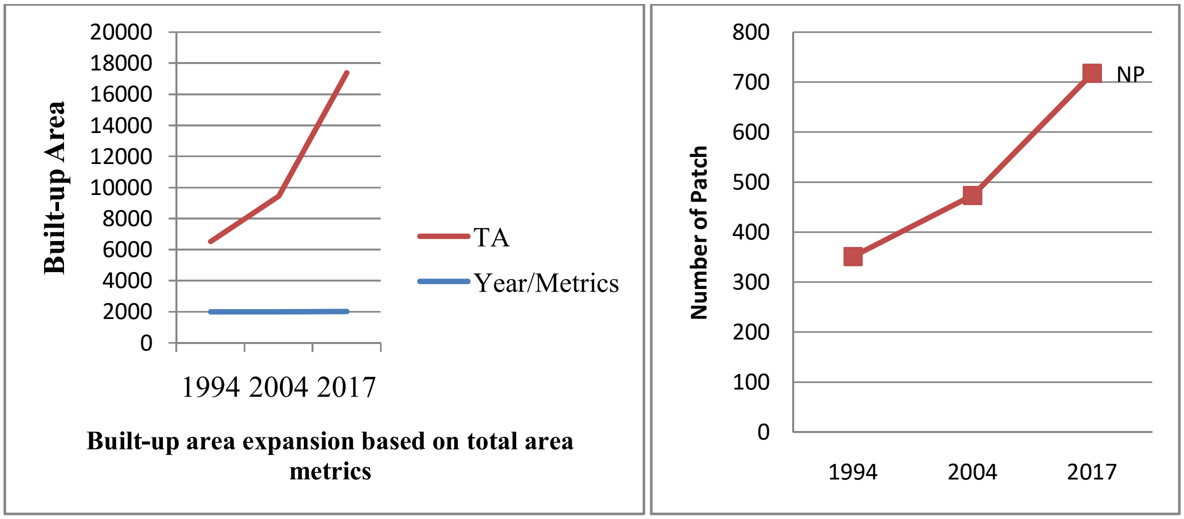


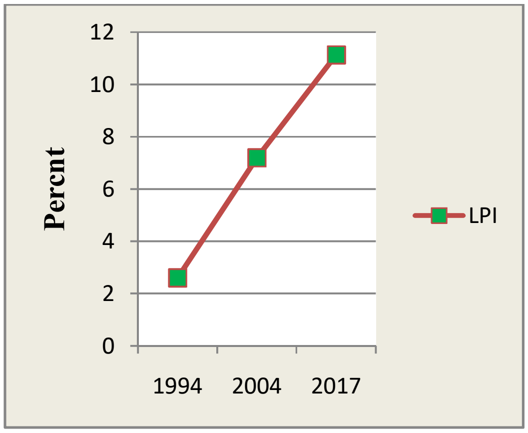
Figure 15. Total area and Number of patches for the entire landscape area

4.6.3. Largest Patch Index

Figure 15 shows that the value of this metric increased during 1994–2017. Largest patch index increased its dominancy from 2.6% in 1994 to about 11.12% in 2017 (Fig 15). 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 words it means that most of the small isolated and fragmented urban sprawl and associated built ups areas were connected with the inner parts of the city.

4.6.4. Mean Patch Size

Figure 15 shows that the value of this metric increased during 1994–2017. In 1994, the MPS was 12.89. In 2004, the expansion of existing patches it become 15.72 with the joining of new patches, and increased to 21.43 in 2017. This wavering is connecting to the progress of new patches and expansion of urban core; and occupation of patches adjoining the urban core. This indicates the agreement between MPS and the effect being visible on increasing largest patch index (LPI).



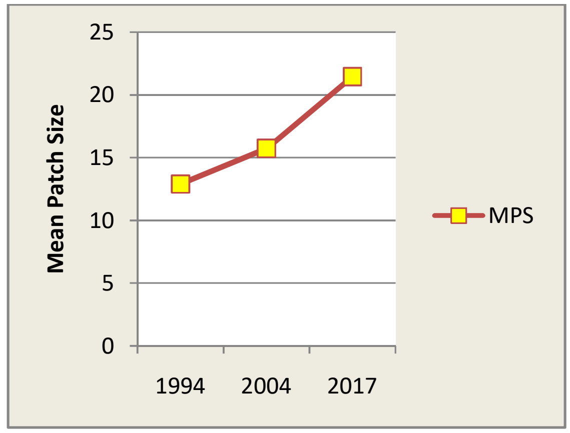


Figure 16. Largest patch index (LPI) and Mean patch size (MPS) for the entire landscape area.

4.7. Area Weighted Mean Patch Fractal Dimension

The area weighted mean patch fractal dimension (AWMPED) is the measure of urban patch shape complication that describes how patch perimeters increases per unit increase in patch area. The area weighted mean patch fractal dimensions (AWMPFD) indicates two conditions (regular form and irregular form). The value of this metrics condensed between 1994 and 2004, indicating regular form growth (Fig 9. Area weighted mean patch fractal dimension for the entire landscape. It was observed that the value of this measure rose since 2004, demonstrating the irregular form of growth in Adama city. This abnormality may well be related with incomplete combination of existing individual patches and maybe the development of fewer new patches during two periods of urbanization. Significantly, the topographical setting of the study area might have brought about the discontinuous urban process may be leading to the fragmented development of the city. The rocky, hilly and gorgy areas are not suitable areas for urban development, which upset connection and isolate or fragment the built up patches.

Results from analysis of spatial metrics of built-up area in the study area has made it possible to quantify the trends and pattern of urban growth at the city level using the selective five metrics. Three of metrics specifically: the total built-up area (TA), number of patches (NP), and the largest patch index (LPI) displaced reliable increasing trend, while mean patch size (MPS) and area weighted mean patch fractal dimension (AWMPFD) discovered both decreasing and increasing trend with remarkable expansion in 2017. The built-up area became more fragmented over the time, in spite of increasing trend of largest patch index (urban core).

In general, the description of Spatio-temporal analysis of spatial metrics over the study area shows that the land-cover of the study area has changed radically due to urbanization.

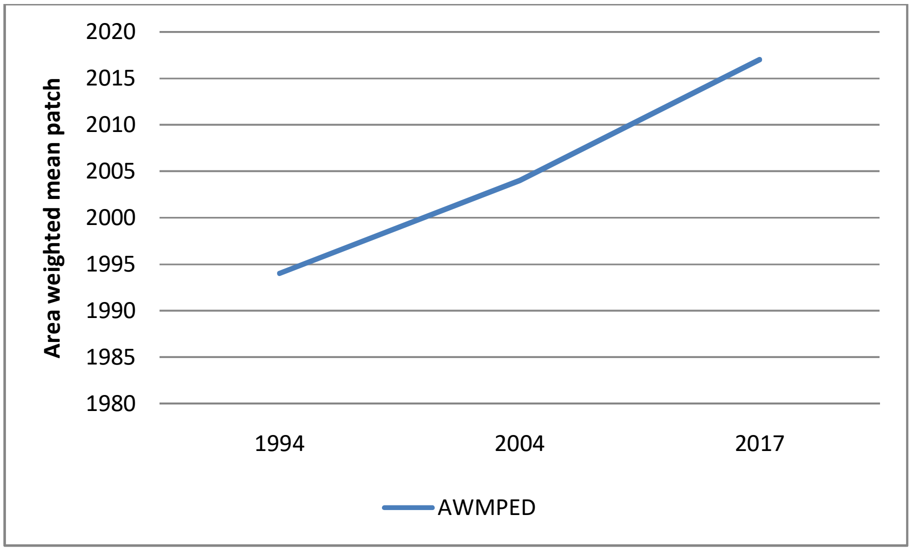


Figure 17. Largest patch index and Mean patch size for the entire landscape area.

4.8. Annual urban spatial expansion index Analysis

Urban growth was analyzed using the indicator system. AUSEI was used to determine temporal changes in urban areas and growth rates (Table 20). Spatial metrics also used to describe and quantify changes in urban land cover trends.

4.9. Population and Urban Growth Rate of Adama city

Table 20 compares the growth rate of population based on data from Central Statistics Agency of Ethiopia (1994 and 2004) and Adama city Administration (2017) to calculate total population growth between 1994 and 2017. The current research does not make any comment by extrapolating the population data of 2017. Rather, the census data of years 1994, 2007, and the citywide data for 2017 from city administration show that in Adma City Administration, the population growth rates were always lower than the built-up growth rates.

Table17:: Growth rate of built-up and population growth of Adama (1994–2017)

Years	Built-up area (km^2)	Population	Annual Growth Rate (%)		
			Interval	Built-up	Population
1994	45.26	127,842			
2004	74.40	220,212	10	6.4	5.3

2017	153.67	419,501	13	8.19	5.7

The data presented in Table 20 indicates the population of Adama city has been increasing significantly from years to years. In 1994, the population of the study area was 127,842 and dramatically increased to 419,501 in 2017. This plays an important role of urbanization. According to migration is the main factor in Adama city for demographic changes because Adama has been one of the areas in both the region and the country that receives heavy arrival of migrants each year. For instance, the 1994 Census indicates that 53.6 percent of the city's populations were migrants. The consequence of change in population number accelerates the demand for land and the dynamics in land-cover/land-use change. The data (Table 20) shows that population size in the study area steadily raised up from 1994 to 2004 as well as 2004 to 2017. This factor triggers the ever-growing demand for urban services such as demand of land for residence, economic and industrial activities and other public services, and leads to changes on land-cover/land-uses.

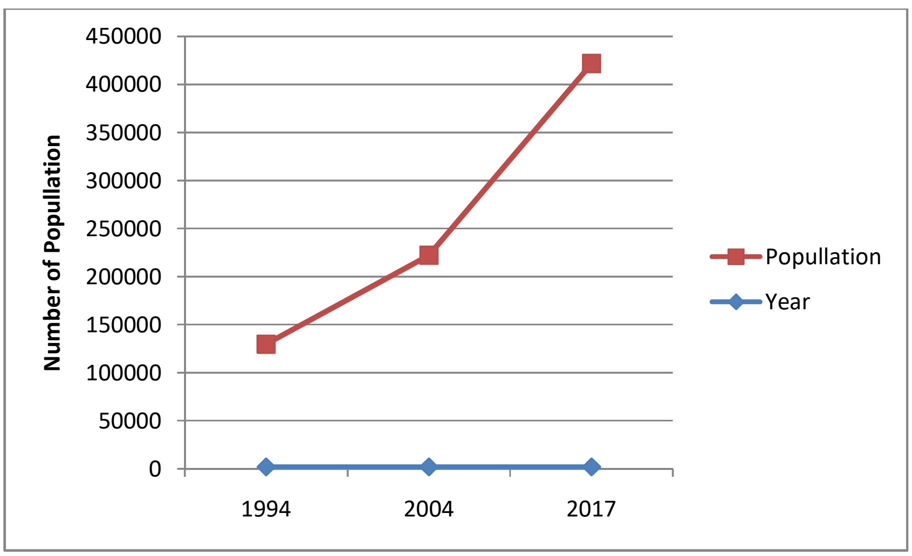


Figure 18. Total population of Adama city during 1994–2017.

Source: (CSA, 2013; OUPI, 2017)

CHAPTER FIVE

5. DISCUSSION

Rapid urbanization in the world is quite alarming, especially, in developing countries like Ethiopia. One of the inevitable outcomes from the rapid pace of urbanization, particularly in the developing countries, is the growth of size of cities without proper monitoring and management results in land-use/land-cover change. This is mainly due to uncontrolled population growth resulting in serious problems viz. scarcity of food, informal settlements, environmental pollutions, destruction of ecological structure and unemployment (Maktav and Erber, 2005). This kind of uncontrolled, chaotic, low-density human settlements will lead to urban sprawl. Urban sprawl, which is characterized by haphazard patchwork of development leads to an improper development in any city usually, happens due to land-use/land cover conversion in which the growth rate of urbanized land significantly exceeds the rate of population growth over a specified time, with a dominance of low-density impervious surfaces (Barnes et al., 2000). Ethiopia being the most heavily populated countries in Africa has been a victim of this phenomenon, especially, the horizontal growth of urban areas often encroaching on arable lands on the periphery. The situation in Adama city and on its surrounding area is also the same as the trends of the country, Ethiopia. The growth rate of built-up area of the study area, Adama city, between 1994 and 2004 was 6.4% and it increased to 8.19% between 2004 and 2017. However, the rate of population growth in the same period was 5.3% and 5.7%. Even if the city has rapid population growth, the growth rate of urbanized land increased excess the growth rate of population. Therefore, such kind urban growth and offensive land development needs an effort like this research to address the problem before it threatens the livelihood of the inhabitants in the hinterlands and protecting ecological impacts.

The LU/LC changes practiced across Adama city shows spatial increased of different LU/LC classes due to corresponding horizontal expansion of urban area as well conversion of LU/LC classes due to increase of built-up areas within the study boundary. Results from the land use/land cover maps derived in the years 1994, 2004 and 2017 has revealed that the study area has undergone tremendous change in a twenty three years period. During this period, the built up areas increased from 45.26 km^2 (14.6%) in 1994 to 153.67 km^2 (49.57%) in 2017 indicating an average annual growth rate of 4.35% (4.7 km^2 per annum), whereas the non-built up ones, in total, were decreased from 264.74 km^2 (85.4%) to 156.33 km^2 (50.42%) of which the dominant part is fertile agricultural lands. The marked increase of built-up area in the study boundary is a result of a conversion of others LULC classes, primarily the agriculture and vegetation-land category. A rapid loss of agricultural lands caused by rapid growth urbanization is prevalent all over the world. A very recent case study on Nairobi Metropolitan Area, Kenya by Monica and Moses Murimi (2017), accounted that built-up showed an overall increment by 17.2% in the period between 2005 and 2015, which mainly came from agricultural and forest land. Another study on urban growth and land-use change detection in Daqahlia governorate, Egypt, by Ibrahim Rizk (2015) reported that built-up area increased from 28 km^2 to 255 km^2 by more than 30% and agricultural land reduced by 33% between 1985 and 2010. Generally, the rate of urbanization which increasing every year has required more development of new area for built-up, as a result of rapid urbanization rapid losses of agriculture land is occurred. The driving factors for urban expansion of the Adama were highly related with rapid population growth, which increased demands of land for the investment and residential housing. In 1994, the total population of Adama city was 127,842. In 2017, this number increased to 419,501. In 23 years, Adama city enforced to gain additional 291,659 dwellers. In average, 12681 people per year came to the city. Bhatta (2010) revealed that Rapid growth of urban areas is the result of two population growth factors: (1) natural increase in population, and (2) migration to urban areas. This huge growth in urban population may force to cause uncontrolled urban growth resulting in sprawl. .

The general analysis of Spatio-temporal change in the past 23 years for monitoring urban growth in Adama city shows that the total built-up area increased by more than 153.67km^2; mainly from conversion of agriculture and vegetated areas. About 63.55 km^2 of agriculture, land converted to built-up area; as well as 47.43km^2 of vegetation-covered area was lost. In many literatures discussed uncontrolled urbanization as the process through which the productive agricultural lands, forests, surface water bodies and groundwater prospects are being irretrievably lost (Pathan et al., 1989, 1991). This is mainly due to uncontrolled population growth resulting in serious problems viz. scarcity of food, informal settlements, environmental pollutions, destruction of ecological structure, unemployment, etc. (Maktav and Erber, 2005). This kind of uncontrolled, haphazard, low-density human settlements will lead to urban sprawl. Urban sprawl, which is characterized by haphazard patchwork of development leads to an improper development in any city usually, happens due to land-use/land cover conversion in which the growth rate of urbanized land significantly exceeds the rate of population growth over a specified time, with a dominance of low-density impervious surfaces (Barnes et al., 2000).

Accordingly, understanding urban growth dynamics and managing it, requires accurate use of appropriate technologies and techniques, in order to monitoring urban growth in planned ways to simulation of its growth should designed to guide the cities in appropriate ways to attain its sustainability. For the purpose of sustainability, urban areas have to be properly monitored to maintain an internal equilibrium (Barredo and Demicheli, 2003).

CHAPTER SIX

6. Conclusions and Recommendations

6.1. Conclusions

This study has expressed that the combination of remote sensing and spatial metrics can be used to calculate and evaluate urban growth and its Spatio-temporal form, pattern and structure. Accordingly, the classification of multi-temporal satellite image (Landsat5 TM) and aerial photos of the three unique year (1994, 2004 and2017) in to built-up, agricultural- land, vegetated- area barren-land and water body has resulted in very simplified and abstracted representation of the study area. Based on this study, the analysis of the results leads to the following findings:

The main findings of our analysis are simple but strong and consistent: urban lands in Adama city expanded dramatically with clear Spatio-temporal differences. The created maps from classified images display a clear pattern of increased urban growth. During the study period, the built-up areas or class area increased from 45.26 km^2 in 1994 to 153.67 km^2 in 2017 at an average growth rate 6.4% and 8.19% annually in the course of 1994 to 2004 and 2004 to 2017 study period respectively. Totally, 108.41km^2 of non-built-up land transformed to urban land. Generally, the result of analysis shows that the city of Adama as growing rapidly and convert non-built-up areas to built-up without pre plane and management.

The results showed that the overall accuracy of classified image data is between 87.5% and 90.6% with for the study area. This could indicate that combining remotely sensed and spatial metrics data are useful to monitor and mapping the LU/LC for urban areas with better spatial and temporal resolution data. However, better spatial and temporal resolution data enables us with improved results to avoid environmental and ecological problems.

Five metrics assess at city level, i.e., TA, NP, LPI, MPS and AWMPFD. Different metrics represent specific spatial and temporal dynamics of urban growth, with extensive urban land change and development of new patches, consequently increasing fragmentation. It was observed in all study periods, number of patches calculated from categorical maps and the results were found to be 351 in 1994, 473 in 2004 and 717 in 2017, respectively. The increasing number of patches indicates that built-up area was extensively increasing. Largest Patch Index (LPI) in percentage also shows a growing trend from 2.6% in 1944 to about 11.12% in 2017. This is a good indication that largest patch is growing more and more in size forming a continuous urban agglomeration at the city center. That is, while the number of patches increase at every year leading fragmentation of the fringe areas, the largest patch is growing bigger and bigger at the center. In general, the approach adopted in this study clearly demonstrated the combination of remote sensing and spatial metrics techniques in measuring change pattern of land -use/land-cover in city area. The study not only provides the scientific way to understand the future urban growth but it also provides a methodology for assessing urban land use cost effectively and in less time period. The present study is useful for decision-making process and helpful for planners and authorities to formulate suitable plan for sustainable urban development in the region.

6.2. Recommendations

The thesis addressed the potential of geospatial tools particularly remote sensing and spatial metrics tools for analyzed urban growth and its impacts on peri-urban productive agricultural lands. It pointed out that the current trend of urban land-use/ land-cover change and on-going urban growth without proper growth monitoring and in unplanned ways will have remarkable impacts on the surrounding land resources and environment. The application of satellite images especially high resolution images with combined with spatial metrics techniques widely being used to understand the pattern of land-use/land-cover change, to quantify and analyze the change , and modeling (to simulate) the urban growth, land-use/land-cover, and sprawl. Therefore, based on the above findings the following provisional recommendations are given.

- The results of the study show that, the pace of urban growth of Adama city is rapid, especially in the last thirteen years with a growth rate of 8.19%. This causes unprecedented, unplanned and rapid expansion of the city that will continue in the coming decades over precise agricultural land. Therefore, it is time for policy makers, city managers and urban planners to plan ahead and cope up with the pace of urban growth depending on with proper implementation.
- The rate of built-up area increased has played a major role for decreasing agricultural land and affecting land-use/land-cover changes. Therefore, the government should be revised the house provision policy, housing modality and housing land provision system.
- Continuous urban expansion at rates higher than population growth has resulted in a massive urban footprint on Adama – fragmenting rural space, blocking ecosystem services and increasing the demand for transport and energy. The government should be provide restrict zone and urban planning policy to protect environmental degradation and promote sustainable development.
- In order to achieve proper management of urban areas, measurement, mapping and

monitoring of urban growth are crucial to understand the past and present in order to plan and prepare for the future. To do that, the application of multi-temporal remotely sensed data combining with spatial metrics techniques are help them to understand and analysis the urban growth trends and patterns.

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DECLARATION

I hereby declare that the work in its entirety is my own work, except explicit citation and acknowledgement is given for published and unpublished sources. The document has not been summated to the university or any other institution for any purpose.

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Signature _____________

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May, 2018

CERTIFICATE

This is to certify that the thesis entitled "Spatio-temporal analysis for monitoring urban growth using geospatial tools. A case study of Adama city' is original work of Mr. Gugsa Dejene Gurmu for the partial fulfillment of the Degree of Masters of science in remote sensing and Geo-informatics from Addis Ababa University under our guidance and supervision.

This is

Dr.K.V.Suryabhagavan	Prof. M. Balakrishnan
Signature ___________	Signature __________
Date _____________	Date ___________

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