Analyzing Spatio-Temporal Urban Physical Growth and Driving Physical Factors: A Case of Adama City

Samrawit Solomon Hailu

A Thesis Submitted to the Department of Geoinformatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Geoinformatics Engineering

Office of Graduate Studies

Adama Science and Technology University

November, 2024

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DECLARATION

I declare that this thesis entitled "**Analyzing Spatio-Temporal Urban physical growth Pattern and Driving Physical Factors: A Case of Adama City"** is my own work and has not been submitted to any university for similar purpose. The references used in this paper are duly recognized by proper citations.

Samrawit Solomon Hailu ________________________ ________________

Name of student Signature Date

RECOMMENDATION OF ADVISOR

I, the major supervisor of this research, here by certify that I have closely supervised the student while developing this paper and read the final thesis entitled **"Analyzing Spatio-Temporal Urban physical growth Pattern and Driving Physical Factors: A Case of Adama City"** prepared under my guidance by Samrawit Solomon Hailu Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures**.**

Dejene Tesema (Ph.D.)	____________________	____________________
Major Advisor/Supervisor	Signature	Date

APPROVAL PAGE FOR THESIS

I hereby certify that the recommendation and suggestion given by the thesis review committee are appropriately incorporated into the final thesis entitled **“Analyzing Spatio-Temporal Urban physical Growth Pattern and Driving Physical Factors: A Case of Adama City”** by Samrawit Solomon Hailu.

Dejene Tesema (Ph.D.)	_________________	________________
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We, the undersigned, members of the Board of Reviewers of the thesis open defense by Samrawit Solomon Hailu have read and evaluated the thesis paper entitled "**Analyzing Spatio-Temporal Urban physical growth and Driving Physical Factors: A Case of Adama City"** and assessed the understanding of the candidate about the conducted research. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Geoinformatics Engineering.

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GIS	Geographic Information System
LULC	Land Use Land Cover
LULCC	Land Us Eland Cover Change
CSA	Central Statistics Agency
AOI	Area Of Interest
CBD	City Business District
USGS	United States Geological Survey

Abstract

This research provides a comprehensive analysis of the spatio-temporal urban growth patterns in Adama City, Ethiopia, focusing on the period from 2000 to 2023. The primary objective is to identify the patterns of urban expansion, the extent of built-up areas, and the implications of this growth on both the environment and socio-economic conditions. The study reveals a dramatic increase in the built-up area of Adama City over the 23-year period, indicating a significant transformation driven by various factors. Key findings indicate that population growth, economic development, and enhanced infrastructure have been major contributors to this urban expansion. The analysis employs remote sensing and geographic information systems (GIS) to quantify changes and visualize growth trends effectively .In examining the implications of urban growth, the research highlights several environmental concerns. These changes pose challenges for sustainable development in the region, necessitating proactive measures to protect natural resources. On the socio-economic front, the study discusses how rapid urbanization has led to increased job opportunities and improved access to services, but it has also resulted in challenges such as housing shortages and rising living costs. This dual impact underscores the complexity of urban growth, where benefits and drawbacks coexist. Overall, the research emphasizes the need for strategic urban planning that addresses the challenges posed by rapid growth while leveraging its potential benefits. Sustainable development practices are essential to ensure that Adama City can accommodate future growth without compromising environmental integrity or social equity.

Keywords: Urban growth, growth pattern, land use land cover

CHAPTER I. INTRODUCTION

1.1 Background of the Study

Urbanization and urban growth are vital spatio-social processes, which leads to changes in human societies and relationship between social, economic, physical, and environmental dimensions (Dadras et al. 2015). Urbanization is the physical growth of urban areas or the territorial progress of a region as a result of increase in population due to migration or peri-urban concentration into cities .The transition happens from rural to urban in terms of industry structure, employment, living environment and social security. Urbanization may be planned with basic infrastructure or organic it occurs as individual, commercial establishment, and the government makes efforts to improve the opportunities for jobs, education, housing, and transportation. (Brockerhoff 2000; Ramachandra et al. 2015b). Rapid urbanization, especially in developing countries is continuing to be one of the crucial issues affecting the physical dimension of cities. Urban expansion in the developing world often takes places in an unplanned manner and administration are unable to keep track of growth related process (Griffiths.et al.2009).

Urban growth is the spatial pattern of land development to accommodate anthropogenic demand that influences other land uses (which includes open spaces, water bodies, etc.). Driven by population increase, urban growth alters the community's social, political and economic institutions with changing land use and also affects the local ecology and environment. It is a common observation that with growing population, urban areas are expanding. The rate of expansion, however, depends upon several other associated factors .It is a common observation that with growing population, urban areas are expanding. The rate of expansion, however, depends upon several other associated factors. It is understandable and several studies also argue that human population growth and resource consumption leads to the expansion of urban land area and bring changes in its land use and land cover (Cheng & Masser, 2003; Haregeweyn Tsunekawa, & Tsubo, 2012; Tian et al., 2005). Land use is the varying activities performed by human beings to divide the landscape into different patterns with concerned changes (Carole Jolly &Barbara, 1993) and varies with human activities and the purpose for which land is being used.

Over the last three decades, advancements in remote sensing technologies have made it possible to study physical changes and patterns (Cohen, W.B, 2004). Remote sensing and Geographic Information Systems (GIS) techniques provide information and the necessary tools to study and understand land use/land cover (LULC) changes over time. GIS and remote sensing have become important tools for conducting change analysis in different parts of the world (Yaun, F.; Sawaya, K.E.; Loeffelholz, 2005). Urbanization in Ethiopia has increased significantly in recent years, and Adama City is a prime example of rapid urban development. Due to various economic and infrastructural advances, Adama experienced a significant population influx and large-scale urbanization occurred. The effects of this rapid urbanization are manifold. Meanwhile, Adama City has seen improvements in employment opportunities, commercial activities and access to basic amenities. However, the rapid pace of urbanization also poses challenges, including increasing pressures on infrastructure, inadequate housing, traffic congestion, and environmental degradation. Important physical factors contributing to Adama's rapid urbanization include its strategic location on major transportation routes, proximity to Addis Ababa, availability of natural resources, and government efforts to promote industrialization. Rapid urban growth is a complex environmental issue because of the multiplicity of its patterns and its impacts on the ecosystem. (Aburas Ho et al., 2018).Rapid development in urban settlement contributes to the changes of environmental, economic and social activities.

Urban growth patterns refer to the spatial and temporal changes in the physical form and extent of urban areas over time. These patterns can vary widely, from compact, high-density cities to sprawling urban regions, and are influenced by a range of factors such as population growth, economic development, land availability, infrastructure investment, and planning policies (Marina and Mohd Noor 2014). In Ethiopia, urban growth patterns have been characterized by significant expansion and transformation in recent decades (Abate, 2016). Major cities like Addis Ababa, Dire Dawa, and regional capitals have experienced substantial population growth, resulting in urban sprawl, increased infrastructure development, and changes in land use (Lu, Mausel et al. 2004). Adama City, has seen substantial growth over the years. According to the Ethiopian Herald, the city has grown from a small village to a bustling urban hub with a robust economy and a quickly growing population (Ethiopian Herald, 2021). Its strategic location along major transportation lines, the development of educational institutions, and infrastructure upgrades have all played important roles in fostering this growth. Managing urban planning and tackling difficulties like as traffic congestion and housing shortages, on the other hand, remain critical factors for sustain this growth.

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1.2 Statement of the Problem

In the 21st century, rapid urbanization and urban growth have been one of the crucial issues of global change that affect the physical dimension of cities. Due to rapid urbanization cities underwent a process of urban growth that has continued until nowadays (Berling-wolff et al.2004). This process has generated several problems derived from the generated urban patterns (chin, N., 2002). Symptoms of horizontal expansion of urban centers are Such as agriculture land loss, fragmentation of natural resources, environmental pollution, residential crowding and traffic congestion. Urban growth is complex processes that can be influenced by various factors and suggest the importance of identification of the factors associated with the existing form of the city.

The factors influencing growth and the characteristics of each city may vary depending on the geographical location of the city and its socioeconomic context, it remains that common features, growth process and regularities are persistently found. A renewed understanding of the nature of cities is key in advancing appropriate tools and methods of analysis that take into consideration the multiplicity of the physical and social aspects of a city as well as the elements and actors that play a role in their transformation. Such tools are needed to ensure that contemporary cities are equipped with the ability to understand the possible impacts of rapid or simultaneous changes and developments (Macartnay s., Krishnamurthy s., 2018).

Ethiopia has been experiencing a rapid urbanization since the implementation of economic development and privatization policy (Kassahun, s. & Tiwari, A., 2014) to stimulate national economic growth. However, as it is observed in numerous developing countries, the intensified constraints following the fast urbanization process in the country are unplanned and uncontrolled that resulting in scattered urban growth, loss of farm land and environmental degradation. Besides, the urban physical growth rate has been faster than the rise in infrastructures and service delivery in Ethiopia cities (MUDHCo, 2014).

Adama is one of the fast growing town in Ethiopia, and entering a new stage of transformation with a large industrialization and rapid urbanization. But many developments have occurred outside of proposed growth area and a majority of uncontrolled urban development or open space encroachments have occurred at the western and eastern part of the town following the main road from Addis Ababa –Djibouti.

In addition, findings revealed that the growth rate of built-up lands exceeds significantly that of a population which demonstrates a massive urban land growth and an inefficient use of land resources in Adama Town (Bulti & Sori, 2017). Excessive alteration of land use has been occurring in the town (Sinha et al.2016).The physical expansion of the town with the fast growing population does not appear to match infrastructural development in the town (Yhdego,S.,2007). All these studies only investigated the dynamics of urban areas without give due consideration of growth framework that limits the urban growth but the current study fills this gap by considering the urban growth morphological aspect by identify major influential factors related to the existing form of the city and identify the urban growth types occurred during the study period. Because a better understanding of those factors that influence the town growth and growth types is needed for a sustainable future development in Adama city and achieving a desired information for local and regional land use planners and policy makers in order to establish the necessary decision and polices. Therefore, to analyze the built-up expansion change in urban structure/morphology and its main driver using spatial regression analysis model will be applied in the GIS environment.

1.3 Research Questions

1, what are the major driving physical forces behind the observed urban expansion in Adama City?

2 What are the patterns of urban expansion in Adama City from 2000 to 2023?

3 How does urban expansion in Adama City impact land use, infrastructure, and environmental factors?

1.4 Objectives

1.4.1Genera objective

To analyze the spatio-temporal urban growth patterns and identify the driving physical factors influencing the expansion of Adama City.

1.4.2 Specific objectives

A. To identify the major driving physical forces behind the observed urban expansion.

B, To assess the urban expansion pattern of Adama City 2000 to 2023.

C, To assess the temporal changes in urban expansion 2000 to 2023.

D. To evaluate the socio economic implications of urban expansion.

1.4. Significance of the Study

The study provides essential insights into the patterns and trends of urban expansion that can aid in urban planning and development policies. The findings can assist in identifying areas that require immediate attention for infrastructure development and resource allocation. Urban Planning, By precisely monitoring urban growth patterns, city planners can develop more efficient strategies for land use, transportation, and infrastructure development, ultimately leading to sustainable urban environments. Resource Allocation, Accurate knowledge about the pattern of urban growth can inform decisions related to resource allocation, ensuring that limited resources are efficiently managed, and future demands are met effectively.

Environmental Impacts, Understanding the patterns of urban growth helps identify areas that may be under threat from environmental degradation, facilitating the implementation of conservation measures and sustainable practices. Economic Development, Geomatics techniques enable the identification of areas with high growth potential, attracting investments and promoting economic development in strategic locations.

1.5. Scope of the study

This study investigates the urban growth pattern of Adama City, Ethiopia and assess the main physical factors contributing to this growth using geospatial techniques. The study focuses on 2000 to 2023 time period and uses geospatial data such as satellite imagery, geographic information system (GIS) data, and remote sensing techniques. The study includes an analysis of the spatial extent and land use changes of Adama City from 2000 to 2023. In addition, physical factors such as proximity to transportation routes, availability of natural resources, and government initiatives that influenced the growth of the city are identified and evaluated. The impact of urban growth on land use, infrastructure, and environmental factors will also be investigated .The results of this study will contribute to a better understanding of the urbanization process in Adama City and provide valuable insights for sustainable urban planning and management.

1.8 Operational Definitions

Spatio-Temporal Urban Growth Pattern: The observable and measurable patterns and trends of urban expansion over time, focusing on how urban areas in specific geographical locations, such as Adama City, have changed spatially from 2000 to 2023. This involves analyzing factors like migration, land use changes, and socio-economic shifts that affect urban landscapes.

Urban Expansion: The process through which urban areas increase in size and population, characterized by the development of new residential, commercial, and industrial spaces. This expansion is influenced by demographic trends, economic growth, changes in land use policies, and the availability of infrastructure. (Aguayo, Wiegand et al. 2007).

Built-Up Area: The segment of land within urban boundaries that is developed primarily for various human activities, including residential housing, office buildings, shopping centers, and manufacturing plants. This area is contrasted with undeveloped land and green spaces within the urban fabric**.**

Driving Physical Factors: The underlying physical and socio-economic elements that spur urban growth. These factors include population density, availability of resources, economic opportunities, transportation networks, government policies, and land use planning practices that enable or restrict development.

Geospatial Techniques: Advanced methodologies, such as remote sensing and Geographic Information Systems (GIS), utilized for collecting, analyzing, and visualizing spatial and geographic data. These techniques are essential for understanding urban growth dynamics and assessing the impacts of urbanization.

Environmental Impacts: The consequences of urban growth on natural ecosystems, which can manifest as increased pollution, loss of biodiversity, strain on water resources, and changes in local climate conditions. Understanding these impacts is crucial for creating sustainable urban development strategies.

Economic Development: A multi-faceted process involving the growth of economic activities within urban areas, leading to improved job opportunities, income levels, and living standards for residents. In the context of urban growth, it examines how economic factors influence spatial expansion and land use changes.

Analytical Hierarchy Process (AHP): A structured decision-making tool that helps assess and prioritize various factors influencing urban growth. It combines qualitative and quantitative aspects, allowing stakeholders to make informed decisions based on multiple criteria.

Image Pre-Processing: The suite of operations performed on satellite or aerial imagery to enhance its quality for further analysis. This includes geometric and atmospheric correction to ensure accurate representation of spatial data, improving the reliability of subsequent analyses such as land use classification.

1.7 Organization of The Study

This thesis is categorized into five chapters. Each chapter systematically and effectively examines the content and data of the study accordingly. The fundamentals of each chapter in the paper are further demonstrated as follows.

Chapter one - Introduction to the study introduce the thesis by emphasizing the main topic of the study, statement of problems, objectives, research questions, significance and the scope in detail.

Chapter two -. Contains a review of related literature, it describes the main concept used in the study i.e. urban land use /land cover and its national and international experiences of the diverse study of land-use changes and modeling techniques.

Chapter three - The section explains the methods used for the study and the process of data collection and analysis in detail.

Chapter four - This is the section where the data is analyzed and discussed in detail with the aim of summarizing major findings.

Chapter five - It is the closing part of the paper which consists of conclusion of the thesis and sets recommendation based on the finding outcomes.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Urban growth is influenced by multiple elements, making it crucial to identify those that contribute to the city's current structure. The term "form" has multiple connotations, including shape, configuration, structure, pattern, organization, and System of relations. In city studies, form refers to the spatial growth pattern of features such as networks, buildings, and spaces. Geometry is typically specified in two dimensions, but can also be three. Form has a global impact on how cities grow and adapt, not just its local characteristics. (Batty and Longley, 1994)

2.2 Theoretical Literature Review

The rapid urban growth in major cities poses enormous opportunities and challenges for the future sustainable development of a country .For instance, large cities are expected to be centers of innovation and wealth creation and need more resilient infrastructures and services resources as compared to smaller towns (Zhang et al., 2013).This development, however also draws energy and materials from distance and nearby ecosystems. Currently, more than 54 percent of the world's inhabitants are living in urban regions. This implies that, by 2050, 68 percent of the world's inhabitants are expected to be urban, with nearly 90 percent of this growth will occur in Asia and Africa (United Nations, 2014).This fast population growth coupled with economic development resulted in rapid urban physical growth (Artmann et al.,2019).consequently, unless managed well it can often lead to a serious negative environmental and socioeconomic issues such as urban heat islands, air pollution, traffic congestion, decreases of green spaces, habitat losses, inadequate infrastructure and services, and inefficient resource utilization (Arsiso et al.,2018),especially in the countries where most urban dwellers growth is expected (United Nations, 2018).

There are numerous studies on the expansion of urban land in single metropolitan regions (Magidi, J. & Ahemed, F., 2018). Changes and differences in the patterns of urban growth have been observed over time among some megacities (Zhang et al., 2013) and scattered pattern of urban has been confirmed in small and mid-sized cities (Anees. et al., 2018).However, particularly in Africa, urban growth patterns and population dynamics of cities, varying in size are not well documented. Africa is the least urbanized continent with 43 percent of its inhabitants living in the urban region (United Nations, 2014).

Nevertheless, most African cities are challenged by problems related to unplanned and uncontrolled rapid urban growth as informal settlements (Magidi, J. & Ahemed, F., 2018), become a part of the urban ecosystems. Therefore, understanding and comparing the evolution of urbanization, in large and mid-sized cities could provide a reference for urban and ecological planning, and for sustainable development

2.3 Urbanization and Urban Expansion

Urbanization is simply defined as "the movement of people from rural to urban areas with population growth equating to urban migration" (United Nation, 2005). Urbanization is also a social process which involves the changes of behavior and social relationships as a result of people living in urban area (Bhatta, 2010).Essentially, it involves the complex change of life styles which result from the Impact of cities on society (Bhatta et al., 2010). Nowadays however, urbanization is commonly used in more broad sense and it refers to much more than simple urban population growth; it involves the physical growth of urban areas as well as the changes in the socioeconomic and political structure of a region as a result of population immigration to an urban area (Cohen, 2004; Deng et al., 2009). Urbanization has been a dynamic complex phenomenon taking place all around the world. This process, without a sign of slowing down has led to the significant changes in land cover and land scape pattern (Braimoh & Onishi, 2007; Deng et al., 2009).

Dramatic urbanization, especially in the developing countries will continue to be one of the important issues of global change influencing the human dimensions (Deng et al., 2009). Associated with the process of rapid urbanization, the spatial expansion of built- up areas has been accelerating. Though urbanization promotes socioeconomic development and improves the quality of life, urban growth inevitably results in significant land cover changes in urban area, such as the conversion from the forest and wetlands into agricultural or built-up lands since more land is used for the production of goods and services and more residential land is required for the people living in the urban. While urban areas currently cover only 3% of the earth's land surface (Dewan & Yamaguchi, 2009). The conversions resulted from the urban growth are among the most significant types of anthropogenic land cover dynamics, and the ecological and environmental impacts of urban growth go for beyond the urban boundaries (Wu et al., 2011; Liu & Lathrop, 2002).

This is particular the case in the fast developing regions where land cover changes caused by rapid urban growth resulted in serious issues threatening urban sustainable development, for example. Local and regional climate change (Kaufmann et al., 2007), forest loss and fragmentation (Miller, 2012) and etc. The process of urban growth can be described as either a change in the area of urban (a measure of extent) or the pace at which non- urban land is converted to urban uses (a measure of rate) (Seto & Fragkias, 2005). However, the extent and rate of urban growth cannot provide detailed information about spatial patterns of urbanization or the underlying processes. Therefore, the urban spatial pattern has been the other subject of interest for geographers and economists to study the changes in urban areas.

2.3.1 Urbanization

Urbanization is a global phenomenon characterized by the increasing concentration of populations in urban areas. Rapid urbanization has resulted in diverse growth patterns worldwide, with variations ranging from compact, high-density cities like Tokyo to sprawling urban regions like Los Angeles. Urbanization is a process through which the productive agricultural lands, forests, surface water bodies and groundwater prospects are being irretrievably lost (Vinoth Kumar, Pathan et al. 2007) .These growth patterns are influenced by a multitude of factors, including population growth, economic development, technological advancements, and urban planning policies(Moeller 1950) .The implications of these patterns extend to various aspects such as land use, infrastructure provision, social dynamics, and environmental sustainability (McGranahan et al., 2001). Understanding and effectively managing urbanization and its associated growth patterns are crucial for promoting sustainable development and enhancing the overall quality of life in urban areas globally. Urban growth patterns refer to the spatial and temporal changes in urban areas, including the expansion, density, and land use transformations that occur over time.(Mushore, Odindi et al. 2017) Understanding these patterns is essential for effective urban planning, resource allocation, and sustainable development strategies.(Gašparović 2020) In Ethiopia, urban growth patterns have been characterized by significant expansion and transformation in recent decades (Abate, 2016). Major cities like Addis Ababa, Dire Dawa, and regional capitals have experienced substantial population growth, resulting in urban sprawl, increased infrastructure development, and changes in land use (Teshome et al., 2019).

The growth patterns in Ethiopia are influenced by factors such as rural-urban migration, economic opportunities, government policies, and investments, which pose both opportunities and challenges for sustainable urban development in the country (Belay et al., 2017; Zewde et al., 2018). Understanding and managing these growth patterns are crucial for promoting balanced urban development and improving the overall quality of life in Ethiopia's cities (Tulu et al., 2019). In the context of Adama City, Ethiopia, urban growth has been a significant phenomenon in recent years (Ayalew & Gebre, 2019). Adama City, also known as Nazret, is located in the Oromia Region and strategically positioned along major transportation routes, including the Addis Ababa-Djibouti railway line and the Addis Ababa-Adama Expressway, which has contributed to its rapid urbanization and economic growth (Girma, 2018).The city has experienced a substantial increase in population due to its proximity to Addis Ababa, the capital city of Ethiopia, and its growing importance as an industrial and commercial hub (Girma, 2018). This population influx has resulted in extensive urban expansion, leading to changes in land use, infrastructure development, and environmental impacts (Lamessa, 2017). Urban growth patterns refer to the spatial and temporal changes in the physical form and extent of urban areas over time. These patterns can vary widely, from compact, high-density cities to sprawling urban regions, and are influenced by a range of factors such as population growth, economic development, land availability, infrastructure investment, and planning policies ((Marina and Mohd Noor 2014). Assessing and monitoring the spatial patterns of urban growth is one of the most important challenges for researchers, planners and decision makers in relation to achieving the principle of sustainable urban development.

Rapid urban growth is a complex environmental issue because of the multiplicity of its patterns and its impacts on the ecosystem (Aburas, Ho et al. 2018).Rapid development in urban settlement contributes to the changes of environmental, economic and social activities. This transition of the metropolitan area, city, town or village from the past to the present condition describe the process of urban growth which gives impacts to the form and structure of settlements. Therefore, urban morphology become as an essential key for the urban development to identify and determine the resilience of the whole urban system that will create urban dynamic as well. The understanding of urban growth and interpretation of urban morphology can be a key challenge to the rapid urbanization of the settlement.

(Marina and Mohd Noor 2014).Geospatial technology has played a crucial role in understanding and monitoring the urban growth patterns in Adama City. Technologies such as satellite imagery, GIS data, and remote sensing techniques have been used to analyze the spatial and temporal dynamics of urban growth, including land cover changes and urban sprawl, as well as to identify the driving factors behind this growth (Ayalew & Gebre, 2019; Yeraswork & Berhanu, 2018).

2.3.1 Urban Growth Types

Urban, as used in this study, is synonymous with developed land, and includes residential as well as commercial and industries land uses that result in a developed or built landscape. When modeling urban growth, therefore, we are looking at the pattern of development on the landscape, rather than referring to relative differences in the density of development or population (i.e. "urban" as distinguished from "rural"). The model identifies three categories of urban growth. Infill, edge-expansion and outlaying with outlaying urban growth further separated into isolated, linear branch, and cluster branch growth.

Figure 2.1a shows an infill growth is characterized by a non-developed pixel being converted to urban use and surrounded by at least 50% existing developed pixels. It can be defined as the development of a small tract of land mostly surrounded by urban land cover. Ellman (1997) defines infill polices as the encouragement to develop vacant land in already built-up areas. Infill development usually occurs where public facilities such as sewer, water, and roads already exist. As shown in figure 2.1b an edge-expansion growth is characterized by a non- developed pixel being converted to developed and surrounded by no more than 50% existing developed pixels.

This conversion represents an expansion of the existing urban patch. Edge- expansion type development has been called metropolitan fringe development or urban fringe development (Heimlich & Anderson, 2001; Wasserman, 2000). Figure 2.1c shows Outlaying growth is characterized by a change from non-developed to developed land cover occurring beyond existing developed areas. This type of growth has been called development beyond the urban fringe (Heimlich & Anderson, 2001). The outlaying growth designation is broken down into the following three classes: isolated, linear branch, and clustered branch. Isolated growth is characterized by one or several non-developed pixels some distance from an existing developed area being developed.

This class of growth is characteristic of a new house or similar construction surrounded by little or no developed land. Linear branch defines an urban growth such as a new road, corridor, or a new linear development that is generally by non- developed land and is some distance from existing developed land. A linear branch is different from isolated growth in that the pixels that changed to urban are connected in linear fashion. Cluster branch defines a new urban growth that is neither linear nor isolated, but instead, a cluster or a group. It is typical or a large, compact and dense development. Harvey and Clark (1965) define a similar type of growth called leap-frog development as the "settlement of discontinuous, although possibly compact, patch of urban uses".

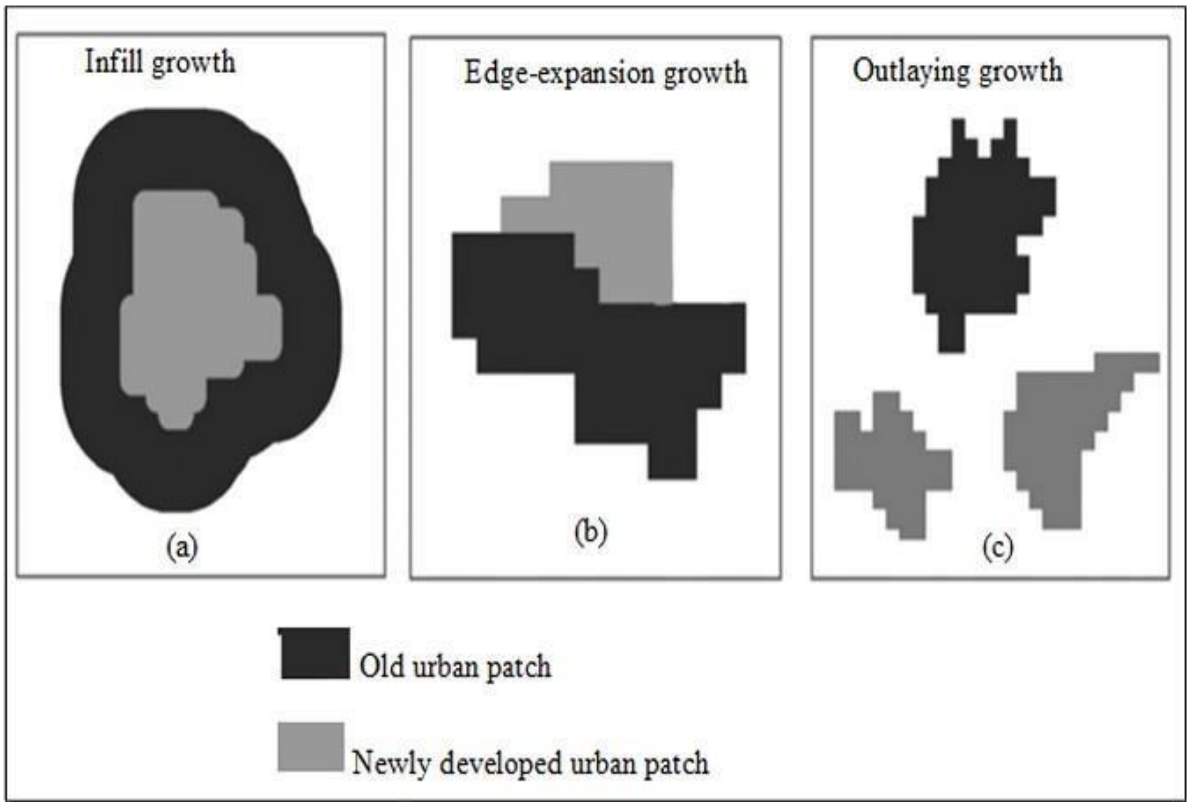

Figure 2. 1 Three types of urban growth.

2.3.2 Urban Growth Challenges

In developing countries, urban growth is subjected to uncontrolled challenges due to rapid population growth, rapid technological change, increasing motorization rates, and urban expansion (Zegras & Gakenheimer, 2000), as well as massive traffic congestion, loss of farmland, urban disinvestment, and high costs of public infrastructure (Nelson, Pendall, Dawkins, & Knaap, 2002).

The rapid growth of the cities in developing countries faced the challenge to provide land and infrastructure to satisfy the massive demand of private households.

2.3.3 Urban Form, Function and Structure

The term "urban form" is used to describe a city's physical characteristics. It refers to the size, shape and configuration of an urban area or its parts. Study of urban form is performed in order to understand the spatial structure and character of a metropolitan area, city, town or village by examining the patterns of its component parts and the ownership or control and occupation. Urban form is closely related to scale and can be described as the "morphological attributes of an urban area at all scales" (Williams et al.2000).This scale at which urban form can be considered includes the individual building, street, urban block, neighborhood, and city. These levels of spatial disaggregation influence how an urban form is understood, measured, analyzed and shaped (Dempsey et al.2010).

- **On the metropolitan scale**, urban form refers to the spatial extension of the city.it refers to land use (rural or urban land), human activities (industries, offices, housing), and the way they are organized and distributed on the territory.
- **At the broad city scale**, urban form has been defined as the spatial configuration of fixed elements (Anderson et al.1996).Feature of urban form at this scale includes urban settlement type, such as a market town, central business district, or suburbs(Dempsey et al .2010).
- **On the district scale**, urban form refers to how streets and transportation networks are organized as well as how urban amenities such as parks, hospitals or schools are distributed within the city.
- **On the neighborhood scale,** urban form relates to the form and the size of urban blocks and the way they are divided into plot subdivisions. It also relates to the physical texture of the urban fabric and its bioclimatic potential. (Urban morphology-complex system institute 2018).

Urban Function can be conceptualized as function of city in relation to the society, hinterland, or other settlements as activities taking place inside of cities or as a relation between urban (social) needs and urban (spatial) forms. Urban functions are generator that shape morphological characteristic of urban space .The location; size and shape of urban space are in direct relation to functional needs of inhabitants or society. Urban functions are complex concepts that depend on the scale at which functionality is studied.

It is possible to distinguish the functions internal to the city, the functions of the city in relation to the territory (countryside, agriculture, villages and hamlets, smaller towns. subordinated with in a networks), and lastly, the functions of the city. Each city in the social whole (the technical and social division of labor between cities, various networks of relations, administrative and political hierarchies).Levels of functions stand in relation to urban structure and can be related to the structure of the city (of each city, morphologically, socially, topologically and topically), then the urban structure of society, and finally the social structure of town –country relations (Lefebvre 1996).

Urban Structure is the arrangement of land use in urban areas. Sociologists, economists and geographers have developed several models explaining where different types of people and businesses tend to exists within the urban setting. Urban structure can also refers to the urban spatial structure, which concerns the arrangements of public and private space in cities and the degree of connectivity and accessibility. The existing of spatial structure take an important roles as appoint of initiation of new growth center of urban growth, In this case when we know how the structure shaped the city ,we will know how should we initiate for planned activities, we do known the flows. Second is as the area of industrial support, education, trade and service.

After we know the flows of human and goods mobility, we can choose which area can be used for support the existing of settlement surrounding such as education, trade etc. Another role is as director of network infrastructure definitely spatial structure made us understand about the space activity and mobility so it can help us to direct the construction of infrastructure because we know which location need it. A review of the city's internal spatial structure can be done with a variety of approaches among others, such as:

- Ecological approach Reviewing the city as an object of study in which there is a complex society

  ,has undergone a process of interrelations between humans and their environment .its product is urban land use pattern regularity.

- Economic approach Economic approach to the spatial structure of the city is based on the understanding that the value of the land rent and cost have a close connection with land use patterns pathways and transport node has a big role to the development of the city.

- Urban morphological approach Urban morphology focus on physical forms an urban area that is reflected from the type of land use, road network system and blocks of buildings, “town scape”, urban sprawl, and the pattern of the road network as an indicator of the morphology of the city.
- Based on this approach, an outline is the spatial expression of the town, which can be seen from the physical pattern or arrangement of the physical elements of the city such as buildings and the environment, so the city can be distinguished from the shape of the city is compact and non- compact urban form (Hoyt H.1939).

2.3.4 Consequences of urban expansion

The rapid rate of urban growth leads to rapid changes in land use and cover than ever before, particularly in developing nations, are often characterized by unrestrained urban rambling, land degradation, or the transformation of agricultural land to other uses and resulting in a massive cost to the environment (Sankhala et al., 2014). The negative effects (disorderly) urban expansion highly increase the land use and land cover changes and becomes many problems such as uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat, loss of prime agricultural farmland, displacement of farm communities, solid waste disposal and land degradation, enclosing surrounding rural land to urban territory, overexploitation of natural resources and conflict (Alexander, 1995; Rosenfeld, 1994).

2.4 Land Cover Change

Mapping and monitoring land cover have long been regarded as critical steps in better understanding and addressing social, economic, and environmental issues (Lu, Mausel et al. 2004). As a result, continuous historical and exact information on land cover and land cover change is becoming increasingly vital for urban planning in the direction of sustainable development (Halmy, Gessler et al. 2015). Despite the fact that most developed countries have detailed land cover information. Longley and Mesev (2000) asserted that our current understanding of land cover change and its consequences is hampered by a lack of accurate and timely land cover data in developing nations. Satellite remote sensing has become an increasingly powerful and successful tool for monitoring and managing land cover since the launch of the first earth resource satellite, Landsat-1, in 1972 (Green, Kempka et al. 1994).

Land cover mapping provides the advantages of low cost, vast area coverage, repeating data, digital format, and accurate geo referencing processes over more traditional mapping approaches such as field survey and basic aerial photointerpretation (Jensen,1996; Yuan et al., 2005). As a result, land use information products derived from satellite pictures have emerged as a critical resource for land cover management and urban planning. An important task of satellite image process is to develop image data analysis approaches suitable to a particular application. The classification of land cover types from satellite images is probably the most important objective of digital image analysis. It is a process of categorizing pixels in an image to one of land cover classes.

The fundamental basis of remote sensing image classification is the spectral characteristics of earth surface features. While it is relatively easy to generate a land cover map from remote sensing image, it is difficult to make it accurate (Zhang & Zhu, 2011).The most often used supervised classification method is the maximum likelihood classifier (MLC), which generates decision surfaces based on the mean and covariance of each class (Jansen and Di Gregorio 2002). These categorization approaches have been widely employed in remote sensing applications, producing reasonably decent results for a wide range of images. However, acquiring reliable land cover information in urban settings presents several complications. The great variability and complexity of the urban environment in terms of spatial and spectral characteristics is linked to a key issue in urban remote sensing processing (Chen, Gong et al. 2003).

The post classification comparison method compares two or more individually categorized photos from various dates to produce land cover change maps that show not only the amount and location of change, but also the nature of change (Civco, Hurd et al. 2002).

Furthermore, the issues associated with multi-temporal images acquired under varied climatic and environmental circumstances can be reduced using this method (Lu et al., 2004). The accuracy of change maps, however, is largely dependent on the quality of individual categorization findings (Chughtai, Abbasi et al. 2021).

2.4.1 Purpose of land use land cover

Remote sensing data can provide land cover information rather than land use information. The properties measured with remote sensing techniques related to land cover, from which land use can be inferred, particularly with ancillary data or a prior (already known) knowledge (Basudeb, 2011). According to (Basudeb, 2011) Land use application involves both baseline mapping and subsequent monitoring since timely information is required to have knowledge on the state of use of the current quantity of land and to identify the land use changes from time to time. This knowledge helps to develop strategies to balance conservation, conflicting uses, and developmental pressure. Issues driving land-use studies include the removal or disturbance of productive land, urban encroachment, and depletion of forest. In addition, a reason for developing and maintaining a land cover monitoring study is to provide a consistent view of the stock and state of our natural and built resources as they change through time.

Knowledge of land use and land cover is important for many planning and management activities concerning the surface of the earth. The survival of the human race depends on its living in harmony. Land use land cover change (LULCC) detection is very essential for a better understanding of landscape dynamics during a known period having sustainable management. Land use land cover changes are a dynamic, widespread, and accelerating process, mainly driven by natural phenomena and anthropogenic activities, which in turn drives changes that would impact the natural ecosystem. Land use and land cover change, as one of the main driving forces of global environmental change, is central to the sustainable development debate. Land use/land cover change has been reviewed from different perspectives to identify the drivers of land use/land cover change, their process, and consequences (Zahra et al, .2004).

Changes in land cover are examined by environmental monitoring researchers, conservation authorities, and departments of municipal affairs, with interests varying from tax assessment to reconnaissance vegetation mapping. Governments are also concerned with the general protection of national resources and become involved in publicly sensitive activities involving land-use conflicts (Basudeb Bhatta, 2014).

According to (Basudeb Bhatta,2014) explanation, land use applications of remote sensing include natural resource management, wildlife habitat protection, baseline mapping for geographic information system (GIS) input, urban expansion or encroachment, routing and logistics planning for seismic/exploration/resources extraction activities, damage delineation (tornadoes, flooding, volcanic, seismic, fire, and terrorist activities), legal boundaries for tax and property evaluation and target detection_ identification of landing strips, roads, clearings, bridges, and land or water interface. Purpose of urban land use/land covers change study and mapping:

- To interpret Landsat images using different Geospatial technologies.
- To learn about the different types of land cover in their GLOBE Study Site.
- To gain a spatial or landscape perspective of their local area.
- To estimate change based on past and present LULC and forecast the future LULCC in magnitude using temporal remote sensing data.
- Check the accuracy of classification knowing the environment using ground truth (GCP).

2.4.2 Factors of LU/LC change and urban expansion

There are several factors of urbanization, such as Economic development, innovation of technology, the industrial revolution, emergence of large manufacturing factors, job opportunities, availability of infrastructures, and migration. Generally, the causes of urbanization and urban expansion are groups into three major classes.

1. **Demographic factors**: Demographic effects include rural to urban migration and natural population growth in the city, the level of urbanization, and the rank of the city/town in the country‘s urban hierarchy. Natural population growth is a major element in urban growth for all countries, and migration of rural to urban contributes fast growth of urban population in many developing countries (Gugler, 1996).

2. **Economic factors**: Economic effects include the level of economic development, the difference in household incomes, exposure to globalization, the level of foreign 8 direct investment, the degree of employment, the level of financial markets, the level and effectiveness of property taxation, and the presence of high inflation and acute shortage of housing (Angel et al).

3. **Natural/environment factors**: Natural /environmental effects include those of climate, slope, mountain barriers, and the existence of drillable water aquifers. In addition, the minor causes such as Redevelopment and rebuilt up of inner cities again cause displacement of citizens (Cernea, 1995).

2.5 Urban Growth Patterns

Urban growth patterns refer to the spatial and temporal changes in the physical form and extent of urban areas over time. These patterns can vary widely, from compact, high-density cities to sprawling urban regions, and are influenced by a range of factors such as population growth, economic development, land availability, infrastructure investment, and planning policies (Marina and Mohd Noor 2014). Assessing and monitoring the spatial patterns of urban growth is one of the most important challenges for researchers, planners and decision makers in relation to achieving the principle of sustainable urban development .Rapid urban growth is a complex environmental issue because of the multiplicity of its patterns and its impacts on the ecosystem .(Aburas, Ho et al. 2018).

Rapid development in urban settlement contributes to the changes of environmental, economic and social activities. This transition of the metropolitan area, city, town or village from the past to the present condition describe the process of urban growth which gives impacts to the form and structure of settlements. Therefore, urban morphology become as an essential key for the urban development to identify and determine the resilience of the whole urban system that will create urban dynamic as well. The understanding of urban growth and interpretation of urban morphology can be a key challenge to the rapid urbanization of the settlements.(Marina and Mohd Noor 2014).

In many urban areas, the growth pattern can be characterized as either infill or expansion. Infill refers to the development of vacant or underutilized land within the existing urban fabric, often resulting in increased density and the revitalization of older neighborhoods. Expansion, on the other hand, involves the outward growth of urban areas into previously undeveloped or rural land, leading to urban sprawl and the creation of new suburbs or exurbs (Geymen and Baz 2008).The choice between infill and expansion growth patterns can have significant implications for land use efficiency, transportation systems, infrastructure provision, and environmental sustainability.

(Roy and Kasemi 2021) Compact, infill-oriented growth patterns tend to promote more efficient land use, reduce the demand for private vehicle travel, and facilitate the provision of public services and amenities within shorter distances. On the other hand, expansive growth patterns often result in increased automobile dependency, longer commuting distances, and the need for extensive infrastructure investments to support new developments on the urban fringe.

Understanding and managing urban growth patterns is essential for sustainable urban development. It requires a holistic approach that integrates land use planning, transportation planning, infrastructure investment, and environmental considerations. By promoting more compact and connected urban forms, communities can reduce energy consumption, minimize environmental impacts, and enhance the quality of life for residents (Hassan 2017).

2.5.1 Methods and Techniques for Monitoring Urban Growth Patterns

Assessing and monitoring the spatial patterns of urban growth is one of the most important challenges for researchers, planners and decision makers in relation to achieving the principle of sustainable urban development (Aburas, Ho et al. 2018).

Empirical study suggests; as urbanization continued to increase, land cover become increasingly diverse in pattern, fragmented in structure and more complex in shape leading to a number of negative consequences to biotic and abiotic resource.(Hassan 2017). Thus, periodic urban growth and its changing patterns must be monitored and characterized, and understood its resultant impact on the land, ecology, and the environment in respect to spatial and temporal context.(Mushore, Odindi et al. 2017).

Remote sensing and GIS-based approaches to tracking urban growth patterns have emerged as valuable tools. These methods allow researchers to collect and evaluate spatial data, allowing them to get insights into the dynamics of urbanization throughout time. Many studies have used remote sensing and GIS to track urban growth patterns in diverse areas.

For example, researchers have used remote sensing data, such as satellite imaging, to observe and quantify changes in land cover in metropolitan areas. Researchers can detect and assess the transformation of land cover types within a specific region by examining multi temporal satellite pictures (Yuan et al., 2005).

This method enables the identification of urban expansion trends as well as an understanding of the underlying processes that drive growth. GIS-based tools have also been useful in tracking urban expansion patterns. Researchers can examine the links between land use change and socioeconomic factors by combining remote sensing data with GIS databases. They can examine the drivers of urbanization and model the spatial patterns of urban growth by merging these data sources. (Yin, Yin et al. 2011).

Furthermore, remote sensing and geographic information systems (GIS) have been used to examine the effects of urbanization on the urban environment. For example, academics have studied the relationship between urban expansion and land surface temperature using satellite imagery and GIS analysis. They can comprehend the effects of urbanization on surface temperature and the urban heat island phenomena by evaluating the distribution of impervious surfaces and vegetation coverage (Yeh and Li 1997).

2.6 Major Driving Physical Factors of Urban Growth

Urban growth is recognized as physical and functional changes due to the transition of rural landscape to urban forms. It occurs when the population distribution changes from being village to town and city currently, half of the world population resides in urban areas (Cohen 2004). Socioeconomic processes such as migration, urban sprawl, agriculture, and forest patterns often contribute to the urban growth (Khamchiangta and Dhakal 2019). As urban growth proceeds, more land is used for the production of goods and services, and more residential land is necessary for those who migrate in the city (Lu & Sasaki, 2008). Urban growth is typically driven by a variety of forces that relate to one another based on different spatial and temporal settings.

Basically, we can consider two main categories of drivers: biophysical and socioeconomic. The biophysical drivers include characteristics and processes of the natural environment such as weather and climate variations, landforms, topography, geomorphic processes, volcanic eruptions, soil types and processes, drainage patterns, and the availability of natural resources (Dadashpoor, Azizi et al. 2019). On the other hand, the socioeconomic drivers comprise demographic, social, economic, political, and institutional factors and processes such as population and its change, industrial structure and its change, and technology and technological change (Thapa and Murayama 2010).

Urban growth patterns are shaped by several major physical driving forces. Firstly, population growth plays a pivotal role as increasing populations lead to higher demands for housing, infrastructure, and services, driving the expansion of urban areas (United Nations, 2018). Secondly, economic activities attract people to cities, as industries, businesses, and employment opportunities thrive in urban centers (Aguayo, Wiegand et al. 2007). Moreover, the presence of well-connected transportation networks, including roads, railways, and airports, facilitates urban growth by enhancing accessibility and facilitating trade and commerce (Alqurashi, Kumar et al. 2016). Additionally, the availability and accessibility of land, influenced by factors like resource distribution, topography, and land-use policies, contribute to the expansion of cities (De la Luz Hernández-Flores, Otazo-Sánchez et al. 2017). Natural resources and the environment also play a role, as the presence of favorable resources, such as water bodies or fertile land, can attract urban development (Grimm et al., 2008).

The geographic location of cities, including access to trade routes or coastal areas, can further drive urban growth (Florida, 2017). Urban planning, policies, and infrastructure development are integral factors that shape the physical growth of cities, guiding the direction, density, and sustainability of urban expansion (Abhishek, Jenamani et al. 2017).

2.7 Methods of Analyzing Driving Forces of Urban Expansion

Various research methods are applied to inspect the driving forces of urban expansion such as structural equation modeling, analytic hierarchy process, and spatial regression analysis.

2.7.1 Analytical Hierarchy Process

The Analytical hierarchy process (AHP) method has a sound mathematical foundation, which has been widely used in several socioeconomic and engineering applications (Banai Kashani,1990; Kauko,2004;Maiczewski,1999).It is one of the best known comparative ratings of the important of various factors, which are extracted from stakeholders and then analyzed to produce a set of consensus weights using a fairly common form of matrix algebra (Banai Kashani,1990).The technique is based on a pairwise comparison of elements (attributes or alternatives), and results in a comparison matrix in which the relative importance of each element or factor is determined numerically .

The technique also has a scientific basis through which the consistency of the driving factors evaluation can be judged. Kauko (2004), argued that most of the classical multi-attribute modeling approaches are based on the assumption of explainable utility functions; however, the AHP does not assume that the evaluator is able to express his or her overall elicitation of the problem as one function. Rather, the AHP is based on the assumption that the relevant dominance of one attribute over another can be measured by a pairwise comparison of preferences, systematically made on each level of a hierarchy of factors (Banai-kashani,1990; Malczewski,1999; Satty,1980). In using AHP to model a problem, one needs a hierarchical structure to represent that problem as well as pairwise comparisons to establish relations with in the structure (satty, 1980).The AHP has been used with absolute or relative types of comparisons to drive ratio scales of measurement (Malczewski,1999;Thape & Murayama,2008). In absolute comparisons, alternatives are compared with a standard that has been developed through one's experience.

In relative comparisons, alternatives are compared in pairs according to a common attribute. The relative measurement wi; i=1n, of each of n elements is a ratio scale derived by comparing the elements with each other is pairs. In paired comparisons, two elements i and j are compared with respect to common property. The i is used as the unit and the j is estimated as a multiple of that unit in the form (mi/mj)/1.where an estimate of the ratio mi/mj is taken from a fundamental scale of absolute values between 1 and 9 (Saaty, 1980). The numbers are used to represent how many times the larger of two elements dominates the smaller with respect to a common property or criterion.

Spatial Regression Analysis Spatial regression methods capture spatial dependency in regression analysis, avoiding statistical problems such as unstable parameters and unreliable significance tests, as well as providing information on spatial relationships among the variables involved. Depending on the specific technique, spatial dependency can enter the regression model as relationships between the independent variables and the dependent, between the dependent variables and a spatial lag of itself, or in the error terms. Regression analysis allows you to model, examine, and explore spatial relationships and can help explain the factors behind observed spatial patters. By modeling spatial relationships however, regression analysis can also be used for prediction. The logistic regression model is used to integrate the social, physical, political, and socio economic factors of the study area into the urban growth modeling process. This model

Demonstrates and explains the relationship of a number of Xs independent variables to a dichotomous single dependent variable Y, which represents the occurrence or non-occurrence of an event .Logistic regression empirically finds the relationship between the independent variables and the function of the probability of an event happening (Klein Baum and Klein 2010). The use of logistic regression can yield the coefficients of independent variables (both continuous and categorical); the dependent variable is a binary categorical variable with a value of either 1 or 0 and can be computed using the well-known logistic regression equation (Huang et al. 2009). This method provides the probability of the existence or nonexistence of each type of land use/cover in every location based on driving factors

Logistic regression is a powerful empirical method used when the outcome-dependent variable is dichotomous. Spatial urban expansion is the dependent variable represented in a raster binary map. A value of 1 on the produced probability map indicates the presence of urban growth, and a value of 0 indicates the absence of urban growth. The probability of urbanization for each cell in the raster map was produced based on the following Logistic regression equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ \beta_n X_n + \varepsilon$$

• Dependent variable (y): This is the variable representing the process you are trying to predict or understand. In the regression equation, it appears on the left side of the equal sign. While you can use regression to predict the dependent variable, you always start with a set of known y-values and use these to build (or to calibrate) the regression model. The known y-values are often referred to as observed values.

• Independent/Explanatory variables (X): These are the variables used to model or to predict the dependent variable values. In the regression equation, they appear on the right side of the equal sign and are often referred to as explanatory variables. The dependent variable is a function of the explanatory variables.

- Regression coefficients (β): Coefficients are computed by the regression tool. They are values, one for each explanatory variable, that represent the strength and the type of relationship the explanatory variable has to the dependent variable. When the relationship is positive, the sign for the associated coefficient is also positive. Coefficients for negative relationships have negative signs. When the relationship is a strong one, the coefficient is relatively large (relative to the units of the explanatory variable it is associated with). Weak relationships are associated with coefficients near zero; β0 is the regression intercept. It represents the expected value for the dependent variable if all the independent (explanatory) variables are zero.
- Residuals: These are the unexplained portion of the dependent variable, represented in the regression equation as the random error term ε. Known values for the dependent variable are used to build and to calibrate the regression model. Using known values for the dependent variable (y) and known values for all of the explanatory variables (the Xs),

- The regression tool constructs an equation that will predict those known y-values as well as possible. The predicted values will rarely match the observed values exactly, however. The difference between the observed y-values and the predicted y-values are called the residuals. The magnitude of the residuals from a regression equation is one measure of model fit. Large residuals indicate poor model fit. Building a regression model is an iterative process that involves finding effective independent variables to explain the dependent variable you are trying to model or understand, running the regression tool to determine which variables are effective predictors, then repeatedly removing and/or adding variables until you find the best regression model possible.
- From the methods mentioned above spatial regression analysis has its advantage over other methods in embracing a wide range of variables and identifying the relative importance of different factors (Abiodun, 2017).

Many authors claimed that logistic regression model has a strong capability to not only incorporate biophysical influence (slope, land use/cover, transport, zoning) but also demographic and social variables to better understand human forces ability in urban growth pattern (Hu and Lo.,2007)..Fundamentally, logistic regression model is simple to interpret Field (2013); moore.et al.(2009),suitable approach to evaluate critical areas for future urban development (informal settlement proliferation on urban growth; i.e. areas that will be highly urbanized and not).Dubovyket al. (2011);Duwal(2013) and as assess the impact of macro-level changes (e.g. major roads, built-up areas etc.) (Lesschen et al.2005).Therefore, in order to comprehensively analyze the driving factors of urban expansion of Adama Town, the spatial regression model is chosen in this study.

2.6 A Comprehensive Review of Urban Growth Studies: Insights and Gaps

This review synthesizes findings from several key studies examining urban growth dynamics across various contexts, focusing on the methodologies, results, and limitations of each research effort.

Demelash's thesis, titled "Multi-Temporal Morphological Analysis of Urban Area: A Case of Adama Town," investigates urban development in Adama Town during two distinct periods, 2000-2010 and 2010-2019. The study identifies factors influencing the town's morphological characteristics and various types of urban growth, utilizing image classification and change detection techniques. Geographic Information System (GIS) tools were employed to categorize urban growth types, while spatial regression analysis assessed potential determinants, revealing that proximity to roads, slope, and distance from key urban features significantly impact urban growth morphology. However, the study does not consider other critical influences such as socio-economic conditions, housing affordability, informal settlements, and the policy frameworks governing urban development.

Liao (2017) explored the driving factors behind rapid urban expansion in China from 2000 to 2010, using GlobeLand30 data. The study found that market demand, GDP growth, and land supply positively correlated with the increase in impervious surfaces. Employing a multilevel regression model, the research effectively examined drivers at both individual and contextual levels. However, it focused solely on the factors influencing land expansion without addressing the consequences of this growth, sustainability issues, or strategies to mitigate adverse effects. Furthermore, the analysis relied exclusively on socio-economic data from 2000 to 2010, raising questions about the relevance of its conclusions today.

Aguayo (2007) investigated urban growth patterns in mid-sized cities, specifically Los Angeles, Chile. Utilizing multi-scale logistic regression models, the study identified road accessibility, agricultural land status, and proximity to urban regions as key influences on urban development. Nonetheless, it lacks an exploration of the negative consequences of urbanization, such as environmental degradation and social inequality.

Another significant study examined urban expansion in Ethiopia from 1987 to 2017, analyzing three major cities' growth patterns. This research utilized remote sensing and GIS technologies, revealing significant urbanization trends. However, it did not provide a comprehensive socio-economic analysis of urban growth effects on residents or a thorough examination of environmental repercussions and their implications for economic development. Additionally, the study failed to offer specific policy recommendations for managing urban growth.

Roy (2021) focused on Raiganj, India, assessing urban growth dynamics through remote sensing and GIS methodologies. The study identified unsustainable expansion patterns leading to agricultural land degradation, yet it did not address the social, economic, or political factors influencing these dynamics or their effects on the local community.

Aziz (2019) investigated urbanization's impact on the morphology and land use patterns of Mymensingh, Bangladesh. While the study highlighted the continuity of the historic core amid urban expansion, it lacked an examination of the social and economic consequences for residents and stakeholders, missing opportunities to explore how urban growth affects different social groups.

Lastly, Taiema (2021) analyzed urban growth trends in Zagazig City, Egypt, using geomatics techniques. The findings indicated a substantial rise in built-up areas, predominantly in the western direction, but did not address the socio-economic, environmental, or cultural impacts of urbanization. The study also lacked community perspectives on urbanization and potential policy implications.

CHAPTER 3. MATERIALS AND METHODS

3.1. Description of the study area

Adama city is located about 100 km south east of Addis Ababa along the main road to Harar, enclosing between 80 26‟ 15” N to 80 37‟ 00” N latitude and 390 11‟ 57” E to “390 21‟ 15” E longitude at an average altitude of 1620m above sea level. East Showa Zone, in which Adama city is located, form a part of the mid central plateau physiographic unit. (Wikipedia) It is found on a nodal location along main national and regional transport lines from the capital Addis Ababa to other important towns. Adama City, is a thriving metropolitan center in Ethiopia's Oromia Region. Adama, located around 100 kilometers southeast of Addis Ababa, serves as an important transportation hub due to its strategic placement along major road and railway networks. A diversified and fast rising population, lively markets, and a combination of contemporary infrastructure and classic architecture characterize the city. Adama City, surrounded by scenic surroundings like as rolling hills and farmlands, offers a unique blend of urban services and natural beauty. Adama City continues to attract visitors and inhabitants alike, owing to its vibrant economy, educational institutions, and cultural attractions, which contribute to its dynamic and developing character.

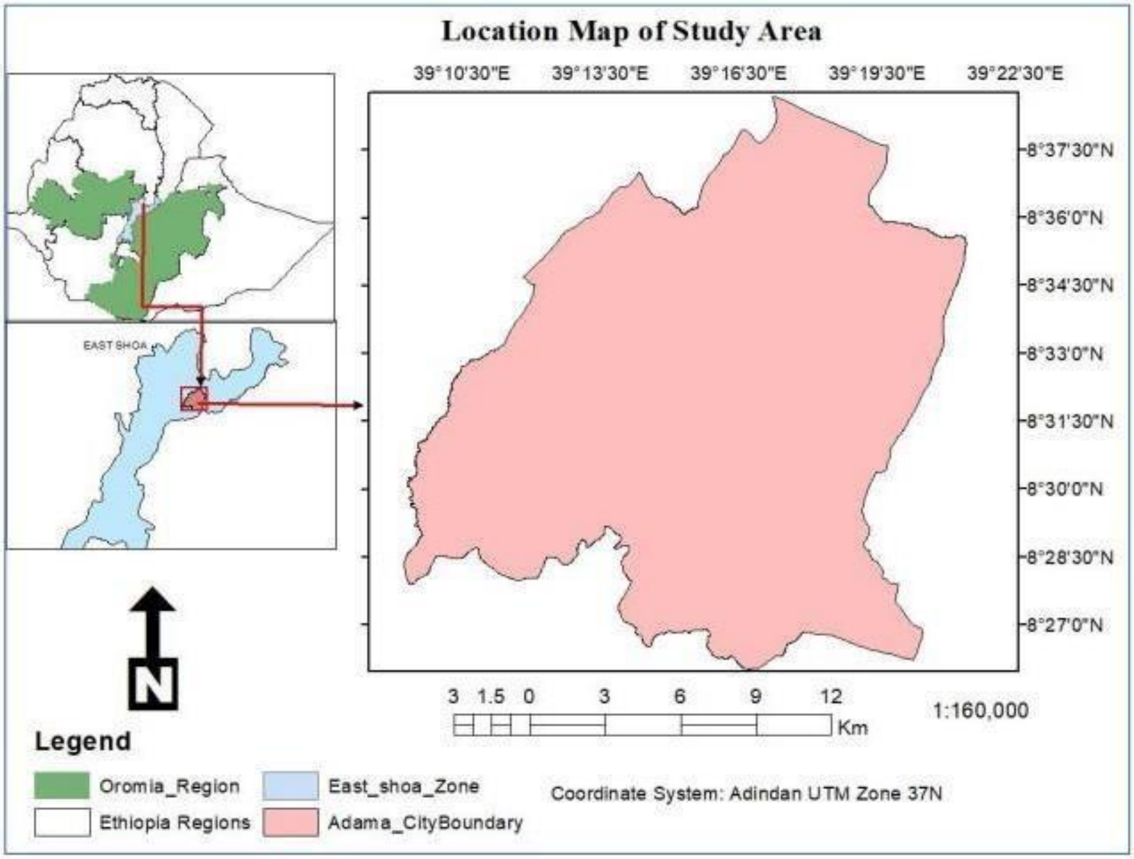

Figure 3. 1 Map of Adama city (Source: researcher, 2024)

3.2 Population

In 1964, the population of the town was estimated to be 27,812. This figure reached about 39221 in 1977. The results of the 1984 census revealed that the population of Adama reached to 77, 237, while the 1994 census counted a total population of 127,842. Based on the 2007 census conducted by the central statistical agency (CSA) it had 220,212. According to the past population a trend, the town population is expected to grow to 375775 in 2017. From 1994 to 2007 census, the growing population size is 92,370 i.e. the annual increment is 5.56% while, the annual population growth rate of Adama city in 1990 was 4.6% and reached to 104,464 and in 2000, 2010, and 2019 was 164,716, 260,203, and 429,266 respectively.

3.2.1 Urbanization History of Study Area

Adama was established as a railway station depot in 1916. Its establishment and location have been influenced by many different factors. Conducive economic, social and geographical conditions are the crucial factors for rise and development of the city. The Italian occupation which lasted from 1936-41 made a great deal of contribution to the development of Adama.

During their stay in the city, the Italians carried out a number of construction works such as road transportation, communication and likes, which accelerated the grown of the town. The expansion of transportation and communication and the development of infrastructure service and facilities such as education, health, water supply, and electric supply have contribution a lot to the development of the town. The construction and improvement of the roads from Addis Ababa via Adama to Wonji, Assela and Harar made the town a focal point of communication for travelers. It also created a favorable condition for city expansion and has greatly influenced its development pattern**.**

3.3 Data

3.3.1 Collection and Data Source

In order to achieve the desired objective, both primary and secondary data were used in the research. The primary data were gathered through field survey at different places of the study area and the secondary data were obtained from different organization and websites. The data for this study are listed in the following tables.

Table 3.1 List of data required and its source

No	Data used	Data source	Purpose	Year
1	Landsat 5 TM Landsat 7 ETM+ Lands sat 8	USGS	Land use land cover analysis	2000.2011,2023
2	Orthophoto	SSGI	For digitize input data	2022
3	Gps survey	Insitu	For accuracy assessment	2024
4	Adama structural plan	Adama Municipality	To Generate boundary map	2017
5	Census data	Adama Municipality	For comparisons of population number	2007
6	Googleearth image	Google earth	Forcomparisons techniques	2000,2011,2023
	DEM	Free ASTER	Slope	2023

Softwares used

In order to achieve the objective of the study ArcGIS, ERDAS IMAGINE and Microsoft Office software were used. ArcGIS is a software application developed by ESRI for working with maps and geographic information. It is used for creating maps and model, 27 compiling geographic data, analyzing spatial information, sharing geographic information and managing geographic information in geo database. ERDAS IMAGINE is an image processing software package that allows users to process geospatial and other imagery as well as vector data and Microsoft office is an application software package with one handle.

It includes Microsoft word, Excel, power point etc. to create professional-looking documents, charts, calculations, reports and presentations at high speed and accuracy

Table 3. 2 List of software and their purpose

No	Software	PURPOSE
1	ArcGIS 10.8	For storing, managing, and analyzing spatial information and produce maps.
2	RDAS IMAGIN 2015	Processing and analyzing satellite images
3	Microsoft Office	Documentation, calculation, chart, and presentation

Image pre-processing

Image pre-processing is the term for operations on images at the lowest level of abstraction. These operations do not increase image information content but they decrease it if entropy is an information measure. The aim of pre-processing is an improvement of the image data that suppresses undesired distortions or enhances some image features relevant for further processing and analysis task. (Kragujevac J. Math, 2009).In this research, some pre-processing techniques of image transformation includes geometric correction or image registration, atmospheric correction and radiometric calibration was used essentially. In addition, image analysis was carryout by using image analysis window such as adjusts the displayed contrast characteristics of image, adjusts the displayed brightness characteristics of image, adjusts the transparency of image, adjusts the gamma transformation applied to all four year Landsat image.

Layer stacking

Layer stacking is a technique used to combine multiple images into a single composite image. For successful stacking, it is essential that all images have the same extent, meaning they must possess identical numbers of rows and columns. This often necessitates the resampling of images or bands that have different spatial resolutions to match a target resolution. While layer stacking can enhance data analysis by consolidating relevant information, it also increases the size of the final stacked image, which can lead to longer processing times during subsequent analyses.

Therefore, if certain images or bands are deemed unnecessary for the analysis, it is advisable to avoid stacking all available images. Instead, selecting only specific images of interest can optimize both processing time and image size. In some research contexts, for example, only bands 1, 2, and 3 may be chosen for layer stacking to streamline the analysis process while retaining essential data. This approach underscores the importance of aligning the choice of images with the objectives of the study.

Image Enhancement

Image enhancement can be defined as the conversion of the image quality to a better and more understandable level for feature extraction or image interpretation (Basudeb B., 2011).Although radiometric corrections (pre-processing) for illumination, atmospheric influences, and sensor characteristics were done for the suitability of visual interpretation Low sensitivity of the detectors, weak signal of the objects present on the earth surface, similar reflectance of different objects and environmental conditions at the time of recording are the major causes of low contrast of the image. Another problem that complicates photographic display of digital image is that the human eye is poor at discriminating the slight radiometric or spectral differences that may characterize the features. The main aim of digital enhancement is to amplify these slight differences for better clarity of the image scene. This means digital enhancement increases the contrast between the interested classes or features. The digital image enhancement may be defined as some mathematical operations that are to be applied to digital remote sensing input data to improve the visual appearance of an image for better interpretability or subsequent digital analysis (Lillesand and Keifer, 1979).

It also valuable to detect and define LULC information classes since different multi temporal images have different spectral characteristics. A proper image enhancement includes multispectral transformation, false color composites and vegetation indices, which is important to achieve information of the area and spectral knowledge. Image enhancement is a method widely used to provide effective display for image interpretation (Cetin, 2009). Therefore, in this study, multispectral images were enhancement using ERDAS software and by IDRISI SELVA image analysis window.

Sub-setting of Study area Images

The first step in image pre-processing is image extraction. Some irrelevant parts of the image can be removed and the image region of interest is focused. Taking out the project area from the whole part of the image is important to reduce the size of the image file to include only the area of interest (AOI). This is not only eliminates the extraneous data in the image. But it speeds up processing due to smaller amount of data to process. This is important when utilizing multi band data Such as Landsat TM imagery. This reduction of data is known as Sub setting. In this stage ERDAS IMAGINE and Arc GIS Software was important. In this process each Landsat scene were clipped through by the project area (Modjo shape file). It has to be done after layer stacking or composite image.

Data analysis techniques

The analysis was conducted in two steps, produced the map of urban built-up areas based on the satellite images and using other ancillary data. By delineating with the town boundaries, the spatial patterns of urban growth trend were analyzed.

Image Classification

Image classification is the process of sorting pixels into finite number of individual classes or categories of data, based on their DN (pixel) values. Classification of remotely sensed data is used to assign corresponding levels with respect to groups with homogeneous characteristics with the aim of discriminating multiple objects from each other within the image. The level is called class (Basudeb Bhatta, 2011).Classification is the most popularly used information extraction technique in digital remote sensing.

Accuracy assessment

If the classification data are to be useful in detection of change analysis, it is essential to perform accuracy assessment for individual classification (Cagalton and Green, 2009).Accuracy assessment is an essential and crucial part of studying image classification and thus LULCC detection is used to understand and estimate the changes accurately. It reveals the extent of correspondence between what is on the ground and the classification results.

It is important to be able to derive accuracy for individual classification if the resulting data are to be useful in change detection analysis (Cagalton and Green, 2009).An overall accuracy was calculated by dividing the sum of the correctly classified sample units by the total number of sample units. Accuracy Assessment is a kind of process to compare the classification with ground truth or other data. It allows evaluating a classified image file (Eastman, J. R., 2009). Usually this data is known as ground-truth data that has been collected in the field. It is not typical to ground truth each and every pixel of the classified image. Therefore some reference pixels are generated. Reference pixels are points on the classified image. Each point of reference pixels represents specific geographic coordinate of the image. These reference pixels are randomly selected (Congalton, R., 1991) The randomly selected points within the classified image list two sets of class. The first set of class values represents the actual land cover type. The second set of class values are known as reference values.

Various mathematical theories develop to determine adequate sample sizes for Classification of Accuracy Assessment but no standardized consent reach yet regarding the adequate sample size determination. For this research Congal-ton and Green (2009) was used. For the accuracy assessment overall kappa which is a statistical measure of overall agreement between two categorical items (Cohen‘s kappa,) and conditional kappa which includes, user‘s accuracy, producer‘s accuracy and overall accuracy were calculated. An error matrix is a square assortment of numbers defined in rows and columns that represent the number of sample units assigned to a particular category relative to the actual category as confirmed on the ground. The rows in the matrix represent the remote sensing derived land use map, while the columns represent the reference data that will be collect from fieldwork. The error matrix tables produce many statistical measures of thematic accuracy including overall classification accuracy, percentage of omission and commission error and kappa coefficient-an index that estimates in the influence of chance (Congalton and Green, 1999).

Overall accuracy

Overall Accuracy is essentially tells us out of all of the reference sites what proportion were mapped correctly. The overall accuracy is usually expressed as a percent, with 100% accuracy being a perfect classification where all reference site were classified correctly. Overall accuracy is the easiest to calculate and understand but ultimately only provides the map user and producer with basic accuracy information. The diagonal elements represent the areas that were correctly classified.

To calculate the overall accuracy you add the number of correctly classified sites and divide it by the total number of reference site.

Omission Error

Errors of omission refer to reference sites that were left out (or omitted) from the correct class in the classified map. The real land cover type was left out or omitted from the classified map. Error of omission is sometimes also referred to as a Type I error. An error of omission in one category will be counted as an error in commission in another category. Omission errors are calculated by reviewing the reference sites for incorrect classifications in columns for each class and adding together the incorrect classifications and dividing them by the total number of reference sites for each class. A separate omission error is generally calculated for each class. This will allow us to evaluate the classification accuracy for each class.

Commission Error

Commission errors are calculated by reviewing the classified sites for incorrect classifications by going across the rows for each class and adding together the incorrect classifications and dividing them by the total number of classified sites for each class.

Producer Accuracy

Producer's Accuracy is the map accuracy from the point of view of the map maker (the producer).This is how often are real features on the ground correctly shown on the classified map or the probability that a certain land cover of an area on the ground is classified as such. The Producer's Accuracy is complement of the Omission Error, Producer's Accuracy = 100%-Omission Error

Kappa coefficient

The Kappa Coefficient is generated from a statistical test to evaluate the accuracy of a classification. Kappa essentially evaluates how well the classification performed as compared to just randomly assigning values, i.e. did the classification do better than random. The Kappa Coefficient can range from -1 to 1. A value of 0 indicated that the classification is no better than a random classification. A negative number indicates the classification is significantly worse than random. A value close to 1 indicates that the classification is significantly better than random. (Jennes etal (2007). Kappa is a statistical measure of overall agreement between two maps (e.g. output of **c**lassified/simulated map and ground truth/reference map) or a matrix (Canada Centre for Remote Sensing, 2010).

3.4 work flow of the study

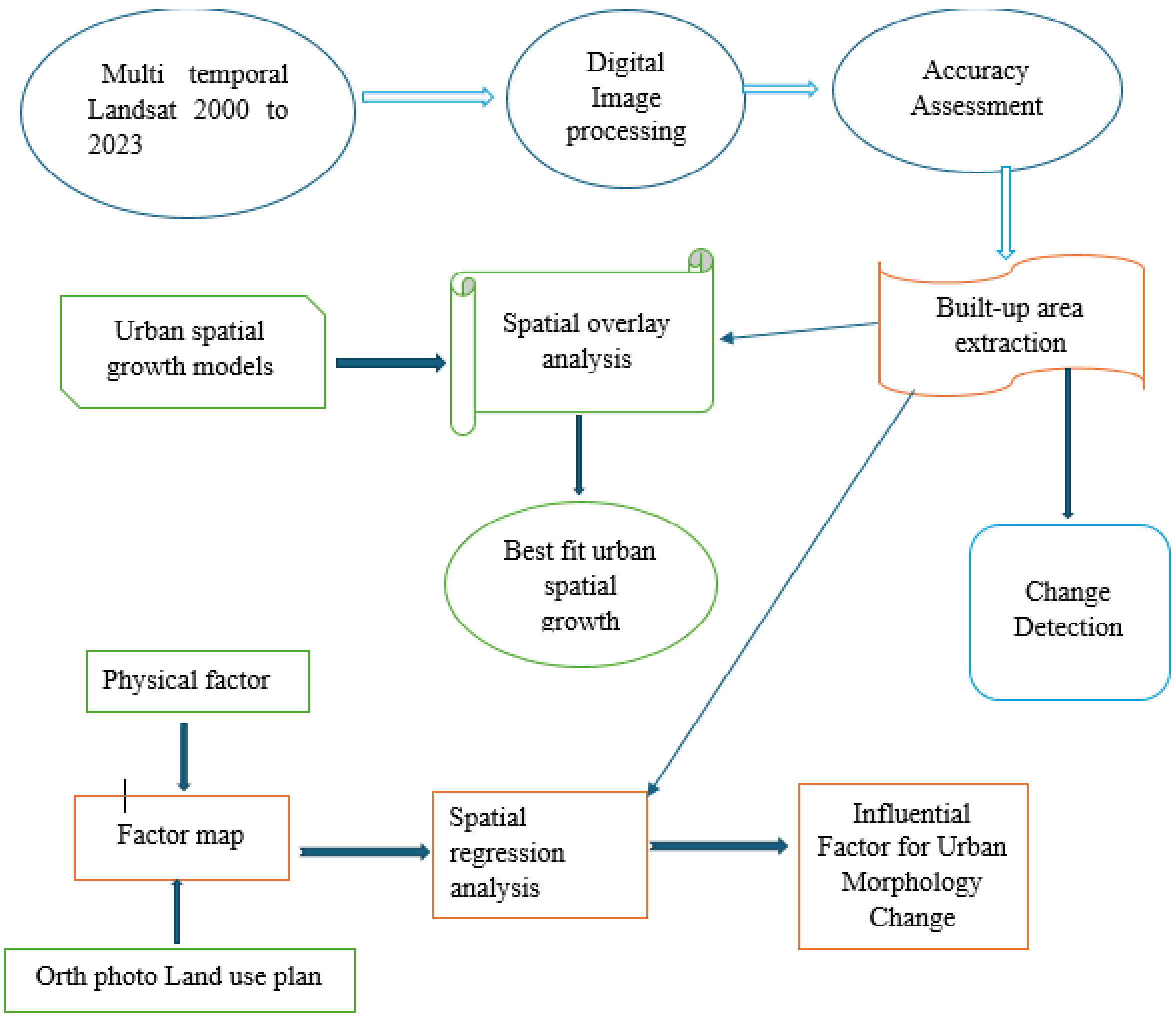

Fig 3.2 work flow

CHAPTER 4. DATAANALYSIS, RESULTS, AND DISCUSSION

4.1 Introduction

This chapter analyzes data and discusses study findings. The finding is relevant to the research topics that motivated the study. Adama city's growth pattern is analyzed using a spatial regression model, beginning with built-up land expansion and progressing to identify key elements influencing urban growth. The majority of the results are supported by maps, tables, and illustrated graphs.

4.2 Image Classification and Accuracy Assessment

This study used remote sensing pictures with a spatial resolution of 30m from the United States Geological Survey (USGS) website to determine land use. Three cloud-free land satellite pictures of Adama city were captured in May 2000 (TM), April 2011 (ETM+), and May 2023 (OLI). The photos are classified using the maximum likelihood approach in supervised classification. The resulting land cover map includes five primary land cover types. They are then categorized into binary files including built-up and non-built-up areas.

The ground reference data was prepared using a random stratified sampling procedure. According to Shalaby and Tateishi (2007), the sample size for each land use is determined by its spatial extent. Accuracy of land use maps is critical in urban studies. In thematic mapping from remote sensing data, classification accuracy refers to how well the final image classification adheres to the truth or agrees with reality. (Foody, G. M. 2002).This is normally accomplished by utilizing data gathered from the map and reference sources. Reference samples are data derived from reliable sources, while map samples are data derived from the assessed map.

A reference sample data for assessing the accuracy of maps created from moderate resolution satellite imagery (e.g., Landsat) can be collected from a variety of sources including previously existing maps, aerial photography, and Google Earth (Fonji SF, Taff GN 2014).

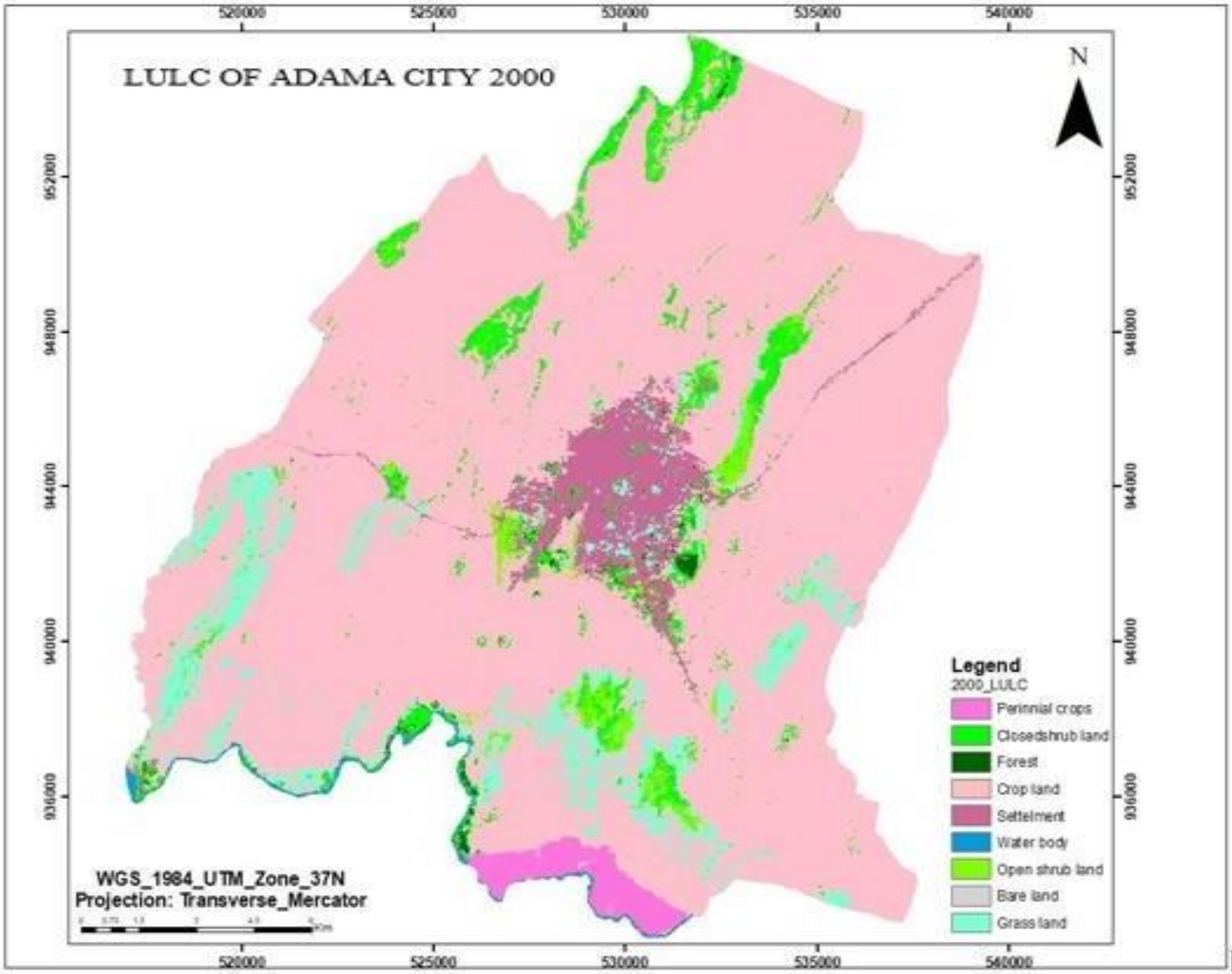

Figure 4.1 Land use/ land cover map of the study area in 2000 (Source: researcher, 2024)

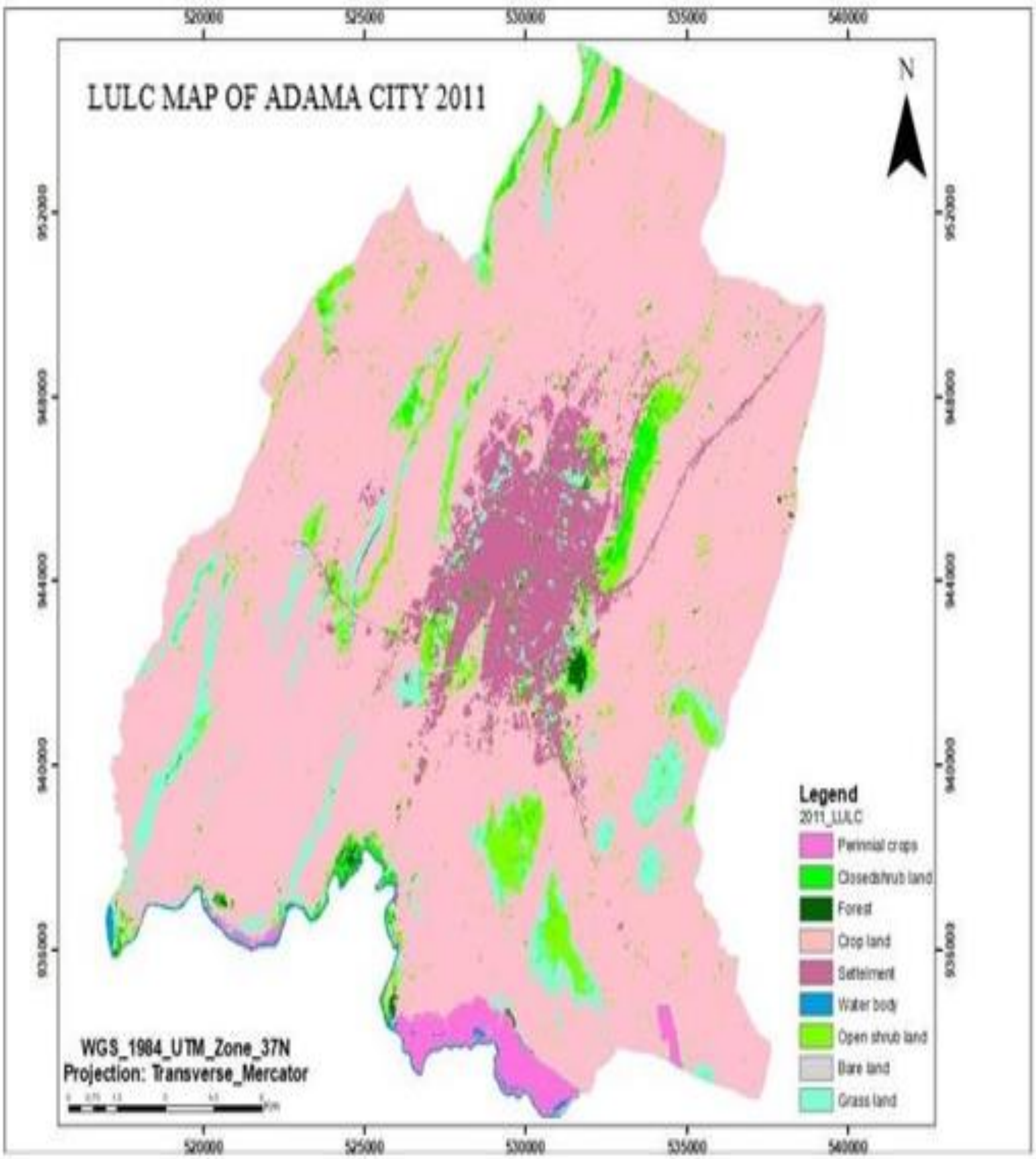

Figure 4.2 Land use/ land cover map of the study area in 2011 (Source: researcher, 2024)

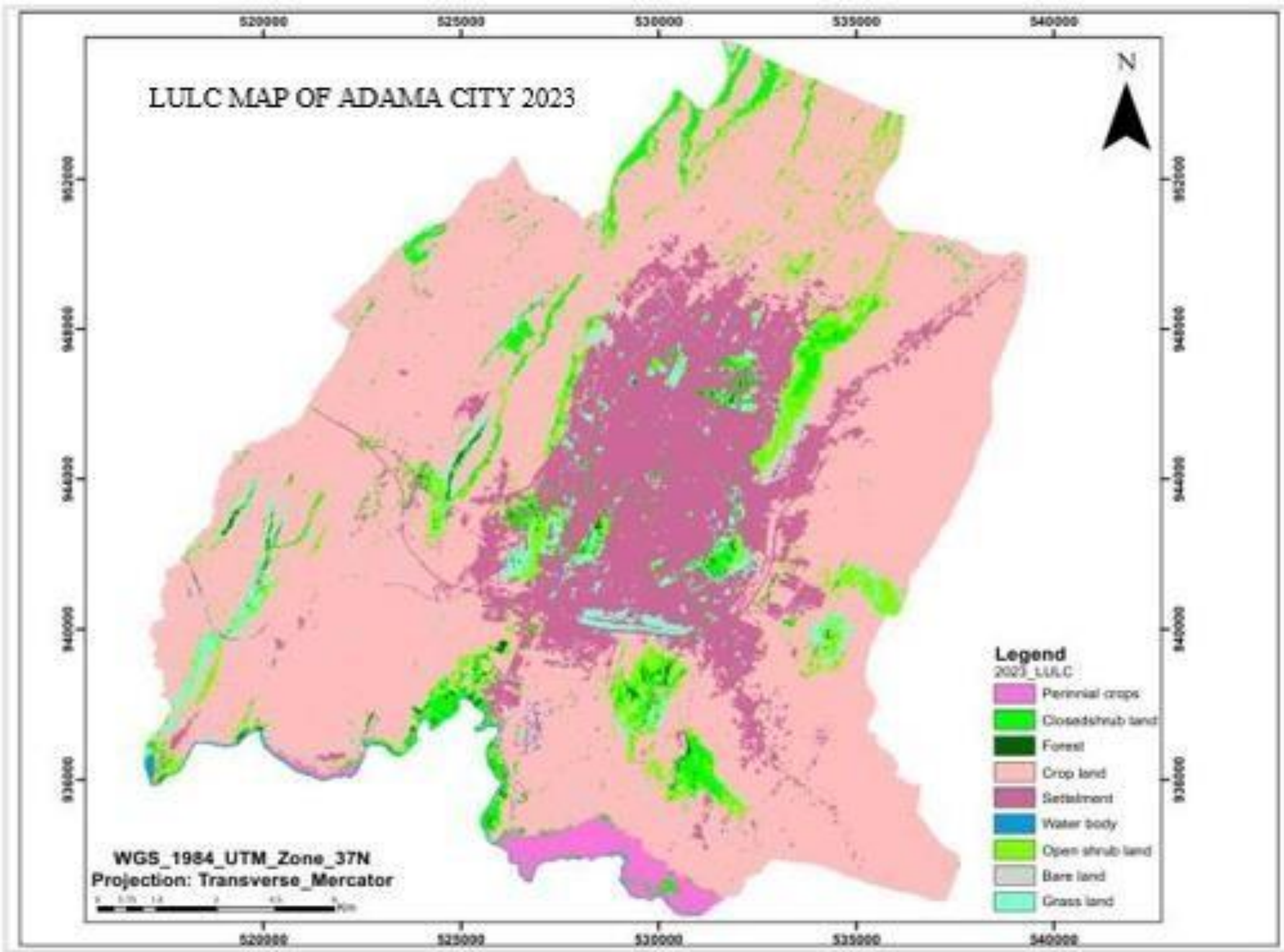

Figure 4.3 Land use/ land cover map of the study area in 2023 (Source: researcher, 2024)

The study tested LULC classification accuracy quantitatively using the error matrix, a commonly used method (Weng Q., 2010). In this regard, sample pixels were collected from each classed image using Erdas Imagine software's stratified random sampling method. According to Shalaby and Tateishi (2007), this sampling strategy allocates sample sizes depending on land use's spatial scope. The samples were overlay with Google Earth and Digital Orthophoto to visually understand and identify their distinct classes.

Based on the error matrix generated for each year classified map over all classification accuracy and overall Kappa statistics were calculated and summarized in table 4.1. The accuracy requirements for change detection analysis were determined based on the suggestion of Congalton and Green (Congalton RG, Green K., 2009). In this study, the value of the kappa statistics greater than 0.75, indicates strong agreement between the class label on the map and on the reference data.

Table 4. 1 Results of accuracy assessment for each year.

Year	Over all classification accuracy (%)	Over all kappa statistics
2000	89.2	0.75
2011	92.4	0.88
2023	88.6	0.86

4.3 Built-up Land Expansion

The reclassification of classified images into built-up and non-built-up area represented by 1 and 0 respectively for the three different time periods of 2000, 2011, and 2023 summarized in table 4.2. The purpose of the classification was to look at built-up area only where by land cover maps built-up pixels in each time periods were quantified and built-up area of each year and percentage of built- up area increased were derived. Thus, it is possible to interpret the growth directions by visualizing the built-up expansion map.

Table 4. 2 Percentage of built-up area increased from 2000-2023

year	Class name	Value	Count	Area in m^2	Area in hectare	% of built up Increased
2000	Non-Built-up	0	329967	296970300	29697.03	
	Built-up	1	17790	16011000	1601.1	
2011	Non-Built-up	0	303001	272700900	27270.09	151.6
	Built-up	1	44756	40280400	4028.04	
2023	Non-Built-up	0	292276	263048400	26304.84	23.96
	Built-up	1	55481	49932900	4993.29	

4.3.1 Built-up Expansion from 2000 to 2023

Figure 4.4 shows that the amount of built-up expansion in Between 2000 and 2023, Adama city experienced significant built-up expansion, with a shift from the city's central to peripheral areas. It was also clear that the urban / built-up areas occurred in the direction of northern and southern areas of town. Urban expansion has not been consistent in all directions, but has proceeded at a greater rate in certain areas in specific directions. Furthermore, some new built-up regions arose in the North-West direction. Furthermore, an examination of overall real urban growth in the first temporal period shows that new built-up land 2427 hectare indicating 243 hectare average annual increase of built-up land.

The development of road indicates that 53 km in 2000 is increased to 116 km in 2023. This development is mainly in northern part where most of built-up expansion occurs. This might be attracted the land development to the area. Besides this, the developments of the road in southern part also encourage built-up expansion and the factors of developments in the area. In addition to this, introduction of office Oromia Broadcast Network (OBN) and Adama Science and Technology University are the potential factors contribute to the development in the area. Moreover, other developments especially the built-up expansion in the North western direction is identified due to proximity to the central city business district (CBD).

Adama city's built-up growth from 2011 to 2023. There has been a clear trend of urban sprawl along major transportation routes, particularly in the eastern and western regions. According to Sudhira et al. (2004), sprawl typically occurs along highways in a linear fashion. Furthermore, large leapfrogging developments away from the dense node were detected in the northwest, south-west, and south-east directions. In contrast to major urban center development, these are smaller and more dispersed built-up regions. During the study period, new built-up land amounted to 965 hectares, with an average yearly increase of 107 hectares. Furthermore, Adama Industrial Park's inception may be a contributing element.

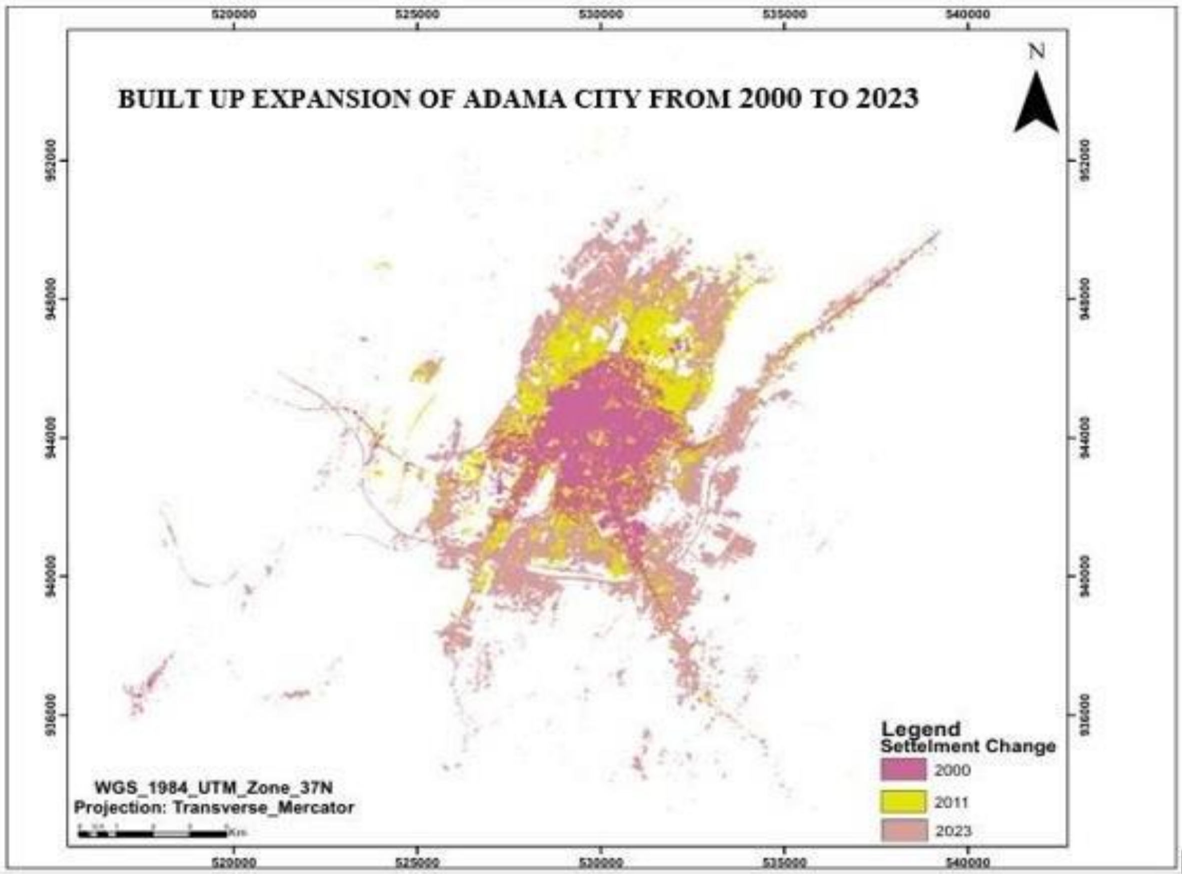

Figure 4.4 Built up expansion from 2000 to 2023 (Source: researcher, 2024)

4.4 Results of Spatial Regression Analysis

4.4.1 Variables used in the Analysis

In this study, the primary goal of spatial regression analysis is to identify the principal driving forces of urban/built-up expansion in the study area and to statistically quantify the interaction between urban growth and its drivers. In the study, the built-up expansion map is treated as a dependent variable, with maps of selected candidate factor maps acting as independent variables. Each cell in the dependent variables is divided into two categories: built-up cells (represented by 1) and non-built-up cells (represented by 0). The numbers of independent variables used for the spatial regression analysis are Road network, CBD, Slope, Institution, and Industry area. Area coverage of built-up land or cell is different for different temporal period.

4.4.2 Spatial Regression Analysis from 2000 to 2011

Spatial regression analysis can assist explain observed geographical patterns by modeling and examining their relationships. Table 4.3 shows that the coefficients for each explanatory variable in a spatial regression analysis report in a GIS context reflect the strength and type of association. The explanatory variables must be dependent variables. The coefficient's negative sign indicates a negative link, whereas a positive sign indicates a positive relationship.

Table 4.3 spatial regression analysis 2000 to 2011

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Summary of OLS Results

Variable	Coefficient[a]	StdError	t-Statistic	Probability[b]	Robust_SE	Robust_t	Robust_Pr[b]	VIF [c]
Intercept	0.622647	0.001874	315.761624	0.000003*	0.004431	301.440022	0.000002*	--------
FID_Road	-0.000219	0.000028	-84.080911	0.000000*	0.000001	-197.217444	0.000000*	2.512600
FID_CBD	-0.000194	0.000022	-76.127656	0.000005*	0.000004	-52.201726	0.000005*	2.105519
FID_slope	0.000201	0.000018	82.156244	0.000002*	0.000001	81.152031	0.000001*	2.001990
FID_inst.	-0.000172	0.000009	-119.565099	0.000008*	0.000002	-115.271722	0.000006*	2.413653
FID_indu.	_0.000094	0.000005	-62.121876	0.000011*	0.000003	-59.141219	0.000009*	1.947611

OLS Diagnostics

Input Feature:	00-10	Dependent Variable:	00-10GRID_CODE
Number of Observations:	900	Akaike's Information Criterion (AICc) [d]:	407.210177
Multiple R-Squared [d]:	0.431921	Adjusted R-Squared [d]:	0.421276
Joint F-Statistic [e]:	142.721927	Prob(>F), (5,870)degrees of freedom:	0.000001*
Joint Wald Statistic [e]:	301.921319	Prob(>chi-squared), (5) degrees of freedom:	0.000001*
Koenker (BP) Statistic [f]:	472.718892	Prob(>chi-squared), (5) degrees of freedom:	0.000001*
Jarque-Bera Statistic [g]:	248.110960	Prob(>chi-squared), (4) degrees of freedom:	0.000005*

All selected variables, except for slope, show a negative correlation with built-up expansion. For example, as the distance from roads increases, the likelihood of land being converted to built-up areas decreases. In contrast, slope is positively correlated with built-up expansion. The Variance Inflation Factor (VIF) for all variables is below 7.5, which, according to ArcGIS Pro documentation, indicates there are no redundant variables contributing to potential over-counting bias. Two columns provide insights into statistical significance: probability and robust probability measure. An asterisk (*) next to the probability indicates that the coefficient is significant. If a variable is not significant, it should be removed from the analysis, as it does not contribute meaningfully. When the Koenker (BP) statistic shows statistical significance, we should rely solely on the robust probability column to assess the significance of coefficients.

Smaller probabilities are considered more significant than larger ones. The adjusted R-squared value, which ranges from 0.0 to 1.0, indicates how much of the variation in the dependent variable is explained by the model. According to the results presented, the adjusted R-squared value is 0.421276.Therefore, the regression equation using the coefficient of five variables can be summarized as, Built-up exp. = 0.622647 - 0.000219 (Road) - 0.000194 (CBD) + 0.000201 (Slope) -0.000172 (Institution) – 0.000094 (Industry area).

4.4.3 Spatial Regression Analysis from 2011-2023

The analysis found a negative correlation between all variables except slope and built-up expansion. This suggests that urban growth is more likely to occur in close proximity to these variables, rather than further away. The research found that the variance inflection factor (VIF) for all variables was less than 7.5.This indicates that the explanatory variables are not redundant, and the coefficients remain stable. This means that urban growth is more likely to occur in close proximity to these variables rather than further away. The research found that all variables have a variance inflection factor (VIF) of less than 7.5, indicating no redundancy I explanatory and stable coefficients variables.

Table 4.4 spatial regression analysis of 2011 to 2023

10:32 AM 8/5/2024

Summary of OLS Results

Variable	Coefficient[a]	StdError	t-Statistic	Probability[b]	Robust_SE	Robust_t	Robust_Pr[b]	VIF [c]
Intercept	0.475178	0.001876	222.781611	0.000001*	0.003711	210.114402	0.000000*	--------
FID_Road	-0.000277	0.000012	-71.701219	0.000005*	0.000002	-69.167809	0.000004*	2.110477
FID_CBD	-0.000168	0.000016	-81.107412	0.000011*	0.000009	-77.122987	0.000009*	1.947400
FID_Slope	0.000212	0.000010	84.116942	0.000004*	0.000003	80.191707	0.000001*	2.002798
FID_inst.	-0.000184	0.000017	-108.172144	0.000010*	0.000001	-101.907819	0.000007*	2.461763
FID_indu.	-0.000117	0.000009	-47.121702	0.000102*	0.000090	-44.121821	0.000092*	1.627112

OLS Diagnostics

Input Feature:	10-19	Dependent Variable:	10-19GRID_CODE
Number of Observations:	750	Akaike's Information Criterion (AICc) [d]:	522.111807
Multiple R-Squared [d]:	0.371840	Adjusted R-Squared [d]:	0.351219
Joint F-Statistic [e]:	132.149907	Prob(>F), (5,710)degrees of freedom:	0.000001*
Joint Wald Statistic [e]:	352.144917	Prob(>chi-squared), (5) degrees of freedom:	0.000002*
Koenker (BP) Statistic [f]:	241.184214	Prob(>chi-squared), (5) degrees of freedom:	0.000000*
Jarque-Bera Statistic [g]:	127.121107	Prob(>chi-squared), (4) degrees of freedom:	0.000001*

In addition, probability and robust-probability indicates the coefficient statistical significance. The result shows that probability and robust- probability is very small which is the coefficient is statistical significance and an asterisk (*) next to the probability witnessed to the coefficient is significance. Based on ArcGIS Help Documentation the adjusted R-squared values are measures of model performance and possible values of range from 0.0 to 1.0. The result value indicates that 0.351219 which is between 0.0 and 1.0. Therefore, the regression equation using the coefficient of five variables can be summarized as,

Built-up exp. = 0.475178 - 0.000277 (Road) - 0.000168 (CBD) + 0.000212 (Slope) – 0.000184 (Institution) – 0.000117 (Industry area)

4.5 Three Types of Urban Growth

Each type of urban growth leads to different planning and environmental consequences. Thus, identifying the types of growth over time is essential for monitoring and alleviating the consequences of the urbanization process (Luck and Wu, 2002). In this context, three types of growth are measured for each density class. The first type of growth is infill.in this type of growth, the non-urban cells which are completely surrounded by urban cells, are converted to cells corresponding to one of the density classes. Infill growth usually occupies vacant land, where public facilities such as sewer, water and roads already exist (Hoffhine Wilson et al., 2003). The second type of growth is edge-expansion. Where non-urban cells, which adjoin existing urban cells, are converted to one of the density classes. This type represents an expansion of the existing urban patch and has been called urban fringe growth (Wasserman, 2000; Hoffhine Wilson et al., 2003). The final type of urban growth is outlaying in which non-urban cells are being converted to one of the density classes beyond existing growth areas.

Using Analysis tools in ArcGIS, if the newly developed urban patch was within the boundaries of existing urban patch, the patch was categorized as infill growth. If the newly developed urban patch touches the boundary of existing urban patches, the patch was categorized as edge expansion. All other newly urban patches were then classified as outlaying growth.

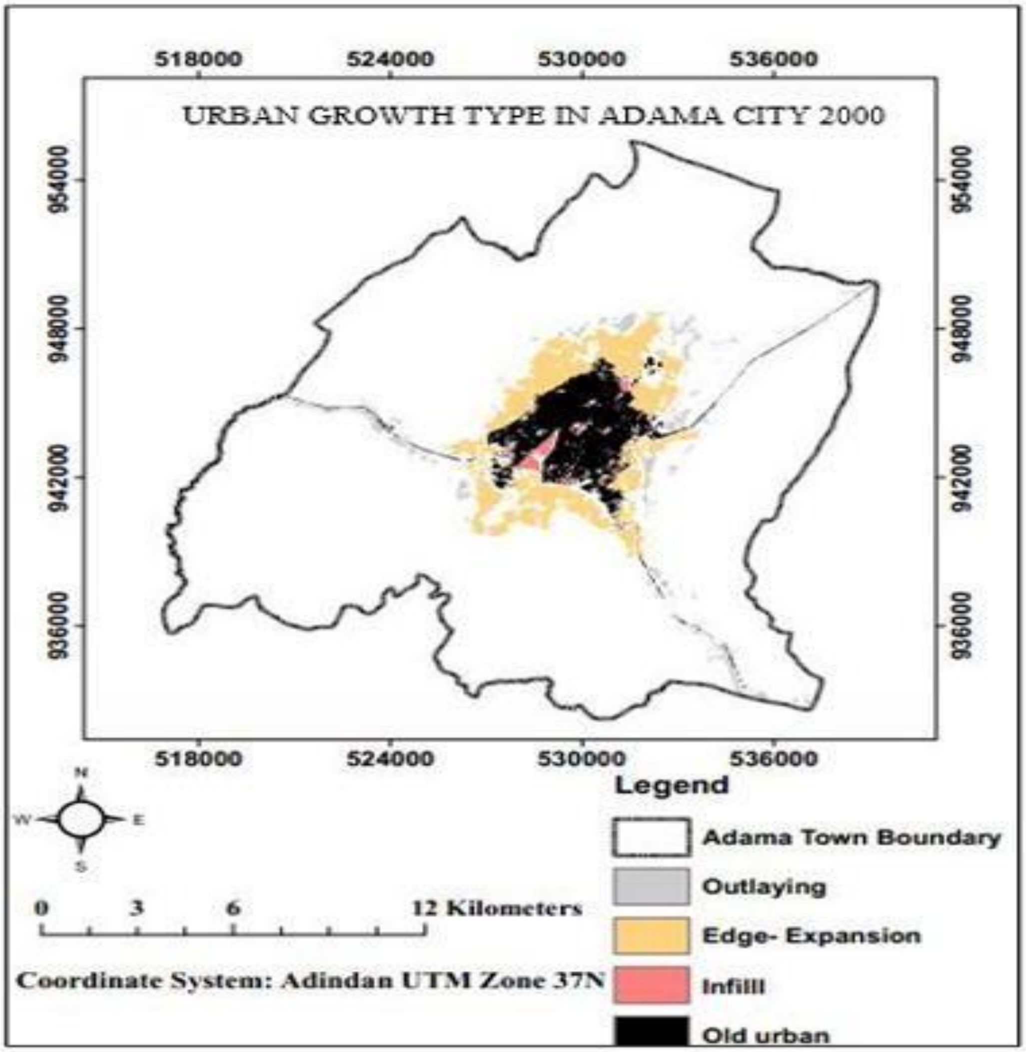

Figure 4.5 Urban growth type in in Adama city 2000

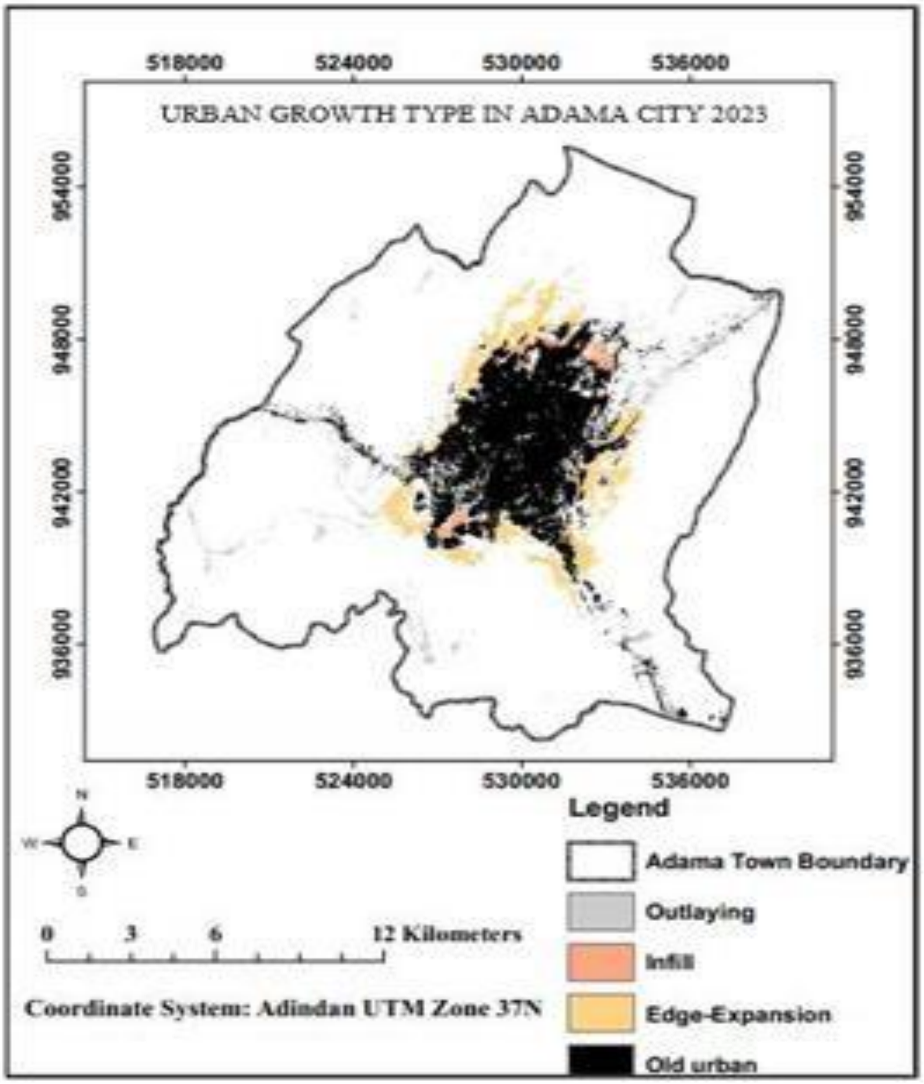

Figure 4.6 Urban growth type in adama city 2023

Although the dominant form was consistently represented edge-expansion growth followed by outlaying and then infilling growth. As in Figure 4.5 distinct urban growth patterns can be shown edge-expansion growth type is dominant in the two different temporal periods. To understand a clear detail of the temporal characteristics of urban growth in the study area, the area of the three urban growth types was calculated for the two temporal periods in figure 4.6 shows the dominancy of edge-expansion urban growth in the two temporal periods as said earlier.

In the first temporal period (2000-2011) the edge-expansion covers79.1 % of the newly built-up area and it covers 49.5% area in 2011-2023. It decreased in the second temporal period. As far as the other types of urban growth are concerned, outlaying growth was low in 2000-2011 then it increased in 2011-2023. The outlaying growth type was mostly developed in the North, South, Northwestern, and Southwestern part of the town. A very little portion of the urban area has accounted for infilling type of growth in the first temporal period (2000-2011) which is 5% and it increased in 2011-2023 to 25.5 %. The increasing trend of edge-expansion urban growth generally reflects the present kind of formation of sprawl whereas infilling growth refers to the agglomerated urban growth. But the high tendency of edge-expansion urban growth in the study area generally portrays the picture of growth of sprawl.

4.6 Implications of urban growth

Urban growth has profound and multifaceted implications that resonate across social, economic, and environmental domains, necessitating a nuanced understanding of its dynamics. Economically, urbanization acts as a powerful engine for job creation and investment, often fostering innovation and entrepreneurship in concentrated areas. However, this rapid growth is frequently accompanied by increased population density, which can exacerbate social challenges such as overcrowding, inadequate housing, and heightened demand for public services. This surge in population places significant pressure on existing infrastructure, requiring substantial investments in transportation systems, utilities, and public amenities, including education and healthcare facilities, to maintain quality of life. Environmentally, the consequences of urban growth are equally critical. The expansion of urban areas often leads to the depletion of natural resources, increased greenhouse gas emissions, and heightened pollution levels, which can adversely affect both public health and local ecosystems.

4.6.1 Sampling Technique

In conducting research on the socioeconomic effects of urban growth, it is crucial to obtain a representative sample of the population. This ensures that the findings can be generalized to the larger population. For a population greater than 10,000, we can use the formula for calculating the sample size with a finite population correction:

$$n_f = \frac{n}{1 + \frac{n-1}{N}}$$

Where:= adjusted sample size

n = initial sample size (calculated based on desired confidence level and margin of error)

N = population size

Determine Parameters

Population Size (N): Assume the total population of the urban area is 50,000.

Confidence Level: Commonly set at 95% (Z-score = 1.96).

Margin of Error (E): Set at 5% (0.05).

Standard Deviation (p): For proportions, we often use p = 0.5 for maximum variability.

Calculate Initial Sample Size (n) Using the formula for sample size:

$$n = \left(\frac{Z^2 \cdot p(1-p)}{E^2} \right)$$

Substituting the values: Z=1.96 E=0.05 p=0.5

$$n = \frac{(1.96)^2 \cdot 0.5 \cdot (1-0.5)}{(0.05)^2}$$

$$n = \frac{3.8416 * 0.5 * 0.5}{0.0025} = \frac{0.9604}{0.0025} = 384.16$$ Thus, the initial sample size (n) is approximately 385

.

Adjust Sample Size with Finite Population Correction

Now, use the finite population correction formula to find the adjusted sample size:

$$n_f = \frac{n}{1 + \frac{n-1}{N}}$$

Substitute the values

n=385

N =50000

$$nf = \frac{385}{1+0.00768} = \frac{385}{1.00768} = 381$$

Data Collection

With a sample size of 385 and a response rate of 90%, the survey yielded 347 respondents in Adama City, reflecting a balanced gender distribution of approximately 50% male (174 respondents) and 50% female (173 respondents). Data was collected through a structured questionnaire distributed to the sample population, which covered various aspects of the socioeconomic effects of urban growth.

The participants were categorized across different districts, with 30% from Bole District (approximately 104 respondents), chosen for its diverse population and commercial activities; 25% from Posta District (approximately 87 respondents), recognized for its vibrant community and accessibility; 20% from Kebele 01 District (approximately 69 respondents), which faces significant socio-economic challenges; and 25% from Collage District (approximately 87 respondents), important for understanding perspectives in a rapidly developing urban area. This selection allows for a comprehensive understanding of the varying socio-economic conditions that influence residents' perceptions of safety and access to services. The questionnaire addressed economic impacts such as employment and income changes; social impacts related to community cohesion and access to services; and environmental impacts, covering issues like pollution and green spaces. This demographic diversity is crucial for gathering insights that can inform local governance, urban planning, and community engagement initiatives, ultimately contributing to policies aimed at improving living conditions and public services in Adama City.

Data Analysis

The survey conducted in Adama City reveals a nuanced understanding of the implications of urban growth, as articulated by residents. This analysis delves into the multifaceted impacts of urbanization, focusing on environmental, socio-economic, employment, and climate-related dimensions, while also considering community dynamics and governance challenges.

Environmental Implications

The environmental consequences of urban growth emerged as a significant concern among respondents. Approximately 65% (about 226 respondents) expressed apprehension regarding increasing pollution levels, particularly air and water quality degradation. Many residents reported that rising vehicle emissions and industrial activities contribute to poor air quality, which they associate with health issues such as respiratory diseases and allergies. Additionally, 70% (about 243 respondents) noted the detrimental effects of urban sprawl on local ecosystems, including habitat loss for wildlife and reduced biodiversity. The decline of green spaces was highlighted by 75% (about 260 respondents), who emphasized the importance of parks and recreational areas for community well-being and mental health. They indicated that the encroachment of urban infrastructure is diminishing these vital spaces.

Furthermore, around 60% (about 208 respondents) raised concerns about inadequate waste management practices, citing overflowing landfills and increased littering as pressing issues.

These respondents called for improved waste collection services and public education campaigns on recycling and waste reduction.

Socio-economic Implications

Urban growth has profoundly reshaped the socio-economic landscape of Adama City. While 80% (about 278 respondents) acknowledged that urbanization has led to increased access to education, healthcare, and essential services, 65% (about 226 respondents) pointed out rising living costs as a significant challenge. The demand for housing has surged, driving up rental prices and making it difficult for low-income families to find affordable accommodations.

Despite these challenges, urban growth has fostered economic opportunities. About 70% (approximately 243 respondents) noted the emergence of new businesses and services, contributing to local economic development. However, 55% (about 191 respondents) expressed concerns about the widening gap between affluent and low-income communities, suggesting that urban policies need to address social equity to ensure that all residents benefit from urban growth. Community cohesion has been affected, with 60% (about 208 respondents) feeling that the influx of new populations has strained social ties. Long-standing community members expressed concerns about losing cultural identity amid the rapid changes, highlighting the necessity for initiatives that foster social integration and preserve local traditions.

Work Opportunities

Urbanization in Adama City has transformed the employment landscape, leading to both opportunities and challenges. Approximately 75% (about 260 respondents) indicated that the expansion of the city has created jobs, particularly in sectors such as retail, construction, and services. Many reported improved access to job opportunities, which has positively impacted their income levels.

However, 40% (about 139 respondents) noted that the job market has become more competitive, with significant numbers of residents, particularly youth, struggling to secure stable positions. While new jobs are available, 50% (about 174 respondents) highlighted concerns regarding job quality. Many positions are characterized by low wages, limited benefits, and job insecurity. This disparity underscores the necessity for targeted vocational training programs and educational initiatives that equip residents with the skills needed for emerging industries.

Climate Change Concerns

Residents of Adama City are increasingly aware of the implications of climate change, especially in the context of urban growth. About 65% (approximately 226 respondents) noted that urbanization exacerbates climate-related challenges, such as increased heat retention and flooding. The loss of green areas contributes to higher urban temperatures, creating what is known as the "urban heat island" effect. Additionally, 55% (about 191 respondents) reported inadequate drainage infrastructure, leading to flooding during heavy rains, causing property damage and disrupting daily life.

Respondents expressed a strong desire for climate action, with 70% (about 243 respondents) advocating for the integration of green infrastructure, such as permeable pavements, green roofs, and urban gardens, to enhance the city's resilience to climate change. This sentiment underscores the potential for community engagement in climate adaptation strategies, fostering a collective responsibility toward preserving the urban environment.

Governance and Policy Implications

The insights gathered from residents highlight the critical role of local governance in addressing the challenges and opportunities presented by urban growth. Approximately 75% (about 260 respondents) stressed the importance of effective urban planning that involves community input and stakeholder engagement. Residents expressed a desire for transparent governance and policies that prioritize sustainable development, social equity, and environmental stewardship. Additionally, the importance of adequate infrastructure cannot be overstated. As urban growth continues, 80% (about 278 respondents) emphasized the need for investment in transportation, waste management, and public services to support the growing population. Ensuring that infrastructure keeps pace with urbanization will enhance residents' quality of life and contribute to a more sustainable urban environment.

The implications of urban growth in Adama City, as articulated by respondents, reveal a complex interplay of challenges and opportunities. While urbanization has led to economic development and improved access to services, it has also introduced significant environmental and social concerns. Addressing these challenges requires comprehensive and inclusive approaches that prioritize sustainable development, community cohesion, and climate resilience.

By leveraging the insights gathered from residents, local governance can formulate policies that not only enhance urban living conditions but also ensure the long-term sustainability of Adama City, fostering a vibrant and equitable community for all its residents

Table 4.5 summary of respondents

Aspect	Concern/Opportunity	Percentage of Respondents
Environmental Implications	Decline of green spaces	75%
	Inadequate waste management practices	60%
	Detrimental effects of urban sprawl on ecosystems	70%
Socio-economic Implications	Increased access to education and healthcare	80%
	Rising living costs	65%
	Strain on community cohesion	60%
Work Opportunities	Increased competition for jobs	50%
	Creation of new jobs in various sectors	75%
Climate Change Concerns	Exacerbation of climate-related challenges	65%
	Inadequate drainage infrastructure leading to flooding	55%
	Advocacy for green infrastructure integration	70%

The analysis of urban growth implications in Adama City reveals significant environmental and socio-economic concerns as expressed by respondents. A substantial 65% highlighted increasing pollution levels, particularly regarding air and water quality, while 70% noted the detrimental effects of urban sprawl on local ecosystems, emphasizing the urgent need for environmental protection. The decline of green spaces, voiced by 75% of respondents, underscores the importance of recreational areas for community well-being, as urban infrastructure encroaches on these vital spaces. Additionally, 60% raised alarms about inadequate waste management practices, pointing to a pressing issue as the population grows. On the socio-economic front, 80% acknowledged improved access to education and healthcare, yet 65% expressed concern over rising living costs, particularly affecting low-income families. While 70% recognized the emergence of new businesses, 55% noted a widening gap between affluent and low-income communities, highlighting a need for equitable economic development. The strain on community cohesion, felt by 60%, further indicates that urbanization may be disrupting social ties, necessitating initiatives to foster integration and preserve cultural identity amidst rapid change.

4.7 Discussion of Results and Analysis

The analysis presented in this chapter reveals significant insights into the urban growth patterns of Adama City from 2000 to 2023. Utilizing spatial regression analysis, several key drivers influencing urban development have been identified, which align with existing literature on urbanization dynamics. The findings indicate a marked expansion of built-up areas, characterized by the transformation of land use across the studied time frames. Notably, urban growth has been most substantial in areas proximal to the central business district (CBD) and along key road networks. This observation corroborates the prevailing theory that urban growth is heavily influenced by accessibility and infrastructure development, as indicated by prior studies.

Furthermore, the analysis has revealed that physical factors such as slope and institutional presence significantly impact urban growth. Areas with favorable inclines and proximity to key institutions demonstrate higher rates of development. This underscores the necessity to consider physical geography in urban planning initiatives. The multifactorial approach applied in this research emphasizes the complexity inherent in urbanization processes, showing that growth results from both economic and physical environment factors.

On the socioeconomic front, the impacts derived from urban growth are profound and multifaceted. Survey results indicate a mixed response among residents; while 60% acknowledge job creation as a positive outcome, 70% express concerns regarding increased pollution levels. Such findings reflect the duality of urban growth, as documented in existing literature, where increased urbanization creates both opportunities and challenges. The concerns surrounding environmental degradation, particularly pollution, highlight the urgent need for policy interventions aimed at mitigating adverse effects while fostering economic opportunities.

In light of these findings, it is imperative to conceive urban development strategies that harmonize growth with sustainability. Collaborative efforts among local governments, urban planners, and communities are essential to implement green infrastructure and promote sustainable practices that counteract negative environmental impacts. As emphasized both in this study and the broader literature, a more nuanced understanding of the drivers of urban growth can lead to more effective policies and planning frameworks, ultimately contributing to creating sustainable urban environments.

In conclusion, the results of the spatial regression analysis underscore the interdependence of socioeconomic factors and physical drivers of urban growth in Adama City. These findings stress the necessity for a balanced approach to urban planning that prioritizes ecological sustainability alongside economic development to ensure a resilient urban future. Future research should delve deeper into the socio-political frameworks that could enforce sustainable growth practices effectively.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research has thoroughly examined the spatio-temporal urban growth patterns in Adama City, Ethiopia, from 2000 to 2023, highlighting the complex interplay of socio-economic and environmental factors driving urban expansion. The findings indicate significant trends in urbanization that have reshaped the city's landscape and significantly impacted its community and environment.

A key conclusion drawn from the study is that urban growth in Adama City has been characterized by a marked increase in built-up areas, accompanied by alterations in land use and land cover. This growth has primarily resulted from the rising population and urban migration, fueled by economic opportunities and infrastructural development. As urban areas expand, they often encroach upon natural landscapes, resulting in habitat loss and increased pressure on essential resources like water and green spaces. This underscores the urgent need for sustainable urban planning practices that recognize the finite nature of urban resources.

Moreover, the study emphasizes the socio-economic implications of urban growth, revealing a dual narrative of opportunity and challenge. While the expansion of Adama City has created new job opportunities and contributed to improve living standards for some residents, it has also triggered concerns regarding community cohesion and environmental degradation. The disparity in positive and negative impacts reflects the necessity for a balanced approach to urban development that prioritizes not only economic growth but also social equity and environmental consciousness.

In terms of methodological contributions, the research utilized a spatial regression model to analyze urban growth dynamics, showcasing a novel approach for capturing the relationships between urban expansion and various influencing factors. The insights gained from this methodological framework can serve as a valuable reference for future studies both in Adama City and in similar urban contexts.

This study's findings are vital for informing policymakers, urban planners, and stakeholders about the intricate factors influencing urban growth and its implications.

Future research endeavors could benefit from more extensive and updated datasets, enabling a more nuanced understanding of short-term fluctuations and their influences on urban growth patterns. Additionally, escalating environmental concerns necessitate a focus on sustainable practices that mitigate adverse effects while enhancing positive outcomes for urban residents.

In conclusion, the research on urban growth in Adama City presents both insights and calls to action. As the city navigates the challenges and opportunities of urbanization, adopting a proactive and integrative approach to urban planning will be crucial. By prioritizing community engagement, sustainable infrastructure, and comprehensive data-driven strategies, Adama City can move toward a balanced future that promotes economic viability while safeguarding social and environmental health. This commitment to sustainable urban growth will play a vital role in shaping a resilient and vibrant community in the years to come.

5.1 Recommendations

The first recommendation is to develop an integrated urban planning framework that combines economic, social, and environmental considerations in decision-making processes. This framework should involve stakeholder consultations to incorporate community perspectives and needs, ensuring that future developments are both sustainable and equitable. Engaging local residents in planning discussions will lend a voice to those directly affected by urban growth and enhance the alignment of urban policies with community aspirations.

Secondly, investment in sustainable infrastructure projects is vital for promoting long-term environmental health. Infrastructure initiatives should prioritize green spaces, efficient public transportation systems, and advanced pollution control measures. By implementing solutions such as green roofs, permeable pavements, and increased vegetation, urban planners can help mitigate urban heat islands and improve overall air quality, thereby enhancing residents' quality of life.

Enhancing data-driven decision-making is another crucial recommendation. There is a need for improved collection and utilization of geospatial and socio-economic data, which can lead to informed urban governance.

Community engagement initiatives should also be a priority. Actively involving local communities in urban planning processes cultivates a sense of ownership and responsibility toward sustainable practices. Public awareness campaigns can educate residents on the implications of urban growth and promote cooperation in maintaining communal spaces, fostering a culture of environmental stewardship

Furthermore, the formulation and enforcement of policies targeting environmental protection are essential. Establishing regulations focusing on pollution reduction and biodiversity conservation will strengthen urban resilience. These policies should encompass clear guidelines on land use, waste management, and the preservation of water resources to ensure a healthier urban environment.

Longitudinal studies are also recommended to assess the long-term impacts of urban growth on socio-economic and environmental conditions. Such research will inform ongoing development strategies and help identify evolving trends and challenges in urbanization. This proactive approach will facilitate timely interventions and adaptations to address the complexities of urban growth.

Lastly, fostering cross-sector collaboration among governmental agencies, non-governmental organizations, and academic institutions is crucial. Such collaborations can harness diverse expertise to address the multifaceted challenges associated with urban growth. By combining efforts, stakeholders can develop comprehensive and innovative solutions that enhance urban sustainability and livability.

By implementing these recommendations, Adama City can strive towards a more sustainable urban future, balancing growth with ecological integrity and fostering a resilient community that thrives amidst the challenges of urbanization. The insights gained from this research can serve as a foundation for further studies and initiatives aimed at enhancing urban sustainability and livability in t

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