Analyzing Spatio-Temporal Dynamics and Urban Sprawl in Akaki Kality Sub-City, Addis Ababa, Ethiopia Using Geo-spatial Technologies.

Melkamu Getinet Gebeyew.

A Thesis Submitted to the Department of Geomatics Engineering.
School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Geomatics Engineering (Specialization in Geoinformatics)

Office of Graduate Studies
Adama Science and Technology University

November, 2024
Adama, Ethiopia

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Approval Sheet

I the advisors of the thesis entitled “Analyzing Spatio-Temporal Dynamics and Urban Sprawl in Akaki Kaliti Sub-City, Addis Ababa, Ethiopia Using Geo-spatial Technologies .” and developed by Melkamu Getinet, here by certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dejene Tesema (PhD) ____________________ ____________________ ______________

Major Advisor/Supervisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Melkamu Getinet have read and evaluated the thesis entitled “Analyzing Spatio-Temporal Dynamics and Urban Sprawl in Akaki Kaliti Sub-City, Addis Ababa, Ethiopia Using Geo-spatial Technologies .” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-informatics.

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Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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Declaration

I hereby declare that this Master Thesis entitled "Analyzing Spatio-Temporal Dynamics and Urban Sprawl in Akaki Kaliti Sub-City, Addis Ababa, Ethiopia Using Geo-spatial Technologies ” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Melkamu Getinet Gebeyew.

Name of student	Signature	Date

Recommendation

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled"Analyzing Spatio-Temporal Dynamics and Urban Sprawl in Akaki Kaliti Sub-City, Addis Ababa, Ethiopia Using Geo-spatial Technologies .” prepared under my guidance by Melkamu Getinet. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dejene Tesema (PhD)

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Major Advisor/Supervisor	Signature	Date

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Acronyms

AVHRR	Advanced Very High-Resolution Radiometer
CSS	Central Statistics Services
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agricultural Organization
GIS	Geographic Information System
LULC	Land Use Land Cover
MODIS	Moderate Resolution Imaging Spectroradiometer
OBIA	Object based image Analysis
RS	Remote Sensing
SSGI	Space Science and Geospatial Institute
TM	Thematic Mapper
UN	United Nation
UNDESA	United Nations Department of Economic and Social Affairs

Abstract

Land use and land cover are dynamically changing in Ethiopia, with significant implications for environmental sustainability and urban development. The rapid urbanization of recent decades has resulted in many regions experiencing seemingly uncontrolled land-use changes (LUCs), accompanied by various environmental and socio-economic challenges. Rapid urbanization and population growth have exerted considerable pressure on land resources in many cities, leading to environmental degradation and loss of agricultural land.This study investigates the spatio-temporal dynamics and urban sprawl trends in Akaki Kality sub-city, Addis Ababa, over a period of 16 years (2003-2019). Located on the periphery of Addis Ababa, Akaki Kality exhibits a dynamic nature of land use and land cover. The study utilized GIS techniques and remote sensing to analyze the spatio-temporal dynamics and urban sprawl trends in Akaki Kality. To obtain an orthomosaic image for the analysis, high-resolution satellite imagery from 2003(50 cm) was utilized alongside aerial images from 2011 (20cm) and 2019 (10cm). The varying resolutions provided a comprehensive view of land use and urban sprawl dynamics over time, enabling a detailed assessment of spatio-temporal changes in Akaki Kality. The researcher utilized Geographic Information System (GIS) tools,e-Cognition, and ERDAS Imagine, to extract and classify the multi-temporal images of the study area. The results from 2003 to 2019 indicate significant changes in land use over the 16-year period. The analysis revealed a substantial increase in built-up areas, rising from 32.9% in 2003 to 62.8% in 2019, at the expense of farmland, which decreased from 59.3% to 26.9% during the same period. Bare land and vegetation cover showed minor fluctuations, while water bodies experienced a decline from 1.7% to 1.0%. Akaki Kality experiences severe urban sprawl patterns characterized by leapfrog development, edge sprawl, and suburban/low-density sprawl across the study periods. Leapfrog development shows isolated built-up clusters surrounded by vacant land, while edge eprawl extends urban areas outward into rural spaces. Suburban sprawl features low-density residential developments with large undeveloped areas between built-up zones. These patterns contribute to inefficient land use, environmental degradation, and economic challenges, driven primarily by population pressure, industrial establishment, and economic factors.

Keywords: *Urban Sprawl Patterns, Orthomosaic image,*Spatial Analysis *,Spatio- Temporal Dynamics.*

CHAPTER ONE

1. Introduction

1.1. Background of the study

Spatio-temporal dynamics and urban sprawl represent critical areas of study in understanding the evolving landscape of urban environments. As cities expand, the interplay between land use changes and population growth creates complex patterns that influence ecological, social, and economic systems (Seto et al., 2012). This phenomenon is particularly pronounced in rapidly developing regions, where urbanization often leads to the transformation of agricultural land into residential and commercial areas, resulting in significant environmental impacts and challenges for urban planning (Angel et al., 2011). By analyzing these dynamics through advanced methodologies such as Geographic Information Systems (GIS) and remote sensing, researchers can gain valuable insights into the patterns and processes driving urban expansion, informing more sustainable development strategies.

The 21st century is witnessing a surge in urbanization across the globe. Cities are experiencing explosive population growth, leading to physical expansion often characterized by urban sprawl (seto, 2012) .Urban sprawl is defined by low-density development patterns, fragmented landscapes, and a heavy reliance on private vehicles (Brueckner, 2001).This phenomenon presents a multitude of environmental, social, and economic concerns.

While urbanization can drive economic growth and innovation, it also presents numerous challenges. A primary concern is the shortage of adequate housing. As urban areas expand, the influx of residents often outpaces the availability of affordable housing, leading to the growth of informal settlements and slums. UN-Habitat (2020) reports that approximately 1.6 billion people globally lack adequate housing, a figure that is anticipated to increase as urban populations rise.

Infrastructure is another critical issue affected by urbanization. Rapid population growth places immense pressure on existing infrastructure, including transportation, water supply, and sanitation systems. The Global Infrastructure Facility (2021) highlights that many cities in developing countries struggle to provide basic services, resulting in traffic congestion, inadequate waste management, and public health risks. These infrastructure deficits not only hinder economic growth but also exacerbate social inequalities, as marginalized communities often suffer the most from inadequate services.

Furthermore, urbanization contributes to various environmental challenges, including increased pollution, loss of green spaces, and heightened vulnerability to climate change. The Intergovernmental Panel on Climate Change (IPCC, 2022) emphasizes that urban areas are responsible for over 70% of global greenhouse gas emissions, underscoring the urgent need for sustainable urban planning and development practices.

Urban growth is a global phenomenon, and the patterns and trends of urbanization are particularly rapid in developing countries like Ethiopia. Urban sprawl and land use/land cover change (LULCC) have emerged as fundamental mechanisms in contemporary strategies for managing land resources and monitoring urban growth. While urbanization occurs in both developed and developing nations, the pace is notably faster in developing countries due to high population growth. This rapid urbanization leads to sprawling cities and towns, resulting in significant challenges such as population pressure, the establishment of manufacturing and industries, and economic factors influenced by changing (Hegazy & Kaloop, 2015).

In developed nations, urban sprawl is often characterized by low-density residential development, reliance on automobiles, and the expansion of suburban areas beyond city limits. Factors contributing to this sprawl include:

Economic Growth and Affordability: With higher income levels, families often seek larger homes in suburban settings, leading to the expansion of urban boundaries (Ewing et al., 2005).

Zoning Regulations: Many developed countries have zoning laws that promote single-use developments, which can lead to fragmented land use and increased sprawl (Burchell et al., 2002).

Infrastructure Investment: Substantial investments in road infrastructure facilitate easy access to suburban areas, encouraging further development (Glaeser & Kahn, 2004).

In contrast, urban sprawl in developing countries often reflects a different set of dynamics:

Rapid Urbanization: Many developing nations experience swift urbanization due to rural-to-urban migration, often outpacing the ability of cities to provide adequate housing and infrastructure (UN-Habitat, 2016).

Informal Settlements: A significant portion of urban growth occurs in informal settlements, where residents build makeshift housing without formal approval, leading to unplanned and unsustainable urban expansion (Davis, 2006).

Limited Infrastructure: Developing countries often lack the necessary infrastructure to support growing populations, resulting in haphazard urban growth and inadequate services (World Bank, 2021).

The African continent is undergoing a particularly rapid pace of urbanization, with projections suggesting that by 2050, over half of its population will reside in cities . This rapid growth presents unique challenges for African cities, many of which lack the infrastructure and resources to accommodate such large-scale urban expansion (Onibokun, 1989) .Additionally, the legacy of colonial planning often results in fragmented urban landscapes with limited public transportation options, further exacerbating sprawl .African cities are experiencing some of the world's fastest urbanization rates. However, the continent faces unique challenges in managing urban growth due to factors like poverty, limited infrastructure, and inadequate urban planning (UN-Habitat, 2018).

According to the United Nations, Ethiopia ranks as the second most populous country in Africa, following Nigeria. with an estimated population of 126.5 million in 2023 . (World Bank, 2020) .Based on the CSA's 2014 annual statistical abstract, the majority of people in Ethiopia live in rural areas. Nevertheless, the urban population of Ethiopia has significantly increased from 4.87 million to 11.86 million between 1984 and 2007. With an annual growth rate of 3.8%, it is projected to reach 23,88 million in 2022 and triple by 2037. Currently, Ethiopia has a relatively low level of urbanization at 19% compared to other sub-Saharan African countries. However, it is expected that the rate of urbanization will accelerate to around 5% annually (World Bank, 2020).

Ethiopia, particularly its capital city Addis Ababa, presents a unique context for examining urban sprawl. The country is experiencing rapid urbanization, with Addis Ababa's population projected to exceed 5 million by 2030 (E Central Statistical Agency, 2021). Several factors contribute to urban sprawl in this context:

Population Growth: High population growth rates drive demand for housing and services, leading to the expansion of urban areas into surrounding rural land (UN-Habitat, 2020).

Economic Development: As Ethiopia's economy grows, urban areas are becoming centers of manufacturing and service industries, attracting more residents and contributing to sprawl (World Bank, 2021).

Infrastructure Challenges: Addis Ababa faces significant infrastructure deficits, including inadequate transportation, sanitation, and housing, which exacerbate the spread of informal settlements and urban sprawl (African Development Bank, 2022).

The majority of cities in developing nations are expanding horizontally, and people are moving to unplanned settlements on the outskirts, which has led to the loss of agricultural land and natural beauty (Ansah et al, 1997).

Land-use and land-cover change is a process for the human modification and biophysical attribute change of the Earth’s terrestrial surface .Historical aerial photos are vital in maintaining previous ground surface data. (Fang-Ju & Yi-Hsing, 2014).

Urban sprawl has been effectively detected and analyzed using geo-information technologies, particularly high-resolution satellite imagery. This approach allows researchers to monitor changes in land use and urban growth patterns over time. Below are several examples of where and how urban sprawl has been detected using geo-spatial technologies.

High-resolution satellite imagery has been employed to analyze urban expansion in Los Angeles over several decades. Studies have shown that urban sprawl in this region is characterized by low-density development and increased impervious surfaces. The use of Landsat imagery has allowed researchers to quantify changes in land cover and assess the impact of urbanization on the environment (Liu et al, 2014).

In Beijing, high-resolution satellite imagery has been utilized to monitor urban sprawl and its effects on surrounding agricultural land. Research indicates that the rapid urbanization has led to significant loss of arable land, and satellite data has been crucial in mapping these changes (Zhao et al., 2015).

In Addis Ababa, high-resolution satellite imagery has been used to assess urban growth patterns. A study by Ayalew et al. (2021) utilized Landsat and Sentinel-2 imagery to analyze land use changes and urban sprawl dynamics, highlighting the rapid expansion of informal settlements.

Gathering information about Land Cover (LC) changes is fundamental for a better understanding of the relationships and interactions between humans and the natural environment. One of the most important data sources for investigations of LC spatial and temporal variations has been remote sensing (RS) data. Moreover, appropriately processed and expanded multi-temporal RS datasets enable mapping and identification of landscape changes, so contributing to effective sustainable landscape design and management(Dewan et al. 2009). In particular, by combining RS and GIS approaches, it is feasible to study and classify the changing pattern of LC over time and, as a result, to grasp the changes within the area of focus.Mapping urban sprawl and land use land cover change in the city is a crucial part of quantifying urban sprawl. Therefore, remote sensing and GIS technologies can help the urban planners and engineers as an alternative means of rapidly measuring the dynamic urban expansion of the town. (Katherine Weber & Padowski, 2014) Satellites images and aerial photographs provide us with digital images of the same geographic areas within a pre-defined interval. This makes it possible to monitor and detecting urban and environmental changes at different times (Kumar, L, & Jain, 2015).

Having precise and up-to-date data on the land cover of urban areas is extremely important for making decisions related to urban land management, monitoring ecosystems, and planning for cities. While traditional methods of conducting inventories and surveys can help track changes in land cover, using satellite or aerial remote sensing is a more affordable approach for detecting changes in land cover. This is because it allows for the explicit visualization of the spatial patterns of land cover change across large geographic areas in a consistent and repeated manner. Change detection has been defined as a process of "identifying differences in the state of an object or phenomenon by observing it at different times (Singh & n.d., 1989)

Unregulated growth of cities has had significant consequences for both the urban environment and economy. Unrestrained development increases the cost of providing basic necessities like housing, roads, water supply, sewage systems, and public services to unaffordable levels. This often occurs in cities built on highly productive agricultural land, leading to the unnecessary loss of these valuable resources. In addition, uncontrolled development results in the consumption of land and natural landscapes that are necessary for creating urban parks and recreational areas. Once an area is fully developed, it becomes challenging and expensive to create open spaces again (Okpala, 2009).

1.2. Statement of the problem

The Akaki Kality sub-city of Addis Ababa, Ethiopia is currently experiencing a period of rapid and uncontrolled urban sprawl, presenting a multifaceted challenge to the region. Population growth and migration further complicate the situation, as an influx of residents increases demand for housing and services, pushing development into less regulated zones . Additionally, the peripheral areas of the sub city are often neglected in development plans, leading to unregulated growth and inadequate infrastructure, which exacerbates the sprawl phenomenon. If these patterns continue unchecked, they could lead to substantial economic wastage, as resources are diverted to address the consequences of haphazard development rather than fostering sustainable growth.This combination of factors creates a pressing need for comprehensive strategies to manage urban sprawl effectively and sustainably, ensuring that all areas of Akaki Kaliti Sub City are adequately served and developed.

A common challenge identified in previous studies is the limited availability of high-resolution data.This data scarcity often hinders the ability to accurately map and analyze urban sprawl, leading to uncertainties in the assessment of its environmental and social consequences. The lack of high-resolution data in previous studies on urban sprawl patterns has been a significant gap in understanding the complexities of this issue. Traditional low-resolution data often fails to capture the intricate details of urban expansion, leading to inaccurate assessments of growth patterns and their impacts. However, recent advancements in remote sensing technology have made it possible to obtain high-resolution data, allowing researchers to identify subtle changes in land use and urban morphology. Additionally, inconsistencies in data quality and resolution can compromise the reliability of research findings. While research on urban sprawl has significantly advanced, a common challenge across studies has been the availability and quality of data .Different authors have discussed land use and land cover (LULC) in Ethiopia, with significant variation in their thematic areas and spatial focus. The research I found on Akaki Kality Sub-city utilized satellite imagery lacking high spatial resolution and was limited by the scope of the study, which was based on the sub-city's previous boundaries.

To address these limitations, researchers have increasingly turned to high-resolution satellite imagery and Orthomosaic data to capture fine-grained details of urban landscapes. These data sources allow for the identification of subtle changes in land use and land cover, such as the expansion of low-density residential areas and sub urban development

The selection of Akaki Kality Sub-city as the focus of this research is motivated by several significant issues. First, existing studies on LULC changes in urban areas often rely on low-resolution images and pixel-based classification methods, which are insufficient for capturing the complexity of urban land use patterns. Secondly, Akaki Kality Sub-city, being situated on the periphery of Addis Ababa City Administration, is particularly susceptible to land use and land cover changes, as evident from the expansion of settlement sites. Thirdly, the newly demarcated boundary of Akaki Kality Sub-city has not been studied in terms of its spatiotemporal dynamics and urban sprawl patterns. These issues collectively underscore the need for a more comprehensive and high-resolution-based analysis of LULC dynamics and sprawl patterns in Akaki Kality Sub-city.

In conclusion, given the challenges associated with traditional methods of analyzing urban sprawl, it is essential to assess the land use and land cover status of Akaki Kaliti, particularly focusing on the identification of sprawl patterns within this rapidly urbanizing sub-city.

To facilitate this analysis, the researcher employ e-Cognition software,and GIS which provides advanced capabilities for analyzing and visually displaying the intricate patterns of urban sprawl. By utilizing high-resolution data , this study aims to reveal the nuanced spatial and temporal dynamics of urban sprawl in Akaki Kaliti, thereby contributing valuable insights for effective urban planning and policy-making in the region.

1.3. Objective of the study

The study has both general and specific objectives.

1.3.1. General objective

This study aims to Analyzing Spatio-Temporal Dynamics and Urban Sprawl in Akaki Kality Sub-City, Addis Ababa, Ethiopia Using Geo-spatial Technologies from 2003 to 2019.

1.3.2 Specific objectives

To achieve the general objective the following sub-objectives are formulated. These are

- To identify the land cover/land-use change of Akaki Kality sub city .
- To calculate land transformation by comparing the classified imges from different years.
- Identify the primary driving forces behind the observed land use and land cover changes.
- To identify the spatial patterns of urban sprawl.

1.4. Research Questions

1. What is the major land-use land cover changes in Akaki Kality sub city from 2003 to 2019?

2. What is the magnitude of land transformation from one land cover/land use class to another?

3. What are the driving factors behind the LULC changes in Akaki Kaliti sub-city?

4.What are the spatial patterns of urban sprawl in Akaki Kality sub-city in 2003,2011 and 2019?

1.5 Significance of the study

The identification of land cover/land-use changes in Akaki Kality sub-city is crucial for understanding the dynamic nature of urban development in this rapidly growing area. By analyzing these changes over time, this study contributes significantly to our understanding of how urban sprawl manifests in peri-urban areas. The spatial patterns of urban sprawl, particularly in areas like Akaki Kality on the periphery of Addis Ababa, hold vital lessons for urban planners seeking to manage sustainable growth and mitigate environmental impacts.

The calculation of land transformation through comparative analysis of classified images across different years provides valuable insights into the rate and extent of urbanization. This information is essential for policymakers and urban planners to develop effective strategies for balancing economic development with environmental conservation. By mapping land-use land cover changes over three specific time periods (2003, 2011, and 2019), this study offers a comprehensive view of Akaki Kality's evolution, allowing for informed decision-making about future development trajectories.

The high-resolution spatial data employed in this study offer unprecedented detail in analyzing urban sprawl patterns. This level of precision is particularly important for Akaki Kality sub-city, where rapid growth may be leading to unintended consequences such as environmental degradation and loss of agricultural land. By providing a comprehensive analysis of these patterns, this research aims to contribute significantly to urban planning efforts in Akaki Kality and similar rapidly developing peri-urban areas, ultimately informing strategies that promote sustainable urbanization and mitigate negative impacts on the environment and local communities.

1.6 Scope of the Study

Recently, most of the towns of the country have little attention in terms of physical expansion and dynamic population growth which create a burden on basic supply of public services and infrastructural developments. The scope of the study include the following aspects:

- Spatial scope: The study area limited to Akaki Kaliti sub-city in Addis Ababa, Ethiopia.
- Temporal scope: The period of study is from 2003 to 2019.
- Thematic scope: The study focused on the spatio-temporal dynamics of LULC changes and urban sprawl in Akaki Kality sub-city.
- Methodological scope: The study used remote sensing, GIS, eCognition ,Global Mapper and statistical techniques to analyze the LULC changes and urban sprawl of the sub city.

1.7. Expected Output

The expected output of the research included:

- A comprehensive understanding of the spatio-temporal dynamics and urban sprawl in Akaki Kaliti sub-city from 2003 to 2019.
- LULC maps and sprawl maps for different years that show the distribution and changes of different LULC categories and urban sprawl trends in Akaki Kaliti sub-city.
- Driving factors and mechanisms of LULC changes and urban sprawl in Akaki Kaliti sub-city.
- Recommendations for sustainable land use planning and management policies that can address the LULC changes and urban sprawl in Akaki Kality sub-city

1.8 Limitation of the study

Analysis of land use land cover change and urban sprawl of the Akaki Kality sub cityas proposed to assess from 2003 to 2019 using high-resolution aerial imagery.Nevertheless, due to the unavailability of the data, the researcher has accessed only the 2011, and 2019 aerial imagery. Therefore, the researcher is enforced to use highresolution satellite imagery of 2003 year of the study area to conduct eight years interval inorder to get the aerial image of the study area.On the other hand, the researcher encountered challenges in obtaining socio-economic data for the sub-city due to the current reformsand restructuring, leading to a lack of well-organized data essential for the study.

CHAPTER TWO

2 .Literature of Review

2.1 Conceptualizing Urbanization and Urban Sprawl

Urbanization, a complex process marked by the concentration of population and activities in urban areas, continues to reshape global landscapes. Driven by factors such as economic opportunities, technological advancements, and social aspirations, cities are expanding rapidly. However, this rapid growth often leads to urban sprawl, a phenomenon characterized by the uncontrolled and low-density expansion of urban areas into surrounding rural land (Seto et al,2012).

2.1.1. Global Trends of Urbanization

In our contemporary, highly interconnected world, more than half of the global population, which amounts to 54%, currently resides in urban regions. This marks a significant increase from the 30% recorded in 1950. The forthcoming decades are expected to introduce substantial transformations in the size and distribution of the world's population. Projections indicate that by 2050, an estimated 66% of the global population will be living in urban areas. Furthermore, it is anticipated that the global urban population will experience a substantial growth of 2.5 billion urban inhabitants between 2014 and 2050, with the majority, approximately 90%, of this increaseconcentrated in Asia and Africa (UNDESA, 2014.).

Urbanization is one of the most significant demographic trends shaping the 21st century. As populations increasingly migrate from rural to urban areas, cities are expanding rapidly, influencing economic, social, and environmental dynamics globally. According to the United Nations (2018), it is estimated that by 2050, approximately 68% of the world's population will reside in urban areas, a significant increase from 55% in 2018. This trend is particularly pronounced in developing countries, where urbanization is occurring at an unprecedented pace, leading to both opportunities and challenges.

2.1.2.Rapid Urban Growth

The phenomenon of rapid urban growth is primarily driven by factors such as economic opportunities, better living standards, and improved infrastructure in urban areas. The United Nations (2018) projects that the number of megacities—defined as cities with a population exceeding 10 million—will rise from 33 in 2018 to 43 by 2030. This growth is exemplified by cities like Tokyo, Delhi, and Shanghai, which are currently among the most populous cities globally. As urban areas expand, they attract rural populations seeking better employment prospects and improved quality of life. However, this rapid influx can strain existing urban infrastructure and services, leading to issues such as overcrowding, inadequate housing, and increased demand for public services (World Bank, 2020).

2.1.3. Suburbanization and Urban Sprawl

In addition to the growth of urban centers, there is a notable trend of suburbanization, where populations move to suburban areas surrounding major cities. This shift often results in urban sprawl, characterized by the uncontrolled expansion of urban areas into rural land. Bhatta (2010) highlights that suburbanization can lead to increased reliance on automobiles, contributing to traffic congestion and air pollution. Furthermore, urban sprawl poses significant environmental challenges, including habitat destruction and increased greenhouse gas emissions. Ewing et al. (2005) discuss how this phenomenon can result in fragmented communities and reduced access to public transportation, exacerbating social inequalities and limiting mobility for lower-income populations.

2.1.4.Economic Impacts of Urbanization

Urbanization is closely linked to economic growth and development. Cities are often centers of innovation, productivity, and job creation, driving national economies forward (Glaeser, 2011). The concentration of resources, talent, and infrastructure in urban areas fosters an environment conducive to business and entrepreneurship. However, the rapid pace of urbanization can also lead to economic disparities and challenges. In many developing nations, the influx of people into cities can result in high unemployment rates and increased poverty levels if economic growth does not keep pace with population growth (World Economic Forum, 2021). Thus, while urbanization can stimulate economic development, it also necessitates effective planning and investment in infrastructure to ensure equitable opportunities for all residents.

2.1.4.Environmental Challenges

The environmental implications of urbanization are profound, as urban areas are responsible for about 70% of global carbon emissions (UN Environment Programme, 2019). The concentration of people and industries in cities contributes to significant environmental degradation, including air and water pollution, waste management issues, and the urban heat island effect (Seto, et al, 2012).Cities must adopt green technologies, improve public transportation systems, and enhance waste management strategies to address the challenges posed by urbanization. Failure to do so could exacerbate climate change and threaten public health in urban populations.

2.1.5.Social Dynamics and Inequality

Urbanization also brings about complex social dynamics. While cities can foster cultural exchange and diversity, they can also exacerbate social tensions and inequalities. The rapid growth of urban populations often leads to the proliferation of informal settlements and slums, where residents face inadequate access to basic services such as clean water, sanitation, and healthcare (UN-Habitat, 2016). Florida (2017) argues that urbanization can create divides between different socioeconomic groups, with wealthier residents often benefiting from improved infrastructure and services while marginalized populations are left behind. Addressing these inequalities is crucial for creating inclusive urban environments that promote social cohesion and equitable access to opportunities.

2.2. Urban Sprawl Definition and Patterns

Urban sprawl is defined as the spreading of urban developments on undeveloped land near a city. Urban sprawl is a form of development that is expensive due to its distinct characteristics. These characteristics include the unrestricted outward expansion into previously undeveloped regions, the low population density, and leapfrog development (Burchell, et al., 2005).Urban sprawl has become a universal problem and is being faced by many cities. As urban areas expand, they encroach upon surrounding lands and natural green spaces to construct residences, roads, and pathways, aligning with the demands and preferences of the resident population. This extension of urban zones into rural areas, farmlands, and forests at the outer perimeters of a city is commonly termed as Urban Sprawl (Yogesh, et al., 2016). Urban sprawl, also known as sprawl or suburban sprawl, refers to the rapid expansion of cities and towns, leading to an increased geographic area. It is often characterized by low-density residential housing, single-use zoning, and a heavy reliance on private automobiles for transportation. While urban sprawl is partly driven by the need to accommodate a growing urban population, it is also fueled by a desire for larger living spaces and various residential amenities. The consequences of urban sprawl are numerous. It has been associated with higher energy consumption, increased pollution levels, and greater traffic congestion. Moreover, it can contribute to a decline in the distinctiveness and cohesiveness of communities.Additionally, urban sprawl leads to the destruction of wildlife habitats and the fragmentation of remaining natural areas, as it expands the physical and environmental footprint of metropolitan regions (Rafferty, 2022). Globally, there is a significant trend of people migrating to urban areas. Based on data from the United Nations Population Division, approximately 29 percent of the world's population resided in cities in 1950. However, by the late 2000s, this percentage had risen to around 49 percent. Notably, in developed nations, the proportion of urban dwellers was considerably higher (Ibid).

Table 1: Re-examination of urban sprawl definitions by (George Galster & Wolman, 2001)

No	Defined by	Description/ characteristics
1	Its repercussion of uncontrolled growth	Urban sprawl is the repercussion of the existence or the absence of developmentpolicy such as zoning, urban growth boundary or development control.
2.	Its unaesthetic and injustice design	Urban sprawl create clusters of homogenous design that produce unaesthetic or unpleasant view, its ugly suburban monotonous housing cause by poor planning or limited autonomy and cause social and economic injustice.
3.	Its driving forces	Urban sprawl is the dispersion of residential and employment development, industrial externalities, market forces and neighborhood incentives that push development further away.
4.	Its undesirable pattern of growth	Urban sprawl has a nasty pattern of development spreading further from the city such as leapfrogging, ribbon, strip development and periphery areas.
5.	Its expansion characterand excessive growth	Urban sprawl expand excessively, with rapid urbanization and population spread outside their periphery and into rural area, convert and create spatial reorganization and functionality change.

6	Its consequences to socio-environment	Urban sprawl affects and changes its environment such as loss of productive agricultural lands, lower accessibility and private transport dependency, increase carbon emission and increase runoff water.

2.3.Spatial Forms of Sprawl

Sprawl development can be categorized into three primary spatial forms: low-density continuous sprawl, ribbon sprawl, and leapfrog development (Harvey & Clark, 1971). Low-density sprawl refers to the extensive utilization of land for urban activities on the peripheries of established metropolitan regions. It involves the incremental expansion of essential urban infrastructure like water, sewer, power, and roads to accommodate this type of sprawl. Ribbon sprawl refers to the pattern of development that extends along major transportation routes radiating from urban centers. In this form of sprawl, the lands adjacent to these corridors are developed, while the areas without direct access to these routes remain in rural use. As time passes, the undeveloped lands in close proximity to these transportation routes may eventually be converted to urban uses as land values rise and necessary infrastructure is extended perpendicularly from the main roads and lines. Leapfrog development sprawl is a fragmented and discontinuous pattern of urbanization where developed areas are scattered and widely separated from each other and from recognized urbanized regions, although boundaries may sometimes appear blurred. This type of development necessitates significant capital investments to provide comprehensive urban services during the development phase (Harvey & Clark, 1971). Leapfrog development sprawl is influenced by various factors. Physical geography, such as challenging topography, wetlands, valuable mineral resources, or bodies of water, can hinder continuous development or make it economically unfeasible. In addition to physical factors, leapfrog sprawl can also be driven by non physical factors, such as restrictive land-use policies in one jurisdiction, leading development to "leap" to another jurisdiction that is more inclined towards development or has limited ability to prevent or regulate it.

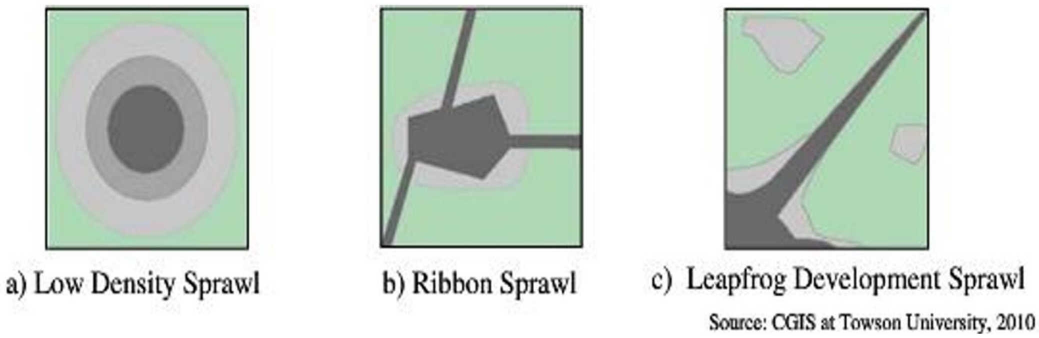

Figure 1 : Form of Urban Sprawl

2.4. Importance of studying urban sprawl

Urban sprawl, characterized by the uncontrolled expansion of urban areas into surrounding rural land, has become a significant concern in contemporary urban planning. As cities grow and populations increase, understanding the implications of urban sprawl is crucial for sustainable development. This literature review discusses the importance of studying urban sprawl, focusing on its environmental, economic, and social impacts, as well as its implications for urban planning practices.

2.4.1. Environmental Aspect of Urban Sprawl

One of the primary reasons for studying urban sprawl is its profound impact on the environment. Urban sprawl often leads to habitat destruction, loss of biodiversity, and increased pollution. As cities expand, natural landscapes are converted into residential and commercial developments, disrupting ecosystems and threatening wildlife habitats (Kahn M. E., 2000).The fragmentation of green spaces not only reduces biodiversity but also diminishes the ecological services these areas provide, such as carbon sequestration and water filtration (McKenzie E. , 2010)

Furthermore, urban sprawl typically results in increased automobile dependency, contributing to higher greenhouse gas emissions. Ewing and Cervero (2010) highlight that sprawl leads to longer commuting distances, which exacerbate air pollution and contribute to climate change. By studying urban sprawl, urban planners can develop strategies to mitigate these environmental impacts, such as promoting public transportation, enhancing green spaces, and implementing smart growth principles.

2.4.2.Economic Considerations

The economic implications of urban sprawl are another critical area of study. While sprawl can stimulate economic growth by increasing housing availability and creating jobs in construction and retail, it often leads to inefficiencies in infrastructure and service delivery. (Nelson A. C., 2009)argue that sprawling developments require extensive infrastructure investments, such as roads, utilities, and public services, which can strain municipal budgets. The costs associated with maintaining infrastructure for low-density areas can outweigh the economic benefits of sprawl, leading to financial burdens for local governments.

Moreover, urban sprawl can exacerbate socio-economic inequalities. As affluent populations move to suburban areas, lower-income residents may be left in urban centers with declining resources and services (Parker, 2013). This spatial segregation can limit access to employment opportunities, education, and healthcare for marginalized communities. By studying urban sprawl, planners can identify patterns of inequality and develop policies to promote equitable development, ensuring that all residents have access to essential services.

2.4.3.Social Implications of Urban Sprawl

The social dimensions of urban sprawl are equally important to consider. Sprawling developments often lead to social isolation, as communities become more dispersed and reliant on automobiles for transportation. This can diminish social interactions and community cohesion, as residents may find it challenging to engage with their neighbors or participate in local activities (Rogers, 1997) .Understanding the social consequences of sprawl is vital for urban planners aiming to foster vibrant, connected communities.

Additionally, urban sprawl can impact public health. The design of sprawling communities often discourages walking and cycling, leading to increased sedentary lifestyles and associated health problems, such as obesity and cardiovascular diseases (Frank, 2006). By studying urban sprawl, planners can advocate for healthier urban designs that promote active transportation options and access to recreational spaces, ultimately improving public health outcomes.

2.4.4.Implications for Urban Planning

Studying urban sprawl is essential for informing effective urban planning practices. As cities continue to grow, planners must develop strategies that balance growth with sustainability. Smart growth principles, which emphasize compact, mixed-use development and efficient public transportation, provide a framework for addressing the challenges of urban sprawl

(Ewing & Chen, 2005) .By incorporating these principles into planning processes, urban planners can create more sustainable and resilient urban environments.

Moreover, the integration of technology, such as Geographic Information Systems (GIS) and remote sensing, allows planners to analyze urban growth patterns and assess the impacts of different development scenarios (Bhatta, B., 2010).These tools enable data-driven decision-making, helping planners to identify areas at risk of sprawl and implement proactive measures to manage growth effectively.

2.5.Models of Urban Sprawl

Urban sprawl refers to the uncontrolled expansion of urban areas into the surrounding rural land, often leading to low-density development and increased reliance on automobiles. To understand the patterns and dynamics of urban sprawl, several models have been developed by urban planners and geographers. Two of the most notable models are the Concentric Zone Model and the Sector Model, both of which offer insights into the spatial organization of cities and the processes that drive urban growth.

2.5.1.The Concentric Zone Model

Developed by sociologist Ernest W. Burgess in 1925, the Concentric Zone Model presents a framework for understanding urban land use and social structures in cities. According to Burgess, cities grow in a series of concentric circles around a central point, typically the central business district (CBD). This model divides urban space into five distinct zones: the CBD, a zone of transition, a zone of working-class homes, a zone of middle-class homes, and a commuter zone.

The first zone, the CBD, is characterized by high land values and dense development, serving as the economic and cultural hub of the city. Surrounding the CBD is the zone of transition, which often contains deteriorating housing and is typically inhabited by lower-income residents and recent immigrants. This area frequently experiences social issues such as crime and poverty. The next zone is the zone of working-class homes, where modest single-family homes are located, typically occupied by blue-collar workers. Beyond this is the zone of middle-class homes, featuring more spacious residences and better living conditions. Finally, the commuter zone encompasses the suburbs, where residents commute to the city for work (Burgess, 1925).

The Concentric Zone Model illustrates how urban areas develop outward from the center, with socio-economic status influencing residential patterns. However, critics argue that the model oversimplifies the complexities of urban growth and does not account for the diverse factors that shape modern cities, such as transportation networks, cultural influences, and government policies (Haggett, 2001) .Despite its limitations, the model remains a foundational concept in urban studies, providing a basis for understanding urban expansion and social stratification.

2.5.2.The Sector Model

In contrast to the Concentric Zone Model, the Sector Model, proposed by economist Homer Hoyt in 1939, offers a more nuanced view of urban land use by emphasizing the role of transportation corridors in shaping urban growth. Hoyt's model suggests that cities develop in sectors or wedges radiating outward from the CBD, rather than in concentric circles. This model is based on the observation that certain areas of a city tend to attract specific types of development, influenced by factors such as transportation routes, topography, and land use preferences.

Hoyt identified five sectors in his model: the CBD, a sector for transportation, a sector for low-income housing, a sector for middle-income housing, and a sector for high-income housing. The transportation sector is particularly significant, as it includes major roads, railways, and highways that facilitate access to and from the city. As a result, industries and residential areas tend to develop along these transportation corridors, leading to the formation of distinct sectors within the urban landscape (Hoyt, 1939).

The Sector Model highlights the importance of transportation in shaping urban growth patterns and demonstrates how different socio-economic groups may cluster in specific areas based on their access to infrastructure and services. For example, high-income residents may prefer to live in sectors with better amenities and lower traffic congestion, while low-income populations may be located near industrial areas or transportation hubs due to affordability (Julie S. Morrill, 1991) Although the Sector Model provides a more dynamic understanding of urban sprawl, it too has its limitations, as it may not fully capture the complexities of modern urban environments influenced by globalization, zoning regulations, and changing demographics.

Both the Concentric Zone Model and the Sector Model have significant implications for urban planning and policy-making. Understanding these models allows planners to analyze urban growth patterns and address the challenges associated with urban sprawl. For instance, recognizing the existence of distinct zones or sectors can inform decisions about infrastructure investment, housing development, and transportation planning.

Moreover, these models highlight the need for sustainable urban development strategies that promote mixed-use development and reduce reliance on automobiles. By integrating residential, commercial, and recreational spaces, cities can create more livable environments that minimize the negative impacts of sprawl, such as traffic congestion, air pollution, and social isolation (Duany & Speck, 2000).

2.6.Drivers of Urban Sprawl

2.6.1. Population Growth and Migration Patterns

Urban sprawl, characterized by the uncontrolled expansion of cities into surrounding rural areas, is driven by a multitude of factors, with population growth and migration patterns being among the most significant. As cities grow in size and population, they face various challenges related to infrastructure, housing, and environmental sustainability. Understanding the dynamics of population growth and migration is essential for addressing the complexities of urban sprawl and its implications for urban planning and development(Ewing et al., 2005).

2.6.1.1.Population Growth

Population growth is a primary driver of urban sprawl, particularly in rapidly developing regions where urban populations are increasing at unprecedented rates. According to the United Nations (2019), the global urban population is expected to rise from 4.2 billion in 2018 to 6.7 billion by 2050, highlighting the pressing need for housing and infrastructure in urban areas. This influx of people into cities often leads to increased demand for residential space, resulting in the expansion of urban boundaries into previously undeveloped land.

In many cases, population growth is fueled by natural increase, where the birth rate exceeds the death rate, leading to a higher number of residents in urban areas. However, migration—both internal and international—also plays a crucial role in shaping urban demographics. As individuals and families move to cities in search of better economic opportunities, education, and healthcare, urban areas become increasingly congested. This phenomenon is particularly evident in developing countries, where rural-to-urban migration is a common trend, driven by the search for improved living conditions and job prospects (World Bank, 2020).

The rapid population growth associated with urbanization often results in the proliferation of informal settlements or slums, where residents face inadequate housing, poor sanitation, and limited access to essential services. These conditions exacerbate the challenges of urban sprawl, as cities struggle to provide adequate infrastructure and resources to accommodate their growing populations (UN-Habitat, 2020). Consequently, unchecked population growth can lead to environmental degradation, increased traffic congestion, and social inequities, necessitating comprehensive urban planning strategies that prioritize sustainable development.

2.6.1.2.Migration Patterns

Migration patterns significantly influence urban sprawl, as they determine the demographic composition of cities and the distribution of populations across urban and suburban areas. Internal migration, which involves the movement of individuals within a country, often leads to the expansion of metropolitan areas as people relocate from rural regions to urban centers. This trend is particularly pronounced in countries experiencing rapid industrialization and economic growth, where job opportunities in cities attract rural residents seeking better livelihoods (Kahn M. E., 2000).

International migration also contributes to urban sprawl, as migrants from various countries settle in urban areas, bringing diverse cultural and economic influences. Cities often serve as gateways for immigrants, providing access to employment, education, and social networks. This influx of newcomers can lead to the development of vibrant multicultural neighborhoods, but it can also strain existing infrastructure and services, particularly in areas that are already experiencing high levels of population growth (Portes & Rumbaut, 2006).

Moreover, migration patterns can result in suburbanization, where individuals and families move from urban centers to suburban areas in search of more affordable housing, better schools, and a perceived higher quality of life. This shift can lead to the expansion of suburban developments, further contributing to urban sprawl. For instance, the phenomenon of "white flight" in the United States, where middle-class families moved from cities to suburbs in response to racial integration and urban decline, exemplifies how migration patterns can shape urban landscapes (Denton's, 1993).

2.6.2.Economic Factors

Urban sprawl, characterized by the expansion of cities into surrounding rural areas, is significantly influenced by various economic factors, particularly housing demand and land prices. These economic dynamics shape the patterns of urban development, affecting not only the physical landscape but also the socio-economic conditions within urban areas. Understanding these drivers is essential for addressing the challenges associated with urban sprawl and promoting sustainable urban development.

2.6.2.1.Housing Demand

Housing demand is a critical factor driving urban sprawl. As populations grow and urbanization accelerates, the need for housing increases, leading to greater pressure on urban land. According to the United Nations (2019), the global urban population is expected to reach 6.7 billion by 2050, resulting in a substantial demand for housing in urban areas. This demand often drives developers to expand into suburban and rural areas, where land is more readily available and often less expensive than in densely populated urban centers.

The desire for single-family homes with yards, a preference that has been culturally ingrained in many societies, particularly in the United States, further fuels housing demand in suburban areas. Families often seek larger living spaces and access to better schools, parks, and recreational facilities, which are typically more abundant in suburban neighborhoods compared to urban centers (Bhatta, 2010) This trend has led to the proliferation of low-density residential developments on the outskirts of cities, contributing to urban sprawl.

Moreover, the housing market's cyclical nature can exacerbate sprawl. During economic booms, increased employment opportunities and rising incomes lead to heightened housing demand, prompting developers to construct new homes in previously undeveloped areas. Conversely, during economic downturns, the demand may shift, but the existing suburban infrastructure remains, perpetuating sprawl as families continue to reside in these areas due to affordability and availability (McKenzie R. D., 2015)

The availability of financing options, such as low mortgage rates and government incentives for homeownership, also plays a significant role in driving housing demand. When interest rates are low, borrowing becomes more accessible, encouraging individuals and families to purchase homes, often in suburban areas where land is cheaper and new developments are plentiful (Morrill, 2014). This trend not only contributes to urban sprawl but also leads to increased traffic congestion and reliance on automobiles, as residents commute to urban job centers.

2.6.2.2.Land Prices

Land prices are another significant economic factor influencing urban sprawl. In urban centers, land prices tend to be significantly higher due to limited availability and high demand for commercial and residential space. As a result, developers often seek cheaper land in suburban and rural areas to maximize profits. This pattern is particularly evident in metropolitan areas where rapid growth has driven up land prices, making it economically feasible for developers to expand outward rather than upward (Glaeser & Kahn, 2004).

The disparity in land prices between urban and suburban areas can lead to a phenomenon known as "leapfrog development," where new developments occur far from the urban core, bypassing existing infrastructure and services. This type of development often results in increased infrastructure costs for municipalities, as they must extend utilities, roads, and services to support new suburban populations (Nelson et al., 2004). Consequently, the economic incentives for developers to build in these areas can create a cycle of sprawl that is difficult to reverse.

Additionally, zoning regulations and land use policies can significantly impact land prices and, consequently, urban sprawl. In many regions, restrictive zoning laws limit the types of developments allowed in urban areas, driving developers to seek opportunities in less regulated suburban or rural areas. This regulatory environment can exacerbate the affordability crisis in urban centers, pushing lower-income residents to the outskirts where housing is more affordable but often lacks access to essential services and public transportation (Fischel, 2001).

Furthermore, speculative investment in land can lead to increased prices and contribute to urban sprawl. Investors may purchase large tracts of land in anticipation of future development, driving up prices and making it more challenging for affordable housing projects to succeed. This speculative behavior can create a disconnect between housing supply and demand, further fueling the cycle of sprawl as developers seek to maximize profits by building in less expensive areas (Bourne, 2001).

2.6.3. Transportation Infrastructure Development

Urban sprawl, characterized by the expansion of cities into surrounding rural areas, is significantly influenced by the development of transportation infrastructure. The relationship between transportation systems and urban growth is complex, with infrastructure often acting as both a catalyst for and a response to patterns of urban development. As cities expand, the need for efficient transportation networks becomes increasingly critical, shaping the spatial organization of urban areas and contributing to the phenomenon of sprawl.

2.6.3.1.The Role of Transportation Infrastructure

Transportation infrastructure encompasses a wide range of facilities, including roads, highways, public transit systems, and airports. The development of these systems plays a pivotal role in determining how cities grow and how residents navigate their environments. Improved transportation options can facilitate access to jobs, services, and amenities, making previously remote areas more attractive for residential and commercial development. This accessibility often leads to increased demand for housing and services in suburban and exurban areas, contributing to urban sprawl.

Historically, the construction of the interstate highway system in the United States during the mid-20th century exemplifies the profound impact of transportation infrastructure on urban development. The Federal-Aid Highway Act of 1956 initiated a massive investment in highways, drastically reducing travel times between urban centers and their surrounding suburbs (Jackson, 1985). As highways made it easier for people to commute from suburban areas to urban job centers, they spurred a wave of residential development in these outlying regions. This trend was particularly pronounced in the post-World War II era, as returning veterans sought affordable housing options, leading to the proliferation of single-family homes in suburban neighborhoods (Fishman, 2000)

The relationship between transportation infrastructure and urban sprawl is not limited to highways. Public transit systems, including buses, light rail, and subways, also influence urban growth patterns. Well-developed transit networks can encourage higher-density development along transit corridors, promoting walkable communities and reducing reliance on automobiles. However, in many cases, inadequate or underfunded public transportation systems can exacerbate sprawl by pushing residents to seek housing in areas that are more car-dependent (Cervero & Kockelman, 1997). The lack of reliable public transit options can lead to increased traffic congestion and longer commute times, further entrenching the cycle of urban sprawl.

2.6.3.2.Suburbanization and Transportation

The expansion of transportation infrastructure has facilitated suburbanization, a key component of urban sprawl. Suburbanization refers to the movement of populations from urban centers to surrounding suburbs, often driven by the desire for larger living spaces, lower housing costs, and perceived better quality of life. As transportation networks have improved, the geographic boundaries of metropolitan areas have expanded, allowing residents to live farther from their workplaces while still maintaining access to urban amenities.

The phenomenon of "drive until you qualify" illustrates this trend, where homebuyers continue to search for affordable housing options further away from urban centers, often sacrificing proximity to jobs and services in the process (Bhatta S. D., 2010) .This tendency is fueled by the availability of highways and arterial roads that make commuting feasible, even over long distances. Consequently, as more individuals and families relocate to suburban areas, demand for housing and services in these regions increases, leading to further sprawl.

Moreover, the interplay between transportation infrastructure and zoning regulations often exacerbates suburbanization. Many suburban areas are characterized by zoning laws that prioritize low-density residential development, which can limit the availability of affordable housing options in urban centers. As a result, the expansion of transportation infrastructure can lead to a cycle where suburban areas become increasingly attractive for development, while urban centers face challenges related to disinvestment and decline (Nelson et al., 2004).

2.6.3.3.Environmental and Social Implications

The development of transportation infrastructure and its contribution to urban sprawl have significant environmental and social implications. The expansion of urban areas into previously undeveloped land often leads to the loss of green spaces, agricultural land, and natural habitats. This encroachment can disrupt ecosystems, contribute to biodiversity loss, and increase the urban heat island effect, exacerbating climate change impacts (Seto et al., 2012). Furthermore, increased reliance on automobiles associated with sprawl contributes to higher greenhouse gas emissions, air pollution, and traffic congestion, posing public health risks to residents.

Socially, urban sprawl can lead to increased inequality and segregation. As wealthier populations move to suburban areas with better amenities and services, lower-income residents may be left behind in urban centers that experience disinvestment and declining infrastructure. This can exacerbate disparities in access to education, healthcare, and employment opportunities, creating a cycle of poverty that is difficult to break (Talen, 2010). Additionally, the lack of affordable housing options in urban centers can force low-income families to seek housing in more distant suburbs, resulting in longer commute times and increased transportation costs.

2.7.Impacts of Urban Sprawl

Urban sprawl has significant impacts on various aspects of society, the economy, and the environment, leading to complex challenges that urban planners and policymakers must address. One of the most notable impacts of urban sprawl is environmental degradation. As cities expand into rural and natural areas, they often result in the loss of green spaces, wetlands, and agricultural land, which are crucial for biodiversity and ecosystem services (Seto et al., 2012). This encroachment can disrupt local wildlife habitats and contribute to the decline of species, ultimately diminishing the ecological health of the region.

The consequences of urban sprawl are multifaceted, affecting the environment, economy, and social fabric of urban areas. Environmentally, urban sprawl leads to habitat destruction, loss of agricultural land, and increased greenhouse gas emissions due to longer commuting distances (Kahn & E., 2000) .The fragmentation of landscapes disrupts ecosystems and biodiversity, posing significant challenges to sustainable development.

Economically, urban sprawl can result in higher infrastructure costs for municipalities, as services must be extended to more dispersed populations. (Nelson & Sanchez, 2009). This sprawl often leads to inefficient land use, where valuable resources are wasted on maintaining infrastructure for low-density developments rather than investing in higher-density, mixed-use areas that promote sustainability. Transportation infrastructure plays a crucial role in facilitating urban sprawl (Ewing R. &., 2010) argue that improved transportation networks enable easier access to suburban areas, leading to increased residential development away from city centers. As a result, the spatial distribution of populations shifts, contributing to the phenomenon of urban sprawl.

Moreover, urban sprawl contributes to increased automobile dependency, as residents in sprawling areas often have limited access to public transportation and must rely on cars for commuting. This reliance leads to higher greenhouse gas emissions, air pollution, and traffic congestion, exacerbating climate change and posing public health risks (Ewing et al., 2008). Studies have shown that areas with higher levels of sprawl tend to have poorer air quality, which is linked to respiratory problems and other health issues among residents (Frank et al., 2006).Socially, urban sprawl can exacerbate economic inequalities and segregation. As wealthier populations migrate to suburban areas with better amenities and schools, lower-income residents may be left behind in urban centers that face disinvestment and declining services (Talen, 2010).

2.8.Theories of Urban Development

Urban development theories play a crucial role in shaping the planning and design of cities, addressing the challenges of urbanization, environmental sustainability, and social equity. Among the most influential theories are New Urbanism and Smart Growth, both of which advocate for more sustainable, livable, and community-oriented urban environments. These theories reflect a growing recognition of the need to create urban spaces that prioritize human well-being, environmental health, and economic vitality.

2.8.1.New Urbanism

New Urbanism emerged in the late 20th century as a response to the negative consequences of suburban sprawl and automobile-dependent development. This movement advocates for the design of walkable neighborhoods that promote a sense of community and encourage social interaction. Key principles of New Urbanism include mixed-use development, pedestrian-friendly streets, and diverse housing options that cater to various income levels and demographics (Duany et al., 2000). By integrating residential, commercial, and recreational spaces, New Urbanism aims to create vibrant communities where residents can live, work, and play within close proximity.

One of the hallmark features of New Urbanism is its emphasis on walkability. Streets are designed to be safe and accessible for pedestrians, with sidewalks, bike lanes, and public transportation options that reduce reliance on cars. This focus on walkability not only enhances the quality of life for residents but also contributes to environmental sustainability by decreasing greenhouse gas emissions associated with vehicular travel (Calthorpe, 1993) Additionally, New Urbanist communities often incorporate green spaces, parks, and public plazas that foster social interaction and promote physical activity.

Critics of New Urbanism argue that while the movement offers valuable insights into urban design, it may not adequately address issues of affordability and social equity. Some New Urbanist developments have been criticized for catering primarily to higher-income residents, potentially leading to gentrification and the displacement of lower-income populations (Talen, 2010) .Nevertheless, proponents of New Urbanism emphasize the importance of inclusive design practices that consider the needs of diverse communities, advocating for policies that ensure affordable housing options within New Urbanist frameworks.

2.8.2.Smart Growth

Smart Growth is another influential theory of urban development that emerged in the 1990s, focusing on sustainable land use and responsible growth management. This approach seeks to combat the negative impacts of urban sprawl by promoting compact, efficient, and environmentally friendly development patterns. Smart Growth principles emphasize the importance of preserving open space, protecting natural resources, and enhancing the quality of life for residents (Agency, 2002)

Key tenets of Smart Growth include mixed-use development, higher-density housing, and the integration of public transportation systems. By encouraging development within existing urban areas, Smart Growth aims to reduce the pressure on rural and undeveloped lands, thereby preserving valuable ecosystems and agricultural land (Nelson et al., 2004). Additionally, Smart Growth promotes the creation of vibrant public spaces, such as parks and community centers, that enhance social interaction and foster a sense of belonging among residents.

One of the central tenets of Smart Growth is the emphasis on transportation choices. By prioritizing public transit, cycling, and walking, Smart Growth seeks to create interconnected communities that reduce dependence on cars. This approach not only alleviates traffic congestion but also contributes to improved public health by encouraging active lifestyles (Litman, 2003). Moreover, Smart Growth policies often incorporate strategies for affordable housing, ensuring that diverse populations can benefit from the advantages of well-planned urban environments.

Despite its strengths, Smart Growth faces challenges related to implementation and public acceptance. Critics argue that some Smart Growth initiatives can lead to increased housing costs and may not adequately address the needs of marginalized communities (Glaeser, 2011). Furthermore, the effectiveness of Smart Growth policies often depends on local political will and community engagement, which can vary significantly across different regions

2.9. Previous Studies and Gaps in the Literature

The images captured by earlier low-resolution remote sensing sensors such as AVHRR,MODIS, and Thematic Mapper (TM) had larger pixels compared to the size of theobjects being imaged. As a result, it was necessary to conduct sub-pixel or per-pixelanalysis to accurately map these objects. However, the complexity of patterns andsmaller urban land covers make it difficult for moderate and low-resolution images toeffectively extract urban land covers(Hossain and Chen, 2022). Researches conductedon urban landuse land cover changes and urban sprawl studies in almost all urbancenters of Ethiopia are conducted using low resolution images like Landsat historicalimages and other low-resolution imageries. As Mitiku and Dessalegn, 2021 conductedresearch on Addis Ababa landuse land cover change and urban expansion they used30m resolution Landsat satellite imagery for their study.To accurately map and quantify urban spatial elements, high-resolution remote sensingphotography offers the apparent benefit of revealing finer details such as individualtrees, vehicles, buildings, and many more (Natalia, 2022).However, these advantagesof high-resolution imagery are not well-exploited in urban land use, land cover, andsprawl change research studies.

2.10. The Role of Remote Sensing and GIS in Urban Sprawl Analysis

Remote sensing and Geographic Information Systems (GIS) play a crucial role in analyzing urban sprawl, providing valuable tools for monitoring land use changes, assessing environmental impacts, and supporting sustainable urban planning. High-resolution imagery enhances these capabilities, allowing for more precise and detailed assessments of urban expansion.

2.10.1.Remote Sensing

Remote sensing involves acquiring data about the Earth's surface from satellites or aerial platforms. This technology enables researchers to monitor land use changes over time, which is essential for understanding urban sprawl dynamics. High-resolution satellite imagery, such as that from Landsat or Sentinel-2, allows for detailed analysis of urban areas, capturing variations in land cover and land use (Huang et al., 2010). For instance, studies have demonstrated how remote sensing can effectively track urban growth patterns, identify the conversion of agricultural land to urban uses, and assess the fragmentation of landscapes due to sprawl (Seto et al., 2012).

One significant advantage of remote sensing is its ability to provide temporal data, enabling comparisons over different time periods. This capability is crucial for understanding the rate of urban expansion and its implications for infrastructure, transportation, and environmental sustainability. For example, a study by Li et al. (2018) utilized Landsat imagery to analyze urban sprawl in Beijing, revealing patterns of rapid expansion and highlighting areas of significant land use change.

2.10.2.Geographic Information Systems (GIS)

GIS complements remote sensing by providing a framework for analyzing spatial data. It allows for the integration of various data sources, including demographic, economic, and environmental information, facilitating a comprehensive understanding of urban sprawl (Batty et al., 2012). Through GIS, planners can visualize and analyze the spatial relationships between urban growth and factors such as population density, land prices, and transportation networks.

GIS tools enable researchers to create models that simulate urban growth scenarios, helping policymakers make informed decisions about land use planning and resource allocation. For example, a study by Zhang et al. (2014) employed GIS to analyze the driving factors of urban sprawl in the Yangtze River Delta, identifying key variables such as transportation accessibility and economic development that influence land use patterns.

2.10.3.High-Resolution Imagery

The advent of high-resolution imagery has significantly enhanced the capabilities of both remote sensing and GIS in urban sprawl analysis. High-resolution images provide more detailed views of urban areas, allowing for the identification of smaller land use changes that may be missed with lower-resolution data. This granularity is particularly important in densely populated urban environments where small-scale developments can have substantial cumulative effects on sprawl (Zhou et al., 2016).

Moreover, high-resolution imagery facilitates the application of advanced machine learning techniques for land cover classification and change detection. These techniques can automate the process of identifying urban features, thus improving the efficiency and accuracy of urban sprawl assessments (Kumar, L, & Jain, 2015) .For instance, using high-resolution satellite data, researchers have successfully mapped urban areas and monitored their growth patterns with greater precision, enabling more effective urban planning and management (Weng, 2010).

CHAPTER THREE

3. Methodology

3.1. Description of study area

Akaki Kality sub-city is one of the largest sub-cities located in the Southeastern part of Addis Ababa.The astronomical location of the study area is situated between 8°50'48" and 8°57'35" latitude and between 38°44'34" and 38°49'29" longitude.It shares boundaries with Bole Sub-city in the North, Kirkos and Nifas Silk Loft Sub cities in the North West, and Oromia regional state in the South. The lowest point is 2,050 meters in the Southern periphery and the maximum elevation is 2,250 meters above sea level.

The climate of the Akaki kality sub-city is characterized by two distinct seasonal weather patterns. The main wet season, locally known as Kiremt, extends from June to September. A minor rainy season, locally known as Belg, contributes moisture to the region from mid-February to mid-April (Daniel, 1977).

Akaki Kality Sub-City with 6644.4 Hectares area is considered as the most industrial sub-city of Addis Ababa having many more resettled populations and having great vacant space this sub-city accepts huge and continuous urban expansion in case of road asses to the city out, hence the study focuses on this sub-city. According to the report prepared by the Central Statistical Service of Ethiopia, in 2013 the population of Aakaki Kality is estimated to be 243,842 where males are 118318 and females constitute 125524.

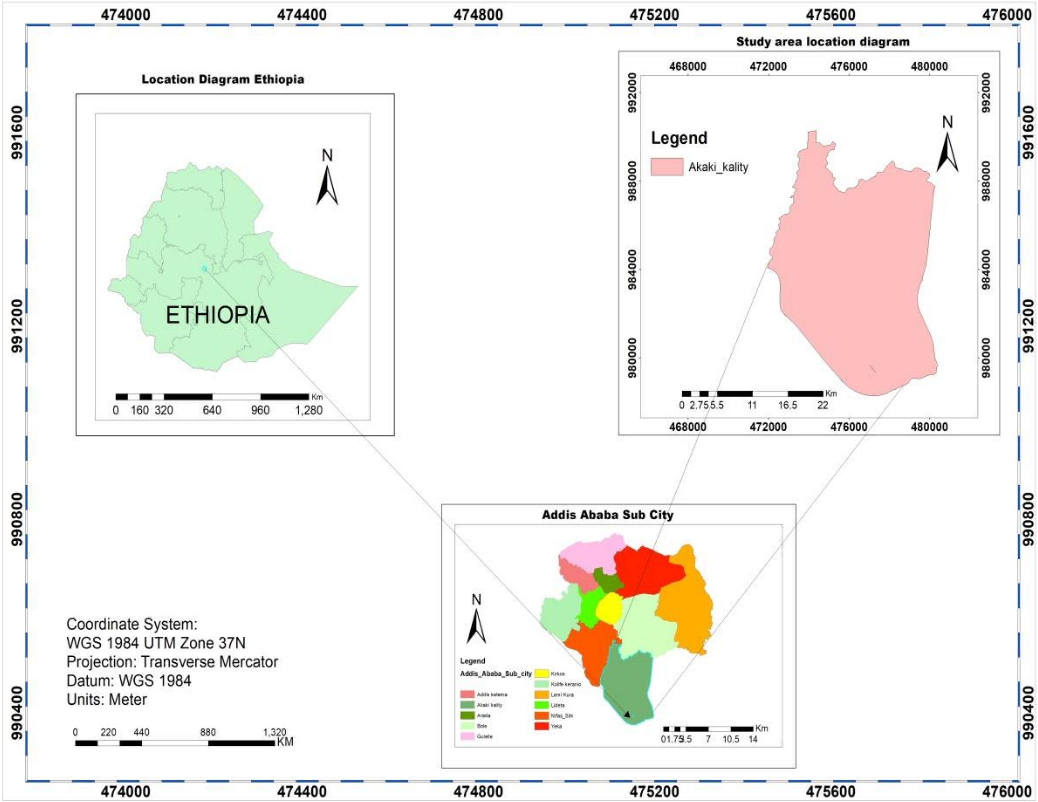

Figure 1:Location Map of Akaki Kality Sub City

3.1.2. Climate and rainfall

The climate of the Akaki kality sub-city is characterized by two distinct seasonal weather patterns. The main wet season, locally known as Kiremt, extends from June to September. A minor rainy season, locally known as Belg, contributes moisture to the region from mid-February to mid-April (Daniel, 1977) .Its average daily temperature is 16oC, which means annual precipitation is about 1180 MMS and has an annual rainfall season starting from June to September. The dry season occurs from January to May. During the dry season, many urban dwellers engage in urban farming. The city has shown extensive physical growth over the past 30 or 40 years. In 1984, the area of the city was only 224 square kilometers; and by 2009, its total area was estimated to be 530.14 square kilometers (ORAAMP 1999).

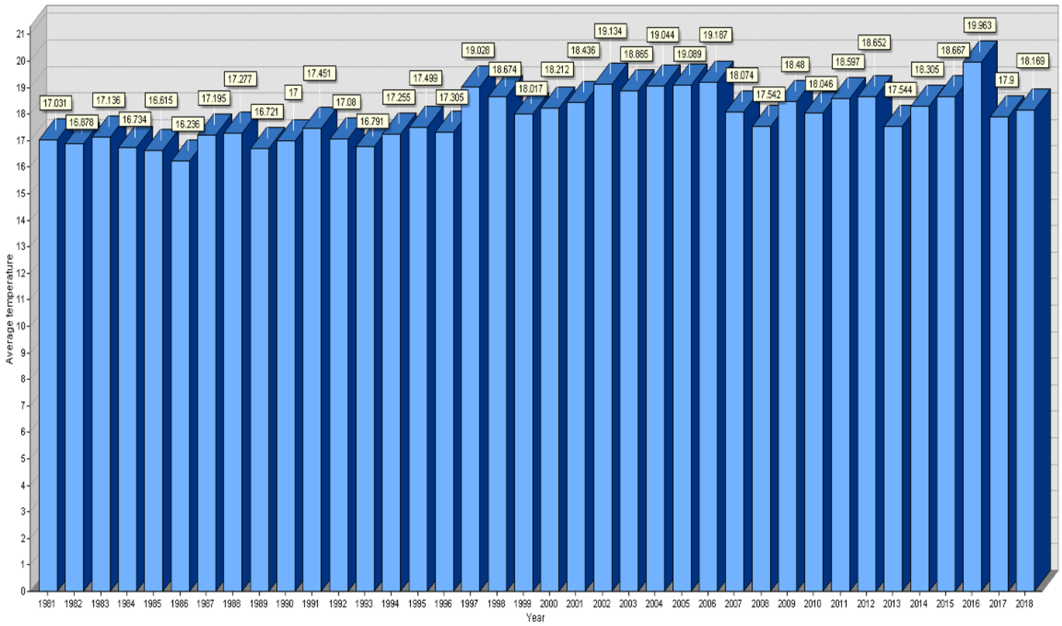

Figure 2: Average temperature of the study area

Source: Ethiopian Meteorology Agency

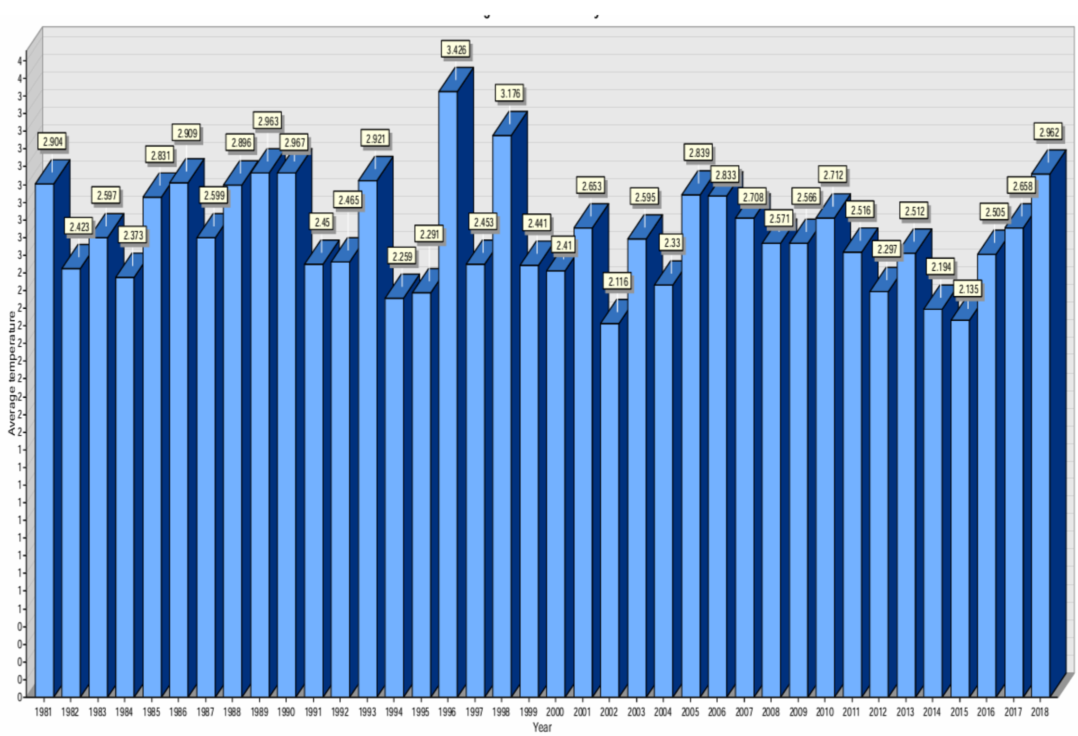

Figure 3:Average Rainfall of study area from 1981-2018

Source: Ethiopian Meteorology Agency

3.1.3. Population Size

According to the Central Statistics Service 2023 projection of the city government, the total population of Addis Ababa was estimated to be 3,945,000, of whom 2,084,000 were females, and the remaining 1,861,000 were males (CSS, 2023). The population sizes of the sub-cities vary across the area. Addis Ababa city covers a total area of 540 square kilometers and currently consists of 11 Sub-City Administrations and 117 Districts. This study is conducted at the sub-city level in Akaki Kality Sub-city. Akaki Kality Sub-city is one of the largest sub-cities. The total area of the sub-city is about 6,644.4 hectares . According to the Central Statistics Service (CSS) projection for July 2023, the total population of the sub-city is 260,967 .(CSS, 2023). Out of the total sub-city population,126,473 were males, and 134,494 were females.

3.2 .Topography

The topographic pattern of Akaki Kality Sub City is with the maximum and minimum elevation of 2250 m and 2050m which is 2150 m mean elevation.

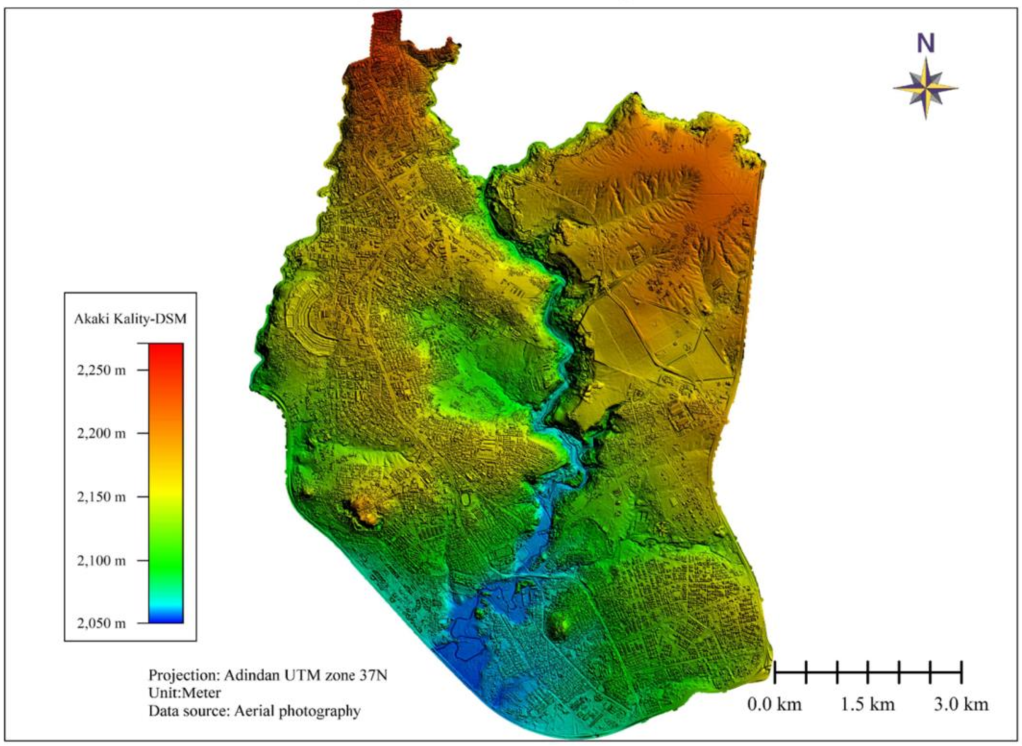

Figure 4: Elevation map of Akaki Kality Sub -City

3.3. Data Type and Source

High-resolution images are crucial for urban land use and land cover (LULC) analysis, particularly in understanding the dynamics of urban sprawl. These images provide detailed insights into the spatial characteristics of urban environments, enabling researchers to assess changes over time with greater accuracy. For instance, the Ultracam Eagle sensors acquired images in 2011 and 2019 with spatial resolutions of 20 cm and 10 cm, respectively, significantly enhancing the detail captured compared to earlier datasets like those from Maxar Technologies in 2003, which has a resolution of 50 cm.

The 2011 imagery from Ultracam Eagle, owned by SSGI, allowed researchers to analyze urban development patterns, identifying areas of expansion and changes in land cover. By 2019, the improved spatial resolution of 10 cm provided even finer detail, facilitating more nuanced analyses of urban sprawl, including the identification of smaller land use changes that may have been overlooked in previous studies. This progression from 2011 to 2019 highlights the importance of high-resolution imagery in capturing the complexities of urban landscapes and informs better planning and management of urban growth.

Table 2: Characteristics of Image data used in this study.

No.	Sensor	Data Type	Acquisition Year	Spatial Resolution	Owner
1	Maxar technologies	Satellite Image	2003	50cm	Google Earth
2	Ultracam Eagle	Orthmosaic	2011	20cm	SSGI
3	Ultracam Eagle	Orthmosaic	2019	1 0cm	SSGI

3.4.Data Collection Techniques

As stipulated above the major data collection technique for this study is done by usingdata extraction methods from higher resolution aerial and satellite image of the timeframe ranging from 2003 -2019. The inclusion of aerial photographs played a crucialrole in enhancing our understanding of the geographical and topographicalcharacteristics of the study area, providing detail visual context. Additionally, satelliteimage was accessed from the Google Earth historical image archive. These satelliteand aerial images served as invaluable resources for tracking temporal changes, spatialpatterns, and developments in the study area over time. The multi-spectral and highresolution attributes of the aerial and satellite imagery facilitated the extraction of richinformation for analysis. Conversely, the elevation model of the sub-city was extractedfrom Addis Ababa City using study area boundary and was used to interpret the topographic patterns of the study area .

3.5. Hardware and Software

In this study, computer hardware and software played a critical role in facilitating various aspects of the research process, including data organization, storage, manipulation, analysis, and output generation. The integration of advanced technological tools was essential to achieving the desired results. For image processing, particularly in high-resolution image classification, the researcher harnessed the power of high-performance digital photogrammetric workstations. These specialized workstations are equipped with advanced hardware components and software applications tailored for the precise and complex tasks involved in object-based image classification and segmentation. They enabled the researcher to work with large and detailed imagery, ensuring accuracy and efficiency in land cover classification tasks. The researcher's choice of high-performance hardware and specialized software underscores the commitment to data quality and the rigorous nature of the study. It also reflects the ever-evolving technological landscape in geospatial research, where cutting-edge tools are essential for producing meaningful and reliable results.

In addition to these advanced workstations, a comprehensive suite of software packages was employed to meet various research needs. These tools facilitated tasks ranging from data correction to visualization, mapping, and documentation, enhancing the overall research process. The seamless integration of hardware and software resources ensured that the study could efficiently process and analyze data, ultimately leading to the generation of valuable insights and meaningful results. The following software packages were employed for this study:

eCognition: This is a powerful image analysis software designed specifically for geospatial data processing, serving a broad spectrum of applications, including land cover classification, vegetation mapping, change detection, and urban planning. A key feature of the eCognition software is its capacity for object-based image analysis (OBIA).

INPHO: This professional, licensed photogrammetry software was used to correct the radiometry of aerial and satellite images.

ArcGIS: ArcGIS was utilized for data analysis, visualization, overlaying, georeferencing, transforming projections, mosaicking, digitizing, organizing, and map preparation.

Google Earth: Google Earth was used for comparative analysis with historical image archives and to verify results against ground truth data.

Microsoft Office: Microsoft Office tools were employed to create word documents, analyze spreadsheets, manage databases, create presentations, and facilitate data management. Other software tools were used as needed.

Global Mapper Software: This software was employed for tasks such as file conversion, reprojecting data, and data manipulation. These hardware and software resources were integral to the successful execution of the study, enabling the researcher to efficiently process and analyze data, and generate meaningful results.

3.6. Data Extraction and Analysis Methods

3.6.1. Object Based Image Classification

To meet the objectives of the study object-based image classification were utilized to extract the land use land cover change and spatial urban sprawl trends of the study area. Object-based image classification is an approach that has gained recognition and popularity in remote sensing and geospatial analysis due to its ability to overcome the limitations associated with traditional pixel-based techniques. It is considered a more effective method for accurate land cover classification, particularly in the context of high-resolution satellite imagery.

Pixel-based techniques have long been the standard for image classification, where each individual pixel is assigned to a specific land cover class based on its spectral properties. However, when dealing with high-resolution satellite images, this approach tends to create what is commonly referred to as the "salt and pepper" phenomenon. This phenomenon arises because high-resolution images capture detailed information at a fine scale, and as a result, individual pixels may exhibit mixed characteristics, making it challenging to accurately classify them. This can lead to inaccuracies in land cover classification.

As noted by (Campagnolo, 2018) their work on "Contextual classification of remotely sensed images with integer linear programming," the "salt and pepper" phenomenon are a recognized challenge in pixel-based classification, and it can hinder the precision of land cover mapping. To address this issue, object-based image classification has emerged as a more effective alternative. This approach groups adjacent pixels with similar spectral characteristics into objects or segments, which are then analyzed in the context of their neighboring features. By considering the spatial and contextual information of these objects, objectbased classification techniques can produce more accurate results, especially in highresolution satellite imagery.

As indicated in a study by(Makinde,et al, 2016) ,the utilization of object-oriented classification methods has shown superior performance in land cover classification. Object-based approaches allow for a more comprehensive understanding of the landscape, taking into account not only the spectral properties of individual pixels but also their spatial relationships, sizes, and shapes. This contextual analysis minimizes the "salt and pepper" effect and enhances the overall accuracy of land cover

classification. The relative merits of pixel-based analysis and object-based analysis have been debated a lot. However, Object-based image analysis (OBIA) is now believed to have advantages compared to pixel-based analysis for the following reasons. Essentially, the greater variability found in high spatial resolution imagery can confound traditional pixel-based classification methods, leading to decreased accuracy (Hay & Castilla, 2006) .Moreover, when image objects are accurately delineated, they exhibit strong associations with real-world objects. After the derivation of these objects, they can be used to establish topological connections with other objects and apply statistical summaries of spectral and textural attributes, as well as shape characteristics, in the classification process. (Rapoza, 2008) When comparing these two techniques, it becomes evident that object-based classification offers greater accuracy and also offers numerous advantages over pixel based classification in the majority of applications, especially for high and very high spatial resolution images (srivastava & Dutta, 2016).

3.6.2. Image Classification

In the research workflow, after successfully completing all pre-processing tasks, the focus turned to the critical task of image classification. This classification step lays the foundation for the subsequent change detection process, making it a pivotal component of the study. Classification serves as one of the key mechanisms employed in the context of change detection methodologies, and, for this particular investigation, a supervised object-based classification approach was adopted. The effectiveness of this method heavily relies on the judicious selection of training samples, which is essential for achieving accurate and reliable classification results. Both the quality and quantity of these training samples play a pivotal role in the production of high-quality classification outcomes. It's worth emphasizing that high-resolution remote sensing images encompass a diverse array of objects, each with unique characteristics and requiring distinct segmentation scales for optimal analysis (Feng & Cheng,

2018) .To address this diversity, the researcher harnessed the power of eCognition, an object-oriented segmentation software. This software allowed for multi-resolution segmentation; an approach that accommodates the diverse scales and resolution in the imagery. Segmentation involves the process of clustering neighboring pixels into distinct regions or segments based on shared characteristics, which may include scale, color, and shape. Within the eCognition software, multiresolution segmentation is a pivotal and initial step. It facilitates the extraction of uniform image objects, often without the need for extensive prior knowledge, at various resolutions, with a particular focus on local variations in contrast. The outcome of this segmentation process generates image objects that can subsequently undergo classification in the subsequent phase (Xiaoxia Zhang & Zhengjun, 2004). Additionally, the utilization of different parameters within the software was employed to fine-tune and enhance the classification process, ensuring that it accommodated the complex and multi-layered nature of the objects within the images.

3.6.3. Major Land-Use and Land-Cover Classes

The study acknowledges the diversity in land-use and land-cover classification schemes employed globally, with notable examples including the Anderson, National Land Cover Data, and FAO Land Cover Classification System (Horning, 2004). Despite the absence of a universally agreed-upon international standard for such classifications, researchers commonly draw upon existing schemes, customizing them to align with the specific objectives of their studies. In this study, five primary land-use and land-cover categories exist, namely built-up areas, bare land, forested areas, water bodies, and agricultural land. The selection of these categories was guided by the nuanced requirements of the research objectives. Notably, the classification methodology aligns with the FAO Africover framework (FAO, 1997)demonstrating a deliberate choice to utilize a recognized and regionally relevant system (‘FAO Africover, 1997). The details of this adjustment are provided in Table 3 ,providing transparency and a comprehensive understanding of the implemented classification scheme within the contextual framework of the study. This customized approach ensures that the classification system not only incorporates international perspectives but also effectively aligns with the regional context, enhancing its suitability and relevance to the specific characteristics of the study area.

Table 3: Major land-use and land-cover class types of the study area.

No	LULC Class	Description
1	Built-up area	Are cities; towns; villages; strip tendencies alongside highways; transportation, power, and conversation facilities; by mills, shopping centers, cultural, industrial, and commercial complexes, institutions, blocks and, roads
2.	Bareland	Is a land of restricted capacity to assist lifestyles and in which much less than one-third of the area has plants or another cover. Includes such areas as dry salt flats, beaches, bare exposed rock, strip mines, quarries, and gravel pits. Wet, no vegetated barren lands are included in the wetland category.
3.	Vegetation	Economic forests such as timber and fuel woodland other natural and Artificial forests; include any kind of woody plant vegetation growing in and around human settlements
4	Farmland	area that is either arable, under permanent farms, or permanent pastures, Crop fields and fallow lands
5	Waterbody	All areas of open water, including rivers, ponds, streams, lakes, and reservoirs

3.7. Methods of Data Analysis

To analyze the data from the provided figure 5 using ArcMap ,eCognition, and Global mapper a combination of remote sensing techniques and advanced image processing methods can be employed. First, the high-resolution imagery acquired from Ultracam Eagle in 2011 and 2019, along with the 2003 data from Maxar Technologies, can be imported into ArcMap for spatial analysis. Utilizing ArcMap's capabilities, researchers performed supervised classification to categorize land use and land cover types, leveraging the varying spatial resolutions to enhance classification accuracy. The 20 cm and 10 cm resolutions from the Ultracam Eagle images allow for more detailed feature extraction compared to the 50 cm resolution of the Maxar imagery.

Following the initial classification in ArcMap, eCognition can be utilized for object-based image analysis, which is particularly effective for urban environments where complex land cover types exist. This method allows for the segmentation of images into meaningful objects, enabling a more refined classification process. By applying eCognition, researchers improved the accuracy of LULC classifications and detect subtle changes over the years. Change detection analysis can then be conducted to compare the classifications from 2003,2011 and 2019, identifying areas of urban sprawl and shifts in land cover. This integrated approach not only enhances the understanding of urban dynamics but also supports effective land management and planning efforts by providing insights into how land use has evolved over time. The methodological flow chart of the study area is developed in Figure 6.

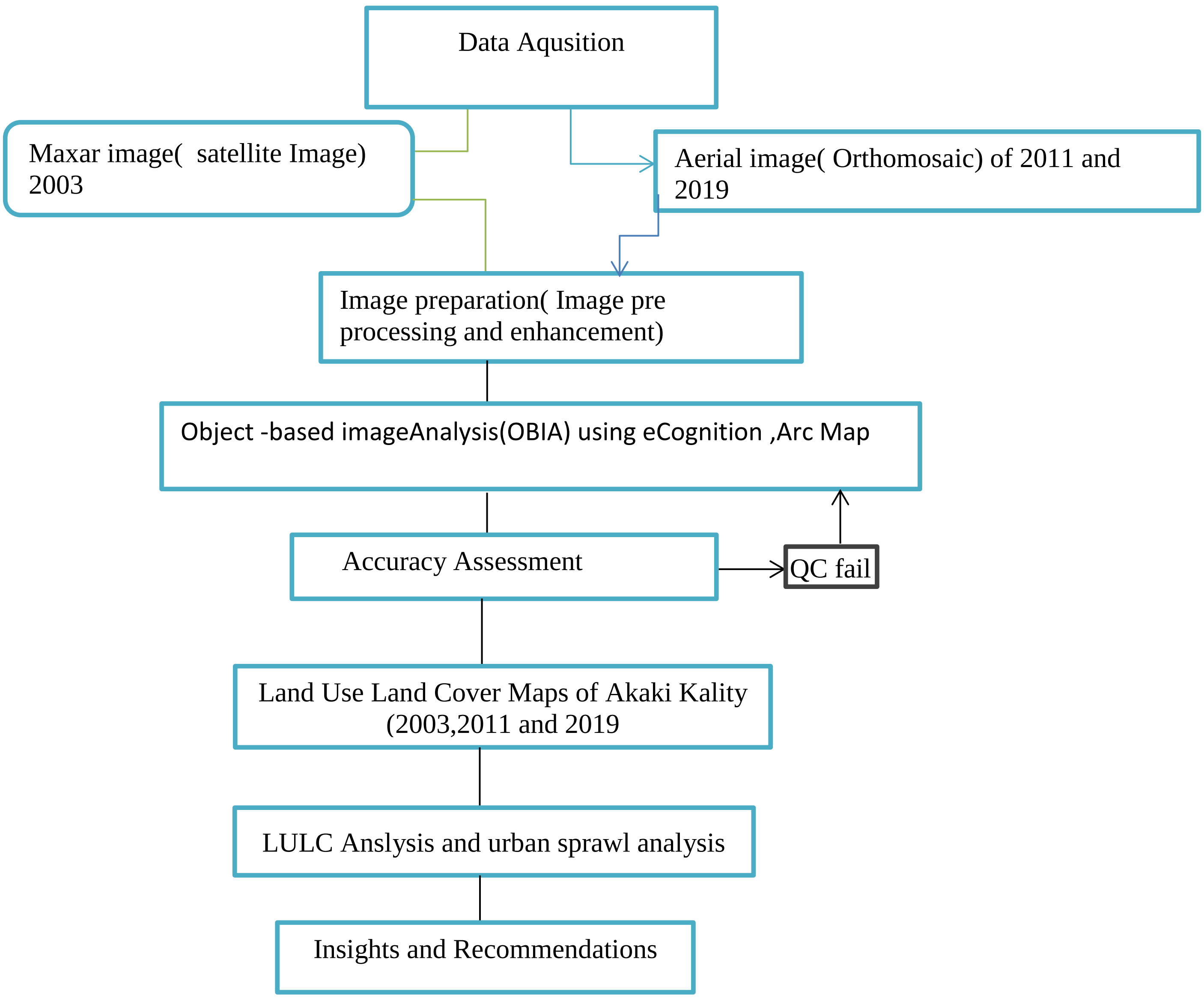

Figure 5: Work Flow Chart

3.8 Accuracy Assessment

Accuracy assessment is the procedure used to quantify the reliability of a classifiedimage. A widely used approach to represent classification accuracy is by creating aclassification error matrix, which is also referred to as a confusion matrix or acontingency table. Error matrices, or confusion matrices, enable a detailed comparisonbetween known reference data (ground truth) and the outcomes of an automatedclassification on a class-by-class basis. These matrices have a square shape, where thenumber of rows and columns corresponds to the number of categories being evaluatedfor their classification accuracy (Kiefer & Chipman, 2004).After classification process is completed, accuracy assessment for each landcover/land-use has been done to make sure the classification is accurate enough for use.To assess classification accuracy the classified map derived from Aerial and Satelliteimage data were checked using error matrixes in Esri Arc GIS software. To accomplishthis, a set of randomly selected 250 points per each 8-year interval classified imageswith well-known true values was identified in ArcMap. These points/features were thenused in the Arc Map Accuracy Assessment tool to conduct an accuracy assessment of the land use/land cover classification in the study area. As the researcher utilized highresolution satellite and aerial images with pixel resolutions ranging from 10 cm to 50 cm, the sample ground objects were clearly identified and visually inspected.

The commonly utilized approaches for accuracy assessment consist of the producer's accuracy, user's accuracy, overall accuracy, and Kappa coefficient. After creating the error matrix for each classification, user accuracy, producer accuracy, overall accuracy and kappa coefficient were computed (Kiefer & Chipman, 2004).The user's accuracy provides information about the frequency at which the represented class on the map corresponds to its actual presence on the ground, which we refer to as its reliability. It is calculated by dividing the number of accurately classified object within each category by the total number of correctly classified objects, and then multiplying the result by 100 (Kiefer & Chipman, 2004).

User Accuracy= $(Number\ of\ correctly\ classified\ object\ in\ each\ class) / (Row\ Total) * \mathbf{100}$ **Eq 3. 1**

The producer's accuracy is the probability that a specific feature in a ground area is correctly classified as such. It is calculated by dividing the number of pixels accurately classified in each category by the total number of sample pixels taken for that category (column total)

$$\text{Producer's accuracy} = (Number\ of\ correctly\ classified\ object\ in\ each\ class) / (Column\ Total) * 100 \quad \text{Eq 3. 2}$$

Overall Accuracy provides us with what percentage of the whole reference (training sample) was correctly mapped. the overall accuracy is computed by dividing the total number of correctly classified pixels/object (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels/objects ((Kiefer & Chipman, 2004).

$$\text{Overall Accuracy} \equiv \frac{Total\ Number\ of\ correctly\ classified\ features(diagonal)}{Total\ Number\ of\ reference\ features} * 100 \quad \text{Eq 3. 3}$$

Kappa coefficient is another measure of accuracy assessment that makes a better estimate than overall accuracy; because it is capable of controlling the PCC index and incorporates off-diagonal values to calculate the coefficients. Kappa coefficient results are always less than 1 and results approaching to 1 indicate excellent agreement between the classified map and reference data.

$$Kappa \equiv \frac{(Total\ number\ of\ feature * Number\ of\ corrected\ featrues) - (Sum\ of\ all\ row\ total * column\ total)}{Total\ Number\ of\ features\ squered) - (Sum\ of\ all\ row\ total * column\ total)} \quad \textbf{Eq 3.4}$$

CHAPTER FOUR

4.Results and Discussion

4.1.Results

This section briefly presents the results of generated land-use and land-cover analysis ,along with the urban sprawl patterns derived from the classification of high-resolution aerial and satellite image for the periods of 16 years.It encompasses the accuracy assessment of the land use and land-cover classification,analysis of the nature, extent, and rate of the land cover changes and urban sprawl patterns.

In this study, five primary land-use and land-cover categories exist, namely built-up areas, bare land, vegetation, water bodies, and agricultural land. The selection of these categories was guided by the nuanced requirements of the research objectives. Notably, the classification methodology aligns with the FAO Africover framework (FAO Africover, 1997),

4.2. Land-Use and Land-Cover of Akaki Kality

To analyze the Land Use Land Cover (LULC) of Akaki Kality sub-city, researcher employed high-resolution aerial and satellite image spanning eight different years of 2003,2011 and 2019. These images were instrumental in classifying the LULC into five major categories, namely built-up areas, bare land, vegetation, farm land, and water bodies. The methodology outlined the systematic categorization of every feature within the study area into one of these five classes.

The results of the LULC analysis for each year are effectively conveyed through maps, figures, and charts, offering a visual representation of the spatial distribution and composition of various land cover types. Subsequently, a comparative analysis of the results from the three different years reveals the temporal changes in LULC dynamics over the specified period.

The classification scheme designates built-up areas, farm land, bare land, vegetation, and water bodies as the principal LULC classes for the study area. The application of ArcGIS software facilitated the implementation of a change detection technique postclassification. This method is widely acknowledged in urban settings for efficiently identifying the location, type, and speed of changes (Hassan et al., 2016).

The study assessed the rate of change in LULC over the difference of eight year period, spanning from2003 to 2019. Change statistics and area estimates were calculated for each land useland cover class.

Table 4 : LULC of Akaki Kality from 2003-2019

No.	LULC Class	2003 Area(ha)	Percentage	2011 Area(ha)	Percentage	2019 Area(ha)	Percentage
1.	Builtup	2188.9	32.9%	2927.2	44.1%	4172.1	62.8%
2.	Farmland	3938.8	59.3%	3127.7	47.1%	1787.9	26.9%
3.	Vegetation	121.3	2.7%	180.6	2.7%	300.5	4.5%
4.	Bareland	281.7	4.2%	324.2	4.9%	317.2	4.8%
5	Waterbody	113.7	1.7%	84.7	1.3%	66.7	1%

As Illustrated in Table 4. above and figure 7 below Akaki Kality is experiencing LULC change in the study period of 2003-2019.

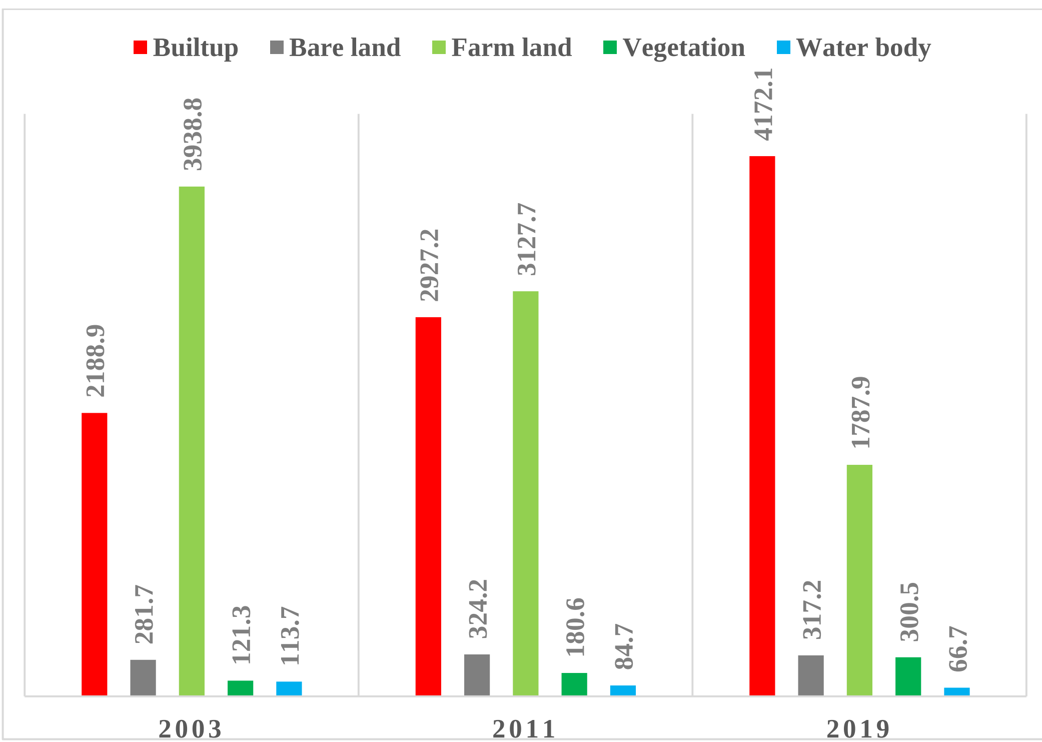

Figure 6: Landuse Land cover change of Akaki Kality Sub City (2003-2019)

4.2.1.Lad use Land cover map in 2003

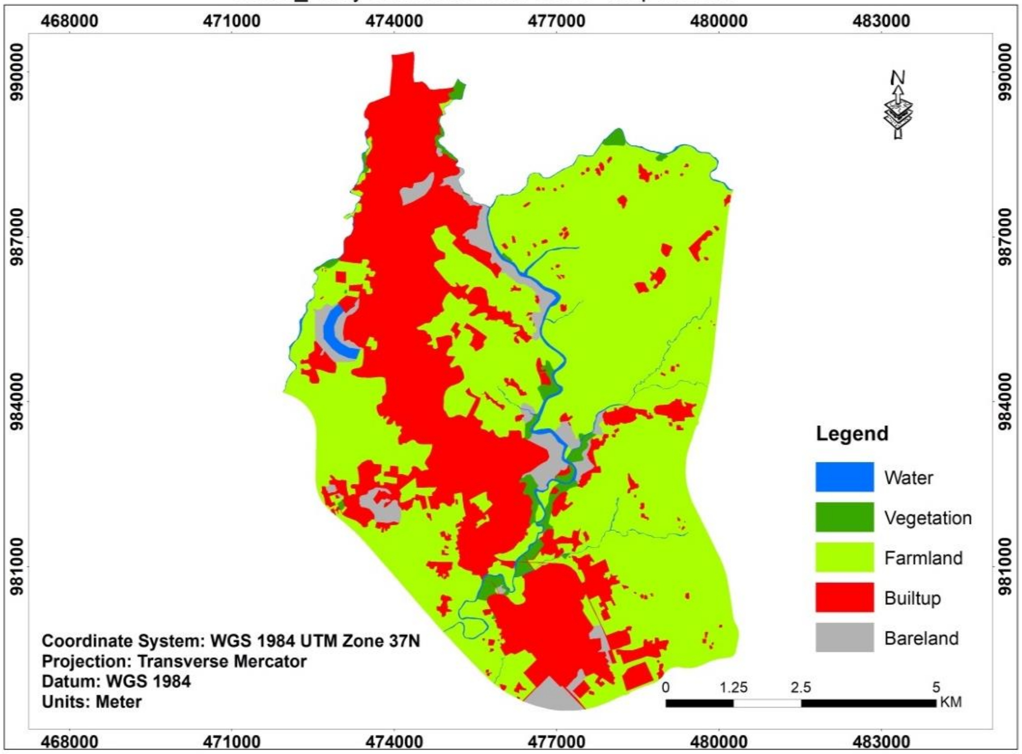

Figure 7. Land use land cover Map of Akaki Kality of 2003

Source: Computed from 2003 Satellite Images

Table 5: LULC of Akaki Kality in 2003.

No.	LULC Class	2003 Area(ha)	Percentage
1.	Builtup	2188.9	32.9%
2.	Farmland	3938.8	59.3%
3.	Vegetation	121.3	2.7%
4.	Bareland	281.7	4.2%
5	Waterbody	113.7	1.7%

In 2003, the dominant land use pattern in the study area was characterized by a mix of agricultural and urban landscapes. Farmland accounted for the largest portion at 59.3%, covering approximately 3938.8 hectares. Urban development was also evident, with built-up areas covering 2188.9 hectares, representing 32.9% of the total area.

Vegetation coverage was minimal at 121.3 hectares, accounting for just 2.7% of the total area. Bare land made up 281.7 hectares, or 4.2% of the area.Water bodies were present but limited, occupying 113.7 hectares or 1.7% of the total area.

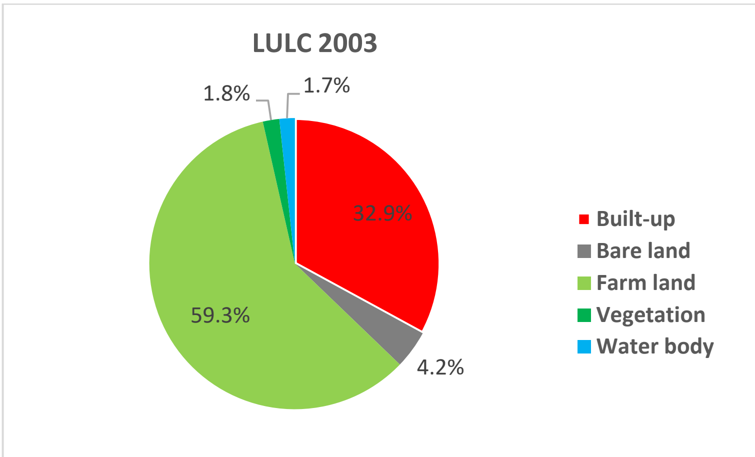

Figure 8 : Land use land cover (LULC) in 2003

Generally, this indicates that in 2003, almost 92.2% of the study area was covered by farmland and built-up areas. Bare land, vegetation, and water bodies covered the remaining portions of the study area in 2003, respectively.

4.2.2. Land Use Land Cover in 2011

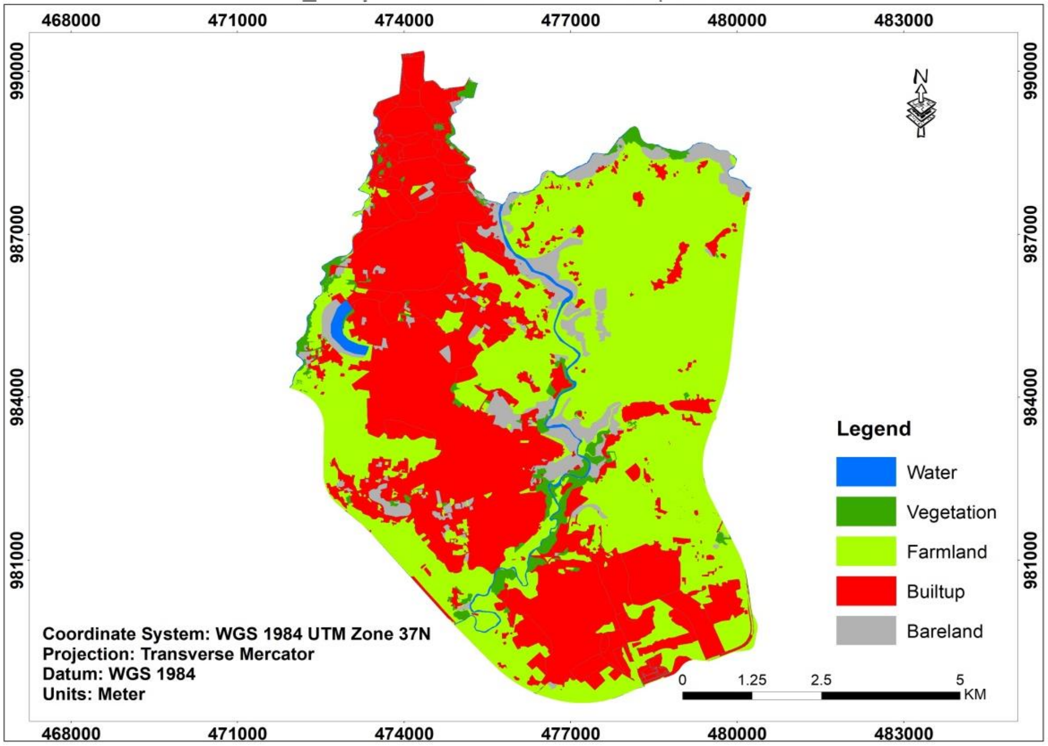

Figure 9 : Land Use Land Cover map of Akaki kality in 2011

Source: Computed from 2011 Aerial image.

The analysis of land use land cover in Akaki kality , as depicted in figure 10 shows the dominance of farmland in 2011. Among the classified land use land cover categories, farmland encompassed the largest share, coveringan extensive area of 3127.7hectares, accounting for 47.1% of the total area. Builtup areas covered the second largest area (2927.2ha) which is 44.1% of the area. 324.2 ha 180.6 ha and 84.7ha were respectively covered by Bareland, Vegetation and Waterbody for the study area.Compared to that of 2003, the significant change is observed in built up areas and farmland. The built up area is rapidly increased to the study area by 11.2% and the farmland is decreased by 12.2% . Modest changes were occurred in vegetation(0.9%) increased, bareland(0.7%) and the coverage for water body is decreased by 0.4 %.

Table 6 : LULC of Akaki Kality in 2011.

No.	LULC Class	2011 Area(ha)	Percentage
1.	Builtup	2927.2	44.1%
2.	Farmland	3127.7	47.1%
3.	Vegetation	180.6	2.7%
4.	Bareland	324.2	4.9%
5	Waterbody	84.7	1.3%

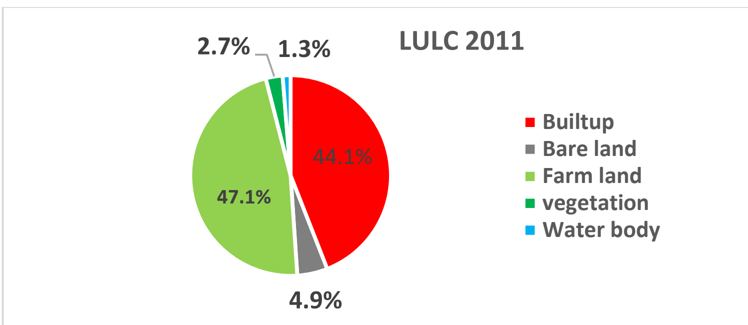

Figure 10 :LULC of Akaki Kality in 2011

Between 2003 and 2011, significant shifts occurred in various land use categories within the studied area. Urban development experienced substantial growth, with built-up areas increasing by 738.3 hectares, representing an 11.2% expansion. Conversely, farmland declined dramatically, decreasing by 811.1 hectares, which translates to a 12.2% reduction. Bare land saw minimal change, with a slight increase of 42.5 hectares (0.7%). Vegetation coverage also showed modest growth, rising by 59.3 hectares (0.9%). Water bodies experienced the most pronounced decline, with a decrease of 29 hectares (0.4%) during this period. These changes reflect the dynamic nature of land use transformation, particularly evident in the rapid expansion of urban areas and the corresponding contraction of agricultural lands.

4.2.3. _Land use land cover in 2019

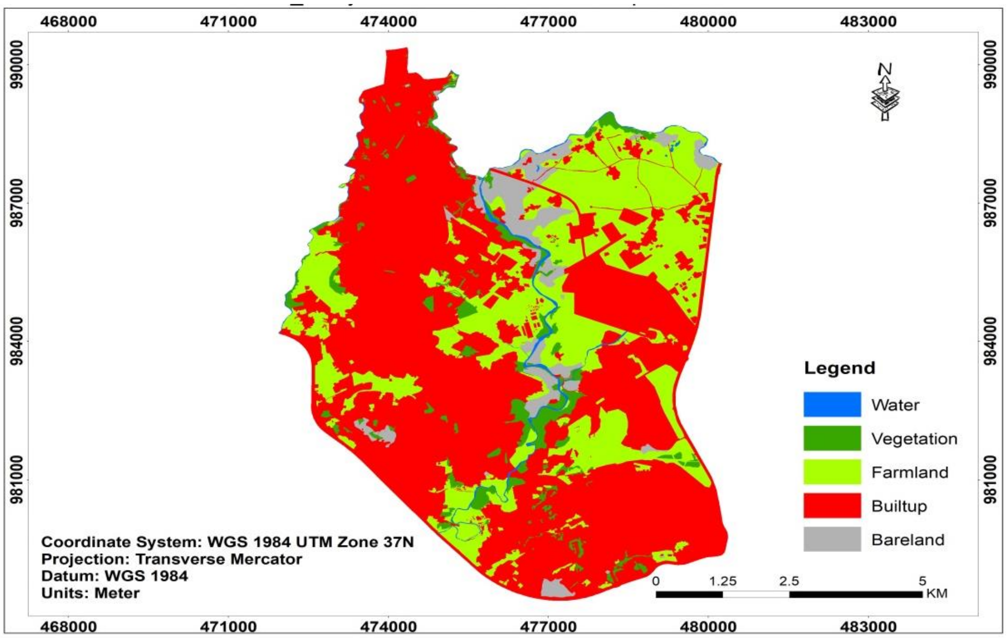

Figure 11: Land use land cover map of Akaki Kality in 2019

Source: Computed from Aerial image of 2019

Table 7: LULC of Akaki Kality in 2019

No	LULC Class	2019	Percentage
		Area(ha)	
1	Built up	4172.1	62.8%
2	Farmland	1787.9	26.9%
3	Vegetation	300.5	4.5%
4	Bareland	317.2	4.8%
5	Water body	66.7	1%

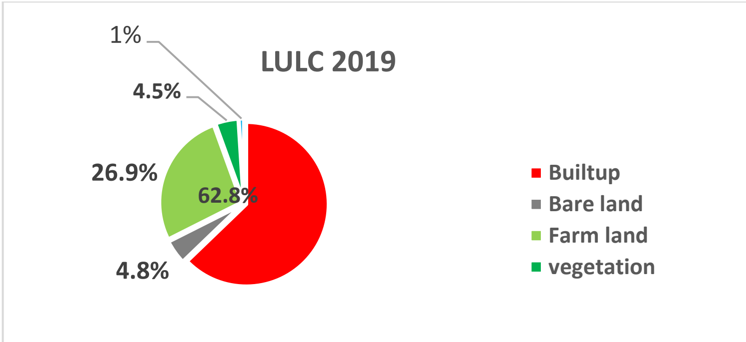

Figure 12:LULC of Akaki Kality in 2019

The land use and land cover (LULC) analysis of 2019 reveals a dominance of built-up areas, accounting for 62.8% of the total land cover. Farmland occupies the second-largest portion, covering 26.9% of the area. Vegetation and bare land constitute relatively smaller proportions, at 4.5% and 4.8%, respectively. Water bodies, make up the remaining 1% of the land cover. This distribution shows the significant level of urbanization in the study area, with built-up areas expanding at the expense of other land cover types, particularly farmland.

4.3. Land Use Land Cover Change Detection

The land-use land cover changes of the Akaki Kality sub-city are shown in two ways:First, by comparing the total area coverage of each LULC and secondly, by computingthe annual land-use land cover change (conversion) rate. It is as follows in the table below:

Table 8: Land use land cover change of Akaki Kality of 2003-2019

No	LU Class	2003		2011		2019	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
1	Built-up	2188.9	32.9%	2927.2	44.1%	4172.1	62.8%
2	Bare land	281.7	4.2%	324.2	4.9%	317.2	4.8%
3	Farm land	3938.8	59.3%	3127.7	47.1%	1787.9	26.9%
4	Vegetation	121.3	1.8%	180.6	2.7%	300.5	4.5%
5	Water Body	113.7	1.7%	84.7	1.3%	66.7	1.0%
Total		6644.4	100	6644.4	100	6644.4	100

Source: computed from satellite image and aerial Images of 2003 and 2019

As table 8 demonstrates the analysis of land use and land cover (LULC) changes in Akaki Kality Sub-City from 2003 to 2019 reveals significant transformations, particularly in built-up areas. In 2003, built-up areas constituted 32.9% of the total land, which increased dramatically to 44.1% in 2011 and further to 62.8% by 2019. This trend indicates a substantial urban sprawl, with built-up areas expanding by nearly 2,000 hectares over the 16-year period.

Conversely, farmland, which comprised 59.3% of the area in 2003, experienced a notable decline, dropping to 47.1% in 2011 and plummeting to 26.9% by 2019. This reduction suggests a shift from agricultural land to urban development, reflecting the pressures of urbanization on agricultural resources.

Bare land showed a slight increase from 4.2% in 2003 to 4.9% in 2011, but it remained relatively stable at 4.8% in 2019. Vegetation cover also increased from 1.8% to 4.5% over the same period, indicating some positive environmental changes amidst urban expansion. Water bodies, however, saw a decrease from 1.7% in 2003 to just 1.0% in 2019, highlighting a concerning trend in water resource management.

The above table 8 data can be illustrated in a graph as follows

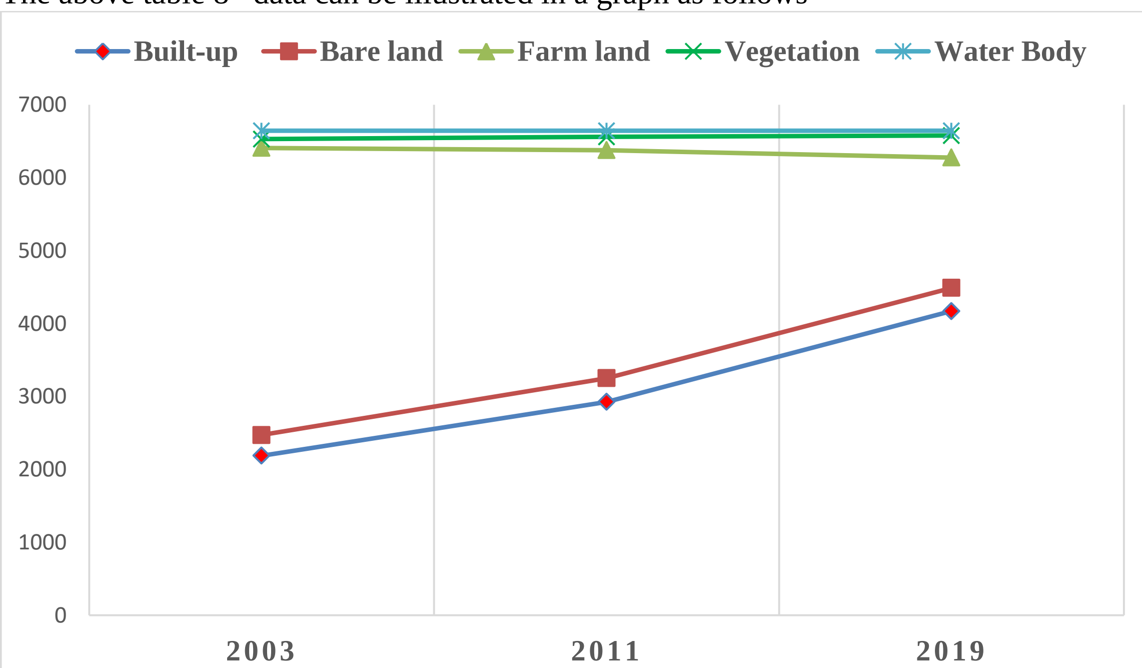

Figure 13:Akaki Kality Sub city LULC Change trend from 2003 to 2019.

To quantify the extent of positive (increase) and/or negative (decrease) change in each category and determine the change in percentage for each year using the following formula (Abdurahman et al., 2023):

LULC $Change\ in\ \%= (\text{Total Area in T2} - \text{Total Area in T1}))/(\text{Total Area T1}) \ast 100$ Eq 4. 1

Where T1 is earlier point of time and T2 is the later or recent point of time in the series

In the other hand annual rate of change in LULC is calculated based on the formula.

Annual rate of change in LULC= $(\%\textbf{in LULC in the study Period}) / (\textbf{years in the study Period})$ ***Eq 4.2***

The annual land use land cover change in hectare is computed with the following equations as follows:

LULC Changes= Area of Year2-Area of year 1 ***Eq 4. 3***

The formula LULC Changes = Area of Year 2 - Area of Year 1 measures the change in a specific land use or land cover type over a defined time period. Here, "Area of Year 2" represents the total area occupied by that land use in the second year, while "Area of Year 1" indicates the area in the first year. By subtracting the first year's area from the second year's area, the formula calculates the net change: a positive value indicates an increase in the land area for that use, whereas a negative value signifies a decrease.

	2003-2011	2011-2019
Builtup	738.3	1244.9
Bare land	42.5	-7
Farm land	-811.1	-1339.8
Vegetation	59.3	119.9
Water Body	-29	-18

Builtup Bare land Farm land Vegetation Water Body

Figure 14 :Akaki Kality sub-City LULC Change in (ha) from 2003 to 2019.

In Akaki Kality sub-C ity, the Land Use and Land Cover (LULC) changes from 2003 to 2019 were significant .The results indicate a significant expansion of built-up areas, with an increase of 738.3 hectares from 2003 to 2011 and an additional 1244.9 hectares from 2011 to 2019, totaling 1983.2 hectares over the 16-year period. Conversely, bare land exhibited a negligible net change, with an initial increase of 42.5 hectares from 2003 to 2011 followed by a decline of 7 hectares from 2011 to 2019. Notably, farm land underwent a substantial decline, with a decrease of 811.1 hectares from 2003 to 2011 and an additional 1339.8 hectares from

2011 to 2019, resulting in a total loss of 2150.9 hectares. In contrast, vegetation cover demonstrated a steady increase, with a gain of 59.3 hectares from 2003 to 2011 and an additional 119.9 hectares from 2011 to 2019, totaling 179.2 hectares. Finally, the water body area experienced a cumulative decline of 47 hectares over the study period, with a decrease of 29 hectares from 2003 to 2011 and an additional 18 hectares from 2011 to 2019. These findings highlight the dynamic nature of LULC changes in Akaki Kality sub-City, with significant implications for urban planning, environmental management, and sustainable development.

Table 9: Akaki Kality Sub –city LULC change in percentage from 2003 to 2019.

Year Range	**Conversion Type**	**Percentage**
2003 to 2011	Farmland converted to built-up	11.2%
	Farmland converted to bare land	0.7%
	Farmland converted to vegetation	0.5%
	Waterbody converted to vegetation	0.4%
2011 to 2019	Farmland converted to built-up	18.7%
	Farmland converted to vegetation	1.4%
	Water body converted to vegetation	0.3%
	Bare land converted to vegetation	0.1%

The findings show significant changes in land use patterns between these two periods. From 2003 to 2011, there was moderate conversion of farmland to built-up areas and minimal changes in other categories. However, from 2011 to 2019, there was a substantial increase in farmland being converted to built-up areas, with nearly double the percentage compared to the previous period. This suggests rapid urbanization during this time frame. Additionally, there was an increase in farmland being converted to vegetation.

Table 10: Annual Land use LULC change rate in percentage

LU CLASS	2003-2011	2011-2019
Built-up	4.23	5.34
Bare land	1.89	-0.32
Farm land	-2.57	-5.35
Vegetation	6.11	8.29
Water Body	-3.18	-2.65

Source: Computed from the classified LULC aerial and satellite image

4.4. Urban Sprawl Patterns of Akaki Kality

In this section, the researcher analyzed the data presented in table 8 below, which provides information on the urban sprawl patterns of Akaki Kality Sub City over theyears from 2003 to 2019.

Table 11: Built-up Vs non-Built-up land-use class Area from 2003 -2019

Land use class	2003	2011	2019
Built-up	2188.9	2927.2	4172.1
Non-built -up	4,455.5	3,717.2	2,472.3

The land use analysis for Akaki Kality from 2003 to 2019 reveals significant transformations in both built-up and non-built-up areas. The built-up area has increased markedly, rising from 2188.9 hectares in 2003 to 2927.2 hectares in 2011, and further expanding to 4172.1 hectares by 2019. This substantial growth indicates a trend of rapid urbanization and development within the sub-city, reflecting increased infrastructure and housing demands. In stark contrast, the non-built-up area has declined significantly, decreasing from 4455.5 hectares in 2003 to 3717.2 hectares in 2011, and plummeting to 2472.3 hectares by 2019. This reduction highlights a concerning loss of open spaces, agricultural land, and natural habitats, raising critical issues regarding environmental sustainability and the need for effective land management practices.

4.4.1.Urban Sprawl Patterns of Akaki Kality in 2003, 2011 and 2019.

The built-up maps of the study area from 2003 ,2011 and 2019 reveals significant urban development characterized by distinct sprawl patterns. The analysis identifies the prevalence of Leapfrog Sprawl , Edge Sprawl, with notable instances of suburban or low-density sprawl for the study periods.

4.4.1.1 Leapfrog Sprawl

This pattern occurs when new developments are established far away from existing urban areas, skipping over vacant land.The map shows isolated pockets of built-up areas surrounded by non-built-up regions. These clusters suggest leapfrog development, where new construction is not contiguous with existing urban fabric but rather jumps over open spaces. Leap-frog development is often viewed negatively due to its inefficiencies and impact on community cohesion. This pattern of growth, where isolated developments are built far from existing urban areas, leads to wasted resources, as infrastructure like roads and utilities must be extended to these distant locations, raising costs significantly. It also results in inefficient land use, with large vacant areas left undeveloped between communities, limiting cohesive future growth. Additionally, leap-frog development hinders community development, as isolated areas often lack essential services, schools, and social amenities, creating a less connected environment. The maps illustrate this with multiple clusters of built-up areas, particularly in the northeastern and southeastern sections, surrounded by large expanses of non-built-up land, indicating clear leapfrog development.

4.4.1.2 Edge Sprawl

Edge sprawl refers to the expansion of urban development at the periphery of a city, often leading to the encroachment of rural land.This growth typically occurs in a contiguous manner while encroaching on rural or undeveloped areas. The map reveals this trend in the northwestern and eastern regions, where built-up areas extend outwards from the main urban core, forming a continuous band of development into previously rural spaces.Egde sprawl can be good or bad , depending on how it's managed. Controlled edge sprawl can accommodate population growth in a planned manner, providing housing and employment opportunities.Unplanned edge sprawl can lead to urban sprawl issues like traffic congestion, pollution, and loss of green spaces. The maps reveal this trend in the northwestern and eastern regions, where built-up areas extend outwards from the main urban core, forming a continuous band of development into previously rural spaces.

4.4.1.3 Suburban or Low-Density Sprawl.

Suburban sprawl is characterized by low-density residential development, typically featuring single-family homes. This sprawl results in significant land consumption and inefficient space utilization. The specific features of low-density urban sprawl that can be seen in the figure are the presence of large areas of undeveloped land between built-up areas,the scattered nature of the built-up areas, with many small, isolated developments ,the low density of the built-up areas, with many single-family homes and large lots and the lack of a clear urban center or cor Leapfrog development and suburban sprawl are generally considered harmful. They lead to Inefficient land use, environmental degradation and economic challenges.

This transformation has been characterized by a marked increase in settlement areas, where previously agricultural land has been converted into urban spaces. Several key factors contribute to this rapid urbanization.

Population Pressure: The growing population in Akaki Kality is a primary driver of urban sprawl. As more people migrate to the area in search of better opportunities, the demand for housing rises, leading to the expansion of residential neighborhoods. This influx not only strains existing infrastructure but also prompts the conversion of agricultural land into housing developments, which further accelerates the sprawl.

Establishment of Manufacturing and Industries: The sub city has become a hub for manufacturing and industrial activities, attracting businesses and workers alike. The establishment of factories and industrial zones contributes to economic growth but also necessitates more housing and services for the workforce. As industries expand, they often encroach on nearby cropland, leading to the loss of agricultural areas and altering the landscape of Akaki Kality.

Economic Factors: Economic development plays a crucial role in driving urban sprawl. With increased investment in the area, both from local and foreign sources, the demand for land for commercial use, housing, and infrastructure has surged. This economic growth often leads to unplanned or poorly managed development, resulting in sprawl that can exacerbate issues like traffic congestion, inadequate public services, and environmental degradation.

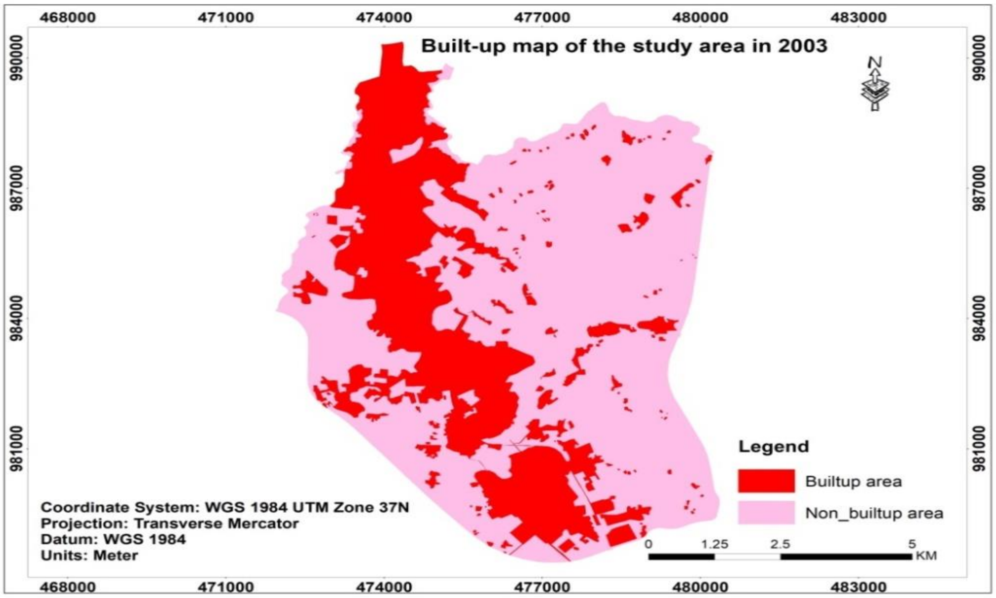

Figure 15 : Built-up area map of the study area in 2003

Figure 16 indicates that the urban sprawl is occurring in a radial or centrifugal manner, with the built-up areas expanding from the central core towards the periphery. The sprawl is not confined to a single direction but is occurring in multiple directions, surrounding the central core and gradually consuming the non-built-up areas.

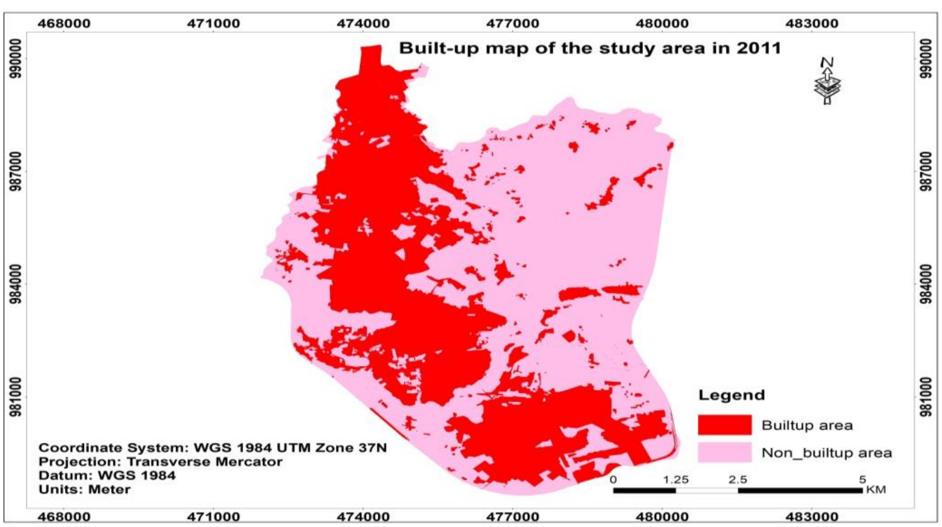

Figure 17 : Built-up area map of the study area 2011

The expansion of the built-up areas between 2003 and 2011 implies a high probability of continued urban sprawl in the future, as the development continues to spread outwards from the central core. This pattern of sprawling growth is likely to pose challenges in terms of efficient resource utilization, infrastructure provision, and environmental sustainability, which are common concerns associated with uncontrolled urban expansion. The built-up map of the study area in 2019 shows a highly fragmented and dispersed pattern of urban development, indicating significant urban sprawl in the region. The fragmented nature of the built-up areas implies that the development is not concentrated in a central core or along major transportation corridors, but is instead spreading out in a more haphazard and uncontrolled manner. This dispersed pattern of growth is likely to pose challenges in terms of efficient resource utilization, infrastructure provision, and environmental sustainability.

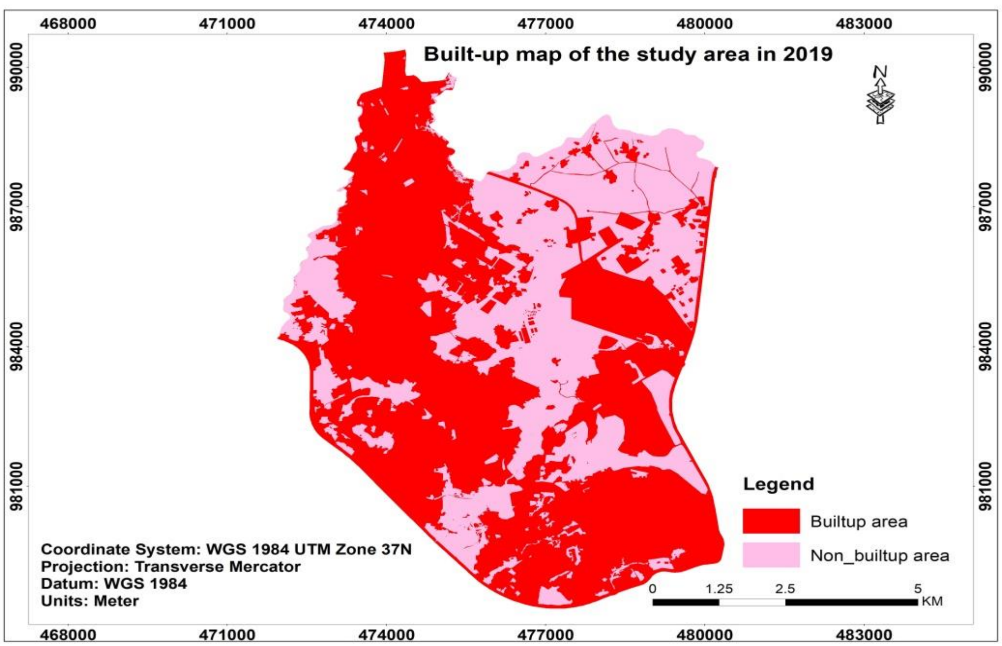

Figure 18: Built-up area map of the study area 2019

To address the challenges posed by leapfrog, low-density, and edge expansion sprawl patterns in Akaki Kaliti Sub-City, a comprehensive strategy leveraging geospatial technologies is essential. First, implementing advanced land-use planning tools, such as Geographic Information Systems (GIS), can help visualize and analyze spatial data to identify areas at risk of sprawl. This analysis can guide zoning regulations that promote higher-density development in urbanized areas, reducing the incentive for leapfrog development.

Additionally, integrating remote sensing technologies can monitor land-use changes over time, providing real-time data to inform policymakers about sprawl patterns and their impacts. This information can facilitate the creation of green belts or buffer zones to contain urban expansion and preserve natural landscapes.

Moreover, promoting infill development through incentives for developers can revitalize underutilized areas, making efficient use of existing infrastructure and reducing the need for new land consumption. Community engagement using participatory mapping can also empower residents to voice their preferences for development, ensuring that growth aligns with local needs and sustainable practices.

By combining geospatial technologies with proactive urban planning and community involvement, Akaki Kaliti Sub-City can minimize the negative impacts of sprawl, fostering a more sustainable, livable urban environment for its residents.

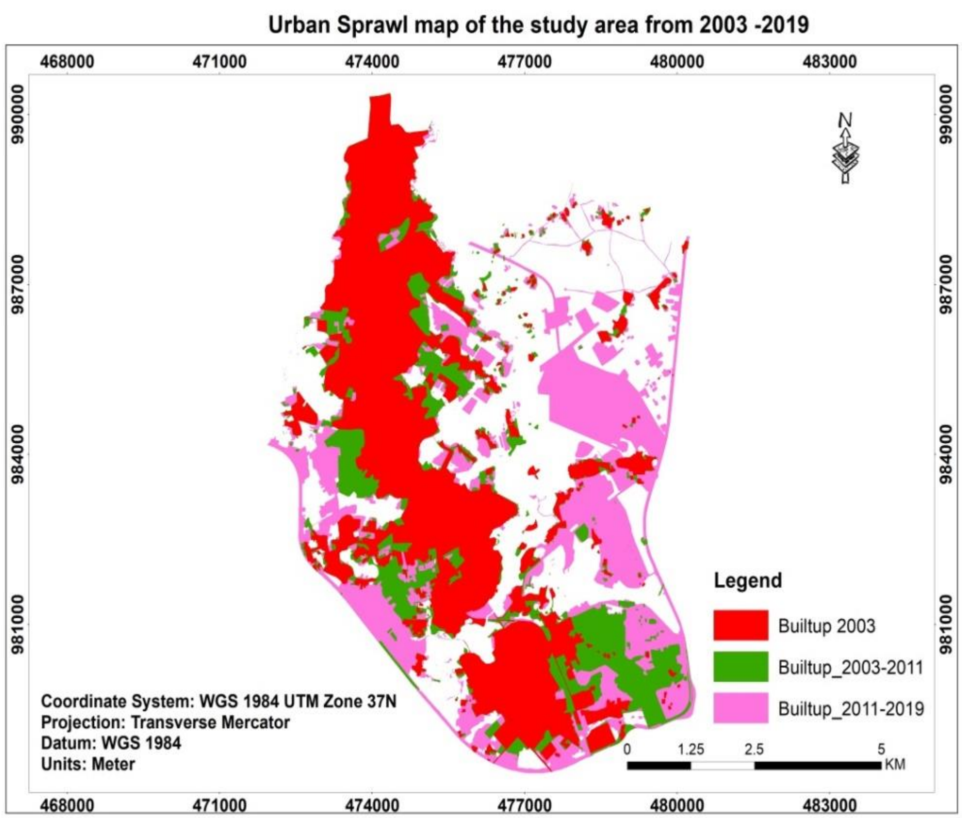

Figure 19:Urban Sprawl Dynamics of Akaki Kality 2003-2019

Table 12: Urban Sprawl Patterns of Akaki Kality Sub city(2003-2019)

Year	Built-up area(ha)	Area(%)	Change in built up Area(ha)	Percentage change in built-up area
2003	2188.9	32.9%	-	
2011	2927.2	44.1%	738.3	33.73%
2019	4172.1	62.8%	1,244.9	42.53%

The data presented in the table 9 illustrates the significant changes in built-up area over a span of 16 years, from 2003 to 2019. In 2003, the built-up area was recorded at 2,188.9 hectares, which constituted 32.9% of the total area. This initial figure highlights the starting point of urban expansion, indicating that a considerable portion of land was still undeveloped. By 2011, the built-up area increased to 2,927.2 hectares, representing 44.1% of the total area. This change of 738.3 hectares corresponds to a percentage increase of 33.73%, showcasing a robust growth in urban development during this period.

The trend continued into 2019, where the built-up area reached 4,172.1 hectares, accounting for 62.8% of the total area. This increase of 1,244.9 hectares marked a substantial growth rate of 42.53% compared to the previous measurement in 2011. The data clearly indicates an accelerating trend in urbanization, with the percentage of built-up area growing significantly over the years. The transition from 2003 to 2019 reflects not only an increase in physical space allocated for urban development but also suggests broader socio-economic changes driving this expansion, such as population growth, and economic development, . This analysis underscores the importance of monitoring urban growth patterns to inform future planning and sustainability efforts.

4.5. Accuracy Assessment

All land use and land cover classified map were compared to the reference image datato assess the accuracy of the classification. As there is no internationally accepted standard for determining the number of sample points for accuracy assessment of land use and land cover; in this study the sample points were made based on factors such as the size and complexity of the study area, the number of land cover classes, and thedesired level of accuracy. Randomly selected 250 reference points used for assessing the land-use and land-cover classification data were collected using a random sample distribution feature in ArcMap (see appendix 1 and 2). Each sample data point was visually inspected by overlaying it on the input satellite and aerial images of the study area.

Over all classification accuracy for 2003, 2011 ,and 2019 are 88%, 93%, and92%, respectively. The Kappa coefficient for 2003, 2011, and 2019, images are 0.84, 0.9, and 0.86, respectively. The summary of accuracy assessment results are presented in table 4.8 below.After classification process is completed, accuracy assessment for each land use/landcover has been done to make sure the classification is accurate enough for use. As mentioned by (Anderson et al., 1976) for a reliable land cover classification, the minimum overall accuracy value computed from an error matrix should be 85%.

The study assessed accuracy of the classification results with 250 randomly sampled reference points for each classified image. The error matrix for each classification was created and then overall accuracy and Kappa coefficient were calculated and summarized (Table 4.8) the overall accuracy is a more accurate estimate of accuracy. An impressive overall accuracy of 88% was attained for the satellite image of 2003, accompanied by a robust Kappa coefficient of 0.84. Subsequently, the accuracy improved in the subsequent years, reaching 93% for the 2011 aerial image with a Kappa coefficient of 0.90. The 2019 aerial image exhibited a commendable accuracy of 92%, accompanied by a Kappa coefficient of 0.86. These high levels of accuracy and Kappa coefficients underscore the reliability and precision of the image classification process across multiple years.

According to (Foody, 2020) when the kappa coefficient is approaches to 1 indicates that the classification is better and if it approaches to negative value indicates that the classification is poor performance. Based on this analysis the kappa coefficients are approaches to 1 therefore the classification is good performance. The producer's and user's accuracy for individual land classes presented with table blow for the whole classified images.

As mentioned by (Anderson et al., 1976) for a reliable land cover classification, theminimum overall accuracy value computed from an error matrix should be 85%. theoverall accuracies for 2003, 2011, and 2019 maps were above 85% based on Anderson's criteria. So, the classification accuracy of the study meets this requirement.

Table 13 : Confusion matrix for land cover map of 2003 – 2019.

LULC	2003		2011		2019	
	PA(%)	UA(%)	PA(%)	UA(%)	PA(%)	UA(%)
Built-up	87	99	95	96	94	98
Farmland	96	92	96	87	100	60
Vegetation	88	86	98	94	83	98
Bare land	83	80	88	92	88	79
Waterbody	100	83	83	83	89	89
Over all accuracy	**88**		**93**		**92**	
Kappa Coefficient.	**0.84**		**0.90**		**0.86**	

Where PA producer Accuracy and UA stands for User Accuracy

4.6. Discussion

The alarming pace of urbanization, particularly in developing countries like Ethiopia, has led to the uncontrolled expansion of cities, resulting in substantial changes in land use and land cover. This is primarily attributed to uncontrolled population growth, giving rise to a host of significant challenges.

Unregulated, disorganized, and sparse human habitation can result in urban sprawl. This sprawl is marked by a random and disjointed growth pattern, which often leads to improper city development. Typically, this occurs due to changes in land use or land cover, where the expansion of urban land outpaces population growth over a certain period. This growth is predominantly characterized by low-density impervious surfaces.” (Barnes et al., 2000).

The land use and land cover (LULC) changes in Akaki Kality subcity, Addis Ababa, Ethiopia, over the period from 2003 to 2019 reflect significant urbanization The data presented in the results indicates a dramatic increase in built-up areas, which rose from 32.9% in 2003 to 62.8% in 2019. This transformation underscores the rapid urban expansion driven by population growth, economic development, and the migration of people from rural to urban settings. The increase in built-up areas highlights the demand for housing, infrastructure, and services, which can be attributed to the urbanization trends observed in many developing countries, including Ethiopia (Berhanu & Hailu, 2020).

Conversely, farmland, which constituted 59.3% of the land cover in 2003, experienced a substantial decline to 26.9% by 2019. This reduction raises concerns regarding food security and sustainable agricultural practices in the region. As urban areas expand, agricultural land is often converted for residential and commercial purposes, leading to a loss of arable land. This phenomenon is particularly alarming in a country like Ethiopia, where agriculture is a cornerstone of the economy and a primary source of livelihood for a significant portion of the population (FAO, 2019). The decline in farmland may also impact local food production, and potentially exacerbating food insecurity issues.

The relatively stable percentage of bare land and the slight increase in vegetation from 1.8% to 4.5% suggest that while urbanization is encroaching on agricultural land, there is also an effort to maintain or restore green spaces within the urban environment. The small percentage of water bodies, which decreased from 1.7% to 1.0%, indicates a concerning trend as well, as water bodies are crucial for biodiversity, recreation, and ecosystem services. The reduction of these areas may be linked to urban development and pollution, further stressing the need for integrated land-use planning that prioritizes environmental sustainability alongside urban growth (Tadesse et al., 2021).

The implications of these LULC changes are multifaceted. Urban planners and policymakers must recognize the importance of balancing urban development with the preservation of agricultural land and natural ecosystems. Strategies such as zoning regulations, green belts, and sustainable agricultural practices can help mitigate the adverse effects of urbanization. Moreover, community engagement in land-use planning is essential to ensure that the needs of all stakeholders, including farmers, residents, and businesses, are considered (World Bank, 2020).

CHAPTER FIVE

5. Conclusion and Recommendations

5.1 Conclusion

The study of land use and land cover (LULC) changes and urban sprawl in Akaki Kality sub-city of Addis Ababa, Ethiopia, using high spatial resolution data, has revealed significant transformations over the years 2003, 2011, and 2019. The analysis of the LULC classes, namely built-up area, and farmland has provided valuable insights into the urbanization process and its impact on the sub-city's landscape.

One of the most striking observations from the data is the substantial increase in the built-up area over the 16-year period. In 2003, the built-up area covered 2,188.9 hectares, accounting for 32.9% of the total sub-city area. By 2011, the built-up area had expanded to 2,927.2 hectares (44.1%), and by 2019, it had further increased to 4,172.1 hectares (62.8%). This rapid growth in the built-up area can be attributed to the increasing population pressure, urbanization, and the sub-city's role as a major industrial hub within Addis Ababa.

The expansion of the built-up area has had a significant impact on other LULC classes, particularly farmland. In 2003, farmland was the dominant LULC class, covering 3,938.8 hectares (59.3%) of the sub-city's total area. However, as urbanization progressed, the farmland area steadily decreased. By 2011, farmland had reduced to 3,127.7 hectares (47.1%), and by 2019, it had further declined to 1,787.9 hectares (26.9%). This reduction in farmland can be attributed to the conversion of agricultural land to urban built-up areas, driven by the increasing demand for housing, infrastructure, and industrial development.

The bare land category, which includes areas with exposed soil and minimal vegetation cover, showed a slight increase between 2003 and 2011, from 281.7 hectares (4.2%) to 324.2 hectares (4.9%). However, by 2019, the bare land area had marginally decreased to 317.2 hectares (4.8%). This fluctuation in bare land can be attributed to various factors, such as construction activities, land clearing for development, and the conversion of bare land to other LULC classes**.**

Vegetation, which includes green spaces, parks, and natural vegetation, exhibited a gradual increase over the study period. In 2003, vegetation covered a modest 1213 hectares (1.8%) of the sub-city's total area. By 2011, the vegetation cover had increased to 180.6 hectares (2.7%), and by 2019, it had further expanded to 300.5 hectares (4.5%). This increase in vegetation cover can be attributed to the sub-city's efforts to maintain and develop green spaces, as well as the natural growth of vegetation in some areas. The area covered by water bodies has decreased from 1.7% in 2003 to 1.0% in 2019, reflecting potential issues related to water management and urban encroachment on these critical resources

The use of high spatial resolution data in this study has enabled a detailed analysis of the LULC changes and urban sprawl in Akaki Kality sub-city. The high-resolution data has allowed for the accurate identification and classification of LULC classes, providing a clear understanding of the spatial patterns and trends of urbanization. The findings of this study have significant implications for urban planning and management in Akaki Kality sub-city and Addis Ababa as a whole. The rapid expansion of the built-up area and the consequent reduction in farmland highlight the need for sustainable urban development strategies that balance the demands of urbanization with the preservation of agricultural land and green spaces. Urban planners and policymakers should consider the results of this study when formulating land use policies, zoning regulations, and development plans to ensure the sustainable growth of the sub-city.

Furthermore, the study underscores the importance of regularly monitoring and assessing LULC changes and urban sprawl using high spatial resolution data. By tracking these changes over time, urban managers can identify emerging trends, assess the effectiveness of current policies, and make informed decisions to mitigate the negative impacts of urbanization on the environment and the quality of life of the sub-city's residents.

5.2. Recommendations.

Urban sprawl is the outward spread of development from urban centers into rural areas. It is typically unorganized and poorly planned, making it an unsustainable form of development. Urban sprawl creates destruction on the natural land, ecosystem, and community.Therefore, based on the findings of this study, the following recommendations are proposed:

- ✓ Implement strategies to manage rapid urban expansion. The built-up area has increased from 32.9% in 2003 to 62.8% in 2019, indicating significant urban growth. Strategies are needed to control and guide this growth in a sustainable manner by using high resolution of spatial data.
- ✓ Promote high-density and vertical development.To minimize urban sprawl and preserve agricultural land and green spaces, encourage high-rise buildings and compact development within the existing urban areas.
- ✓ Enforce zoning regulations and land use policies.Establish and enforce zoning regulations and land use policies to ensure balanced growth, protect environmentally sensitive areas, and maintain a mix of residential, commercial, industrial, and recreational zones.
- ✓ Prioritize the preservation of farmland. Farmland has decreased significantly from 59.3% in 2003 to 26.9% in 2019, threatening food security and the livelihoods of local farmers. Measures should be taken to protect and preserve remaining agricultural lands.
- ✓ Establish urban agriculture programs.Encourage urban agriculture, such as community gardens and rooftop farming .
- ✓ Implement policies and incentives for sustainable farming. The city administration has to Provide incentives and support for local farmers to adopt sustainable farming practices
- ✓ Develop a comprehensive green space plan. Green legacy is recommended to Create a detailed plan for increasing vegetation cover, which has shown a gradual increase from 1.8% in 2003 to 4.5% in 2019, but still remains relatively low.
- ✓ Create and maintain public parks and urban forests. Establish and maintain public parks, urban forests, and green corridors throughout the city to improve air quality, and provide recreational spaces for residents.

- ✓ Protect and restore natural water bodies.
- ✓ Conduct public education and awareness campaigns. Green legacy of government campaign during the summer is very very important to educate residents on the importance of sustainable urban development, environmental conservation, and their role in preserving the city's natural resources**.**
- ✓ Establish a robust monitoring and evaluation .Utilize geospatial technologies and data analysis. Apply geospatial technologies, such as remote sensing and GIS, to continuously monitor land use/land cover changes, urban growth patterns, and environmental indicators by utilizing high resolution of spatial data.
- ✓ Conduct periodic assessments and make data-driven decisions. Regularly assess the collected data and use the insights to inform decision-making processes, prioritize interventions, and adjust strategies as needed.

These recommendations aim to address the challenges of rapid urbanization, loss of agricultural land, and environmental degradation in Akaki Kality sub-city. They emphasize sustainable urban planning, protection of natural resources, promotion of green spaces, water resource management, community involvement, and continuous monitoring and evaluation.

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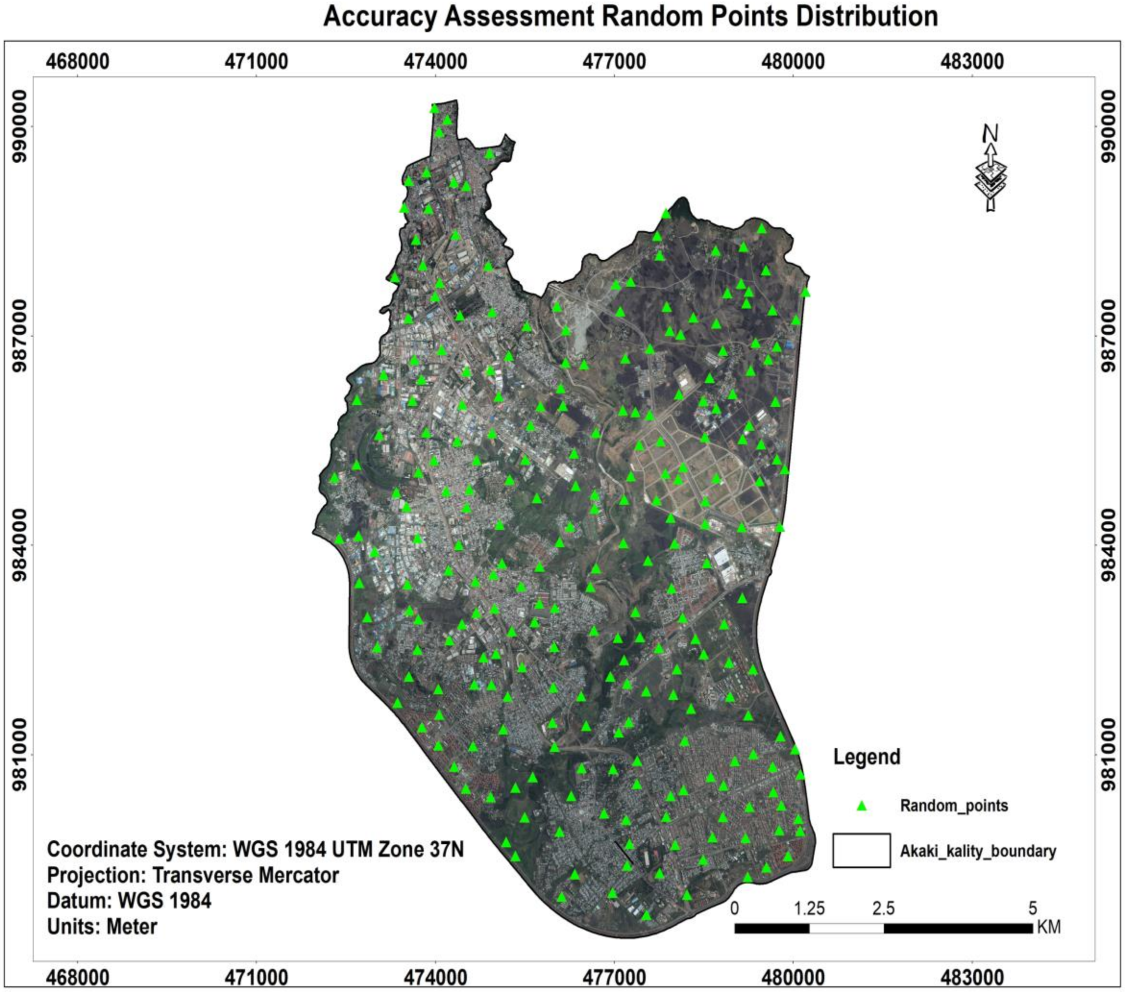
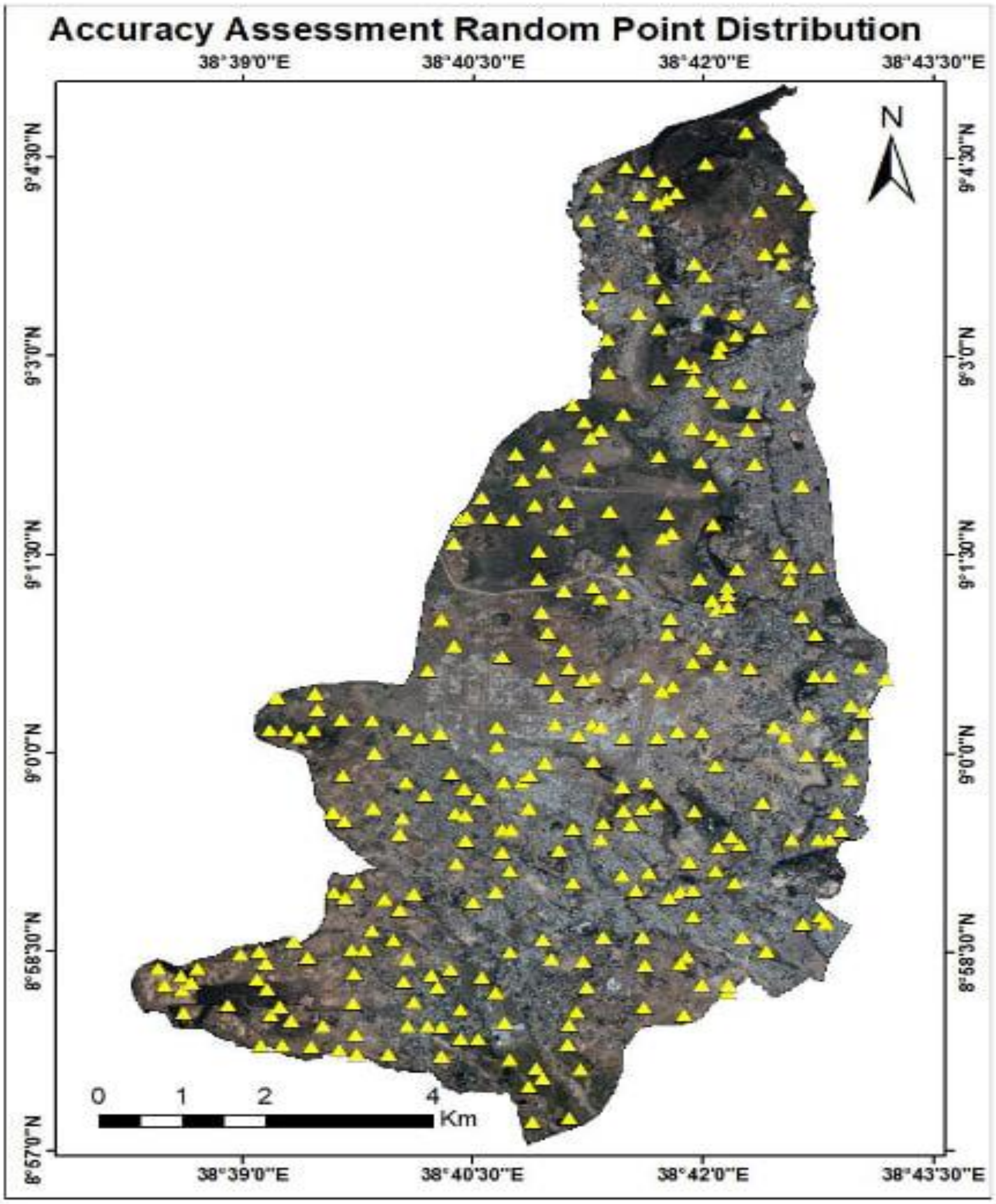
APPENDICES

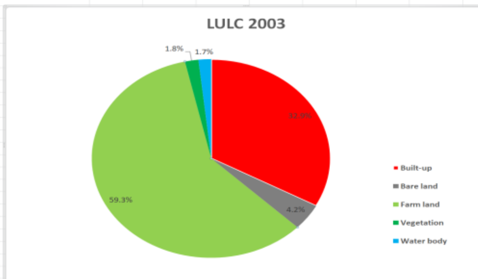
Appendix 1.Accuracy assessment Random point distribution for 2011 image



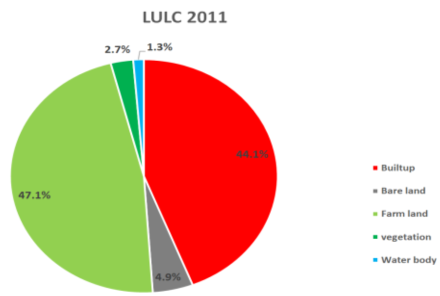
Appendix 2. Accuracy assessment Random point distribution for 2019 image



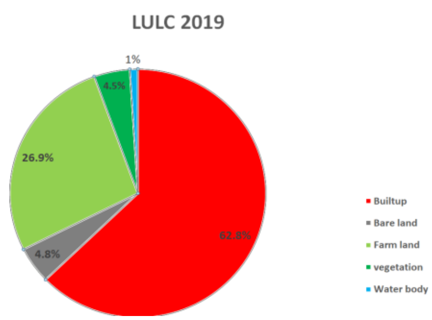
Appendix 3.The rate of LULC Change during the period of study (2003-2019)



Type	Area(ha)	Percentage
Built-up	2188.9	32.9%
Bare land	281.7	4.2%
Farm land	3938.8	59.3%
Vegetation	121.3	1.8%
Water body	113.7	1.7%
Total Area	6644.4	100

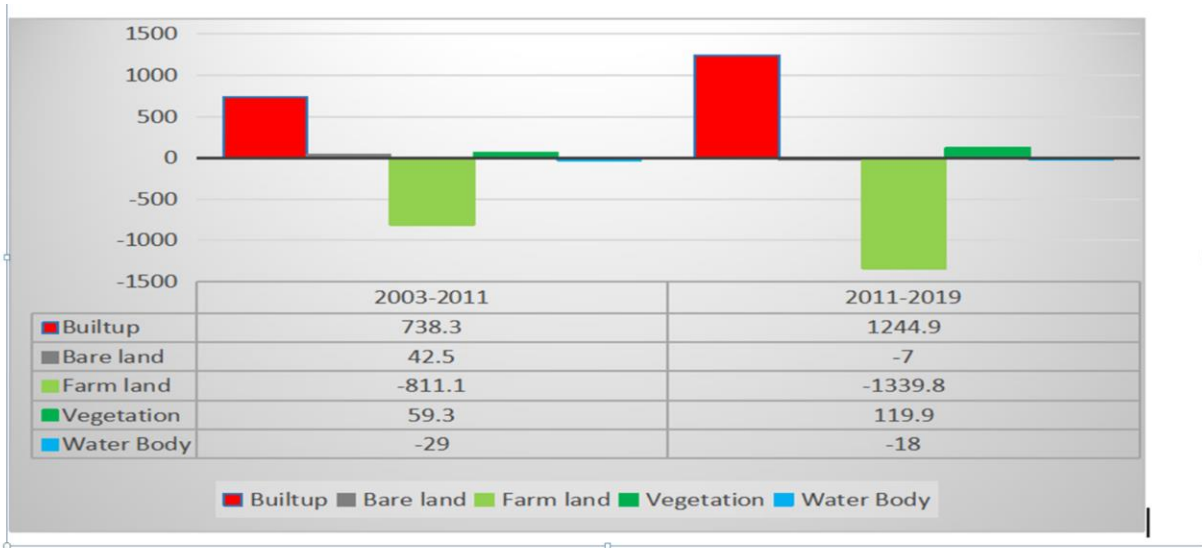


Type	Area(ha)	Percentage
Builtup	2927.2	44.1%
Bare land	324.2	4.9%
Farm land	3127.7	47.1%
vegetation	180.6	2.7%
Water body	84.7	1.3%
Total area	6644.4	100



Type of LULC	Area(ha)	Percentage
Builtup	4172.1	62.8%
Bare land	317.2	4.8%
Farm land	1787.9	26.9%
vegetation	300.5	4.5%
Water body	66.7	1.0%
Total Area.	6644.4	100

Appendix 4.The table that illustrate the general LULC change during 2003 -201



Summary of LULC investigation during the examined period of 2003-2019.

In Akaki Kality sub-C ity, the Land Use and Land Cover (LULC) changes from 2003 to 2019 were significant .The results indicate a significant expansion of built-up areas, with an increase of 738.3 hectares from 2003 to 2011 and an additional 1244.9 hectares from 2011 to 2019, totaling 1983.2 hectares over the 16-year period. Conversely, bare land exhibited a negligible net change, with an initial increase of 42.5 hectares from 2003 to 2011 followed by a decline of 7 hectares from 2011 to 2019. Notably, farm land underwent a substantial decline, with a decrease of 811.1 hectares from 2003 to 2011 and an additional 1339.8 hectares from 2011 to 2019, resulting in a total loss of 2150.9 hectares. In contrast, vegetation cover demonstrated a steady increase, with a gain of 59.3 hectares from 2003 to 2011 and an additional 119.9 hectares from 2011 to 2019, totaling 179.2 hectares. Finally, the water body area experienced a cumulative decline of 47 hectares over the study period, with a decrease of 29 hectares from 2003 to 2011 and an additional 18 hectares from 2011 to 2019. These findings highlight the dynamic nature of LULC changes in Akaki Kality sub-City, with significant implications for urban planning, environmental management, and sustainable development.