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SPATIO-TEMPORAL CHANGE OF URBAN SPRAWL PATTERN IN GAMBELLA TOWN

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This is to certify that the thesis prepared by Goanar Jal Dup, entitled: **Spatio-Temporal Change of Urban Sprawl Pattern in Gambella town**, western Ethiopia and submitted in partial fulfillment of the requirements for the Degree of Master of Arts (Geography and Environmental Studies, specialization: Geographic Information System, Remote Sensing and Digital Cartography) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Declaration

I hereby declare that this research entitled "**Spatio-Temporal Change of Urban Sprawl Pattern in Gambella town"** Gambella Peoples; National Regional State, Ethiopia" is my original work under the guidance and supervision of Degefie Tibebe (PhD). I also declare that this thesis has not been previously or concurrently submitted or presented for a degree in any other university in whole or in part and all sources of material used for this thesis have been dully acknowledged.

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Lists of acronym

ATM - Automated Teller Machine

CSS - Central Statistical Services

SSGI – Space Science and Geo Spatial Institute

EROS – Earth Resources Observation Satellites

ETM+ - Enhanced Thematic Mapper Plus

FBI - Federal Bureau of Investigation

GIS - Geographic Information Systems

GPNRS - Gambella Peoples' National Regional State

GPS - Global Positioning System

IP - Intellectual Property

LULC - Land Use and Land Cover

LULCC- Land Use and Land Cover Classes

MLC- Maximum likelihood classification

OECD - Organization for Economic Co-operation and Development

OLI - Operational Land Imager

PCA - Principal Component Analysis

SPOT - Satellite Pour observation de la Terre

TM - Thematic Mapper

TVA - Tennessee Valley Authority

UN - United Nations

UNDESA - United Nations Department of Economic and Social Affairs

UN-WWAP - United Nations World Water Assessment Programme

USB - Universal Serial Bus

USGS - United States Geological Survey

UTM - Universal Transverse Mercator

WGS - World Geodetic System

Abstract

Understanding land use and land cover (LULC) changes and urban sprawl, along with their drivers and impacts on socio-economic and environmental conditions, is essential for designing knowledge-based interventions that promote sustainable development. Gambella Town is a key area experiencing significant LULC changes and urban sprawl, driven by a range of interconnected factors. This study investigates these changes over the past 24 years (2000–2023) and identifies the main drivers and socio-economic and environmental impacts. Using multi-temporal Landsat satellite imagery and supervised image classification, along with a socio-economic survey of 277 respondents, the study classified land into six categories: Agricultural Land, Bush with Grass, Built-Up Area, Bare Land, Forest Land, and Water Bodies. The classification achieved high accuracy, with overall accuracies of 90%, 90%, and 89% for 2000, 2010, and 2023, respectively. The analysis reveals substantial LULC changes, notably the conversion of Bush with Grass into residential and commercial zones. Agricultural Land increased from 13.4% (634 ha) in 2000 to 36.9% (1,750 ha) in 2023, while Built-Up Areas expanded from 2% (93 ha) to 41.3% (1,956 ha). In contrast, Bush with Grass sharply declined from 71.1% (3,375 ha) to 13.7% (652 ha), and declines in Bare Land and Forest Land indicate a shift toward settlements and agriculture. Socio-economic analysis shows that rural-to-urban migration, natural population growth, and increased demand for jobs and services are the primary factors driving these changes. Urban sprawl has displaced residents, heightened infrastructure demands, and limited access to essential services. Environmentally, this expansion has led to habitat loss and biodiversity decline. These findings offer crucial insights for policymakers and planners aiming to mitigate urban sprawl challenges and advance sustainable development in Gambella Town.

Keywords: *LULC, Urban Sprawl, Remote Sensing, Landsat satellite imagery, Environmental Impact, and Sustainable Development*.

CHAPTER ONE

INTRODUCTION

This chapter presented the introductory part of the study. It attempted to highlight the background of the study, statement of the problem, the objectives of the study, research questions, scope of the study, significance of the study, limitation of the study and the summary of the other chapters that make up the study report.

1.1 Background

The world faces an unprecedented rate of urbanization nowadays. More than 50 percent of the world's population lives in high densely populated areas with different urbanization levels (UNDESA, 2014). Though urbanization occurs in both developed and developing countries, urbanization rate occurs at rapid pace in developing countries and causes significant pressure on the available limited resources in these countries (UN-WWAP, 2015)

Urban sprawl refers to the extent of urbanisation, which is a global phenomenon mainly driven by population growth and large scale migration. In developing countries like India, where the population is over one billion, one-sixth of the world's population, urban sprawl is taking its toll on the natural resources at an alarming pace. Urban planners require information related to the rate of growth, pattern and extent of sprawl to provide basic amenities such as water, sanitation, electricity, etc. In the absence of such information, most of the sprawl areas lack basic infrastructure facilities. Pattern and extent of sprawl could be modelled with the help of spatial and temporal data. GIS and remote sensing data along with collateral data help in analysing the growth, pattern and extent of sprawl. With the spatial and temporal analyses along with modelling it was possible to identify the pattern of sprawl and subsequently predict the nature of future sprawl (Jagadish, 2004). In order to understand this increasing rate of urban sprawl, an attempt is made to understand the sprawl dynamics and evolve appropriate management strategies that could aid in the region's sustainable development. Understanding such a phenomenon and its pattern helps in planning for effective natural resource utilisation and provision of infrastructure facilities(Jagadish, 2004).

Developing countries have higher uncontrolled rapid urbanization process than developed countries. This uncontrolled rapid urban expansion causes remarkable changes in the landscape as a result of rapid economic developments in those parts of the world, Unrestrained change in landscape increases loss of green cover and forests, loss of fertile lands, environment degradation, ugliness of urban areas, and many more. Urbanization process (urban sprawl) is one of major significant drivers of land cover/use change, and it is associated with growth of populations (Al-sharif et al., 2013) Furthermore, the uncontrolled population growth is considered as the main factor of urban sprawl and urban spatial problems (Al-sharif et al., 2013)

The rapid expansion of urban areas due to rise in population and economic growth is increasing additional demand on natural resources thereby causing land-use changes especially in cities and citys (Theobald, 2001; Nwafor, 2006). One essential component of study on global change is the assessment and tracking of the earth's surface condition (Committee on Global Change study, National Research Council, 1999; Lambin et al, 2001). Urban sprawl is one of the foremost threats facing agricultural lands in Nigeria (Nwafor, 2006). Sprawl has been criticized for eliminating agricultural lands, spoiling water quality, and causing air pollution. Other frequently mentioned consequences are green space consumption, high costs of infrastructure and energy, increasing social segregation and land use functional division (N. G. Johnson et al., 2021).

The direct implication of urban sprawl is the change in land use and land cover (LULC) of the area involved. Patterns of sprawl can take place either in radial direction, around a well-established city or linearly along the highways (Theobald, 2001). However, the identification of the patterns and analyses of spatial and temporal changes would help immensely in the planning for proper infrastructural facilities. This could be done effectively and efficiently with the help of spatial and temporal technologies such as GIS and remote sensing, along with other ancillary data such as survey data and existing maps (Barnes et al., 2001).

Urban sprawl has become a global or universal problem, and is being faced by both developed and developing countries. It all began during the post war prosperity of the 1950's and60's, when housing developments popped up across the landscape like mushrooms after a rain. A half century later, it is understood that many environmental problems accompany the outward spread of cities: fragmenting and destroying wildlife habitat, for example, and discharging polluted runoff water into streams and lakes. In developing countries sprawl is largely the result of mobility of people to the city in search of better employment and opportunity (Menno, 2004).

African cities are rapidly becoming more urbanized. According to UN estimates, its pace of urbanization increased from 15% in 1940 to 40% in 2010 and is expected to reach 60% by 2050.The rise of cities in Africa is consistent with patterns seen in the majority of established and rising nations with the lowest levels of urbanization Burundi, Ethiopia, Malawi, Burkina Faso, and Uganda remain below 20%. However, almost 60% of people now reside in cities in South Africa's quickly industrializing economy (UN, 2007).

The predicted urban population increase of Ethiopia, one of the most populated countries in Sub-Saharan Africa (SSA), is 6%, which is significantly higher than the average for other SSA nations. According to The World Fact Book (2004), the nation is among the least urbanized in the third world, and agriculture accounts for nearly all of its economic activity. Ethiopia, like the majority of developing nations, has a high rate of rural-to-urban migration as people look for better jobs and other opportunities. The requirement to save land and avoid horizontal expansion is not intertwined with the need for housing. From the central capital, formal and informal communities are dispersed horizontally in all directions. New developments are typically developed on virgin ground, leapfrogging from cores, and land is exploited inefficiently.

According to Nechyba et al. (2004) list a number of issues associated with sprawl, including the loss of open space, urban deterioration, the construction of unsightly strip malls, the diminished sense of community, patchwork housing developments in the middle of agricultural land, a growing reliance on cars, the division of residential and commercial areas, and the expansion of urbanized developments throughout the landscape. According to Haregewoin (2007), population pressure from both natural births and migration is typically the cause of sprawl in Ethiopia. Therefore, using geospatial technologies, this study will try to determine changes in the urban sprawl pattern in the study area between 2000 and 2023.

1.2 Statement of the Problem

Urban sprawl is currently a widespread issue in the majority city of the world. Because of uncontrolled urban growth and residential housing in many of its cities, Ethiopia, like many other emerging nations, has struggled with urban sprawl (Zewdu, 2011). Urban sprawl has resulted in numerous issues pertaining to land usage, the environment, socioeconomic activity, and other areas. Reduced regional open space, higher energy and air pollution, less cropland, fewer species, greater storm water runoff, and ecosystem fragmentation are some of the negative effects of land use change on the environment (Burchell et al., 1998).

Urban sprawl is one of the expected consequences of urbanisation that may be defined as the unrestricted and unplanned expansion of accommodations, business centres, and infrastructure in urban areas. It is a customary after-effect of converting an agrarian society to an industrial one fuelled by the accumulation of people in cities or citys (Cobbinah & Darkwah, 2016; Xu et al., 2019; Sharma & Kumar, 2022). As sprawl is not monitored and taken into consideration in its initial stages, it soon speeds up due to the growth in population and becomes uncontrolled, causing several social and environmental snags. The associated environment always remains a silent cost-payer for unplanned urbanisation. Mainly, agriculture and forests become the prime and soft targets to fulfil the land demands for other urban uses (Sharma & Kumar, 2023).

The spatial and sequential operations on land or its consumption by humans determine the land use pattern in any area. Detecting change in different land utilisation helps local administrations and urban planners recognise the causes and consequences of this transformation and formulate an effective strategy to solve the uninvited problems (Sharma & Kumar, 2023).

The implications of urban sprawl are not only on the surrounding public settlement, but with loss of agricultural land, ecological habitats, and on the basic amenities like, transportation, water supply, sanitation facilities within the inner core of the city. The type, rate, direction, density and the pattern of urban sprawl has a great consequence on the environment, because it is not the urban sprawl that is the problem but the type, rate, direction, density and pattern of the urban sprawl that could determine the nature of its environmental consequence. (Mairiga et al., 2023)

Hence, this study seeks to assess the spatial pattern of urban sprawl with the view to understanding and quantifying the causes, drivers and consequences of urban sprawl as a result of the type, rate and pattern of urban sprawl and its environs. (Mairiga et al., 2023)

It also has social effects, such as desertification and soil erosion; deforestation and soil degradation linked to agricultural output lower agricultural productivity and land quality. Urban growth trends also have an impact on people's lives and society, making it more difficult for local residents to make ends meet. Periodically, their quality of life deteriorates in comparison to their prior income level, which changes socioeconomic activities and transforms land use practices throughout time (Bhagawats, 2011).

Therefore, it is necessary to map and analyse the phenomenon of urban sprawl patterns. The use of geospatial technologies will aid in the spatial analysis of data, which is crucial for sensible land use management and urban planning. One of the cities in Ethiopia that has been experiencing a state of sprawling over the past few years is Gambella town. For many years, Gambella Peoples' National Regional State (GPNRS) has been subjected to ethnic violent conflicts between the Nuer and Anywaa (Feyissa, 2013) and (Berhe & Adaye, 2006). The conflict has remained the most prominent of all conflicts in the region. In both tribes, the tradition of violence was so strongly marked in their social life.

There hasn't been any study done on the urban sprawl pattern and changes in land use in Gambella town, and the city doesn't have any updated maps showing these changes in urban growth with a resolution that is suitable enough to at least paint an image (impression) of the physical alterations and rate of growth of the city's urban area. Numerous researches on the effects of urban sprawl have been conducted. Despite the fact that, there has been no study conducted on spatial temporal changes of urban sprawl pattern in Gambella town.

Being concerned with these spatial temporal changes of Urban sprawl pattern in Gambella town were continue to present critical implications and challenges to the settlement patterns among the ethnic groups in the town; this study is motivated by the desire to contribute to the settlement patterns efforts and urban master plan in Gambella town. The main goal of this study was to evaluate and track the urban sprawl pattern while also examining the characteristics of settlement patterns.

In order to formulate and carry out the geographical and temporal changes, GIS and remote sensing are highly helpful. GIS and remote sensing have been used in a variety of research pertaining to urban sprawl. Manishika Jain, for instance, studies Undapur, India's urban sprawl using remote sensing and geographic information systems. In addition, he only focuses on one factor LULC change to identify urban sprawl, ignoring other factors. In the methodology section, he only uses Landsat imagery, which has low resolution and poor image quality and is primarily used to show land use and land cover types of study areas. In addition, a number of other scholarly works have been produced. For example, Adane Zeleke (2013) used aerial photographs, Landsat and Spot-5 satellite data, and other data to create LULC maps and analyze urban sprawl. Sudhira et al. (2003) used Landsat images, topo sheets, and various attribute data to analyze urban sprawl.

On the other hand, this study aims to assess the environmental effects of urban sprawl patterns with the goal to recognize urban sprawl and its patterns using time series data in addition to identify trends in the change of land use and land cover (LULC). This can directed land use planning in Gambella town and provide concrete information on masters planning progress, which will help policy makers adopt measures.

1.3 The objective of the study

General objective

The General objective of this study is to examine urban sprawl pattern based on spatiotemporal data and surrounding environments using Geospatial technologies which were acquired three satellite images from two decade (2000, 2010, and 2023) and processed with the supervised classification to create LC maps in the Gambella town.

Specific objective

- ✓ To identify urban sprawl and its patterns based on time series data of land use land cover (LULC) change between 2000 and 2023.
- ✓ To investigate the impact of socio-economic for urban sprawl pattern.
- ✓ To examine the impact of urban sprawl of related to physical environment.

1.4 Research questions

- ➢ How do the spatial patterns of urban sprawl vary across different time intervals?
- ➢ How has the urban sprawl pattern affected the availability of green spaces in the study area?
- ➢ What role does population growth play as a key indicator of urban sprawl in the study area?

1.5 Scope of the study

The study focus at spatial temporal changes of Urban sprawl pattern and the impact of urban sprawl pattern on the Environment, and agricultural land in the Gambella town within the Gambella region. This study only covers the two decade trend of spatial temporal change of urban sprawl pattern from 2000 to 2023, and the data source was mainly from satellite images from remote sensing and secondary sources were from Gambella region Land administrative urban and development agency and others Government facilities.

1.6 Significance of the study

This study may benefit different stakeholders. It can primarily assist policy makers, administrators, and urban and/or regional planners by offering data that facilitates decision-making. Additionally, the study aids in identifying patterns of urban expansion that are helpful for planning and utilizing natural resources as well as for providing infrastructure facilities within the studied area. The generated urban sprawl map is also used to pinpoint areas where natural resources and the environment are seriously threatened, as well as to recommend future directions and growth patterns for spreading development. Lastly, it may act as a foundation or input for additional research

1.7 Limitation of the study

The main challenge encountered while writing the research was obtaining the necessary and appropriate imagery data. Obtaining current and high-quality data was the main challenge the researcher encountered when carrying out this study.

1.8 Organization of the thesis

The following chapters make up the structure of the paper. An overview of the study's background, problem statement, objective, research questions, significance and scope, study delimitation, and thesis organization are all included in the six chapters. A review of relevant literature is provided in the second chapter. Techniques for gathering pertinent data and evaluating field data are covered in the third chapter. The study area, design, and data description and data sources, primary and secondary data collection methods, and the sections on Techniques and method of data analysis and interpretation are among them. The study's results are presented in the fourth chapter. The discussion in fifth chapter and its conclusion and recommendations are provided in the final chapter.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2. Introduction

This section's goal is to evaluate related studies that have been done on Spatio-temporal change of urban sprawls. Research and review materials helped lay the groundwork for the current study and identify any shortcomings of Spatio-temporal change of urban sprawls.

2.1 Origin of the term

Earle Draper of the Tennessee Valley Authority (TVA) coined the term "sprawl" in 1937 while speaking at a national meeting of planners (Wassmer 2003). The term "UN aesthetic and uneconomic settlement form" was used to describe sprawl. The phrase "urban sprawl" was first used, according to Wassmer (2003), in the first line of a 1958 Fortune magazine article written by sociologist William Whyte. Since then, planners have classified urban development's using this phrase, which has had unfavourable societal implications. The phrase was also embraced by urban economists, who also introduced terms like scatter, leapfrogging, and ribbon development to the discussion (Franz et al., 2005)

2.2 Concept of urban sprawl

In essence, "Sprawl" refers to the process of a city and its suburbs expanding into increasingly rural terrain on the outskirts of an urban region, but in actuality, it is a multifaceted phenomenon that can signify many things depending on the context. Back then, the phrase implied that it over consumes space in an unmanaged, disorganized way, which results in inadequate distribution and the loss of open spaces, a high need for transportation, and social segregation(Ababa,2016).

Throughout the years, this definition has not evolved significantly. In 1937, Earle Draper, one of the first city planners in the United States, created the term "sprawl," as it is used today (Black, 1996). Urban sprawl is described as "lands that have lost their rural characteristics but cannot be classified as urban." These lands contain certain ambiguities that lead to a number of issues, including unplanned urban growth and the use of these areas for purposes other than agriculture (Karakayaci, 2016).

2.3 Causes of urban growth and sprawl

The reasons of sprawl and urban growth are fairly similar. Due to the strong links between urban sprawl and expansion, they are typically unable to be distinguished from one another. It's crucial to understand, though, that sprawl cannot cause urban expansion; rather, sprawl must spur urban growth. Population expansion is one of the causes, for example, which can lead to either uncoordinated sprawling growth or coordinated compact growth. The pattern, process, and outcomes of the growth determine whether it is positive or negative. Additionally, a few factors contribute specifically to sprawl since they are unable to produce a neighbourhood that is compact. For instance, some people have a strong desire to live in the country; yet, this propensity always leads to sprawl (Bhatta, 2010).

According to Siedentop (2010), there are two competing theories as to why urban sprawl occurs: First, the need for urban land explains why sprawl has occurred. The land consumption of businesses, homes, and public purposes are the driving forces. The framework is provided by variables like wealth, income, and car use, and decisions on locations are based on weighing the costs and benefits of various options. Second, particular regulatory systems explain sprawl. Urban sprawl is perpetuated by the large public subsidies for low-density, suburban lifestyles as well as the publicly funded development of local infrastructure and street networks.

Decision-making autonomy

The rivals (public and/or private) have different expectations for the future and different demands for development; frequently, these rivals are free to make decisions on their own to satisfy their expectations and demands for development; this independence eventually leads to unplanned, uncontrolled, and uncoordinated development (Harvey and Clark 1965).

Land hunger attitude

The desire for land ownership is shared by many institutions and even individuals. Frequently, these lands remain undeveloped within the core city area, which hinders the success of infill policies (Harvey and Clark 1965).

Lack of proper planning policies

Urban sprawl may also result from a lack of predictable and thoroughly tested planning policies. Plans for a city may include exclusive zoning, which divides land uses into categories such as institutional, office, commercial, industrial, and residential. Every kind of development was isolated into its own island due to totally different zoning. The majority of the time, a mixed land-use policy is preferred to combat sprawl because the automobile had become the means of transportation between large fields of residentially zoned housing and the distinct commercial and office strips, creating problems of automobile dependency and increased consumption of fossil fuels and consequent pollution.

Failure to enforce planning policies

The successful implementation and enforcement of a planning policy is of more importance than its mere existence. In developing nations, one of the main causes of sprawl is the ineffective implementation of land-use plans, as these laws are frequently corrupted and applied sporadically.

2.4 Consequences of urban growth and sprawl

Consequences of both positive and negative effects may result from urban growth; however, as the growth is frequently unplanned or unregulated, the negative effects usually take precedence over the positive ones. Urban expansion has several positive effects, such as increased economic output, employment chances for the unemployed and underemployed, improved lifestyles and access to better opportunities and services. Better specialized services, such better educational and healthcare facilities, can be made available to more people through urban growth, as well as improved fundamental services like water, sewage, and transportation. However, unplanned and uncoordinated urban growth frequently results in sprawl, which makes the positive effects disappear and invites the negative ones (Bhatta, 2010).

As per the findings of the OECD (2006), there are several adverse effects of urban sprawl. Consequences that are often stated include the utilization of green space, expensive energy and infrastructural expenses, growing social segregation, and a functional division of land use. Sprawl is also linked to the necessity of travel, reliance on personal vehicles, and the ensuing rise in energy use, pollution emissions, and traffic congestion.

Impacts on wildlife and ecosystem

Uncontrolled sprawl development can result in altered ecosystem patterns and processes due to the concentration of people in residential and industrial settings (Grimm et al., 2000). Sprawl-related development not only reduces the amount of forest area (Macie and Moll, 1989;

MacDonald and Rudel, 2005), farmland (Harvey and Clark, 1965), woodland (Hedblom and Soderstrom, 2008), and open space, but also fragments what is left into small pieces that disturb ecosystems and fragment habitats, loss of wildlife habitat is mostly caused by urban sprawl encroaching on rural natural areas like wetlands and woodlands. Natural areas are often traversed by roads, power lines, pipelines, and subdivisions, which fragments wildlife habitat and changes the patterns of wildlife movement (Lassila 1999; McArthur and Wilson McArthur 2016; O'Connor et al., 1990).

Loss of farmlands

Farmlands and open spaces are lost as a result of urbanization in general and sprawl in particular. A farm's woodlots and hedgerows provide habitat for plants and animals, so losing agricultural land to urban sprawl results in the loss of both species diversity and fresh local food sources. Benefits from farms include green space, rural economic stability, and the maintenance of the traditional rural way of life (Berry and Plaut 1978; Fischel 1982; Nelson 1990; Zhang et al. 2007).

Impacts on water quality and quantity

According to Jacquin et al. (2008), sprawl has a significant negative influence on both the quantity and quality of water. Because rural areas are covered with miles of paved roads, parking lots, and houses, precipitation and snowmelt cannot seep into the ground and replenish groundwater aquifers. Moreover, urban growth and sprawl increase imperviousness, which raises total runoff volume and exposes urban areas situated in flood-prone areas to increased flood hazards, such as inundation and erosion. The public, government, planners, and insurance companies are growing increasingly concerned about flooding disasters and rising damages as new construction continues to be built on the outskirts of the current urban landscape (Wisner et al. 2004; Jacquin et al. 2008). Water from the urban area drains into storm drains which lead to rivers and lakes, when it rains heavily, excess water can quickly increase the flow through wetlands and rivers, removing vegetation and ruining habitats along riverbanks, Along with increasing water pollution from runoff tainted with motor oil, road salt, and chemicals used for lawn and garden care, it can also result in destructive floods downstream. More pavements are needed for widely scattered development, which increases urban runoff and pollutes rivers (Lassila 1999; Wasserman 2006).

The ability to access nature was one of the primary drivers of suburban migration. It is often preferred by people to live in suburban areas rather than more densely populated ones since suburbs offer easier access to things like trees, birds, and flowers. Furthermore, there may be health benefits to being in nature beyond only aesthetic ones; these benefits could include mental and physical wellness. Furthermore, some people may find solace and restoration in the suburban sensation of retreating from the bustle of city life. Suburban lives may promote health in various ways (Frumkin 2002).

2.5 Consequences of urban sprawl on bordering rural areas

Urban expansion can have both beneficial and negative effects; however, as the consequences of the growth are frequently unplanned or unmanaged, the negative effects usually take precedence over the benefits. Higher economic output, possibilities for the underemployed and jobless, better lives due to greater opportunities and services, and better lifestyles are all benefits of urban expansion. Greater access to specialized services like improved educational and healthcare facilities, as well as better fundamental services like transportation, sewage, and water facilities, can be provided to a larger population through urban expansion. However, sprawl is frequently the outcome of unplanned and uncontrolled urban growth (Ababa, 2016).

2.6 Environmental impacts of urban sprawl

According to (Johnson, 2001), the following environmental effects of urban development have been found: elimination of native vegetation excessively, loss of ecologically fragile lands, reduction of open space in the region, increased air pollution, higher energy consumption, decreased landscape aesthetic appeal, loss of farmland, decreased species diversity, increased storm water runoff, increased risk of flooding, monotonous (and regionally inappropriate) residential visual environment, lack of mountain views, and existence of environmentally wasteful golf courses ecological dispersion.

All throughout the world, environmental change is an issue of concern. Environmentalists are concerned about the rising land surface temperature (LST) brought on by urbanization and industry. Natural habitat is being destroyed by urban sprawl, which has a negative impact on air quality, ground water levels, fertility, and many other areas. The urban thermal environment is negatively affected by changes in land use and land cover (Moazzam et al. 2022; Zullo et al. 2019; Gohain et al. 2021; Mohammad and Goswami 2022a; Khan et al. 2022). The future of LULC alterations will worsen the thermal environment and make the urban heat island phenomenon worse (Mohammad and Goswami 2022b; Mohammad et al. 2017; Kafy et al. 2022). Thus, understanding the mechanisms of urban sprawl change is crucial for planning sustainable future growth. Understanding the various effects of urban sprawl, such as changes in land surface temperature, deterioration of ground water quality, and loss of urban vegetation, may pave the way for sustainable design and improved future living standards (Das et al., 2023).

2.7 Measure of urban sprawl

Recent advancements in geographic information systems and remote sensing have made it possible for us to periodically gather a set of physical data quickly and at a reasonable cost. In order to construct sensible urban planning and land use management, the remote sensing data and GIS both greatly aid in the spatial analysis of the data. Because of its versatility in handling many kinds of geographical data, a tool like a GIS is therefore perfect for use in research on urban sprawl. The amount of urban sprawl can be estimated using a variety of geographical and non-spatial methods. But every method employed is arbitrary and up for discussion. (Glaster, 2001) investigated six distinct metrics for the evolution of urban sprawl.

1. Density: the mean quantity of dwelling units per square mile
2. Concentration: the extent to which development is found inside an urbanized area's few square miles.
3. Compactness: the degree of development that has been grouped together;
4. Centrality: the degree to which a development is situated in close proximity to the CBD;
5. Nuclearity: the degree to which a single hub of development characterizes an urbanized area;
6. Proximity of land uses: - the degree of proximity between various land uses.

2.8 Solutions for urban sprawl

For residents and decision-makers who wish to build a sustainable, cheap, and healthy urban future, Understanding Sprawl is a useful resource. It explores the forces that shape cities and what individuals can do about them, rather than serving as an architectural blueprint. In order to comprehend contemporary urban trends, it delves into the past of city and suburban development. It examines the characteristics of the city and lists the financial and social consequences of more recent growth (Mills, 2003).

According to Haregewoin (2007), the following solutions are crucial to resolving the issues with urban sprawl:

- ❖ The establishment of job prospects outside of big cities; several minor city and cities nearer the hinterland could be established as possible work options for those living in rural areas. This would alleviate the strain on larger cities and generate a substitute employment source, so tackling the issues of joblessness and urban sprawl.
- ❖ Better and more efficient land use policies should be developed and implemented. Communities can grow efficiently by utilizing the infrastructure that already exists or by constructing away from areas that are home to animals. Because of this, development policies might be directed more toward an area that is already urbanized.
- ❖ Implement strategies to reduce or halt migration; apart from the push causes, it is important to address the pull factors aside from work opportunities that draw migrants to cities. If migration persists, increasing land use efficiency or other suggested remedies won't work in the long run.
- ❖ Instead of using undeveloped property beyond the city limits, unused building sites, such as former schools, industrial land, and parking lots, can be converted to new uses. This will help concentrate expansion and reuse existing municipal land. This deals with the problem of urban sprawl encroaching on newly developed territory outside of cities.

2.9 Global trends of urban growth and its implication for urban sprawl

Nowadays, urbanization is a global trend that is growing, particularly in poorer nations where it is happening at an alarming rate. Cities increase in number and physical area as a result of this. By 2030, there will be 4.98 billion people living in urban areas worldwide, up from 2.86 billion in 2000. Of this total, only 28 million will reside in high-income nations out of an anticipated 2.12 billion increase. Global urban growth is expected to reach 1.8% annually, whereas rural growth is expected to reach 0.1% (State of the World Cities, UN Habitat, 2006).

Between 1995 and 2000, the urban growth rate in less developed regions was 3.0% year, while in more developed regions it was far lower at 0.5%. In less developed nations, this growth rate will continue to be especially high in metropolitan areas. The global rural population, on the other hand, is anticipated to stay essentially constant. The degree and rate of urbanization vary significantly, even among the less developed regions category. In terms of regionalism, the Caribbean and Latin America are heavily urbanized. Due to their far lower rates of urbanization, Africa and Asia are predicted to see significant increases in urbanization starting in the year 2000. Europe is the most urbanized continent; with 80% of its population living in cities (Haregewoin, 2007). Metropolitan sprawl can result from an uncontrolled and unchecked increase in the global population living in metropolitan areas, as indicated by the worrisome rate of urban growth.

2.10 Trends of urban growth in Africa and its implication for urban sprawl

Compared to wealthy nations like Europe (72.7%) and North America (79.1%), Africa has a low rate of urbanization (37.1%). Urbanization rates in industrialized countries may reach 3% or even 4% annually, but in the poor world, the pace of urbanization is generally significantly faster. According to Soubbotina (2004), Rapid urbanization in emerging nations can be attributed to a number of factors, such as population increase, economic expansion, migration from rural to urban regions, and technological advancements. In 2009, there were over one billion people living in Africa, with around 40% of them residing in cities. By 2050, it is projected to reach 2.3 billion, with 60% of them living in cities. Over the coming decades, urbanization will be a significant problem (UN, 2011).

In contrast to comparable patterns in extreme poverty is a defining feature of urbanization in Africa, while in Asia and South America. Sub-Saharan African countries have the highest rates of urban poverty worldwide. Despite the fact that cities in Africa account for between 55 and 60 percent of the continent's GDP, 43 percent of urban dwellers live in poverty. One of the most prevalent indicators of urban poverty in Africa is unequal access to suitable housing. For instance, most urban and peri-urban poor people reside in environmentally sensitive areas where they overuse the nearby grounds. Africa's urbanization is marked by a large percentage of urban poor people living in slums; as of late, more than 60% of all urban residents in Sub-Saharan Africa were estimated to reside in slums. They frequently lack access to fundamental urban services including energy, clean water, sanitary facilities, and solid waste disposal. Given their difficult living conditions, which leave them especially exposed to disease and natural disasters, this community is likely to be negatively impacted by climate change and its repercussions (Arouri et al, 2014).

2.11 Trends of urban growth in Ethiopia and its implication for urban sprawl

Ethiopia is only beginning to urbanize. Considering the close connection between economic growth and urbanization, the nation should continue to encourage urbanization. Ethiopia is among the least urbanized nations in the world; according to MOFED (2006), merely 16% of its populace resides in metropolitan areas. Nonetheless, the rate of urbanization is expanding at a pace of 4.4% because of the high rate of in-migration to cities, the increase in the number of urban centres, and the yearly population growth rate of 2.73%. Additionally, it is projected that by 2050, 42.1% of the population will reside in urban areas, increasing the country's urban population by an average of 3.98% (UN-HABITAT, 2010).

Inadequate management of the fast urban population increase could lead to urban sprawl and demographic challenges as cities struggle to supply housing, infrastructure, and services, as well as jobs. Growing urban areas and tight municipal budgets are already undermining infrastructure and service delivery in many cities, while formal labour markets are unable to meet the demand for jobs. Cities in Ethiopia face the danger of losing their appeal to tourists and business travellers. Furthermore, restrictions on rural-urban migration, such as the loss of land rights for individuals who leave rural regions, lessen the motivation for people to relocate to cities. This might eventually limit agglomeration, which would lower economic development and productivity (World Bank, 2007).

Due to uncontrolled urban expansion and residential housing in many of its city and cities, Ethiopia has an issue with urban sprawl, which makes it difficult for urban administrators, planners, and other relevant organizations to provide the necessary infrastructure and service facilities (Zewdu, 2011). Therefore, the relevant bodies should plan and control rapid urban growth in order to maximize the positive externalities of urbanization and minimize its negative effects on the urban environment and livelihoods.

2.12 Application of GIS and RS for analysis of urban sprawl

These days, there are a lot of fascinating and glamorous prospects in the fast growing fields of remote sensing and GIS. They are highly helpful in formulating and carrying out the temporal and spatial modifications, which are crucial elements of regional planning to guarantee sustainable growth. According to Yeh and Xia (2001), there are several general steps involved in developing and implementing a regional development strategy, including setting goals, inventorying available resources, analysing the current state of affairs, modelling and projecting, developing and selecting planning options, putting the plan into action, and evaluating, monitoring, and providing feedback.

The suggested plan can be implemented with the help of highly developed and functional GIS and remote sensing tools. Using satellite imagery, the temporal patterns of urban spread are examined and analysed. The geographical and temporal data obtained by the remote sensing techniques can be used by the image processing techniques to discern the pattern of urban growth. These are useful in distinguishing the radial and linear growth patterns of urban sprawl (Yeh and Xia, 2001). In order to detect changes in urban land use and cover, remotely sensed satellite images are crucial for creating land use and land cover maps. Land use refers to the various ways that land is used, such as for economic, recreational, or forest purposes. The area covered by different physical characteristics, such as flora, hills, water bodies, etc., is referred to as land cover. Thus, remote sensing technology is essential to mapping urban land cover and land use (Yeh and Xia, 2001).

2.13 Conceptual framework

A conceptual framework is an illustration that depicts the expected relationship between cause and effect in research. It outlines the relevant objectives of the investigation and demonstrates how they interconnect to produce logical findings. When analysis LULC and their correlation with urban sprawl, a conceptual framework were developed to understand the relationship between different satellite images, including LULC types and their impact on urban sprawl.

This framework considers various Landsat imagers with landscapes such as built-up areas, , water bodies, forests, bush with grasslands, bare lands, and cultivated land, each having distinct effects on urban sprawl.

The conceptual framework provides a methodical approach to understanding the complex relationship between land use, land cover change, and urban sprawl. It serves as a guide for research, helping to define research objectives, identify variables, and analyze the expected cause of urban sprawl.

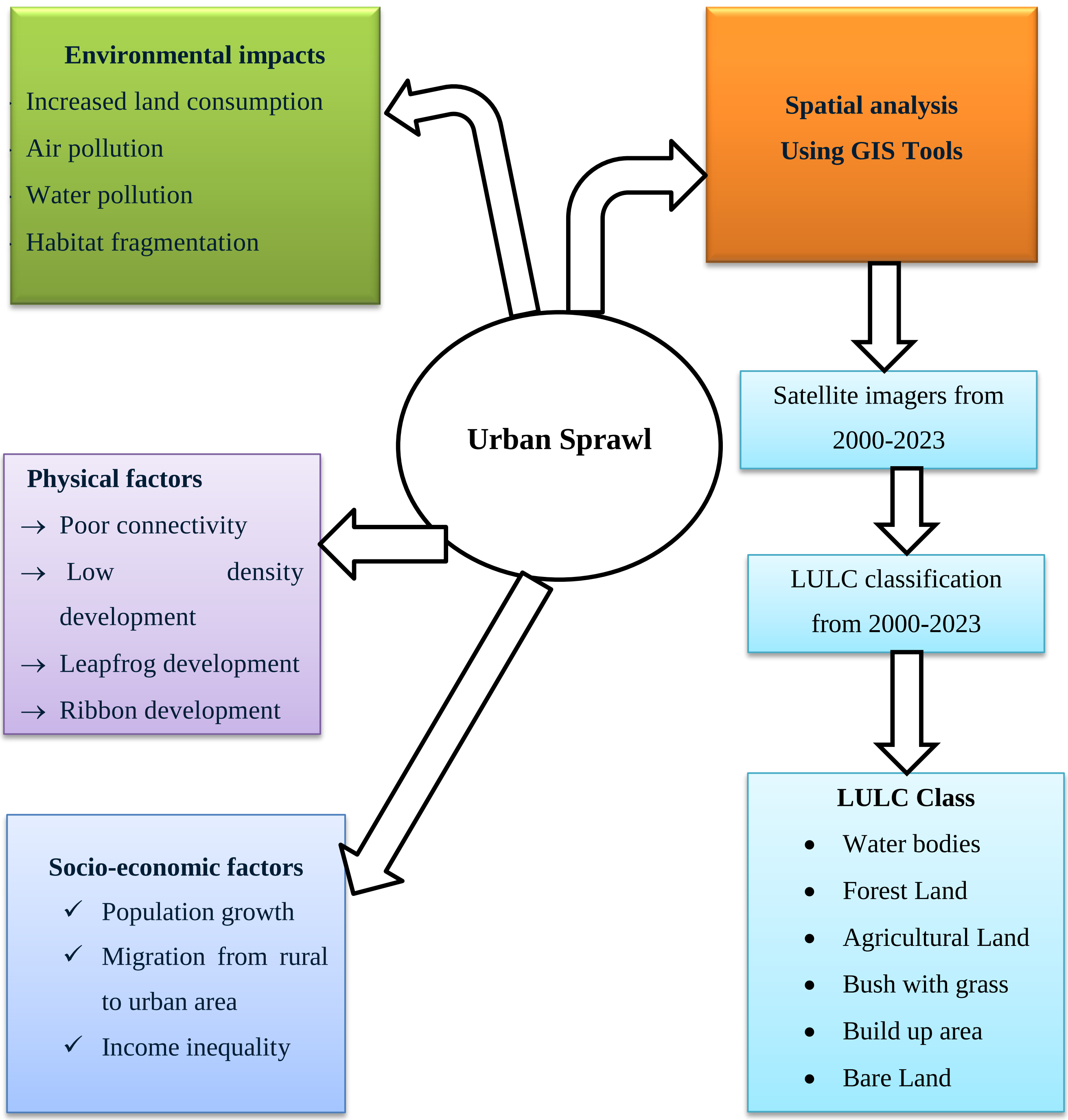

Figure 2.1 Conceptual framework of urban sprawl

CHAPTER THREE

METHODOLOGY

3. Introduction

This section contained five major components; the first part description of the study area, second part presented issues related with population and sampling technique, the third part of the chapter-discussed research design, the fourth part described data description and data sources and finally the fifth part discussed the method, techniques of data analysis and ethical consideration.

3.1 Description of the study area

Gambella town, located in the Gambella Region of Ethiopia, has a unique historical background. The area has been inhabited by various indigenous ethnic groups, and others, Ethiopian highlanders who are lives in the region. The Gambella Region is situated in the western part of Ethiopia, bordering South Sudan to the west and south.In the late 19th and early 20th centuries, the Gambella area became part of the Ethiopian Empire. During the Italian occupation of Ethiopia (1936-1941), Gambella experienced some changes in administration and infrastructure (Berhe & Adaye, 2006)

Gambella Peoples' National Regional State (GPNRS) is located in the southwestern part of Ethiopia, at a distance of 777 km from Addis Ababa. Administratively speaking, the region has three zones and one Special Woreda. There are 226 Kebeles. Five of the kebeles are that of Gambella town. According to the regional government's policy documents, GPNRS is one of the emerging regions of the country and a home for the five indigenous ethnic groups, the Nuer, Anywaa, Majang, Opo, and Komo. In addition, following the resettlement program of the 1980s, a good number of people from different parts of the country moved to the region. Recently, the refugees from South Sudan (estimated 350,000) are becoming the most dominant, imposing a threat to the environment, socioeconomic and cultural values (Jimma, 2017). Gambella is located in Ethiopia with (8.25, 34.5833) coordinates. Its astronomical location is 8° 15´ 0.0000'' and between 34° 34´ 59.9880". Relatively it serves as the capital city of the Gambella Region. It shares a long border with South Sudan and two other Ethiopian regions: Oromia to the north and east and the Southern Nations, Nationalities and Peoples' Regional State (SNNPRS) to the south (Jimma, 2017)

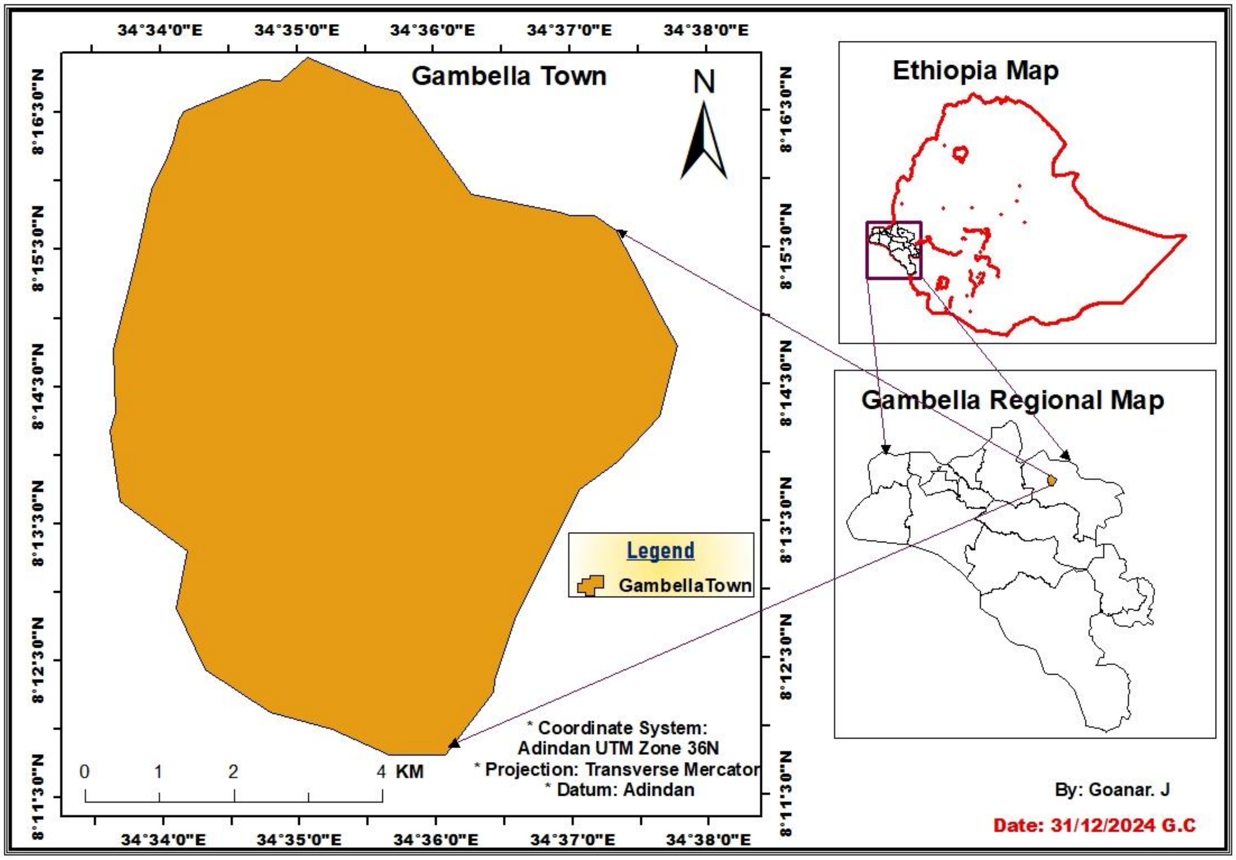

Figure 3.1 Location Map of Study Area

3.2 Population

According to the official estimates from the Ethiopian Statistics Service, the projected population of Gambella town in 2017 was 75,098. In the 2017 projected population included 35,802 women, making up approximately 47.7% of the total, and 39,296 men, accounting for about 52.3%. This gender distribution indicates a slightly higher number of males compared to females. The detailed demographic information can be further explored in the accompanying figure (Fig. 3.2), which illustrates the population dynamics and proportions within the town.

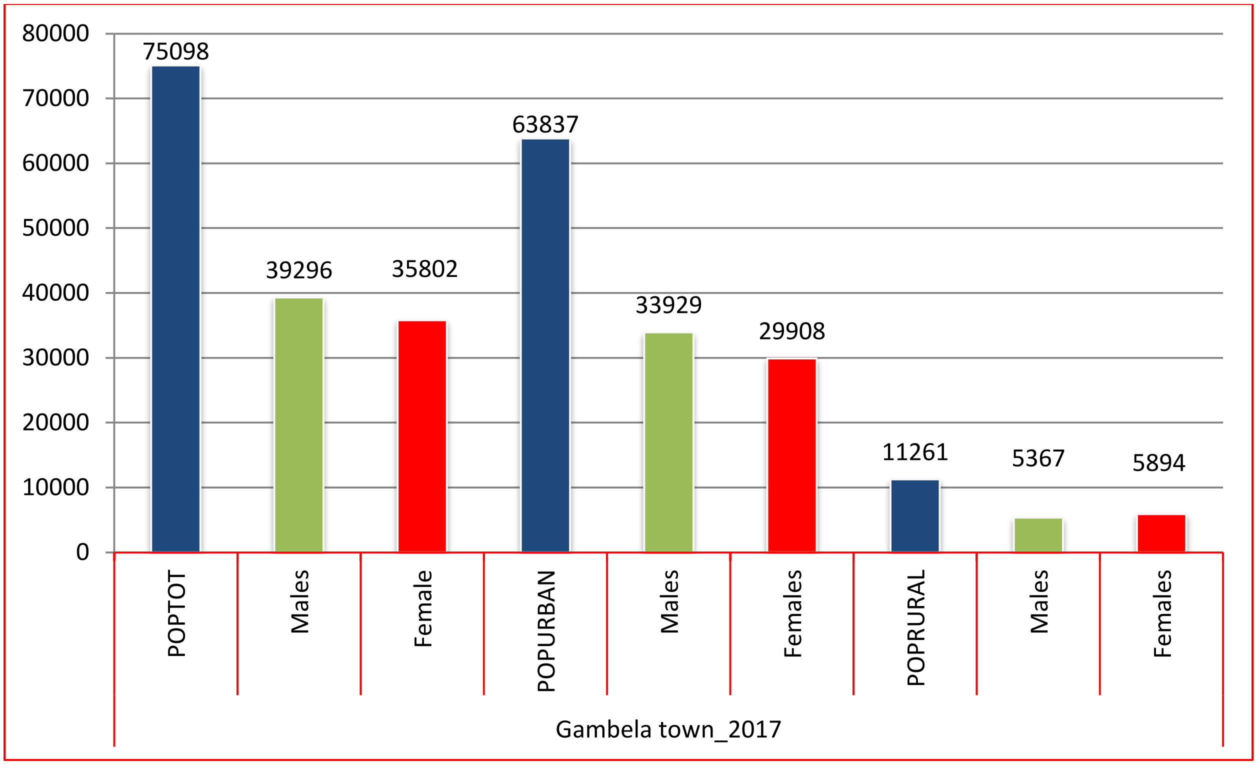

Figure 3.2 Population of the Study Area

3.3 Topography and climatic condition

The study area elevation is range from lowers 403 up to highest 521 m, which the Gambella town covered area. Temperature and rainfall of the region are conducive for agricultural activities, the annual rainfall ranges between 800 and 1200 mm and 85% of rainfall occurs between May and October. The mean annual temperature of the region varies from 17.3 to 28.3 degrees Celsius (◦C), (Jimma, 2017).

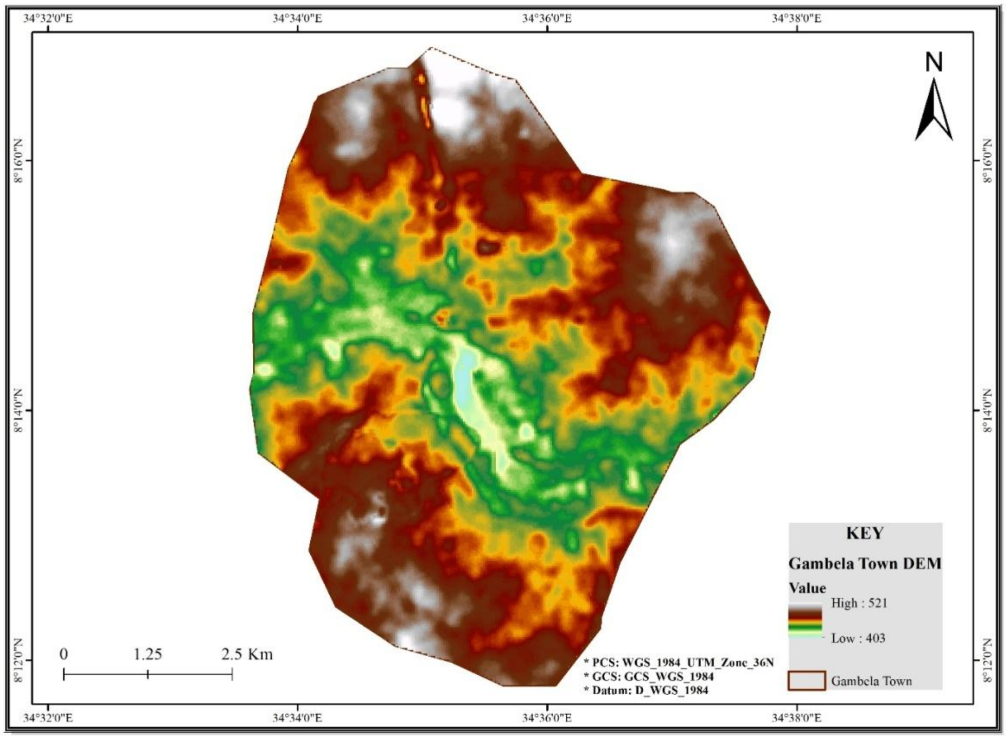

Figure 3.3 Digital Elevation model of the study area

3.4 Sample size and sampling techniques

Acquiring data from the local population is necessary to meet the study's goal and provide answers to queries about the effects of urban sprawl. Data was gathered using both probability and non-probability sampling methods. The selection of the GIS specialists was based on their background in addressing the problem. In addition, a straightforward random sampling technique was used to choose the sample household heads. Data from CSS (2017) shows that there were 75,098 people living in Gambella town overall, this simplified approach uses the maximum variance (p = 0.05) and a 95% confidence level to calculate the necessary sample size. The equation is:

n= N/1+N (e) 2.. (Kasunic, 2005)

Where

n -is the sample size

N -is the population size (total household)

e -specifies the desired level of precision (6% (0.06)

1 = a theoretical or statistical constant

Step: 1. Calculate N (e) 2 = 75,098 * (0.06) 2 = 75,098*0.0036 = 270.3528

Step: 2. Calculate denominator 1+ N (e) 2 = 1+ 270.3528 = 271.3528

Step: 3. Calculate the sample size n = 75,098/ 271.3528 = 276.62

n= 277

The proper sample size for this investigation, determined by using the preceding simplified technique, was 277 respondents.

3.5 Research design

Research techniques, a quantitative method and qualitative method, mixed were used for this study. When describing a phenomenon, a quantitative technique is used to investigate the relationship between urban sprawl pattern and its contributing components. The researcher also employed research design, which examines how urban sprawl changes over time in the study area, to collect quantitative data. Using this approach, three distinct satellite images within the same parameter were used. The data from focus group discussions (FGD), and observations, was used to analyse a qualitative method, which supports a quantitative one.

3.6 Data description and data source

The study has used Landsat satellites imageries of 2000, 2010 and 2023 was the main data source for the dependent variable for spatial temporal change of Urban sprawl pattern. Is a freely available satellite image downloaded from the USGS database (https://earthexplorer.usgs.gov/), all data are supplemented with secondary data sources. Full details are displayed in Table 3.1 below.

Table 3.1 Description of the description and data sources

GIS Data layer	Data Description	Data source
Vector (polygon)	Woreda Boundary	Ethio-GIS
Vector (line)	River, Contour and Roads	Ethio- GIS
Attribute table	Population	CSS,2017
Vector (point)	Major Town	Ethio-GIS
Raster	Elevation	DEM 12.5m from SSGI
Raster	Satellite Image 2000 Landsat4 TM 2010 Landsat7ETM+ 2023 Landsat 8 OLI & TIRs	USGS 2000,2010 and 2023 (Image courtesy of the U.S. Geological Survey)
Ground truth	Google Earth pro	Google Earth pro

Data from many sources have been gathered for the study. First, structured questionnaires are used to analyze the effects of urban sprawl on the study area; digital cameras are used to take photos of the sample filed area; GPS is used to obtain ground truth points for accuracy assessments; field observations are conducted; and data obtained from other sources is substantiated by questioners with experts and affected individuals. The history and current state of the city's LULC are also discussed with local specialists and elders who work for the municipality.

The Space science and Geo-spatial Institute (SSGI) is one of the offices from which secondary data is gathered. A variety of published and unpublished sources, including books, journals, the internet, research reports, articles, documents studied for this investigation, and other materials from the Gambella Land administrative and urban development plan provided additional supplementary data for this study.

3.7 Remote sensing data acquisition and methods of data collection

As shown in Table 3.2: LU/CC was calculated using remote sensing imagery in Gambella town. Thermal infrared sensors, which gather radiation released by the earth's surface and translate it into temperature data, are the source of LST values. To assess the quality and quantity of vegetation, a multispectral data especially red and near-infrared band is used to construct the NDVI, or vegetation index. The LU/CC classification was carried out using GIS methodologies and classification algorithms to quantify the extent of each land cover class within the study area. This included classifying land cover categories such as agricultural land, urban areas, forests, water bodies and grass land.

Most of the data for this study comes from satellites, both primary and secondary data sources were used to achieve the intended objectives. Among the well-known open-source satellite imagery, Landsat satellite imageries are ideal for this purpose of analysing the spatial and temporal changes of urban sprawl pattern with good spatial resolution. Therefore Landsat 4-5 TM, Landsat 7 ETM+ and Landsat 8-9 OLI_TIRS imageries was used for this study to assess the spatial temporal change of sprawl pattern over the period considered when downloaded from the USGS database. Others data were used to collected from the Ethiopia Geospatial institutes. Full details are displayed in Table 3.2 below.

Table3.2 Description of the metadata of satellite images

№	Data type	Raw and Path	Acquisition Date	Spatial Resolution	Data Source
1	LANDSAT_4-5 TM	171/054	2000-02-02	30m x 30m	USGS Earth Explorer
2	LANDSAT_7ETM+	171/054	2010-01-04	30m x 30m	USGS Earth Explorer
3	LANDSAT_8-9 OLI_TIRS	171/054	2023-01-08	30m x 30m	USGS Earth Explorer

The Land use and land cover changes (LU/LCC) in Gambella town between 2000 and 2023 the area of interest was extracted from the larger scene of, Landsat 4-5 TM, Landsat 7 ETM+ and Landsat 8-9 OLI_TIRS imageries using the. Machine Learning Classification techniques were used to employed the categorize of images into different land cover types, such as built-up areas, bare land, forest land, water body, grassland and Agricultural land. The rate of urban sprawl was determined by comparing the resulting value generated from the classified images of the data set for 2000, 2010 and 2023.

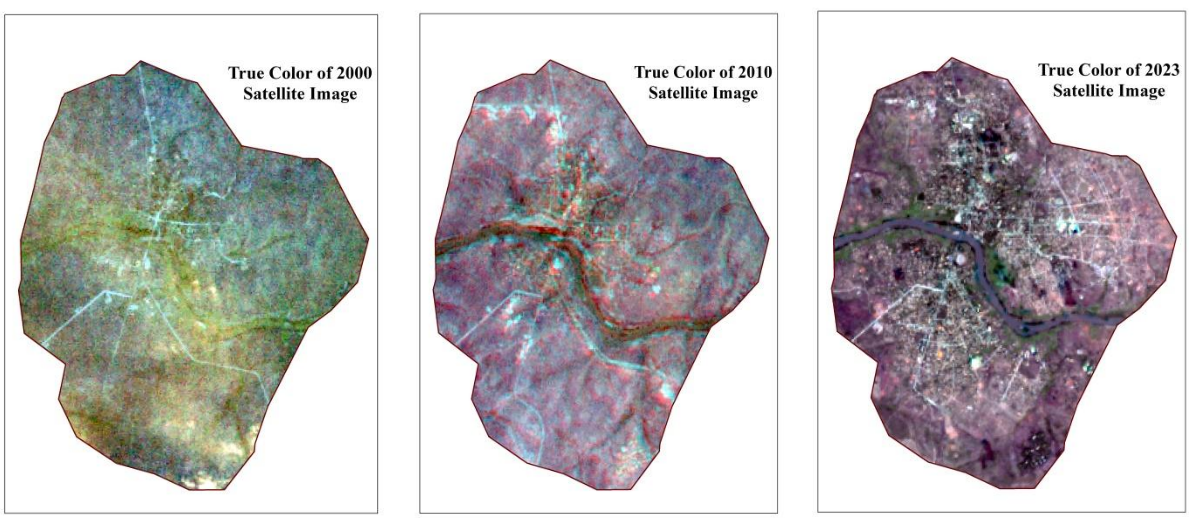

Figure 3.4 Landsat images of 2000TM, 2010 ETM+ and 2023 OLI_TIRS

3.7.1 Landsat thematic mapper (TM)

The TM sensor, a crucial component of the Landsat program, was fitted aboard the Landsat four and five satellites. It was eventually retired in May 2012, having served an amazing 30-year existence from July 1982 to that date. Over a three-decade period, systematic and comprehensive earth observations were made possible by the 16-day repeat cycle of the TM sensor, which yielded invaluable insights into the dynamics of the planet’s environment. Sophisticated features characterize the TM sensor. It has seven spectral bands, three of which are visible and four of which are infrared. Nuanced observations on the earth's surface features, vegetation health, changes in land cover, and other factors were made possible by this configuration's many facets. Because of its precise tuning to thermal infrared radiation, Band six of the TM sensor was particularly noteworthy. This spectral band plays a key role in measuring variations in surface temperature across different landscapes. Surface temperature is a crucial factor for understanding climate patterns, the effects of urban heat islands, and the dynamics of ecosystems.

The Landsat TM sensor has been instrumental in furthering scientific understanding and environmental monitoring during its operational lifetime. With a wealth of data essential for global policy formation, resource management, and scientific research, its legacy as a cornerstone of remote sensing technology continues to this day.

3.7.2 Landsat 7 enhanced thematic mapper plus (ETM+)

Since July 1999, the Landsat ETM+ sensor, which is part of the Landsat 7 satellite, has taken images of the planet almost constantly, repeating every 16 days. Taking regular, very detailed high-quality images of the surface of the earth is its goal. After operating practically continuously for 20 years, Landsat 7ETM+ has shown to be an important source of knowledge for a variety of uses, such as urban planning and environmental monitoring. Among its distinctive features is the 16-day repetition cycle of the Landsat 7ETM+ sensor, which allows it to systematically and regularly return to the same areas of interest. This periodicity makes it possible for researchers and decision-makers to precisely track changes over time in the environment, land use, and cover. The imagery obtained by the Landsat 7ETM+ sensor comprises eight spectral bands, each offering a unique viewpoint on a different region on the earth's surface. Data with a 30m spatial resolution are available for bands 1 through 5 and 7, which provide comprehensive details about the health of vegetation, geological features, and other characteristics of the land cover.

Monitoring changes in vegetation dynamics and classifying land cover are two applications that benefit greatly from this resolution. The Landsat 7ETM+ sensor has additional bands in addition to these regular bands: band 6 for thermal imaging and band 8 for panchromatic imaging, each with unique features. Band 6 of the TM sensor absorbs thermal infrared radiation from the earth's surface, enabling the identification of thermal anomalies such as volcanic eruptions and urban heat islands through temperature fluctuations and activity. Band 6 offers important insights into surface temperature trends and energy fluxes with a 60m spatial resolution. With a remarkable resolution of 15 meters, band 8 provides the highest spatial resolution of all the Landsat 7ETM+ bands. Applications requiring in depth visual interpretation, such as infrastructure building, disaster response, and urban planning, are especially well-suited for this panchromatic spectrum. Its exceptional resolution makes it possible to distinguish fine-scale details and accurately draw boundaries, which makes it a vital tool for mapping and analysis.

3.7.3 Thermal infrared sensor and operational land imager of Landsat 8

Launched on February 11, 2013, Landsat 8 is a sophisticated imaging system with nine spectral bands, each of which provides valuable knowledge about the surface of the earth. With a 30 m spatial resolution for bands 1-6, 9, and TIRS, precise observations of terrain features are guaranteed. Two new bands-10 and 11-among the improvements provide greater thermal imaging capabilities, supporting surface temperature variations and environmental change research. Furthermore, the advent of band 1, often known as ultra-blue, is beneficial for aerosol and coastal studies, allowing for more accurate observation of atmospheric conditions and coastal dynamics. In addition, Landsat 8 adds band 9, which is dedicated to cirrus cloud detection, improving the satellite's capacity to recognize and assess clouds at high altitudes. Increasing our understanding of cloud dynamics and how they impact the earth's climate system requires this development, as well as raising the accuracy of weather forecasting models. With these enhancements, Landsat 8 continues to be an essential tool for academics, researchers, and policymakers, allowing unprecedented levels of precision and detail in in-depth analyses of the earth's surface and dynamic processes.

3.8 Spectral properties and principal applications

The Landsat programme is the oldest civil earth observation programme. It started in 1972 with the landsat-1 satellite carrying the MSS multispectral sensor. In 1982, the Thematic Mapper (TM) replaced the sensor. Both MSS and TM are scanners. In April 1999 Landsat-7 was launched carrying the ETM+ scanner. Recently, only Landsat -5 and Landsat-7 are operational. Full details are displayed in table 3.3 below.

Table 3.3 Description of the Spectral properties and principal applications

Band	**Wavelength (μm)**	**Principal applications**
B-1	0.45 - 0.52 (Blue)	This band is useful for mapping coastal water areas, differentiating between soil and vegetation, forest type mapping, and detecting cultural features.
B-2	0.52 - 0.60 (Green)	This band corresponds to the green reflectance of healthy vegetation. Also useful for cultural feature identification.
B-3	0.63 - 0.69 (Red)	This band is useful for discriminating between many plant species. It is also useful for determining soil boundary and geological boundary delineations as well as cultural features.
B-4	0.76 - 0.90 (Near-Infrared)	This band is especially responsive to the amount of vegetation biomass present in a scene. It is useful for crop identification and emphasizes soil/crop and land/water contrasts.
B-5	1.55 - 1.75 (Mid-Infrared)	This band is sensitive to the amount of water in plants, which is useful in crop drought studies and in plant health analyses. This is also one of the few bands that can be used to discriminate between clouds, snow, and ice.
B-6	10.4 - 12.5 (Thermal Infrared)	This band is useful for vegetation and crop stress detection, heat intensity, insecticide applications, and for locating thermal pollution. It can also be used to locate geothermal activity.
B-7	2.08 - 2.35 (Mid-Infrared)	This band is important for the discrimination of geologic rock type and soil boundaries, as well as soil and vegetation moisture content.

3.9 Methods and techniques of data analysis

The Earth Explorer website (USGS) provided Landsat images for 1987, 2005, and 2023, while https://libra.developmentseed.org provided Landsat 8 imagery. These sources served as the first step in the study technique. The availability of data played a role in the selection of these particular years. The images that were obtained or downloaded were deliberately selected to avoid excessive cloud cover and to align with the dry season. This method made sure that the analysis procedure was reliable and consistent. The study's overall methodological flow is depicted in Figure 3.5

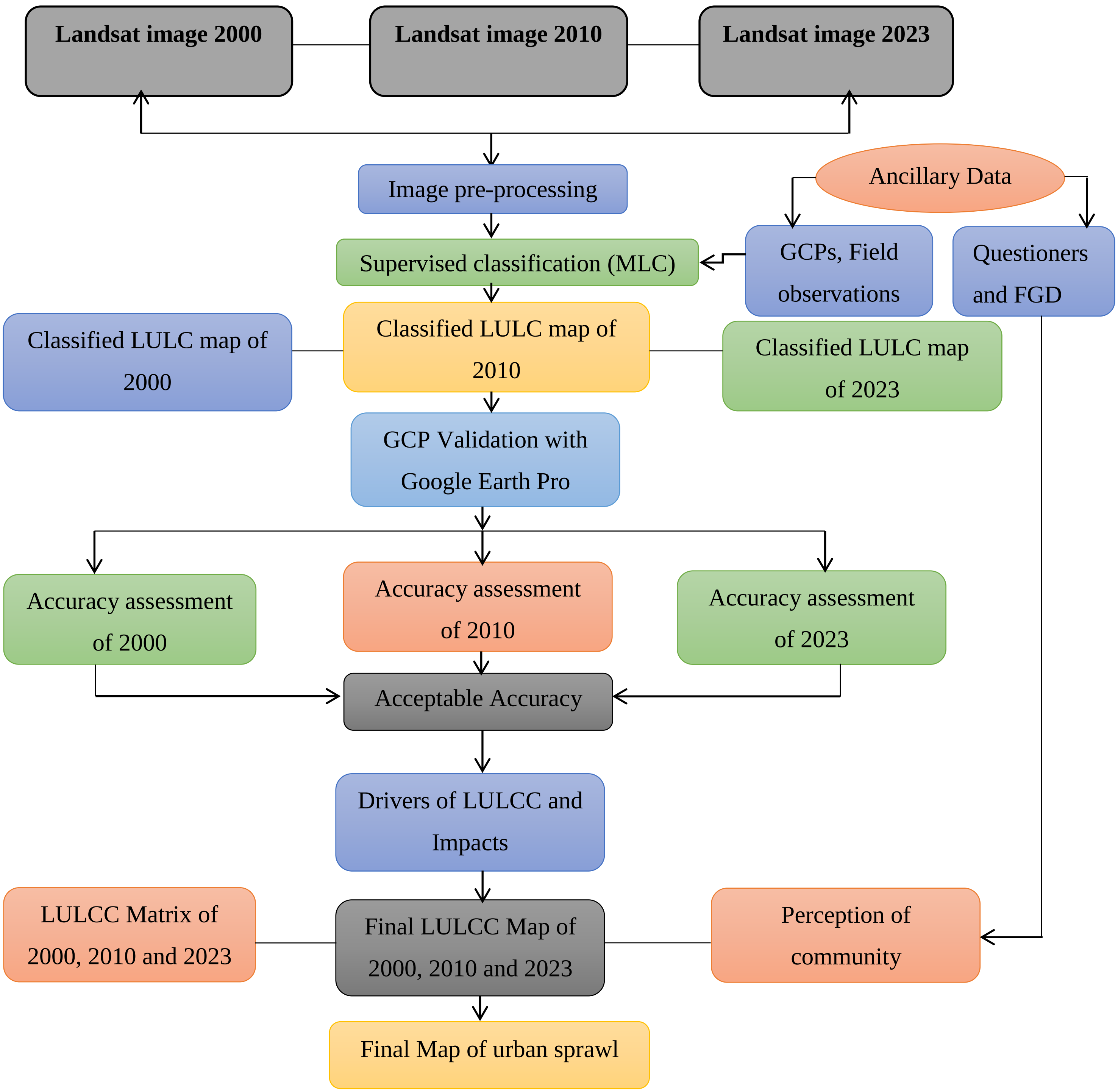

Figure 3.5 Methodology flow chart frameworks

The acquisition of Landsat images from the GLCF website is insufficiently complete for direct use; therefore, image preprocessing is necessary to prepare the raw data for various uses. As a result, In order to analyze urban sprawl and its effects on the research area, the obtained photos were pre-processed before being categorized into several urban LULC classifications. Image pre-processing methods like layer stacking, which joins layers to prepare them for categorization, are included in this image processing.

To improve visualization and classification (supervised classification), images can be enhanced to provide more tonal vibration. Additionally, post-classification is done using ERDAS 2015 software, and the study area's LULC map for 2023 is created using ArcGIS10.8 or Arc GIS Pro software, using spatial reference of the Universal Transverse Mercator (UTM) zone 36 N projections with datum World Geodetic System (WGS) 1984 UTM, In order to inform land-use planning.

Error matrix or confusion matrix techniques were used with ERDAS IMAGINE 2015 to address errors of commission and omission that occurred during data processing. These five LULC class categories each had five training regions selected for the supervised classification. A small-scale farm that grows subsistence crops like maize is the earliest use of agricultural land. A piece of property that is home to a variety of structures, including commercial, office, residential, industrial, and recreational ones, uses land that has been developed. Any territory that has both naturally occurring trees and man-planted trees is considered a forest. Undeveloped territory with a stony topography is referred to as "bare land."

Finally Open space used for grazing that is primarily covered in grass with a few sparsely planted trees scattered throughout the area between farmed areas and streams. Following the conclusion of the picture classification process, the accuracy of the urban LULC classification result was assessed using a technique that collected ground truth points using a GPS instrument. Using ERDAS IMAGINE 2015, error matrix or confusion matrix techniques were used to address commission and omission mistakes that occurred during data processing. The spatial analyst tool in ArcGIS 10.8 uses the reclassification procedure to discover changes after creating urban LULC maps for the years 2000, 2010, and 2023. Ultimately, a map of Gambella town's urban sprawl is created. Data collected from field surveys utilizing questionnaires, digital cameras, and field observations, quantitative were evaluated using tables, graphs, percentages, pie charts, and figures.

3.10 Digital image processing

By correcting distorted or inferior image data, these processes seek to improve the image's usability for further alteration and produce a more accurate portrayal of the original scene. To do this, raw image data must first be processed to eliminate noise, calibrate radiometric data, fix geometric deformities, and modify the image extent via sub-setting or mosaicking. Computers are used to modify and interpret digital images, which are numerical representations of two-dimensional scenes made up of pixels. Digital image processing has traditionally been used in remote sensing for two main purposes: processing picture data for computer-assisted interpretation and improving information for human interpretation. Increasing an object's spectral reparability within an image is the main objective of digital image processing operations.

3.11 The Landsat 7ETM+ scan-line corrector error

Data classified as SLC-off are images from Landsat 7 ETM+ acquired after May 31, 2003, the day of the Failure of the Scan Line Corrector (SLC) are known as SLC-off data. The imaging had gaps in the scan lines due to the SLC failure, which made it less suitable for some applications, especially ones that needed continuous data coverage. When the proper geometric and radiometric corrections are applied, these SLC-off data can still be beneficial for various applications.

To maintain uniformity and accuracy in reflecting the true reflectance or radiance of the earth's surface, radiometric correction entails modifying the pixel values. To provide accurate spatial representation, geometric correction entails correcting the image to remove distortions brought on by sensor and platform features. Despite the SLC failure-related data gaps, Landsat 7 SLC-off data can still provide valuable information for various applications, such as change detection, environmental monitoring, land cover classification, and land use analysis. Users need to implement the necessary safety precautions and be aware of the limitations posed by the gaps in the data while evaluating and interpreting it.

3.12 Image enhancement

The method by which a technique to image data to improve its display or recording for later visual interpretation is known as image enhancement, Image enhancement often entails methods for improving the scene's visual feature differentiation (Billah and Rahman, 2004). Making images easier for people to understand or to utilize as input for automated image processing techniques is the primary objective of image enhancement, which is a crucial step in the digital image processing pipeline. A picture's visual quality can be improved by using several enhancement techniques, like contrast stretching, histogram equalization, and spatial filtering, which make it easier for human observers to perceive and understand important details. Improved photos can also give more reliable input for later automated analysis, making it easier for algorithms to find and extract important information. Subtle details can be brought to light, noise can be minimized, and overall image quality can be improved by image enhancement, which will ultimately produce more accurate and trustworthy results from image interpretation and analysis.

3.13 Image classification

Sorting each pixel in a digital image into a different land cover class, or theme, is the classification process. Then, using these classified data, one may create summary statistics of the areas covered by each category of land cover or create themed maps of the land cover shown in a picture to ascertain the research area's LULCC, GIS, and ERDAS imagine supervised The classification technique employed was the maximum likelihood approach. The supervised classification method with a maximum likelihood (MLC) algorithm is the most accepted classification method used in RS data (Kamusoko, 2022). The reflectance statistics for individual pixels are used in image classification. Pixels were arranged into clusters, which are groups according to their reflectance characteristics. The users decide which bands to use and how many clusters to create. The picture categorization software creates clusters based on this data. Supervised classification techniques are employed in this study.

3.14 Supervised classification

In the field of remote sensing, supervised classification is a reliable and popular method in light of the quantitative analysis of picture data. It is predicated on the idea that because of differences in their reflectance characteristics, various earth surface features show distinct spectral signatures in remotely sensed pictures. These spectral characteristics act as fingerprints, allowing different features to be identified from one another. Each year's supervised classification involved categorizing pixels into LULC classes using training sites for bare land, farmland, shrub land, and settlement, and sites for plantation and water body types. Verification through field assessments ensured the accuracy of LULC classifications based on distinctive signatures in digital images, following (Coppin and Bauer 1996).

The initial action in the procedure is gathering training samples, which are ground-level representations of each class or interest category (such as different forms of land cover). The spectral variability within every class ought to be captured by these training samples. Many remote sensing software packages have an image classification toolbar that makes it easier to create and choose training examples by letting users interactively specify areas that match several classes straight on the picture. The next stage is to use the training samples to train a classification algorithm after they have been gathered. Neural networks, Random Forests, Support Vector Machines, and Maximum Likelihood are examples of common algorithms. While training, the algorithm constructs a classification model by acquiring knowledge of the spectral signatures linked to every class. Following training, the classifier is applied to the full image, classifying each pixel according to its spectral similarity to the training samples, therefore placing it in one of the predetermined classes. Pixel-based classification is the term used for this procedure. As a result, an image is classed, with labels identifying each pixel's class. It is possible to extract useful information from remotely sensed pictures through supervised categorization. It is compatible with numerous applications, including land-use planning, agriculture, forestry, urban development, and environmental monitoring, by recognizing and mapping diverse land-cover types or other properties of relevance. However, the standard and applicability of training data, the algorithm used for the classification, and the preprocessing techniques used on the imagery (such as atmospheric correction and radiometric calibration) all affect how well-supervised classification works. Additionally, by contrasting the categorized outcomes containing foundation truth data or higher-resolution images, validation techniques are frequently utilized to assess the correctness of the results. Bands 1 through 7 of the preprocessed pictures were used to map the land-use/land-cover pattern using multispectral bands from bands 1 to 5 and 7 for TM 2000 ETM+ 2013 and OLI 2023. This was done by supervised classification using the likelihood classification algorithm of the ERDAS Imagine 2015 program and accuracy assessment in ArcGIS software. When it comes to supervised classification, the user-specified kinds of LULC classes are classified with the aid of image processing techniques. Farmland, bare land, settlement, shrubland, forests, as well as water bodies were the six main classes studied in Gambella town. The creation of information classes and self-assessment through training sites were benefits of the supervised classification. Conversely, though, information classes might not coincide with spectral classes, and information class signature homogeneity and uniformity might differ. When correct to preprocess data, apply spectral enhancement techniques like principal component analysis (PCA) or spectral un-mixing to improve the spectral differences between classes, thereby enhancing the distinction between information and spectral classes. Additionally, reduce noise in the spectral data using filters or algorithms to make the classes more distinguishable.

3.15 Maximum likelihood classification

In remote sensing, MLC is a popular technique for classifying pixels. MLC helps classify overlapping signatures by assigning a pixel to the most fitting class or group based on statistical decision metrics. This approach, which places pixels in the class with the highest probability, outperforms parallelepiped categorization in terms of accuracy. The disadvantage of it is that computational extraction is slower. When allocating cells to one of the classes listed in the signature file, the MLC classification tool considers the variations in class signatures.

3.16 Ground truthing

In the study area, a ground-truthing activity was conducted to validate various LULC classes. This involved verifying different types of terrain, such as farmland, bush with grass land, water bodies, bare land, and settlements, in Gambella town. These observed LULC classes were crucial in developing accurate map legends. Additionally, with the aid of GPS technology, data for the training set used in image classification was collected and most of the GPS point was collected at the centers of the Gambella town due to the security instability of the town between the two ethnic group nuer and anyuak.

During the ground-truthing process, photographs of significant scenes and coordinates representing sampled LULC classes were meticulously captured. This meticulous approach ensured that the data collected was reliable and representative of the diverse landscapes within the study area. Through this comprehensive validation process, the study could effectively establish the groundwork for accurate mapping and classification of the region's LULC.

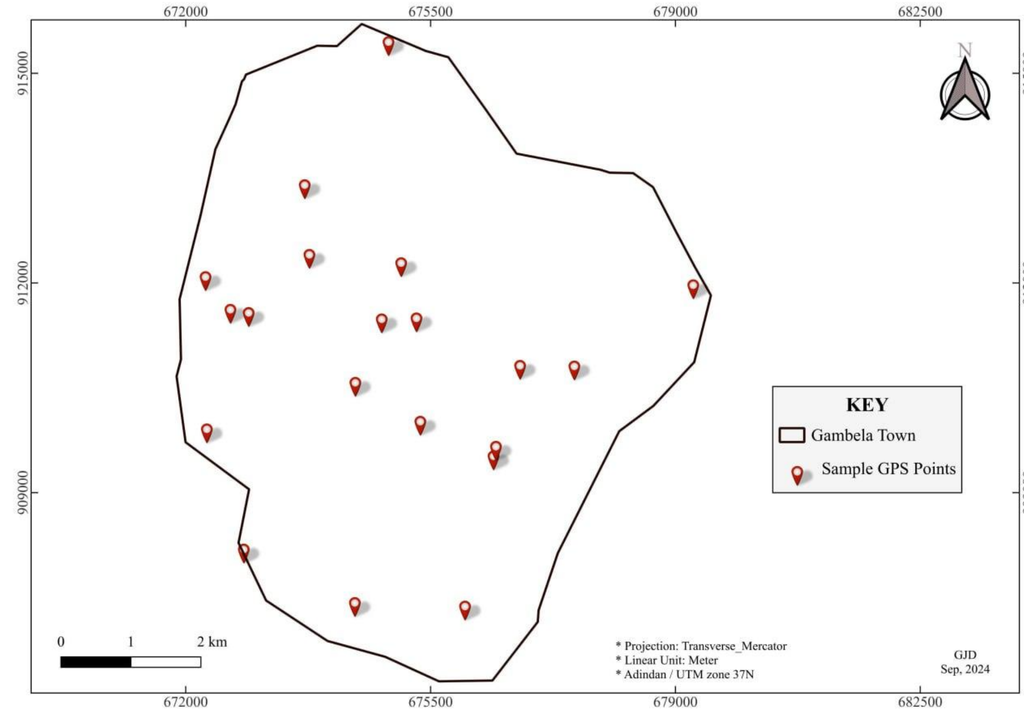

Figure 3.6 Ground truthing map

3.17 Classification accuracy assessment

Documenting the categorical precision of the classification outcomes is crucial after the land cover categorization process. Until the correctness of a classification is evaluated, it remains incomplete. Making a classification error matrix, additionally referred to as a confusion matrix or a contingency table, is among the most popular ways to describe classification accuracy. Error matrices compare the outcomes of an automated classification process with known reference data, or ground truth, on a category-by-category basis. To evaluate how accurate the findings of the classification are, representative points from each category of land cover will be included in a confusion matrix. The LULC classification accuracy was assessed using Google Earth and the field survey. For the years 2000, 2013, and 2023, the classification accuracy's ultimate output was determined by a map of land cover and use.

A comprehensive comprehension of the research area's biological and geographical context is necessary to identify and categorize the LULC. A comprehensive comprehension of the region is necessary to interpret the features that are seen using Google Earth Pro and field observations.

Once the Google Earth Pro version of 7.3.3.7786 was verified, six prominent LULC classes were identified, each of which embodied unique aspects of the topography's composition and use patterns. The foundation for later analysis and categorization projects is laid by these classes.

Table 3.4 Description of the LULC along with a description of each

LULC classes	Description
Shrubs land	Scrubland: Less thick than forests, these regions are defined by shrubs, bushes, and small trees scattered with patches of crabgrass. The trees usually produce little useful wood.
Farmland	This term refers to spaces where annual and perennial crops are grown as their primary usage. A combination of small rural farms and expansive agricultural fields may be seen in the landscape.
Settlement/ Build up area	These sites include residences, workplaces, and including buildings used for business, residential, and industrial purposes. It includes a system of highways, urban facilities, and transportation infrastructure.
Waterbody	Ponds, lakes, rivers, and other man-made and natural water bodies, envelop these regions. They are essential to maintaining aquatic habitats and supplying water for many human uses.
Bare land	Beaches, dunes, exposed rocks, and salt flats are examples of non-vegetated landscapes that fall under barren land. It also includes degraded areas with rocky outcrops and eroded soil and sites and quarries.
Forest	A forest is a large area of land covered with trees and plants, where trees are the dominant life form. Forests are complex ecosystems that are efficient at photosynthesis and support a variety of plant and animal life. Trees of various densities and species predominate in these areas. Timber resources, biodiversity preservation, and carbon sequestration are just a few vital ecological services that forests offer.

3.18 Software and instruments

The GIS software utilized in this investigation was widely known and used for image processing. A GPS device is used in order to gather ground truths for field verification. Image processing was also accomplished with the aid of ERDAS IMAGINE 2015. The structured questionnaire was initially written in English and then translated into Amharic. The questionnaire is then given out to the sample of expert and the community. Full details are displayed in the Table 3.5 below.

Table 3.5 Description of the software and their purposes

No.	Software Version	Purpose
1	ArcGIS 10.8	To do tasks such as cutting, Georeferencing for cross-tabulation (calculating the LULC class matrix between photos taken at various times), creating a map layout, extracting polygons from raster's, and creating slope and elevation maps using SRTM data
2	ERDAS IMAGINE 2015	For layer stacking, sub-seting, clipping, classifying the various LULC categories, post-classification, computing area, and evaluating the classification accuracy.
3	SPSS (Statistical Package for the Social Sciences)	Is a powerful software suite used for statistical analysis, data management, and data documentation
4	Garmin 72 GPS/ Essentials GPS	To gather the control point for ground truth.
5	Digital Camera	To take pictures of the research area for photography

3.19 Ethical consideration.

During a study's design and data gathering phases, ethical considerations come up. Conducting ethical research involves acknowledging data created by others and properly citing books, websites, and other relevant documents, as well as academic research results. By recognizing this, the researcher has included all of the data from academic publications in citations and acknowledgements. The researcher respected the norms, values, secrecy, and privacy of the respondents, as well as herself as a part of the community.

- Researchers practice in accordance with the profession's ethical norms, values, and goals and they are always conscious of these things. Researchers must to look after their personal and professional needs. Encourage moral behavior from the groups they are associated with and act in an honest and responsible manner themselves.
- Researchers who welcome participants treat them with consideration, humanity, and a sense of value and respect. Acceptance is demonstrated by showing real concern, listening intently, respecting the opinions of others, and fostering an environment of understanding
- The researcher is aware of and opens to the perspectives of the participants. It suggests a non-blaming attitude and action rather than judges judging others as good or evil, worthy or unworthy, dignified or undignified, or making decisions.
- The researcher is required to keep participant information private, including their name, any conversations they had with the researcher, any expert comments regarding them, and any records. Since participants frequently divulge private and sensitive information to researchers, maintaining confidentiality or privacy is crucial to building trust, which is a necessary component of any productive working partnersh

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4. Introduction

This chapter discusses the findings from both quantitative and qualitative data collected from various Landsat images, questionnaires, interviews, and field observations concerning urban sprawl and its effects on the land cover, land use, on the environmental consequences of urban sprawl pattern and major indicators of urban sprawl in study area.

4.1 Socio economic

4.1.1 Character of respondents

The Respondents' demographic information, including sex, age, marital status, education, occupation, and family size, was gathered because socio demographic traits of a population have an impact on the issue of urban sprawl. The distribution of family chores and decision-making is significantly impacted by the sex makeup of the population, which in turn affects the community's standard of living. With men making up 56% of the total and women 44%, male respondents were generally found to be more numerous than female respondents. This is due to the fact that male partners often make the majority of decisions about landholding and land use.

The respondent's age distribution is important to determine which age group is most at risk of losing their means of subsistence. According to the data, most of the respondents are in the working or operating age range. The sample's adult age group comprises around 61% of the total respondents (20–40 years old). Of the 277 respondents, 169 (61%) were between the ages of 20 and 40, 65 (about 23%) were between the ages of 41 and 60, and 43 (16%) were over the age of 60, according to the study. Generally speaking, the age group structure shows a significant percentage of the respondents were discovered to be between the ages of 20 and 40, which is reproductive age and suggests the possibility of population growth, one of the factors contributing to urban sprawl, which is the unplanned spread of cities or towns as a result of a growing population and migration.

Most of the town's residents have a high level of education. The educational attainment of 114 (41%) of the respondents who are educated is shown in the table below, they have a first degree or above. Of the responders, roughly 21 (8%) finished primary school, while roughly 54 (19%)

finished secondary school. About 34 (12%) and 46 (17%) of the population have certificates and diplomas, respectively, while the remainder 8 (3%) are illiterate. With the assistance of the researcher or data collector, these 85 respondents completed the questionnaire.

Family plays a key role in social adjustment, economic standing, and income maintenance. Statistics on marriages therefore have socioeconomic ramifications 87 (31%) of the respondents were single or never married, 35 (13%) were divorced, and 12 (4%), respectively, were widowed, whereas 143 (52%) were married. As a result, the respondents' responses might draw from their personal experiences managed caregiving and family responsibilities.

Table 4.1 Description of the demographic conditions of the respondents

Socio-demographic variables	**Number of Respondents**	**In percentage**
Sex		
Male	154	56
Female	123	44
Total	**277**	**100**
Socio-demographic variables	**Number of respondents.**	**In percentage**
Age		
20-40	169	61
41 – 60	65	23
>60	43	16
Total	**277**	**100**
Socio-demographic variables	**Number of respondents**	**In percentage**
Educational status		
Unable to read and write	8	3
Primary	21	8
Secondary	54	19
Certificate	34	12
Diploma	46	17
degree & above	114	41

Total	**277**	**100**
Socio-demographic variables	**Number of respondents**	**In percentage**
Marital status		
Married	143	52
Single	87	31
Divorced	35	13
Widowed	12	4
Total	**277**	**100**

Source: The data collected from a field survey.

4.1.2 Family size

The typical size of households in the research region, the largest household size was found to be 142 (5–10) members; the second largest was 75 (0–5) persons; and the third was 60 (>10) or more than nine members. In general, the figure indicates that the majority of sample homes had large families, with the average respondents' family size being between five and ten members. It is employed as a gauge of population crudeness and has significant effects on how urban sprawl affects their means of subsistence. The majority of suburbanites struggle to provide for their families with the resources available to them.

4.1.3 Household occupational status

The respondents from sample households are not all in the same line of work. These include daily workers, farmers, civil servants, traders, and those engaged in private employment. As the figure shows, traders make up 27% of the 264 sample households overall. Farmers make up 23% of the sample, daily workers make up 18%, and civil servants or government employers make up 16 and 15% of the sample respondents, respectively. One percent of the respondents are unemployed. In general, the figure indicates that the number of farmers is declining periodically, or, to put it another way, that trade or built-up areas are replacing agricultural land.

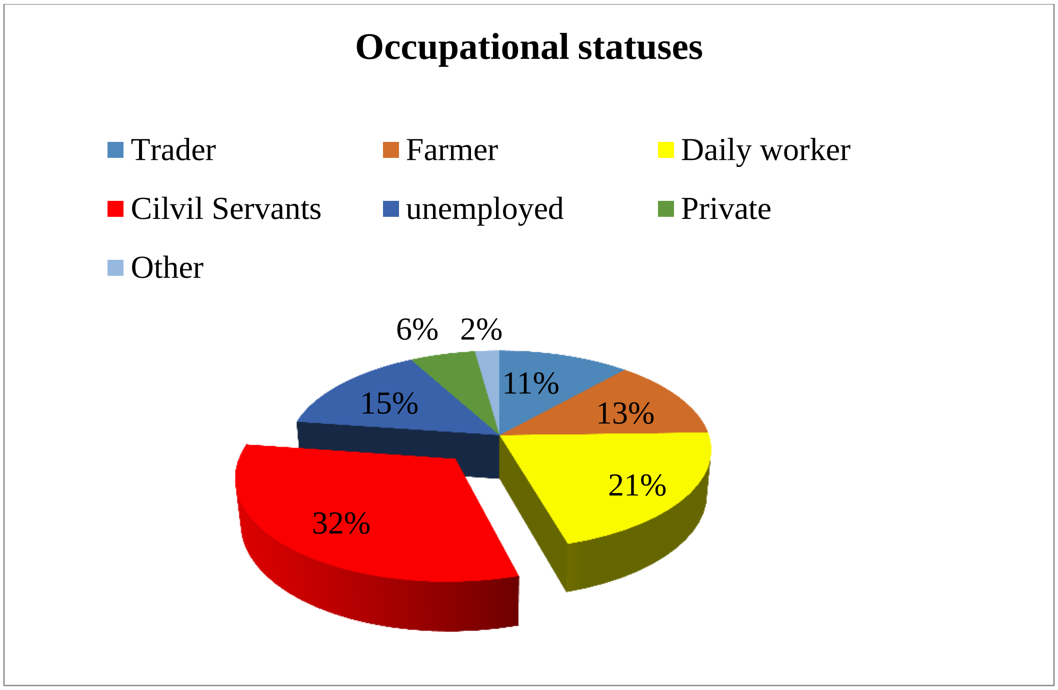

Figure 4.1 Household occupational statuses

Source: The data from field survey (2024)

4.1.4 Monthly income of households

The socioeconomic element of income is another reason why people leave their place of origin, and they are looking for work, which makes it challenging to forecast the rate of local population growth. For a variety of factors, including poor educational attainment, looking for batter job, health services and infrastructures likes roads, which makes people dread taxes, particularly traders, the difficulty to maintain sales records, and the fact that most had inconsistent and changeable income, it was exceedingly difficult to find information on the household heads' income. The numbers of respondents, however, have monthly incomes which are greater than 5000 birr (35%) and between 2001 and 5000 birr (23%). The monthly incomes of 18.0% and 12.0% of respondents, respectively, are between 1501 and 2000 and 1001 and 1500 birr. However, the remaining 9% are between 501 and 1000 birr and less than 3% have 500 birr a monthly, respectively this data was analysis from collected data from respondents.

Table 4.2 Description of the monthly income

No	Monthly income per month (ETB)	Frequency	In percentage
1	<500	7	3
2	500-1000	26	9
3	1000-1500	32	12
4	1500-2000	49	18
5	2000-5000	65	23
6	>5000	98	35
Total	**277**	**100**	

Source: The data collected from a field survey.

4.1.5 The status length of residence in the Gambella town

According to the respondents' length of residency in the Gambella town, 73% of the respondents are indigenous citizens and were born in Gambella regions. The remaining 26%, however, were immigrants, particularly from Ethiopia highlanders, South Sudanese refugee who seeks for slum and the surrounding region. One of the signs of the urban sprawl issue is the high rate of migration in the town, as seen in figure 4.2

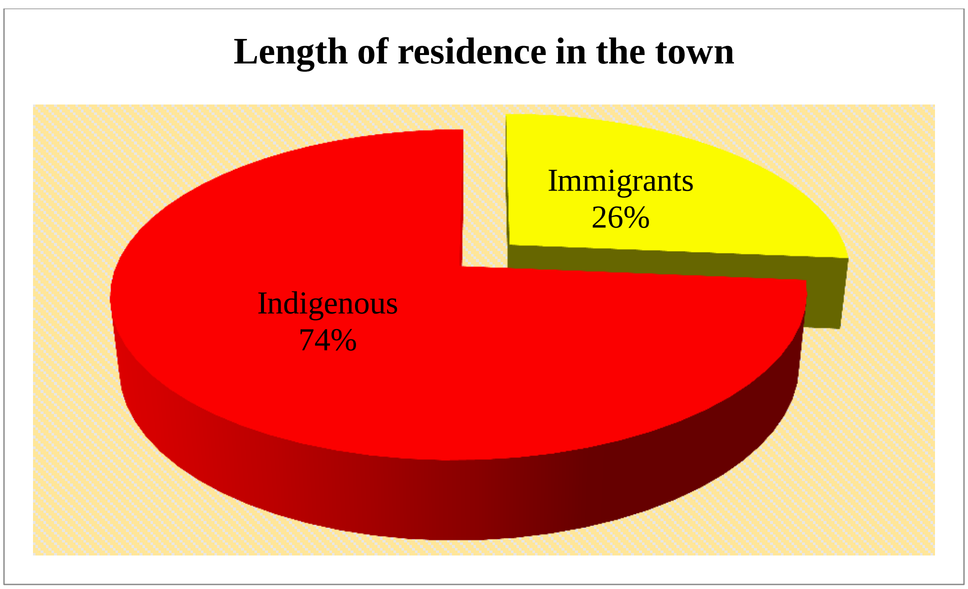

Figure 4.2 Length of residence in the town

Source: The data from field survey (2024)

4.2 The socioeconomic characteristics of the respondents' household heads

4.2.1 Land ownership status

About 67% of all respondents own land, whereas the remaining 33% have no land due to the lack of urban settlement policy, and poor management of land use in the study area.

That the majority of respondents (161, or 58%) do not own any land in hectares, while 35, or 13%, have land in the hectares. The remaining 81, or 29%, of the respondents own land in care.

4.2.2 Land use categories

The respondents are also using their land for a variety of purposes, including housing, grazing, cultivating crops along the Baro river bank, and mixed uses. Crop land accounts for 16% of their total land, followed by pasture land, fruit and vegetable land, and crop land combined. Housing and grazing land make up 39% and 12% of their amount, respectively. Consequently, the farmers' land contributes to their income or means of subsistence. This suggests that their source of income is directly impacted by losing the land they own, unless it is replaced by another source of income.

Table 4.3 Description of the Land use categories

Land use type	Number of respondents	In percent
Cultivating crop land	45	16
Agricultural, land and Grazing land	69	25
housing	108	39
Bush with grazing land	32	12
none	23	8
Total	**277**	**100**

Source: The data collected from a field survey.

4.3 Urban sprawl of Gambella town

Reaction towards Urban Expansion

The respondents were asked if they thought Gambella town was growing or not, 99% of them indicated that it was, while only 1% said that it was not.

4.4 Type of change observed in Gambella town.

As shown in figure.4.3 below, the majority of respondents (34%) respond that the expansion of built-up area and the replacement of agricultural land in built-up areas. This accounted for 34% of the population increase, followed by the expansion of built-up land, infrastructure, and investment in agricultural areas to built-up areas, which accounted for 25% of the population increase. The expansion of built-up land accounts for 13% and 10% of both population growth and investment, respectively, according to 18% of respondents who noted the conversion of agricultural land to built-up area. Therefore, it is feasible to draw the conclusion that the primary shift affecting the lives of farmers who depend on their land and the nation whose economic activity is heavily reliant on agriculture is the conversion of agricultural land to built-up space. The second that is most commonly described is population increase, which contributes to low employment opportunities for town residents and is a major factor in sprawl.

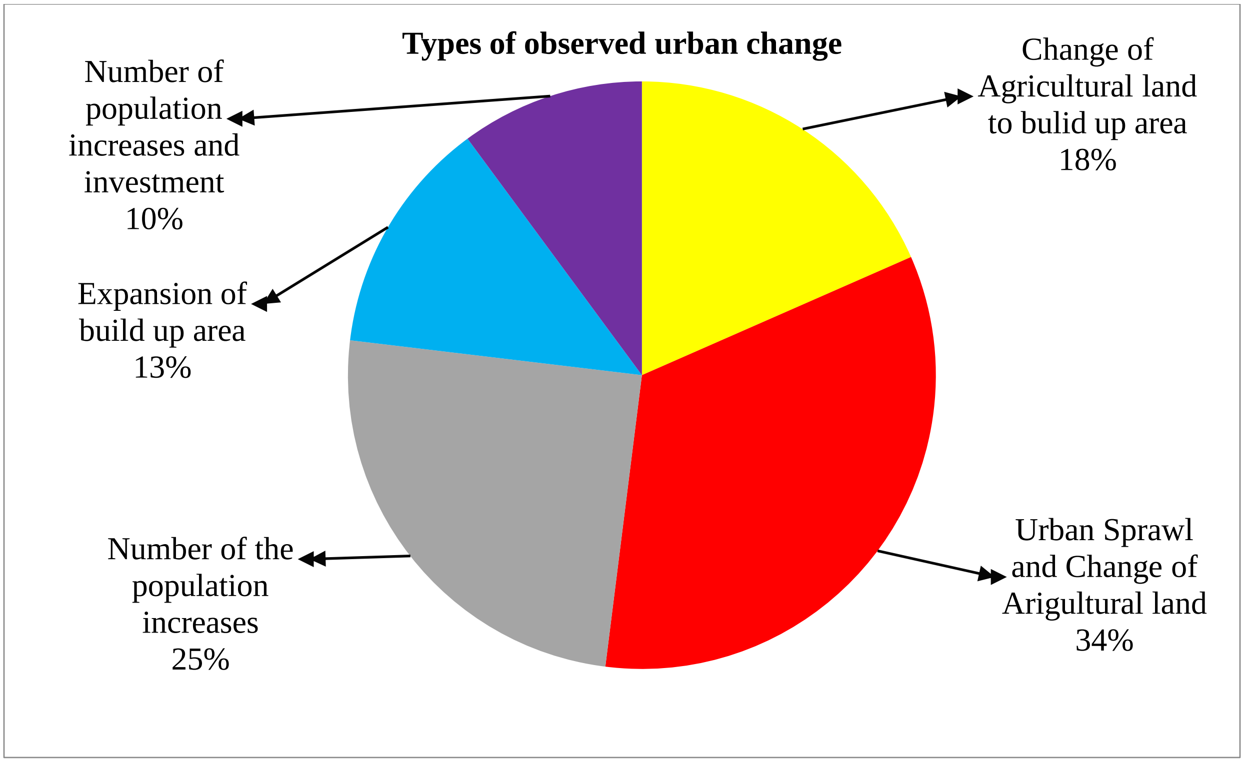

Figure 4.3 Type of observed urban change

Source: The data from field survey (2024)

Factors of expansion

Migration from rural area to urban area, to seek for batter services and population increase together are the main factors contributing to Gambella town's with %69 growth, as seen in fig 4.4 The combined percentage of low land costs, migration, population growth, infrastructure, and land sales is 69%. Forty eighty percent is taken via migration. Migration and cheap land have a combined 14%, whereas 7% of respondents claim that infrastructure and land sales make up 10%. Towns, that determine rapid population growth and migration become unplanned, which leads to illegal home construction (houses without plans) and leapfrogging development.

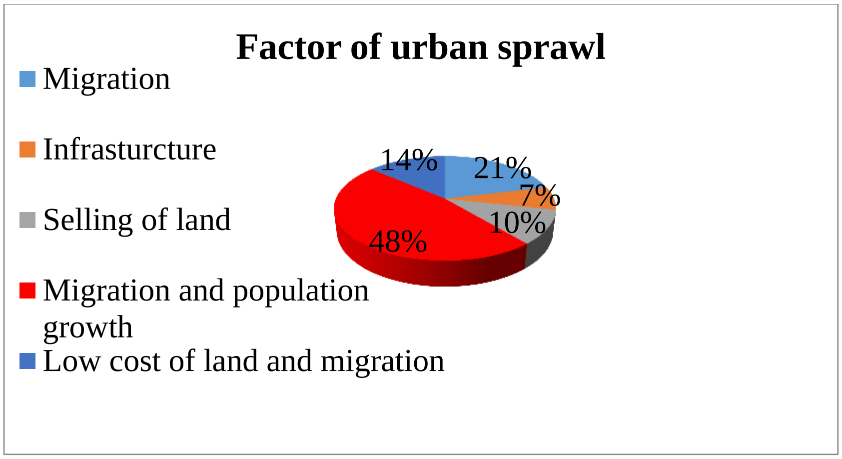

Figure 4.4 Factor of urban sprawl

Source: The data from field survey (2024)

4.5 Impact of Urban Sprawl in Gambella town

Table 4.4 Shows, that 68% of the land taken both from bush with grass and farmers has been used for residential use (6%) is used for agriculture, housing, and grazing, while the remaining portion has been used for grazing and/or one or more of the aforementioned uses. Farmers' livelihoods are thus immediately impacted by urban expansion's impact on nearby farmland since it alters their farming practices, within the Baro Rivers Bank and the fertility of soil due to gentle slope which are impossible without land, and the town's land usage and cover and the environment impact on the loss of biodiversity spaces and wild animals.

Table 4.4 Description of the vacates type of land

Type of land uses	Number of respondents	In Percentage
Land used for agriculture	28	10
Land for residential use	188	68
Bush with grazing land	23	8
Land used for agriculture, housing, and grazing	16	6
Land used for agriculture and grazing	12	4
Both residential and agricultural property used for grazing	10	4
Total	**277**	**100**

Source: The data collected from a field survey.

4.6 The Effects of Urban sprawl

About 98% of the respondents said that the town's growth and selecting of new site due to the urban sprawl was having an impact on their lives which can cause the ethnic valances, resources competition and power struggle among indigenous citizens, when asked if sprawl affected their lives, as shows in table 4.5 The town's expansion isn't hurting their lives, according to just 2% of respondents.

Table 4.5 Description of the responses of the participants to the impact of urban growth

Recognizing the impacts of urban sprawl	**Number of respondents**	**In percent**
Yes	272	98
No	6	2
Total	**277**	**100**

Source: The data collected from a field survey.

The majority of respondents, work for environmental management and land administration bureaus, but some are employed by municipal bureaus. The majority of the answers provided by experts are somewhat standard. They think that distinct land use and land cover classes are changing, and that the amount of built-up land is increasing significantly from 2000 up to 2023 by an estimated 40.2% for various purposes while the amount of agricultural increasing and bush with grasses and forest land is decreasing. People's need for fixed assets (land), the necessity for a market place, industry, and bad land management, which leads to an increase of unlawful buildings, is the main causes of this transformation. It is well acknowledged that the displacement of local residents or farmers due to changes in land cover has an effect on the lifestyles of urban dwellers. Due to the land's difficulty, the town's management is forced to focus on this matter rather than other matters. Natural resource depletion significantly reduces the output of crops like maize, beans and cotton and also leads to many environmental issues like pollution. Ultimately, the proposed solution to the issue caused by the growth of the built-up area is raising awareness, properly implementing the master plan (creating good governance), enforcing the law and regulations, and fostering collaboration among the community, town administration, and the relevant body of government.

4.7 Causes of urban sprawl

4.7.1 Population pressure on agricultural land expansion

The focus group participants agreed with the findings and explained that the study area's population was increasing annually due to a combination of strong natural growth and immigration from neighboring districts. The majority of the local population and investors relied heavily on agriculture as their primary source of income to meet their basic necessities, and while there were occasional increases in buildup area to offset the pressures of population growth and the growing demand for food, other land cover classes, such as agricultural, bush with grass and forest land, continued to decline as urban expansion grew annually.

Conversion of agricultural land and bush with grass into residential or commercial spaces was one of the main signs of urban expansion; this shows that the town is growing out of control. Inadequate urban planning and sprawl are often linked to increase in-migration from rural to urban areas, the emergence of informal settlements, and rapid population growth.

4.8 Urban sprawl and its environment consequences

Naturally occurring habitats are frequently transformed into residential, commercial, and industrial sectors as cities grow, a phenomenon known as urban sprawl. This change can result in loss of wildlife, habitat fragmentation, and species being pushed into more confined, isolated places, which makes it harder for them to live and procreate. Wildlife populations are declining and certain species are going extinct as a result of urban sprawl's encroachment on ecosystems (McKinney, 2002).

4.9 Urban Sprawl and Its Impact on Socio economic and environment

Urban sprawl has both positive and negative effects on economic growth. Job creation, services, higher property tax income, and inexpensive housing for residents are some beneficial effects. These advantages, however, frequently come at the expense of increased infrastructure costs, inefficient transportation, and a decrease in agricultural area, which has a detrimental effect on the populations that depend on it and increases the risks to food security. Agricultural land is regularly displaced by sprawling construction, which lowers the quantity of land available for the agrarian population to produce food. Increased landfill usage and garbage production: Because of larger households and less effective waste management systems, expansive communities tend to produce more waste. Sprawling communities typically generate more garbage that ends up in landfills due to less chance for centralized recycling and waste collection, which contributes to pollution from landfill leachate and land degradation. Because it generates methane, a powerful greenhouse gas, and necessitates additional resources for management, this waste burden puts a pressure on the ecosystem.

4.10 Land covers types and its coverage in 2000 and 2023

This chapter is devoted to analysis of both qualitative and quantitative data related the urban sprawl on other Land use classes in Gambella town.

From the classified image of 2000, the percentage coverage of Bush with Grass (Bush land mixed with grassland) is higher it covers 71.1% of the area. The LULC classification for 2000 from the TM satellite image (Table 4.11 below) showed that Agricultural land makes up 13.4% (634 ha.), bare land covers 9.8% (466 ha.), Built-Up area covers 2% (93 ha.), Water Body (river and ponds) covers 1.7% (83 ha), and Forest Land holds 2% (93 ha), of the district in 2000. Bush with Grass and Agricultural land are the dominant cover types in the district, while water bodies, Forest land and Built-Up area accounted for a very small percentage in 2000

As the table below from the 2010 classified image, here also, the percentage coverage of Bush with Grass (Bush land mixed with grassland) is higher it covers 64.4%. The LULC classification for 2010 from the TM satellite image (Table 4.12 below) showed that Bush with Grass makes up 64.4% (3,053 ha.), Agricultural land covers 15.9% (754 Ha.), bare land covers 6.8% (323 ha.), Built-Up area covers 9.6% (456 ha.), Water Body (river and ponds) covers 1.6% (77 ha), and Forest Land holds 1.7% (81 ha), of the district in 2010. Bush with Grass and Agricultural land are the dominant cover types in the district, while water bodies, Forest land and Built-Up area accounted for a very small percentage in 2010

As the table show for the 2023 classified image, the percentage coverage of agricultural land makes up it covers 36.9% (1,750 ha). The LULC classification for 2023 from the TM satellite image (Table 4.13 below) in the 2023 the classification showed that Built-Up area is makeup it covers 41.3% (1,956 ha), bare land covers 4.9% (234 ha.), Agricultural Land covers 36.9% (1,750 ha.), Water Body (river and ponds) covers 1.7% (82 ha), and Forest Land holds 1.5% (70 ha), of the district in 2023. Built-Up area and Agricultural land are the dominant cover types in the district due to the natural population increases, migration from rural to urban and fertility of the soil for cultivation the crops and cotton, while water bodies and Forest land accounted for a very small percentage in 2023 (Table 4.6 below).

Table 4.6 Descriptions of the Land Cover Types and its coverage in 2000-2023

ID	2000 Class Name	Area_Ha	Area %
1	Water Body	83	1.7
2	Forest Land	93	2.0
3	Agricultural Land	634	13.4
4	Bush with Grass	3,375	71.1
5	Built-Up area	93	2.0
6	Bare Land	466	9.8
	Total	**4,744**	**100**
ID	**2010 Class Name**	**Area_Ha**	**Area_%**
1	Water Body	77	1.6
2	Forest Land	81	1.7
3	Agricultural Land	754	15.9
4	Bush with Grass	3,053	64.4
5	Built-Up area	456	9.6
6	Bare Land	323	6.8
	Total	4,744	100
No	**2024 Class Name**	**Area_Ha**	**Area_%**
1	Water Body	82	1.7
2	Forest Land	70	1.5
3	Agricultural Land	1,750	36.9
4	Bush with Grass	652	13.7
5	Built-Up area	1,956	41.3
6	Bare Land	234	4.9
	Total	**4744**	**100**

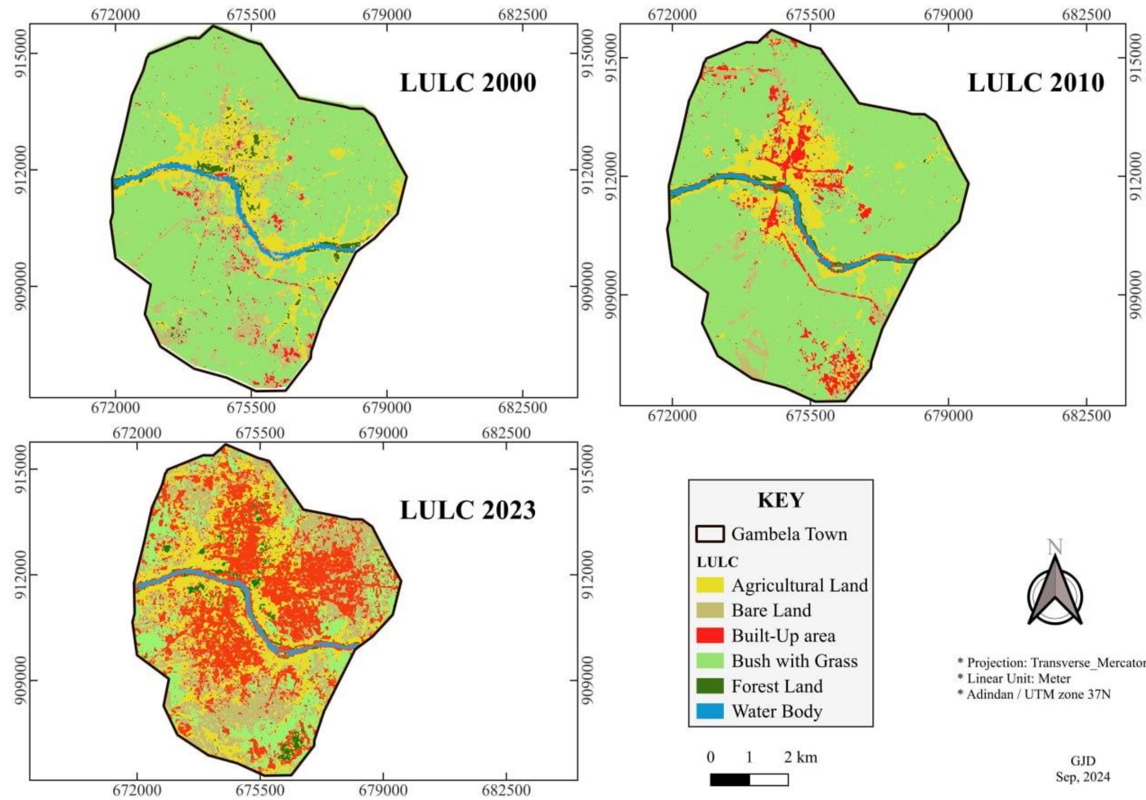

Figure 4.5 Impact on the urban sprawl trend of LULUC in Gambella town

4.11 Accuracy assessment

4.11.1 Accuracy assessment for LULC mapping of 2000

The Confusion Matrix in Table 4.14 below showed that both commission and omission error and also the majority of the pixels were misclassified to one another and this is due to spectral similarities for the vegetation. User's accuracy, producer's accuracy, kappa coefficient and overall accuracy value for the classified image of 2000. The overall accuracy and kappa coefficient of this period of classification results 90% and 82 and accuracy of each LULC classes are presented in the table (Table 4.7 below).

Table 4.7 Description of the Accuracy Assessment for LULC Mapping of 2000

Class Name	Water Body	Forest Land	Agricultural Land	Bush with Grass	Built-Up area	Bare Land	Total	U_Accuracy	Kappa
Water Body	4.00	0.00	0.00	0.00	0.00	0.00	4.00	1.00	0.00
Forest Land	0.00	4.00	1.00	0.00	0.00	0.00	5.00	0.80	0.00
Agricultural Land	1.00	2.00	27.00	0.00	1.00	1.00	32.00	0.84	0.00
Bush with Grass	3.00	0.00	6.00	153.00	3.00	0.00	165.00	0.93	0.00
Built-Up area	0.00	0.00	0.00	0.00	8.00	2.00	10.00	0.80	0.00
Bare Land	1.00	0.00	1.00	2.00	1.00	29.00	34.00	0.85	0.00
Total	9.00	6.00	35.00	155.00	13.00	32.00	250.00	0.00	0.00
P_Accuracy	0.44	0.67	0.77	0.99	0.62	0.91	0.00	0.90	0.00
Kappa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82

4.11.2 Accuracy Assessment for LULC Mapping of 2010

Accuracy of LULC classification in 2010, Table 4.9 displays the accuracy of each LULC class, and the total accuracy and kappa coefficient for this period of classification results are 90% and 81, respectively.

Table 4.8 Description of the Accuracy Assessment for LULC Mapping of 2010

Class Name	Water Body	Forest Land	Agricultural Land	Bush with Grass	Built-Up area	Bare Land	Total	U_Accuracy	Kappa
Water Body	9.00	0.00	0.00	1.00	0.00	0.00	**10.00**	**0.90**	**0.00**
Forest Land	0.00	8.00	1.00	1.00	0.00	0.00	**10.00**	**0.80**	**0.00**
Agricultural Land	0.00	1.00	29.00	1.00	1.00	1.00	**33.00**	**0.88**	**0.00**
Bush with Grass	2.00	4.00	3.00	172.00	1.00	2.00	**184.00**	**0.93**	**0.00**
Built-Up area	0.00	1.00	0.00	1.00	13.00	0.00	**15.00**	**0.87**	**0.00**
Bare Land	1.00	1.00	0.00	0.00	2.00	7.00	**11.00**	**0.64**	**0.00**
Total	**12.00**	**15.00**	**33.00**	**176.00**	**17.00**	**10.00**	**263.00**	**0.00**	**0.00**
P_Accuracy	**0.75**	**0.53**	**0.88**	**0.98**	**0.76**	**0.70**	**0.00**	**0.90**	**0.00**
Kappa	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.81**

4.11.3 Accuracy assessment for LULC mapping of 2023

The Confusion Matrix in Table 4.9 below showed that both commission and omission error and also the majority of the pixels were misclassified to one another and this is due to spectral similarities for the vegetation. User's accuracy, producer's accuracy, kappa coefficient and overall accuracy value for the classified image of 2023. The overall accuracy and kappa coefficient of this period of classification results 89% and 85 and accuracy of each LULC classes are presented in the table (Table 4.9 below).

Table 4.9 Description of the Accuracy Assessment for LULC Mapping of 2023

Class Name	Water Body	Forest Land	Agricultural Land	Bush with Grass	Built-Up area	Bare Land	Total	U_Accuracy	Kappa
Water Body	7.00	1.00	1.00	0.00	0.00	0.00	9.00	0.78	0.00
Forest Land	1.00	6.00	0.00	1.00	1.00	0.00	9.00	0.67	0.00
Agricultural Land	1.00	1.00	41.00	2.00	1.00	2.00	48.00	0.85	0.00
Bush with Grass	0.00	0.00	2.00	31.00	0.00	0.00	33.00	0.94	0.00
Built-Up area	1.00	2.00	0.00	2.00	77.00	2.00	86.00	0.90	0.00
Bare Land	2.00	1.00	0.00	1.00	1.00	60.00	65.00	0.92	0.00
Total	**12.00**	**11.00**	**44.00**	**37.00**	**80.00**	**64.00**	**250.00**	**0.00**	**0.00**
P_Accuracy	**0.58**	**0.55**	**0.93**	**0.84**	**0.96**	**0.94**	**0.00**	**0.89**	**0.00**
Kappa	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.85**

4.12 Land Use/Land cover change three time periods

Table 4.10 presents the rate of change for various land cover types in Gambella Town. The outcome demonstrates how cover kinds increase and decrease with time. During the years 2000 and 2023, the Gambella Town practiced many LULC changes. Throughout the study periods of 2000 to 2023

In the period between 2000 and 2010, Agricultural Land increased by 120 ha; (2.5%), Barren Land decreased by 142.98 ha; (-3.0%), Bush with grass decreased by 322 ha; (-6.7%), Built-Up area increased by 363 ha; (7.6%), Forest Land decreased by 12 ha, (-0.3), and Water body decreased by 6. ha, (-0.1%) respectively.

The result for the second period 2010 and 2023, Agricultural Land increased by 996 ha; (21.0%), Barren Land decreased by 89 ha; (-1.9%), Bush with grass decreased by 2,401 ha; (50.7%), Built-Up area increased by 1,500 ha; (31.7%), Forest Land decreased by 11 ha; (-0.2), and Water body increased by 5.ha (0.1%) respectively.

The rate of change between three decades which is between 2000 and 2023 indicated that Agricultural land, and Built-Up area is increased by 1,750 ha; (36.9%) 1,956 ha; which is (41.3%) respectively. The remaining, bare land, Bush with grass, water body and Forest land decreased by 234 ha; (4.9%) 652 ha; (13.7%) 6 ha (0.01%) and 70 ha; (1.5%) respectively, (table 4.17 below).

Table 4.10 Description of the land cover change rate over three time periods

No	Class Name	2000-2010		2010-2023		2000-2013	
		Rate ha.	%	Rate ha.	%	Rate ha.	%
1	Water Body	-6.56	-0.1	5	0.1	-1	-0.02
2	Forest Land	-12	-0.3	-11	-0.2	-23	-0.5
3	Agricultural Land	120	2.5	996	21.0	1,750	36.9
4	Bush with Grass	-322	-6.7	-2,401	-50.7	-652	-13.7
5	Built-Up area	363	7.6	1,500	31.7	1,956	41.3
6	Bare Land	-142.98	-3.0	-89	-1.9	-234	-4.9

+ Increase in the rate of land cover class - Decrease in the rate of land cover class

4.13 Land use/Land covers change in Gambella Town from 2000 to 2023

The following change detection tables are change matrices that display what has been changed to what. The row (2000-2023) in the table represents the first stage, while the column (2000-2023) represents the last stage. The table's diagonal values display the constant values that appear in the image at both times. The class change, as opposed to the diagonal values, indicates the total altered image areas of each LULC during the first stages. The LULC classes' final stage area is represented by the row total. There is a notable LULCC seen in the area; generally, the LULCC in all land use types is not static. The tables below show LULCC between the years 2000-2023, respectively.

The total areas that each of the land cover types listed below covers in the districts varies to some extent. Table 4.11 major LULC change matrix below showed that the change study covered the 30-year period from 2000 to 2023. LULC change analysis using TM Landsat imagery revealed that, between 2000 and 2023, according to table 4.18 below, of the predominant Bush with grass, 568.49 Ha. Remained, and a significant portion of it, about 1,137.83, was converted to Built-Up area and other cover types in varying amounts. Conversely, a significant portion of Bare land about 189 Ha; was transformed to Built-Up area of it, with the remaining portion being used for various kinds of cover. From 2000 to 2023, the amount of Agricultural Land that remained was around 278 Ha; the remainder was divided into other cover types, with 223 Ha; And 35.50 Ha; of the Agricultural Land being converted to Built-Up area and Bare Land, respectively. The percentage of Forest Land that changed from 2000 to 2023 was likewise substantial, with 28.01 Ha, going to Built-Up area, 32.84 Ha. To Agricultural land and the remaining percentage going to other land cover types.

Table 4.11 Description of the LULC class conversions in percent between 2000 and 2023

Class Name		2023						
		Agricultural Land	**Bare Land**	**Built-Up area**	**Bush with Grass**	**Forest Land**	**Water Body**	**Total**
2000	**Agricultural Land**	**278**	35.50	223.04	47.29	38.21	20.81	642.86
	Bare Land	113.40	**78.00**	189.51	57.53	15.86	9.73	464.03
	Built-Up area	21.80	9.86	**41.74**	11.81	4.32	3.18	92.72
	Bush with Grass	728.39	903.03	1137.83	**568.49**	30.61	0.39	3368.74
	Forest Land	32.84	4.62	28.01	4.63	**6.29**	16.83	93.23
	Water Body	20.43	0.69	22.89	1.06	6.61	**30.81**	82.48
	Total	1194.86	1031.70	1643.03	690.82	101.89	81.77	**4,744**

4.14 LULC class conversions 2000 and 2023

As you see in the figure 4.6 below it indicates that the urban sprawl changes in the Gambella Town with in the two decade. The conversion map of 2000- 2023 clarify the changes between the Agricultural land with Bare land, Build up area, Bush with grass, forest land, water body and others Land use and covers classes.

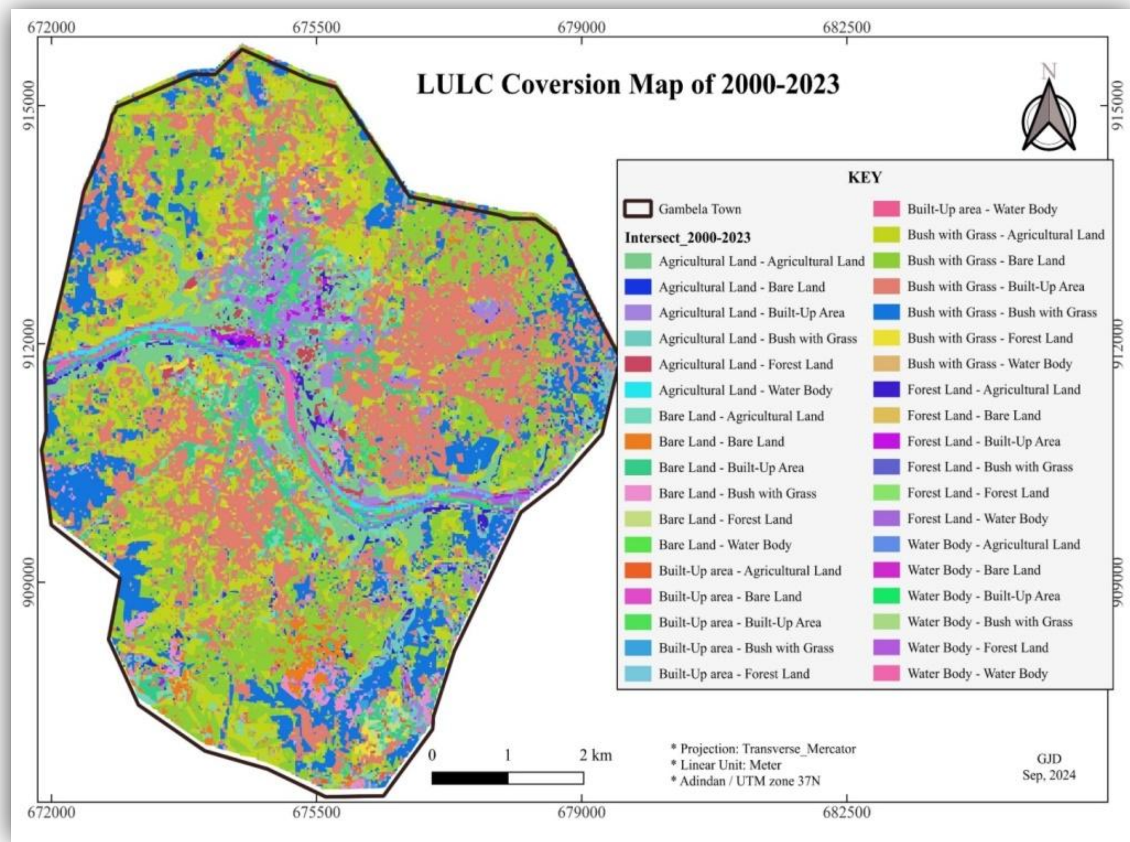

Figure 4.6 LULC conversion from 2000-2023

4.15 Impact on the urban sprawl trend of LULCC in Gambella town (2000-2023)

The study indicate that this two decade trend of LULCC on urban expansion in the Gambella town have both positives and negatives impacts on the community who are living in the study area. The positive impact on the urban expansion majority of peoples they can enjoy of having many position of services like good health, education, batter job opportunity and good life of social standard and the other hand it effects the Agro ecology society because their Agricultural land is converted to the residents area or build up this may lead them not adapt their living standard because they depend on the agriculture as the main sources of their economy income.

Urban expansion has also the negatives impact on the environment to loss the bio diversity, soil erosion, land degradation, air pollution and wildlife, the endemics wild animal are migrating to the neighbor regions and country as the region share the borders with South Sudan in the west due to the unplaning of urban expansion.

4.16 Urban sprawl Map of Gambella Town from 2000 and 2023

The figure below on environmental degradation, urban growth can have an adverse effect on ecosystems and biodiversity by destroying habitat, increasing pollution, and reducing green areas. Inefficient land use, social inequality, and urban growth can all be caused by this. As cities grow, distinctive local cultures and customs may be eclipsed by a more homogenous urban identity, which could result in a loss of heritage. Disenfranchised communities are frequently forced to the periphery or without access to basic services. The finally study area indicated that the urban sprawl of Gambella Town is increasing changed and it is dominate by Buildup area then others classes, Agricultural land, forest land, bush with grass, water body and bare land they are decrease in the rate of land cover class due to the expansion of the town. Three colors green, purple, and red they represents differences urban expansion in the study area. Urban built-up area mapping is one of the greatest ways to visualize the pace and direction of urban sprawl.

According to Barnes et al. (2001); Epstein et al. (2002), the built-up is usually regarded as the best metric for quantifying the state of urban sprawl. To show the expansion and direction of the built-up, maps of the study region were created at various points in time.

However the total land area, only 968.87 hectares were 11% inhabited in 2000. In 2010, this was expanded to 2786.64 acres of land. The increase was 33%. A significant increase of 33 % from 2010 and 56% from 2023 was noted in 2023, with a total land cover of 4744 hectare. A significant rate of built-up land expansion was seen between 2000 and 2023, a 20-year difference and a 39.3% increase, in addition to the time separation between the study periods due to the fast growth of the town many indigenous are seeking for the settlements land to differences site location. Full details in figure 4.7 map of urban sprawl it’s below.

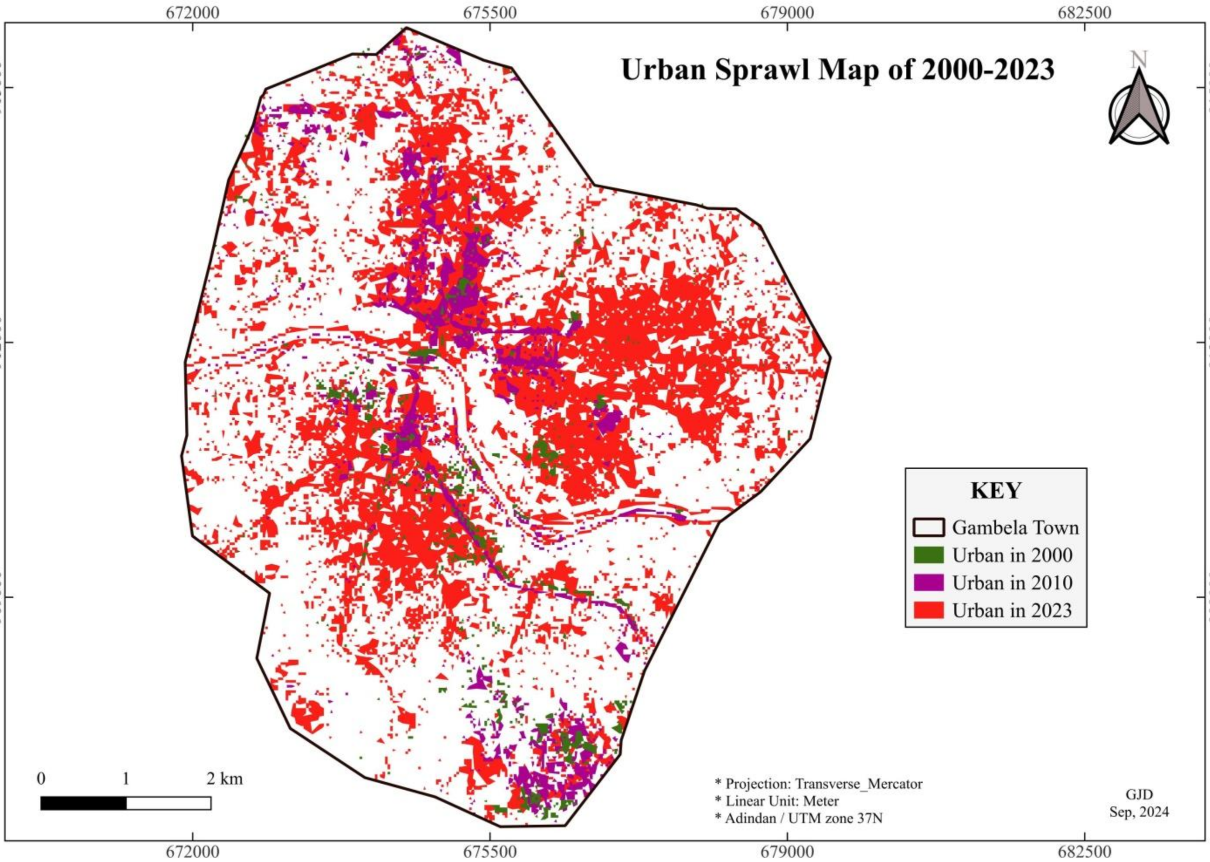

Figure 4.7 Urban sprawl of in Gambella town

4.17 Net changes of land use land cover from 2000-2023 in Gambella town.

The data presented illustrate changes in land use over time across several categories. In 2000, the area of water bodies was 83 hectares, which decreased slightly to 77 hectares by 2010, then increased to 82 hectares in 2023, resulting in a net change of -1 hectare. Forest land declined from 93 hectares in 2000 to 81 hectares in 2010 and further to 70 hectares by 2023, reflecting a total decrease of 23 hectares. In contrast, agricultural land experienced significant growth, expanding from 634 hectares in 2000 to 754 hectares in 2010 and surging to 1,750 hectares by 2023, resulting in a net increase of 1,116 hectares. The area of bush with grass saw a dramatic decline, dropping from 3,375 hectares in 2000 to 3,053 hectares in 2010 and plummeting to 652 hectares by 2023, which amounts to a loss of 2,723 hectares. Built-up areas expanded rapidly, growing from 93 hectares in 2000 to 456 hectares in 2010 and further increasing to 1,956 hectares by 2023, marking a net change of 1,866 hectares. Lastly, bare land decreased from 466 hectares in 2000 to 323 hectares in 2010 and further to 234 hectares in 2023, showing a net decrease of 232 hectares. The figure 4.8 below show the decrease and increase of the land use classification net changes from the years of 2000- 2023 in Gambella town.

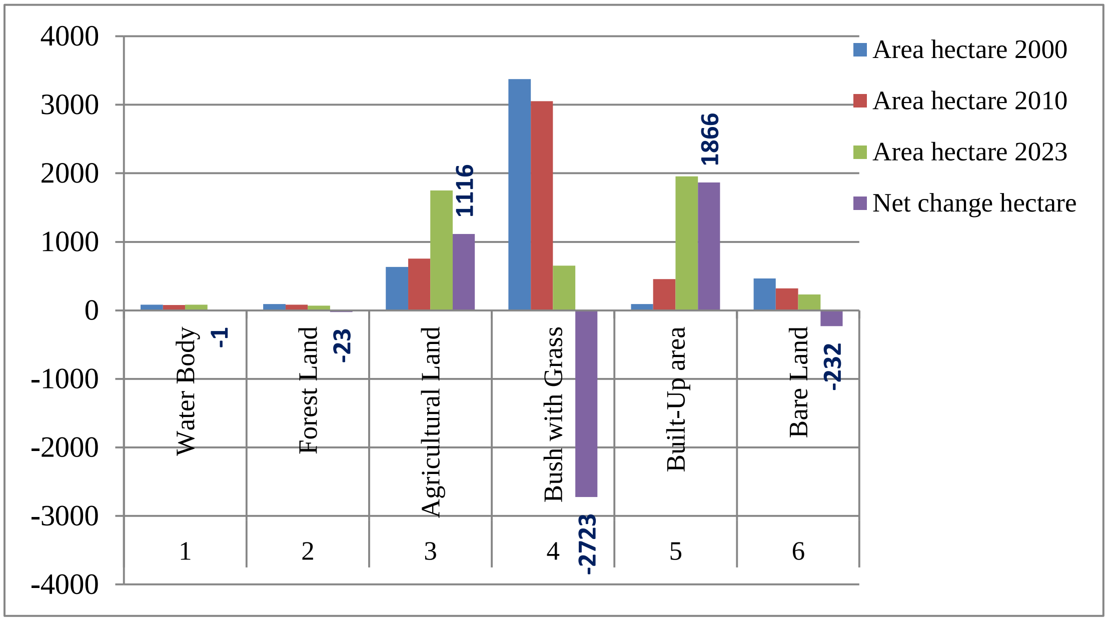

Figure 4.8 Net changes of land use land cover from 2000-2023 in Gambella town

4.18 Discussion

4.18.1 Land-Use/ Land-Cover, status of urban sprawl in Gambella Town

Gambella Town's land-use and land-cover (LULC) changes are closely related to several socioeconomic variables, chief among them the migration of rural to urban residents looking for safety and opportunity in the host town. Due to the increased demand for land for residents and habitation purposes brought about by this demographic transition, there have been major environmental effects. Technology, environmental changes, economic development, and human population expansion are all identified by Houghton (1994) as important factors that influence LULC variability. These elements are reshaping the environment and the socioeconomic structure of Gambella as they appear.

The settlement area increased dramatically from 93 hectares (2.0%) in 2000 to 1,956 hectares (41.3%) in 2023, highlighting the pressing need for infrastructure and housing to support the expanding population. This urban sprawl is indicative of a larger pattern seen in areas that are quickly urbanizing, where the growth of human settlements frequently comes at the price of natural ecosystems. The pressure on land resources can lead to habitat loss, increased pollution, and challenges in water management, as noted by studies on urbanization impacts (McKinney, 2002; Seto et al., 2011).

The remarkable increase in agricultural land from 634 hectare (13.4%) in 2000 to 1,750 hectares (36.9%) in 2023 highlights, Gambella’s appeal as a fertile agricultural zone this expansion can be attributed to the area's rich soil and favorable climate, attracting both local and foreign investors seeking to capitalize on agricultural opportunities. The shift towards commercial agriculture, particularly for crops like beans, grains, cotton, and sugarcane, is reflective of a global trend where fertile lands are increasingly utilized for large-scale agricultural production (Turner, 2003). While this agricultural boom has the potential to enhance food security and generate economic benefits, it also raises concerns about sustainability and land management.

The decline of bush with grass from 3,375 hectares (71.1%) in 2000 to 652 hectares (13.7%) by 2023 signals a significant loss of biodiversity and natural habitat. This loss poses risks not only to local wildlife but also to ecosystem services that communities depend on, such as soil stability and water regulation. As noted by Zhao et al. (2019), the conversion of natural landscapes bush with grass and others land use classes to urban use can lead to ecological imbalances, exacerbating environmental degradation and undermining resilience to climate change.

Additionally, the reduction in bare land from 466 hectares (9.8%) in 2000 to 234 hectares (4.9%) in 2023 reflects a broader trend of land reclamation for productive uses. While this may indicate positive land utilization, it also suggests a shift away from less productive or unmanaged land, further emphasizing the need for careful land-use planning and management. The fluctuations in forest cover, decreasing from 93 hectares (2.0%) in 2000 to 70 hectares (1.5%) in 2023, reveal the precarious balance between urban expansion, agriculture, and conservation efforts.

The stable area of water bodies, from 83 hectares (1.7%) in 2000 to 82 hectares (1.7%) in 2023, raises important questions about water resource management amidst growing demands. Population growth inevitably leads to increased water consumption, necessitating sustainable water management practices to ensure that both human and ecological needs are met. The consistent presence of water bodies highlights their critical role in the local ecosystem, but also the potential for conflicts over water access as urban and agricultural demands increase.

Overall, socio demographic data and the classified satellite images provide compelling evidence of LULC changes over the past two decades in Gambella Town. These transformations reflect complex interactions between human activity and environmental systems have both positives and negatives impacts on socio economic and environment, underscoring the need for integrated planning that considers ecological sustainability alongside socio-economic development. Effective land management strategies must prioritize the preservation of critical ecosystems while accommodating the needs of a growing population.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5. Introduction

This chapter sums up the findings of the study. Accordingly, the first section presents conclusion for the findings and, the second's section reveals the recommendations for the findings.

5.1 Conclusions

This study aimed to assess the impact of urban sprawl on land use and cover changes in Gambella Town, on socio economic and environment over a two-decade period, specifically from 2000 to 2023. Utilizing classified satellite images and data analyzed with ArcGIS 10.8 and socio demographic data was analyzed used it with the SPSS, the findings reveal significant transformations in the landscape, most notably an 41.3% increase in built-up land and a staggering 36.9% increase in agricultural land. In contrast, bush with grass experienced a dramatic decline of 13.7%, illustrating the profound impact of urban expansion on this natural ecosystem. Furthermore, both bare land and forest land show the decreases of 4.9% and 0.2%, respectively, further underscoring the shifting dynamics of land use in the region.

The increase in built-up land reflects a complex interplay of factors, primarily driven by rapid population growth and migration, particularly due to the influx of rural to urban area for seeking better living conditions. This demographic shift has escalated the demand for housing and infrastructure, leading to the encroachment of agricultural land, bush with grass to urban areas. The lack of a comprehensive government master plan has exacerbated this situation, resulting in unregulated development that prioritizes immediate housing needs over sustainable land management. As urban areas expand haphazardly, the strain on local administration becomes evident, with challenges in providing essential services and infrastructure.

The resultant urban sprawl poses significant threats to traditional livelihoods, particularly for farming communities. As agricultural land is converted to build up environments and biodiversity environments as bush with grasses lands is converted to build up area, the capacity of farmers to produce sufficient food for themselves and the market diminishes, jeopardizing food security in the region and loss of wildlife due to destruction of the bush land. Additionally, as urbanization progresses, the rural workforce is further depleted, exacerbating the challenges faced by those who remain in agricultural sectors. This phenomenon creates a cycle of dependence on increasingly limited resources, threatening the socio-economic stability of the community.

Moreover, the increase in urban population density has implications for environmental sustainability. The burgeoning demand for land has led to increased deforestation and land degradation, as individuals clear areas for habitation and agricultural production. Such activities contribute not only to the loss of biodiversity but also to climate change, as carbon sinks are diminished and greenhouse gas emissions potentially rise.

In conclusion, the findings of this study illuminate the urgent need for strategic urban planning and sustainable land management practices in Gambella Town. Policymakers must prioritize the development of comprehensive master plans that address the challenges of urban sprawl while safeguarding agricultural land and natural ecosystems. This requires a holistic approach that integrates community needs, environmental considerations, and economic viability. As urban sprawl continues to evolve, the lessons learned from Gambella's experience can serve as a crucial reference for other regions facing similar pressures, ultimately promoting a balance between growth and sustainability. Food security may be threatened by the loss of agricultural land, while environmental issues including soil erosion, water scarcity, and climate change may result from the deterioration of natural ecosystems, were the main findings.

5.2 Recommendation

The uneven growth of towns puts pressure on natural resources, impact on socioeconomic and environment, and affects the equitable provision of services to the community. In order to mitigate the adverse effects of urban sprawl and encourage sustainable urban growth in Gambella Town, the following recommendations are proposed:

- **Establish stringent zoning laws to avoid random construction and maintain green spaces, and create a thorough spatial plan that details land use and zoning principles to manage urban growth and save agricultural land.**
- **Controlling urban sprawl and managing urban land using Geo spatial tool and remote sensing. The concerned governmental bodies, the municipal administration, and the community would collaborate to find a solution.**

- **Engage local communities in the planning and decision-making process to make sure their goals and needs are taken into account. Through outreach and education initiatives, increase public understanding of the negative impact on urban expansion on socio economics and the environment.**
- **Strengthen property rights and land administration to prevent land grabbing, illegal land use and adopt environmental regulations and standards to protect natural resources.**

By adopting these recommendations, Gambella Town can ensure a brighter future for its citizens by implementing the above suggestions, which will strike a balance between environmental sustainability and economic progress.

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APPENDICES

ADDIS ABABA UNIVERSITY

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Introduction

Good morning/ after noon,

Dear my name is Goanar Jal Dup and I am a post graduate student of Geography and Environmental Studies at A.A.U. Currently, I carry out an academic research aimed at the "Spatio-Temporal Change of Urban Sprawl Pattern Using Geospatial Technologies to Guide Land Use Planning in Gambella town". The target population for this study is household heads in the study area. The result of the study will give insight about the impacts of urban sprawl on land use planning in Gambella town. The participation in the discussion and interviewing process is on voluntary basis. The study is for academic purpose as a partial fulfillment for the requirement of MA Degree and the information you provide is strictly confidential and will be used anonymously in my thesis document.

Thanks for cooperation.

Appendices: 1: Questionnaire to be filled by selected household heads

Part I Background information

1. Kebele ---------------

2. Sex --------------- (1) Male (2) Female

3. Age --------------

4. Education level ------ (1) Unable to read and write (2) Primary (1-8) (3) Secondary 9-12 (4) Certificate (5) Diploma (6) Degree and above

5. Family size: -----------

6. Household Occupation. (1)Trading (2) civil service (3) farming (4) daily laborer (5) Others-

7. Marital status of the households (1) Married (2) Divorced. (3) Single (4) Widowed

8. Average monthly income (in birr)

(1) Less than 500 (2) 500-1000 (3)1001-1500 (4)1500-2000 (5) Greater than2000

9. Duration of stay in the city --------------------

Part II Socio-Economic Profile of respondent household head

10. Do you have a plot of land? 1. Yes 2.No

11. If your answer for question No.10 is yes, how many Hectare of land do you have?

----

13. For what purposes have you been using your land?

1 Crop Land 2 Grazing land 3. Agriculture land 4. If any other please mention-----------

14. If your answer for question No.10 is yes, how many Hectare of land do you have?

____

15. For what purposes have you been using your land?

(1) Crop- Land (2) Grazing land (3) Fruits and vegetation 4. If any other please mention--------

Part III Factors that contributed for the expansion of Gambella town

13. Do you perceive the expansion of Gambella town to the surrounding area?

1. Yes 2.No

14. If your answer for the question No 13 is yes, what do you think are the factors that Contribute to such expansion of the city? --

----

15. What type of change you observe because of the expansion? ------------------------------

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16. Is there any portion of your land that has been taken in the last 30 years for different?

1. Yes 2. No

17. If your answer for question No.16 is yes, what types of land was it?

(1)Agricultural land (2) Residential land (3) both residential and agricultural land (4) Grazing land (5) If any other specify_________________

18. If a plot of land has been taken from you because of urban expansion/induced Development, when was it taken?

1. Over the last 10 years (2000– 2013) 2. Over the previous 10 years (2013– 2023)

Part IV. Effects of the expansion on the area

19. Do you think that the expansion of the city has an impact on your livelihood?

1. Yes 2.No

20. If your answer for question No.19 is yes, what are the impacts?

1. Loss of land 2.Social fragmentation

3. Loss of livelihood 4.If any other please specify---------------

21. What do you feel the effect of development induced on your area especially on?

LULC Please explains? --

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Appendices: 2: Questions to be filled by expert

Observed changes in the land use/cover of the city

1. Have you observed any change in the LULC in the city in the past?
2. What type of change was occurred (increase or decrease in the bare land, open land, built upland, agricultural land and/or forest land)?
3. Estimate the percentage of increase or decrease of each LULC category
4. What do you think is the cause for the increase or decrease of the LULC classes that was increased or decreased?
5. Do you think that the major cause for the observed impacts was the expansion of the built up land if it was in what way?
6. What possible solution you suggest to overcome the problems occurred particularly with the expansion of the built up area

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Appendices: 3: Questionnaires for Focused Group Discussion

1. What do urban sprawl deals with?
2. What do you think the factors for urban sprawl in your area?
3. When do you think major changes are taken place and what are the cause for changes?
4. What merit and demerit you believe are the result of urban expansion in the town especially in terms of change in LULC?
5. Who is the concerned body to reduce the negative impacts of urban expansion for you?
6. What possible solution you suggest to overcome the problems occurred with urban expansion.

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Appendices 4: Classification accuracy assessment report for the year 2000

Accuracy Assessment for LU/LC Mapping of 2000

Class Name	Water Body	Forest Land	Agricultural Land	Bush with Grass	Built-Up area	Bare Land	Total	U_Accuracy	Kappa
Water Body	4.00	0.00	0.00	0.00	0.00	0.00	4.00	1.00	0.00
Forest Land	0.00	4.00	1.00	0.00	0.00	0.00	5.00	0.80	0.00
Agricultural Land	1.00	2.00	27.00	0.00	1.00	1.00	32.00	0.84	0.00
Bush with Grass	3.00	0.00	6.00	153.00	3.00	0.00	165.00	0.93	0.00
Built-Up area	0.00	0.00	0.00	0.00	8.00	2.00	10.00	0.80	0.00
Bare Land	1.00	0.00	1.00	2.00	1.00	29.00	34.00	0.85	0.00
Total	9.00	6.00	35.00	155.00	13.00	32.00	250.00	0.00	0.00
P_Accuracy	0.44	0.67	0.77	0.99	0.62	0.91	0.00	0.90	0.00
Kappa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82

Appendices 5: Classification accuracy assessment report for the year 2010

Accuracy Assessment for LU/LC Mapping of 2010

Class Name	Water Body	Forest Land	Agricultural Land	Bush with Grass	Built-Up area	Bare Land	Total	U_Accuracy	Kappa
Water Body	9.00	0.00	0.00	1.00	0.00	0.00	**10.00**	**0.90**	**0.00**
Forest Land	0.00	8.00	1.00	1.00	0.00	0.00	**10.00**	**0.80**	**0.00**
Agricultural Land	0.00	1.00	29.00	1.00	1.00	1.00	**33.00**	**0.88**	**0.00**
Bush with Grass	2.00	4.00	3.00	172.00	1.00	2.00	**184.00**	**0.93**	**0.00**
Built-Up area	0.00	1.00	0.00	1.00	13.00	0.00	**15.00**	**0.87**	**0.00**
Bare Land	1.00	1.00	0.00	0.00	2.00	7.00	**11.00**	**0.64**	**0.00**
Total	**12.00**	**15.00**	**33.00**	**176.00**	**17.00**	**10.00**	**263.00**	**0.00**	**0.00**
P_Accuracy	**0.75**	**0.53**	**0.88**	**0.98**	**0.76**	**0.70**	**0.00**	**0.90**	**0.00**
Kappa	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.81**

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Appendices 6: Classification accuracy assessment report for the year 2023

Accuracy Assessment for LU/LC Mapping of 2023

Class_Name	Water Body	Forest Land	Agricultural Land	Bush with Grass	Built-Up area	Bare Land	Total	U_Accuracy	Kappa
Water Body	7.00	1.00	1.00	0.00	0.00	0.00	9.00	0.78	0.00
Forest Land	1.00	6.00	0.00	1.00	1.00	0.00	9.00	0.67	0.00
Agricultural Land	1.00	1.00	41.00	2.00	1.00	2.00	48.00	0.85	0.00
Bush with Grass	0.00	0.00	2.00	31.00	0.00	0.00	33.00	0.94	0.00
Built-Up area	1.00	2.00	0.00	2.00	77.00	2.00	86.00	0.90	0.00
Bare Land	2.00	1.00	0.00	1.00	1.00	60.00	65.00	0.92	0.00
Total	12.00	11.00	44.00	37.00	80.00	64.00	250.00	0.00	0.00
P_Accuracy	0.58	0.55	0.93	0.84	0.96	0.94	0.00	0.89	0.00
Kappa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85

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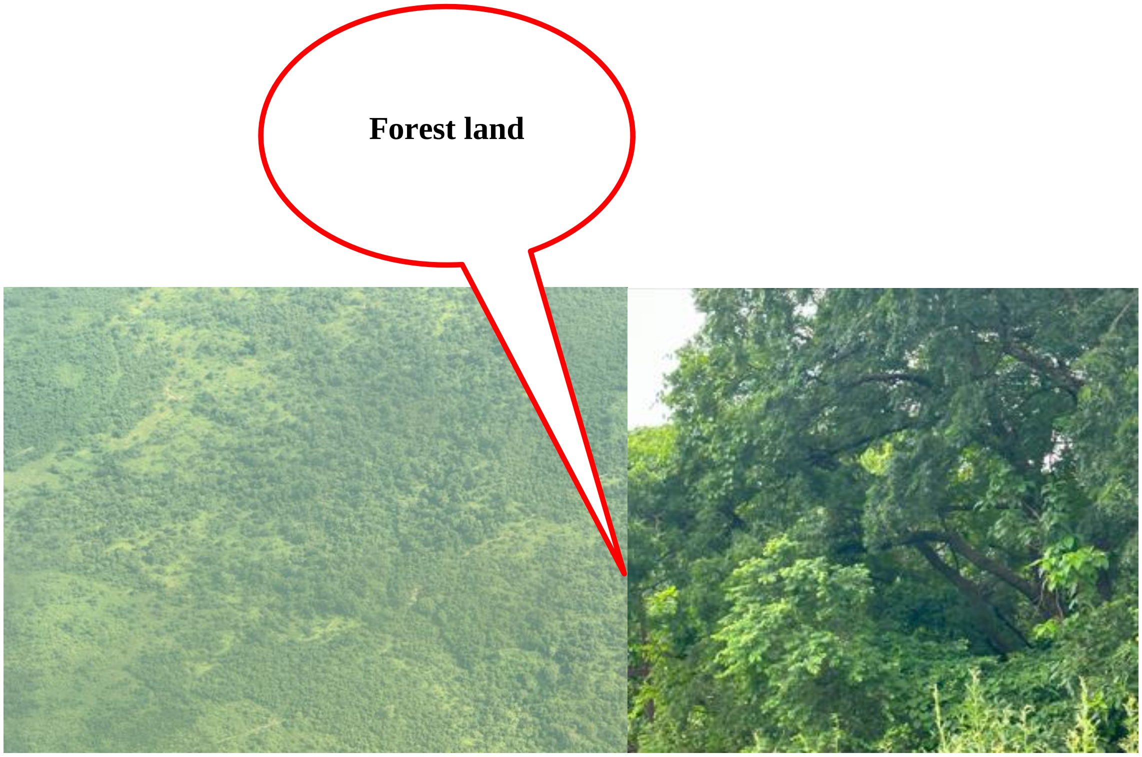
Appendices 7: A differences of LULC photo samples.


Agricultural land


Water bodies
BALENCIAGA



Appendices 5: Map of GPS point data map.