Addis Ababa University

Ethiopian Institute Architecture Building Construction and City Development

Analysis of the Trends of Land Use Land Cover Change and its Management: The Case of Dukem Town, Oromia Regional State of Ethiopia

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, Ethiopian Institute of Architecture, Building Construction and City Development (EiABC), in Partial Fulfillment of the Requirements for the Award of Master's of Science Degree in Urban Planning

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Declaration

I, Neguma Hika, certify that the Thesis entitled **'Analysis of the Trends of Land Use Land Cover Change and its Management: the case of Dukem Town, Oromia Regional State'** is entirely my own work, and it has not been previously submitted to any educational institution for any degree or diploma, nor has it been used for any other purpose. All sources and information used in this study, except for my own original contributions, are properly acknowledged and cited.

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Signiture: _______________

Approval

As members of the examination board, we have read and evaluated the Master's thesis submitted by Neguma Hika, the topic entitled '**Analysis of the Trends of Land Use Land Cover Change and its Management: The Case of Dukem Town, Oromia Regional State**.' and recommend to the Ethiopian Institute of Architecture, Building Construction and City Development, Addis Ababa University to accept the thesis as it fulfilled the requirements for a Master's degree in Urban Planning.

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Abstract

This study investigates the trends of land use and land cover changes and its management in Dukem town between the years 1994-2024 through identifying driving factors and actors. The study used both qualitative and quantitative approaches using spatial analysis of remote sensing and GIS techniques and survey methods. Both primary and secondary data sources were used for the study; and the Primary data were collected using questionnaires and observations. While the secondary data were collected using satellite images. Accordingly, the result showed a significant increase in the built-up area of the town. Between 1994 and 2024, the study town expanded from 498 hectares (5%) to 3447 hectares (36%). This rapid growth meant that built-up areas were taking over large portions of other land types, such as agricultural land. Unfortunately, agricultural land decreased substantially during this period, declining from 6258 hectares (65%) in 1994 to 3889 hectares (40%) in 2024. Besides, the research found that the rate at which land is being consumed is significantly higher than the rate of population growth, except between 2014 and 2024. This suggests inefficient utilization of land, as the ideal scenario is for land consumption to be slower than population growth. Therefore, to improve land use efficiency in study town, efforts should focus on managing urban land and addressing the factors that are driving these land use changes. The goal is to reduce the ratio of land consumption to population growth to a level below one. This study recommended for several key actions. Firstly, it emphasized the need for ongoing monitoring of land use changes through technologies like remote sensing and Geographic Information Systems (GIS). This will help track urban growth and assess the success of urban planning policies. Secondly, the study stressed the importance of protecting natural resources and mitigating the environmental damage caused by urban expansion. Essentially, the study calls for a multi-faceted approach to sustainable urban development that involves continuous monitoring, environmental protection, improved planning regulations, community engagement, and strong inter-agency collaboration.

Key words*: land use land cover change, change detection, Key factors, Key actors, ratio of land consumption rate to population growth rate (LCRPGR)*

Table of Contents

List of Tables

List of Figures

Acronym

EIZ	Eastern Industry Zone
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
LCR	Land Consumption Rate
LCRPGR	Land Consumption Rate to Population Growth Rate
LULC	Land Use Land Cover
LULCC	Land Use Land Cover Change
MUDH	Ministry of Urban Development and Housing
OUPI	Oromia Urban Planning Institute
PGR	Population Growth Rate
RS	Remote Sensing
SPSS	Statistical Package for Social Science
ULUE	Urban Land Use Efficiency
UN	United Nation
UNCCD	United Nations Convention to Combat Desertification
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER ONE

1 Introduction

1.1 Background of the Study

The world has experienced in using more land consumption per capita. The population of cities in less developed countries doubled between 1990 and 2015, and their urban extents increased on average by a factor of 3.5. In developed countries, however, the population of cities was increased by a factor of 1.2 between the same year; and their urban extents increased by a factor of 1.8 (Angel et al., 2016; Kumera & Woldetensae, 2023).

The same document suggested that between 2015 and 2050 urban extents in less developed countries will increase by a factor of 3.7 at the current rate of increase in land consumption, by a factor of 2.5 at half the current rate, and by a factor of 1.8 if land consumption remains constant (Angel et al., 2016). Accordingly, substantial changes have been taken place in land use patterns globally. About 1.2 million km^2 of forest and woodland and $5.6km^2$ of grassland and pastures have been covered to the other uses (Ahlqvist et al., 2017).

One of the empirical study conducted in sixteen regional cities of Ethiopia has investigated the urban land use efficiency (Koroso et al., 2021). In this, study the ratio of land consumption to population growth rate, and the rate of urban infill were assessed. According to this study, there is a prevalence of urban land use inefficiencies in all cities.

Consequently, accurate and timely information on land cover changes is essential for comprehending and assessing their environmental ramifications (Lambin, 2006). The ongoing need for up-to-date land use and land cover data is vital for any sustainable development program, as it serves as a primary input criterion.

Satellite imagery has become crucial for comprehending how human actions affects our planet's natural resources. Especially in regions with fast-paced and undocumented land transformations, satellite observations offer unbiased insights into human land use. In recent years, data from Earth-observing satellites has proven indispensable for mapping Earth's features, overseeing resource management, and examining environmental shifts (Kumera & Woldetensae, 2023; Mulatu et al., 2024; Wiley & Sons, 2015).

One of the most precise ways to understand LULC mechanisms is through LULC studies. Accurate and timely information about changes in LULC is essential for informed decision-making. Since LULC data is a critical component of sustainable development plans, there is a constant demand for current LULC information(Mariye et al., 2022).

Geographic Information Systems (GIS) and Remote Sensing (RS) are modernizing ecosystem management. RS data enables comprehensive analyses of Earth's systems, patterns, and changes at various scales over time. This data bridges the gap between localized ecological studies and broader-scale conservation and management efforts for biodiversity (Lambin, 2006; MEER, 2005, p. 5).

The aim of this study is, therefore, to analyze the trend of land use and land cover changes and its management in Dukem town by integrating remote sensing with Geographical Information System (GIS) and the driving factors for these changes. Hence, the results of this study will provide valuable insights to aid decision-makers, land managers, and planners in the sustainable development and management of natural resources.

1.2 Problem Statement

Ethiopia has experienced rapid urbanization over the past three decades, several cities expanded rapidly, and many satellite towns sprung up around the major cities. The high rate of urbanization and urban growth resulted in high demand for urban land, mainly for industrial, commercial, and residential purposes. In order to meet the demand, an enormous amount of land has been made available for urban use, mainly through land conversion (Koroso et al., 2021).

Likewise, in the study town, Land use changes arising from high rate of urbanization (settlements), industrialization, and socioeconomic factors (Debela et al., 2020). These changes in LULC reflect the population growth, land consumption rate and climate (Seto et al., 2011). Accordingly, the urban expansion of Dukem town has led to the depletion of natural resources, which is evident in the conversion of agricultural and forested land into residential and other urban areas.

Furthermore, its proximity to the primate city has led to attract potential investments, which in turn resulted in high economic growth, and social development this condition reduced the farmland and increased built areas through time. Furthermore, the growth of the town is a continuous process so that it is important to measure its spatial extents using GIS and RS techniques and assess major factors and key actors, and eventually to identify the level of the efficiency of the utilization of scarce resources to recommend the future direction in this regard. Given the widespread issue of urban expansion, it is imperative that this research be undertaken within the specific context of the study town.

Over time, change in land use and land cover will negatively affect the livelihoods of small-scale farmers. This research is crucial in that even though previous(Koroso et al., 2021; Kumera & Woldetensae, 2023) studies have used Geographic Information Systems (GIS) and remote sensing to analyze and quantify urban land use and land cover changes in this specific area; they were not emphasized the land use consumption rate to determine the efficient utilization of scarce natural resource. By mapping land cover and land changes over time, and identifying land use consumption rate along with driving forces for the change, the researcher can provide valuable insights into the extent and patterns of these changes. This information will help inform decision-making on strategies to mitigate the negative impacts on land and resources.

1.3 Objective of the Study

1.3.1 General Objective of the Study

The main objective of this study is to analyze LULC changes in Dukem Town from 1994 to 2024 using Landsat 5, 7, 8 and 9-satellite imagery.

1.3.2 Specific Objectives of the Study

The specific objectives of the study are-

1. To examine the patterns, rate and extent of urban land use change from 1994 to 2024,
2. To examine the major causes of urban land use land cover change in Dukem town,
3. To assess the efficiency of urban land utilization in the study town,

1.4 Research Questions

The basic questions that are answered while conducting this research: -

1. What is the extent and characteristics of urban land use and cover change in Dukem from 1994 to 2024?
2. What specific factors led to changes in land use and land covers in Dukem town?
3. What is the degree of efficiency in land utilization within the study town during the designated period?

1.5 Significance of the Study

The implications of urban growth are not well understood and could potentially be a threat for achieving sustainable urbanization. Hence, it is very essential to understand the phenomena of urban growth especially from the perspective of a developing country, like Ethiopia. This would finally aid in developing policy and management options for effectively addressing the problem of unbalanced urban growth. Further, the problem of urban sprawl is observed to be an outcome of improper planning, inadequate policies and lack of good governance due to various reasons. The inability of the administration and planning equipment to visualize probable areas of sprawl and its growth was a persistent with the lack of appropriate spatial information and indicators.

The land use and land cover change within the study area has scientific and developmental importance for the future. The researcher believes this project will provide base line information on issues of land use and land cover change and dynamics in the study town. Such information is vital for comparing the past and present condition and predicts the future trends of the LU/LC change.

The subject of urbanization and urban sprawl had drawn attention from ecologists, urban planners, civil engineers, sociologists, administrators, policy makers and finally to common urban or rural residents. The study on urban sprawl caters basic data for local government body to process and make information on the current situation and future threat of urban sprawl that would demonstrate a possible action to be taken in order to control the negative implication.

Furthermore, it serves as a reference for those who would like to conduct research on the subject.

Accordingly, the findings of the study benefit the local government, the residents of the town, the researcher, other researcher as well as benefit in policy formulation; and therefore, the study would contribute to the overall economic, social, environmental and political development of Dukem town.

1.6 Scope and Delimitation of the Study

Spatial Scope

This research is limited to the Dukem town administrative area. However, while the primary focus is on Dukem town itself, the surrounding areas with significant influence on the town's physical infrastructure needs are also included in the study's scope.

Thematic Scope

Thematically, the research analyzes trends of land use and land cover changes, predicts future changes, and offers recommendations for optimizing land resource, that means proposes strategies for sustainable land resource management in the study town.

Temporal Scope

The time limit of this study starts from the proposal preparation until the ending process of the whole work that is from February 2022 to June 2022 and for extent of urban sprawl from 1994 to 2024.

1.7 Limitation of the Study

Accessing and downloading high-resolution satellite imagery presented a significant limitation for this research. To address this constraint, I explored alternative options to minimize the impact of spatial resolution limitations. Consequently, I employed Landsat TM 5 for 1994 data, Landsat TM 7 for 2004 data, and Landsat 8-9 for 2013 and 2024 data, all of which offer varying levels of resolution. Additionally, I incorporated high-resolution Ortho-photo to streamline feature extraction throughout the preprocessing and processing stages.

A further constraint encountered during this research was the difficulty in securing supplementary relevant data from the requisite sources.

1.8 Organization of the Study

The research paper is organized in five chapters, within each chapter there are different but interrelated subtopics; the contents of those chapters are discussed briefly.

The first chapter addresses the introduction part, which comprises the background information, problem statement, objectives, significance, scope of the study, and organization of the paper and limitations of the study.

The second chapter comprises the literature review part. In this regard, relevant academics discourses that were important for the study were reviewed. The reviews are related to general theoretical concepts of land use and land cover changes, and its driving factors as well as land use consumption rate, GIS and RS techniques or tools for analyzing the trends of land use and land cover change.

In the third chapter the research methodology, research design, data source, data type, data gathering tools, data analysis and data presentation were discussed.

The fourth chapter is about the findings, discussions and interpretations were addressed. This chapter is discussing the results and discussion in respect to the research questions. Under the result section description of data, spatial data analysis using GIS mapping techniques, qualitative and quantitative analysis were discussed using map, graphs, charts and tables.

The last chapter provides the conclusions and recommendations parts, which conclude, and recommends the possible solutions. Accordingly, the research findings are summarized in respective to research questions and the recommendations are based on the findings of research questions.

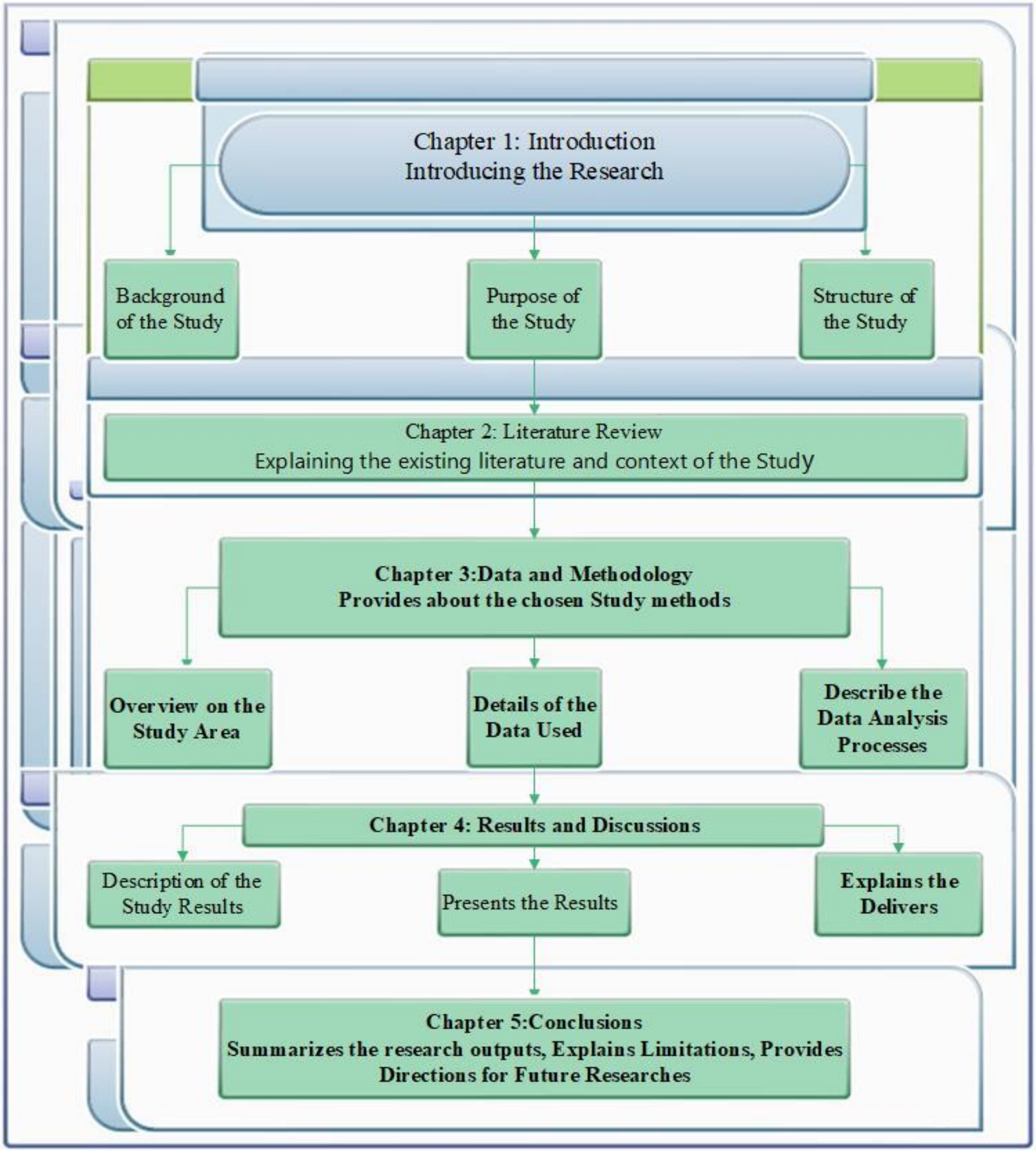


Figure 1.1 : Organization of the Study

CHAPTER TWO

2 Literature Review

2.1 Introduction

This section presented the review of literature including research papers and reports regarding theoretical concepts and theories of urban land use change. The review extensively examined the forces driving land use and land cover changes, the key actors involved, and the resulting impact on land use and land cover (LULC) change. It also investigated into the application of Geographic Information Systems (GIS) and Remote Sensing (RS) technologies, and their significance in analyzing trends of land use changes. Additionally, the review explored policies aimed at managing rapid urban growth. The section further summarized various methodological techniques and tools employed by researchers in this field, identified research gaps, and concluded by reviewing relevant studies.

2.2 The Concept and Definition of Land, Land Use and Land Cover

Various authors, primarily due to varying emphases on specific characteristics, define the concept of ‘land’ differently. The Food and Agriculture Organization (FAO) (Briassoulis, 2020a) defines land as a distinct area of Earth's surface, encompassing all aspects of the surrounding environment, both above and below the ground. This includes factors like climate, terrain, soil, water, and vegetation, all of which influence how the land can be used. The FAO(FAO, 1976) also acknowledges the impact of human activities, both beneficial and detrimental, on the land.

Wolman (Briassoulis, 2020a) provides a similar, comprehensive definition, viewing land as an integrated system of natural resources. He emphasizes a range of attributes, including climate, landforms, soil, vegetation, wildlife, and water, extending from the atmosphere to several meters beneath the surface.

Furthermore, many scholars frequently use the terms land use and land cover interchangeably; but their actual meanings are quite different. It is important to differentiate this difference between land cover and land use, and the information that can be ascertained from each. Land cover refers to the physical elements that cover the surface of the ground at a given location; and it may include vegetation cover, urban infrastructure, water body, bare land and others. It is defined by the attributes of the Earth's land surface and immediate subsurface, including biota, soil, topography, surface and groundwater, and human (mainly built-up) structures (Lambin & Geist, 2006) in which Land-cover conversions is about the replacement of one cover type by another(Tesfaye et al., 2024). On the other hand, land use refers to the purpose the land serves, for instance, recreational use, residential uses, manufacturing, commercial uses, agricultural uses and the likes. It is defined as the purposes for which humans exploit the land cover which involves both the manner in which biophysical attributes of the land are manipulated and the intent underlying that manipulation, i.e., the purpose for which the land is used (Lambin & Geist, 2006).

According to (FAO/UNEP 1999) as cited in (Wu., 2014) "Land use" refers to more than simply the pattern of different land covers in space. Rather, it is "the total of arrangements, activities, and inputs that people undertake in a certain land cover type to produce, change, or maintain it." This means that, land use for a specific tract incorporates land cover, as well as management intensity and practices. Therefore, changing land use could mean changing land cover, or it could mean maintaining the same land cover while altering management.

It is quite clear by now from the above discussion that land use and land cover are not same although they may overlap. The distinction of them is described in the following (Table 2.1)

Table 2.1: Types of Land Cover and Associated Land Uses

Type of Land Cover	Type of Land Use
Forest	Natural forest; Timber Production; Recreation; mixed Use(Timber production and Recreation);
Grass Land	Natural area; Pastures; Recreation; mixed (Pastures and Recreation)
Agricultural Land	Crop land (annual and perennial); Recreational, tourism; and mixed
Built-up Land	City; Village; Industrial area; archaeological site; Residential area; Commercial area; transportation area, mixed uses; etc.

Source: (Briassoulis, 2020a , p.16)

2.3 Land Use and Land Covers Change

In the analysis of land use and land cover change, it is important to conceptualize the meaning of change to identify it in real world circumstances. In simple, land use and land cover change means change in the areal extent (increases or decreases) of a given type of land use or land cover, respectively (Gondwe et al., 2021). It is important to note that the detection and measurement of change depends on the spatial scale; that means the higher the spatial level of detail, the larger the changes in the areal extent of land use and land cover which can be detected and recorded.

Two types of changes have been conceptualized in both cases (land cover and land use) by relevant literature: conversion and modification as (Briassoulis, 2020a , p.17; Liping et al., 2018). Land cover conversion involves a change from one cover type to another whereas modification involves alterations of structure or function without a wholesale change from one type to another (Briassoulis, 2020a).

Some researchers suggested that land use changes involve both the introduction of new land uses and the relocation of existing ones. New land uses frequently trigger redevelopment, resulting in new constructions, land consolidation or division, and, in certain cases, modifications to the street pattern (Carmona et al., 2010).

More specifically (Briassoulis, 2020a), land use and land cover changes processed in three ways: converting the land cover; modifying it; and maintaining it in its condition against natural agents of change.

2.4 Driving Factors of Land Use and Cover Change

Land use and land cover change (LUCC) is driven by many factors, but human activity, particularly the use of land for production and urbanization, is the most significant driver today. Therefore, LUCC projects and research are essential for understanding, describing, and measuring the factors that cause these changes, as well as their impacts. To effectively manage land resources, we need to monitor how land use changes due to population growth and natural forces, and we also need accurate information about existing land cover. Accordingly, different scholars have distinguished explanatory variables/drivers that have been frequently used in models of urban land use change; and some of them were reviewed and presented under this sub-topic (Briassoulis, 2020b; Pourghasemi & Gokceoglu, 2019; Weith et al., 2021).

2.4.1 Bio-Physical Drivers

The bio-physical drivers include characteristics and processes of the natural environment such as: weather and climate variations, landform, topography, and geomorphic processes, volcanic eruptions, plant succession, soil types and processes, drainage patterns, availability of natural resources (Briassoulis, 2020a; Weith et al., 2021). Biophysical factors define the natural capacity or predisposing environmental conditions for land use change, with the set of abiotic and biotic factors – climate, soils, lithology, topography, relief, hydrology, and vegetation – varying among localities and regions and across time (Lambin & Geist, 2006). Each of these biophysical factors plays their roles in determining land use land cover changes. These biophysical factors and natural environmental changes interact with the human factors to cause the land change. For instance, biophysical limitations such as steep slopes and difficulty of access can provide considerable protection for a forest.

2.4.2 Socio-Economic Drivers

The socioeconomic drivers comprise demographic, social, economic, political and institutional factors and processes such as population and population change, industrial structure and change, technology and technological change, the family, the market, various public sector bodies and the related policies and rules, values, community organization and norms, property regime (Briassoulis, 2020a; Weith et al., 2021).

2.4.2.1 Demographic Factors

Even though the world's population growth rate is not uniform (much of the population growth in the recent past has occurred in the Global South), Global population is projected to reach 9.6 billion in 2050 out of which 66% is expected to be urban population (Cai et al., 2020; Hancock et al., 2015; UNCCD, 2017 , p.226). This population increase/ population growth must be expected to play a major role in explanations of land use/cover change as these population need areas for residences, productions; and they need basic services to improve their daily lifestyles. To provide them such services there must be a change of the uses of the land or modifying on some parts of the uses of the land and land cover as well.

2.4.2.2 Economic and Technological Factors

Economic factors appear to play a strong role in land use and land cover changes. According to Millennium Ecosystem Assessment 2005 as cited in (Briassoulis, 2020a) global economic activity increased nearly seven-fold between 1950 and 2000 while global population doubled in roughly the past 40 years, thus increasing the demand for many ecosystem goods and services. Accordingly, land-use changes mostly result from individual and social responses to economic conditions, which are mediated by institutional factors.

2.4.2.3 Institutional Factors

It deals with government structures used to establish and formulate norms, standards, and legal and policy frameworks used to guide overall development frameworks of a given locality within a given period; and to provide a decision-making power. For example, economic policy, land management policy, urban planning norms and standards, and the likes. From a wide array of case studies, it appears that institutional factors in combination with biophysical limitations, play a major role in protecting limited forest areas from deforestation and erosion for example (Lambin & Geist, 2006).

2.5 Effects of Land Use Land Cover Change

The possible changes that would happen on land due to the drivers would bring impacts on environmental and socioeconomic of a particular locality within a given period. The impacts could be either positive or negative. Accordingly, the impacts of land use change are broadly categorized into environmental and socioeconomic (Briassoulis, 2020a).

Land use change impacts development sustainability at all levels. Since sustainability balances social, economic, and environmental goals, land use and its changes are crucial. Negative environmental and socioeconomic impacts from land use change undermine these goals by depleting resources, reducing an area's ability to equitably meet its population's needs, both now and in the future. Therefore, land use planning and management are essential (Briassoulis, 2020a).

2.6 Land Use Change Indicators

Land consumption is very high especially in expansion areas of the cities in both developed and developing countries; and hence, it is necessary to have necessary information on both existing land use cover and the capability to monitor the dynamics of the resulting changes in land use (UN-Habitat, 2018c). Land cover is primarily shaped by human activity, and this must be considered alongside the impact of population growth and natural forces. A key indicator of land use change, widely recognized and included in the Sustainable Development Goals for 2030 (Indicator 11.3.1), is the ratio of land consumption rate to population growth rate. This metric assesses how efficiently urban areas use land by comparing the rate of urban land expansion to the rate of population increase(Biswajeet & Serdang, 2017; UN-Habitat, 2018a). Compact cities are generally more efficient. They use land better, making it cheaper to provide public services. They also tend to consume less energy, manage waste more effectively, and benefit more from economic clustering compared to sprawling, less compact cities.

Precisely the notion of land consumption and population growth is expressed as:

> *"Land consumption is the uptake of land by urbanized land uses, which often involves conversion of land from other uses to urban functions. Land use consumption rate is the rate at which land occupied by urban area changes during a period, expressed as a percentage of the land occupied by the urban area at the start of that time. Furthermore, Population growth rate is the rate at which population size changes in a country during a period, usually one year, expressed as a percentage of the population at the start of that period (*UN-Habitat, 2018c*;* Zhang et al., 2020*)".*

The cited notions can farther be represented by the following formula to measure land consumption to population growth rate, and in so doing to check the efficient utilization of the scares natural resource, the land.

$$\text{LCR} = \frac{(LN(Urb(t2)/Urb(t1)\,)}{(y)}$$; Where: …Equation 2-1

Urbt1 is the total area covered by the urban area in the initial year *t1*;

Urbt2 is the total area covered by the urban area in the final year *t2*; and y is the number of years between the two measurement periods (*t1* and *t2*)

$\text{PCR} = \frac{(LN(Pop(t2)/Pop(t1)))}{(y)}$; Were …Equation 2-2

Popt1 is the total population within the urban area in t1 (initial year)

Popt2 is the total population within the urban area in t2 (final year); and y is the number of years between the two measurement periods.

Furthermore, the final indicator, land consumption rate to population growth rate (LCRPGR), is computed by dividing the calculated land consumption and population growth rates as (Zhang et al., 2020, p. 7):

$\text{LCRPGR} = \frac{(Annual\ Land\ Consumption\ rate)}{(Annual\ Population\ growth\ rate)}$…Equation 2-3

In general, compact, walkable cities benefit from having activities and services nearby, reducing infrastructure costs and service delivery expenses. This approach also protects surrounding land for other uses, positively influencing the environment. Efficient land use is key, and a Land Consumption Rate per Population Growth Rate (LCRPGR) of less than one indicates such efficiency. Conversely, an LCRPGR greater than one suggests inefficient land use (DASHTI, 2022 , p.20; UN-Habitat, 2018a). According to (Biswajeet & Serdang, 2017), the value of LCRPGR fall in the range of −1 to 1, where 0 indicates moderate conditions; a positive value reflects higher built-up area consumption per capita; and a negative value indicates population crowding, which may result in serious negative effect at the social, economic, and urban levels.

2.7 The Role of Actors on Land Use Land and Cover Change

Land Use Land Cover Change (LUCC) is a complex process driven by, both natural and human induced. Among these factors, the role of various actors, ranging from individuals to governments, is particularly significant. These actors, through their decisions and actions, shape the landscape and influence the trajectory of LUCC (Wahyudi et al., 2019). Actors play a special role because actors are responsible for, and play an important role in, the driving forces of land change, and they make decisions, act accordingly, and influence other actors and the environment with their action (Juniyanti et al., 2021). Accordingly, there are three actors influence the land change process (Juniyanti et al., 2021, p. 6):

Direct land change actors are actors who carry out activities that cause immediate change at the site level, Decision-making actors who contribute to the underlying causes of land change Actor who, through their political power, are decision-makers or formulate regulations that affect land use, and Supporting actors are actors who support government policies related to land use, or actors that support solving problems regarding land management.

Government officials play a crucial role in shaping land use and land cover change (LULCC). They, by the formulation of local government policy, rules and regulations, are responsible for land use and land cover change; and hence, is one of the key actors (Allan et al., 2022; Lambin, 2006); and hence, they are decision making actors.

Developers and local community who are the direct users of the land are among the direct land change actors who carry out activities that cause immediate change at the site level. Among the urban development actors, private land developers play a critical role driving the process of urban growth (Wahyudi et al., 2019). The conversion of undeveloped rural land to urban use, driven by their decisions, make them one of the key actors in urban growth. On the other hand, experts are catheterized under the supporting actors who support government policies related to land use, or actors that support solving problems regarding land management

2.8 Application of GIS and Remote Sensing in Land Use and Cover change

Land Use Land Cover (LULC) change detection involves comparing images taken at different times to find out what has changed in a specific area. A Geographic Information System (GIS) is a powerful tool that can help us measure and understand how land use and land cover (LULC) has changed over time(Pourghasemi & Gokceoglu, 2019). By using remote sensing data, which provides information about the Earth's surface from satellites, GIS can create maps and visualizations that show how LULC patterns have evolved in different places and at different points in time.

Satellites are generally able to provide useful spatial and temporal information from land in a low cost, quick, and easy way. The Landsat satellites (namely Landsat 1 to Landsat 8) are among the most used and reliable imagery tools that have provided one of the longest temporal records of space-based surface observations in the decades since 1972 (Gokceoglu, 2019).
Remote sensing, on the other hand, is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in

contact with the object, area, or phenomenon under investigation (Al-Fares, 2013; Wiley & Sons, 2015). These remotely collected data can be of many forms, including variations in force distributions, or electromagnetic energy distributions which eventually be corrected for further analysis and interpretations.

In general, as stated above, GIS and Remote Sensing (GIS/RS) are versatile tools in addressing various issues in urban planning, land use land cover changes detection, monitoring, and producing spatial maps. Remote sensing offers a practical and affordable way to data accusations from aerial photos and satellite images. This data can be invaluable for evaluating, monitoring, and mapping urban growth.

2.9 Digital Image Processing and Analysis

To analyze satellite images using computers, these images need to be captured and saved in a digital format that can be easily stored on computer system(Mesev, 2007 ; Weng, 2010). This means Satellite data must be transformed into a digital format for computer processing. This requires a specialized computer system, equipped with appropriate hardware and software, known as an image analysis system. Digital image analysis then uses this system to analyze and manipulate the digital images; and this involves various techniques and algorithms to extract information, identify patterns, and make decisions based on the visual content of the images(Jensen, 2015, p. 24).

According to (Gondwe et al., 2021; Jensen, 2015; Pradhan, 2017), digital image processing and analysis passes through three successive analytical processes: pre-processing to correct the geometric, radiometric, and atmospheric errors; processing to subset the images and apply the image classification method and change detection in a selected scenario; and post-processing to produce a map, layout the results, and check accuracy assessment.

2.9.1 Image Prepossessing

The process of image prepossessing involves enhancing and improving image data to represent the original scene. This includes removing noise, adjusting color and brightness, correcting distortions, and combining multiple images. These steps ensure that the image is suitable for further analysis or manipulation (Gondwe et al., 2021; Wiley & Sons, 2015). In other words, it is the processes made on the remotely sensed raw data to correct geometric distortions, to calibrate the data radiometrically, and to eliminate the noise present in the data by applying these three methods: geometric correction, radiometric correction, and atmospheric correction methods (REDDY, 2008). The purpose of image prepossessing is to restore proper image data from distorted raw data (Pradhan, 2017).

2.9.2 Image Enhancement

Image enhancement involves techniques for heightening the visual distinctions among features in a scene, ultimately increasing the amount of information that can be interpreted from the data(Wiley & Sons, 2015). By applying linear contrast stretch technique, which can be capable of expanding the dynamic range of radiometric resolution, according to (REDDY, 2008), image enhancement deals with the individual values of the pixels in the image to make certain features more visible. According to (Weng, 2010, p. 30), image-enhancement involves three methods: contrast Enhancement, spatial enhancement, and spectral transformation.

2.9.3 Image Classification and Analysis

Broadly, image classification is a process of drawing meaningful information by differentiation and extraction of different classes or types (e.g., land-use types, vegetation species) from remote sensing data through several image processing procedures including image prepossessing (Thenkabail, 2016; Weng, 2010).

Image classification and analysis operations are used to digitally identify and classify pixels in the data(Al-Fares, 2013). This process assigns each pixel in an image to a particular class or theme based on statistical characteristics of the pixel brightness values. Statistical classification, a method used to categorize data into different groups: unsupervised, supervised(Lunetta & Lyon, 2000; Mason, 2016; REDDY, 2008) and hybrid approach(Wiley & Sons, 2015). According to (Pradhan, 2017; Thenkabail, 2016), the classification group of change detection techniques includes supervised and unsupervised classification followed by post classification comparison of results of change/no-change identification. The main purpose of image classification process according to (Pradhan, 2017), is to automatically classify all pixels in an image into LU/LC classes or patterns.

Unsupervised Classification

In this classification is entirely based on the statistics of the image data distribution and is often called clustering which does not provide any predefined categories or labels. Instead, it analyzes the data to identify natural patterns or groupings within the data itself; and the method is therefore objective and entirely data driven (Mason, 2016, p. 91; REDDY, 2008).

Supervised classification

In contrast to the supervised classification, supervised classification method is based on the statistics of training areas representing different ground objects selected subjectively by users based on their own knowledge or experience. That means it is controlled by users' knowledge but, on the other hand, is constrained and may even be biased by their subjective view (Lunetta & Lyon, 2000; Mason, 2016).

In supervised classification, according to (Thenkabail, 2016), a prior knowledge about some cover types is obtained in advance through a combination of fieldwork, aerial photo interpretation, existing maps, and other sources. Based on this, the analyst attempts to locate specific sites (class representation) for these cover classes in remote sensing data.

Hybrid classification

Some scholars recommend a hybrid classification approach (Al-Fares, 2013; Mason, 2016; REDDY, 2008; Wiley & Sons, 2015) in realizing the limitations of both unsupervised and supervised classification methods. In hybrid classification, first process a multi-spectral image using an unsupervised method. Once this initial grouping is complete, the result is interpreted using ground truth knowledge. Finally, the original image is re-classified using a supervised classification with the aid of the statistics of the unsupervised classification as training knowledge. In essence, the hybrid classification process combines the advantages of both unsupervised and supervised methods.

2.9.4 Change Detection

One of the most powerful advantages of remote sensing images is their ability to capture and preserve a record of conditions at different points in time, to determine the extent and nature of changes over time (Wiley & Sons, 2015). Furthermore, according to (Adepoju, 2007; Canty, 2009) change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. According to (Thenkabail, 2016), for any change detection project, the following conditions must be satisfied: (1) accurate and precise registration between multi-temporal images; (2) precise radiometric and atmospheric normalization between multi-temporal images; (3) similar phonological or seasonal conditions between multi-temporal images; and (4) selection of the same spatial and spectral resolution images if possible.

2.9.5 Accuracy Assessment

One of the most important final steps in the classification process is the accuracy assessment, which quantitatively determine how well the pixels were sampled in the appropriate land cover categories (Diallo et al., 2022).

Once satellite images have been classified, accuracy assessment is the crucial final step in remote sensing data analysis. It helps us evaluate the reliability of our classification results. This is typically done using a contingency table (confusion matrix). By comparing a random sample of pixels or clusters to known ground truth data (the reference data, we can determine the percentage accuracy of our classification (Campbell & Wynne, 2011).

The standard format for reporting site-specific classification error is the error matrix, often termed the confusion matrix as it clarifies not only the overall error rate for each class but also the specific instances of mis-classification between categories (Congalton & Green, 2009). The rows of the matrix correspond to the reference ground truth classes, while the columns represent the predicted classes derived from the classification result. The diagonal elements of the matrix, extending from the upper left to the lower right, indicate the number of pixels that were correctly assigned to each class (Campbell & Wynne, 2011, pp. 412-416).

In accordance with standard accuracy assessment practices (Campbell & Wynne, 2011; Congalton & Green, 2009; Jeffrey et al., 2024; Jensen, 2015, p. 558; KNUDBY, 2012, p. 70; Richards, 2013), the performance of image classification activities needs to be evaluated using producer's accuracy, user's accuracy, overall accuracy, and the Kappa coefficient.

Producer’s Accuracy

The producer’s accuracy is the accuracy of the map from the point of view of the map maker (the “producer”) and is calculated as the number of correctly identified pixels of a given class divided by the total number of pixels actually in that class as shown below. The producer’s accuracy for a given class tells us the proportion of the pixels in that class that were classified correctly (Congalton & Green, 2009, p. 133; Jeffrey et al., 2024, p. 139).

User's accuracy

User accuracy, or consumer's accuracy, evaluates the map's accuracy from the standpoint of the map user. It is computed as the ratio of correctly identified pixels within a particular class to the total number of pixels claimed to be in that class (Campbell & Wynne, 2011; Congalton & Green, 2009; KNUDBY, 2012)

Overall accuracy

The overall accuracy tells us what proportion of the reference data was classified correctly and is calculated as the total number of correctly identified pixels divided by the total number of pixels in the sample (Campbell & Wynne, 2011; Congalton & Green, 2009).

Kappa Coefficient

The kappa coefficient a discrete multivariate technique (Congalton & Green, 2009, p. 105) is another widely used accuracy metric that assesses the extent to which the classification results surpass random chance. The value of the kappa coefficient can range from − 1 to 1: A kappa value less than 0 suggests that the classification is inferior to random assignment, a value of 0 signifies no improvement over random, and a positive value denotes superior performance compared to random (Jeffrey et al., 2024, p. 141). According to (Campbell & Wynne, 2011, p. 420) Kappa is a statistical measure that assesses the degree to which the observed concordance between two maps, as represented by the diagonal elements of the error matrix, exceeds the level of agreement that might arise solely from random coincidence.

Sample size is an important consideration while assessing the accuracy of remotely sensed data. A good rule of thumb is to have at least 50 samples for each land cover type. For larger areas or maps with more than 12 land cover types, you may need even more samples, up to 75 or 100 per type (Congalton & Green, 2009; Wiley & Sons, 2015, p. 581).

2.10 Policies to Control Rapid Urban Growth and Horizontal Expansion of Cities

Urban development policies and strategies are important because they help to shape the future of cities. Hence, almost all countries formulated such policies and strategies to control the development of their cities. In line to this, Ethiopia has formulated such policies and strategies to attain sustainable objectives of urbanization.

One of the policies related to this subject matter is urban land management and development policy and strategy. This policy advocates the efficiency of land utilization and compact development unlike sprawl (MUDH, 2016a, pp. 27-28).

One of the strategies used for controlling unbalanced growth is urban plan preparation and implementation strategy (MUDH, 2016b, p. 26). The strategy guaranteeing that the principle of compact settlement is adhered to during urban plan preparation and implementation.

2.11 Research Gap

To ensure sustainable urbanization, the management of urban growth plays a pivotal role. To realize this, The UN has set a goal to make cities more sustainable by 2030. This means managing urban growth in a way that protects the environment and improves people's lives. To achieve this, we need to use land efficiently and avoid urban sprawl (Koroso et al., 2021).

Most of the studies regarding land use land cover changes in Ethiopia that were carried out in Ethiopia focused on assessing urban expansion and its socio-economic impacts and the driving forces for the changes (Debela et al., 2020; Kumera & Woldetensae, 2023; Malede et al., 2022; Mariye et al., 2022; Mulatu et al., 2024). The studies did not consider how efficiently land is being consumed as cities grow which is an important factor, as cities need to use land wisely to accommodate their growing populations (UN-Habitat, 2018b, p. 3).

There is one study conducted by (Koroso et al., 2021) intended to focus on urbanization and urban land efficiency. The study investigated the urban land use efficiency (ULUE) of sixteen cities in Ethiopia mainly on the regional cities, and hence, less focused on other lower urban center like Dukem town. In this, study the ratio of land consumption to population growth rate, and the rate of urban infill were assessed, found out that there is a prevalence of urban land use inefficiencies in all cities.

Therefore, this study aims to investigate the trends of land use and land cover have changed in Dukem town over the past 30 years to address the research gap. In so doing, it explored the reasons for these changes and assessed how efficiently land is being used in the town. Finally, the study tried to predict future trends in land use and land cover, and to measure land use efficiency to recommend the best ways to utilize the scares resource.

CHAPTER THREE

3 Research Methodology

3.1 Introduction

To answer the research questions of the study properly, literature of different scholars had been reviewed in chapter two to come up with a comprehensive methodology. Accordingly, this section presents description of the study area, materials and methods that were used in the study. Specifically, data types, data source, method of data collection, method of data analysis or processing; and tools or software programs used for data collection and analysis are discussed in detail under this chapter.

3.2 Description of the Study Area

3.2.1 Location of the Study Area.

Dukem town is located at 37km Southeast of Addis Ababa along the main road to Adama. Geographically, the study area located by latitude $8^0$45’25’’N-$8^0$50'30"N and longitude $38^0$51'55"E - $38^0$56'5" E covering a total area of 6,953 hectare; and located at an average altitude of 2100m above sea level(OUPI, 2017a). It is among rapidly developing towns of Oromia region state towns. According to the 2007 census, the total population of the town was 24,024. The population is rapidly growing due to its proximity to Addis Ababa and the economic opportunities generated by expanding investments. The city is experiencing rapid population growth due to several key factors. Its strategic location provides convenient access to the capital's benefits, while a thriving economy, driven by investments in various sectors, is creating a strong demand for workers. This influx of people from both within and outside the town is straining the city's existing infrastructure and services. To address these challenges, comprehensive urban planning strategies are crucial to ensure adequate housing, transportation, and other essential amenities for the growing population. The town is divided into four administrative units known as kebeles.

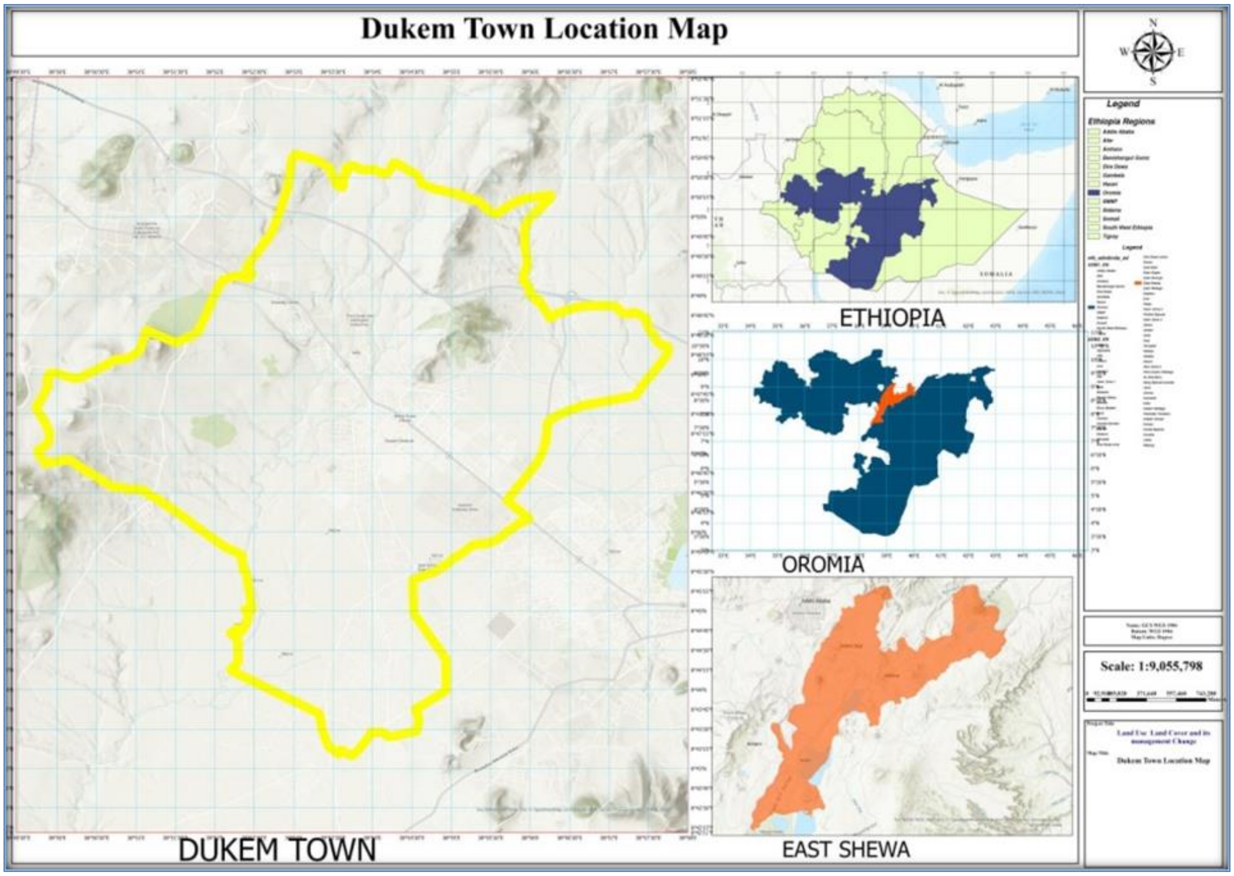


Figure 3.1: Location Map of the Study area

3.2.2 Physical Characteristic of study area

3.2.2.1 Topography

Understanding a topographic feature is a crucial point to identify the characteristics of the study area. Accordingly, the elevation difference, slope as well as aspects of the study town were analyzed based on the contour feature of the site.

As indicated in Figure 3.2 below, the altitude of the study town ranges from 1890m to 2300m above Mean Sea Level; and hence, its elevation difference between the two extremes is about 410 meters. The northeastern, northern and eastern parts of the town are generally characterized by rugged topography. Whereas, the southern and western parts of the town are flat topography (OUPI, 2017a). This topography has its own impact in the development of the town.

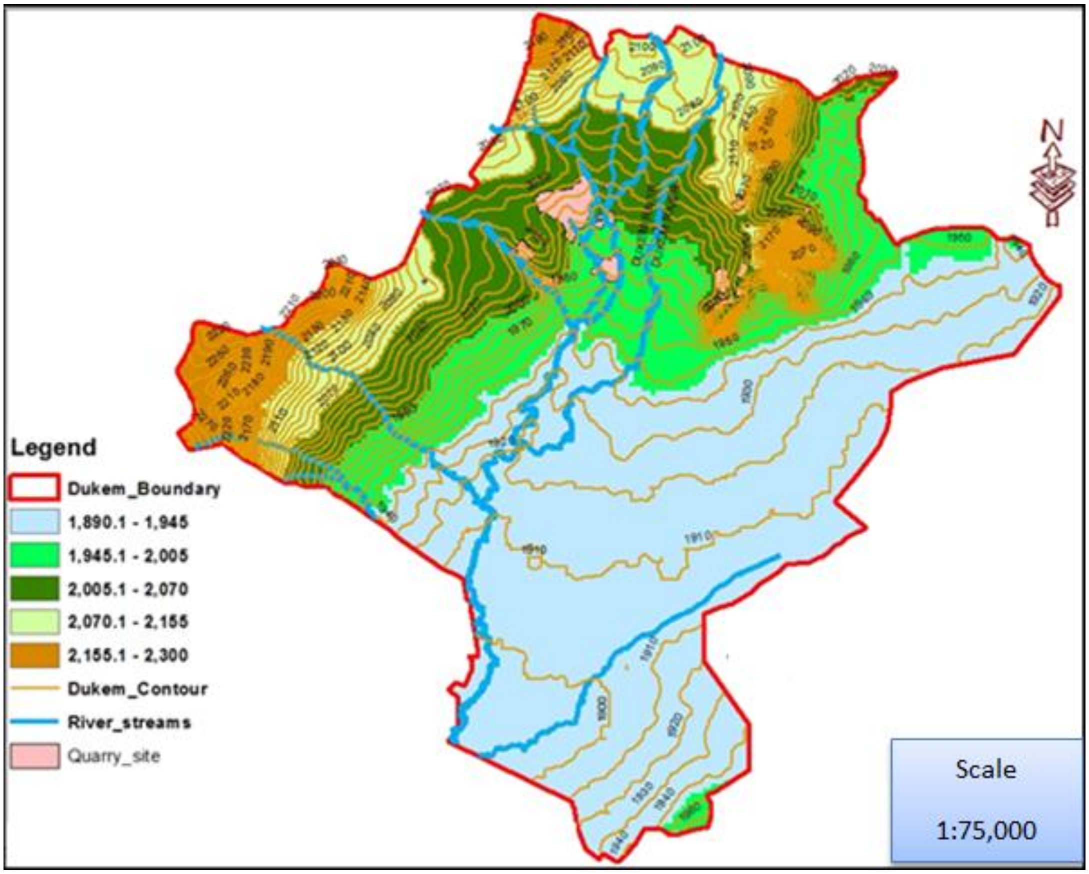


Figure 3.2: Elevation Map of the study town

Slope, also known as gradient or grade, measures how steep somewhere is. Analyzing slope is crucial for choosing a building site. By examining a topographic map, planners can match land use to the existing slopes and identify areas suitable for construction. Flat land is the cheapest to develop; steeper slopes increase costs due to the extra work needed for roads, utilities, and building foundations. Slope analysis involves breaking down of topographic configuration into different categories, which will establish the desired patterns for given land use. Accordingly, the slope categories according to (MUDH, 2018) were established and presented by the Table 3.1 below.

Table 3.1: Slope Patterns and their Development Suitability

No	Slope category (%)	Description	Development Suitability
1	1-5	Generally flat	Highly buildable
2	5-10	Gently rolling	Moderately Buildable
3	10-15	Gentle to mild slopes	Moderately difficult to build
4	15-20	Mild to steep slopes	Difficult to Build
5	20 and above	Harsh, steep slopes	Unbuildable

Source: Structure plan manual (2012)

As expressed by Table 3.2 about 86% of the site is categorized as a slope category less than 10%; hence, described as flat topography, which is a highly buildable site. Therefore, the site is suitable for any development from the topographic point of view. On the other hand, slope category above 20% accounts about 6%, which is characterized as harsh and steep slope that is not buildable.

Table 3.2: Slope Classification of the project site

No	Slope Category	Area m2	Area in Hectare	%age
1	0-2%	33537486.71	3353.75	34.74
2	2-5%	27406134.26	2740.61	28.39
3	5-10%	22408878.07	2240.89	23.21
4	10-15%	5858385.38	585.84	6.07
5	15-20%	1888414.14	188.84	1.96
6	>20%	5430771.76	543.08	5.63
Total		96530070.30	9653.01	100.00

Source: Owner Calculation (2024)

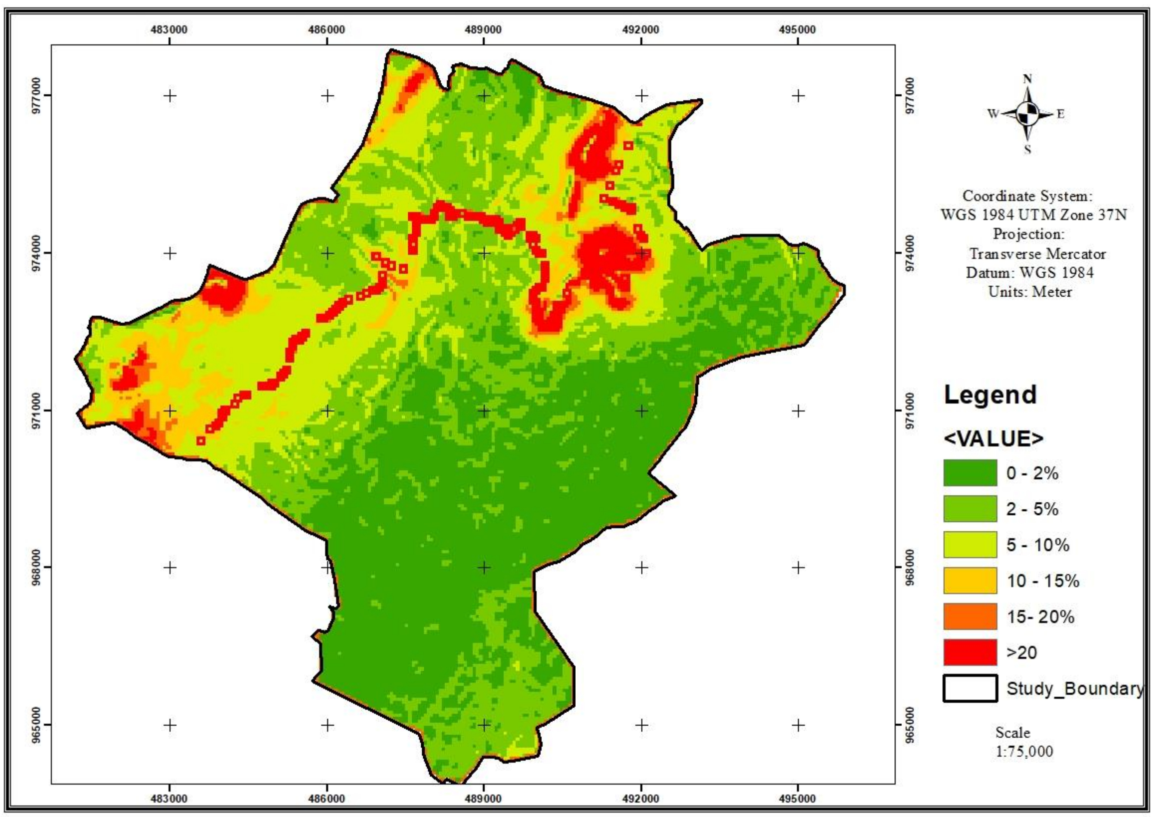


Figure 3.3: Slope Map of the Study Town

3.2.2.2 Climate

In tropical regions like Ethiopia, altitude significantly influences climate. Analyzing climate data is crucial for urban planning, particularly for managing watersheds in and around towns. This analysis is especially important in areas with steep slopes unsuitable for agriculture or other land uses requiring flat terrain. It helps pinpoint flood-prone zones and allows for the design of water-harvesting systems on steeper slopes, thereby boosting groundwater potential. In the case of Dukam town, its location within Ethiopia places it in a semi-temperate agro-climatic zone, with temperatures ranging from 15 to 20°C, due to the altitude's effect on temperature. On the other hand, the metrological station of Akaki, which is located at a distance of 15kms, is used to analyze the climate of Dukam town (Table 3.3).

Table 3.3: Climatic data of Dukam town from 1997 to 2017

Climatic element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PPT (CM)	13	17	52	80	76	107	228	241	114	22	8	5
Temp ($0_{C)}$	19	20	21	22	22	20	19	19	19	20	19	19

Source: The National Meteorological Agency of Ethiopia, 2017.

Data from the Akaki meteorological station (1997-2017) shows Dukam town and its surrounding area receive an average annual rainfall of 803mm (80.3cm). Rainfall in the region is seasonal, beginning in spring and continuing through August (summer). The dry season occurs during winter (December to February). Autumn and spring have moderate rainfall, less than the summer months. This rainfall pattern supports a growing season that extends from spring through autumn.

Dukam's highest temperatures, as illustrated by rainfall and temperature graphs, coincide with the Northern Hemisphere's spring, peaking in May after a steady rise from January. However, the temperature of the town falls down during summer and autumn seasons of the northern hemisphere due to the impact of cloud cover (Figure 3.4).

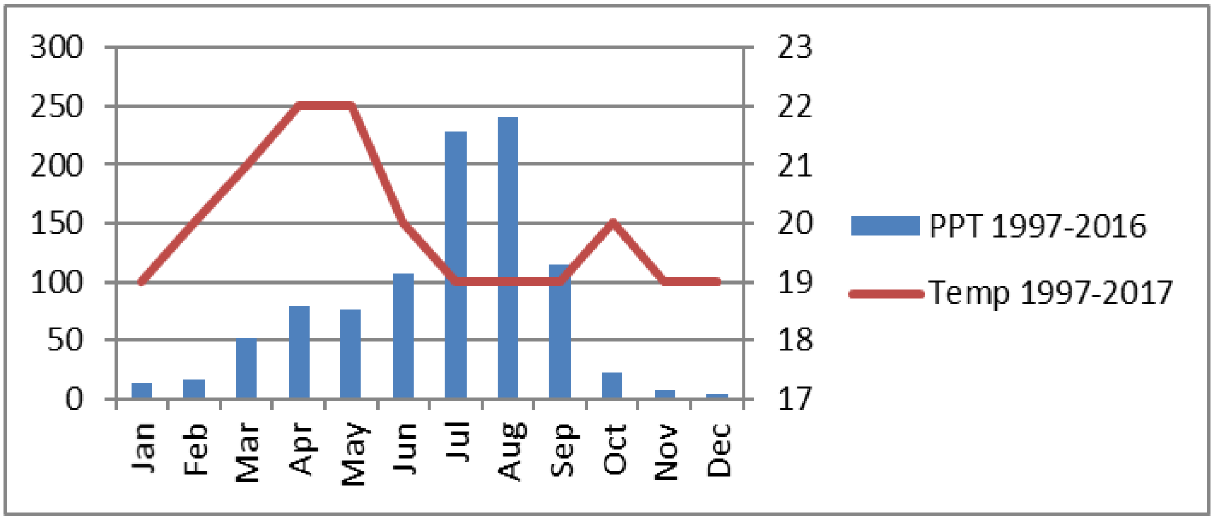


Figure 3.4: Seasonal distribution of Rainfall and temperature of Dukam town

Source: Generated from Meteorological data of Akaki, April 2017

3.2.2.3 Wind Direction and Speed

According to the analysis of wind direction and speed data at Bole International Airport station (2006-2015), it can be generalized that 57.6% of the prevailing winds of the hinterland including Dukam town blow from east or south or southeast to west or north or northwest (Table 3.4).

Table 3.4: Wind direction of Dukam town and its hinterland

Wind direction	Frequency	Percent
Calm	644	2.7
Northwest	680	2.9
Northeast	724	3
Southwest	804	3.3
North	2045	8.6
West	2840	11.9
Southeast	3233	13.6
South	6297	26.4
East	6571	27.6
Total observation	23838	100

Source: Ethiopian Meteorological Station, 2015

Figure 3.5 shows it, the dominant wind of Dukam town and its hinterland are blowing from east or south. The effect of prevailing winds in Dukam town and its hinterland implies that any pollutant uses such and pollutant industries, waste dumping site or abattoir should be proposed to the northwestern parts of the town by considering the existing settlement and resources of the town. In connection with wind direction, it is important to curb the speed of the southeasterly wind by building windbreaks of vegetation in the southeastern parts of large institutions.

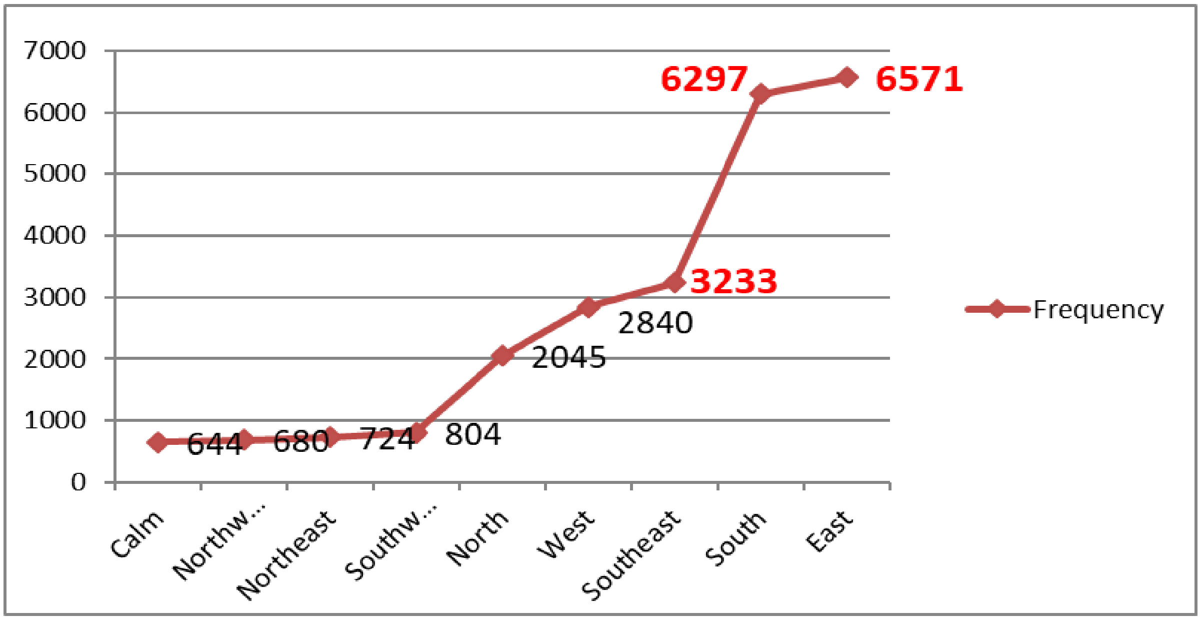


Figure 3.5: Dominant winds of Dukam town and its hinterland

3.2.2.4 Vegetation

There is scanty vegetation like acacia in Dukam town and its surrounding areas. Because of human pressure on the natural vegetation, there are few scrubs vegetation in areas that are less affected by human activities. In areas with steeper slopes and thin settlements eucalypts trees are common on hills of eastern and northeastern parts of the town. There are also few of acacia trees on individual farmlands, which can serve as shade trees for livestock during scorching sunny days,

3.2.2.5 Drainage

Dukam River and other seasonal streams that are originating from the uplands of the northeast direction of the town fall in the drainage basin of Awash. Dukam River and all these streams flow from either north or northeast to south or to southwest direction, respectively. They are highly utilized and hence have low volume during the dry season. Besides, their banks are not properly managed and most are used as waste dumping sites. Because of this, the banks should have proper buffer to protect them from any pollution and improper utilization.

The existing solid waste disposal site of Dukam town is found near Dukam River. The short distance between solid waste disposing site and Dukam River, decomposed liquid is released to the river. Windblown light solid wastes are also dropped to the compounds of the nearby factories, institutions and residents. Besides, the area looks filthy and has effect on the nearby residents and their animals (Figure 3.6).

Figure 3.6: Improper utilization of Dukam River as waste dumping site near Dukam cattle market

Source: Generated from Dukam base map by overlying image of Dukam, January 2017

3.3 Research Approach

In order to address the stated objectives of the study both qualitative and quantitative approach (Mixed approach) (Asenahabi, 2019)) were used and also both primary and secondary data sources were used. The Primary data sources were collected using data collection instruments such as closed-ended and open-ended questionnaires and observations. The secondary data sources were collected using remote sensing technique, processed, and analyzed using GIS platforms.

3.4 Research Method

The researcher used spatial analysis method using RS and GIS techniques. Satellite images of the study town for 1994, 2004, 2014 and 2024 years were used to assess the trends land use changes using remote sensing; the images were downloaded from Earth Explore USGS website and then processed and analyzed using GIS 10.8 software. The findings were presented in the forms of text percentage, graphs, and tables.

The survey method, a common tool in scientific research, involves collecting data through a series of questions administered to a sample of individuals. In this specific context, the researcher employed questionnaires, both close-ended and open-ended, to gather insights from officials, experts, local administrators, and the community about the factors and actors driving rapid land use change in the study town.

In this regard, the sampled respondents rated the listed urban land use change driving factors and actors based on the provided five-point Likert scale (from strongly agree to strongly disagree). While for open-ended questionnaire, the sampled respondents listed any explanations they have related to the factors and actors that contributed to rapid land use change of the study town between 1994 and 2024. Up on the finalization of data collection, data analysis was conducted using different software including SPSS, Excel, and GIS software tools. The data were organized in such a way that descriptive and inferential statistical methods and techniques were used for data analyses i.e. mean, mode, median, standard deviation and skewness and presented in tables, graphs.

3.5 Research Design

The researcher used both descriptive and explanatory research types. The researcher used descriptive research to describe the extent and nature of LULC changes over a specific period and within a specific area, and to map these changes to visualize their spatial distribution. On the other hand, the investigator used explanatory research to clarify the reasons behind the observed LULC changes, to explain the efficiency of the utilized land within the study town, and to extrapolate future LULC trends to suggest possible development scenarios.

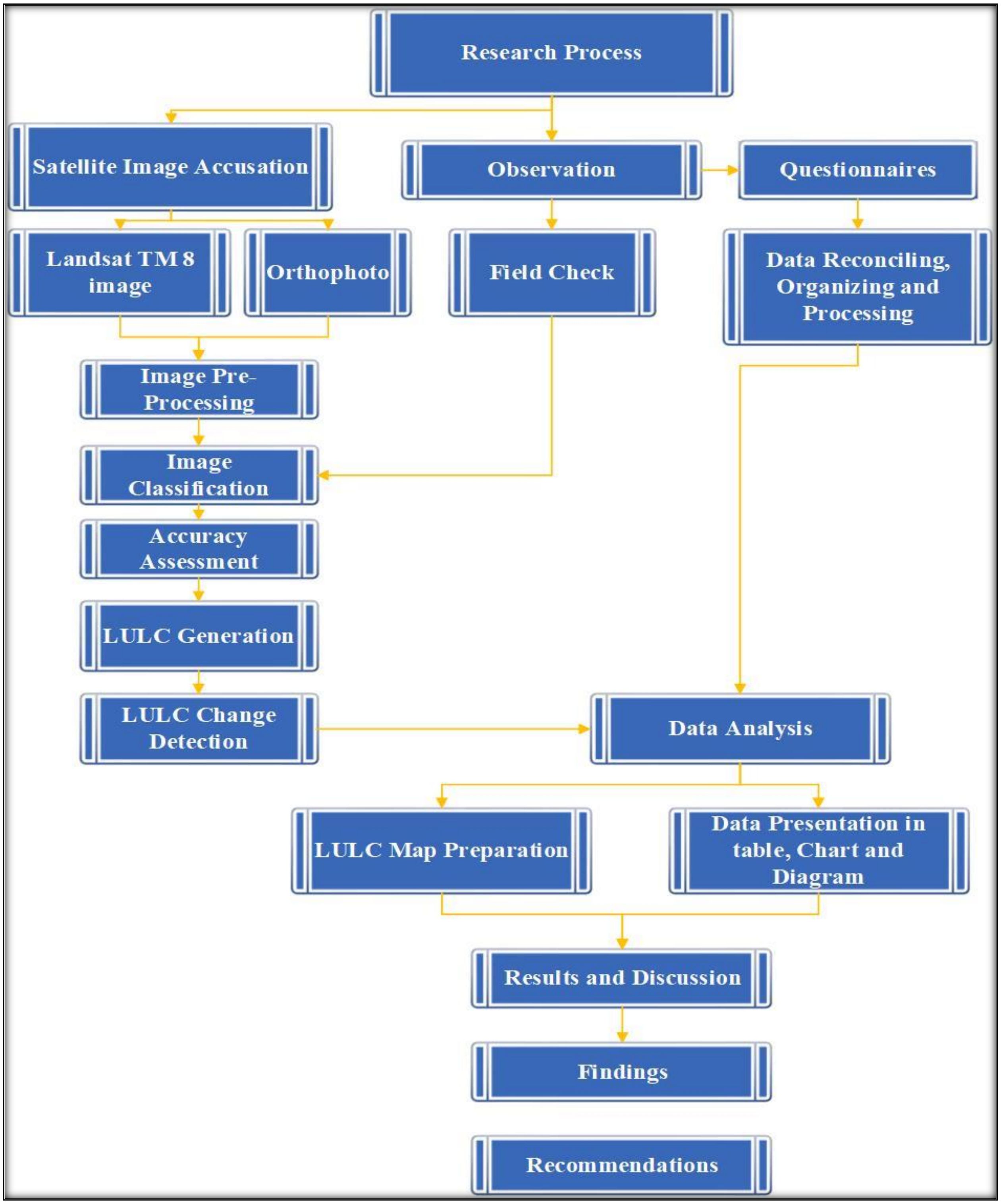


Figure 3.7: Research Process Diagram (Organized by the researcher, 2024)

Source: Organized by the Researcher, 2024

3.6 Data Type and Sources

The researcher used both quantitative and qualitative data type. Quantitative data, expressed numerically, and qualitative data, described in words, were gathered from primary and secondary sources. Primary data was collected directly from the study participants, while secondary data was obtained from existing sources. The use of reliable data is crucial for the successful accomplish the study's objectives. Overall, the study relies on two types of data sources: primary and secondary.

3.6.1 Primary Data Source

The primary data for this study was gathered through various methods, including:

Frequent observations: The researchers regularly visited the town of Dukem to observe its land development and management practices firsthand.

Closed-ended and open-ended questionnaires: These questionnaires were administered to officials and experts from the Dukem town Land Development and Management office, as well as community and Kebele administrators (Melka Dukem, Tedecha, Koticha, and Gogecha Kebeles). The questionnaires included both closed-ended questions with pre-determined answer choices and open-ended questions that allowed for more detailed and in-depth responses.

3.6.2 Secondary Data source

The researcher collected secondary data for this research from a variety of sources, including books, academic articles, government publications, online resources, legal documents, satellite images, previous research, population statistics; and aerial photographs obtained from the Dukem town Land Development and Management Office. Generally, the detail of satellite image, data types used in the study and data sources from which they were obtained is summarized and presented by Table 3.5 below.

Table 3.5: Data types and Data sources

SN	Data	Year	Platform	Source	Data Type
1	Satellite Image	1994	Landsat TM	USGS web.	Secondary
2	Satellite Image	2004	Landsat TM	USGS web.	Secondary
3	Satellite Image	2014	Ortho-photo	DTLDMO	Secondary
4	Satellite Image	2024	Landsat TM	USGS web.	Secondary
5	Population Data			CSA/DTSAO	Secondary

6	Reports	DTLDMO	Secondary
7	Administrative Boundary of the town	DTLDMO	Secondary
8	Structure Plan of the Study Town	OUPI	Secondary

Source: Organized by the author, 2024

3.7 Methods of Data Collections

3.7.1 Data Collection Instruments

The study used a combination of GIS, remote sensing, questionnaires, and observations to gather data. Categorical maps created from satellite images were analyzed to measure the spatial expansion of the town over different periods. This analysis helped to quantify the expansion trends and their impact on land use and land cover (LULC) change. GIS and remote sensing techniques were used to conduct spatial analysis and understand the relationship between the town's growth and changes in land use.

The LULC change detection process involves analyzing satellite images to identify changes in land cover types over time. This is done by comparing images taken at different points in time for the study area. By studying these differences, the researcher assessed how land use and land cover (LULC) has evolved over time.

In this study, satellite images from 1994, 2004, 2014, and 2024 were used. These images were processed and classified to create thematic maps for each year, which represent the different land cover categories present in the area. By comparing and overlaying these maps, the land has changed over the years can be visualized.

Additionally, it is possible to quantify the changes by calculating the increase or decrease in each land cover category and expressing these changes as percentages for each year. This provides a numerical representation of the extent and direction of land cover changes.

Justifications for the selected Data Collection Instruments

According to (Weng, 2010), remotely sensed data can be used to extract thematic and metric information, making it ready for input into GIS. Thematic information provides descriptive data about earth surface features, which are a diversified information as per the areas of interest, such as soil, vegetation, and land cover.

The integration of geographic information systems and remote sensing essentially involves combining data provided by both, sensibly and consistently (Mesev, 2007).

The process of combining remote sensing data with a GIS involves, according to (Mesev, 2007), converting interpreted remote sensing data into a layer, like other layers within a GIS. This approach is commonly used in classification schemes, where thematic maps are classified into layers, each representing a distinct class. Additionally, remote sensing data can be used to extract geometric features through algorithms designed for building identification and recognition. These extracted features can then be converted into vector formats that are compatible with GIS systems.

Furthermore, GIS data can be used to enhance the functions of remote sensing image processing at various stages: selection of the area of interest for processing, prepossessing, and image classification (Weng, 2010, p. 65). In addition to enhancing the functions of remote sensing image processing at various stages, GIS technology provides a flexible environment for entering, analyzing, managing, and displaying digital data from the various sources necessary for remote sensing applications.

Many remote sensing projects need to develop a GIS database to store, organize, and display aerial and ground photographs, satellite images, and ancillary, reference, and field data (Weng, 2010, p. 68).

Therefore, both Geographic Information Systems (GIS) and Remote Sensing (RS) are invaluable resources for addressing various challenges in urban areas. These technologies can be used effectively for planning, tracking changes, monitoring, and creating maps. Remote Sensing offers a practical and affordable solution for gathering crucial data. By utilizing aerial photography and satellite imagery, it provides valuable information that can be used to evaluate, monitor, and map urban growth (Lynch, 1960).

3.7.2 Primary Data Collection Instruments

To understand what influences a particular situation and who is involved, the researcher gathered information using two primary methods: questionnaires and observations. Questionnaires involve asking people direct questions to get their views, while observations involve watching and recording what people do.

3.7.2.1 Questionnaires

The researcher designed a questionnaire with both closed-ended and open-ended questions for officials, experts, community members, and local government representatives in Melka Dukem, Tedecha, Koticha, and Gogecha Kebeles. Experts and office heads were given more weight in the questionnaire due to their direct involvement in the issue and their presumed wealth of knowledge. Open-ended questions were included to allow community members to describe changes they have observed over time. The same questions were used for all respondents in the selected sample.

The survey included open-ended questions to allow respondents to freely express their concerns about the factors and individuals that contributed to the rapid growth of Dukem town between 1994 and 2024. The researcher also used open-ended questions in addition to the closed-ended questions; and it was believed that comparing the answers from both types of questions would provide a more comprehensive understanding of the respondents' perspectives.

The study used a Likert scale survey to understand how officials, experts, local leaders, and residents of Dukem town perceive the factors and individuals that contributed to its rapid growth between 1994 and 2024. The Likert scale, ranging from "strongly agree" to "strongly disagree," was chosen because people's opinions and beliefs can vary widely, and the scale allowed researchers to measure the level of agreement or disagreement among respondents.

The researcher created questionnaires in English, and then translated into two local languages: Afaan Oromo and Amharic. All participants in the selected sample were given the same questionnaires regardless of their language preference.

3.7.2.2 Observations

The researcher conducted field observation to realize Ground truth data and collected the necessary visual information with the help of camera on the existence of urban expansion.

3.7.3 Secondary Data Collection Instruments

3.7.3.1 Satellite Image

The study used high-resolution satellite images (30 meters) from Landsat satellites to create land use maps. These images were acquired in specific months (January and December for 2024) to ensure the best quality. Data was also obtained from OUPI structure plan maps. The satellite images were color composites, meaning they combined specific bands to create a natural-looking view. For TM images, bands 3, 2, and 1 were used, while OLI/TIRS images used bands 4, 3, and 2.

3.8 Sampling Techniques

3.8.1 Sampling Method

To gather insights of the driving factors and actors responsible for the changes of land use and land cover of the study town, the researcher used specifically chose to interview officials and experts. This was done by a non-probability purposive sampling method for qualitative data and random probability selection technique were used to choose individuals from officials, experts of the study town Land Development, Management office, and Kebele Administrators (Melka Dukem, Tedecha, Koticha, and Gogecha Kebeles). This approach was selected due to the varying lengths of service among these individuals, prioritizing those with more experience.

The study also focused on communities as another target group. Again, a probability random sampling method was used to select communities who had resided in study town.

3.8.2 Sampling Frame

The sampling frame, which is the target group from which the sample is chosen, consisted of land development and management office specialists, officials, kebele administrators, and residents of the study town. These individuals were the participants in this study.

To determine the appropriate sample size from the entire pool of informants related to Dukem town's land development and management, information was gathered from various sources, including municipal and kebele offices, as outlined in table 3.6 and table 3.7 This data collection process enabled the identification and selection of a representative sample of experts, officials, and kebele administrators from the overall study population, ensuring that the sample size was adequate for the research objectives.

Table 3.6: Sampling frame data used to identify office employees

SN	Target Population	Kebele	Gender		Total number of employees
			Male	Female	
1	Dukem town land development and management office Experts	-	67	29	96
2	Dukem town land development and management office Experts at kebele level	Melka Dukem	3	2	20
		Tedecha	3	2	
		Koticha	3	2	
		Gogecha	3	2	
3	Dukem town land development and management office Officials	-	3	2	5
4	Kebele administrators	Melka Dukem	2	1	11
		Tedecha	2	1	
		Koticha	1	1	
		Gogecha	2	1	
Total			89	43	132

Source: Organized by the researcher, 2024

Table 3.7: Sampling frame data used to identify communities

Target Population	Kebele	Households
Community	Melka Dukem	3885
	Tedecha	2621
	Koticha	1138
	Gogecha	2216
Total		9860

Source: Organized by the researcher, 2024 (*based on CSA 1994 and 2007, and OUPI Structure plan report).

3.8.3 Sample Size Determination

The size of the sample needed for a study depends on several factors, including the purpose of the study and the population being studied (Glenn & Israe, 2013; Kumar, 2011). Additionally, to define the appropriate sample size, three factors must typically be specified. These are the desired level of accuracy, the level of confidence, and the amount of variation in the characteristics being measured (Glenn & Israe, 2013).

Sample size calculation is a fundamental requirement for research. The function of minimum sample size is to produce fair representation of the population where sample statistics could be used for population inference and efficient means for population studies (Louanglath, 2017).

Quantitative research uses random selection to ensure a fair and representative sample. This helps minimize bias in the study. Qualitative research, on the other hand, takes a different approach. Researchers purposefully choose participants who are likely to provide the most relevant and detailed information for the study (Kumar, 2011).

There are several strategies to determining the sample size. These include using a census for small populations, imitating a sample size of similar studies and applying formulas to calculate a sample size (Glenn & Israe, 2013). To determine an appropriate sample size, one can either reference the sample size of a similar study or calculate it using a specific formula. The formula-based approach allows for customization based on desired levels of precision, confidence, and variability.

In the process of the sample size selection, purposely selection for the informants was used. Therefore, the first step is calculating the sample size of the total respondents (experts, officials, kebele administrators and communities in the town).

The strategies used for determining the sample size of this study was using a simplified Taro Yamane (Glenn & Israe, 2013) formula to calculate a sample size because of small populations.

In accordance with our calculations, a sample size of 99 office employees and 384 community members was deemed appropriate to attain a 95% confidence interval and a ±5% precision level as computed below.

$n = N / (1 + N(e)^2)$; Where:

n = required sample size

N = Study Population

e = level of precision = 95% confidence i.e. e = 0.05%

Sample Office Employees	Sample Community
$n = N/(1+N(e)^2)$	$n = N/(1+N(e)^2)$
$n = 132/(1+132(0.05)^2)$	$n = 9860/(1+9860(0.05)^2)$
n = 132/1.33	n = 9860/25.65
n = 99	n = 384

To determine the sample size for each subgroup, we divided the population of that subgroup by the total population and multiplied the result by the total calculated sample size. The resulting sample sizes are presented in Table 3.8 below.

Table 3.8: Proportional sample size determination for Office Employees and Community

No	Target Population	Kebele	Total Number/ Household	Sample Size	Selection/sampling methods
1	Dukem town land development and management office Experts	-	96	72	Randomly selected
2	Dukem town land development and management office Experts at kebele level	Melka Dukem	5	4	
		Tedecha	5	4	
		Koticha	5	3	
		Gogecha	5	4	
	Sub Total		20	15	
3	Dukem town land development and management office Officials	-	5	4	
4	Kebele administrators	Melka Dukem	3	2	
		Tedecha	3	2	
		Koticha	2	2	
		Gogecha	3	2	
	Sub Total		11	8	
Total			**132**	**99**	
5*	Community	Melka Dukem	3885	151	Randomly selected
		Tedecha	2621	102	
		Koticha	1138	44	
		Gogecha	2216	86	
	Sub Total		**9860**	**384**	

Source: Organized by the researcher, 2024 (*based on CSA 1994 and 2007, and OUPI Structure plan report).

Therefore, a sample size of 483 respondents, consisting of kebele administrators, officials, experts from the Dukem town land development and management office, and community members, was determined to be suitable for the survey (as outlined in Table 3.8 above).

A non-random, purposive sampling technique was employed to select participants. For employees, the researcher prioritized those with more years of service to capture a range of experiences. For community members, he focused on individuals who had resided in Dukem for at least 15 years, as they were considered more likely to provide detailed information about the town's evolution over time.

3.9 Research Variables

To achieve the goal the study of examining trends in land use and land cover (LULC) change and its management, variables such as respondent demographics, factors driving urban land use and land cover changes, characteristics of LULC, and land use consumption rate were utilized.

The study investigated the background of the respondents encompassing variables such as address, gender, age, place of birth, educational attainment, qualifications, occupation, workplace, position, and years of service in the current position.

The determinants/driving factors of land use and land cover change in Study Town, as investigated in this study, are multifaceted. However, the most prominent factors are Population growth, Investment potentials, Availability of basic infrastructure, location preferences of household, spatial and urban planning policies, Proximity of the town to the primate city, and biophysical specially topography of the town.

The Land Use and Land Cover change of Study town is largely attributable to the contributions of four key actors: private developers, government officials, experts, and the local community.

The characteristics of land use and land cover change detection were utilized to evaluate the spatial and temporal transformations of land use and land cover (LULC) within the designated study area. Five distinct land use and land cover (LULC) variables—built-up area, agricultural area, green area, bare land/open space, and forest—were identified for analysis. The aggregate area encompassed by each class in each study year was calculated, facilitating the quantification of both the magnitude and rate of change for each land cover class.

3.9.1 Variable Types and Measurement Methods

The specific types of variables utilized in this research, alongside with their associated analytical methodologies and measurement techniques, are comprehensively outlined in Table 3.9.

Table 3.9: Description of Variable Types

No	Variables	Types of variables	Measuring Techniques
1	Address, Gender, Age, Birth place, Level of educations, Qualification background, Occupation, Work place, Work position and Year of services	Independent	Descriptive statistics graphs were used
2	Population Growth Investment Potentials Availability of basic infrastructure Location preferences of household Spatial and urban planning policies Proximity of the town to the primate city Biophysical specially topography of the town	Independent	Ranked data with five points of Likert scales from strongly agree to strongly disagree used and Descriptive statistics were used to describe their results were used
3	Private developers, Government officials, Experts, Local Community/residents,	Independent	Ranked data with five points of Likert scales from strongly agree to strongly disagree were used and Descriptive statistics were used to describe their results
4	LULC	Dependent	Map, graphs and charts were used
5	Rate of change	Independent	Graphs and charts were used

Source: Organized by the researcher, 2024

3.10 Data Processing Method

The activities undertaken in this portion included the acquisition of satellite imagery for the years 1994, 2004, 2014, and 2024. Subsequent to image prepossessing, image classification was performed to generate categorical maps. Accuracy assessment was conducted to evaluate the classification results. Furthermore, land use and land cover change detection and spatial expansion analysis were carried out.

3.10.1 Image Prepossessing

In the prepossessing stage, satellite images were acquired from the USGS Landsat archive via the Earth Explorer website. Following extraction and stacking, image selection was based on data availability and cloud-free conditions. Geometric rectification was conducted using ArcGIS 10.8, aligning the images with the 1994, 2004 2014, and 2024 images. The images were subsequently re-projected and calibrated to the Universal Transverse Mercator (UTM) Zone 37N coordinate system, referenced to the World Geodetic System 1984 (WGS 1984) datum, to ensure compatibility with the study area.

All images underwent geometric rectifications, re-projections, and clipping operations to align with the study area. Iterative strip line removal was made to eliminate any residual lines and enhance image clarity. Subsequently, the images were clipped to the precise boundaries of the study area using ArcGIS 10.8 software.

3.10.2 Image Classification

Following image preparation steps, a key part of this study involves classifying the images. This classification is crucial for detecting changes. There are two main approaches: supervised and unsupervised (Mason, 2016, p. 91). Supervised classification requires an expert to identify pixels representing specific land cover types. Unsupervised classification, on the other hand, is more automated. In this method, the expert defines certain parameters, allowing the computer to uncover hidden patterns within the data, does not depend on the knowledge of the ground truth and does not require the availability of external information for assigning the pixels to the different classes (Gomarasca, 2009; Mason, 2016). Owing to the presence of related spectral features, the application of unsupervised classification techniques may not produce satisfactory results. Consequently, supervised image classification was employed for this study. Supervised classification necessitates the selection of training areas to obtain accurate classification outputs (Britz, 2022). The quality and quantity of these training samples exert a significant influence on the quality of the resulting classification (Gomarasca, 2009).

3.10.3 Accuracy Assessment

Accuracy may be defined as the degree (often as a percentage) of correspondence between observation and reality (Levin, 1999); and according to (Campbell & Wynne, 2011), accuracy defines "correctness"; it measures the agreement between a standard assumed to be correct and a classified image of unknown quality. Accuracy assessment determines the quality of the map created from remotely sensed data; and its goal is the identification and measurement of map errors (Congalton & Green, 2009). Previously, several image classification methods were examined, including supervised and unsupervised classification. To measure the efficacy of these methods, accuracy assessment is crucial which involves evaluating the precision of the generated categorical map.

After classifying satellite images, it is essential to check how accurate the classification is. This is usually done by comparing a sample of the classified image to known, real-world data (ground truth). A confusion matrix is a common tool used in this process to calculate the overall accuracy of the classification. (Campbell & Wynne, 2011).

The rows of the matrix correspond to the reference ground truth classes, while the columns represent the predicted classes derived from the classification result. The diagonal elements of the matrix, extending from the upper left to the lower right, indicate the number of pixels that were correctly assigned to each class (Campbell & Wynne, 2011, pp. 412-416).

In accordance with standard accuracy assessment practices (Campbell & Wynne, 2011; Congalton & Green, 2009; Jeffrey et al., 2024; Jensen, 2015, p. 558; KNUDBY, 2012, p. 70; Richards, 2013), the performance of image classification activities needs to be evaluated using producer's accuracy, user's accuracy, overall accuracy, and the Kappa coefficient.

Producer's Accuracy

The producer's accuracy is the accuracy of the map from the point of view of the map maker (the "producer") and is calculated as the number of correctly identified pixels of a given class divided by the total number of pixels actually in that class as shown below. The producer's accuracy for a given class tells us the proportion of the pixels in that class that were classified correctly (Congalton & Green, 2009, p. 133; Jeffrey et al., 2024, p. 139).

$$\boldsymbol{Producer's Accuracy}\ \% = \frac{\boldsymbol{Total\ number\ of\ correct\ pixels\ in\ a\ category}}{\boldsymbol{Total\ number\ of\ pixels\ of\ that\ category\ derived\ from\ the\ reference\ data}\ (\boldsymbol{i.e.,row\ total})} * \mathbf{100},\ \ldots.. \text{(Equation 3-1)}$$

User's accuracy

User accuracy, or consumer's accuracy, evaluates the map's accuracy from the standpoint of the map user. It is computed as the ratio of correctly identified pixels within a particular class to the total number of pixels claimed to be in that class(Campbell & Wynne, 2011; Congalton & Green, 2009; KNUDBY, 2012).

$$User's Accuracy\ \% = \frac{Total\ number\ of\ correct\ pixels\ in\ a\ category}{Total\ number\ of\ pixels\ of\ that\ category\ derived\ from\ the\ Classified\ data\ (i.e.,Columen\ total)} * 100,\ \ldots.. \text{(Equation 3-2)}$$

Overall accuracy

The overall accuracy tells us what proportion of the reference data was classified correctly and is calculated as the total number of correctly identified pixels divided by the total number of pixels in the sample (Campbell & Wynne, 2011; Congalton & Green, 2009).

$$Overall\ Accuracy\ \% = \frac{Sum\ of\ the\ diagonal\ elements\ (true\ samples)}{Total\ number\ of\ accuracy\ sample\ pixels} * 100,\ \ldots \text{(Equation 3-3)}$$

Kappa Coefficient

The kappa coefficient a discrete multivariate technique(Congalton & Green, 2009, p. 105) is another widely used accuracy metric that assesses the extent to which the classification results surpass random chance. The value of the kappa coefficient can range from − 1 to 1: A kappa value less than 0 suggests that the classification is inferior to random assignment, a value of 0 signifies no improvement over random, and a positive value denotes superior performance compared to random (Jeffrey et al., 2024, p. 141). According to (Campbell & Wynne, 2011, p. 420) Kappa is a statistical measure that assesses the degree to which the observed concordance between two maps, as represented by the diagonal elements of the error matrix, exceeds the level of agreement that might arise solely from random coincidence, and is computed by the equation 3-4 below.

$$\text{Kappa Coefficient (K)} = \frac{observed\ accuracy - chance\ agreement}{1 - chance\ agreement},\ \ldots\ldots\ \text{(Equation 3-4)}$$

Here observed designates the accuracy reported in the error matrix (overall accuracy, and expected designates the correct classification that can be anticipated by change agreement between the two images.

3.10.4 Land Use Land Cover (LULC) Change Detection

Real-world land cover types are rarely clearly separated. Therefore, it is best to define the classification categories before collecting training data. In this study, a custom classification scheme was developed by visually analyzing satellite imagery. Because the goal is to map land-use/land cover change in Dukem town, the study focused on five main categories: built-up areas, agricultural areas, green areas, bare land/open space, and forest (Table 3.10).

Table 3.10: Land-use land-cover (LULC) categories applied for classification in the study

SN	Land use Category	Description
1	Built-up Area	The study area included all developed areas such as roads, buildings, residential and commercial zones, both existing and under construction, as well as industrial and manufacturing sites.
2	Agricultural Area	The scope of the study encompassed all areas utilized for agricultural activities, including both arable farmland and grazing land.
3	Green Area	Geographical areas characterized by the presence of vegetation, encompassing both natural and manmade green spaces.
4	Bare land	Areas characterized by open spaces with minimal vegetation, sandy or rocky terrain, and land enclosed by fences for potential investment but currently undeveloped.
5	Forest	Areas covered by dense forest

Source: Organized by the researcher, 2024

3.11 Data Analysis Methods

Data analysis methods such as trend analysis, LULC change detection analysis, spatial expansion and Land Use Consumption rate analysis, and qualitative data analysis were used.

3.11.1 Trend Analysis

To investigate the spatial and temporal patterns of urban expansion and its subsequent impact on land use and land cover (LULC) changes in Dukem town, four pivotal years (1994, 2004, 2014, and 2024) were chosen, representing a period of significant urban growth. Urban expansion maps were produced using ArcGIS 10.8 software. Landsat TM imagery was georeferenced and clipped to the study area's extent; and different land use categories were identified from the satellite imagery.

Certain features within the imagery might not be adequately identified during the process of digitalization. To rectify this, the study area's images were processed using visual interpretation techniques, such as analyzing patterns, tones, textures, shapes, shadows, associations, and aspects of features, to extract LULC information. The acquired LULC data was subsequently presented and analyzed using tables, figures, charts, and reports.

3.11.2 LULC Change Detection Analysis

Subsequent to the determination of land cover features through image processing, classification, and categorical map generation, the succeeding phase entails the analysis of land cover change detection and spatial expansion.

Change detection, a common technique in digital image analysis, involves comparing images taken at different times to identify and analyze any alterations. To ensure accuracy, the images should be captured by the same or similar sensor, with consistent settings for spatial resolution, viewing angle, spectral bands, radiometric resolution, and time of day (Wiley & Sons, 2015).

Accordingly, the Spatial- temporal satellite images of the study area were processed and classified to produce thematic maps for 1994, 2004, 2014 and 2024, and then the classified maps were compared and overlaid to visualize the changes on the area in the span of time.

It is also possible to compute the amount of increase or decrease of each category and see the change in percent in each year using the following formula (Kindu et al., 2013; Mulatu et al., 2024) as shown in (Equation 3.5)

$$\text{Change in } \% = \frac{A2-A1}{A1} * 100, \ldots \ldots \text{ (Equation 3-5)}$$

Where: A1 and A2 area of LULC type in the initial year and final year respectively.

Besides, Spatial Expansion Rate Analysis will be analyzed using the dynamic degree of spatial structure is an indicator that can reflect rate of spatial expansions and were calculated using

$$\text{DC} = [\frac{A2-A1}{A1} * \frac{1}{T2-T1}] * 100, \ldots \ldots \text{ (Equation 3-6)}$$

Where DC is the dynamic change rate of urban expansion for a period, T1 and T2 are specific years, A1 is total built-up area at time T1, and A2 is total built-up area at T2.

The total areas covered by each class in each study year will be calculated and the amount and rate of change for each land cover classes should be analyzed.

3.11.3 Rate of Land Use Land Cover Change and Land Use Consumption Rate Analysis

The rate of land use land cover change (LULCC) refers to the speed at which land is transformed from one type of cover to another over a specific period. The magnitude of the changes between two periods was used to compute the percent and rate of changes as indicated by equation 3.7 below (Mulatu et al., 2024).

$$\text{Change in } \% = \frac{A2 - A1}{A1(T2 - T1)} * 100, \dots \dots \quad \text{(Equation 3-7)}$$

Where: A1 and A2 area of LULC type in the initial year and final year respectively; and T1 and T2 are initial and final time respectively

Urban land consumption refers to the process of land being used for urban purposes, often replacing other land uses while Urban land consumption rate measures how quickly a city or urban area grows in size over a specific period (usually a year). This rate is expressed as a percentage of the city's original size(UN-Habitat, 2018b) as of equation 3.8

$$\mathbf{LCR} = \frac{(\boldsymbol{LN}(\boldsymbol{Urb}(\boldsymbol{t2})/\boldsymbol{Urb}(\boldsymbol{t1})))}{(\boldsymbol{y})}; \text{ Where: …Equation 3-8}$$

Urb**t1** is the total area covered by the urban area in the initial year *t1*;

Urb**t2** is the total area covered by the urban area in the final year *t2*; and y is the number of years between the two measurement periods (*t1* and *t2*)

3.11.4 Future Built-up Area Computation

It is important to know the future built up area to arrive at the desired study objectives. Accordingly, the Exponential Growth Model (EGM) method is used to forecast future urban built up area of the study town (Hathout, 2013). In so doing, calculating average growth rate of the built up area is mandatory (Gao et al., 2023).Therefore, the following formulae (equation 3.8 and 3.9) were customized for predicting future urban built up area of the study town for the coming 2030.

$$CA = IA * e^{rt} \dots \dots . r = \frac{1}{t} \ln(\frac{CA}{IA}) \dots \dots \dots \text{ Equation 3-9}$$

Where, CA Current Built up area, IA= Initial Built UP area, r rate of Change; and t = time in year.

$Af = IA * (1 + r/100)^t$.. Equation 3-10

Where AF=future built up area, IA initial Area, r= rate of change, and t= time period from initial to final.

3.11.5 Future Population Size of the Study area

An exponential population growth model was used to predict the population of the study area assuming that the population growth is directly related to the current population size as presented by equation

$Pt = Po * e^{rt}$ ....Equation 3-11

Where Pt is the population at the required time, Po is the current population, r is population growth rate, and t is the projection time.

3.11.6 Qualitative Data Analysis

To ensure a comprehensive understanding on the driving factors and key actors in land use and land cover change in the study town as well as for crosschecking, both the open-ended and closed-ended questionnaires were distributed to all participants in the sample. The responses were categorized into major themes based on their content, and analyzed accordingly.

3.12 Software Programs and Tools Used

This study focuses on analyzing changes in land use and land cover (LULC). Accordingly, ArcGIS 10.8 was chosen as a primary software used for data processing and trend analysis. A detailed list of tools and software used is provided in Table 3.11.

Table 3.11: Software programs and Tools used for the study

No	Software &Tools	Function
1	ArcGIS 10.8	To create a shapefile, To identify the specific geographic area of interest, To analyze and manage the relevant data, To Georeference the data to align it with a geographic coordinate

		system, To Process and enhance the images to improve their quality, To Transform the data into a suitable format, to Classify the data into different categories, To Delineate and clip the data to focus on specific areas, and To create a final map layout to visualize the results.
2	Remote Sensing Techniques (RST)	To detection of land use land covers (LULC) change in different period of time
3	USGS website	The source of satellite image free of charge
4	SPSS 25	To process, manage and analyze the statistical data's collected
5	Camera	To capture Photos
6	Micro-soft excel	To perform different statistical calculations.
7	Micro-soft word	To write the study paper

Source: Organized by the researcher, 2024

3.13 Validity of Methods and Materials

The reliability of the research methods, materials, and findings is guaranteed by implementing specific safeguards. The combination of quantitative and qualitative approaches enhances the significance of the conclusions.

The researcher consulted with advisor and other experts; and reviewed existing research to gain insights into relevant issues. The researcher also conducted surveys and gathered information from local offices and community members in Dukem town. Additionally, he analyzed various town profiles and published materials related to the subject matter. The researcher believes that the input from expert respondents contributed to the reliability and validity of the collected information.

Remote sensing offers a big advantage consistent data over time. This allows us to track how cities and land use change over long periods (Lunetta & Lyon, 2000). Even better, researchers are now combining remote sensing with GIS software (Mesev, 2007) to get a more detailed picture of these changes. This approach, backed by research, proves valuable for mapping urban areas and analyzing how they grow and how land cover changes over time (LULC stands for

Land Use Land Cover. Therefore, this approach has been proven by numerous academics to Model urban development and LULC dynamics.

To evaluate the performance of different classification methods and ensure the reliability of the results, it is crucial to assess the accuracy of each classified category and the overall image. A sufficient number of samples, ranging from 50 to 220 pixels per class, were collected for this purpose. Furthermore, to validate the accuracy of the classified images, both ground truth data (physical surveys) and high-resolution Ortho-photo were utilized.

CHAPTER FOUR

4 Result and Discussion

4.1 Trend Detection Mapping

The study results were discussed to accomplish the study's objective of detecting land use and land cover (LULC) changes in the study town using Satellite imageries. Initially, unsupervised method was used for image pre-processed. Then, supervised image processing techniques was applied to detect trends and changes.

4.1.1 Un-Supervised Change Detection

To study the land use and land cover change in the study town, the researcher analyzed satellite images from 1994, 2004, 2014, and 2024 as presented in Figure 4.1. These images were obtained from the Earth Explorer USGS Landsat website. Accordingly, Landsat-5 images were selected for 1994, Landsat-7 images for 2004, and Landsat-8, 9 images for 2014 and 2024, based on their availability and cloud-free conditions. Before analysis, the researcher processed the images to ensure they were consistent. This included cropping the images to focus on the study area, re-projecting them to a common coordinate system, and merging different image resolutions.

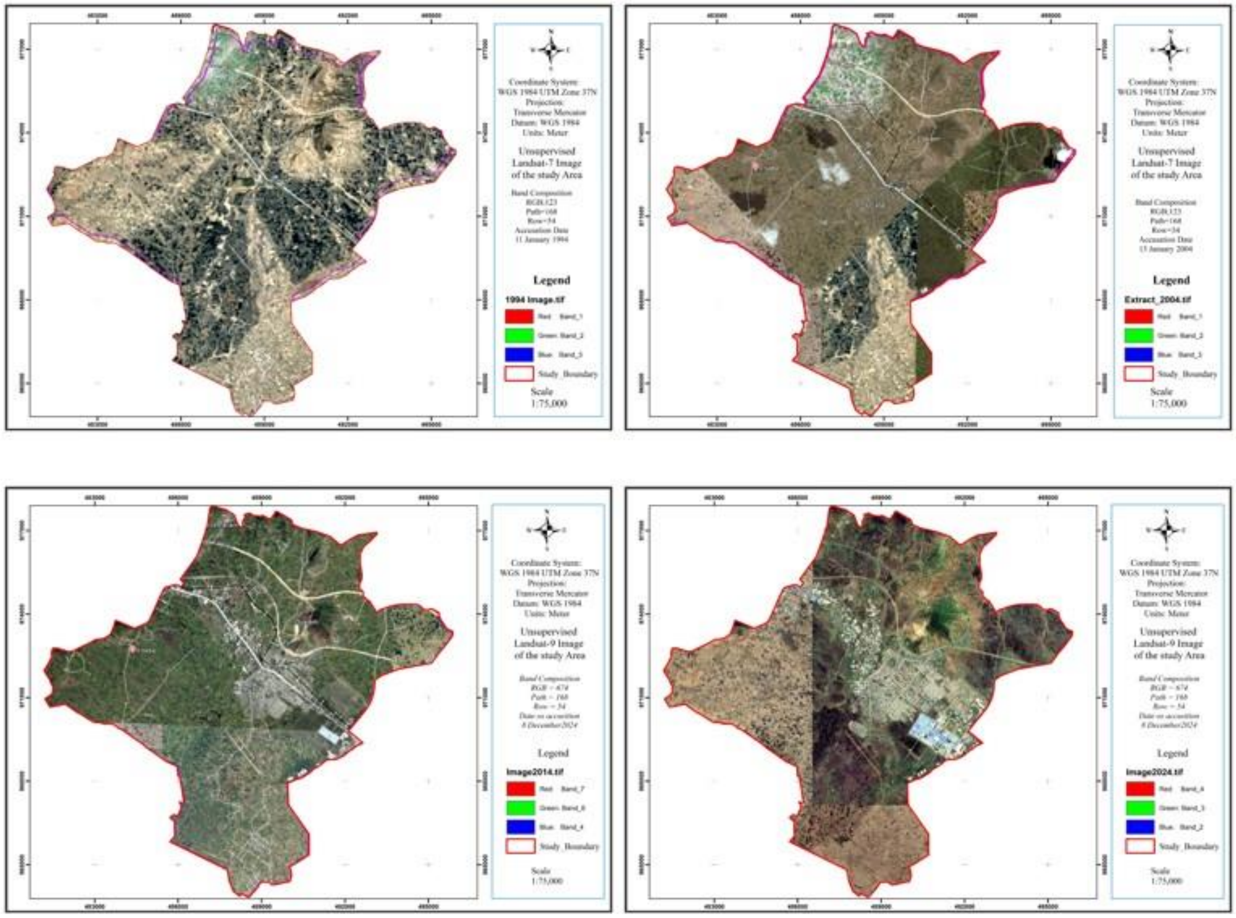


Figure 4.1: Unsupervised Images for the selected periods

4.1.2 Supervised Change Detection

To analyze how land use and land cover changed in the study town between 1994 and 2024, maps were created using satellite imagery obtained from Earth Explore USGS Landsat web site. These maps Figure 4.2 differentiate between various land uses: built-up areas with structures and infrastructure (red), land dedicated to agriculture and crop cultivation (orange), Bare land/unproductive land lacking vegetation (gray), green spaces like parks and gardens (green), and forested regions (dark green).

The maps provide a clear picture of Dukem town's urban growth trajectory from 1994 to 2024. In 1994, the town's built-up area was limited to a small central zone. While there was little change in the following decade, a significant expansion phase commenced, primarily along the main asphalt road, stretching in both eastern and western directions.

Dukem town experienced significant growth between 2004 and 2014, largely due to the establishment large investments including Eastern Industry Zone (EIZ) and the construction of the Ethio-Djibouti Heavy Railway line. This period saw major developments that contributed to the town's expansion. Between 2014 and 2024, the town continued to grow, especially in terms of residential development. As depicted in Figure 4.2, the town expanded rapidly in all directions during this decade.

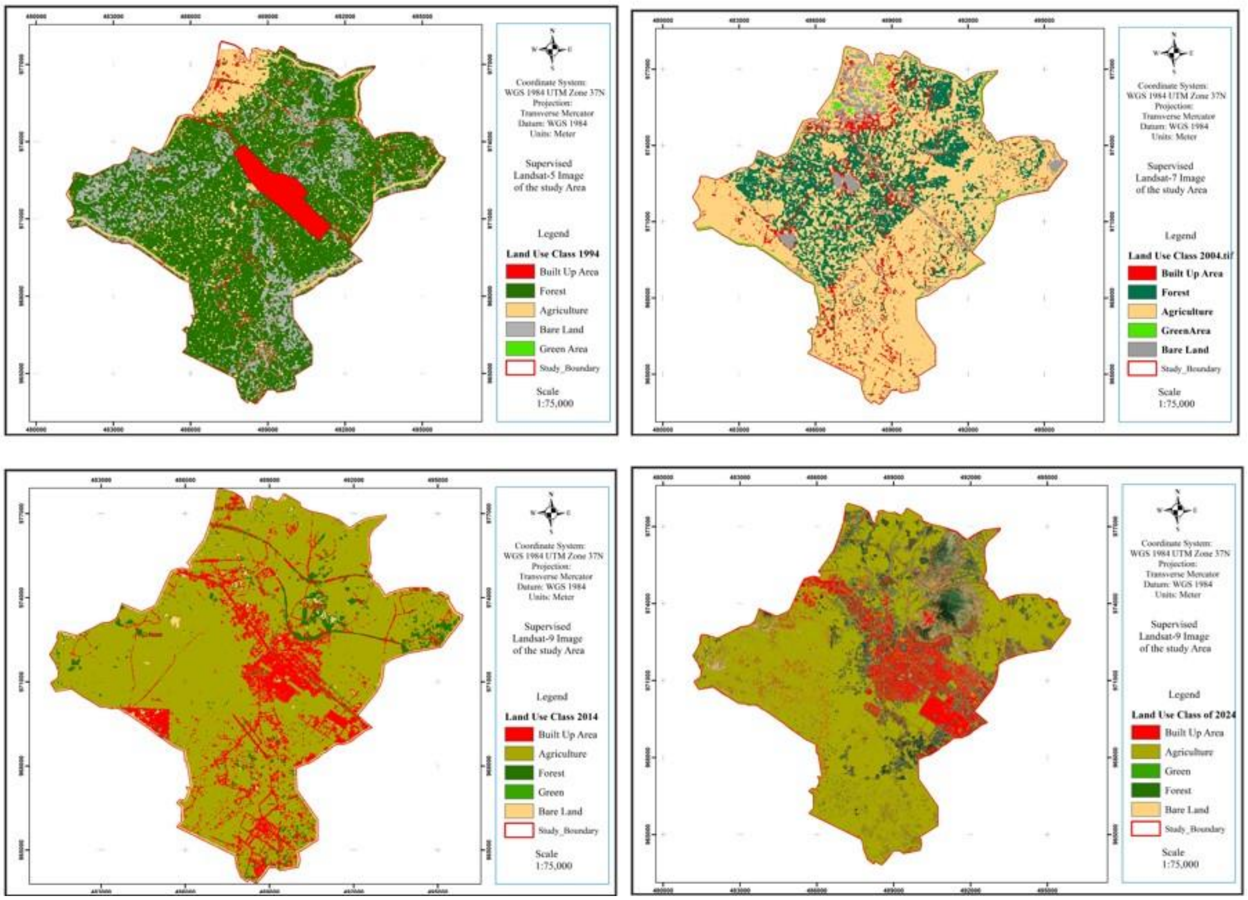


Figure 4.2: Supervised LULC maps

4.1.3 Accuracy Assessment

Once satellite images have been classified, accuracy assessment is the crucial final step in remote sensing data analysis. It helps us evaluate the reliability of our classification results. This is typically done using a contingency table (confusion matrix). By comparing a random sample of pixels or clusters to known ground truth data (the reference data, we can determine the percentage accuracy of our classification (Campbell & Wynne, 2011).

Accordingly, in accordance with standard accuracy assessment practices (Campbell & Wynne, 2011; Congalton & Green, 2009; Jeffrey et al., 2024; Jensen, 2015, p. 558; KNUDBY, 2012, p. 70; Richards, 2013), the accuracy of the image classification was evaluated using several metrics, including producer's accuracy, user's accuracy, overall accuracy, and the Kappa coefficient. These metrics were calculated using an error matrix, or confusion matrix, which is a standard format for evaluating the accuracy of image classification. The equations used to calculate these metrics are given in section 3.10.3 (equation 3.1 to 3.4) of the study report. Besides, a sample size of 50 to 200 pixels was taken for each land use class to ensure that the accuracy assessment was statistically valid. Additionally, ground truth data, which was collected through physical surveys, and high-resolution ortho photo were used to further validate the accuracy of the classified images. Accordingly, the accuracy results were summarized by sees also Table 4.1 to Table 4.4 below.

Accordingly (Islami et al., 2022, pp. 3-4), the users of LULC maps need to know the level of accuracy of the map so that it can be used more efficiently and correctly. They state that the acceptable accuracy for interpreting LULC change should not fall below 80%. The error matrix is a common method for assessing classification accuracy, providing valuable statistics for analysis.

Furthermore, the document outlines Kappa statistics rating criteria: 0.41-0.60 indicates moderate agreement, 0.61-0.80 substantial agreement, and 0.81-1.00 almost perfect agreement. These criteria can serve as a benchmark for evaluating the accuracy assessments of relevant studies.

4.1.3.1 Producer’s Accuracy

The producer's accuracy, which provides image analysts with the proportion of pixels accurately categorized within a particular class, was assessed across different years. The study found that this accuracy varied between 85% and 95% for 1994, between 81% and 93% for 2004 and 2014, and consistently remained at 84% in 3024. Importantly, all accuracy values surpassed the 80% benchmark, indicating they are within an acceptable range. For a comprehensive view of the data, please refer to Table 4.1 to Table 4.4.

4.1.3.2 User’s Accuracy

User’s accuracy is calculated by dividing the number of correctly classified pixels within a specific category by the total number of pixels assigned to that category. For example, in the

1994 assessment, user accuracy for the built-up area was 92% (110 correct pixels out of 120 total). This represents the likelihood that a pixel classified on the image truly corresponds to that category on the ground. User accuracy ranged from 87% to 94% in 1994, 83% to 93% in 2004, 81% to 94% in 2014, and 86% to 93% in 2024(refer Table 4.1 to Table 4.4 for the details). Therefore, all the results are above 80%; and hence, the user's accuracy indicated that the performance of image and its classification was achieved very well and the error margins are within acceptable accuracy.

Table 4.1: Accuracy assessment results of the year 1994

		Classified Image						Producer's Accuracy (%)
		Built Up Area	Agriculture	Bare Land	Green Area	Forest	Row Total	
Reference Image	Built Up Area	**110**	0	3	5	1	119	92%
	Agriculture	0	**81**	0	2	2	85	95%
	Bare Land	5	2	**53**	0	1	61	87%
	Green Area	2	2	4	**45**	0	53	85%
	Forest	3	5	2	0	**62**	72	86%
	Column Total	120	90	62	52	66	**390**	
User's Accuracy (%)		92%	90%	85%	87%	94%		
Overall Accuracy		90%						
Kappa Coefficient		0.87						

Table 4.2: Accuracy assessment results of the year 2004

		Classified Image						Producer's Accuracy (%)
		Built Up Area	Agriculture	Bare Land	Green Area	Forest	Row Total	
Reference Image	Built Up Area	**95**	0	3	4	0	102	93%
	Agriculture	0	**75**	1	2	3	81	93%
	Bare Land	3	0	**45**	1	2	51	88%
	Green Area	3	2	3	**35**	0	43	81%

	Forest	2	4	2	0	**42**	50	84%
	Column Total	103	81	54	42	47	**327**	
User's Accuracy (%)		92%	93%	83%	83%	89%		
Overall Accuracy		89%						
Kappa Coefficient		0.86						

Table 4.3: Accuracy assessment results of the year 2014

		Classified Image						Producer's Accuracy (%)
		Built Up Area	Agricultu re	Bare Land	Green Area	Fore st	Row Total	
Reference Image	Built Up Area	**98**	0	3	4	0	105	93%
	Agriculture	0	**65**	0	3	4	72	90%
	Bare Land	3	0	**34**	1	2	40	85%
	Green Area	2	3	3	**35**	0	43	81%
	Forest	1	4	2	0	**36**	43	84%
	Column Total	104	72	42	43	42	**303**	
User's Accuracy (%)		94%	90%	81%	81%	86%		
Overall Accuracy		88%						
Kappa Coefficient		0.85						

Table 4.4: Accuracy assessment results of the year 2024

		Classified Image						Producer's Accuracy (%)
		Built Up Area	Agricultu re	Bare Land	Green Area	Fore st	Row Total	
Reference Image	Built Up Area	**110**	0	3	4	2	119	92%
	Agriculture	0	**78**	0	3	2	83	94%

	Bare Land	3	0	**42**	0	2	47	89%
	Green Area	3	3	0	**46**	0	52	88%
	Forest	2	3	2	0	**38**	45	84%
	Column Total	118	84	47	53	44	**346**	
User's Accuracy (%)		93%	93%	89%	87%	86%		
Overall Accuracy		91%						
Kappa Coefficient		0.88						

4.1.3.3 Overall Accuracy

To assess the overall accuracy of the maps for all land cover classes, the researcher calculated the proportion of correctly classified pixels to the total number of reference pixels. This is essentially the sum of correctly classified pixels divided by the total number of pixels. For instance, in the 2024 accuracy assessment, this would be ((110+78+42+46+38)/346)*100=91%. Using this method, the overall accuracy were determined for the years 1994, 2004, 2014, and 2024 to be 90%, 89%, 88%, and 91%, respectively.

4.1.3.4 Kappa Analysis

Kappa analysis generates a kappa coefficient or statistics. It is a measure of the agreement between two maps taking into account all elements of error matrix. The values are varies between 0 and 1 and thus the results converging to 1 show excellent conformation between the classified map and reference image (Islami et al., 2022, pp. 3-4). Accordingly, overall kappa statistics results indicated 0.87, 0.89, 0.85 and 0.88 for the year 1994, 2004, 2014 and 2024 classification maps respectively. Therefore, these resulted implies that the classification process was avoiding 87%, 89%, 85% and 88% of the error that a completely random classification would generate. Accordingly, the results are more than substantial which approximate to the perfection as compared to the benchmark stated above.

4.1.4 Land Use Land Covers (LULC) Analysis

4.1.4.1 Land use Land Covers (LULC) Analysis in 1994

As shown in Table 4.5 and Figure 4.2, the dominant land use in the study town in 1994 was agricultural land, covering about 65% of the total area (6258 hectares). Forestland constituted 16%, while bare land, built-up areas, and green areas occupied 13%, 5%, and 1% of the land, respectively.

Table 4.5: Area Summary of Land Use and Land Cover of the year 1994

SN	Land Use Class	Area m^2	Area Hectare	%
1	Built Up Area	4975871	498	5%
2	Agriculture	62582413	6258	65%
3	Bare Land	12281699	1228	13%
4	Green Area	1418668	142	1%
5	Forest	15269977	1527	16%
Total		96528629	9653	100%

Source: Organized by the researcher, 2024

4.1.4.2 Land use Land Covers (LULC) Analysis in 2004

Similarly, in 2004, agricultural land was the dominant land use in the study town, accounting for approximately 61% (5888 hectares) of the total land area. However, this figure represents a decline from the 1994 land use data. Forestland and bare land each accounted for 14%, while built-up areas and green areas occupied 9% and 2%, respectively, as detailed in Table 4.6 below.

Table 4.6: Area Summary of Land Use and Land Cover of the year 2004

SN	Land Use Class	Area m^2	Area in Hectare	%
1	Built Up Area	8418210	842	9%
2	Agriculture	58882463	5888	61%
3	Bare Land	13889821	1389	14%
4	Green Area	1448313	145	2%
5	Forest	13889822	1389	14%
Total		96528629	9653	100%

Source: Computed from the Classified Image GIS Data, 2024

4.1.4.3 Land use Land Covers (LULC) Analysis in 2014

In 2014, the amount of land used for built up area was growing. It made up around 18% (1,756 hectares) of the total land. This period was a time of rapid urban expansion, fueled by the establishment of many industries in different parts of the town and widespread construction projects. Agricultural land accounted for about 52% (5,064 hectares). The remaining land uses bare land (15%), forest (12%), and green areas (3%). Notably, the amount of forestland was decreasing (see Table 4.7 below for the details).

Many people were moving from different parts of the country to the town in search of jobs and better economic opportunities. This rapid population growth, fueled by the demand for industrial employment, was a major factor in the town's expansion. Additionally, the development of new transportation infrastructure, such as the new National Railway Line (HRT) and the expressway and highway lines passing through Dukem, contributed to the town's growth and its expansion into surrounding areas in 2014.

When compared to the land use and land cover (LULC) data from 2014, the town has experienced significant changes. Agricultural land has been converted into other land use categories. Overall, there has been a decrease in most land use categories, while the built-up area has significantly increased.

Table 4.7: Area Summary of Land Use and Land Cover of the year 2014

SN	Land Use Class	Area m2	Area in Hectare	%
1	Built Up Area	17650312	1765	18%
2	Agriculture	50635187	5064	52%
3	Bare Land	14479294	1448	15%
4	Green	2413216	241	3%
5	Forest	11350619	1135	12%
Total		96528629	9653	100%

Source: Computed from the Classified Image GIS Data, 2024

4.1.4.4 Land use Land Covers (LULC) Analysis in 2024

Over the past 30 years, the town has undergone significant changes in land use and land cover. Built-up areas have expanded rapidly, now covering 36% of the total land area. This is second only to agricultural land, which still occupies 40%. The remaining land uses barren land, forest and green areas constituted about 11%, 10% and 3%, respectively. The rapid growth of the town has led to a dramatic decline in these other land use categories as they are converted into built-up areas.

Table 4.8: Area Summary of Land Use and Land Cover of the year 2024

SN	Land Use Class	Area m2	Area in Hectare	%
1	Built Up Area	34472706	3447	36%
2	Agriculture	38889052	3889	40%
3	Green	2895859	290	3%
4	Bare Land	10618149	1062	11%
5	Forest	9652863	965	10%
Total		96528629	9653	100%

Source: Computed from the Classified Image GIS Data, 2024

4.1.5 Change Comparison of the Selected Study Periods (1994 to 2024)

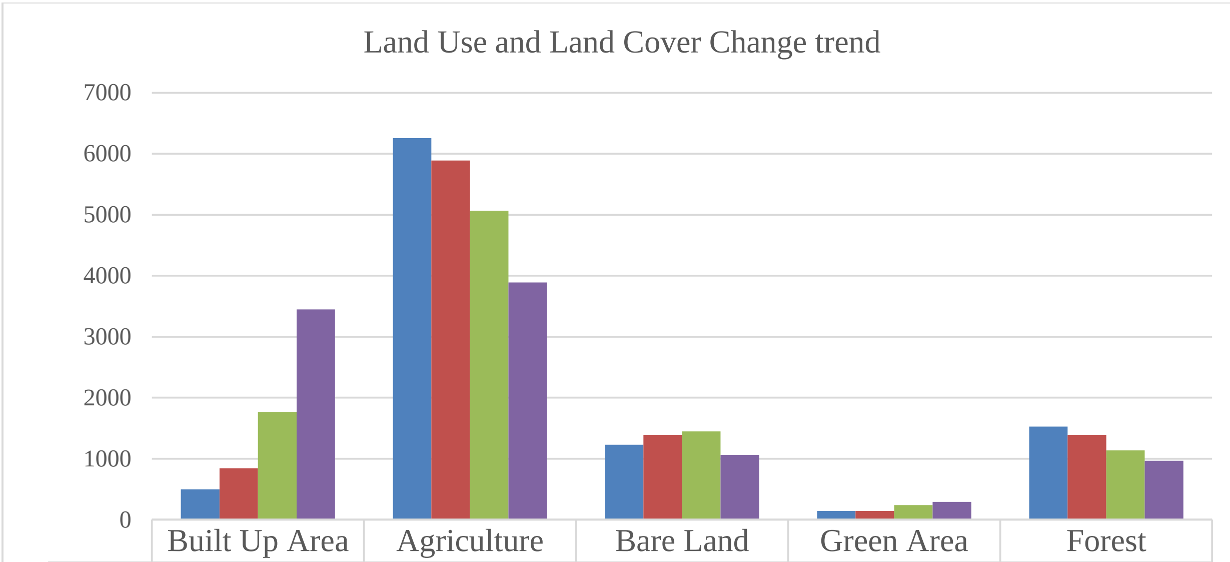
Additionally, to analyze how land use and land cover (LULC) changed between 1994 and 2024, the total area (in hectares) and percentage of each LULC category for the periods were calculated quantitatively using Arc GIS software platform (see Table 4.9 for the details).

Table 4.9: summary of the land use and land cover of the study periods (1994 to 2024)

SN	Land Use Class	1994		2004		2014		2024	
		Area Hectare	%	Area Hectare	%	Area Hectare	%	Area Hectare	%
1	Built Up Area	498	5%	842	9%	1765	18%	3447	36%
2	Agriculture	6258	65%	5888	61%	5064	52%	3889	40%
3	Bare Land	1228	13%	1389	14%	1448	15%	290	3%
4	Green Area	142	1%	145	2%	241	3%	1062	11%
5	Forest	1527	16%	1389	14%	1135	12%	965	10%
Total		9653	100%	9653	100%	9653	100%	9653	100%

Source: Computed from the Classified Image GIS Data, 2024

As presented in the above (Table 4.9) the total area of built-up class increased dramatically from 498 hectares (5%) in 1994 to 3447 hectares (36%) in 2024 while agricultural land extremely decreased in all years from 6258 hectares (65%) in 1994 to 3889 hectares (40%) in 2024 which indicating its highest contribution to built-up areas. The trend of other categories varies increasing and decreasing at various, times (refer Figure 4.3 for the details).



	Built Up Area	Agriculture	Bare Land	Green Area	Forest
1994	498	6258	1228	142	1527
2004	842	5888	1389	145	1389
2014	1765	5064	1448	241	1135
2024	3447	3889	1062	290	965

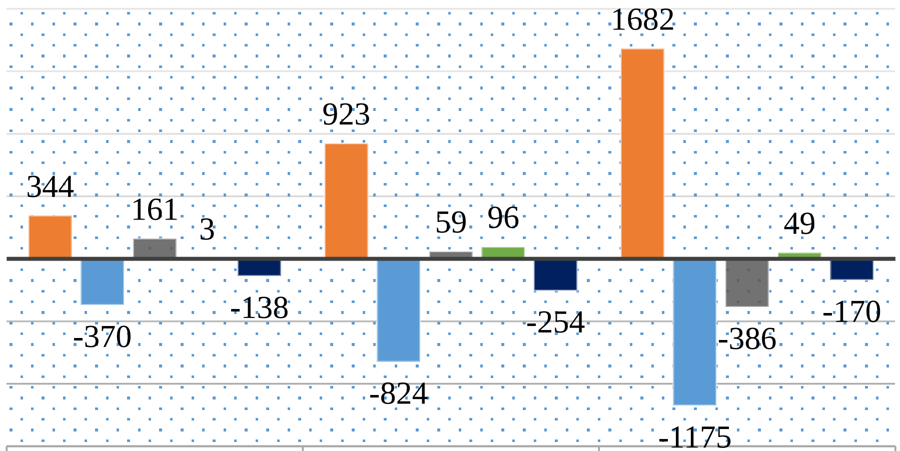
Figure 4.3: Trends of land use land and cover for the selected periods (1994–2024)

Besides the time series, analysis results were presented in Table 4.10 and Figure 4.4 below which showed the amount of increased (positive) and decreased (negative) in each year.

Table 4.10: The Time Series Analysis of the Land Use and Land Cover Change

SN	Land Use Class	1994-2004		2004-2014		2014-2024	
		Area Hectare	%	Area Hectare	%	Area Hectare	%
1	Built Up Area	344	69%	923	110%	1682	95%
2	Agriculture	-370	-6%	-824	-14%	-1175	-23%
3	Bare Land	161	13%	59	41%	-386	-27%
4	Green Area	3	2%	96	67%	49	20%
5	Forest	-138	-9%	-254	-18%	-170	-15%

Source: Computed from the Classified Image GIS Data, 2024



	1994-2004	2004-2014	2014-2024
Built Up Area	344	923	1682
Agriculture	-370	-824	-1175
Bare Land	161	59	-386
Green Area	3	96	49
Forest	-138	-254	-170

Figure 4.4: Graph of the time series Analysis of Land use and Land Cover change

The above result showed that, between 1994 and 2024, the built-up area of the town significantly expanded, increasing by a total of 2,949 hectares. The most substantial growth occurred in the last decade (2014-2024), with a 1,652-hectare increase.

Conversely, agricultural and forestland decreased over the same period. Agricultural land declined by 2,369 hectares, with the most significant loss occurring in the last decade (1,175 hectares). Forestland also experienced a decrease, even though the rate of decline was fluctuated.

Green areas, however, showed a slight increase, while bare land exhibited a fluctuating trend. It increased in the first two decades but decreased in the most recent decade (see Table 4.10 and Figure 4.4 for the details).

4.1.6 Change in Built-up Area (1994 to 2024)

The changes in built-up area between the year 1994 and 2024 were determined irrespective of the other land classes as shown in Table 4.11 below.

Table 4.11: Change Built up Area across the continuum

Year	Area in Hectare	Change in Hectare	Change (%)
1994	498		
2004	842	344	69%
2014	1765	923	110%
2024	3447	1682	95%

Source: Computed from the Classified Image GIS Data, 2024

From the above table one can observe that the built up are of the year 2024 is more than five folds indicating (see Table 4.11) the rapid and unprecedented urban growth of the town consuming the surrounding non urbanized areas.

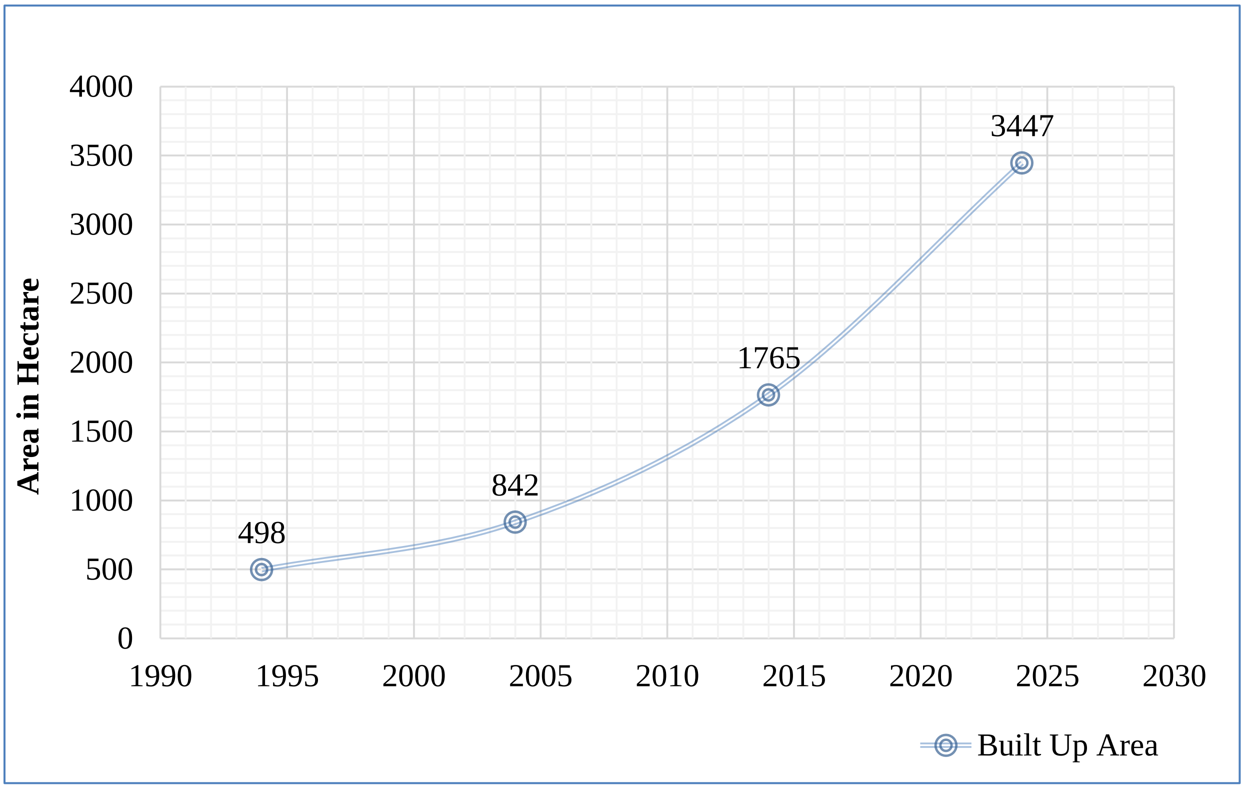


Figure 4.5: Trends of Land Use Changes in built up area across the continuum

The graph in Figure 4.5 shows an exponential trend, suggesting that the growth of built-up areas in the town followed an exponential pattern. Therefore, using an exponential model to predict future growth seems reasonable, assuming that current trends continue without significant changes in other factors.

4.1.7 Dynamic Change Detection

To determine the growth of built-up areas between different periods (1994-2004, 2004-2014, and 2014-2024), the researcher calculated the rate of change in spatial expansion. This calculation was performed using Equation 3.6, which is detailed in Section 3 of this paper as presented below.

$$\mathrm{DC(T1-T2)} = \frac{A2 - A1}{A1(T2 - T1)} * 100$$

$$\mathrm{DC}(19994 - 2004) = \frac{842 - 498}{498(10)} * 100 = 7\%$$

$$\mathrm{DC}(2004 - 2014) = \frac{1765 - 842}{842(10)} * 100 = 11\%$$

$$\mathrm{DC}(2014 - 2024) = \frac{3447 - 1765}{1765(10)} * 100 = 10\%$$

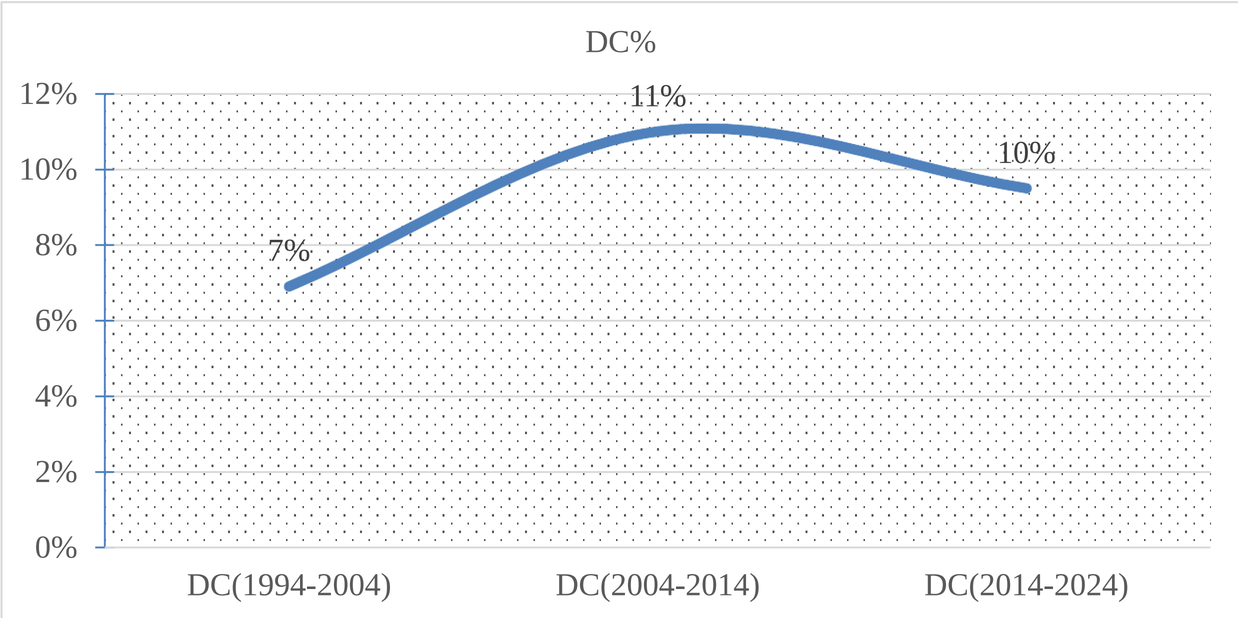


Figure 4.6: Trends of Dynamic Changes in Built Up area of the Continuum

Figure 4.6 illustrates that the urban area of the town expanded significantly between 1994 and 2024. The annual growth rate was 7% from 1994 to 2004, 11% from 2004 to 2014, and 10% from 2014 to 2024. The most rapid expansion occurred between 2004 and 2014, driven by the conversion of surrounding agricultural land into valuable urban zones for housing and industry.

4.2 Descriptions of the Respondents

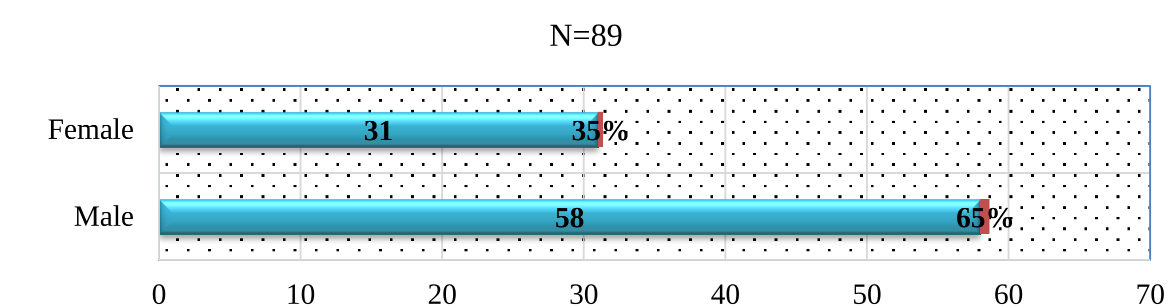
Of the planned 483 survey participants (99 office staff and 384 community members) from each kebele, 436 individuals (89 office staff and 347 community members) were successfully interviewed face-to-face across all four kebeles. To ensure data quality, the researcher prioritized surveying individuals with higher seniority, education levels, and relevant work experience in the Dukem town land development and management office and the local communities.

Therefore, all 436-survey participants attempted all the close - ended survey questionnaires properly. Moreover, 106 of them (50 office workers and 56 community members) responded to the open-ended questions as well. The majority of the respondents did not attempted for the open ended questions as many of them are tied with urgent office works at that time.

4.2.1 Background of the Employee

A comprehensive data collection exercise was undertaken to capture the background and professional characteristics of office employees, including government officials, Kebele administrators, and experts. Data points such as gender, age, level of education, educational qualifications, their position, and year of service were recorded. The results of this data collection are presented as follows.

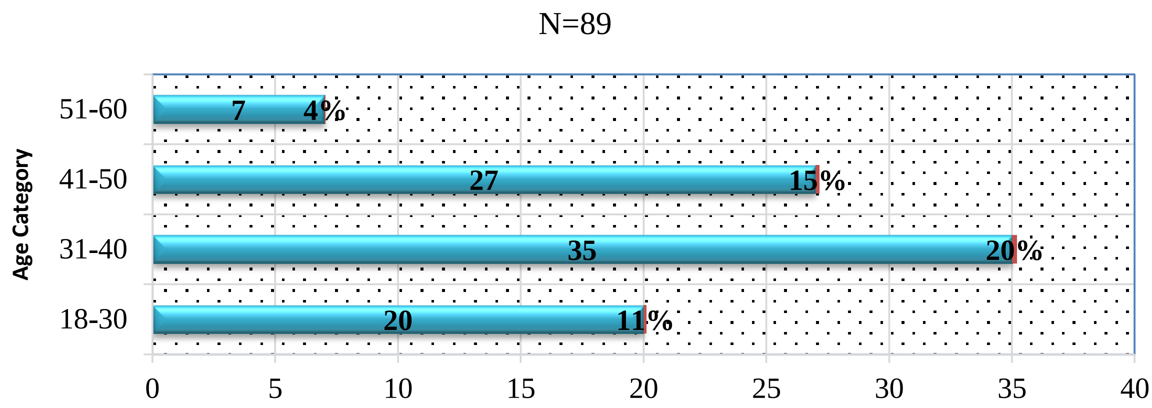
Gender plays a crucial role in fairness and involvement. Our sample of 89 respondents was predominantly male (65%) with a smaller female representation (35%).



	Male	Female
Frequency	58	31
Percentage	65%	35%

Figure 4.7: Gender Character of the employees

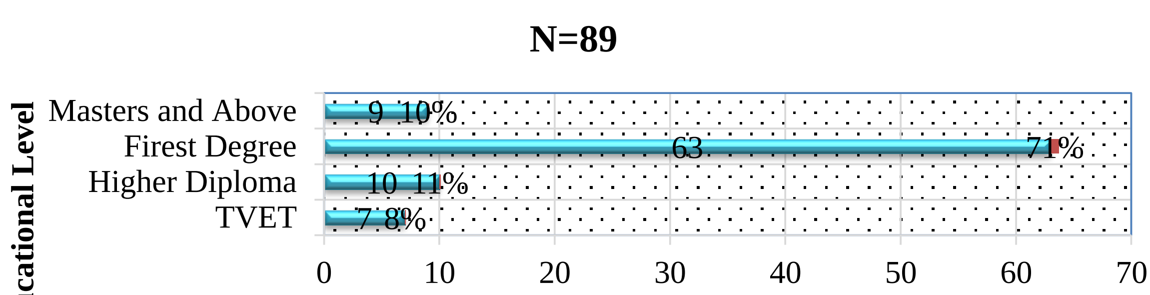
In terms of age, the majority of participants were experienced workers, with 39% in their (31-40) and 30% in their (41-50). Younger respondents (18-30) constituted 20%, while older age groups (51-60) made up 8%.



	18-30	31-40	41-50	51-60
Frequency	20	35	27	7
Percentage	11%	20%	15%	4%

Table 4.12: Age character of the respondents of the office employees

Regarding educational attainment, the survey data reveals that most office employees (71%) had a bachelor's degree. A significant minority held higher education diplomas (11%), while master's degrees and above, as well as TVET qualifications, were represented by 10% and 8% of respondents, respectively (Table 4.13).

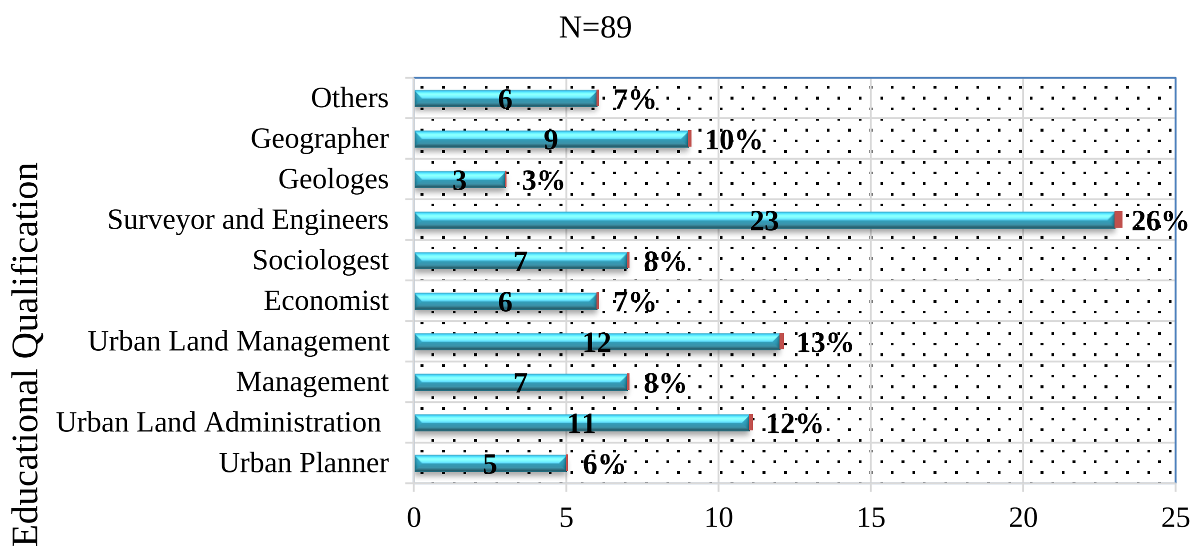


	TVET	Higher Diploma	Firest Degree	Masters and Above
Frequency	7	10	63	9
Percentage	8%	11%	71%	10%

Table 4.13: Level of Education of office employees

Most of the survey participants were surveyors and engineers (26%), followed by urban land management (13%), urban land administration (12%), and geographers (10%). Economists, sociologists, and management professionals each accounted for 7% and 8%, respectively. Urban planners made up 6%, geologists 3%, and other fields constituted 7%.

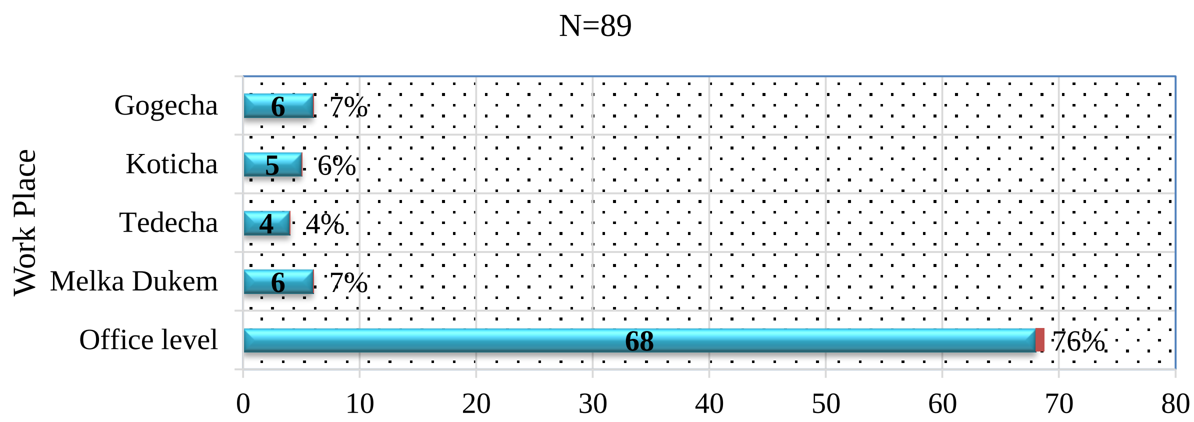
This diverse range of professional backgrounds (Figure 4.8), particularly in relevant fields like surveying, engineering, urban land management, and planning, ensures that the information gathered is reliable and valid. These experts have firsthand knowledge of the issues being studied



	Urban Planner	Urban Land Administration	Management	Urban Land Management	Economist	Sociologest	Surveyor and Engineers	Geologes	Geographer	Others
Frequency	5	11	7	12	6	7	23	3	9	6
Percentage	6%	12%	8%	13%	7%	8%	26%	3%	10%	7%

Figure 4.8 : Educational qualification background of office employees

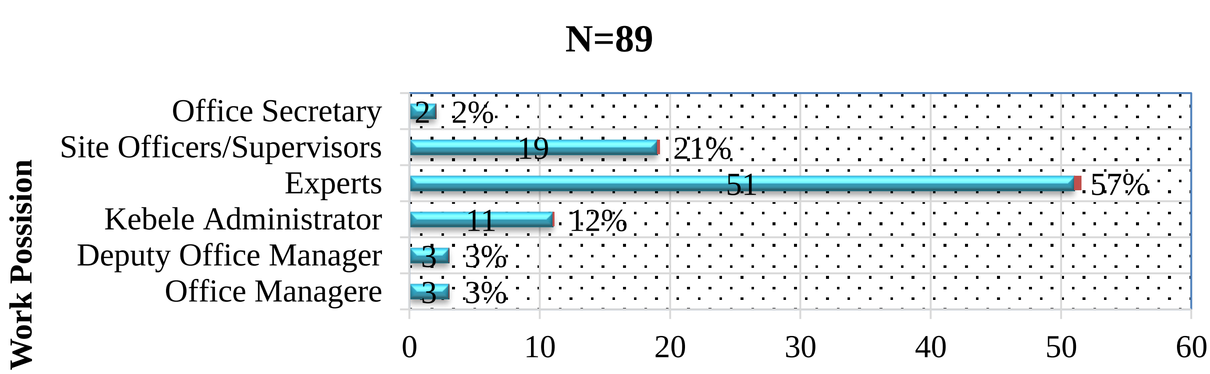
Regarding the work place of the respondent employees, most respondent employees (76%) worked at the Dukem Town Land Development and Management Office. The remaining respondents were from the four-kebele administrations: Melka Dukem (7%), Tedecha (4%), Koticha (5%), and Gogecha (7%). (See Figure 4.9 below for a visual representation).



	Office level	Melka Dukem	Tedecha	Koticha	Gogecha
Frequency	68	6	4	5	6
Percentage	76%	7%	4%	6%	7%

Figure 4.9: Work Place of the respondent Employees

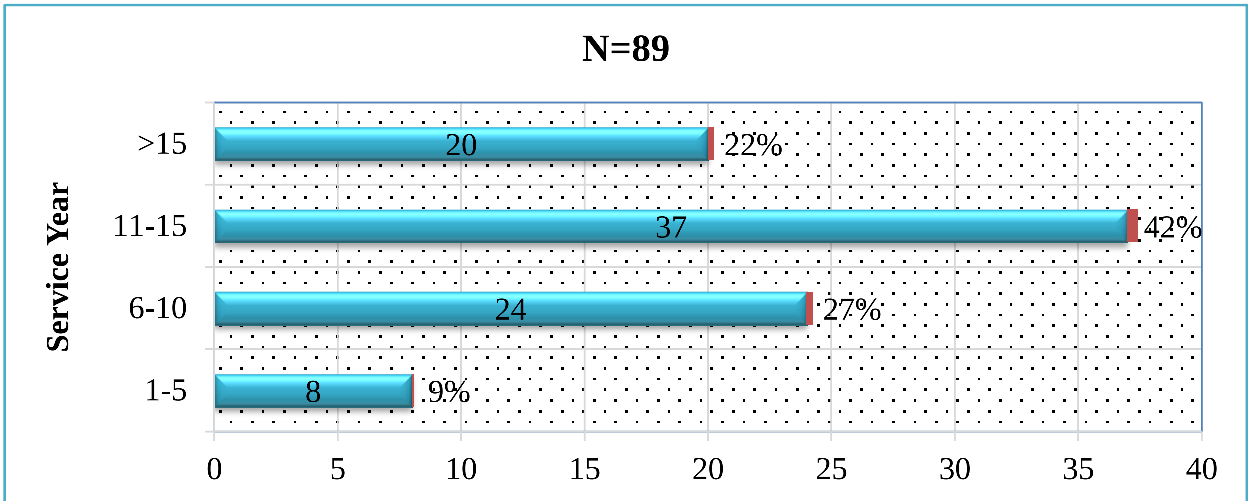
The majority of respondent employees (57%) were experts in their field. Other roles included site supervisors (21%), kebele administrators (12%), office secretary (2%), office manager (3%), and deputy office manager (3%). This diverse group ensured (Figure 4.10) that the study captured information from various levels within the town. By involving experts, the research benefited from firsthand knowledge and insights directly related to the specific programs and issues being investigated



	Office Managere	Deputy Office Manager	Kebele Administrator	Experts	Site Officers/Supervisors	Office Secretary
Frequency	3	3	11	51	19	2
Percentage	3%	3%	12%	57%	21%	2%

Figure 4.10: Work Position of the respondent Employees

Regarding the service year of the respondent employees, most employees (42%) had served for 11-15 years, with significant experience also in the 6-10 year (27%) and over 15 year (22%) ranges. Only 9% were in the 1-5 year range. This suggests that a majority of respondents were senior employees well positioned to observe and understand long-term changes (Figure 4.11).



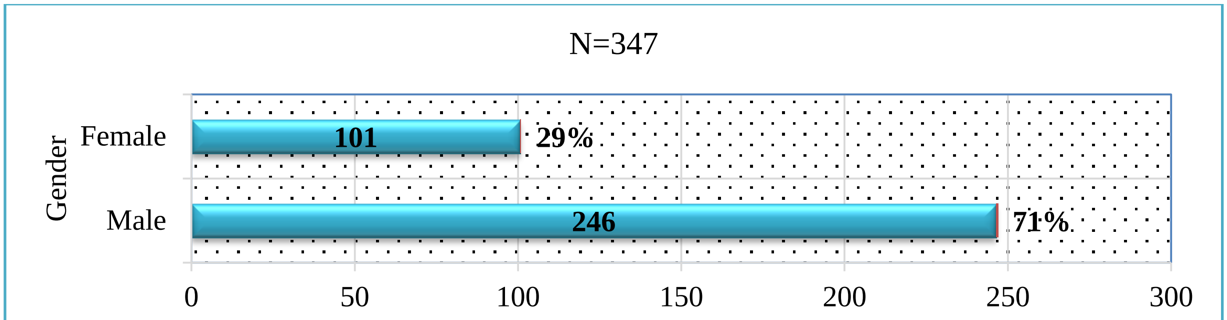
	1-5	6-10	11-15	>15
Frequency	8	24	37	20
Percentage	9%	27%	42%	22%

Figure 4.11 : Year of services in the work position of office employees

4.2.2 Backgrounds of the Community

Data on the background characteristics of Dukem town of the respondent communities, including their address (kebele), gender, age, birthplace, education level, and occupation, was obtained and presented in the following section.

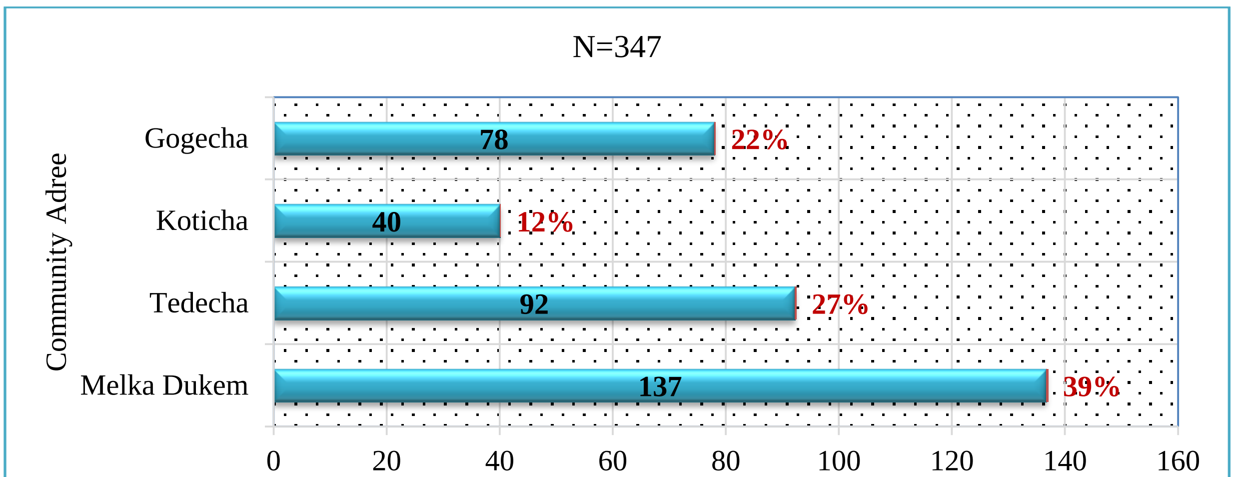
Gender plays a crucial role in determining equal opportunity and participation. Figure 4.12 blow shows that out of the 347 surveyed individuals, a majority (71%) were male, while the remaining 29% were female.



	Male	Female
Frequency	246	101
Percentage	71%	29%

Figure 4.12: Gender of the Community Respondents

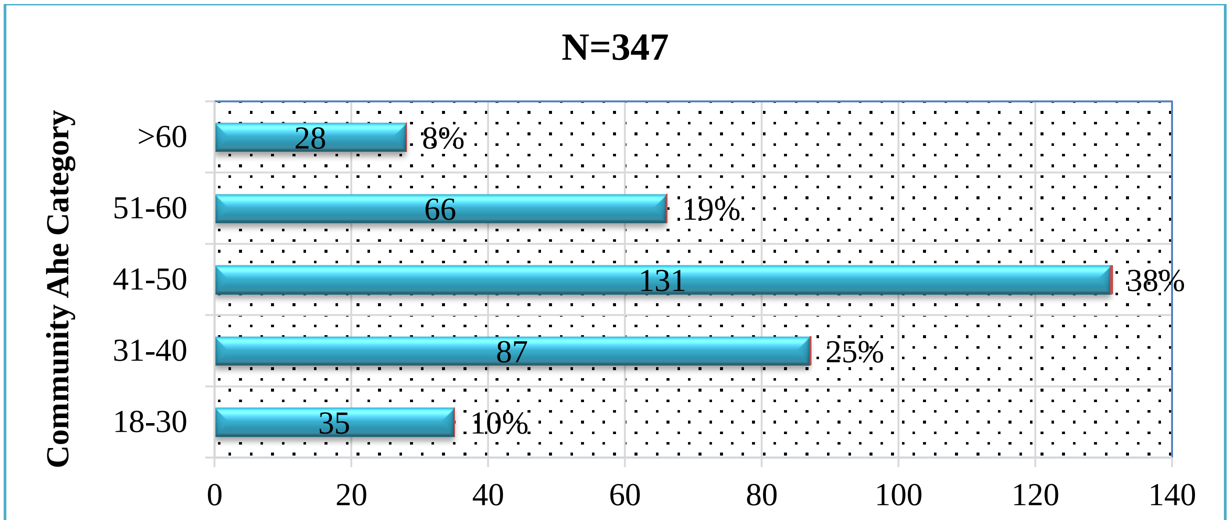
The specific location (kebele) of a community member significantly affects their level of participation and representation. As shown in Figure 4.13, of the 347 respondents, the majority (39%) were from Melka Dukem, followed by Tedecha (27%), Gogecha (22%), and Koticha (12%).



	Melka Dukem	Tedecha	Koticha	Gogecha
Frequency	137	92	40	78
Percentage	39%	27%	12%	22%

Figure 4.13: Address of the Respondent Community

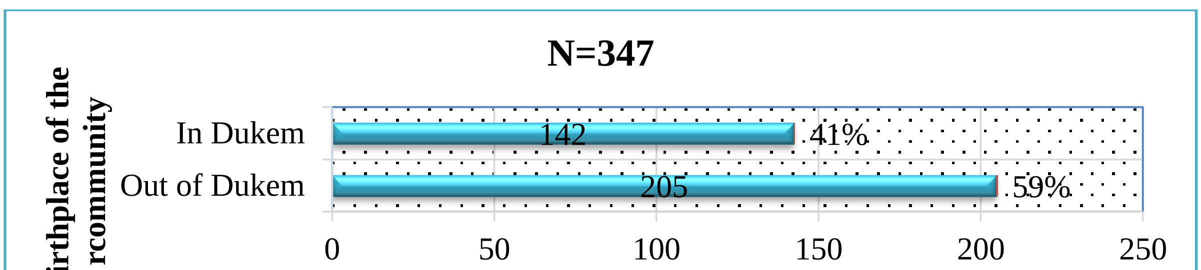
As depicted in Figure 4.14, the majority of respondents (38%) belonged to the 41-50 age group, followed by the 31-40 age group (25%). Besides, a smaller proportion was aged 18-30 (10%), 51-60 (19%), and over 60 (8%).



	18-30	31-40	41-50	51-60	>60
Frequency	35	87	131	66	28
Percentage	10%	25%	38%	19%	8%

Figure 4.14: Age Character of the Respondent Community

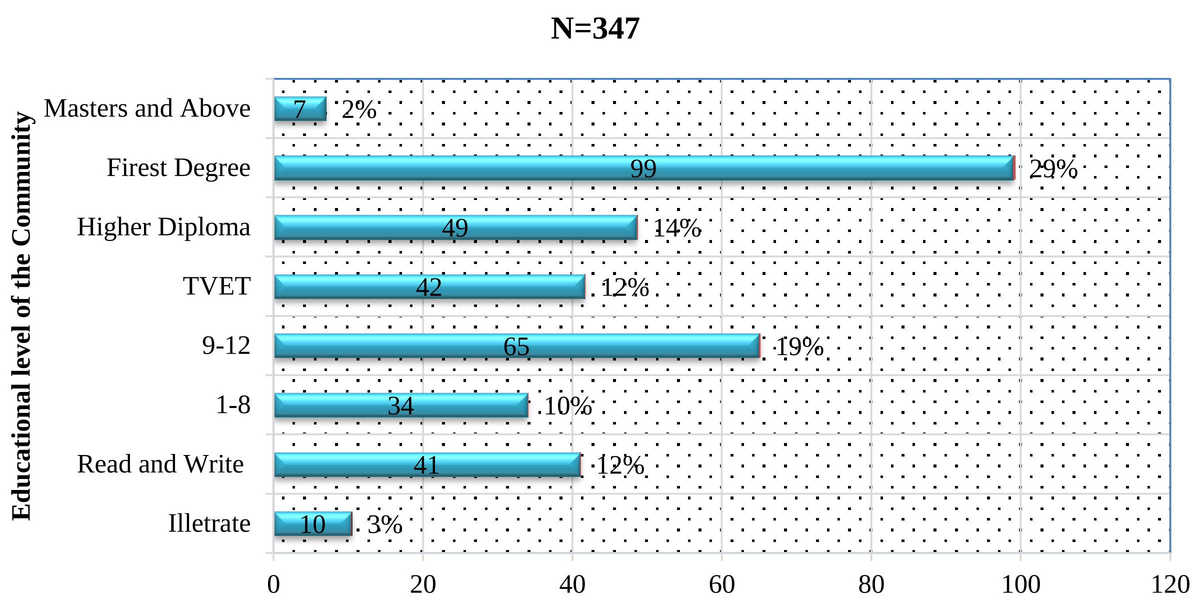
Regarding birthplace of the respondent community, the majority (Figure 4.15) were born in the study town, while others migrated from different areas. This indicated that the significant number of people migrate to the town yielding in population increase as the results of the establishment of many industries and other infrastructure. Furthermore, its geographical proximity to Addis Ababa made the town economic importance and a townhouse for many residences.



	Out of Dukem	In Dukem
Frequency	205	142
Percentage	59%	41%

Figure 4.15: Birthplace of the Respondent Community

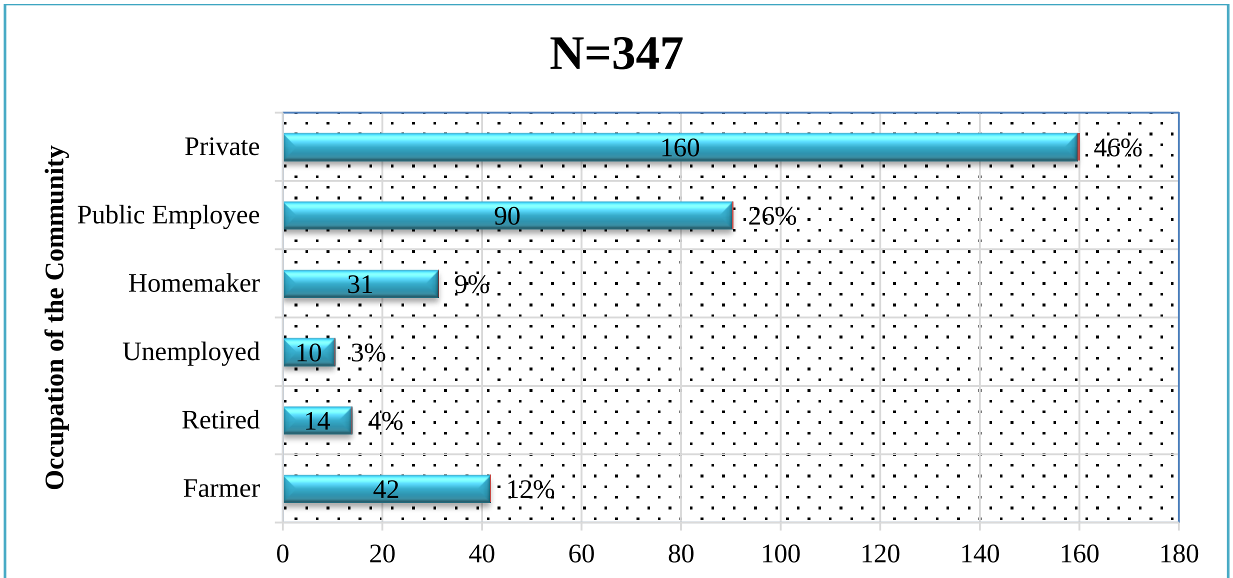
Regarding the educational level of the respondent community, the majority of them (29%) is a first-degree holders followed by 9-12 (19%), and Higher diploma (14%). Insignificant number of the community is master holders (2%), and about 3% are those cannot read and write. Besides, about 12% of the can read and write, TEVET holders is about 12% too. In general, the majority of the respondents are literate implying that they can provide required information for the study



	Illetrate	Read and Write	1-8	9-12	TVET	Higher Diploma	Firest Degree	Masters and Above
Frequency	10	41	34	65	42	49	99	7
Percentage	3%	12%	10%	19%	12%	14%	29%	2%

Figure 4.16: Educational Level of the Respondent Community

Regarding the respondent community's occupation, the predominant occupation among respondents is employment in private firms (46%), followed by public service (26%). Approximately 12% are farmers, 9% are homemakers, 4% are retired, and 3% are unemployed.



	Farmer	Retired	Unemployed	Homemaker	Public Employee	Private
Frequency	42	14	10	31	90	160
Percentage	12%	4%	3%	9%	26%	46%

Figure 4.17: The respondent Community by their Occupation

4.3 The Driving Factors

To understand the driving force behind Dukem town's land use and cover changes from 1994 to 2024, a survey using a Likert scale (strongly agree to strongly disagree) was conducted. This method was chosen because the data relied on people's personal views, which can vary depending on their perspective on the factors and individuals involved in the town's rapid growth.

The driving forces of changes in land use and land cover are multifaceted. This study focuses on several key factors: population growth, economic factor (such as commercial and service sector investment, industrialization, and availability of transportation infrastructure), social Factors (location preferences of households), institutional factors (spatial and urban planning policies), and biophysical/geographic characteristics like accessibility/location and topography). Each of these factors was examined individually.

4.3.1 Office Employee's Perceptions on Driving Factors

To understand how office employees in the town perceived the reasons behind rapid land use and land cover changes between 1994 and 2024, a survey was conducted. The survey asked respondents to rate the importance of seven factors on a 5-point Likert scale. These factors included Population growth, Investment potentials, Availability of basic infrastructure, location preferences of household, spatial and urban planning policies, Proximity of the town to the primate city, and biophysical specially topography of the town.

Accordingly, the survey result revealed that most participants agreed with the identified factors causing land use and land cover changes. Specifically, as presented by Figure 4.18, a high percentage of respondents (around 92%) cited population growth as a major driver. Additionally, a significant number (approximately 90%) pointed to investment potential, infrastructure availability, and proximity to the primate city. Other factors, such as household location preferences, spatial and urban planning policies, and biophysical/topography, were considered less influential, with ratings of 73%, 60%, and 57%, respectively.

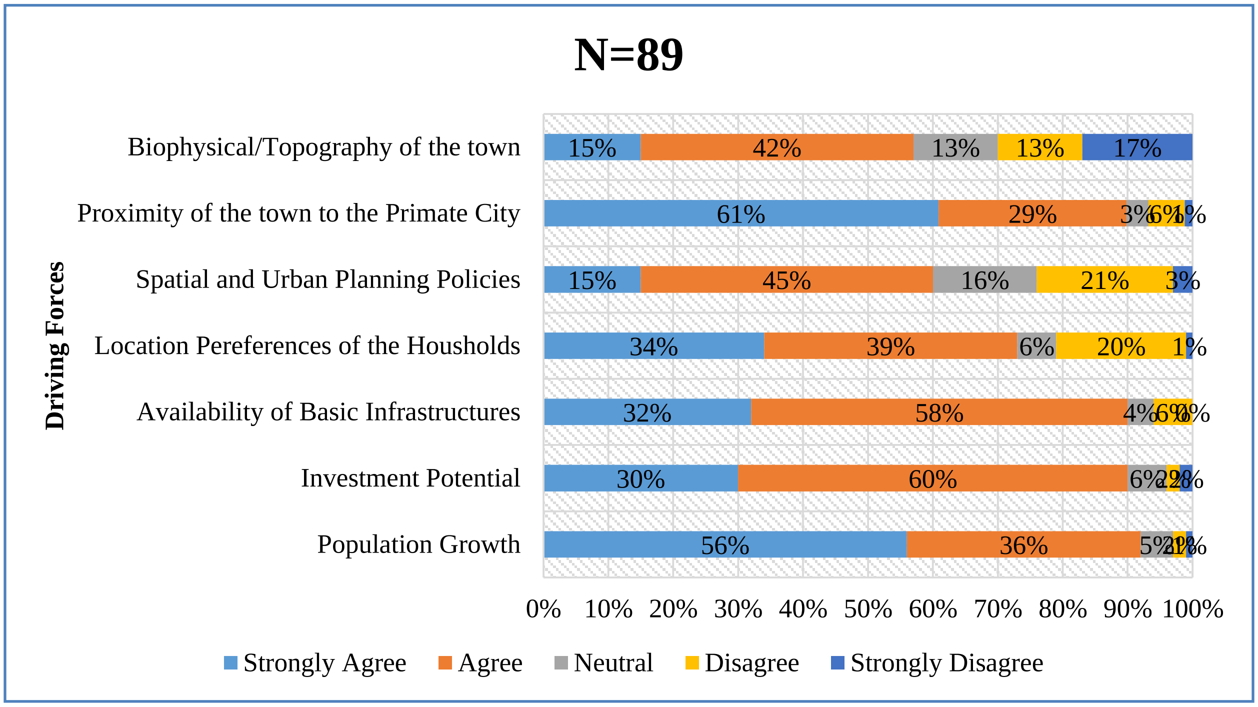


Figure 4.18: Land Use Land Cover Driving Factors Rating of the Office Employees Respondents

To gain deeper insights into the factors driving land use and land cover changes in the study town, the survey included open-ended questions. This allowed office employees to freely express their concerns and observations about unlisted factors. By combining these open-ended responses with the data from the close-ended questions, the researcher aimed to identify the key factors responsible for the rapid land use and land cover change of the town between 1994 and

2024. Out of the 89 surveys, 50 responses from office employees provided additional information on driving factors through the open-ended questions.

In this regard, in addition to the factors already discussed, the respondent identified land grabbing with 31 response rate and speculation with 19-response rate as key actors of land use and land cover change. These topics were analyzed in more detail in the appropriate sections.

4.3.1.1 Descriptive Analysis of Office Employees on the Driving Factors

To understand how office employees perceived the main causes of rapid land use and land cover changes in the study town between 1994 and 2024, seven key factors were identified. Descriptive analysis methods were used to analyze and quantify these perceptions. To examine deeper into the characteristics of these perceptions, measures of central tendency (median and mode), dispersion (standard deviation, variance), and distribution (skewness) were calculated and presented in Table 4.14, The results in the table are based on a Likert scale ranging from 1 to 5, where 1 indicates strong disagreement and 5 indicates strong agreement. The closer a factor's score is to 5, the stronger the agreement among office employees regarding its influence on land use and land cover change.

Consequently, most participants expressed strong agreement with the positive impact of the listed driving factors on land use and land cover change. As detailed in Table 4.14, all factors, with the exception of Biophysical/Topography, were rated favorably, with at least four (4) median and mode. This suggests that respondents generally concur that these factors are the main drivers of the observed changes.

The study also examined the symmetry of the data distribution using skewness. Skewness measures how much a distribution leans to one side or the other of the average value. A perfectly symmetrical distribution has a skewness of zero. Negative skewness means the distribution has a long tail to the left, indicating larger values. Positive skewness means the tail is to the right, suggesting smaller values.

Ideally, a skewness value between -1 and +1 is excellent, while -2 to +2 is generally acceptable. Values beyond -2 and +2 suggest substantial non-normality (Hair et al., 2022). Furthermore, according to (Joseph et al., 2014, p. 54), When skewness values are close to zero, the pattern of responses is considered a normal distribution.

As Table 4.14 shows, all skewed values are within acceptable limits, confirming the identified driving factors as the primary causes of land use land and cover change in the study area.

Table 4.14: Descriptive Analysis Result of office employees on driving factors

Descriptive Statistics						
	N	Median	Mode	Std. Deviation	Variance	Skewness
Population growth	89	5	5	.783	.613	-1.827
Investment Potential	89	4	4	.800	.641	-1.610
Availability of Basic Infrastructures	89	4	4	.752	.566	-1.088
Location Preferences of the Households	89	4	4	1.137	1.293	-.727
Spatial and Urban Planning Policies	89	4	4	1.088	1.183	-.466
Proximity of the town to the Primate City	89	5	5	.890	.793	-1.849
Biophysical/Topography of the town	89	4	4	1.332	1.773	-.505

Source: Computed from the SPSS Data, 2024

4.3.2 Perceptions of Communities on Driving Factors

Similarly, to gain insight into how the sampled local communities of the study town perceive the driving forces behind land use and land cover changes between 1994 and 2024, a survey was conducted. Respondents were asked to rate seven factors on a 5-point Likert scale. These factors comprised population growth, investment opportunities, availability of essential infrastructure, household location preferences, spatial and urban planning regulations, proximity to the main city, and the town's natural features, especially its topography.

Accordingly, the survey result revealed that most participants agreed with the identified factors causing land use and land cover changes. Specifically, as presented by Figure 4.19, a high percentage of respondents (around 91%) cited proximity to the primate city as a major driver. Additionally, infrastructure availability, investment potential, and population growth pointed a significant number approximately 88%, 83%, and 74% respectively. Other factors, such as household location preferences, spatial and urban planning policies, and biophysical/topography, were considered less influential, with ratings of 73%, 65%, and 57%, respectively.

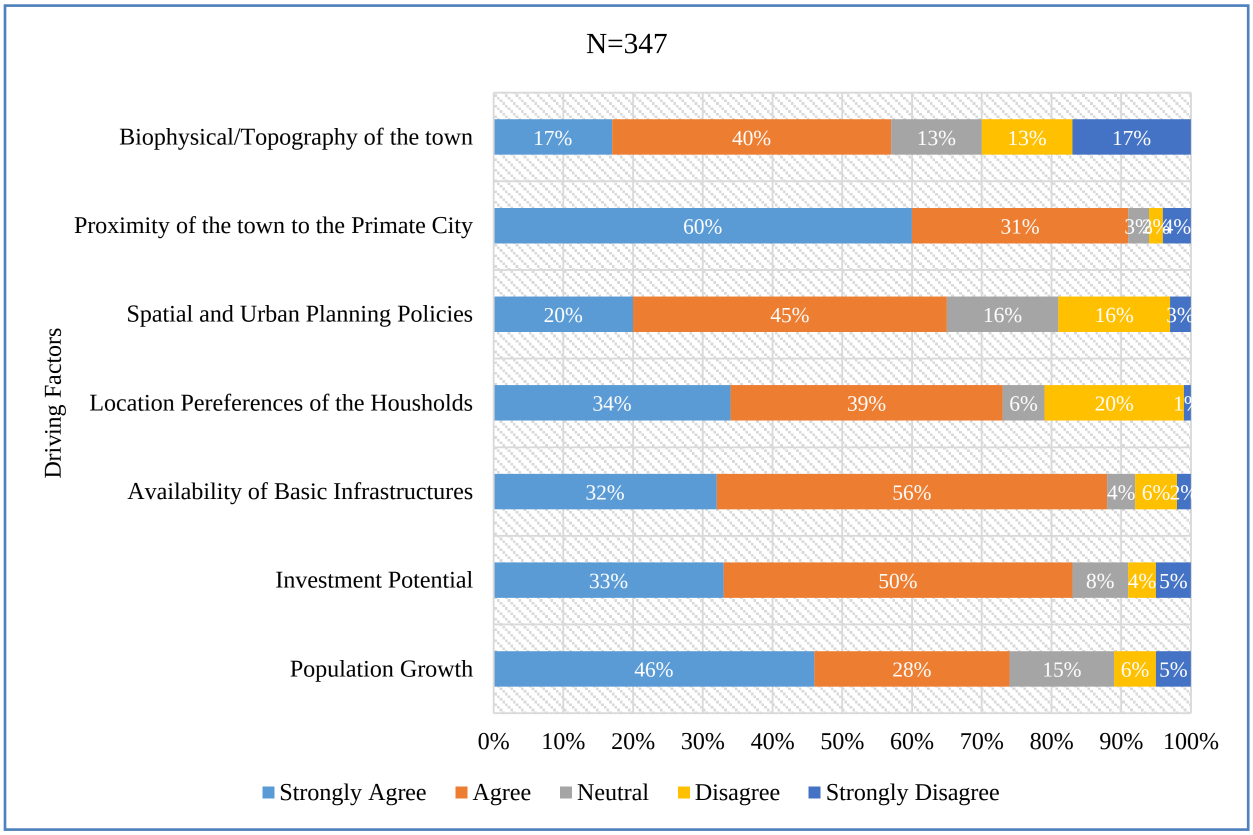


Figure 4.19: Land Use Land Cover Driving Factors Rating of the Community Respondents

To gain deeper insights into the factors driving land use and land cover changes in the study town, the survey included open-ended questions. This allowed the respondent community to freely express their concerns and observations about unlisted factors. By combining these open-ended responses with the data from the close-ended questions, the researcher aimed to identify the key factors responsible for the rapid land use and land cover change of the town between 1994 and 2024. Out of the 347 surveys, 56 responses from community provided additional information on driving factors through the open-ended questions.

In this regard, in addition to the factors already discussed, the respondent identified land grabbing with 31 response rate and speculation with 25-response rate as key actors of land use and land cover change. These topics were analyzed in more detail in the appropriate sections.

4.3.2.1 Descriptive Analysis of Communities on Driving Factors

In a similar manner to office employees, seven key factors were identified to understand how the respondent community perceived the main causes of rapid land use and land cover changes in the study town between 1994 and 2024. Consequently, descriptive analysis methods were used to analyze and quantify these perceptions. To examine deeper into the characteristics of these perceptions, measures of central tendency (mean, median, mode), dispersion (standard deviation, variance), and distribution (skewness) were calculated and presented in Table 4.15. The results in the table are based on a Likert scale ranging from 1 to 5, where 1 indicates strong disagreement and 5 indicates strong agreement. The closer a factor's score is to 5, the stronger the agreement among office employees regarding its influence on land use and land cover change.

Subsequently, most participants expressed strong agreement with the positive impact of the listed driving factors on land use and land cover change. As detailed in Table 4.15, all factors, with the exception of Biophysical/Topography, were rated favorably, with at least four (4) median and mode scores. This suggests that respondents generally concur that these factors are the main drivers of the observed changes.

The study also examined the symmetry of the data distribution using skewness. Skewness measures how much a distribution leans to one side or the other of the average value. A perfectly symmetrical distribution has a skewness of zero. Negative skewness means the distribution has a long tail to the left, indicating larger values. Positive skewness means the tail is to the right, suggesting smaller values.

As Table 4.15 shows, all skewed values are within acceptable limits as explained in the previous subsection, confirming the identified driving factors as the primary causes of land use land and cover change in the study area.

Table 4.15: Descriptive Analysis Result of the Respondent Community on driving factors

Descriptive Statistics						
	N	Median	Mode	Std. Deviation	Variance	Skewness
Population growth	347	4	5	1.138	1.296	-1.137
Investment Potential	347	4	4	.995	.990	-1.444
Availability of	347	4	4	.881	.776	-1.441

Basic Infrastructures						
Location Preferences of the Households	347	4	4	1.125	1.266	-.705
Spatial and Urban Planning Policies	347	4	4	1.063	1.129	-.615
Proximity of the town to the Primate City	347	5	5	.952	.907	-2.170
Biophysical/Topography of the town	347	4	4	1.350	1.822	-.503

Source: Computed from the SPSS Data, 2024

4.3.3 Driving Factors Analysis

To determine the primary factors behind the study Town's land use and land cover change between 1994 and 2024, a Likert scale questionnaire was administered. Respondents were asked to express their agreement or disagreement with statements concerning various factors and actors that may have influenced the town's rapid changes. It is important to acknowledge that the data is subjective and influenced by individual viewpoints.

This study examined several key factors influencing land use and land cover changes in the town, including population growth, investment potentials, infrastructure availability, location preferences of the households, spatial and urban planning policies, proximity to the primate city, and local topography. Comparison has been made on the perspectives of office workers and local communities on these factors and cross-referenced the findings with various planning documents, such as the town's structure plan and sector reports as detailed in the following sub sections

4.3.3.1 Population Growth

Population growth is a key driver of urban land use and land cover change (LULCC). As cities expand to accommodate increasing populations, natural landscapes are converted into built environments, leading to significant alterations in the urban landscape.

In this study, both office employees and community members were considered reliable sources of information about changes over time. They were believed to possess a wealth of knowledge.

The survey results regarding population growth indicated strong agreement from both groups, with 92% of office employees and 74% of community members concurring, as shown in Figure 4.18 and Figure 4.19.

On the other hand, when it comes to descriptive analysis, both office employees and community members expressed strong agreement with the idea that population growth significantly contributed to land use and land cover changes in the study town between 1994 and 2024.

Moreover, to see the population profile of the town for crosschecking, the researcher used the 1994 and 2007 of the Central Statistical Agency census result as a baseline in computing the population size for the stated study period as illustrated in below.

Furthermore, to substantiate the town's population distribution, the researcher utilized the 1994 and 2007 census results from the Central Statistical Agency. These data served as a base line for estimating the population size within the defined study time-frame, as detailed in Table 4.16.

Table 4.16: Population size of Dukem town in 1994 and 2007 CSA

No	**CSA Year**	**Male**	**Female**	**Total**
1	1994	6644	6698	13,342
2	2007	14,702	14,127	28,829

(Source: OUPI, 2017 structure plan report)

Accordingly, to calculate population size of an area ought to known population growth rate of the area, which is about 5.93% annual population growth rate according to the structure plan report 2017 for the study town since 2007 using medium variants and 4.13% between 1994 and 2007. Thus, using equation 3-8 exponential growth rate model as detailed below the population sizes for the study time-frame can be determined.

$Pt = Po * e^{rt}$ ……..Equation 4-1

Where Pt is the population at the required time, Po is the current population, r is population growth rate, and t is the projection time.

Thus, the population size of the year 1994 is give (13,342), the population for the year 2004 could be:

$P (2004) = P (1994)*e^{rt}$

$P (2004) = P (1994)*e^{rt}$, r=0.4.13, t=10

$P (2004) =13,342*e^{0.0413*10}$

$P (2004) =13,342*e^{0.413}$

P (2004) =13,342* 1.511345026

<u>P (2004) = 20,164</u>

Similarly, by using the 2007 census data as a baseline, the 2014 population size can be computed using 5.93% medium variant rate.

$P (2014) = P (2007)*e^{rt}$

$P (2014) = P (2007)*e^{rt}$; r=0.0593, t=7

$P (2014) =28,829*e^{0.0593*7}$

$P (2014) = 28,829*e^{0.4151}$

P (2014) = 28,829* 1.51452218534

<u>P (2014) = 43,662</u>

In a similar manner, by using the 2017 census projection data as a baseline, which is already used by Oromia Urban Planning Institute for Structure plan preparation, the 2024 population size can be computed using 5.93% medium variant rate.

$P (2024) = P (2017)*e^{rt}$

$P (2024) = P (2017)*e^{rt}$; r = 0.0593, t=7

$P (2024) =85,839*e^{0.0593*7}$

$P (2024) = 85,839*e^{0.4151}$

P (2024) = 85,839* 1.51452218534

<u>P (2024) = 130,005</u>

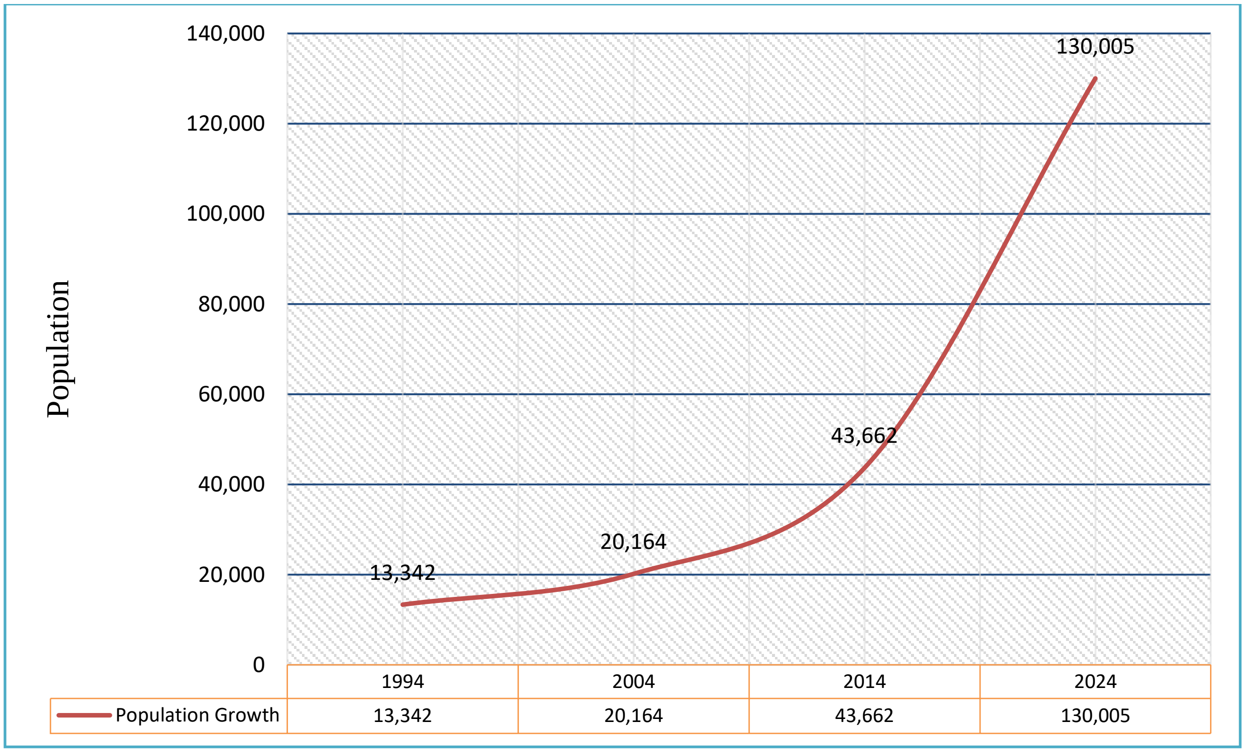


Figure 4.20: Population growth trend from 1994-2024

(Source: Own computation using CSA and OUPI projection in 2017)

Population growth is a complex phenomenon influenced by several factors, including fertility, mortality, and migration. In the case of Dukem, it appears that in-migration from surrounding areas is a significant driver of population growth (OUPI, 2017b). This inflow of people from rural areas and smaller towns can lead to rapid population increases, putting pressure on resources and infrastructure.

As identified during field observation and from the profile of the town, the presence of numerous industries/investments, particularly the Eastern Industry Zone (EIZ) has significant impacts in population growth of the town, leading to substantial in-migration and economic growth in attracting a large number of job seekers from various regions. This influx of people is transforming the town, making it stand out from other towns in the area.

As presented by Figure 4.20, the population of the study town is increasing at an alarming rate confirms the availability of many pulling factors in the town.

The 2019 Dukem town profile report states that the town's economy is booming due to industrial growth, with over 22,000 people working in the Eastern Industry Zone alone, and many more employed in other factories. This economic activity is attracting a large number of migrants seeking employment opportunities. As a result, the town is experiencing a very high rate of population growth, which is classified as a high variant rate.

4.3.3.2 Investment Potential/ Proximity to Addis Ababa

In addition to the population growth, investment potentials of the town have played a greater role in land use and land cover change of the study town. Due its economic importance, a number of commuters per day those who preferred to work and reside in the town are increasing affecting the land uses. The rise in investment potentials including manufacturing industry, service industry, trade and agro-industry has led to the rapid land use and land cover change in the study town.

In this study, both office employees and community members were considered reliable sources of information about changes over time; and they were believed to possess a wealth of knowledge. The survey results regarding investment potential indicated strong agreement from both groups, with 90% of office employees and 83% of community members concurring, as shown in Figure 4.18 and Figure 4.19.

On the other hand, when it comes to descriptive analysis, both office employees and community members expressed strong agreement with the idea that population growth significantly contributed to land use and land cover changes in the study town between 1994 and 2024.

In addition, the primary economic drivers of the town are trade and services, and industries according to (OUPI, 2017b) structure plan report. Hence, the town is known for its significant investment activity, which plays a significant role in land use changes of the study town.

Figure 4.21: Eastern Industry Zone (EIZ)
(Source: Own photo, 2024)

4.3.3.3 Availability of Basic Infrastructures

Basic infrastructures Basic infrastructure is the backbone of any urban center, providing essential services that support the daily lives of residents and businesses. They are many in types a transport infrastructure is one and the main among them providing the movement of people and goods.

The study town is situated along the National Trade Route. Its strategic location on the national highway connecting Addis Ababa and Djibouti ensures easy access to all major urban areas within the country, region, and district. Additionally, the National Railway Line traverses the town, and the Addis-Adama expressway passes through it, further strengthening its transportation network.

Figure 4.22: Addis Adama Expressway Passing through the town

Figure 4.23: National Railway passing through the town to Djibouti

Transportation networks, particularly roads, play a crucial role in urban development by connecting cities to surrounding areas and stimulating linear expansion. This is evident in the case of Dukem, which serves as a major transit point for commuters traveling between Addis

Ababa and various destinations like Bishoftu, Modjo, Adama, Djibouti, and other eastern regions.

The high volume of traffic, including both passengers and freight, has led to significant urban growth along the main roads. The increased accessibility and demand for services have attracted residential, commercial, and recreational developments, further fueling expansion. As a result, Dukem has experienced rapid growth on both sides of the road, connecting it to nearby rural areas.

It is evidenced by the study that both office employees and community members were considered reliable sources of information about changes over time due to the developments of the basic infrastructures. The survey results regarding the changes due to the availability of basic infrastructure indicated strong agreement from both groups, with 90% of office employees and 88% of community members concurring, as shown in Figure 4.18 and Figure 4.19.

Besides, when it comes to descriptive analysis, both office employees and community members expressed strong agreement with the idea that the availability of basic infrastructures significantly contributed to land use and land cover changes in the study town between 1994 and 2024.

4.3.3.4 Location Preferences of the Households

Household location preferences are multifaceted, influenced by a complex interplay of factors, including socioeconomic status, lifestyle choices, and cultural considerations. These preferences significantly influence urban land uses. As discussed in details in this study, the study town is the hosts of many investment potentials with developed basic infrastructure puling many job seekers. Accordingly, occupation is one of the socioeconomic factors for location preferences in those professionals and business owners may prioritize proximity to workplaces or business districts; and hence, prefer to settle there.

In this study that both office employees and community respondents were considered reliable sources of information about changes over time due to the location preferences of the households. The survey results regarding the changes due to this variable indicated strong agreement from both groups, with 73% each, as shown in Figure 4.18 and Figure 4.19.

Besides, when it comes to descriptive analysis, both office employees and community members expressed strong agreement with the idea that the availability of basic infrastructures significantly contributed to land use and land cover changes in the study town between 1994 and 2024. However, office employees tended to agree more strongly with this factor than community members, as indicated by the slightly higher average mean score of 4.16 for office employees compared to 4.10 for community members.

Furthermore, both group's office employees and community members—agreed that the location preference of the households was a key driver of land use and land cover changes in the town between 1994 and 2024.

4.3.3.5 Spatial and Urban Planning Policies

Spatial and urban planning policies play a pivotal role in shaping land use and land cover change. Such policy document includes urban development policies, rules and regulations, and specifically urban development plans (structure plan of urban centers) which is revised regularly within ten-year planning period.

Accordingly, the structure plans of the study town has played a greater role in land use and land cover changes of the town as depicted by the Table 4.17 below by taking in to consideration of the 2008 and 2017 development plans so far prepared by Oromia Urban Planning Institute.

Table 4.17: Land Use Summary of the proposed development plans of the two periods

SN	Land use Type	Proposed LUP 2008		Proposed LUP 2017	
		Area (Ha)	(%)	Area (Ha)	(%)
1	Administration	11.2	0.26	20.8	0.2
2	Residence	1308.6	30.82	3612.2	37.5
3	Commerce	215.3	5.07	204.8	2.1
4	Service	63.4	1.49	246.3	2.6
5	Industry	658.9	15.52	1735.7	18
6	Agriculture	1244.86	29.32	1698	17.6
7	Road & Transport	542.5	12.78	1926.9	20
8	Others	201.47	4.74	185.5	1.9
Total		4245.89	100	9630.3	100

Source: OUPI, 2008 & 2017

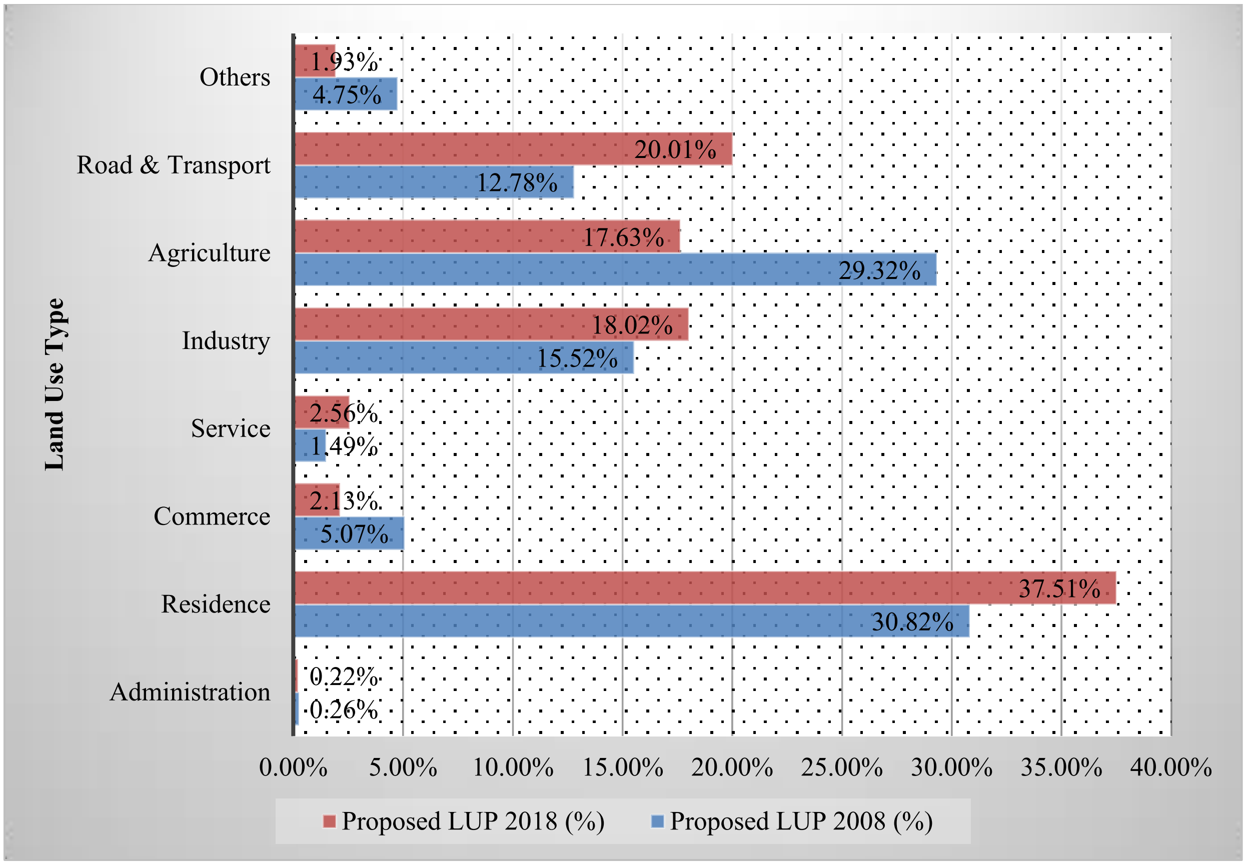


Figure 4.24: Land use summary of the proposed development plans of the two respective planning periods

It is clear that Table 4.17 and Figure 4.24 show significant changes in land use and land cover between the two planning periods. The area coverage is changed from 4245.89 hectare to 9630.3 hectare, which is more than double. Regarding the use change some of the land uses are declining in coverage, for example, agriculture reduced from 29% to 17%; residence and industry are increased their area coverage. In summary structure plan as a legal document to frame the implementation of all spatial development activities in harmony with other legal documents play a vital role in land use and land cover changes of the study area.

Apart from this, the study revealed that both office employees and community members trusted information about changes resulting from Spatial and Urban Planning Policies. Survey data indicated high levels of agreement from both groups, with 60% of office workers and 65% of community members affirming these changes, as illustrated in Figure 4.18 and Figure 4.19.

Furthermore, when analyzing the descriptive data, both office staff and community members strongly agreed that Spatial and Urban Planning Policies had a significant impact on land use and land cover transformations in the study town between 1994 and 2024.

In addition, among regulations that contributes, more on urban expansion of the study town is the directive N0.1/1998 EC; the directive enacted by the Oromia Regional Government followed the 1997 EC election. Here, regulating the nearby residents to allowed urban land; and hence, this directive plays a greater role in horizontal urban expansion of the town.

4.3.3.6 Proximity of the Town to the Primate City/Addis Ababa

The proximity of a town to a primate city can have a significant impact on its development. Being close to a primate city can expose a town to new ideas, technologies, and research. , infrastructure and economic development.

As discussed earlier, the study town is located at 37km southeast of the capital city in a strategic position along a major transportation corridor. This proximity makes it easily accessible and attractive for various urban functions particularly for industries & manufacturing and residential uses. Therefore, the town's strategic location, accessibility, and potential for urban development make it susceptible to rapid land use and land cover changes.

The study demonstrates that both office employee respondents and sampled community members were deemed reliable sources of information regarding temporal changes in the town due to the geographic proximity of the town to the primate city. Survey findings revealed a high level of agreement (90% and 91%, respectively) between these two groups concerning the effects of this proximity on the overall land use and land cover change of the town, as depicted in Figure 4.18 and Figure 4.19.

Additionally, when it comes to descriptive analysis, both office workers and local residents largely agreed that the proximity to the primate city was a major driver of land use and land cover changes in the town between 1994 and 2024.

4.3.3.7 Biophysical/Topography of the Town

It is evidenced by the study that both office employees and community members were considered reliable sources of information about changes over time due to the biophysical factor.

According to the study, office employees and community members were equally reliable in providing insights into changes caused by infrastructure development. Both groups largely concurred (57%) on the influence of biophysical factors, as depicted in Figure 4.18 and Figure 4.19.

In addition, neither office employees nor community members strongly agreed or disagreed with the idea that biophysical factors significantly influenced land use and land cover changes in the study town between 1994 and 2024. This is evident from the mean score ratings of both groups, which were close to neutral (3.24 for office employees and 3.27 for community members, as shown in Table 4.15. Among all the factors considered, only biophysical factors were perceived as having a neutral impact. Therefore, all other factors were seen as contributing significantly to the observed land use and land cover changes during the study period.

4.3.3.8 Land Speculation and Grabbing

Land speculation and land grabbing play a pivotal role in shaping land use and land cover change (LUCC). They are people who buy or take land for profit, often without considering the impact on the environment or the people who live there. This can lead to land use land cover change (LUCC), which is the process of changing the way land is used, and what covers it.

Urban land grabbing is a complex issue with a variety of causes and consequences. It happens when powerful people or groups take land in cities through informal or illegal means. This can be caused by many factors like rapid urbanization and weak government.

Urban land speculation on the other hand is the practice of buying land in anticipation of future development and price increases, which can lead to land use and land cover change in several ways: Increased demand for land, Conversion of agricultural land, Fragmentation of land.

Thus, this study found that Land grabber and land speculators are the main cause of rapid land use and land cover changes in the town, according to both office employees and community member respondents. Both groups strongly agree that these individuals are responsible for the changes. Specifically, 62% of office employees and 56% of community members identified land grabbers as a cause, while 38% of office employees and 44% of community members identified land speculators (see Table 4.18 for the details).

Table 4.18: Reflections of the respondents on Land Grabbing and Speculations as driving Factors

Driving Factors	Office Employee Respondents		Community Respondents	
	Frequency	%	Frequency	%
Land Grabbing	31	62%	31	56%
Land Speculation	19	38%	25	44%
Total	50	100%	56	100%

Source: Organized by the researcher, 2024

4.4 The Driving Actors

Land Use Land Cover Change (LUCC) is a complex process driven by, both natural and human induced. Among these factors, the role of various actors, ranging from individuals to governments, is particularly significant. These actors, through their decisions and actions, shape the landscape and influence the trajectory of LUCC (Wahyudi et al., 2019). For this study, private developers, government officials, experts, and local residents were identified as key Actors influencing land use and land cover changes in the town.

4.4.1 Perceptions of Office Employee's on Key Actors

To understand how office employees view the key actors to rapid land use and land cover changes in the study town from 1994 to 2024, a survey questionnaire were administered. This questionnaire asked respondents to rate four key actors—private developers, government officials, experts, and the local community—on a five-point Likert scale.

Accordingly, most office workers surveyed (93%) believe that private developers, local residents (78%), government officials (86%), and experts (88%) have been the primary drivers of rapid land use and land cover changes in the town between 1994 and 2024 (see Figure 4.25).

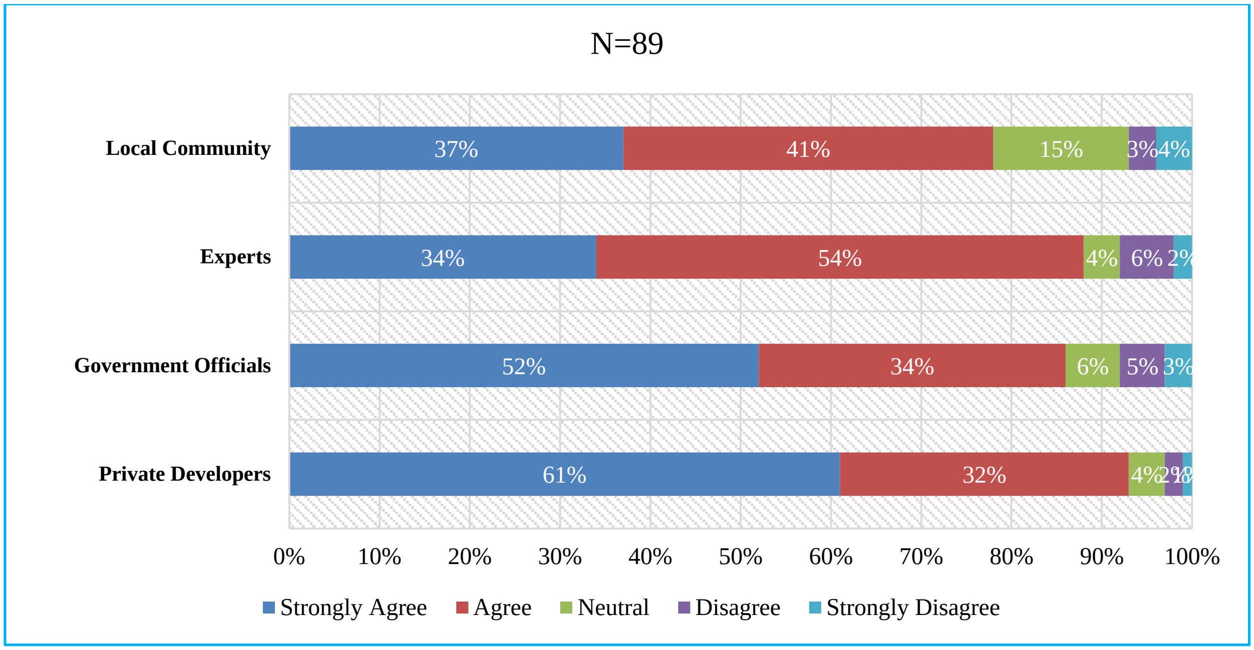


Figure 4.25: Rating key Actors According to the Office Employees

Similarly, office employees were asked open-ended questions to identify other key Actors who significantly contributed to rapid land use and land cover change of the study town between 1994 and 2024. Out of 89 surveys, 24 responses were forwarded to these open-ended questionnaires. In this regard, in addition to the actors already discussed, the respondent identified land grabbing with 15 response rate and speculation with 9-response rate as key actors of land use and land cover change. These topics were analyzed in more detail in the appropriate sections.

4.4.1.1 Descriptive Analysis of Office Employee's on Key Actors

To gain insights into how office employees perceive the key actors responsible for land use and land cover change in the study town between 1994 and 2024, survey questionnaires were employed. This questionnaire asked respondents to rank four key groups—private developers, government officials, experts, and the local community—on a five-point Likert scale.

In order to understand and measure these perceptions, descriptive analysis techniques were utilized. Specifically, the average attitude was determined based on 89 survey responses. Additionally, the most common responses for each question were identified. A detailed breakdown of these findings can be found in Table 4.19.

The findings were used to examine deeper into the nature of people's opinions. The researcher examined these opinions using various statistical measures. These included measures of central tendency (median and mode) and measures of dispersion (like how spread out the responses were). The researcher also examined the skewness of the responses to see if they were skewed towards one side or another.

The responses were rated on a Likert scale from 1 to 5, where 1 meant 'strongly disagree' and 5 meant 'strongly agree'. The results in the table show that responses closer to 5 indicate strong agreement with the listed key actors.

Table 4.19: Descriptive Analysis result of Office Employees on the Key Driving Actors

Descriptive Statistics						
	N	Median	Mode	Std. Deviation	Variance	Skewness
Private Developers	89	5	5	.771	.594	-2.039
Government Officials	89	5	5	1.006	1.012	-1.639
Experts	89	4	4	.897	.805	-1.480
Local Community	89	4	4	1.016	1.033	-1.265

Source: Computed from the SPSS Data, 2024

As presented by the table above the medians are above the neutral values implying that all the respondents are strongly agree to the listed actors contributing to the changes observed within the study town within the stated study time frame. Furthermore, the skewness values are within the acceptable range talking that the stated lists of actors are their real actors among many actors contributing to the land use and land cover changes of the study town.

4.4.2 Perceptions of Communities' on Key Actors

To further explore the sampled community's viewpoint on the key actors in the rapid land use and land cover changes in the study town between 1994 and 2024, a survey questionnaires were administered. This questionnaire asked respondents' ratings of four key groups—private developers, government officials, experts, and the local community—on a five-point Likert scale.

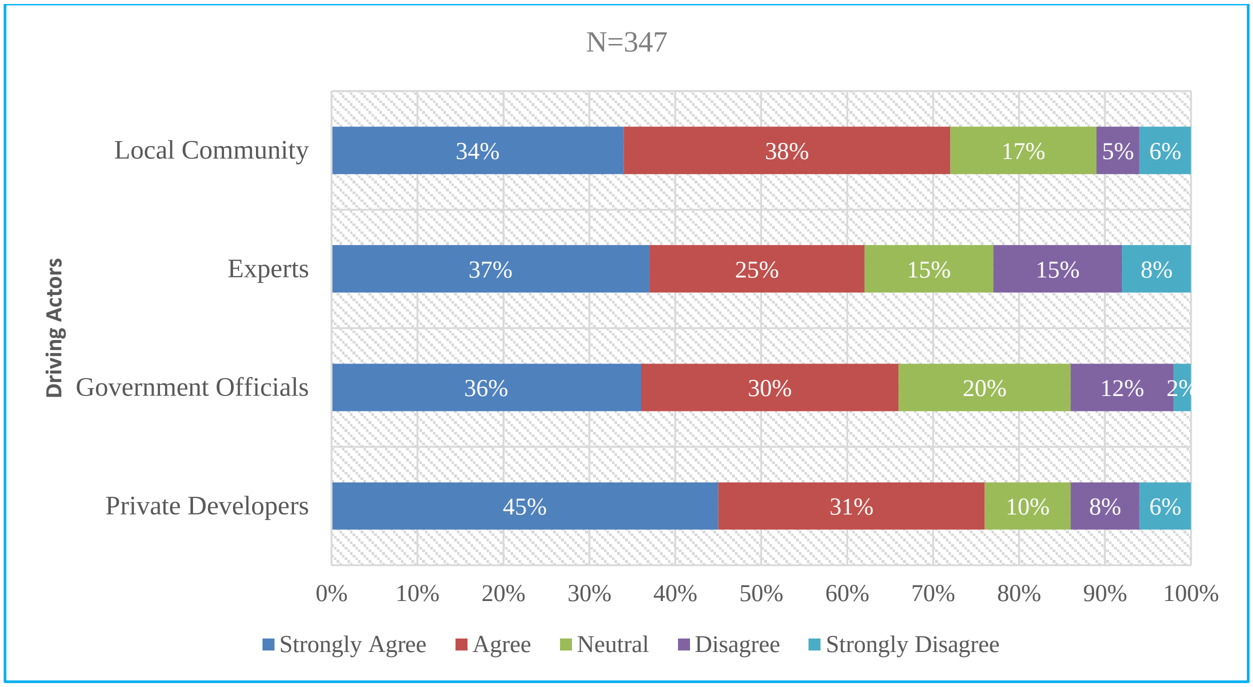


Figure 4.26: Rating key Actors According to the Community

Accordingly, most community surveyed (76%) believe that private developers, local residents (72%), government officials (66%), and experts (62%) have been the primary drivers of rapid land use and land cover changes in the town between 1994 and 2024 (see Figure 4.26).

Similarly, the community were asked open-ended questions to identify other key Actors who significantly contributed to rapid land use and land cover change of the study town between 1994 and 2024. Out of 347 surveys, 18 responses were forwarded to these open-ended questionnaires. In this regard, there are other two driving forces for land use and land cover change raised by the respondent which include Land Grabbing (former as well as official, investors, experts and communities) with ten (10) responses and land speculators with eight (8) responses. All of them were discussed in corresponding sections of analyses.

4.4.2.1 Descriptive Analysis of Communities' on Key Actors

In the same manner, to understand how the community views the key actors involved in land use and land cover changes in the town between 1994 and 2024, a survey was conducted. Participants ranked four key groups: private developers, government officials, experts, and the local community, on a scale of one to five.

To comprehend and quantify these perceptions, descriptive analysis techniques were utilized. The average attitude was computed based on 347 survey responses. Furthermore, the most common responses for each question were identified. A detailed breakdown of these findings is presented in Table 4.20.

To understand people's viewpoints, the data were analyzed using statistical methods including central tendencies median, mode; distributions and skewness. The responses were rated on a Likert scale from 1 to 5, where 1 meant 'strongly disagree' and 5 meant 'strongly agree'. The results in the table show that responses closer to 5 indicate strong agreement with the listed key actors.

Table 4.20: Descriptive Analysis result of the Community on the Key Driving Actors

Descriptive Statistics						
	N	Median	Mode	Std. Deviation	Variance	Skewness
Private Developers	347	4	5	1.191	1.419	-1.172
Government Officials	347	4	5	1.099	1.208	-.637
Experts	347	4	5	1.321	1.745	-.630
Local Community	347	4	4	1.115	1.242	-1.055

Source: Computed from the SPSS Data, 2024

As presented by the table above both the mode and the medians are above the neutral values implying that all the respondents are strongly agree to the listed actors contributing to the changes observed within the study town within the stated study time frame. Furthermore, the skewness values are within the acceptable range talking that the stated lists of actors are their real actors among many actors contributing to the land use and land cover changes of the study town.

4.4.3 Driving Actor’s Analysis

The study examines the key Actors of rapid land use and land cover change in Dukem town between 1994 and 2024. These key actors include private investors, government officials, experts, and the local community, each of whom is analyzed in detail in subsequent sections.

4.4.3.1 Private Developers

Multiple stakeholders influence urban development, the process of converting nonurban into urban spaces. Among these, private land developers are particularly influential. Their choices to develop undeveloped land are crucial in shaping the growth of cities (Wahyudi et al., 2019). In real-world scenarios, developers display individual preferences and methods when devising multiple operational approaches or making spatial choices related to land development. The developers could be local or foreign developers having capacity/potential to develop land for different economic uses: for commercial, industrial, real estate, and the likes. Accordingly, private developers as a key actors played a greater role in land use and land cover changes in the study town within the stated study period.

Accordingly, this study found that both office employees and community members believe that private developers are the primary cause of rapid land use and land cover changes in the town. Both groups strongly agreed on this, with 93% and 76% respectively, as shown in Figure 4.25 and Figure 4.26.

In terms of descriptive analysis, On the other hand, both office employees and community members held positive views, when asked about the role of private developers in land use and land cover changes between 1994 and 2024. However, there was a slight difference in their perceptions. Office employees expressed stronger agreement with an average rating of 4.49, while community members agreed with an average rating of 4.01 (see Table 4.19 and Table 4.20). This suggests that both groups recognize the significant contribution of private developers to the town's land transformation.

4.4.3.2 Government Officials

Government officials play a crucial role in shaping land use and land cover change (LULCC). They, by the formulation local government policy, rules and regulations, are responsible for land use and land cover change; and hence, is one of the key actors (Allan et al., 2022; Lambin, 2006).

Accordingly, this research indicates that both individuals working in government offices and local residents share the same view: they believe government officials are the primary causes of land use and land cover within the town. The level of agreement on this issue is quite significant, with a strong majority of 86% among office employees and 66% among community members expressing this sentiment. This consensus is visually represented in Figure 4.25 and Figure 4.26

In terms of descriptive analysis, On the other hand, both office employees and community members held positive views, when asked about the role of private developers in land use and land cover changes between 1994 and 2024. However, there was a slight difference in their perceptions. Office employees expressed stronger agreement with an average rating of 4.26, while community members agreed with an average rating of 3.86 (see Table 4.19 and Table 4.20). This suggests that both groups recognize the significant contribution of government officials to the town's land transformation. Furthermore, the data recognized that the identified variable is a key actor of land use and land cover changes within the specified timeframe, as their distribution/skewness values is within acceptable limits.

4.4.3.3 Experts/Office Worker

The role of office workers/experts in land use and land cover change (LULCC) is complex and multifaceted. While they might not be directly involved in land clearing practices, their daily decisions and actions can have significant indirect impacts on LULCC.

According to some information from office employees and communities during survey the office experts facilitates land transactions; and hence, accelerating land conversion by Enabling Supply and Demand through Information Dissemination; making market analysis; Connecting Buyers and Sellers (act as intermediaries); and providing Legal and Regulatory Guidance. Accordingly, they possess knowledge about land availability, zoning regulations, development potential, and market trends; and disseminate this information to potential buyers and sellers, creating transparency and awareness about land opportunities.

Consequently, this study found that both office employees and community members believe that the experts as a key actor in rapid land use and land cover changes in the town. Both groups strongly agreed on this, with 88% and 62% respectively, as shown in Figure 4.25 and Figure 4.26: In terms of descriptive analysis, On the other hand, both office employees and community members held positive views, when asked about the role of private developers in land use and land cover changes between 1994 and 2024. However, there was a slight difference in their perceptions. Office employees expressed stronger agreement with an average rating of 4.11, while community members agreed with an average rating of 3.68 (see Table 4.19 and Table 4.20). This suggests that both groups recognize the significant contribution of private developers to the town's land transformation. Likewise, the data recognized that the identified variable is a key actor of land use and land cover changes within the specified timeframe, as their distribution/skewness values is within acceptable limits.

4.4.3.4 The Local Community

Local communities play a pivotal role in shaping land use and land cover change (LUCC). Their decisions, practices, and cultural values significantly influence how land is utilized and how its physical characteristics evolve over time. Understanding this role is crucial for sustainable land management and environmental conservation.

The local community in this study town is composed of individuals with diverse needs and priorities. Some residents choose to live in the study town while working in nearby urban areas, including the primary city. These individuals require land for housing purposes. Additionally, local farmers, who own land in the area, often informally transfer their land to those in need, particularly the aforementioned group. Given these dynamics, the local community is a key player in influencing land use and land cover changes within the study town.

Thus, this study found that both office employees and community members believe that local community are the primary cause of rapid land use and land cover changes in the town. Both groups strongly agreed on this, with 78% and 72% respectively, as shown in Figure 4.25 and Figure 4.26.

On the other hand, in terms of descriptive analysis, both office employees and community members held positive views, when asked about the role of local community in land use and land cover changes between 1994 and 2024. However, there was a slight difference in their perceptions. Office employees expressed stronger agreement with an average rating of 4.03, while community members agreed with an average rating of 3.89 (see Table 4.19 and Table 4.20). This suggests that both groups recognize the significant contribution of private developers to the town's land transformation. Similarly, the identified variable was identified as one of the key actors of land use and land cover changes within the specified timeframe, as their skewness values is within acceptable limits.

4.4.3.5 Land Speculator, Land Grabber and Land Broker

Land speculators, land grabbers and Land Brokers play a pivotal role in shaping land use and land cover change (LUCC). They are people who buy or take land for profit or facilitating the transaction of land, often without considering the impact on the environment or the people who live there leading to land use and land cover change (LUCC).

Urban land grabbing is a complex issue with a variety of causes and consequences. It happens when powerful people or groups take land in cities through informal or illegal means. This can be caused by many factors like rapid urbanization and weak government.

Urban land speculation on the other hand is the practice of buying land in anticipation of future development and price increases, which can lead to land use and land cover change in several ways: Increased demand for land, Conversion of agricultural land, Fragmentation of land.

Furthermore, Land brokers are people who facilitate the buying and selling of land. They can be a driving force for land use and land cover change because they can help to connect buyers and sellers of land, and they can influence the price of land.

Thus, this study found that Land grabber and land speculators are the main cause of rapid land use and land cover changes in the town, according to both office employees and community member respondents. Both groups strongly agree that these individuals are responsible for the changes. Specifically, 42% of office employees and 39% of community members identified land grabbers as a cause, 33% of both office employees and community members identified land brokers as a cause, while 25% of office employees and 28% of community members identified land speculators (see Table 4.21 for the details).

Table 4.21: Reflections of the respondents on Land Grabbers and Speculators as driving Actors

Driving Factors	Office Employee Respondents		Community Respondents	
	Frequency	%	Frequency	%
Land Grabber	10	42%	7	39%
Land Speculator	6	25%	5	28%
Land Broker	8	33%	6	33%
Total	24	100%	18	100%

Source: Computed from the SPSS Data, 2024

4.5 Future Expansion of Dukem Town

4.5.1 Estimation of Population for the year 2030

To estimate the population size, it is necessary to calculate the town's population growth rate. This growth rate can be estimated using three different scenarios: high, medium, and low, depending on various factors affecting population growth. Using this method, the annual growth rate of Dukam town was calculated to be 5.93% (CSA, 1994-2007, customized by Oromia Urban Planning Institute). This rate is higher than the annual growth rate of 4.13% for the entire Oromia urban area (CSA, 1994-2007).

This study considered three different growth rate scenarios for the period 2024-2030: a high growth rate of 6.93%, a medium growth rate of 5.93%, and a low growth rate of 4.93%. These growth rates were calculated using equation 4.1above and are detailed in Table 4.22.

Table 4.22: Estimated Population size of Dukem Town for 2030

Projection Variants	Growth Rates	Base Year Population	Estimated Population
		2024	2030
High	6.93	130,005	197,033
Medium	5.93	130,005	185,559
Low	4.93	130,005	174,753

As presented in the above (Table 4.22), in 2030 the population of the town will be varying between 174,753 and 197,033 when the population growth rate varies from the lower to highest variants respectively. Therefore, the population of the town assumed to grow at the average (medium variant) growth rate per annum during 2024-2030 because the town has many pulling factors for high in migration rate. In the view, Dukem town will be expected to reach about an average of 185,559 populations by the year 2030. Accordingly, Figure 4.27 below presented the population growth trend for the selected study periods.

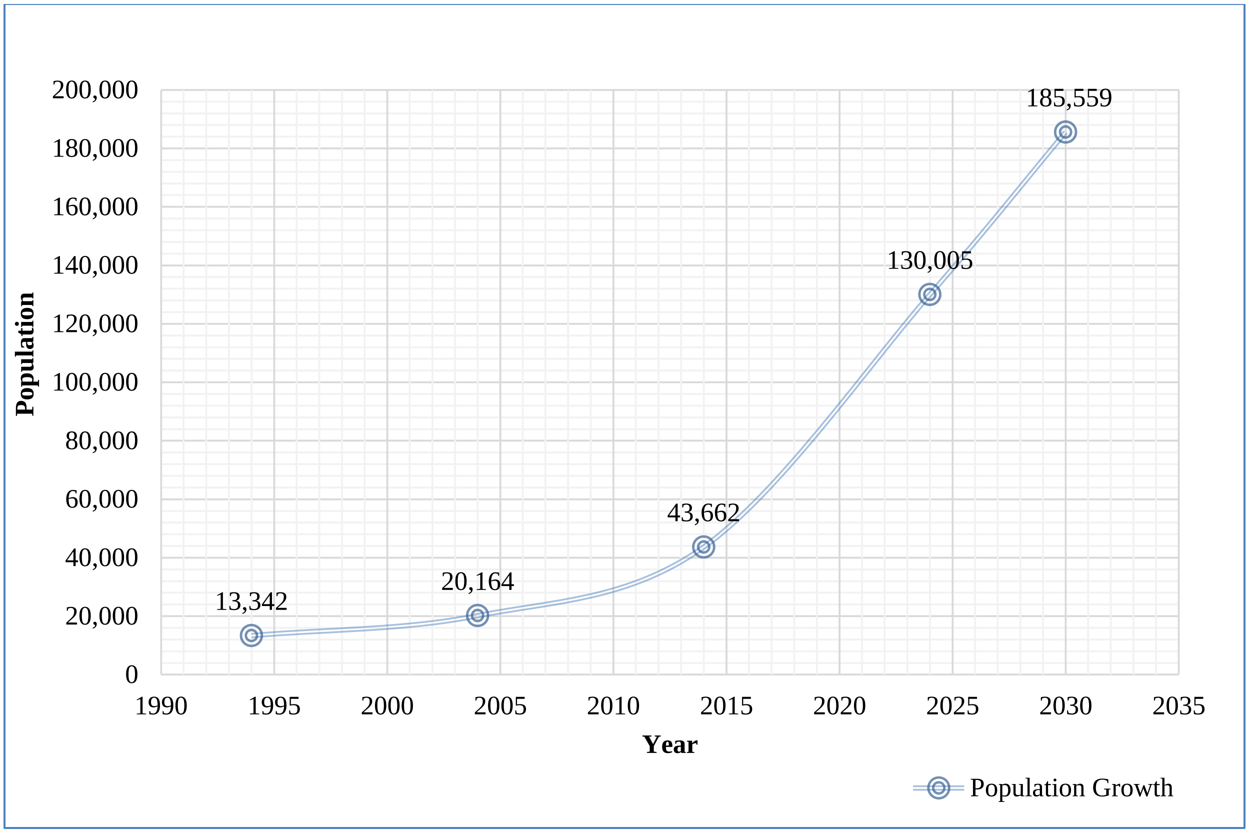


Figure 4.27: Population Growth from 1994 to 2030

Source: Own computation based on CSA 1994-2007 data and OUPI 2017

4.5.2 Estimation of Built up Area for the year 2030

It is important to know the future built up area to arrive at the desired study objectives. Accordingly, the Exponential Growth Model (EGM) method is used to forecast future urban built up area of the study town (Hathout, 2013). In so doing, calculating average growth rate of the built up area is mandatory (Gao et al., 2023).Therefore, the following formulae (equation 3.8 and 3.9) were customized for predicting future urban built up area of the study town for the coming 2030.

$CA = IA * e^{rt} \ldots \ldots . r = \frac{1}{t} \ln(\frac{CA}{IA})$………………………………………………………………… Equation 4-2

Where, CA Current Built up area, IA= Initial Built UP area, r rate of Change; and t = time in year.

$Af = IA * (1 + r/100)^{t}$…………………………………………………………………… Equation 4-3

Where AF=future built up area, IA initial Area, r= rate of change, and t= time from initial to final.

Accordingly, rate of change from 1994 to 2024 could be:

$$\boldsymbol{r = \frac{1}{30}\ \ln(\frac{3447}{498})}$$

$$\boldsymbol{r = 0.333\ln(6.921686747) * 100}$$

$$\underline{\boldsymbol{r = 6.448864965} = 6.45}$$

Hence, the built up are for the coming 2030 could be:

$$\boldsymbol{A(2030) = A(2024) * (1 + 6.45/100)^6}$$

$$\boldsymbol{A(2030) = A(2868) * (1.0645)^6}$$

$$\underline{\boldsymbol{A(2030) = 5015}}$$

Accordingly, by 2030, the town is projected to expand by 5015 hectares, a 1568-hectare increase from 2024, representing a 45% growth. Figure 4.28: below illustrates this trend in urban growth from 1994 to 2030 as a line graph.

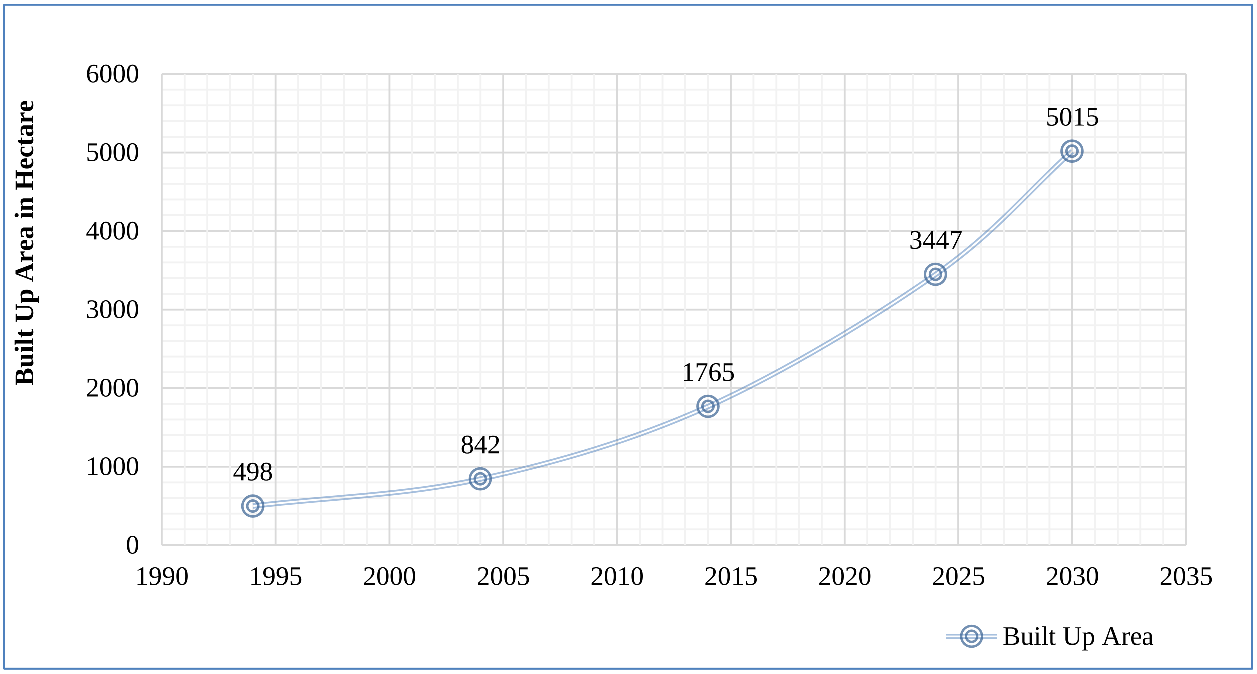


Figure 4.28: Trends of Urban Growth across the continuum

4.5.3 Comparison of Population Size and Built-up Area

As the population of the study town increases, so does its urban area. For instance, in 1994, when the population was 13,342, the built-up area covered 498 hectares. By 2004, the population had grown to 20,164, and the built-up area expanded to 842 hectares. This trend continued, with the population reaching 43,662 in 2014 and the built-up area increasing to 1765 hectares. In 2024, the population soared to 130,005, and the built-up area expanded to 3447 hectares. Projections for 2030 indicate that the population will further increase to 185,559, and the built-up area will reach 5015 hectares.

In addition, the study town witnessed a dramatic population growth. Between 1994 and 2004, its population grew by 51%. This growth accelerated over the next decade, increasing by a staggering 117% from 2004 to 2014. The trend continued, with an estimated 198% population increase from 2014 to 2024. Looking ahead, the town's population is projected to grow by an additional 43% between 2024 and 2030.

In parallel, the town's built-up area expanded significantly. It increased by 69% of the total land from 1994 to 2004, 110% from 2004 to 2014, and 95% from 2014 to 2024. The estimated built-up area is expected to grow by 45% between 2024 and 2030. For a detailed breakdown of these figures, please refer to Table 4.23 and Figure 4.29 for the details.

Table 4.23: Rate of Population and urban growth of the target periods

Year	Built Up Area	Change	%Change	Population	Growth	%Growth
1994	498			13,342		
2004	842	344	69%	20,164	6,822	51%
2014	1765	923	110%	43,662	23,498	117%
2024	3447	1682	95%	130,005	86,343	198%
2030	5015	1568	45%	185,559	55,554	43%

Source: Organized by the Researcher, 2024

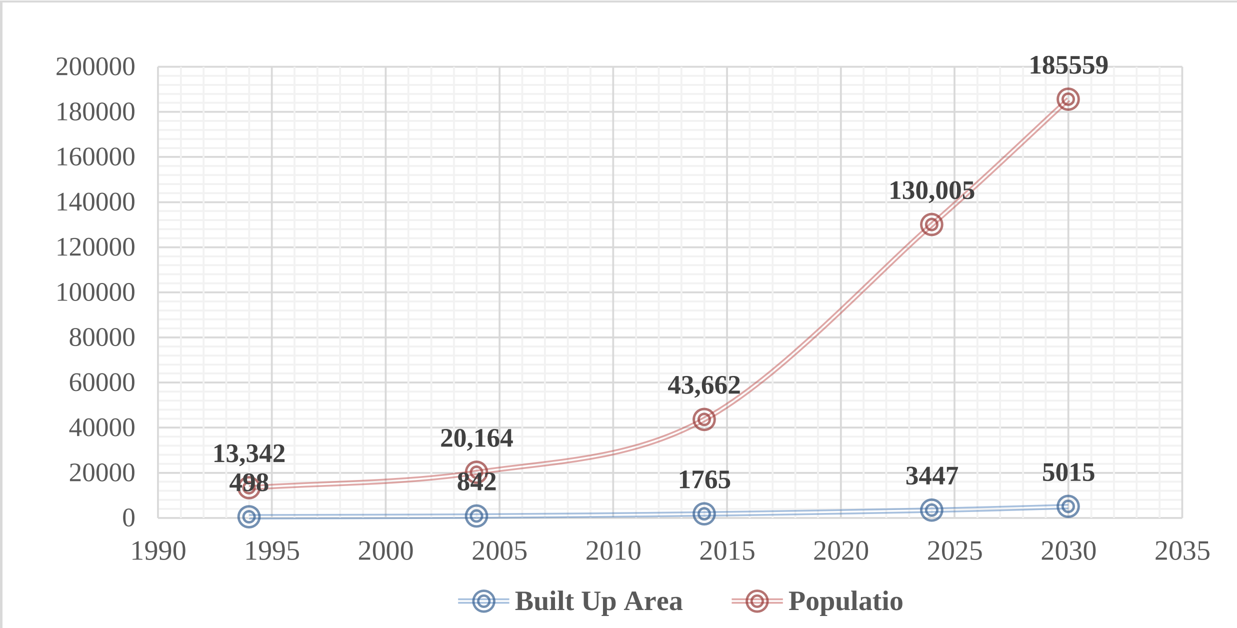


Figure 4.29: Built up Area Vs Population Growth for the years 1994 to 2030

4.5.4 Land Use Consumption Rate

Urban land consumption refers to the process of land being used for urban purposes, often replacing other land uses while Urban land consumption rate measures how quickly a city or urban area grows in size over a specific period (usually a year). From urban management points of views land, consumption rate measures the degree of the efficiency of the utilization of urban land. It is one of the indicators set by the united nation of the sustainable development goals.

Therefore, to measure the efficiency of urban land use in the study town, the land consumption rates for the given years were computed using equations 2.1, 2.3, and 2.3 state in the literature review sections, which rely on population growth rate, land consumption rate, and the ratio of land consumption to population growth.

$\mathrm{LCR} = \frac{(LN(Urb(t2)/Urb(t1)\,)}{(y)}$; Where: …Equation 4-4

Urbt1 is the total area covered by the urban area in the initial year *t1*;

Urbt2 is the total area covered by the urban area in the final year *t2*; and y is the number of years between the two measurement periods (*t1* and *t2*)

$\mathrm{PGR} = \frac{(LN(Pop(t2)/Pop(t1)\,)}{(y)}$; Were …Equation 4-5

Popt1 is the total population within the urban area in t1 (initial year)

Popt2 is the total population within the urban area in t2 (final year); and y is the number of years between the two measurement periods.

Furthermore, the final indicator, land consumption rate to population growth rate (LCRPGR), is computed by dividing the calculated land consumption and population growth rates as (Zhang et al., 2020, p. 7):

$\text{LCRPGR} = \frac{(Annual\ Land\ Consumption\ rate\ )}{(Annual\ Population\ growth\ rate)}$…Equation 4-6

Accordingly:

$$\text{PGR}(1994 - 2004) = \frac{(LN(Pop(2004)/Pop(1994)\ )}{(2004 - 1994)}$$

$\text{PGR}(1994 - 2004) = \frac{\ln\left(\frac{20,164}{13342}\right)}{(10)}$ = 0.041298 = 4.13%

$$\text{PGR}(2004 - 2014) = \frac{(LN(Pop(2014)/Pop(2004)\ )}{(2014 - 2004)}$$

$\text{PGR}(2004 - 2014) = \frac{\ln\left(\frac{43,662}{20,164}\right)}{(10)}$ = 0.074257932= 4.43%

$$\text{PGR}(2014 - 2024) = \frac{(LN(Pop(2024)/Pop(2014)\ )}{(2024 - 2014)}$$

$\text{PGR}(2004 - 2014) = \frac{\ln\left(\frac{130,005}{43,662}\right)}{(10)}$ = 0.109109475= 10.91%

$$\text{PGR}(2024 - 2030) = \frac{(LN(Pop(2030)/Pop(2024)\ )}{(2030 - 2024)}$$

$\text{PGR}(2024 - 2030) = \frac{\ln\left(\frac{185,559}{130,005}\right)}{(6)}$ = 0.059299997= 5.93%

$$\text{LCR}(1994 - 2004) = \frac{(LN(Urb(2004)/Urb(1994)\ )}{(2004 - 1994)}$$

$\text{PGR}(1994 - 2004) = \frac{\ln\left(\frac{842}{498}\right)}{(10)}$ = 0.052517994= 5.25%

$$\text{LCR}(2004 - 2014) = \frac{(LN(Urb(2014)/Urb(2004)\ )}{(2014 - 2004)}$$

$\text{PGR}(2004 - 2014) = \frac{\ln\left(\frac{1765}{842}\right)}{(10)}$ = 0.0781517994= 7.82%

$$\text{LCR}(2014 - 2024) = \frac{(LN(Urb(2024)/Urb(2014)\ )}{(2024 - 2014)}$$

$$\text{PGR}(2004-2014) = \frac{\ln\left(\frac{3447}{1765}\right)}{(10)}$$ = 0.086935= 8.7%

$$\text{LCR}(2024-2030) = \frac{(LN(Urb(2030)/Urb(2024)\,)}{(2030-2024)}$$

$$\text{PGR}(2024-2030) = \frac{\ln\left(\frac{5015}{3447}\right)}{(6)}$$ = 0.062488189= 6.25%

Table 4.24: Summary of Land Consummation Rate and Population growth rate for the selected study years

	1994-2004	2004-2014	2014-2024	2024-2030
LCR	5.25	7.82	8.7	6.25
PGR	4.13	7.43	10.91	5.93
LCR/PGR	1.271	1.052	0.797	1.054

Source: Organized by the Researcher, 2024

Table 4.24 shows that, with the exception of the years 2014 to 2024, the ratio of Land Consumption Rate to Population Growth Rate (LCRPGR) has been consistently above one. This indicates that land is not being used efficiently, as ideal values for LCRPGR should be less than one (DASHTI, 2022 , p.20; UN-Habitat, 2018a).

Research by (Biswajeet & Serdang, 2017) suggests that LCRPGR values typically range from -1 to 1. A value of 0 indicates moderate land use, a positive value signifies excessive built-up area percapita, and a negative value implies population density that may lead to negative social, economic, and urban consequences. Given these findings, there is a clear need to re-evaluate urban land management strategies to address the inefficient use of scarce resources in the study town.

4.5.5 Future Expansion Direction and its Constraints of the town

The historical development of Dukem town is closely tied to the establishment of its railway terminal. As the town evolved into an urban center, it experienced typical growth patterns of developing cities, including unplanned settlements and reliance on existing infrastructure. The town expanded outward from its core, particularly along the main road, and further outward as industries, infrastructure, government institutions, and other establishments were built in the surrounding agricultural areas.

Another key factor influencing the expansion area and direction is the population size. The anticipated population growth necessitates future housing needs, as seen in Dukem's significant population increase.

By analyzing satellite images from 1994 to 2024, one can predict the future growth of Dukem town which is located southeast of Addis Ababa on the main road to Adama. This road is the most significant factor influencing the town's development. Additionally, the expansion of various services has contributed to the overall growth patterns.

In 2004, development followed the main road and railway; by 2014, growth shifted towards the south and southwest, likely due to the flat topography, which is conducive for construction and movement. Currently, the town is expanding in all directions, with notable growth along major roads in the north-south, southwest, and southeast regions.

Additionally, the OUPI developed a 10-year structural plan for Dukem town in 2017. The newly drafted plan allocates a significant 9,653 hectares of land for development by 2027, signaling substantial future growth. Presently, key functions like government offices, banks, and commercial zones are clustered in the town center. The town's expansion is primarily projected towards the northeast and southwest, as growth to the east and west is constrained by the neighboring towns of Bishoftu and Galan.

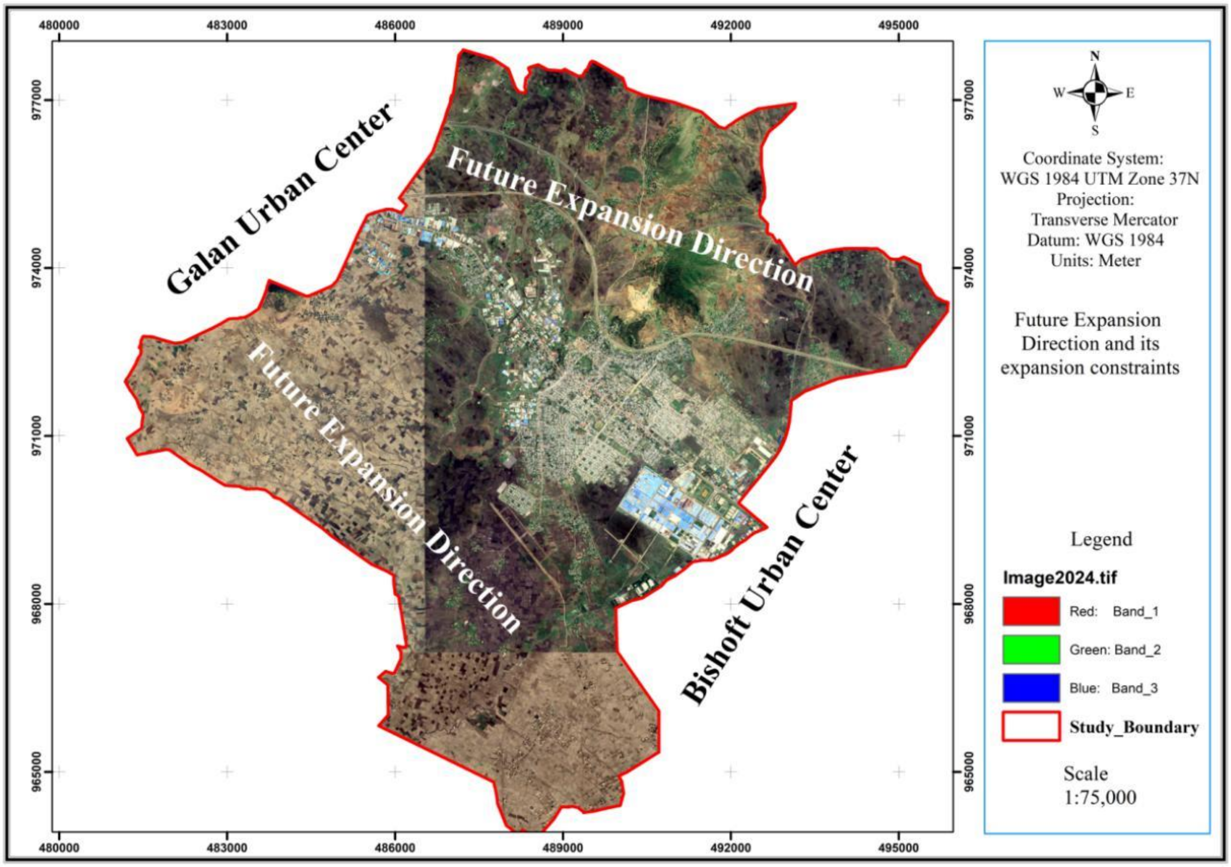


Figure 4.30: Future Expansion and Expansion Constraints of the town

4.6 Discussion of the Results

4.6.1 Trend of Expansion and Land use land covers (LULC) Change

As it is already known, Towns typically grow around permanent settlements that form near religious sites, government centers, or places of trade. This is exactly how Dukem came to be. Historical records show the town's founding is directly linked to the construction of the Djibouti-Addis Ababa railway in the late 1800s. Dukem's growth exploded after 1914 (according to OUPI). This study reveals the town's expansion pattern stretching northwest towards Addis Ababa and southeast towards Bishoftu, following the main road that connects to the eastern region. Since the early 2000s, Dukem has become a major industrial hub in the region and even the country, for instance, the establishment of the Eastern Industrial Zone (EIZ) in the town. This rapid growth has caused the town to spread significantly, even incorporating nearby rural villages.

Like other studies (Debela et al., 2020; Kumera & Woldetensae, 2023), this research showed a significant increase in the built-up area of the town. Between 1994 and 2024, this area expanded from 498 hectares (5%) to 3447 hectares (36%). This rapid growth meant that built-up areas were taking over large portions of other land types, such as agricultural land. Unfortunately, agricultural land decreased substantially during this period, declining from 6258 hectares (65%) in 1994 to 3889 hectares (40%) in 2024. This suggests that agricultural land was the primary source of land for urban expansion. Likewise, the trend of other categories varies increasing and decreasing at various, times.

Moreover, the built-up areas of the study town was increases in its spatial extent. Accordingly, the urban area of the town expanded significantly between 1994 and 2024. The annual growth rate was 7% from 1994 to 2004, 11% from 2004 to 2014, and 10% from 2014 to 2024. The most rapid expansion occurred between 2004 and 2014, driven by the conversion of surrounding agricultural land into valuable urban zones for housing and industry.

Many researches revealed that population growth contributed a lot for urban development. This research witnessed this in that as the population of the study town increases, so does its urban area. For instance, in 1994, when the population was 13,342, the built-up area covered 498 hectares. By 2004, the population had grown to 20,164, and the built-up area expanded to 842 hectares. This trend continued, with the population reaching 43,662 in 2014 and the built-up area increasing to 1765 hectares. In 2024, the population soared to 130,005, and the built-up area expanded to 3447 hectares. Projections for 2030 indicate that the population will further increase to 185,559, and the built-up area will reach 5015 hectares.

In addition, the study town witnessed a dramatic population growth. Between 1994 and 2004, its population grew by 51%. This growth accelerated over the next decade, increasing by a staggering 117% from 2004 to 2014. The trend continued, with an estimated 198% population increase from 2014 to 2024. Looking ahead, the town's population is projected to grow by an additional 43% between 2024 and 2030.

In parallel, the town's built-up area expanded significantly. It increased by 69% of the total land from 1994 to 2004, 110% from 2004 to 2014, and 95% from 2014 to 2024. Accordingly, the estimated built-up area is expected to grow by 45% between 2024 and 2030.

Another key issue of this research is the notion of the ratio of land consumption rate to that of population growth rate, which measures the efficiency of the utilized urban land. Accordingly, with the exception of the years 2014 to 2024, the ratio of Land Consumption Rate to Population Growth Rate (LCRPGR) has been consistently above one. This indicates that land is not being used efficiently, as ideal values for LCRPGR should be less than one; and hence, due considerations shall be given in managing urban land and controlling driving forces behind this land use land cover changes.

4.6.2 Driving Factors that contribute a lot for the Expansion of Dukem town

Dukem is a booming industrial hub attracting many residents who commute to the surrounding urban centers including the primate city, Addis Ababa. This rapid growth, fueled by its location near the capital, excellent transportation links, and surrounding farmland, has created a housing need.

The driving factors, were considered in this study as determinants of land use land cover change which take different forms but this study focused on Population growth, Investment potentials, Availability of basic infrastructure, location preferences of household, spatial and urban planning policies, Proximity of the town to the primate city, and biophysical specially topography of the town.

Accordingly, the survey result of the office employee revealed that most participants agreed with the identified factors causing land use and land cover changes. Specifically, a high percentage of respondents (around 92%) cited population growth as a major driver. Additionally, a significant number (approximately 90%) pointed to investment potential, infrastructure availability, and proximity to the primate city. Other factors, such as household location preferences, spatial and urban planning policies, and biophysical/topography, were considered less influential, with ratings of 73%, 60%, and 57%, respectively. Besides, in order to understand the feelings of the respondents, Descriptive analysis were used to analyze and quantify their perceptions. To examine deeper into the characteristics of these perceptions, measures of central tendency (mean, median, mode), dispersion (standard deviation, variance), and distribution (skewness) were analyzed. Consequently, most participants expressed strong agreement with the positive impact of the listed driving factors on land use and land cover change. Accordingly, all factors, with the exception of Biophysical/Topography, were rated favorably, with mean scores above 3.24. This suggests that respondents generally concur that these factors are the main drivers of the observed changes.

On the other hand, the survey result the community respondents revealed that most participants agreed with the identified factors causing land use and land cover changes. Particularly, a high percentage of respondents (around 91%) cited proximity to the primate city as a major driver. Additionally, infrastructure availability, investment potential, and population growth pointed a significant number approximately 88%, 83%, and 74% respectively. Other factors, such as household location preferences, spatial and urban planning policies, and biophysical/topography, were considered less influential, with ratings of 73%, 65%, and 57%, respectively. Similarly, descriptive analysis was used; and accordingly, most participants expressed strong agreement with the positive impact of the listed driving factors on land use and land cover change. Consequently, all factors, with the exception of Biophysical/Topography, were rated favorably, with mean scores above 3.27. This suggests that respondents generally agree that these factors are the main drivers of the observed changes.

In general, both community and office employees agreed on the listed key land use and land cover driving factors; and hence, they played a greater role growth of the town within the study town during the specific selected time frames.

4.6.3 Driving Actors that contribute a lot for the expansion of Dukem town

Land Use Land Cover Change (LUCC) is a complex process driven by, both natural and human induced. Among these factors, the role of various actors, ranging from individuals to governments, is particularly significant. These actors, through their decisions and actions, shape the landscape and influence the trajectory of LUCC (Wahyudi et al., 2019). For this study, private developers, government officials, experts, and local residents were identified as key actors influencing land use and land cover changes in the town.

To understand how office employees view the key actors to rapid land use and land cover changes in the study town from 1994 to 2024, a survey questionnaire were administered. This questionnaire asked respondents to rate four key actors—private developers, government officials, experts, and the local community—on a five-point Likert scale.

The survey result of the office respondents, accordingly revealed that, most office workers surveyed (93%) believe that private developers, local residents (78%), government officials (86%), and experts (88%) have been the primary drivers of rapid land use and land cover changes in the town between 1994 and 2024. Likewise, in the descriptive analysis, the mean score values of the respondents are above the neutral values in that almost all of them agree to the actors in contributing land use land cover change of the study town. Besides both the mode and the medians are also above the neutral values implying that all the respondents are strongly agree to the listed actors contributing to the changes observed within the study town within the stated study time frame.

Similarly, most community surveyed (76%) believed that private developers, local residents (72%), government officials (66%), and experts (62%) have been the primary drivers of rapid land use and land cover changes in the town between 1994 and 2024.

In general, the study found that private investors, government officials, experts, and the local community were the main drivers of rapid land use and land cover change in Dukem town between 1994 and 2024. This was discussed in detail in the analysis section of the study.

4.6.4 Future Expansion of Dukem town

Dukem town confronted high rapid increase in population due to investment potential of the town, its location advantage, availability of basic infrastructures, and its proximity to the primate city. According to (OUPI, 2017b), the population of the town is expected to be 171,653 by the year 2027. This study also revealed that the population of the town will reach 185,589 by the year 2030. This population growth in turn has direct impact on the built up area to be consumed by this population to need their basic needs.

Accordingly, Dukem town is growing quickly, especially along the main roads. According to this study result, the built up area of the town is expected to grow by 105% by 2030, reaching about 5,015 (increased by 2568 ha from 202) hectares. Additionally, the town's structure plan, which goes until 2027, has set the town's boundary at 9,653 hectares.

Generally, these all are the good indication of the future fate of urban expansion of the study town for the coming 2030 taking in to considerations the urban growth trends of the town.

CHAPTER FIVE

5 Conclusion and Recommendations

5.1 Conclusion

This research investigated how land use and land cover have changed in Dukem town between 1994 and 2024. It used remote sensing (RS) and geographic information systems (GIS) to analyze these changes and assess how efficiently the land is being used. The study also aimed to identify the key driving factors and actors that have influenced these changes as well as to assess the efficiency of the utilization of urban land. The findings of the research was summarized in this conclusion section, addressing the specific research questions.

Accordingly, this research showed a significant increase in the built-up area of the town. Between 1994 and 2024, this area expanded from 498 hectares (5%) to 3447 hectares (36%). This rapid growth meant that built-up areas were taking over large portions of other land types, such as agricultural land. Unfortunately, agricultural land decreased substantially during this period, declining from 6258 hectares (65%) in 1994 to 3889 hectares (40%) in 2024. This suggests that agricultural land was the primary source of land for urban expansion. Likewise, the trend of other categories varies increasing and decreasing at various, times.

Moreover, the built-up areas of the study town was increases in its spatial extent. Accordingly, the urban area of the town expanded significantly between 1994 and 2024. The annual growth rate was 7% from 1994 to 2004, 11% from 2004 to 2014, and 10% from 2014 to 2024. The most rapid expansion occurred between 2004 and 2014, driven by the conversion of surrounding agricultural land into valuable urban zones for housing and industry.

Many researches revealed that population growth contributed a lot for urban development. This research witnessed this in that as the population of the study town increases, so does its urban area. For instance, in 1994, when the population was 13,342, the built-up area covered 498 hectares. By 2004, the population had grown to 20,164, and the built-up area expanded to 842 hectares. This trend continued, with the population reaching 43,662 in 2014 and the built-up area increasing to 1765 hectares. In 2024, the population soared to 130,005, and the built-up area expanded to 3447 hectares. Projections for 2030 indicate that the population will further increase to 185,559, and the built-up area will reach 5015 hectares.

In addition, the study town witnessed a dramatic population growth. Between 1994 and 2004, its population grew by 51%. This growth accelerated over the next decade, increasing by a staggering 117% from 2004 to 2014. The trend continued, with an estimated 198% population increase from 2014 to 2024. Looking ahead, the town's population is projected to grow by an additional 43% between 2024 and 2030.

In parallel, the town's built-up area expanded significantly. It increased by 69% of the total land from 1994 to 2004, 110% from 2004 to 2014, and 95% from 2014 to 2024. Accordingly, the estimated built-up area is expected to grow by 45% between 2024 and 2030.

Another key issue of this research is the notion of the ratio of land consumption rate to that of population growth rate, which measures the efficiency of the utilized urban land. Accordingly, with the exception of the years 2014 to 2024, the ratio of Land Consumption Rate to Population Growth Rate (LCRPGR) has been consistently above 1. This indicates that land is not being used efficiently, as ideal values for LCRPGR should be less than 1; and hence, due considerations shall be given in managing urban land and controlling driving forces behind this land use land cover changes.

Above all, the driving factors and actors that played greater roles in land use and land cover change in the study town were identified by this study. among the driving factors the main ones includes Population growth, Investment potentials, Availability of basic infrastructure, location preferences of household, spatial and urban planning policies, Proximity of the town to the primate city, and biophysical specially topography of the town while the identified driving actors are private developers, government officials, experts, and local residents.

Finally, it is witnessed by the study that Dukem town confronted high rapid increase in population due to investment potential of the town, its location advantage, availability of basic infrastructures, and its proximity to the primate city. Accordingly, the population of the town will reach 185,589 by the year 2030, which in turn has direct impact on the built up area to be consumed by this population to need their basic needs.

Besides, Dukem town is growing quickly, especially along the main roads, and according to this study result, the built up area of the town is expected to grow by 105% by 2030, reaching about 5,015 (increased by 2568 ha from 202) hectares. Additionally, the town's structure plan, which goes until 2027, has set the town's boundary at 9,653 hectares.

5.2 Recommendations

In light of the research, questions and findings related to the challenges of rapid land use/cover change and the pursuit of improved land use efficiency, the following recommendations have been formulated.

1. **Monitor and Evaluate Land Use Change:** Conduct regular land use/land cover change assessments using remote sensing and GIS techniques to track urban growth patterns and identify emerging trends by establishing a Land Use Information System and Evaluate the Effectiveness of Policies. In so doing, regularly evaluate the effectiveness of urban planning policies and make necessary adjustments to ensure they are achieving their intended goals. Furthermore, it is crucial to implement measures to protect green spaces, agricultural land, and other natural resources from urban encroachment; and develop strategies to mitigate the environmental impacts of urban growth.
2. **Improve Land Use Efficiency**: Establish and enforce building codes and regulations to encourage the efficient use of land and minimize environmental impacts. This could include regulations on building height, density, and setbacks; encourage the development of denser, more compact urban forms to minimize urban sprawl and reduce the need for extensive infrastructure development. Encourage the development of mixed-use areas that integrate residential, commercial, and recreational spaces to increase land use efficiency and reduce the need for long-distance travel. Develop a Comprehensive and Updated Structure Plan to accommodate the projected growth until 2030 and beyond. This plan should incorporate realistic population projections, land use zoning regulations, and infrastructure development plans. Furthermore, provide training and capacity-building programs for local planners and officials on urban planning, land use management, and sustainable development principles.
3. **Address the Driving Factors and Actors of Urban Growth:**

   Implement sustainable population growth strategies, including family planning programs and promoting economic opportunities in surrounding rural areas to manage population growth; Develop policies and incentives to discourage urban sprawl and promote development within existing urban boundaries to control urban sprawl; and involve local communities in the urban planning process to ensure that their needs and concerns.

Besides, enhance coordination and collaboration between government agencies, private developers, and local communities to ensure that urban development is planned and implemented effectively as well as Increase their accountability.

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Annexes

Annex I: Questionnaires for Government officials, Kebele administrators and Experts

Survey date_________ Survey place_______ who collected the survey______________

Dear Respondent:

The main aim of this questionnaire is to collect data as input for the study titled "Analysis of the Trends of Land Use Land Cover Change and its Management: the case of Dukem Town, Oromia Regional State". The purpose is to qualify the requirement for awarding the Master of Science (MSc.) in Urban Planning at EiABC Addis Ababa University. Therefore, you are expected to provide genuine and accurate information with respect to the factors that contributed a lot for rapid land use and land cover change Dukem town.

Thank you!

Part I: Background of the Respondents

1. Address: 1. Gogecha ☐ 2. Koticha ☐ 3. Tedecha ☐ 4. Malka Dukam ☐
2. Gender: 1. Male ☐ 2. Female ☐
3. Age: 1. 18-30 ☐ 2. 31-40 ☐ 3. 41-50 ☐ 4. 51-60 ☐ 5. 61 and above ☐
4. Education Level: 1. 1-8 ☐ 2. 9-12 ☐ 3. Higher Diploma ☐ 4. First Degree ☐ 5. Masters and Above ☐
5. Qualification: 1. Urban Planner ☐ 2. Urban Land Administration ☐ 3. Urban Management ☐ 4. Surveyor ☐ 5. Economist ☐ 6. Management ☐ 7 Engineer 8. Sociologist ☐ 9 Geologist ☐ 10. Others Specify ___________________________
6. Work Place: 1. land development and management office of the town ☐ 2. Gogecha ☐ 3. Koticha ☐ 4. Tedecha ☐ 5. Malka Dukam ☐
7. Position: 1. Office Manager ☐ 2. Deputy Manger ☐ 3. Kebele Administrator ☐ 4. Deputy Kebele Administator ☐ 5. Site supervisor ☐ 6. Experts ☐ 7. Others_______
8. Service year: 1. below 10 ☐ 2. 10-15 ☐ 3. Above 15 ☐

Part II: Factors that contributed for the rapid land use and land cover change in Dukem Town

9. What do you think on the following factors that contributed a lot for the rapid land use and land cover change Dukem town between 1994 and 2024?

Key Factors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Population Growth					
Investment potentials of the town					
Availability of basic infrastructure					
Location preferences of household					
Spatial and Urban planning policies					
Proximity of the town to the primate city					
Biophysical specially topography of the town					

10. What are some other significant factors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?

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Part III: Key Actors who contributed for the rapid land use and land cover change in Dukem Town

11. What do you think on the following key actors who contributed a lot for the rapid land use and land cover change in Dukem town between 1994 and 2024?

Key Actors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Private developers					
Government officials					
Experts					
Local community					

12. What are some other significant actors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?

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____
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Annex II: Questionnaires for the Respondent Community

Survey date_________ Survey place_______ who collected the survey_ _____________

Dear Respondent:

The main aim of this questionnaire is to collect data as input for the study titled "Analysis of the Trends of Land Use Land Cover Change and its Management: the case of Dukem Town, Oromia Regional State". The purpose is to qualify the requirement for awarding the Master of Science (MSc.) in Urban Planning at EiABC Addis Ababa University. Therefore, you are expected to provide genuine and accurate information with respect to the factors that contributed a lot for rapid land use and land cover change Dukem town.

Thank you!

Part I: Background of the Respondents

1. Address: 1. Gogecha ☐ 2. Koticha ☐ 3. Tedecha ☐ 4. Malka Dukam ☐
2. Gender: 1. Male ☐ 2. Female ☐
3. Age: 1. 18-30 ☐ 2. 31-40 ☐ 3. 41-50 ☐ 4. 51-60 ☐ 5. 61 and above ☐
4. Birth Place: 1. Dukam Town ☐ 2. Out Side the town ☐
5. Education Level: 1. Illiterate ☐ 2. Read and Write ☐ 3. 1-8 ☐ 3. 9-12 ☐
   4. Higher Diploma ☐ 5. First Degree ☐ 6. Masters and Above ☐
6. Occupation: 1. Private ☐ 2. Public Employee ☐ 3. Stay Home ☐ 4. Unemployed ☐
   5. Retired ☐ 6. Farmer ☐ 7. Others_______

Part II: Factors that contributed for the rapid land use and land cover change in Dukem Town

7. What do you think on the following factors that contributed a lot for the rapid land use and land cover change Dukem town between 1994 and 2024?

Key Factors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Population Growth					
Investment potentials of the town					
Availability of basic infrastructure					
Location preferences of household					
Spatial and Urban planning policies					
Proximity of the town to the primate city					
Biophysical specially topography of the town					

8. What are some other significant factors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?

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____
____.

Part III: Key Actors who contributed for the rapid land use and land cover change in Dukem Town

9. What do you think on the following key actors who contributed a lot for the rapid land use and land cover change in Dukem town between 1994 and 2024?

Key Actors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Private developers					
Government officials					
Experts					
Local community					

10. What are some other significant actors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?

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____.

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Annex III. Questionnaires for Office Employees in Afan Oromo Language

Gaaffilee Hojjettota Mootummaa, Bulchitoota Gandaa fi Ogeessotaa Magaalaa Dukamiif

Guyyaa gaaffii ____________Bakka gaaffii______________ Maqaa Gaafataa_____________

Kabajamtoota Yaada Laatan Hundaaf:

Dhimmi ijoon gaaffii kanaa qorannoo mata dureen isaa ''Analysis of the Trends of Land Use Land Cover Change and its Management: the case of Dukem Town, Oromia Regional State'' jedhuuf odeffannoo fayyadu funaanuufiidha. Sababni inni barbaachiseefis barumsa digrii lammaffaa (Maastersii) Yuunivarsiitii Finfinnerraa gosa barnootaa Pilaanii Magalaatiin (Urban Planning) eebbifamuuf ta"uu isaa isin beeksisa. Kanaafuu, deebiin isin laattan dhimma barumsaa qofaaf waan barbaadameef, Sababoota babal"ina magaalaa dukamiif gumaacha taasisan irratti, deebii haqaa fi qabatamaa ta"e akka laattan kabajaan isin gaafadha.

Galatoomaa!

Kutaa I: Seenaa Duubbee Deebii kennitootaa

1. Teessoo: 1. Gogecha ☐ 2. Koticha ☐ 3. Tedecha ☐ 4. Malkaa Duukam ☐
2. Saala: 1. Dhiira ☐ 2. Dhalaa ☐
3. Umurii: 1. 18-30 ☐ 2. 31-40 ☐ 3. 41-50 ☐ 4. 51-60 ☐ 5. 61 oli ☐
4. Sadarkaa Barnootaa: 1. 1-8 ☐ 2. 9-12 ☐ 3. Diploomaa ☐
   4. Digrii Jalqabaa ☐ 5. Mastersii fi isaa oli ☐
5. Ulaagaa Barnootaa: 1. Pilaanera Magaalaa ☐ 2Bulchiinsa Lafa Magaalaa ☐ 3. Manajimentii Laffaa ☐ 4. Qiyya ☐ 5. Ikonod ☐ ii 6. Man ☐ entii 7 Injiinera 8. Sosholoojistii ☐ 9 Geolojist ☐ 10. Kan Biraa ____________________
6. Bakka Hojii: 1. Waajjira Misoomaa fi Manajimentii Magaalaa Duukam ☐ 2. Gogecha 3. Koticha ☐ 4. Tedecha ☐ 5. Malka Dukam ☐
7. Gita Hojii: 1. Manajera ☐ 2. I/Aanaa Manajera ☐ 3. Bulchaa Ganda ☐ 4I/Aanaa Bulchaa Gandaa ☐ 5. Supervaasera Dir ☐ 6. (☐ ssa ☐ 7. Han Biraaa_______
8. Bara Tajaajilaa: 1. 10 gadi ☐ 2. 10-15 ☐ 3. 15 ol

Kutaa II: Sababoota jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif Gumaacha Taasisan

9. Sababoota jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif gumaacha taasisan keessattuu, Bara 1994 kaasee hanga Bara 2024 tti tarreeffaman armaan gadii keessaa isa kamtu irra caalaatti sababa ta'a jette yaadda?

Sababota Ijoo	Eeyyeen Sirriitti (5)	Eeyyeen (4)	Hin Murteessine (3)	Miti (2)	Gonkumaa Miti (1)
Guddina Baayʻina Ummataa					
Carraa Investimentii					
Jiraachuu Bu'uuraalee Misoomaa					
Filannoo Bakka Jireennyaa Uummataa					
Imaammata Karrora Misooma Magaalaa					
Finfinneef Dhiheynaairrati Argamu					
Teessuma Lafa Magaalichaa					

10. Yaada dabalataa yoo qabaatteef bakka duwwaa arman gadii irrati barreesi

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Kutaa III: Qaamota Ijoo/Key Actors jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif Gumaacha Taasisan

11. Qaamota Ijoo jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif gumaacha taasisan keessattuu, bara 1994 kaasee hanga bara 2024 tti tarreeffaman armaan gadii keessaa isa kamtu irra caalaatti gaʻee guddaa taphate jette yaadda?

Key Actors	Eeyyeen Sirriitti (5)	Eeyyeen (4)	Hin Murteessine (3)	Miti (2)	Gonkumaa Miti (1)
Misoomsitoota Dhuunfaa					
Qondaaltota mootummaa					
Ogeeyyii					
Hawaasa Naannoo					

12. Yaada dabalataa yoo qabaatteef bakka duwwaa arman gadii irrati barreesi

____

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____.

Annex IV. Gaaffilee hawaasa Deebii kennaniif Afaan Oromootiin

Guyyaa gaaffii ____________Bakka gaaffii______________ Maqaa Gaafataa_____________

Kabajamtoota Yaada Laatan Hundaaf:

Dhimmi ijoon gaaffii kanaa qorannoo mata dureen isaa "Analysis of the Trends of Land Use Land Cover Change and its Management: the case of Dukem Town, Oromia Regional State" jedhuuf odeffannoo fayyadu funaanuufiidha. Sababni inni barbaachiseefis barumsa digrii lammaffaa (Maastersii) Yuunivarsiitii Finfinnerraa gosa barnootaa Pilaanii Magalaatiin (Urban Planning) eebbifamuuf ta‟uu isaa isin beeksisa. Kanaafuu, deebiin isin laattan dhimma barumsaa qofaaf waan barbaadameef, Sababoota babal‟ina magaalaa dukamiif gumaacha taasisan irratti, deebii haqaa fi qabatamaa ta‟e akka laattan kabajaan isin gaafadha.

Galatoomaa!

Kutaa I: Seenaa Duubbee Deebii kennitootaa

1. Teessoo: 1. Gogecha ☐ 2. Koticha ☐ 3. Tedecha ☐ 4. Malkaa Duukam ☐
2. Saala: 1. Dhiira ☐ 2. Dhalaa ☐
3. Umurii: 1. 18-30 ☐ 2. 31-40 ☐ 3. 41-50 ☐ 4. 51-60 ☐ 5. 61 oli ☐
4. Sadarkaa Barnootaa:1. Hibaranne ☐ 2. Dubbisuu fi Barreessuu ☐ 3. 1-8 ☐ 4. 9-12 ☐
   5. Diploomaa ☐ 6. Digrii Jalqabaa ☐ 7. Mastersii fi isaa oli ☐
5. Bakka Dhalootaa: 1. Magaalaa Duukam ☐ 2. Duukamii ala ☐
6. Hojiii: 1. Dhuunfaa ☐ 2. Hojjetaa Mootum ☐ 3. Man ☐ raa 4. Hoji ☐ Dhabeeyyii
   5. Sooroma Ba'e ☐ 6. Qonnaan Bulaa ☐ 7. Kan Biraa_______

Kutaa II: Sababoota jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif Gumaacha Taasisan

7. Sababoota jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif gumaacha taasisan keessattuu, Bara 1994 kaasee hanga Bara 2024 tti tarreeffaman armaan gadii keessaa isa kamtu irra caalaatti sababa ta'a jette yaadda?

Sababota Ijoo	Eeyyeen Sirriitti (5)	Eeyyeen (4)	Hin Murteessine (3)	Miti (2)	Gonkumaa Miti (1)
Guddina Baay'ina Ummataa					
Carraa Investimentii					
Jiraachuu Bu'uuraalee Misoomaa					
Filannoo Bakka Jireennyaa Uummataa					
Imaammata Karrora Misooma Magaalaa					
Finfinneef Dhiheynaairrati Argamu					
Teessuma Lafa Magaalichaa					

8. Yaada dabalataa yoo qabaatteef bakka duwwaa arman gadii irrati barreesi

____
____
____________________________________.

Kutaa III: Qaamota Ijoo/Key Actors jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif Gumaacha Taasisan

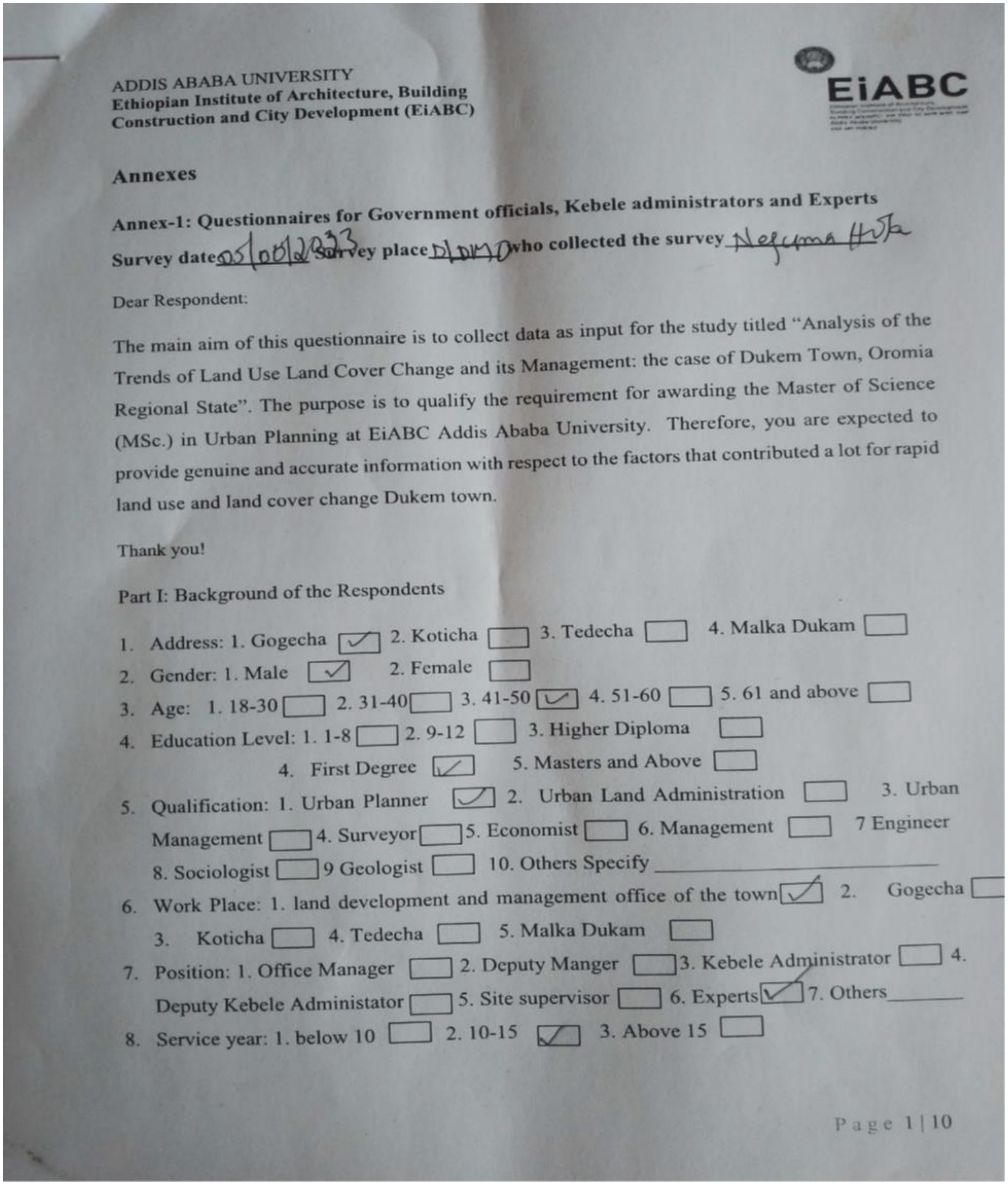
9. Qaamota Ijoo jijjiirama itti fayyadama fi uwwisa lafaa Magaalaa Dukamiif gumaacha taasisan keessattuu, bara 1994 kaasee hanga bara 2024 tti tarreeffaman armaan gadii keessaa isa kamtu irra caalaatti ga'ee guddaa taphate jette yaadda?

Key Actors	Eeyyeen Sirriitti (5)	Eeyyeen (4)	Hin Murteessine (3)	Miti (2)	Gonkumaa Miti (1)
Misoomsitoota Dhuunfaa					
Qondaaltota mootummaa					
Ogeeyyii					
Hawaasa Naannoo					

10. Yaada dabalataa yoo qabaatteef bakka duwwaa arman gadii irrati barreesi

____
____
____.

Annex V: Example of properly attempted survey questionnaire



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Annexes

Annex-1: Questionnaires for Government officials, Kebele administrators and Experts

Survey date 05/06/2023 **Survey place** DLDMO **who collected the survey** Nejuma Huka

Dear Respondent:

The main aim of this questionnaire is to collect data as input for the study titled "Analysis of the Trends of Land Use Land Cover Change and its Management: the case of Dukem Town, Oromia Regional State". The purpose is to qualify the requirement for awarding the Master of Science (MSc.) in Urban Planning at EiABC Addis Ababa University. Therefore, you are expected to provide genuine and accurate information with respect to the factors that contributed a lot for rapid land use and land cover change Dukem town.

Thank you!

Part I: Background of the Respondents

1. Address: 1. Gogecha [✓] 2. Koticha [ ] 3. Tedecha [ ] 4. Malka Dukam [ ]
2. Gender: 1. Male [✓] 2. Female [ ]
3. Age: 1. 18-30 [ ] 2. 31-40 [ ] 3. 41-50 [✓] 4. 51-60 [ ] 5. 61 and above [ ]
4. Education Level: 1. 1-8 [ ] 2. 9-12 [ ] 3. Higher Diploma [ ] 4. First Degree [✓] 5. Masters and Above [ ]
5. Qualification: 1. Urban Planner [✓] 2. Urban Land Administration [ ] 3. Urban Management [ ] 4. Surveyor [ ] 5. Economist [ ] 6. Management [ ] 7 Engineer 8. Sociologist [ ] 9 Geologist [ ] 10. Others Specify ____________
6. Work Place: 1. land development and management office of the town [✓] 2. Gogecha [ ] 3. Koticha [ ] 4. Tedecha [ ] 5. Malka Dukam [ ]
7. Position: 1. Office Manager [ ] 2. Deputy Manger [ ] 3. Kebele Administrator [ ] 4. Deputy Kebele Administator [ ] 5. Site supervisor [ ] 6. Experts [✓] 7. Others______
8. Service year: 1. below 10 [ ] 2. 10-15 [✓] 3. Above 15 [ ]

Page 1 | 10

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Part II: Factors that contributed for the rapid land use and land cover change in Dukem Town

9. What do you think on the following factors that contributed a lot for the rapid land use and land cover change Dukem town between 1994 and 2024?

Key Factors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Population Growth	✓				
Investment potentials of the town	✓				
Availability of basic infrastructure		✓			
Location preferences of household		✓			
Spatial and Urban planning policies		✓			
Proximity of the town to the primate city		✓			
Biophysical specially topography of the town			✓		

10. What are some other significant factors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?

Private developers play a greater role in land use and land cover change in Dukem town.

Part III: Key Actors who contributed for the rapid land use and land cover change in Dukem Town

11. What do you think on the following key actors who contributed a lot for the rapid land use and land cover change in Dukem town between 1994 and 2024?

Key Actors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Private developers	✓				
Government officials	✓				
Experts		✓			
Local community		✓			

12. What are some other significant actors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?

Land speculation is another factors in contributing land use and land cover change in our town.

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Annex II: Questionnaires for the Respondent Community

Survey date 25/06/2023 **Survey place** Dukem **Who collected the survey** [illegible]

Dear Respondent:

The main aim of this questionnaire is to collect data as input for the study titled "Analysis of the Trends of Land Use Land Cover Change and its Management: the case of Dukem Town, Oromia Regional State". The purpose is to qualify the requirement for awarding the Master of Science (MSc.) in Urban Planning at EiABC Addis Ababa University. Therefore, you are expected to provide genuine and accurate information with respect to the factors that contributed a lot for rapid land use and land cover change Dukem town.

Thank you!

Part I: Background of the Respondents

1. Address: 1. Gogecha [✓] 2. Koticha [ ] 3. Tedecha [ ] 4. Malka Dukam [ ]
2. Gender: 1. Male [ ] 2. Female [✓]
3. Age: 1. 18-30 [ ] 2. 31-40 [ ] 3. 41-50 [✓] 4. 51-60 [ ] 5. 61 and above [ ]
4. Birth Place: 1. Dukam Town [✓] 2. Out Side the town [ ]
5. Education Level: 1. Illiterate [ ] 2. Read and Write [ ] 3. 1-8 [✗] . 9-12 [✓]
   4. Higher Diploma [ ] 5. First Degree [ ] 6. Masters and Above [ ]
6. Occupation: 1. Private [✓] 2. Public Employee [ ] 3. Stay Home [ ] 4. Unemployed [ ]
   5. Retired [ ] 6. Farmer [ ] 7. Others_______

Page 3 | 10

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Part II: Factors that contributed for the rapid land use and land cover change in Dukem Town

7. What do you think on the following factors that contributed a lot for the rapid land use and land cover change Dukem town between 1994 and 2024?

Key Factors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Population Growth	✓				
Investment potentials of the town	✓				
Availability of basic infrastructure	✓				
Location preferences of household		✓			
Spatial and Urban planning policies		✓			
Proximity of the town to the primate city			✓		
Biophysical specially topography of the town					✓

8. What are some other significant factors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?
Land grabing is another contributer factor.

Part III: Key Actors who contributed for the rapid land use and land cover change in Dukem Town

9. What do you think on the following key actors who contributed a lot for the rapid land use and land cover change in Dukem town between 1994 and 2024?

Key Actors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Private developers	✓				
Government officials	✓				
Experts	✓				
Local community				✓	

10. What are some other significant actors that have greatly influenced the rapid changes in land use and land cover within Dukem town between 1994 and 2024 if any?
Land speculation is another contributing factors for the changes.

Annex VI: Observed Changes

Assessing the Efficiency of Urban Land Utilization: The Case of Dukem Town, Oromia Regional State

[1]Neguma Hika & [2]Birhanu Girma

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   Author: hikaneguma@gamil.com
2. Associate Professor, Ethiopian Institute of Architecture, Building Construction and City Development, Addis Ababa University.

Advisor: birhanu.girma@eiabc.edu.et
Addis Ababa University
Addis Ababa, Ethiopia

ABSTRACT

Projections indicate a substantial increase in global population by 2050, necessitating increased land area for residential, production, and service infrastructure. This demographic pressure will inevitably drive alterations in land use patterns and cover, affecting both urban and rural environments. This study aimed to assess the land use efficiency in Dukem Town. The primary data sources were gathered by means of questionnaires and secondhand data sources were gathered from reports, legal documents, previous study documents, and socio-economic data as well as satellite images. The study reveals a discrepancy between land consumption and population growth rates, with the former exceeding the latter in most periods. This indicates inefficient land use, diverging from the optimal scenario where land consumption should ideally lag behind population growth. To enhance land use efficiency, the research emphasizes the need for effective urban land management strategies and addressing the underlying drivers of land use change. The objective is to achieve a land consumption-to-population growth ratio below unity.

Key Words: *inefficient land use, Population Growth Rate, Land Consumption Rate, ratio of land consumption rate to population growth rate (LCRPGR)*

1. Introduction

The world has experienced in using more land consumption per capita. The population of cities in less developed countries doubled between 1990 and 2015, and their urban extents increased on average by a factor of 3.5. In developed countries, however, the population of cities was increased by a factor of 1.2 between the same year; and their urban extents increased by a factor of 1.8 (Angel et al., 2016).

The same document suggested that between 2015 and 2050 urban extents in less developed countries will increase by a factor of 3.7 at the current rate of increase in land consumption, by a factor of 2.5 at half the current rate, and by a factor of 1.8 if land consumption remains constant (Angel et al., 2016). Accordingly, substantial changes have been taken place in land use patterns globally. About 1.2 million km^2 of forest and woodland and 5.6km^2 of grassland and pastures have been covered to the other uses (Ahlqvist et al., 2017).

Even though the world's population growth rate is not uniform (much of the population growth in the recent past has occurred in the Global South), Global population is projected to reach 9.6 billion in 2050 out of which 66% is expected to be urban population (Cai et al., 2020; Trevor et al., 2015; UNCCD, 2017 , p.226). This population increase/ population growth must be expected to play a major role in explanations of land use/cover change as these population need areas for residences, productions; and they need basic services to improve their daily lifestyles. To provide them such services there must be a change of the uses of the land or modifying on some parts of the uses of the land and land cover as well.

Consequently, accurate and timely information on land cover changes is essential for comprehending and assessing their environmental ramifications (Lambin, 2006). The ongoing need for up-to-date land use and land cover data is vital for any sustainable development program, as it serves as a primary input criterion.

Lastly, the following particular aim is considered in order to acquire the accurate findings:

- To assess the efficiency of urban land utilization in Dukam town from 1994 to 2024 based on the available collected data.

2. Literature Review

In the analysis of land use and land cover change, it is important to conceptualize the meaning of change to identify it in real world circumstances. In simple, land use and land cover change means change in the areal extent (increases or decreases) of a given type of land use or land cover, respectively (Gondwe et al., 2021). The ability to detect and measure changes depends on the level of detail observed. Higher levels of detail allow for the detection and recording of more significant changes in land use and land cover area.

Two types of changes have been conceptualized in both cases (land cover and land use) by relevant literature: conversion and modification as (Briassoulis, 2020a , p.17; Liping et al., 2018). Both developed and developing countries are experiencing rapid land consumption, especially in their expanding urban areas. Therefore, it is crucial to have up-to-date information on current land use and the ability to track how it changes over time (UN-Habitat, 2018c). Land cover is constantly changing due to population growth and natural forces. Essentially, all land today has been significantly altered by human activity. A key indicator of this change, used to track progress towards the 2030 Sustainable Development Goals, is the ratio of land consumption rate to population growth rate. Specifically, Sustainable Development Goal indicator 11.3.1 measures urban land use efficiency by comparing the rate at which cities expand spatially to their population growth rate (Biswajeet & Serdang, 2017; UN-Habitat, 2018a). Generally, compact cities tend to be more efficient. They use land better, making it cheaper to provide public services. They also typically consume less energy, handle waste more effectively, and benefit more from economic clustering compared to sprawling, less dense cities.
Precisely the notion of land consumption and population growth is expressed as:

> *"Land consumption is the uptake of land by urbanized land uses, which often involves conversion of land from other uses to urban functions. Land use consumption rate is the rate at which land occupied by urban area changes during a period, expressed as a percentage of the land occupied by the urban area at the start of that time. Furthermore, Population growth rate is the rate at which population size changes in a country during a period, usually one year, expressed as a percentage of the population at the start of that period (*UN-Habitat, 2018c*;* Zhang et al., 2020*)".*

The cited notions can farther be represented by the following formula to measure land consumption to population growth rate, and in so doing to check the efficient utilization of the scares natural resource, the land.

$$LCR = \frac{(LN(Urb(t2)/Urb(t1)\,)}{(y)};\ Where$$

Urbt1 is the total area covered by the urban area in the initial year *t1*;

Urbt2 is the total area covered by the urban area in the final year *t2*; and y is the number of years between the two measurement periods (*t1* and *t2*)

$$PCR = \frac{(LN(Pop(t2)/Pop(t1)\,)}{(y)};\ Were$$

Popt1 is the total population within the urban area in t1 (initial year)

Popt2 is the total population within the urban area in t2 (final year); and y is the number of years between the two measurement periods.

Furthermore, the final indicator, land consumption rate to population growth rate (LCRPGR), is computed by dividing the calculated land consumption and population growth rates as (Zhang et al., 2020, p. 7)

$$LCRPGR = \frac{(Annual\ Land\ Consumption\ rate\ )}{(Annual\ Population\ growth\ rate)}$$

In general. a compact, walkable city thrives by placing activities and services within easy reach of residents. This approach reduces infrastructure costs and the expense of providing essential services. It also helps protect surrounding land for other uses, benefiting the environment. Efficient land use is key, and a Land Consumption Rate per population growth rate (LCRPGR) of less than one indicates such efficiency. Conversely, an LCRPGR above one suggests land is not being used effectively (DASHTI, 2022 , p.20; UN-Habitat, 2018a). According to (Biswajeet & Serdang, 2017), the value of LCRPGR fall in the range of −1 to 1, where 0 indicates moderate conditions; a positive value reflects higher built-up area consumption per capita; and a negative value indicates population crowding, which may result in serious negative effect at the social, economic, and urban levels.

3. Materials and Methods

3.1 Study Area Description

Dukem town is located at 37km Southeast of Addis Ababa along the main road to Adama. Geographically, the study area located by latitude $8^0$45'25''N-$8^0$50'30"N and longitude $38^0$51'55"E - $38^0$56'5" E covering a total area of 9,953 hectare; and located at an average altitude of 2100m above sea level (OUPI, 2017a). The town is bordered by the towns of Bishoftu and Gelan in the Southeast and most of the north, respectively.

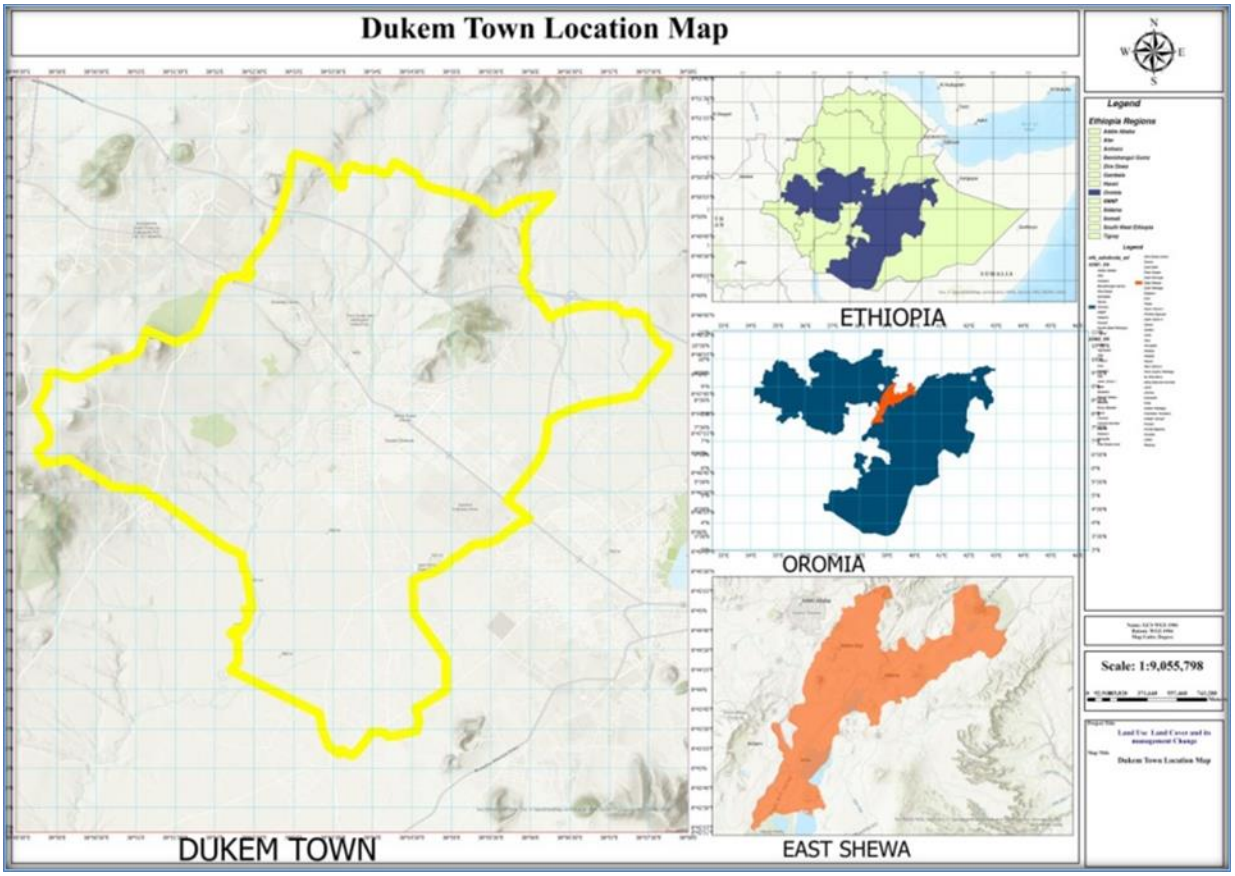

Figure 1: Location Map of the Study area

1.1 Data Collection, Analysis, and Methods

This study used a survey approach in collecting primary data through questionnaires. Participants assessed their perceptions of contributing factors and actors on a five-point Likert scale. Secondary data was obtained from reports, court records, past research, and socioeconomic data. Data analysis involved using SPSS 25 and Excel software to calculate mean, mode, median, and standard deviation. Both descriptive and inferential statistical methods were applied. The findings were presented through tables, graphs, and descriptive analyses.

1.2 Methods

The activities undertaken in this portion included the acquisition of satellite imagery for the years 1994, 2004, 2014, and 2024. Subsequent to image prepossessing, image classification (Mason, 2016, p. 91) was performed to generate categorical maps. Accuracy assessment (Campbell & Wynne, 2011; Congalton & Green, 2009; Jeffrey et al., 2024; Jensen, 2015, p. 558; KNUDBY, 2012, p. 70; Richards, 2013), was conducted to evaluate the classification results. Furthermore, land use and land cover change detection(Wiley & Sons, 2015); (Kindu et al., 2013; Mulatu et al., 2024) and spatial expansion analysis(UN-Habitat, 2018b were carried out.

1.3 Sampling Techniques

A non-random, purposive sampling technique was employed to select participants. For employees, the researcher prioritized those with more years of service to capture a range of experiences. For community members, he focused on individuals who had resided in Dukem for at least 15 years, as they were considered more likely to provide detailed information about the town's evolution over time. Consequently, a total of 483 respondents were considered for the poll, including 99 office workers and 384 residents of the town.

Accordingly, out of the intended 483 participants (99 office staff and 384 community members) from each local area (kebele), 436 individuals (89 office staff and 347 community members) were successfully interviewed. To maintain data accuracy, the researcher focused on interviewing individuals with more experience, higher education, and relevant job experience within the Dukem town land development and management office and local communities.

Consequently, all 436-survey participants completed the closed-ended survey questions correctly. Additionally, 106 of them (50 office workers and 56 community members) also provided answers to the open-ended questions.

1.4 Study Variables and Measuring Methods

The specific types of variables utilized in this research, alongside with their associated analytical methodologies and measurement techniques, are comprehensively outlined in Table 1 below**.**

Table 1: Types of Variables and their Measuring techniques

No	Variables	Types of variables	Measuring Techniques
1	Address, Gender, Age, Birth place, Level of educations, Qualification background, Occupation, Work place, Work position and Year of services	Independent	Descriptive statistics graphs were used
2	Population Growth	Independent	Ranked data with five points of Likert scales from strongly agree to strongly disagree used and Descriptive statistics were used to describe their results were used
	Investment Potentials		
	Availability of basic infrastructure		
	Location preferences of household		
	Spatial and urban planning policies		
	Proximity of the town to the primate city		
	Biophysical specially topography of the town		
3	Private developers,	Independent	Ranked data with five points of Likert scales from strongly agree to strongly disagree were used and Descriptive statistics were used to describe their results
	Government officials,		
	Experts,		
	Local Community/residents,		
4	LULC	Dependent	Map, graphs and charts were used
5	Rate of change	Independent	Graphs and charts were used

4. Results

4.1 Estimation of Population for the year 2030

To estimate the population size, it is necessary to calculate the town's population growth rate. This growth rate can be estimated using three different scenarios: high, medium, and low, depending on various factors affecting population growth. Using this method, the annual growth rate of Dukam town was calculated to be 5.93% (CSA, 1994-2007, customized by Oromia Urban

Planning Institute). This rate is higher than the annual growth rate of 4.13% for the entire Oromia urban area (CSA, 1994-2007).

This study considered three different growth rate scenarios for the period 2024-2030: a high growth rate of 6.93%, a medium growth rate of 5.93%, and a low growth rate of 4.93%. These growth rates were calculated using as detailed in Table 4.22.

Table 2: Estimated Population size of Dukem Town for 2030

Projection Variants	Growth Rates	Base Year Population	Estimated Population
		2024	2030
High	6.93	130,005	197,033
Medium	5.93	130,005	185,559
Low	4.93	130,005	174,753

As presented in the above (Table 2), in 2030 the population of the town will be varying between 174,753 and 197,033 when the population growth rate varies from the lower to highest variants respectively. Therefore, the population of the town assumed to grow at the average (medium variant) growth rate per annum during 2024-2030 because the town has many pulling factors for high in migration rate. In the view, Dukem town will be expected to reach about an average of 185,559 populations by the year 2030. Accordingly, Figure 2 below presented the population growth trend for the selected study periods.

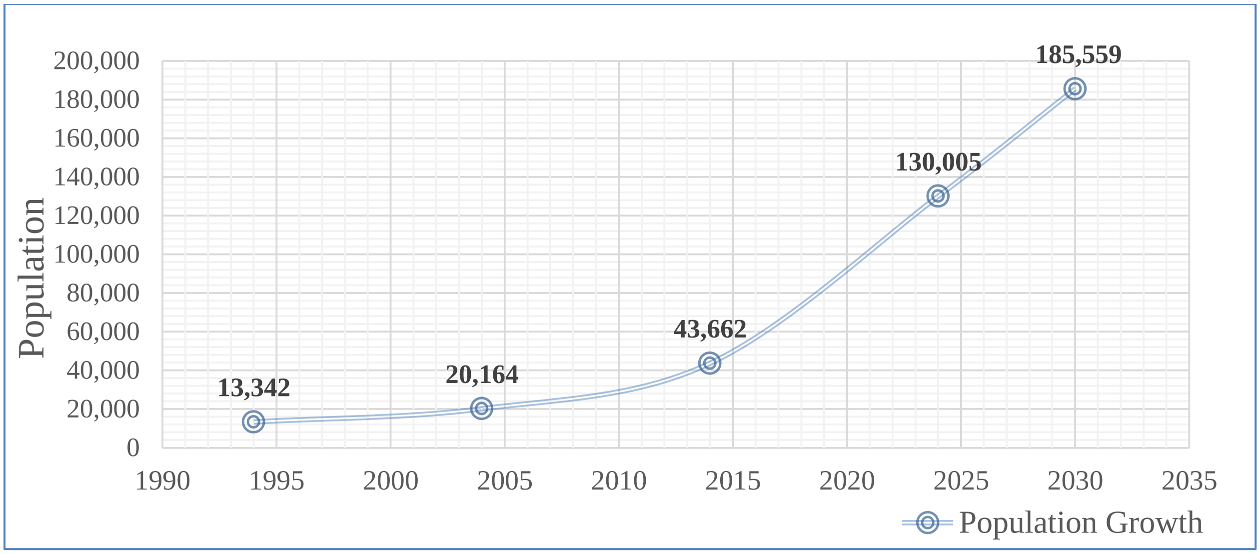

Figure 2: Population Growth from 1994 to 2030

Source: Own Computation based on CSA 1994-2007 data and OUPI 2017

4.2 Change in Built up Area (1994 to 2024) and Estimation for the year 2030

To analyze how land use and land cover changed in the study town between 1994 and 2024, maps were created using satellite imagery obtained from Earth Explore USGS Landsat web site. These maps (Figure) differentiate between various land uses: built-up areas with structures and infrastructure (red), land dedicated to agriculture and crop cultivation (orange), Bare land/unproductive land lacking vegetation (gray), green spaces like parks and gardens (green), and forested regions (dark green).

The maps provide a clear picture of Dukem town's urban growth trajectory from 1994 to 2024. In 1994, the town's built-up area was limited to a small central zone. While there was little change in the following decade, a significant expansion phase commenced, primarily along the main asphalt road, stretching in both eastern and western directions.

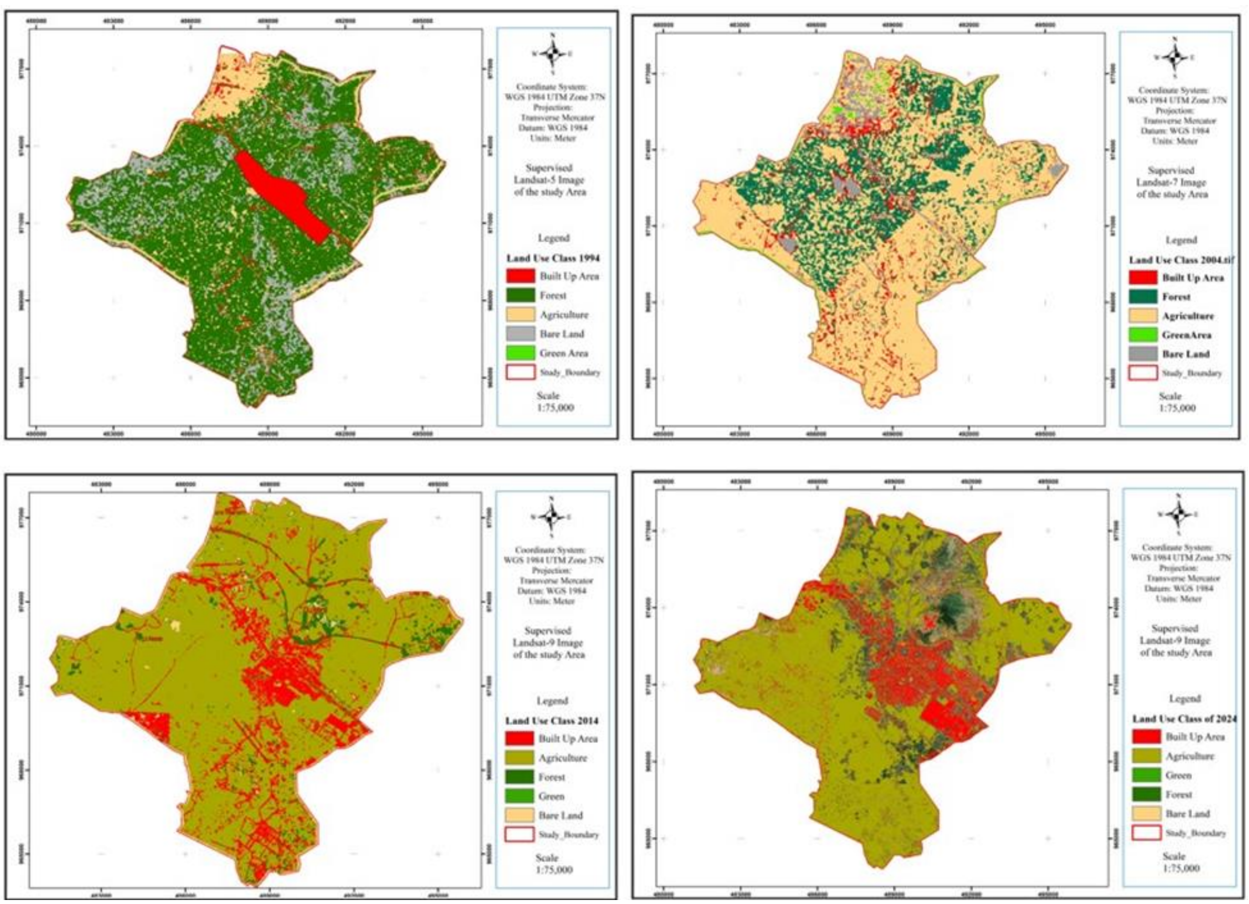

Figure 3: Urban Growth Trend of Dukem Town (1994 – 2024)

The changes in built-up area between the year 1994 and 2024 were determined irrespective of the other land classes and the projected built up area for the 2030 were shown in *Table* 3 below.

Table 3: Change Built up Area and prediction for the year 2030

Year	Area in Hectare	Change in Hectare	Change (%)
1994	498		
2004	842	344	69%
2014	1765	923	110%
2024	3447	1682	95%
2030	5015	1568	45%

It is important to know the future built up area to arrive at the desired study objectives. Accordingly, the Exponential Growth Model (EGM) method is used to forecast future urban built up area of the study town (Hathout, 2013). In so doing, calculating average growth rate of the built up area is mandatory (Gao et al., 2023).Therefore, the following formulae were customized for predicting future urban built up area of the study town for the coming 2030.

$$CA = IA * e^{rt} \ldots\ldots . r = \frac{1}{t}\ ln(\frac{CA}{IA})$$

Where, CA Current Built up area, IA= Initial Built UP area, r rate of Change; and t = time in year.

$$\mathrm{Af} = \mathrm{IA} * (1 + \mathrm{r}/100)^{\mathrm{t}}$$

Where AF=future built up area, IA initial Area, r= rate of change, and t= time from initial to final.

Accordingly, rate of change from 1994 to 2024 could be:

$$r = \frac{1}{30}\ ln(\frac{3447}{498})$$

$$r = 0.333l\,n(6.921686747) * 100$$

$$\underline{\underline{r = 6.448864965\ = 6.45}}$$

Hence, the built up are for the coming 2030 could be:

$$A(2030) = A(2024) * (1 + 6.45/100)^6$$

$$A(2030) = A(2868) * (1.0645)^6$$

$$\underline{\underline{A(2030) = 5015}}$$

Accordingly, by 2030, the town is projected to expand by 5015 hectares, a 156-hectare increase from 2024, representing a 45% growth. Figure 4 below illustrates this trend in urban growth from 1994 to 2030 as a line graph.

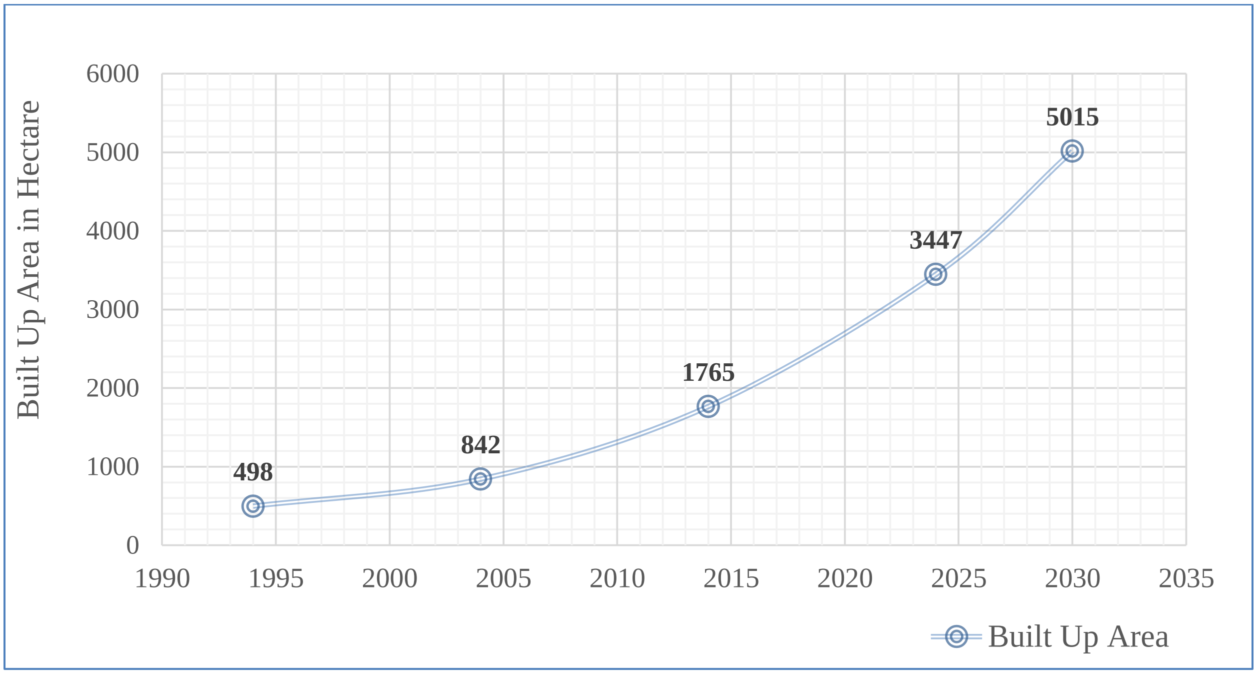

Figure 4: Trends of Urban Growth across the Continuum

4.3 Dynamic Change Detection

To determine the growth of built-up areas between different periods (1994-2004, 2004-2014, and 2014-2024), the researcher calculated the rate of change in spatial expansion as follows.

$\mathrm{DC(T1-T2)} = \frac{A2-A1}{A1(T2-T1)} * 100$; Where: A1= Initial built up area at initial time T1, and A2 is the current built up area at the present time T2

$$\mathrm{DC}(19994-2004) = \frac{842-498}{498(10)} * 100 = 7\%$$

$$\mathrm{DC}(2004-2014) = \frac{1765-842}{842(10)} * 100 = 11\%$$

$$\mathrm{DC}(2014-2024) = \frac{3447-1765}{1765(10)} * 100 = 10\%$$

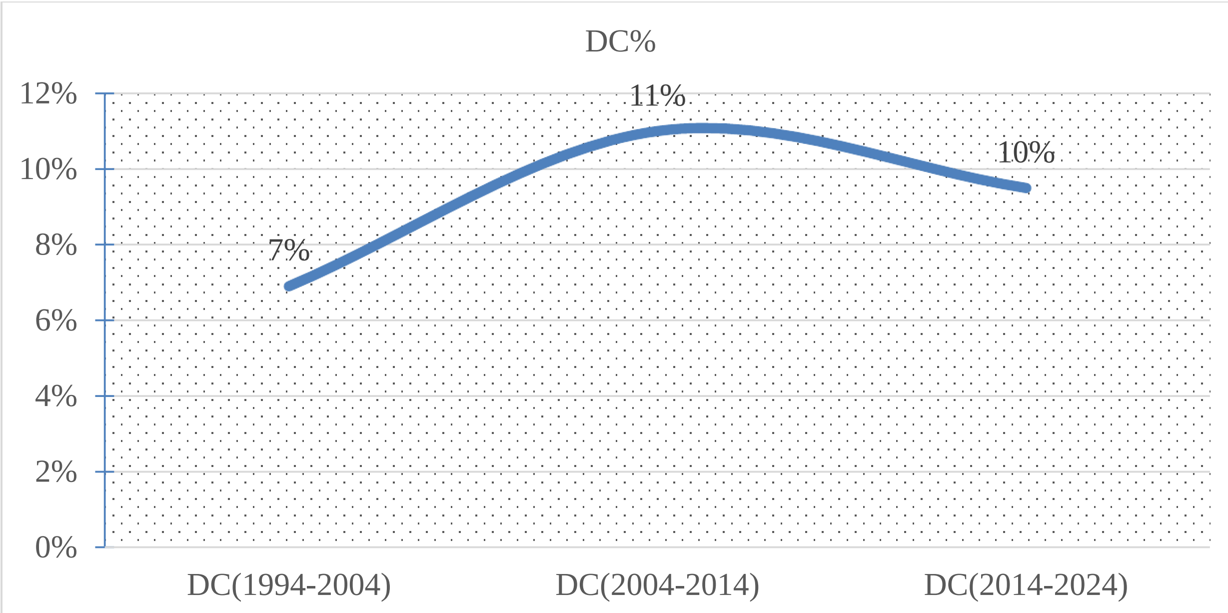

Figure 5: Trends of Dynamic Changes in Built Up area of the Continuum

Figure 5 above illustrates that the urban area of the town expanded significantly between 1994 and 2024. The annual growth rate was 7% from 1994 to 2004, 11% from 2004 to 2014, and 10% from 2014 to 2024. The most rapid expansion occurred between 2004 and 2014, driven by the conversion of surrounding agricultural land into valuable urban zones for housing and industry.

4.4 Comparison of Population Size and Built-up Area

The study revealed that as the population of the study town increases, so does its urban area. For instance, in 1994, when the population was 13,342, the built-up area covered 498 hectares. By 2004, the population had grown to 20,164, and the built-up area expanded to 842 hectares. This trend continued, with the population reaching 43,662 in 2014 and the built-up area increasing to 1765 hectares. In 2024, the population soared to 130,005, and the built-up area expanded to 3447 hectares. Projections for 2030 indicate that the population will further increase to 185,559, and the built-up area will reach 5015 hectares.

In addition, the study town witnessed a dramatic population growth. Between 1994 and 2004, its population grew by 51%. This growth accelerated over the next decade, increasing by a staggering 117% from 2004 to 2014. The trend continued, with an estimated 198% population increase from 2014 to 2024. Looking ahead, the town's population is projected to grow by an additional 43% between 2024 and 2030.

In parallel, the town's built-up area expanded significantly. It increased by 69% of the total land from 1994 to 2004, 110% from 2004 to 2014, and 95% from 2014 to 2024. The estimated built-up area is expected to grow by 45% between 2024 and 2030. For a detailed breakdown of these figures, please refer to Table 4 and Figure 6 for the details.

Table 4: Rate of Population and urban growth of the target periods

Year	Built Up Area	Change	%Change	Population	Growth	%Growth
1994	498			13,342		
2004	842	344	69%	20,164	6,822	51%
2014	1765	923	110%	43,662	23,498	117%
2024	3447	1682	95%	130,005	86,343	198%
2030	5015	1568	45%	185,559	55,554	43%

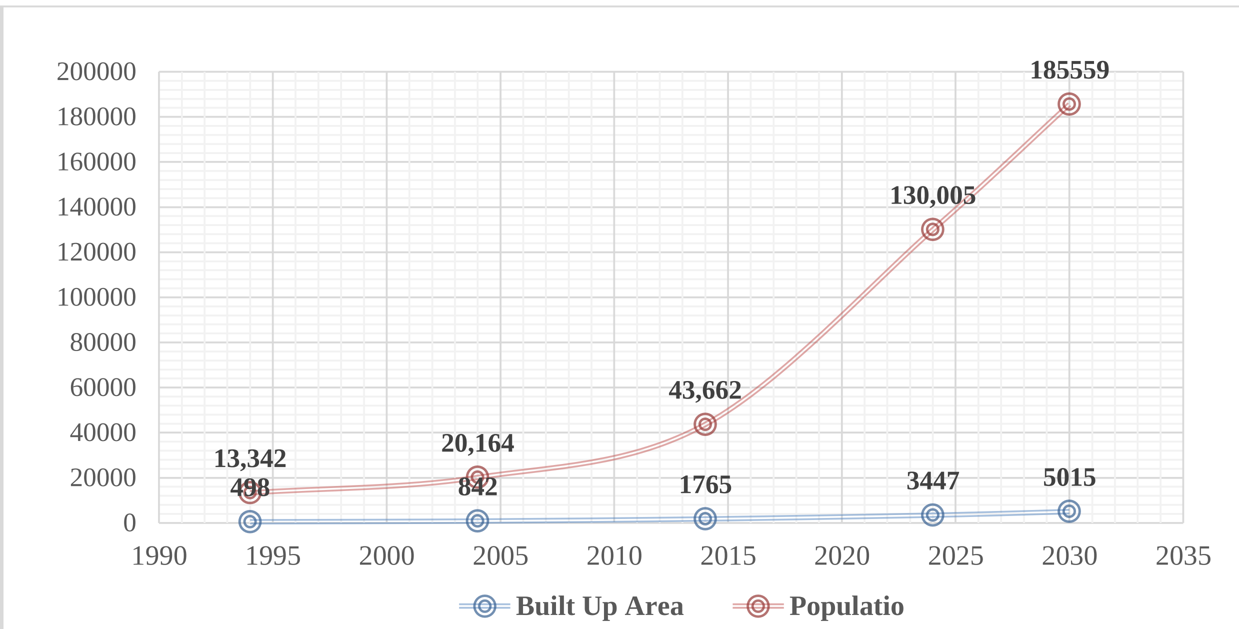

Figure 6: Built up Area Vs Population Growth for the years 1994 to 2030

4.5 Land Use Consumption Rate

Urban land consumption refers to the process of land being used for urban purposes, often replacing other land uses while Urban land consumption rate measures how quickly a city or urban area grows in size over a specific period (usually a year). From urban management points of views land, consumption rate measures the degree of the efficiency of the utilization of urban land. It is one of the indicators set by the united nation of the sustainable development goals.

Therefore, to measure the efficiency of urban land use in the study town, the land consumption rates for the given years were computed as follows, which rely on population growth rate, land consumption rate, and the ratio of land consumption to population growth.

$$LCR = \frac{(LN(Urb(t2)/Urb(t1))}{(y)}$$ *; Where:*

Urbt1 is the total area covered by the urban area in the initial year *t1*;

Urbt2 is the total area covered by the urban area in the final year *t2*; and y is the number of years between the two measurement periods (*t1* and *t2*)

$$PGR = \frac{(LN(Pop(t2)/Pop(t1))}{(y)}$$ *; Were*

Popt1 is the total population within the urban area in t1 (initial year)

Popt2 is the total population within the urban area in t2 (final year); and y is the number of years between the two measurement periods.

Furthermore, the final indicator, land consumption rate to population growth rate (LCRPGR), is computed by dividing the calculated land consumption and population growth rates as (Zhang et al., 2020, p. 7).

$$LCRPGR = \frac{(Annual\ Land\ Consumption\ rate)}{(Annual\ Population\ growth\ rate)}$$

Accordingly:

$$\mathrm{PGR}(1994 - 2004) = \frac{(\mathrm{LN}(\mathrm{Pop}(2004)/\mathrm{Pop}(1994))}{(2004 - 1994)}$$

$$\mathrm{PGR}(1994 - 2004) = \frac{\ln\left(\frac{20,164}{13342}\right)}{(10)} = \underline{\underline{0.041298 = 4.13\%}}$$

$$PGR(2004 - 2014) = \frac{(LN(Pop(2014)/Pop(2004))}{(2014 - 2004)}$$

$$\mathrm{PGR}(2004 - 2014) = \frac{\ln\left(\frac{43,662}{20,164}\right)}{(10)} = \underline{\underline{0.074257932 = 4.43\%}}$$

$$PGR(2014 - 2024) = \frac{(LN(Pop(2024)/Pop(2014))}{(2024 - 2014)}$$

$$\mathrm{PGR}(2004 - 2014) = \frac{\ln\left(\frac{130,005}{43,662}\right)}{(10)} = \underline{\underline{0.109109475 = 10.91\%}}$$

$$PGR(2024 - 2030) = \frac{(LN(Pop(2030)/Pop(2024))}{(2030 - 2024)}$$

$$\mathrm{PGR}(2024 - 2030) = \frac{\ln\left(\frac{185,559}{130,005}\right)}{(6)} = \underline{\underline{0.059299997 = 5.93\%}}$$

$$LCR(1994-2004)=\frac{(LN(Urb(2004)/Urb(1994)\ )}{(2004-1994)}$$

$$\mathrm{PGR}(1994-2004)=\frac{\ln\left(\frac{842}{498}\right)}{(10)}=\underline{\underline{0.052517994=5.25\%}}$$

$$LCR(2004-2014)=\frac{(LN(Urb(2014)/Urb(2004)\ )}{(2014-2004)}$$

$$\mathrm{PGR}(2004-2014)=\frac{\ln\left(\frac{1765}{842}\right)}{(10)}=\underline{\underline{0.0781517994=7.82\%}}$$

$$LCR(2014-2024)=\frac{(LN(Urb(2024)/Urb(2014)\ )}{(2024-2014)}$$

$$\mathrm{PGR}(2004-2014)=\frac{\ln\left(\frac{3447}{1765}\right)}{(10)}=\underline{\underline{0.086935=8.7\%}}$$

$$LCR(2024-2030)=\frac{(LN(Urb(2030)/Urb(2024)\ )}{(2030-2024)}$$

$$\mathrm{PGR}(2024-2030)=\frac{\ln\left(\frac{5015}{3447}\right)}{(6)}=\underline{\underline{0.062488189=6.25\%}}$$

Table 5: Summary of Land Consummation Rate and Population Growth Rate for the Selected Study Years

	1994-2004	2004-2014	2014-2024	2024-2030
LCR	5.25	7.82	8.7	6.25
PGR	4.13	7.43	10.91	5.93
LCR/PGR	1.271	1.052	0.797	1.054

Table 5 shows that, with the exception of the years 2014 to 2024, the ratio of Land Consumption Rate to Population Growth Rate (LCRPGR) has been consistently above one. This indicates that land is not being used efficiently, as ideal values for LCRPGR should be less than one (DASHTI, 2022 , p.20; UN-Habitat, 2018a). Research by (Biswajeet & Serdang, 2017) suggests that LCRPGR values typically range from -1 to 1. A value of 0 indicates moderate land use, a positive value signifies excessive built-up area per-capita, and a negative value implies population density that may lead to negative social, economic, and urban consequences.

Given these findings, there is a clear need to re-evaluate urban land management strategies to address the inefficient use of scarce resources in the study town.

4.6 Conclusion and Recommendations

4.6.1 Conclusion

This research investigated how land use and land cover have changed in Dukem town between 1994 and 2024 using remote sensing (RS) and geographic information systems (GIS) to analyze these changes and assess how efficiently the land is being used.

Accordingly, this study showed a significant increase in the built-up area of the town. Between 1994 and 2024, this area expanded from 498 hectares (5%) to 3447 hectares (36%). This rapid growth meant that built-up areas were taking over large portions of other land types, such as agricultural land. Unfortunately, agricultural land decreased substantially during this period, declining from 6258 hectares (65%) in 1994 to 3889 hectares (40%) in 2024. This suggests that agricultural land was the primary source of land for urban expansion. Likewise, the trend of other categories varies increasing and decreasing at various, times.

Moreover, the built-up areas of the study town was increases in its spatial extent. Accordingly, the urban area of the town expanded significantly between 1994 and 2024. The annual growth rate was 7% from 1994 to 2004, 11% from 2004 to 2014, and 10% from 2014 to 2024. The most rapid expansion occurred between 2004 and 2014, driven by the conversion of surrounding agricultural land into valuable urban zones for housing and industry.

This research witnessed this in that as the population of the study town increases, so does its urban area. For instance, in 1994, when the population was 13,342, the built-up area covered 498 hectares. By 2004, the population had grown to 20,164, and the built-up area expanded to 842 hectares. This trend continued, with the population reaching 43,662 in 2014 and the built-up area increasing to 1765 hectares. In 2024, the population soared to 130,005, and the built-up area expanded to 3447 hectares. Projections for 2030 indicate that the population will further increase to 185,559, and the built-up area will reach 5015 hectares.

In addition, the study town witnessed a dramatic population growth. Between 1994 and 2004, its population grew by 51%. This growth accelerated over the next decade, increasing by a staggering 117% from 2004 to 2014. The trend continued, with an estimated 198% population increase from 2014 to 2024. Looking ahead, the town's population is projected to grow by an additional 43% between 2024 and 2030.

In parallel, the town's built-up area expanded significantly. It increased by 69% of the total land from 1994 to 2004, 110% from 2004 to 2014, and 95% from 2014 to 2024. Accordingly, the estimated built-up area is expected to grow by 45% between 2024 and 2030.

Another key issue of this research is the notion of the ratio of land consumption rate to that of population growth rate, which measures the efficiency of the utilized urban land. Accordingly, with the exception of the years 2014 to 2024, the ratio of Land Consumption Rate to Population Growth Rate (LCRPGR) has been consistently above one. This indicates that land is not being used efficiently, as ideal values for LCRPGR should be less than one; and hence, due considerations shall be given in managing urban land and controlling driving forces behind this land use land cover changes.

4.6.2 Recommendations

In light of the research, question and finding related to the challenges of rapid land use/cover change and the pursuit of improved land use efficiency, the following recommendations have been formulated.

- ✧ The study revealed that Dukem town has experienced rapid urban growth. To ensure sustainable and balanced development, it is crucial for all relevant stakeholders to collaborate and work towards achieving the United Nations' Sustainable Development Goals to **Improve Land Use Efficiency**: Establish and enforce building codes and regulations to encourage the efficient use of land and minimize environmental impacts. This could include regulations on building height, density, and setbacks; encourage the development of denser, more compact urban forms to minimize urban sprawl and reduce the need for extensive infrastructure development. Encourage the development of mixed-use areas that integrate residential, commercial, and recreational spaces to increase land use efficiency and reduce the need for long-distance travel. Develop a Comprehensive and Updated Structure Plan to accommodate the projected growth until 2030 and beyond. This plan should incorporate realistic population projections, land use zoning regulations, and infrastructure development plans. Furthermore, provide training and capacity-building programs for local planners and officials on urban planning, land use management, and sustainable development principles.

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