



**ADDIS ABABA UNIVERSITY  
INSTITUTE OF TECHNOLOGY  
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**Spatiotemporal Analysis of Land Use/Land Cover Change  
and Urban Sprawl using GIS and Remote Sensing:  
The Case of Bahir Dar City, Ethiopia**

**A thesis submitted to School of Civil and Environmental Engineering  
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## Approval sheet

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## **DECLARATION**

I now declare that this thesis has been solely authored by me and was completed under the guidance of Hamere Yohannes (phD), and that it hasn't been submitted to any other university or institution in order to be considered for a degree. I confirm once again that all the information sources used in the thesis have been appropriately acknowledged through citations.

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## **List of Acronyms**

AUER	Annual Urban Expansion Rate
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
ETM+	Enhanced Thematic Mapper Plus
ERDAS	Earth Resource Data Analysis System
GIS	Geographic Information System
KML	Keyhole Markup Language
LULC	Land Use And Land Cover
MASL	Meter Above Sea Level
NASA	National Aeronautics And Space Administration
OLI	Operational Land Imagery
RS	Remote Sensing
SLC	Scan Line Corrector
TIFF	Tagged Image File Format
UAE	Urban Area Expansion
UEII	Urban Expansion Intensity Index
USGS	United States Geological Survey

## Abstract

Spatiotemporal analysis is a method used in Geographic Information Systems (GIS) and Remote Sensing to analyze changes in land use and land cover over specific time. This study was conducted to produce maps of the spatiotemporal changes over the study area from 2002 to 2022, quantify gain and losses of land use/land cover (LULC) classes, examine land use transitions, assess spatial trends of changes, and analyze the extent and patterns of urban sprawl over the study area. The LULC classes include Bare Land, Crop Land, Vegetation Area, Water Body, and Buildup Area. According to the analysis, the area of built-up land was increased time to time from 2002 to 2022, more than doubling in size, which increased from 1253.951 ha to 5519.19 ha. This indicates substantial urbanization and infrastructure development during the study period. With decrease in cropland and bare land but significant growth in built-up areas. To some extent, there was an increment of Vegetation area but water bodies remained relatively the amount of coverage area decrease in the first three consecutive period. Overall, the study highlights significant shifts in land use land cover over the 20-year timeframe. Moreover, the urban expansion intensity index analysis reveals fluctuations in the rate of urban expansion over the years, with periods of limited growth followed by accelerated expansion and then a slowdown. The urban expansion rates for the periods 2002-2007, 2002-2012, 2002-2017, and 2002-2022 were 4.204%, 10.763%, 7.332%, and 7.632%, respectively, these rates indicate fluctuations in urban growth within the region over the years.

**Key words:** Geographic Information Systems (GIS), land use land cover, Remote Sensing, Spatiotemporal analysis, urban expansion, urban sprawl.

# CHAPTER ONE

## INTRODUCTION

### 1.1. Background of the Study

Urbanization is currently recognized as a significant phenomenon. The level of urbanization or its growth drives the change in land use/cover pattern, which can have harmful effects on the ecology of the area (Barow et al., 2019). Social scientists, urban planners, and geographers from various angles, including the geography, demography, economies, have studied the unprecedented urban concentration and spatial evolution of cities (McIntyre et al., 2000) as well as urban green infrastructure (Mell, 2014). Urban environments and their quality are important as urbanization grows and urban areas continue to expand quickly because they directly affect social and economic growth. Growing urban populations and built-up areas are both aspects of the urbanization process. By the year 2050, there will be 66% more people living in urban area around the world, with 90% of them living in Africa and Asia (UN, 2014). Because of this population explosion, built-up regions will quickly expand, consuming nearby fertile land and encroaching on essential ecosystems. In addition, the horizontally quick growth of built-up regions will result in discontinuous suburbs with low density and uneven pattern (Tewolde, 2011).

The urban environment is a highly complex region that depicts continuum of varied land use and land cover variations in terms of space, time, and spectral diversity (Haregeweyn et al., 2012). The varied environment creates spatial diversity; temporal differences are described to recurring seasonal changes throughout the year; spectral variability is attributed to the wide range of building materials and structures in metropolitan areas (Zoran, 2007). In order to comprehend urban ecology, it is consequently crucial to investigate the spatiotemporal patterns of land use/land cover change (McIntyre et al., 2000). Land use/land cover change (LULCC) refers to the earth's territorial surface modification by human activities (Anderson et al. 1976). The process of LULCC affects biodiversity, climate, soil, and air in particular, and the ecosystem in general, and it has become the greatest environmental concern for human beings to date (Tsegaye et al., 2010; Haile Mariam et al., 2016). LULCC is helpful for understanding environmental changes because it can provide a tool to assess ecosystem changes

And their environmental implication at various temporal and spatial scales (Haregeweyn et al., 2012).

Built-up areas encompass various land uses in commercial, institutional, and residential regions make up urban space. Additionally, it includes undeveloped land that is primarily made up of vegetation and open areas (Moroney and Jones, 2006).

Urban green spaces are defined by previous studies (Kong and Nakagoshi 2006; Phan and Nakagoshi 2007; Byomkesh et al., 2012) as being lands that are covered in natural or artificial vegetation but exist in built-up regions. However, there is still debate over the term that is generally accepted. The majority of wealthy nations have their own definition (Byomkesh et al., 2012). Since the Ethiopian Ministry of Urban Development and Housing (MoUDH) provided the following explanation, it was used in this study as its working definition. "green infrastructure typologies to include parks, sports fields, roadside and squares, plazas and festive areas, river and riverside areas, lakes and lakeside areas, watershed areas, urban agriculture development, wood lots and green belts (inside and surrounding forests), private compounds and surroundings , institutional compounds and surround."

Although the latter is more comprehensive than the former, green infrastructure is sometimes used interchangeably with greenspace. Greenspace may improve air quality and the environment, provide shade for ground and pedestrians, and lessen the heat-related consequences of buildings (Nooret al., 2013).

Important data from LULCC research are needed to build urban green infrastructure design and management techniques (Yang et al., 2014). Previous research suggested that conventional urban environment examination was not considered GI (Miller and Hobbs, 2002). However, the urban green infrastructure enables city dwellers to physically and visually enjoy the outdoors. Any metropolitan area's green infrastructure network is important because it aims to give urban people the best possible experience characteristics and to combat the drawbacks of living in an urban built environment (Mansor et al., 2012). Furthermore, a better understanding of the connections between LULCC and GI change demands studying the underlying mechanisms, patterns, and processes of land conversion, as well as the response of the urban environment.

## 1.2. Statement of the Problem

The primary means of food production are limited natural resources like land that have the potential to be fruitful. The diversity of people causes unprecedented changes in land use and land cover and intensive use of resources brought on by population growth, economic activity, and the global market (Gashu & Gebre-Egziabher, 2018). Land use land cover change (LULC) is alteration of the Earth's surface due to human activities, such as urbanization, deforestation, agriculture expansion, and infrastructure development. This transformation of land cover has impacts on various aspects of the environment and society. LULC changes have a direct impact on urban sustainability by influencing factors such as air and water quality, biodiversity, and overall livability of urban areas. Urban sprawl, which is often a result of unchecked LULC changes, can lead to increased pollution, habitat loss, and strain on resources (Zhang et al., 2022). As a result, specific consideration and ongoing evaluation are needed for decision-making, monitoring, and planning urban growth.

Bahir Dar City is one of Ethiopia's largest and fastest-growing cities. It serves as the political, economic, and cultural hub of Amhara National Regional State, the country's second most populated area. Furthermore, the city is a prominent tourist destination in the country due to its cultural history (the Lake Tana Monasteries and religious festivals) and natural attractions (the Blue Nile Falls, birds, and hippos). The area is also marked by high biodiversity, and as such, UNESCO has declared it as a Biosphere Reserve (Fitawok et al., 2020).

Planners and policymakers lack the precise, timely, and cost-effective urban land use data that is necessary to make decisions about the management of land resources due to this rapid increase on the urban-rural border. As a result, a large number of individuals are leaving rural areas. The surrounding environment would be significantly impacted by this, including loss of agricultural land, destruction of the forest cover, water depletion, and effects on benefits derived from the land. For tracking and addressing the negative effects, it is crucial to quantify land use land cover changes, and simulate them for the future in Bahir Dar, Ethiopia. This might help with improved environmental development and land use planning in the research area.

This study emphasizes the vital connections between changes in urban green infrastructure and

spatiotemporal land use/cover. In this study, green infrastructure is one type of land use or land cover that refers to a network of multipurpose areas, most of which are un built, that support ecological and social activities (Kambites and Owen 2006; Tzoulas et al., 2007; MoUDH 2015). The structure and purpose of green infrastructure services alter because of changes in land use and land cover types (Lei and Zhu, 2017). Because LULCC is moving toward rapid urbanization, it is becoming more and more necessary to maintain a balance among economic, social, and natural ecosystems (Song et al., 2016).

Previously, various studies were conducted related to this research title in other study areas. Among these, Barow et al.(2019) studied on Spatiotemporal analysis of urban expansion using GIS and remote sensing in Jigjiga town of Ethiopia. In addition, tries to Analyze land use/land cover dynamics and spatial trend of urban area expansion. Sarif & Gupta (2022) conducted on Spatio-temporal analysis of land use - land cover changes. In Delhi using remote sensing and GIS techniques. Moreover, tried to analyze land use land cover change detection. Getu & Bhat (2021) tried to assess and monitor the spatiotemporal dynamics of urban sprawl and its growth pattern in similar study area of the current study.

The current study is conducted to analyze the spatiotemporal variation over the study area, to quantify gain and losses of land use/land cover classes, examine land use transitions, and asses spatial trends of changes and to analyze the extent and patterns of urban sprawl over the study area. Therefore, the study concentrate on the rates of LULCC from 2002 to 2022; LULCC trends from 2002 to 2007, 2007 to 2012, 2012 to2017, and 2017 to 2022; land-cover types were most affected by the change process; and the rates of change.

## **1.3. Objectives of the Study**

### **1.3.1. General Objective of the Study**

The main objective of this study was to detect and analyze spatiotemporal land use and land cover changes in Bahir Dar city by integrating GIS and remote sensing techniques.

### **1.3.2. Specific objectives of the study**

The specific objectives of this study are listed as follows:

- To produce maps of the spatiotemporal variation over the study area from 2002 to 2022
- To quantify gain and losses of land use/land cover classes, examine land use transitions, and assess spatial trends of changes
- To analyze the extent and patterns of urban sprawl over the study area

## **1.4. Basic Research Questions**

Basic research questions were set as follow:

- Where are the significant changes in the spatial distribution of urban land use and land cover classes between 2002 and 2022
- How much gain and losses of land use/land cover classes exist during the study periods?
- How was the spatial trend and patterns of the urban sprawl during the study periods?

## **1.5. Scope of the study**

The scope of this study is designed to provide a comprehensive assessment of land use/land cover change and urban sprawl. Specifically, focus on Bahir Dar City, located in the Amhara Region of Ethiopia. The temporal scope of the study starts from 2002 to 2022 over a period of two decades. This extended timeframe enable the identification of long-term trends and patterns in urban development and land use dynamics. The research involved in-depth analysis of changes in land use and land cover within Bahir Dar City and its surrounding areas. This includes the identification of shifts in agricultural land, urban expansion, deforestation, and other

relevant land use changes. A specific focus was placed on analyzing the phenomenon of urban sprawl within Bahir Dar City. This involves mapping the outward expansion of urban areas; the study was heavily rely on Geographic Information Systems (GIS) and remote sensing technologies for data collection, analysis, and visualization. These tools enabled the creation of detailed maps, spatial models, and imagery interpretation to support the research objectives.

## **1.6. Significance of the Study**

A significant feature of the pressure on the scarce land resources, which is caused by several biophysical and anthropogenic processes, particularly population growth, is land use and land cover change. As a result, understanding the effects of land use and land cover changes in the Bahir Dar area depends more on analyzing and modeling urban land use changes for the research community, urban planners, stakeholders, and decision-making groups. The results of this study provided better information about the changes in urban land use quantified through integrated application of GIS, remote sensing and land change modeler. In addition, it also provides the opportunity to understand the trends of changes in built up areas as a result of driving variables. Moreover, the findings of this study will be an initial input for future research direction for interested groups in the area.

## **1.7. Organization of the thesis**

The current study is organized with five key chapters: The introduction is the first chapter of the study and includes the study's history, problem statement, study objectives (generic and specific), significance, and scope. The literature review is presented in the second chapter. This chapter covers numerous pieces of literature related to the current study's subject and uses them to provide a brief review of the theoretical foundations of Spatiotemporal Analysis of Land Use/Land Cover Change and Urban Sprawl Using GIS and Remote Sensing. The third chapter provides a wide overview of the research topic, as well as data sources, data processing, and methodological flow charts. This chapter describes the study area in detail, including its location and the measures taken to attain the stated goal. The fourth chapter contains the results and a commentary. This chapter describes the results of the data analysis technique as well as

thematic data layer maps. The fifth chapter is about the conclusion and recommendations.

## CHAPTER TWO

### LITRATURE REVIEW

#### 2.1. Concept of Urban Sprawl and Land use and Land cover

Earle Draper developed the concept of sprawl in 1937 in the United States of America. City planners to refer to a wasteful type of urban growth have used this concept. Different scholars in the field define urban sprawl in different way. Most researchers argue that urban sprawl is an expansion and spread of development across the urban landscape to agricultural land due to increasing population growth and rural urban migration. On the other hand, Urban sprawl is not to be considered as increase of urban lands in a given area rather it is an extent of urbanization mainly caused by population growth and large-scale migration which is mainly unplanned and unchecked (Mohammady & Delavar, 2016). It is also described as scattered development on the outer part of compact urban and village centers along high ways and in rural countryside. It is defined as a source of an externality, such as a heavy reliance on automobiles, the isolation of the poor in the inner city, the spatial mismatch between jobs and housing, or the loss of environmental quality. He also explained it as the consequence or effect of some independent variables such as fragmented local government, poor planning, or exclusionary zoning.

Urban sprawl is a trend of uncontrolled development surrounding a city's periphery that is becoming increasingly widespread in both industrialized and developing countries' built environments. As a result, peri-urban community's experience the most visible and significant effects of urban sprawl. The development in these peri-urban settlements is patchy, scattered, and spread out, with a tendency for discontinuity (Kebebew et al., 2019). There are three basic spatial forms of sprawl: low-density sprawl, which has an unfair feature of use of land for housing purpose along them origins of existing urban areas associated with Services like water, power and roads. Ribbon sprawl which is follow main road corridors away from the center leaving lands some distant from the roads. The third form of sprawl is Leapfrog development, which is characterized by an irregular pattern piece of developed land that is widely separated (Wubie et al., 2020).

Throughout history, urbanization has been a key force in human and economic development. In contrast, urbanization is defined as the demographic process in which a growing proportion of the national population resides in urban settlements. Settlements are also classified as urban only if the majority of their population earns their living from nonfarm jobs. If population growth in metropolitan areas is unplanned and unrestrained, it leads to urban sprawl (Kebebew et al., 2019). Urbanization also deals with the increase in the proportion of people living in towns and cities. Urbanization occurs because people move from rural areas to urban areas. This usually occurs when a country is still developing. Rural to urban migration is happening on a massive scale due to population pressure and lack of resources in rural areas. People living in rural areas are pulled to the city. Therefore, the concept of urban sprawl is interrelated with urban growth because the increased population in urban area can cause urban sprawl unless it is managed and controlled.

Land use refers to the usage of land for various reasons such as built-up recreation, commercial use, and forest management. Furthermore, it is tied to the human activities or economic functions associated with a given piece of land. In other terms, land use refers to the multifarious usage of land, including both use and misuse of the land. Land cover refers to the types of features found on the earth's surface (Nyongesa et al., 2022). It can also be regarded as a ground blanket for the natural and cultural landscapes. It is made up of plants, soils, snow, rocks, and settlements.

## **2.2. Physical Patterns and Forms of Urban Growth and Sprawl**

Although urban growth, urban expansion, and urban sprawl are distinct concepts, the public frequently uses them interchangeably. Urban growth is the result of an increase in developed land. One of its manifestations is growth. Sprawl, on the other hand, has certain unique traits and is often associated with negative connotations. Urban expansion can be defined using Forman's (1995) landscape change techniques. Although the processes are very similar, urban expansion describes growth in terms of an increasing urban patch, whereas landscape transformation processes characterize fragmentation types as a reduction in non-developed land-cover kinds. Pattern of urban land-use/cover refers to the arrangement or spatial distribution of built environment. Wilson et al. (2003) recognized three types of urban growth:

infill, expansion, and outlying. Without lying urban growth is further classified as isolated, linear branch, and clustered branch growth. The proximity (or distance) to existing developed regions is significant in determining the type of urban expansion that has happened. Infill growth is defined as a non-developed pixel converted to urban usage and surrounding by at least 40% existing built pixels. It can be characterized as the development of a small plot of land surrounded by urban land (Wilson et al., 2003). Ellman (1997) defines infill policies as the encouragement to develop vacant land in already built-up areas. Infill development usually occurs where public facilities such as sewer, water, and roads already exist (Wilson et al., 2003). Forman (1995) describes infill attrition as the disappearance of objects such as patches and corridors. An expansion growth is characterized by a non-developed pixel being converted to developed and surrounded by no more than 40% existing developed pixels. This conversion represents an expansion of the existing urban patch (Wilsonetal, 2003). Expansion-type development has been called metropolitan fringe development or urban fringe development. Forman (1995) discusses it as edge development, land type spreading unidirectional in parallel strips from an edge. The analogous land transformation is shrinkage, defined as the decrease in size of objects, such as patches (Forman, 1995). Outlying growth is characterized by a change from non-developed to developed land-cover occurring beyond existing developed areas (Wilson et al., 2003). This type of growth has been called development beyond the urban fringe. Outlying growth is classified into three types: isolated, linear branch, and clustered branch (Wilsonetal., 2003). Isolated growth is defined as the development of one or more non-developed pixels at a distance from an already developed area. This class of growth is characteristic of a new house or similar construction surrounded by little or no developed land (Wilson et al., 2003). Forman (1995) defines it as perforation, which is the process of making holes in an object such as a habitat.

### **2.3. Temporal Process of Urban Growth and Sprawl**

Urban sprawl should be viewed as both a pattern of urban land use—that is, a spatial configuration of a metropolitan region in a given temporal instant—and a process, i.e., the evolution of the spatial structure of cities over time. Sprawl as a pattern or process is distinct from the factors that give rise to it, as well as the effects of such patterns (Galster et al., 2001). If the sprawl is viewed as a pattern, it is a static phenomenon, whereas as a process, it is a dynamic phenomenon; however, some scholars regard sprawl to be a static phenomenon, while others see it as a dynamic phenomenon; however, the majority of researchers argue for both. Sprawl as a pattern, while useful in understanding spatial distribution, is a static phenomenon; in practice, spread areas are often part of a changing urban environment (Harvey and Clark, 1965). The dynamics of the sprawl process can be explored using the theoretical framework of the urban expansion process. Herold et al. (2005b) presents a hypothetical schema of urban growth process using a general conceptual representation. According to Herold et al. (2005b), provide a hypothetical schema for the urban expansion process utilizing a broad conceptual representation. According to Herold et al. (2005b), urban area growth begins with a historical seed or core that spreads to new individual development hubs. This diffusion process continues to build organically and expand outwardly. The continuing spatial evolution leads to the coalescence of separate urban blobs. This phase transition begins with development in the open region between the primary urban core and periphery centers. This conceptual growth pattern continues and the system progresses toward a saturated state. In most traditional urbanization-studies this ‘scaling up’ has been represented by changing the spatial extent of concentric rings around the central urban core. The preceding framework suggests that some parts of an urban area may pass through a sprawl stage before eventually thickening so that they can no longer be characterized as sprawl. However, from this point of view what, when and where it can be characterized as sprawl, becomes ambiguous. Therefore, sprawl as a process without considering the pattern cannot be characterized. Rather, it should be considered as a pattern in the light of multiple temporal process snap shots. ‘In any event, measuring the respective dimensions of development patterns for an urban area at different times will reveal the process (or progress) of sprawl’ (Galster et al., 2001).

## **2.4. Application of GIS and RS in Analysis of Land LULC Change**

Now a day the field of Remote Sensing and GIS has become exciting and glamorous with rapidly expanding opportunities. They are very useful in formulating and implementing spatial and temporal changes, which are essential components of regional planning to ensure sustainable development. The different phases in the formulation and implementation of a regional development strategy can be summarized as follows: determination of objectives, resource inventory, analysis of the current situation, modeling and projection, development of planning options, selection of planning options, plan implementation, and plan evaluation, monitoring, and feedback (Sishah, 2022).

GIS and remote sensing techniques are quite developed and operational to implement such a proposed strategy. The spatial patterns of urban sprawl on temporal scale are studied and analyzed using the satellite imageries. Image processing techniques are also quite effective at identifying urban growth patterns from spatial and temporal data collected by remote sensing techniques. These aids in distinguishing the growth patterns of urban sprawl, such as the linear and radial growth patterns (Sishah, 2022).

Therefore, integrated use of GIS and remote sensing technology plays key role in land use /land cover mapping as well as detection of extent and patterns sprawl of urban landscape. According to Sadidy et al. (2009), Landsat pictures with varied resolutions are among the most extensively used data sources for obtaining critical input for mapping and planning projects. The Landsat photos was geo-referenced to the digitized map of the related area using first-order polynomial transformation and nearest neighborhood resembling (Yuan et al. 2005; Murat et al., 2006).

## **2.5. Driving Force of Urban Expansion**

Driving forces of urban expansion have attracted increasing attention. However, a generally recognized analytical framework of driving forces for urban expansion has not been established (Li et al., 2018). Urban land expansion is one of the most direct representation forms of land use/land cover change, and refers specifically to change in land use pattern and

urban space distribution resulted from land, social and economic pressure (Ma & Xu, 2010). Economic and infrastructure development, population increase, and industrial structures have all been linked to urban expansion (Hu et al., 2007). Population density is an important factor in determining urban expansion. As population, density grows the demand for housing, infrastructure, and services increases. This, in turn, leads to the expansion of urban areas to accommodate the growing population. As a result, new settlements and built-up areas, such as new towns and industrial lands, are developed to provide adequate space and resources for the increasing population (Pravitasari et al., 2018).

## **2.6. Previous Related Studies in Ethiopia**

Nowadays, the use of Remote Sensing and Geographic Information Systems techniques has become important for quantifying the degree of urban sprawl, mapping, monitoring, and managing urban land-use/land cover changes. Mapping urban sprawl paints a picture of where this type of growth is taking place, aids in identifying the environmental and natural resources affected by such sprawls, and predicts the likely future directions and patterns of sprawling development. There are limited number of studies conducted on quantifying the extent and detecting the pattern of urban sprawl in Ethiopia using GIS and Remote Sensing. Contrary to this, there are quite significant numbers of studies conducted on the impact of urban sprawl in altering land use, especially the impact it has on consumption of agricultural land on the outer skirts of cities. (Shiferaw, 2017) did notable contribution on quantifying the rate of urban sprawl and mapping for the city of Addis Ababa and its surroundings. A comparable study, recently undertaken in Ethiopia using GIS to investigate the primary causes of urban expansion and their effects on land use conversion in the peri-urban kebeles of Dukem, one of the cities in the Oromia Special Zone around Addis Abeba. In this study expansion of residential and industrial developments over agricultural land were mapped using GIS instead of detecting spatiotemporal land use/land cover dynamics in the study area. In the study, only a single period data was used and land uses are mapped. In such cases, it is in fact difficult to analyze the extent and pattern of urban sprawl .LULC change maps. Another study of urban sprawl in Ethiopia was conducted in Debre Berhan town, which is located northeast of Addis Ababa (Goodchild, 2010). This study focused on assessing urban sprawl of Debre Berhan town using satellite imageries. The findings of the study showed that rapid population pressure

has resulted in unplanned growth in the area, which in turn led to urban sprawl. Urban sprawl has resulted in loss of productive agricultural lands. In this study, too major emphasis was given to how land use/land cover, particularly the built-up area, has been increasing between 1986-2009 than detecting the town's extent and pattern of sprawl (Goodchild, 2010) on his part studied the rate and effect of sprawling of Addis Ababa city. The study indicated that the rate of urban sprawl along the Mojo (south of Addis Ababa on the way to Adama city) and Jimma outlets, compared to other outlets, is high causing both positive and negative effects to the areas and the people. Similar to other studies, this study did not explicitly show the pattern of sprawl and emphasis was given to land use/land cover change due to urban growth.

## **CHAPTER THREE**

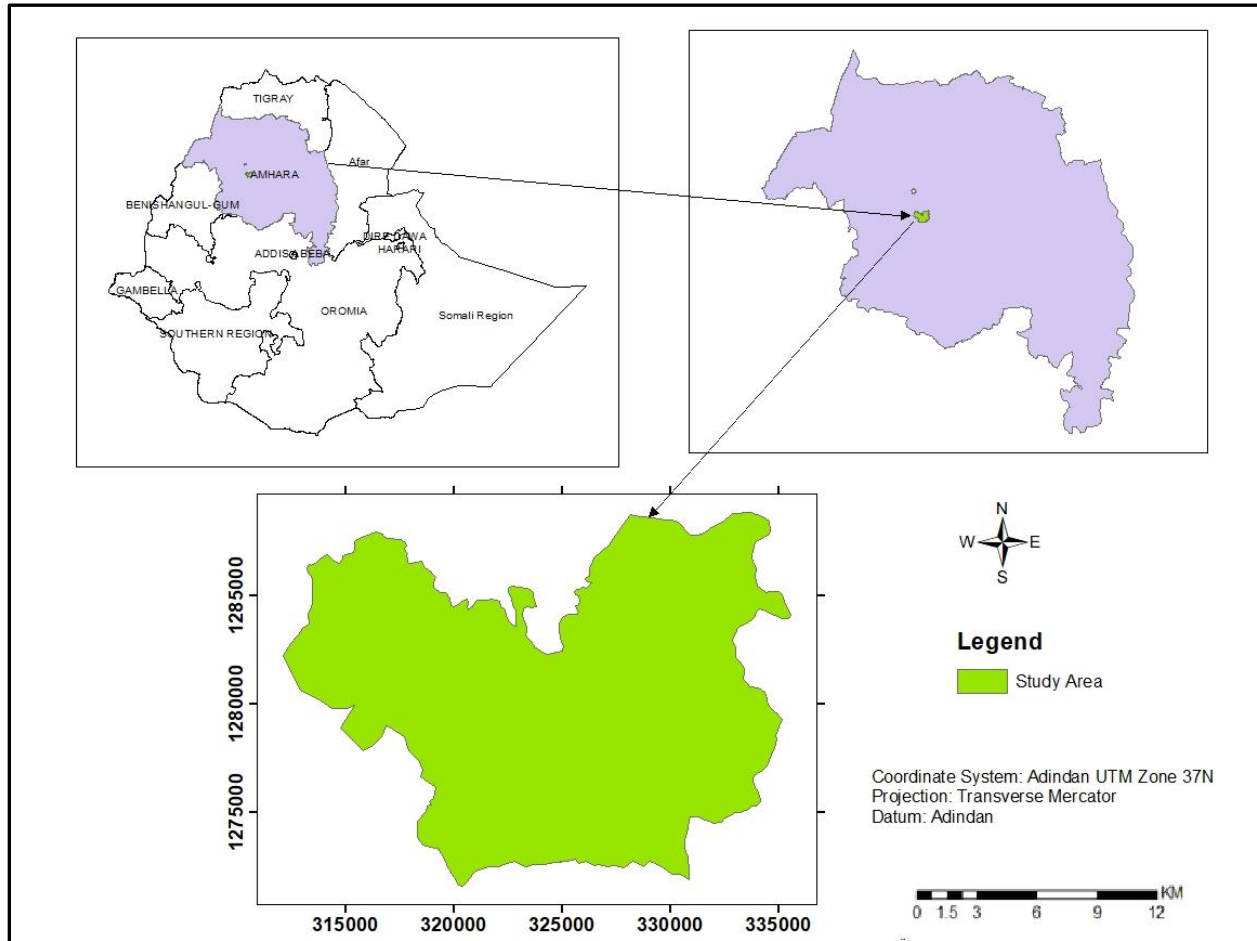
### **METHODOLOGY**

#### **3.1. Description of the Study Area**

Bahir Dar is the capital city of Amhara Region, Ethiopia. Bahir Dar is one of Ethiopia's leading tourist destinations, with various attractions in the nearby Lake Tana and Blue Nile River. The city is famous for its broad avenues adorned with palm trees and a variety of vibrant flowers. In 2002, it received the UNESCO Cities for Peace Prize for resolving the issues of growing urbanization (Fitawok et al., 2020).

Bahir Dar, which has a total area of about 253 km<sup>2</sup>, is located in the northwestern part of Ethiopia. It is located at 11° 36' N and 37° 23' E. It is likewise situated 1,820 meters (5,970 feet) above sea level, at the Abbay's outflow into Lake Tana. Bahir Dar's central city, along with Zegie, Tis Abay, and meshenti, are three smaller urban settlements that the Amhara National Regional State (ANRS) council designated under the revised proclamation No.91/2003, and their surrounding rural areas. In relative terms, Bahir Dar is found at a distance of 578 km and 497 km from the capital city of Ethiopia, Addis Ababa along the road Addis Ababa –Debre Markos and Addis Ababa – Motta respectively. It is one of Ethiopia's top tourist sites, having a range of sights in the neighboring Lake Tana and Blue Nile River (Gashu & Gebre-Egziabher, 2018). The first national population and housing census was conducted in 1984 and the population of Bahir Dar was 54,800. After 10 years in 1994, the second census has also been conducted and the total population was 96,140 with an increase of about 75% from 1984. In 2007, the total population has become 180,174. The value increased by about 87% of the population of 1994 according to the CSA (Gashu & Gebre-Egziabher, 2018).

According to the National Meteorological Agency (NMA), Bahir Dar's average annual temperature and precipitation are 19.6 °C and 1419 mm, respectively. The city is one of Ethiopia's largest and fastest-growing metropolitan centers. In addition to its rapid population growth, Bahir Dar was chosen as the study's research location because it is a lake front city, the regional capital, is expanding quickly, and has relatively greater access to green infrastructure than other cities and villages in the nation.



*Fig. 3.1. Study Area Map*

### **3.2. Data and Data Source**

This study was used five different sets of Land sat satellite data for Bahir Dar city over from 2002 to 2022. These the five Land sat satellite images with 30 m resolution was acquired for January 13 2002, January 21 2007, January 3 2012, December 17 2016 and January22 2022 form USGS sites (<https://earthexplorer.usgs.gov/>). In addition to Land sat satellite data, ground control point (GCP) data or coordinates derived from Google earth are used for validation of the accuracy of land use classification of each land use class. These satellite images taken are explained in Table 3. The data clearly shows that satellite photos from different years were obtained during the same season, allowing for easy discrimination between land cover and

land usage. Data sets are projected in UTM projection with zone number 37 and WGS 84 datum.

Table 3.1. Description of the collected Landsat Data

Image	Sensor	Path/row	Pixel size	Date of acquisition
Landsat 7	ETM+	170/052	30 ×30	1/13/2002
Landsat 7	ETM+	170/053	30×30	1/21/2007
Landsat 7	ETM+	170/054	30×30	1/3/2012
Landsat8	OLI	170/055	30 ×30	12/17/2016
Landsat 8	OLI	170/056	30×30	1/22/2022

### 3.3. Image pre-processing

To identify LULC changes in the city of Bahir Dar, using multi-temporal satellite imaging, with digital image processing such as geometric correction, radiometric correction, image sub Setting and classification. Radiometric correction is a fundamental process in image analysis that ensures the reliability and accuracy of remotely sensed data for various applications. By correcting for radiometric errors, researchers can obtain consistent, quantitative, and interpretable information from images. ERDAS IMAGINE 2015 software was used for image preprocessing and supervised classification using a maximum likelihood method was used to categorize areas of interest. Maximum likelihood is a crucial technique for LULC studies due to its accuracy, robustness, versatility, and interoperability (Hütt et al., 2016). Five distinct categories: Built up area, vegetation, water bodies, agricultural land and bare land were applied. Landsat satellite images were used for the detection region. moreover, On May 31, 2003, the scan line corrector (SLC) on the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) failed, resulting in wedge-shaped scan-to-scan gaps in the scanning pattern (Storey et al., 2005). With the SLC turned off, the ETM+ continues to collect data, resulting in images that are missing around 22% of the regular scene area (Storey et al., 2005) . To improve the utility, the current study fix scan line error by employing QGIS software to eliminate the scan gaps present in a single SLC-off scene and develop scan gap-free imagery.

## **3.4. Data Analysis and Presentation**

### **3.4.1. Image Classifications**

Supervised and unsupervised classifications are two ways of land use classification methods. For this study, LULC maps for Bahir Dar city was prepared using supervised classifications method using a classifier based on the maximum likelihood algorithm. The five land-use/land-cover types that are mapped are cropland, Bare Land, water bodies, vegetation area, and urban built-up areas and for each land use type, the study used 100 signatures during classification. These five land use/land cover classification were chosen by taking in to account the standard classes established by the National Aeronautics and Space Administration (NASA) and the US Geological Survey (USGS) (Mohan et al., 2011). The requirement to contextualize LULCC classification systems for the local situation was also noted in some studies (Thompson 1996). ERDAS Imagine 2015 was employed to perform LULC classification in a multi-spectral approach. To display the spatiotemporal patterns of the LULC in the study areas, satellite images and remote sensing methods were used. Each Landsat7 ETM+ and Land sat 8 OLI for Bahir Dar city was classified independently for the study's five time periods (2002, 2007, 2012, 2017 and 2022).

Google Earth data and GPS points to collect ground-referenced data. The resulting samples were loaded into the ERDAS Imagine software, where the intersection files were generated. LULCC can be summarized using a unique change statistic that measures the fraction of pixels that have changed over the entire study region, regardless of class. In this study, supervised classification was carried out using the multi-date images to classify the images into clusters and to identify the type of potential changes. Post-classification comparison is used to detect LULCC among five images in Bahir Dar. According to Hussainet al. (2013), Past and recent studies have identified image differences as being the most accurate change detection technique. The most accurate change detection technique Past and recent studies have identified image differences as the most accurate change detection technique. In this study, supervised classification was carried out using the temporal images to classify the images into clusters and to identify the type of potential changes. Post-classification comparison is used to detect LULCC among five images in Bahir Dar. Object based supervised classification was

carried out using maximum likelihood algorithm method (MLC) for each image separately to test the accuracy assessment of the classification (Hussain et al., 2013).

Table 3. 2. Land covers classes of the study area

<b>LULC class</b>	<b>Description</b>
Bare Land	This class refers to areas of land that are devoid of vegetation or significant human development. Bare land can include deserts, rocky terrain, and other areas where the soil is exposed.
Built up Area	Built-up areas consist of regions that are densely populated or have significant human-made structures such as buildings, roads, and infrastructure. Urban areas fall under this category.
Crop land	Cropland includes areas that are used for agricultural purposes, such as growing crops for food production. These areas are typically characterized by cultivated fields
Vegetation Area	Vegetation areas encompass regions covered with various forms of plant life, including forests, grasslands, shrub lands, and wetlands. These areas play a crucial role in supporting biodiversity and ecosystem services.
Water body	Water bodies are bodies of water such as rivers, lakes, and reservoirs. These areas are essential for supporting aquatic ecosystems and providing water resources for various human activities.

### **3.4.2. Accuracy Assessment of LULC Classification**

Accuracy evaluation of LULC Classification Accuracy testing is required for each classification if the classification data is to be used in change detection. For the accuracy assessment of land cover, maps were extracted from Landsat images. For each of the five years, 256 coordinate points were collected at random from images of 2002, 2007, 2012, and 2017 and 2022 on Google Earth respectively to assess accuracy. Then the kml file which was produced from Google earth was converted to a layer file and a point shape file was created to generate x and y coordinates by using ArcGIS 10.7. The imagery on Google Earth and Landsat acquisition dates are similar with identified land use in different periods. Finally, utilizing these processed points, ERDAS IMAGINE 2015 was used to test the accuracy. The accuracy

assessment also conducted using 200 ground truth data and a 100-point visual interpretation (Butt et al.2015). For comparing reference data and classification results, statistical error matrices and the nonparametric Kappa index was employed (Robertson and King. 2011) formula used to compute the producer accuracy, user accuracy, overall accuracy, and Kappa coefficient for the classified maps of 2002, 2007,2012, 2017, and 2022. The following is the formula for calculating the Kappa index coefficient, producer accuracy, user accuracy, and overall accuracy:

$$\text{Producers accuracy} = \frac{n_{ii}}{G_{ii}} * 100\% \quad (4)$$

$$\text{User's Accuracy} = \frac{n_{ii}}{C_{ii}} * 100\% \quad (5)$$

$$\text{Overall Accuracy} = \frac{\sum_{i=1}^n n_{ii}}{N} * 100\% \quad (6)$$

$$\text{kappa index} = \frac{\sum_{i=1}^k n_{ii} - \sum_{i=1}^k (G_i C_i)}{n^2 - \sum_{i=1}^k (G_i C_i)} \quad (7)$$

Where N refers to the rows and columns number in the error matrix, i is the class number, n is the total number of classified pixels that are being compared to ground truth,  $n_{ii}$  is the number of pixels belonging to the ground truth class i. That have also been classified with a class i,  $C_i$  is the total number of classified pixels belonging to class i and  $G_i$  is the total number of ground truth pixels belonging to class i. A nonparametric Kappa index is a measure of agreement between predefined producer ratings and user assigned ratings (Foody, 2002)

### 3.4.3. Change Rate and Gain-Lose of Land Use Land Cover Changes

The land use change rate index is mainly used to calculate the quantitative value of a land use type change, and can also be used to estimate the land use change trend and the change speed in the next few years. According to Miheretu & Yimer (2018), the quantification of land use/land cover changes has been determined using a rate of change calculation. The researcher utilized the following equation to calculate the change rate of LULCC detection:

$$K = \frac{U_b - U_a}{U_a} * \frac{1}{T} * 100\% \quad (1)$$

Where K indicates the change rate of a land use type during the study period;  $U_a$  indicates the

area of the land use type at the beginning of the study period;  $U_b$  indicates the area of the land use type at the end of the study period;  $T$  indicates the study period. Land use transfer matrix is a two-dimensional table that represents the transfer of land uses from one category to another. It consists of rows representing the initial land use categories, columns representing the final land use categories, and cells containing the transition probabilities between these categories. According to Zhao et al.(2020) , the land use transfer matrix is a matrix that describes the change in the number of areas as well as the pattern of transfer between various land use categories over time. The equation goes as follows.

$$C_{i x j} = A_{i x j}^k \times 10^n + A_{i x j}^{k+1} \quad (3)$$

In the equation,  $n$  is generally 1 or 2. When the number of land use types,  $m < 10$ ,  $n$  is 1; when the number of land use types,  $10 < m < 100$ ,  $n$  is 2.  $A_{i x j}^k$  and  $A_{i x j}^{k+1}$  refers to the two types of land use type maps, respectively.  $C_{i x j}$  refers to the land use type change matrix from the  $k$  period to the  $k+1$  period.

#### 3.4.4. Urban Expansion Analysis

The extent and direction of the cities' expansion for the year 2002, 2007, 2012, 2017 and 2022 were analyzed by superimposing the different time-series images and calculating the corresponding areas in GIS software. The annual rates of urban area expansion (UAE) for the periods: 2002 – 2007, 2002 -2012, 2002 -2017, and 2002 -2022 was calculated for the current study area in similar way of Alam et al.(2023) as follows:

$$AUER = \left\{ \left( \frac{BLA_i^{t2}}{BLA_i^{t1}} \right)^{\frac{1}{t2-t1}} - 1 \right\} * 100 \quad (8)$$

BLA = Built-up area,  $i$  = the spatial unit,  $t1$  = the base year, and  $t2$  = the ending year. The result of the AUER represents the amount of change in the Built-up land area over time.

The second is the Urban Expansion Intensity Index (UEII), which describes the degree of differentiation of urban expansion and depicts the proportion of urban growth in a spatial unit in relation to the overall study area and duration. The Urban Expansion Intensity Index (UEII) is a quantitative metric that can be used to assess differences in urban spatial expansion. It

allows you to examine your preferences for urban growth and compare the rate or intensity with which urban land use changes over time. The formula to calculate UEII is represented by Equation (8).

$$UEII_{it} = \frac{UL A_{i,b} - UL A_{i,a}}{t} / TLA_i * 100 \tag{9}$$

Where “UEII<sub>it</sub>” is the annual average urban expansion intensity index of (ith) zone in time period (t) ULA<sub>i,a</sub> and ULA<sub>i,b</sub> are the quantity of built up area at time periods a and b in (ith) spatial zone, respectively. TLA<sub>i</sub> is the total area of (ith) spatial zone.

### 3.4.5. The work flow diagram of the study

In order to understand the workflow of the current study, it is essential to first grasp the various stages involved in conducting a research study. Each stage has its own set of tasks and responsibilities, which can be represented in a workflow diagram (Fig 3.2).

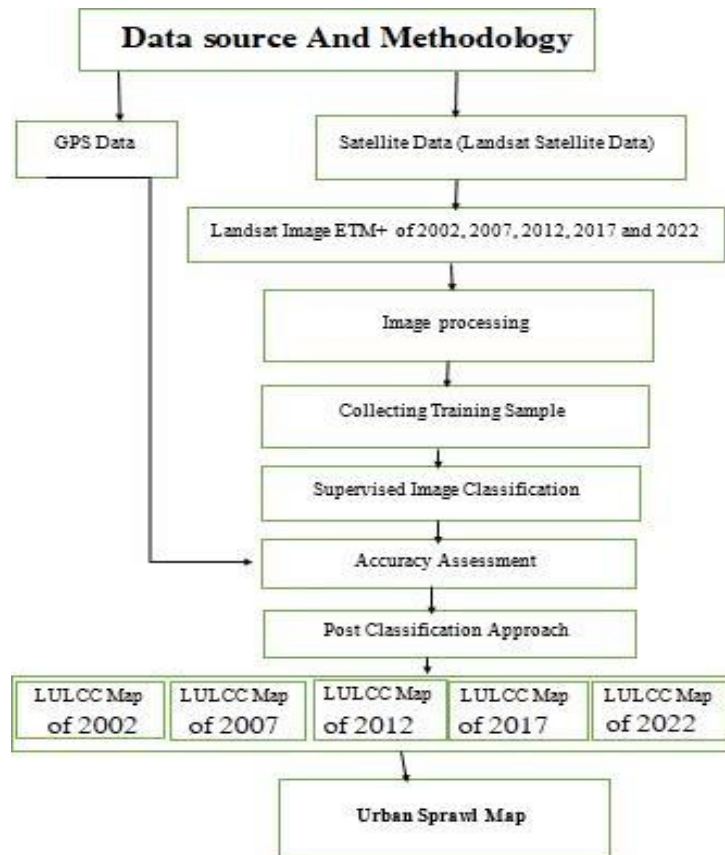


Fig .3.2 . Over all flow of the study

## CHAPTER FOUR

### RESULTS

#### 4.1. Land Use Land Cover accuracy Assessment

Overall, the classification results show a high accuracy across all categories, with the Overall Kappa Statistics is 0.8631 and Overall Classification Accuracy is 89.06%. This indicates that the classification method used is effective in identifying the correct class for each image (Table 4.1).

Table 4.1. Land use land covers accuracy assessment

<b>Class Name</b>	<b>Reference Totals</b>	<b>Classified Totals</b>	<b>Number Correct</b>	<b>Producers Accuracy</b>	<b>Users Accuracy</b>	<b>Kappa</b>
Bare Land	50	46	43	86.00%	93.48%	0.9190
Vegetation area	49	65	47	95.92%	72.31%	0.6575
Water body	51	36	36	70.59%	100.00%	1.0000
Built-Up area	59	60	56	94.92%	93.33%	0.9134
Cropland	47	49	46	97.87%	93.88%	0.9250
Totals	256	256	228			
Overall Classification Accuracy = 89.06%.			Overall Kappa Statistics = 0.8631			

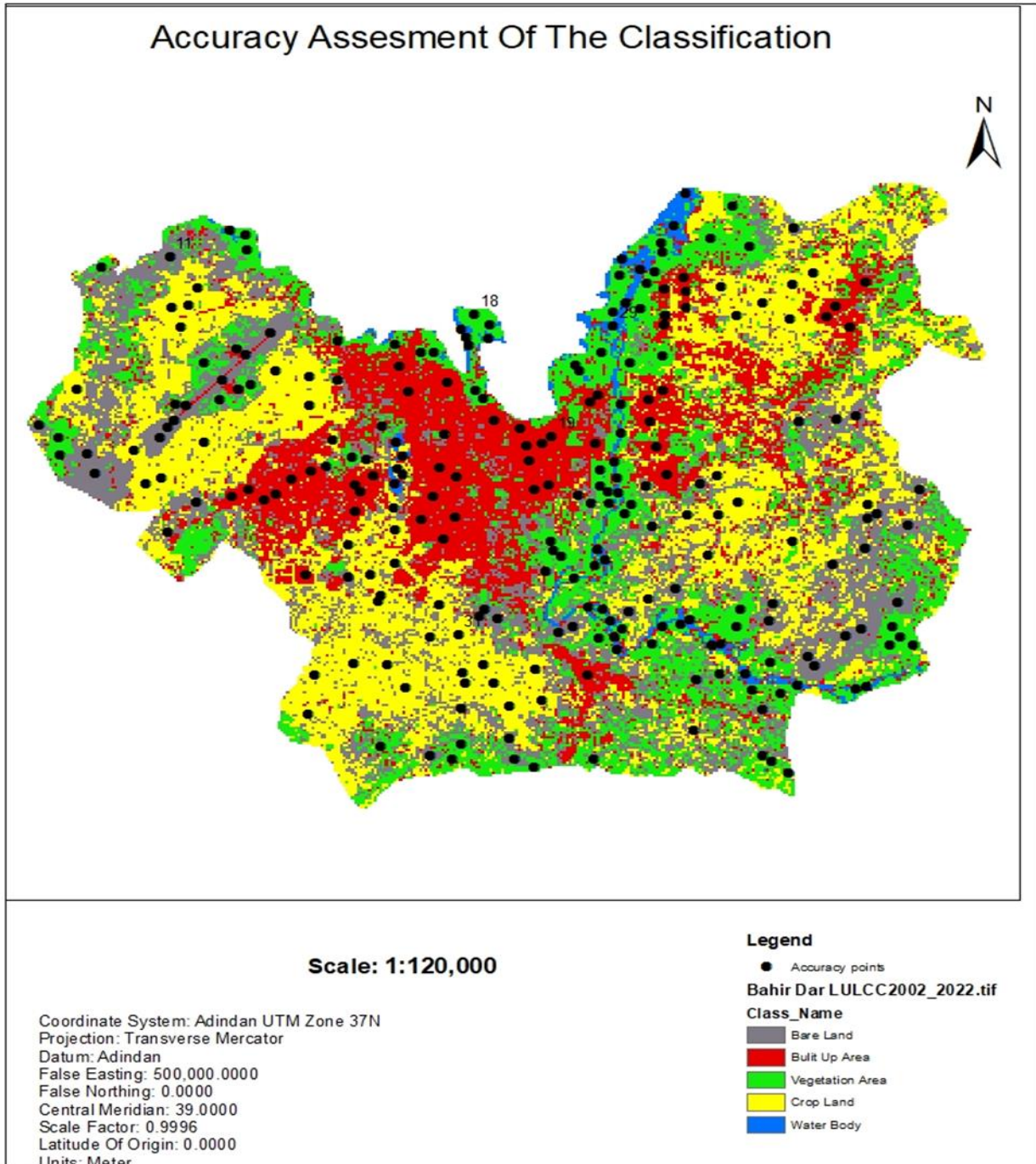


Fig .4.1. Classification accuracy assessment

### **3.1. Spatiotemporal Variation over the Study Area (2002-2022)**

The study examines the Land Use Land Cover (LULC) of a specific area during five consecutive years, namely 2002, 2007, 2012, 2017, and 2022. The LULC data includes Bare Land, Crop Land, Vegetation, Water Body, and Buildup Area.

Between 2002 and 2007, there was a decrease in cropland, with an area from 11,667.18 to 11,139.68 hectares. During this period, vegetation area also increased, reaching 2,544.48 from 2,336.96 hectares in 2002. On the other hand, water bodies slightly decrease in area, from 744.28 hectares in 2002 to 722.39 hectares in 2007. Build-up area experienced an increase, reaching from 1,253.95 to 1,540.66 hectares. Bare land experienced increase, going from 9,339.52 hectares in 2002 to 9,394.67 hectares in 2007.

From 2007 to 2012, there was a further decrease in cropland, from 11,139.68 to 10,691.96 hectares. During this period, vegetation area continued to grow, reaching 3,960.15 hectares in 2012 from 2,544.48 hectares in 2007. Water bodies continued to decrease in area, with 509.77 hectares in 2012 compared to 722.39 hectares in 2007. Build-up area experienced a significant increase, reaching 3,485.15 hectares in 2012 from 1,540.66 hectares in 2007. Bare land continued to decrease, going from 9,394.67 hectares in 2007 to 6,694.85 hectares in 2012.

From 2012 to 2017, cropland experienced a slight decrease, with a total area of 10,269.07 hectares in 2017, down from 10,691.96 hectares in 2012. During this period, vegetation area continued to grow, reaching 5,248.47 hectares in 2017 from 3,960.15 hectares in 2012. Water bodies continued to increase in area, with 524.51 hectares in 2017 compared to 509.77 hectares in 2012. Build-up area experienced increase, reaching 3,624.07 hectares in 2017 from 3,485.15 hectares in 2012. Bare land continued to decrease, going from 6,694.85 hectares in 2012 to 5,675.84 hectares in 2017.

From 2017 to 2022, there was a further decrease in cropland, from 10,269.07 to 7,991.15 hectares. During this period, vegetation area continued to decrease, reaching 5,222.502 hectares in 2022 from 5,248.47 hectares in 2017. Water bodies continued to increase in area, with 600 hectares in 2022 compared to 524.51 hectares in 2017. Build-up area experienced a significant

increase, reaching 5519.19 hectares in 2022 from 3624.07 hectares in 2017. Bare land increase, going from 5,675.84 hectares in 2017 to 6069.08 hectares in 2022.

In general, from 2002 to 2022, it is evident that the region has undergone significant changes in its LULC classes. The cropland area has seen a significant reduction, while the vegetation area has increased. The water body has also decreased, and the built-up area has expanded.

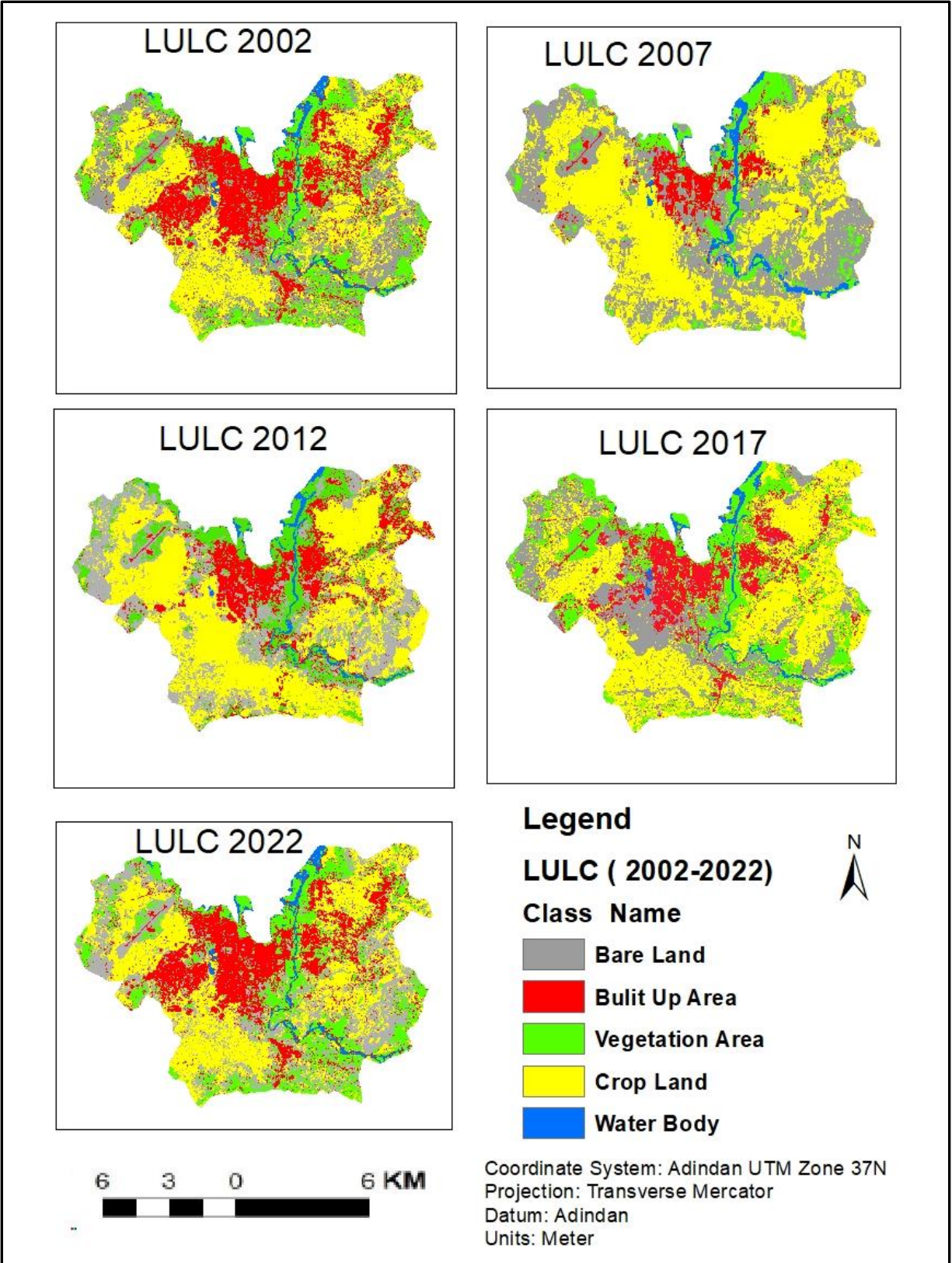


Fig.4.1. LULC Change maps from 2002-2022

Table 4. 2 . LULC area coverage of the study between 2002 and 2022

LULC classes	2002 area (Ha)	2007 area (Ha)	2012 area (Ha)	2017 area (Ha)	2022 area (Ha)
Bare Land	9339.52	9394.67	6694.85	5675.84	6069.08
Crop Land	11667.18	11139.68	10691.96	10269.07	7991.15
Vegetation Area	2336.96	2544.48	3960.155	5248.47	5222.50
Water Body	744.28	722.39	509.77	524.51	600.10
Buildup Area	1253.95	1540.66	3485.15	3624.07	5519.19
SUM	25341.91	25341.91	25341.91	25341.91	25341.91

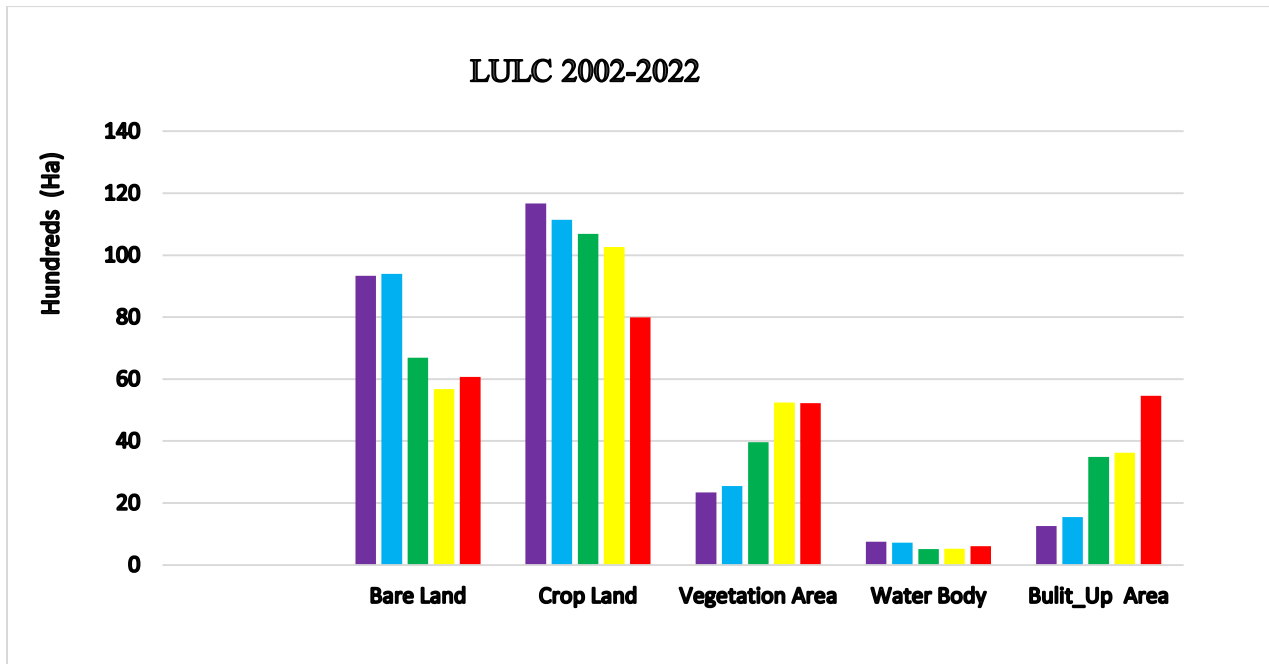


Fig.4. 2. Land use land cover change in Ha (2002-2022)

### **4.3. Rate of Land use Land cover Change (2002-2022)**

The study presents the annual rate of LULC change for various classes between the years (2002 and 2022). The LULC classes include Bare Land, Crop Land, Vegetation Area, Water Body, and Buildup Area (Table 4.3).

The Bare Land class experienced a decrease in LULC change rate from 2002 to 2022, with the most significant decrease occurring between 2012 and 2017. The overall change rate for this class is -1.751%.

Crop Land saw a continuous decline in LULC change rate between 2002 and 2012, with the most significant decrease occurring between 2007 and 2012. The overall change rate for this class is -1.575%.

Vegetation Area experienced a steady increase in LULC change rate between 2002 and 2022. The most significant increase occurred between 2002 and 2007, with the overall change rate for this class being 6.174%.

Water Body class experienced a decrease in LULC change rate between 2002 and 2022, with the most significant decrease occurring between 2017 and 2022. The overall change rate for this class is 0.969%.

Buildup Area saw an increase in LULC change rate between 2002 and 2022, with the most significant increase occurring between 2012 and 2017. The overall change rate for this class is 17.072%.

As presented in table 4.3 of land use land cover rate of change presents a complex picture of gains and losses in different LULC classes. The negative signs indicate decreases or losses in specific LULC classes such as cropland and water bodies, while positive signs indicate gains or expansions in other LULC classes such as vegetation area and built-up area. The data provided can be used to study the changing patterns of land use and land cover over time.

Table 4. 3 . Land use land cover Annual rate of change

LULC classes	2002-2007	2007-2012	2012-2017	2017-2022	2002-2022
Bare Land	0.118	-5.748	-3.044	1.386	-1.751
Crop Land	-0.904	-0.804	-0.791	-4.436	-1.575
Vegetation Area	1.776	11.127	6.506	-0.099	6.174
Water Body	-0.588	-5.886	0.578	2.882	-0.969
Buildup Area	4.573	25.242	0.797	10.458	17.072

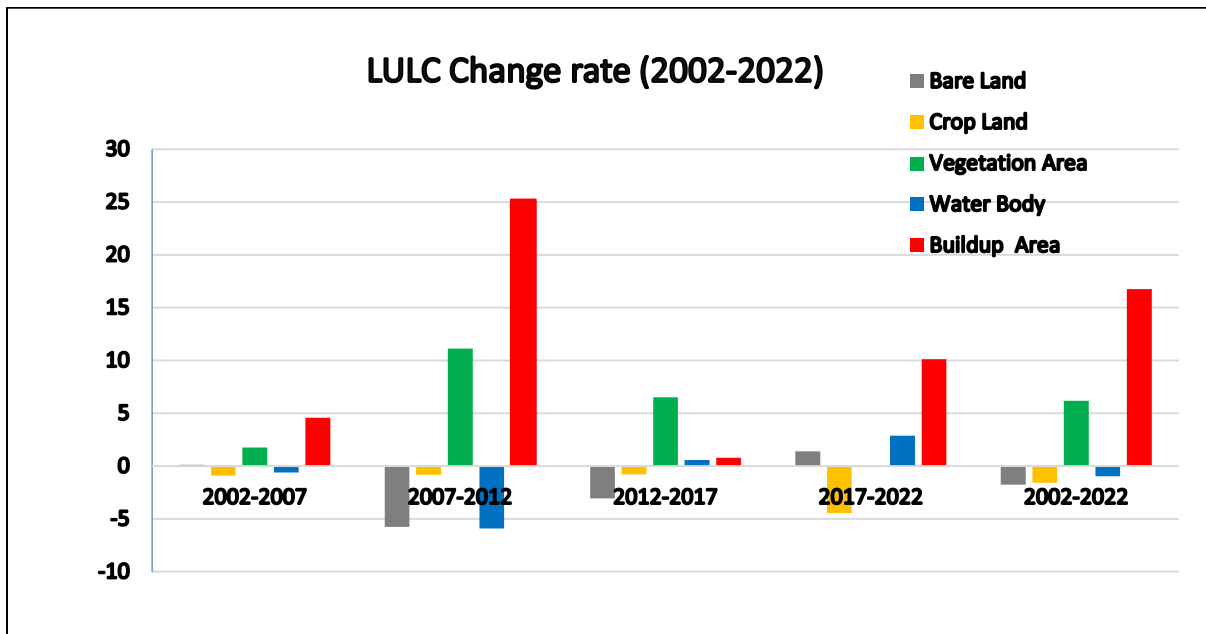


Fig.4. 3. Land use land cover change rate of the study area (2002-2022)

#### 4.4. Land Use Transitions and Spatial Trends of Changes

According to the result of the study, during the period from 2002 to 2007, the Land use land cover change matrix shows: 6383.06 hectares remained as bare land, 387.5624 hectares were converted to buildup, 1849.8254 hectares were converted to cropland, 676.7438 hectares were converted to vegetation, and 5.806 hectares were converted to water bodies. Whereas, 242.592 hectares converted from build up to bare land, 837.207 hectares were remained as built up area, 110.292 hectares were converted to cropland, 77.601 hectares were converted to vegetation, and 0.476 hectares were converted to water bodies. Moreover, 2217.568 hectares converted cropland to bare land, 210.434 hectares were converted to buildup, 9028.893 hectares remained as cropland, 161.754 hectares were converted to vegetation, and 2.85 hectares were converted to water bodies. In this similar period, 492.718 hectares of vegetation area converted to bare land, 103.8204 hectares were converted to buildup, 137.896 hectares were converted to cropland, 1519.401 hectares remained as vegetation, and 20.676 hectares were converted to water bodies. On the other hand, 63.74 hectares water bodies converted to bare land, 1.644 hectares were converted to buildup, 15.78 hectares were converted to cropland, 108.985 hectares were converted to vegetation, and 654.585 hectares remained as water bodies (Table 4.4)

Table 4. 4. Land use land cover change detection matrix between (2002-2007)

Land use classes		LULC 2007					
		Bare Land	Buildup Area	Crop Land	Vegetation Area	Water Body	Grand Total
LULC 2002	Bare Land	6383.060	387.562	1849.825	676.744	5.806	9302.998
	Buildup Area	242.592	837.207	110.292	77.601	0.476	1268.168
	Crop Land	2217.568	210.434	9028.893	161.754	2.850	11621.500
	Vegetation Area	492.718	103.820	137.896	1519.401	20.676	2274.511
	Water Body	63.740	1.644	15.780	108.985	684.585	874.734
	Grand Total	9399.677	1540.669	11142.688	2544.484	714.393	25341.911

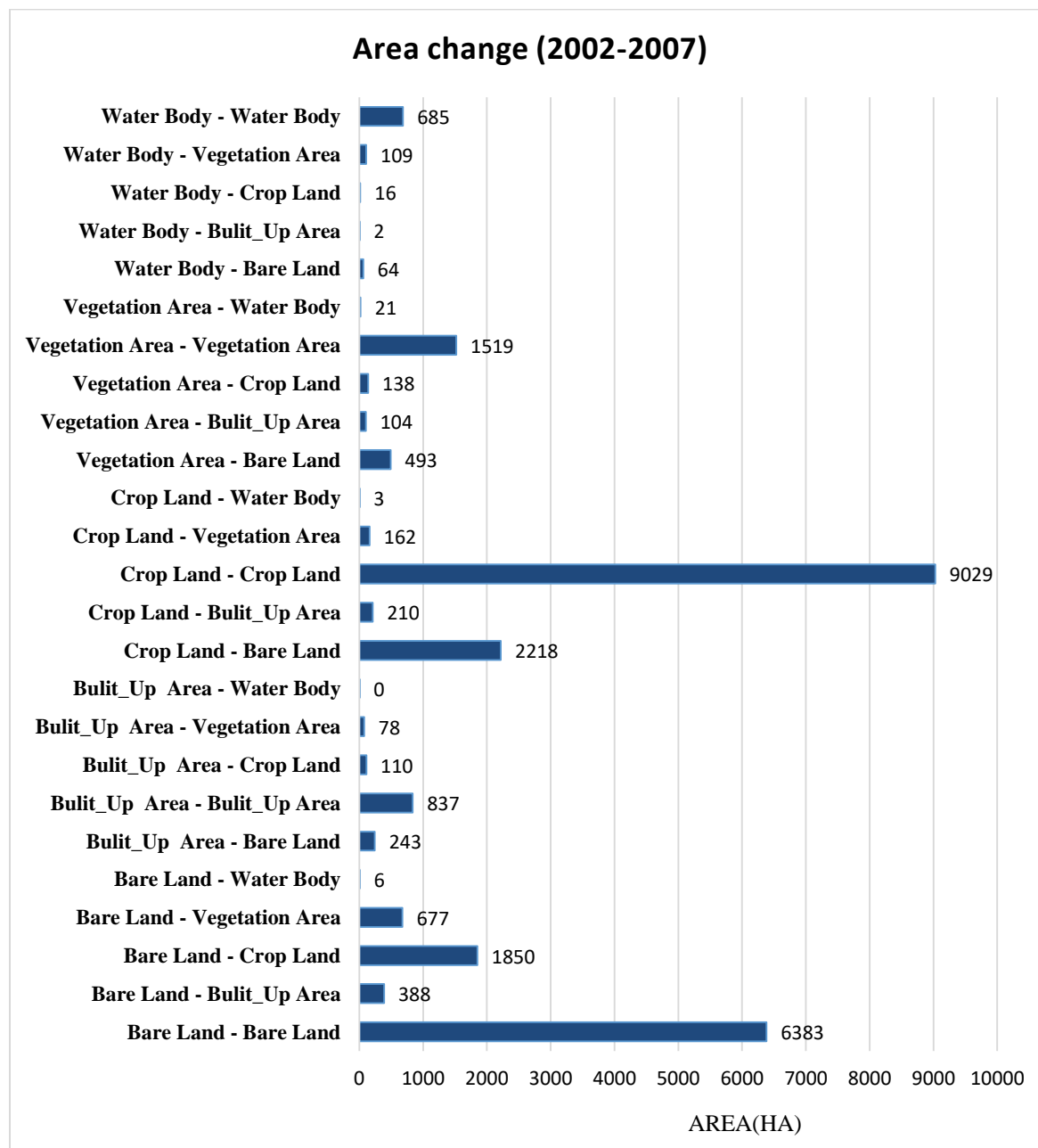


Fig.4. 4. LULC Transitions (2002-2007)

The transition matrix presented in Table 4.5 shows important information on how different land use categories changed during the specified time (2007-2012). The values represent the amount of land that transitioned from one category to another. Specifically, the matrix shows the amount of change (in hectares) from one land use category to another.

In the transitions matrix table between different land use categories, it reveals that a significant portion of bare land is being converted into built-up areas, cropland, vegetation, and water bodies. Specifically, 4,479.244 hectares remain as bare land, while 2,292.77 hectares became cropland, 1,445.338 hectares turned into vegetation, and 10.916 hectares converted into water bodies. Conversely, built-up areas experienced some changes as well, with 159.367 hectares turning back into bare land, 33.600 hectares becoming cropland, 208.0214 hectares transforming into vegetation, and 3.172 hectares changing into water bodies. Whereas, 1155.234 hectares were remained as built up area, 33.600 hectares were converted to cropland, and 208.0214 hectares were converted to vegetation.

The transition patterns for cropland, vegetation, and water bodies are also outlined in the matrix, with each category undergoing conversions to different land use types. These numbers provide valuable insights into the dynamic nature of land use and highlight the shifts taking place between different categories over time.

Table 4.5. Land use land cover change detection matrix between (2007-2012)

Land use Class		LULC 2012					
		Bare Land	Built-up Area	Crop Land	Vegetation Area	Water Body	Grand Total
LULC 2007	Bare Land	4479.2444	1129.8326	2292.7704	1445.3384	10.916	9358.102
	Built-up Area	159.3674	1155.2336	33.6004	208.0214	3.172	1559.395
	Crop Land	1734.7324	940.7106	8079.6464	369.4994	2.115	11126.704
	Vegetation Area	293.1234	214.6886	269.4554	1686.6394	21.954	2485.861
	Water Body	28.3914	44.6916	16.4914	250.6564	471.62	811.851
	Grand Total	6694.859	3485.157	10691.964	3960.155	509.777	25341.912

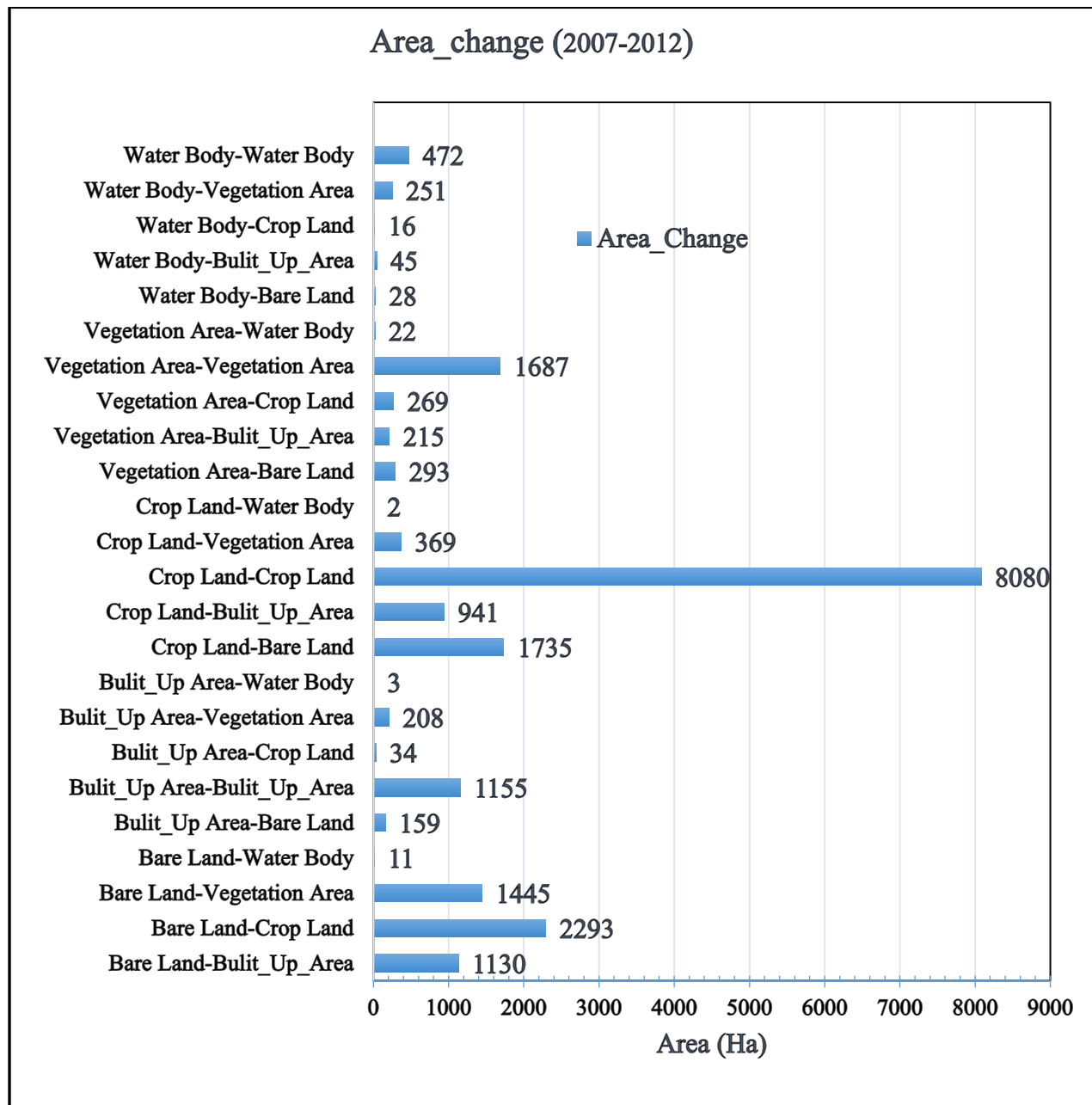


Fig.4. 5. LULC Transitions (2007-2012)

Table 4.6 represents a transition matrix showing land use land cover change detection between 2012 and 2017. The values in the table represent the area in hectares of each land use category transitioning to another land use category. Between 2012 and 2017, significant land use and land

cover changes were observed. The transition matrix reveals that Bare Land, which initially covered a large area, remained relatively stable, with 2533.140 hectares remaining in the same category. However, it also experienced substantial transitions, with 609.084 hectares converting to Build up Land, 2356.100 hectares converting to Crop Land, 1151.449 hectares converting to Vegetation, and 16.833 hectares converting to Water. Built up Land also underwent considerable changes, with 1866.616 hectares remaining in the same category and 931.979 hectares converting to Crop Land, 428.842 hectares converting to Vegetation, and 6.707 hectares converting to Water. Crop Land, the largest land use category, saw transitions of 2679.520 hectares to Bare Land, 851.530 hectares to build up area, 6469.001 hectares remaining in the same category, 654.208 hectares to Vegetation, and 21.612 hectares to Water.

Vegetation likewise, experienced changes, with 201.102 hectares converting to Bare Land, 283.300 hectares converting to build up Land, 498.046 hectares to Crop Land, and the remaining 2887.555 hectares in the same category. Water, the smallest land use category, saw minor changes, with 8.693 hectares converting to Bare Land, 13.478 hectares to build up Land, 13.953 hectares to Crop Land, 126.420 hectares to Vegetation, and 461.204 hectares remaining in the same category. Overall, these transitions highlight the dynamic nature of land use and land cover over this five-year period.

Table 4.6. Land use land cover change detection matrix between (2012-2017)

Land Use Classes		LULC 2017					
		Bare Land	Built up Area	Cropland	Vegetation Area	Water body	Grand Total
LULC 2012	Bare Land	2533.140	609.084	2356.100	1151.449	16.833	6686.606
	Built-up Area	253.387	1866.616	931.979	428.842	6.707	3497.531
	Crop Land	2679.520	851.530	6469.001	654.208	21.612	10675.871
	Vegetation Area	201.102	283.300	498.046	2887.555	18.154	3958.157
	Water Body	8.693	13.478	13.953	126.420	461.204	523.748
	Grand Total	5675.842	3624.007	10269.079	5248.474	524.511	25341.913

### Area\_change(2012-2017)

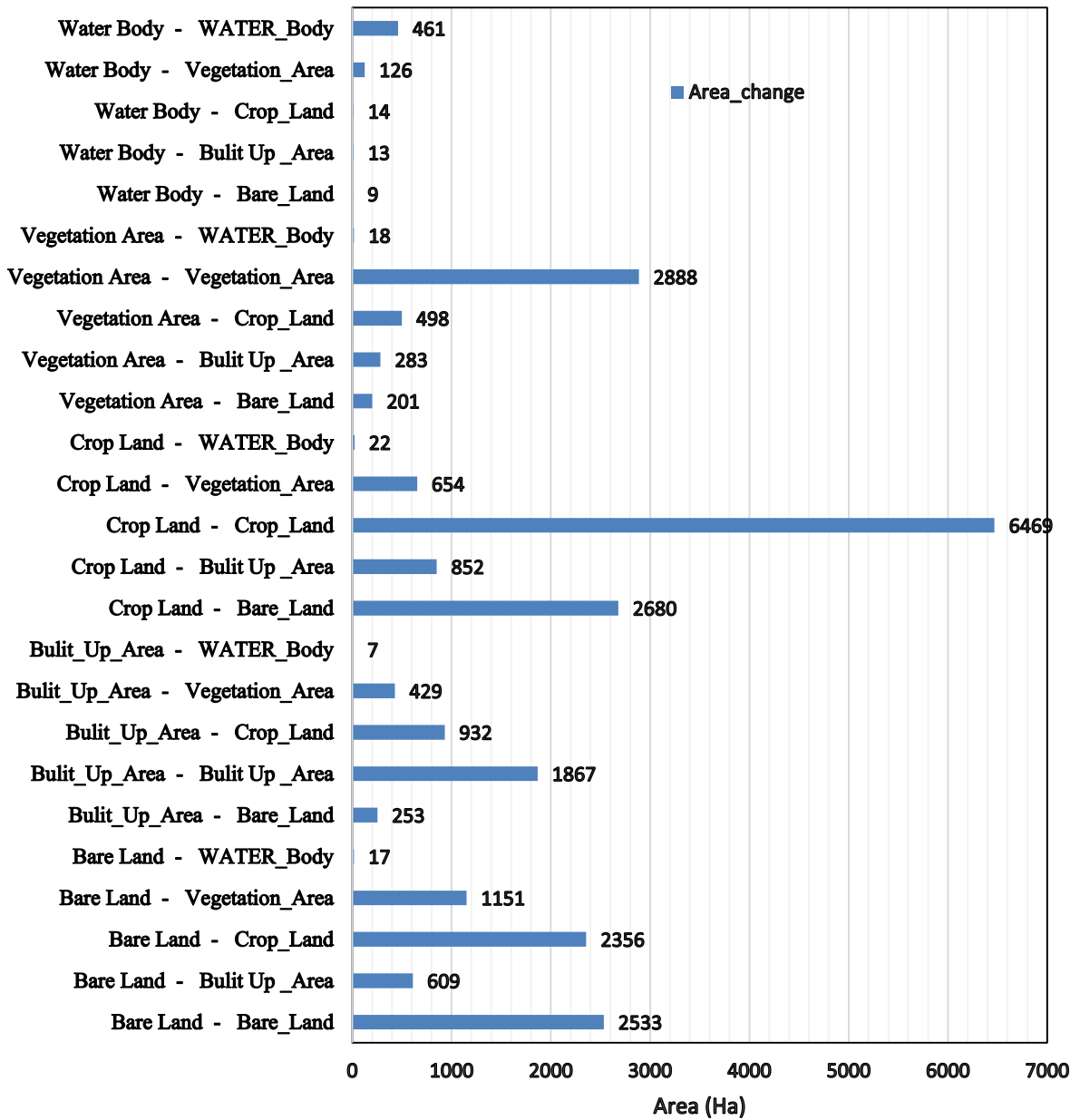


Fig.4.6. LULC Transitions (2012-2017)

Between 2017 and 2022, there were significant land use and land cover changes in the studied area. The most transitions occurred with built-up areas, with 319.049 hectares Converted to bare land, 2959.849 hectares remained as built up area, 317.746 hectares Converted to cropland, and 231.614 hectares converted to vegetation. Likewise, bare land experienced transitions of 957.127 hectares to built-up areas, 1956.827 hectares to crop land, 336.388 hectares to vegetation, and 9.925 hectares to water.

Cropland exhibited transitions of 2516.603 hectares to bare land, 1017.209 hectares to built-up areas, 5451.560 hectares to cropland, and 1051.181 hectares to vegetation. Additionally, vegetation areas saw transitions of 815.484 hectares to bare land, 579.602 hectares to built-up areas, 154.133 hectares to cropland, and 3536.555 hectares to vegetation area. Finally, water transitioned to 45.289 hectares to bare land, 5.411 hectares to built-up areas, 10.888 hectares to cropland, 66.763 hectares to vegetation, and 565.447 hectares remain as water. These changes in land use and cover highlight the dynamic nature of the studied area during the five-year period.

Table 4.7. Land use land cover change detection matrix between (2017-2022)

Land use classes		LULC 2022					
		Bare Land	Built up Area	Crop Land	Vegetation Area	Water Body	Grand Total
LULC 2017	Bare Land	2412.533	957.127	1956.827	336.388	9.925	5672.800
	Built up Area	319.049	2959.849	317.746	231.614	9.692	3837.950
	Cropland	2516.603	1017.209	5451.560	1051.181	1.918	10038.471
	Vegetation Area	815.484	579.602	154.133	3536.555	13.119	5098.893
	Waterbody	45.289	5.411	10.888	66.763	565.447	693.798
	Grand Total	6108.958	5519.198	7891.154	5222.502	600.101	25341.913

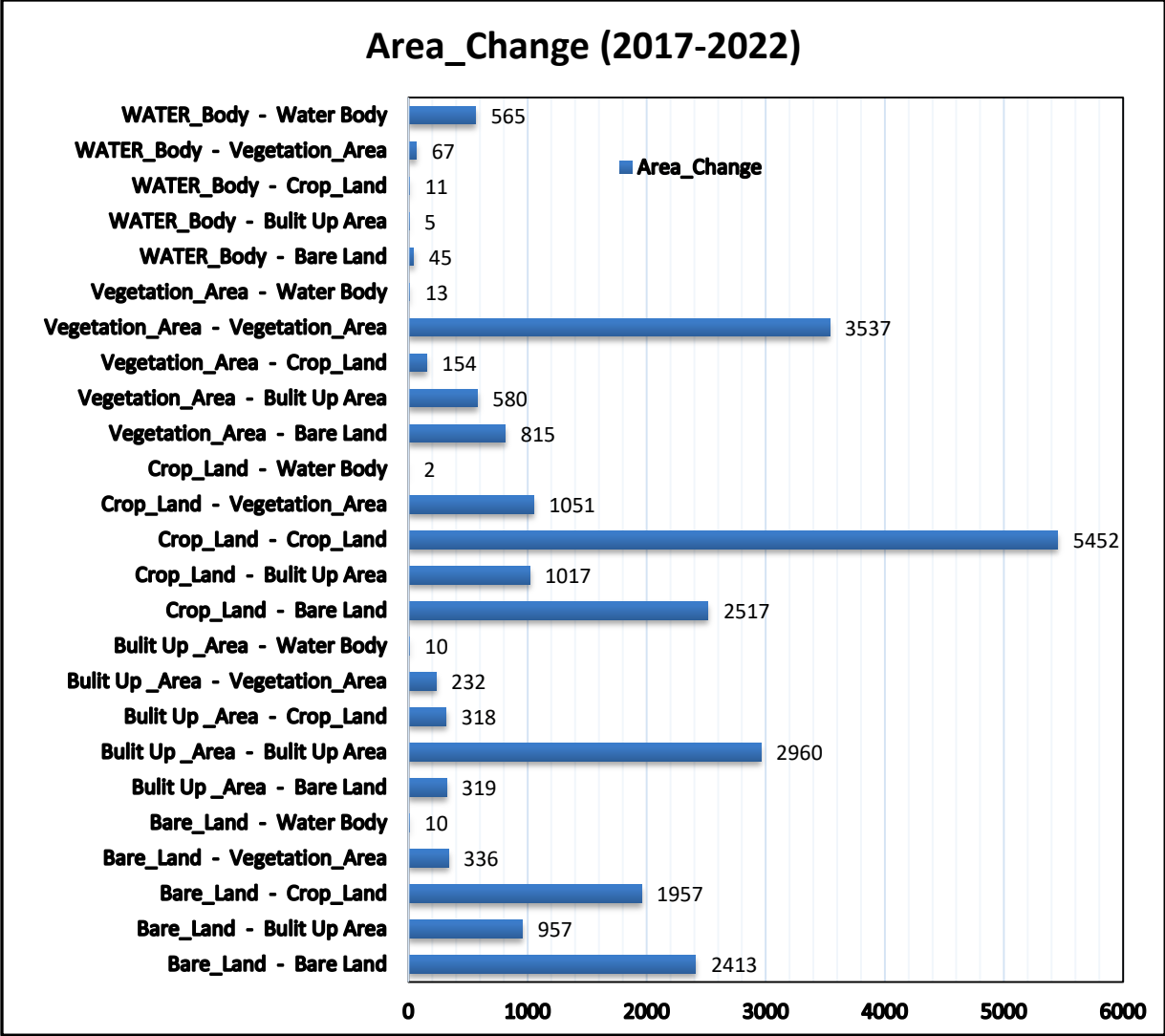


Fig. 4.7. LULC Transitions (2017-2022)

## **4.5. Extent and Patterns of Urban Sprawl over the Study Area**

The results of the study on urban area expansion from 2002 to 2022 show a significant increase in the area covered by urban regions. From 1253.951 hectares in 2002, the urban area expanded to 5519.19 hectares in 2022. The result of the study presented in table 4.8, showed land use and land cover (LULC) conversion for different time periods. It shows the extent of conversion from various land categories to built-up areas.

From 2002-2007, there was a conversion of 387.562 hectares of bare land to built-up areas. Similarly, 837.207 hectares remains as built-up area during this period. Cropland witnessed the conversion of 210.434 hectares to built-up area, while vegetation and water bodies saw conversions of 103.82 and 1.644 units, respectively.

From 2007-2012, the conversion of land use types continued. The land use and land cover (LULC) conversion data from 2002 to 2022 reveals significant changes in different areas. From 2002 to 2007, there was a conversion of 387.562 hectares of bare land into built-up areas, indicating rapid urbanization or infrastructure development during that period. The conversion of cropland into built-up areas also increased from 210.434 hectares in 2002-2007 to 940.7106 hectares in 2007-2012, reflecting potential agricultural land loss due to urban expansion. Vegetation was also affected, with 103.82 hectares of conversion in 2002-2007, which further increased to 214.6886 hectares in 2007-2012. This emphasizes the impact on green spaces during these periods. However, there seems to be a slight decrease in the conversion of water bodies into built-up areas.

Table 4. 8. Conversion of Different LULC to Built-Up Area from 2002-2022

No	LULC Conversion to built-up area	2002-2007	2007-2012	2012-2017	2017-2022
1	Bare Land - built up area	387.562	1129.8326	609.084	957.127
2	built up area - built up area	837.207	1155.2336	1866.616	2959.849
3	Cropland - built up area	210.434	940.7106	851.53	1017.209
4	Vegetation - built up area	103.82	214.6886	283.3	579.602
5	Water body - built up area	1.644	44.6916	13.478	5.411
	total	1540.667	3485.157	3624.008	5519.198

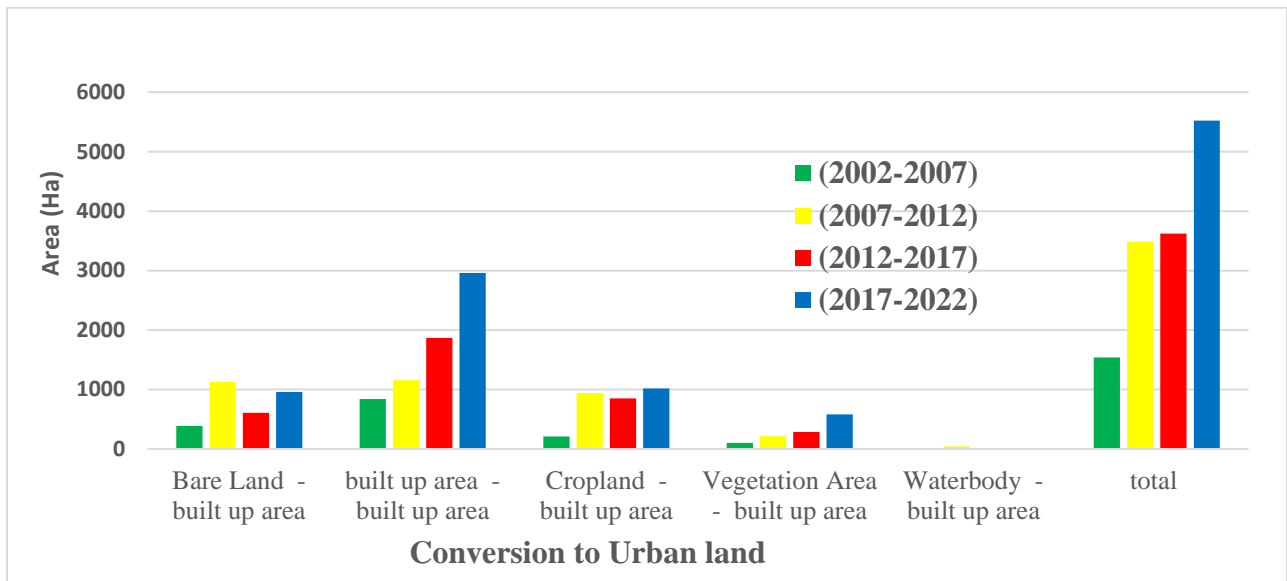


Fig. 4.8. LULC converted to Built-up area (2002-2022)

### **4.5.1. Urban Expansion Intensity Index (UEII)**

The Urban Expansion Intensity Index (UEII) measures the rate or intensity of urban expansion in a given period. The values presented in the table represent the UEII for four different time periods: 2002-2007, 2002-2012, 2002-2017, and 2002-2022.

According to the result of the study, the UEII for the period 2002-2007 is 0.226%. This indicates a relatively low rate or intensity of urban expansion during this period. It suggests that the urban areas grew at a slower pace or experienced limited expansion during these five years.

In the next period, 2002-2012, the UEII notably increased to 0.88%. This suggests a significant acceleration in the rate or intensity of urban expansion compared to the previous period. It indicates that during these ten years, urban areas experienced rapid growth and expansion.

However, the UEII for the period 2002-2017 dropped to 0.623%. This signifies a considerable decrease in the rate or intensity of urban expansion compared to the previous period. It indicates a slowdown in the growth or limited expansion of urban areas during these fifteen years.

Lastly, the UEII for the period 2002-2022 increased to 0.830% (Fig 4.9). It indicates that the urban areas were expected to experience a rapid growth and expansion in 20 years.

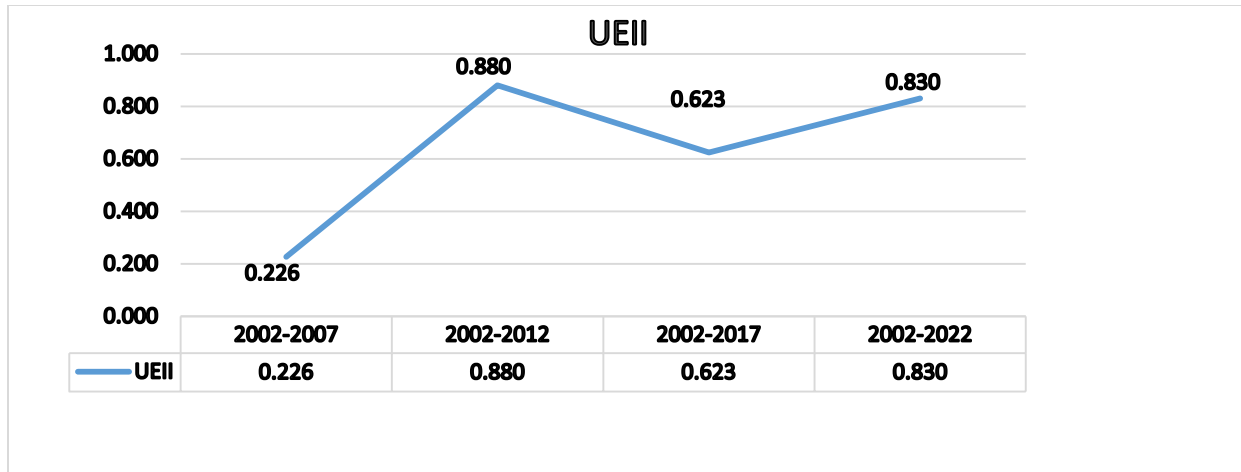


Fig.4.9. The graph indicated Urban Expansion Intensity Index

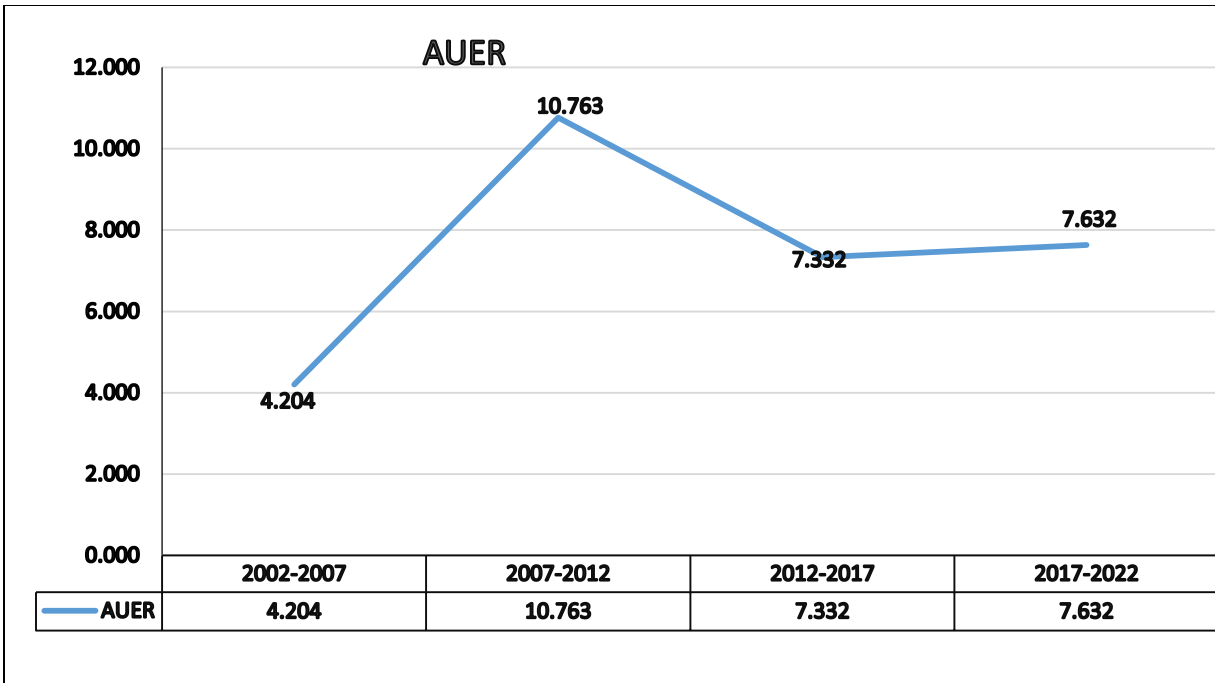
#### 4.5.2. Annual Urban Expansion Rate (AUER)

The annual urban expansion rates for the periods 2002-2007, 2002-2012, 2002-2017, and 2002-2022 were 4.204, 10.763, 7.332, and 7.632, respectively. These rates highlight the fluctuations in urban growth within the region over the years. From 2002 to 2007, the annual urban expansion rate was 4.204%. This shows that the urban growth during this period was relatively moderate.

However, from 2007 to 2012, the urban expansion rate increased significantly to 10.763%. This indicates a period of rapid urban growth within the region.

In the subsequent period from 2012 to 2017, the urban expansion rate dropped to 7.332%. This low growth rate from the previous period suggests a slowdown in urban development.

From 2017 to 2022, the urban expansion rate increased again to 7.632%. This suggests a return to a period of rapid urban growth within the region. The reasons behind this could be similar to the period from 2012 to 2017 (Fig 4.10).



**Fig. 4.10. The graph indicated annual urban expansion rates**

## CHAPTER FIVE

### Discussions

The LULC classes included are Bare Land, Crop Land, and Vegetation, Water Body, and Buildup area. The study examined the changes in land use and land cover (LULC) in Bahir Dar city of five years, from 2002 to 2022. The results showed that there was a decrease in cropland and bare land area between 2002 and 2007, while water bodies slightly decreased and build-up areas increased. From 2007 to 2012, cropland decreased, vegetation area continued to grow, water bodies decreased, and build-up areas significantly increased. From 2012 to 2017, cropland slightly decreased, vegetation area continued to grow, water bodies decreased, and build-up areas significantly increased. Finally, from 2017 to 2022, cropland further decreased, vegetation area continued to grow, water bodies decreased, and build-up areas significantly increased. The result reflects changes in land use and cover over the specified period, with reductions in bare land, cropland, and water bodies, alongside slight increase in vegetation cover and significant expansion of built-up areas. The observed reductions in bare land and cropland, over the specified period are consistent with global trends related to urbanization.

The finding of the study is consistent with the decrease in cropland observed in the study from 2002 to 2022. The study conducted by Gebre (2018) analyzed land cover changes in the Lake Tana Basin, where Bahir Dar City is located, from 1973 to 2014. The study found that water bodies in the basin had significantly decreased over the years due to human activities such as irrigation and dam construction. This finding aligns with the slight decrease in water bodies observed in the study from 2002 to 2022. Additionally, a study by Gebremichael et al. (2020) investigated land use and land cover changes in the Upper Blue Nile Basin, which includes the Bahir Dar City region, from 1985 to 2017. The study revealed a substantial increase in built-up areas and a decrease in cropland during the study period, which is consistent with the findings of the study in Bahir Dar City.

These related studies support the findings of the study in Bahir Dar City, emphasizing the common trends of land use and land cover changes in the region. Cropland has continuously decreased over the years, likely due to agricultural intensification and urban expansion. Vegetation cover has generally increased, possibly indicating afforestation efforts or natural

regeneration. Water bodies have consistently decreased, reflecting the impact of human activities on the local hydrological system. Finally, build-up areas have significantly increased, indicating urbanization and infrastructure development in Bahir Dar City.

By analyzing the Urban Expansion Intensity Index for four different interval periods - 2002-2007, 2007-2012, 2012-2017, and 2017-2022 - there are significant changes in the rate of urban expansion. Values across these time periods reveal significant fluctuations in the rate of urban expansion. During the period 2002-2007, the UEII was recorded at 0.226, indicating a certain level of urban expansion during those five years. However, in the subsequent period of 2007-2012, there was a notable increase in the UEII to 0.88, signifying a substantial acceleration in the rate or intensity of urban expansion compared to the previous period. This indicates that urban areas experienced rapid growth and expansion during this period. In contrast, the UEII for the period 2012-2017 dropped to 0.623, indicating a considerable decrease in the rate or intensity of urban expansion compared to the previous period. This signifies a slowdown in growth or limited expansion of urban areas during these five years. For the period 2017-2022 is 0.83, showing increase in the rate or intensity of urban expansion compared to the preceding period.

Several studies have focused on analyzing urban expansion trends and their implications. A study by Smith et al. (2018) examined urban expansion patterns in various regions and highlighted the impact of rapid urbanization on land use and environmental sustainability. The findings of this study align with the observed acceleration in urban expansion indicated by the notable increase in UEII during the period 2007-2012. In contrast, research by Johnson and Brown (2016) investigated factors contributing to the slowdown of urban growth in specific metropolitan areas. Their findings emphasized the influence of economic fluctuations and policy interventions on moderating urban expansion rates, which resonates with the decreased UEII recorded for the period 2012-2017. Furthermore, a comparative analysis conducted by Garcia et al. (2020) explored projected urban expansion trends using advanced modeling techniques. Urban expansion rates regions, reflecting similarities with the rise in UEII for the period 2017-2022.

## CHAPTER SIX

### CONCLUSIONS AND RECOMMENDATIONS

#### 6.1. Conclusions

Based on the analyzed information, the land use and land cover (LULC) classes from 2002 to 2022, the area coverage of built-up areas consistently increased, nearly doubling from 1253.951 hectares in 2002 to 5519.19 hectares in 2022. This indicates significant urbanization and infrastructure development over the study period. The study indicates changes in land use and land cover over the 20-year period. There is a decrease in cropland and bare land, while built-up areas experienced significant growth. Vegetation and water bodies remained relatively stable in terms of area coverage.

The study identifies significant changes in the LULC classes over the 20-year period. The Cropland area has shown a slight reduction, potentially indicating shifts in agricultural practices or land use policies. The growth observed in the Vegetation area suggests improving ecological conditions. The decrease in Water Bodies implies changes in water management or environmental factors. The significant expansion of the Buildup Area signifies urban or industrial development. The continuous decrease in Bare Land could be associated with land conversion or natural regeneration processes.

These findings shown that, potential urbanization and development trends in the studied area. Have important implications for land use planning, environmental management, and sustainable development within the study area. The LULC classification process demonstrated a strong level of accuracy, with an overall classification accuracy of 89.06% and a Kappa statistics value of 0.8631.

Buildup Area saw an increase in LULC change rate, with the most significant increase occurring between 2007 and 2012. This indicates an expansion in built-up areas or urbanization. The study presents a complex picture of gains and losses in different LULC classes. The study indicates changes in different LULC classes over different periods. Various factors may have contributed

to these changes, such as urbanization, agricultural practices, and environmental conditions.

The net change in each LULC class between (2002-2022) provides understandings into the overall land use dynamics and their implications for the environment and society in the study area. The slight increase in vegetation cover observed in the current study reflects efforts towards reforestation, afforestation. It is important to assess whether this trend is a result of conservation initiatives or natural ecological processes.

The study shows significant land use and land cover changes in the area under investigation between 2002 and 2022. The findings reveal dynamic transitions between different categories, including bare land, built-up areas, cropland, vegetation, and water bodies. These changes indicate the ongoing transformation of the landscape and emphasize the need for effective land use planning and sustainability efforts. The study provides valuable understanding and managing land use changes over time, which can contribute to informed decision-making and the promotion of sustainable land management practices.

## **6.2. Recommendations**

According to the findings of the study, the following recommendations are presented as follows:

- The increase in Land Use/Land Cover (LULC) change rate in the Buildup area indicates an expansion in built-up areas or urbanization. It is essential to monitor and plan for sustainable development in the area to ensure a balance between urban growth and the preservation of natural resources. This includes promoting sustainable land use practices, encouraging produce green environment and. sustainable agricultural practices
- The result of the current study shows a decrease in cropland, while built-up areas experienced significant growth the decrease in cropland, by integrating urban agriculture into new built-up areas, it is possible to maintain some level of crop production while accommodating population growth. This approach can help ensure food security and contribute to a more sustainable urban environment.
- Conduct regular monitoring and assessment of land use transitions and spatial trends to effectively manage land use changes and their impacts. The result of the current study can guide decision-making and adapt policies to achieve sustainable development objectives.

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# Appendixes

## Appendix1: CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File: d:/aaaa-research2016/aaaaresearchs/habte/LULC\_2022.img

User Name: habtamu

Date : Wed Dec 27 23:59:27 2023

### ERROR MATRIX

-----

Classified Data	BARELAND			
-----	-----	-----	-----	-----
BARELAND	0	0	0	43
VEGETATION	0	0	0	3
WATER	0	0	0	0
BUILTUP	0	0	0	2
CROPLAND	0	0	0	2
Column Total	0	0	0	50

### Reference Data

-----

Classified Data			VEGETATION	WATER
-----	-----	-----	-----	-----
BARELAND	0	0	2	0
VEGETATION	0	0	47	14
WATER	0	0	0	36
BUILTUP	0	0	0	1
CROPLAND	0	0	0	0
Column Total	0	0	49	51

Reference Data

Classified Data	BUILTUP		CROPLAND	
BARELAND	0	1	0	0
VEGETATION	0	1	0	0
WATER	0	0	0	0
BUILTUP	0	56	0	1
CROPLAND	0	1	0	46
Column Total	0	59	0	47

----- End of Error Matrix -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Bare land	50	46	43	86.00%	93.48%
Vegetation	49	65	47	95.92%	72.31%
Water	51	36	36	70.59%	100.00%
Built-up	59	60	56	94.92%	93.33%
Cropland	47	49	46	97.87%	93.88%
Totals	256	256	228		

Overall Classification Accuracy = 89.06%

----- End of Accuracy Totals -----

KAPPA (K<sup>^</sup>) STATISTICS

Overall Kappa Statistics = 0.8631

Conditional Kappa for each Category.

Class Name	Kappa
Bare land	0.9190
Vegetation	0.6575

Water	1.0000
Built-up	0.9134
Cropland	0.9250

----- End of Kappa Statistics -----

**Appendix 2: LULC Change transitions from one to another between five years**

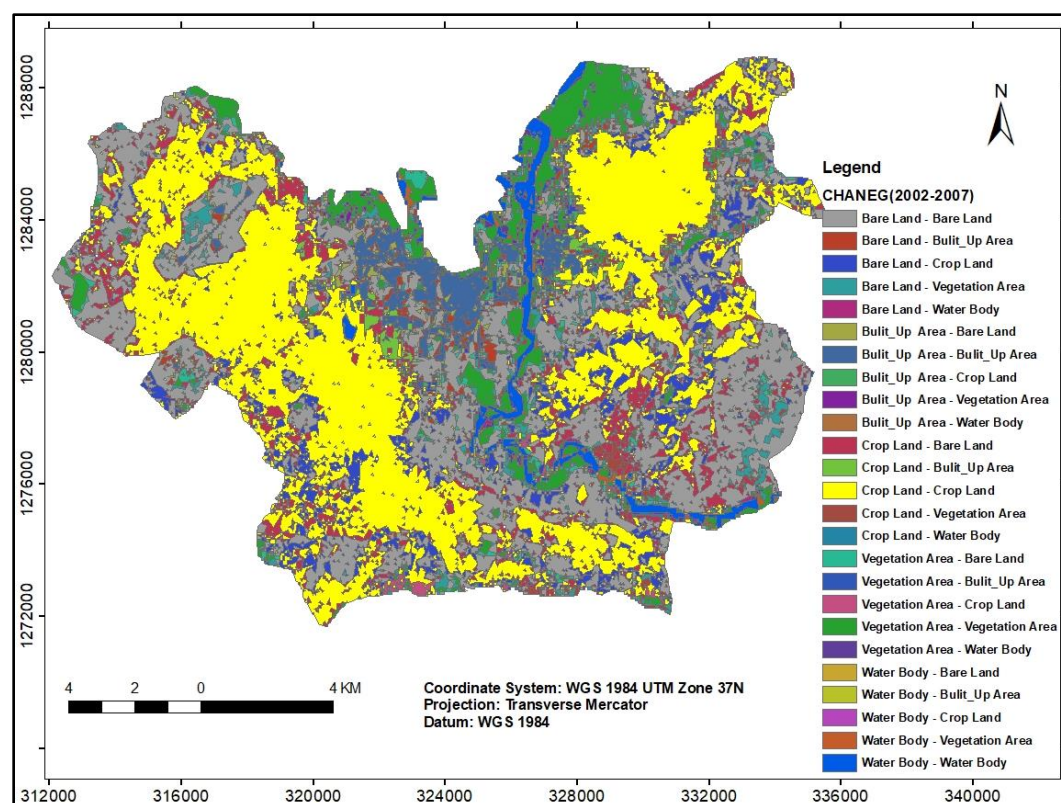
ID	Change(2002-2007)	Area change(Ha)
1	Bare Land - Bare Land	6366.829
2	Bare Land - Built-up area	386.471
3	Bare Land - Cropland	1838.732
4	Bare Land - Vegetation Area	674.386
5	Bare Land - Water Body	22.806
6	Built-up area - Bare Land	231.361
7	Built-up area - Built-up area	836.116
8	Built-up area - Cropland	99.199
9	Built-up area - Vegetation area	75.243
10	Built-up area - Water body	7.476
11	Cropland - Bare Land	2206.337
12	Cropland - Built-up area	209.343
13	Cropland - Cropland	9014.800
14	Cropland - Vegetation area	159.396
15	Cropland - Water body	22.850
16	Vegetation area - Bare Land	481.487
17	Vegetation Area - Built-up area	102.729
18	Vegetation Area - Cropland	126.803
19	vegetation Area - vegetation area	1517.043
20	vegetation Area - Water body	90.676
21	Water body - Bare Land	51.509
22	Water body - Built-up area	2.553
23	Water body - Cropland	4.687

24	Water body - vegetation area	105.627
25	Water body - Water body	571.184
<b>ID</b>	<b>Change (2007-2012)</b>	<b>Area change</b>
1	Bare Land - Bare Land	4474.437
2	Bare Land - Built-up area	1127.315
3	Bare Land - Cropland	2286.497
4	Bare Land - Vegetation Area	1439.579
5	Bare Land - Water Body	24.071
6	Built-up area - Bare Land	154.560
7	Built-up area - Built-up area	1152.716
8	Built-up area - Cropland	27.327
9	Built-up area - Vegetation area	202.262
10	Built-up area - Water body	1.327
11	Cropland - Bare Land	1729.925
12	Cropland - Built-up area	938.193
13	Cropland - Cropland	8073.373
14	Cropland - Vegetation area	363.740
15	Cropland - Waterbody	0.270
16	Vegetation area - Bare Land	288.316
17	Vegetation Area - Built-up area	212.171
18	Vegetation Area - Cropland	263.182
19	vegetation Area - vegetation area	1680.880
20	vegetation Area - Waterbody	80.109
21	Waterbody - Bare Land	23.584
22	Waterbody - Built-up area	42.174
23	Waterbody - Cropland	10.218
24	Waterbody - vegetation area	244.897
25	Waterbody - Waterbody	394.775
<b>ID</b>	<b>Change(2012-2017)</b>	<b>Area change</b>

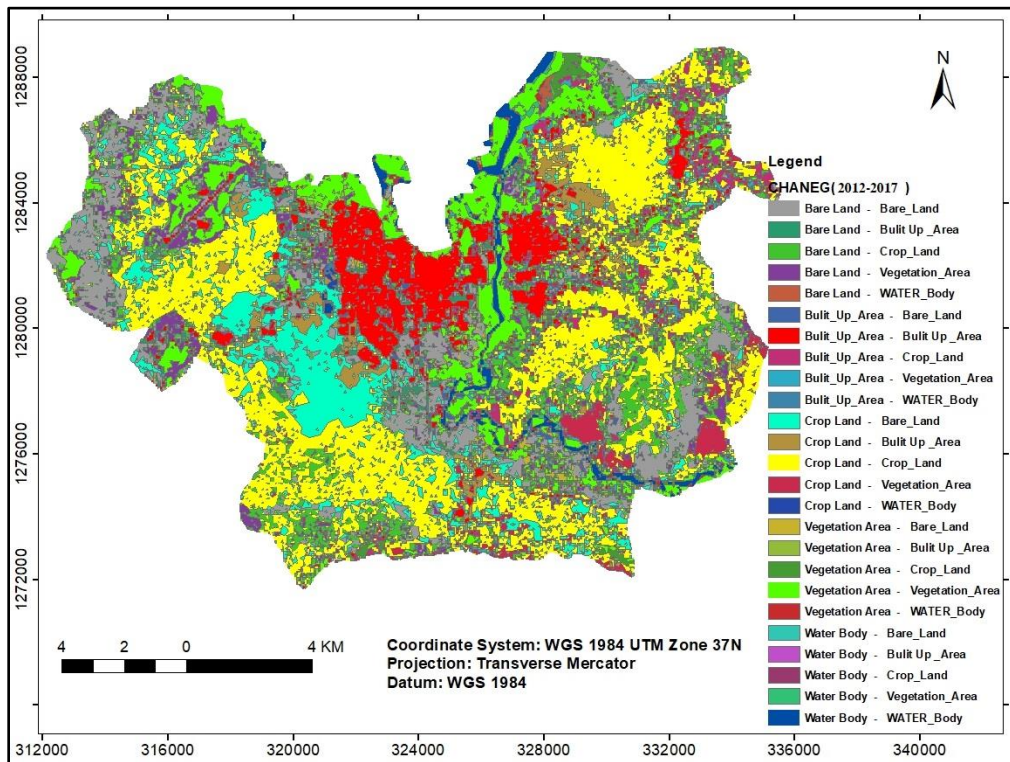
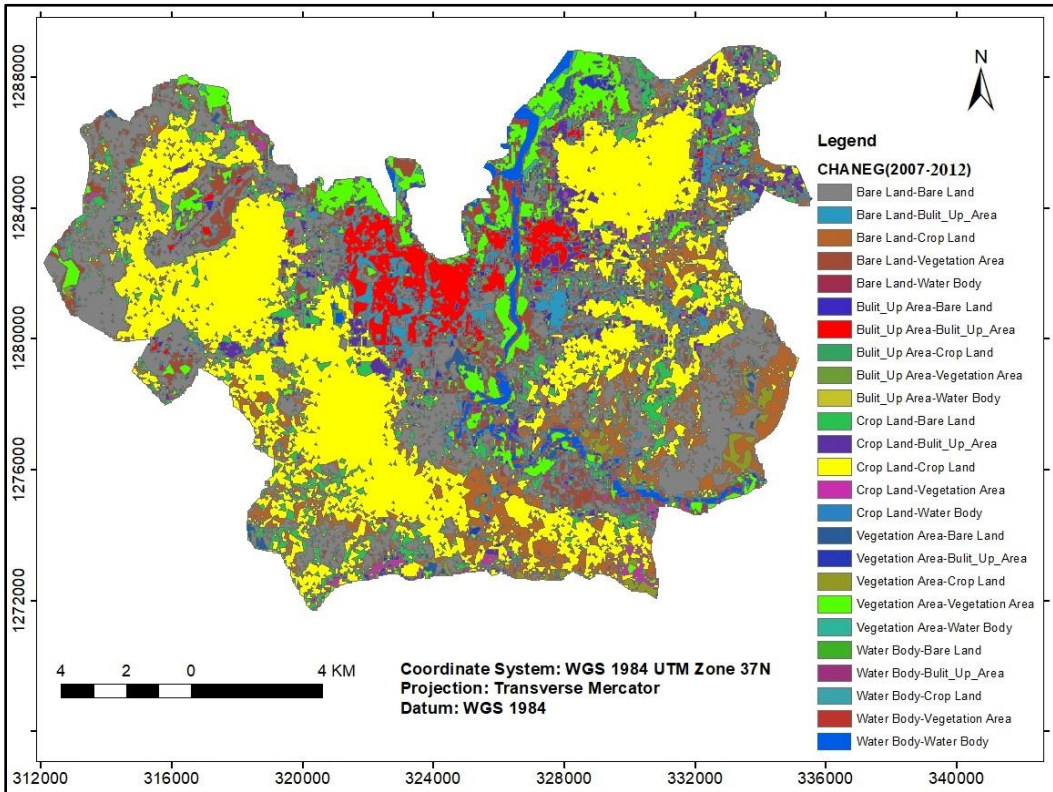
1	Bare Land - Bare Land	2528.035
2	Bare Land - Built-up area	607.254
3	Bare Land - Cropland	2346.678
4	Bare Land - Vegetation Area	1143.574
5	Bare Land - Water Body	35.348
6	Built-up area - Bare Land	248.282
7	Built-up area - Built-up area	1864.786
8	Built-up area - Cropland	922.557
9	Built-up area - Vegetation area	420.967
10	Built-up area - Water body	15.222
11	Cropland - Bare Land	2674.415
12	Cropland - Built-up area	849.700
13	Cropland - Cropland	6459.579
14	Cropland - Vegetation area	646.333
15	Cropland - Waterbody	20.127
16	Vegetation area - Bare Land	195.997
17	Vegetation Area - Built-up area	281.470
18	Vegetation Area - Cropland	488.624
19	vegetation Area - vegetation area	2879.680
20	vegetation Area - Waterbody	86.669
21	Waterbody - Bare Land	3.588
22	Waterbody - Built-up area	11.648
23	Waterbody - Cropland	4.531
24	Waterbody - vegetation area	118.545
25	Waterbody - Waterbody	359.719
<b>ID</b>	<b>Change(2017-2022)</b>	<b>Area Change</b>
1	Bare Land - Bare Land	2407.738
2	Bare Land - Built-up area	953.301
+3	Bare Land - Cropland	1949.419

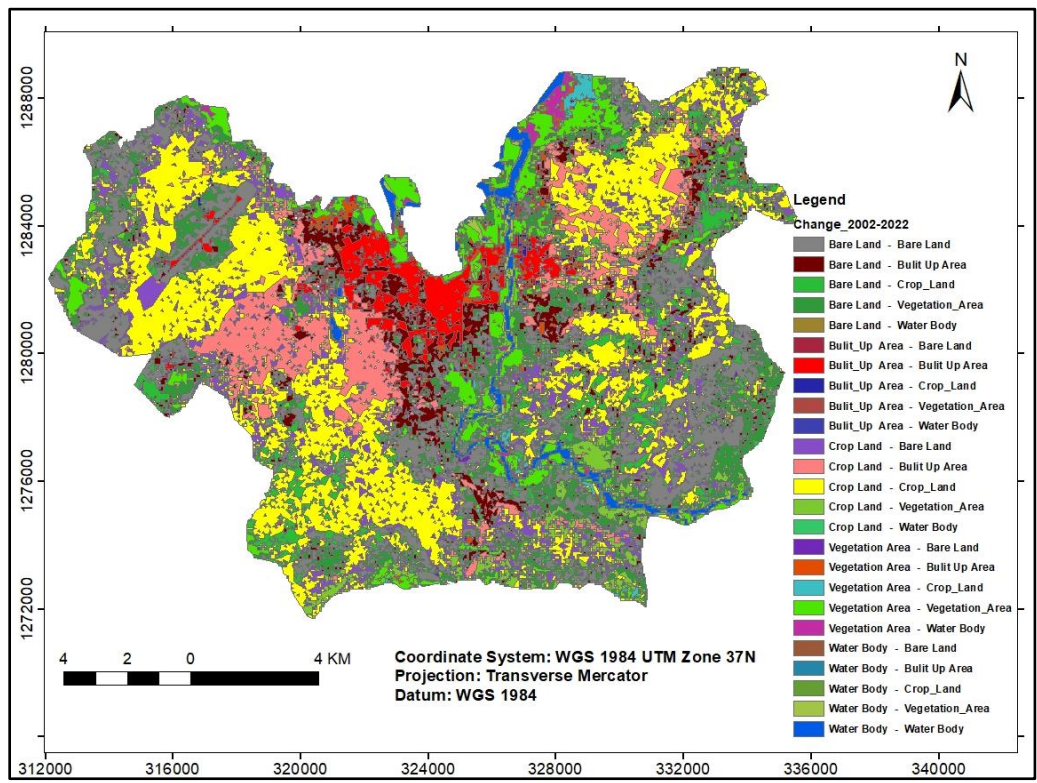
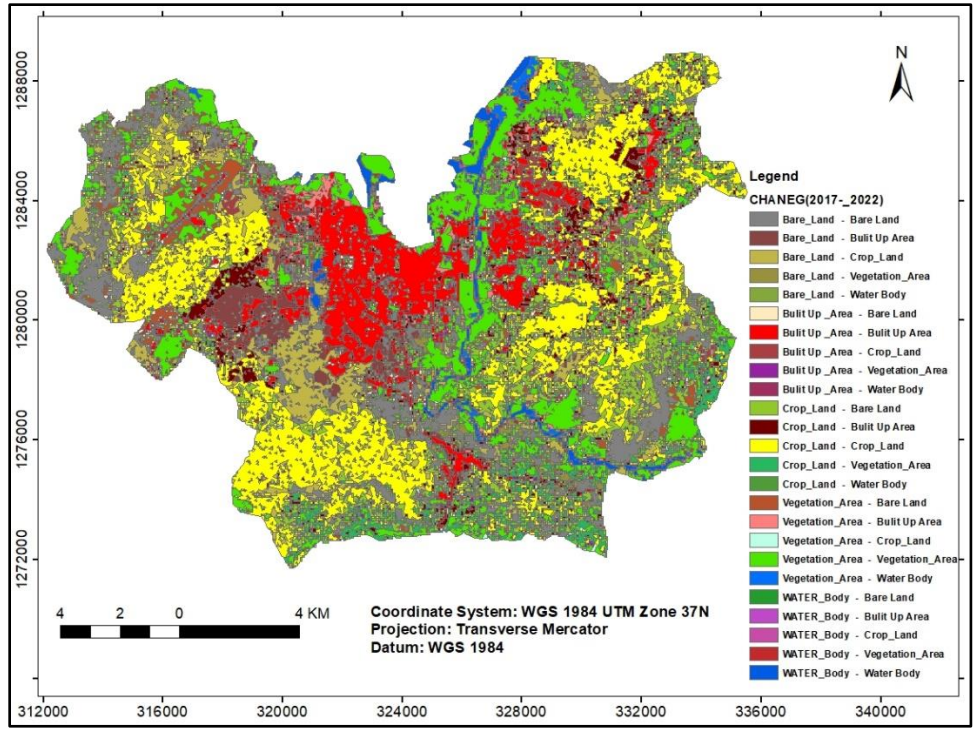
4	Bare Land - Vegetation Area	331.107
5	Bare Land - Water Body	8.159
6	Built-up area - Bare Land	314.254
7	Built-up area - Built-up area	2656.023
8	Built-up area - Cropland	410.338
9	Built-up area - Vegetation area	226.333
10	Built-up area - Water body	7.926
11	Cropland - Bare Land	2511.808
12	Cropland - Built-up area	1213.383
13	Cropland - Cropland	5444.152
14	Cropland - Vegetation area	1045.900
15	Cropland - Waterbody	10.152
16	Vegetation area - Bare Land	810.689
17	Vegetation Area - Built-up area	575.776
18	Vegetation Area - Cropland	146.725
19	vegetation Area - vegetation area	3531.274
20	vegetation Area - Waterbody	151.353
21	Waterbody - Bare Land	0.616
22	Waterbody - Built-up area	41.463
23	Waterbody - Cropland	3.480
24	Waterbody - vegetation area	61.482
25	Waterbody - Waterbody	413.681
<b>ID</b>	<b>Change (2002-2022)</b>	<b>Area – change</b>
1	Bare Land - Bare Land	3758.774
2	Bare Land - Built-up area	1621.421
3	Bare Land - Cropland	1653.252
4	Bare Land - Vegetation Area	2244.456
5	Bare Land - Water Body	3.787
6	Built-up area - Bare Land	66.501

7	Built-up area - Built-up area	997.536
8	Built-up area - Cropland	54.489
9	Built-up area - Vegetation area	126.651
10	Built-up area - Water body	3.992
11	Cropland - Bare Land	2109.576
12	Cropland - Built-up area	2432.179
13	Cropland - Cropland	6054.580
14	Cropland - Vegetation area	997.842
15	Cropland - Waterbody	10.224
16	Vegetation area - Bare Land	98.504
17	Vegetation Area - Built-up area	289.211
18	Vegetation Area - Cropland	169.160
19	vegetation Area - vegetation area	1623.937
20	vegetation Area - Waterbody	135.958
21	Waterbody - Bare Land	3.713
22	Waterbody - Built-up area	94.025
23	Waterbody - Cropland	6.362
24	Waterbody - vegetation area	194.858
25	Waterbody - Waterbody	439.210



**Appendix3:**  
**LULC**  
**Transition**  
**maps of the**  
**study area**  
**(2002-2022)**





#### Appendix 4: accuracy assessment point

NO	Classes	Classification_Codes	X	Y
1	Bare_Land	11	315597.2146	1286834.07
2	Bare_Land	11	315332.6308	1281838.726
3	Bare_Land	11	313734.5442	1280854.474
4	Bare_Land	11	313544.0438	1281404.809
5	Bare_Land	11	312379.8749	1282177.394
6	Bare_Land	11	316232.2159	1280060.723
7	Bare_Land	11	315523.1311	1279245.804
8	Bare_Land	11	319934.2733	1277982.152
9	Bare_Land	11	322279.968	1281942.866
10	Bare_Land	11	319692.3378	1283427.182
11	Bare_Land	11	320382.9017	1281228.49
12	Bare_Land	11	319414.5248	1281030.052
13	Bare_Land	11	332482.0571	1276580.281
14	Bare_Land	11	333386.934	1277294.657
15	Bare_Land	11	332878.9329	1279755.287
16	Bare_Land	11	333910.81	1280406.163
17	Bare_Land	11	333625.0594	1279421.911
18	Bare_Land	11	331341.7007	1275535.174
19	Bare_Land	11	330243.6777	1276791.948
20	Bare_Land	11	330336.282	1277268.199
21	Bare_Land	11	332108.9939	1276381.843
22	Bare_Land	11	326790.8583	1277036.688
23	Bare_Land	11	323278.8131	1277118.849
24	Bare_Land	11	323580.4387	1276864.848
25	Bare_Land	11	325421.9424	1276642.598
26	Bare_Land	11	331877.7887	1282335.384
27	Bare_Land	11	332354.0396	1282430.634

28	Bare_Land	11	330957.0368	1282282.467
29	Bare_Land	11	332639.7902	1279626.045
30	Bare_Land	11	332597.4568	1278800.544
31	Bare_Land	11	331803.7052	1278345.46
32	Bare_Land	11	331189.8706	1275820.271
33	Bare_Land	11	327932.3141	1277668.125
34	Bare_Land	11	328465.7152	1275178.92
35	Bare_Land	11	329037.2163	1275324.97
36	Bare_Land	11	330084.9684	1274347.068
37	Bare_Land	11	325076.7928	1276463.078
38	Bare_Land	11	327385.287	1279393.344
39	Bare_Land	11	327206.6929	1280491.367
40	Bare_Land	11	328536.2268	1280583.971
41	Bare_Land	11	325870.5444	1280041.574
42	Bare_Land	11	321958.6719	1273057.883
43	Bare_Land	11	323871.6133	1273565.884
44	Bare_Land	11	324022.4261	1272978.508
45	Bare_Land	11	322695.2734	1274389.799
46	Bare_Land	11	330823.5543	1287634.602
47	Bare_Land	11	331319.649	1286391.058
48	Bare_Land	11	329447.7182	1285193.816
49	Built_Up area	19	324910.1049	1281882.549
50	Built_Up area	19	324285.687	1281617.965
51	Built_Up area	19	324126.9367	1282094.216
52	Built_Up area	19	324370.3539	1281205.214
53	Built_Up area	19	324476.1874	1280422.046
54	Built_Up area	19	322179.5995	1281025.297
55	Built_Up area	19	322020.8492	1280220.962
56	Built_Up area	19	321724.5152	1279596.544
57	Built_Up area	19	322274.8497	1279035.627

58	Built_Up area	19	322539.4335	1279649.461
59	Built_Up area	19	322370.0999	1283353.635
60	Built_Up area	19	321407.0146	1283099.635
61	Built_Up area	19	321195.3475	1283808.719
62	Built_Up area	19	319015.1765	1280908.88
63	Built_Up area	19	318549.5089	1280697.213
64	Built_Up area	19	318168.5081	1280284.462
65	Built_Up area	19	317872.1742	1280136.295
66	Built_Up area	19	317099.5893	1280220.962
67	Built_Up area	19	320094.6786	1280549.046
68	Built_Up area	19	322571.1836	1280750.13
69	Built_Up area	19	324687.8545	1281692.049
70	Built_Up area	19	327735.8606	1280834.797
71	Built_Up area	19	327312.5264	1282295.3
72	Built_Up area	19	327630.027	1283141.968
73	Built_Up area	19	327291.3597	1282898.551
74	Built_Up area	19	331842.2021	1285459.723
75	Built_Up area	19	331619.9517	1285173.972
76	Built_Up area	19	332572.4536	1286137.057
77	Built_Up area	19	332202.0362	1284888.222
78	Built_Up area	19	328144.3781	1286249.241
79	Built_Up area	19	328188.8282	1285861.89
80	Built_Up area	19	328188.8282	1285423.739
81	Built_Up area	19	327674.4771	1284966.538
82	Built_Up area	19	327706.2272	1285201.489
83	Built_Up area	19	327668.1271	1285950.79
84	Built_Up area	19	326048.8739	1283004.385
85	Built_Up area	19	325839.3235	1282813.884
86	Built_Up area	19	325966.3237	1281664.532
87	Built_Up area	19	327458.5767	1281588.332

88	Built_Up area	19	323486.1146	1282324.933
89	Built_Up area	19	317248.55	1283158.372
90	Built_Up area	19	317207.5395	1284294.76
91	Built_Up area	19	318040.9787	1284719.417
92	Built_Up area	19	317441.6962	1284124.103
93	Built_Up area	19	316857.4951	1283442.535
94	Built_Up area	19	315985.4267	1282714.401
95	Built_Up area	19	315710.2594	1282752.501
96	Built_Up area	19	315543.0424	1282125.966
97	Built_Up area	19	315680.6261	1282331.283
98	Built_Up area	19	317481.913	1280410.228
99	Built_Up area	19	320242.8456	1280344.082
100	Built_Up area	19	320553.7316	1280793.875
101	Built_Up area	19	320097.3245	1279801.685
102	Built_Up area	19	325773.3098	1275295.16
103	Built_Up area	19	319568.8182	1281782.757
104	Built_Up area	19	318891.4835	1278057.416
105	Built_Up area	19	323241.2422	1282925.759
106	Built_Up area	19	329464.2547	1280047.087
107	Crop_Land	31	322649.0942	1276403.4
108	Crop_Land	31	323231.1787	1275583.19
109	Crop_Land	31	323879.4091	1274445.479
110	Crop_Land	31	321352.6333	1274945.542
111	Crop_Land	31	320066.7557	1275612.294
112	Crop_Land	31	319114.2538	1275310.668
113	Crop_Land	31	318947.5659	1274207.353
114	Crop_Land	31	319957.218	1278876.2
115	Crop_Land	31	321060.5327	1279916.015
116	Crop_Land	31	321155.7829	1280979.642
117	Crop_Land	31	330072.9205	1285569.511

118	Crop_Land	31	330813.7553	1286058.991
119	Crop_Land	31	330747.6093	1285106.489
120	Crop_Land	31	328961.6683	1280793.772
121	Crop_Land	31	330800.5261	1278994.602
122	Crop_Land	31	328750.0012	1278597.726
123	Crop_Land	31	328220.8335	1279708.978
124	Crop_Land	31	324503.4302	1275449.178
125	Crop_Land	31	324675.4097	1274602.509
126	Crop_Land	31	323484.7823	1275065.531
127	Crop_Land	31	322743.9475	1275369.803
128	Crop_Land	31	322810.0935	1275065.531
129	Crop_Land	31	320891.8605	1275581.47
130	Crop_Land	31	320680.1934	1277340.952
131	Crop_Land	31	320468.5263	1278068.558
132	Crop_Land	31	321077.0692	1278386.059
133	Crop_Land	31	320742.6352	1277492.294
134	Crop_Land	31	321085.5358	1279308.398
135	Crop_Land	31	321288.7363	1280832.401
136	Crop_Land	31	318981.8296	1282733.172
137	Crop_Land	31	318998.366	1283526.923
138	Crop_Land	31	318171.5415	1283692.288
139	Crop_Land	31	315360.3379	1280732.256
140	Crop_Land	31	314979.9986	1280566.891
141	Crop_Land	31	315608.3853	1285412.083
142	Crop_Land	31	315839.8962	1284882.915
143	Crop_Land	31	316021.7976	1285478.229
144	Crop_Land	31	316269.845	1285957.787
145	Crop_Land	31	313309.813	1283179.657
146	Crop_Land	31	314715.4148	1281492.935
147	Crop_Land	31	316419.9963	1281717.17

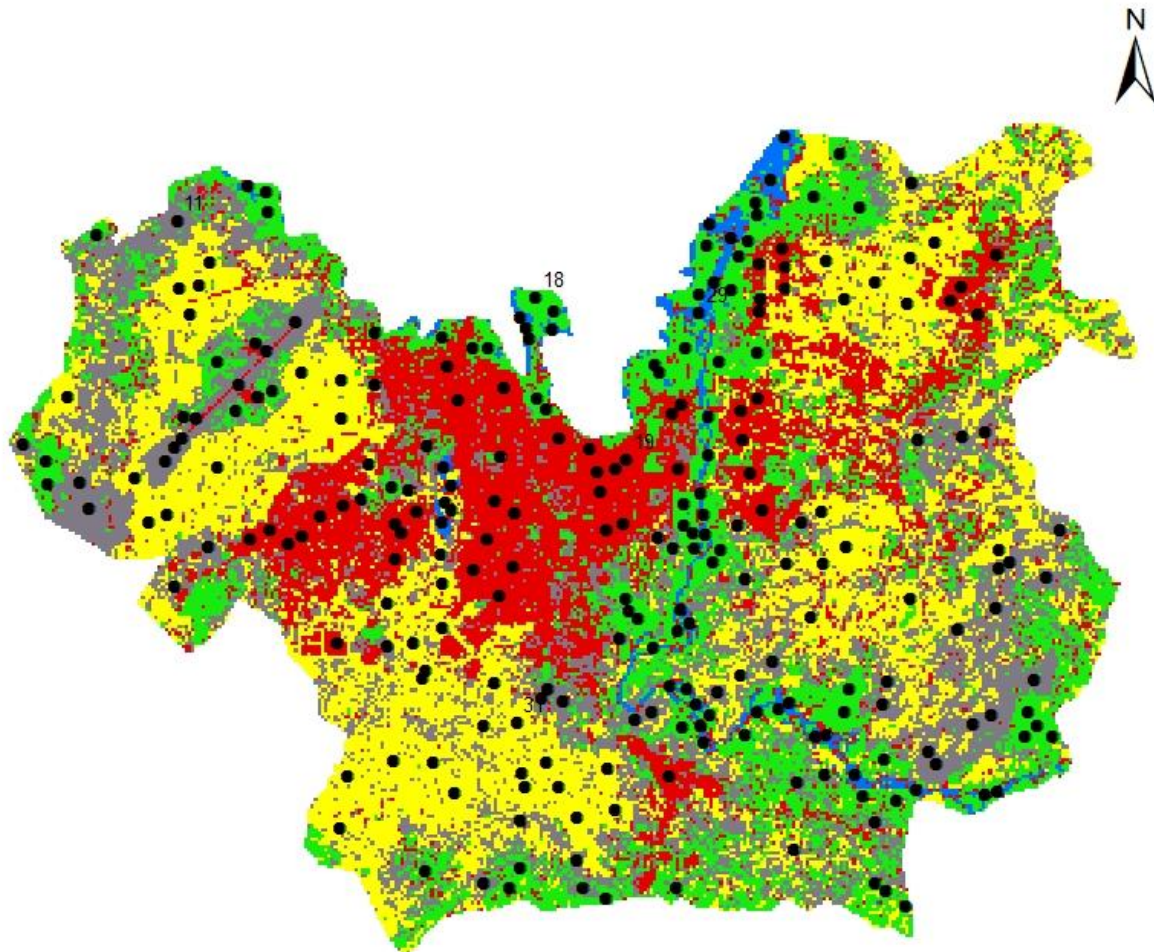
148	Crop_Land	31	332642.9558	1280009.942
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150	Crop_Land	31	329004.9277	1279695.749
151	Crop_Land	31	328400.3536	1273777.008
152	Crop_Land	31	321944.5074	1276359.346
153	Crop_Land	31	324763.6484	1278139.996
154	Vegetation_area	18	323032.7408	1285231.24
155	Vegetation_area	18	323413.7415	1284945.49
156	Vegetation_area	18	326408.8309	1285305.324
157	Vegetation_area	18	326588.7479	1286331.909
158	Vegetation_area	18	327583.5832	1287199.744
159	Vegetation_area	18	328811.2523	1287347.911
160	Vegetation_area	18	329742.5875	1287125.661
161	Vegetation_area	18	329329.8367	1288226.329
162	Vegetation_area	18	327086.1656	1285400.574
163	Vegetation_area	18	327445.9996	1286416.576
164	Vegetation_area	18	327636.5	1284109.405
165	Vegetation_area	18	326821.5817	1283897.737
166	Vegetation_area	18	326101.9136	1280955.565
167	Vegetation_area	18	326091.3302	1280500.481
168	Vegetation_area	18	329425.0869	1276637.556
169	Vegetation_area	18	329530.9204	1277092.641
170	Vegetation_area	18	325149.4117	1278553.143
171	Vegetation_area	18	324905.9945	1278976.478
172	Vegetation_area	18	326694.5814	1279727.896
173	Vegetation_area	18	326853.3318	1279981.896
174	Vegetation_area	18	322027.3221	1284204.655
175	Vegetation_area	18	317465.8963	1287030.41
176	Vegetation_area	18	317434.1463	1287432.578
177	Vegetation_area	18	313920.4726	1286554.159

178	Vegetation_area	18	312883.3038	1281368.316
179	Vegetation_area	18	312862.1371	1281833.983
180	Vegetation_area	18	316407.5609	1283908.321
181	Vegetation_area	18	317558.5007	1283287.872
182	Vegetation_area	18	316791.2075	1282897.61
183	Vegetation_area	18	320025.7452	1281310.107
184	Vegetation_area	18	320753.3508	1282163.39
185	Vegetation_area	18	333436.1783	1276342.545
186	Vegetation_area	18	333261.5529	1276644.171
187	Vegetation_area	18	333753.6789	1276120.295
188	Vegetation_area	18	333198.0528	1276120.295
189	Vegetation_area	18	330062.734	1273064.351
190	Vegetation_area	18	330284.9845	1272929.413
191	Vegetation_area	18	330713.6103	1272596.038
192	Vegetation_area	18	329808.7335	1274897.917
193	Vegetation_area	18	330523.1099	1274786.792
194	Vegetation_area	18	330269.1094	1275659.919
195	Vegetation_area	18	325943.1633	1272977.039
196	Vegetation_area	18	324474.7228	1272754.788
197	Vegetation_area	18	322704.6568	1273397.727
198	Vegetation_area	18	322482.4063	1272992.914
199	Vegetation_area	18	320728.2153	1273342.164
200	Vegetation_area	18	325490.7249	1283835.56
201	Vegetation_area	18	329052.0237	1285999.856
202	Vegetation_area	18	324839.8486	1280528.262
203	Vegetation_area	18	322151.6765	1277247.422
204	Water_Body	29	326431.8497	1284930.871
205	Water_Body	29	326733.4753	1285565.873
206	Water_Body	29	327098.601	1286486.624
207	Water_Body	29	326654.1001	1286764.437

208	Water_Body	29	327908.2276	1287693.127
209	Water_Body	29	328186.0407	1288574.191
210	Water_Body	29	322717.0922	1284827.684
211	Water_Body	29	326598.5375	1282755.992
212	Water_Body	29	326439.7872	1281184.364
213	Water_Body	29	326558.8499	1280303.3
214	Water_Body	29	326034.9739	1278771.359
215	Water_Body	29	326245.318	1278485.608
216	Water_Body	29	326368.3495	1276802.855
217	Water_Body	29	325808.7547	1277183.856
218	Water_Body	29	326515.1936	1275997.197
219	Water_Body	29	327630.4146	1276624.261
220	Water_Body	29	328281.2909	1276834.605
221	Water_Body	29	329654.4811	1275326.477
222	Water_Body	29	330932.4212	1275001.039
223	Water_Body	29	332345.299	1274929.601
224	Water_Body	29	332599.2995	1274977.226
225	Water_Body	29	329043.2924	1276167.854
226	Water_Body	29	328840.8857	1276108.322
227	Water_Body	29	321109.9437	1281716.177
228	Water_Body	29	321102.0062	1280557.3
229	Water_Body	29	321292.5066	1281335.177
230	Water_Body	29	317042.0991	1287567.913
231	Water_Body	29	326598.3391	1281967.73
232	Water_Body	29	326515.6566	1280727.494
233	Water_Body	29	326333.7552	1280036.268
234	Water_Body	29	325473.8576	1277949.363
235	Water_Body	29	326158.4684	1277122.538
236	Water_Body	29	326442.896	1276345.323
237	Water_Body	29	322832.8008	1284610.593

238	Water_Body	29	323383.1353	1284578.842
239	Water_Body	29	322885.7176	1284367.175
240	Water_Body	29	327621.7687	1286938.931
241	Water_Body	29	327261.9347	1286108.137
242	Water_Body	29	326140.0991	1284181.967
243	Water_Body	29	325589.7647	1283668.674
244	Water_Body	29	326293.5577	1280361.376
245	Water_Body	29	324970.6384	1278726.247
246	Water_Body	29	323044.4679	1283144.798
247	Water_Body	29	321716.2569	1284192.55
248	Water_Body	29	321070.6723	1284425.384
249	Water_Body	29	319689.5445	1284499.467
250	Water_Body	29	325981.3488	1278318.788
251	Water_Body	29	326637.5168	1276561.951
252	Water_Body	29	326060.7239	1276323.826
253	Water_Body	29	327362.4765	1276138.617
254	Water_Body	29	328060.9779	1276688.952
255	Bare_Land	11	325558.4159	1280262.829
256	Bare_Land	11	323151.7611	1276903.672

# Accuracy Assesment Of The Classification



**Scale: 1:120,000**

Coordinate System: Adindan UTM Zone 37N  
Projection: Transverse Mercator  
Datum: Adindan  
False Easting: 500,000.0000  
False Northing: 0.0000  
Central Meridian: 39.0000  
Scale Factor: 0.9996  
Latitude Of Origin: 0.0000  
Units: Meter

## Legend

● Accuracy points

Bahir Dar LULCC2002\_2022.tif

### Class\_Name

- Bare Land
- Built Up Area
- Vegetation Area
- Crop Land
- Water Body