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GEODESY AND GEOMATICS PROGRAM, Specialization in Geomatics

The Use of GIS and Remote Sensing for Land Use/ Land Cover Change Analysis: The case of Dejen Town, Ethiopia

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Approval Sheet

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Declaration

I certify that this thesis work entitled to, "The Use of GIS and Remote Sensing for Land Use/Land Cover Change Analysis: The case of Dejen Town, Ethiopia" by the advisor of **Andenet Ashagrie (Dr.)** is my work. The work is not done by anyone before.

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Abstract

Technologies like geographic information system (GIS) and Remote Sensing (RS) are used to monitor urbanization, map it, and monitor environmental changes. Since Dejen town is expanding improperly due to growth of population and improper settlers from remote/rural areas to the city, planned development and up-to-date information is needed on the Land Use and Land Cover (LULC) and population of the town to improve the problems. The project's overall goal was to use GIS and remote sensing methods to study LULC classification and analyze trends in Dejen town between 1993 and 2023. The literature review mainly focused on the concepts and definitions of GIS, Remote Sensing, LULC, LULC Mapping, LULC Change detections, and causes for urban expansion in the study area. The Landsat imagery data were used for the research study. Those data were processed using ArcGIS 10.7, and ERDAS (Earth Resource Data Analysis System) software. Accordingly, the satellite images were used to monitor LULC changes from the years 1993-2023 for the five identified LULC classes. The Landsat images were classed into built-up and non-built-up areas to concentrate on urbanization after five distinct kinds of land use and land cover classes were found using supervised classification. The finding of the study showed that, the built up area has increased from 177ha in 1993 to 958ha in 2023, forest area increased from 0.45ha to 107ha, barren land decreased from 334ha to 162ha, agricultural land decreased from 1613ha to 868ha and a slight change occurred in open area decreased from 269ha to 298ha. Built up area has exhibited the most noticeable changes (7.39% to 40.03%) from 1993 to 2023, which come from agricultural land and barren land. The result of the study showed that the most fertile and productive part of the agricultural land has changed to urban land. The study results provide valuable information for the city administration for planning unmanaged urban growth. It also provides useful knowledge for policy relevant land administration for future development related to land use plan associated to urban expansion.

Keywords: Change analysis, Geographic information system, Land use land cover, Remote Sensing, Urban growth.

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List of Acronyms

UNHCR: United Nations High Commissioner for Refugees

LULC: Land Use Land Cover

GIS: Geographic Information System

RS: Remote Sensing

DN: Digital Number

MSS: Multi-Spectral Scanner

TM: Thematic Mapper

USGS: United States Geological Survey

ETM^+: Enhanced Thematic Mapper Plus

OLI: Operational Land Imager

TIRS: Thermal Infrared Sensors

FAO: Food and Agricultural Organization

UNESCO: United Nations Educational, Scientific and Cultural Organization

OBIA: Object-based Image Analysis

ANN: Artificial Neural Network

CA: Cellular Automata

MLP: Multi-layer Perception

PCA: Principal Component Analysis

CSA: Central Statistics Agency

GPS: Geographic Positioning System

Chapter One

1. INTRODUCTION

1.1. Background

Land-Use and Land-Cover (LULC) changes are a major issue in Ethiopia and have been becoming worse every year. The primary causes of this are population growth (Hurni et al., 2005) and local community perceptions of land management systems (Belay et al., 2014), which greatly contribute to landscape conversion and resource depletion, including forests and their biodiversity, water resources, and soil resources. Due to severe land-cover degradation, the nation is consequently susceptible to surface runoff, floods, and sedimentation (Hurni et al., 2005). All around the nation, the land is highly dynamic, but in the Amhara regional state in particular, the issue is very serious since there is not enough land to maintain the people of the area. As a result, large amounts of land have been substantially cleared for farming, grazing, and settlement, especially forest, woodland, and shrub land land-covers. Thus, these contribute to soil erosion, land degradation, biodiversity loss, deforestation, and climate change.

Land-Use and Land-Cover Change development is necessary for urban expansion (Musa, 1994). Land use and land cover changes have been found to be primarily caused by very high urbanization and town expansion in the majority of developing nations (Odjo, 2007, Oyinloyye, and Adesina, 2006). Given that urbanization is the primary driver of changes in land-use and land-cover, it is necessary to detect certain critical data when monitoring cities through the use of GIS and remote sensing applications. This data is then analyzed to project future trends in LU/LC changes and to identify the factors that lead to urbanization in the majority of developing nations, especially in Africa. This is a result of government agencies' and universities' ignorance of the data sources.

Geographic Information Systems (GIS) and Remote Sensing (RS) have significant limitations in developing nations, especially when it comes to technical know-how for obtaining high-quality data for GIS analysis, which is necessary to extract meaningful information from the data (Okpala, 1983, Adesina, 2005). However, there had been a reduction in financial resources available to universities and other higher education institutions, namely for the purpose of doing research on geographic information systems and remote sensing (Stren, 1994). The second reason is political instability in some developing nations, which makes it difficult to successfully develop remote sensing, GIS applications, data sources, and data collection. These technologies have the primary benefit of monitoring urban growth and providing thematic mapping, which gives policy makers and administrators reliable information to use for other development control and urban area planning reviews. For this reason, geographic information systems and remote sensing are required.

Urban change is resulted due to urbanization process. Urbanization, in general, is known as the process of growth of population in urban places. This is characterized by high population growth within the town as well as migration of people from outside areas mainly rural to urban. The urbanization process also involves the increase in number of urban fringes. Agricultural land is continuously being changed to urban uses in the urbanization process in the world (Perera, 2005). Therefore, rural areas get urbanized as their economy become less and less dependent upon agriculture. In summary, we can say that demography and land use pattern change, industrialization and social transformation occur during the urbanization processes. Urbanization is the change from traditional rural economies to modern ones industrial economies. Urban regions are expanding in size and population every day, necessitating more resources, better housing, and better management. In 1950, only 28 percent of population in the world was urban (UNCHS, 2001). In addition, today, more than 45 percent of the world stays in urban areas. More than half of People will reside in cities. Areas by 2008, and by 2030, it's predicted that this percentage would reach 60% (World Bank, 2005).

Monitoring Urban Growth is a process of studying state of object differences by observing it remotely at different times. Growth monitoring is determining changes in LULC properties using data collected remotely (Pilon, 1998). The main thing for detecting changes utilizing data from remotely sensed sources analysis is to identify changes between different dates which are uncharacteristic of normal variation. When economy grows it attracts new residents and significant urban growth conditions. About the worlds current urban population is half and total urban population has also increased between 1950 and 1990. 2 billion new residents being added to the cities of the developing countries in the next 25 years and industrial development will continue putting pressure on land use and environment in the major city areas. Remote sensed data have been highly used to provide the LULC information like urbanization rates, degradation levels of forests and wetlands and other human-induced changes (Pradhan, Perera, 2005).

Rapid urbanization has resulted in changes to the land-use patterns and types of land-cover in Dejen town and its surroundings. Land uses like agriculture and bare land have consequently substantially decreased. As a result of the most productive and fertile lands being changed into urban areas, crop production is reduced. Therefore, it is essential to track the dynamics of land-use and land-cover change in order to provide sustainable management of LULC change.

1.2 Statement of the problem

Dejen town is expanding improper way; this is because of the growth of population and improper settlers in the town that comes from the rural areas. Consequently, there is a rising demand of land for residential use. Large numbers of hectares of fertile and productive agricultural land area were lost to urbanization, and quarrying of sand, soil, and stone. Improper urban development caused an adverse impact not only on agriculture and other land but also on the environmental condition and the livelihoods of the area in the long run (Dejen town administration office annual report, 2020).

Dejen town is selected due to its rate of increasing urbanization and the urban planners mostly use manual method rather than digital method. So the main thing here is to show that using GIS and RS it is easy to plan/manage the urban growth of the study area for the urban planners on the area. Urban growth is among the problems in the town that reduces the limited highly fertile land. In this context, Dejen is experiencing various urban environmental problems. For sustainability of urban systems, a balanced land use/land cover is to be planned to minimize these problems and needs up-to-date information on the land use/cover and population of the city. Therefore, the study was intended to use Remote Sensing and Geographic Information System tools to acquire the information from Landsat images for providing knowledge on the trend of land utilization and urban growth that can be useful for assessing the effects on sensitive areas and planning unmanaged urban growth in Dejen town.

1.3 Objectives

1.3.1 The General Objective

The general objective of the research was to apply GIS and Remote Sensing tools for LULC change analysis of Dejen town from 1993-2023.

1.3.2 The Specific Objectives

The following things listed below are the specific objectives

- To monitor land-use and land-cover of Dejen town and its surroundings from 1993-2023.
- To assess LULC changes in the city and its surroundings and examine effects of land-use and land-cover changes.
- To identify which land-use and land-cover class type is highly converted to urban lands from 1993-2023 on the study area.

1.4. Research questions

The study was mainly focused to answer the following research questions:

- What is the land use classes/practices in the town?
- Which land use classes are mostly used for urban growth?
- What influences urban expansion will have on land-use and land-cover of an area?

1.5 Scope of the study

This study only focused on the impact of urban expansion on the land-use and land-cover of Dejen town.

1.6 Significance of the study

This study was designed to address contributions to scientific knowledge related to extracting information from remotely sensed data and provides insightful analysis techniques to fully exploit these data for better urban monitoring. The results of this study will be of great use for policy makers and urban planner in the study area.

1.7 The thesis's structure

There are five distinct chapters in the thesis.

The context of urbanization, the problem statement, the study's purpose, its research questions, and its significance are all covered in *Chapter one*. Urban growth, analysis of satellite images, geographic information systems, and remote sensing, Land Use/Land Cover: Concepts and Definitions, Maps of Land Use and Land Cover, Land Use Land Cover Change Detection, Application of Remote Sensing in Land Use and Land Cover Change, Geographical Information Systems (GIS), Identification of Patterns of Land Cover Change, Image Transformation, Causes of Urban Sprawl in Dejen Town and conclusion of the literature review are discussed on *Chapter two*. *Chapter three* covers the study area, data and methods, software to be utilized, LULC Change Detection, image classification, and accuracy assessment process. The results and discussions are explained in depth in *Chapter four*. Finally, the study's conclusions and recommendations are discussed in *Chapter five*.

Chapter Two

2. Literature Reviews

2.1 Land Use/Land Cover: Concepts and Definitions

Although "land-use" and "land-cover" are commonly used synonymously, they each have a different meaning. Land use refers to how people use the land cover, which is the bio-physical layer that covers the surface of the planet. The term "land-cover" refers to the distribution of flora, water, desert, and ice on the surface of the earth as well as the immediate subsurface biota, soil, terrain, etc. It also refers to an activity area, such as a settlement, a mine exposure, etc (Lambin, et al., 2003; Oumer, 2009). Contrarily, land-use refers to how people use the land to further their own objectives and includes elements like residential areas, farms, logging areas, etc (Zubair, 2006; Oumer, 2009). Therefore, LULC change can be described as the modification of surface characteristics on Earth's landscape that is achieved by the difference in their surface appearance measured at two different times. In this context, land-use influences changes in land-cover (Ayele, 2011). The urgency of LULC change detection research in many parts of the world is made clear by the current state of mass environmental change and sustainability challenges on a worldwide scale. Although both natural (such as weather, flooding, earthquakes, etc.) and anthropogenic factors contribute to LULC variations, the mushrooming population's constant demand has made anthropogenic affects the most significant (Weinzettel, et al., 2013; Turner, et al., 2007; Foley, et al., 2011).).

It is vital to review the concepts of the terms of Land-Cover (LC) dynamics before embarking on the study. According to the definition of Food and Agricultural Organization (FAO, 2016), Land cover (LC) is the biophysical cover on the earth's surface such as forest, herbaceous/grassland, Shrubland, built-up area, agriculture, wetlands, barren areas, open water etc. On the other hand, Land-Use (LU) is defined by Lillesand et al. as all human activities that are performed on the land, including forestry, agriculture, and even the context in which the land is managed.

Examples of land use include plantations, built-up areas, recreation, and wildlife habitat. A long-term dynamic in reaction to diverse local or global human or climate changes is called a LULC change, and it is detected and monitored. The phrase "urban sprawl" refers to the process of population migration from densely populated center urban regions to low-density residential areas in rural areas, making it impossible to manage the expansion of urban areas (urbanization).

2.2 Maps of Land-Use and Land-Cover

The electromagnetically discernible information classes of the imagery are digitally categorized into a number of thematic categories through the LULC mapping process. Several studies have devoted for LULC cover mapping (Mallupattu and Reddy, 2013; Olokeogun and Iyiola, 2014; Rawata and Kumarb, 2015). For instance, (Olokeogun and Iyiola ,2014) used remote sensing and GIS for LULC mapping of the Shasha Forest reserve in Nigeria to map five thematic categories, including water bodies, forest reserves, built-up areas, vegetation, and farming. In a similar vein, Rawata and Kumarb (2015) carried out LULC mapping in the Hawalbagh block of Uttarakhand, India, and mapped five different LULC classes, including vegetation, agricultural, barren land, built-up areas, and water bodies. Furthermore, Cheruto et al. (2016) classified Landsat data from Makueni County, Kenya into seven key LULC classifications, including built-up regions, croplands, water bodies, evergreen forests, bushlands, grasslands, and barren land Finally, Mallupattu and Reddy (2013) identified eight LULC classes for mapping and used Landsat images to map the metropolitan areas of Tirupati, India. These included farming, populated areas, dense forests, mining, open forests, plantations, and water distribution areas. In order to detect and map any number of 3 to 5 classes of LULC in Dejen town and its surroundings, this study chose to employ a similar approach.

2.2.1 LULC Mapping Applications

According to Paiboonvorachat (2008), Araya (2009), Paul et al. (2012), RS and GIS work well together for earth observations and the analysis of related information. By observing the earth's surface from space, we may comprehend the combined effect of human activity on its surface. Using RS and GIS approaches, this data can be gathered and evaluated to provide an accurate and timely record of LULC (Ridd & Liu, 1998; Chen, et al., 2013).

For LULC change detection and modeling, the availability of multiple satellite sensors that provide image data with fine spatial resolution, high geometric precision, and brief revisit intervals has made satellite remote sensing more desirable than aerial photography and manual data collection techniques (Aplin, et al., 1997; Stabile, 2012). The use of satellite remote sensing for LULC change research has grown significantly as a result of the development of satellite image analysis technologies and the accessibility of numerous commercially available image processing programs. In the Beykoz area of Istanbul, for instance, Musaoglu et al. (2005) examined Landsat and SPOT satellite pictures for land-use change monitoring (1975-2001). Using high spatial resolution satellite data, Brink & Eva investigated the dynamics of land-cover change across Africa (2009). El-Kawy, et al. (2011) used Landsat imagery to perform supervised classification in order to provide historical and current LULC conditions for the western Nile delta.

2.3 Land-Use and Land-Cover Change Detection

According to Yirsaw (2017), LULC Change Modeling is defined as it is a process that quantifies current land resources and how they are changing into thematic categories, such as forest, water, paved surfaces, built up, and vegetation. For instance, research conducted by Cheruto et al (2016), in Makueni County, Kenya, over the periods between 2000-2016 significant land conversions was observed. According to this study evergreen forests converted to bushlands by 58.2% and croplands by 51%; croplands to bare lands by 9%, grasslands by 8.7% and bushlands changed to grasslands by 42.4% and bare lands by 30%.

2.4 Identifying Patterns of Land-Cover Change

The delineation, classification, and mapping of land surfaces occurs before the multi-temporal analysis of land-cover change. A standard classification system that is accepted by scientists worldwide has not yet been produced despite the development of several land-cover classification systems in recent decades (Gregorio, 2005). Some classification schemes concentrate on a specific type of land-cover, such as the UNESCO vegetation classification scheme (Wenger and Foresters, 1984). A variety of land-cover categories are included at various levels in other classification systems, as those used by the FAO and Anderson (1979).

Usually, algorithms built within RS tools are used in automated procedures for land-cover classification. The two techniques that have been developed thus far are object-based and pixel-based picture classification. The semi-automated image analysis method known as "object-based image analysis" (OBIA) allows for user control over and modification of the result classification (Benz et al., 2004; Kressler et al., 2005). All pixels that belong to a specific object are grouped according to their texture, shape, textural and contextual information, as well as the structure of the neighboring object, in addition to taking into account the spectral qualities of classes (Laliberte et al., 2004; Im et al., 2008).

On the other hand, pixel-based image classification is only dependent on the spectral characteristics of the pixels. This technique is suitable for employing multispectral medium resolution images, but it mostly relies on training samples and may neglect the effect mixed pixels, leading to a classification error (Myint et al., 2011).

2.5 Geographic Information Systems and remote sensing

Remote sensing is defined in various ways in the literature, but with similar meaning. For example, United Nations (1986) defined remote sensing as" The utilization of electromagnetic wave properties emitted, reflected, or diffracted by sensed objects to enhance land use, natural resource management, and environmental protection by sensing the Earth's surface from space." Remote sensing is described as follows by Lillesand et al. (2008) (p. 1):The analysis of data collected by a device that is not in contact with the thing, area, or phenomenon being studied is described as "the science and art of learning about an object, phenomenon, or place."

Remote sensing is the study of satellite or aerial photos that can distinguish between various land use and land cover types on earth based on electromagnetic signature variations. Geographic information systems (GIS), on the other hand, relate to any scientific endeavor that uses geographic data to visualize, analyze, and explore information that is referenced to a specific location.

GIS is defined as follow by the United States Geological Survey (USGS, 2007): GIS is a computer system that can assemble store, manipulate, and display geographically related information, or data that is identified by their locations.

In the contemporary, the term Remote Sensing connotes techniques of collecting earth's information from a distance. On the other hand, GIS is a computer-based information system for collecting, storing, managing, and manipulating geographical data to visualize, interpret, and analyze the relationships, trends, and patterns of spatial phenomena. Mapping and monitoring LULC dynamics benefit from GIS and remote sensing integration While LULC types, such as urban or built-up areas, bare lands, forests, open areas, and agricultural were collected by remote sensing in Dejen town; GIS is used to analyze the aerial extents, and the temporal changes.

2.6 Remote Sensing Application in Land Use and Land Cover Change

In this study of urban land use and infrastructure, in particular, remote sensing techniques and applications were helpful in understanding environmental changes in the urban landscape. Global Monitoring Report (2013) states that using change detection analysis in the remote sensing application, global or regional studies such as global monitoring vegetation cover, global food change, and regional resource management will make use of the remote sensing application to extract changes that occur over time in the study area.

Remote sensing techniques are very good in data capturing and analysis in the process of quantifying the nature of urbanization and rapid growth. According to Miller and Small (2003), a thematic mapping of the general environment during the research periods and the production of study results and guidelines for policy makers are now crucial methods for confronting urban challenges.

2.7 Geographical Information Systems (GIS), Application in LU/LC Change

Geographic Information Systems (GIS) software, remote sensing, and GIS techniques, combined with robust tools that can incorporate a range of data sets, specifically in this study, considerably contribute in the identification of urban change in land-use and land-cover investigations. The historical map of the study area, which was created during data collecting at the study area, was processed using GIS techniques as a source data to discover changes in land-use and land-cover in the research region. A decision-support tool called a GIS can make urban planning easier. The field of urban sprawl study has seen a significant increase in the usage of GIS modeling. GIS has been used in some urban sprawl research to better understand how it affects the environment.

This Geographical Information Systems (GIS) application offers the significant benefit of utilizing powerful functions, with ArcGIS software serving as a solid example and having excellent capabilities for the processing of multi-source data for studies on change detection in Geographical Information Systems (GIS).tools for multi-source data processing of the change detection studies to the Geographical Information Systems (GIS). Data accuracy and the formats that often have an impact on the outcomes of change detection analysis are involved in this investigation.

2.8 Analysis of Satellite Image

To show and extract useful information about the surface of the earth, satellite image analysis requires digital image processing, which entails editing and interpretation of the digital image data by computer programs. The majority of the LULC change detection study is governed by digital image classification, one of the fundamental image analysis procedures (Matinfar, et al., 2007). When doing image classification, which is typically done on multispectral images (i.e., images with more than one spectral band), all the image pixels are automatically categorized into different land-cover classes based on how similar their digital number (DN) values are (Lillesand, et al., 2008).

The satellite sensors measures the variations in electromagnetic radiation coming from different parts of the earth's surface and give each spectral band a unique DN value (Oumer, 2009). The radiometric resolution, which is related to the sensor's sensitivity to different levels of incoming energy, determines the digital number range for each sensor (Ayele, 2011). For instance, the Landsat Multispectral Scanner (MSS) sensor measures radiation in the DN range of 0 to 63, while the Landsat Thematic Mapper (TM) sensor measures radiation in the DN range of 0 to 255. (NASA, 2011).

2.9 Urban Growth

Urban growth, the increase and decline of urban areas, as a financial phenomenon is inextricably connected with the technique of urbanization. Urbanization itself has punctuated monetary development. Economic hobbies have a concentrated geographic distribution when examined separately for population, output, and profits.

One of the most interesting phenomena in city economics is the patterns of these concentrations and how they relate to measured economic and demographic variables. They have got vital implications for the financial position and length distribution of towns, the efficiency of manufacturing in a financial system, and standard financial growth Since the "dawn of records," a rising number of concentrated population densities have been closely linked with advancements in agriculture and transportation, as shown by Paul Bairoch's magisterial paintings (Bairoch (1988). However, as economies advance from those of traditional cultures to their modern level, the city region's role shifts from merely dispensing services to taking the lead in innovation and acting as engines of growth.

Significant advances in urban/built-up regions at the expense of open or green places are characteristics of urban expansion. According to previous studies (Yin et al. 2011, Boori and Vozenilek 2014, Salari et al. 2013), the urban/built-up land cover class refers to areas that are mostly constructed of buildings, concrete, and asphalt and include areas used for transportation, business, and residential functions. The urban/built-up class does not include other forms of urban land uses like golf courses and urban green parks. Planners who want to prevent the permanent and cumulative consequences of urban growth and to maximize the distribution of urban services can benefit from studying urbanization (Dewan and Yamaguchi 2009a; Barnsley and Barr 1996; Boori et al. 2014b, Thinh et al. 2013).

The examination and evaluation of sustainable urban and environmental planning initiatives also require such information (Wu and Hao 2012; Alphan 2003; Jensen and Im 2007). Because it has an impact on choices about where and how we live, land use planning is a crucial component of a metropolitan area's viability and liveability. Government organizations and municipal councils in various nations have been continuously creating and implementing land use planning methods to control and manage urban expansion throughout the past few decades (Yin et al. 2011).

2.9.1 Causes of Urban Growth

Urban population growth is the main and most significant factor in urban expansion. The following population-growing factors contribute to urban regions' rapid growth:

(1) Natural increase in population

- Decreased work opportunities in the rural. All of these push forces, along with poor crop production; explain why people leave a certain area.

(2) Migration to urban regions.

- Better paid jobs within the towns, an anticipated higher widespread of residing, and extra reliable food are all pull elements which give an explanation for why humans are interested in the town.
- People who migrate to cities and cities have a tendency to be younger and so those locations have better beginning fees in that age variety.
- Better scientific offerings in towns and towns compared to the countryside mean extra a success births and higher existence expectancy in those areas.

2.9.2 Impacts of Urban Growth on Environment

The sheer significance of the urban populace, haphazard and unplanned boom of city regions, and a desperate lack of infrastructure are the principal reasons of such a scenario. The speedy boom of urban population each herbal and via migration, has positioned heavy stress on public utilities like housing, sanitation, shipping, water, housing, sanitation, shipping, water, strength, fitness, education, and so forth. The rural immigrants suffer by poverty, unemployment, underemployment, beggarly, thievery, dacoities, burglaries, and other social ills. The valuable agricultural land is being swiftly encroached upon by urban sprawl. Consequently, the city surroundings, especially in big cities, are deteriorating very swiftly.

2.10 Causes of Urban Sprawl in Dejen town

a) The growth rate of the urban population naturally

It's a common misconception that families with larger numbers of children are more stable financially and can better care for their older members (Todaro, 1997). When population grows, urban expansion becomes sparse, and low-density pushes city limits further out. It also leads to urbanization to increase, unemployment, income inequalities, city congestion, ecological stress, and population mal distribution. This finally causes urban sprawl since there would be higher demand for land.

b) Rural – urban Migration

Migration the main "pulling" forces behind the widespread movement of people from rural to urban regions are the contrasts in improved facilities and comfortable living conditions between urban and rural areas (Tiffen, 1995).

Chapter Three

3. Materials and Methods

3.1 Study Area

Dejen town is an administrative center for Dejen woreda and the city is located 144kms distance in the Northwest direction of Addis Ababa and 178kms to Bahir Dar, the capital of Amhara region. Dejen town is bounded by Abay River in the South which separates it from the Oromia, on the West by Awabel, on the Northwest by Debay Telatgin, on the North by Enemay, and on the East by Shebel Berenta (Dejen town administration office).

Dejen town is in the west-central Ethiopia, on the canyon of the Abay River, located in the Misraq Gojjam Zone. The geographic location of Dejen lies between 10°10′ N Latitude and 38°8′ E longitude and its elevation ranges from 2421 up to 2490 meters above mean sea level. The temperature of the town is averaged to 23.72 ℃. Dejen town is among the growing towns in Amhara region and has its own town administration, municipality and there are 2 kebeles in the town.

The Central Statistical Agency (CSA) (2005) reported, the total population of Dejen town was estimated to 15,483, from this 7,688 were men and 7,795 were women. The 1994 census reported that, the town's total population was estimated to 8,930 from this 4,885 were women and 4,045 were men. From this number the majority of the peoples were Orthodox Christian and covers, 97.01%, and the rest 2.85% were Muslims.

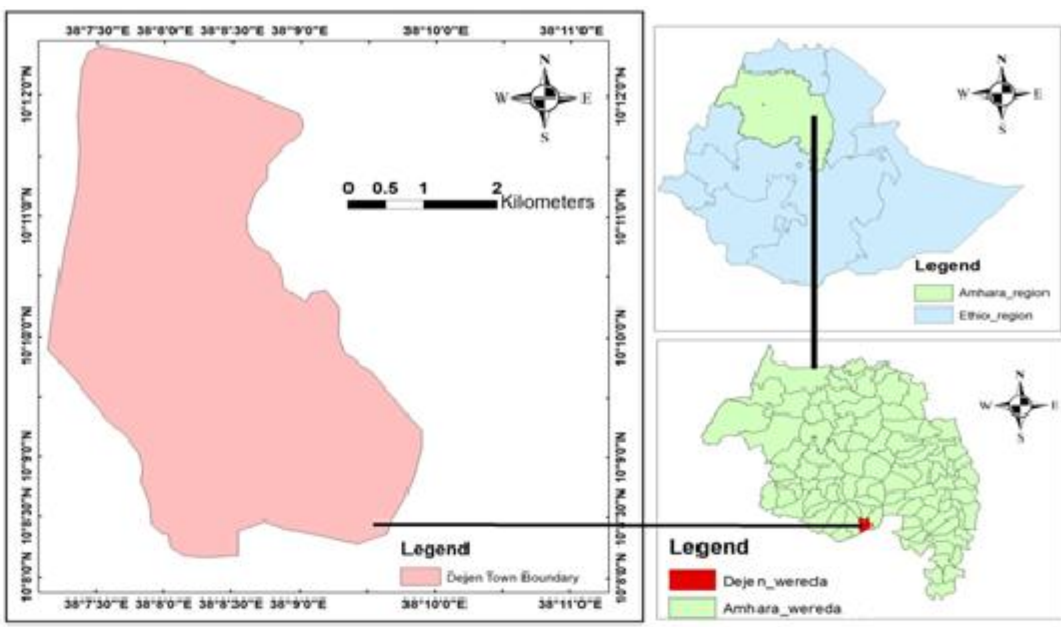

Figure 3.1: The Study Area

3.2. Data and Methods

3.2.1 Data

The USGS Earth Explorer was used to download the necessary satellite imagery for the research area. The land use land cover map for the study area was developed by processing and interpreting the downloaded satellite imageries using ERDAS Imagine software. The maps which were obtained by processing and interpreting the satellite imageries using ERDAS Imagine software was analyzed and studied to detect the changes in urban expansion. Three Landsat imageries for a period of 30 years were used for the study. The dates are 1993, 2008 and 2023 and were downloaded freely from different agencies' Websites. The date gap of all three acquired imageries was about a week of May and June.

In this study, the LULC variations of Dejen town expansion between 1993 and 2023 were assessed using historical data from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI).

Details of Landsat imageries and characters are given below (Table 3.1). In addition to the satellite imageries the digital topographic map of the study area was used.

Table 3.1 Detail characteristics of the Landsat imageries

S.N.	Satellite	Sensor	Band	Imagery date	Spatial Resolution (meter)	Source
1	Landsat 5	TM	7	01-01-1993	30	USGS
2	Landsat 7	ETM+	8	01-01-2008	30	USGS
3	Landsat 8	OLI	9	01-01-2023	30	USGS

According to Sadidy, Firouzabadi and Entezari (2009), Landsat imageries are the most satellite remote sensing data which are used for mapping areas and planning project works, because of their resolution properties such as spatial, spectral and temporal.

3.2.2 Methods

Different approaches underlying the Accuracy assessment and LU/LC change analysis process was applied in the study. These entail mostly the theoretical and practical implication of Remote Sensing and Geographic Information System knowledge to make use of spatial and temporal data sets for acquiring feature information, analyzing the dynamics on land surfaces to use for the future assumptions of LU/LC. The major landmark processes of the study can be summarized by the flow chart presented as under (Figure 3.2).

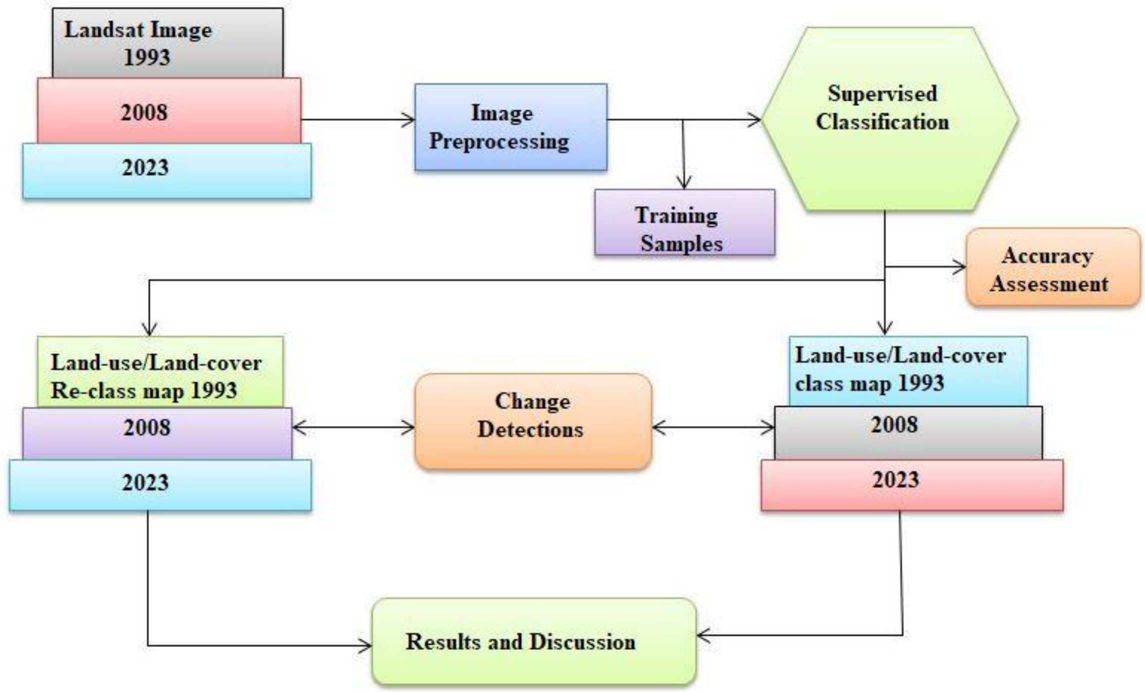

Figure 3.2: The Methodology of the overall study

3.3. Software

The images were processed with various software programs to get required analysis results. Mentioned below are the software programs that were used in the research study.

- ArcGIS 10.7
- ERDAS IMAGINE 2015

Table 3.2 Software's and their applications that were used in the research study

No.	Software's to be used	Applications
1.	ArcGIS 10.7	To resample resolution of image into grid cells and to compose map.
2.	ERDAS IMAGINE 2015	For the image classifications.
3.	Google Earth	For visualizing the study area (to identify what was existed and what is existed on the area for each time periods).
5.	MS office	For writing, preparing charts, graphs and statistical analysis

3.4. Image Classification and Accuracy Assessment Process

3.4.1 Image Classification

Five land-use and land-cover classes were determined for supervised classification in the study. This was done by using the Anderson Land Use/Land Cover Classification System. The broadest or most aggregated classification (level I) covers categories like "agriculture," "urban and built-up," "forested," and "barren".

Table 3.3 image classification details

LULC class types	Methods of category
Agriculture	All land areas with agricultural crops
Built up	Individual and clusters of building (Residential, Commercial and services, Industrial), road networks,
Forest	Areas characterized by relatively sparse forest vegetative (dominantly eucalyptus trees).
Open area	The land areas with small vegetative ground covers (grasses).
Bare soil	agricultural lands without crops and exposed areas

Preprocessing

Preprocessing of the image involved applying geometric and radiometric corrections, which involve choosing the appropriate map projection registration (simple point-to-point match between an image and another image or map) and rectification (correcting an image to a specific map projection) for the study area. Like a black and white digital photo, each unique wavelength range's data is saved as a separate image and is referred to as a band. To construct a color image, the analyst must put the images from the various wavelengths together (Horning, 2009). So, after the entry of the images into the software program, composite layers were made by stacking all band layers of each three year's images (1993, 2008 and 2023). Composite layer of all three images were again subset into the study area.

Land-Use and Land-Cover Classification:

Supervised classification: The method most frequently used for quantitatively assessing image data from remote sensing is supervised classification. Following the training classes, or designated area of interest (AOI), the supervised classification was implemented. A given class was represented by multiple training areas. The training sites were selected in accordance with the Landsat image.

Supervised Re-classification: The land-use and land-cover maps were also reclassified into built up and non-built up land classes because the study's primary focus is on urban land-use and land-cover class change. This was done by merging agriculture, forest, open area and bare soil into one class called non-built up.

Identifying training sites: The initial stage of a supervised classification involves determining the areas that will be used as training sites for every of land-use and land-cover class. Areas of interest (AOI) are the features that have been created. The areas that could be easily recognized in all image sources were used to determine which training sites to use.

Signature Extraction: Following the digitization of the training site (AOI), each piece of information was statistically characterized. In ERDAS Imagine 2015, these are referred to as signature editors. Making a signal (SIG) file for each informational class was the goal of this step. Numerous details regarding the land-use and land-cover classes are included in the SIG files. The SIG file was saved as a dialog once the complete signature had been produced. Numerous methods, including maximum likelihood, minimum distance, parallelepiped classification, and others, can be applied to supervised classification techniques (Al-doski et al., 2013). Since the minimum likelihood approach is one of the most popular classifiers in remote sensing, I used it in this study. A pixel is assigned to the class for which it has the maximum likelihood of membership using this technique. Using training data, this classification algorithm calculates the means and variances of the classes, which are then used to calculate the probabilities of pixels to belong to distinct classes. When classifying data, the maximum likelihood classification takes into account not just mean or average values but also the variation in brightness values within each class with respect to the mean. When appropriate training data is provided and certain assumptions about the distributions of classes are valid, it is the most powerful classification algorithm (Hull, 2021).

Post-processing: included geometric correction and filtering, classification decoration, and an accuracy assessment of the study area using Google Earth.

Accuracy Assessment: The final step for classification process is accuracy assessment. An accuracy assessment of a classified image gives the quality of information that can be obtained from remotely sensed data. The accuracy assessment is performed by comparing a map produced from remotely sensed data with google earth. Overall accuracy for a particular classified image/map is calculated by dividing the sum of the entries that form the major diagonal (i.e. the number of correct classification) by the total number of samples (Story and Congalton, 1986). After image is classified, a total of 220 random points (60 points for agriculture, 50 points for forest, 30 points for open area, 30 points for bare soil, and 50 points for built up) were generated for each years on the classified image of the study area. A total of 150 random points were used for the accuracy assessment of the classification results. For this study overall classification accuracy and overall kappa statistics were calculated. In addition to this user's and producer's accuracy were also calculated for each time periods.

3.5 LULC Change Detection

Detecting changes in an object or phenomenon's status over time by applying remote sensing techniques is the process of change detection.

Due to the recurring geographic coverage and consistent image quality of remotely sensed data obtained from Earth-orbiting satellites, change detection is one of their primary applications. Choosing the best change detection technique is essential to getting a more accurate change detection result since change detection is influenced by elements including spatial, spectral, thematic, and temporal aspects. Distinct change detection algorithms might provide distinct maps of changes depending on the strategy employed (Sahalu, 2014).

A method for recognizing changes that have taken place in a certain area over time is called change detection. It is crucial for identifying changes in different types of land use, such as a rise in the area covered by built-up cities or a decline in agricultural land, among other things. The user can identify changes in the land use and land cover in a given area by examining the same region across time using satellite or aerial imagery. Some of the most popular techniques for change detection when using satellite images include image differencing, Principal Component Analysis, image regression, and post-classification comparison, change detection methods (Muhammed, 2018).

Information regarding the change in land use and land cover has been produced using the quantification of amount of change. Equations 3.5 and 3.6 were used to compute the percent and rate of change for each land-use and land-cover (Gashaw, 2018), as shown below.

$Area\ Change\ in\ hectare = Ay - Ax$…………………………………………………... (3.1)

Where:

Ax = initial area of land use classes

Ay = final area of land classes

A = the total study area

Area change in % $= \frac{Ay-Ax}{A} \times 100$……………………………….……………………… (3.2)

Chapter Four

4. Results and Discussions

4.1. Image classification

Images from the years 1993, 2008, and 2023 were divided into five categories (Figure 4.1). The total area of the study area's land-use and land-cover classes was 2393 hectare. Here are maps and detailed statistics about the classification outcomes.

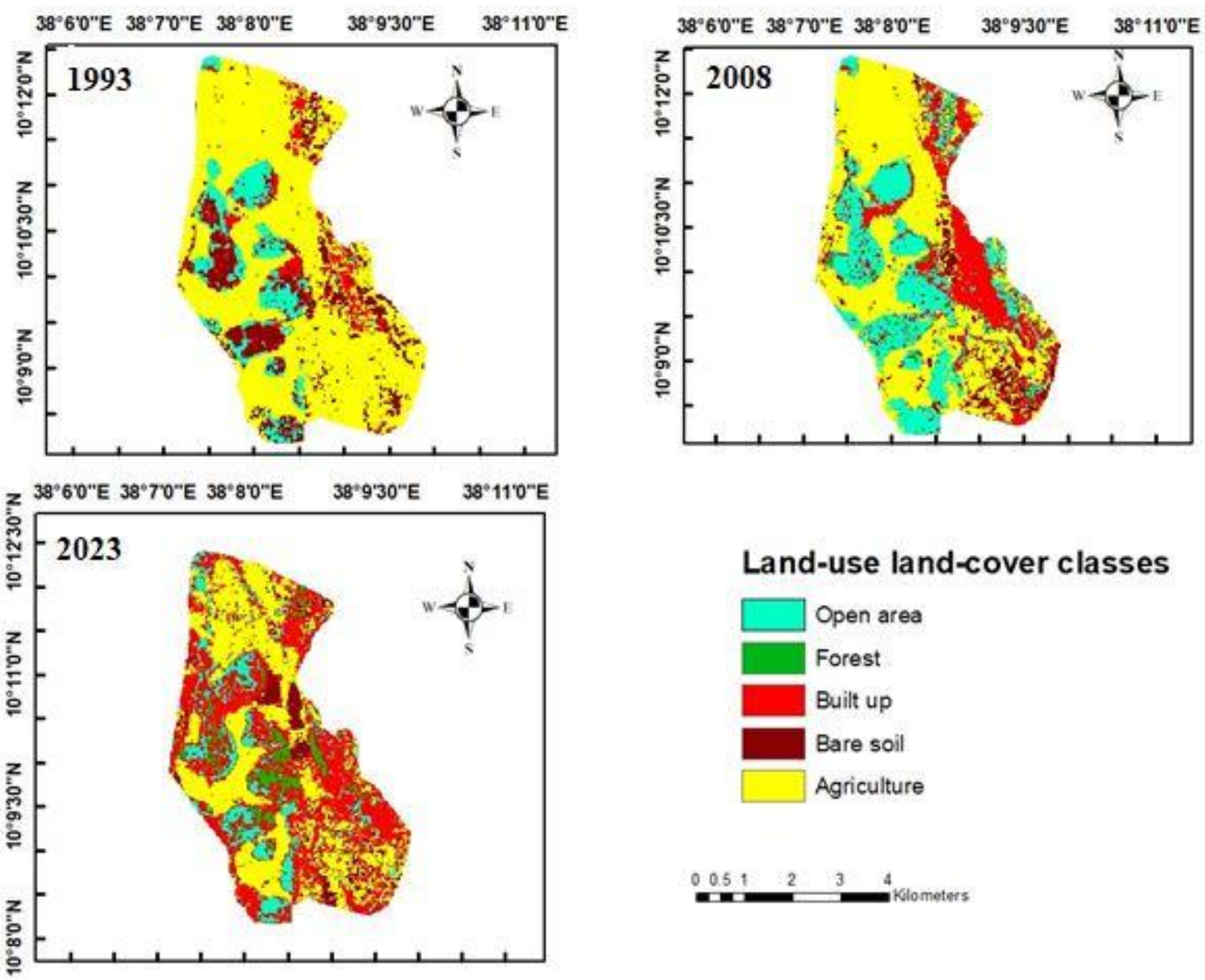

Figure 4.1: Land-use and land-cover classification maps of Dejen Town

The following table 4.1 lists the land-use and land-cover classifications and the areas generated from the classification of images from 1993, 2008, and 2023. If understood using visual support rather than numerical help, the area statistics of the land uses and land coverings might be quantified more effectively.

Table 4.1: Land-use and land-cover class types of class areas in hectare

ID	Land-use and land-cover class	Area in hectare		
		1993	2008	2023
1	Open area	269	630	298
2	Forest	0.45	25	107
3	Built up	177	450	958
4	Bare soil	334	157	162
5	Agriculture	1613	1131	868
	Total	2,393	2,393	2,393

The five land uses in each date are shown visually in the bar chart below, which also shows transitions between various land use classes (Figure 4.3). For the whole study period, both the built-up area (since buildings, road networks and different constructions are highly increased) and the forest area (this is because of the forest type found on the study area is totally eucalyptus, so it is the source of income for the local communities and they cultivate it highly, even they use some part of the agricultural area for this purpose) had grown. The chart demonstrates that the Agricultural land class was also the land class that experienced the greatest loss, followed by Open area and bare soil land classes.

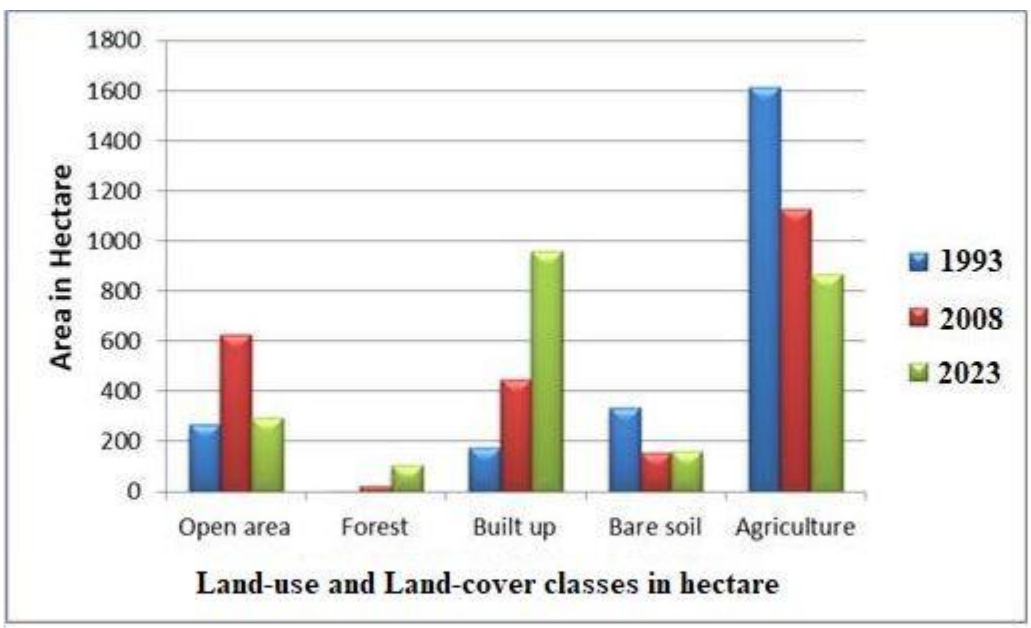

Figure 4.2: Bar chart land-use and land-cover quantization in hectare for 1993, 2008 and 2023

The following table 4.2 lists the land use classifications and the areas in percent generated from the classification of images from 1993, 2008, and 2023.

Table 4.2: Land use class types of class areas in percent

ID	**Land use class**	**Area in %**		
		1993	**2008**	**2023**
1	Open area	11.24	26.33	12.45
2	Forest	0.02	1.04	4.47
3	Built up	7.39	18.80	40.03
4	Bare soil	13.95	6.57	6.77
5	Agriculture	67.40	47.26	36.28
	Total	100	100	100

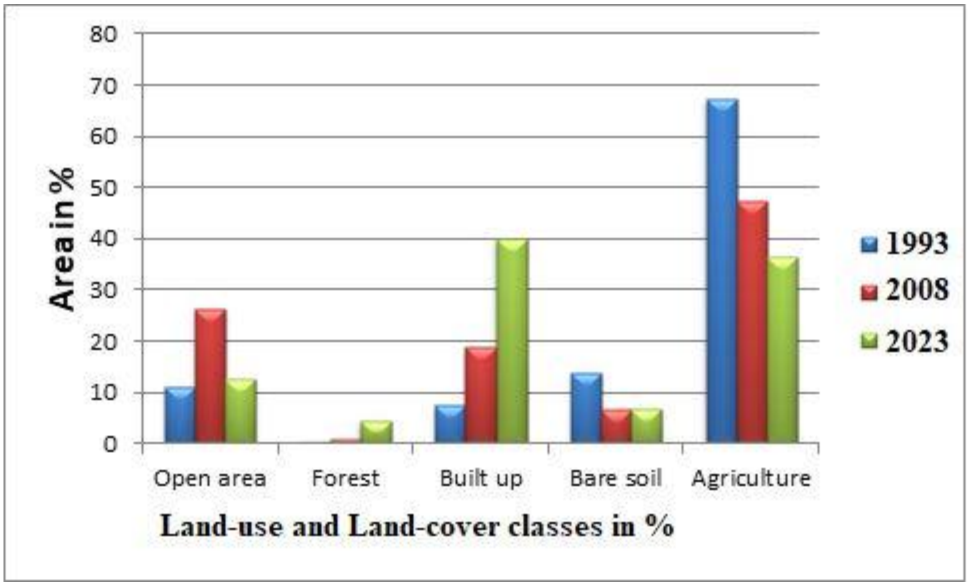

Figure 4.3: Bar chart land use quantization in % for 1993, 2008 and 2023

4.2 Accuracy Assessment

Through the accuracy assessment process, the classifications of the 1993, 2008, and 2023 images were assessed. The accuracy assessment method began with the collection of test samples from an image that was used for classification, followed by sample verification using a high resolution image as a reference.

Overall accuracy, overall Kappa (κ), as well as producer and user accuracy for certain land classes, were the indices used for the assessment. The outcomes are displayed below (Table 4.3).

Table 4.3: Overall accuracy and Kappa (κ) statistics for the classifications

	1993	2008	2023
Overall classification accuracy (%)	87.73	89.09	92.27
Overall Kappa (κ) statistics	0.8230	0.8459	0.8832

The outcomes show that for the classification of images from 1993, 2008, and 2023, the attained overall classification accuracies were 87.73%, 89.09%, and 92.27%, respectively, while the overall Kappa (*k*) values were 0.8230, 0.8459, and 0.8832. For specific land classifications, the accuracy of the producer and the user was as follows: (Table 4.4).

Table 4.4: Producer's and User's accuracy for individual land classes

Class name	**1993 (%)**		**2008 (%)**		**2023 (%)**	
	Producer's	**User's**	**Producer's**	**User's**	**Producer's**	**User's**
Open area	75.00	78.95	89.23	85.29	50.00	60.00
Forest	100.00	65.09	52.86	60.00	85.71	82.76
Built up	85.71	97.30	100.00	98.51	99.06	96.32
Bare soil	94.44	87.93	66.67	66.67	83.33	83.33
Agriculture	96.77	85.71	86.30	88.73	90.32	94.92

For the classification of images from 1993, 2008, and 2023, the producer's accuracy ranges were 75% - 100%, 52.86% - 100%, and 50% - 99.06%, whereas the user's accuracy ranges were 65.09% - 97.30%, 60% -98.51%, and 60% -96.32%, respectively. The results showed that it was impossible to achieve the lowest producer and user accuracies for the same land classes during the classification years. Higher producer and user accuracy, though, could primarily apply to the built-up land class. This could be as a result of the study's increased emphasis on the analysis of urban change.

4.3 Land-use and land-cover Reclassification

The land-use and land-cover maps were reclassified into built up and non-built up land classes because the study's primary focus is on urban land class change (Figures 4.4). The results and statistics of the image reclassification are listed below (Table 4.5).

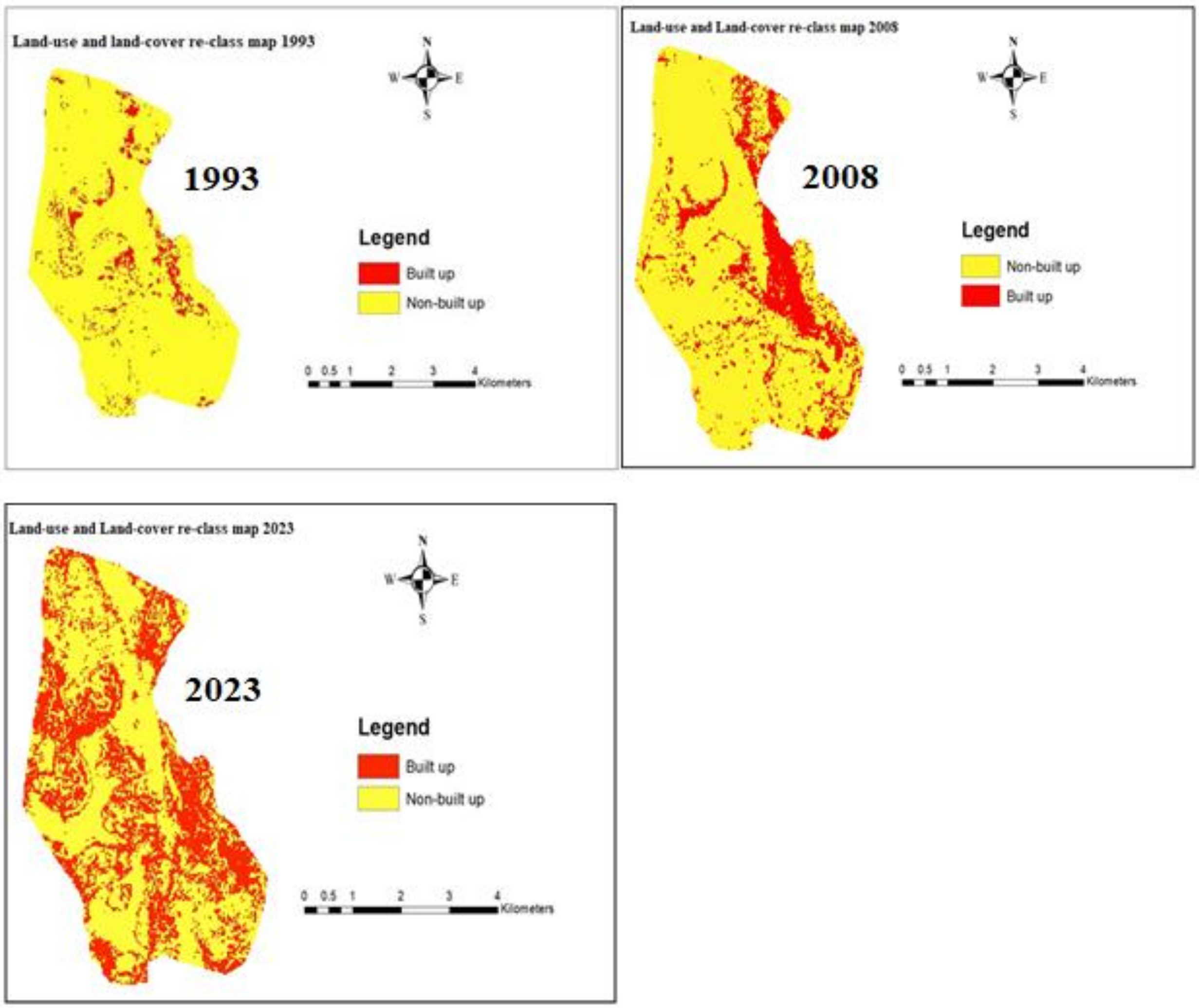

Figure 4.4: Land-use and land-cover re-classification map of Dejen Town (1993, 2008 and 2023)

The following table 4.5 lists the land classes and areas obtained from the reclassification of the 1993, 2008, and 2023 images. The accompanying bar chart has been used to explain the results statistics in the table below.

Table 4.5: Land use re-class and areas in hectare

ID	Land use class	Area in hectare		
		1993	2008	2023
1	Built up	177	450	958
2	Non-built up	2216	1943	1435
	Total	2393	2393	2393

The bar graph (4.5) below provides a visual representation of the amounts of built-up and non-built up land class changes. According to the statistics on the chart, built-up areas increased by over two times during the study period.

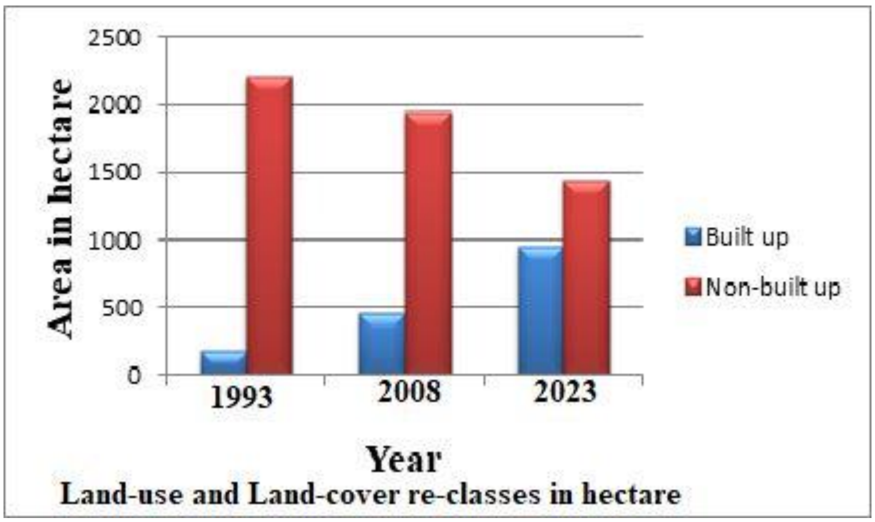

Figure 4.5: Bar chart land use re-classes quantization in hectare 1993, 2008 and 2023

The following table 4.6 lists the land classes and areas in % obtained from the reclassification of the 1993, 2008, and 2023 images. The accompanying bar chart has been used to explain the results statistics in the table below.

Table 4.6: Land use re-class and areas in %

ID	Land use class	Area in %		
		1993	2008	2023
1	Built up	7.39	18.80	40.03
2	Non-built up	92.61	81.20	59.97
	Total	100	100	100

The bar graph (4.6) below provides a visual representation of the amounts of built-up and unbuilt-up land class changes in %. According to the statistics on the chart, built-up areas increased by over two times during the study period.

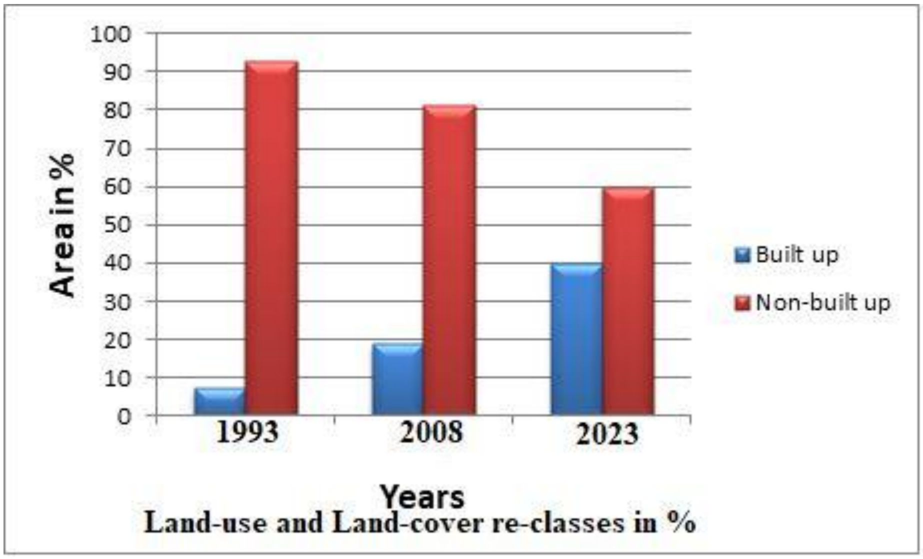

Figure 4.6: Bar chart land use re-classes quantization in % 1993, 2008 and 2023

4.4 LULC Change Detections

The following table shows change in percentage and area in hectare across all land use classes and land use re-classes.

4.4.1 LULC changes for land use classes from 1993 to 2008 in Dejen town

Table 4.7: LULC change for land use classes from 1993 to 2008

ID	Land use classes	1993		2008		Area Change	
		Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
1	Open area	269	11.24	630	26.33	+361	+15.0
2	Forest	0.45	0.02	25	1.04	+24.55	+0.98
3	Built up	177	7.39	450	18.80	+273	+12.0
4	Bare soil	334	13.95	157	6.57	-177	-7.33
5	Agriculture	1613	67.40	1131	47.26	-482	-20.0

As shown on the table 4.7 above for the years 1993-2008 open area, forest and built up are increased by 15%, 0.98% and 12% respectively. Whereas the land classes bare-soil and agriculture are decreased by 7.33% and 20% respectively.

4.4.2 LULC Change for land use classes between 2008 and 2023 in Dejen town

Table 4.8: LULC change for land use classes between 2008 and 2023

ID	Land use classes	2008		2023		Area Change	
		Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
1	Open area	630	26.33	298	12.45	-332	-14.0
2	Forest	25	1.04	107	4.47	+82	+3.0
3	Built up	450	18.80	958	40.03	+508	+21.0
4	Bare soil	157	6.57	162	6.77	+5	+0.33
5	Agriculture	1131	47.26	868	36.28	-263	-11.0

As indicated on table 4.8 from 2008-2023 the land classes forest, built up and bare soil are increased by 3%, 21%, and 0.33% respectively. For the land classes open area and agriculture are decreased by 14% and 11% respectively.

4.4.3 LULC Change for land use classes between 1993 and 2023 in Dejen town

Table 4.9: LULC change for land use classes between 1993 and 2023

ID	Land use classes	1993		2023		Area Change	
		Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
1	Open area	269	11.24	298	12.45	+29	+1.0
2	Forest	0.45	0.02	107	4.47	+106.55	+3.98
3	Built up	177	7.39	958	40.03	+781	+33.0
4	Bare soil	334	13.95	162	6.77	-172	-7.0
5	Agriculture	1613	67.40	868	36.28	-745	-31.0

From table 4.9 it is shown that from the years between 1993-2023 the land use classes such as open area is increased by 1%, forest is increased by 3.98% and built up is increased by 34%. The bare soil and agriculture are decreased by 7% and 31% respectively. So we can generalized that from 1993 to 2023 the built up land classes is highly increased, on the other hand the agriculture land class is highly decreased.

4.4.4 LULC changes for land use re-classes from 1993 to 2008 in Dejen town

Table 4.10: LULC change for land use re-classes from 1993 to 2008 in Dejen town

ID	Land use classes	1993		2008		Area Change	
		Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
1	Built up	177	7.39	450	18.80	+273	+12.0
2	Non-built up	2216	92.61	1943	81.20	-273	-12.0

As shown on the table above the built up area has increased by 12% from the year 1993-2008. That means the non-built up areas decreased by 12% for the time periods.

4.4.5 LULC Change for land use re-classes between 2008 and 2023 in Dejen town

Table 4.11: LULC change for land use re-classes between 2008 and 2023

ID	Land use classes	2008		2023		Area Change	
		Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
1	Built up	450	18.80	958	40.03	+508	+21.0
2	Non-built up	1943	81.20	1435	59.97	-508	-21.0

As indicated above on table 4.11 the built up area has increased by 21% from the year 2008-2023.

4.4.6 LULC Change for land use re-classes between 1993 and 2023

Table 4.12: LULC change for land use re-classes between 1993 and 2023

ID	Land use classes	1993		2023		Area Change	
		Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
1	Built up	177	7.39	958	40.03	+781	+33.0
2	Non-built up	2216	92.61	1435	59.97	-781	-33.0

The land classes in the agricultural and bare soil decreased considerably. As shown in table 4.12, the Built Up area has grown by 33% during the study periods.

Chapter Five

5. Conclusions and Recommendation

5.1 Conclusions

This study has tried to identify LULC change and its impact on urban growth from 1993-2023 time periods. The study used Geographic Information System (GIS), Remote Sensing (RS), and Earth Resource Data Analysis System (ERDAS) techniques. LULC is one of the important factors for urban growth monitoring. In this study the urban growth has increased from 1993-2023 on the study area. The study showed that agriculture is the dominant land-use and land-cover class which is changed to built-up area due to unplanned management of urban growth on the study area.

Generally, most of the land area is changed to built-up area and the built up area is increasing from year to year, to the contrary the agricultural land use class is decreasing from year to year. Due to this fact it can be concluded that the LULC change has negative influence on the agricultural sector of the study area.

The result of this study is useful for the decision makers to have proper policy for managing the land-use and land-cover change on the area.

5.2 Recommendations

As the main objective of the study was the use of Geographic Information System and Remote Sensing tools for LULC change analysis of Dejen town the following recommendations are forwarded based on the results.

1. The town administration should develop an up-to-date land use management system.
2. It should also use digital method rather than manual method, as I checked mostly they use the manual one. Using Geographic Information System (GIS), and Remote Sensing (RS) tools it is simple and not time consuming to manage LULC change.
3. To have solutions, the town administration should give digital trainings for the stakeholders involved in land use management cases.

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Appendices

1. **Sample GCPs taken from the area**

Easting (X)	Northing (Y)
404312	1123581
404017	1123307
404300	1123368
404479	1123500
404658	1123519
404192	1123223
404443	1123167
404801	1123158
405101	1123259
405310	1123179
404879	1123647
404934	1123802
404901	1124019
404925	1124301
404829	1124444
404770	1124584
404920	1124552
405061	1124739
405017	1124905
404903	1125020
404716	1124865
404615	1124759
405043	1122231
405158	1122152
405290	1122215
405623	1122415
405778	1122466
405875	1122295
405774	1122096
405877	1122009
405844	1121909
406683	1122012
406876	1122460
407069	1122331
407265	1122268
406858	1121989
406678	1123052
407881	1122135
408090	1122051
408126	1121803

407391	1121701
405655	1124801
405798	1124996
405836	1125256
405600	1125477
405587	1125875
405568	1126304
404799	1126456
404187	1127028
405063	1127034
405421	1127683
404296	1127366
403765	1124171
404183	1124440
404327	1124413
404363	1124380
404457	1124330
404435	1124191
404463	1124133
404396	1124050
404240	1123998
404151	1123952
404494	1124010
404422	1123828
404586	1123843
405326	1123689
405437	1123644
405609	1123668
405559	1123586
405771	1124115
405919	1123348
406199	1123263
405542	1122271
404930	1122528
404967	1122631
405022	1122556
404980	1122631
405071	1122637
405072	1122641
405163	1122676
405227	1122510
405380	1122533
405540	1122662
405472	1122766
405565	1122808

404577	1122849
404606	1122769
404711	1122805
404730	1122733
404999	1122915
405104	1122902
405133	1122794
405204	1122868
405264	1122956
404721	1125771
404814	1125575
404913	1125238
405226	1124591
406173	1127411
406291	1127310
406268	1127381
407615	1122923
407594	1123051
407311	1123473
407325	1123424
403792	1124078
403645	1124097
403976	1124369
404453	1124376
404522	1124629
404770	1124282
404605	1123905
404736	1123850
404285	1124076
405027	1124580
405064	1124590
404536	1125686
404448	1125529
404217	1125880
404256	1126299
404333	1126566
404208	1126563
405776	1123146
405492	1122994
405942	1122631
406022	1122424
406076	1122154
405945	1123745
406038	1123949
406093	1123864

406360	1123641
406319	1123522
406274	1123481
406393	1123467
406311	1123360
406385	1123287
407280	1120913
407457	1121007
407227	1121045
407195	1121197
407237	1121446
406513	1121165
406404	1121161
406384	1121401
406478	1122014
405490	1125920
405667	1125888
405778	1126242
405887	1126114
405915	1125858
405851	1125678
405789	1125652
405870	1125565
406304	1124137
406336	1123983
406264	1123903
406335	1123916
403898	1125152
403920	1124975
403876	1125215
404084	1125037
404094	1124969
404099	1125047
407814	1120929
407050	1122919
407010	1122992
407014	1123011
407329	1122989
407551	1122860
407662	1122890
407476	1123176
407420	1123246
407346	1123189
407401	1123181
407023	1123237

406981	1123268
406883	1123343
406901	1123377
407011	1123380
407233	1123379
407348	1123378
407231	1123407
407209	1123408
407016	1123601
406957	1123593
406996	1123806
407007	1123704
407018	1123672
407115	1123738
407116	1123771
407112	1123794
407088	1123766
407084	1123781
407047	1123790
407003	1123809
407040	1123823
407080	1123851
407044	1123865
407021	1123877
406816	1124226
407030	1124242
407066	1124381
406968	1124353
406946	1124345
406899	1124343
406906	1124361
406912	1124381
406948	1124395
406674	1124541
406820	1124548
406361	1125237
406342	1125255
406612	1124669
406533	1123586
403737	1124224
403779	1124197
403796	1124160
403766	1124124
403756	1124098
403744	1124171

Classification Accuracy Assessment Reports

1. Classification Accuracy Assessment Report 1993

```
               CLASSIFICATION ACCURACY ASSESSMENT REPORT
               -----------------------------------------
Image File : g:/aby/1993/supervised_1993.img
User Name  : user
Date       : Sat Mar 16 16:39:04 2024


ERROR MATRIX
-------------

                               Reference Data
                               --------------
Classified Data Unclassifi
--------------- ----------     ----------     ----------     ----------
   Unclassified          0              0              0              0
                         0              0              0              0
                         0              0              0              0
                         0              0              0              0
      Open area          0              0              0              0
         Forest          0              0              0              0
      Bare soil          0              0              0              0
                         0              0              0              0
       Built up          0              0              0              0
    Agriculture          0              0              0              0

Column Total             0              0              0              0
```

Reference Data

Classified Data	Open area	Forest	Bare soil	
Unclassified	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Open area	15	1	1	0
Forest	0	1	0	0
Bare soil	1	3	51	0
	0	0	0	0
Built up	0	0	1	0
Agriculture	4	6	1	0
Column Total	20	11	54	0

Reference Data

Classified Data	Built up	Agricultur	Row Total
Unclassified	0	0	0
	0	0	0
	0	0	0
	0	0	0
Open area	1	1	19
Forest	0	0	1
Bare soil	1	2	58
	0	0	0
Built up	36	0	37
Agriculture	4	90	105
Column Total	42	93	220

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

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Open area	20	19	15	75.00%	78.95%
Forest	11	1	1	100.00%	65.09%
Bare soil	54	58	51	94.44%	87.93%
	0	0	0	---	---
Built up	42	37	36	85.71%	97.30%
Agriculture	93	105	90	96.77%	85.71%
Totals	220	220	193		

Overall Classification Accuracy = 87.73%

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

```
KAPPA (K^) STATISTICS
---------------------

Overall Kappa Statistics = 0.8230

Conditional Kappa for each Category.
------------------------------------

    Class Name           Kappa
    ----------           -----
  Unclassified          0.0000
                        0.0000
                        0.0000
                        0.0000
     Open area          0.7684
        Forest          0.6321
     Bare soil          0.8400
                        0.0000
      Built up          0.9666
   Agriculture          0.7525

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

2. Classification Accuracy Assessment Report 2008

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : g:/aby/2008/supervised_2008.img
User Name : user
Date : Sat Mar 16 11:54:25 2024

ERROR MATRIX

Reference Data

Classified Data	Unclassifi			
Unclassified	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Open area	0	0	0	0
Forest	0	0	0	0
Bare Soil	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Agriculture	0	0	0	0
Built up	0	0	0	0
Column Total	0	0	0	0

Reference Data

Classified Data		Open area	Forest	Bare Soil
Unclassified	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Open area	0	58	0	3
Forest	0	0	3	0
Bare Soil	0	2	1	6
	0	0	0	0
	0	0	0	0
	0	0	0	0
Agriculture	0	5	3	0
Built up	0	0	0	0
Column Total	0	65	7	9

Reference Data

Classified Data				Agricultur
Unclassified	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Open area	0	0	0	7
Forest	0	0	0	2
Bare Soil	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Agriculture	0	0	0	63
Built up	0	0	0	1
Column Total	0	0	0	73

Reference Data

Classified Data	Built up	Row Total
Unclassified	0	0
	0	0
	0	0
	0	0
	0	0
Open area	0	68
Forest	0	5
Bare Soil	0	9
	0	0
	0	0
	0	0
Agriculture	0	71
Built up	66	67
Column Total	66	220

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

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Open area	65	68	58	89.23%	85.29%
Forest	7	5	3	42.86%	60.00%
Bare Soil	9	9	6	66.67%	66.67%
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Agriculture	73	71	63	86.30%	88.73%
Built up	66	67	66	100.00%	98.51%
Totals	220	220	196		

Overall Classification Accuracy = 89.09%

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

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.8459

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
	0.0000
	0.0000
	0.0000
	0.0000
Open area	0.7913
Forest	0.5869
Bare Soil	0.6524
	0.0000
	0.0000
	0.0000
Agriculture	0.8314
Built up	0.9787

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

3. Classification Accuracy Assessment Report 2023

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : c:/users/user/desktop/1/supervised_2023.img
User Name : user
Date : Sat Mar 16 09:41:15 2024

ERROR MATRIX

		Reference Data		
Classified Data	Unclassifi			
Unclassified	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Bare Soil	0	0	0	0
Open area	0	0	0	0
Forest	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Built up	0	0	0	0
Agriculture	0	0	0	0
Column Total	0	0	0	0

		Reference Data		
Classified Data	Bare Soil	Open area	Forest	
Unclassified	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Bare Soil	3	2	0	0
Open area	0	24	1	0
Forest	2	0	15	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Built up	0	1	1	0
Agriculture	1	1	1	0
Column Total	6	28	18	0

Reference Data

Classified Data				
Unclassified	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Bare Soil	0	0	0	0
Open area	0	0	0	0
Forest	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
Built up	0	0	0	0
Agriculture	0	0	0	0
Column Total	0	0	0	0

Reference Data

Classified Data	Built up	Agricultur	Row Total
Unclassified	0	0	0
	0	0	0
	0	0	0
	0	0	0
Bare Soil	0	0	5
Open area	1	3	29
Forest	0	1	18
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
Built up	105	2	109
Agriculture	0	56	59
Column Total	106	62	220

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

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Bare Soil	6	5	3	50.00%	60.00%
Open area	28	29	24	85.71%	82.76%
Forest	18	18	15	83.33%	83.33%
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Built up	106	109	105	99.06%	96.33%
Agriculture	62	59	56	90.32%	94.92%
Totals	220	220	203		

Overall Classification Accuracy = 92.27%

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

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.8832

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
	0.0000
	0.0000
	0.0000
Bare Soil	0.5888
Open area	0.8024
Forest	0.8185
	0.0000
	0.0000
	0.0000
	0.0000
	0.0000
Built up	0.9292
Agriculture	0.9292

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