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The Diachronic Analysis of Spatiotemporal Evolution of Land Cover in the City of El Meghaier - Application of Landsat 5, 7 and 9 satellite images (1984-2023)

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إهـــداء

إلى روح أبي الزكية الطاهرة...

إلى من وضع المولى – سبحانه وتعالى – الجنة تحت قدميها، ووقّرها في كتابه العزيز...

"أمي العزيزة الغالية" أدامها الله وأطال في عمرها

إلى جميع اخوتي واخواتي الذين كانوا دعما وسندا لي...

أستاذي المحترم الذي كان لي الشرف العظيم على تأطيره مذكرتي *هيمة عمارة*.

إلى كل الأساتذة الذين ساهموا في إرشادي وتوجيهي خلال هذه الرحلة التعليمية...

إلى أصدقائي ومعارفي الذين أجلّهم وأحترمهم...

إلى كل هؤلاء وهؤلاء أهدي هذا العمل المتواضع

سيف الدين

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Abstract:

The present study aims to monitor and analyze land cover changes in the city of El Meghaier over a period of time 1984–2023 using Landsat 5, 7, and 9 satellite imagery (TM, ETM+, and OLI-TIRS). The chosen approach for this analysis is the Diachronic Analysis of Spatiotemporal Evolution (DASE), with the following objectives: (i) Detecting spatiotemporal changes attributed to urbanization and territorial policies, particularly the administrative division upgrade as the provincial capital; (ii) Understanding the complexity of urban expansion and redefining the urban boundaries of El Meghaier along the National Road 03; and (iii) Assessing the environmental impact, specifically the risk of urban expansion on the palm groves and the urbanization of low-lying areas prone to flooding. Based on the main results obtained, an ambiguous situation of conurbation is observed between the city of El Meghaier and its neighboring agglomerations (Dendouga and N'sigha), leading to a compacted territory that includes the palm groves. This dynamic and transformation are characterized by a growth rate of **251.35%,** with **142.83%** observed during the period **2000–2023,** indicating an increase of **8.37 km²** compared to the total area of **14.23 km².** There is also a **108.9%** increase in agricultural areas, equivalent to an additional **15.37 km²,** at the expense of a **45.03%** decrease in **bare soil.**

Finally, the study concludes with interpretations and proposals for urban expansion scenarios as part of a Master's degree project in Urban Management (GTU).

Keywords: Remote sensing, Landsat, TM and ETM+ and OLI-TIRS, Spatiotemporal dynamic, Urbanization, DASE, El Meghaier.

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Abbreviations

DASE: Diachronic Analysis of Spatiotemporal Evolution.

ESRI: Environmental Systems Research Institute.

ETM+: The Enhanced Thematic Mapper Plus

GIS: Geographic Information Systems.

Landsat: Land Satellite.

LWIR: Long Wavelength Infrared.

NASA: National Aeronautics and Space Administration.

NIR: Near Infrared.

OLI: Operational Land Imager.

SWIR: Short Wavelength Infrared.

TIRS: Thermal Infrared Sensor.

TM: Thematic Mapper.

USGS: United States Geological Survey.

VNIR: Visible and Near Infrared.

Introduction

The world is currently witnessing a big advance in technology as a result of scientific and knowledge accumulations, which have resulted in many changes in human life and the environment in which they live.

Especially those that assist them in learning about their vast surroundings quickly with high quality and low cost. Geographical and natural studies are two of the most prominent fields in which this high-resolution technology is used. This technology is being used as a highly reliable resource for many disciplines, such as urban planning and emergency management.

This technology or these technologies may help policymakers and urban planners avoid natural disasters such as floods and landslides. It may also assist them in determining the appropriate suggestions for cities to take as targets for expansion, also known as urban expansion, which "is responsible for many issues that include soil degradation, flood, air quality degradation, and extreme weather" (Ding et al., 2022).

Urban expansion is a common phenomenon in developing countries such as Algeria. Each one of our cities sees its surface expand at different rates, depending on its population and location. It is frequently viewed as a flaw in planning that directly threatens the development of the city.

To be here, we combined geographical data from different dates using the geographic information system (GIS) and remote sensing, the most reliable new resources for planning, urban studies, and many other studies.

By combining GIS and remote sensing data and techniques, researchers can gain a more comprehensive understanding of urban expansion and its impacts. GIS and remote sensing can provide powerful tools for analyzing the complex spatial and temporal patterns of urban expansion, identifying its drivers and impacts, and guiding urban planners and policymakers to mitigate its negative effects.

Thus, the Diachronic Analysis of Spatiotemporal Evolution (DASE) of the city of El Meghaier makes it possible to qualify and quantify the evolution of spatial and urban expansion. A diachronic study from multi-date sources presents a significant progression compared to the old cartographic procedures.

The path to take is undoubtedly that of integrating multi-date sources into a GIS, processing them, and analyzing them so as to obtain a layer of the history of urbanization in El Meghaier.

The work presented in this master’s thesis is a cartographic study, in a precise way, of the detection of changes in land cover over a period of time 1984–2023 by the technique of diachronic analysis of spatiotemporal evolution of land cover, that is, the detection of changes in agriculture cover, urban areas, and bare soil in the city of El Meghaier by using the Landsat 5 TM images from 1984, Landsat 7 ETM+ images from 2000, and Landsat 9 OLI-TIRS images from 2023.

The image processing was conducted using ArcGIS software version 10.7, with a particular focus on land cover change and the delineation of the urban space of the city within its surrounding area. This was done with the following objectives:

(i) Detecting spatiotemporal changes attributed to urbanization and territorial policies, particularly the administrative division upgrade as the provincial capital.
(ii) Understanding the complexity of urban expansion and redefining the urban boundaries of El Meghaier along the National Road 03.
(iii) Assessing the environmental impact, specifically the risk of urban expansion on the palm groves and the urbanization of low-lying areas prone to flooding.

Based on the results obtained, we can identify the risks associated with this transformation. The findings will ultimately lead us to understand the complexity of the expansion, redefine the boundaries and spatial composition of the city, and draw conclusions and interpretations. This will help to conclude by presenting interpretations and suggesting urban expansion scenarios as part of a Master's degree project in Urban Management (GTU).

CHAPTER I

Methodology

1. Research Problem

The city of El Meghaier witnessed an urban and agricultural expansion beginning in 1984. In fact, it was noticed that the city witnessed excessive urban expansion in the 2000s. In fact, it has been noticed that an ambiguous situation of conurbation is observed between the city of El Meghaier and its neighboring agglomerations (Dendouga and N'sigha), especially after being upgraded to a town center after the administrative division of 2022, which will lead to an expansion and compacted territory that includes the palm groves and an expansion in the risk zone (low altitude). And therefore, there is a need for more detailed and nuanced analyses of spatiotemporal evolution in order to better understand the factors that contribute to it and the ways in which it affects different areas of study. In particular, a diachronic analysis of spatiotemporal evolution can help us track changes over time and identify trends and patterns that may not be visible through other approaches.

For this purpose, some satellite images were obtained over a 39-year period (1984–2023) in order to analyze changes in the urban fabric and in agricultural cover and try to quantify their evolution and environmental impact.

2. Research Questions

- How has the urban morphology of El Meghaier changed over time, and what factors have influenced these changes?
- How well do you understand this spatial dynamic?
- What is the impact of urban expansion and the dynamics of the field, especially after the year 2000, on the environment and the field in general?

3. Hypotheses

Our hypotheses are based on the following two questions:

- ❖ Major extensions and new housing programs, initiated by the municipal level of the city of El Meghaier, especially after being upgraded to a provincial capital after the administrative division of 2022, oriented by the PDAU, do they reflect the uncontrolled anarchic extension that has compacted the air bordering the agglomerations of Nsigha and Dendouga to the detriment of the palm plantations, thus placing them in the zone of risk?

- ❖ How do these changes and recompositions will mark the territory of El Meghaier, especially, their impact on the environment?

4. Objectives

- ❖ Detecting spatiotemporal changes attributed to urbanization and territorial policies, particularly the administrative division upgrade as the provincial capital.
- ❖ Understanding the complexity of urban expansion and redefining the urban boundaries of El Meghaier along the National Road 03.
- ❖ Assessing the environmental impact, specifically the risk of urban expansion on the palm groves and the urbanization of low-lying areas prone to flooding.
- ❖ The extent of translating the results of the study into a project to choose **alternatives to urban planning and expansion based mainly on mitigating the impact on the environment**, which allows obtaining a master's degree in city management.
- ❖ To make recommendations for future research and applications of spatiotemporal evolution analysis.

5. The Structure of The Thesis

Our thesis is divided into three main chapters:

The methodological chapter **(Chapter I)** will allow us to detail the methodology of the study, including the problem, the hypotheses of the study, its objectives, the composition of the note, the inventory of the results of previous studies, as well as the control of terminology, concepts, and theoretical definitions, which allows us later to control the applied study. It is easy for the reader to follow the study.

As for the second chapter **(Chapter II),** it was devoted to defining the study area, and this is so that we can understand the conditions and factors controlling the dynamics of the field, in addition to adjusting the current status of the field.

The third chapter **(Chapter III)** was devoted to the applied study analysis, the Diachronic Analysis of Spatiotemporal Evolution (DASE) of Land Cover in the City of El Meghaier.

The results of the study DASE allow us later to prepare the end-of-graduation project (the second part of the end of the master's study in urban management), which is mainly represented in three proposals for the expansion of El Meghaier city.

6. State of the art

Studies on land use and land cover change are of great importance as they provide insights into current trends in urban expansion processes. Four research studies have enriched our understanding of the applied issue and focused our choice of tools and methods adopted in this study:

The first study: By (Fouzia Bendraoua, 2011), she evaluated the spatial evolution of the city of Oran by defining urban spaces between 1991 and 2003. The methodology applied is effective for monitoring and assessing the spatial dynamics in a regional city such as Oran.

The second study: By (Elodie, & Serradj, 2016), where they followed the interesting spatiotemporal evolution of the urban area of the city of Blida using old maps, satellite images, and GIS over a long period (1936–2015), as this allowed them to highlight not only the main trends of spreading this extension but also to measure its spatial evolution.

The third study: By (Benyahya, & Dridi, 2017) entitled “L’analyse diachronique de la superficie urbaine par télédétection et SIG d’une grande ville algérienne (Batna)”. This research aims at following the extension of the urban fabric of the town of Batna and identifying the various stages of urbanization and the changes induced over 40-year period.

The fourth study: By (HAJI, & HIMA, 2022) entitled “The Diachronic Analysis of Evolution Spatiotemporal of the city of Algiers - Application of Satellite Images Landsat 5 and 8 (TM and OLI-TRS)”. aims to monitor and analyse the metropolitan changes induced, mainly, over a period of time (1984-2021), From the main results obtained: we find ourselves in the ambiguous situation of a metropolitan conurbation compacting a mega metropolis territory (1984_2021).

7. Concepts and Definitions

7.1. Concept of Remote Sensing

7.1.1. What is Remote Sensing?

Remote sensing “is the art, science and technology of acquiring information about physical objects and the environment through recording, measuring and interpreting imagery and digital representations of energy patterns derived from noncontact sensors” (Yang, 2011, p. 4).

In other words, “**Remote sensing** refers to the activities of recording, observing, and perceiving (sensing) objects or events in far-away (remote) places. In remote sensing, the sensors are not in direct contact with the objects or events being observed” (Qihao Weng, 2010, p. 1). It has as its goal: “... acquisition and measurement of information about certain properties of phenomena, objects, or materials by recording device not in physical contact with the features under surveillance” (Khorram et al., 2012, p. 2).

Also, “**Remote sensing** is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth” (USGS, 2022).

The remote sensing process of inferring surface parameters from measurements of the electromagnetic radiation from the earth’s surface. The electromagnetic radiation can either be reflected or emitted from the earth’s surface. (GIS & REMOTE SENSING).

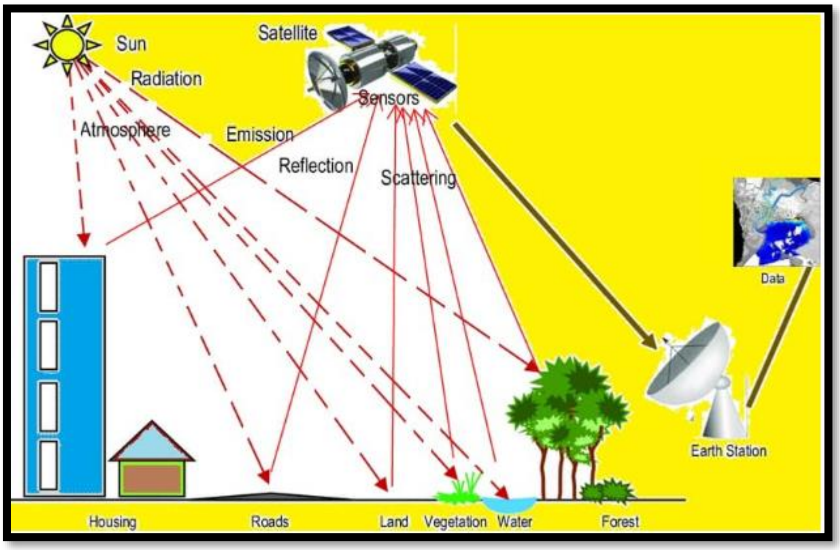


Figure N° 1: The remote sensing process. (GIS & REMOTE SENSING).

7.1.2. History and scope of Remote Sensing

The scope of the field of remote sensing can be clarified by looking at its history and tracing the development of some of its key concepts. A few key events can be offered to trace the field's evolution.

Table N° 1: Milestones in the History of Remote Sensing (Campbell & Wynne, 2011, p.7).

1800	Discovery of infrared by Sir William Herschel
1839	Beginning of practice of photography
1847	Infrared spectrum shown by A. H. L. Fizeau and J. B. L. Foucault to share properties with visible light
1850-1860	Photography from balloons
1873	Theory of electromagnetic energy developed by James Clerk Maxwell
1909	Photography from airplanes
1914-1918	World War I: aerial reconnaissance
1920-1930	Development and initial applications of aerial photography and photogrammetry
1929-1939	Economic depression generates environmental crises that lead to governmental applications of aerial photography
1930-1940	Development of radars in Germany, United States, and Unites Kingdom
1939-1945	World War II: applications of nonvisible portions of electromagnetic spectrum; training of persons in acquisition and interpretation of airphotos
1950-1960	Military research and development
1956	Colwell's research on plant disease detection with infrared photography
1960-1970	First use of term *remote sensing* TIROS weather satellite Skylab remote sensing observations from space
1972	Launch of Landsat 1
1970-1980	Rapid advances in digital image processing
1980-1990	Landsat 4: new generation of Landsat sensors
1986	SPOT French Earth observation satellite
1980s	Development of hyperspectral sensors
1990s	Global remote sensing systems, lidars

7.1.3. Applications of Remote Sensing (NASA, USGS)

Remote sensing applications refer to the practical use of remote sensing technology in various fields. Here are some specific applications:

- Land-use Planning and Mapping: Remote sensing can be used to map land use and land cover changes, monitor urban growth, and identify areas that are suitable for agriculture, forestry, or urban development.
- Forest monitoring: Remote sensing is widely used to monitor and assess forest resources. It can provide data on forest extent, health, and changes over time. This information is crucial for forest management, conservation, and combating deforestation.

- Agriculture: Remote sensing can be used to monitor crop health, identify crop stress, estimate crop yields, and optimize irrigation and fertilization. It can also help in predicting weather conditions and natural disasters like floods and droughts.
- Energy exploration and monitoring: Remote sensing is employed in the exploration and monitoring of energy resources such as oil, gas, and minerals. It helps in identifying potential extraction sites and monitoring pipelines and infrastructure.
- Water resource management: It also helps in monitoring water resources, including lakes, reservoirs, rivers, and groundwater. It provides data on water levels, quality, and changes over time, facilitating effective water resource management and planning.
- Mapping and monitoring of wetlands: Remote sensing plays a crucial role in mapping and monitoring wetlands, including their extent, vegetation cover, and hydrological changes. This information supports wetland conservation, water resource management, and biodiversity preservation.

Remote sensing technology has revolutionized these fields, empowering decision-makers with crucial information for effective land management, environmental conservation, agriculture, energy exploration, and water resource management. Its ability to gather data from a distance has proven invaluable, making it an indispensable tool in various applications.

7.2. Concept of GIS

7.2.1. What is GIS?

"A **GIS** is an integrated software package specifically designed for use with geographic data that performs a comprehensive range of data handling tasks. These tasks include data input, storage, retrieval and output, in addition to a wide variety of descriptive and analytical processes" (Qihao Weng, 2010, p. 21). According to Tomaszewski (2015), a GIS is composed of several essential components as follows:

- **Software:** Software is used for running GIS operations.
- **Hardware:** Hardware is the platform in which software is run and/or data is stored.
- **People:** People include those who work with GIS in a variety of capacities such as using GIS to make decisions, or students learning about GIS.
- **Knowledge:** Knowledge is perhaps the most abstract part of GIS but as equally important as the other parts.

- **Data:** Data will always be the more important component of a GIS.
- **Network:** The network can be considered the element that connects all the other parts together.

These different components of GIS are integrated to enable effective utilization and analysis of geographic data for various purposes, such as urban planning, natural resource management, navigation, scientific exploration, and more.

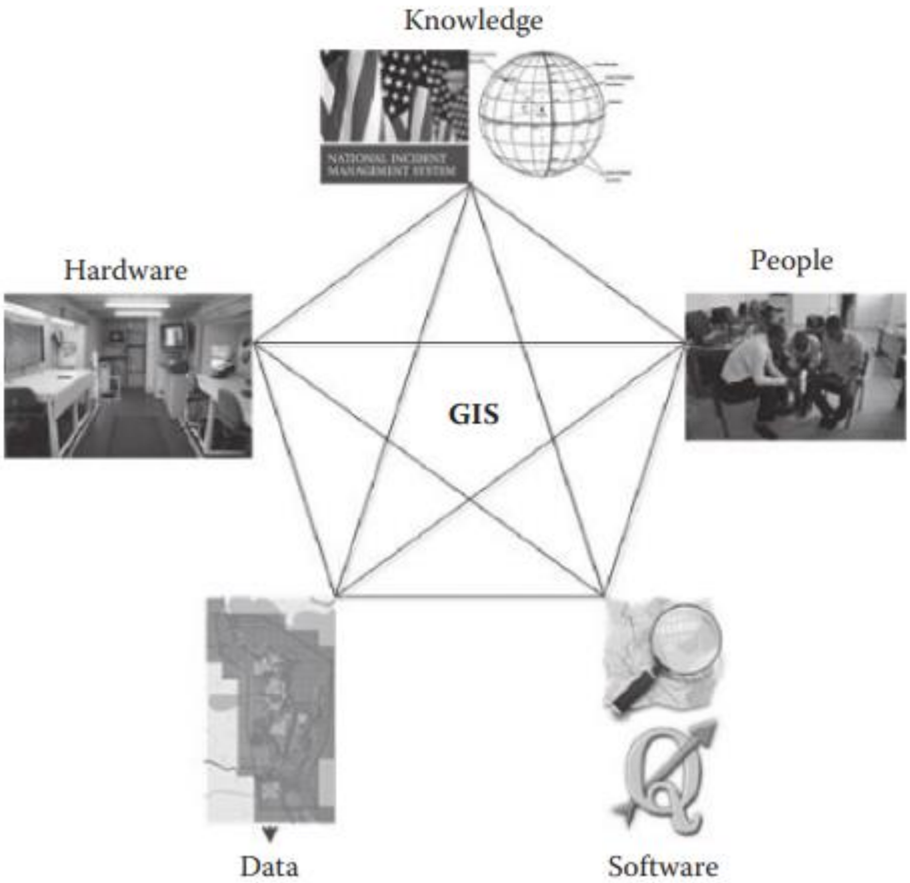


Figure N° 2: The components of GIS. The lines represent networks that connect all of the other. (Tomaszewski, 2015, p. 75).

8. Materials and Methods

8.1. Materials

8.1.1. Satellite images

Using the Landsat 5 TM images from 1984, Landsat 7 ETM+ images from 2000, and Landsat 9 OLI-TIRS images from 2023, image processing was carried out using ArcGIS software version 10.4, in terms of image clarity and determination of land use changes. This method allows for the delimitation of the city in its surrounding space.

- **Landsat 5 TM:**

The Landsat TM 5 satellite was launched in 1984. It has an inclination angle of 98.3° and a period of 98.5 minutes, making 14 to 15 revolutions per day with distances to the equator between two consecutive traces of 2,752 km, and covering the same trace every 16 days. The TM (Thematic Mapper) sensor of Landsat 5 is characterized by a large number of spectral bands and offers a good ground resolution. Each TM scene covers an area of 172 x 185 km.

The instrument has 7 spectral bands with a resolution of 30 meters for bands 1-5 and 7 and, one thermal band with a resolution of 120 meters (band 6). (Table N° 2).

Figure N° 3: Landsat 5 TM (USGS).

Table N° 2: Landsat 5 TM images.

Band Number	Description	Wavelength	Resolution
B1	Visible Blue	0.45 to 0.52 µm	30 meter
B2	Visible Green	0.52 to 0.60 µm	30 meter
B3	Visible Red	0.63 to 0.69 µm	30 meter
B4	NIR	0.76 to 0.90 µm	30 meter
B5	SWIR	1.55 to 1.75 µm	30 meter
B6	Thermal	10.40 to 12.50 µm	120 meter
B7	SWIR	2.08 to 2.35 µm	30 meter

Source: GISGeography.

- **Landsat 7 ETM+:**

Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) is a satellite sensor used to capture images of the Earth's surface from space. It is part of the Landsat program, which is a series of Earth-observing satellites operated by NASA and the United States Geological Survey (USGS).

Landsat 7 ETM+ was launched in 2003 as a replacement for the original Landsat 7 satellite. It is equipped with an improved version of the ETM sensor called the Enhanced Thematic Mapper Plus (ETM+). The ETM+ sensor is capable of collecting data in seven spectral bands, including a panchromatic band (band 8) with a higher spatial resolution of 15 meters and six multispectral bands (bands 1–5 and 7) with a spatial resolution of 30 meters. The sensor also has a thermal infrared band (band 6) with a spatial resolution of 60 meters, which can be used to measure surface temperature.

Figure N° 4: Landsat 7 ETM+ Satellite Sensor (15m) (NASA).

Table N° 3: Landsat 7 (ETM+) images.

Band Number	Description	Wavelength	Resolution
B1	Visible Blue	0.45 to 0.52 µm	30 meter
B2	Visible Green	0.52 to 0.60 µm	30 meter
B3	Visible Red	0.63 to 0.69 µm	30 meter
B4	NIR	0.76 to 0.90 µm	30 meter
B5	NIR	1.55 to 1.75 µm	30 meter
B6	Thermal	10.4 to 12.3 µm	60 meter
B7	Mid Infrared	2.08 to 2.35 µm	30 meter
B8	Panchromatic	0.52 to 0.90 µm	15 meter

Source: GISGeography.

- **Landsat 9 OLI-TIRS**

Landsat 9 refers to the latest Earth observation satellite in the Landsat program, which was launched on September 27, 2021. Landsat 9 orbits the Earth at an altitude of approximately 705 kilometers with an angle of inclination of 98.21°.

Landsat 9 is equipped with two main instruments: the Operational Land Imager 2 (OLI-2) and the Thermal Infrared Sensor 2 (TIRS-2). The OLI-2 instrument captures images of the Earth's surface in nine spectral bands, including visible, NIR, and SWIR, with a spatial resolution of 30 meters for most bands. These images are useful for a wide range of applications, such as land use and land cover mapping, and natural resource management. On the other hand, the TIRS-2 instrument, measures thermal radiation emitted from the Earth's surface, providing temperature data that can be used to monitor changes in land surface temperature and to detect and track wildfires.

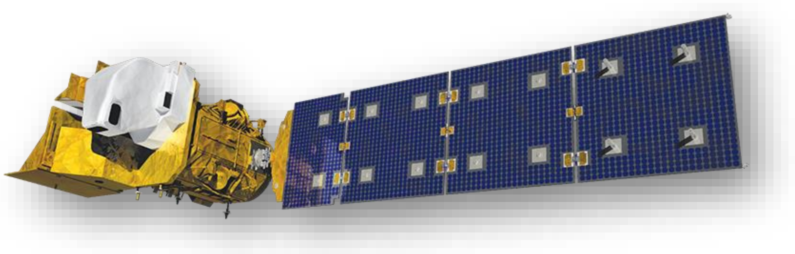


Figure N° 5: Landsat 9 instruments (NASA).

Table N° 4: Landsat 9 OLI-TIRS images.

Band Number	Description	Wavelength	Resolution
B1	Coastal / Aerosol	0.433 to 0.453 µm	30 meter
B2	Visible Blue	0.450 to 0.515 µm	30 meter
B3	Visible Green	0.525 to 0.600 µm	30 meter
B4	Visible Red	0.630 to 0.680 µm	30 meter
B5	NIR	0.845 to 0.885 µm	30 meter
B6	SWIR	1.56 to 1.66 µm	30 meter
B7	SWIR	2.10 to 2.30 µm	60 meter
B8	Panchromatic	0.50 to 0.68 µm	15 meter
B9	Cirrus	1.36 to 1.39 µm	30 meter
B10	LWIR	10.3 to 11.3 µm	100 meter
B11	LWIR	11.5 to 12.5 µm	100 meter

Source: GISGeography.

8.1.2. Softwares used

- **ArcGIS software**

ArcGIS is a geographic information system (GIS) software developed by Esri, a global leader in GIS technology. It allows users to create, manage, analyze, and display geographic data in a variety of ways, including maps, charts, and reports. ArcGIS provides tools for data visualization, spatial analysis, and geoprocessing, which enable users to explore patterns and relationships within their data. The software is widely used in fields such as urban planning, natural resource management, emergency management, and many others where spatial analysis and data visualization are important.

- **Google Earth Pro**

Google Earth is software that allows the visualization of the Earth thanks to an assembly of aerial photographs or satellite images. (Institut Français de l'Education).

- **Excel**

Microsoft Excel is a spreadsheet software program in the Microsoft Office suite developed and distributed by the publisher Microsoft. It used for creating and manipulating data in a table format, performing calculations, and creating charts and graphs based on that data.

8.1.3. Choice of images

Our choice of Landsat 5, 7, and 9 satellite images for the same month in the years 1984, 2000, and 2023 is crucial to obtaining a characterization of land cover changes induced by human activity.

They were all acquired during the same season, where different types of land cover can be distinguished.

Table N° 5: Details of satellite data images in the study.

Images	PATH	ROW	Instrument	Date	Bands	Resolution
Image 1	193	036	Landsat 5 TM	20/04/1984	1-2-3-4-5-6-7	30 meter
Image 2	193	037	Landsat 5 TM	20/04/1984	1-2-3-4-5-6-7	30 meter
Image 3	193	036	Landsat 7 ETM+	24/04/2000	1-2-3-4-5-6-7-8	30 meter
Image 4	193	037	Landsat 7 ETM+	24/04/2000	1-2-3-4-5-6-7-8	30 meter
Image 5	193	037	Landsat 9 OLI-TIRS	08/04/2023	1-2-3-4-5-6-7-8-9-10-11	30 meter
Image 6	193	036	Landsat 9 OLI-TIRS	08/04/2023	1-2-3-4-5-6-7-8-9-10-11	30 meter

Source: Student 2023.

8.2. Methods

8.2.1. Preprocessing of satellite images:

When an image is acquired by a sensor, it contains geometric and radiometric errors. These errors must be corrected with an accuracy depending on the type of application. Preprocessing operations can be divided into:

Atmospheric correction: Is the process of removing the effects of atmospheric scattering and absorption from remotely sensed imagery. The Earth's atmosphere affects the way that light is reflected and transmitted from the surface to the sensor, which can cause distortions in the data. Atmospheric correction attempts to remove these distortions by modeling the scattering and absorption properties of the atmosphere.

Radiometric calibration: Includes, among others, correction for sensor irregularities, noise caused by the sensor or atmosphere, and conversion of the data to accurately represent the reflected or emitted radiation measured by the sensor.

Geometric correction: Includes correction for geometric distortions due to variations in the Earth-sensor geometry, and transformation of the data to true coordinates (e.g., latitude and longitude) on the surface of the Earth.

Mosaic: Refers to the process of combining multiple images into a single, seamless image. Mosaicking is commonly used in remote sensing and GIS applications to create large-scale maps and to cover areas too large for a single image. The process involves adjusting the images for geometric and radiometric consistency, aligning them spatially, and blending the edges to create a seamless mosaic. (Figure N°6 and Figure N°7)

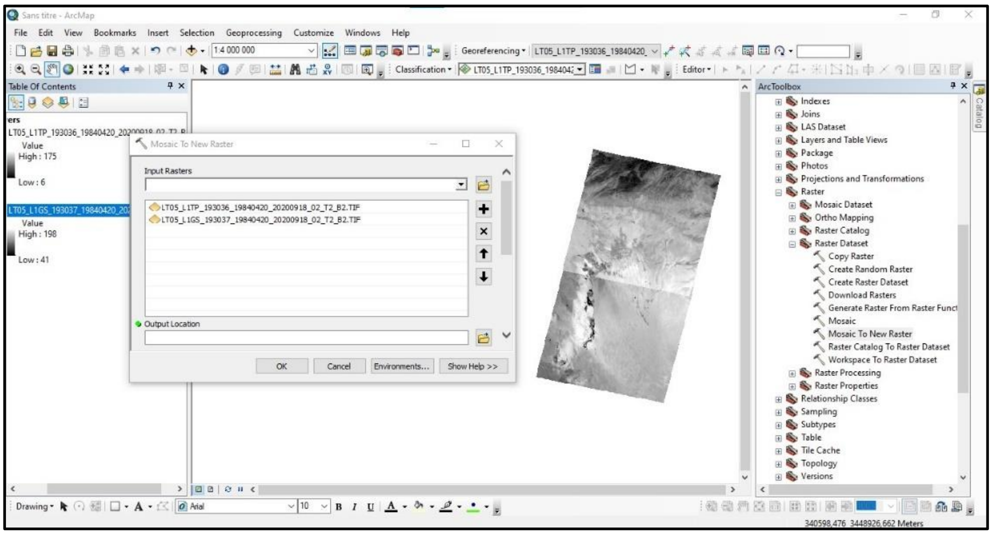
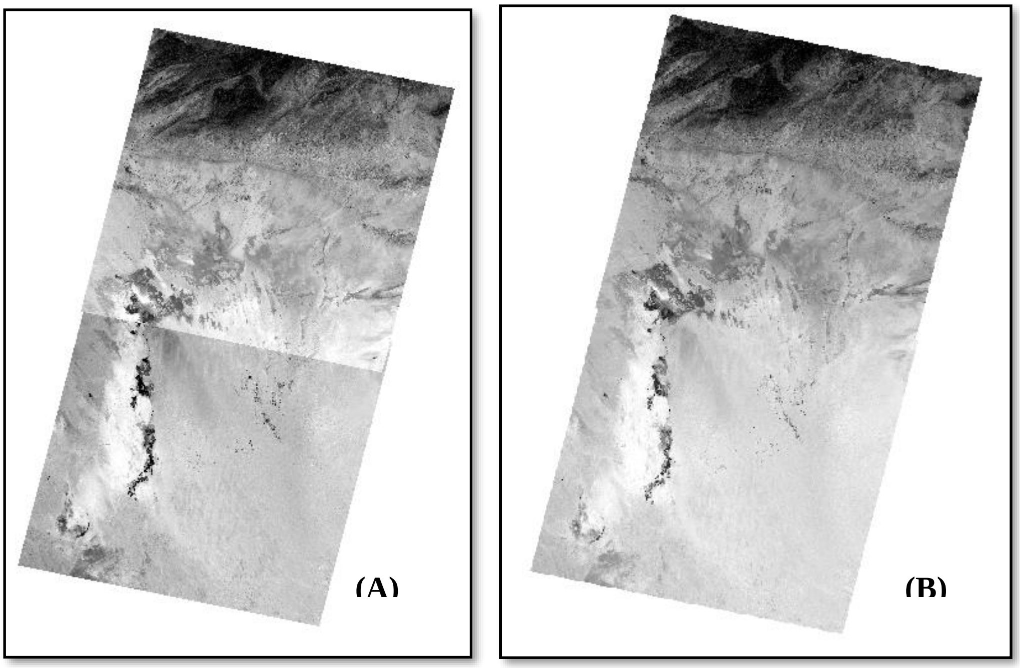


Figure N° 6: The mosaic process in ArcGIS 10.7.



Source: Student 2023.

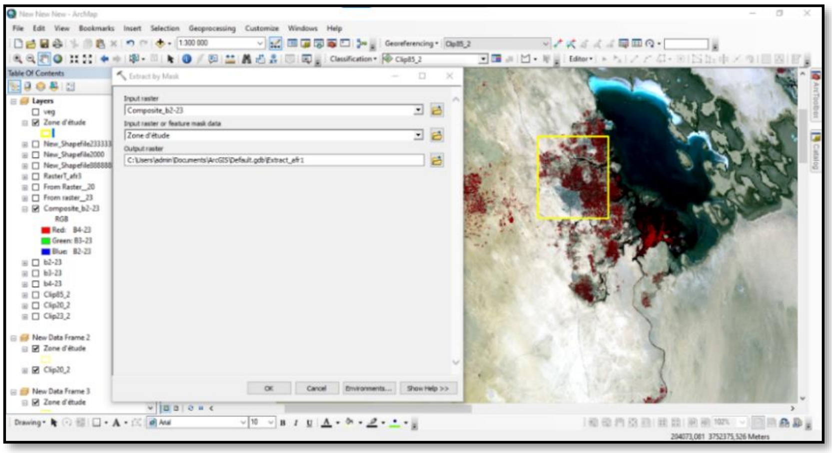
Figure N° 7: Satellite images before mosaicking (A) and after mosaicking (B).

8.3. Extraction of the study area

We applied a shapefile mask representing our study area to satellite images. We didn't apply the administrative boundary of the wilaya because the study area would appear very small compared to the administrative area of the wilaya. The mask we created is a rectangle with an area of 101,93 km² and the following coordinates:

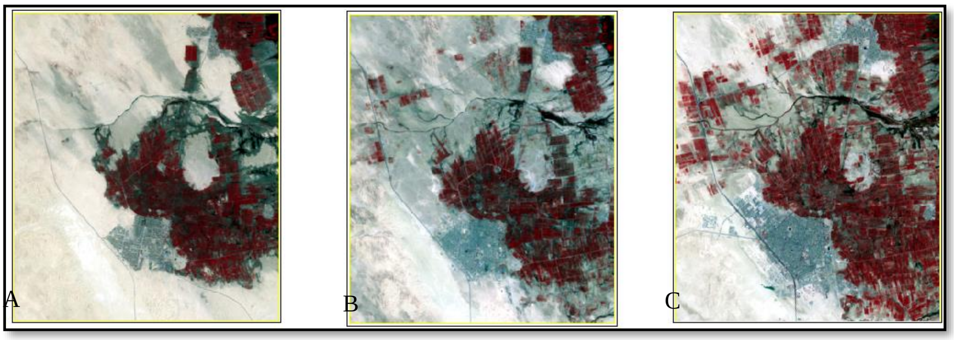
a) 34.025330 N 5.974168 E.
b) 34.025330 N 5.872930 E.
c) 33.927521 N 5.974168 E.
d) 33.927521 N 5.872930 E

Using the mask allowed us to extract the area of the region of El Meghaier for the years 1984, 2000, and 2023. **(The applied color composition in the images is the NIR color composition).**



Source: Student 2023.

Figure N° 8: The masking process in ArcGIS 10.7.

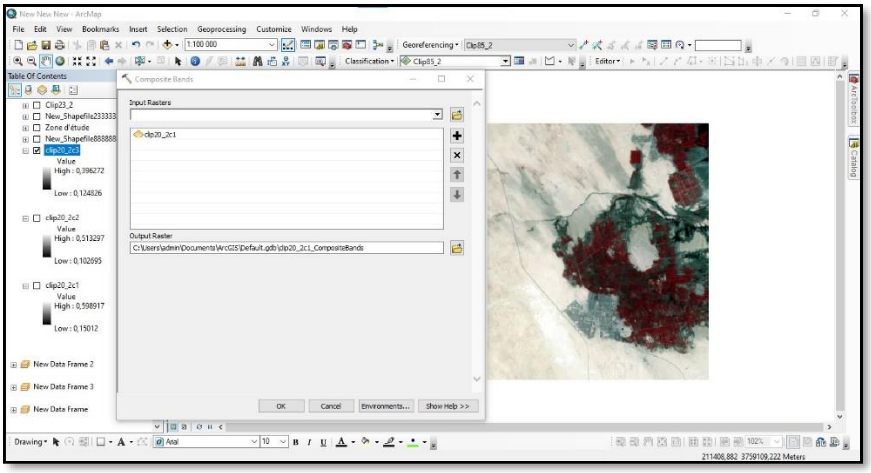


Source: Student 2023.

Figure N° 9: Extracting the study area for 1984 (A), 2000 (B), and 2023 (C).

8.4. Color composite

In remote sensing, “each natural object is identified by its spectral signature. It does not react in the same way across the electromagnetic spectrum. Analyzing the spectral signature of different land cover objects is an important step in selecting the channels of Landsat scenes” (BENSAID, 2006, p. 183). An RGB (Red, Green, Blue) color image contains three color modes. Each color mode corresponds to a specific spectral band, that is, a wavelength at which the image was acquired, with shades ranging from 0 to 255. 0 represents black, and 255 represents the color white.



Source: Student 2023.

Figure N° 10: Color composition process in ArcGIS 10.7.

8.5. Image Classification

In this study, we used a supervised classification method that involves using training areas as reference to perform the classification. The training areas consist of thematic classes representing land cover types, and spatial regions where regions of interest are created. ROIs (regions of interest) are polygons drawn on the image, for which we indicate the class.

8.5.1. Supervised Classification

Before the classification, training samples were selected by choosing several polygons for each class of land cover from reference data. The Google Earth software was also used as a reference for calibrating the classification and increasing the classification accuracy. It was employed for land cover classification and change analysis.

Supervised classification technique based on the maximum likelihood classifier was used for extracting each land cover maps independently. Land cover classification should be unified to ensure that the classification of the multi-temporal, Landsat images is compatible to each other.

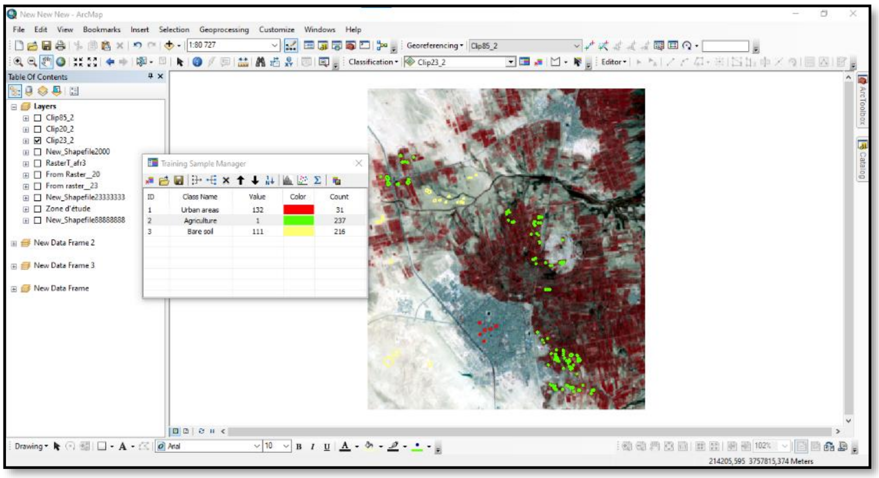
The maximum likelihood classifier is one of the most popular classification algorithms and provides the best results from remotely sensed data. It is a supervised statistical approach to pattern recognition. It estimates the probability of a pixel belonging to each of a predefined set of classes, and then allocates each pixel in the right class with highest probability. Finally, three land cover classes were extracted:

- **Urban areas:** This class includes urban infrastructure, buildings, roads…
- **Agriculture:** Merging these two classes into one broader category can simplify the classification process and provide a more generalized representation of vegetated and cultivated areas when the distinction between natural vegetation and cultivated land is not crucial for this study, as in our region of interest. Thus, this class includes palm oases, land used for cultivation, and agricultural practices.
- **Bare soil:** This class represents areas with exposed soil, barren land, or rocky surfaces.

Table N° 6: Land cover classification scheme.

Land cover classes	Description
Urban areas	Urban infrastructure, buildings, roads.
Agriculture	Palm oases, land used for cultivation, and agricultural practices.
Bare soil	Non-vegetated areas

Source: Student 2023.



Source: Student 2023.

Figure N° 11: Steps of maximum likelihood classification in ArcGIS 10.7.

8.6. Classification Validation

It is possible to evaluate the performance of classification or the quality of thematic maps derived from remote sensing data by estimating the percentage of correctly classified pixels. This evaluation was completed using Google Earth images.

Conventional methods for assessing the thematic accuracy of a map were employed. These include the confusion matrix and analysis using the Kappa coefficient.

Confusion Matrix (or Error Matrix) provides an evaluation of the overall accuracy of mapping and classification results for each thematic class. **The Kappa index** assesses the agreement between the obtained results and the ground truth in the confusion matrix. It ranges from 0 to 1 and is divided into three groups: (Lunetta & Lyon, 2004, p. 4).

- A value greater than 0.80 (i.e., 80%) represents strong agreement.
- A value between 0.40 and 0.80 (i.e., 40% to 80%) represents moderate agreement.
- A value below 0.40 (i.e., 40%) represents poor agreement.

8.7. Change Detection

Change detection refers to the process of identifying differences in the state of an object or phenomenon by observing it at different time periods. Remote sensing has been widely used in research to monitor and analyze changes in the Earth's surface and their consequences, such as vegetation degradation, urban expansion, and more. There are several methods available for change analysis in remote sensing. (GANA, 2018, p. 78)

8.7.1. Evolution of land cover

The spatio-temporal evolution of each land cover class was evaluated through a series of ensemble transformations. The relationship between the same class at two different dates allowed for the extraction of "stable," "regressing," and "progressing" zones for that class. It is considered that A1 represents the area occupied by the land cover classes at date 1, and A2 is the surface area of the same classes at date 2.

8.7.2. Calculation of change rates

The change rates (annual evolution rate and global change rate) of the land cover class areas between the years 1984 and 2000 and 2023 were determined, respectively, using the equations proposed by the FAO (1996) (1) and Bernier (1992) (2), which are commonly used to measure the growth of macroeconomic aggregates between two given periods.

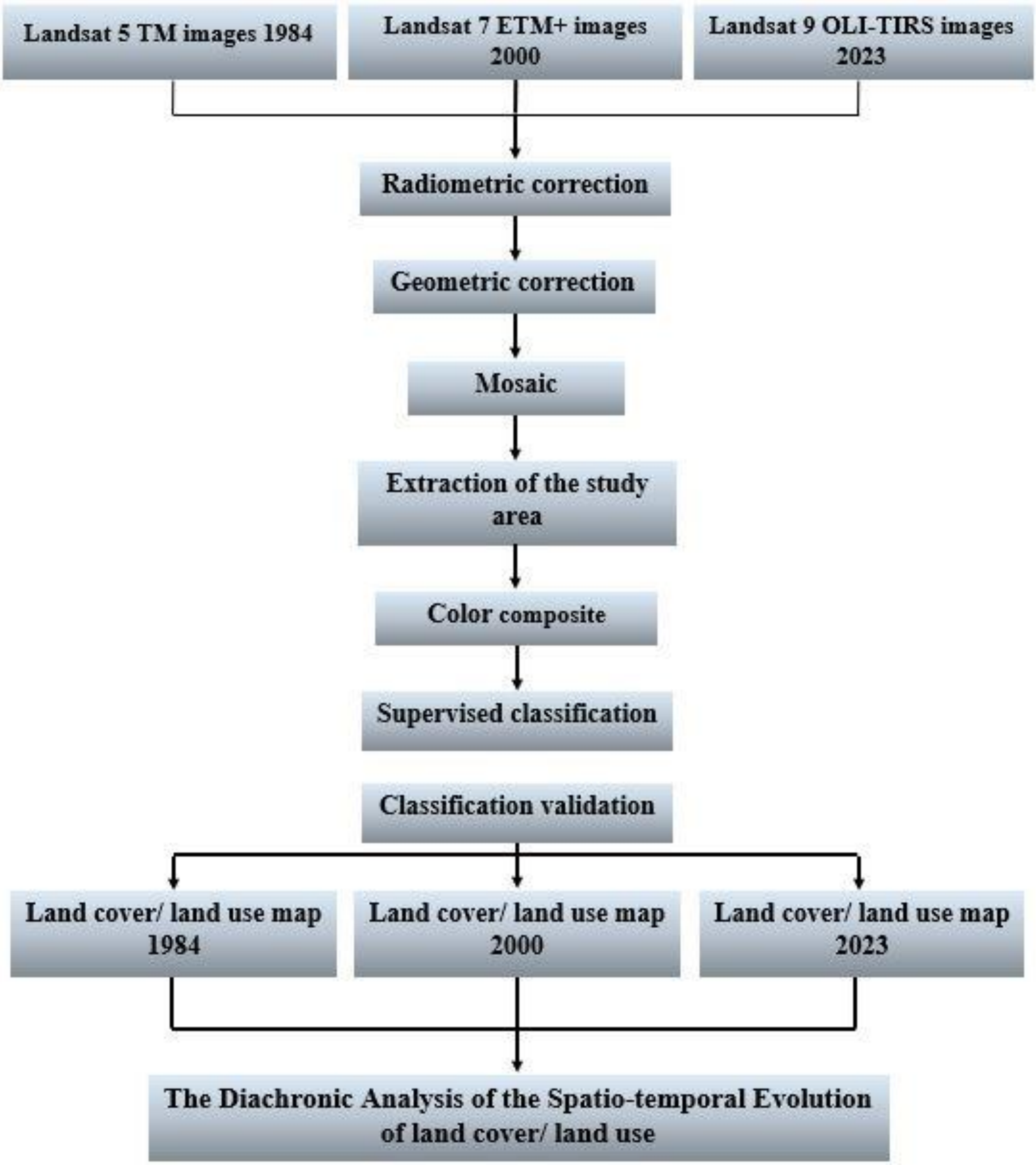
In this study, the global rate was calculated using the following formula:

$$\mathbf{GR = ((A2 - A1)/A1)*100}$$

GR: the global rate.

A1: represents the surface area of a land cover class at date *t1*.

A2: represents the surface area of the same land cover class at date *t2*.



Source: Student 2023.

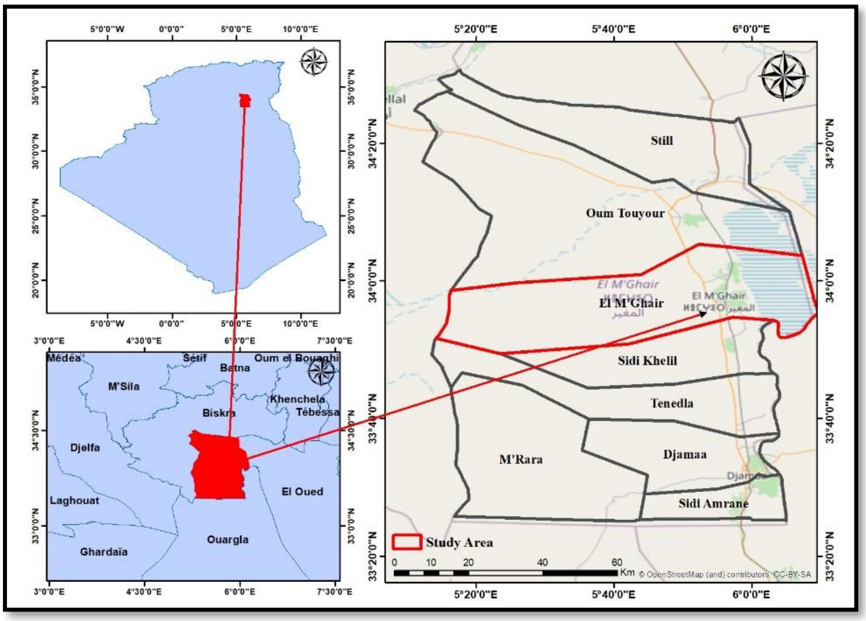
Figure N° 12: Methodological chart.

CHAPTER II

Study Area Presentation

1. Description of the study area

El Meghaier is an oasis city located at approximately at 500 km south-east of the capital Algiers. It is a low area with a depression of 1.51 m compared to sea level, with latitude of 33° 57' 0" north and a longitude of 05° 56' 0" east. The study area is located in one of the largest deserts in the south-east of Algeria, specifically the Northeastern Sahara, enclosed to the north by the wilaya of Biskra, to the south by the wilayas of Ouargla and Touggourt, to the west by the wilaya of Ouled Djellal, and to the east by the wilayas of Oued Souf and Touggourt.



Source: Student 2023.

Figure N° 13: Localization of the study area.

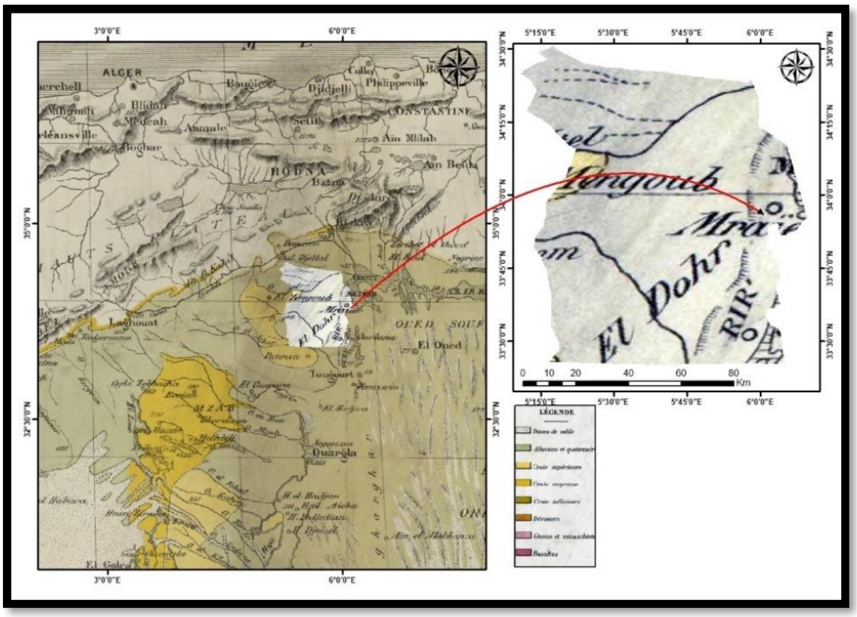
2. Geological and Hydrogeological context (Hammadi et al., 2023).

2.1. Geology

In terms of structure, the territory of Algeria can be divided into two main geological regions: the Alpine domain in the north and the Saharan platform domain in the south. The study area is located within the lower Sahara region, which is bounded to the north by the South Atlas fault and the foothills of the Aures mountains, to the south by the Southern cliff of Tinhert, to the east by the Cretaceous outcrops of Dahar, and to the west by the Mzab ridge. It lies between the northern edge of the Hoggar and the southern edge of the Saharan Atlas, encompassing the extensive sedimentary basin of the Lower Sahara.

Geologically, the lower Sahara consists of two structural units: the Precambrian basement composed of igneous and metamorphic rocks, overlain by thousands of meters of sedimentary layers ranging from the Cambrian to the Quaternary. In the southern part, Paleozoic lands are exposed between the Tadmait and Tinhert plateaus and the Hoggar massif. The Mesozoic and early Cenozoic terrains form a significant portion of the boundary outcrops, while Tertiary and Quaternary continental deposits occupy the central part of the basin.

The study area spans from the Barremian period to the Quaternary, characterized by the absence of major tectonic deformations.



Source: Carte géologique du Sahara, du Maroc à la Tripolitaine et de l'Atlas au Ahaggar.

(Modified by the student 2023).

Figure N° 14: Geological map of the study area.

2.2. Hydrogeology

From a hydrogeological point of view, the Northern Sahara basin is composed of a number of wide-ranging heterogeneous formations separated by impermeable formations, known as non-renewable resources, represented by the two large aquifers: the Intercalary Continental and the Terminal Complex. In the study area, the following three layers, from bottom to top, are encountered:

- Phreatic aquifer.
- The Continental Intercalary aquifer.
- The Complex Terminal aquifer.

Since the Holocene, the current level of aquifers reflects the result of a pure drying up.

In the Oued Righ region, there are three aquifers were well differentiated in the Complex Terminal:

The first and second layers of Mio- Pliocene sands followed by the limestone of the Eocene inferior as presented in Figure N° 15.

From the figure it's understood that the continuity of the underground flow passing from one zone to another area**.**

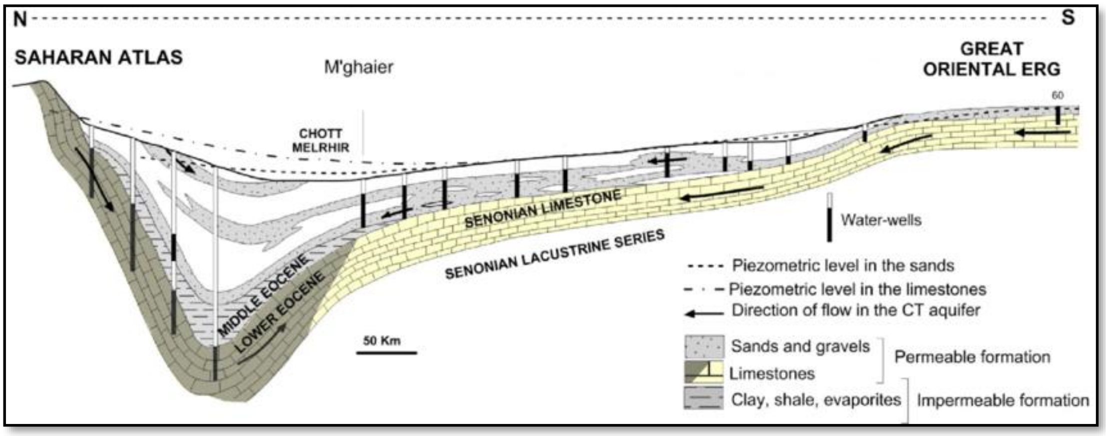


Figure N° 15: Hydrogeological transversal cutting of the Complex Terminal aquifer.

(Hammadi et al., 2023)

3. The risks of the territory of El Meghaier

The ecological and environmental question is becoming more and more essential in the treatment of the problems of the engineering of the territories.

3.1. Natural risks

These include:

- Groundwater rise;
- Wind erosion;
- Desertification;
- Threat to flora and fauna;
- Threat to protected sites.

3.2. Risks due to industrial activities

Industrial risks are currently poorly represented due to the weakness of the industrial fabric of the wilaya. It is nevertheless represented by:

- Water pollution
- Landscape pollution (brickworks, etc.)

3.3. Risks due to human activities

The risks due to human activities are essentially:

- The risks of massive and uncontrolled urbanization;
- Sanitation problems;
- Threats to drinking water;
- Contamination of groundwater by wastewater;
- Epidemics and diseases due to water stagnation;
- The sprawl of agricultural land and oases;
- Uncollected household waste, and consequently, lack of recycling and treatment.
- Air pollution from urban automobile traffic.

3.4. Management of household and similar waste:

In terms of household waste management, we have noticed the absence of a controlled landfill or a sanitary landfill site in the eight municipalities of the wilaya of El Meghaier.

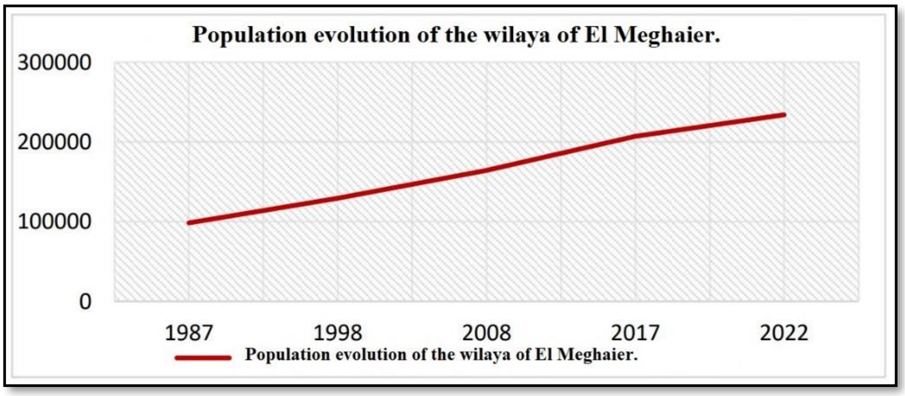
The municipalities of the wilaya of El Meghaier have not been provided with master plans for the management of household and related waste. In addition to that, they face challenges due to their limited human and material resources.

4. Demographic Dynamics, Human Development

4.1. Population evolution

El Meghaier is experiencing a growing population. According to the latest general census in 2008, its average annual growth rate is estimated at 2.22%.

In 2017, approximately 10 years later, this rate increased to 2.5%, confirming the gradual form of demographic development in the El Meghaier province. The demographic evolution of the past two decades is depicted in the graph below.



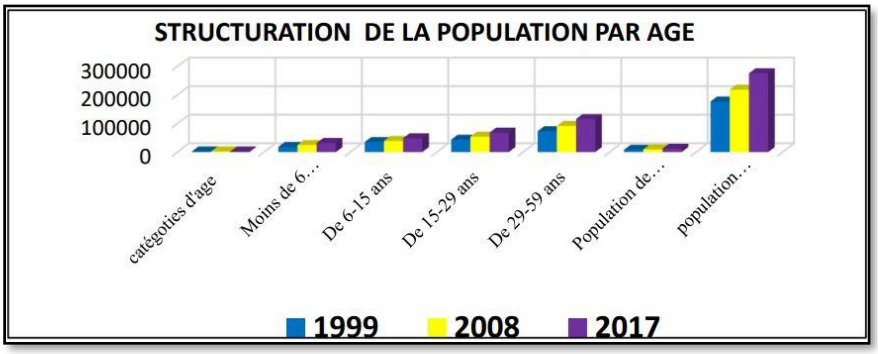
Source: Centre National d'Etudes et d'Analyses pour la Population et le Développement.

(Modified by the student 2023).

Figure N° 16: Population evolution of the wilaya of El Meghaier.

4.2. Population structure: According to age

Identifying the age categories that make up the population of the administrative district of El Meghaier is fundamentally important for assessing the human resources available in the area.



Source: Centre National d'Etudes et d'Analyses pour la Population et le Développement.
Figure N° 17: Population structure by age.

It appears that the population of the wilaya of El Meghaier is predominantly young. The age group between [15-29 years] represents 24.70%, and the age group [29-59 years] represents nearly 42%. According to the latest standards of the World Health Organization (WHO), the young population in the El Meghaier accounts for approximately 67%.

4.3. Natural population movements

4.3.1. Birth rate and infant mortality rate

The birth rate and infant mortality rate are reliable indicators for measuring, among other things, the conditions of childbirth and maternal health. For the wilaya of El Meghaier, the average birth rate is high, estimated at 2.86%, while the infant mortality rate is low, at approximately 0.36%. However, the number of stillbirths recorded in 2017 is high, estimated at 12.60% of the total number of births.

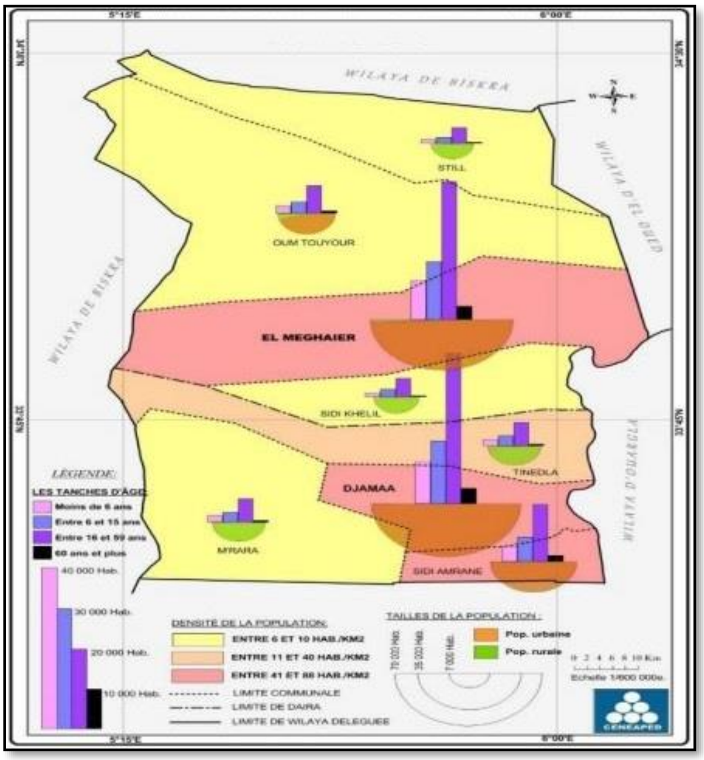
4.3.2. Population distribution

The population distribution by commune is irregular. It is notably concentrated in the communes of MEGHAIER (30%) and DJAMAA (33%), resulting in a demographic bipolarization. The distribution of the population by type of settlement highlights a high level of urbanization, estimated at 86.10%.

This means that the population of this wilaya is predominantly urban.

4.3.3. Population density:

The average residential density is low, at 27.48 inhabitants/km² in the wilaya, while in the city of El Meghaier is 48.48 inhabitants/km² (DPSB W. d'ElMeghaier 2022). This allows for increased land occupancy densities and the adoption of compact urban forms as a model for urban development.



Source: Centre National d'Etudes et d'Analyses pour la Population et le Développement.

Figure N° 18: Demographic map of the wilaya of El Meghaier.

The city of El Meghaier serves as a transit point as it lies along national road No. 3 (RN3), connecting three provinces: Biskra, El Oued, and Ouargla. Each of these wilayas holds regional or sub-regional significance.

The wilaya of Biskra serves as a link between the north and south of Algeria and is known for its agricultural region, particularly for producing high-quality dates. The wilaya of El Oued is an international transit point between Algeria and Tunisia. The wilaya of Ouargla is renowned for its industrial sector, especially its oil and petroleum fields. It also serves as a gateway to the Algerian Sahara.

5. Vision and Strategic Development Axes

5.1. General Principle of Development

This development plan combines two (02) models of development:

❖ Voluntary actions by the State, aligned with the national territorial development strategy and various sectoral strategies.

❖ Bottom-up development, meaning the valorization of local territorial dynamics.

This plan seeks to create the conditions for:

- Rebalancing between rural and urban areas
- Rebalancing between different zones (communes) within the territory of the Wilaya, promoting development through territorial dynamics

5.2. Territorial Image of The Wilaya By 2030

The future image of the El Meghaier will be established based on development actions and programs to be established:

- Building upon the current potential and trends to reinforce and develop further.
- Implementing action plans to address the existing deficits and challenges faced by the citizens.
- Introducing innovative and comprehensive projects for human and economic development, following a time-based approach, which will:
  - Enable the emergence of new economic hubs capable of achieving territorial rebalancing.
  - Ensure controlled mobility, balanced and coherent urbanization, and population redistribution.

5.3. Building a project... "For an Attractive, Balanced, and Cohesive Territory"

The project for the planning and development of the wilaya of El Meghaier aims to create conditions for sustainable development capable of enhancing the attractiveness of the territory while respecting its fundamental balances. This quality objective requires significant changes in the modes of organization, operation, and spatial planning of the territory.

The principle of this development plan is therefore to build a territory that is open to its regional environment by establishing conditions for a proactive demographic and economic dynamic, in a logic of efficient space management and respect for its natural, landscape, and cultural heritage. The construction of this planning and development plan takes into account the temporal scale through which various projects are implemented, with a long-term perspective.

5.4. General Principle of Planning: A New Scale of Reflection…

5.4.1. In Terms of Natural, Environmental, and Heritage Aspects

This proposed plan aims to enhance attractiveness through the valorization of the territory's specific features (agriculture, landscapes, natural potential, tourism, etc.). The environment becomes a driving force for development and enables a transformation of the image of the wilaya’s territory.

5.4.2. In Terms of Social and Cultural Aspects

The complementarity and solidarity between territories contribute to achieving the objectives of equity, solidarity, and social cohesion. It is important to note that this plan is based on a market economy perspective; therefore, there may be significant risks of social exclusion for communities on the outskirts of economic development.

To address this, palliative measures involving all local stakeholders (local authorities, community organizations, and citizens) and government authorities are desirable and even necessary.

5.4.3. In terms of Economic and Territorial Organization: A territorial organization around defined poles

The territory development project is also based on a network of poles whose specific vocations will be asserted and strengthened for the benefit of a stronger overall attractiveness. Their specializations will facilitate the sustainability of the local economy.

Therefore, we could enable the emergence of specialized areas, namely:

- **The El Meghaier area towards an Administrative Polarity**

The provision of infrastructure and facilities to the El Meghaier agglomeration, commensurate with its new status, will enhance its attractiveness and territorial influence.

- **The Djamaa-Sidi Amrane area: The Beginning of an Industrial and Tourist Pole**

The municipality of Djamaa already has a promising industrial fabric, which, with some industrial projects (SMEs, SMIs, micro-enterprises) (date processing), can act as a catalyst for new ancillary sectors to industrial activity.

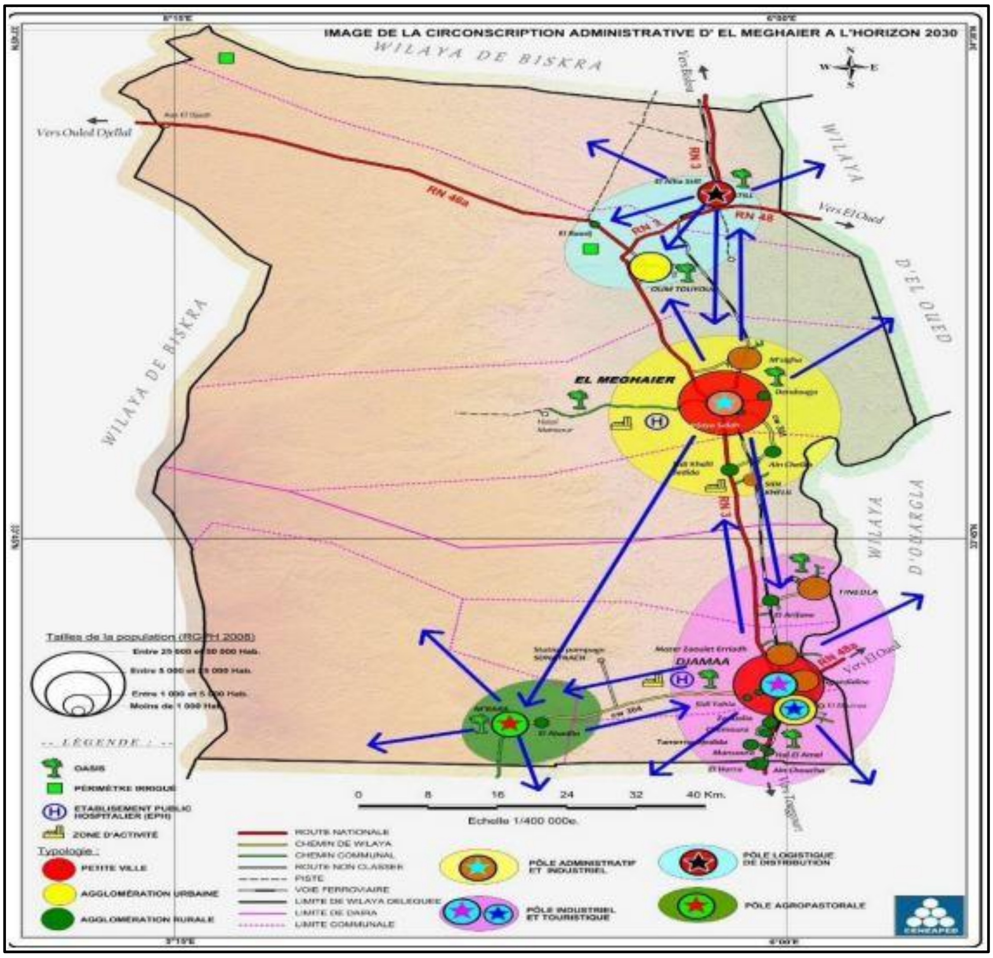
The Tamerna ksar in the municipality of Sidi Amrane, through its development for tourism, is conducive to creating a tourist dynamic (oasis tourism) and cultural and artisanal development in the province.

- **The Still area: Logistics and Distribution Platform**

Thanks to its location on the north-south territorial axis (RN03), in the northern part of the administrative district, and its proximity to the wilaya of Biskra and the capital of the wilaya of El Meghaier, the municipality of Still possesses all the qualities of a regional hub and transit point, favorable for hosting large-scale distribution activities.

- **The M'rara area: Towards an Agro-Pastoral Pole**

The municipality of M'rara is known for being an attractive agricultural hub. It has a successful agro-pastoral experience, providing ample opportunities to develop other related sectors such as cheese and dairy production, meat processing, and packaging and transformation of agricultural products.



Source: Centre National d'Etudes et d'Analyses pour la Population et le Développement.
Figure N° 19: Image of the wilaya of El Meghaier by 2030.

Conclusion

The significant contribution of major infrastructure to the development of the city of El Meghaier is undeniable. Beyond the process of peri-urbanization, we are witnessing a modification in the center-periphery relationship with the emergence of new centralities. With these clear signs associated with ongoing or future development programs, many of which bear the marks of urban modernity, we affirm that the urbanization of El Meghaier is underway. As a provincial center, El Meghaier plays an essential role as a focal point for other surrounding municipalities. In order to position itself on the national stage, it is crucial for the city to have enhanced organizational capacities and effective governance that can stimulate development and wealth creation. It is important to emphasize that only the emergence of a qualitative level of governance and the completion of various ongoing or planned projects can infuse.

CHAPTER III

The Diachronic Analysis of Spatiotemporal Evolution (DASE) of Land Cover in the City of El Meghaier

1. Evaluation of the classification accuracy

1.1. Evaluation of the classification accuracy in 1984:

The evaluation of classification accuracy using the confusion matrices indicates that the classification results for 1984 are of good quality, with an overall accuracy of 88,89% and a kappa coefficient of 0,83. The table indicates that the classifications are of good quality.

Table N° 7: Confusion matrix of the 1984 classification.

	Urban areas	Agriculture	Bare soil	Total user
Urban areas	7	0	0	7
Agriculture	1	8	1	10
Bare soil	1	0	9	10
Total producer	9	8	10	27

Source: Student 2023.

The accuracy results for the classification of classes in the 1984 image are as follows:

Urban areas	7/7*100	100%
Agriculture	8/10*100	80%
Bare soil	9/10*100	90%

Source: Student 2023.

1.2. Evaluation of the classification accuracy in 2000:

The evaluation of classification accuracy using the confusion matrices indicates that the classification results for 2000 are of good quality, with an overall accuracy of 91,42% and a kappa coefficient of 0,87. The table indicates that the classifications are of good quality.

Table N° 8: Confusion matrix of the 2000 classification.

	Urban areas	Agriculture	Bare soil	Total user
Urban areas	15	0	3	18
Agriculture	0	10	0	10
Bare soil	0	1	6	7
Total producer	15	11	9	35

Source: Student 2023.

1.3. Evaluation of the classification accuracy in 2023:

The evaluation of classification accuracy using the confusion matrices indicates that the classification results for 2023 are of good quality, with an overall accuracy of 88,89% and a kappa coefficient of 0,83. The table indicates that the classifications are of good quality.

Table N° 9: Confusion matrix of the 2023 classification.

	Urban areas	Agriculture	Bare soil	Total user
Urban areas	15	0	3	18
Agriculture	0	10	0	10
Bare soil	0	1	7	8
Total producer	15	11	10	36

Source: Student 2023.

2. Mapping and analyzing land cover cases for each year 1984-2000-2023 using the maximum likelihood method

2.1. Analysis of land cover cases in 1984, 2000, and 2023:

Using remote sensing data, three land cover maps were generated for the years 1984, 2000, and 2023, along with respective statistics for all land cover classes for each date. These classification results were used for a diachronic analysis to understand the evolution of land cover between the different study periods.

Table N° 10: Area in km² and as a percentage of land cover categories.

Land cover categories	Area (Km²)			%		
	1984	2000	2023	1984	2000	2023
Urban areas	4,05	5,86	14,23	3,98%	5,75%	13,97%
Agriculture	22,02	30,63	46,00	21,60%	30,06%	45,13%
Bare soil	75,85	65,43	41,69	74,42%	64,19%	40,90%
Total	**101,93**	**101,93**	**101,93**	**100,00**	**100,00**	**100,00**

Source: Student 2023.

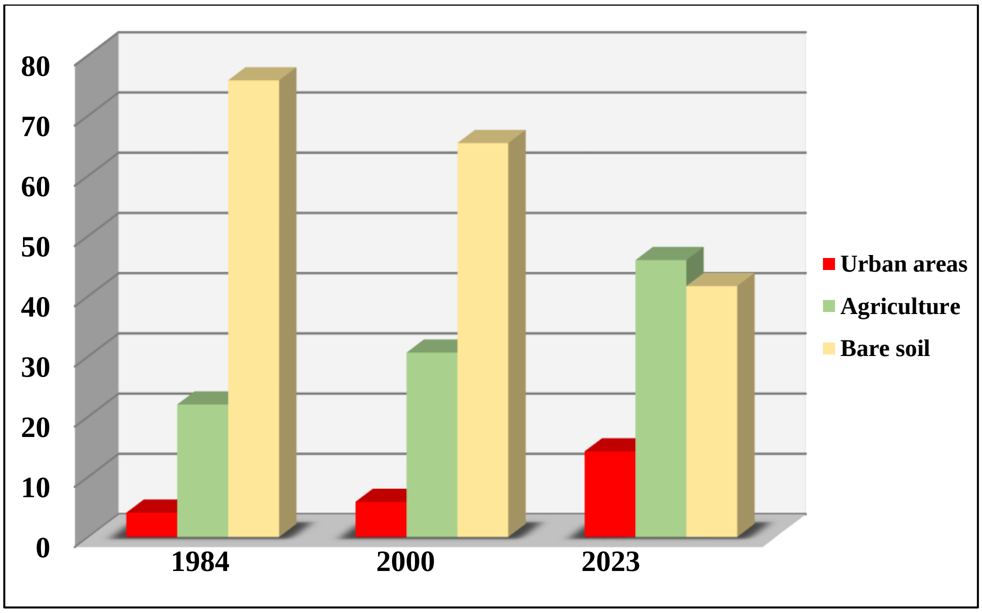


Figure N° 20: Graph of land cover class areas.

2.2. Land cover case in 1984

At this date, land cover is dominated by the bare soil class (including fallow agricultural plots and vacant land), covering an area of 75,85 km², representing 74,42% of the total area.

The agriculture class covers an area of 22,02 km², representing 21,60% of the total area. The urban area occupies an area of 4,05 km², representing 3,98% of the total area.

Table N° 11: Land cover in 1984.

Land cover categories	Area (Km²)	%
Urban areas	4,05	3,98
Agriculture	22,02	21,60
Bare soil	75,85	74,42
Total	**101,93**	**100**

Source: Student 2023.

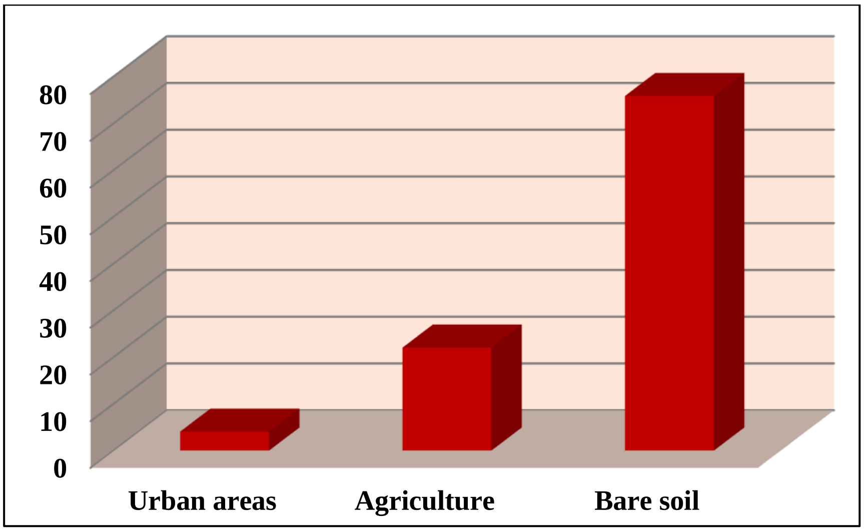


Figure N° 21: Graph of land cover area (Km²) distribution in 1984.

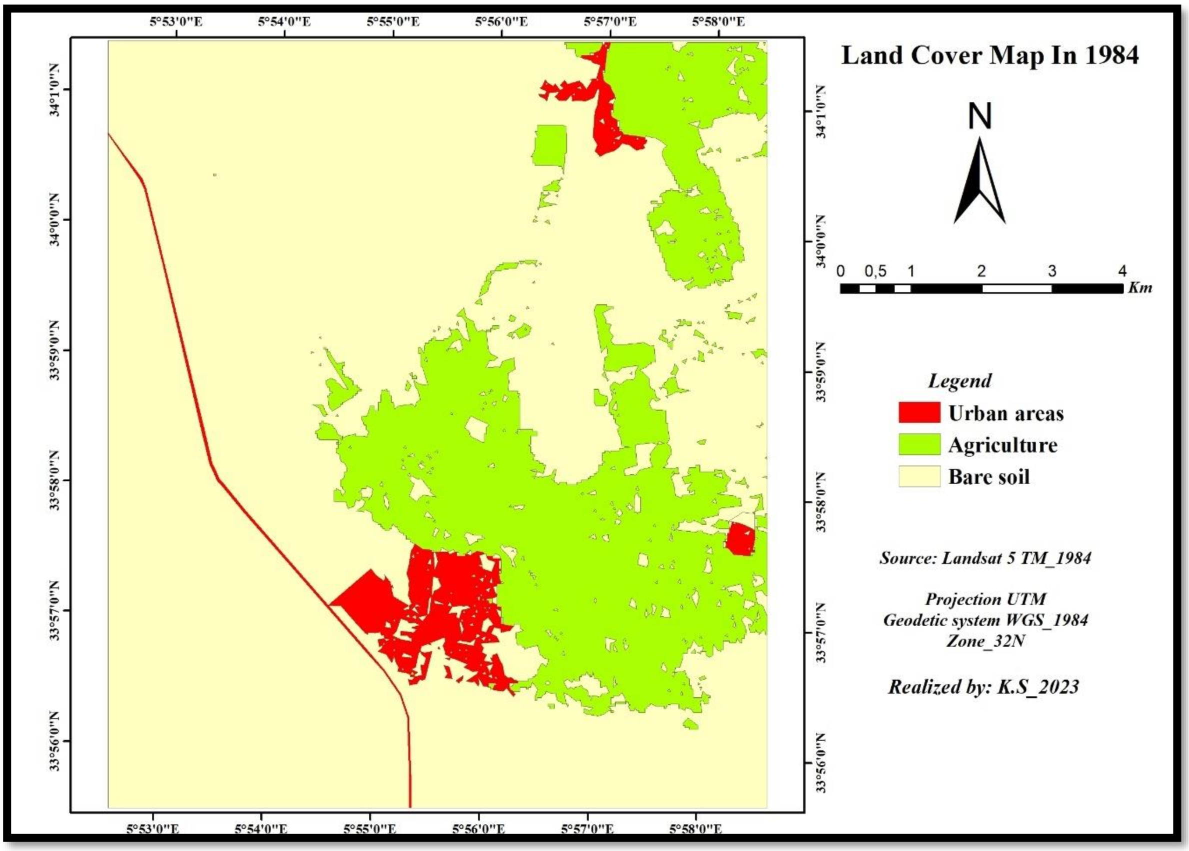


Figure N° 22: Land cover map in 1984.

2.3. Land cover case in 2000

In 2000, urban areas covered 5.86 km², accounting for 5.75% of the total area. Agriculture occupied a larger area of 30.63 km², representing 30.06% of the land, while bare soil covered 65.43 km², making up the majority with 64.19%.

Table N° 12: Land cover in 2000.

Land cover categories	Area (Km²)	%
Urban areas	5,86	5,75
Agriculture	30,63	30,06
Bare soil	65,43	64,19
Total	**101,93**	**100**

Source: Student 2023.

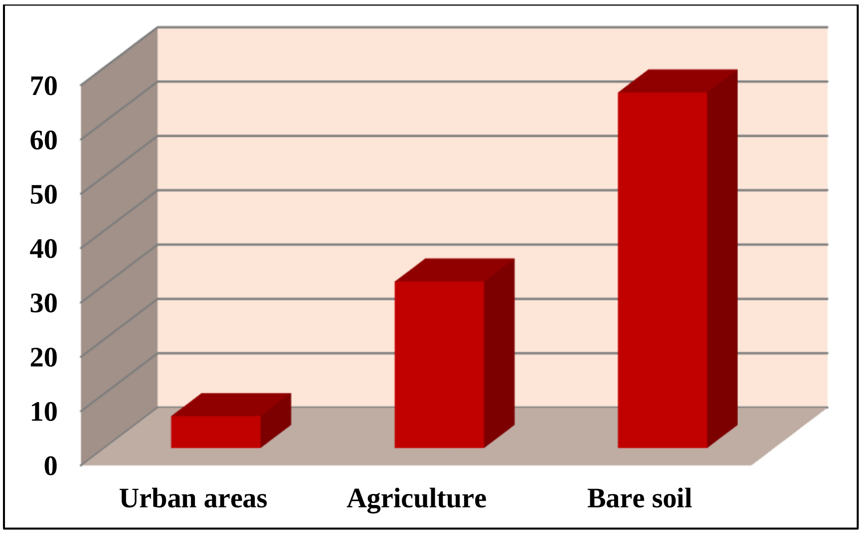


Figure N° 23: Graph of land cover area (Km²) distribution in 2000.

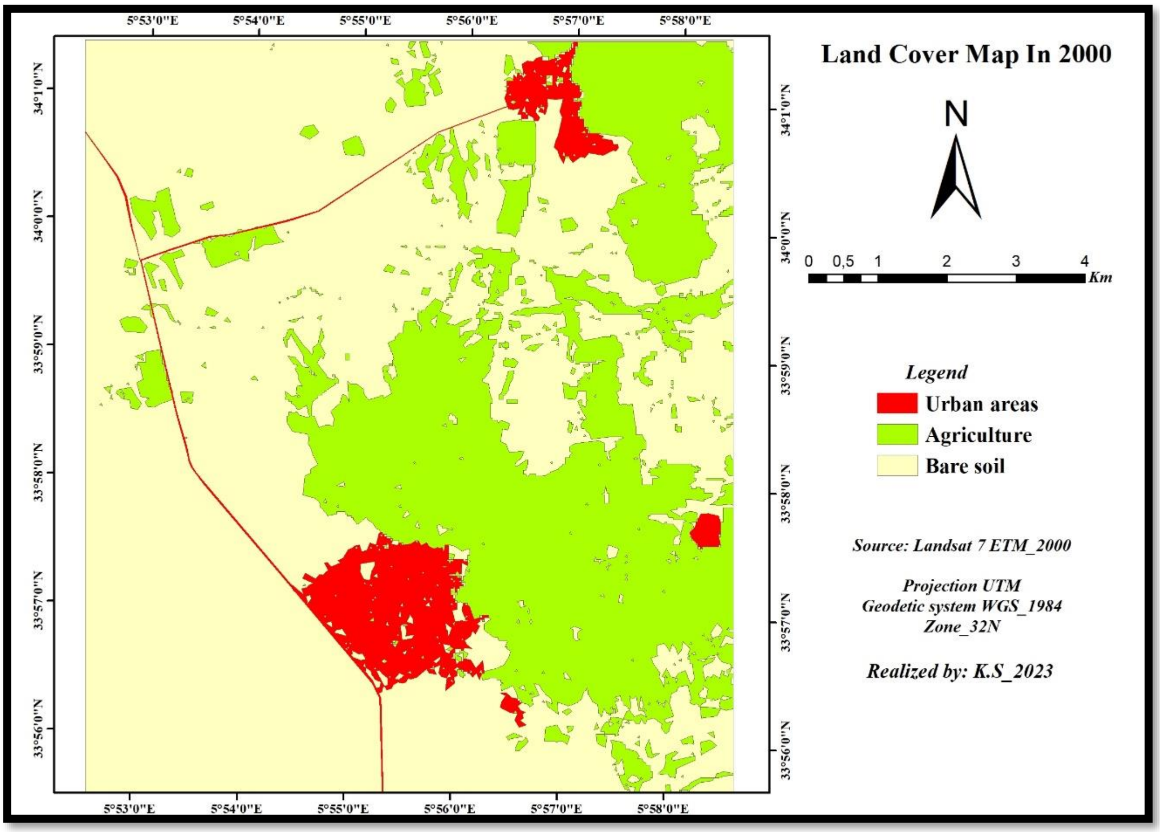


Figure N° 24: Land cover map in 2000.

2.4. Land cover case in 2023

By 2023, there was a noticeable increase in urban areas, which expanded to 14.23 km², accounting for 13.97% of the total area. Agriculture also expanded significantly, covering 46 km², representing 45.13% of the land.

Bare soil, on the other hand, decreased in area to 41.69 km², making up 40.90% of the land.

Table N° 13: Land cover in 2023.

Land cover categories	Area (Km²)	%
Urban areas	14,23	13,97
Agriculture	46,00	45,13
Bare soil	41,69	40,90
Total	**101,93**	**100**

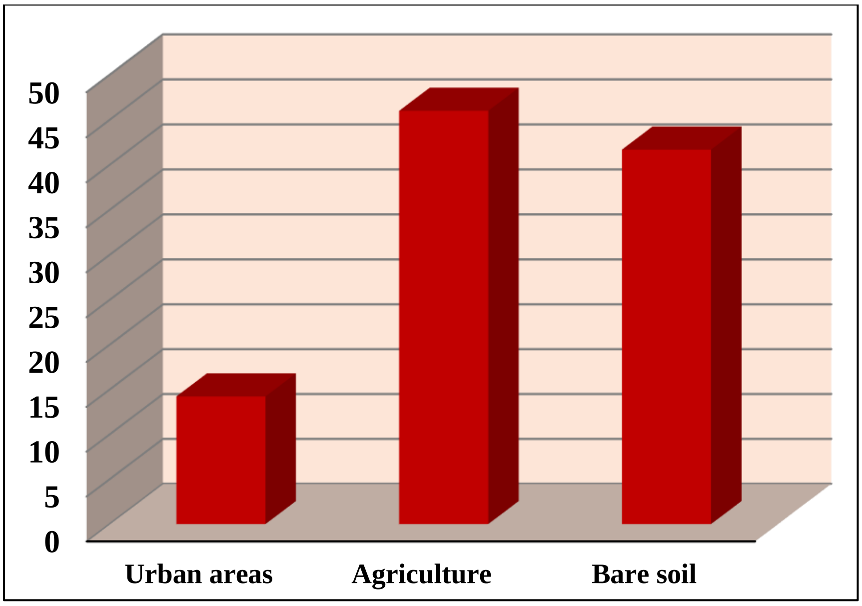


Figure N° 25: Graph of land cover area (Km²) distribution in 2023.

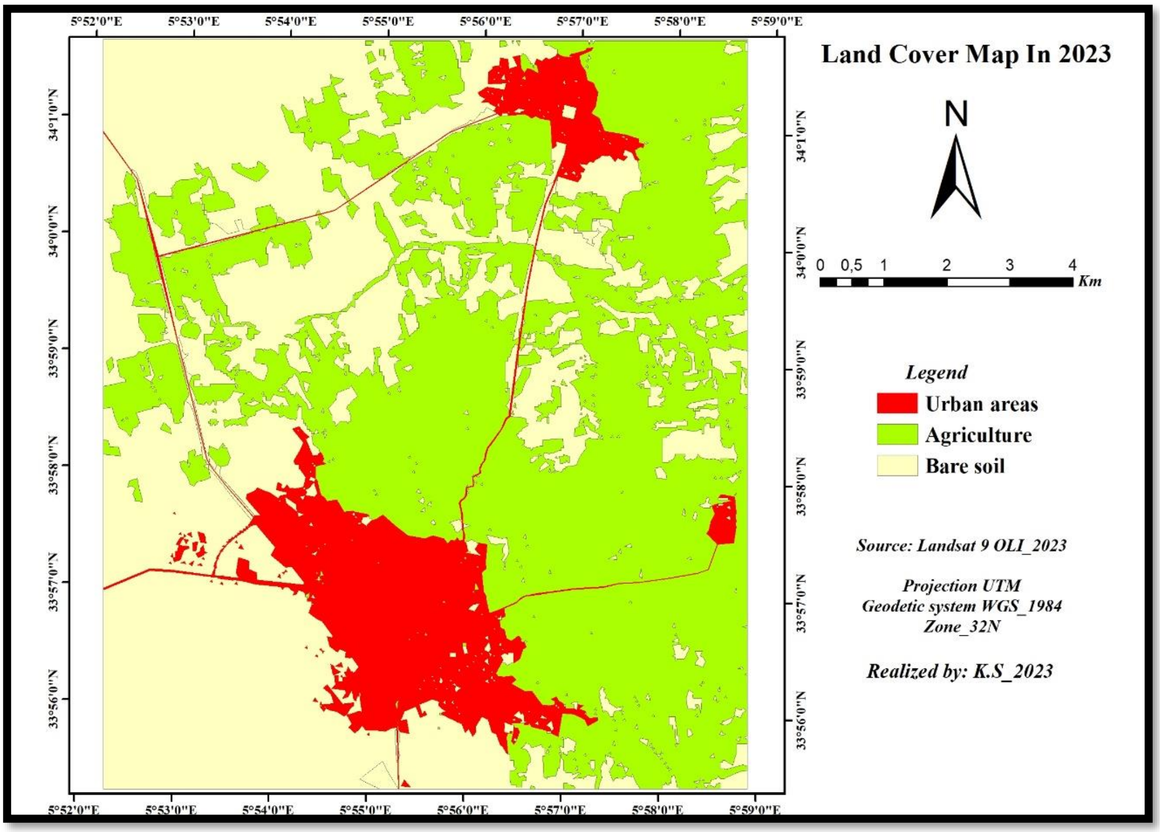


Figure N° 26: Land cover map in 2023.

3. Detection of changes in the (DASE)

3.1. Detecting land cover change between 1984 and 2000

During this period, there was a slight change in the land cover area for the three categories, which are presented in graphical form in Figure N°27, and Figure N°28 (as a percentage), and Table N°14, as follows:

- A little increase in the urban areas, with an area of 1,81 km², representing a percentage increase of 44,69%.
- Increase in surface area of the agriculture, with an area of 8,61 km², representing a percentage increase of 39,1%.
- Decrease in the surface area of the bare soil, with an area of -10,42 km², representing a percentage decrease of 13,73%.

Table N° 14: Change detected between 1984-2000.

	Area (Km²)			Global Change Rate (GR)	
Land cover categories	**1984**	**2000**	**1984-2000 (+/-)**	**(+/-)**	**%**
Urban areas	4,05	5,86	+1,81	**Increase**	44,69
Agriculture	22,02	30,63	+8,61	**Increase**	39,1
Bare soil	75,85	65,43	-10,42	**Decrease**	13,73

Source: Modified by the student 2023.

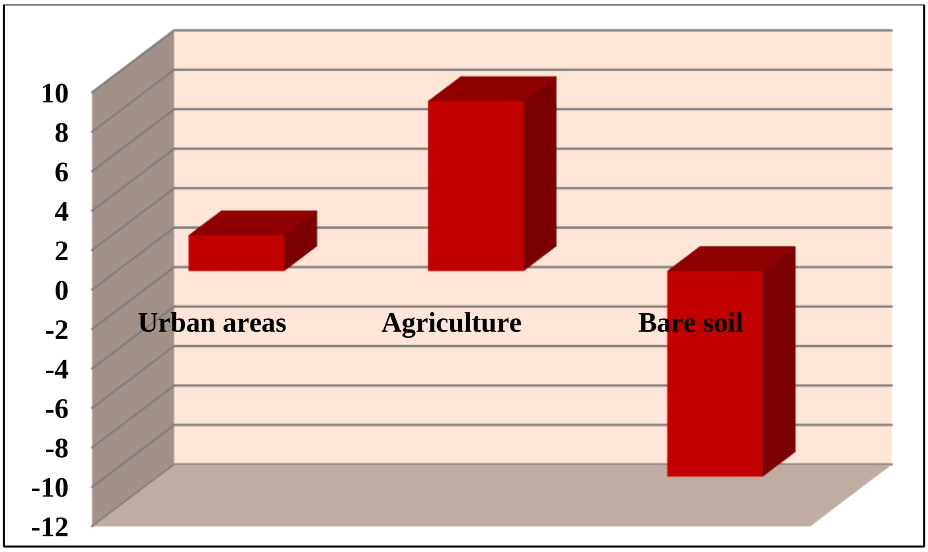


Figure N° 27: Graph of detected change between 1984-2000.

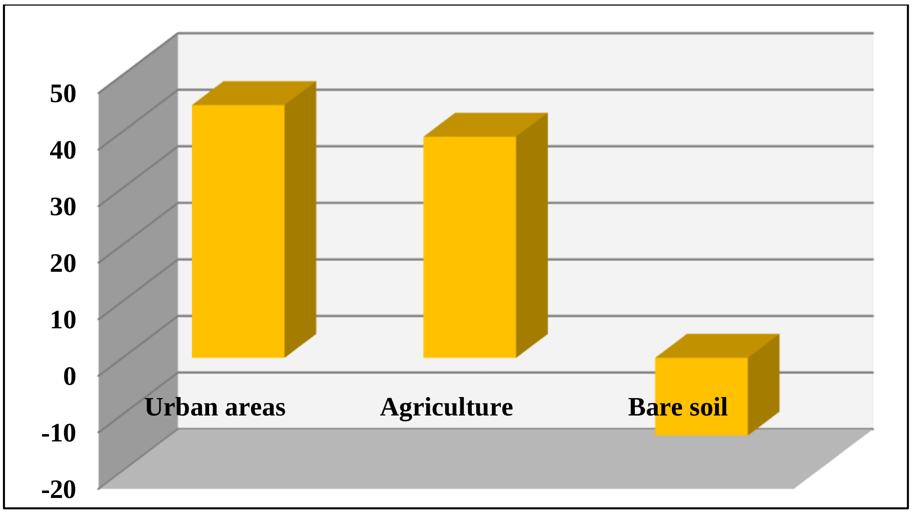


Figure N° 28: Graph of detected change (%) between 1984-2000.

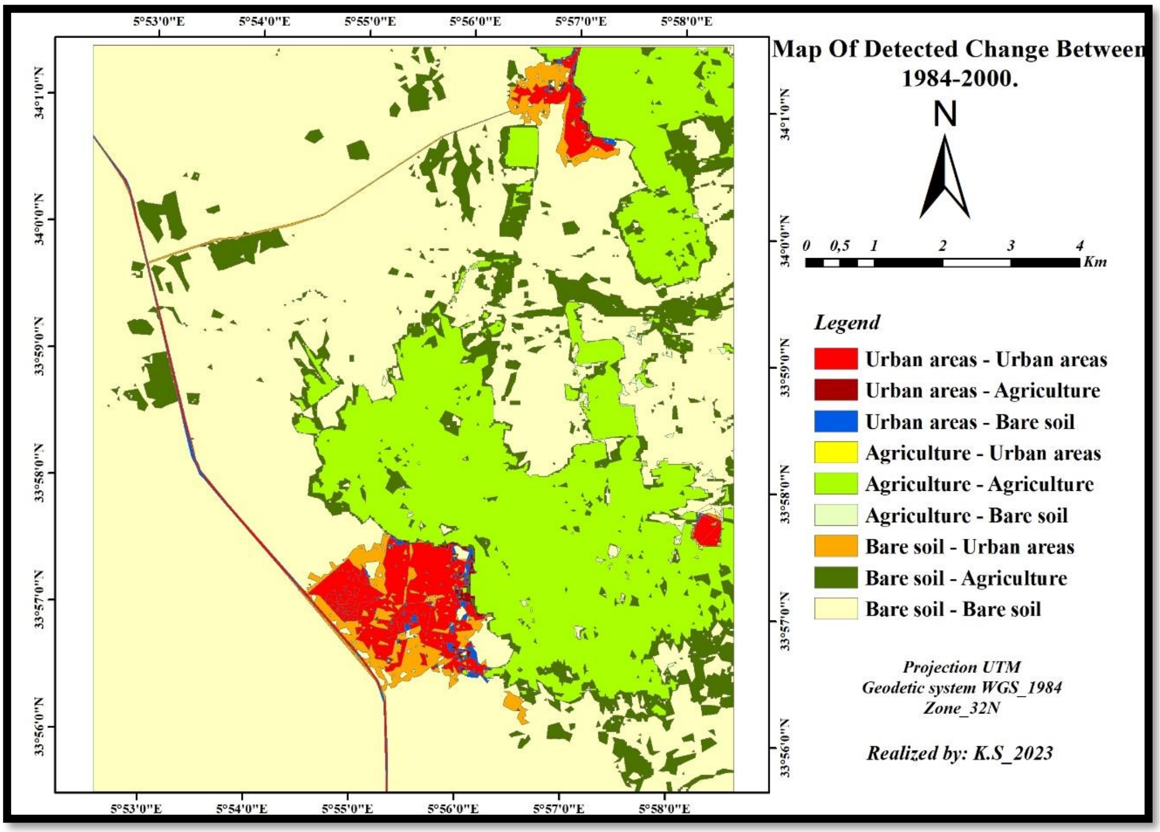


Figure N° 29: Map of detected change between 1984-2000.

3.2. Detecting land cover change between 2000 and 2023

The changes in land cover between 2000 and 2023 for the three classes are presented in graphical form (Figure N°30, and Figure N°31) and (Table N°15), which show that the study area has undergone noticeable changes, corresponding to:

- Increase in the urban areas, with an area of 8,37 km², representing a percentage increase of 142.83%.
- Increase in surface area of the agriculture, with an area of 15,37 km², representing a percentage increase of 50,17%.
- Decrease in the surface area of the bare soil, with an area of --23,74 km², representing a percentage decrease of 50,17%.

Table N° 15: Change detected between 2000-2023.

	Area (Km²)			Global Change Rate (GR)	
Land cover categories	**2000**	**2023**	**2000-2023 (+/-)**	**(+/-)**	**%**
Urban areas	5,86	14,23	+8,37	**Increase**	142,83
Agriculture	30,63	46,00	+15,37	**Increase**	50,17
Bare soil	65,43	41,69	-23,74	**Decrease**	36,28

Source: Modified by the student 2023.

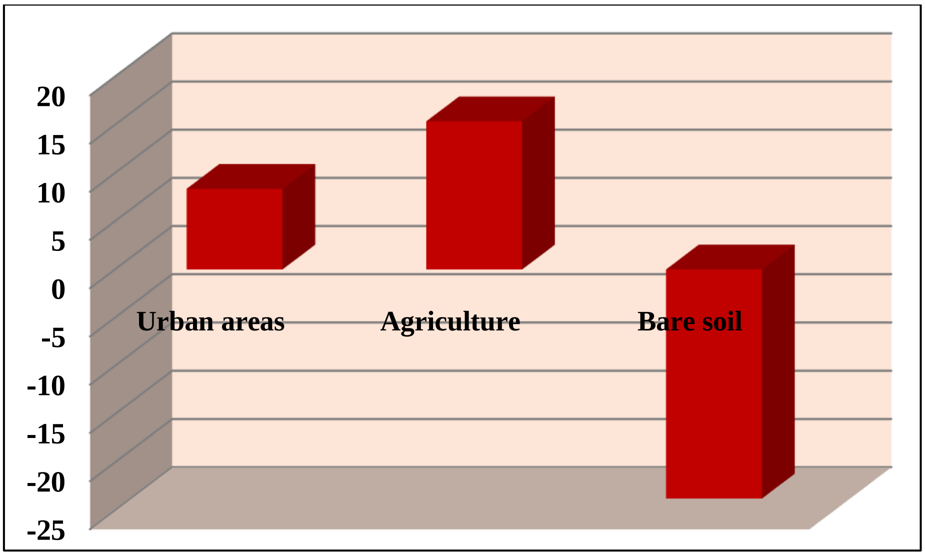


Figure N° 30: Graph of detected change between 2000-2023.

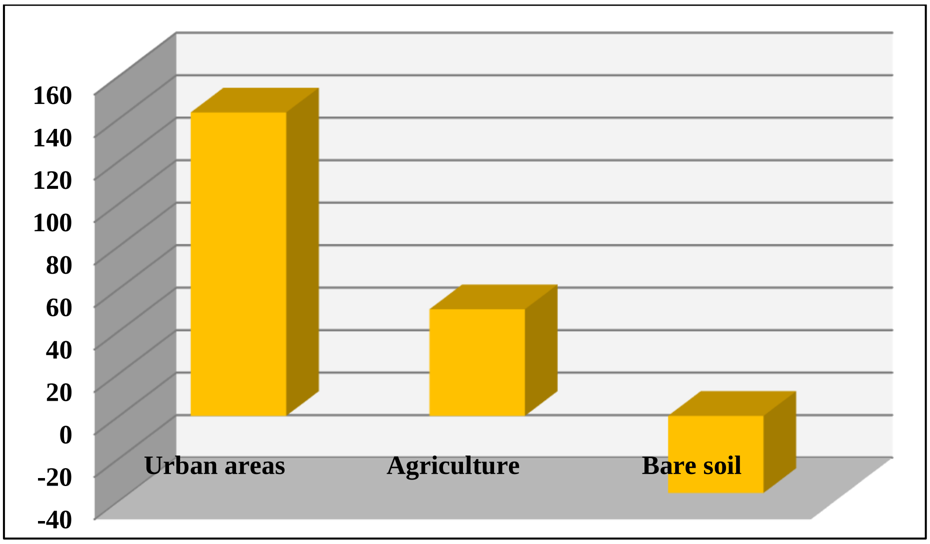


Figure N° 31: Graph of detected change (%) between 2000-2023.

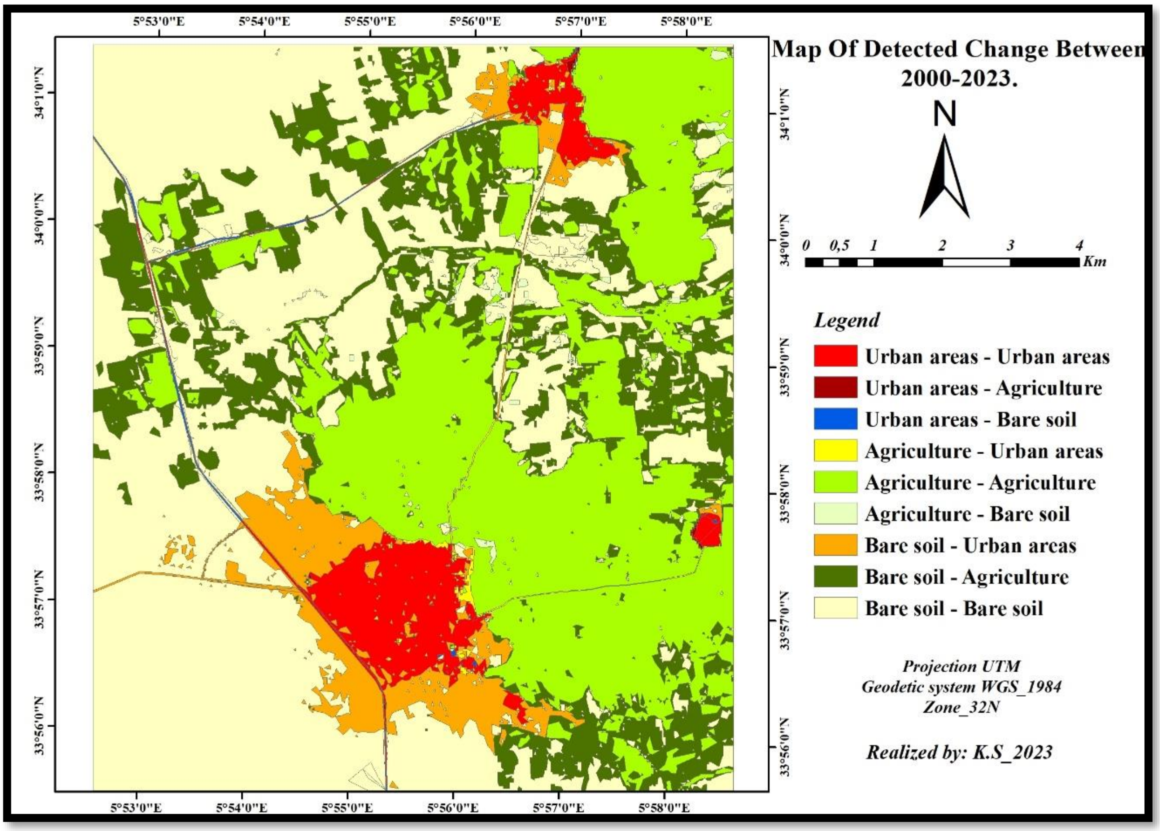


Figure N° 32: Map of detected change between 2000-2023.

3.3. Detecting land cover change between 1984 and 2023

The analysis of remote sensing data through the diachronic analysis of three land cover maps allowed us to highlight the different changes in the three land cover classes between the years 1984 and 2023, spanning a period of 39 years. These changes are presented in Table N°16, Figure N°33, and Figure N°34, which show:

- Increase in the urban areas, with an area of 10,18 km², representing a percentage increase of 251,35%.
- Increase in surface area of the agriculture, with an area of 23,98 km², representing a percentage increase of 108,9%.
- Decrease in the surface area of the bare soil, with an area of -34,16 km², representing a percentage decrease of 45,03%.

Table N° 16: Change detected between 1984-2023.

	Area (Km²)			Global Change Rate (GR)	
Land cover categories	**1984**	**2023**	**1984-2023 (+/-)**	**(+/-)**	**%**
Urban areas	4,05	14,23	+10,18	**Increase**	251,35
Agriculture	22,02	46,00	+23,98	**Increase**	108,9
Bare soil	75,85	41,69	-34,16	**Decrease**	45,03

Source: Modified by the student 2023.

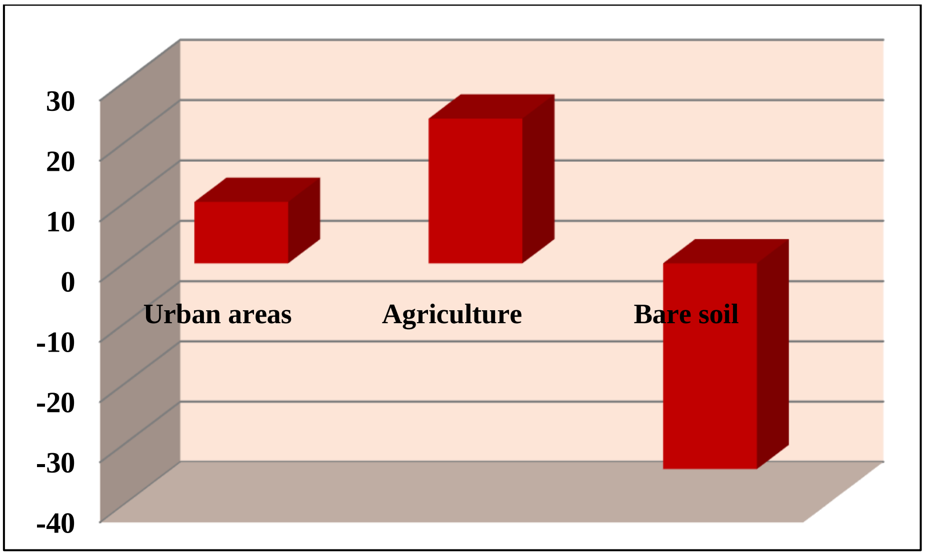


Figure N° 33: Graph of detected change between 1984-2023.

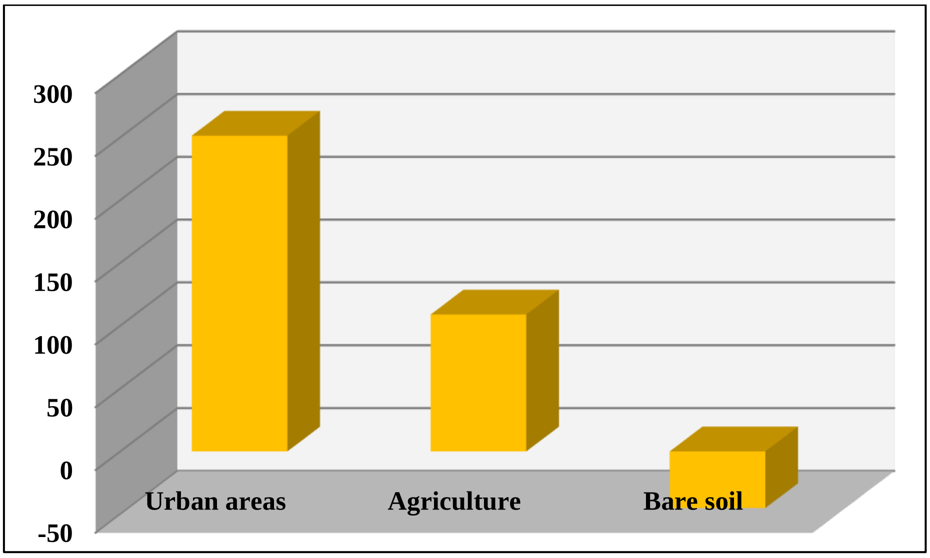


Figure N° 34: Graph of detected change (%) between 1984-2023.

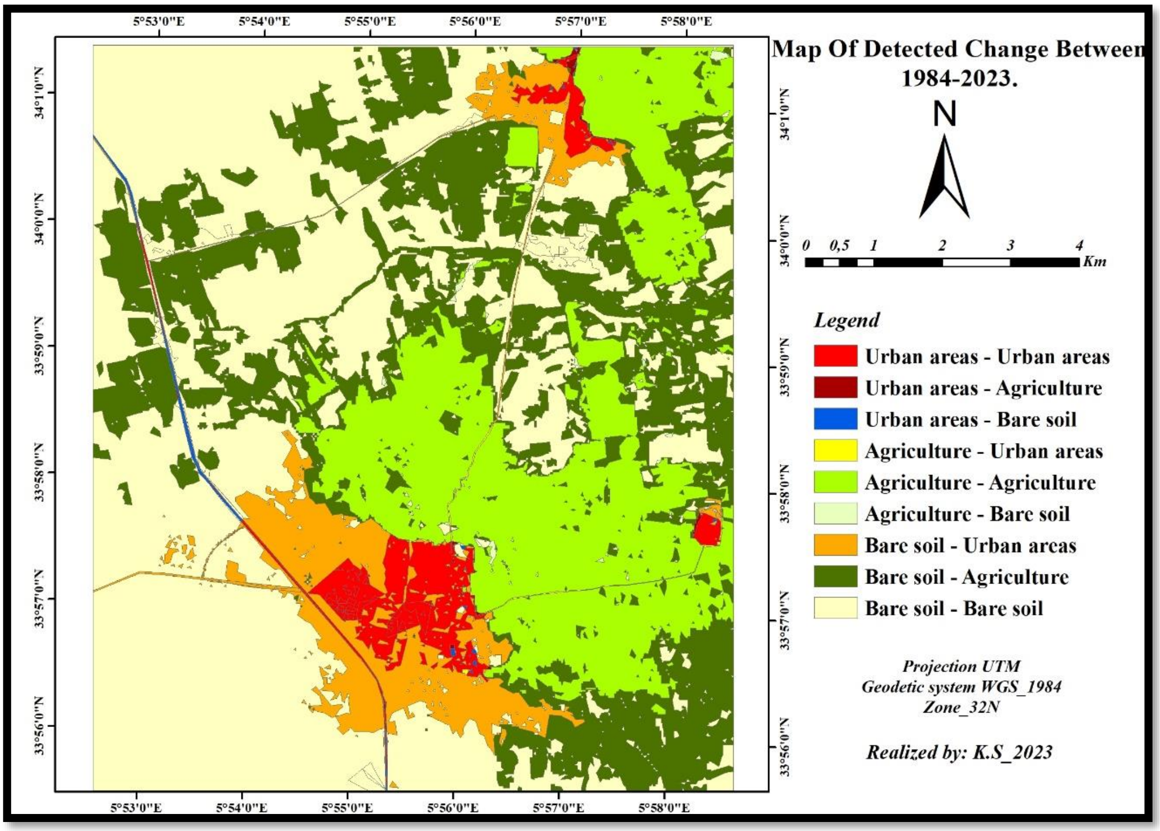


Figure N° 35: Map of detected change between 1984-2023.

4. Conclusions and interpretations

4.1. Understanding the urban expansion

Recent urbanization dynamics, as presented by satellite images taken in 1984, 2000, and 2023, show that the urban area has expanded and widened, from which we obtained results and maps for the built-up area.

Compared to the previously mentioned years, where we noticed remarkable urban growth and expansion from 1984 to 2023, as discussed in our previous analysis, the built-up area in 1984 was estimated at 4.05 km² with a rate of 3.98%. Then, the urban area expanded in the year 2000, with an estimated area of 5.86 km², representing 5.75% of the total land cover. It further expanded in the year 2023, with an estimated area of 14.23 km² and a percentage of 13.97%.

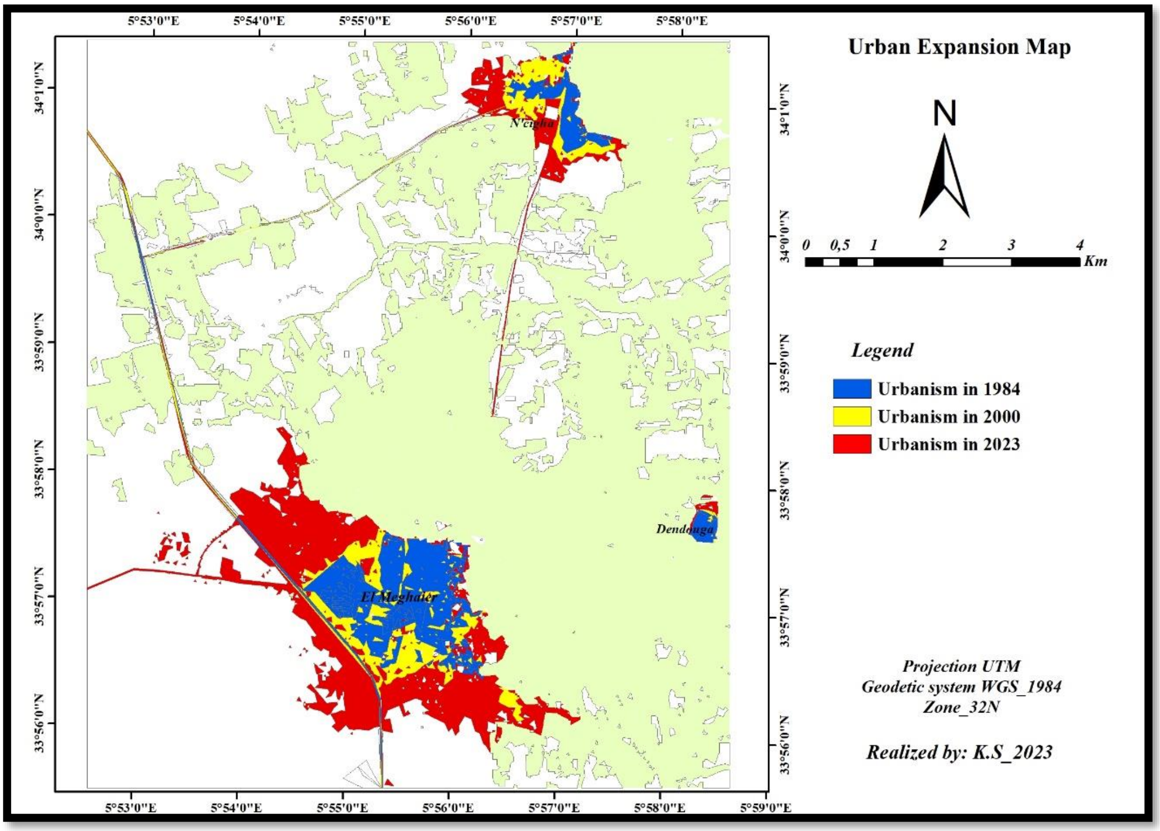


Figure N° 36: Urban expansion map.

4.2. Measuring urban expansion

According to the urban expansion map created between 1984, 2000, and 2023, we can observe that the urban expansion has taken multiple dimensions. It has moved parallel to National Road N°3 towards the south and from the southeast to the northwest, towards the intersection of National Road N° 3 with Provincial Road N° 301 (towards N'sigha). Additionally, there has been expansion towards the west and southwest, at the expense of low-lying lands prone to flooding. However, expansion towards the north and northeast has been limited due to the presence of palm groves and the presence of a railway track in the eastward direction. (Figure N°37)

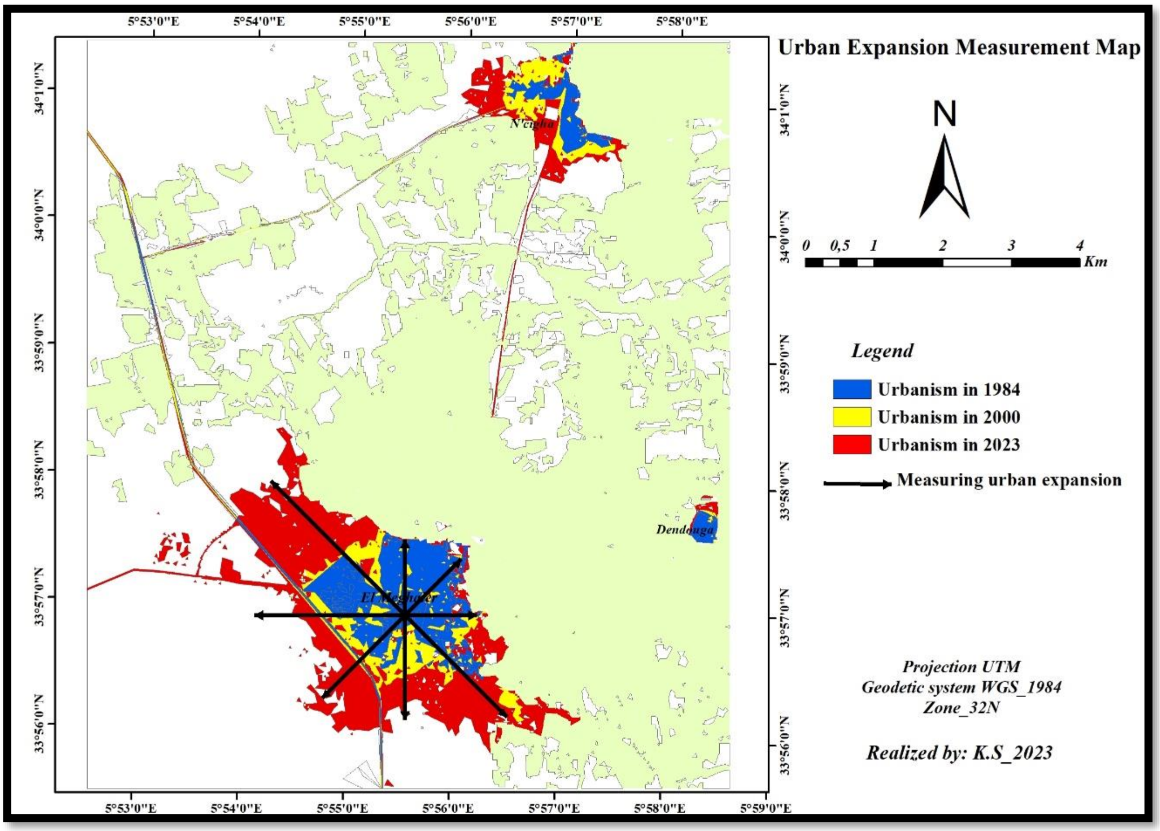


Figure N° 37: Urban expansion measurement map.

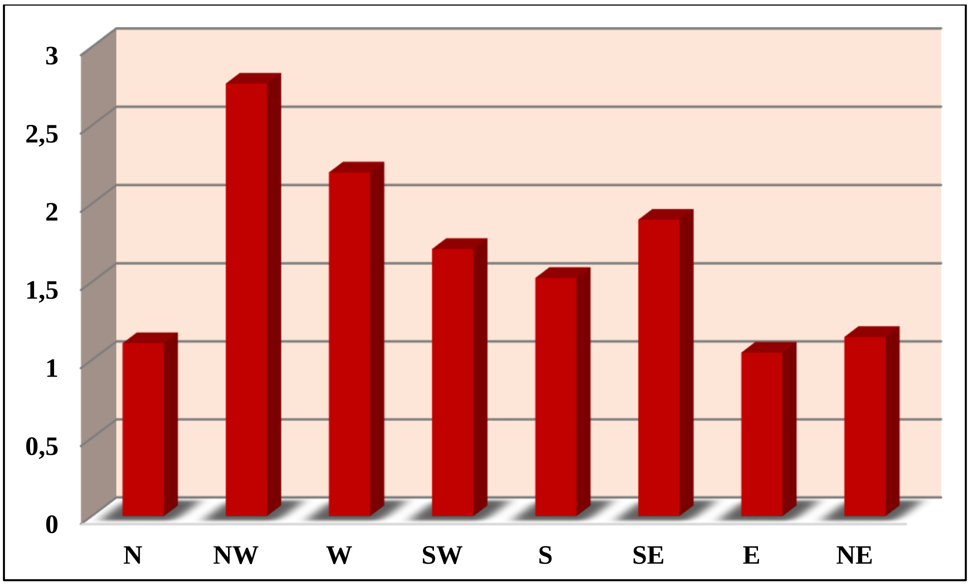


Figure N° 38: Graph of urban expansion measurement (distance in km).

Conclusion

Through the results obtained from the processing of Landsat 5, 7, and 9 satellite images, supervised classifications of sufficient quality and overall high resolution were achieved (88,89% for the 1984 image, 91,42% for the 2000 image, and 88,89% for the 2023 OLI image). These results help to prove that the observed changes in all the images correspond well to differences in land cover in the city of El Meghaier.

The analysis of the results indicates that the dynamics of urbanization and agriculture in the city of El Meghaier experienced an increase during the study periods. By observing land cover maps, especially after the new millennium, this growth is evident at the expense of the surrounding bare soil due to the implemented urban development policies, and to agricultural support policies.

Conclusion

The study focused on monitoring and analyzing urban changes in the region of "Wadi Righ", specifically in the city of El Meghair, during the time period of 1984–2023. Satellite imagery from Landsat and GIS were utilized. The aim of the study is to understand the conditions of urban dynamics, measure the levels of spatial development, and assess the resulting impacts.

The study reviewed the main challenges facing the city of El Meghair, particularly after its recent upgrade in the administrative division as a province according to Law N° 19/12 dated 11/12/2019. The main challenge identified is the rapid urban expansion, which has encroached upon agricultural lands (palm groves), faced difficulties in expanding into the low-lying (flood-prone areas), and exhibited continuous linear expansion along National Road N° 03, compromising its regional function regardless of the gradual urban conurbation towards secondary agglomerations in the vicinity of the municipality (Dendouga, N'sigha). In this study, we used the diachronic analysis of spatiotemporal evolution and monitoring to achieve the following objectives:

(i) Detecting spatiotemporal changes attributed to urbanization and territorial policies, particularly the administrative division upgrade as the provincial capital.
(ii) Understanding the complexity of urban expansion and redefining the urban boundaries of El Meghaier along the National Road 03.
(iii) Assessing the environmental impact, specifically the risk of urban expansion on the palm groves and the urbanization of low-lying areas prone to flooding.

In reality, the results were shocking. The city of El Meghair experienced a significant growth rate of 44.69% between 1984 and 2000, at the expense of palm groves and low-lying lands (flood-prone areas). However, the growth rate further increased to 142.83% in the period between 2000 and 2023. This can be attributed to active urban dynamics driven by the implementation urban development policies, including extensive housing programs. On the other hand, the weak monitoring allowed for unplanned expansion, encroaching upon palm groves and low-lying lands. Additionally, the city's promotion and elevation to a provincial center (wilaya) contributed to this growth.

It is also worth noting that El Meghair has witnessed a significant expansion in agricultural areas, particularly between 2000 and 2023, with a growth rate of 50.17%. This can be attributed to agricultural support policies such as the FRDMA (Farmers' Support Policy), financing policies, and the debt relief program for farmers.

It is also important to mention that El Meghair has experienced significant loss of barren lands, particularly between 2000 and 2023, with a decrease of 36.28% of its total area. This loss can be attributed primarily to urban development areas and the expansion of agricultural surroundings. This will require local authorities to formulate new policies for the expansion of El Meghair based on three scenarios, which we will delve into further in our study project.

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Résumé :

La présente étude vise à suivre et d'analyser les changements d'occupation des sols de la ville d'El Meghaier, induits, principalement, sur un laps temps (1984-2023) à partir d'imagerie satellite Landsat 5, 7, et 9 (TM, ETM+ et OLI-TIRS). C'est ainsi que s'est imposée la démarche de (ADES) pour L'Analyse Diachronique de l'Evolution Spatiotemporelle, dans le but: (i) La détection les changements spatiotemporels, imputables à l'urbanisation et à la politique territoriale, essentiellement, la promotion de dernier découpage administrative, comme chef-lieu wilaya (ii) Comprendre de la complexité de l'étalement urbain et redéfinir les digitation urbaine de la ville de El'meghaier sur la RN03, (iii) L'évaluation de l'impact sur l'environnement, spatialement, le risque de l'extension urbaine sur la palmeraie, notamment en matière de la bétonisation des terrains agricoles et l'urbanisation sur les terrain à basse altitude (zone inondable). À partir des principaux résultats obtenus: l'on se trouve en situation ambigüe de conurbation entre la ville El Meghaier et ces agglomération limitrophe (Dendouga et N'sigha) de compacte un territoire compact sur la palmeraie, cette dynamique et métamorphose est marqué, essentiellement, par un taux de croissance 251,35%, dont 142,83% est constaté dans la période 2000-2023, c'est t-dire un plus de 8,37 km² par rapport au totale 14,23km² et une augmentation de 108.9% de la superficie des terres agricoles, dont un plus de +15,37 km2 , au détriment d'une diminution des sols nus 45,03 %. Enfin des conclusions et des interprétations vont nous par la suite la proposition des scénarios d'extension de la ville sous forme d'un projet PFE pour l'adoption du diplôme Master (GTU) en spécialité : Gestion des villes.

Mots clés : Télédétection, Landsat, TM et ETM+ et OLI-TIRS, Dynamique spatiotemporelle, Urbanisation, ADES, El Meghaier.

ملخص:

تهدف هذه الدراسة إلى متابعة وتحليل تغيرات الاستعمال الأرضي في مدينة المغير خلال فترة زمنية محددة (1984–2023) باستخدام صور القمر الصناعي لاندسات 5، 7 و9 (OLI–TIRS, ETM+, TM) ، أين تم استعمال تقنية لتحليل التطور المجالي/الزماني(ADES) بهدف: (1) كشف التغيرات المجالية/الزمنية التي تؤدي إلى التحضر والسياسات الإقليمية، ولا سيما التقسيم الإداري الأخير الذي أرقى المدينة إلى مركز ولاية، (2) فهم تعقيد التوسع الحضري وإعادة تعريف حدود المدينة على طول الطريق الوطني رقم 03، (3) تقييم التأثير البيئي، ولا سيما المخاطر المرتبطة بالتوسع الحضري على واحات النخيل، مثل تحويل الأراضي الزراعية إلى أسطح من الخرسانة وتحويل المناطق المنخفضة المعرضة للفيضانات إلى مناطق حضرية. تشير النتائج الرئيسية إلى وجود حالة من التلاحم بين مدينة المغير والتجمعات الثانوية المجاورة (دندوقة وانسيغة)، حيث يشكلون ترابًا مدمجًا داخل بساتين النخيل. يتميز هذا التحول الديناميكي بمعدل نمو يبلغ 251.35%، حيث يلاحظ 142.83% منه خلال الفترة من 2000 إلى 2023، مما يؤدي إلى زيادة قدرها 8.37 كم^2 مقارنةً بالمساحة الإجمالية للمدينة البالغة 14.23 كم^2. بالإضافة إلى ذلك، حدث زيادة بنسبة 108.9%، تعادل 15.37 كم^2 إضافي من الأراضي الفلاحية على حساب انخفاض الأراضي الجرداء بنسبة 45.03.%.

وأخيرًا، سيتم اقتراح سيناريوهات لتوسع المدينة استنادًا إلى الاستنتاجات والتفسيرات في شكل مشروع PFE للحصول على شهادة الماستر في تخصص إدارة المدن.

الكلمات المفتاحية: الاستشعار عن بعد، لاندسات، الديناميكية الزمانية المكانية، التحضر، المغير.