الجمهورية الجزائرية الديمقراطيـة الشعبيــة
République algérienne démocratique et populaire
وزارة التـعليـم العالـي والبحـث العلمــــي
Ministère de l’enseignement supérieur et de la recherche scientifique
جامعة عين تموشنت بلحاج بوشعيب
Université –Ain Temouchent- Belhadj Bouchaib
Faculté des Sciences et de la Technologie
Département de Génie Civil et Travaux Publics

Projet de Fin d’Etudes
Pour l’obtention du diplôme de Master en :
Domaine : SCIENCE ET DE LA TECHNOLOGIE
Filière : TRAVAUX PUBLIC
Spécialité : VOA
Thème

GIS MAP USING FREE GEOSPATIAL DATA FOR ENHANCED 3D VISUALIZATION OF RURAL ROAD NETWORKS. CASE OF STUDY: WILAYA OF AIN TEMOUCHENT

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Année Universitaire 2023/2024

People's Democratic Republic of Algeria

وزارة التعليم العالي والبحث العلمي

Ministry of Higher Education and Scientific Research

جامعة عين تموشنت بلحاج بوشعيب

University of Ain-Temouchent- Belhadj Bouchaib
. Faculty of Science and Technology

Master’s degree thesis
Sector: SCIENCE AND TECHNOLOGY.
Specialty: ROADS AND WORKS OF ART
Topic:

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SESSION YEAR 2023/2024

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

Acknowledgment

We begin these thanks by expressing our gratitude to the Creator, Allah, for granting us the strength, perseverance and wisdom necessary to carry out this graduation thesis.

Our thanks also go to the members of the jury Dr MAROUF Hafida and Dr ELHADJ MIMOUNE Arezki for agreeing to evaluate this work.

We would also like to warmly thank the most person who has left a beautiful mark on us with his creativity, cooperation and fatherly love, the supervisor of our memory, Mr KADDOUR Hakim for his valuable accompaniment, enlightened advice and constant support throughout this work.

His availability and experience have greatly contributed to the success of this project.

We would like to express our gratitude to all the people who have participated directly or indirectly in the realization of this work.

Finally , We want to thank all the professors who contributed to teaching us and providing us with information throughout the past academic years.

Thanks.

Dedication

و اخر دعواهم ان الحمد لله رب العالمين

الحمد لله عند البدأ و عند الختام فما تناهى درب و لا ختم جهد و لا تم سعي الا بفضله

اهدي و بكل حب بحث تخرجي:

الى نفسي القوية التي تحملت كل العثرات..

الى من كان دعائها سر نجاحي الى التي كانت لي نوورا في عتمتي "امي".. لك يا أمي كل الحب والامتنان على كل لحظة قضيتها في تشجيعي ودعمي.

إلى أبي ، الذي كان دائمًا مصدر الدعم والإلهام في حياتي. كان لبنة القوة والإرشاد التي بنيت عليها طموحاتي وأحلامي. بفضله وبفضل الله، استطعت تحقيق هذا النجاح الذي أفتخر به.

الى من قيل فيهم " سنشد عضضك باخيك "

ال اخوتي سندي في الحياة ادامكم الله لي .

الى جدتي و عمي ، شكرًا لكم على كل الدعم والتشجيع الذي قدمتموه لي طوال رحلتي الدراسية

روميسرة

من قال أنا لها "نالها"

لم تكن الرحلة قصيرة و لا ينبغي لها أن تكون ,لم يكن الحلم قريبا و لا الطّريق كان محفوفا بالتّسهيلات لكني فعلتها و نلتها .

إلى ملاكي الطّاهر ,و قوّتي بعد الله ,داعمتي الأولى الأبدية "أمي" أهدي لكي هذا الإنجاز الذّي لولا تضحياتك لما كان له وجود ,ممتنّة لأن الله قد إصطفاكي لي من البشر أما يا خير سند و عوض .

إلى من دعمني بلا حدود و أعطاني بلا قيود و الذّي أضاء دروبي و طريقي و قدوتي في كل خطوة أخطوها "أبي الحبيب "

إلى الرجل العظيم الذّي أخرج أجمل ما في داخلي و شجّعني للوصول إلى طموحاتي رفيق دربي و قرّة عيني إلى "زوجي العزيز"

إلى من دعمتني و ساندتني بعد أ مي و أ عطتني بلا مقابل " جدّتي "

إلى من آمنت بقدراتي وذكّرتني بقوّتي و تقف خلفي كظلّي "أختي"

إلى من مدّ يده دون كلل و لا ملل وقت ضعفي "أخي" أدامك الله ضلعا ثابتا لي.

خولة فادية

Abstract

The use of three-dimensional GIS maps has become an indispensable tool in civil engineering projects, especially those related to road networks and utilities.

However, their design requires costly acquisition tools and mastery of specific software. This can be overcome by utilizing current GIS platforms such as Google Earth, OSM, and ESRI, as they provide free visualization of geospatial data, even in 3D.

Nevertheless, these platforms impose restrictions and limitations on the nature, accuracy, and downloading of raw online data.

Our objective is to address these limitations by developing a methodology for obtaining geospatial data freely for offline use, focusing on a specific case study area: rural road networks in the Wilaya of Ain Temouchent.

Geoprocessing geospatial data from satellite images such as LANDSAT 9, Sentinel 2, SRTM, and ASTER, as well as geological data, has enabled us to establish a 3D GIS map of the road network, enhanced by the integration of dozens of thematic layers using Globalmapper V25. emphasis is placed on reading integrated metadata.

Keywords: GIS, Geospatial Data, 3D Visualization, Metadata, Geospatial Sources

Résumé

L'utilisation des cartes SIG tridimensionnelles est devenue un outil indispensable dans les études des projets de génie civil, notamment ceux liés aux réseaux VRD.

Par ailleurs, leur conception nécessite des outils d'acquisition coûteux et une maîtrise des logiciels spécifiques. Cependant, cela peut être dépassé par l'utilisation de plateformes SIG actuelles telles que Google Earth, OSM et la plateforme ESRI, car elles offrent gratuitement l'opportunité de visualiser des données géospatiales, même en 3D.

Néanmoins, ces plateformes imposent des restrictions et des limites sur la nature, la précision et le téléchargement des données brutes en ligne.

Notre objectif est de pallier ces lacunes en recherchant une méthodologie pour obtenir gratuitement des données géospatiales pour une utilisation hors ligne, pour un cas d'étude spécifique : le réseau routier rural dans la Wilaya de Ain Temouchent.

Le géo traitement des données géospatiales à partir des images satellites LANDSAT 9, Sentinel 2, SRTM et ASTER, ainsi que des données géologiques, nous a permis d'établir une carte SIG 3D du réseau routier améliorée par l'intégration d'une dizaine de couches thématiques sous l'environnement Globalmapper V25, tout en mettant l'accent sur la lecture des métadonnées intégrées.

Mots clés : SIG, Données géospatiales, Visualisation 3D, Métadonnées, Sources géospatiales

ملخص

اصبح استخدام الخرائط ثلاثية الأبعاد تحت نظم المعلومات الجغرافية GIS أداة لا غنى عنها في دراسة مشاريع الهندسة المدنية، خاصة تلك المرتبطة بالطرق و الشبكات المتنوعة VRD.

بالإضافة إلى ذلك، فإن تصميمها يتطلب أدوات اقتناء مكلفة واحتراف في برامج محددة. إلا أنه يمكننا تجاوز هذا المشكل جزئيا من خلال استخدام منصات GIS الحالية مثل Google Earth و OSM ومنصة ESRI ، حيث توفر فرصة مجانية لعرض البيانات الجغرافية، حتى في البعد الثلاثي. و لكن تفرض هذه المنصات قيودًا وحدودًا على طبيعة ودقة وتحميل البيانات الخام عبر الإنترنت.

هدفنا هو التغلب على هذه العوائق من خلال البحث عن منهجية للحصول على مثل هذه البيانات الجغرافية مجانًا للاستخدام ، و دون الاتصال بالأنترنت ، و ذلك عبر دراسة حالة محددة لشبكة الطرق الريفية في ولاية عين تموشنت.

تمكنا عبر معالجة البيانات الجغرافية لصور الأقمار الصناعية LANDSAT 9 ، Sentinel 2 و SRTM و ASTER ، بالإضافة إلى البيانات الجيولوجية، من إنشاء خريطة GIS ثلاثية الأبعاد للشبكة الطرق ، مع تحسينها من خلال دمج عشرات الطبقات الموضوعية بإستعمال برنامج Globalmapper V25 ، مع التركيز على قراءة البيانات الوصفية المدمجة.

الكلمات المفتاحية :GIS البيانات الجغرافية، التصور ثلاثي الأبعاد، البيانات الوصفية، المصادر الجغرافية

Contents

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Notation List:

GIS: geographic information system.

DEM: degetal elevation model

SRTM: stands for Shuttle Radar Topography Mission.

BIM: Building Information Modeling.

OSM: open street map.

AI: artificial intelegence.

USGS: United States Geological Survey.

GPS: Global positioning systeme

KML: keyhole markup language.

GCS: Geographic cordiantion system.

PCS: project coordinate system.

SDSS: spatiale descision sport.

DBMS: data management system.

UTM: universal transvese Mercator.

WGS: world geodetic system.

ML: machine learning.

IOT: internet of things.

AR: augmented reality.

SAAS: software-as-a-service.

VR: vitual reality.

HTML: HyperText Markup Language.

TIFF: taged image file format.

GEOTIFF: georeferenced taged image file format.

JPEG : joint plotgraphic expert groupe.

ESDS: earth science data système .

General introduction:

The use of Geographic Information Systems (GIS) in the field of civil engineering has significantly evolved over the past decades, providing powerful tools for infrastructure planning, design, and management. GIS enables civil engineers to visualize and analyze spatial data with unprecedented precision, thus facilitating informed decision-making in complex projects such as the construction and maintenance of road networks.

Traditionally, the visualization of civil engineering projects, particularly in the realm of roads, has been carried out using two-dimensional methods. However, this approach has major drawbacks, including the difficulty of combining cross-sectional profiles with plan views. This limitation often hinders the overall understanding of projects and can lead to costly errors during execution.

The introduction of three-dimensional (3D) visualization in the field of civil engineering has revolutionized the way projects are designed, modeled, and managed. 3D visualization provides a more realistic and immersive representation of infrastructure, allowing engineers to better assess topographical aspects, identify potential conflicts, and optimize construction plans. Additionally, 3D visualization facilitates the integration of data into processes such as Building Information Modeling (BIM), thereby improving coordination and communication among project stakeholders.

Over the past decade, access to free and open geospatial data has significantly expanded the possibilities for spatial analysis and visualization. Sources such as OpenStreetMap (OSM), NASA's Shuttle Radar Topography Mission (SRTM), and governmental data are now widely accessible, offering researchers and practitioners the opportunity to conduct in-depth analyses without the financial constraints associated with proprietary data.

In this thesis, we explore the use of free geospatial data to enhance the 3D visualization of rural road networks, with the Wilaya of Ain Temouchent in Algeria as a case study. This thesis is structured into three main chapters:

Chapter 1: State of the Art in GIS

In this chapter, we review recent advancements in Geographic Information Systems applied to civil engineering, as well as technological and methodological developments that have led to the emergence of new approaches, including 3D visualization.

Chapter 2: Geospatial Data

This chapter examines in detail the various sources of free geospatial data available, such as topographic data, satellite imagery, and data from different web platforms . We discuss the advantages and limitations of each data source, as well as methods for integrating and processing them within a GIS environment.

Chapter 3: Application

In this final chapter, the focus shifts to the application of the concepts and techniques discussed in the preceding chapters specifically to the road network. A case study is conducted in the Wilaya of Ain Temouchent, where the methodology for collecting, processing, and visualizing geospatial data is applied to generate a detailed 3D visualization of the road network in the study area. The chapter provides a comprehensive overview of the process, highlighting the challenges encountered, the methodologies employed, and the insights gained from the 3D visualization of the road network.

CHAPTER ONE : STATE OF ART IN GIS

I.1) Introduction:

This chapter presents an overview of the Evolution of Geographic Information Systems (GIS) and introduces fundamental concepts and terminology essential for understanding the current state of GIS in the context of Public Works.

I.2) Evolution of GIS:

Within the last five decades, GIS has evolved from a concept to a science. The phenomenal evolution of GIS from a rudimentary tool to a modern, powerful platform for understanding and planning our world is marked by several key milestones. (1)

Early Development (1960s-1970s):

GIS originated from computerized mapping efforts in the 1960s and early 1970s. Early systems focused on digitizing maps and storing geographic data in computer systems. These systems were rudimentary by today's standards, with limited analytical capabilities and data storage capacities (1)

Development of Spatial Analysis (1980s):

In the 1980s, GIS evolved significantly with the development of spatial analysis capabilities. This allowed users to perform more sophisticated geospatial analyses, such as overlay analysis, buffering, and network analysis. These advancements paved the way for GIS to become a powerful tool for spatial data analysis and decision-making (1; 1)

Integration of Remote Sensing (1990s):

The 1990s marked a period of integration between GIS and remote sensing technologies. This integration enabled GIS users to incorporate satellite imagery and aerial photographs into their analyses, enhancing the visualization and interpretation of spatial data. It also expanded the range of applications for GIS, including environmental monitoring and land use planning (1)

Web-Based GIS (2000s):

The 2000s witnessed the rise of web-based GIS, which transformed how GIS data was accessed and shared. Web-based GIS allowed users to access and interact with GIS data through web browsers, democratizing access to spatial information. This accessibility led to increased collaboration and the development of online mapping services like Google Maps (2)

Mobile GIS (2010s):

The 2010s saw the emergence of mobile GIS, driven by the proliferation of smart phones and tablets. Mobile GIS enabled users to collect, update, and analyze geospatial data in the field, reducing the reliance on desktop GIS systems. This technology revolutionized field data collection and asset management workflows in industries such as utilities and transportation (2)

Cloud-Based GIS (Present):

Today, GIS is undergoing a paradigm shift towards cloud-based solutions. Cloud-based GIS offers scalability, flexibility, and cost-effectiveness by hosting GIS software and data on remote servers. This approach allows users to access GIS capabilities and data from anywhere with an internet connection, making GIS more accessible and reducing infrastructure costs. (3)

Focus on Big Data and AI (Future):

Looking ahead, the future of GIS is likely to be shaped by big data and artificial intelligence (AI). The increasing volume and variety of geospatial data require advanced analytical techniques to extract meaningful insights. AI and machine learning algorithms can help analyze big geospatial data, enabling GIS to provide more accurate predictions and decision support in areas such as urban planning and disaster management (3)

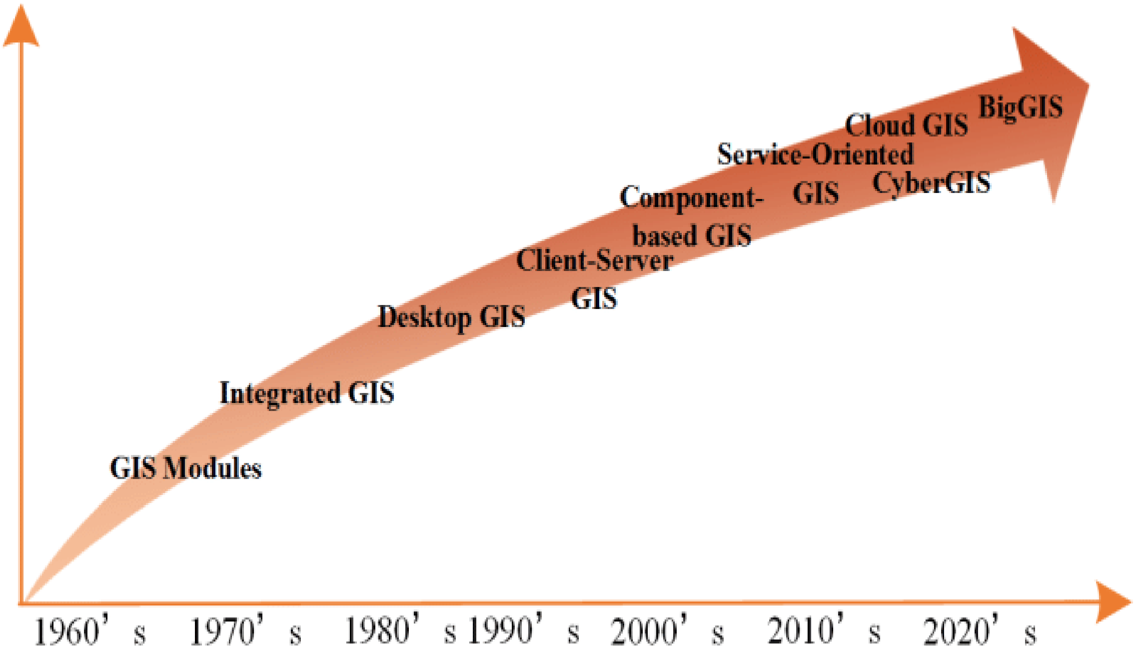


Figure 1 :GIS evolution and future trends (4)

I.3) Key Concepts and Terminology:

I.3.1) Definition and Scope:

Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. It allows users to view, understand, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts (Longley et al., 2015). GIS encompasses a wide range of technologies, tools, and methods for collecting, managing, and analyzing spatial data. It is used in various fields, including urban planning, natural resource management, transportation, and public health, to support decision-making processes and solve complex spatial problems.

(5)

I.3.2) Components of GIS:

The versatility of GIS allows it to be applied in numerous fields, providing spatial insights and facilitating informed decision-making across a broad spectrum of disciplines.

Geographic Information Systems (GIS) consist of several key components that work together to capture, store, analyze, and visualize spatial data. The main components of GIS include.

1. Hardware:

This includes the physical equipment used to collect, process, store, and display geographic information. Hardware components may include computers, servers, GPS devices, scanners, printers, and other peripherals.

2. Software:

GIS software is the set of programs and applications used to perform various GIS tasks. This includes software for data input, analysis, visualization, and output. Examples of GIS software include ArcGIS, QGIS, and Google Earth.

3. Data:

Data is a fundamental component of GIS, and it comes in two main types:

Spatial Data: Represents the geographic location and shape of features on the Earth's surface. It includes points, lines, polygons, and raster images.

Attribute Data: Contains information associated with the spatial features, often stored in tables. This data provides details such as names, population, or other characteristics.

4. Methods/Procedures:

GIS methods involve the processes and procedures used to collect, analyze, and interpret spatial data. This includes data capture methods (e.g., GPS, remote sensing), analysis techniques, and visualization methods.

5. Networks and Communication:

GIS often relies on communication networks to share and distribute spatial information. This includes internet connectivity for online mapping and data sharing, as well as local networks for collaboration among users.

6. Standards:

Standards are essential for ensuring interoperability and consistency in GIS. Standards define how spatial data is organized, exchanged, and shared. Examples include data format standards (e.g., Shapefiles) and protocols for data exchange.

7. Policies and Regulations:

GIS implementation is influenced by policies and regulations that govern data collection, sharing, and usage. Privacy concerns, data ownership, and ethical considerations are addressed through policies to ensure responsible Gis practices.

8. Quality Control:

Ensuring the accuracy and reliability of spatial data is crucial. Quality control involves validating data, maintaining metadata, and implementing procedures to identify and correct errors.

9. Training and Education:

As GIS technology evolves, continuous training and education are essential. Users need to stay informed about new tools, methods, and best practices to effectively apply GIS in different domains.

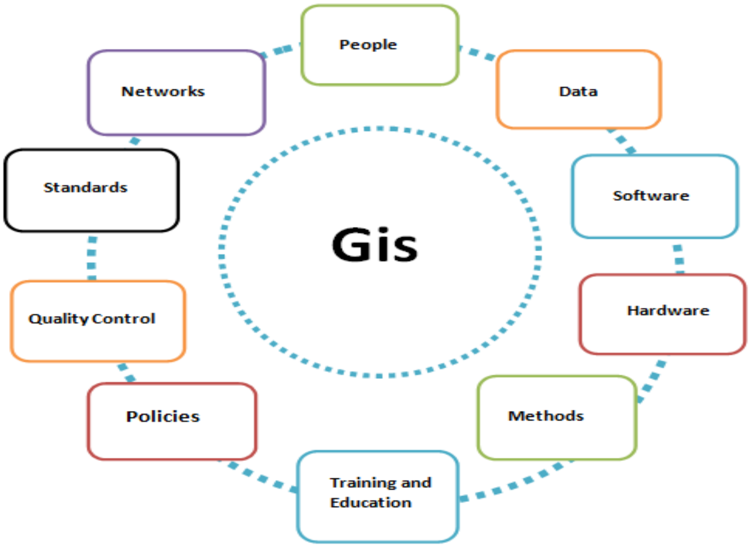


Figure 2: Components of GIS

These components work collaboratively to enable the creation, analysis, and interpretation of geographic information for a wide range of applications and industries

I.3.3) Spatial Data and Attribute Data:

Spatial data and attribute data are two key components in the field of geographic information systems (GIS). These types of data provide different but complementary information for the analysis and representation of geographic phenomena.

Examples:

Maps, satellite imagery, GPS coordinates, and any data with a clear spatial reference.

I.3.3.1) Spatial Data:

Definition: Spatial data refers to information that has a geographic or locational component, often represented by coordinates (latitude, longitude, and sometimes elevation).

A) Types of Spatial Data:

Vector Data: Represents points, lines, and polygons. Points indicate specific locations (e.g., a city), lines represent linear features (e.g., roads), and polygons define areas (e.g., a country boundary).

Raster Data: Consists of a grid of cells where each cell holds a value representing a certain attribute. It is often used for continuous data like satellite imagery.

B) Spatial Data Formats:

Shapefiles : A common vector format containing geometric and attribute data.

GeoTIFF: A widely used raster format with georeferencing information.

KML (Keyhole Markup Language): Used for representing geographic features in 2D and 3D.

C) Coordinate Systems:

Geographic Coordinate System (GCS): Uses latitude and longitude to define locations on the Earth's surface.

Projected Coordinate System (PCS): Utilizes a flat, 2D plane and is often used for mapping purposes.

I.3.3.2) Attribute Data:

Definition:

Attribute data, also known as non-spatial data or tabular data, consists of descriptive information related to the spatial features. These are usually stored in tables or databases and are linked to spatial data through identifiers

Examples:

Population figures, temperature, land use classifications, or any information that provides details about the characteristics of a location.

Data Types:

Categorical Data: Represents discrete categories (e.g., land use types).

Numerical Data: Involves measurable quantities (e.g., temperature, population).

Date and Time Data: Indicates temporal information related to a specific location.

Attributes in GIS:

Joining and Relating Data: Spatial data is linked to attribute data through identifiers, allowing for the combination of different datasets for analysis.

Attribute Tables: Each spatial dataset (e.g., a layer in a GIS) has an associated attribute table containing detailed information about each spatial feature.

Examples of Attribute Data:

Demographic Information: Population density, age distribution.

Environmental Characteristics: Soil types, climate data.

Infrastructure Details: Road conditions, building types.

Spatial Data and Attribute Data Integration:

Spatial Analysis:

Overlay Analysis: Combining spatial datasets to identify relationships or intersections.

Spatial Queries: Extracting information based on spatial conditions.

Visualization:

Thematic Mapping: Representing attribute data on maps to visualize patterns and trends.

Decision Support:

Spatial Decision Support Systems (SDSS): Using spatial and attribute data to assist in decision-making processes.

Database Management Systems (DBMS):

Attribute data is often stored in databases, and GIS software can connect to various DBMS to retrieve and manage this information.

In GIS, these two types of data are often combined through a process known as spatial data integration. This integration allows analysts to study the relationships between the spatial and attribute data, enabling a more comprehensive understanding of geographic patterns and trends. For example, a GIS might use spatial data to represent the location of cities and attribute data to show the population of each city.

I.3.4) Cartographic projection

I.3.4.1) North Sahara Geodetic System 1959

The North Sahara coordinate system was created by the IGN (National Geographic Institute) in the 1950s for Algeria. It is used for measuring distances and angles on a map. This system includes several elements: the UTM projection (Universal Transverse Mercator), the unit system (meter or foot), the reference ellipsoid (Clarke 1880 English), the origin position, and the characteristics of the geodetic network. This system is very useful for performing calculations and projections on maps. It also allows specifying the position of a point on a map and calculating distances between two points. Finally, it provides a database for digital geographic applications. (6)

I.3.4.2) Le système de référence WGS84 :

The Global Positioning System (GPS) satellite positioning system provides the user with their position (x, y, z) WGS84 or (λ, ϕ, h) WS84 at each moment. For this, WGS84 (World Geodetic System 84) serves as the global reference and is specifically designed to meet the needs of a global navigation system. This reference allows for calculating the distance between points and determining the exact position of each point in space. (6)

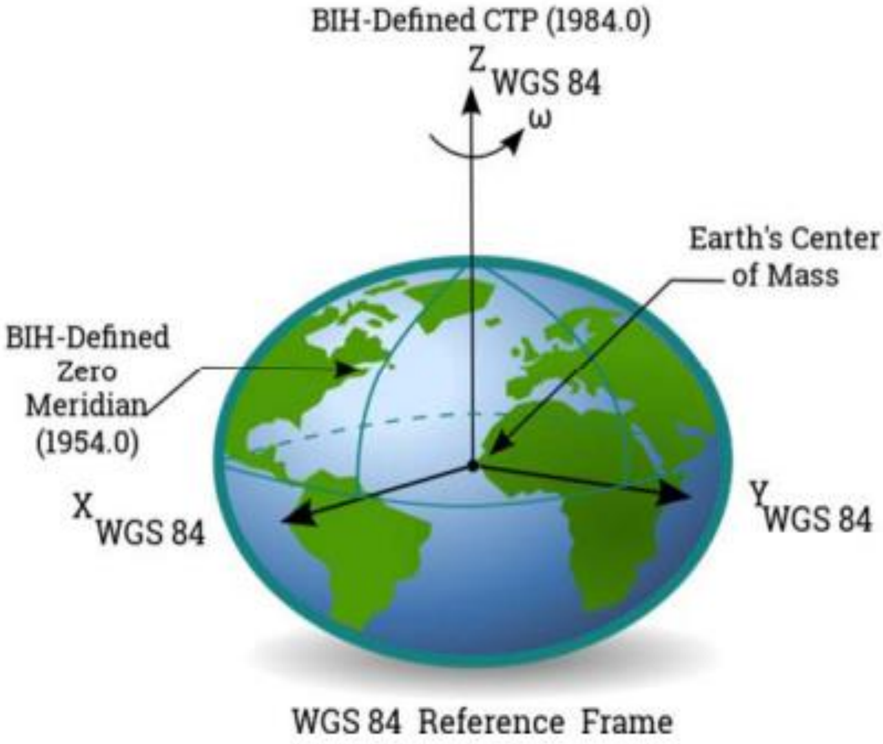


Figure 3:Global geodetic coordinate system WGS84. (6)

The WGS 84 system defines a geocentric Cartesian coordinate system (X, Y, Z) with the origin at the center of gravity of the Earth's mass, the Z-axis passing through the astronomical North Pole (Earth's axis of rotation), the X-axis being the intersection of the equator and the Greenwich meridian, and the Y-axis being a direct axis. To use GPS coordinates, transformation programs between coordinate systems (WGS84 and North Sahara 1959) exist.

In the case of GIS, information layers must be defined in the same system, and GIS software allows conversion between different systems (WGS84, North Sahara 1959, etc.). This allows working with consistent and accurate information and obtaining reliable results. (6)

I.3.4.3) Cartographic Projections Used in Algeria

A) Lambert Projection

The conformal, conical Lambert projection was used for mapping Algeria at 1/50,000 scale from 1943 to 1960.

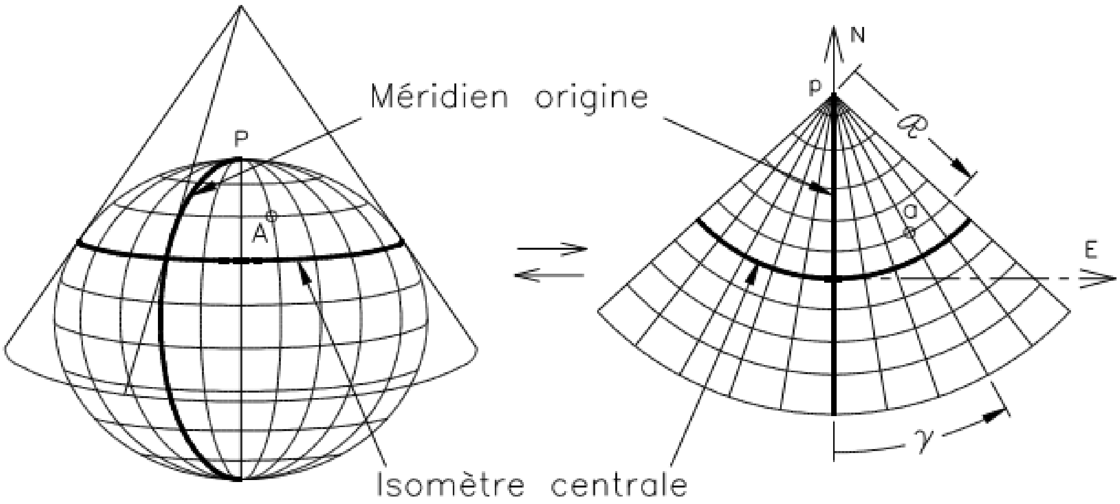


Figure 4: Projection Lambert conique direct. (6)

It is characterized by a red kilometer grid called "Lambert corroyage," which delimits a square of 1 km on each side. This system makes it easier to identify planimetric and altimetric details.

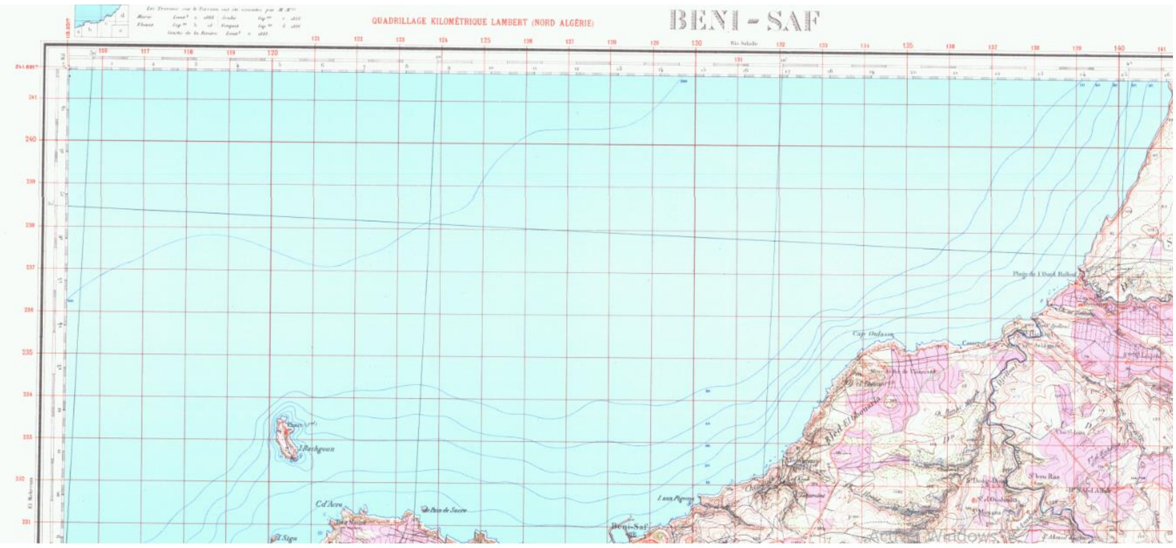
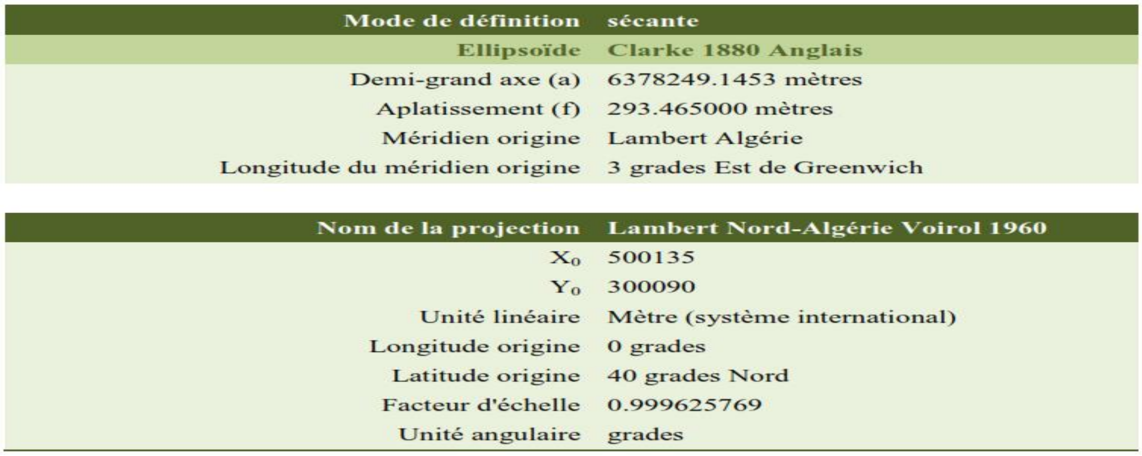


Figure5: Excerpt from the 1:50,000 map of Bénisaf, old edition; Lambert VLU projection.

The Lambert North-Algeria Voirol projection was adopted for the former Algerian mapping. Its parameters are:



Mode de définition	sécante
Ellipsoïde	Clarke 1880 Anglais
Demi-grand axe (a)	6378249.1453 mètres
Aplatissement (f)	293.465000 mètres
Méridien origine	Lambert Algérie
Longitude du méridien origine	3 grades Est de Greenwich

Nom de la projection	Lambert Nord-Algérie Voirol 1960
X_0	500135
Y_0	300090
Unité linéaire	Mètre (système international)
Longitude origine	0 grades
Latitude origine	40 grades Nord
Facteur d'échelle	0.999625769
Unité angulaire	grades

Figure 6 : Parameters of the Lambert VLU projection.

B) UTM Projection (Universal Transverse Mercator)

The Mercator projection, dating back to 1569, has significant distortions near the poles, and it divides the world into 60 zones. Each zone covers 6° of longitude, and the rectangular coordinates are expressed in meters or kilometers.

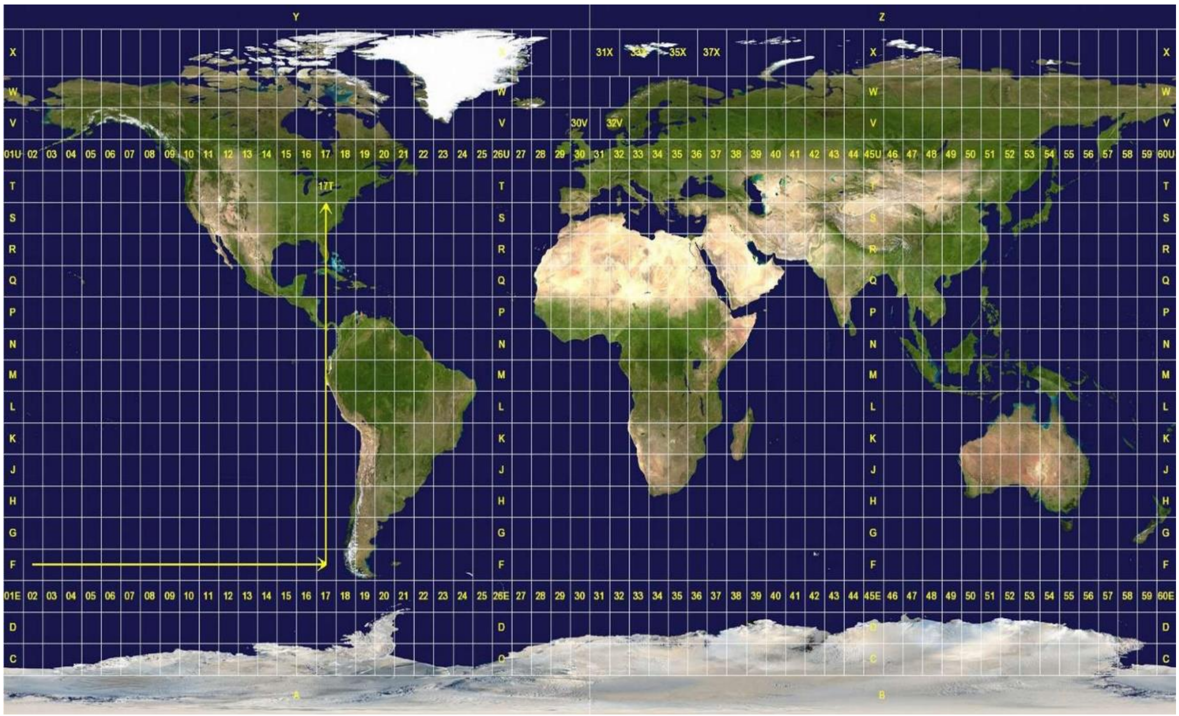
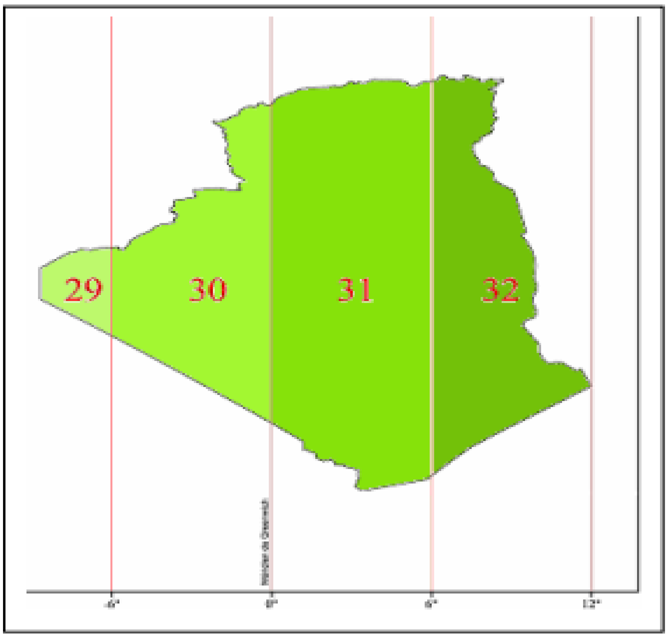


Figure 5 : Cartographic division of the Earth's globe using the UTM projection.

In Algeria, the UTM projection is currently used, and it covers 6° of longitude per zone. Algeria occupies 4 zones: numbers 29, 30, 31, and 32, which means there are 4 zones. (Nadir, 2019/2020)



- Zone n°29: From -12° to -6°
- Zone n°30: From -6° to 0°
- Zone n°31: From 0° to 6°
- Zone n°32: From 6° to 12°

Figure 6: La disposition des fuseaux horaires de l'Algérie (6)

Transformation between WGS 84 and North Sahara

To transform coordinates from GPS positioning expressed in the WGS 84 system to the local North Sahara system in use, one must know the transformation parameters. These parameters were determined from a set of double known geodetic points in both systems, and the three-dimensional transformation model used is the Helmert or Bursa Wolf model with seven parameters.

The transformation parameters from WGS 84 to North Sahara are as follows:

Translation into X [m]	**209.362198**
Translation into Y [m]	**87.816200**
Translation into Z [m]	**-404.619830**
Rotation into X [sec]	**-0.00461215**
Rotation into Y [sec]	**-3.47842207**
Rotation into Z [sec]	**-0.58048472**
Scale factor correction [ppm]	**1.4547220**

Table 1:Transformation Parameters from WGS 84 to North Sahara

The standard deviation of this determination, being 0.9288 m, is considered acceptable for cartography work. (6).

I.4) Current Trends and Developments:

I.4.1) Developments in Geographic Information Systems (GIS):

are characterized by several key trends that are reshaping the field and influencing its applications across various sectors. Some of the prominent trends in GIS development include:

Increased Use of Artificial Intelligence (AI) and Machine Learning (ML)*:* AI and ML are being integrated into GIS to automate tasks, provide new insights into spatial data, and enhance decision-making processes. These technologies are already being used for image classification, object detection, and predictive analytics, with future applications expected to further automate tasks and provide deeper insights into spatial data.

Greater Adoption of Cloud Computing*:* Cloud-based GIS platforms are becoming more prevalent, offering scalability, flexibility, and cost-effectiveness. Cloud computing has democratized GIS, making it accessible to organizations of all sizes and enabling users to access computing power and storage capacity as needed. This trend is expected to continue, making GIS more accessible and affordable for small and medium-sized businesses and governments.

Widespread Use of Mobile GIS*:* Mobile GIS applications are increasingly being used for field data collection and analysis. This trend is expected to grow, improving the efficiency of field operations and providing real-time data to decision-makers. For example, inspectors equipped with mobile GIS can assess road conditions and update databases on-site, facilitating timely maintenance decisions. (7)

Integration of GIS with Other Technologies*:* GIS is being integrated with technologies such as the Internet of Things (IoT), big data analytics, and augmented reality (AR). This integration is leading to the development of new and innovative GIS applications for infrastructure development, disaster management, and urban planning. For instance, integration with IoT enables real-time monitoring of infrastructure assets, such as bridges, with sensors providing data on structural integrity for proactive maintenance.

Real-Time GIS*:* Real-time GIS involves integrating dynamic data sources, such as IoT sensors and social media feeds, into GIS systems. This trend enables organizations to monitor and respond to changing conditions promptly, facilitating real-time decision-making in areas like traffic management, emergency response, and supply chain optimization.

Market Expansion and Growth*:* The market value of GIS is expected to continue growing, driven by factors such as population growth, urbanization, and technological advancements. GIS technology is evolving rapidly, with the adoption of cutting-edge technologies like cloud computing, AI, Geo-AI, and machine learning. These advancements are expected to fuel the growth and adoption of GIS technology in various industries and sectors. (8)

I.4.2) Challenges in GIS for Infrastructure Development:

GIS is a powerful tool for infrastructure development, but it also faces a number of challenges. Here are some of the key challenges in GIS for infrastructure development:

I.4.2.1) Data Integration and Quality:

Gathering data from diverse sources including satellite imagery, surveys, government records, and sensor networks, presents a formidable challenge. Ensuring the quality, accuracy, and compatibility of these disparate datasets remains a pressing issue.

***Example*:** Inaccurate or incompatible data can lead to errors in locating underground utilities during construction, potentially resulting in accidents and project delays.

I.4.2.2) Scalability:

As urban areas expand and infrastructure demands grow, GIS systems must efficiently handle increasingly extensive and intricate spatial data

Example: Processing and analysing large datasets become cumbersome and time-consuming, hindering prompt decision-making in response to urban growth.

I.4.2.3) Interoperability:

The use of different software platforms and data formats across GIS systems complicates seamless data sharing and utilization throughout various stages of infrastructure projects.

Example: When GIS is not integrated with engineering or asset management systems, it leads to redundant efforts and inefficient data management.

I.4.2.4) Data Privacy and Security:

As infrastructure data goes digital, concerns about data privacy and security have surged. Striking a balance between safeguarding sensitive information and providing access to authorized personnel is an ongoing challenge.

Example: Protecting critical infrastructure data from cyber threats while ensuring accessibility for authorized personnel remains a complex endeavour.

I.4.2.5) Workforce Skill Gap:

The field of GIS is evolving rapidly, demanding a growing pool of skilled professionals who can harness its full potential. Bridging the skill gap is pivotal for successful infrastructure development.

Example: Inadequate GIS expertise can lead to inefficient planning, costly errors, and project delays.

I.4.2.6) Future Trends in GIS for Infrastructure Development

GIS technology is constantly evolving, and new trends are emerging all the time. Here are some of the future trends in GIS that are likely to have a significant impact on infrastructure development:

• ***Increased use of artificial intelligence (AI) and machine learning (ML):*** AI and ML are already being used in GIS for tasks such as image classification, object detection, and predictive analytics. In the future, AI and ML are likely to be used even more extensively in GIS, to automate tasks and to provide new insights into spatial data.

Example**:** AI algorithms can predict when maintenance is needed for a bridge by analysing data on usage, weather conditions, and structural health, thereby enhancing infrastructure maintenance.

- ***Greater use of cloud computing:*** Cloud computing is making it easier and more affordable to access GIS software and data. In the future, cloud GIS is likely to become even more widely adopted, making GIS more accessible to small and medium-sized businesses and governments.

Example: Cloud GIS allows infrastructure developers to collaborate seamlessly on a shared platform, eliminating geographical constraints and enhancing data accessibility.

- ***Widespread use of mobile GIS:*** Mobile GIS apps are making it possible to collect and analyze spatial data in the field. In the future, mobile GIS is likely to be used even more extensively in infrastructure development, to improve the efficiency of field operations and to provide real-time data to decision-makers.

Example: Inspectors equipped with mobile GIS can assess the condition of road surfaces and update databases on the spot, facilitating timely road maintenance decisions.

- ***Increased use of 3D GIS and digital twins*****:** 3D GIS and digital twins are being used to create virtual representations of the real world. This technology is likely to play an increasingly important role in infrastructure development, to support planning, design, and construction activities.

Example: 3D GIS can visualize the visual impact of a proposed building project on its surroundings, aiding in assessing its appropriateness and mitigating environmental concerns.

- ***Integration of GIS with other technologies****:* GIS is increasingly being integrated with other technologies, such as the Internet of Things (IoT), big data analytics, and augmented reality (AR). This integration is leading to the development of new and innovative GIS applications for infrastructure development.

Example: Integration with IoT enables real-time monitoring of infrastructure assets, such as bridges, with sensors providing data on structural integrity, allowing for proactive maintenance.

As we look ahead, GIS will continue to evolve and redefine the way we plan, build, and manage infrastructure. By staying at the forefront of these trends and addressing current challenges, we can create more resilient, sustainable, and efficient infrastructure systems for the future.

I.4.3) Cloud-Based GIS: (GIS dashboard):

I.4.3.1) An Overview:

Cloud-based Geographic Information Systems (GIS) leverage cloud computing services for managing, storing, and analyzing geographic data. Unlike traditional on-premises GIS systems, cloud-based solutions offer flexibility, scalability, and accessibility. They allow users to work online, offline, or install the platform on-premises These systems enable real-time mapping, data visualization, and collaboration across various domains

I.4.3.2) Key Features of Cloud-Based GIS:

Real-Time Mapping: Cloud GIS platforms provide real-time visualization of people, assets, and fleet locations on maps. Users can track their movements, generate in-depth reports, and analyze historical data based on various parameters

Online and Offline Capabilities*:* Users can work seamlessly whether connected to the internet or offline. This flexibility is crucial for field data collection and operations management

Collaboration*:* Cloud GIS fosters collaboration among teams by allowing multiple users to access and work with spatial data simultaneously

Security and Compliance*:* These platforms ensure data security and adhere to compliance standards

Customization: Users can customize the interface, making it easier to train new users and adapt to specific workflows

Figure 7:the cloud Gis (9)

I.4.3.3) Types of Cloud Computing:

Software-as-a-Service (SaaS) - uses the cloud for provisioning of software.

Infrastructure-as-a-Service (IaaS) - providing backup of data and ITS backs up the data from your email and the H and W drive. Some data is stored both onsite and offsite but is readily accessible from anywhere.

Platform-as-a-Service (PaaS) - The Monarch Virtual Environment provides that you don't need to have the software installed because you can access it via the Internet.

Software-as-a-Service removes the need for organizations to install and run applications as the software runs through the Internet Service. This is cost-efficient, ensures the software is always up-to-date, and scalable to many users.

Some downsides of SaaS include*:*

Speed of Internet connectivity,

Latency (many users may slow the transfer of information from the cloud)

- Time for the program to refresh
- Management issues in terms of authorizing users
- Security issues of personal information

Limited functionality

- For example, ArcGIS Pro, professional GIS software, is much more powerful and provides a greater array of geospatial analysis and other capabilities than ArcGIS Online, its purely cloud-based counterpart. (9)

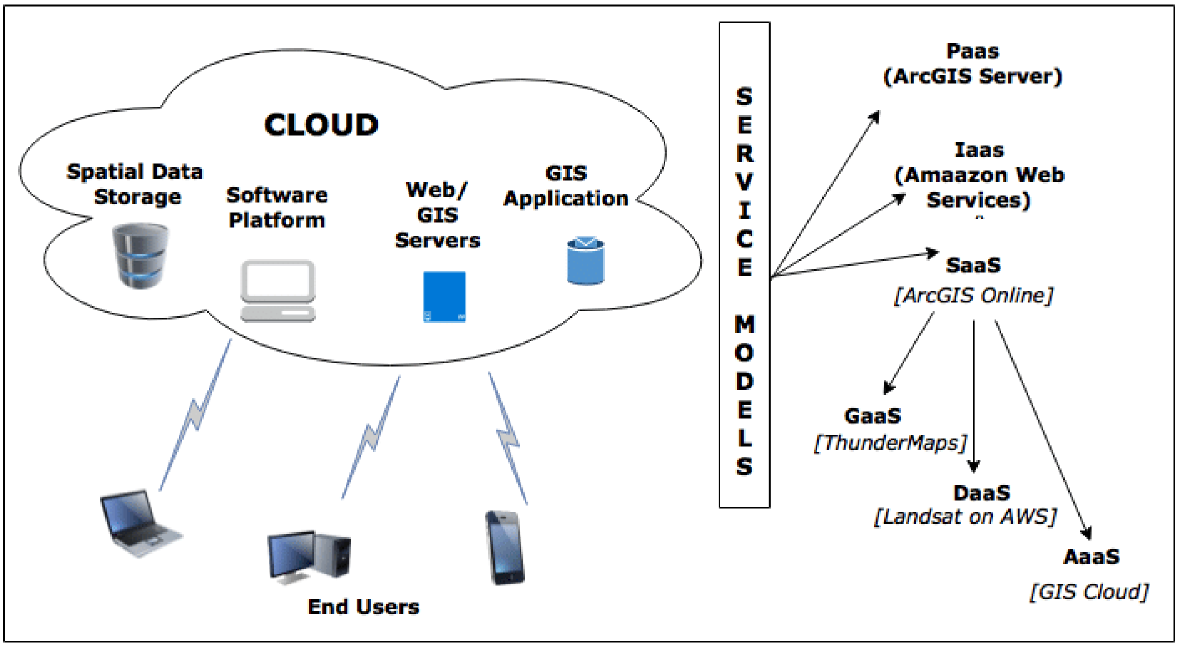


Figure 8 : Overview of Cloud based GIS Model (10)

I.4.4) Big Data and Analytics:

Big data analytics describes the process of uncovering trends, patterns, and correlations in large amounts of raw data to help make data-informed decisions. These processes use familiar statistical analysis techniques—like clustering and regression—and apply them to more extensive datasets with the help of newer tools. Big data has been a buzz word since the early 2000s, when software and hardware capabilities made it possible for organizations to handle large amounts of unstructured data. Since then, new technologies—from Amazon to smartphones—have contributed even more to the substantial amounts of data available to organizations. With the explosion of data, early innovation projects like Hadoop, Spark, and NoSQL databases were created for the storage and processing of big data. This field continues to evolve as data engineers look for ways to integrate the vast amounts of complex information created by sensors, networks, transactions, smart devices, web usage, and more. Even now, big data analytics methods are being used with emerging technologies, like machine learning, to discover and scale more complex insights.

I.4.4.1) The Works of big data analytics:

A) Collect Data

Data collection looks different for every organization. With today's technology, organizations can gather both structured and unstructured data from a variety of sources — from cloud storage to mobile applications to in-store IoT sensors and beyond. Some data will be stored in data warehouses where business intelligence tools and solutions can access it easily. Raw or unstructured data that is too diverse or complex for a warehouse may be assigned metadata and stored in a data lake.

B) Process Data

Once data is collected and stored, it must be organized properly to get accurate results on analytical queries, especially when it’s large and unstructured. Available data is growing exponentially, making data processing a challenge for organizations. One processing option is batch processing, which looks at large data blocks over time. Batch processing is useful when there is a longer turnaround time between collecting and analyzing data. Stream processing looks at small batches of data at once, shortening the delay time between collection and analysis for quicker decision-making. Stream processing is more complex and often more expensive.

C) Clean Data

Data big or small requires scrubbing to improve data quality and get stronger results; all data must be formatted correctly, and any duplicative or irrelevant data must be eliminated or accounted for. Dirty data can obscure and mislead, creating flawed insights.

D) Analyze Data

Getting big data into a usable state takes time. Once it’s ready, advanced analytics processes can turn big data into big insights. Some of these big data analysis methods include:

Data mining sorts through large datasets to identify patterns and relationships by identifying anomalies and creating data clusters.

Predictive analytics uses an organization’s historical data to make predictions about the future, identifying upcoming risks and opportunities.

Deep learning imitates human learning patterns by using artificial intelligence and machine learning to layer algorithms and find patterns in the most complex and abstract data. (11)

I.4.4.2) Big data analytics tools

Harnessing all of that data requires tools. Thankfully, technology has advanced so that many intuitive software systems are available for data analysts to use.

Hadoop: An open-source framework that stores and processes big data sets. Hadoop can handle and analyse structured and unstructured data.

Spark: An open-source cluster computing framework for real-time processing and data analysis.

Data integration software*:* Programs that allow big data to be streamlined across different platforms, such as MongoDB, Apache, Hadoop, and Amazon EMR.

Stream analytics tools**:** Systems that filter, aggregate, and analyse data that might be stored in different platforms and formats, such as Kafka.

Distributed storage: Databases that can split data across multiple servers and can identify lost or corrupt data, such as Cassandra.

Predictive analytics hardware and software: Systems that process large amounts of complex data, using machine learning and algorithms to predict future outcomes, such as fraud detection, marketing, and risk assessments.

Data mining tools**:** Programs that allow users to search within structured and unstructured big data.

NoSQL databases: Non-relational data management systems ideal for dealing with raw and unstructured data.

Data warehouses: Storage for large amounts of data collected from many different sources, typically using predefined schemas. (12)

I.4.5) Machine Learning in GIS

Machine Learning (ML) is a subset of artificial intelligence that focuses on developing algorithms and statistical models that enable computers to learn from and make predictions or decisions based on data. In the context of Geographic Information Systems (GIS), Machine Learning algorithms are used to extract insights from spatial data, automate mapping processes, and improve the accuracy of spatial analysis

I.4.5.1) Applications of Machine Learning in GIS

Classification*:* ML algorithms can classify land cover types in satellite imagery, such as forests, water bodies, and urban areas, by learning from labeled training data.

Object Detection and Recognition: ML algorithms can detect and recognize objects in aerial or satellite images, such as buildings, roads, and vehicles, by analyzing image features.

Spatial Analysis: ML algorithms can analyze spatial patterns and relationships in data, such as identifying clusters of similar features or predicting future trends based on historical data.

Geocoding and Address Matching*:* ML algorithms can improve the accuracy of geocoding and address matching by learning from past matching patterns and errors.

Predictive Modeling*:* ML algorithms can be used to develop predictive models for various applications, such as predicting land use changes, traffic patterns, or natural disasters

I.4.6) 3D GIS and Virtual Reality

I.4.6.1) Introduction to 3D GIS:

3D Geographic Information Systems (GIS) integrate spatial data with three-dimensional visualization techniques, providing a more immersive and realistic representation of geographic features. It allows users to analyze spatial data in a more intuitive manner by adding the third dimension to traditional 2D maps. 3D GIS applications are widely used in urban planning, environmental modeling, disaster management, and navigation systems (13)

I.4.6.2) Benefits of 3D GIS:

3D GIS offers several advantages over traditional 2D GIS, including improved spatial analysis capabilities, enhanced visualization of complex spatial relationships, better communication of spatial information, and increased realism in simulations and modeling. These benefits make 3D GIS an invaluable tool for various industries such as architecture, engineering, and urban planning (14)

I.4.6.3) Integration of Virtual Reality (VR) with 3D GIS:

Virtual Reality (VR) technology can be integrated with 3D GIS to create immersive virtual environments that allow users to interact with spatial data in real-time. By wearing a VR headset, users can explore 3D GIS models as if they were physically present in the environment, enhancing their spatial understanding and decision-making processes. This integration opens up new possibilities for visualizing and analyzing complex spatial data (15)

I.4.6.4) Applications of 3D GIS and VR:

The combination of 3D GIS and VR has numerous applications, such as urban planning and design, environmental modeling, archaeological reconstruction, and disaster management. For example, urban planners can use VR to simulate the impact of new developments on the cityscape, while archaeologists can use it to reconstruct ancient sites and visualize historical landscapes

I.4.6.5) Challenges and Future Directions:

Despite its potential, the integration of 3D GIS and VR faces several challenges, including the need for high-quality spatial data, computational resources, and user-friendly interfaces. Future research directions include the development of more efficient algorithms for 3D data processing, the integration of real-time sensor data with 3D GIS models, and the enhancement of user interfaces to improve the usability of VR applications (3)

.

Figure 9:Virtual reality glasses provides a touch-less interaction to manipulate a given 3D scene. (14)

I.4.7) Open Source GIS

I.4.7.1) Overview

Open Source GIS encompasses a range of tools and software that adhere to an open-source model, allowing users to access, modify, and distribute the code. This open accessibility encourages collaborative development, innovation, and community-driven enhancements in the field of geographic information systems (GIS). From mapping and spatial analysis to data management, Open Source GIS platforms offer a wide array of functionalities, catering to diverse geospatial needs (15)

I.4.7.2)Key Features of Open Source GIS:

Open Access and Customization: Open Source GIS software allows users to access, view, and modify the source code, providing flexibility to customize the software according to specific requirements. This open access promotes collaboration and innovation within the GIS community, leading to the development of tailored solutions for different use cases

Cost-Effectiveness: One of the main advantages of Open Source GIS is its cost-effectiveness. Since the software is freely available, users do not need to purchase expensive licenses, making it an affordable option for individuals and organizations with limited budgets. This cost-effectiveness enables wider access to GIS technology, particularly in resource-constrained environments

Community Support and Development: Open Source GIS benefits from a large and active community of developers, users, and contributors who provide support, share knowledge, and contribute to the ongoing development of the software. This community-driven approach ensures that the software remains up-to-date, secure, and well-supported, with regular updates and improvements.

Interoperability and Compatibility: Open Source GIS software is designed to be interoperable with other GIS software and data formats, allowing users to integrate data from different sources and work with a variety of file formats. This interoperability enables seamless data exchange and analysis, enhancing the usability and effectiveness of the software

Geospatial Analysis and Visualization: Open Source GIS provides a wide range of tools and functionalities for geospatial analysis and visualization. Users can perform various spatial analysis tasks, such as buffering, overlay analysis, and terrain modeling, as well as create visually appealing maps and visualizations to communicate their findings effectively. (16)

Scalability and Performance: Open Source GIS software is designed to be scalable, allowing users to work with large datasets and perform complex geospatial analysis tasks. The software is optimized for performance, ensuring that users can work efficiently with their data, even when dealing with large or complex projects (16)

I.4.7.3) Advantages of Open Source GIS:

One of the main advantages of Open Source GIS is its cost-effectiveness, as it eliminates the need for expensive software licenses. This makes Open Source GIS accessible to a wider range of users, including small organizations and individuals with limited budgets. Additionally, the open-source nature of the software promotes transparency and allows users to customize the software to meet their specific needs. Furthermore, the collaborative development model of Open Source GIS often leads to faster bug fixes and updates, ensuring that users have access to the latest features and improvements

I.4.8) Web Mapping and APIs

Web mapping refers to the process of creating, displaying, and interacting with maps on the internet. It involves the use of web technologies such as HTML, CSS, JavaScript, and various mapping libraries and APIs to present geographic information in a visual and interactive way. Web mapping allows users to view maps, overlay multiple layers of data, perform spatial analysis, and interact with geographic information through features such as zooming, panning, and querying. It has become an essential tool for accessing and sharing geospatial data and information online (17)

I.4.8.1) APIs for Web Mapping:

Application Programming Interfaces (APIs) play a crucial role in web mapping by providing developers with access to mapping libraries and geospatial data services. These APIs allow developers to integrate maps and geospatial functionalities into their web applications, enabling them to create custom mapping solutions tailored to their specific needs. APIs for web mapping often include functionalities for displaying maps, adding markers and overlays, performing geocoding and routing, and interacting with spatial data layers. Popular web mapping APIs include Google Maps API, Leaflet, and Open Layers, among others (17)

I.4.8.2) Key Components of Web Mapping

Base Maps*:* The foundational maps that provide context and background information for overlaying additional data layers.

Data Layers: Information overlays displayed on base maps, including points, lines, polygons, and raster images representing various spatial datasets.

Interactive Tools: Features that enable user interaction with maps, such as zooming, panning, querying data, measuring distances, and changing map styles.

Geocoding and Routing: Functions that allow users to search for locations on maps and find optimal routes between multiple points.

Visualization Techniques: Methods for displaying and representing spatial data effectively, such as thematic mapping, heat maps, and 3D visualization.

I.4.8.3) Benefits of Web Mapping APIs

Simplified Integration**:** APIs streamline the process of integrating maps and spatial data into web applications, reducing development time and complexity.

Customization Options: Developers can customize map styles, add interactive elements, and incorporate geospatial features tailored to specific requirements.

Geolocation Services**:** APIs provide geocoding, routing, and spatial analysis capabilities that enhance the functionality of web mapping applications.

Cross-Platform Compatibility: Web mapping APIs support seamless deployment across various devices and platforms, ensuring consistent user experiences.

I.4.9) Mobile GIS

Mobile GIS refers to the use of geographic information systems (GIS) on mobile devices such as smartphones, tablets, and other portable devices. It enables users to collect, store, analyze, and visualize geospatial data in the field, providing real-time access to spatial information and enhancing decision-making processes. Mobile GIS leverages the capabilities of mobile devices, such as GPS, camera, and wireless connectivity, to enable location-based data collection, navigation, and situational awareness

I.4.9.1) Key Features of Mobile GIS:

Mobile GIS applications offer several key features that enhance field data collection and analysis. These features include offline capabilities, which allow users to collect and store data in areas with limited or no internet connectivity. Mobile GIS applications also provide interactive mapping tools, enabling users to view and analyze spatial data in the field. GPS integration allows for real-time location tracking and data collection, while data synchronization features ensure that field data can be seamlessly integrated with desktop GIS systems. Overall, mobile GIS applications provide a flexible and efficient solution for field data collection and decision-making.

I.4.9.2) Components of Mobile GIS Technology

GPS (Global Positioning System): GPS is a critical component of Mobile GIS technology that provides accurate positioning information for mobile devices. It allows real-time tracking of the device's location, enabling users to collect geospatial data, navigate, and perform location-based analysis.

Applications of Mobile GIS: Mobile GIS finds extensive applications in fields such as urban planning, natural resource management, emergency response, and public health. It enables field data collection, asset management, environmental monitoring, and spatial analysis, supporting timely decision-making and enhancing operational efficiency

(18)

Mobile computing: refers to the use of portable computing devices to access, process, and transmit information on the go. It encompasses a broad range of technologies and applications that enable users to perform computing tasks using mobile devices, such as smartphones, tablets, laptops, and wearable device

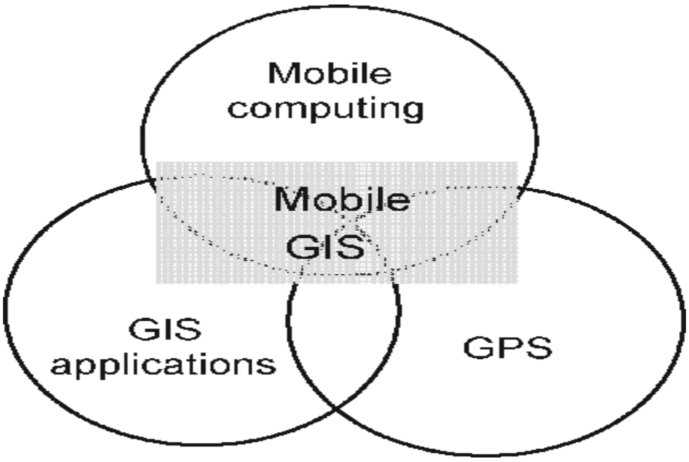


Figure 10: the components of Mobile GIS technology. (19)

I.4.9.3) Mobile GIS APIs

APIs play a crucial role in Mobile GIS, enabling developers to integrate geospatial functionalities into mobile applications. Mobile GIS APIs provide tools for embedding maps, capturing GPS data, conducting spatial analysis, and visualizing geospatial information on mobile devices. They also facilitate seamless integration with location-based services and geodatabases, empowering developers to create custom mobile GIS applications with tailored features and functionality (20)

I.4.9.4) Benefits of Mobile GIS APIs

Location-based Services: Mobile GIS APIs provide access to location-based services such as geocoding, routing, and geofencing, enhancing the spatial capabilities of mobile applications.

Real-time Data Collection: Developers can leverage mobile GIS APIs to collect and update spatial data in real-time, improving data accuracy and timeliness.

Enhanced User Experience: APIs enable the integration of interactive maps, geospatial analysis tools, and spatial visualization features, enhancing the user experience of mobile GIS applications.

Offline Functionality: Mobile GIS APIs support offline data storage and synchronization, allowing users to access and update spatial information in disconnected environments.

I.4.10) Spatial Data Infrastructure (SDI)

Spatial Data Infrastructure (SDI) is the infrastructure that facilitates the discovery, access, management, distribution, reuse, and preservation of digital geospatial resources2. These resources can include maps, data, geospatial services, and tools.SDI is similar to other types of infrastructure, such as electricity grids and water supplies, in that it plays a fundamental role in the socioeconomic and environmental development of a country or region. SDI enables the sharing and efficient use of geospatial data, reducing duplication of effort and costs (21)

I.4.10.1) Components of an SDI:

***Spatial Data*:** The foundation of SDI is spatial data, which includes geographic information such as maps, satellite imagery, and geospatial datasets. SDI aims to make spatial data more accessible and usable by standardizing data formats and metadata.

***Metadata**:* provides information about the spatial data, such as its source, quality, and accuracy. SDI includes standards for creating and managing metadata, ensuring that users can easily discover and evaluate spatial data.

Users: are a key component of SDI, as they are the ones who access and use spatial data to support decision-making processes. SDI aims to provide users with the tools and resources they need to find, access, and use spatial data effectively.

Tools: Software applications and services that allow users to access, analyze, and visualize spatial data.

Policies: SDI is supported by policies and guidelines that govern the collection, sharing, and use of spatial data. These policies help ensure that spatial data is managed responsibly and used effectively. (22)

CHAPTER TOW:

GEOSPATIAL DATA

II.1) The types of geospatial data

II.1.1) Vector data

in GIS represents geographic features as discrete geometric objects, such as points, lines, and polygons. Here’s a bit more detail about each type:

Points: Points are the simplest type of vector data and are used to represent features that can be located by a single coordinate pair, usually in x, and y format. Examples include locations of ATMs, tree positions in a forest, or the epic entre of an earthquake.

Lines: Lines are ordered sequences of points that represent the shape and location of linear features. Roads, rivers, and utility lines are often represented as lines. Each line is composed of multiple points, and the arrangement of these points determines the shape of the line.

Polygons: Polygons are close dloops of lines that enclose an area. They are used to represent features that have a defined area and boundary, such as buildings, lakes, or land use zones (residential, commercial, etc.). A polygon is essentially a line who se start and end points are the same, there by enclosing an area. (22)

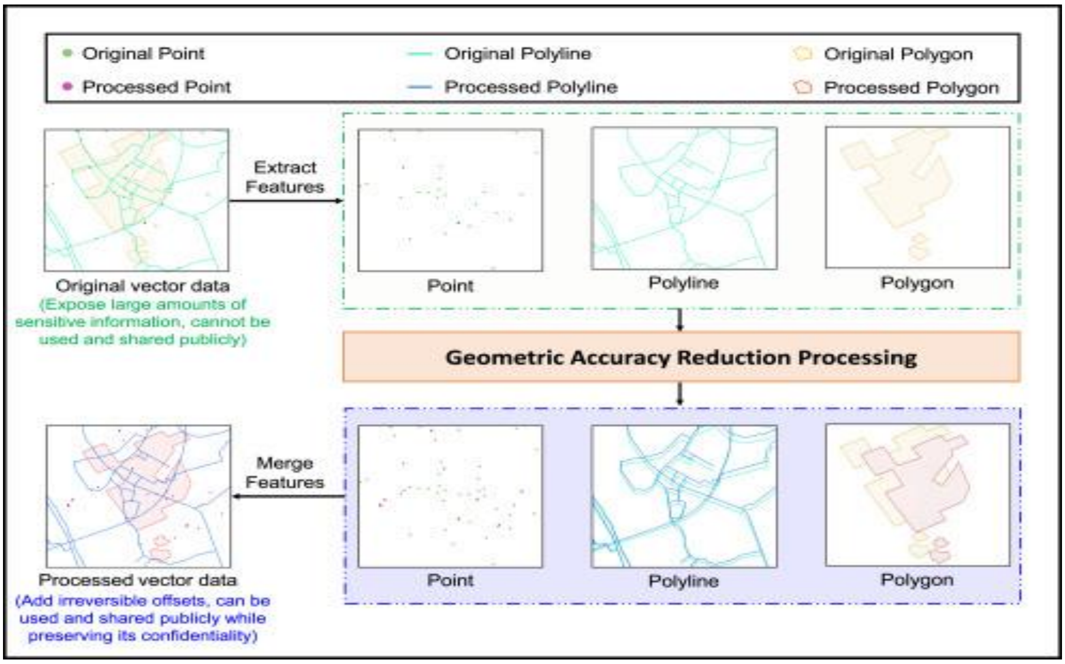


Figure 11:Geometric Accuracy Reduction processing for vector data

II.1.2) Raster data:

Raster data is a fundamental component of Geographic Information Systems (GIS), representing geographic phenomena as a grid of cells or pixels, each containing a value. This data type is prevalent in GIS due to it's versatility in representing various spatial phenomena. Continuous and discrete raster data are two main types commonly en countered:

Continuous Raster: This type of raster data represents continuously varying phenomena across space, such as elevation, temperature, precipitation, or slope. In a continuous raster dataset, each cell value corresponds to a measurement of the quantity of interest at that particular location. For example, in an elevation model, each cell value represents the height above sea level at that specific point on the Earth's surface.

Discrete Raster: Discrete raster data, on the other hand, represent phenomena with distinct categories or classes. Examples include land cover types, soil types, vegetation classes, or land use categories. Eachcell in a discrete raster data set is assigned a value corresponding to a specific class or category. For instance, in a land cover classification raster, eachcell value represents the land cover type (e.g., forest, urban, water) present in that area. (23)

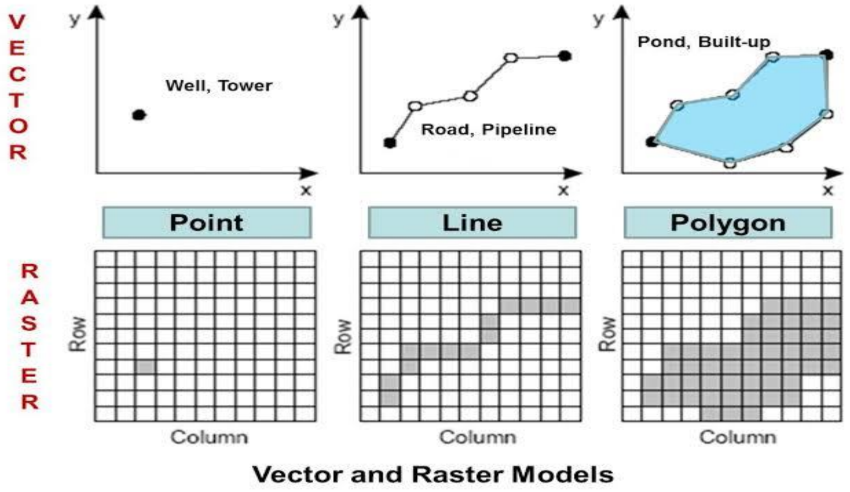


Figure 12:Vector and raster models

II.1.2.1) Characteristics of Raster Data:

Resolution

Resolution refers to the level of detail or granularity present in a raster dataset. It is determined by the size of the grid cells or pixels used to represent the data. Higher resolution datasets have smaller cells, resulting in finer spatial detail and greater accuracy. Conversely, lower resolution datasets have larger cells, leading to reduced detail but potentially smaller file sizes and faster processing times.

Pixel Depth (Bit Depth)

Pixel depth, also known as bit depth, refers to the number of bits used to represent each pixel in a raster dataset. It determines the range of values that can be assigned to each pixel, which in turn affects the precision and accuracy of the data. Higher pixel depth allows for a greater range of values and more nuanced representation of continuous phenomena, such as elevation or temperature. Common pixel depths include 8-bit (256 levels), 16-bit (65,536 levels), and 32-bit (over 4 billion levels).

Spatial Reference System

Raster data is georeferenced using a spatial reference system (SRS), which assigns coordinate values to each cell in the dataset based on its geographic location. This enables the raster data to be accurately positioned on the earth's surface and integrated with other geospatial datasets. Common spatial reference systems include latitude and longitude coordinates (e.g., WGS84) and projected coordinate systems (e.g., UTM, State Plane).

Data Format

Raster data can be stored in various file formats, each with its own characteristics and advantages. Common raster data formats include TIFF (Tagged Image File Format), JPEG (Joint Photographic Experts Group), PNG (Portable Network Graphics), and GeoTIFF (Georeferenced Tagged Image File Format). The choice of data format depends on factors such as compression requirements, compatibility with software and hardware, and support for geospatial metadata.

Data Structure

Raster data is organized into a regular grid of cells or pixels, with each cell containing a value representing a specific attribute or phenomenon. This grid structure allows for efficient storage and processing of spatial data and facilitates operations such as querying, analysis, and visualization. Raster datasets may also include metadata, such as cell size, coordinate system information, and data source details, to provide context and facilitate interpretation. (22)

II.1.2.2) Raster Data Formats:

Grids: organize spatial data into a regular grid of cells, where each cell represents a specific geographic location and contains attribute information. This format is commonly used for representing continuous phenomena such as elevation, temperature, and land cover.

Grids are a fundamental component of raster data formats within Geographic Information Systems (GIS). In GIS, raster data represents spatial information as a grid of cells, where each cell corresponds to a specific geographic location on the Earth's surface. These cells are organized in rows and columns, creating a regular and structured framework for storing and analyzing spatial data.

One of the defining characteristics of grids in GIS is their uniformity. Unlike vector data formats, where geographic features are represented as discrete points, lines, or polygons, raster data divides the Earth's surface into a grid of equally sized cells. Each cell covers a specific area on the ground and is assigned a value that represents a particular attribute, such as elevation, land cover type, temperature, precipitation, or any other continuous geographic phenomenon. (22)

Images: Images represent spatial information as digital images captured by remote sensing instruments or digital cameras. These images can be aerial photographs, satellite imagery, scanned maps, or any other type of visual representation of the Earth's surface.

One of the primary uses of images in GIS is for remote sensing, which involves the collection and analysis of spatial data from a distance, typically using satellite or aerial sensors. Remote sensing images provide valuable information about land cover, land use, vegetation health, urban development, and environmental changes over time. In addition to remote sensing, images are also used in GIS for cartography, visualization, and analysis purposes. Digital elevation models (DEMs) derived from satellite imagery or airborne LiDAR data are used to represent terrain elevation and support various applications such as flood modeling, slope analysis, and viewshed analysis. (24)

JPEG (***Joint Photographic Experts Group):*** Widely used for storing and transmitting photographic images on the web and in digital cameras. It offers lossy compression, which reduces file size but may result in some loss of image quality.

PNG: (Portable Network Graphics): PNG is commonly used for web graphics and images with transparency. It supports lossless compression, preserving image quality without sacrificing file size. PNG is often used for maps, diagrams, and icons in GIS applications.

TIFF (Tagged Image File Format): TIFF is a flexible format widely used in professional imaging applications. It supports multiple layers, transparency, and a wide range of color depths. TIFF files are commonly used for high-quality aerial and satellite imagery in GIS.

GeoTIFF: GeoTIFF is a variation of the TIFF format that includes georeferencing information. It is widely used for storing spatially referenced raster data in GIS applications, making it suitable for aerial imagery, digital elevation models, and satellite imagery.

JPEG2000*:* JPEG2000 is an advanced image compression standard that offers improved image quality and compression efficiency compared to JPEG. It is commonly used for high-resolution satellite imagery and medical imaging applications.

ECW (Enhanced Compression Wavelet): ECW is a proprietary raster image format developed by ERDAS for efficient storage and transmission of large geospatial datasets. It provides high compression ratios while preserving image quality, making it suitable for aerial and satellite imagery.

BMP (Bitmap): BMP is a simple raster image format commonly used in Windows environments. It supports uncompressed image data and is suitable for storing small images and icons.

GIF (Graphics Interchange Format): GIF is commonly used for simple graphics and animations on the web. It supports lossless compression and transparency but is less suitable for photographs due to its limited color depth.

ESRI File Geodata base (.gdb):

File Geodatabases are proprietary data formats developed by ESRI for storing and managing spatial data in a file-based structure.

They support multiple datasets, including feature classes, tables, raster datasets, and network datasets.

File Geodatabases provide efficient data storage and management capabilities, making them suitable for large-scale GIS projects. (25)

II.1.2.3)Types of raster data

- ***Satellite Imagery:***

Satellite imagery refers to raster data captured by satellites orbiting the Earth.

It provides visual representations of the Earth's surface, capturing various features such as land cover, urban areas, water bodies, and natural phenomena

Satellite imagery can be acquired in different spectral bands, including visible, near-infrared, and thermal infrared, allowing for the extraction of valuable information about the Earth's surface and atmosphere.

These images are widely used in GIS for tasks such as land cover classification, change detection, environmental monitoring, disaster assessment, and urban planning.

- ***Digital Elevation Models (DEMs):***

DEMs represent the elevation of the Earth's surface as a grid of regularly spaced elevation values.

They provide a detailed three-dimensional representation of terrain features, including mountains, valleys, hills, and plains.

DEMs are derived from various sources, including airborne LiDAR (Light Detection and Ranging) surveys and satellite-based radar or stereo imagery.

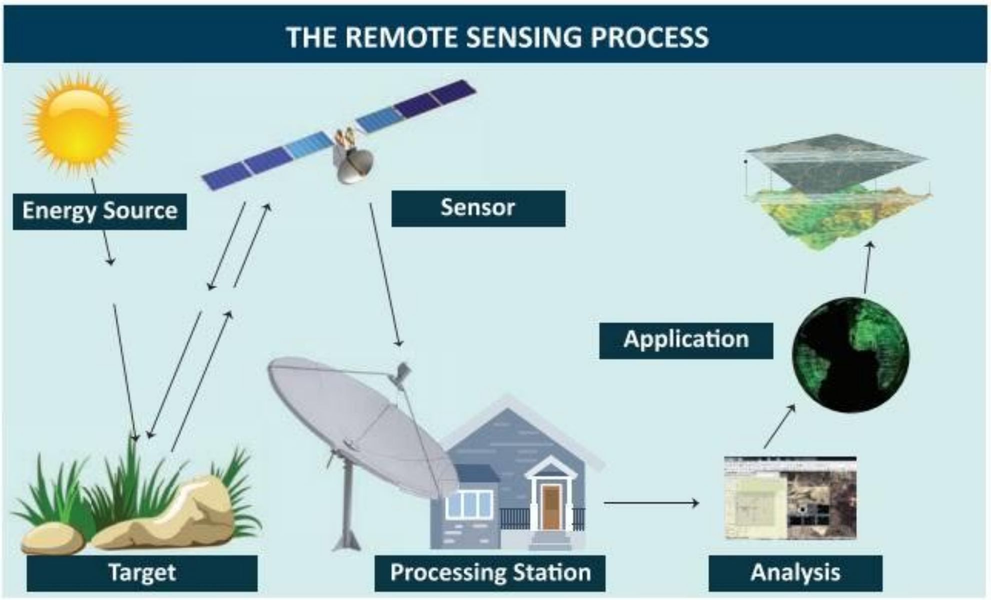
These models are essential for terrain analysis, hydrological modeling, slope analysis, viewshed analysis, and visualization of landscapes in GIS applications. (22)

II.2) Data Acquisition Methods:

II.2.1) Collecting New Data:

- ***Remote Sensing:***

Remote sensing involves the acquisition of spatial data from a distance, typically using sensors mounted on satellites, aircraft, drones, or ground-based platforms. Remote sensing data includes imagery (such as satellite images and aerial photographs) and non-imagery data (such as LiDAR point clouds and thermal infrared data). Remote sensing is used to capture information about the Earth’s surface, atmosphere, and oceans, and is valuable for monitoring environmental changes, land cover mapping, and disaster assessment.



(28)

Figure 13:The remote sensing process

Global Positioning System (GPS): GPS is a satellite-based navigation system that provides accurate positioning information in real-time. GPS receivers are used to collect spatial data with precise location coordinates (latitude, longitude, and sometimes elevation) on the Earth’s surface. GPS data acquisition is commonly used for mapping, navigation, asset tracking, and field data collection tasks in GIS.

Field Surveys: Field surveys involve collecting spatial data directly from the field using surveying equipment such as total stations, GPS receivers, and surveying instruments. Field surveys may include measurements of land boundaries, topographic features, infrastructure assets, environmental parameters, and other spatial attributes. Field surveys are essential for creating accurate base maps, updating GIS databases, and validating remote sensing data.

(26)

Ground truthing: is a crucial process in remote sensing and GIS. It involves validating data obtained from satellite imagery or other remote sensing methods by comparing it with real-world, on-the-ground observations. Here are five key points:

1. ***Purpose and Importance***:

- Ground truthing ensures the accuracy and reliability of remotely sensed data.
- It helps confirm whether features identified in satellite images truly exist on the ground.

2. ***Field Verification:***

- Field teams visit specific locations to collect ground-level data.
- They verify the presence of features such as roads, buildings, vegetation, or land cover classes.

3. ***Sampling Strategy:***

- Ground truthing involves selecting representative sample points across the study area.
- These points are visited, and observations are recorded.

4. ***Challenges:***

- Ground truthing can be time-consuming and resource-intensive.
- Factors like weather conditions, accessibility, and safety must be considered.

5. Applications:

- Ground truthing is essential for land cover classification, change detection and environmental monitoring.
- It ensures that remote sensing data aligns with the reality on the ground. (27)

II.2.2) Sharing/Exchanging Data

Data Interpolation: Data interpolation techniques involve estimating values for unmeasured locations based on known data points. Common interpolation methods include inverse distance weighting, kriging, spline interpolation, and nearest neighbor interpolation. Interpolation is used to fill in missing values in raster datasets, generate contour lines, and create continuous surfaces from point data.

II.2.3) Converting/Transforming Legacy Data :

Data Conversion and Digitization: Data conversion involves converting existing analog or digital data into a digital GIS-compatible format. Digitization is the process of manually tracing features from scanned maps, aerial photographs, or other sources to create digital vector datasets. Data conversion and digitization are used to create GIS datasets from historical maps, engineering drawings, and other legacy data sources.

Web-based Data Sources: Web-based data sources provide access to spatial data over the internet through online mapping services, web GIS platforms, and data portals. These sources offer a wide range of spatial data layers, including base maps, satellite imagery, demographic data, environmental data, and real-time sensor data. Web-based data sources are valuable for accessing up-to-date information, conducting spatial analysis, and sharing GIS data with stakeholders.

Figure 14:Web Gis ecosystem (28)

II.3) Free Geospatial data provider:

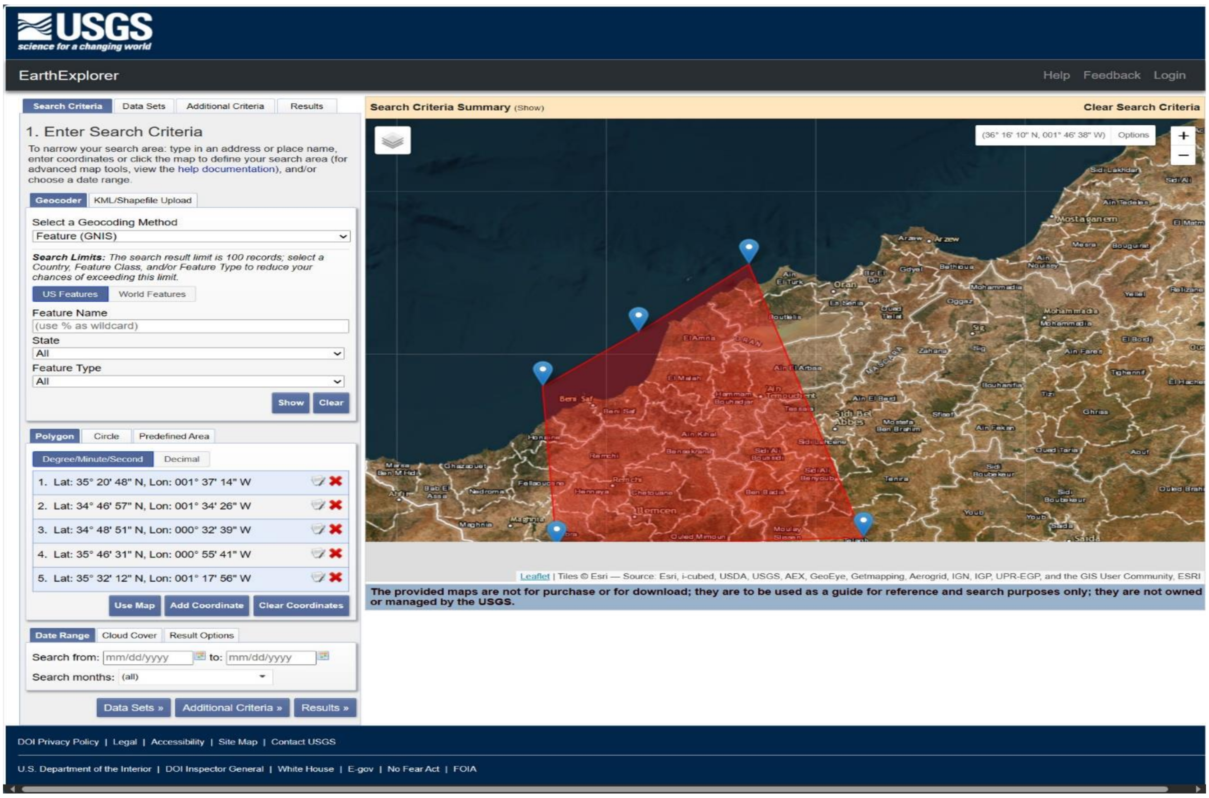
We live in the information age. We get blasted by truckloads of information each day. In terms of free GIS data sources, it seems never-ending.

In other words: There are many GIS datasets, and among them these ten free ones are the best

II.3.1) USGS Earth Explorer:

The USGS Earth Explorer is a web-based platform providing access to an extensive collection of satellite and aerial imagery, as well as other geospatial data products. It allows users to search, visualize, and download data from various Earth observation missions such as Landsat, Sentinel, and MODIS. The platform supports a wide range of applications including environmental monitoring, land cover mapping, and natural resource management. Users can specify their search criteria based on location, date, sensor type, and data format to retrieve relevant datasets. USGS Earth Explorer is widely used by researchers, government agencies, and the general public for access

(29)



1. Enter Search Criteria

To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the help documentation), and/or choose a date range.

Select a Geocoding Method: Feature (GNIS)

Search Limits: The search result limit is 100 records; select a Country, Feature Class, and/or Feature Type to reduce your chances of exceeding this limit.

Feature Name: (use % as wildcard)

State: All

Feature Type: All

1. Lat: 35° 20' 48" N, Lon: 001° 37' 14" W
2. Lat: 34° 46' 57" N, Lon: 001° 34' 26" W
3. Lat: 34° 48' 51" N, Lon: 000° 32' 39" W
4. Lat: 35° 46' 31" N, Lon: 000° 55' 41" W
5. Lat: 35° 32' 12" N, Lon: 001° 17' 56" W

Search from: mm/dd/yyyy to: mm/dd/yyyy

Search months: (all)

(36° 16' 10" N, 001° 46' 38" W)

Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, ESRI

The provided maps are not for purchase or for download; they are to be used as a guide for reference and search purposes only; they are not owned or managed by the USGS.

Figure 15: USGS Earth explorer interface

II.3.1.1) Advantages :

Satellite imagery is worldwide and not just within the United States.

User interface is state-of-the-art with easy-to-use filters.

Data Visualization Tools: The platform offers built-in tools for data visualization, allowing users to preview and explore datasets before downloading them. This helps users assess data quality and suitability for their needs.

Download Options: USGS Earth Explorer provides multiple download options, including direct download links, bulk download capabilities, and the ability to order data on physical media for larger datasets.

Support for Various Applications: The data available through USGS Earth Explorer supports a wide range of applications including land cover mapping, environmental monitoring, natural resource management, disaster response, and scientific research.

II.3.1.2) Data Types:

1) *Aerial imagery*:

refers to photographs or raster images of the Earth's surface captured from an elevated position, typically from an aircraft. The images are commonly used for mapping, land use planning, environmental studies, and infrastructure development. Aerial imagery provides high-resolution visuals of the landscape, offering detailed information about land cover, land use, and topographic features.

2) Satellite Imagery

Satellite imagery involves visual or digital images of the Earth's surface captured by satellites orbiting the planet. These images are utilized for various applications such as environmental monitoring, urban planning, agriculture, and disaster response. Satellite imagery provides a consistent and comprehensive view of the Earth's surface, offering insights into changes over time and supporting spatial analysis.

3) Digital Elevation Models (DEM)

Digital Elevation Models are digital representations of the Earth's topography, providing elevation data for specific geographic locations. DEMs are crucial for terrain analysis, watershed modeling, and natural resource management. They are widely used in geographic information systems to visualize and analyze changes in elevation across landscapes.

4) Land Cover Data

Land cover data represents the physical material at the Earth's surface, such as vegetation, water, or impervious surfaces. It is used for monitoring urbanization, habitat assessment, and environmental impact analysis. Land cover data provides valuable information for understanding the distribution of different surface features and for assessing changes in land use over time.

5) Land Use Data

Land use data captures the activities and human interventions on the land, including categories such as residential, commercial, industrial, agricultural, and recreational uses. This data is essential for urban planning, zoning, and understanding the human-environment interaction.

6) Hydrologic Data

Hydrologic data encompasses information related to the distribution, movement, and properties of water on Earth. It includes data on rivers, streams, lakes, watersheds, and hydrological infrastructure. Hydrologic data is important for water resource management, flood modeling, and environmental impact assessments.

7) Geologic Data

Geologic data comprises information about the Earth's structure, composition, and geological formations. It includes data on rock types, fault lines, mineral deposits, and geological hazards. Geologic data is critical for geological mapping, mineral exploration, and assessing geological risks for infrastructure development.

8) Vegetation Index Data

Vegetation index data measures the health, density, and vigor of vegetation. It is derived from remote sensing data and is valuable for monitoring vegetation growth, assessing crop health, and detecting changes in land cover due to deforestation or land degradation.

9) Thermal Infrared Data

Thermal infrared data captures the thermal radiation emitted by the Earth's surface. It is used to assess land surface temperatures, detect heat anomalies, and study the thermal characteristics of different land cover types. Thermal infrared data has applications in environmental monitoring, urban heat island analysis, and energy efficiency assessments.

10) Topographic Maps

Topographic maps are detailed and accurate graphic representations of natural and man-made features on the Earth's surface. These maps depict elevation contours, water bodies, vegetation, and cultural features such as roads and buildings. Topographic maps are essential for navigation, land use planning, and outdoor recreational activities.

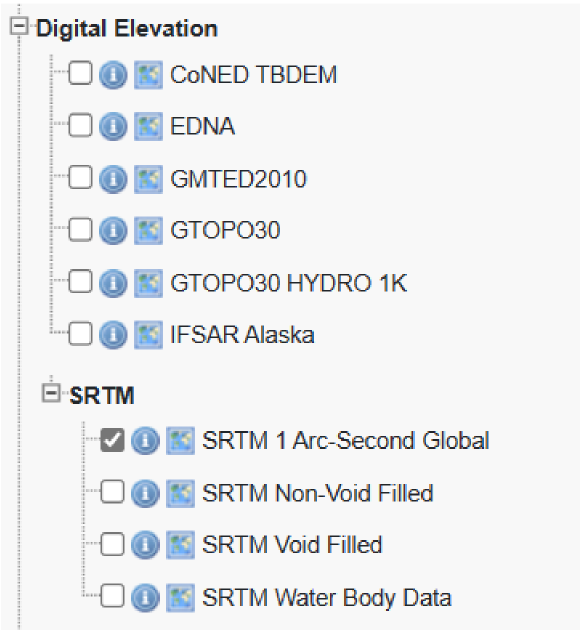
Each type of geospatial data plays a critical role in various fields such as environmental science, urban planning, natural resource management, and emergency response. These data sources provide valuable information for understanding the Earth's surface and supporting informed decision-making.

II.3.1.3) Disadvantages

Not all of these data types are offered freely by USGS, and it's important to note that not all data cover the entire terrestrial globe. Availability and coverage may vary depending on the specific dataset and its sources.

The use of the USGS platform, particularly Earth Explorer, requires a certain level of knowledge to explore, select the data source, and data type. For example, the SRTM product, which represents a digital elevation model, is offered in four categories: SRTM 1 arc-second global, SRTM non-void filled, SRTM void filled, and SRTM water body data. This can make it difficult to make the right choice without referring to the SRTM documentation.

Additionally, the platform offers other products besides SRTM, as illustrated in the screenshot in the figure below

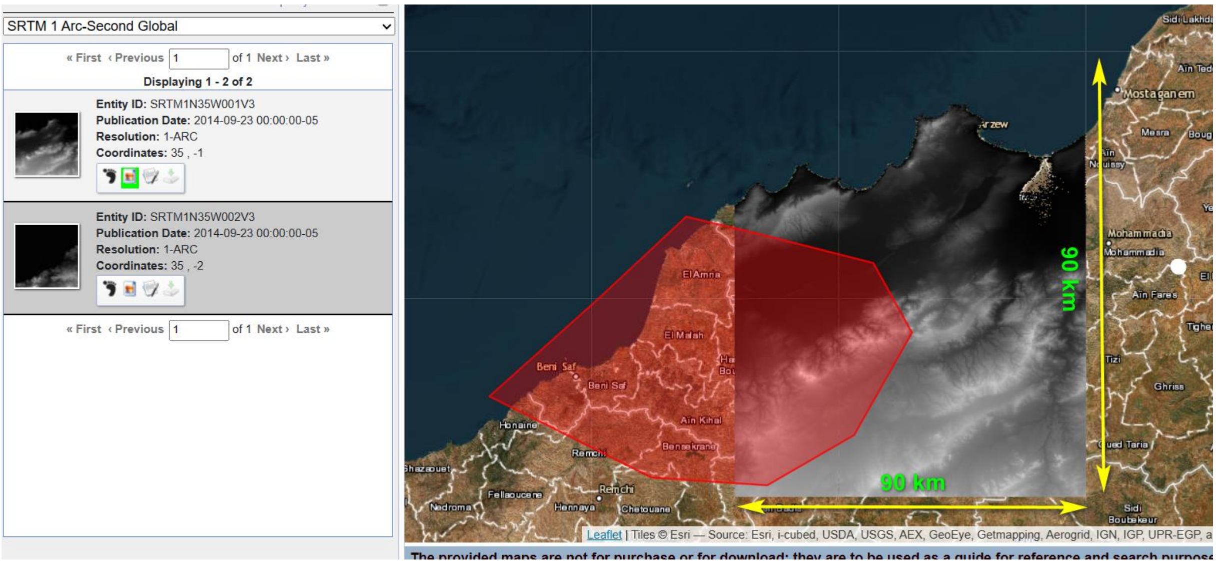


Digital Elevation
- ☐ CoNED TBDEM
- ☐ EDNA
- ☐ GMTED2010
- ☐ GTOPO30
- ☐ GTOPO30 HYDRO 1K
- ☐ IFSAR Alaska

SRTM
- ☑ SRTM 1 Arc-Second Global
- ☐ SRTM Non-Void Filled
- ☐ SRTM Void Filled
- ☐ SRTM Water Body Data

Figure 16 : List of DEM dataset source offred by Earth explorer (USGS) (29)

The second disadvantage is due to the limitation of the coverage area covered by each SRTM file. For example, as shown in the figure below, to cover the Ain Temouchent province, we need at least 2 files. Furthermore, we also need to crop the area according to the administrative division.



SRTM 1 Arc-Second Global

« First ‹ Previous 1 of 1 Next › Last »

Displaying 1 - 2 of 2

Entity ID: SRTM1N35W001V3
Publication Date: 2014-09-23 00:00:00-05
Resolution: 1-ARC
Coordinates: 35 , -1

Entity ID: SRTM1N35W002V3
Publication Date: 2014-09-23 00:00:00-05
Resolution: 1-ARC
Coordinates: 35 , -2

« First ‹ Previous 1 of 1 Next › Last »

Figure 17:Area covered by SRTM file (Earth explorer)

II.3.1.4) Free Satellite Imagery from Authoritative Sources

The latest satellite viewlike:

LANDSAT*:* Silently, Landsat has been circling our planet archiving historical satellite imagery. As early as today, it uploads it to the USGS Earth Explorer.

SPY SATELLITES: Imagine being able to look back more than 50+ years in the past. How much would that be worth? Spy satellite imagery like CORONA has been declassified over the years and is completely available to the public.

HYPERSPECTRAL*:* If you don't know what hyper spectral imagery is, it's like having spectral detail on steroids. Hyperion was the experimental instrument imagined by NASA. Now, Earth Explorer is the only place where you can download this hyper spectral imagery. (30)

II.3.2) Natural Earth Data

Natural Earth Data is a public domain dataset providing vector and raster map data at various scales. It includes global coverage of geographic features such as coastlines, rivers, and political boundaries. The dataset is designed for cartographic use and supports map creation for print, web, and multimedia applications. Natural Earth Data is widely used by cartographers, educators, and researchers for creating high-quality maps. It offers detailed and accurate geographic information suitable for a wide range of mapping purposes. The data is freely available and can be used, modified, and redistributed without restrictions. (31)

About: Unlike many datasets which were designed for measurement and analysis, Natural Earth was made for cartography.

Data Available: Shape files of the world, individual countries, states, communities, railroads, airports, parks, physical features, raster imagery, and much more-- all of which can be easily stylized to make any map look visually stunning. Many of the features come paired with corresponding attribute information. Vector downloads are available in ESRI Shape file Format. Rasters are downloaded as TIFF files, with TFW world file

II.3.2.1) Natural Earth organizes its data into three categories:

Cultural Vectors:

You will find a range of vector data specifically for different map scales for example, it includes the following cultural features:

- Administrative boundary lines (countries, states, provinces, populated places, urban areas, and disputed areas).
- Transportation (airports, roads, railways, and sea ports).
- Geographic lines and graticules.

Physical Vector Data:

For physical features, it contains a mix of hydrography, terrain, and ocean features. For example, it includes the following:

- Hydrography (Oceans, rivers, and lakes).
- Terrain (Mountain peaks, major and minor islands).
- Ocean (Coastlines, coral reefs, and ocean bathymetry).

Raster Data

The raster datasets consist of low-resolution grids on a global scale. These are perfect for continental or global scale base maps.

- Cross-blended hypsometric tints.
- Ocean bottom bathymetry.
- Shaded relief and gray Earth. (30)

II.3.2.2) Advantages

Download global free GIS data in the public domain.

Supported by the North American Cartographic Information Society (NACIS).

Global Coverage: Natural Earth data provides global coverage of geographic features, including coastlines, rivers; lakes, political boundaries, and land cover, making it suitable for mapping projects anywhere in the world.

Consistent Quality: The dataset maintains a consistent level of quality and accuracy across different geographic features and scales, ensuring reliable and trustworthy cartographic results.

Ease of Use: Natural Earth data is easy to access and use, with downloadable files available in multiple formats (shape file, GeoJSON, raster) for compatibility with various GIS and mapping software. (31)

II.3.3) Open Street Map

OpenStreetMap (OSM) is a collaborative project that creates a free editable map of the world. The data in OpenStreetMap is crowdsourced and constantly updated by volunteers, providing a detailed and up-to-date map that can be used for various purposes. OSM data includes information about streets, trails, cafés, railway stations, and much more, comprising a wide variety of geographic features globally.

Businesses, educational institutions, governments, and individuals utilize OSM data for applications ranging from navigation and location-based services to urban planning and disaster response. The open nature of OSM data allows for extensive customization and adaptation to specific requirements, making it a valuable resource in the field of geospatial information. (32)

II.3.3.1) Benefits of Open Street Map for GIS Mapping

One of the key advantages of OSM is that it is free to use and open-source. This means that you can access, use, and modify the map data for your own purposes without any cost or licensing restrictions.

Additionally, OSM is maintained and updated by a global community of volunteers. This means that the map data is continuously improving and evolving, with regular updates and additions being made by contributors around the world.

Furthermore, OSM provides extensive coverage of the world, including detailed mapping of rural areas and developing countries. This makes it a valuable resource for GIS mapping projects that require comprehensive and up-to-date geographical data

II.3.3.2) Using Open Street Map for GIS Mapping

You can access OSM data through various means, including the OSM website, which provides access to the map data through an interactive map interface. You can also download raw OSM data in a variety of formats, including XML and GeoJSON.

OSM data is available in a variety of formats that are compatible with most GIS software, including Arc GIS and QGIS. This makes it easy to integrate OSM data into your GIS mapping projects and use it alongside other data sources.

Many GIS software packages, such as QGIS, have built-in support for OSM data, allowing you to easily import and use OSM data in your projects. This makes it easy to incorporate OSM data into your GIS mapping workflow.

II.3.3.3) Data structure

The data structure of Open Street Map (OSM) is based on the concept of key-value pairs assigned to geographic elements. Here's a basic overview:

Nodes: These represent individual points on the map and are defined by their latitude and longitude coordinates. They can be used to mark specific locations, such as landmarks or points of interest.

Ways*:* Ways are ordered lists of nodes that represent linear features such as roads, rivers, or boundaries. They can have tags that describe the characteristics of the feature they represent, such as the type of road or the name of a river.

Relations*:* Relations are used to describe more complex relationships between elements, such as the members of a road network or the boundaries of a multi-polygon area. Relations can contain nodes, ways, and other relations as members.

Each of these elements can have tags associated with them, which provide additional information about the element. Tags are key-value pairs that describe attributes such as the name of a feature, its type, and any other relevant information.

Overall, the data structure of Open Street Map is flexible and allows for the representation of a wide range of geographic features and their attributes.

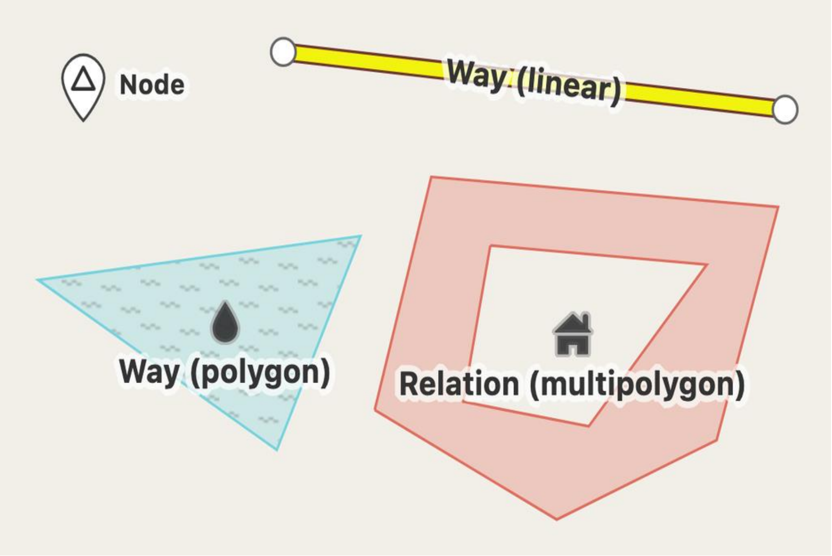


Figure 18: Elements of a Geospatial Mapping System. (32)

II.3.3.4) Data sources

Open Street Map (OSM) primarily relies on several data sources for its map data, which are contributed by volunteers and organizations worldwide. Some of the key data sources include:

User contributions: The primary source of data for OSM is contributions from its community of users. Volunteers collect and edit map data using various editing tools provided by OSM.

GPS devices: Users can contribute to OSM by recording GPS tracks while traveling and uploading them to the platform. These tracks can then be used to add or update map features.

Aerial imagery: OSM uses aerial and satellite imagery from sources such as Bing Maps, Map box, and others to trace map features. This helps improve the accuracy and detail of the map.

Government data: In some cases, government agencies and organizations release geospatial data under open licenses, which can be imported into OSM to improve the map's coverage and detail.

Crowd sourcing: OSM occasionally conducts mapping parties and other events to encourage local communities to contribute data to the map.

Third-party data imports: OSM sometimes imports data from third-party sources, such as public transportation schedules or building footprints, to enhance the map's detail and accuracy.

Software: Open Street Map applications utilize multiple components to provide services. The map data is rendered using pre-generated tiles for various levels of zoom. Editing applications typically support display of imagery, and field mapping data in the form of GPS traces and voice, photo, video annotations to aid in editing map. JOSM, ID, Street Complete, Rapid, Potlatch are the top 5 editing tools for contributions during 2018–2023 according to a study by Heigit (32)

II.3.3.5) Features of OSM:

Geospatial Data: OSM provides vector data representing geographic features across the globe.

Customizable Maps: Users can create customized maps by selecting specific layers and styles.

API Access: Developers can access OSM data via APIs for integration into their applications.

Routing and Navigation: OSM data supports routing and navigation services.

II.3.4) NASA Earth data

II.3.4.1) Introduction:

NASA's Earthdata platform serves as a crucial entry point, providing unrestricted access to an extensive array of Earth observation data gathered by NASA. This portal is supported by the Earth Science Data Systems (ESDS) Program which oversees data management from various sources such as satellites, aircraft, and ground-based measurements. Managing these diverse data sources ensures a seamless end-to-end process for handling Earth observation data

examples of NASA Earth data

Landsat satellite imagery: Landsat is a series of Earth-observing satellites that have been collecting satellite imagery since the 1970s. The most recent Landsat satellite, Landsat 8, provides images with a resolution of 30 meters, making it useful for mapping features such as roads and buildings.

ASTER topographic data: The Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) is a instrument aboard the Terra satellite that provides high-resolution topographic data. ASTER data has a resolution of 30 meters for topographic features and 90 meters for thermal data.

Shuttle Radar Topography Mission (SRTM) data: SRTM is a joint mission between NASA and the National Geospatial-Intelligence Agency (NGA) that provides high-resolution digital elevation models (DEMs) of the Earth's surface. SRTM data has a resolution of 30 meters and is available for most of the Earth's land surface.

II.3.4.2) Importance of NASA Earth data

Scientific Advancement: Accessing NASA's Earth observation data accelerates scientific progress by providing researchers, scientists, and educators with valuable information to study and understand Earth's processes and systems.

Informed Decision-Making: The availability of diverse Earth science datasets allows policymakers, environmental organizations, and government agencies to make informed decisions regarding environmental conservation, resource management, and disaster response.

Global Impact: By monitoring air quality, tracking wildfires, and studying surface water levels, NASA's data contributes to addressing global environmental challenges and health threats, fostering a more sustainable and resilient planet.

Educational Resources: Earthdata provides a rich repository of educational resources, enabling students, teachers, and the general public to engage with real-world Earth science data, fostering environmental literacy and awareness

II.3.4.3) Delving into Earth Science: Exploring with Earthdata

Within the Earthdata platform, users can engage in the exploration of NASA’s Earth science data by selecting discipline-specific icons tailored to their areas of interest. This interactive feature allows for a personalized journey through NASA's vast collection of Earth science datasets, facilitating in-depth research and analysis

II.3.4.4) Earthdata's Key Features and Tools for Exploration

Earthdata offers several notable features and tools to enhance the user experience. The Worldview tool, integrated into NASA's Earth Observing System Data and Information System (EOSDIS), enables users to navigate through over 1,000 high-resolution global satellite imagery layers. Additionally, Earthdata advocates for open science principles, monitors air quality globally, and provides valuable resources for tracking wildfires and assessing surface water through specialized missions

II.3.4.5) Environmental Justice and NASA's Contributions

The NASA Environmental Justice Data Search Interface within Earthdata facilitates the exploration of numerous datasets related to environmental and climate justice. This platform empowers users to delve into crucial data sets that shed light on issues of environmental equity and climate resilience (29)

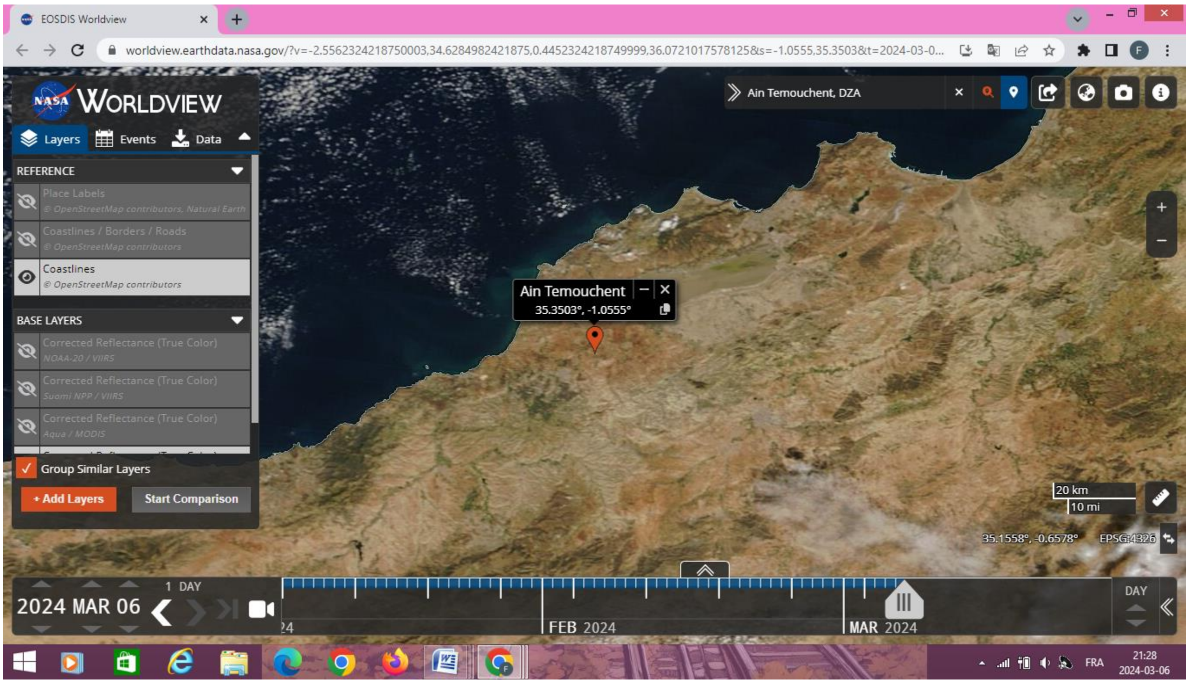


Figure 19 : Interface of NASA Earth Data

II.3.5) US Census Bureau's TIGER/Line Data

The US Census Bureau's TIGER/Line Data stands for Topologically Integrated Geographic Encoding and Referencing system. It is a digital mapping database that contains information about the geographic features of the United States. TIGER/Line Data is widely used by government agencies, businesses, researchers, and the general public for a variety of purposes.

II.3.5.1) importance of TIGER/Line Data

TIGER/Line Data plays a crucial role in a wide range of applications, including urban planning, transportation planning, emergency response, and natural resource management. The data is used to create maps, analyze spatial patterns, and make informed decisions about a variety of issues.

II.3.5.2) Origins of TIGER/Line Data

The TIGER/Line Data program was launched in the early 1990s to improve the accuracy and completeness of the Census Bureau's geographic databases. Since then, the program has undergone several updates and enhancements to keep pace with changing technology and user needs.

II.3.5.3) Evolution and updates

The TIGER/Line Data program has evolved over the years to include a wide range of geographic information, including roads, rivers, lakes, political boundaries, and demographic data. The database is updated regularly to reflect changes in the landscape, such as new roads, subdivisions, and other developments.

II.3.5.4) Geographic coverage

TIGER/Line Data covers the entire United States, including all 50 states, the District of Columbia, and Puerto Rico. The data is organized into a series of layers, each representing a different type of geographic feature.

II.3.5.5) Types of data included

TIGER/Line Data includes a wide range of geographic information, such as:

- Roads and highways.
- Rail roads.
- Rivers, lakes, and other bodies of water.
- Political boundaries (e.g., state, county, and municipal boundaries).
- Census tracts and blocks.
- Landmarks and points of interest.

II.3.5.6) Government applications

Government agencies use TIGER/Line Data for a variety of purposes, including:

- Census data collection and analysis
- Emergency response planning
- Transportation planning
- Environmental protection
- Land use planning

II.3.5.7) Commercial applications

Businesses use TIGER/Line Data to:

- Create maps for marketing and sales purposes.
- Analyze market trends and consumer behavior.
- Plan logistics and distribution routes.

II.3.5.7) Data accuracy

One of the challenges of using TIGER/Line Data is ensuring its accuracy. While the data is generally reliable, errors can occur due to changes in the landscape or inaccuracies in the original source data.

II.3.5.8) Data complexity

TIGER/Line Data is complex and can be difficult to work with, especially for users who are not familiar with geographic information systems (GIS). However, there are a number of tools and resources available to help users navigate the data and extract the information they need. (33)

II.3.6) The Copernicus Open Access Hub:

The Copernicus Open Access Hub is a free and open-access data repository for the Earth Observation (EO) data provided by the European Union's Earth Observation Program, Copernicus. The data is acquired by the Sentinel satellites and is available to users worldwide, without any restrictions or limitations. The Open Access Hub provides access to a wide range of EO data products, including optical and radar imagery, land cover maps, and atmospheric data.

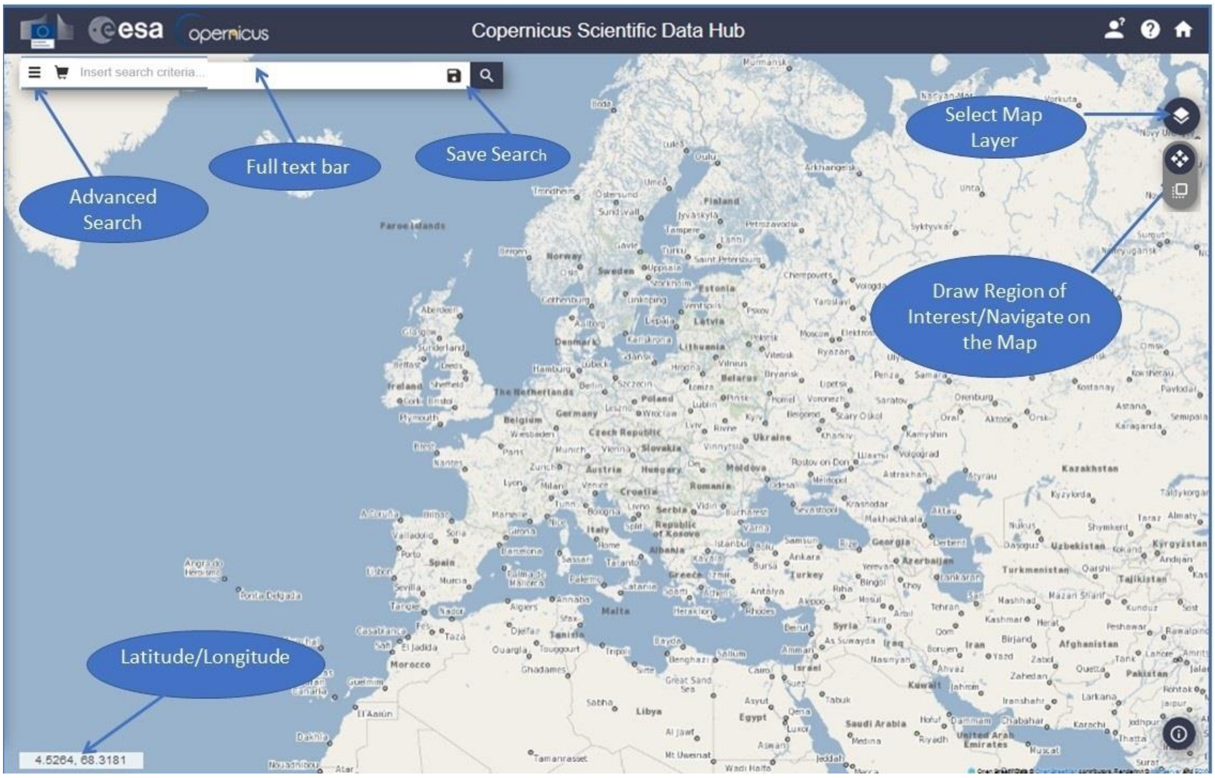


Figure 20:Interface of The Copernicus Open Access Hub (34)

II.3.6.1) Importance of Copernicus Open Access Hub:

The Copernicus Open Access Hub is an important resource for researchers, scientists, and professionals working in various fields, such as environmental monitoring, urban planning, disaster management, and agriculture. The data provided by the Hub can be used for a variety of purposes, including land cover mapping, change detection, surface deformation analysis, and crop monitoring.

II.3.6.2) Origins of Copernicus Open Access Hub:

The Copernicus Open Access Hub is a part of the European Union's Copernicus Program, which was launched in 2014 to provide free and open access to EO data and information. The Hub is operated by the European Space Agency (ESA) and is funded by the European Commission.

II.3.6.3) Evolution and updates:

The Copernicus Open Access Hub has undergone several updates and enhancements since its launch, with new features and improvements being added regularly. The Hub now provides access to data from the Sentinel-1, Sentinel-2, and Sentinel-3 satellites, with new data being added daily.

II.3.6.4) Geographic coverage:

The Copernicus Open Access Hub provides data for the entire globe, with a focus on Europe. The data is organized into different "products," each representing a different geographic area and time period.

II.3.6.5) Types of data included:

The Copernicus Open Access Hub provides access to a wide range of EO data products, including:

Optical imagery (Sentinel-2): This type of data is collected by sensors that detect light in various wavelengths, providing information about the Earth's surface in visible and near-infrared bands. Examples of optical imagery available in the Copernicus Open Access Hub include data from the Sentinel-2 and Landsat missions.

Radar imagery (Sentinel-1): This type of data is collected by sensors that emit and detect radar signals, providing information about the Earth's surface in microwave bands. Radar imagery can be used to detect changes in the Earth's surface, even in cloudy or dark conditions. The Copernicus Open Access Hub provides access to data from the Sentinel-1 mission.

Land cover maps: The Copernicus Open Access Hub provides access to global land cover maps through the Copernicus Land Monitoring Service (CLMS). These maps are delivered annually and are available at a resolution of 100 meters. They are generated from satellite observations from the PROBA-V mission and other ancillary datasets. The land cover maps provide a main discrete classification map according to the UN-FAO Land Cover Classification System LCCS. Additionally, continuous fractional layers for all basic land cover classes, which give the percentage of a 100 m pixel that is filled with a specific land cover class, are also included in the Land Cover.

Atmospheric data (Sentinel-4 and Sentinel-5): The Copernicus Open Access Hub also provides access to data about the Earth's atmosphere, such as atmospheric temperature, humidity, and composition. These data are collected by sensors on satellites such as Sentinel-4 and Sentinel-5.

Ocean color data (Sentinel-3): The Copernicus Open Access Hub provides access to data about the color of the ocean, which can be used to measure the concentration of phytoplankton and other marine organisms. These data are collected by sensors on satellites such as Sentinel-

3

II.3.6.6) Commercial applications:

Businesses use the Copernicus Open Access Hub to:

- Create maps and visualizations for marketing and sales purposes.
- Analyze market trends and consumer behavior.
- Plan logistics and distribution routes.

II.3.6.7) Data accuracy:

The data provided by the Copernicus Open Access Hub is generally reliable and accurate, with a high spatial resolution and a wide range of spectral bands. However, users should be aware of the limitations and assumptions associated with each product and should use appropriate data processing techniques to ensure accurate results.

II.3.6.8) Data complexity:

The Copernicus Open Access Hub provides a wide range of data products, each with its own format, structure, and metadata. Users should be familiar with the data processing techniques and software required to work with the data and should consult the documentation and user guides provided by the Hub.

II.3.7) The Global Land Cover Facility (GLCF)

The Global Land Cover Facility (GLCF) is a renowned organization that provides comprehensive land cover data and related services to the global community. Established in [year], GLCF has been a pioneer in land cover research, contributing significantly to environmental studies, natural resource management, and sustainable development.

The GLCF is currently working on various land-use and land-cover change mapping efforts using data from the Landsat series of sensors. The GLCF recently created the first globally consistent Landsat-based estimates of Earth's surface reflectance and made the data publicly available online. The Global Forest Cover Change project, funded by the NASA MEaSUREs program, is mapping changes in Earth's forest cover at sub-hectare resolution using the NASA/USGS Global Land Survey datasets circa 1975, 1990, 2000 and 2005. The GLCF will supply the earth-system modeling community a much needed high–resolution, multi-temporal record of forest cover that will be instrumental in monitoring and under-standing forest cover changes and their global implications.

II.3.7.1) History and Background of GLCF

GLCF was founded with the vision of creating a centralized hub for land cover data that could be easily accessible and utilized by researchers, policymakers, and the public worldwide. Over the years, the facility has amassed a vast collection of high-quality land cover datasets, ranging from satellite imagery to ground-based observations.

II.3.7.2) Objectives and Mission of GLCF

The primary objective of GLCF is to facilitate the study and understanding of global land cover dynamics. By providing access to reliable data and tools, GLCF aims to support research efforts aimed at addressing critical environmental challenges, such as deforestation, urbanization, and climate change.

II.3.7.3) Data Collection and Processing Methods

GLCF employs a variety of remote sensing techniques and data processing algorithms to collect and analyze land cover data. These methods include satellite imaging, aerial photography, and ground-based surveys, which are used to create detailed land cover maps and datasets.

II.3.7.4) Applications of GLCF Data

The data provided by GLCF has a wide range of applications in various fields, including agriculture, forestry, urban planning, and biodiversity conservation. It is used to monitor deforestation rates, assess the impact of land use changes on ecosystems, and develop strategies for mitigating climate change.

II.3.7.5) File type

GeoTIFF (Tagged Image File Format): This is a widely used format for georeferenced raster data. GeoTIFF files include georeferencing information, allowing the data to be easily integrated into Geographic Information Systems (GIS) and other software for analysis.

ArcGrid: This is a raster format specific to Esri's ArcGIS software. ArcGrid files are used to store and manipulate geospatial raster data, such as satellite imagery and land cover maps.

NetCDF (Network Common Data Form): This is a self-describing, machine-independent data format for storing multidimensional arrays of arbitrary size and shape, together with metadata, such as descriptions of the data and ancillary information.

II.3.7.6) data types.

The most common data types available include:

Satellite imagery: GLCF provides satellite data from various sensors, such as Landsat, MODIS, and AVHRR. These images are captured at different resolutions and cover various spectral bands, allowing researchers to study land cover and land cover change.

Land cover classifications: GLCF offers land cover maps that categorize Earth's surface into different classes, such as forests, urban areas, croplands, and sand dunes. These classifications can be used to analyze and understand the distribution of land cover types.

Land cover change maps: GLCF also provides land cover change maps that show where and how land cover has changed between two points in time. These maps are crucial for understanding the dynamics of land cover change and its drivers.

Figure 21:The types of GLCF

II.3.8) National Centers for Environmental Information (NCEI)

II.3.8.1) Introduction to NOAA National Centers for Environmental Information (NCEI)

The NOAA National Centers for Environmental Information (NCEI) is a federal agency that serves as the nation's leading authority for environmental data, including climate, weather, oceans, and coasts. It was established to provide comprehensive access to the nation's environmental data and information, with a focus on long-term climate monitoring and data stewardship.

II.3.8.2) History and Background

NCEI has its roots in the early 19th century, with the establishment of the National Oceanic and Atmospheric Administration (NOAA) in 1970. Over the years, NOAA's focus on environmental data collection and analysis led to the formation of NCEI in 2015, through the merger of three existing NOAA data centers.

II.3.8.3) Mission and Goals:

NCEI's mission is to provide scientific stewardship of environmental data, ensuring its long-term preservation, integrity, and accessibility. The agency aims to support informed decision-making, advance scientific research, and promote environmental awareness and understanding.

II.3.8.4) Key Services Offered

NCEI offers a range of services to support its mission, including:

Data Access and Archives: NCEI maintains a vast archive of environmental data, including historical climate data, satellite observations, and oceanographic data.

Climate Monitoring: NCEI monitors and analyzes global climate patterns, providing essential information for climate research and forecasting.

Environmental Assessments: NCEI conducts assessments of environmental trends and impacts, helping to inform policy decisions and resource management.

International Collaboration: NCEI collaborates with international partners to share data and expertise, supporting global environmental monitoring and research efforts.

II.3.8.5) Significance of NCEI

NCEI plays a crucial role in climate change research, providing essential data and analysis for understanding climate trends and impacts. The agency also supports disaster response and preparedness efforts, providing critical information for emergency planning and response. Additionally, NCEI's data and assessments are used to inform policy-making at the national and international levels.

II.3.8.6) Future Outlook and Challenges

Looking ahead, NCEI faces several challenges, including the need to adapt to changing environmental conditions and technological advancements. The agency will continue to focus on expanding its data archives, improving data accessibility, and enhancing its research capabilities to meet the evolving needs of the environmental science community.

II.3.8.7) Types of GIS Data Offered by NCEI:

Climate Data: NCEI provides a wide range of climate-related GIS datasets, including temperature, precipitation, and drought indices. These datasets are valuable for understanding long-term climate trends and variability.

Weather Data: NCEI offers GIS datasets related to current and historical weather conditions, such as temperature, humidity, wind speed, and atmospheric pressure. These datasets are useful for weather forecasting and analysis.

Oceans and Coasts Data: NCEI provides GIS datasets on oceanic and coastal conditions, including sea surface temperature, sea level rise, coastal erosion, and marine biodiversity. These datasets are essential for studying marine environments and coastal ecosystems.

Geophysical Data: NCEI offers GIS datasets related to geophysical phenomena, such as earthquakes, tsunamis, volcanoes, and magnetic anomalies. These datasets are crucial for understanding geological processes and natural hazards.

Environmental Hazards Data: NCEI provides GIS datasets on environmental hazards, including wildfires, floods, hurricanes, and landslides. These datasets are valuable for disaster management and risk assessment.

Historical Data: NCEI offers GIS datasets containing historical information, such as past climate conditions, land use changes, and natural disasters. These datasets are useful for studying long-term environmental trends and impacts.

Satellite Data: NCEI provides GIS datasets derived from satellite observations, including imagery, land cover maps, and vegetation indices. These datasets are valuable for monitoring and assessing environmental changes on a global scale.

Land Use Data: NCEI offers GIS datasets on land use and land cover, including urban areas, agricultural land, and natural habitats. These datasets are valuable for land management and planning purposes. (35)

II.3.9) European Space Agency (ESA) Earth Online

The European Space Agency (ESA) plays a pivotal role in advancing our understanding of Earth and its environment through its Earth observation programs. One such program is Earth Online, an online platform that provides access to a wealth of Earth observation data and tools..

The European Space Agency (ESA) offers a wide range of Earth observation data products and resources through its Earth Online portal. This platform serves as a centralized access point for various missions and datasets, providing direct access to satellite data, operational news, events, and tools in support of data use (ESA PR 43-2006). Users can access data from ESA's Third-Party Missions and Heritage missions programs through a Fast Registration mechanism. Additionally, ESA coordinates the acquisition and delivery of data for Europe’s Copernicus program, which includes the Sentinel missions. The Sentinel online website provides technical information and access to the data systematically processed and available online. For higher resolution data, users may check the Copernicus Contributing Missions website, which offers data free of charge to eligible users following registration and confirmation of their user category.

II.3.9.1) The Access to Earth Online

Accessing Earth Online is simple and straightforward. Users can visit the Earth Online website and create an account to access the platform. Once logged in, users can browse and download a wide range of Earth observation data, as well as access tools for processing and analyzing this data.

II.3.9.2) Importance of Earth Observation

Earth observation plays a crucial role in understanding and monitoring Earth's environment. By collecting data from space, scientists can track changes in the atmosphere, oceans, and land surfaces. This information is invaluable for studying climate change, predicting natural disasters, and managing natural resources.

II.3.9.3) Data Sources

In the realm of Earth observation and GIS, the availability and quality of data are paramount. ESA's Earth Online platform draws from various sources, ranging from satellites and sensors in space to ground-based measurements, ensuring comprehensive coverage and accuracy in its datasets.

Satellites and Sensors

Satellites equipped with advanced sensors form the backbone of Earth observation initiatives. These satellites capture high-resolution imagery and collect a wide array of data across different spectral bands. ESA operates a fleet of satellites, including the Sentinel series, which are specifically designed for environmental monitoring and resource management. These satellites capture imagery with varying spatial and temporal resolutions, catering to diverse user needs and applications.

Ground-Based Measurements

While satellite imagery provides a macroscopic view of the Earth's surface, ground-based measurements offer detailed insights into local environmental conditions. Ground-based sensors, weather stations, and other monitoring devices collect data on parameters such as temperature, precipitation, soil moisture, and air quality. ESA collaborates with national agencies and research institutions to integrate ground-based measurements into its Earth observation programs, enhancing the accuracy and reliability of its datasets.

Data Processing and Integration

The sheer volume of data generated by satellites and ground-based sensors necessitates sophisticated data processing and integration techniques. ESA employs advanced algorithms and processing workflows to preprocess raw data, correct for atmospheric effects, and derive actionable information. Data integration involves the fusion of multi-source datasets, including satellite imagery, ground-based measurements, and geospatial datasets, to create comprehensive and interoperable datasets. By harmonizing data formats and standards, ESA ensures seamless access and interoperability across its Earth observation platforms, empowering users to harness the full potential of geospatial data for decision-making and analysis.

II.3.9.4) Future Developments and Potential of ESA Earth Online

ESA Earth Online continues to evolve to meet the growing demands of Earth observation users. Future developments include improvements in data processing algorithms, enhancements in data fusion techniques, and greater integration with other Earth observation systems. These developments are expected to further enhance the platform's capabilities and expand its potential applications in the future. (36)

II.3.10) United Nations Geospatial Information Section:

The United Nations Geospatial Information Section (UNGIS) is a vital component of the United Nations' efforts to harness the power of geospatial information for sustainable development and humanitarian assistance. UNGIS plays a crucial role in collecting, analyzing, and disseminating geospatial data to support decision-making processes within the UN system and its Member States.

Geospatial information, which includes data related to geographic features, populations, and resources, is essential for understanding and addressing complex global challenges.

UNGIS works to ensure that this information is accurate up-to-date, and accessible to decision-makers, planners, and analysts across the United Nations.

Through its work, UNGIS contributes to the achievement of the United Nations' Sustainable Development Goals (SDGs) by providing the necessary tools and information to monitor progress and identify areas where interventions are needed.

II.3.10.1) Importance of Geospatial Information

Geospatial information plays a crucial role in understanding the Earth's surface and its dynamics. It provides spatial context to various phenomena, enabling better decision-making, planning, and management of resources and activities.

II.3.10.2) Role of the United Nations in Geospatial Information Management

The United Nations (UN) recognizes the significance of geospatial information for sustainable development, disaster management, environmental conservation, and socio-economic planning. As such, it actively promotes the use of geospatial data and technologies among member states and facilitates collaboration in geospatial information management.

II.3.10.3) Services Provided by UNGI:

Geospatial Visualization: UNGIS offers services in creating maps and visual representations of data. This involves utilizing geospatial technologies to present information in a spatial context, aiding in the communication and understanding of complex data sets.

Data Management: UNGIS is involved in handling and organizing geospatial datasets. Efficient data management is crucial for ensuring the accuracy, accessibility, and usability of geospatial information for various applications and decision-making processes.

Analysis: UNGIS conducts spatial analyses to extract meaningful insights from geospatial data. By applying analytical tools and techniques, UNGIS helps in deriving valuable information that can support evidence-based decision-making within the United Nations system.

Technology Support: UNGIS provides assistance with geospatial tools and software. This includes offering guidance on the use of geospatial technologies, recommending appropriate tools for specific tasks, and supporting the implementation of geospatial solutions within UN offices and departments. (12)

II.3.10.4) Mapping for Sustainable Development Goals (SDGs):

UNGIS collaborates with the International Cartographic Association to map the SDGs and publishes best practices in cartography to illustrate progress toward achieving the SDGs. Geospatial data is highlighted as playing a vital role in monitoring and achieving sustainable development targets.

II.3.10.5) Key Documents and Frame works:

Geospatial Strategy for the United Nations: UNGIS has developed a strategy to enable location information for the UN Secretariat and collaborates with the UN Geospatial Network and Member States to enhance geospatial data ecosystems.

Blueprint Geospatial for a Better World: This strategic document, prepared by the UN Geospatial Network, guides geospatial activities across seven transformation pathways focusing on improving lives, places, and the planet through geospatial information.

Integrated Geospatial Information Framework (IGIF): Adopted by UN-GGIM, the IGIF provides guidelines for geospatial information management with the goal of bridging the digital divide, promoting socio-economic prosperity, and leaving no one behind. (12)

II.4) Free Geospatial data satellites

II.4.1) LANDSAT

II.4.1.1) Origins of the Landsat Program:

The Landsat program originated in the mid-1960s through a collaboration between the United States’ National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), and the Department of Agriculture.

II.4.1.2) Purpose of the Landsat Program:

The primary objective of the Landsat program was to offer civilian Earth observation data from space. Landsat satellites capture images of the Earth's land surface, facilitating scientists, researchers, and policymakers to track and analyze changes occurring over time, aiding in various fields such as environmental monitoring, agriculture, urban planning, and natural resource management.

This program has played a crucial role in advancing our understanding of Earth's dynamic landscape and has become a fundamental resource for monitoring and managing our planet's resources and environment.

II.4.1.3) Characteristics of Landsat Satellites

Landsat 8 (LDCM)

Landsat 8, launched in 2013, is part of the Landsat program, a joint initiative of the US Geological Survey (USGS) and NASA. It continues the legacy of its predecessors, providing invaluable data for understanding and managing Earth's resources.

Applications of Landsat 8 Data

Environmental Monitoring

Landsat 8 plays a crucial role in monitoring environmental changes such as deforestation, urban expansion, and land degradation. Its data are instrumental in assessing the impact of human activities on the environment.

Agriculture

For agriculture, Landsat 8 provides valuable information for crop monitoring, yield prediction, and drought assessment. Farmers and policymakers use this data to make informed decisions and optimize agricultural practices.

Urban Planning

In urban areas, Landsat 8 imagery is used for urban planning, infrastructure development, and monitoring of urban growth. It helps cities plan sustainable development strategies and mitigate environmental impacts.

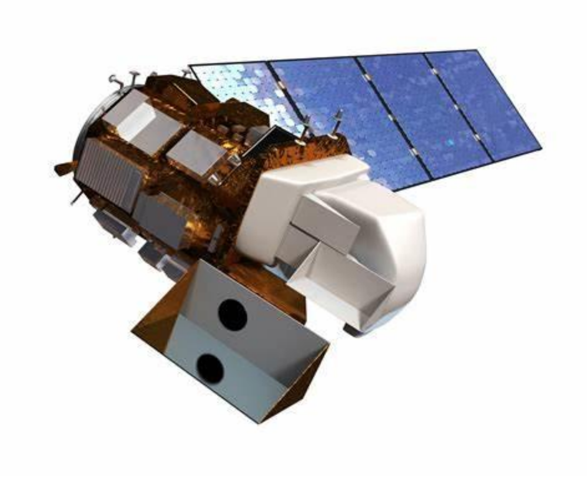


Figure 22:Landsat 8

Landsat9

In April 2015, NASA announced its intention to order a new Landsat 9 satellite. It was ordered from Orbital ATK in October 2016 for a sum of $130 million, which includes ground support during the primary mission but does not include the provision of instruments and the launch. The satellite adopts the architecture and instrumentation of Landsat 8. Like Landsat 8, it is a 2.8-ton satellite using the Leostar-3 platform from Orbital ATK. The instruments are the Ball Aerospace & Technologies OLI-2 multispectral camera and the TIRS-2 multispectral radiometer developed directly by the Goddard Space Flight Center. The launch - originally planned for 2023 - was moved up to December 2020 and then to September 2021 to allow for the replacement of Landsat 7, which was launched in 1999 and in 2016 depleted its fuel the reserves. satellite also serves as a backup for Landsat 8, launched in 2013. (37)

Expanded Applications and Benefits

The enhanced capabilities of Landsat 9 open up new possibilities for applications in various fields. For environmental monitoring, Landsat 9 provides valuable data for tracking changes in land cover, deforestation, and urbanization. In agriculture, the satellite's imagery is used for crop monitoring, yield prediction, and drought assessment. Additionally, Landsat 9's data are valuable for urban planning, natural resource management, and disaster response.

Uses of Landsat imagery

Landsat data provides information that allows scientists to predict the distribution of species, as well as detecting both naturally occurring and human-generated changes over a greater scale than traditional data from fieldwork. The different spectral bands used on satellites in the Landsat program provide many applications, ranging from ecology to geopolitical matters. Land cover determination is a common use of Landsat imagery around the world. Landsat imagery provides one of the longest uninterrupted time series available from any single remote sensing program, spanning from 1972 to the present. Looking to the future, the successful launch of Landsat-9 in 2021 shows that this time series will continue forward.

A false-color image of irrigated fields near Garden City, Kansas, taken by the Landsat 7 satellite.

In 2015, the Landsat Advisory Group of the National Geospatial Advisory Committee reported that the top 16 applications of Landsat imagery produced savings of approximately 350 million to over 436 million dollars each year for federal and state governments, NGOs, and the private sector. That estimate did not include further savings from other uses beyond the top sixteen categories. The top 16 categories for Landsat imagery use, listed in order of estimated annual savings for users, are:

- U.S. Department of Agriculture risk management
- U.S. Government mapping
- Agricultural water use monitoring
- Global security monitoring
- Support for fire management
- Detection of forest fragmentation
- Detection of forest change
- World agriculture supply and demand estimates
- Vineyard management and water conservation
- Flood mitigation mapping
- Agricultural commodities mapping
- Waterfowl habitat mapping and monitoring
- Coastal change analysis
- Forest health monitoring
- National Geospatial-Intelligence Agency global shoreline mapping
- Wildfire risk assessment

Further uses of Landsat imagery include, but are not limited to: fisheries, forestry, shrinking inland water bodies, fire damage, glacier retreat, urban development, and discovery of new species. A few specific examples are explained below. (12)

II.4.2) Sentinel

II.4.2.1) Introduction to Sentinel

The Sentinel program is an ambitious Earth observation initiative led by the European Space Agency (ESA) in partnership with the European Commission (EC). It aims to provide a wealth of data and information to support a wide range of environmental and societal applications. Through a series of satellite missions equipped with advanced sensors, the Sentinel program offers global, timely, and freely accessible data, revolutionizing the way we monitor and understand our planet.

II.4.2.2) The Sentinel Program

The Sentinel Program, an initiative led by the European Space Agency (ESA) in collaboration with the European Commission (EC), is a groundbreaking Earth observation effort. This program comprises a constellation of satellites equipped with cutting-edge sensors that provide high-quality, timely, and freely accessible data for various applications. The Sentinel satellites monitor Earth's environment, supporting activities such as environmental protection, climate change monitoring, disaster management, and urban planning. This program's open data policy allows users worldwide to access and use Sentinel data, contributing to a better understanding of our planet and its changes.

II.4.2.3) The Components of the Sentinel Program

Sentinel Satellites

The Sentinel program currently consists of several satellite missions, each focusing on different aspects of Earth observation. These satellites are equipped with a variety of sensors, including radar and optical instruments, to capture data about the Earth's surface, atmosphere, and oceans.

Sentinel-1**:** The Sentinel-1 mission comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather.

Sentinel-1 will work in a pre-programmed operation mode to avoid conflicts and to produce a consistent long-term data archive built for applications based on long time series. (38)

Sentinel-2: Sentinel-2 is a multispectral imaging mission designed to monitor changes in the Earth's land surface, including vegetation, forests, and urban areas. It is equipped with a high-resolution optical instrument that captures images in 13 spectral bands, allowing for detailed analysis of land cover and land use changes.

Sentinel-3: Sentinel-3 is a mission dedicated to monitoring the Earth's oceans, land surfaces, and atmosphere. It is equipped with a suite of instruments that measure sea surface temperature, ocean color, sea level, and land surface temperature, among other parameters. Sentinel-3 data is used for applications such as marine pollution monitoring, ocean circulation studies, and monitoring of land and vegetation health.

Sentinel-5P**:** Sentinel-5P is a mission focused on monitoring the Earth's atmosphere. It is equipped with a spectrometer that measures trace gases in the atmosphere, including pollutants such as nitrogen dioxide, ozone, and carbon monoxide. Sentinel-5P data is used for air quality monitoring, climate research, and atmospheric composition studies.

Sentinel Hub:

Sentinel Hub is a powerful platform that provides easy access to Sentinel satellite imagery.

It offers a range of features, including:

Global Coverage**:** Access imagery from anywhere on Earth.

Custom Scripting**:** Define your own processing scripts to extract specific information.

Time-Lapse Functionality**:** Observe changes over time.

Multi-Temporal Processing**:** Analyze data from different dates.

Preconfigured EO Products**:** Choose from various preprocessed products. (38)

II.4.2.4) Sentinel Applications

The data collected by the Sentinel satellites is used for a wide range of applications, including environmental monitoring, disaster management, and urban planning. For example, Sentinel data can be used to monitor changes in land use, track deforestation, and assess the impact of natural disasters.

Environmental Monitoring: Sentinel satellites provide valuable data for monitoring environmental changes on Earth. They are used to track deforestation, urbanization, land use changes, and water quality. The data from Sentinel satellites helps researchers and policymakers better understand the impact of human activities on the environment and develop strategies for conservation and sustainable development.

Natural Disasters: Sentinel satellites are instrumental in monitoring and responding to natural disasters such as floods, wildfires, earthquakes, and volcanic eruptions. The high-resolution images and data they provide can help emergency responders assess the extent of damage, plan evacuation routes, and allocate resources more effectively.

Agriculture and Forestry: Sentinel satellites are used in agriculture to monitor crop health, estimate crop yields, and assess soil moisture levels. In forestry, they are used to track deforestation, monitor forest health, and plan reforestation efforts. The data from Sentinel satellites can help farmers and foresters make informed decisions about crop management and land use.

Climate Studies: Sentinel satellites play a crucial role in studying and monitoring the Earth's climate. They provide data on sea surface temperature, ice cover, vegetation, and greenhouse gas concentrations. This data is used by climate scientists to track changes in the Earth's climate over time, understand the drivers of these changes, and develop models to predict future climate trends.

II.4.3) POLARIS

II.4.3.1) Overview of POLARIS

Polaris is a project brought together by a team of contributors from around the world and Libre Space Foundation.

Polaris is an open-source tool used for the exploration and analysis of satellite telemetry data by building machine learning models. It is built on Python and uses the telemetry data provided by the SATNOGS network. The models are used for better understanding and predicting more accurately the behaviour of a satellite. By analysing telemetry and other data sources and converting the data into useful information for spacecraft operators.

II.4.3.2) Machine Learning Models

Polaris also offers a range of machine learning models that can be used to predict future trends and outcomes based on historical data. These models are highly customizable and can be tailored to suit specific data sets and analytical requirements.

II.4.3.3) Graph Visualization

Graph visualization is another area where Polaris excels. It provides a range of tools for creating and manipulating graphs, making it easier to visualize complex data relationships and dependencies.

II.4.3.4) Benefits of Polaris

Open-Source: Polaris is open-source, meaning it is freely available to use and can be customized to suit individual needs.

User-Friendly Interface*:* Polaris features a user-friendly interface that makes it easy to navigate and use, even for those with limited technical expertise.

Scalability: Polaris is highly scalable, making it suitable for analyzing large data sets and handling complex analytical tasks.

II.4.3.5) Use Cases

Polaris has a wide range of use cases across various industries and domains. Some common use cases include:

Financial Analysis: Polaris can be used to analyze financial data and predict market trends.

Healthcare: Polaris can help healthcare providers analyze patient data and improve treatment outcomes.

Manufacturing: Polaris can be used to optimize production processes and reduce costs.

II.4.4) MODIS

II.4.4.1) Overview of modis

MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra

MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MODIS is playing a vital role in the development of validated, global, interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment.

II.4.4.2) The MODIS Data

MODIS (Moderate Resolution Imaging Spectroradiometer) is an essential program that utilizes sensors on two satellites, providing complete daily coverage of the Earth.

MODIS operates on both the Terra and Aqua spacecraft.

It has a viewing swath width of 2,330 km and captures data from the entire Earth’s surface approximately every one to two days.

The instrument measures 36 spectral bands spanning wave lengths from 0.405 µm to 14.385 µm.

Data is acquired at three spatial resolutions: 250m, 500m, and 1,000m.

II.4.4.3) Land Cover

The MODIS instrument tracks land use change by examining its spectral properties over the land. For example, the 500-meter MODIS Land Cover Maps (17 land cover classes) describe the dominant class based on a 10-year span (2001-2010). Additionally, there is a 23-class ESA global land cover product available at 1km resolution

II.4.4.4) Applications

With its high temporal resolution although low spatial resolution, MODIS data are useful to track changes in the landscape over time. Examples of such applications are the monitoring of vegetation health by means of time-series analyses with vegetation indices,long term land cover changes (e.g. to monitor deforestation rates) global snow cover trends, water inundation from pluvial, riverine, or sea level rise flooding in coastal areas, change of water levels of major lakes such as the Aral Sea, and the detection and mapping of wildland fires in the United States.The United States Forest Service's Remote Sensing Applications Center analyzes MODIS imagery on a continuous basis to provide information for the management and suppression of wildfires. (12)

II.4.4.5) Data Acquisition and Transmission:

Data Transfer: MODIS data, along with data from other instruments on Terra and Aqua, are transmitted to ground stations in White Sands, New Mexico, using the Tracking and Data Relay Satellite System (TDRSS).

Data Delivery: Following transmission, the data reach the EOS Data and Operations System (EDOS) at the Goddard Space Flight Center.

Data Processing and Distribution:

Data Processing: Various data products are generated by the MODIS Adaptive Processing System (MODAPS) at the Goddard Space Flight Center.

Distribution Channels: The produced data products are then distributed to different Distributed Active Archive Centers (DAACs) where they are made available to users for further analysis and utilization.

Ocean Color Products: Ocean color products are created separately by the Ocean Color Data Processing System (CDPS), which may stream data to specific DAACs or distribution channels specialized in oceanic data.

CHAPTER THREE:

APPLICATION

III.1) Presentation of Used GIS software:

"Global Mapper is a comprehensive geographic information system (GIS) software developed by Blue Marble Geographic. Renowned for its versatility and user-friendly interface, Global Mapper provides powerful tools for data visualization, analysis, and modeling. With support for over 250 spatial data formats, including raster, vector, and elevation data, the software empowers users to import, manipulate, and export geospatial data with ease. Its advanced features encompass terrain analysis, spatial analysis, LiDAR processing, and map publishing, making it an indispensable tool for professionals across diverse fields such as natural resource management, urban planning, environmental monitoring, and geologic exploration."

In our case, we used the last version of Global mapper 25.1

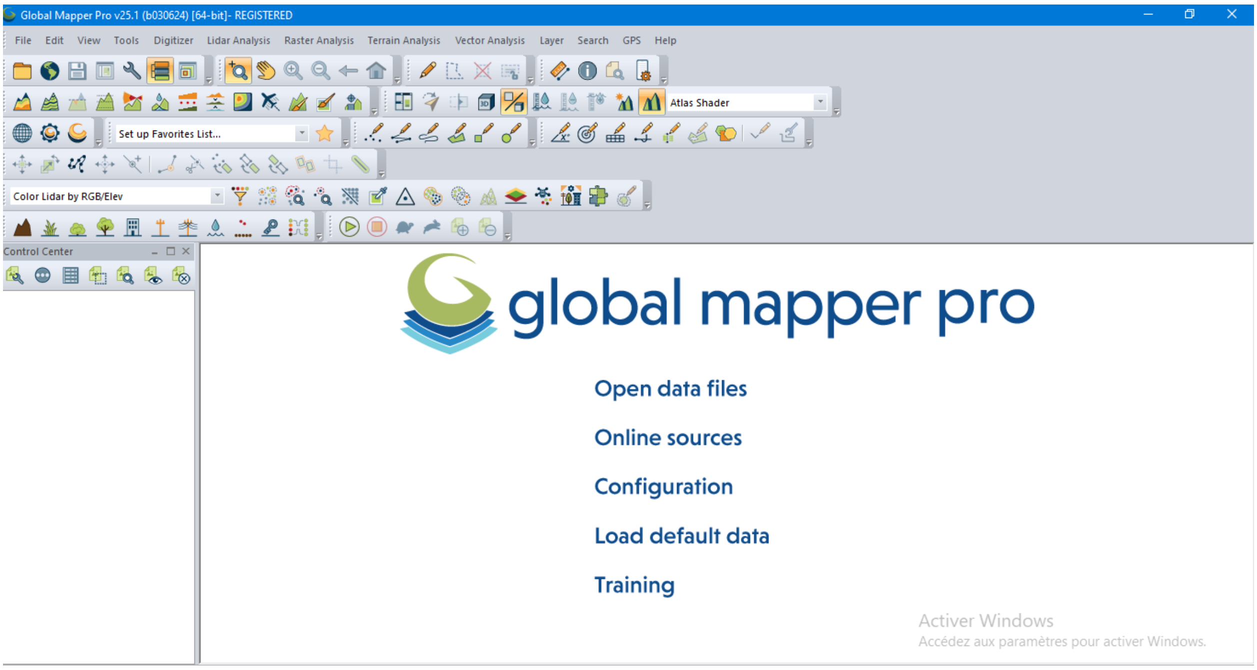


Figure 23:interface of global mapper v25.1

III.2) Presentation of the study area:

Ain Temouchent is a province located in the northwestern part of Algeria, along the Mediterranean coast. It covers an area of approximately 2,376 square kilometers and is bordered by the provinces of Tlemcen to the west, Sidi Bel Abbes to the south, and Oran to the east. The province is known for its diverse geography, which includes coastal plains, mountainous areas, and fertile valleys.

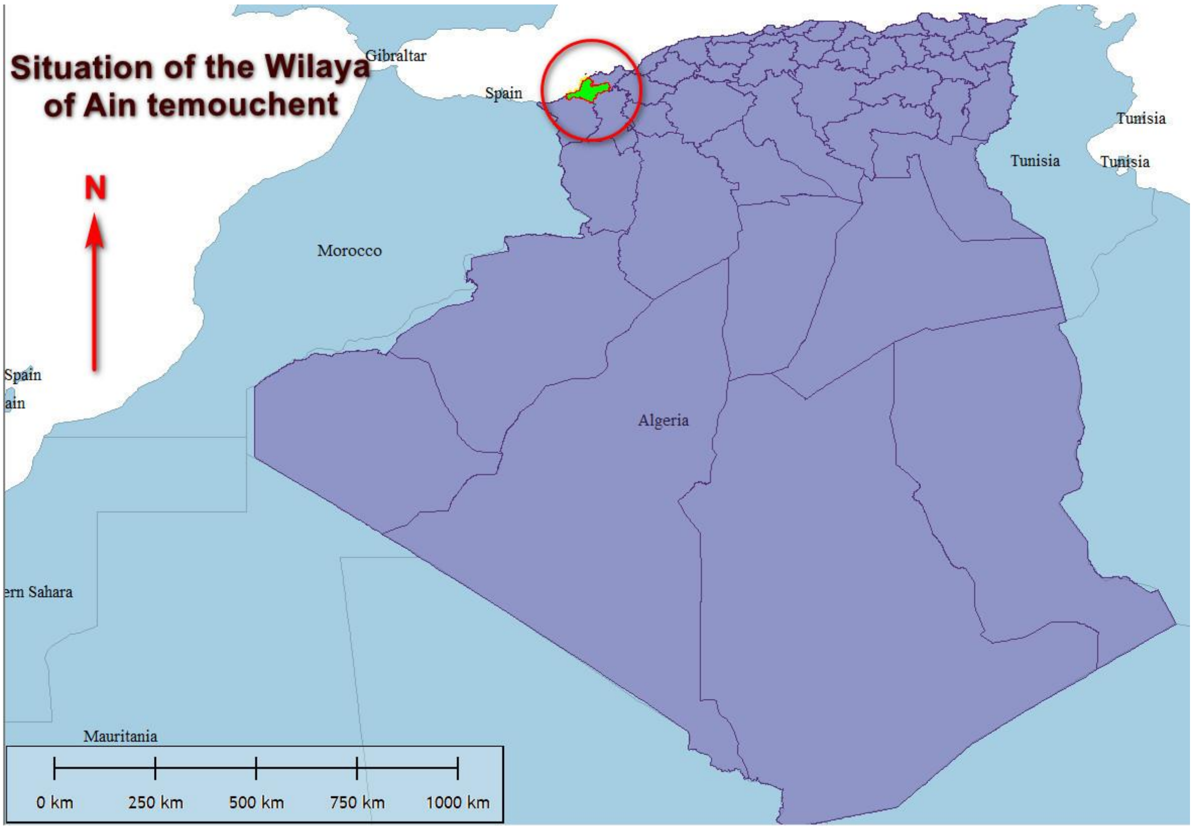


Figure 24:Situation of the Wilaya of Ain Temouchent

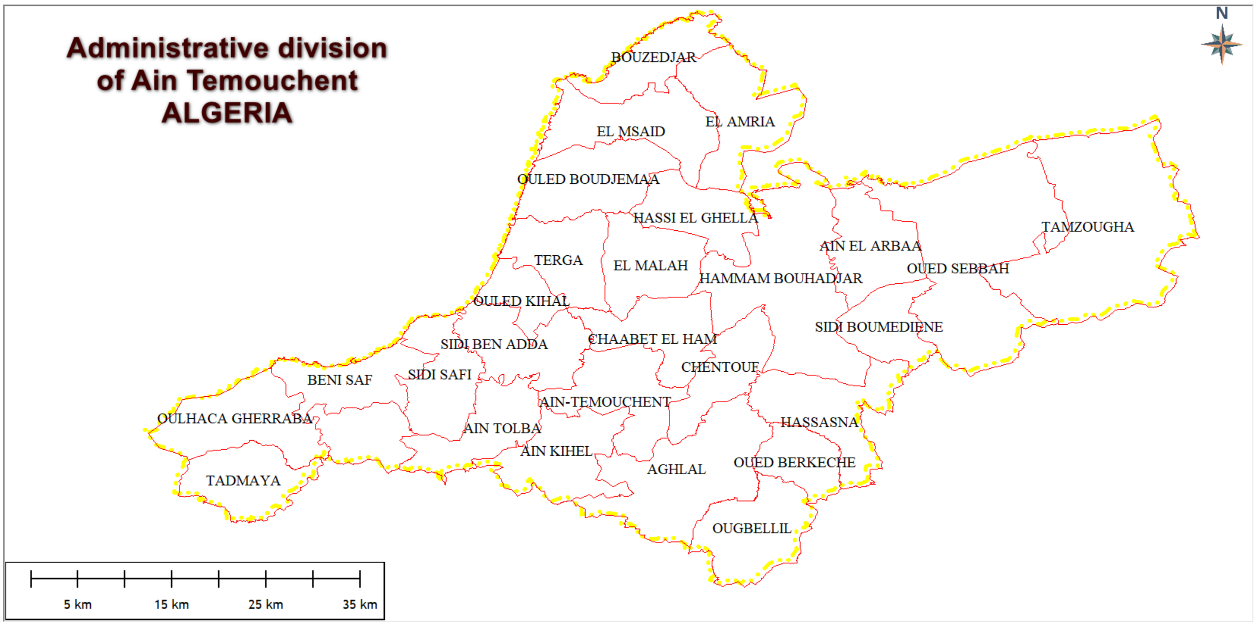


Figure 25:ADM map (situation)

The coastal region of Ain Temouchent boasts picturesque sandy beaches and clear blue waters, making it a popular destination for tourists and beachgoers. Inland, the landscape transitions into rugged mountains and rolling hills, offering stunning panoramic views of the surrounding countryside.

Ain Temouchent is home to several historical and cultural landmarks, including ancient ruins, mosques, and traditional villages. Agriculture is an important economic activity in the province, with crops such as cereals, olives, and citrus fruits being grown in the fertile valleys.

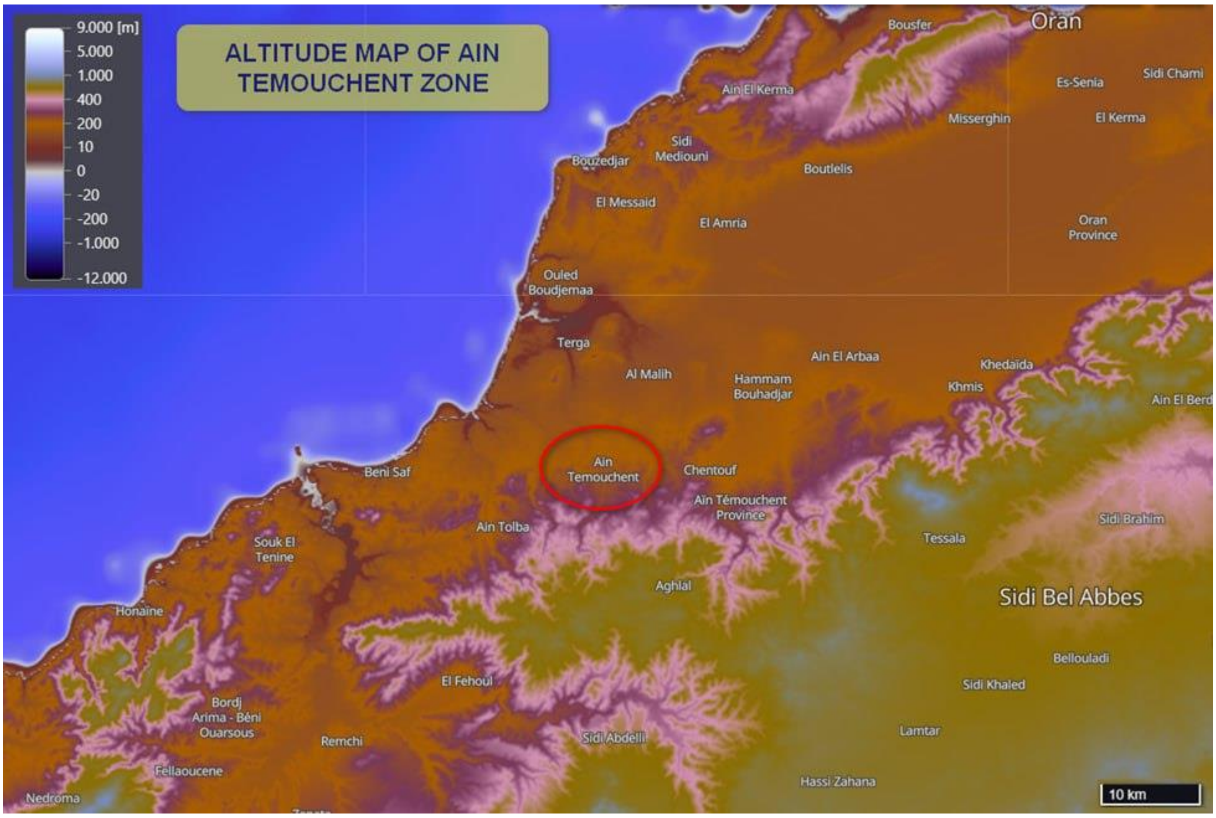


Figure 26 :Altitude map of Ain Temouchent zone

III.2.1) Land use:

In addition to its diverse geography and cultural heritage, Ain Temouchent is characterized by various land uses that contribute to its unique landscape. The province is divided into 28 "communes," each with its own distinct patterns of land occupation. While some areas are predominantly residential, with scattered habitation clusters and urban developments, the majority of Ain Temouchent land is dedicated to agricultural activities. Across the province, there are over a hundred agricultural farms, cultivating a wide range of crops and contributing to the region's agricultural economy.

The configuration of the rural road network in Ain Temouchent plays a crucial role in facilitating access to these different land uses. Roads traverse the province, connecting residential areas with agricultural farms, markets, and transportation hubs. They provide essential links for farmers to transport their produce to markets and for residents to access amenities and services. The layout and maintenance of these rural roads are essential for ensuring the efficient flow of goods and people throughout the province, contributing to the overall socio-economic development of Ain Temouchent.

By understanding the relationship between land use patterns and the rural road network configuration, stakeholders can make informed decisions regarding infrastructure planning, land management, and agricultural development in Ain Temouchent. This holistic approach to spatial planning ensures that the province's natural resources are utilized sustainably, while also fostering economic growth and improving the quality of life for its residents.

Figure 27 :Land use / Land cover of Ain Temouchent

III.3) Methodology:

To achieve our objectives discussed at the beginning of our document, we have outlined the major sequential steps to follow. Firstly, data collection from free data sources is conducted. Secondly, ensuring information about the collected data, namely metadata. The third step entails processing the collected data to obtain the desired results. Subsequently, we will provide detailed descriptions of the procedures and relevant information for each step outlined in the organizational chart (refer to figure)

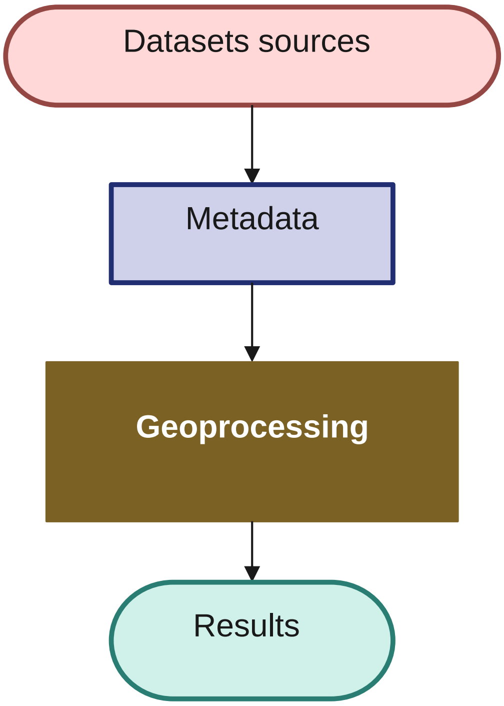


Figure 28 :Global organization chart process

III.3.1) dataset sources:

We utilize five web platforms to acquire free datasets. Specifically, we utilize USGS to obtain both DEM data and Landsat imagery. The land cover image is sourced from the ESRI platform, while tables containing road data and associated information are sourced from OpenStreetMap. Administrative division data is obtained from DIVA-GIS, and finally, high-resolution imagery is gathered from Google Earth.

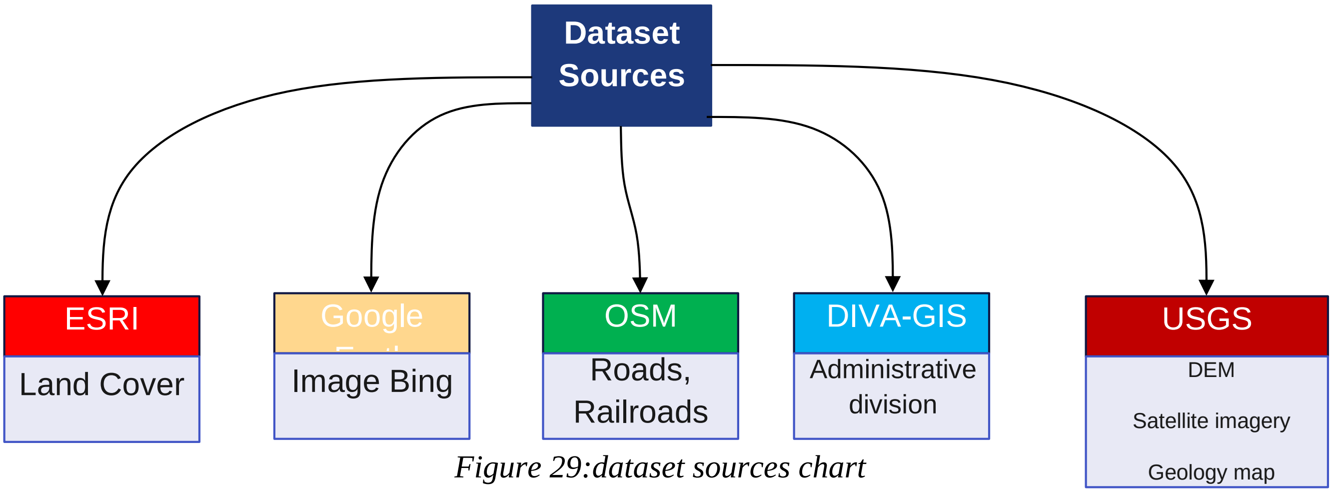
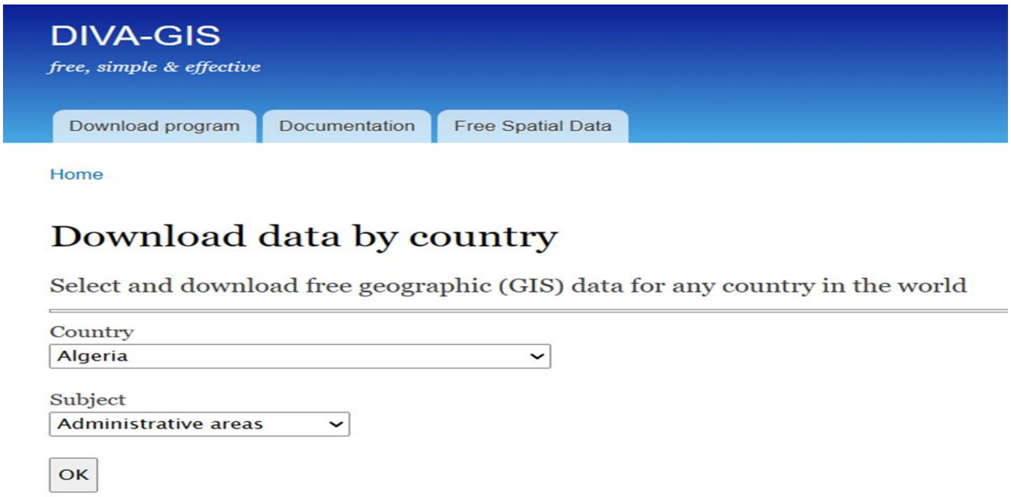


Figure 29:dataset sources chart



Download data by country

Select and download free geographic (GIS) data for any country in the world

Country: Algeria

Subject: Administrative areas

Figure 30: DIVA-GIS plate form interface to download Shape file of Administrative areas of Algeria

III.3.2) Metadata:

Let's recall that metadata refers to data about data. They are crucial as indicators of data quality, including information such as update dates, geometric and semantic accuracy, etc. This type of data is provided either in a separate file or integrated into the same data file, as is the case with Landsat images.

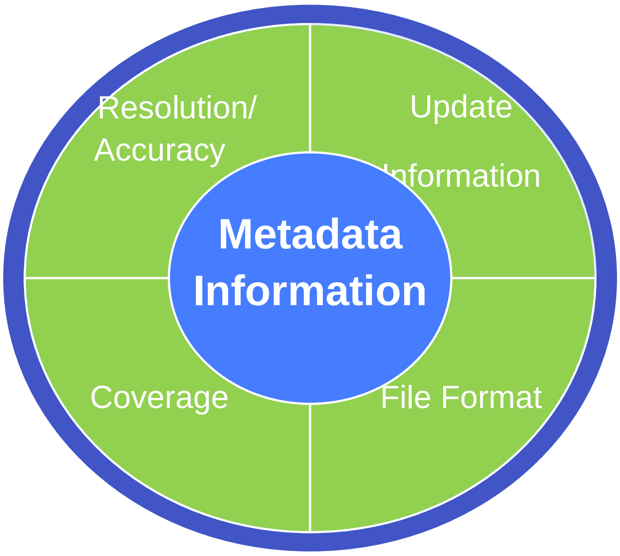
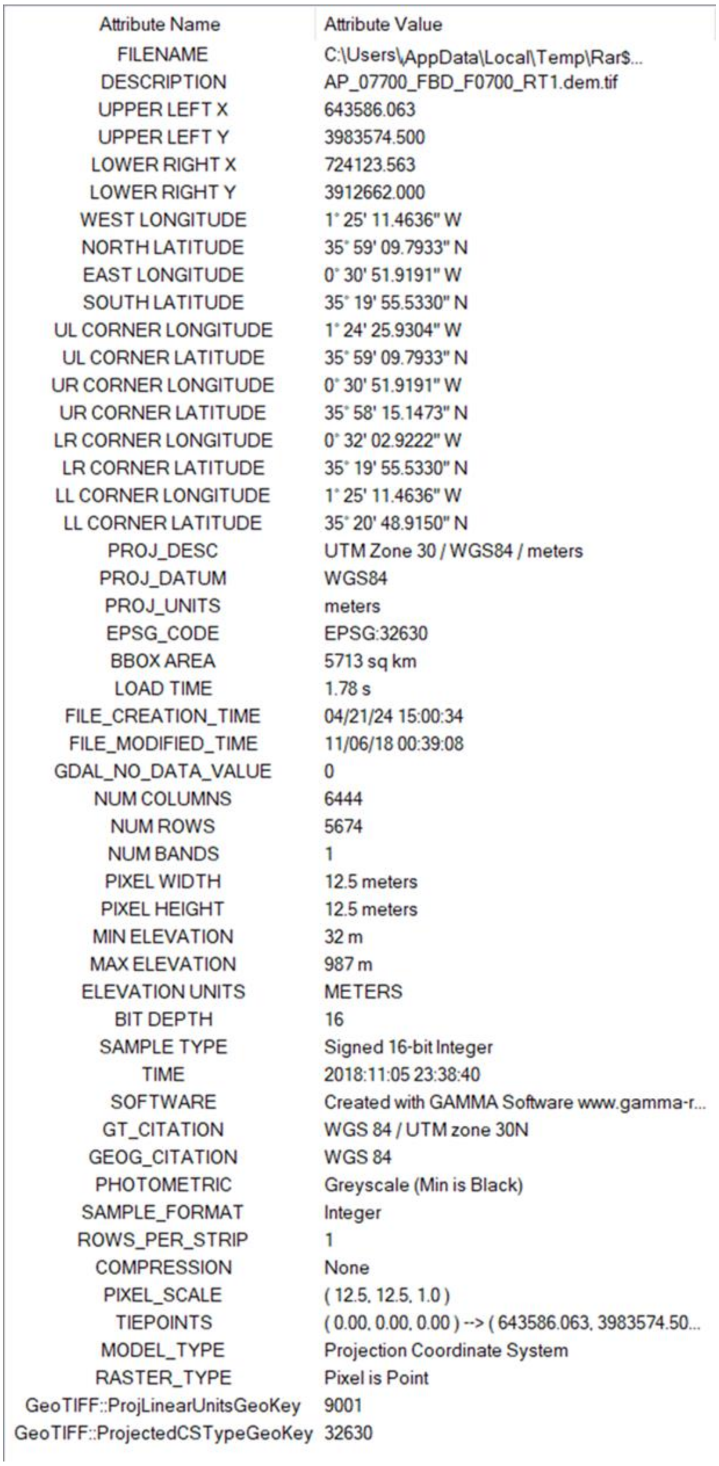


figure 31:Metadata information chart



Attribute Name	Attribute Value
FILENAME	C:\Users\AppData\Local\Temp\Rar$...
DESCRIPTION	AP_07700_FBD_F0700_RT1.dem.tif
UPPER LEFT X	643586.063
UPPER LEFT Y	3983574.500
LOWER RIGHT X	724123.563
LOWER RIGHT Y	3912662.000
WEST LONGITUDE	1° 25' 11.4636" W
NORTH LATITUDE	35° 59' 09.7933" N
EAST LONGITUDE	0° 30' 51.9191" W
SOUTH LATITUDE	35° 19' 55.5330" N
UL CORNER LONGITUDE	1° 24' 25.9304" W
UL CORNER LATITUDE	35° 59' 09.7933" N
UR CORNER LONGITUDE	0° 30' 51.9191" W
UR CORNER LATITUDE	35° 58' 15.1473" N
LR CORNER LONGITUDE	0° 32' 02.9222" W
LR CORNER LATITUDE	35° 19' 55.5330" N
LL CORNER LONGITUDE	1° 25' 11.4636" W
LL CORNER LATITUDE	35° 20' 48.9150" N
PROJ_DESC	UTM Zone 30 / WGS84 / meters
PROJ_DATUM	WGS84
PROJ_UNITS	meters
EPSG_CODE	EPSG:32630
BBOX AREA	5713 sq km
LOAD TIME	1.78 s
FILE_CREATION_TIME	04/21/24 15:00:34
FILE_MODIFIED_TIME	11/06/18 00:39:08
GDAL_NO_DATA_VALUE	0
NUM COLUMNS	6444
NUM ROWS	5674
NUM BANDS	1
PIXEL WIDTH	12.5 meters
PIXEL HEIGHT	12.5 meters
MIN ELEVATION	32 m
MAX ELEVATION	987 m
ELEVATION UNITS	METERS
BIT DEPTH	16
SAMPLE TYPE	Signed 16-bit Integer
TIME	2018:11:05 23:38:40
SOFTWARE	Created with GAMMA Software www.gamma-r...
GT_CITATION	WGS 84 / UTM zone 30N
GEOG_CITATION	WGS 84
PHOTOMETRIC	Greyscale (Min is Black)
SAMPLE_FORMAT	Integer
ROWS_PER_STRIP	1
COMPRESSION	None
PIXEL_SCALE	(12.5, 12.5, 1.0)
TIEPOINTS	(0.00, 0.00, 0.00) --> (643586.063, 3983574.50...
MODEL_TYPE	Projection Coordinate System
RASTER_TYPE	Pixel is Point
GeoTIFF::ProjLinearUnitsGeoKey	9001
GeoTIFF::ProjectedCSTypeGeoKey	32630

Figure 32 : example of the DEM metadata of the used reference file (AP_07948_FBD_F0690_RT1.dem.tif).

In the following section, we will discuss each metadata according to our study case.

III.3.2.1) Updating:

The data update frequency varies from a few days to a decade. Indeed, the SRTM mission was conducted in February 2000 to obtain the digital elevation model of the Earth with a resolution of 90 meters. Since then, no SRTM mission has been launched. The freely provided DTM can be accessed using the ASTER satellite (2007).

Regarding OpenStreetMap, the platform provides weekly updates since Google Maps users can enrich this database for free.

It is worth noting that for geology, recent updates are not necessary. The date of 2023 found in the documentation is related to the file itself and not the data content.

For LANDSAT 8 or 9 satellites, the revisit cycle is every 16 days, meaning they return to the same location on Earth every 16 days to take a picture. However, there may be a high percentage of cloud cover, which poses a limitation for our cas

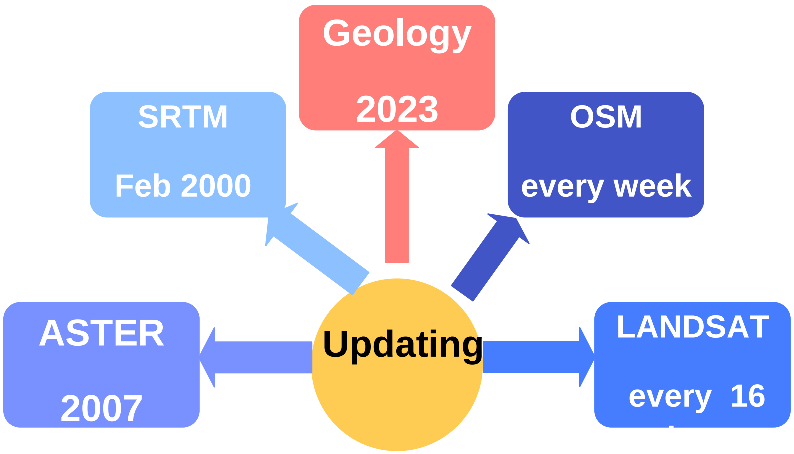


Figure 33: used updating dataset.

III.3.2.2) Dataset format:

In the realm of GIS software, standardized file formats are utilized, with Shape files serving for vector data and Tiff files for raster data.

Geotiff files, essentially Tiff files with embedded georeferencing parameters, are commonly employed for satellite imagery, ensuring spatial accuracy. Conversely, files containing elevation data are typically in raster format, available in various extensions like .DEM,. SRTM, or .HGT, wherein each pixel integrates both color and elevation values.

OpenStreetMap datasets, on the other hand, are distributed in a compressed .OSM file format, exclusively housing vector layers. The summary figure below encapsulates this description.

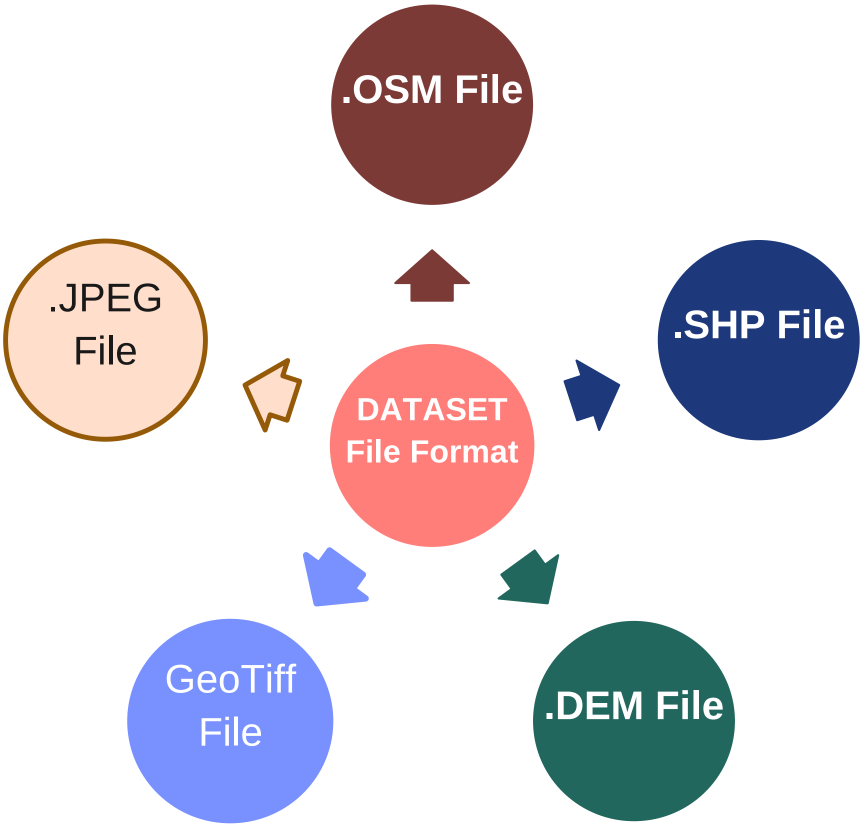


Figure 34:Different used Dataset File format

III.3.2.3) dataset area coverage Per file:

The coverage area of each downloaded file depends on the dataset source. For example, Landsat 8 or 9 images cover exactly 185 km x 185 km on the ground. However, they may cover only a part of the area due to the path of the satellite. In our case, the challenge is not only to find a suitable image to cover our zone but also to ensure it has 0% cloud coverage. The image used is from January 2024 and covers 90% of the province (see figure below).

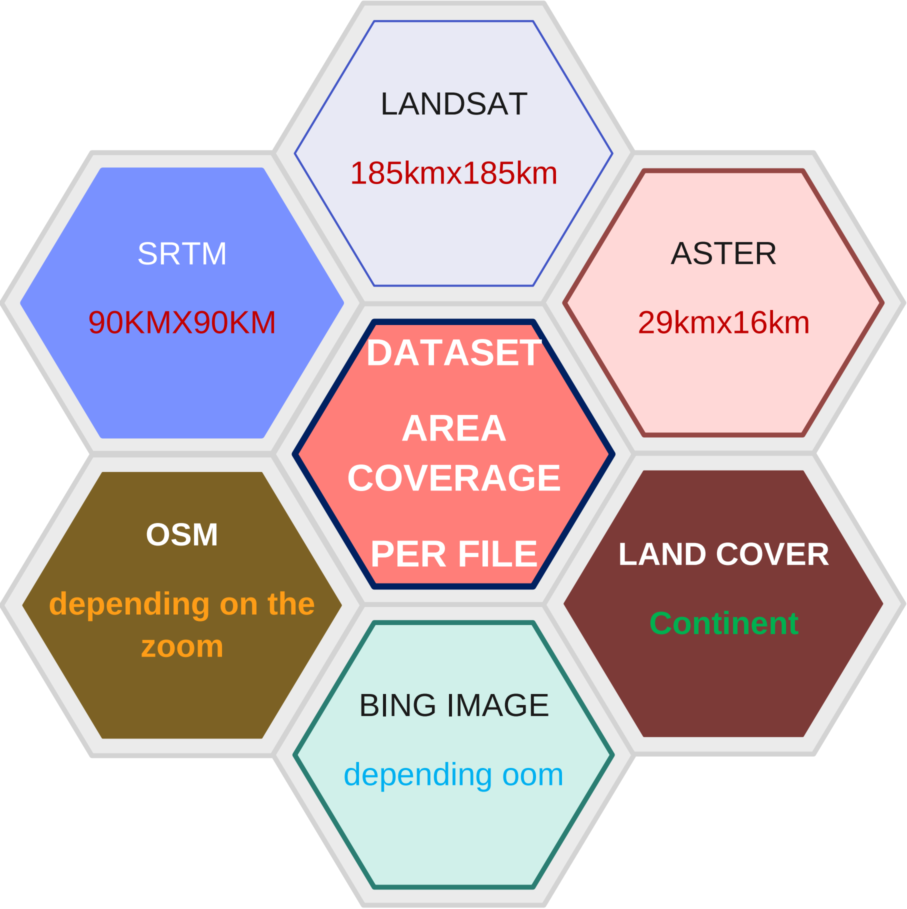


Figure 35:Dataset area coverage chart.

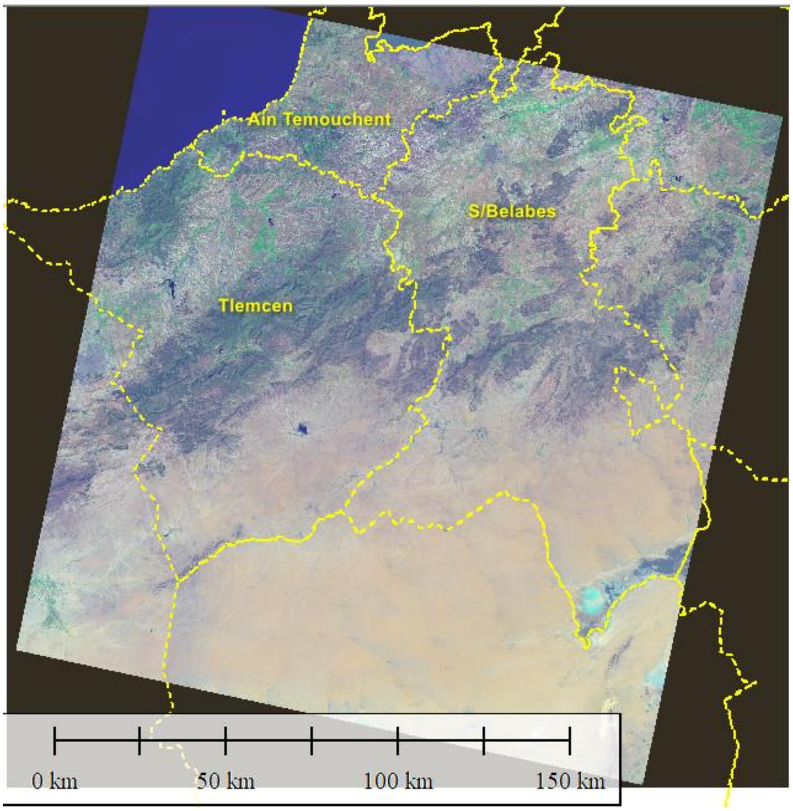


Figure 36 : coverage of Landsat 9 image in relation of division provinces

On the other hand, the coverage area of the digital elevation model is 90 km x 90 km from SRTM or 29 km x 26 km from ASTER satellite. Hence, we may need to obtain a mosaic of up to four radar images to cover Ain Temouchent province.

Additionally, there are platforms that provide the option to download the required area based on the zoomed area on the screen, such as OSM or Bing Images.

The geological map is provided by continent in this case.

Finally, ESRI offers the possibility to download the entire coverage area of southwestern Europe and northwestern Africa in the same dataset (see figure below).

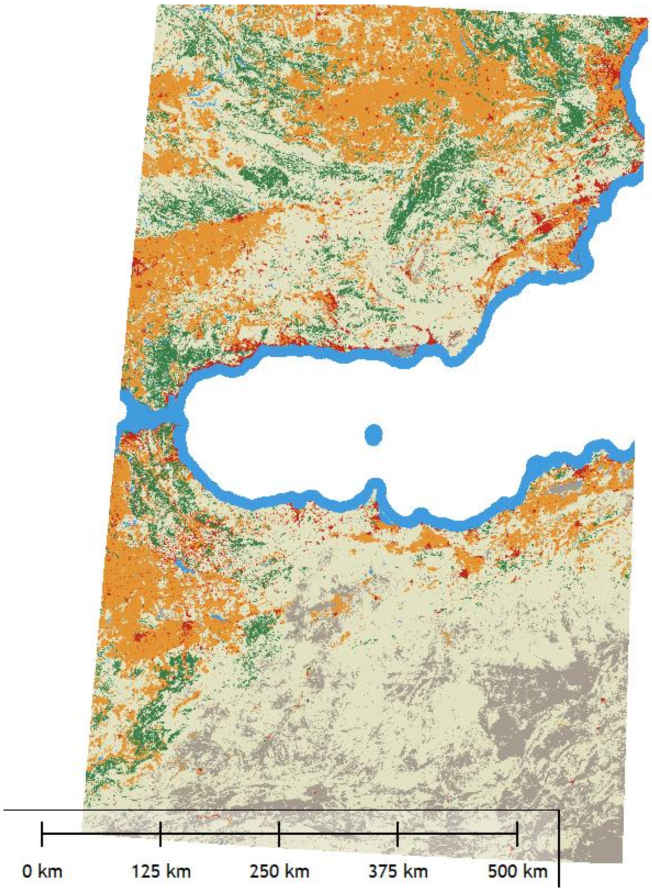


Figure 37 :Land cover 2024 from ESRI platform

III.3.2.4) resolution / accuracy:

We note that the accuracy value is required to be known as metadata; it provides the quality index of the product document. However, we are obligated to integrate multiple files with varying accuracies. Moreover, there are two types of files, as discussed in the 2nd chapter (vector / raster). Therefore, we must also know the resolution of the raster integrated images.

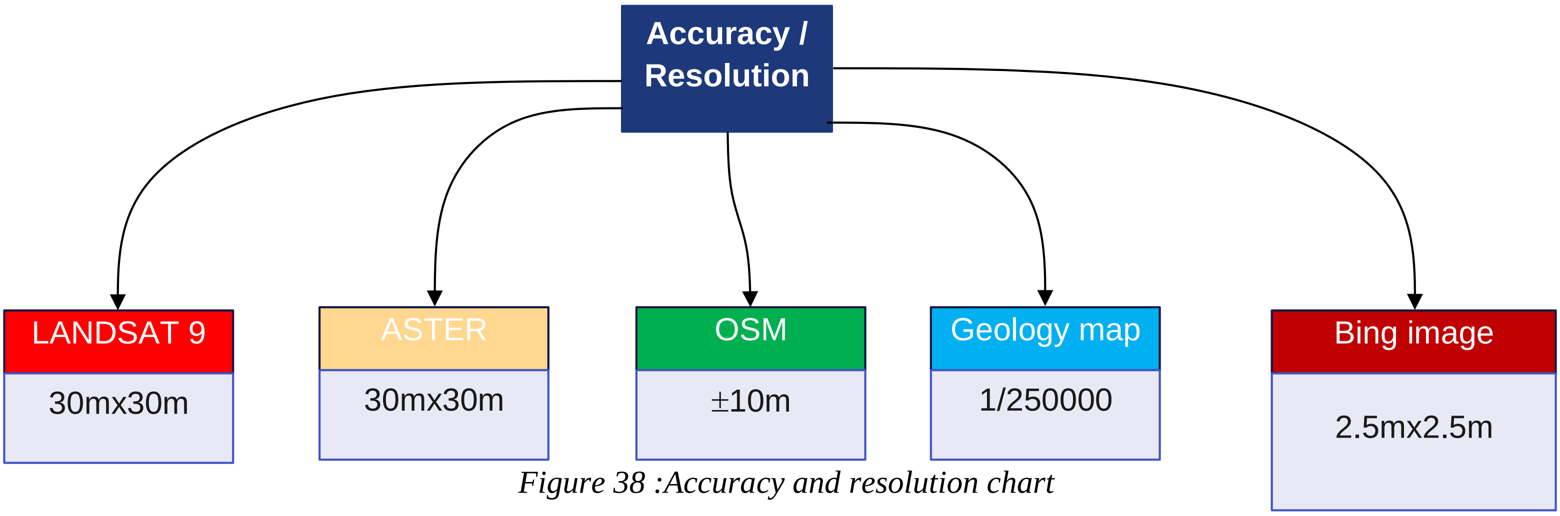


Figure 38 :Accuracy and resolution chart

The organizational chart above shows the values of the accuracy or resolution of the different downloaded files. These values are obtained from the documentation of each other.

III.3.3) Geoprocessing:

The geoprocessing step represents the crucial operation in the process. We mean by geoprocessing the treatment of geospatial data; it differs, of course, from traditional processing where we deal only with the attribute part of the data. We suggest typically dividing this operation into three parts: treatment of the shapefiles, treatment of the digital elevation models, and finally, 3D visualization geoprocessing.

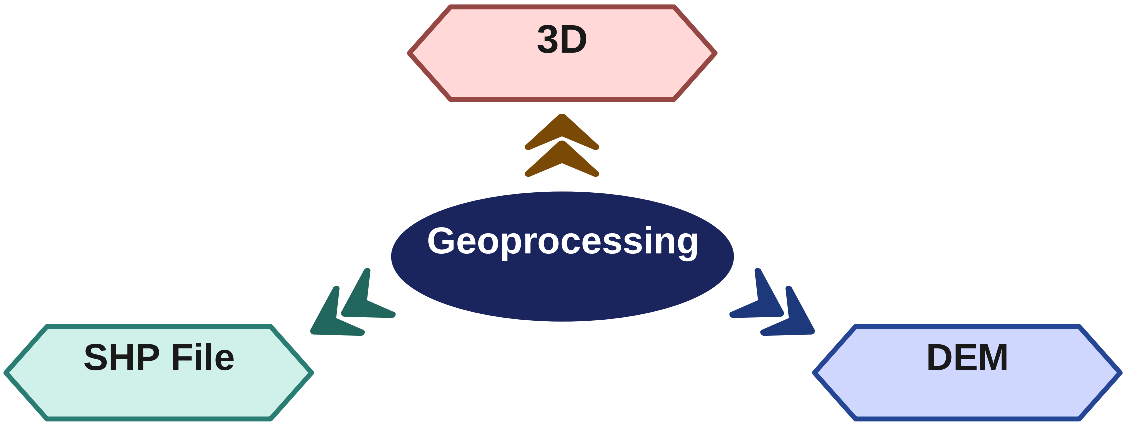


Figure 39:Geoprocessing chart.

III.3.3.1) geoprocessing SHP and file:

Certainly, we receive the data freely, but these data are given in a raw form. They require being firstly classified, organized, cropped, and given the appropriate symbology to each type of dataset. This allows us to easily generate a statistical report, as we will detail in the following.

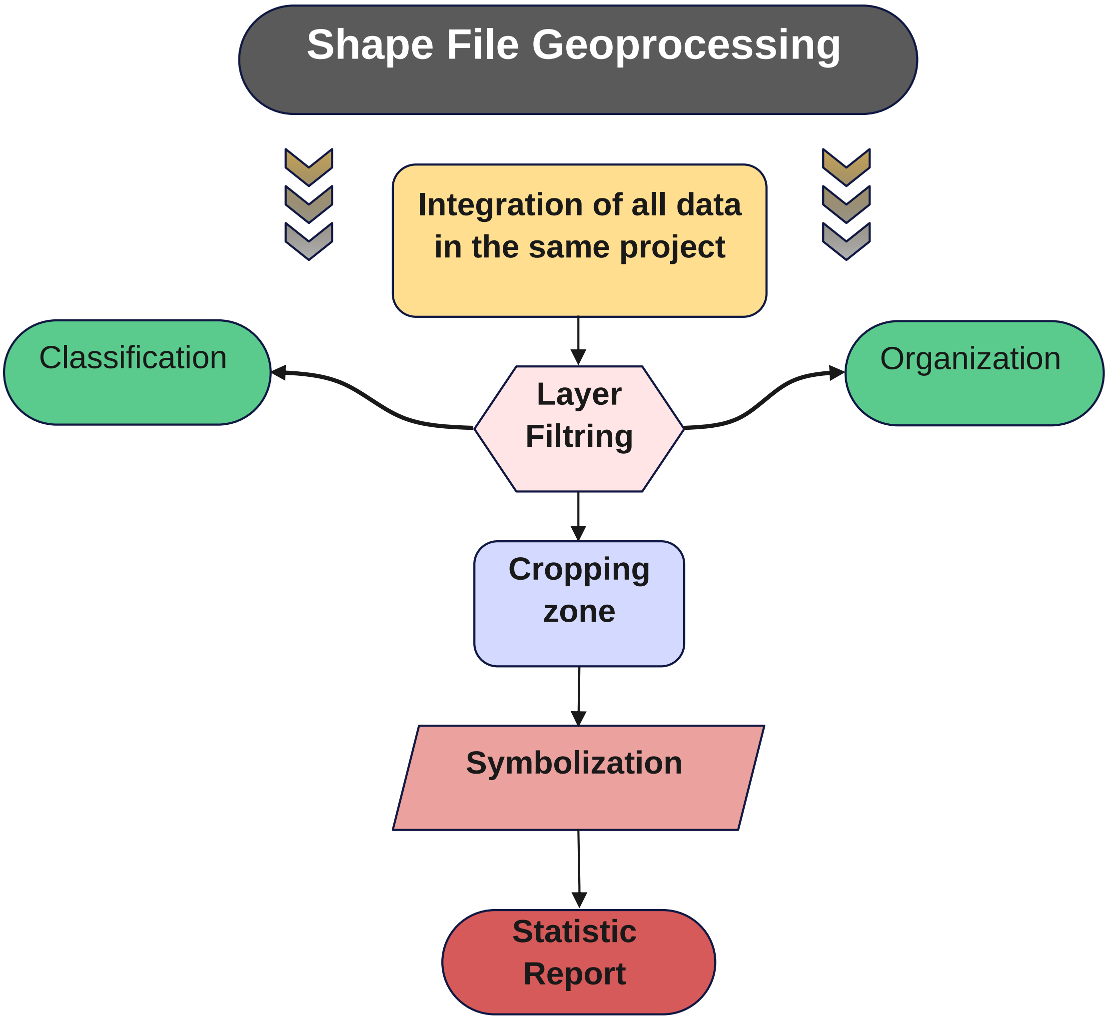


Figure 40:Shape file geoprocessing chart

By organization operation, we mean:

Renaming the layers to appropriate names according to our project.

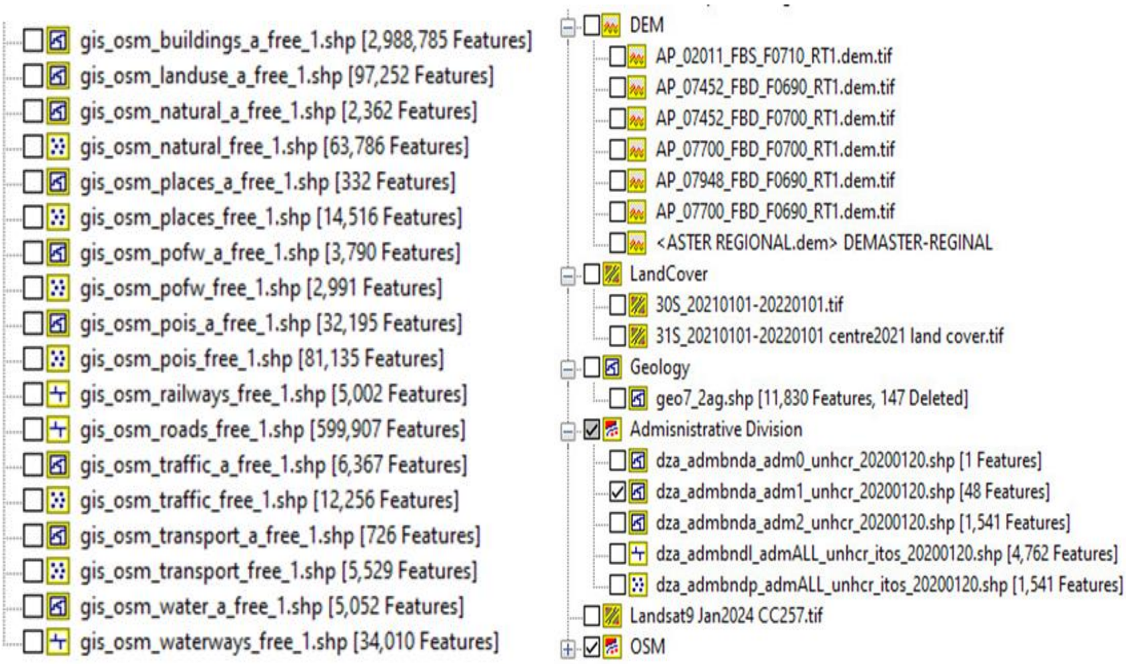
Grouping layers according to their global item or type.

Deleting unnecessary layers integrated into the raw data file.

This operation will facilitate our task of data classification by the appropriate attribute.

The cropping operation allows us to work only with the study area limited by the administrative division polygon. Furthermore, this segmentation will lighten the PC's memory for 3D visualization geoprocessing.

A) Organizations of layer group :

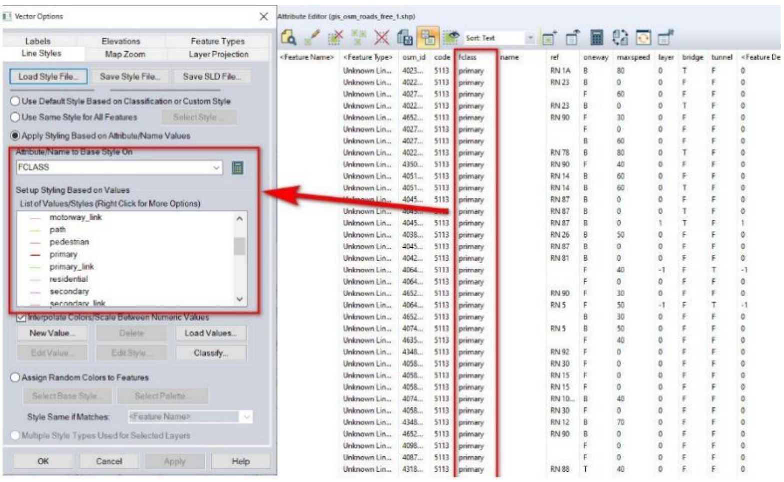


☐ gis_osm_buildings_a_free_1.shp [2,988,785 Features]
☐ gis_osm_landuse_a_free_1.shp [97,252 Features]
☐ gis_osm_natural_a_free_1.shp [2,362 Features]
☐ gis_osm_natural_free_1.shp [63,786 Features]
☐ gis_osm_places_a_free_1.shp [332 Features]
☐ gis_osm_places_free_1.shp [14,516 Features]
☐ gis_osm_pofw_a_free_1.shp [3,790 Features]
☐ gis_osm_pofw_free_1.shp [2,991 Features]
☐ gis_osm_pois_a_free_1.shp [32,195 Features]
☐ gis_osm_pois_free_1.shp [81,135 Features]
☐ gis_osm_railways_free_1.shp [5,002 Features]
☐ gis_osm_roads_free_1.shp [599,907 Features]
☐ gis_osm_traffic_a_free_1.shp [6,367 Features]
☐ gis_osm_traffic_free_1.shp [12,256 Features]
☐ gis_osm_transport_a_free_1.shp [726 Features]
☐ gis_osm_transport_free_1.shp [5,529 Features]
☐ gis_osm_water_a_free_1.shp [5,052 Features]
☐ gis_osm_waterways_free_1.shp [34,010 Features]

- ☐ DEM
  - ☐ AP_02011_FBS_F0710_RT1.dem.tif
  - ☐ AP_07452_FBD_F0690_RT1.dem.tif
  - ☐ AP_07452_FBD_F0700_RT1.dem.tif
  - ☐ AP_07700_FBD_F0700_RT1.dem.tif
  - ☐ AP_07948_FBD_F0690_RT1.dem.tif
  - ☐ AP_07700_FBD_F0690_RT1.dem.tif
  - ☐ <ASTER REGIONAL.dem> DEMASTER-REGINAL
- ☐ LandCover
  - ☐ 30S_20210101-20220101.tif
  - ☐ 31S_20210101-20220101 centre2021 land cover.tif
- ☐ Geology
  - ☐ geo7_2ag.shp [11,830 Features, 147 Deleted]
- ☑ Admisnistrative Division
  - ☐ dza_admbnda_adm0_unhcr_20200120.shp [1 Features]
  - ☑ dza_admbnda_adm1_unhcr_20200120.shp [48 Features]
  - ☐ dza_admbnda_adm2_unhcr_20200120.shp [1,541 Features]
  - ☐ dza_admbndl_admALL_unhcr_itos_20200120.shp [4,762 Features]
  - ☐ dza_admbndp_admALL_unhcr_itos_20200120.shp [1,541 Features]
- ☐ Landsat9 Jan2024 CC257.tif
- ☑ OSM

Figure 41:raw layer data of OSM file.

Symbolization: Generally, the data are given in black/white color. It requires assigning the appropriate color for each grouped item. For example, the geology map symbology is assigned according to the "GLG" attribute, where the terrain is classified by age (Tr, Q, Qe, and so on). For the roads table, the symbology is assigned by the "fclass" attribute (see figure below), where the roads are classified by road order (primary, secondary, path, and so on).



○ Use Default Style Based on Classification or Custom Style
○ Use Same Style for All Features
● Apply Styling Based on Attribute/Name Values

Attribute/Name to Base Style On: FCLASS

Set up Styling Based on Values
List of Values/Styles (Right Click for More Options)
- motorway_link
- path
- pedestrian
- primary
- primary_link
- residential
- secondary
- secondary_link

☑ Interpolate Colors/Scale Between Numeric Values

○ Assign Random Colors to Features

Style Same if Matches: <Feature Name>

○ Multiple Style Types Used for Selected Layers

Attribute Editor (gis_osm_roads_free_1.shp)

<Feature Name>	<Feature Type>	osm_id	code	fclass	name	ref	oneway	maxspeed	layer	bridge	tunnel	<Feature De
	Unknown Lin...	4023...	5113	primary		RN 1A	B	80	0	T	F	0
	Unknown Lin...	4022...	5113	primary		RN 23	B	0	0	F	F	0
	Unknown Lin...	4027...	5113	primary			F	60	0	F	F	0
	Unknown Lin...	4022...	5113	primary		RN 23	B	0	0	T	F	0
	Unknown Lin...	4652...	5113	primary		RN 90	F	30	0	F	F	0
	Unknown Lin...	4027...	5113	primary			F	0	0	F	F	0
	Unknown Lin...	4027...	5113	primary			B	60	0	F	F	0
	Unknown Lin...	4022...	5113	primary		RN 78	B	80	0	T	F	0
	Unknown Lin...	4350...	5113	primary		RN 90	F	40	0	F	F	0
	Unknown Lin...	4051...	5113	primary		RN 14	B	60	0	F	F	0
	Unknown Lin...	4051...	5113	primary		RN 14	B	60	0	T	F	0
	Unknown Lin...	4045...	5113	primary		RN 87	B	0	0	F	F	0
	Unknown Lin...	[illegible]	[illegible]	primary		RN 87	B	0	0	T	F	0
	Unknown Lin...	4045...	5113	primary		RN 87	B	0	1	T	F	1
	Unknown Lin...	4038...	5113	primary		RN 26	B	50	0	F	F	0
	Unknown Lin...	4045...	5113	primary		RN 87	B	0	0	F	F	0
	Unknown Lin...	4042...	5113	primary		RN 81	B	0	0	F	F	0
	Unknown Lin...	4064...	5113	primary			F	40	-1	F	T	-1
	Unknown Lin...	4064...	5113	primary			F	0	0	F	F	0
	Unknown Lin...	4652...	5113	primary		RN 90	F	30	0	F	F	0
	Unknown Lin...	4064...	5113	primary		RN 5	F	50	-1	F	T	-1
	Unknown Lin...	4652...	5113	primary			B	30	0	F	F	0
	Unknown Lin...	4074...	5113	primary		RN 5	B	50	0	F	F	0
	Unknown Lin...	4635...	5113	primary			F	40	0	F	F	0
	Unknown Lin...	4348...	5113	primary		RN 92	F	0	0	F	F	0
	Unknown Lin...	4058...	5113	primary		RN 30	F	0	0	F	F	0
	Unknown Lin...	4058...	5113	primary		RN 15	F	0	0	F	F	0
	Unknown Lin...	4058...	5113	primary		RN 15	F	0	0	F	F	0
	Unknown Lin...	4074...	5113	primary		RN 10...	B	40	0	F	F	0
	Unknown Lin...	4058...	5113	primary		RN 30	F	0	0	F	F	0
	Unknown Lin...	4348...	5113	primary		RN 12	B	70	0	F	F	0
	Unknown Lin...	4652...	5113	primary		RN 90	B	0	0	F	F	0
	Unknown Lin...	4098...	5113	primary			F	0	0	F	F	0
	Unknown Lin...	4087...	5113	primary			F	0	0	F	F	0
	Unknown Lin...	4318...	5113	primary		RN 88	T	40	0	F	F	0

Figure 42 : classification of the roads by FCLASS Attribute on OSM table.

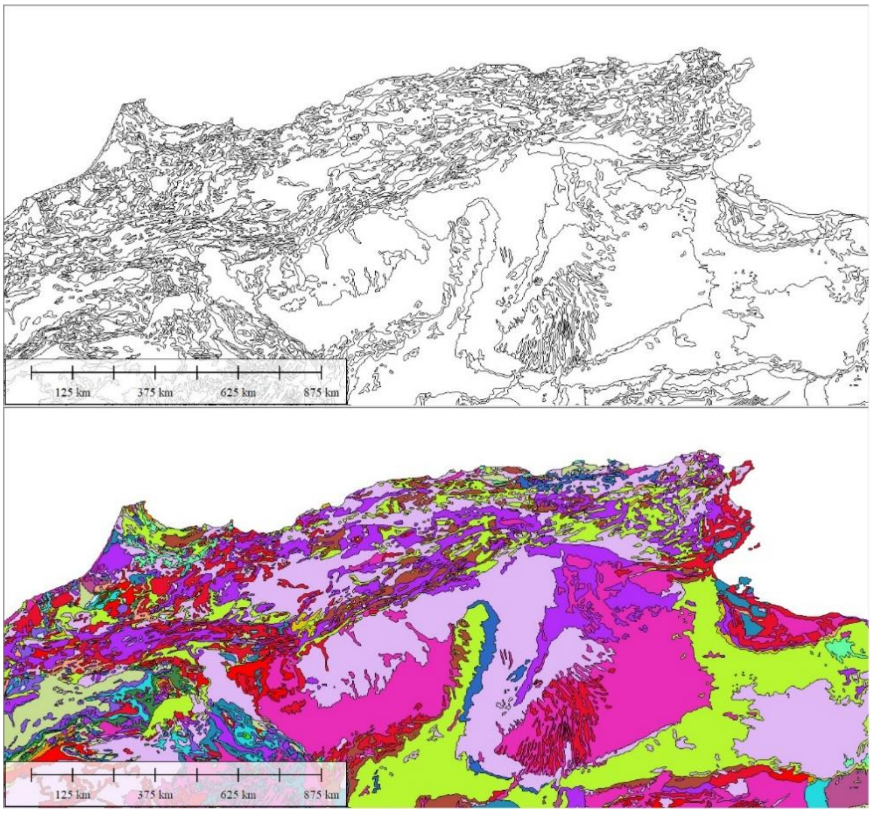


Figure 43 : symbolization of the geological map.

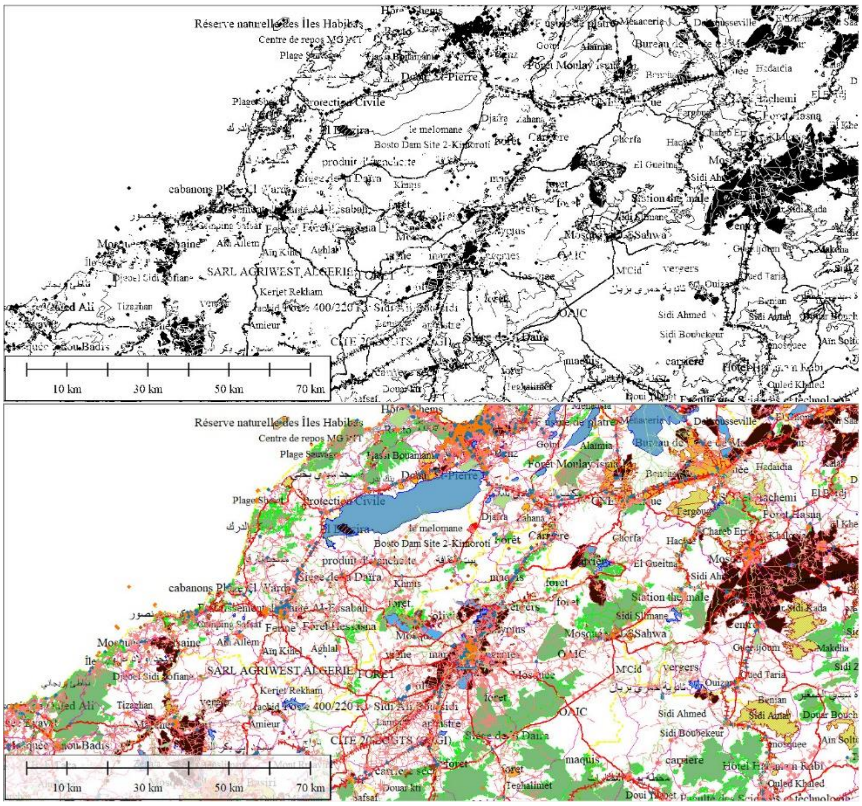


Figure 44:OSM symbolization .

B) Statistic report:

Once the previous operations are completed, it is possible to generate a statistical report based on any attribute of the tables. In our case, we have generated the statistical report of the roads in relation to the study area.

FCLASS	Point Count	Line Count	Total Line Length (m)
bridleway	0	1	155.31
footway	0	110	5899.4
living_street	0	114	19295
path	0	50	5477.7
primary	0	298	279477
primary_link	0	43	2201.5
residential	0	5383	1088544
secondary	0	265	367441
secondary_link	0	23	886.66
service	0	575	109517
steps	0	44	1777.5
tertiary	0	201	277081
tertiary_link	0	5	159.09
track	0	941	828132
track_grade1	0	3	920.12
track_grade2	0	2	291.45

track_grade3	0	11	6500.1
trunk	0	224	233096
trunk_link	0	127	22071
unclassified	0	354	413882

Table 2:Statistic report table.

III.3.3.2) DEM geoprocessing:

The digital elevation model can be downloaded in many formats such as. DEM, HGT, SRTM, GeoTiff, etc. All of these formats contain the elevation value of each point on the ground according to the resolution of acquisition. This product represents basic information from which we can extract various maps through simple calculations. For example, the slope map is a representation of the slope terrain value at each point, which can be calculated in degrees or meters. We assign a color to each interval.

By using Global Mapper, we can extract up to seven maps as shown in the figure. The results will be useful for enhanced 3D visualization.

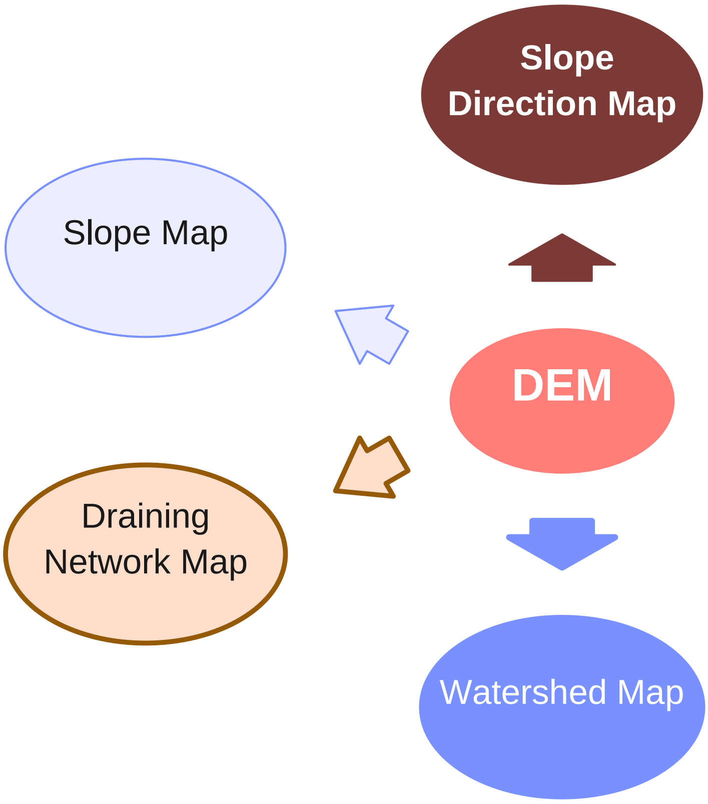


Figure 45:DEM organization chart.

The figures below represent the 2D map before the integration of the road networks.

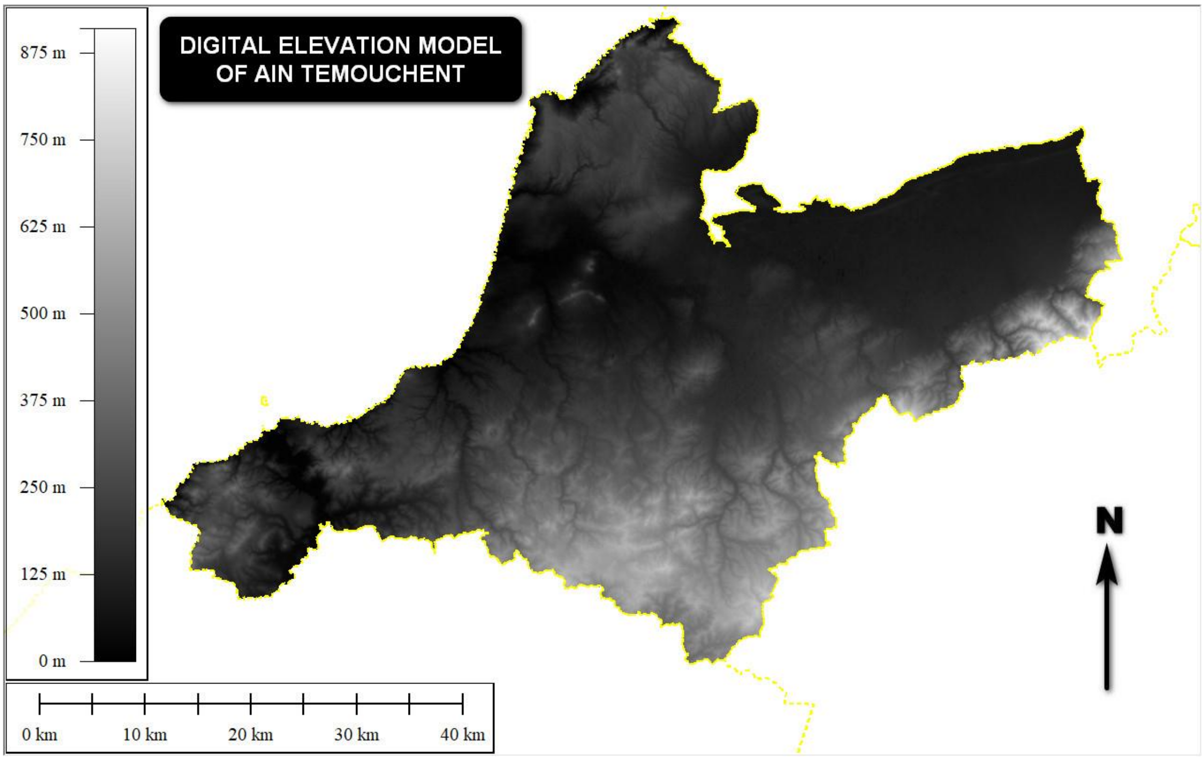


Figure 46:Digital Elevation model of Ain Temouchent.

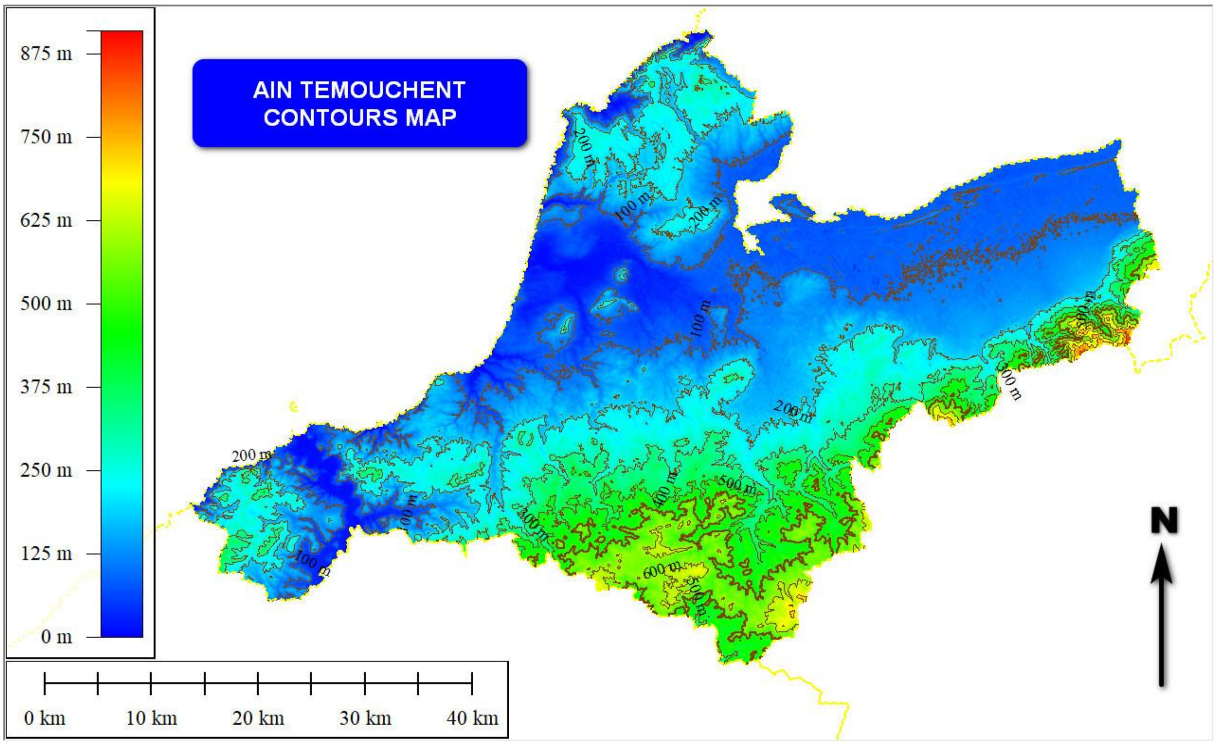


Figure 47:Ain Temouchent contours map.

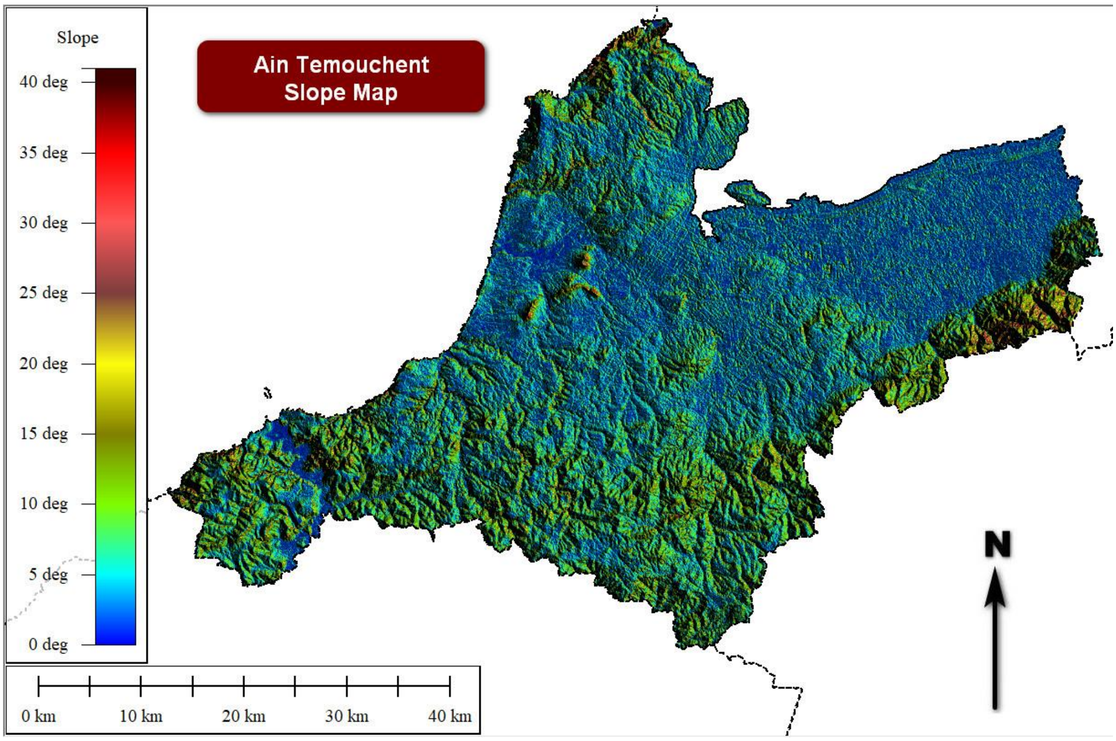


Figure 48:Ain Temouchent slope map.

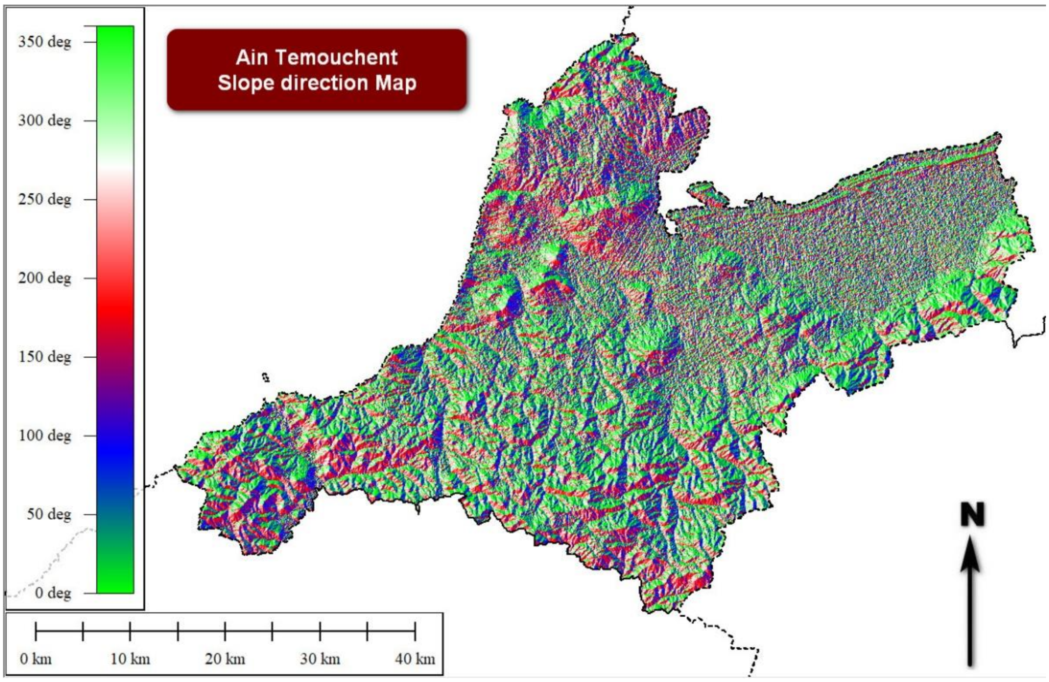


Figure 49:Ain Temouchent slope direction map.

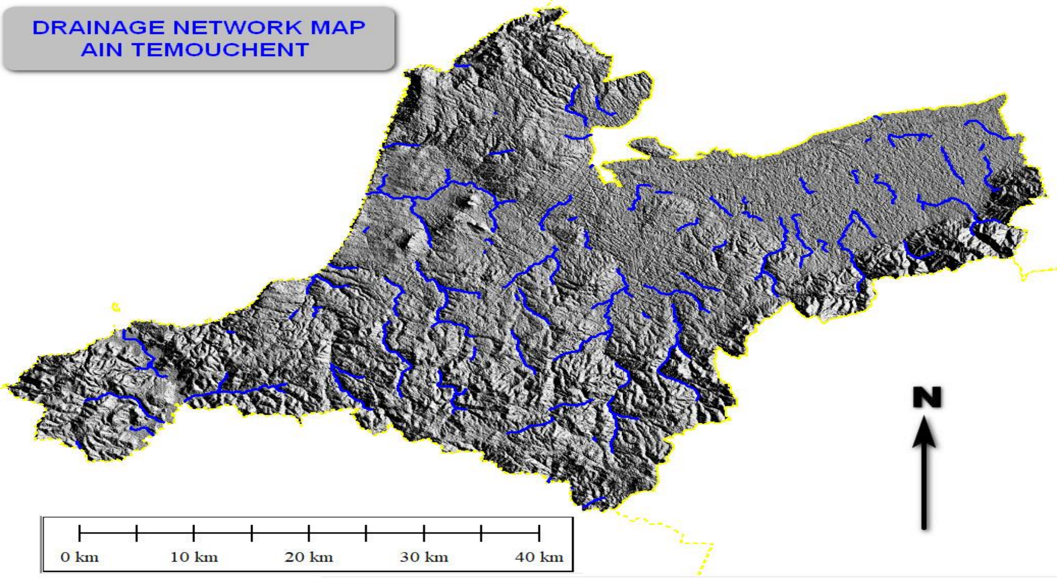


Figure 50:Drainage network map of Ain Temouchent.

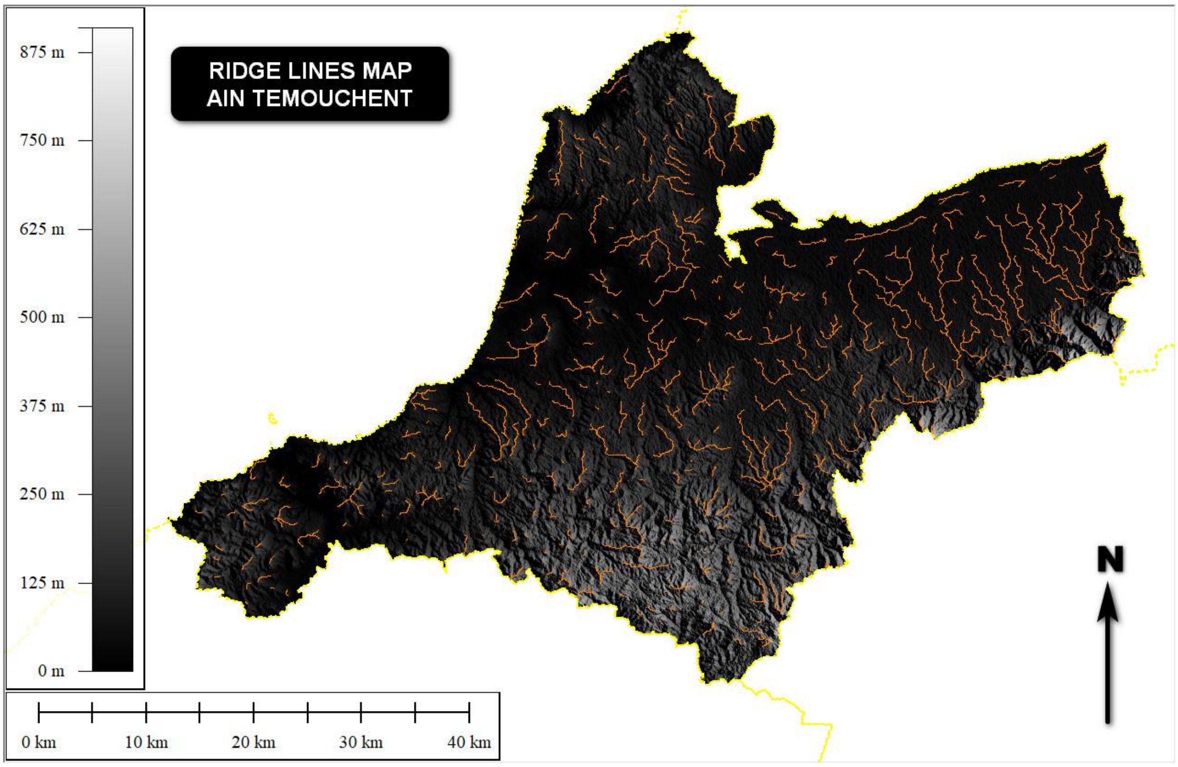


Figure 51:Ridge line map of Ain Temouchent.

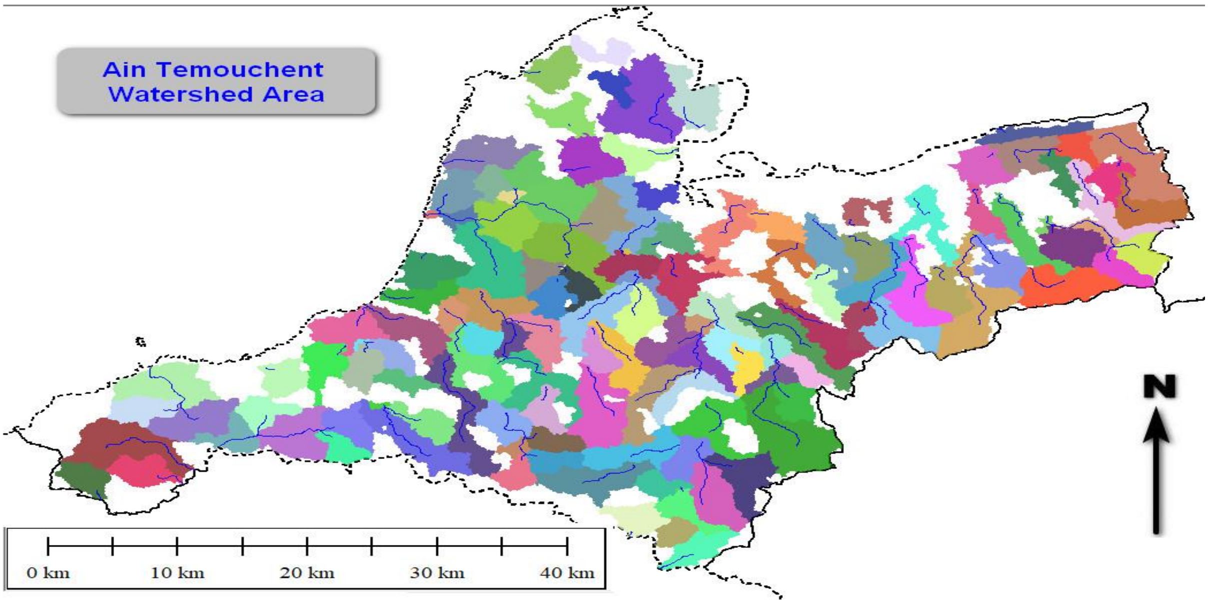


Figure 52 : Watershed area Ain Temouchent.

III.3.3.3) 3D geoprocessing:

3D Geoprocessing is the final step of the operation. All datasets, both 2D and 3D, raster and vector, are in the same project. All 2D datasets will be draped on the DEM surface. We can visualize more than two layers simultaneously by adjusting transparency and switching on/off the undesired layers. For enhanced visualization, we can program a default flypath. To do that, we follow the organization chart.

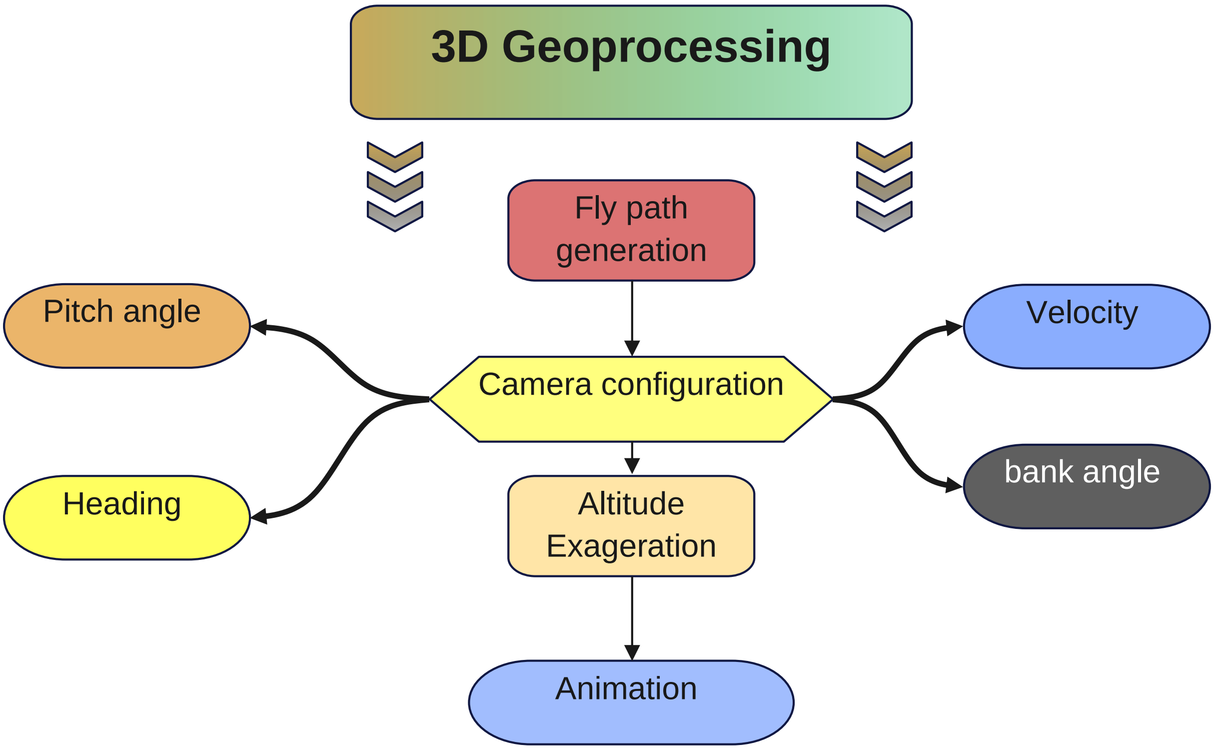


Figure 53:3D geoprocessing chart.

We observe that the extent of the area is proportionally greater than the elevation values of the terrain. Therefore, if we maintain the real scale for the Z-axis, we cannot clearly visualize the topographic variation of the terrain. To address this, we adjust a value called "exaggeration" to better visualize the entire area with the Z variation. This operation is traditionally used when dealing with terrain profiles, where the XY scale generally differs from the Z scale.

In the figure below, a demonstrative comparison is shown between exaggeration values of 1 and 6 on our study area.

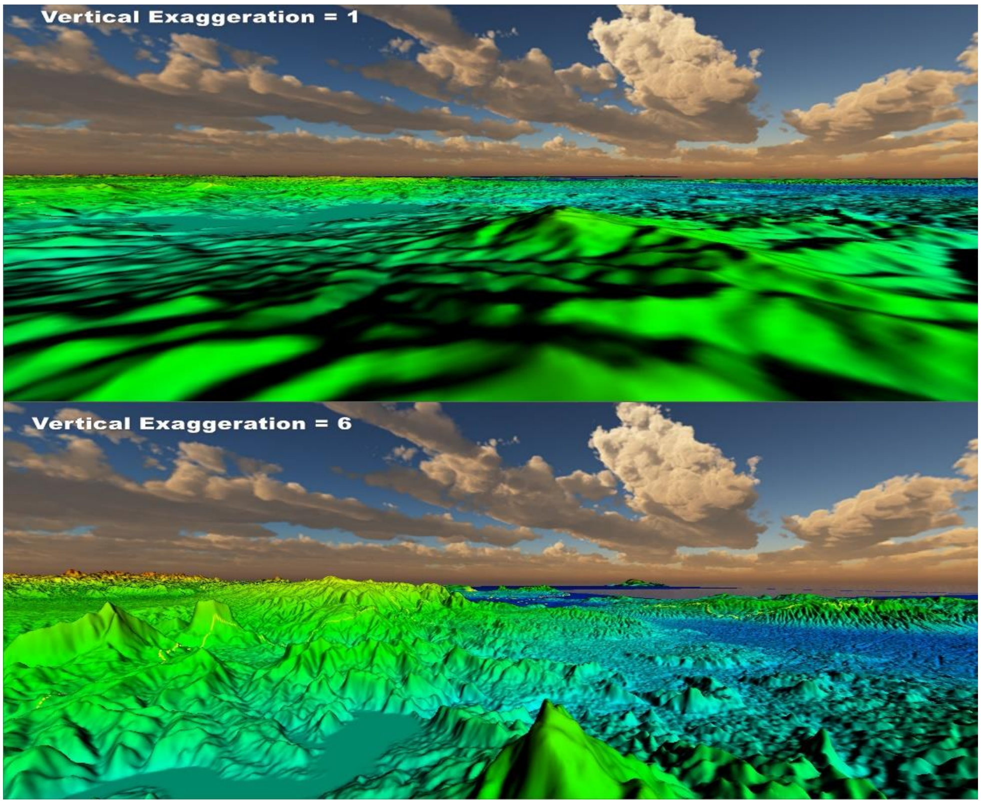


Figure 54:Vertical Exaggeration.

III.3.4) Result:

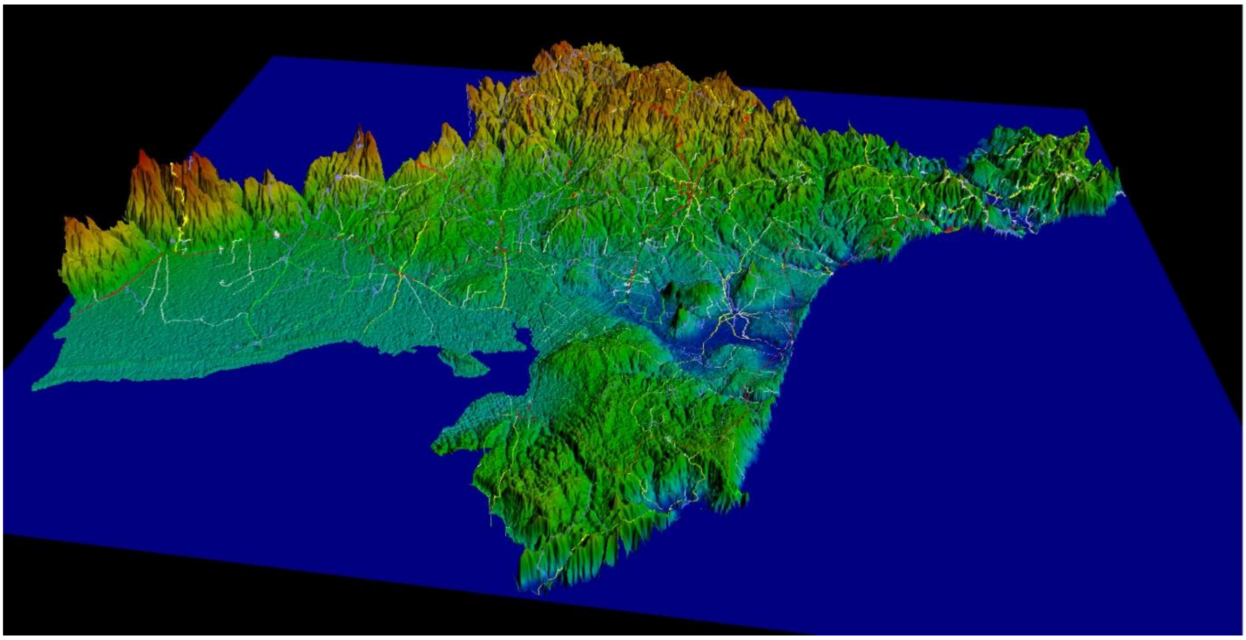


Figure 55:3D visualization of the DEM layer with the Roads networks of Ain Temouchent.

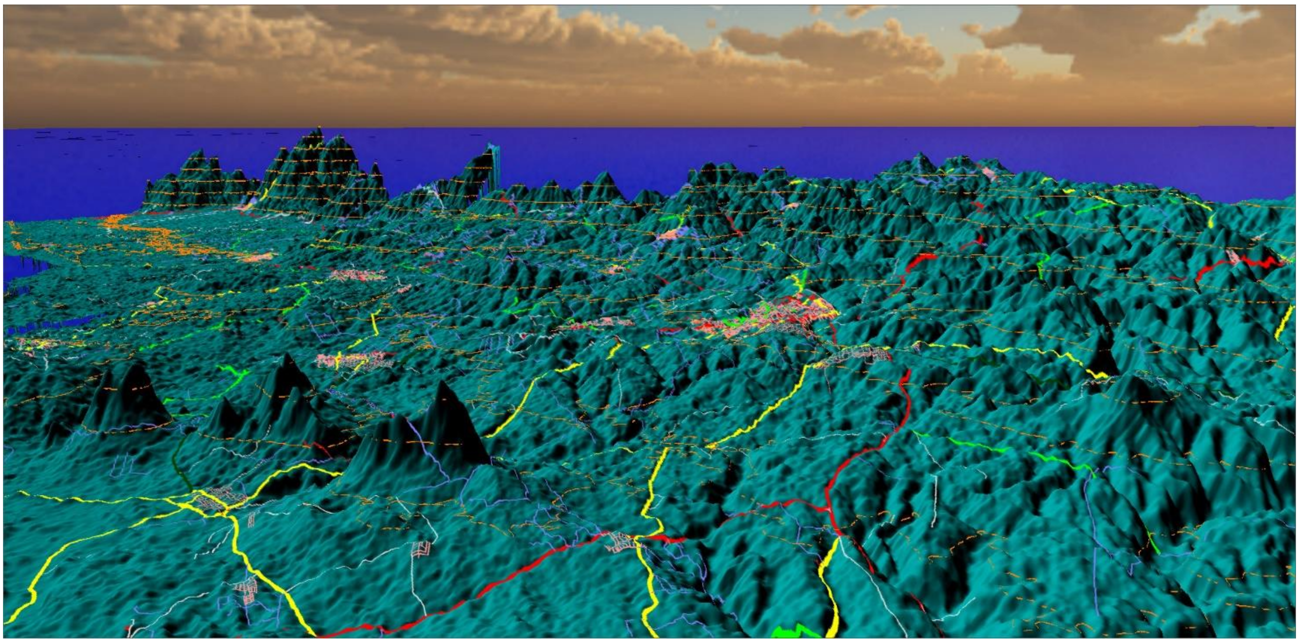


Figure 56:3D visualisation of the contours line layer with the roads networks of Ain Temouchent.

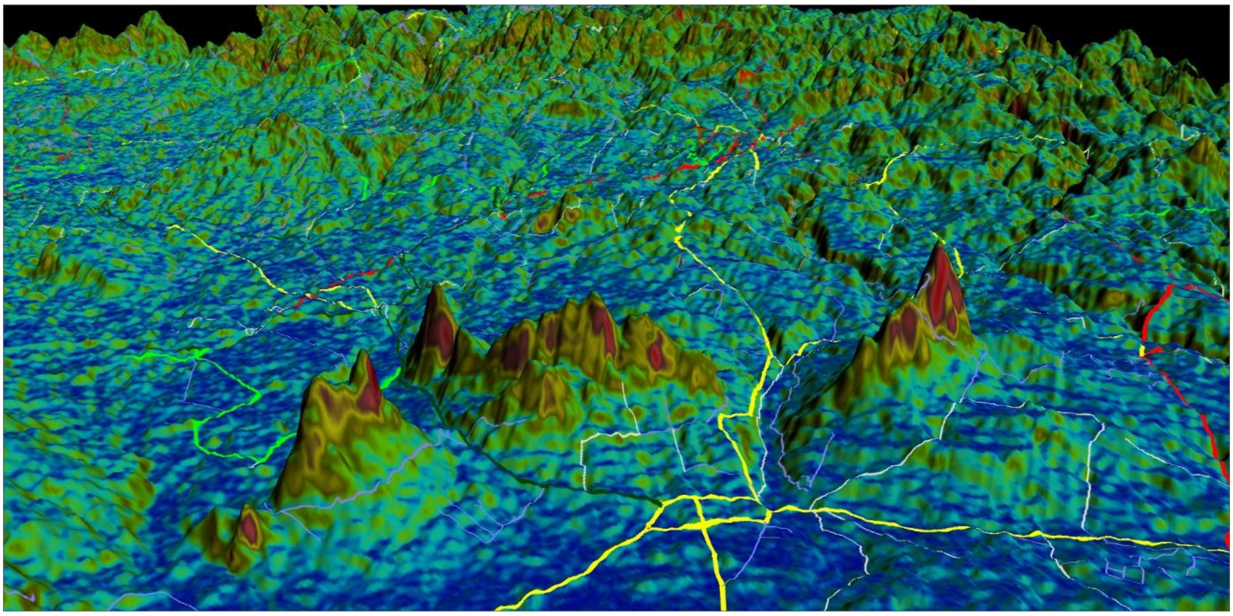


Figure 57:3D visualization of the slop map layer with the roads networks of Ain Temouchent.

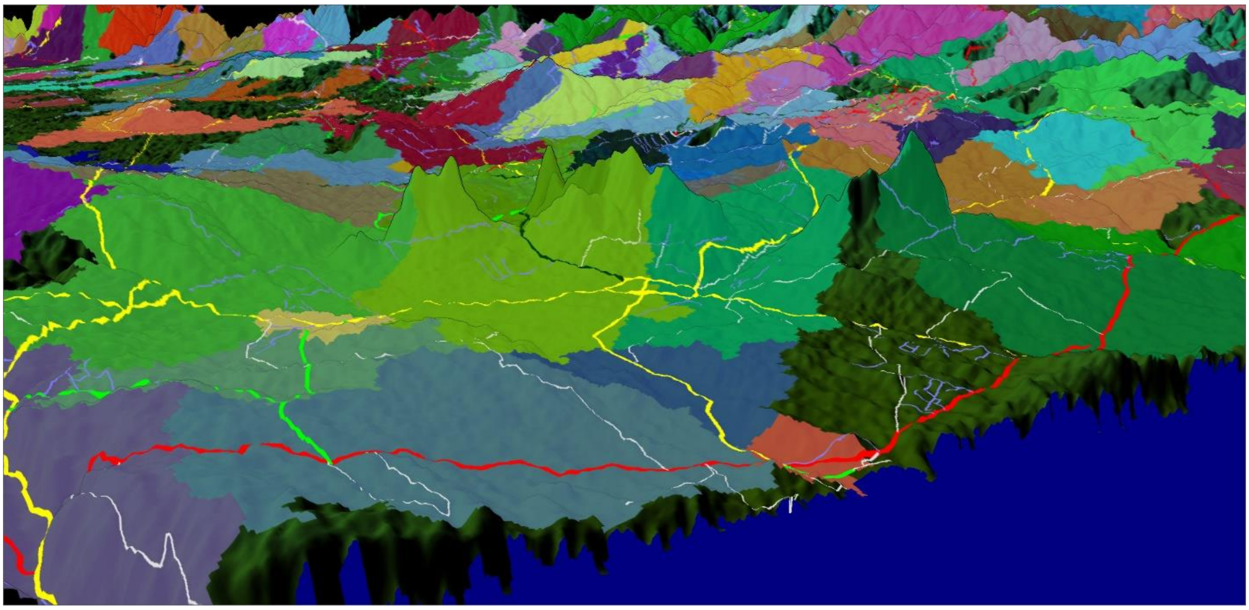


Figure 58:3D visualization of the Drainage map layer with the roads networks of Ain Temouchent.

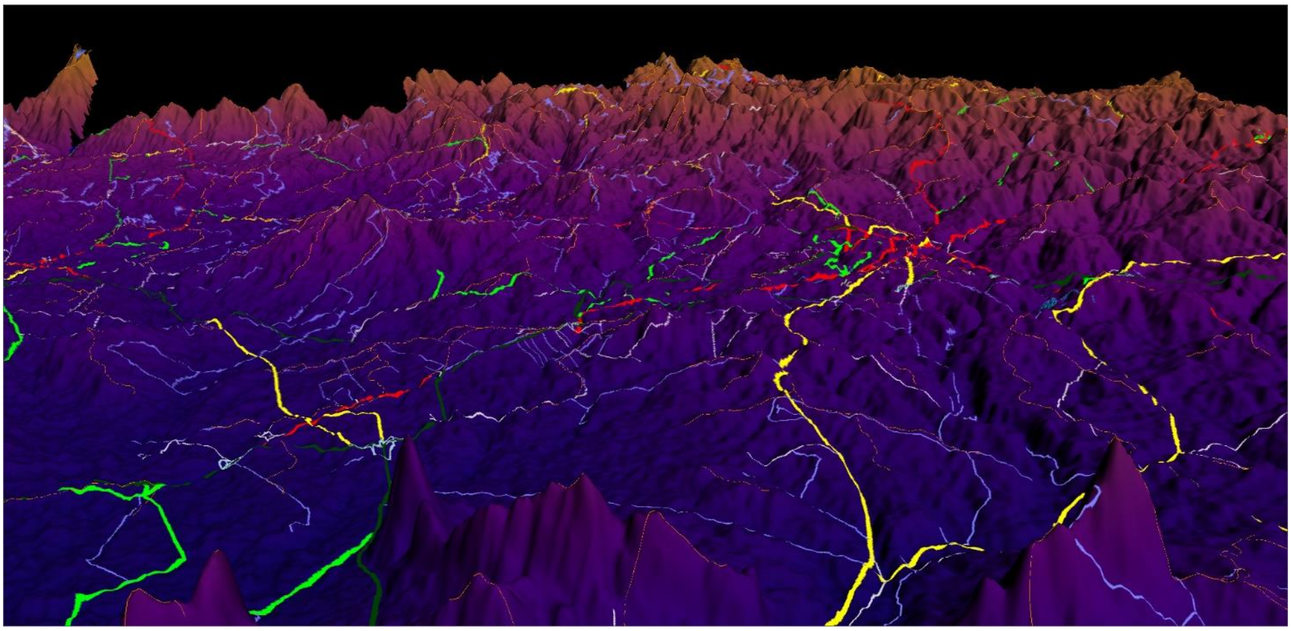


Figure 59:3D visualization of ridge layer with the roads networks of Ain Temouchent.

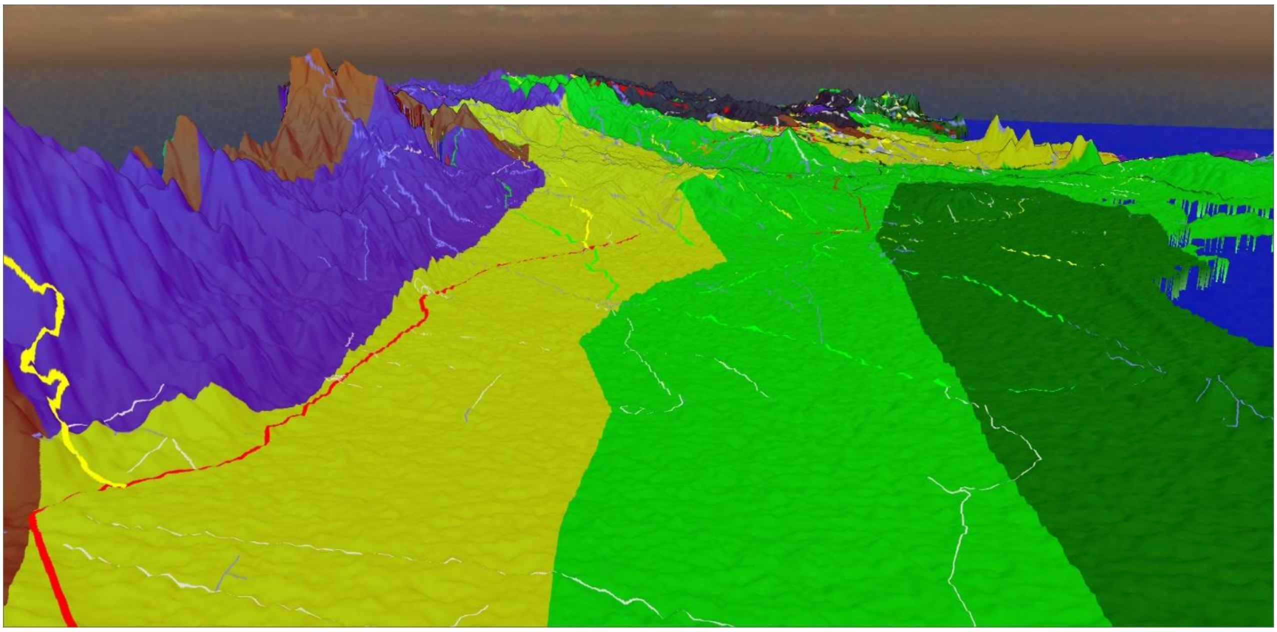


Figure 60 :3D visualization of the Geology layer with the roads networks of Ain Temouchent.

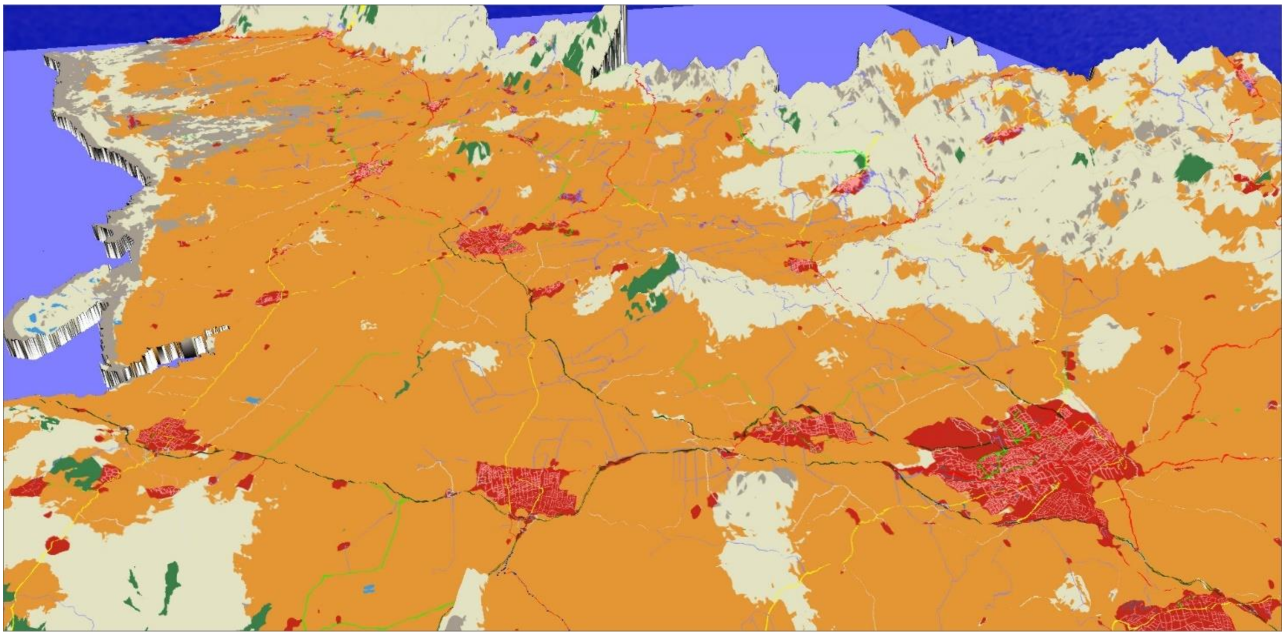


Figure 61:3D visualization of the land cover layer with the road networks of Ain Temouchent.

Figure 62:3D visualization of the watershed map layer with the roads networks of Ain Temouchent.

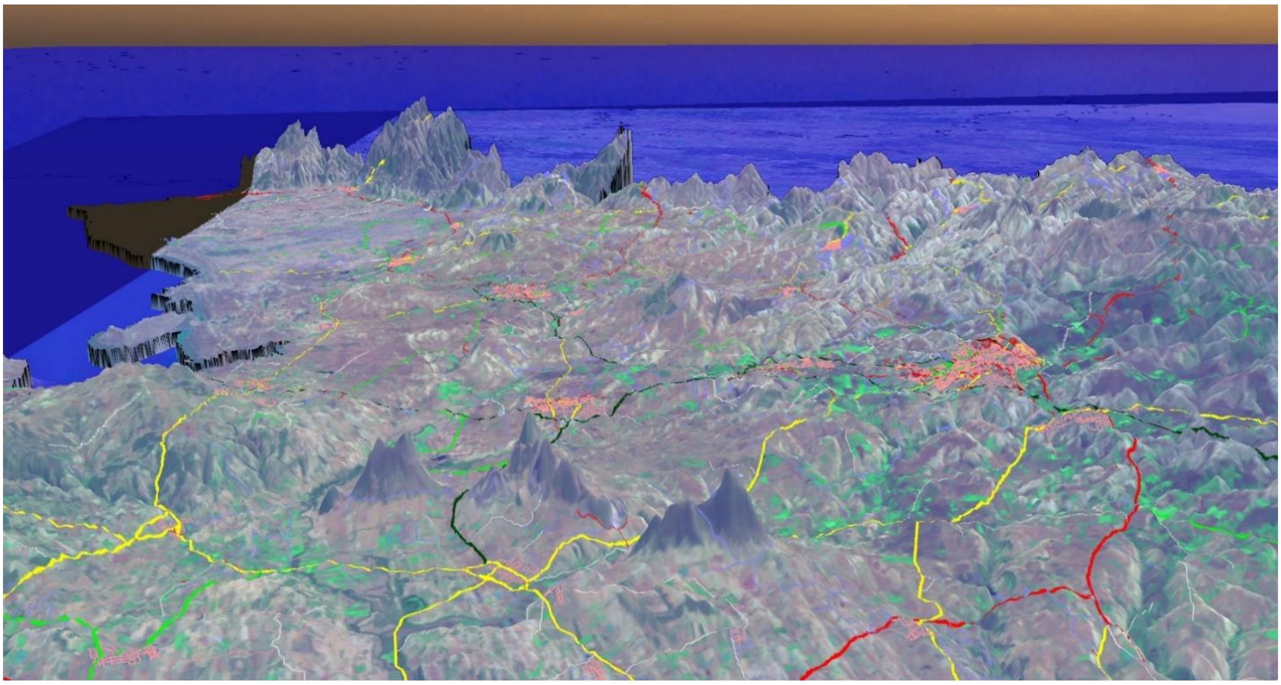


Figure 63:Landsat image draped with the Roads networks on the DEM.

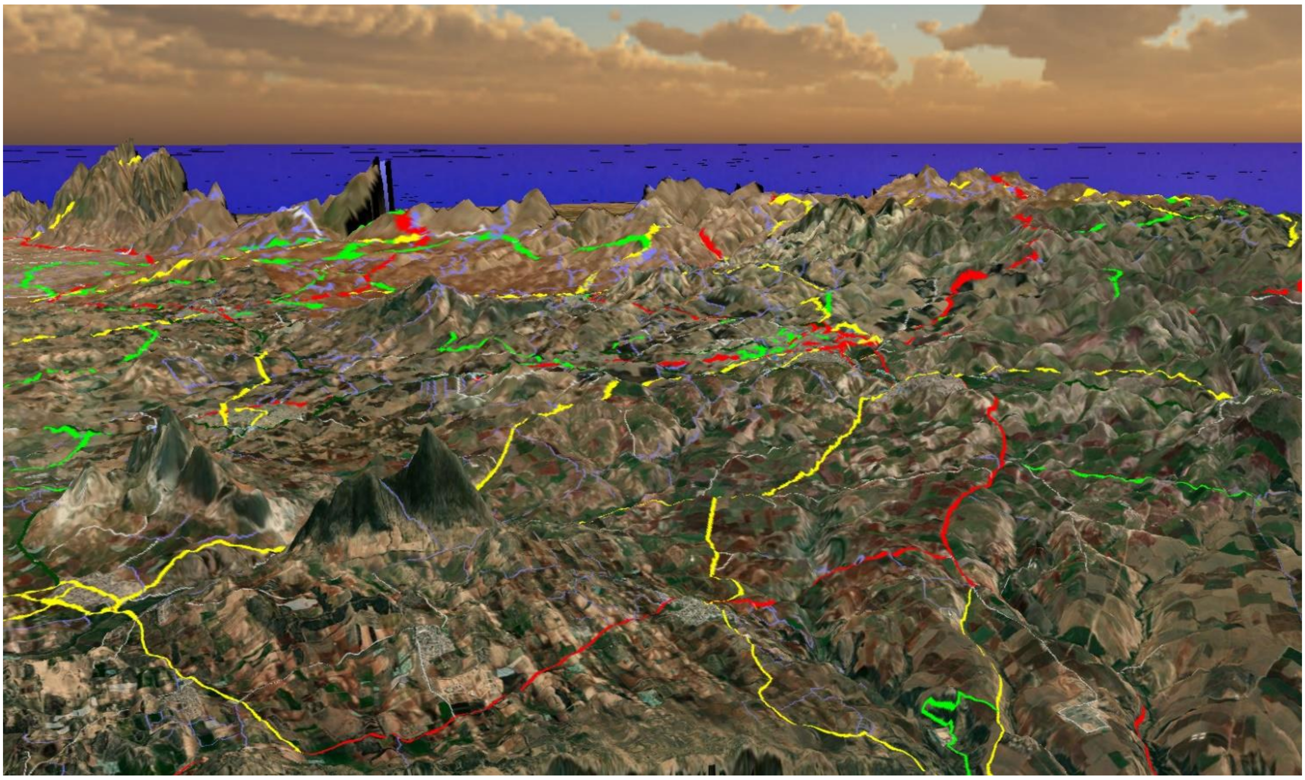


Figure 64:3D World imagery with Raods networks.

We note that with Global Mapper, we can access a powerful tool for real-time dynamic interaction between the 2D plan, the 3D view, and the profile path, as shown in the figure below

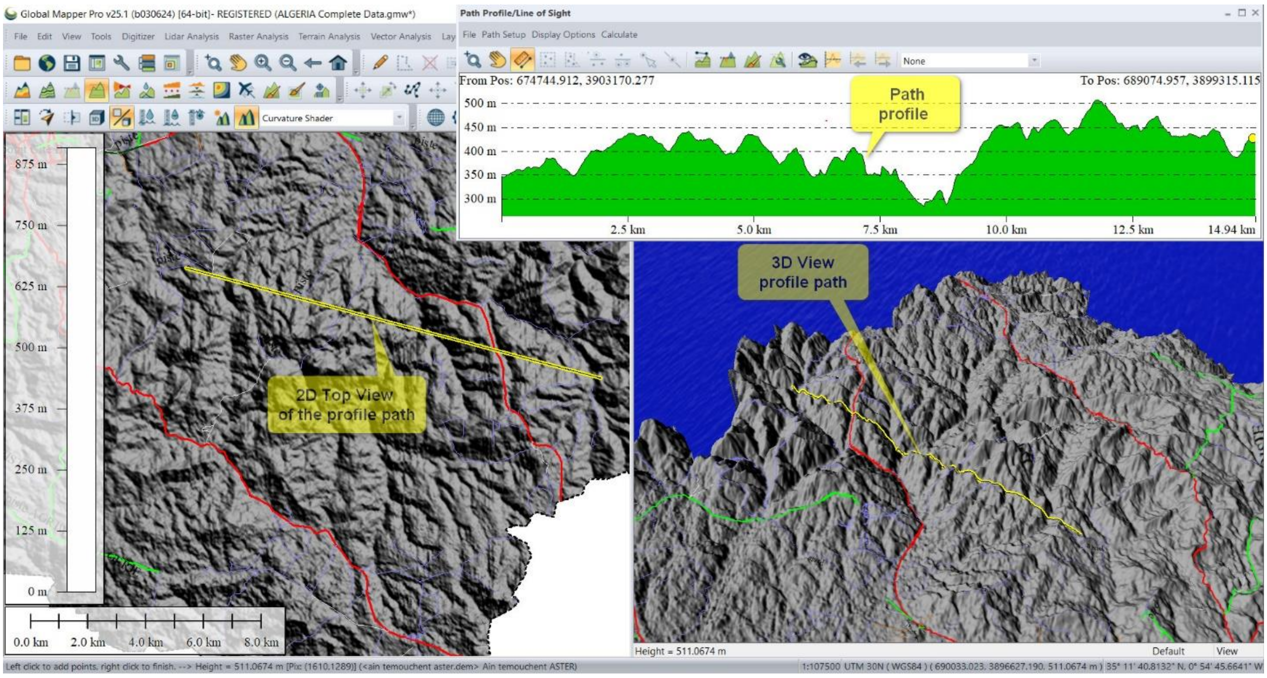


Figure 65:Dynamique view in real time path profile.

Furthermore, this enhanced 3D GIS maps derived from freely available geospatial data of road networks offer several benefits:

1.Improved Visualization: 3D GIS maps provide a more realistic and immersive representation of road networks compared to traditional 2D maps. This enhanced visualization helps users better understand the spatial relationships and topography of the area.

2.Enhanced Spatial Analysis: By incorporating elevation data, 3D GIS maps enable more accurate spatial analysis. Users can analyze aspects such as slope, terrain ruggedness, and elevation changes along road networks, which can be crucial for infrastructure planning, environmental assessment, and disaster management.

3.Better Decision Making: The detailed and realistic representation of road networks in 3D GIS maps facilitates better decision-making processes for urban planning, transportation management, and infrastructure development. Stakeholders can visualize proposed changes or developments more effectively, leading to informed decisions.

4.Effective Communication: 3D GIS maps are valuable communication tools for conveying complex spatial information to a wide range of audiences. They can be used in public consultations, presentations, and reports to effectively communicate ideas, plans, and proposals related to road networks.

5.Simulation and Modeling: Enhanced 3D GIS maps enable the simulation and modeling of various scenarios related to road networks. This includes traffic flow analysis, emergency response planning, and urban development simulations. Such simulations help in predicting the impact of proposed changes and optimizing resource allocation.

6.Integration with IoT and Sensor Data: 3D GIS maps can be integrated with data from IoT devices and sensors deployed along road networks. This integration enables real-time monitoring of traffic conditions, environmental factors, and infrastructure performance, leading to proactive decision-making and management.

7.Support for Navigation and Routing: By providing a more realistic representation of the road environment, 3D GIS maps enhance navigation and routing applications. Users can benefit from improved route visualization, accurate terrain information, and better understanding of the surrounding context.

8.Accessibility and Collaboration: Free geospatial data and open-source GIS tools facilitate the creation and sharing of 3D GIS maps, making them more accessible to a wider audience. This fosters collaboration among stakeholders, researchers, and communities, leading to innovative solutions and knowledge sharing.

Conclusion:

In this thesis, we embarked on a journey to explore the utilization of free geospatial data and Geographic Information Systems (GIS) technology to enhance the 3D visualization of rural road networks, focusing on the case study of the Wilaya of Ain Temouchent in Algeria. Let us first revisit the objectives of the thesis

The primary objective of this thesis was to investigate the potential of utilizing free geospatial data and GIS technology to improve the visualization of rural road networks. We aimed to leverage open-access datasets to generate a comprehensive 3D map of the road network in the Wilaya of Ain Temouchent, providing insights into infrastructure planning and management.

To attempt these objectives, we establish the important concept in the initial chapters one and two, we explored the state of the art in GIS technology and geospatial data sources, highlighting the advancements that have democratized access to spatial information.

Chapter 3 was dedicated to the practical application of the concepts discussed in the preceding chapters. We employed Digital Elevation Models (DEMs) from ASTER and SRTM to create a detailed 3D map of Ain Temouchent. The road network data, extracted from OpenStreetMap (OSM), was modified and categorized based on road class, including national roads, communal roads, highways, and tracks. Additional layers, such as administrative divisions and hydrographic networks, were integrated into the 3D model.

The resulting 3D map provided a multitude of visualization options derived from the DEM, allowing simultaneous 2D and 3D visualization of the road network, slope maps, azimuth maps, contours maps, watershed maps, and more. An immersive feature of this visualization was the automatic integration of real sun shadows based on geographic coordinates. Furthermore, statistical reports for each road class were extracted in Excel format, providing valuable insights into road infrastructure.

Encountered Challenges: Throughout the project, several challenges were encountered, including selecting the appropriate GIS software based on hardware capabilities and available features. Additionally, addressing the lack of geometric and semantic information in the OSM road network dataset posed a significant challenge.

Recommendations for Future Work: As a recommendation for future work, it is essential to establish quality indices, both geometric and semantic, for the road network extracted from OSM. This would enhance the accuracy and reliability of the visualization. Additionally, integrating missing information about the road network, such as width, number of lanes, pavement date, and degradation type, would improve visualization capabilities, especially in street view mode.

Bibliography

1. **all, PAUL A.LONGLY And.** https://www.google.dz/books/edition/Geographical_Information_Systems_and_Sci/toobg6OwFPEC?hl=fr&gbpv=1&dq=Longley+et+al.,+2015).&printsec=frontcover. [Online] 2015.

2. **Burrough, P. A., & McDonnell, R. A.** https://books.google.dz/books?hl=fr&lr=&id=kvoJCAAAQBAJ&oi=fnd&pg=PP1&dq=Burrough,+P.+A.,+%26+McDonnell,+R.+A.+(2015).+Principles+of+Geographical+Information+Systems.+Oxford+University+Press.&ots=aMB55kA5KI&sig=9nd888mCqjuGf6JVKzTQu-7Ey_I&redir_esc=y#v=on. [Online] 2015.

3. **Yuan, M., & Shaw, S. L.** *Big Data and Urban and Regional Public Policy Evaluation. Springer.* 2018.

4. **all, Fausta Mbura and.** https://www.researchgate.net/figure/GIS-evolution-and-future-trends_fig1_282724755. [Online] 2014.

5. *https://www.scirp.org/journal/paperinformation?paperid=71676.* **Sandro Laudares, João Bosco Laudares, Matheus Pereira Libório.** 2016.

6. **nadir.** https://www.univ-chlef.dz/fsnv/wp-content/uploads/Cours-SIG-appliqu%C3%A9-L3-Sol-et-eau-partie1-Mr.-Naded-N..pdf. [Online] 2019/2020.

7. **said, ben lakhdar.** https://www.asjp.cerist.dz/en/article/109544. [Online] 2020.

8. **Srivastava, Akhilesh.** https://www.akhilesh.info/blogs/challenges-and-future-trends-in-gis-for-infrastructure-development. [Online] 2023.

9. **bbc, amine.** https://storymaps.arcgis.com/stories/773b81d5f446441d893a2551d13ed388. [Online] 2019.

10. **may.** An integrated architectural framework for geoprocessing in cloud environment - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Overview-of-Cloud-based-GIS-Model_fig1_312267072 [accessed 8 May, 2024]. [Online] 2024.

11. **force, sales.** https://www.tableau.com/learn/articles/big-data-analytics. [Online] 2024.

12. **stuff, cousra.** https://www.coursera.org/in/articles/big-data-analytics. [Online] 2023.

13. **deiter.** https://www.researchgate.net/publication/2519030_Three-Dimensional_Geographic_Information_Systems_-_Status_And_Prospects. [Online] 2001.

14. **Tang, W., Shao, Z., Liu, Y., & Xiao, X.** *https://www.researchgate.net/publication/370870733_Integrated_optimization_of_urban_rail_transit_line_planning_timetabling_and_rolling_stock_scheduling.* [Online] 2019.

15. **Rautenbach, V., Coetzee, S., & Cockeran, M.** *https://www.researchgate.net/publication/303868923_Investigating_the_use_of_3D_geovisualizations_for_urban_design_in_informal_settlement_upgrading_in_South_Africa.* [Online] 2017.

16. **amtaweel, mark.** https://www.geographyrealm.com/gis-virtual-reality/. [Online] 2017.

17. **borjigin, jimo.** https://www.researchgate.net/publication/259350534_Reply_to_Chawla_and_Seneff_Near-death_electrical_brain_activity_in_humans_and_animals_requires_additional_studies. [Online] 2013.

18. *the role of open source softare in geospatial analysis.* **Mohammed, M.A.** 2019.

19. **sons, john wiley &.** the geographic information science & technlogy. 2018.

20. **esri.** https://www.esri.com/training/catalog/search/. [Online] 2024.

21. **hasiang, man.** https://www.researchgate.net/figure/The-components-of-Mobile-GIS-technology_fig2_237105601. [Online] 2003.

22. **elezabeth, micha and.** https://ieeexplore.ieee.org/document/8397258. [Online] 2017.

23. **.w, HI .Y And Li.** https://ieeexplore.ieee.org/document/8397258. [Online] 2017.

24. **all, longley p.a & goodchild M.F and.** *geographic information science and systems.* 2015.

25. **all, dk and.** GIS For evryone . 2004.

26. **jensen, john r.** remote sensing of the environment : an earth resource persective. [Online] 2015.

27. **bolstad, paul.** GIS fundamentals :A First text on geographic information systems . [Online] 2016.

28. ***https://earthobservatory.nasa.gov/features/RemoteSensingv.* [Online]**

29. *International Journal of Spatial Data Infrastructures Research (kuleuven.be).* amy. 2008, pp. 146-166.

30. rahman, dedek. ground truth data for satellite image classification . [Online] 2017.

31. vision. https://www.esri.com/about/newsroom/insider/empowering-gis-professionals-and-transforming-organizations/. [Online] 2015.

32. n.d. https://earthexplorer.usgs.gov/. [Online] 2024.

33. GIS. https://gisgeography.com/free-satellite-imagery-data-list/. [Online] 2024.

34. natural. https://www.naturalearthdata.com/. [Online] 2024.

35. open. OpenStreetMap. [Online] 2024.

36. smith, jhon. https://www.geospatialworld.net/article/us-census-bureaus-tigerline-data-a-comprehensive-guide/. [Online] 2023.

37. https://scihub.copernicus.eu/userguide/GraphicalUserInterface. [Online] 2024.

38. noancie. https://www.ncei.noaa.gov/. [Online] 2024.

39. esa. https://earth.esa.int/web/guest/home. [Online] 2020.

40. l.s. https://fr.wikipedia.org/wiki/Programme_Landsat#Le_programme_LDCM_(2002-2021). [Online] 2021.

41. s.t. https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1. [Online] 2024.

42. Burrough, P. A., & McDonnell, R. A. *Principles of Geographical Information Systems. Oxford University Press.* 2015.

43. *https://earthquake.usgs.gov/monitoring/gps/about.php.* [Online]