الجمهوريــة الجزائريــة الديمقراطيــة الشعبيــة
وزارة التعليـم العالـي والبحـث العلمـي

جامعة محمد بوضياف بالمسيلـــة
كليـــة العلـــوم
رقم 703/ك ع/2024

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جامعة محمد بوضياف - المسيلة
Université Mohamed Boudiaf - M'sila

المسيــلة في: 2024/12/19

شهادة موافقة علمية على مطبوعة بيداغوجية

للأستاذ خضور جمال - أستاذ محاضر أ -

يشهد رئيس المجلس العلمي لكلية العلوم بجامعة محمد بوضياف بالمسيلة، أنه بعد الإطــلاع على تقاريـــر الخبـــرة الواردة من طرف الخبـــراء من صف الأستاذيـــة:

- السيد **بونار رابح**، أستاذ التعليم العالي بجامعة محمد بوضياف- المسيلة.
- السيد **رحاب حاجي** أستاذ التعليم العالي **بجامعة سطيف1** .

والمعينين طرف المجلس العلمي لكلية العلوم في الاجتماع المنعقد في دورته العادية يوم2024/11/25 لإجراء الخبرة للمطبوعة البيداغوجية الخاصة بالأستاذ **خضور جمال** - أستاذ محاضر- أ - **قسم علوم الطبيعة والحياة** والمتعلقة بخبرة للمطبوعة البيداغوجية للمــادة المعنونة بــ: **Geographic Information System** والمقررة في برنامج التكوين ماستر، تخصص: « **M2 Ecology of Natural Environments** » و المفتوح بقسم **علوم الطبيعة والحياة** .

تــمت الموافقــة عليها شكــلا ومضمونــا.

رئيس المجلس العلمي لكلية العلوم

بعزيز حكيم

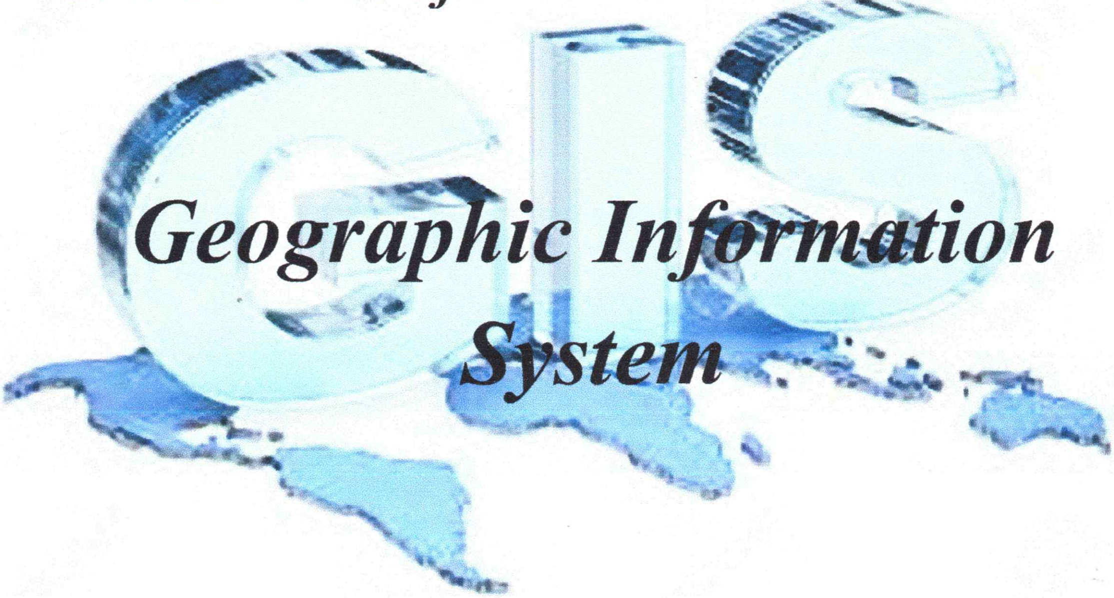
الجمهورية الجزائرية الديمقراطية الشعبية
People's Democratic Republic of Algeria
وزارة التعليـم العالــي و البحـث العلمـي
Ministry of Higher Education and Scientific Research

جامعة محمد بوضياف- المسيلة
University Mohamed BOUDIAF of M'sila

كلية العلوم
Faculty of Sciences

قسم علوم الطبيعة والحياة
Department of Natural and Life Sciencesde

Course Notes of :



Geographic Information System

Intended for 2nd year Master students.
Sector : Ecology and Environment.
Specialty: Ecology of Natural Environments.

Presented by : Dr. Djamel KHOUDOUR
Grade: Lecturer "A"

Teacher-Researcher at the Department of Natural and Life Sciences
Faculty of Sciences - University Mohamed BOUDIAF of M'sila

University Year 2024-2025

Summary

Chapter III :
General Information on Geomatics

Chapter IV :
Technical Aspects and Architecture of GIS

Chapter V :
Applications (ecosystem management and conservation, wildlife, flora...)

Practical Work

Part One : Getting Started with ArcGIS

Part Two : Practical work

List of Figures

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Geographic Information System program according to the current training canvas in French :

Intitulé du Master : Ecologie des milieux naturels
Semestre : S3
Intitulé de l'UE : Méthodologique
Intitulé de la matière : Système d'information géographique (SIG)
Crédits : 3
Coefficient : 2

Objectifs de l'enseignement:
Acquisition de connaissances sur les avancées récentes dans le domaine de l'informatique et notamment le développement des techniques satellitaires, etinitiation aux connaissances théoriques de base sur le traitement et l'analyse des images satellitaires.

Connaissances préalables recommandées :
Notions de base en informatique.

Contenu de la matière :
Introduction (définition, objectifs, utilisations, apports)
Les spécificités de l'information spatiale
Généralités sur la géomatique (définition et concepts, aperçu sur l'utilisation des graphes en SIG)
Aspects techniques et architecture des SIG
Applications (gestion et conservation des écosystèmes, faune, flore…)
Mode d'évaluation : Contrôle continu + examen

Références (Livres et polycopiés, sites internet, etc).

BEGUIN M. & PUMAIN D. (2003) : La représentation des donnéesgéographiques-Statistique et cartographie. 2èmeédition. Ed : Armand Colin. 192p.
BORDIN P. (2002) : SIG concepts, outils et données. 1èreédition. Ed :HermèsLavoisier. 260p.
DENEGRE J. & SALGE F. (2004) : Les systèmes d'information géographiques. 2Eme édition. Presses universitaires de France (PUF). 128p.
GIRARD M.C. (2004) : Traitement des données de télédétection- Série environnementet sécurité. 1èreédition. Ed : Dunod. 530p.
LAARIBI A. (2000) :SIG et analyse multicritère. 1ère édition. Editions Hermès-Lavoisier. 192p.
LIER P., VALORGE C. & BRIOTTET X. (2008) : Imagerie spatiale- Des principes d'acquisition au traitement des images optiques pour l'observation de la terre. 1ère édition. Ed : Cépaduès. 492p.

Geographic Information System program according to the current training canvas in English :

Title of the Master : Ecology of Natural Environments
Semester: S3
TU title: Methodological
Subject title: Geographic Information System (GIS)
Credits: 3
Coefficient: 2

Teaching objectives:
Acquisition of knowledge on recent advances in the field of computing and in particular the development of satellite techniques, and introduction to basic theoretical knowledge on the processing and analysis of satellite images.

Recommended prior knowledge:
Basic notions of computer science.
Content of the material:
- Introduction (definition, objectives, uses, contributions)
- The specificities of spatial information
- General information on geomatics (definition and concepts, overview of the use of graphs in GIS)
- Technical aspects and architecture of GIS
- Applications (management and conservation of ecosystems, fauna, flora, etc.)
Evaluation method: Continuous monitoring + examination)

References (Books and handouts, websites, etc.).

BEGUIN M. & PUMAIN D. (2003) : La représentation des données géographiques-Statistique et cartographie. 2èmeédition. Ed : Armand Colin. 192p.
BORDIN P. (2002) : SIG concepts, outils et données. 1èreédition. Ed :HermèsLavoisier. 260p.
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Foreword

This course, in accordance with the title of the subject, concerns only the Geographic Information System in a precise manner, addressed to Master 2 students in Ecology of Natural Environments in the field of Nature and Life Sciences, Sector: Ecology and Environment , By first introducing the basic concepts of GIS (GIS components, data types), then explaining the growing importance of GIS in general and specifically for their field. We conclude with a presentation of the ArcGIS software and the acquisition of fundamental GIS skills and integrated into geomatics according to the objectives set and among which: Acquisition of knowledge on recent advances in the field of computing and in particular the development of satellite techniques, and introduction to basic theoretical knowledge on the processing and analysis of satellite images.

The course has been developed gradually by drawing on the regulatory content of the training framework of this Master whose harmonization has been formalized by Ministerial Order No. 1156 of 09/08/2016harmonizing the other specialties for qualified under theM'Sila University for the field "Natural and Life Sciences" on the one hand and on the other by a number of books.

The course is accompanied by practical sessions in which students will perform various operations using ArcGIS software.

The primary objective of this course is to offer a scientific and methodological synthesis of GIS, based on the knowledge and skills acquired in the 1st cycle. The second objective is to assimilate the scientific approach. To do this, we were keen to present the means of study and the data acquired in the laboratory or through modeling. The third objective, and not the least, is to develop your curiosity and to pass on to you our common passion for the study of geomatics. The passion for the subject, the passion for teaching and transmitting it.

The illustrations are very simple but the effort required of the student is immense, especially in the LMD system where the knowledge gaps must be filled with the consultation of documentation, especially digital, which is quite accessible today.

Dr. Djamel KHOUDOUR

Introduction

Introduction

The demand for digitized geographic information is increasing both in industrialized countries and in developing nations. However, due to the large volume, great diversity, and growing user demands, their presentation and manipulation are delicate tasks.

For over thirty years, the development of computer science has led to significant changes in geography and cartography. Data production has accelerated due to new methods of collection and acquisition. The processing of localized data has greatly expanded with the digital capture of graphic data, maps, and plans, along with database management systems and the storage capabilities of computer systems. Finally, many aspects of cartography have been automated, and production techniques have been completely transformed, leading to an acceleration in the dissemination and use of geographic data **[25]**.

Geographic information systems are unique in that they draw on numerous scientific and technical fields such as geodesy, database management systems, image processing, geometric algorithms, modeling and geometric interpolation, statistics, automated cartography, spatial analysis, and more. They also have the unique ability to integrate various computer methods and techniques, enabling them to model, digitize, store, manage, query, analyze, and represent geographic objects or collections of objects. These systems specifically account for the spatial characteristics of these objects as well as the descriptive attributes associated with them.

The GIS proves to be a powerful tool through its ability to represent reality in the form of thematic maps with layers of information (spatial distribution of a configurable category of entities). It allows for the integration of data from different sources as well as the management of large databases (DBMS). The measurements and samples in the database must represent the real world as comprehensively and consistently as possible. However, the complexity of the real world is so great that we create models of reality that are merely simplified representations. The content of a spatially referenced database thus presents a partial view of the real world (a particular representation as well). We are currently witnessing a true revolution in data production with the emergence of numerous applications. This revolution is directly related to hardware and technological advancements that allow for the integration of GIS software on smartphones or tablets, enabling the capture of a multitude of geolocated information which is directly stored in servers via an Internet connection.

This course material is dedicated to the study of various concepts surrounding geographic information systems. It considers that students will face geographic information management issues in their future activities. It presents different keys that will enable them to either perform technical functions related to GIS or manage projects dealing with geographic data (managing service providers, project ownership, GIS team management, the GIS component of a broader project, etc.). Thus, upon completing this course, students will be able to:

- Understand the concept of digital geographic information ;
- Grasp the basic concepts of GIS ;
- Discover the functionalities of GIS ;
- Effectively use GIS tools for urban data processing available to them in their professional lives ;
- Explore the variety of application domains ;
- Gain practical experience with the ArcGIS software.

Chapter I :

Definitions

and

Functionalities of a GIS

Chapter I :
Definitions and Functionalities of a GIS

I.1. Definitions

System (S): A system links a set of objects and activities so that they interact towards a common goal **[35]**.

Geographic Information (GI): Information is considered geographic when it relates to one or more locations on the Earth's surface. This information has the characteristic of being localized, pinpointed, or geocoded **[9]**.

All information related to a spatially referenced object on the Earth's surface **[35]**.

It refers to any information on objects or phenomena (called geographic entities) that can be located on the surface of the earth. It is of primary importance for all those who have to manage a space or objects dispersed in a given space. The term spatial information includes data as diverse as the distribution of natural resources (soils, water, vegetation), the location of infrastructures (roads, buildings, various equipment networks), administrative and political boundaries, even statistical data relating to the population, employment, etc.

Geographic Information System (GIS) : A GIS is an information system capable of organizing, capturing, storing, updating, manipulating, analyzing, and presenting spatially referenced alphanumeric data, as well as producing plans and maps. Its applications cover geomatics activities related to the processing and dissemination of geographic information. Finally, a GIS can be defined as a computerized system capable of representing a territory or part of a territory in digital form **[44]**.

A GIS is a system that creates, manages, analyzes, and maps all types of data. The GIS links data to a map, integrating location data (where things are) with all types of descriptive information (what things look like there). This provides a foundation for mapping and analysis that is used in science and in nearly every industry. GIS helps users understand patterns, relationships, and geographic context. *www.esrifrance.fr/application.asp*

The definitions that various authors and organizations give to GIS are quite similar: A GIS is powerful set of tools for gathering, storing, retrieving on demand, and visualizing spatial data from the real world for a particular set of objectives **[10]**.

According to the *French Society of Photogrammetry and Remote Sensing*: A GIS is a computer system that allows, from various sources, to gather, organize, manage, analyze, combine, develop, and present geographically located information, contributing notably to spatial management.

A GIS is a computer system for capturing, manipulating, storing, and visualizing digital spatial data **[24]**.

In a broader definition, it is a digital system for acquiring, managing, analyzing, modeling, and visualizing spatial data for the purposes of planning, administration, and control of the natural environment and socio-economic applications.

As for the company *ESRI* (Environnemental Systems Research Institute), the GIS is an organized set of hardware, software, geographic data, and personnel designed to efficiently capture, store, retrieve, update, query, analyze, and display any form of geographically referenced information.

A Geographic Information System (GIS) is primarily a database management system capable of handling localized data, and thus able to capture, store, retrieve (especially based on geographic criteria), query, analyze, and finally represent and map the data **[13]**.

I.2. Bit of history

During the 1950s and 1970s, new practices increasingly emphasized the use of maps for natural resource management. With the growing awareness of the interrelation between various phenomena occurring on the Earth's surface, the necessity to develop comprehensive and multidisciplinary management tools quickly became evident.

By the late 1970s, Computer-Assisted Design (CAD) technology had made significant progress, with more than a hundred systems available on the market. At the same time, new techniques were being developed in related fields such as pedology, hydrography, topography, photogrammetry, and remote sensing.

The rapid pace of development of these new techniques, along with the lack of maturity in this sector, initially resulted in a duplication of efforts in related disciplines without real coordination. However, as systems multiplied and experience was gained, the potential for linking different spatial data processing methods began to emerge. This gave rise to a new field: geographic information systems, which are universally used today.

In the early 1980s, as information became both more sophisticated (through miniaturization and increased computing power) and more popular (with the advent of affordable computers), GIS benefited from the widespread adoption of computer platforms. Today, GIS is used by all stakeholders in land use planning **[9]**.

Tab.1 The Main Periods in the Evolution of GIS **[28]**.

Period	Evolution of GIS
Late1950s – Mid -1970s	Early computing,first automatic cartography
Mid – 1970s –Early 1980s	Spread of automatic,Cartography / GIS tools is govemment agencies (military,cadastral services,topographic services,etc.).
Since the 1980s	Growth of the software market, devlopment of applications on PCs, networking (databases)
Since the 1990s	Applications on the Internet and the mainstream use of geographic information (online mapping, route calculation, use of GPS – related embedded tools,etc.).

I.3.Sciences related to GIS

Geographic Information Systems are the result of the combination and integration of multiple disciplines **[4]** :

Geography : Organization and spatial analysis (population, resources, etc.);

Cartography : Which provides methods for representing geographic space;

Remote Sensing : Technique for acquiring and processing data obtained with satellite and airborne sensors (images or photos);

Photogrammetry : Which explains aerial photographs;

Geodesy : Which provides very precise location measurements;

Mathematics : Which offers specialists in Geographic Information Systems various methods for matrix calculations, differential and integral calculus, trigonometry, geometry, interpolation, and extrapolation of curves;

Statistics : Which provides the means for analysis and interpretation of measurements;

Computer Science : Which enables the creation of databases, Computer--Assisted Design (CAD), computer graphics, database management systems (DBMS), algorithms, and artificial intelligence;

Topography : (from Greek topo = place and graphe = drawing). It is the science that measures and represents on a map the forms and details visible on the ground (relief, hydrography, etc.) with the objective of determining the position and altitude of any point.

On completion of Data analysis GIS helps in Planning and Managing the environmental hazards and risks. In order to plan and monitor the environmental problems, the assessment of hazards and risks becomes the foundation for planning decisions and for mitigation activities. GIS supports activities in environmental assessment, monitoring, and mitigation and can also be used for generating Environmental models. Below are some of the applicable areas where GIS can be implemented for effective planning and management (Fig. 1)

GIS applicable Areas :

- Wild Land Analysis ;
- Emergency Services like Fire Prevention ;
- Hazard Mitigation and Future planning ;
- Air pollution & control ;
- Disaster Management ;
- Forest Fires Management ;
- Managing Natural Resources ;
- Waste Water Management ;
- Oil Spills and its remedial actions ;
- Sea Water – Fresh water interface Studies ;
- Coal Mine Fires.

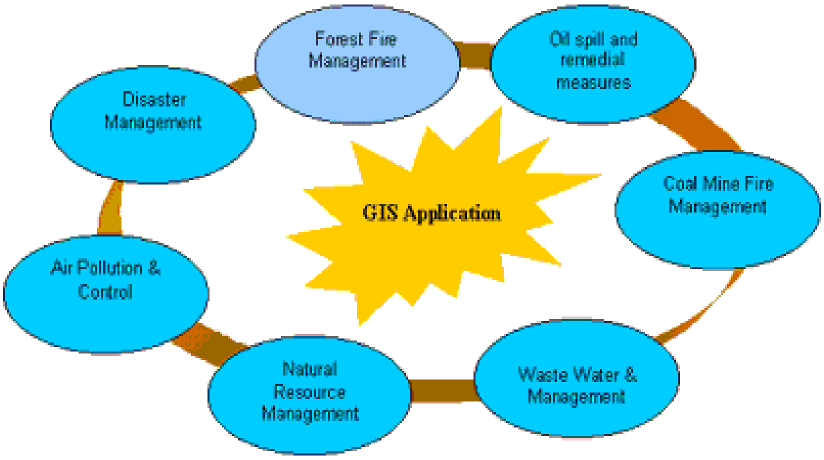


Fig. 1 Diagram showing the application of GIS for various environmental solutions **[26]**

I.4.Components of GIS

According to ESRI France, a geographic information system consists of five (5) major components (Fig.2) :

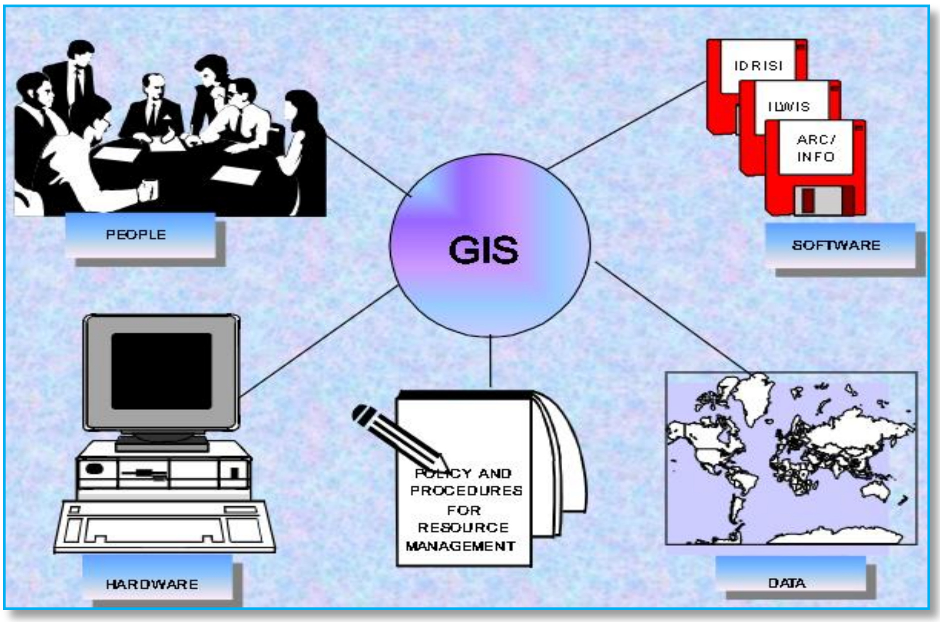


Fig. 2 The components of GIS **[28]**

➢ *Software* : Specialized applications and programs for managing, analyzing, and visualizing geospatial data. They provide the following six functions (sometimes grouped under the term "6A») **[39]**, as shown in Fig.3 and Fig.4 :

- Acquisition: Capturing geographic information in digital form;
- Archiving: Database management;
- Analysis: Manipulating and querying geographic data;
- Advertise: Formatting and visualization;
- Abstraction: Representing the real world;
- Anticipation: Forecasting.

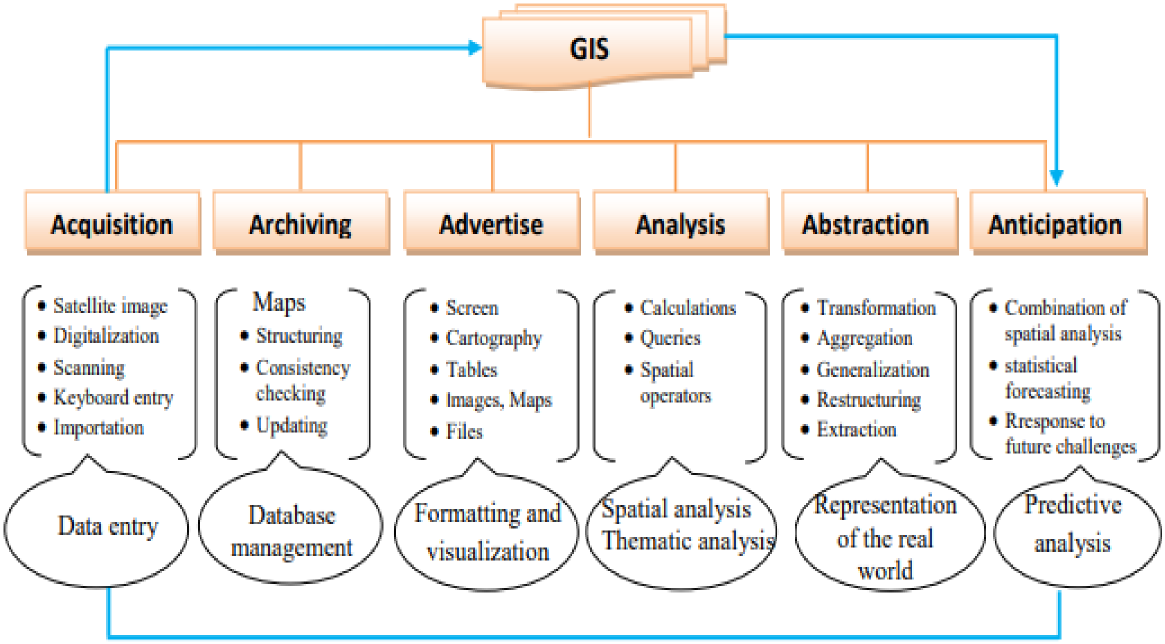


Fig. 3 The most important functionalities of GIS

➢ *Spatial data* : Spatial data refers to data that contains the geographic position of specific entities on the Earth's surface, as well as attribute information describing what these entities represent. This data is the most important component of GIS. It is either imported from files or directly entered by an operator. Furthermore, the utility and reliability of the GIS are determined by good data quality **[39]**.

➢ *Computer hardware:* Currently, data processing using software cannot be done without a computer. Furthermore, to facilitate the dissemination of results produced by a GIS, client-server systems on intranets, extranets, and even the Internet are increasingly used **[39]**.

➢ *Know-how (methods):* The correct design of a GIS requires the intervention of an interdisciplinary team, where know-how will be united **[32]** :

- Technical: mastery of development languages and computer modeling, graphic processing, and the translation of queries into computer language;

- Theoretical: geodesy, graphic and cartographic semiology, and, depending on the field, other fundamental knowledge that needs to be mastered.

➢ *Users / Trained personnel :* GIS addresses a very large community of users, from those who create and maintain the systems to those who use the geographic dimension in their daily work. With the advent of GIS on the Internet, the community of GIS users is growing significantly, and it is reasonable to think that in the near future, we will all be GIS users at different levels **[17]**.

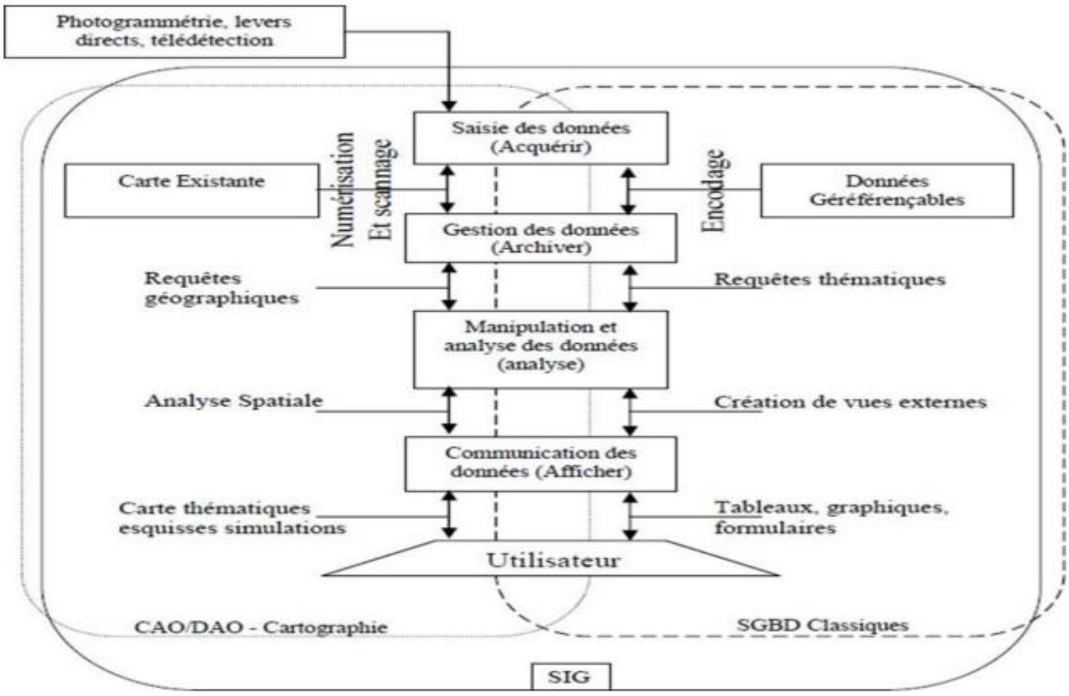
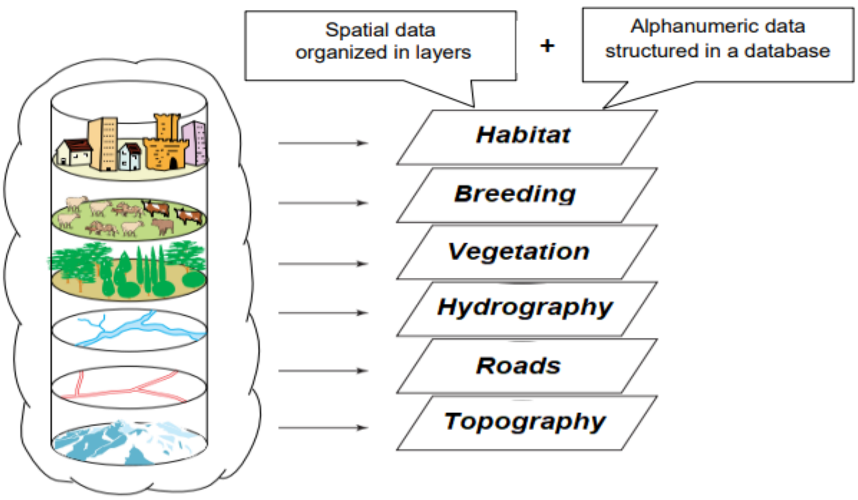


Fig. 4 The functionalities of GIS **[30]**

I.5. How does a GIS work? ***Structuring geographic information in layers.***

A GIS stores information about the world in the form of thematic layers, which are inter connected through the georeferencing of data.



Geographic DataBase = Set of superimposable layers

Fig. 5 Structuring Geographic Information

I.6. Questions a GIS can answer

According to ESRI (2004), a GIS must answer five questions, regardless of the application domain **[36]** :

Where : Where is the study area located and what is its geographical extent? Where is this phenomenon found? This question highlights the spatial distribution of a geographical object.

What : What objects can be found in the studied area? This question provides information about the geographical objects present in a given area.

How : How are the objects distributed in the studied area, and what are their relationships? This is spatial analysis.

When : What is the age of an object or phenomenon? This is temporal analysis.

What if : What would happen if a certain event occurred? This last question allows for predictions or simulations about the future.

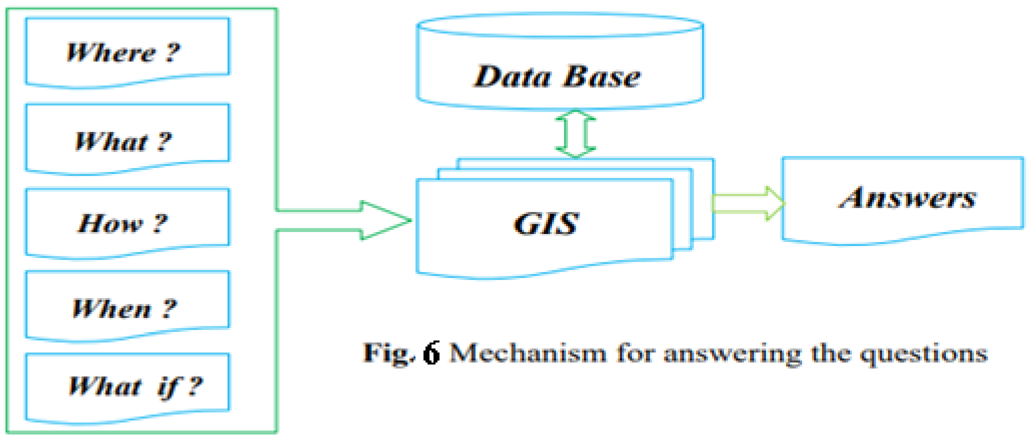


Fig. 6 Mechanism for answering the questions

I.7. Types of GIS

I.7.1. Mobile GIS (nomadic)

Geographic Information Systems on mobile phones, known as mobile GIS, are tools designed for decentralized use of geographic databases, which is particularly useful for performing field operations. They offer several functions, the main ones being **[11]** :

- Data consultation (maps, data layers, attributes, etc.);
- Data acquisition and modification;
- Tool localization via a GPS receiver (integrated or not);
- Data collection through sensors (GPS, thermometer, theodolite, etc.);
- Spatial analysis functions.

A mobile GIS mainly consists of a mobile terminal, which can be either a field computer or various versions of mobile phones, depending on the type of device. The localization component is fundamental to ensure the georeferencing of all collected and updated information; some mobile devices have a GPS functionality **[11]**.

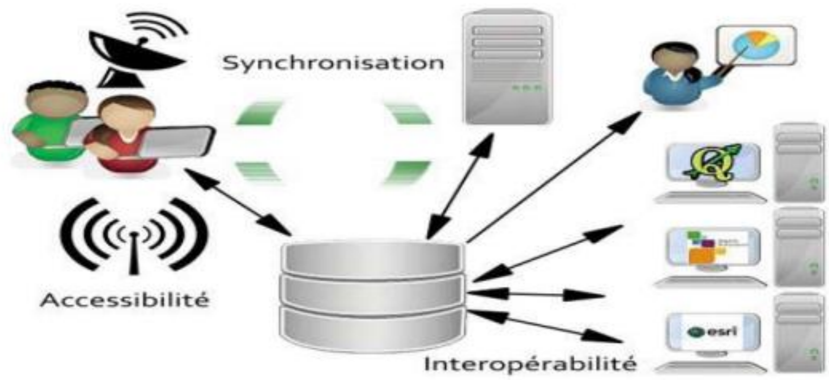


Fig. 7 Key Concepts of Mobile GIS **[44]**

I.7.2. Desktop GIS

A GIS is a globally organized set comprising elements (data, equipment, procedures, human resources) that coordinate, based on a common spatial reference, to achieve a result. It is therefore a management and decision-support system. This Geographic Information System handles localized information, thereby adding a geometric dimension to traditional Information Systems (Fig.8). Access to this information is facilitated through identification and query functions; this access is achieved by querying a geographic database located on a desktop computer server **[35]**.

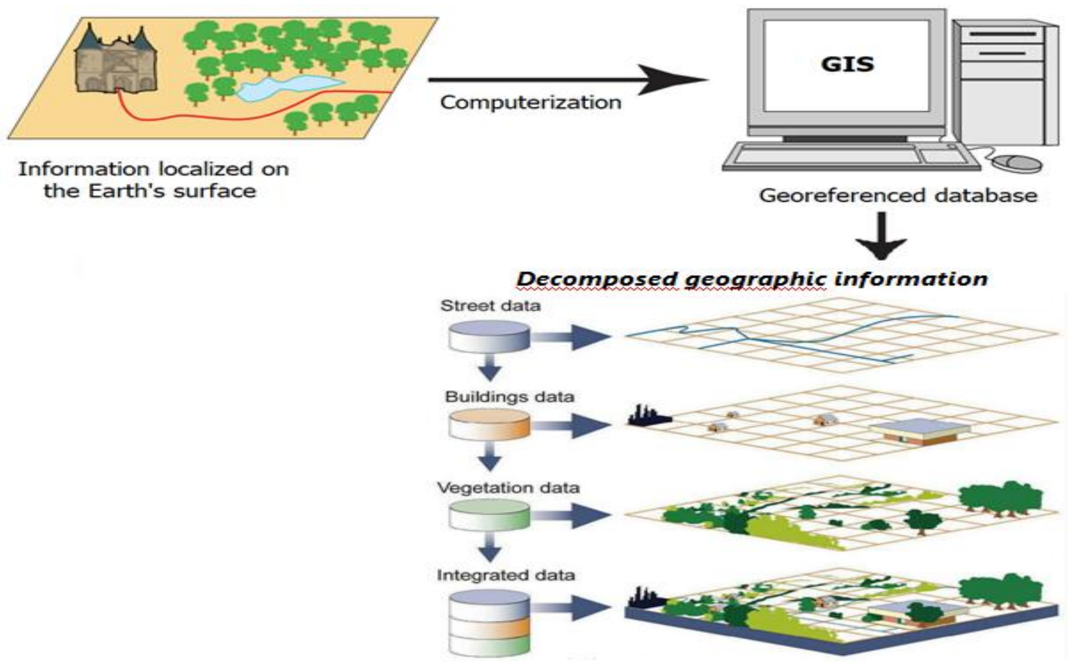


Fig.8 Basic Operation of a GIS

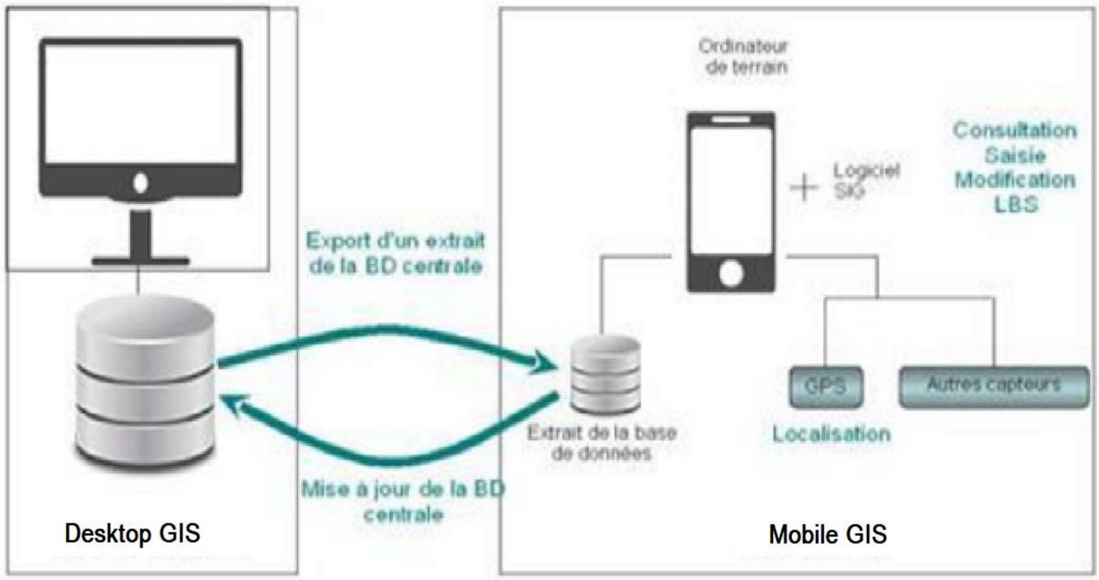


Fig. 9 Architecture and interaction between a desktop GIS and a mobile GIS **[44]**

I.8. Technologies related to GIS

I.8.1. CAD (Computer-Aided Design)

The Computer-Aided Design (CAD) can be defined as the set of software tools and computer techniques that assist designers in the design and development of a product **[22]**.

A CAD software generally consists of four major parts, which can be organized as follows. A CAD system is designed to aid in the design and modeling of buildings, infrastructure, and manufactured products. Computer-aided design is the first step that allows for the design and three-dimensional drawing of simple basic elements of a product, which can then be assembled to create more or less complex assemblies. All simple elements are stored in database files and can therefore be reused later in each new study by the system's users. CAD thus allows for the standardization of products. However, it requires good organization and classification of the references for the created subassemblies and assemblies. CAD not only replaces traditional design but also allows for the following **[8]** :

- Manage all projects (designs, plans, models, and sketches) as digital files in terms of updating, modification, and transfer;
- Minimize design costs;
- Create large and complex designs;
- Optimize design time;
- Reduce design defects;
- Study and simulate all kinds of models.

I.8.2. DBMS (DataBase Management Systems)

In computing, a database management system (DBMS) is system software designed to store, manipulate or manage, and share information in a database, ensuring the quality, durability, and confidentiality of the information while hiding the complexity of operations. A DBMS allows for the recording, retrieval, modification, sorting, transformation, or printing of the information in the database. It enables the reporting of recorded information and includes mechanisms to ensure information consistency, prevent data loss due to failures, ensure confidentiality, and allow its use by other software. Depending on the model, a DBMS can range from a simple graphical interface to sophisticated programming languages. The objectives of a DBMS are as follows **[17]**:

- Data manipulation by non-computer specialists;
- Efficient (fast) access to data;
- Elimination of data redundancy, ensuring better consistency;
- Data shareability among different users;
- Confidentiality and security of data by restricting access rights.

I.9.The fields of application

The fields of application for GIS are as numerous as they are varied. However, they include:

- Tourism (infrastructure management, tourist routes) ;
- Marketing (customer location, site analysis) ;
- Urban planning (cadastre, roads, sewage networks) ;
- Civil protection (disaster management and prevention) ;
- Transportation (urban transport planning, route optimization) ;
- Hydrology ;
- Forestry (mapping for land use planning, management of logging, and silviculture) ;
- Geology (mapping, land movement, environmental asbestos, mining exploration) ;
- Biology (studies of animal population movements) ;
- Telecommunications (placement of mobile phone antennas).

I.10. Some GIS software

I.10.1. Open-source software

GRASS GIS: Combines satellite image processing capabilities and advanced geospatial data management.

MapServer : An open-source platform for publishing maps on the web.

QGIS: Allows for the visualization and transformation of maps, and is known for its user-friendly interface.

PostGIS : An extension for the PostgreSQL database that enables both SQL and spatial queries.

u Dig, gvSIG : Open-source GIS software developed in Java for Linux and Windows.

I.10.2. Free Software

DIVA-GIS : Provides tools for statistical and geostatistical analysis of geographic information.

AutoDEM : Offers tools for generating Digital Elevation Models (DEMs) from contour lines. It supports various formats, including raster images and vector contour lines.

I.10.3. Commercial Software

ArcGIS : (ArcInfo, ArcView, etc.) by Esri.

GeoMapGIS : Industry-focused software that leverages Autodesk environments (AutoCAD, Autodesk Map, Autodesk MapGuide, etc.).

Manifold : An innovative software with features like server support, geocoding, 3D visualization, .NET scripting, and database management.

I.11. Advantages and disadvantages of GIS

I.11.1. Advantages

• A GIS allows for reducing the costs of map and plan production. In many town halls, maps and plans are created manually, leading to delays and costs associated with corrections, updates, and drawing. A GIS enables faster and more cost-effective production.

• A GIS also allows the creation of maps and plans that could not be produced manually. With computer technology, it is possible to create new products that were previously impossible to achieve by hand.

• A GIS prevents the need to repeat the same surveys multiple times. It avoids different departments conducting topographic surveys on the same area and prevents the loss of information over time by accumulating the data collected in the field.

• A GIS facilitates the execution of studies for all projects with a geographic component. It allows for multiple visual representations, thereby aiding decision-making and reducing the risk of errors.

• The GIS enhances the service provided to users by allowing for the rapid and reliable delivery of high-quality information they need. For instance, all the information provided by the urban planning department will, in principle, be up-to-date and complete **[41]**.

• Storage capacity and reliability **[9]**.

I.11.2. Disadvantages

Geographic Information Systems (GIS) are powerful tools for spatial data analysis and visualization, but they have several disadvantages:

• Cost: High-quality GIS software and data can be expensive, both in terms of initial purchase and ongoing maintenance, including updates, training, and licensing fees.

• Data Availability and Quality: Accessing high-quality, up-to-date spatial data can be challenging. In some regions, data may be outdated, inaccurate, or incomplete. Additionally, acquiring detailed data can be costly.

• Privacy Concerns: Using GIS data, especially when linked to personal information, raises privacy issues. Mismanagement or unauthorized access to sensitive data can lead to privacy breaches.

• Data Interpretation: Misinterpretation of GIS data can lead to incorrect conclusions. Effective interpretation requires a deep understanding of the data, methods, and context.

• Maintenance: Keeping GIS systems updated with the latest software and data can be labor-intensive. Regular updates are essential to ensure accuracy and reliability.

While GIS offers many benefits, these disadvantages must be considered when implementing and using GIS technology.

I.11.3. Setting up a GIS

Setting up a Geographic Information System (GIS) requires a few foundational steps to ensure it's functional and fits your project's needs. Here's a step-by-step guide to help you set up a GIS:

- *Define the Purpose and Scope*
  - Determine Project Needs: Decide on the data types, scale, resolution, and analysis you plan to conduct.
  - Select GIS Software: Common options include ArcGIS, QGIS (open-source), and MapInfo. Each has different capabilities, depending on your budget and requirements.
- *Prepare and Install GIS Software*
  - Download and Install: Install your chosen software on your computer or server.
  - Check System Requirements: Ensure your computer meets the software's requirements, especially if handling large datasets or conducting intensive analyses.
  - Licensing: For software like ArcGIS, make sure you have the appropriate license, as it's required for full functionality.
- *Set Up the Coordinate System and Projection*

- Understand Projections: Choose a suitable projection system for your data to ensure accurate spatial representation.
- Set Default Coordinate System: Ensure your GIS is set to your region's standard projection, or the one most appropriate for your analysis.

o *Gather and Prepare Data*

- Collect Data: Find datasets relevant to your project (e.g., demographic data, environmental layers, topographic maps). Sources include government agencies, open data portals, and satellite imagery providers.
- Format Data: Organize your data in compatible formats (e.g., shapefiles, GeoTIFF, CSV) and load them into your GIS.
- Data Transformation: If datasets are in different coordinate systems, reproject them to a common system.

o *Organize Your Workspace*

- Create Project Folders: Set up a logical folder structure for project data, outputs, and backups.
- Set Workspace Paths: In GIS software, specify workspace paths for data access and output storage to keep everything organized.

o *Data Visualization and Layers*

- Add Layers: Import different layers (e.g., roads, rivers, elevation) into your GIS project.
- Style and Symbology: Customize the appearance of layers to highlight specific features.
- Attribute Tables: Review and clean attribute tables for each layer to ensure they contain useful information for analysis.

o *Initial Analysis and Map Layout*

- Run Initial Analysis: Conduct preliminary spatial analyses, like buffering, overlay, and spatial joins, to test data accuracy and refine project goals.
- Design Layouts: Use your GIS’s layout tools to create map layouts, legends, scales, and other map elements for presentation.

o *Set Up Data Sharing and Output Options*

- Export Data and Maps: Decide on data formats and resolutions for exporting maps, whether for web or print.
- Coordinate Sharing: Set up sharing options if your GIS project will be collaborative, using file geodatabases or web services.

o *Test and Document Your GIS Setup*

- Check for Errors: Verify data accuracy and functionality, ensuring that all tools and layers work as intended.

- Document the Setup: Keep a record of data sources, projection details, analyses, and any customizations for reproducibility and troubleshooting.

Starting a GIS project involves setting up the technical foundation and defining a systematic workflow. Let me know if there's a specific tool or part of this process you'd like to dive deeper into!

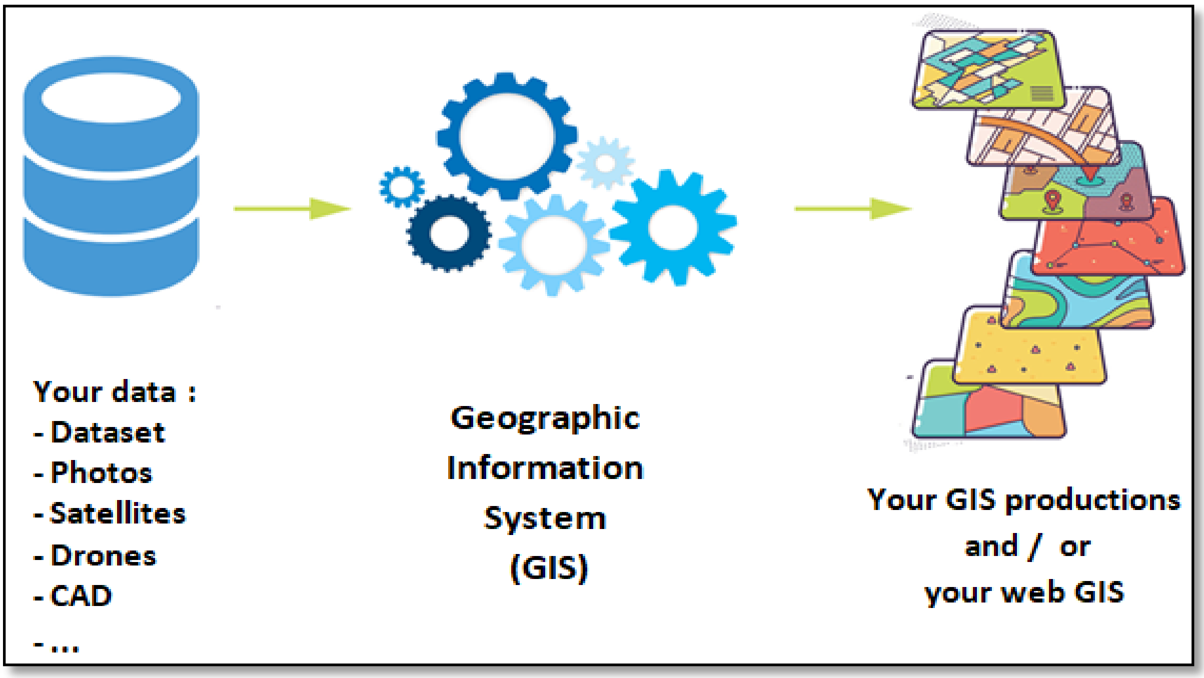


Fig. 10 Setting up a Geographic Information System (GIS) **[44]**

Chapter II :

Specificities

of

Spatial Information

Chapter II :
Specificities of Spatial Information

II.1. What data (information) do I need ?

Generally, for a spatial object to be well-described and ready to be used by a GIS, three pieces of information need to be provided **[44]** :

- Its geographical position in space;
- Its spatial relationship with other spatial objects: topology;
- Its attribute, meaning what the object is with an identification character (code).

Geographic information systems allow for the processing of spatial and associated data.

II.2. Definitions

Geographic information(GI) is the representation of an object or phenomenon that is real, located in space at a given time, and has a spatial reference, either in the form of **[4]**:

Geographic coordinates ;

Place name ;

Postal address or other.

The term localized information or spatial information refers to any information related to a point or a set of points spatially referenced on the Earth's surface **[14]**.

Geographic information consists of several levels (Fig.11) :

- *Semantic Level (Descriptive)*: Textual, qualitative, and quantitative information about an entity; this encompasses the attributes of the object (e.g., the name of a road, a municipality, etc.).

- *Geometric Level*: Information describing the shape and location of the object on the Earth's surface, expressed in an explicit coordinate system (e.g., road, municipality, station, etc.).

- *Topological Level*: This information describes the relationships between geographic objects within the same territory. It involves concepts like superposition, adjacency, intersection, and inclusion (e.g., the inclusion of a parcel within a municipality, adjacency between different nodes of road segments, etc.).

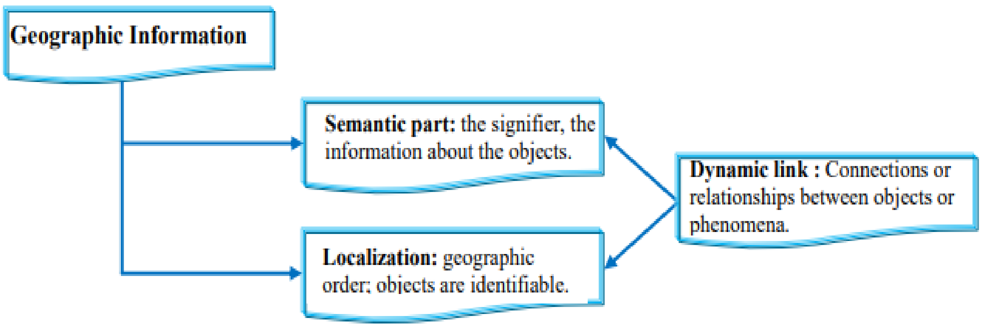


Fig. 11 Different levels of Geographic Information **[28]**

II.3. Characteristics of Geographic Information

Any geographic information must meet certain characteristics **[29]**, as shown in the Fig.12:

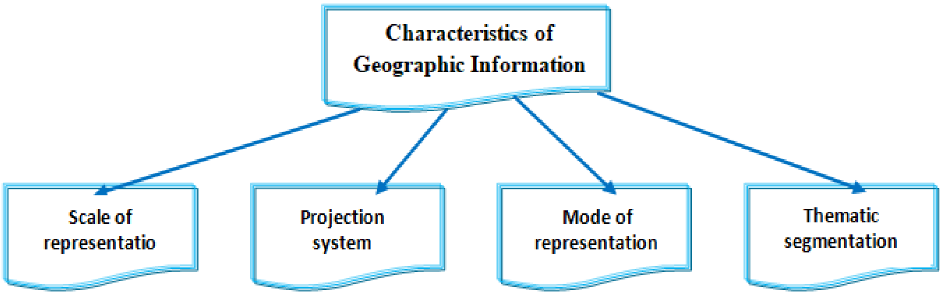


Fig. 12 Characteristics of Geographic Information **[9]**

II.4. Types of data in GIS

All spatial geometries can be described by four types of properties:

- Their position on the Earth's surface ;
- Their spatial relationships (topology) ;
- Their attributes ;
- Their metadata.

II.4.1. Spatial / Geographical Data

They determine the spatial characteristics of a geographic entity where all graphic elements are represented and identified **[44]**:

- Location: Coordinated with respect to a reference graphic scale ;
- Shape: Point, line, surface ;
- Size: Length, perimeter, area. The information refers to objects of three types ;
- Point: Defined by its coordinates and is the smallest spatial dimension ;
- Line : Has a spatial dimension made up of a series of closely spaced points ;
- Polygon (area or surface): A surface element defined by a closed line or the line that delineates, it see figure 12.

II.4.2. Associated Data

The associated data of geographic entities enhance the geometric representation of the spatial entity. Each element of space is assigned an identification code, which can be numeric or literal. This code serves as a label characterizing the point, line, or polygon. Among these data, the following distinctions are made **[44]**:

- *Classification Data* : These allow the point, line, or polygon to be classified into a specific category, such as parcel type (irrigated, non-irrigated), road type (primary, secondary), etc.

- *Identification Data* : These enable the distinction of each object depicted on the map, such as the proper name of the object (e.g., the name of the municipality) or a number that identifies it (e.g., parcel number, valve number).

- *Attribute Data (alphanumeric or semantic)*: Descriptive information about the geographic objects. Attributes are stored in an *attribute table*, which is associated with geographic objects of the same theme, see figure 13.

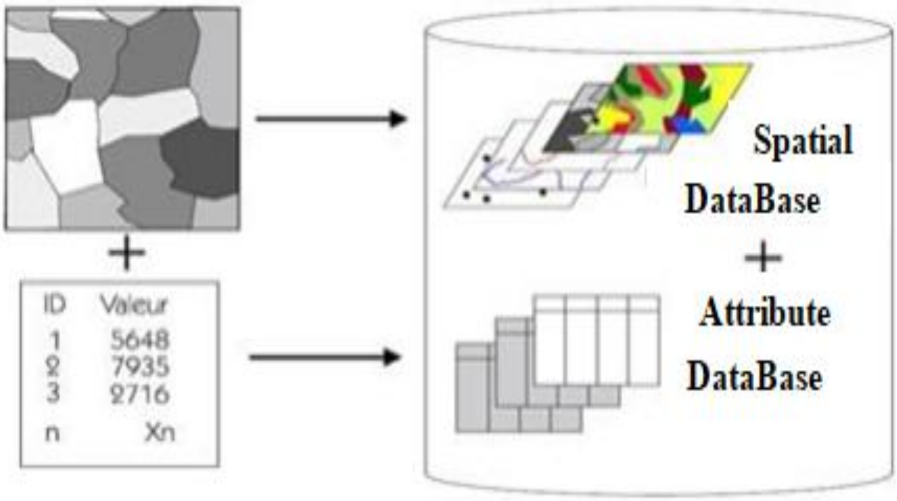


Fig. 13 Data in a Geographic Information System (GIS) **[2]**

For example, the attributes describing the sub-basins of Hodna (database) are stored in the attribute table defined by fields such as ID_CODE_NAME, etc., where the type can be "Character," "Numeric," "Date," etc. Each sub-basin corresponds to a record in the attribute table and has a unique identifier. Attribute data can come from other sources such as text files (e.g., .dbf format) or databases (Postgre SQL, SQL Server, Oracle, etc.).

Definition of a layer

The combination of geometric data and attribute data forms a layer. For each graphic object (such as sub-basins represented by polygons), there is a corresponding record in the attribute table. *The most commonly used storage format for a layer is the shapefile format*.

- *Attribute data*, are stored in a file with a '.dbf`' extension.

- *Coordinates of the nodes* (points), that make up the polygons are stored in a file with a '.shp`' extension.

Additionally, a file with a '.shx' extension *links the graphic data to the attribute data*. A layer, such as a "sub-basins" shapefile, will be stored in the following manner :

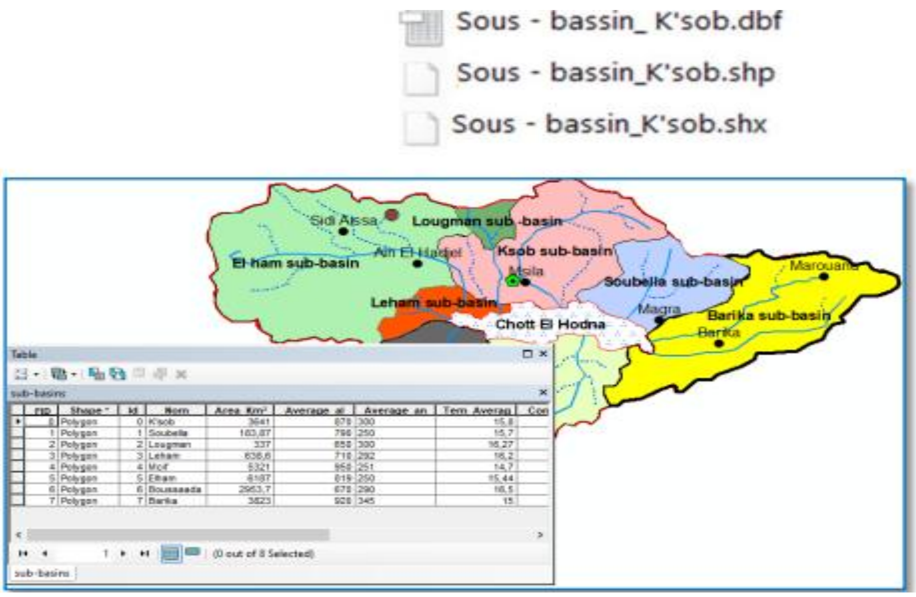


Fig. 14 Example of a Thematic Layer

II.4.3. Metadata

Metadata is literally data about data. More specifically, it is a structured set of information describing any given resource. Metadata provides information about the nature of other data, enabling its relevant use. For example, metadata for a road network might include details about the types of roads, their classifications, attributes, and how they were collected or processed.
Metadata is the label of the database.

Metadata must be properly filled out to be accessible to as many users as possible. *There are three types of metadata* :

- *Metadata for Discovery* : A minimum of information that allows users to identify data that may meet their needs.
- *Metadata for Cataloging* : More detailed information that serves as specifications and controls during data delivery.
- *Metadata for Use*: Allows the user to understand the data and better grasp its limitations and potential applications.

GIS metadata is like an instruction manual for data because it describes the who, what, when, where, why, and how of data. It's important because it's the record we rely on to find out how it was created.

Metadata is data about digital images.And the whole point of assigning metadata fields and values to your images (and all brand assets) is to make them findable and manageable – regardless of the amount of content your enterprise produces, and no matter how big your organization gets.Metadata allows digital marketers to label and describe digital assets so that they are simple to decipher and use.

As you scale your content creation, metadata is a must. And, when managing your digital assests, there are three types of metadata – descriptive, administrative, and technical (fig.15) **.**

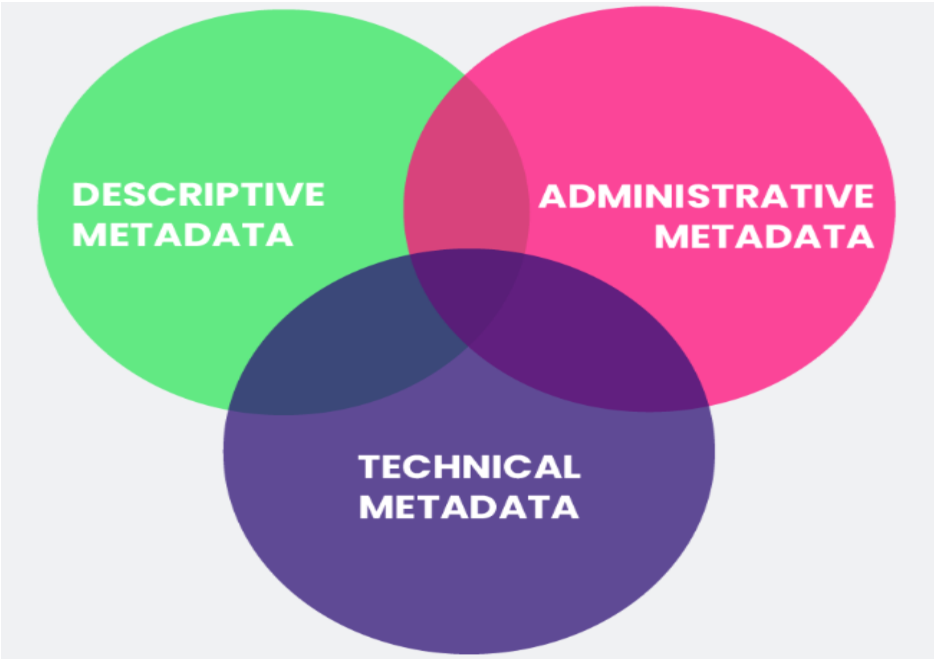


Fig. 15 The three types of metadata
https://www.keyshot.com/blog/metadata/

II.5. Component of geographic information

The Geographic Information, traditionally represented in cartographic forms, with its two (02) components:

1. The shape and location of the located object, in graphical form (***The graphic component***): The map, which describes the shape and characteristics of the entity while locating it using geographic or cartographic coordinates (Fig. 16).

Example: Shape and location of the Wilayas (administrative boundaries of the Wilayas).

2. The qualitative and quantitative characteristics of the located object, in tabular form (***The attribute component***): The legend, which identifies the represented entities.

Example: Highlighted in color, the qualitative and quantitative information of the Wilayas (administrative boundaries of the Wilayas) is presented in the attribute table: Wilaya code and name. It should be noted that Geographic Information *(GI)* is increasingly present in our lives in digital form.

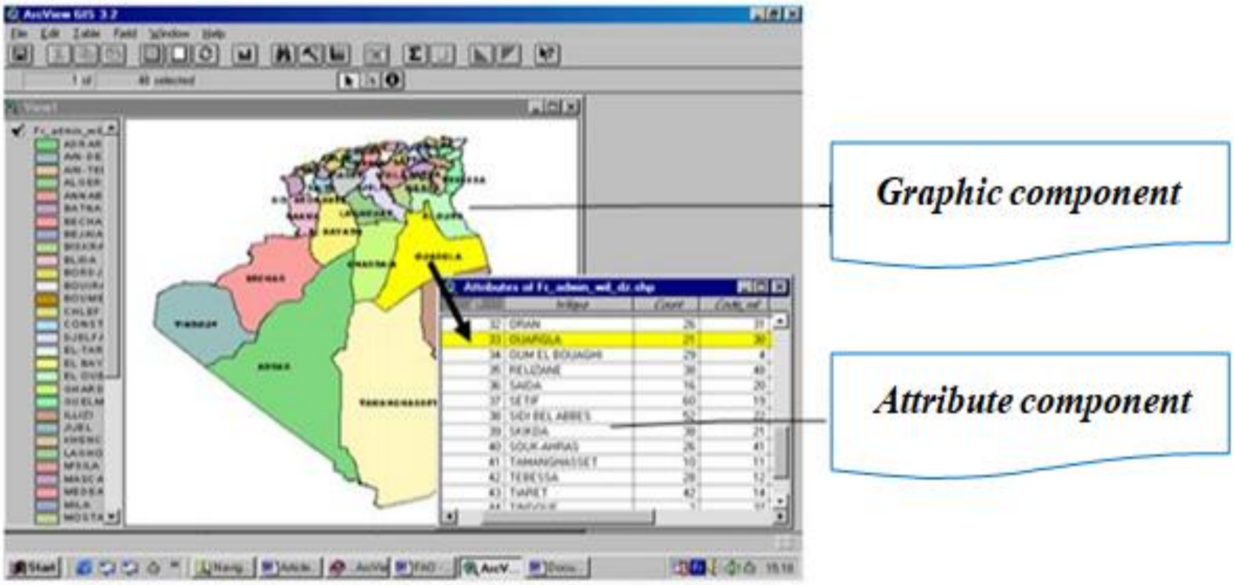


Fig. 16 Link between geometric and thematic descriptions

Geographic information about the Wilaya of Ouargla:

- *Graphic Component* : Its shape and location (on a cartographic reference and according to geographic coordinates based on a projection system).
- *Attribute Component (descriptive information*): Name, code, area, etc.

II.6. Source of geographic information / Mode of acquisition of geographic data

The acquisition of geographical data involves gathering various sources to capture data for integration into a GIS. Below, we present the different methods of acquiring geographical data. The Geographic Information comes from various data sources (Fig. 17):

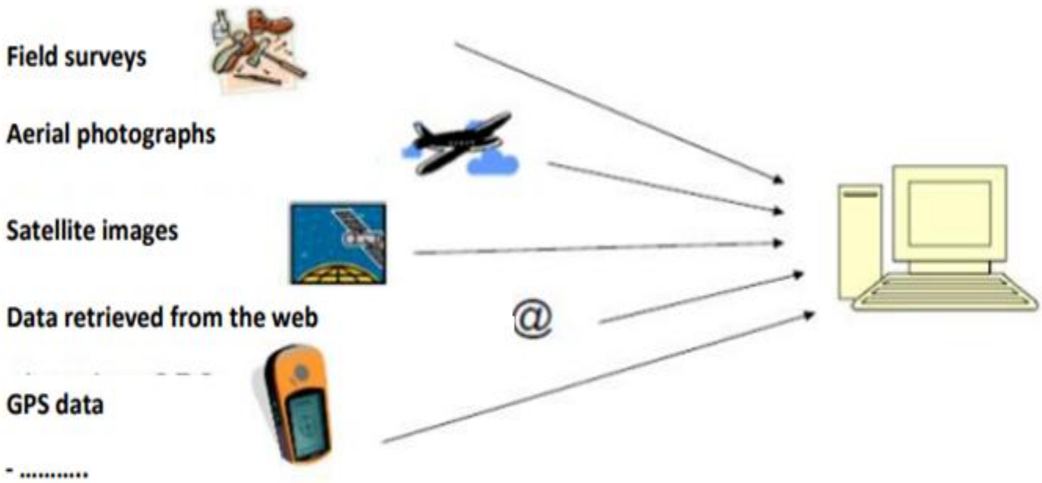


Fig. 17 Different sources of geographic information

II.6.1. Import files

II.6.1.1. The data already exists : it just needs to be imported into the system.

There are generally three ways to import spatial data **[21]** :

- Importing a database arranged in a format internal to a GIS. This method works well between

GIS of the same type but becomes complicated when dealing with different types or versions of GIS.

- Importing a text file (Txt) that contains all the information in a primitive, structured manner. It's important to note that this method requires the imported data to be arranged so that it aligns with the internal structure of the GIS.

- Using one of the exchange standards available on the market. This third method is the most cost-effective in the long term.

II.6.1.2. The data does not exist : a database needs to be created.

GIS store spatial and attribute data in the form of a geographic database (Figure 4), which consists of a series of layers of geographic information organized efficiently for use by one or more applications. It is important to note that the data must be made "overlayable," meaning it must be in the same coordinate system or in compatible systems (with a "geographic transformation" to convert from one system to another). The creation process involves the following steps **[25]**:

- *Determine the purpose of your database* : This helps you prepare for the remaining steps.

- *Research and organize the required information*: Gather all types of information you might want to record in the database.

- *Divide the information into tables* : Split your information into key entities or subjects. Each subject then becomes a table.

II.6.2. Topographic surveys (using a theodolite)

A theodolite (Figure 18) is a geodetic device equipped with an optical system that calculates angles in both the horizontal and vertical planes to determine a direction. It is used for measuring triangulation. This instrument allows for the plotting from one neighbor to another starting from an origin point. These are representations made through topographical surveys according to meridians, parallels, and a coordinate reference system **[21]**.

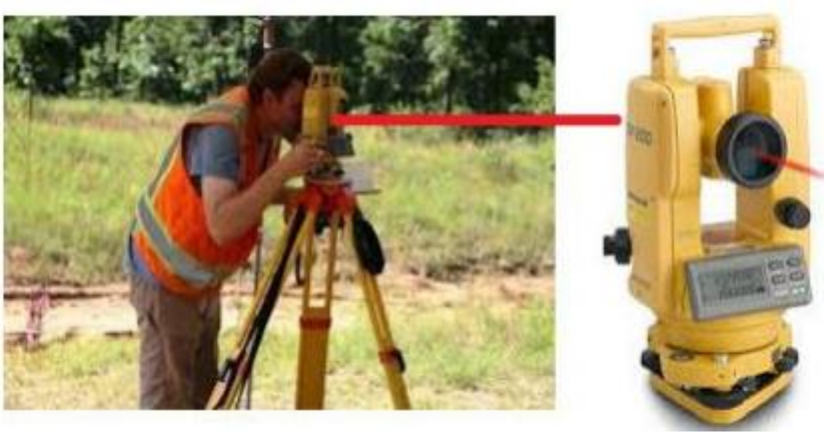


Fig. 18 Example of a theodolite
www.mesure-laser.com

II.6.3. Aerial photos

The set of merged images provides a complete photograph of an area. The photographic images obtained allow us to determine the coordinates and elevation of points, either using airborne cameras (airplanes, drones, etc.). Aerial photography makes it possible to collect, with relatively good accuracy, the longitude and latitude of an observed point based on a reference point. After photography, the information in this case requires some geometric correction **[2]**.

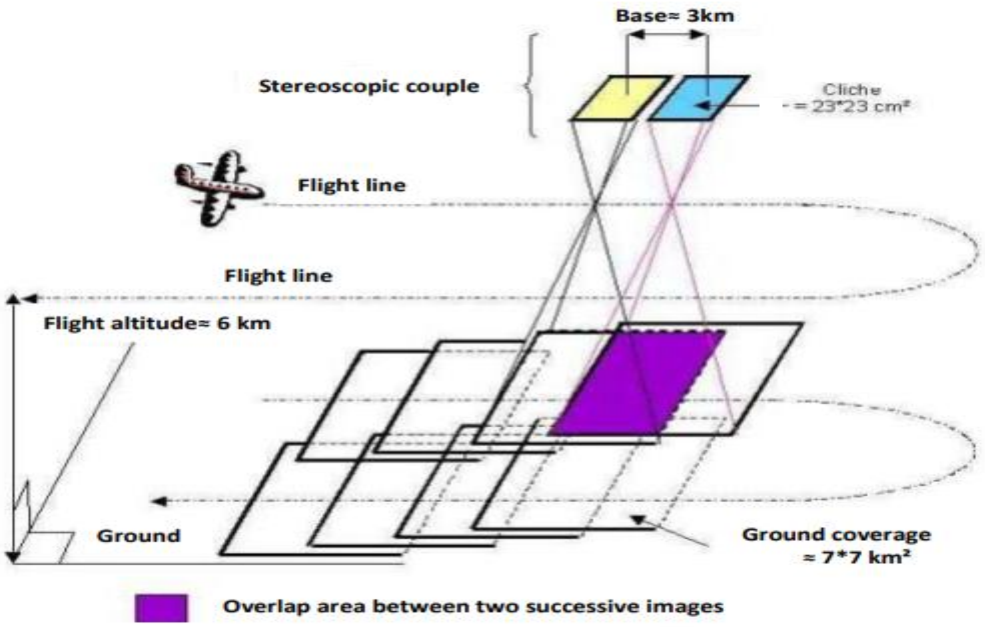


Fig. 19 Flight plan of an aerial photography acquisition aircraft
https://perso-sdt.univ-brest.fr

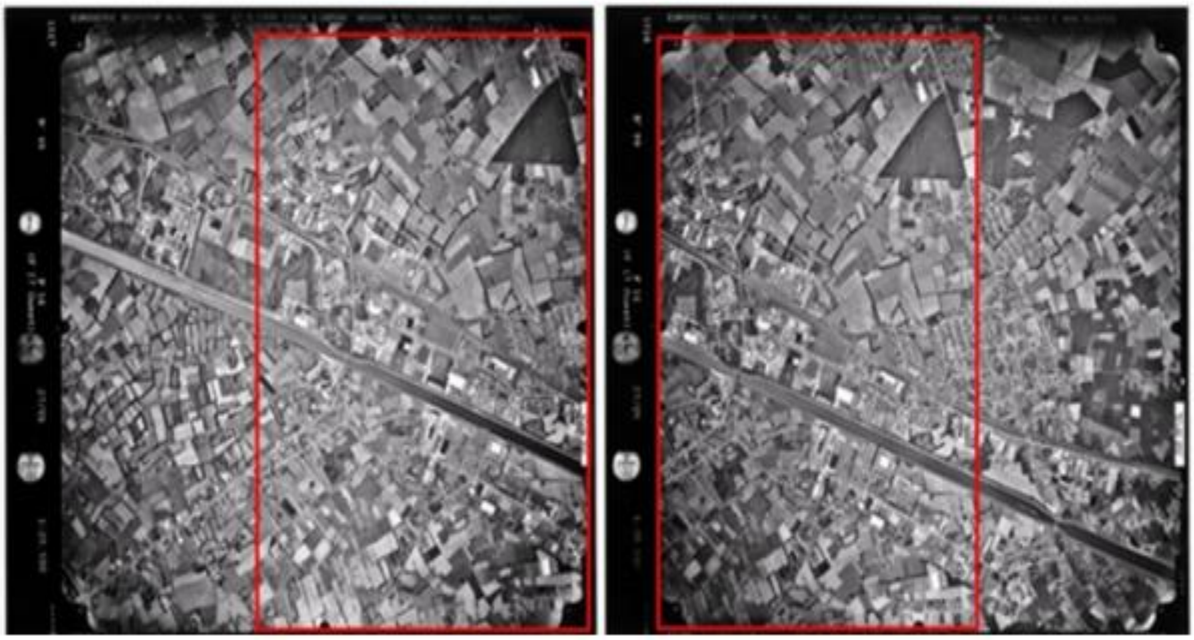


Fig. 20 Stereoscopic pair of Tongerlo, Belgium, 17-05-1999. The overlap is indicated by the red rectangles.
http://www.seos-project.eu

II.6.4. Satellite images

This method allows for the extraction of information through photogrammetry. Earth observation satellites provide data transmitted as digital images in raster format (Figures 21 and 22). The data must undergo certain corrective processing before being integrated into a GIS **[33]**.

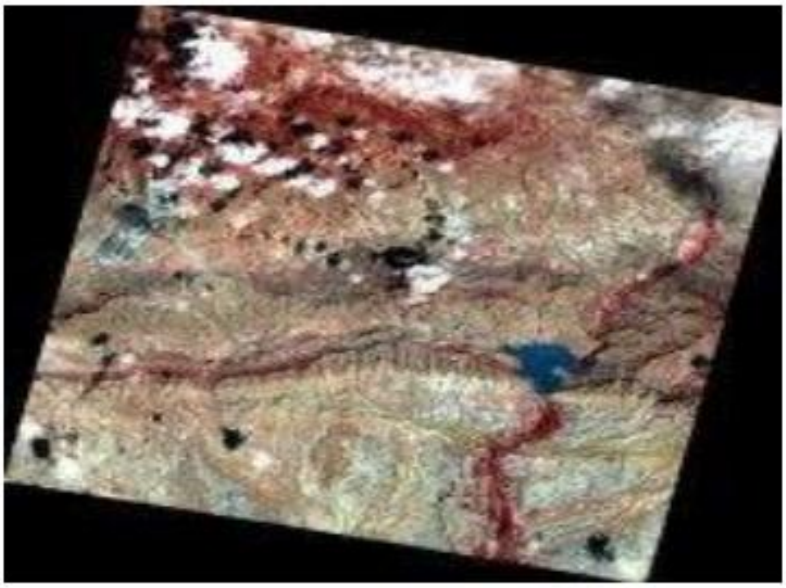


Fig. 21 Satellite image taken by the ALSAT-2A satellite
http://www.asal.dz

II.6.5. Global Positioning System (GPS)

The GPS system (Figures 22 (a)) is based on a constellation of 24 observation satellites orbiting the Earth (Figures 22 (b,c)), continuously transmitting time-stamped signals to the globe and to a network of ground-based monitoring stations. GPS is designed to provide, via an appropriate receiver, spatiotemporal data (latitude, longitude, elevation) for navigation, regardless of geographical location on Earth. Localization is possible if at least four satellites are visible, enabling the determination of four unknowns: the three spatial coordinates and time **[15]**.

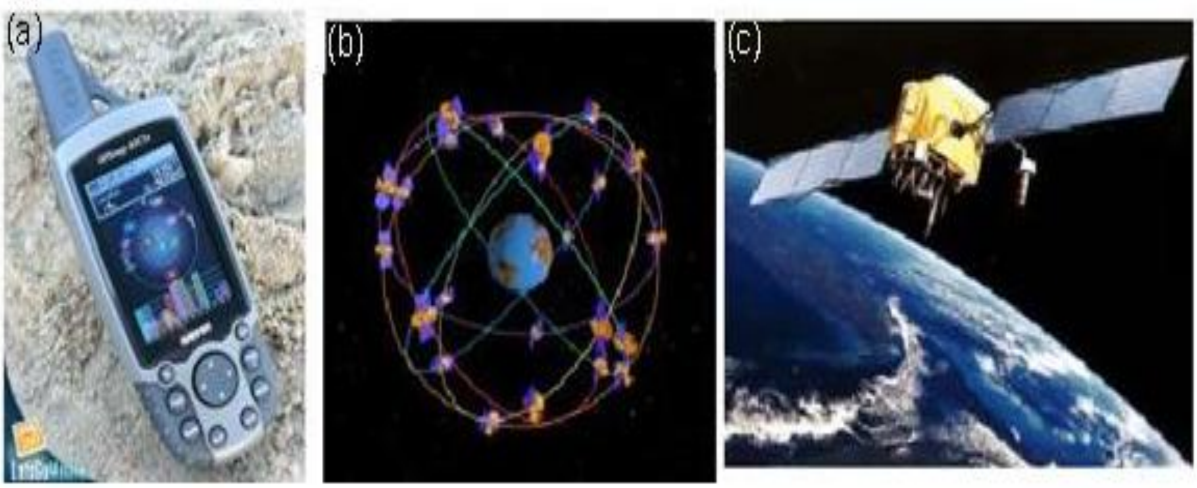


Fig. 22 (a) Satellite-based localization system (GPS) and satellites (b and c).

II.6.6. Digitization

Digitalization (Figure 23) is suited for vector representation. This technique ensures the preservation of the information presented in the original document. Preliminary processing of the base documents may be necessary if they are too complex **[27]**.

Fig. 23 Digitalization operation

II.6.7. Scanning of plans / Electronic scanning (digitization)

Perfectly suited for raster representation (Figure 24a, 24b). This input mode is fast and inexpensive. If the data is scanned and georeferenced, it is considered 'raster' data. The only issue with this method is the potential for errors inherited from the original medium. Electronic scanning (performed with a scanner) is another way to capture an existing plan (map). It is faster than manual digitization **[21]**.

Fig. 24: a: Automatic scanner & b: Extract from a scanned map

II.6.8. Remote Sensing

According to Canadian Centre for Remote Sensing 2008, remote sensing is defined as:

"Remote sensing encompasses techniques that allow the acquisition of images to obtain information about the Earth's surface (including the atmosphere and oceans) without direct contact with it. Remote sensing includes the entire process of capturing and recording the energy of emitted or reflected electromagnetic radiation, processing and analyzing the information it represents, and then applying this information.It is applied in land use mapping, forest fire detection, deforestation, climate change, management (cadastre, road traffic, emergency and rescue services); decision support (land use planning, protection measures, allocation of human or financial resources, intervention decisions, forecasting, etc.) **[35]**.

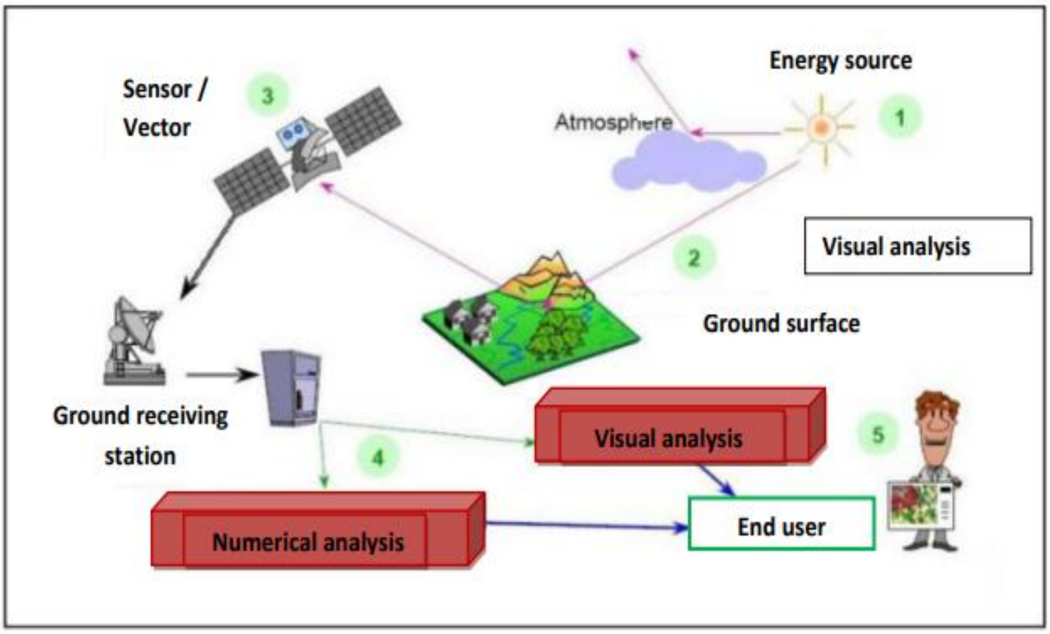


Fig. 25 Principle of Remote Sensing **[35]**

II.7. Representation of geographic information in GIS

Geospatial information (GI) is acquired, stored, analyzed, visualized, and distributed using geographic information systems (GIS). They are represented in geographic information systems through the following steps:

II.7.1. Localization of Geographic information

II.7.1.1. Textual Location

The textual mode refers to the name of the place where one is located or the description of the route to get there. The postal address is the most common example. There are also other forms of location addresses, such as the cadastral plot number, the municipality number, etc. These localization systems are widely used in daily life and in administrative contexts (taxes, electricity and telephone subscriptions, etc.), but they do not easily lend themselves to direct representation on a map **[40]**.

II.7.1.2. Mathematical Location

The Earth is a sphere, but an imperfect one **[39]**:

- *The geoid* is the theoretical shape that most closely resembles the actual surface of the Earth, which is the mean sea level. It serves as a reference for determining altitudes.

- *The ellipsoid* is the mathematical surface that closely approximates the shape of the geoid; it allows for the calculation of geographical coordinates in longitude and latitude.

a. Geographical Coordinates

Any point M on the Earth's surface can be projected onto a geodetic ellipsoid at a point P and defined by its two geographical coordinates, as illustrated in (Fig. 26), **[40]**:

The *longitude* of the point is the oriented angle between the prime meridian (Greenwich, by convention) and the meridian plane of that point ;

Latitude is the oriented angle, in the meridian plane of the point, between the equator and the normal to the ellipsoid at that point.

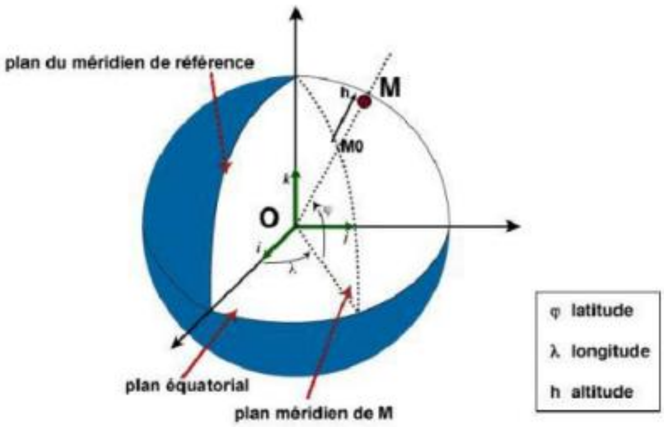


Fig. 26 Coordinate System **[35]**

b.Plane Cartographic Coordinates: Cartesian Coordinates

Cartesian coordinates (x, y) are defined by perpendicular axes, the abscissa x and the ordinate y, which intersect at an origin.

c. Geodetic System Nord Sahara 1959

The *NORD SAHARA* is a geodetic system created by the IGN (National Geographic Institute) in the 1950s for Algeria.

d. Cartographic projections .Among the cartographic projections used in Algeria :

UTM Projection (Universal Transverse Mercator) : The Mercator projection, one of the oldest (1569), has significant distortions as one moves away from the equator towards the poles (North and South). Here are some characteristics of this projection:

- It divides the world into 60 zones, each covering 6° of longitude.
- It is a transverse cylindrical conformal projection, meaning it preserves angles.
- Rectangular (Cartesian) coordinates are expressed in meters or kilometers.

This projection allows for the representation of the Earth's image on a flat surface.

To represent the Earth's image, modeled as an ellipsoid, on a flat surface requires the use of a plane representation (or projection). The resulting plane coordinates allow for direct measurements on the map (such as angles and areas). Thus, a cartographic projection is a mathematical operation that enables the representation of a portion of the ellipsoid on a plane, while estimating the distortions introduced by this operation on curved distances, angles, directions, and curved areas, etc.

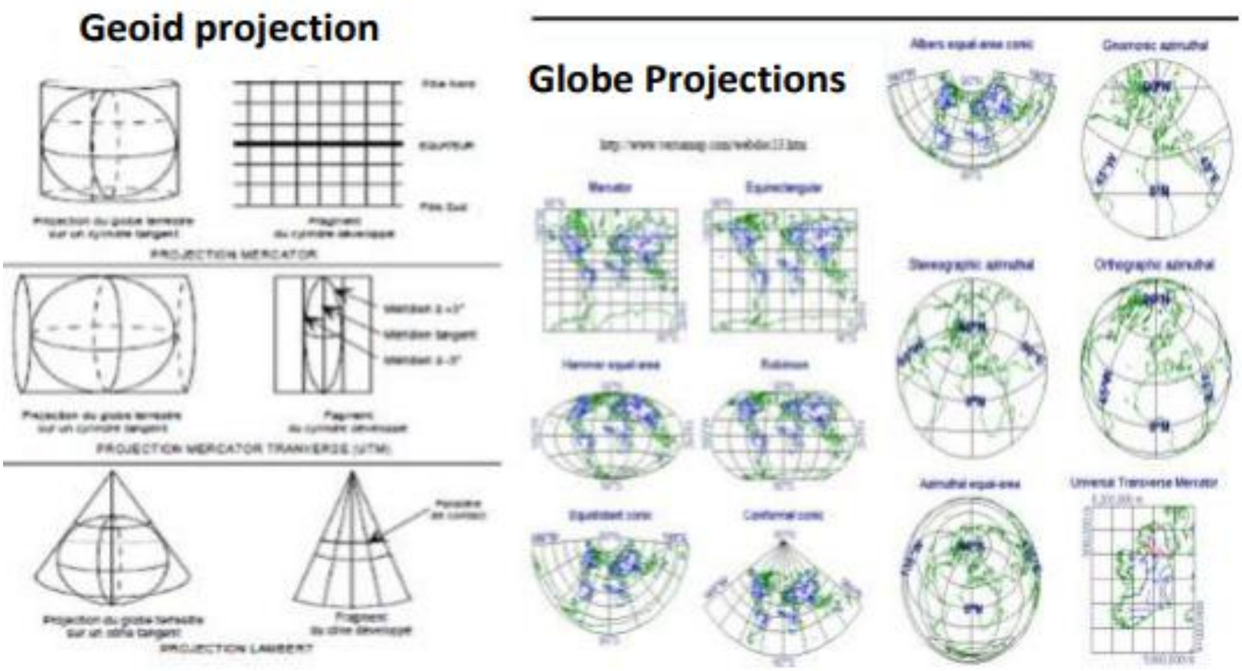


Fig. 27 Projection Systems **[29]**.

e. Geodetic System: World Geodetic System 1984 (WGS84)

The GPS satellite positioning system aims to provide the user's position (x, y, z) WGS 84 or (λ,Φ, h) WGS84 at any given moment. This reference system is known as WGS84 (World Geodetic System 84).

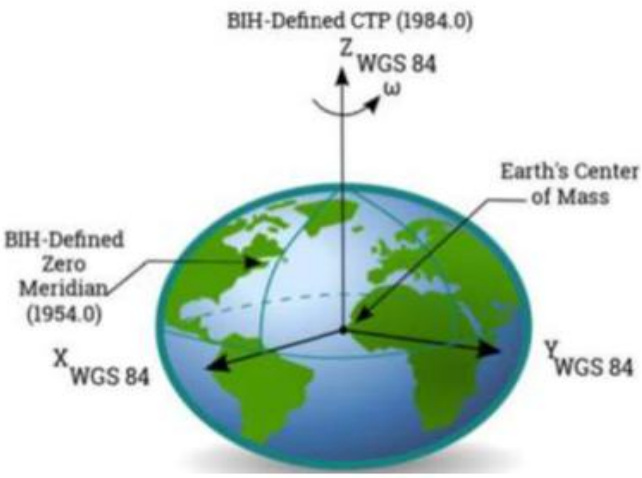


Fig. 28 Geodetic System: World Geodetic System 1984 (WGS84)

For Algeria, the UTM projection is currently used. Each UTM zone covers 6° of longitude. Algeria spans four (04) zones: n°29, n°30, n°31 and n°32, making a total of four (04) zones (or strips).

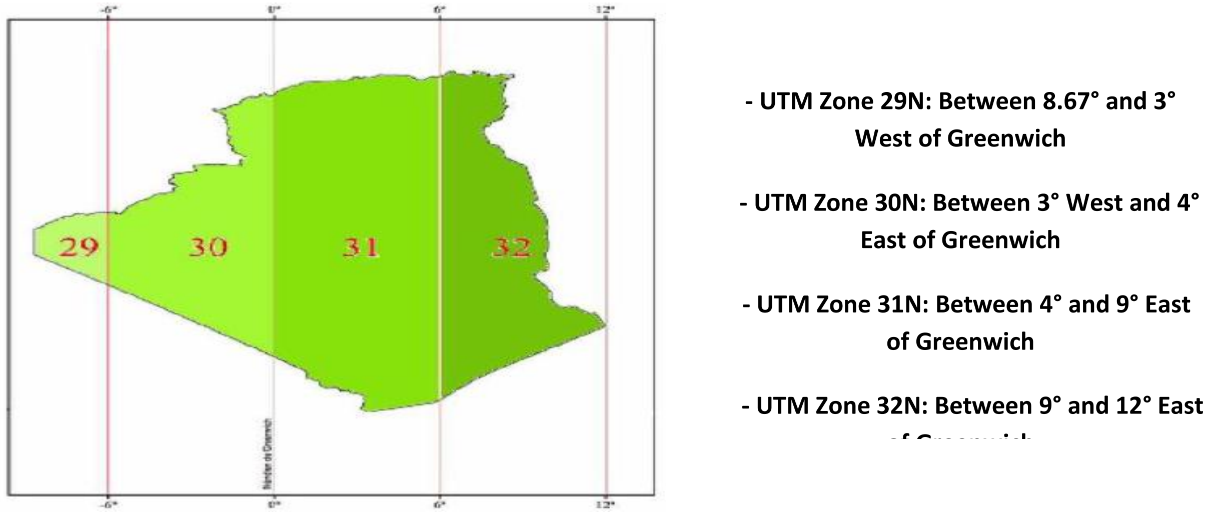


Fig. 29 UTM projection zones in Algeria **[38]**

II.7.2. Data presentation in GIS

A geographic information system encompasses two types of information, namely **[4]**:

- Graphic information (geometric or spatial data). In the form of drawing objects.
- Attribute information (descriptive or semantic data). In the form of tables.

II.7.2.1. The shape and location of the mapped object, presented graphically.

The map (Fig.30), which describes the shape and characteristics of the entity while locating it using geographic or cartographic coordinates.

II.7.2.2. The qualitative and quantitative characteristics of the mapped object, presented in tabular form.

The legend, which identifies the represented entities (Fig. 30).

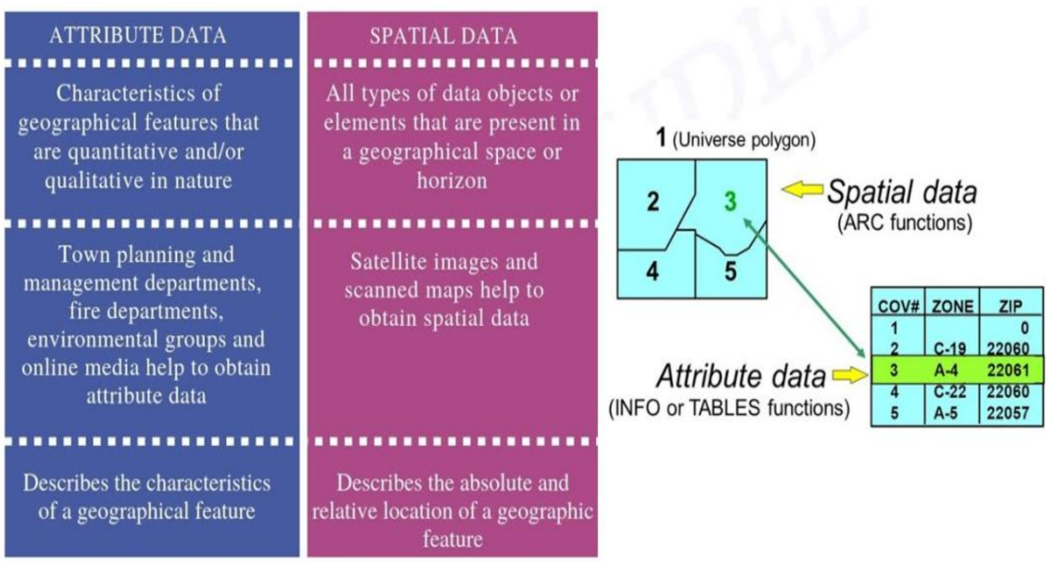


Fig. 30 Difference between Spatial and Attribute Data **[25]**

II.7.3. Modes of Geographic Information [Methods of representing = Digitization = Structuring of GI] in a GIS

Geographic Information Systems use two different types of geographic models **[18]**. The integration of existing paper-based cartographic documents into a GIS could involve different techniques, such as digitization and electronic scanning. The first technique directly leads, as illustrated in the figure below, to vector-type digital cartographic data, while the second results in raster data.

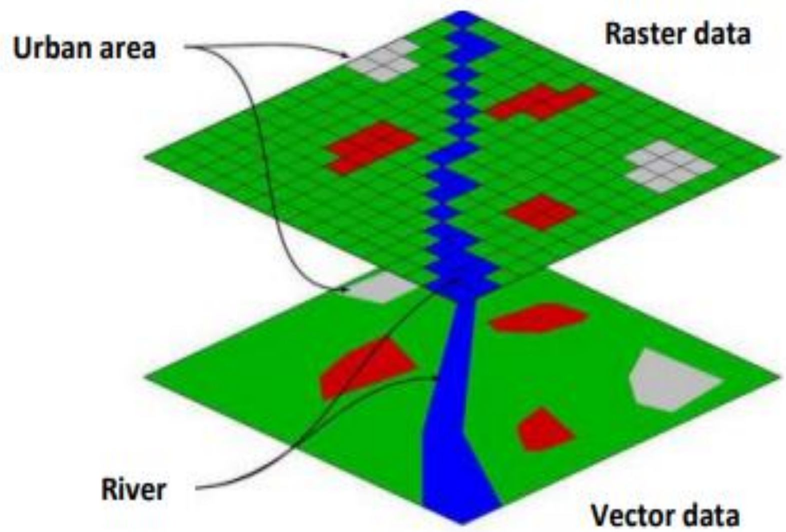


Fig. 31 Data modes in a GIS

Geographic Information Systems utilize two types of geographic models, both aimed at representing the real world as accurately as possible :

II.7.3.1. Vector Mode

The boundaries of spatial objects are described through their basic components: points, arcs, and polygon arcs. Each spatial object has an identifier that links it to an attribute table. To represent objects on the Earth's surface, GIS use three geometric objects: point, line, and area **[9]**. It is most suitable for representing discrete variables (Fig.32) :

Points: wells, etc. ; Lines: roads, rivers, etc. ; Areas: parcels, etc.

II.7.3.2. Raster Mode

In raster mode, reality is broken down into a regular, rectangular grid, organized into rows and columns, with each cell in the grid having a gray intensity or color. The arrangement of these points recreates the visual appearance of the map and each piece of information. For example, a forest would be "represented" by a collection of points with identical intensity (Fig. 32). Several data sources provide geographic information in raster mode **[9]**:

Aerial photographs ; Scanned maps ; Radar images ; Satellite images.

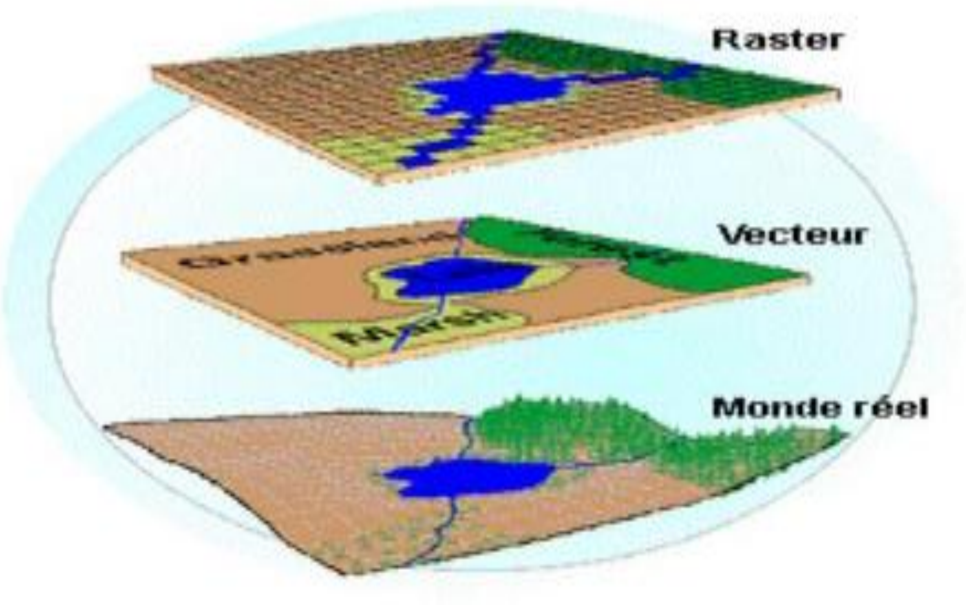


Fig. 32 Spatial Data Models in a GIS

II.8. Representation of descriptive data in GIS

Attribute data is linked to the geometry of the object and organized within a database in the GIS. A database is a collection of information (comprehensive, non-redundant, and structured around a specific theme) or documents (in digital or analog form), such as an archive center or a library **[35]**.

II.9. Specificities of Geographique Information

Geographic information is not just "orinary" information. It has specific characteristics. First, it is characterized by information about the absolute position of objects in space, known as coordinates **[6].**

II.9.1.GIS as a project - GIS as a Decision-Making Support Tool

GIS projects initially aimed to automate cartography. The association of attribute data with graphic entities and the adoption of interoperability standards opened up new possibilities and motivated new objectives, positioning GIS as a key component of the information system, specialized in the management and analysis of spatial data. Evaluating the effectiveness of GIS should measure the contribution of these tools to the overall outcomes of the organization **[20]**.

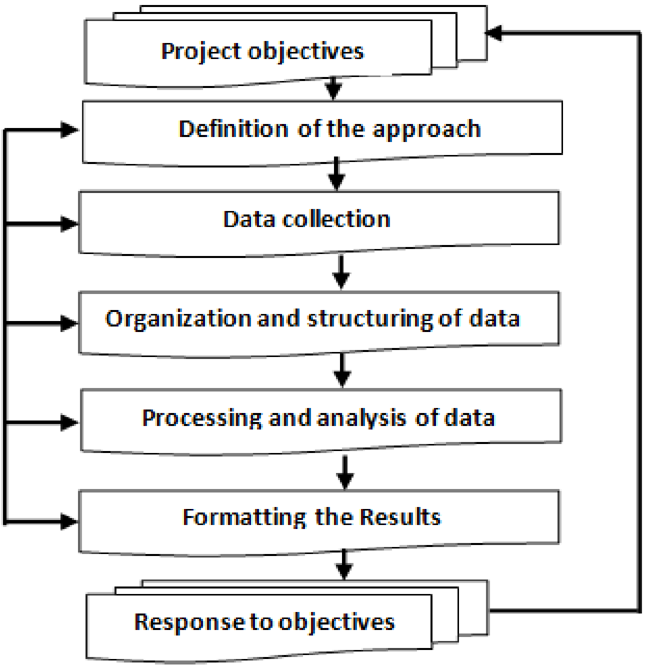


Fig. 33 GIS Project Approach
https://fr.slideshare.net/doncostavooldyou/cours-gestion-de-projet-sig

II.9.2. A GIS : a project like any other / The Steps

A GIS project is both a "typical" project and a "specific" one, due to its geographical nature. *There are four steps in the management of a GIS project*:

1. *Use r Needs Analysis Report :* A thorough investigation is necessary to identify explicit needs. The challenge lies in anticipating usé applications even before the tool is available and its full potential can be demonstrated.
2. *Design Report :* The goal of this second stage is to specify the functions of the product or process, quality standards, control procedures, and all functionalities that correspond to the needs. This phase results in a design report, including the modeling of the phenomenon or product and the detailed definition report.
3. *Implementation Report :* This third stage aims to specify the tools, techniques, software, hardware, training, standards, and tests that will ensure the functions defined in the previous stage. This phase results in an implementation report, including the technical study report, the specifications, and the proposed schedule.
4. *Product Implementation :* This fourth stage should lead to the completion of the project, which involves the integration of tools, data structuring, procedure setup, etc. At this stage, the GIS becomes a fully operational tool. A production phase allows for the enrichment of the GIS with all types of data, making the GIS fully functional.

II.9.3. A GIS: a project different from the others / The Specificity of Geographic Data

- GIS projects differ depending on their environment. On one hand, each project must take into account the organizational context in which it operates. On the other hand, among the essential information for a GIS, some are specific to the objectives pursued and the territory involved. Geographic data have the particularity (and challenge) of being distributed in a 2D (or 3D) space and being visualizable as maps.

- **Choosing Geographic Data**

❖ **Nature of the Data**

Geographic information, which combines alphanumeric data with spatial data, must answer the following questions: What is this object? What are its attributes? Where is it located? What is its shape? What is its relationship with others?

❖ **Type of Data**

The two types of data (vector or raster) are more or less suitable for actions performed on the data: collection, management, manipulation, analysis, display on screen. Even today, it is still challenging to switch from one format to another without losing information.

❖ **Database Structure**

This is defined by the data format (physical model) and the conceptual data schema. The latter organizes the data and describes the relationships between them.

The structure of a database is crucial for organizing, storing, and efficiently managing data. In GIS and geospatial contexts, the database structure needs to handle both spatial and attribute data, which are essential for mapping and spatial analysis. Here are some key elements of database structure:

- *Data Models*: Database structure begins with selecting a data model, typically either relational **or** object-oriented**.** Relational databases (e.g., PostgreSQL with PostGIS, MySQL) use tables to represent data and relationships, while object-oriented databases (e.g., MongoDB) manage data as objects, allowing for complex and varied data types, such as 3D models or spatial data ;
- *Tables and Relationships***:** In relational databases, data is organized in tables, with each row representing an individual data entry and columns holding specific attributes (e.g., location name, latitude, longitude). Relationships between tables (one-to-one, one-to-many, or many-to-many) allow for structured data linking. For example, a city table might link to a table of buildings based on the city's ID ;
- *Spatial Data Types*: Geospatial databases often need specialized spatial data types, such **as** points, lines, and polygons, to represent real-world features (e.g., cities, roads, boundaries).

These data types are essential for managing spatial relationships and performing spatial queries, such as calculating distances or finding intersections ;

- *Indexes*: Indexes help speed up data retrieval, particularly for large datasets. Spatial indexes, such **as** R-tree or quad-tree indexes, optimize the database for geospatial queries, enabling efficient handling of large spatial datasets by reducing the need to scan the entire dataset ;
- *Attribute Data*: Attribute data refers to non-spatial data that describes spatial features. For instance, a river's attribute data could include its name, length, and water quality metrics. This data is typically stored alongside spatial data in the same table or linked through relationships ;
- *Primary and Foreign Keys*: Primary keys uniquely identify each record in a table, while foreign keys link records across tables. In a geospatial database, a city table might use a city ID as a primary key, with this ID acting as a foreign key in a building table to associate buildings with their respective cities ;
- *Metadata*: Metadata provides information about the data itself, including its source, resolution, accuracy, and date of collection. This is crucial for data provenance and quality control, especially in geospatial databases where accuracy and origin are often critical ;
- *Views and Query Layers* : Database views are virtual tables created by querying existing tables, allowing users to see a subset of data or join data across tables without storing it redundantly. In GIS, query layers let users dynamically filter or aggregate spatial data for analysis and visualization ;
- *Storage Optimization*: Depending on data volume and usage, database storage should be optimized by partitioning tables, compressing data, or utilizing cloud storage. This is particularly important for handling large datasets like satellite imagery or LiDAR data in GIS ;
- *Temporal Data:* Many GIS databases also include temporal data, capturing how spatial features change over time (e.g., tracking urban development). Temporal fields or tables help manage time-based data and support time-based queries.

Designing a database structure that aligns with these elements allows for efficient data handling and analysis, especially when managing large, complex, or constantly updating datasets in GIS.

❖ Georeferencing

The coordinates of objects always relate to a geographic reference system. The coordinates may be geographic (latitude, longitude) or sometimes come from planar representations (Lambert projections, UTM, etc.), often specific to suppliers or countries.

Georeferencing in the digital file allows for basic cartographic analyses, such as pointing and clicking on the map to determine the coordinates of a point, calculating distances and areas, and determining other information.

❖ Data Volume

The type of data and the format chosen for the database result in significant variations in its volume. GIS projects typically require hardware capable of managing a large amount of data and objects.

Data volume refers to the quantity of data collected, stored, and processed, which can greatly impact both the economic and technical aspects of a project. In GIS and geospatial applications, data volume is particularly significant due to the high level of detail and variety in spatial data. Here are some key considerations:

- *Large Datasets* : Geospatial datasets are often large, especially when dealing with high-resolution satellite imagery, LiDAR scans, or extensive time-series data. For instance, a single high-resolution satellite image can be several gigabytes, and a detailed 3D model from LiDAR can reach hundreds of gigabytes or more ;
- *Storage Costs*: Storing large data volumes is costly, as high-capacity physical or cloud storage is necessary. The costs rise with the need for backups, redundant storage, and fast-access systems to ensure data is available and secure ;
- *Data Processing Power*: Large volumes of data require significant processing power for tasks like analysis, visualization, and modeling. Processing big datasets demands more powerful hardware, such as multicore processors or GPUs, and can increase software costs for high-capacity processing environments ;
- *Bandwidth and Transfer Costs:* Transferring large datasets, especially over the internet or between cloud environments, can incur bandwidth costs. High data transfer speeds may be necessary for remote teams, adding to infrastructure expenses ;
- *Impact on Performance*: As data volume increases, the performance of data management and GIS software can be affected. Larger datasets can slow down applications, reduce responsiveness, and require optimizations, adding to software and labor costs ;
- *Scalability:* Managing large data volumes calls for scalable systems that can grow with the data. Implementing scalable solutions involves higher initial investments but allows for handling growing datasets without sacrificing performance.

Optimizing data acquisition methods, storage solutions, and processing workflows is essential for managing high data volumes efficiently.

Economic Aspects: Data Acquisition

The particularity of GIS is that the diversity of costs is significant: needs analysis, hardware, software, maintenance, database creation or updating, staff training, etc. Data is the central element of a GIS, and its cost varies greatly from one GIS to another depending on the size of the territory involved and the diversity of applications.

In terms of economic aspects, data acquisition for geographic or GIS-based projects often includes costs tied to collecting, purchasing, and managing data **[47]**. These costs can vary widely based on factors such as the type of data, the scale of the project, and the technology used. Here are some key economic considerations (Fig.34) :

- *Data Collection Costs*: Collecting original data through surveys, remote sensing, or fieldwork can be very costly, especially if it involves extensive or complex areas. For example, acquiring high-resolution satellite images or performing aerial surveys can require substantial investment ;
- *Purchasing and Licensing*: When obtaining data from third-party sources, costs are associated with purchasing or licensing data. Many governments and private organizations sell datasets, and costs depend on data quality, update frequency, and usage rights. In some cases, organizations may need to pay for data each time it's updated. ;
- *Equipment and Technology*: Investing in data collection equipment, such as GPS units, drones, or LiDAR technology, can incur substantial upfront and maintenance costs. Additionally, specialized software is required to process and visualize data, which may come with licensing fees ;

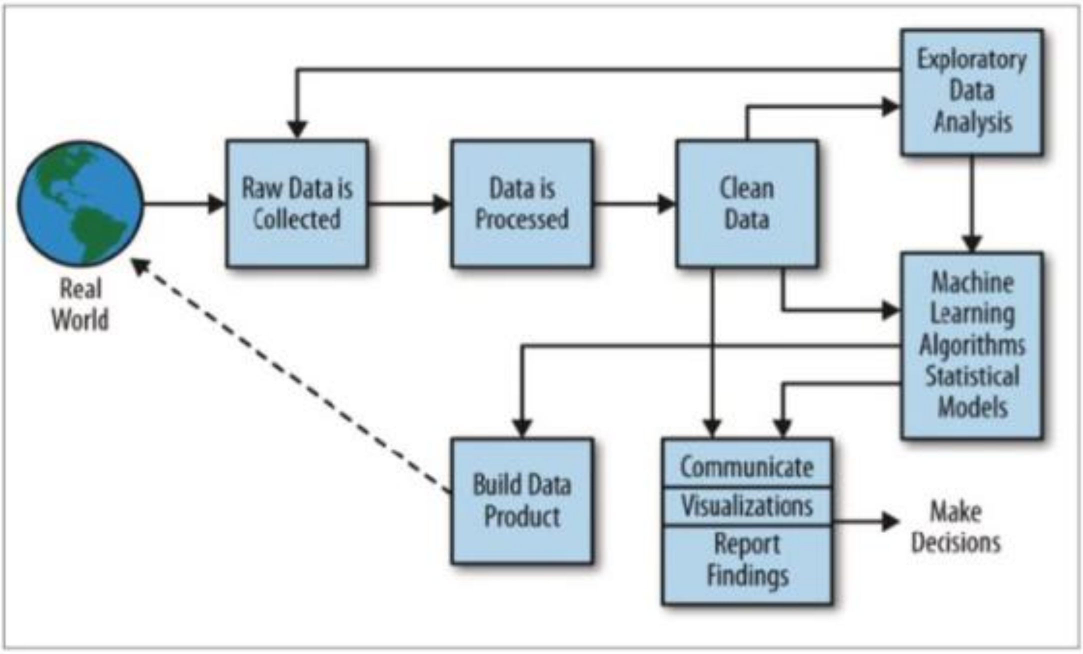


Fig. 34 The Data Acquisition Process **[47]**

- *Labor and Expertise*: Skilled personnel are essential for data acquisition, processing, and analysis, which can represent a major expense. This includes hiring or training GIS specialists, data scientists, and technicians who can handle the tools and interpret the data effectively ;

- *Data Storage and Management*: Data management incurs ongoing costs for storage, backup, and security. Large datasets, especially high-resolution spatial data, require high-capacity servers or cloud storage solutions that increase operational expenses ;
- *Data Quality and Accuracy*: Ensuring data quality often involves additional processing and validation, which can add to costs. High-quality data might require more advanced equipment or specialized expertise, further increasing expenses.

Carefully evaluating these factors is essential for effective budgeting and for making informed decisions about the data acquisition process.

Legal Aspects: Data Protection

Geographic data, maps,and databases are protected by:

- *Intellectual Property Law (Copyright)* : The formatting of data must have
- originality. The project manager must ensure that they have the author's permission to reproduce all or part of their work.
- *Economic Law ("Sui Generis" Right)* : This protects data due to the substantial investment required to produce it. The "sui generis" right allows protection the content of the database and not just its structure. These two forms of protection can be cumulative or invoked independently.

Data protection in the context of data acquisition, particularly for GIS and geospatial data, involves navigating various legal and regulatory requirements to ensure that data handling is secure, transparent, and compliant with laws. Here are the main legal aspects of data protection:

- *Data Privacy Regulations*: Laws like the General Data Protection Regulation (GDPR) in the EU, the California Consumer Privacy Act (CCPA) in the U.S., and other regional privacy laws set strict rules on how personal data can be collected, stored, and processed. Geospatial data can often be personally identifiable (such as detailed location information), making compliance essential to avoid legal penalties ;
- *Consent for Data Collection*: Consent from individuals is often required when collecting geospatial data that could identify or track individuals (e.g., GPS data from mobile devices). Clear consent forms and opt-in mechanisms help ensure compliance and build trust with data subjects ;
- *Data Anonymization*: In many cases, data must be anonymized or aggregated to prevent identification of individuals. Techniques like data masking, encryption, or aggregation help in transforming personal data to comply with privacy standards while retaining data utility ;
- *Data Security Requirements*: Legal frameworks often require that data be stored and transferred securely to prevent unauthorized access or breaches. This includes implementing

access controls, encryption, and secure data storage practices to protect data integrity and confidentiality ;

- *Data Retention Policies*: Many regulations require that data is only stored for as long as it's needed for the intended purpose. Establishing clear data retention policies ensures compliance with these rules and minimizes the risks associated with keeping data longer than necessary ;
- *Cross-Border Data Transfer*: For organizations operating internationally, data transfer across borders may involve additional legal requirements. Countries have different standards for data protection, and some restrict the transfer of data to locations with less stringent protections, requiring agreements or data localization measures.
- *Accountability and Transparency*: Legal frameworks often require organizations to maintain transparent data handling practices. This involves documentation of data sources, purposes, handling methods, and sharing practices, which can be demonstrated in data audits or regulatory reports ;
- *Right to Access and Erasure*: Data protection laws often give individuals rights to access their data and request its deletion. Organizations handling geospatial data must establish processes to address these requests effectively and within the required timeframes.

Complying with data protection laws is crucial for reducing the risk of legal issues and for fostering trust with data subjects and stakeholders. These considerations should be integrated from the outset of any data acquisition project.

Chapter III :

General Information

on

Geomatics

Chapter III :
General Information on Geomatics

When discussing geographic information in the professional world, two terms frequently come up: "Geomatics" and "GIS". In the early 1970s, a geographer engineer first used the word "geomatics" to refer to the combination of the sciences of Earth study and measurement (geography) with computer science. Today, geomatics can be defined as a field of activities aimed at integrating modern methods of acquiring and managing spatially referenced data to produce information that supports decision-making, within a systemic framework.

The acronym GIS (Geographic Information System) is often mistakenly associated solely with software for managing geographic information and producing maps:

- Desktop tools (MapInfo, ArcGIS, QGIS, etc.)
- Web mapping engines (MapServer, GeoServer, MapX, etc.)

The two terms "geomatics" and "GIS" have similar meanings, although the former emphasizes more the use of IT tools and methods in managing information.

III.1. Definition and Concepts

Geomatic is a high-precision portrait of reality from which projects can be developed and past errors can be corrected. It provides an accurate representation of the territory with all the necessary information. The widespread use of user-friendly personal computers has led to a proliferation of software for processing spatially referenced data.

Geomatics (*geography and computing*) is a discipline focused on the management of spatially referenced data, involving the sciences and technologies related to their acquisition, storage, processing, and dissemination.

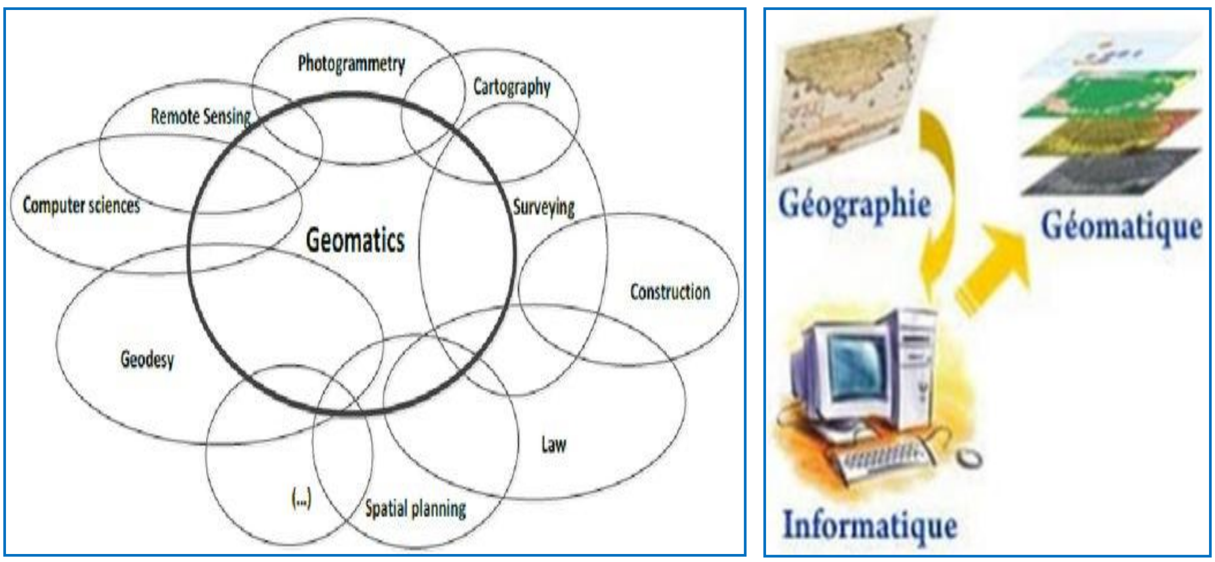


Fig. 36 Disciplines of Geomatics **[28]**

The word "Geomatics" is formed from the prefix "geo" (short for geography) and the suffix "matics" (short for informatics).

Geomatics : A set of methods and techniques from computer science dedicated to the acquisition, processing, storage, analysis, interpretation, presentation, and dissemination of geographic data.

Geomatics is a contraction of the terms "geography" and "informatics."It encompasses a range of technologies for modeling, representing, and analyzing the territory to create virtual representations: geolocation, satellite imagery, databases, GIS (Geographic Information Systems), web technologies, etc.

Geomatics is a science focused on the acquisition, processing, and dissemination of spatially referenced data. It aims to produce a continuous digital chain of data production on the territory using topometry, photogrammetry, geodesy, satellite positioning, remote sensing, geographic information systems, and cartography **[32]**.

Geomatics refers to all the technical uses of computer science in geography: the tools and methods for observing and representing geographic data, as well as the transformation of these measurements into information useful to society **[28]**.

➢ Among the disciplines of geomatics, we can mention:

- ***Topometry*:** The set of methods that allow the acquisition of geographic data in the field, enabling the metric surveys necessary for the creation of a map ;
- *Geodesy*: The science of the mathematical determination and study of the Earth's shape and geometry ;
- *Photogrammetry and Remote Sensing*: These techniques are based on imagery and enable the observation and measurement of objects on the Earth's surface ;
- *Photogrammetry:* Originating in the 1930s, photogrammetry encompasses the equipment and techniques used to represent a territory through aerial photographs, with the precision of the photos (scale) depending on the flight altitude. It is the art of obtaining accurate measurements of objects through photography ;
- *Remote Sensing*: Remote sensing refers to the set of techniques that allow the acquisition of images to gather information about systems (Earth/ocean/atmosphere) without direct contact. This is typically done using remote sensing satellites. While remote sensing focuses on characterizing the nature of terrestrial phenomena depicted in the images, photogrammetry measures their shape and position ;
- *Cartography*: Cartography is the science of creating and studying maps, which are always presented at a precise scale (varying depending on the detail or portion of territory to be represented) and allow the geographic representation of both natural and artificial features of an

area. Cartography involves a set of scientific, artistic, and technical studies and operations in the creation of a map, plan, or other forms of representation, based on direct observations or the use of documentation, as well as in their application **[23]**.

- *Computer Science*: The use of computer tools known as Geographic Information Systems (GIS) is central to geomatics. GIS are computer tools that enable the representation and analysis of data. Computer science is not just another science for geomatics; it is at its core, as it conceptualizes and implements the digital nature of the data being processed. GIS refers to a system that allows for the acquisition, organization, management, processing, analysis, and presentation of geographic data in the form of maps and plan.

Thus, geomatics encompasses at least three distinct activities: the collection of geographic data, the processing of this data, and the dissemination of the results. Computer tools are essential for all these activities. Geomatics is therefore a discipline where geography (geographic data) and computer science are inseparable. One of the main features of geomatics is its ability to integrate information from various domains.

This information is linked to specific portions of territory, with geographic positions tied to geometric entities such as points (buildings, land evaluation units, etc.), lines (streets, rivers, etc.), and areas (lots, lakes, zoning, etc.).

This discipline is applied in numerous fields such as land use planning, natural risk prevention, natural resource management, urban planning, and environmental issues. Geomatics calls upon the sciences and technologies of Earth measurement. It encompasses practices, methods, and technologies for collecting, analyzing, and disseminating geographic data.

The ultimate goal of geomatics is the spatial representation of collected data to identify, represent, and demonstrate analysis results. Therefore, geomatics is a robust tool for territorial management, serving as a backbone to which various databases related to the same territory are connected.

➢ *Geomatics thus enables* :

- Acquisition of Geolocated Data: Using technologies such as GPS, aerial photographs,satellite imagery, etc. ;
- Transformation of Data into Meaningful and Structured Information: Integration into information systems through various computer technologies such as GIS ;
- Spatial Simulation and Analysis of Phenomena Occurring on the Territory: Includes studying urban development, natural or agricultural areas, traffic and mobility analysis, infrastructure placement, risk prevention and management, civil security, defense, and more.

III.2. Application of Geomatics

This discipline is applied in many fields such as land use planning, natural risk prevention, and the management of natural resources and urban planning. However, the use of geomatics is increasingly expanding into the fields of economics and marketing.

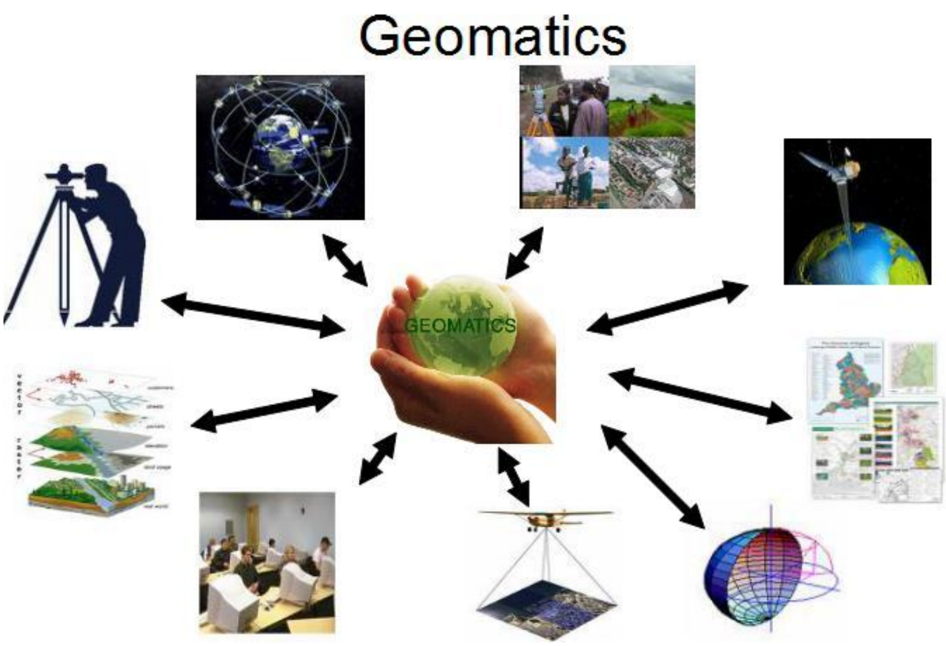
Indeed, the spatial representation of data facilitates market studies, thereby enabling the identification of trends or the analysis of competition in specific geographic areas.

Since geomatics is related to computer science, its application involves the use of computer tools known as Geographic Information Systems (GIS).

III.3. The Role of GIS in Geomatics

Geographic Information Systems (GIS) hold a central role in geomatics, as they are the computer tools that enable the representation and analysis of data. Moreover, nearly 80% of a company's data has a geographic component (customer and supplier addresses, location coordinates of sales points, network infrastructure, etc.).

As a result, the geographic dimension of data is often underutilized, even though it provides a significant competitive advantage and serves as an ideal decision-making tool. https://www.esrifrance.fr/produits/geomatique.aspx



Chapitre IV:

Technical Aspects

And

Architecture of GIS

Chapter IV :
Technical Aspects and Architecture of GIS

The basic functionalities of a GIS can beclassified into: Data capture and inputprocessing; Data storage and management; Datamanipulation; Data display and output **[28]**. Toserve each of these functional components, thelogical architecture based on a 3-tier client-server specification for the Web-GIS isdescribed below. Conforming to the SDIframework and its defined OGC standards, thedesign of a GIS system based on thisarchitecture will lead to an optimal systemperformance. Also, since the requirement for auser to access Web-GIS is only a browser, theneed for high-costing GIS systems is no longera concern. As shown in Fig.37, the architecture consists of 3tiers: The Client tier that presents the data to theuser; the Middleware Tier consisting of theWeb Application and GIS Servers; and theServer Tier including the database that storesthe spatial and non-spatial data **[29]**.

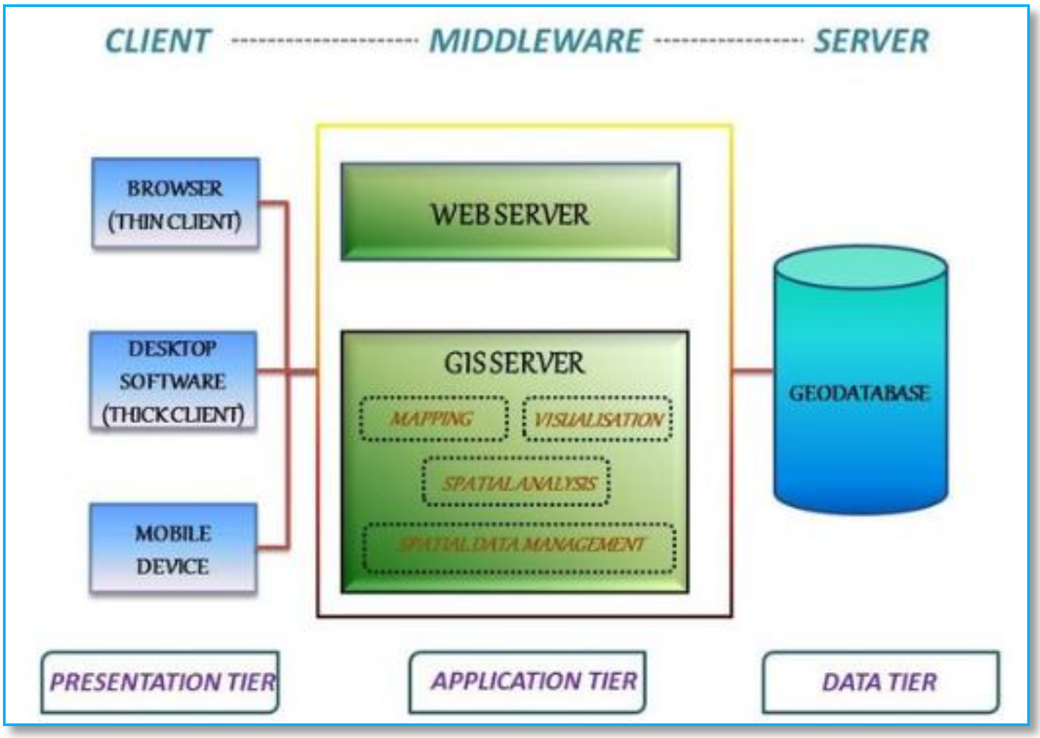


Fig. 37 GIS Architecture based on sdi framework **[29]**

From what was previously mentioned, especially in the first chapter, the geographic information systems must contain at least seven components :

- A spatial and thematic database ;
- A cartographic representation system ;
- A digital input system ;
- A geographic database management system ;
- A spatial analysis system ;

- An image processing system ;
- A statistical analysis system.

These aforementioned components include the six functions (modules) or what is called: ‘“ the 6As ” which are: *Abstraction, Acquisition, Archiving, Anticipation, Analysis and Display*.

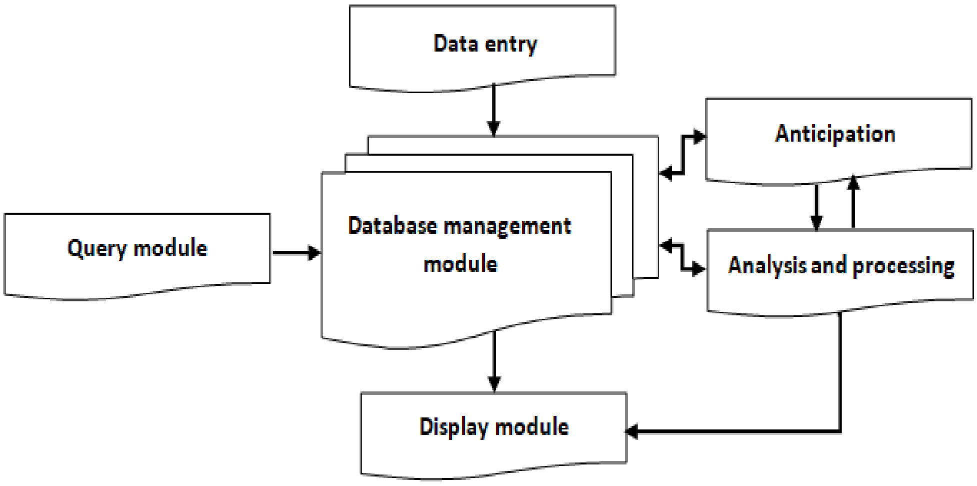


Fig. 38 The computer aspects of GIS **[30]**

IV.1. GIS functionalities

- ***Abstraction***

It is the modeling of the real world through different perspectives. The construction of the conceptual data schema allows for modeling the database by defining the objects (object classes), their attributes, and their relationships. This step is necessary before any digitization and serves as the starting point for the creation of geographic databases and as a communication tool among the various stakeholders. The goal of modeling is to be understood by as many people as possible.

The second step is to find software capable of transcribing and "storing" the schema. Each software implicitly has a Conceptual Data Model. The important thing is the result; the software is just a tool. The GIS tool must be capable of transcribing and storing the model.

- ***Acquisition***

We can obtain information from national or international organizations that produce or resell data :

- Reference data: INCT (National Institute of Cartography and Remote Sensing), ANC (National Cadastre Agency), INPS (National Institute of Planning and Statistics), CNTS (National Center for Space Techniques), Spot Image, etc. ;

- Thematic data: ANRH (National Agency for Water Resources), DGF (General Directorate of Forests) ;

- From local professionals, expert surveyors' offices, state study bureaus, local authorities (APC).

If the data is not available in digital form, it can be created either by oneself or by a service provider :

- Digitization of the cadastre ;
- Topographic survey.

What are the acquisition techniques ?

- Acquisition from vector data: The sources can either be indirect, such as maps, photos, or satellite images, or direct, with field surveys. This acquisition is done from existing paper documents (maps or plans) through digitization using a digitizing table or scanning the data on a computer screen, where objects drawn on the plan are digitized into vector data. The disadvantage of this method is the transcription of errors due to the original medium (paper deformation, line thickness, etc.).

- If the data is scanned and geo-referenced, it is "raster" data.

- Acquisition from photos: From (scanned) ortho-rectified photos to vector data, this is one of the main sources for precise digitization over large areas. The accuracy of the data is related to the accuracy of the photo. This type of acquisition requires either field surveys or cross-referencing with other data to qualify the data; the photo is simply a collection of pixels.

- Acquisition from satellite images: Satellite imagery is the main source of information for land use through remote sensing. Remote sensing encompasses the knowledge and techniques used to determine the physical and biological characteristics of objects through measurements taken remotely, without physical contact with them.

-Acquisition from the field: Generally used for small-scale projects or as a complement to other techniques. GPS (Global Positioning System) surveying is a positioning system on a global scale, based on a network of artificial satellites.

- ***Archiving***

- *Management* : Once the data is acquired, it must be stored and easily retrievable. This is one of the least visible functions for the user. It depends on the software architecture, with the presence or absence of an integrated relational or object-oriented Database Management System (DBMS).

- *Work environment* : This is no longer about "storage space" but "workspace." It concerns the space for project management (organization) as well as the software's ergonomics (interface).

- ***Anticipation***

Anticipation in GIS (Geographic Information Systems) refers to the ability to predict and plan for future events or conditions based on spatial data and analysis. This can involve forecasting trends, modeling scenarios, and preparing for potential changes or challenges. Key aspects of anticipation in GIS include:

- *Predictive Modeling:* Using historical data and statistical methods to predict future spatial phenomena or changes ;

- *Scenario Analysis:* Creating and analyzing different scenarios to understand potential outcomes and impacts ;

- *Trend Analysis:* Identifying and interpreting patterns and trends in spatial data to anticipate future developments ;

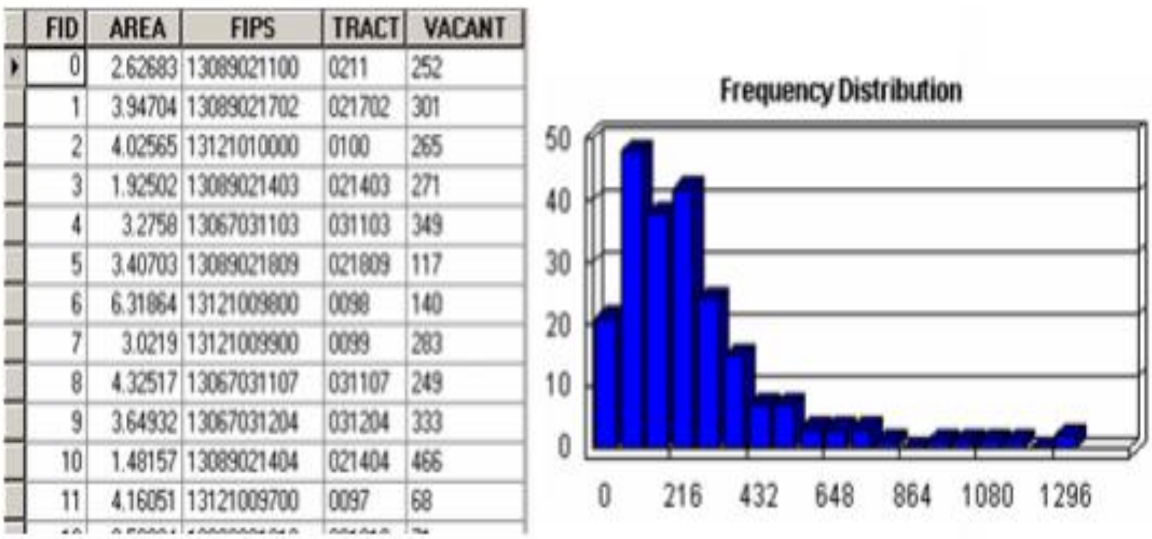
- *Risk Assessment:* Evaluating potential risks and vulnerabilities based on spatial information to prepare for and mitigate possible issues.

These anticipatory methods help in making informed decisions and strategic planning by leveraging spatial data and analytical tools.

➢ ***Analysis***

The purpose of geographic information systems is not just to create plans or maps or to manage data but to serve as a tool for geographic information.

- *Spatial analysis based on semantic(Alphanumeric):* qualitative and/or quantitative description of a space using alphanumeric data stored in the geometric object or in an external database via a link. This analysis can be performed through queries or calculations. Cartography often serves as its support **[9],** (figure 38 and 40).



FID	AREA	FIPS	TRACT	VACANT
0	2.62683	13089021100	0211	252
1	3.94704	13089021702	021702	301
2	4.02565	13121010000	0100	265
3	1.92502	13089021403	021403	271
4	3.2758	13067031103	031103	349
5	3.40703	13089021809	021809	117
6	6.31864	13121009800	0098	140
7	3.0219	13121009900	0099	283
8	4.32517	13067031107	031107	249
9	3.64932	13067031204	031204	333
10	1.48157	13089021404	021404	466
11	4.16051	13121009700	0097	68

Fig. 39 Semantic spatial analysis

- *Geometric spatial analysis*: This analysis is based on the position of the object, its shape, and any existing relationships. The distance between objects is one of the simple functionalities of spatial analysis. One can work on topology when it exists. Data can be manipulated by clipping, joining, or excluding it **[9],** (figures 39 and 40).

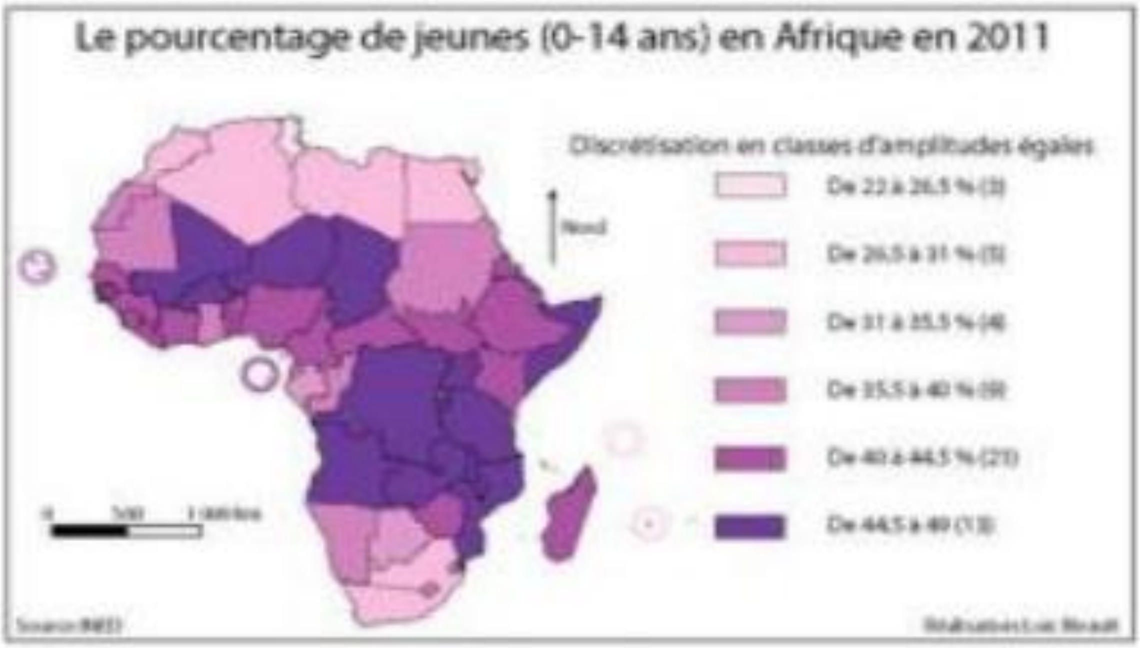


Fig. 40 Geometric spatial analysis

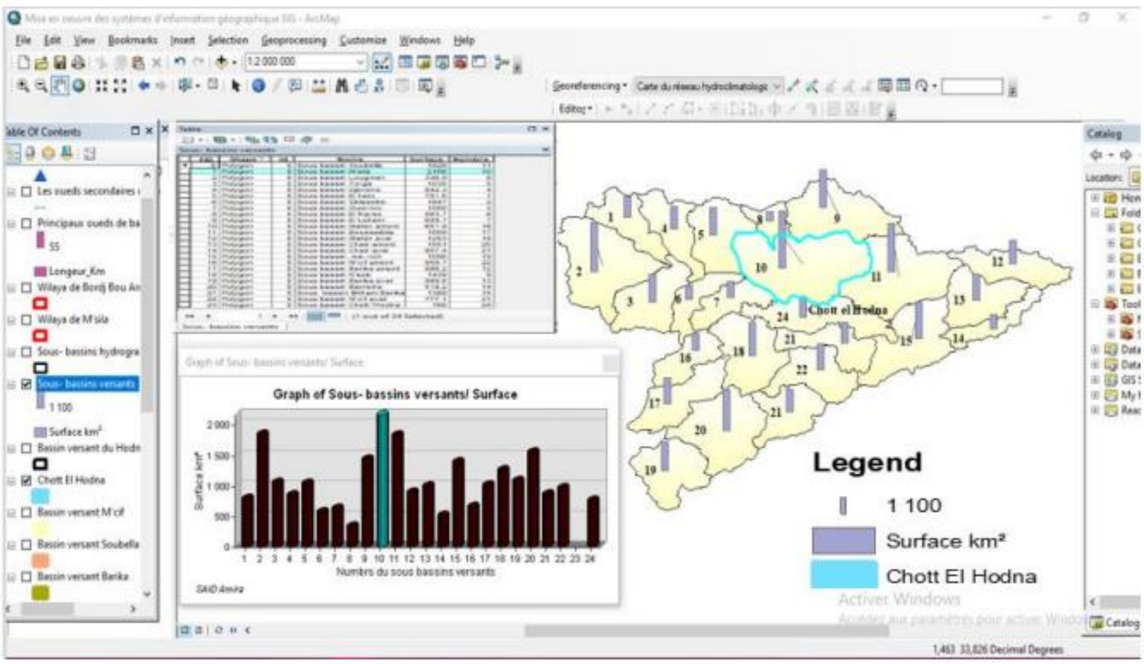


Fig. 41 Geometric and Semantic spatial analysis

➢ ***Display***

Its purpose is to enable the user to understand spatial phenomena as long as the graphical representation adheres to cartographic rules. Display serves to communicate:

- On a computer during the development of a study ;

- On the internet while adhering to constraints such as file size, color, format, etc. ;

- On paper for work documents, reports, promotional materials.

IV.2. Data Management

In all GIS applications, managing GIS data flows is a critical component. GIS users rely on geoprocessing functions to import and export data from databases, publish data in various formats, join contiguous datasets, update database structures, and perform batch processing on their databases.

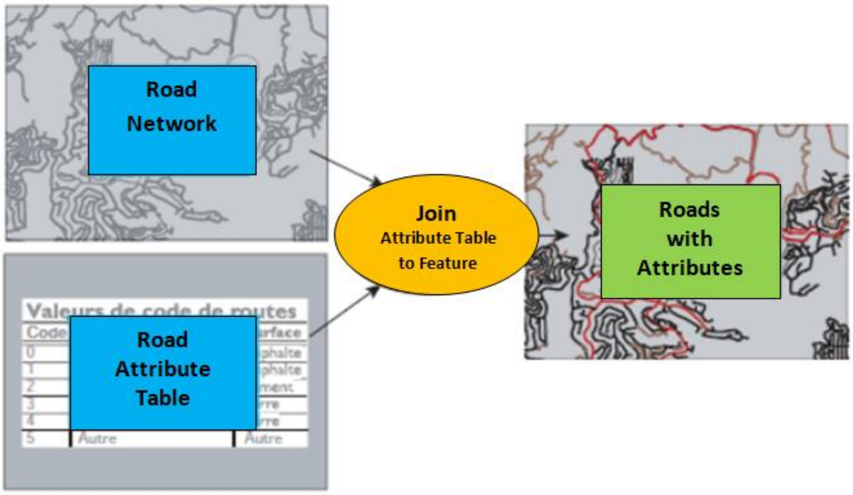


Fig. 42 Creating new data by combining existing data

IV.3. Structure of a GIS: Organization of a GIS

Figure 37 highlights four groups of functionalities below an application layer: the acquisition of geographic data from various sources, management for data storage and retrieval, spatial analysis for processing and utilization, and finally, the presentation of results in cartographic form. A GIS allows the integration and analysis of data to generate information and knowledge. GIS stands out from other geographic information acquisition and processing echnologies (geomatics and cartography) by its ability to integrate multi-source data, perform analysis, and conduct spatial modeling.

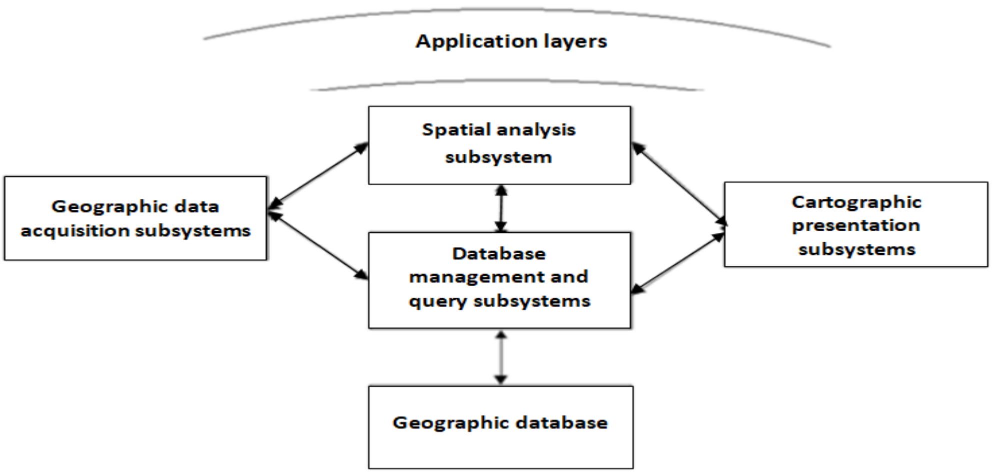


Fig. 43 Structure of a GIS **[1]**

The structured SIG will allow evaluating the relative importance of all variablesusedand in addition to treatand evaluate the various data on the environment,population and other related aspects. From these analyzes and correlations, it isexpected to obtain an objective and integrated tool that based on indicators andinteractive maps indexes, that can support the decision-making process of theregulatory bodies and municipalities involved, seeking to minimize the impact onhuman life and environment due to the disposal of radioactive wasteb **[45]**. Figure 40 presents an overview of the structure of the GIS system that has been prepared all the information that is incorporated into the adopted information system.

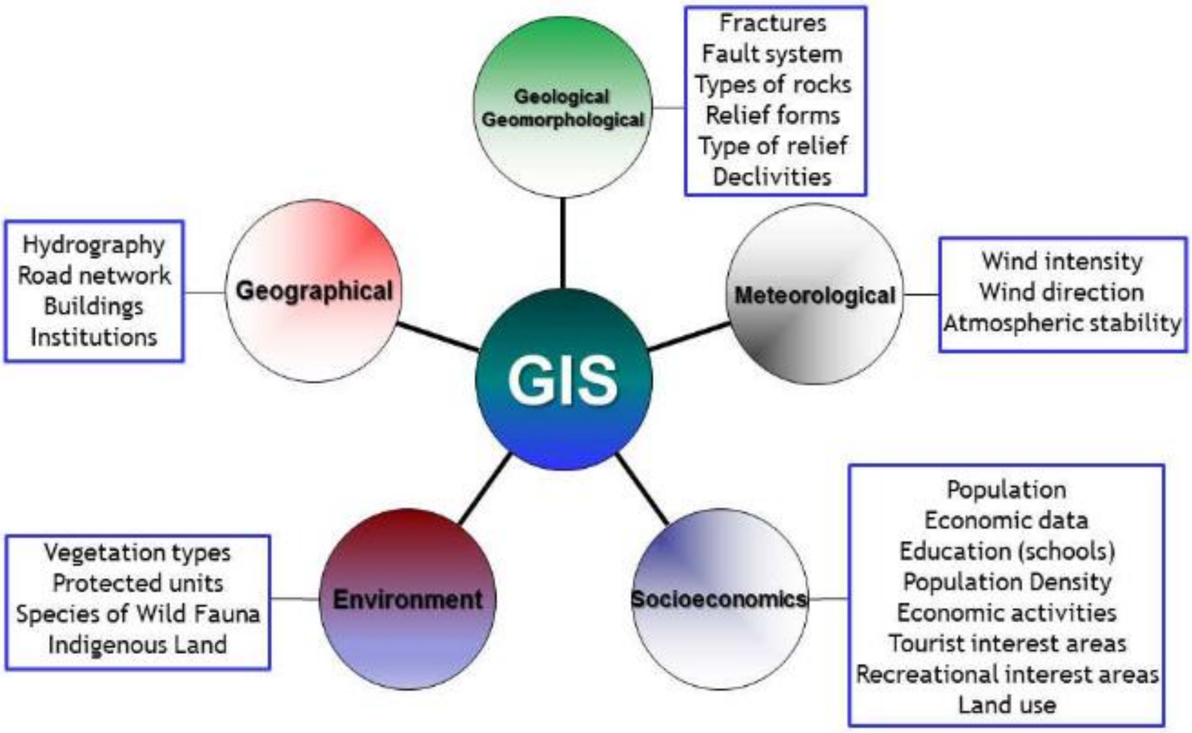


Fig. 44 Structure of the GIS system under development **[45]**

IV.4. Setting Up a GIS

Setting up a Geographic Information System (GIS) can be quite involved, but here's a general outline to help you get started:

. *Define Your Objectives*: Understand what you need the GIS for. Are you managing spatial data, performing analysis, or creating maps?

. *Choose Your GIS Software*:

- Desktop GIS: ArcGIS, QGIS, or similar.
- Web GIS: ArcGIS Online, Mapbox, or Google Maps API.
- Open Source Alternatives: GRASS GIS, GDAL, PostGIS.

. *Install the Software*: Download and install the GIS software that fits your needs. Ensure your system meets the software requirements.

. *Acquire Spatial Data*:

- Data Sources: You can get spatial data from various sources like government databases, open data portals, or create your own.
- Formats: Common formats include shapefiles (.shp), GeoJSON, KML, and raster formats like TIFF.

. *Set Up Your Data Environment*:

- Create a Database: For larger projects, use a spatial database like PostgreSQL with PostGIS.
- Organize Your Data: Structure your files and data layers in a logical manner.

. *Configure Your GIS:*

- Coordinate Systems: Set up appropriate coordinate systems and projections for your data.
- Layers and Symbology: Add layers to your project and configure their appearance and behavior.

. *Perform Data Analysis*:

- Spatial Analysis: Use tools for buffering, overlay analysis, or spatial statistics.
- Attribute Analysis: Analyze and query the attribute data associated with your spatial features.

. *Create Maps and Reports*:

- Map Design: Design your maps to effectively communicate the information. Include legends, scales, and other elements.
- Export and Share: Export maps and results in formats like PDF, JPEG, or share via web maps.

. *Maintain and Update*:

- Data Maintenance: Regularly update and maintain your data to keep it current.
- Software Updates: Keep your GIS software up to date for new features and security improvements.

. *Training and Support*:

- Learn: Take advantage of tutorials, courses, and forums.
- Support: Use community forums or support services if you encounter issues.

Chapitre V:
Applications
(Ecosystem management and Conservation, Wildlife, Flora...)

Chapter V :
Applications
(Ecosystem management and conservation, wildlife, flora...)

Geographic Information Systems (GIS) are extremely useful for ecosystem management and conservation, as well as for wildlife and plant monitoring. Here are some specific applications:

V.1. Ecosystem Management

Ecosystem management using Geographic Information Systems (GIS) is a powerful approach for monitoring, analyzing, and managing natural resources and habitats. GIS allows for the collection, storage, analysis, and visualization of spatial data related to ecosystems, aiding in informed decision-making for conservation and sustainable management.

Here are some applications of GIS in ecosystem management:

- *Habitat Mapping*: Identifying and delineating habitat areas for plant and animal species. This helps in understanding species distribution and planning targeted conservation actions ;
- *Biodiversity Monitoring*: GIS enables the tracking of biodiversity changes by mapping variations in vegetation cover, species movements, and changes in environmental conditions ;
- *Environmental Threat Analysis*: GIS can identify areas at risk of erosion, deforestation, or other threats, helping to plan interventions to mitigate these risks ;
- *Ecosystem Modeling*: GIS allows for the modeling of interactions between different ecosystem elements, such as water cycles, fire spread, or habitat fragmentation ;
- *Resource Management Planning*: GIS aids in optimizing the use of natural resources by identifying priority areas for protection, restoration, or sustainable exploitation ;
- *Monitoring Climate Change Impacts*: GIS enables the analysis of potential climate change impacts on ecosystems, such as sea level rise, temperature variations, or shifts in precipitation patterns.

In summary, GIS offers an integrated framework for adaptive ecosystem management by facilitating data-driven decision-making based on accurate and up-to-date spatial information.

V.2. Wildlife Conservation:

Wildlife conservation using Geographic Information Systems (GIS) is a crucial approach for protecting animal species and their habitats. GIS enables the visualization, analysis, and management of geospatial data related to wildlife, which is essential for developing effective conservation strategies. Here are some applications of GIS in wildlife conservation:

- *Habitat Mapping*: GIS is used to map and delineate animal habitats, identifying critical areas where species live, feed, breed, and migrate ;
- *Species Tracking*: GIS allows for the tracking of animal movements using telemetry data (such as GPS) and analyzing their patterns to understand migration corridors, breeding grounds,

and feeding areas ;

- *Threat Assessment*: GIS helps identify and assess threats to wildlife, such as habitat fragmentation, deforestation, urbanization, or pollution. This information is crucial for developing mitigation plans ;
- *Habitat Connectivity Analysis*: GIS can model the connectivity between habitats, which is essential for maintaining viable populations by avoiding genetic isolation and allowing species movement between protected areas ;
- *Protected Area Planning*: GIS is used to design and plan nature reserves and other protected areas, taking into account species-specific needs and environmental constraints ;
- *Monitoring Environmental Changes*: GIS enables the tracking of environmental changes, such as land use alterations, that can affect habitats and biodiversity ;
- *Human-Wildlife Conflict Management*: GIS can identify areas where human-wildlife interactions are frequent, helping to implement measures that reduce conflicts and protect both animals and local communities ;
- *Species Distribution Modeling*: By combining habitat, climate, and threat data, GIS can model potential species distributions, aiding in predicting where conservation efforts will be most needed in the future (fig.45).

The Geographic Database Model (GDBM) is an easily understandable representation for describing the information system. The GDM is used to formalize the description of the information that is stored in the GIS (Fig.45, 46, and 47).

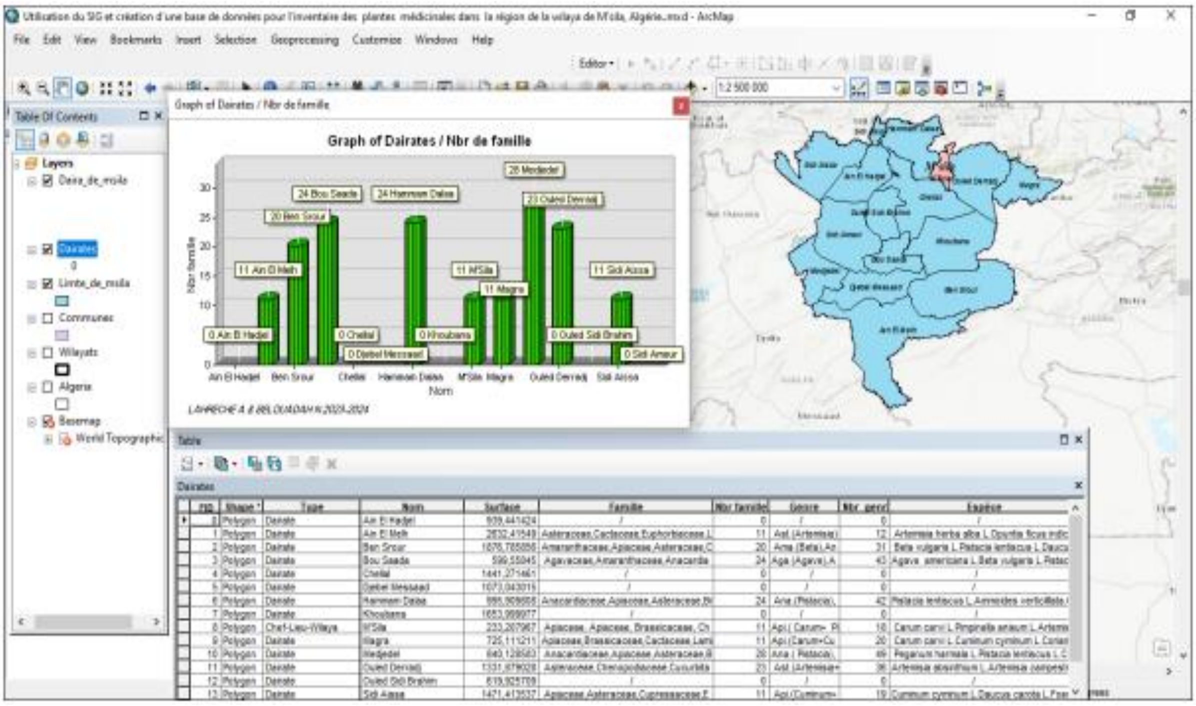


Fig. 45 GDBM - Presentation of the number of medicinal plant families in the Dairats of the M'sila region **[48]**

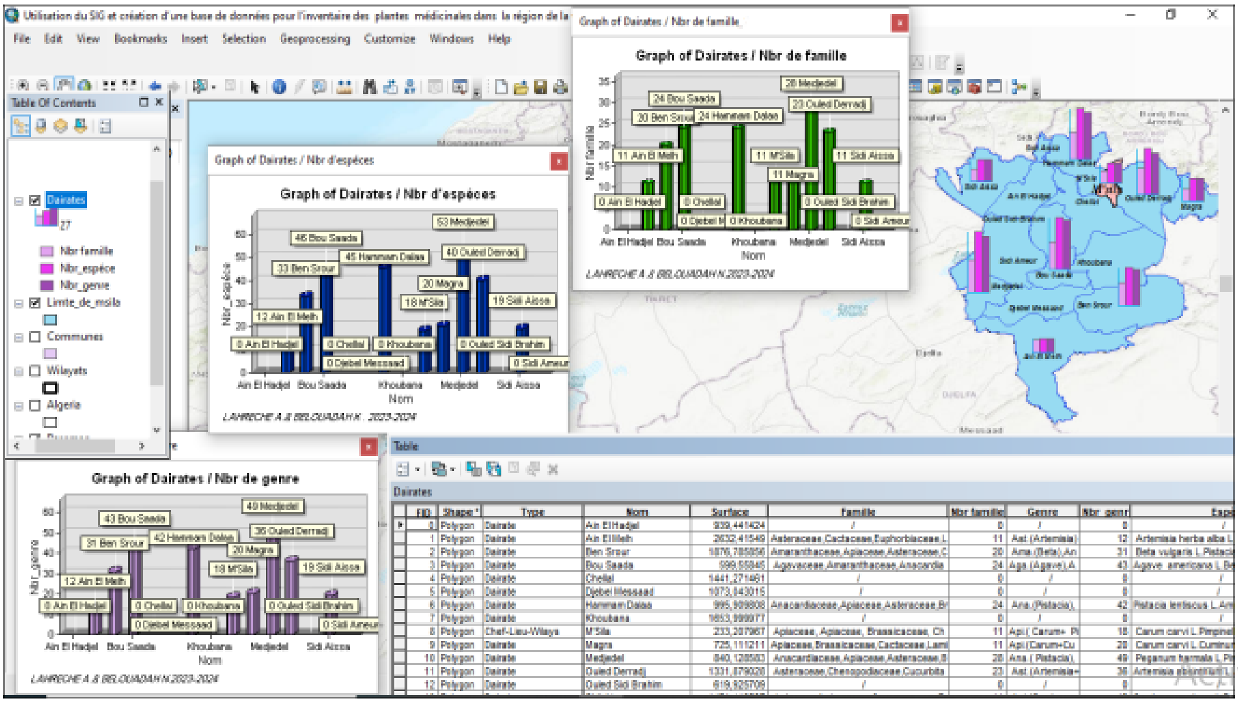


Fig. 46 GDBM - Inventory of medicinal plants in the M'sila region **[48]**

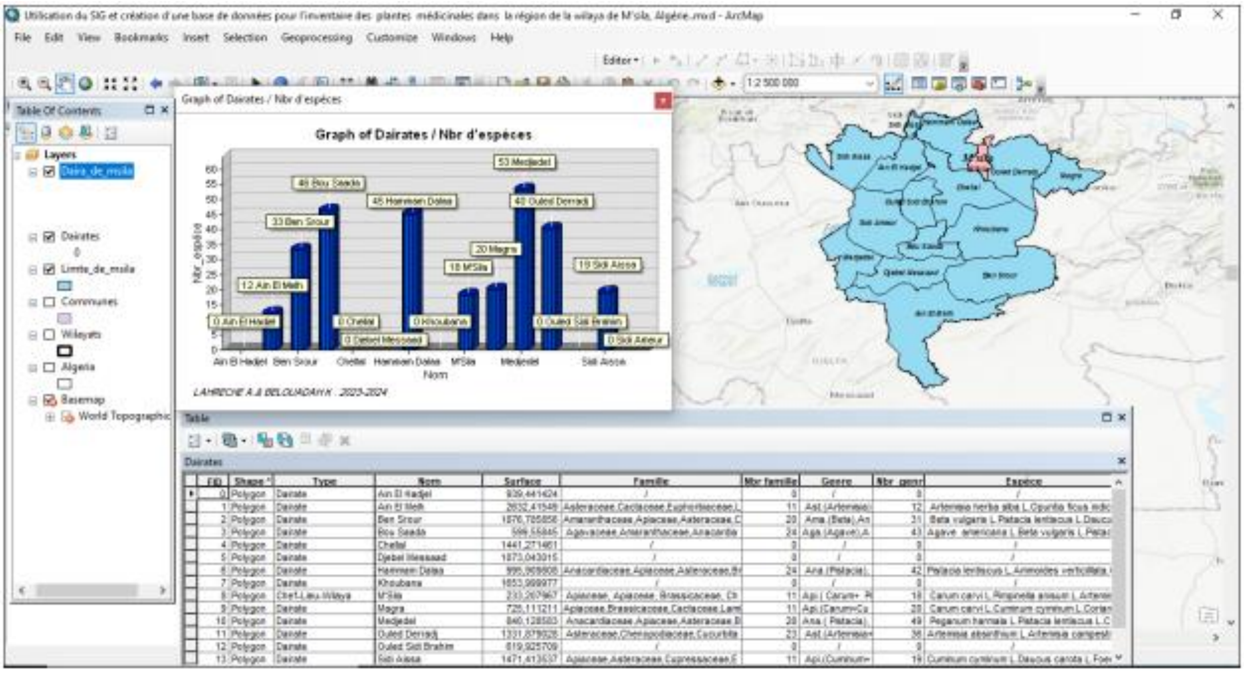


Fig. 47 GDBM - Presentation of the number of medicinal plant species in the Dairats of the M'sila region **[48]**

The data structured in the model of a database from figures (45), (46) and (47) were implemented in a computer system, and the attributes of the various entities (tables) were populated using data collected in the field.

In summary, GIS plays a central role in wildlife conservation by providing tools for data-driven management, which is essential for preserving biodiversity and ecosystems.

V.3. Flora Conservation :

Conserving plant species and their habitats using Geographic Information Systems (GIS) is an effective method for protecting vital ecosystems. GIS provides a platform to map, analyze, and manage geospatial data that is crucial for preserving plant biodiversity. Here's how GIS is applied in flora conservation:

- *Vegetation Habitat Mapping*: GIS enables the mapping of areas where different plant species are found, helping to identify critical habitats for rare or endangered species and vulnerable ecosystems ;
- *Monitoring Changes in Vegetation Cover*: Using satellite imagery and remote sensing data, GIS tracks changes in vegetation cover over time. This is vital for detecting deforestation, desertification, or agricultural expansion that threatens natural habitats ;
- *Threat Assessment*: GIS helps evaluate threats to flora, such as habitat fragmentation, wildfires, climate change, and invasive species. This information is crucial for prioritizing conservation actions ;
- *Plant Species Distribution Modeling*: GIS can model the current and potential distribution of plant species based on various environmental factors (such as soil, climate, and altitude). This helps predict areas where species may thrive or decline in the future ;
- *Ecological Restoration Planning*: GIS is used to identify priority areas for ecological restoration, such as ecological corridors or reforestation zones. This aids in reconnecting fragmented habitats and enhancing ecosystem resilience ;
- *Protected Area Management*: GIS facilitates the management of nature reserves by identifying sensitive areas and monitoring their condition. It also assists in planning the expansion of protected areas to include essential habitats for flora conservation ;
- *Monitoring Climate Change Effects*: GIS can analyze the impacts of climate change on flora by modeling changes in temperature, precipitation, and other climatic factors. This helps predict potential shifts in vegetation zones ;
- *Plant Diversity Analysis*: GIS allows for the analysis of plant species richness and diversity in different regions. These analyses are essential for identifying biodiversity hotspots that require increased protection.

In summary, GIS offers powerful tools for flora conservation, enabling precise, data-driven management of plant resources and their habitats. With these technologies, informed decisions can be made to protect and restore plant biodiversity in the face of current threats.

V.4. Natural Resource Management :

Managing natural resources using Geographic Information Systems (GIS) is an innovative approach that maximizes the efficiency of land, forest, water, mineral, and other essential resource management. GIS facilitates the analysis, visualization, and management of complex geospatial data, which is crucial for planning and decision-making in natural resource management. Here’s how GIS is used in this field:

- *Resource Mapping and Inventory*: GIS is used to create accurate maps of natural resources, such as forests, fishing areas, watersheds, and mineral deposits. These maps help inventory available resources and assess their condition ;
- *Land Use Planning*: By combining data on soil, topography, vegetation, and human infrastructure, GIS assists in planning sustainable land use. It helps determine which areas are best suited for agriculture, conservation, urbanization, or other uses ;
- *Forest and Agricultural Land Management*: GIS is used to monitor the health of forests and agricultural lands, detecting changes in vegetation cover, signs of deforestation, or soil degradation. This aids in planning interventions like reforestation, crop management, or erosion control ;
- *Water Resource Management*: GIS helps manage watersheds, groundwater, and water distribution networks. It assists in monitoring water quality, predicting floods, and planning the allocation of water resources for agriculture, industry, and human consumption ;
- *Environmental Impact Monitoring*: GIS facilitates the analysis of human activities' impacts on natural resources, such as mining, infrastructure construction, or logging. It helps assess environmental consequences and plan mitigation measures ;
- *Protected Area Management*: GIS is used for managing national parks, nature reserves, and other protected areas. It helps monitor ecosystem conditions, assess human pressures, and plan biodiversity conservation ;
- *Natural Hazard Analysis*: GIS allows for the modeling and mapping of natural hazards, such as landslides, wildfires, floods, and droughts. This information is essential for risk management and emergency planning ;
- *Land Use Planning*: GIS supports land use planning by integrating data on infrastructure, urban areas, natural spaces, and agricultural zones. This promotes balanced and sustainable development ;
- *Mineral Resource Optimization*: GIS is used to locate and assess mineral deposits, plan their extraction, and minimize the environmental impacts of mining operations.

In summary, GIS plays a crucial role in natural resource management by providing tools to analyze, monitor, and manage resources sustainably. It enables decision-makers to make informed choices that balance economic, environmental, and social needs.

V.5. Awareness and Education: GIS for Awareness and Education.

Geographic Information Systems (GIS) are powerful tools for awareness and education, as they allow for the visual and interactive presentation of complex data. By integrating geospatial data with contextual information, GIS can help inform and educate various audiences about environmental, social, and economic issues. Here's how GIS can be used for awareness and education:

- *Data Visualization*: GIS enables the creation of interactive maps and visualizations that help users understand complex concepts. For instance, maps showing the impacts of climate change or the distribution of natural resources can make these issues more tangible for the general public ;
- *Environmental Education*: GIS can be used to teach students about how human activities affect the environment. By using data on pollution, deforestation, or natural disasters, GIS illustrates the importance of conservation and sustainable resource management ;
- *Practical Learning Projects*: GIS is often integrated into educational projects where students collect and analyze their own geospatial data. For example, students might monitor water quality in their community, map biodiversity hotspots, or analyze changes in land use ;
- Community Awareness: Community organizations can use GIS to raise awareness about local issues, such as flood risks or pollution hotspots. Interactive maps and GIS applications can help residents understand these issues and engage in actions to improve their environment ;
- *Professional Training*: GIS is used in the training of professionals across various fields, such as natural resource management, urban planning, and territorial planning. Learning to use GIS equips professionals with essential skills for making data-driven decisions ;
- *Participatory Planning*: GIS facilitates public participation in planning and management processes by providing tools to visualize project impacts and gather citizen feedback. This enhances transparency and collaboration in decision-making ;
- *Risk Awareness*: GIS can be used to raise public awareness about natural risks and disasters, such as wildfires, earthquakes, or tsunamis. By showing risk zones and prevention measures, GIS helps communities prepare and reduce disaster impacts ;
- *Research Promotion*: GIS supports research by providing tools for analyzing geospatial data, leading to significant discoveries and a better understanding of natural and social phenomena. Research findings can then be shared with the public to increase awareness ;

- Land Rights Education: GIS can be used to educate communities about land rights, property, and land resources. By providing accurate maps of property boundaries and natural resources, GIS helps resolve conflicts and promote equitable land management.

In summary, GIS offers diverse opportunities for awareness and education by facilitating the visual understanding of geospatial data. It enables the communication of complex information in an accessible and engaging way, promoting better awareness and informed action on important issues.

GIS allows for manipulation through queries written in SQL language. The database designed must be usable and understandable for individuals who may not necessarily be proficient in GIS software. For this reason, it was essential to create a simple and user-friendly graphical interface (forms) for session startup, data entry, data updating, and data utilization. This way, users can operate the tool without needing to understand GIS functionality or language.

Practical Work

Practical Work

Part One : Getting Started with ArcGIS

I. Choice and Functions of ArcGIS

GIS software is designed to ensure its main functions (acquisition, manipulation, creation, and management of geographic data, cartography, etc.). The number of GIS software available on the market is substantial; they have been categorized into open-source software, free proprietary access software, and commercial proprietary software (such as ArcGIS, MapInfo, GeoConcept, etc.). For our module, we have chosen to work with ArcGIS, a software from the world leader in GIS, ESRI. This choice is justified by the fact that ArcGIS is one of the most comprehensive and widely used GIS software globally.

Faced with numerous geographic information systems adapted to the world of microcomputing, we chose the ArcGIS 10.8 geographic information system (see Figure 48) to benefit from a high-performance, scalable product that is widely used among users.

Fig.48 Presentation of ArcGIS 10.8 Software

ArcGIS is a suite of geographic information system (GIS) software developed by the American company Esri (Environmental Systems Research Institute, Inc.). Esri has developed the ArcGIS system (formerly known as ArcView GIS). This system consists of various platforms that enable GIS users, whether desktop, web, or mobile, to collaborate and share geographic information.

In 1999, Esri launched ArcGIS 8.0, which can be run on the Microsoft Windows operating system. ArcGIS combines the visual user interface of ArcView GIS 3.x with elements from Arc/INFO version 8.2. This combination gave rise to the ArcGIS suite. A new data management tool, called ArcCatalog, is an integral part of ArcGIS. The release of the ArcGIS suite marked a shift in Esri's software offerings, consolidating all products into a single architecture.

The current version is 10.8, available since February 2020, and includes version 2.3 of ArcGIS Pro.

II.General Architecture of ArcGIS

ArcGIS is built on a modular architecture that integrates various components to provide a comprehensive GIS solution. Here is a breakdown of its general architecture:

- ***Core Components***
  - *ArcGIS Desktop*: Includes applications like ArcMap, ArcCatalog, and ArcGIS Pro. These tools provide functionalities for mapping, analysis, and data management ;
  - *ArcGIS Server*: A server-based platform that allows for the sharing and management of GIS services across a network. It supports web-based GIS applications and provides access to geospatial data and tools ;
  - *ArcGIS Online*: A cloud-based platform that offers mapping and analysis tools, data sharing, and collaboration features. It allows users to access GIS services and data via the internet.
- ***Data Management***
  - *ArcCatalog*: A tool for managing and organizing geographic data, metadata, and GIS projects. It is integrated into ArcGIS Desktop and provides a user-friendly interface for data management ;
  - *ArcGIS Enterprise*: An on-premises deployment option that includes ArcGIS Server, Portal for ArcGIS, and additional components for data management and sharing within an organization.
- ***Data Formats and Storage***
  - *Geodatabase*: A database or file system used to store, manage, and query spatial and attribute data. It can be a file geodatabase, personal geodatabase, or enterprise geodatabase ;
  - *Shapefiles and Raster Data*: Common file formats for storing vector and raster data, respectively.
- ***Tools and Extensions***
  - *Spatial Analyst*: Provides advanced spatial analysis tools for raster data ;
  - *Network Analyst*: Offers tools for analyzing and solving network-based problems, such as routing and network tracing ;
  - *3D Analyst*: Enables the visualization and analysis of three-dimensional data.
- ***User Interface***
  - *ArcMap*: The traditional interface for desktop GIS tasks, including mapping, analysis, and data management ;

- *ArcGIS Pro*: The modern, 64-bit application that integrates mapping, analysis, and 3D visualization in a single environment with advanced functionality.

➢ ***Web and Mobile Applications***

- *ArcGIS Web AppBuilder*: Allows users to create custom web applications with a drag-and-drop interface ;
- *ArcGIS Collector*: A mobile app for field data collection and mapping.

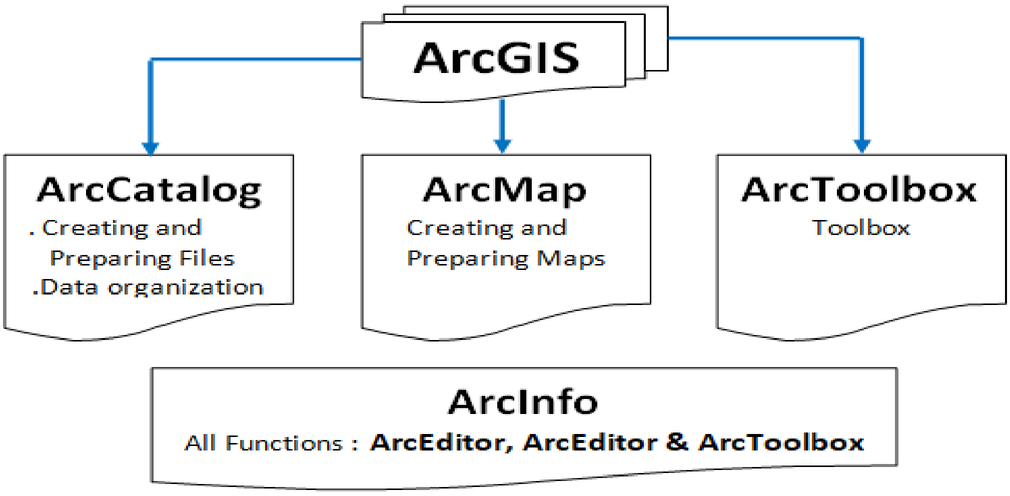


Fig.49 General Architecture of ArcGIS

This modular and integrated architecture ensures that ArcGIS can handle a wide range of GIS tasks, from basic mapping to complex spatial analysis, while providing flexibility and scalability for different user needs.

III. Principles of Operation of ArcGIS

a. ***Data Acquisition***

- *Acquisition of non-digital data*: scanning maps, georeferencing, digitization, and creating attribute tables ;

- *Acquisition of digital data*: importing files, GPS coordinates, etc.

b. Data Analysis

This function is one of the primary tasks of GIS

- *Queries*: selecting all areas with schools ;

- *Spatial analysis or geoprocessing*: creating buffer zones, calculating areas.

c. Data Representation

- *Data visualization*: interaction with the map is possible (zooming, panning, etc.; Fig.50)

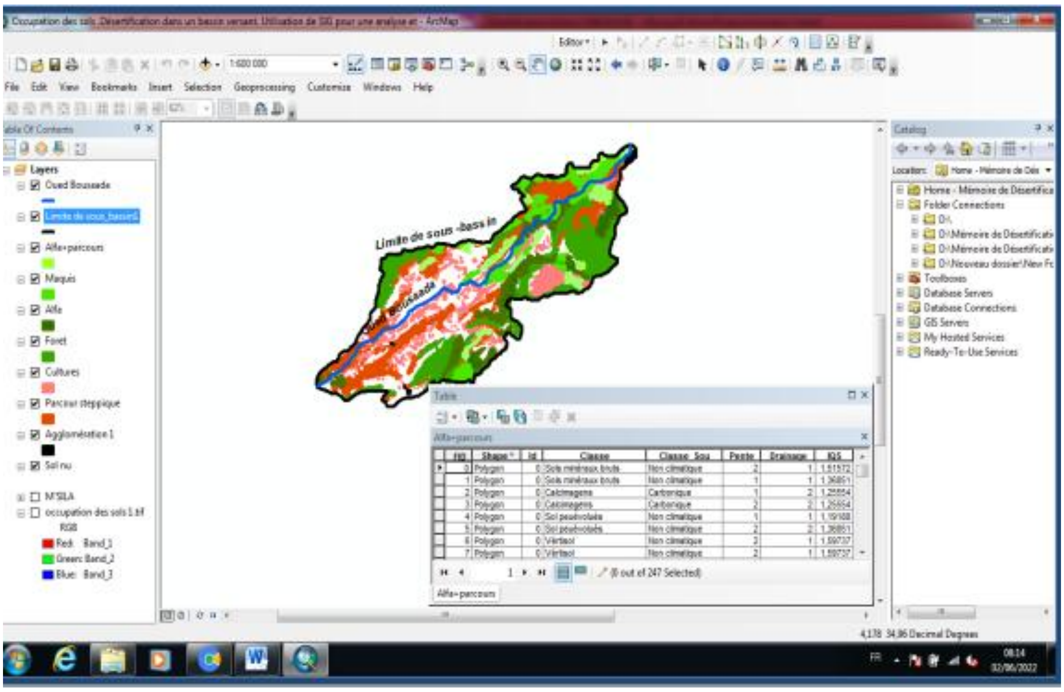


Fig.50 Data visualization using the ArcMap interface

- *Calculations in Attribute Tables*: Calculating population densities from columns showing population numbers by district and district area (see below).

d. Thematic Mapping

This involves representing spatial relationships of one or more themes or phenomena (see Fig. 51).

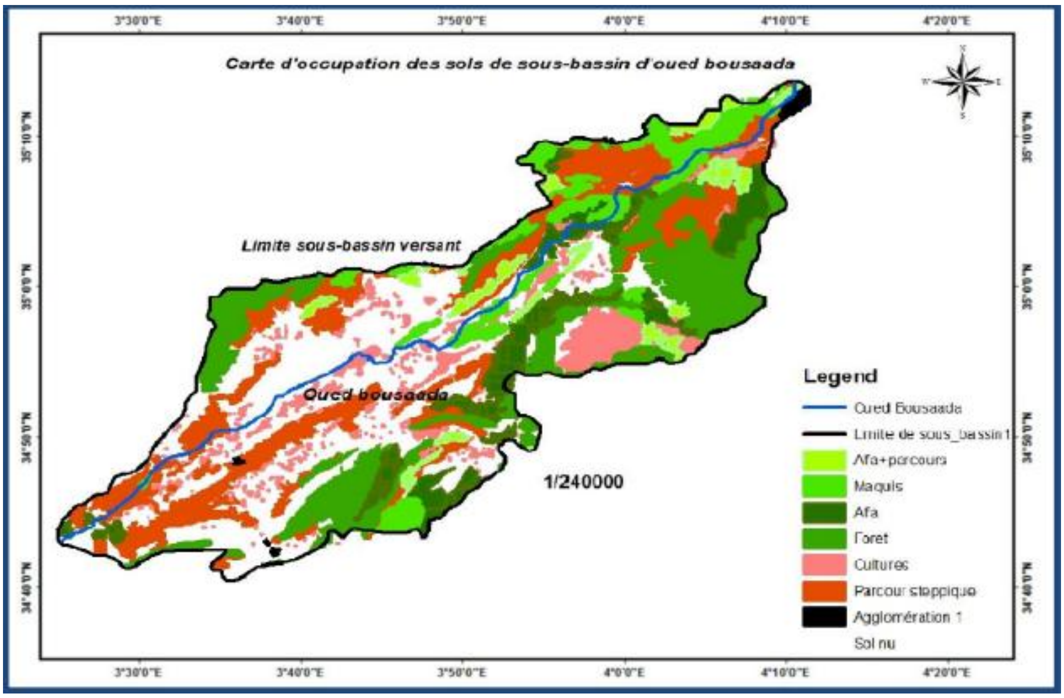


Fig.51 Land use map for desertification of the sub-watershed of Boussaada wadi

IV. Familiarization with ArcGIS Software

To add, visualize, or analyze data, we often launch ArcMap. By doing so, we automatically create an ArcMap document, which serves as a link to the data we add.

The ArcMap document (.mxd) represents the visible face of the GIS. ArcMap document files contain the presentation of shapefiles, details on the GIS data used, display information (scale, symbology, labeling, etc.), and other elements utilized in ArcMap. In reality, the ArcMap document (.mxd) does not physically store the data but rather stores paths to them. This is why it is important not to move files between work sessions. If the files are moved, the path will be lost when reopening the ArcMap document (.mxd), and the moved or deleted data will be marked with an exclamation point in the ArcMap table of contents (legend section).

Each (.mxd) document requires several files, the main ones being (Fig. 52):

- Shapefiles (minimum of 3 files: .shx, .shp, .dbf): the source of raw data for layers, especially geometry and attributes ;
- Additional files are created as more information is added.

BV.dbf	13/10/2011 18:50	Fichier DBF	1 Ko
BV.prj	13/10/2011 18:50	Fichier PRJ	1 Ko
BV.sbn	13/10/2011 18:50	Fichier SBN	1 Ko
BV.sbx	13/10/2011 18:50	Fichier SBX	1 Ko
BV.shp	13/10/2011 18:50	Fichier SHP	8 Ko
BV.shp	13/10/2011 18:50	Document XML	9 Ko

Fig.52 Files comprising a vector layer (shapefile) in a GIS

First part BV: The file name here is BV.

Second part after the dot .dbf is the file extension, with the essential or shapefiles being:

- *.shp (shape):* Contains the geometry of the entities (X and Y coordinates).
- *.dbf (database file):* Contains the attribute data of the entities (characteristics).
- *.shx (shape index):* Reading order of the data, ensuring the link between geometric data and attribute data.

There are other supplementary files:

- *.prj:* Projection information.
- *.sbn and .sbx:* Spatial index, which only exists after performing a spatial query or join.

IV.1.Discovery and Familiarization with ArcMap

This section will teach you how to launch, display, and work with data in ArcMap.

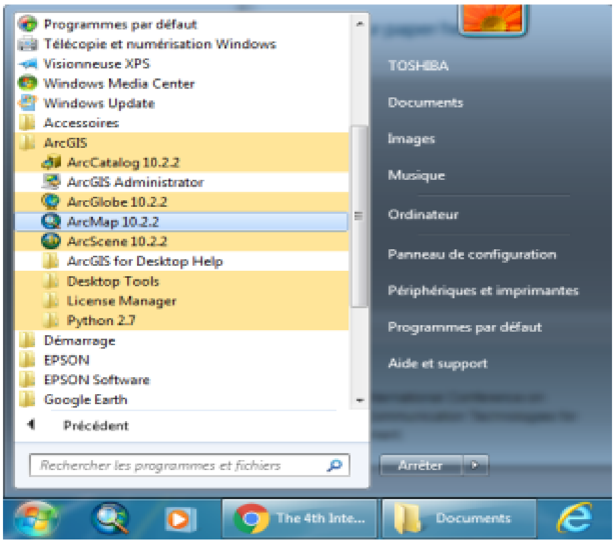
IV.1.1. Getting Started or Launching the ArcMap

Depending on the locations defined by the user, ArcMap can be started from:

- ArcMap shortcut on the desktop 

- Pinned on the taskbar 

- Start menu ⟶ All Programs ⟶ ArcGIS ⟶ ArcMap



IV.1.2. Creating an ArcMap Document

1. *File* / *New*, Go to the *My Templates* / *tab* or *Blank Document*, then click *OK*. If there is already an open document in ArcMap, you may be prompted to save changes to the open document.

2. Naming (*or Renaming*) : Right-click on Layers / *Properties* / *General* / *Name (Principal)*, enter the desired *name*, then click *OK*.

IV.1.3. The ArcMap Interface

This interface is organized into two possible viewing windows (Fig. 53):

➢ ***Data View***

1. A **menu bar** containing a set of functionalities.

2. **Toolbars** that allow various operations, with tools being activated or deactivated as needed. Tools can be activated or deactivated by right-clicking on the toolbar.

3. A main window that displays the **spatial view of the data** opened and selected in the Table of Contents.

4. **Table of Contents**: Lists the files opened in the ArcMap project.

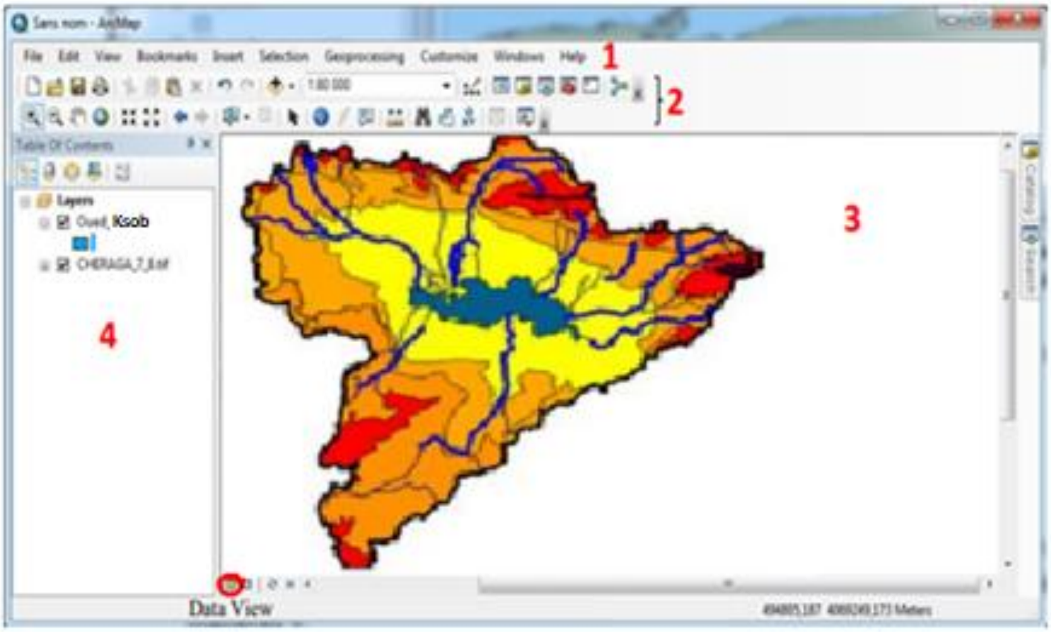


Fig. 53 ArcMap Interface in Data View: 1. Menu Bar, 2. Toolbars, 3. Main Window, 4. Table of Contents.

➢ **Layout View**

This mode allows for editing map documents by adding map elements (title, orientation, scale, legend, etc.) to documents opened or created in Data View (Fig. 54).

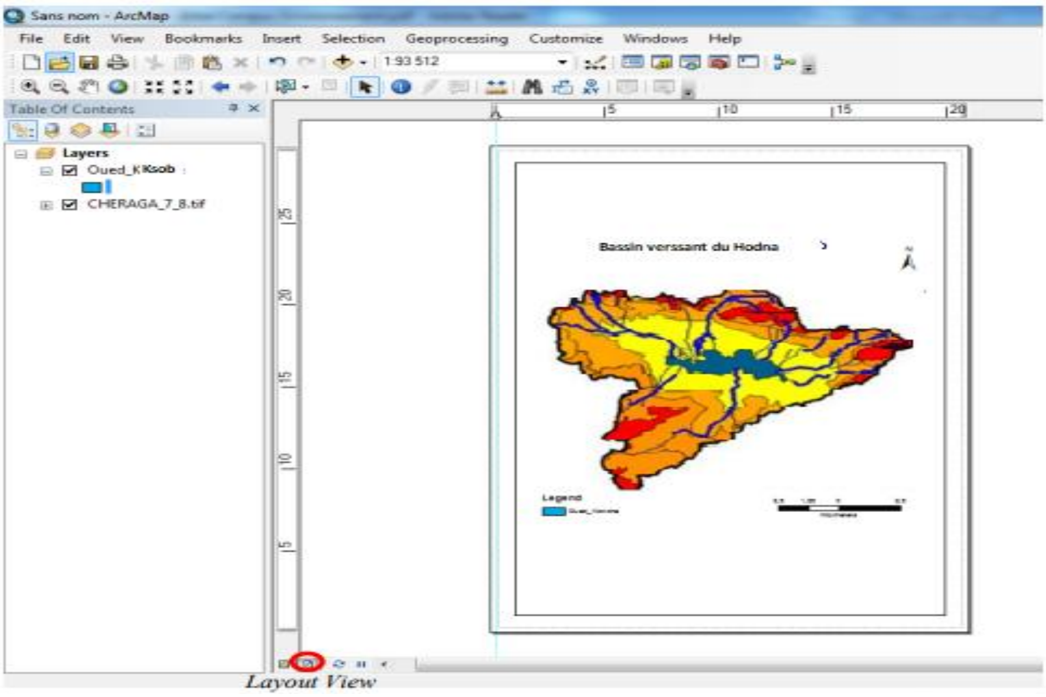
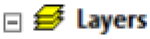


Fig.54 ArcMap interface in Layout View mode

IV.1.4. Add, view, and create data frames

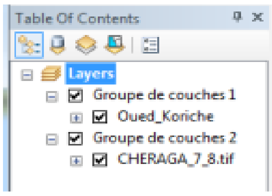
As mentioned earlier, when launching ArcMap, an ArcMap document is automatically created, which will serve as the link to the data you add. To add data, you have two options:

-  : Open ArcMap documents (.mxd)  : Add data



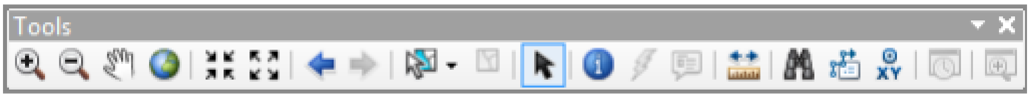
: This symbol represents the data frame (datatram) in the Table of Contents.

The data frame can group multiple layers (*Group Layer*) within the same map. On a single page, you can have several groups of layers.



Data visualization allows for interaction with the map (navigation, zoom, panning, etc.).

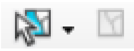
If the *Tools* option is not displayed, you need to activate it: right-click on the *Toolbar*, then select Tools to enable it.



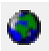
 Zoom in and out

 Constant zoom in and out

 Pan the map

 Select the entity (ies). Once selected, the entities appear highlighted in blue.

 Select, resize, and move text, graphic elements, and other items on the map.

 Display the full extent of the map elements, and other items on the map.

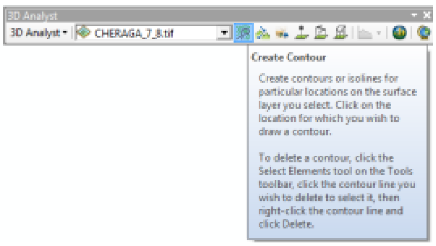
 Go back (or move) to the previous Extent.

 Measure the length of one or more segments on the map.

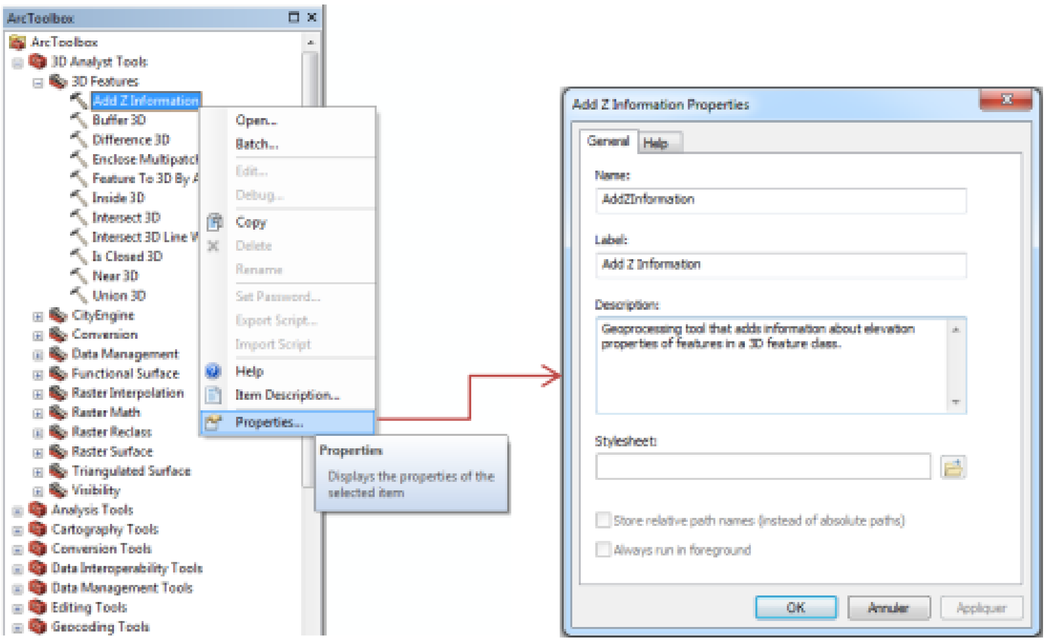
Find features using their X and Y coordinates

Above, we mentioned some features of the Tools tool. ArcToolbox contains hundreds of tools, and there are two ways to learn about their functions:

- Activate the tool in question from the Toolbar, then simply hover the cursor over it for its.



- You can check the function of a given tool in ArcToolbox. In this case, you need to find the tool, right-click on it, select Properties, and the features are listed in the Description section.



IV.1.5. Modify layer appearance: The ArcMap interface offers the ability to change the appearance of shapefile layers (vector data).

➢ ***Modify colors***

a. Quick modification: Double-click or right-click on the symbol in the Table of Contents. From there, you can change the color and texture of the polygon, as well as the color and type of its outline.

1. Symbol categories

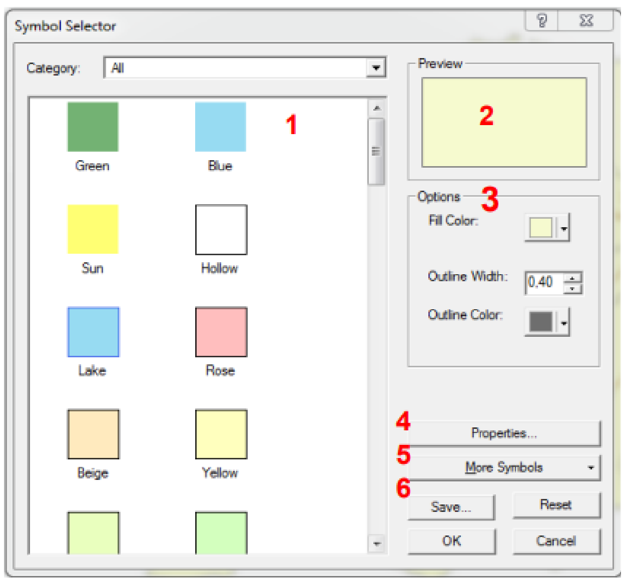
2. Current symbol on the layer

3. Define the main characteristics of the symbol (fill color, border width, and border color)

4. Properties: Further define the symbol

5. More symbols: Other than those defined by default

6. Additional symbols: Save the newly defined symbol using the Properties button.

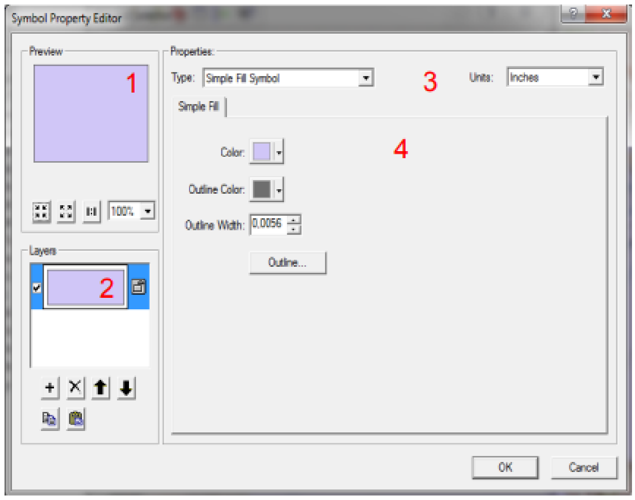


1. Final preview

2. Displayed, added, and removed overlay pattern layers

3. Choose the pattern type

4. Settings for the selected pattern layer.



b. Using Additional Symbol (the Properties button), you can modify the color and texture by creating a new pattern with at least two layers (Simple Fill Symbol, Marker Fill Symbol).

IV.2. Discovery and Familiarization with ArcCatalog

As mentioned earlier, ArcCatalog allows for the organization and management of files (creation, deletion, modification of the projection system, etc.). This section will cover how to launch, display, and utilize data in ArcCatalog.

IV.2.1. Starting or Launchin ArcCatalog

Based on the locations defined by the user, ArcMap can be launched from:

- ArcCatalog shortcut on the desktop 
- Pinning it to the taskbar 

- Start menu ⟶ All Programs ⟶ ArcGIS ⟶ ArcCatalog

The ArcCatalog interface is organized into five main sections (Fig. 55).

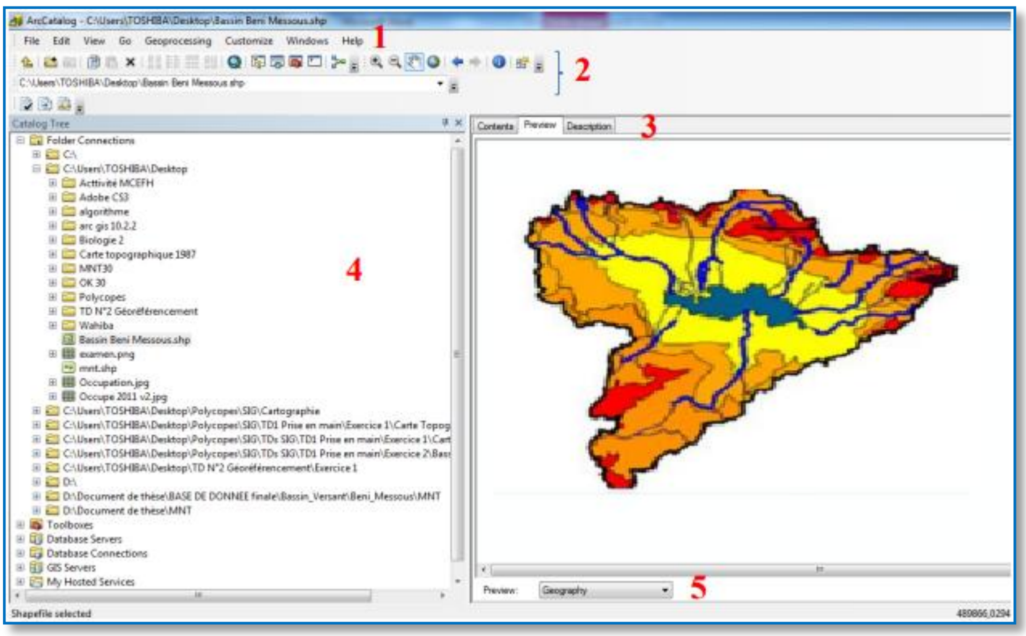
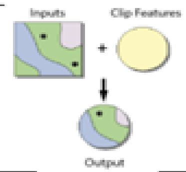
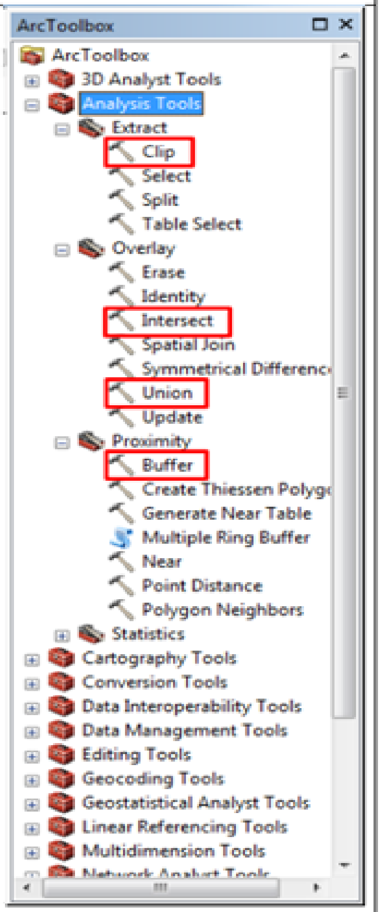
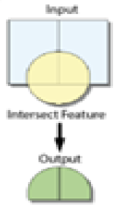
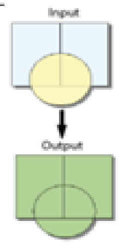
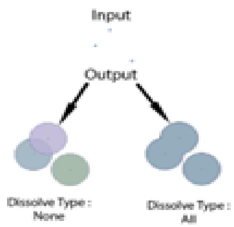


Fig.55 ArcCatalog Interface: 1. Menu bar 2. Toolbar 3. Display window with tabs: Contents, Preview, Description (or metadata) 4. Catalog tree 5. Preview mode (geographic, tabular)

IV.2.2. Frequently used tools in ArcCatalog (also available in ArcMap) include

Analysis Tools One of the most commonly used tools is primarily for handling shapefiles (features). For rasters, a different tool is typically used Spatial Analyst Tools (Tab.2).

Tab.2 Frequently used tools in ArcCatalog and ArcMap

<table>
<tr><th>Tool</th><th colspan="2">Function</th><th>Path in ArcToolbox</th></tr>
<tr><td>Clip</td><td>Extraction of input features that overlap with the clip feature (Clip Features).</td><td></td><td rowspan="4"></td></tr>
<tr><td>Insert</td><td>Intersection of two (or more) shapefiles, with their attributes written to the output feature class.</td><td></td></tr>
<tr><td>Union</td><td>Union of two shapefiles; their attributes will be written to the output feature class.</td><td></td></tr>
<tr><td>Buffer</td><td>Creation of a buffer zone (polygon) around a spatial feature, at a specified distance.</td><td></td></tr>
</table>

IV.3. Georeferencing Spatial Entities in ArcGIS

In GIS, all spatial entities must be georeferenced in a coordinate system. All layers forming the same data block (same project) must use the same coordinate system; otherwise, spatial analysis of these layers will be impossible (incorrect locations and dimensions).

IV.3.1. Some Concepts

The principles of georeferencing can be summarized through three main concepts:

- Geoid
- Geodetic Reference System (datum)
- Projection associated with the datum

❖ *Geoid*: The description of the Earth's shape and dimensions that most closely approximates reality (Fig. 56).

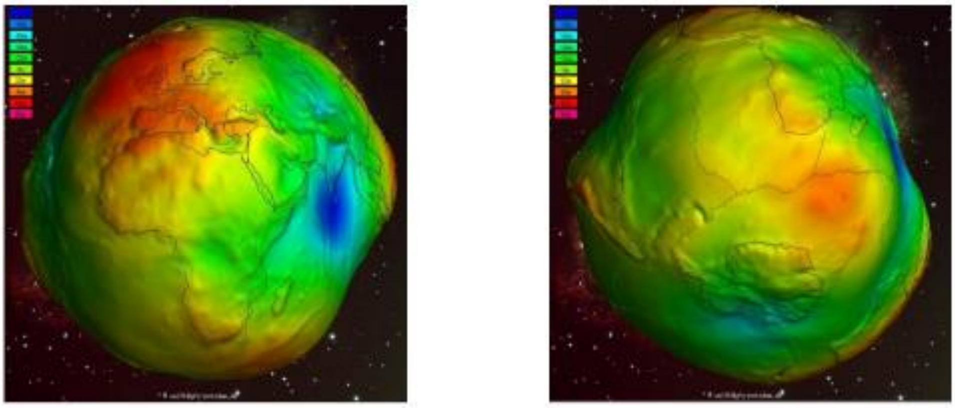
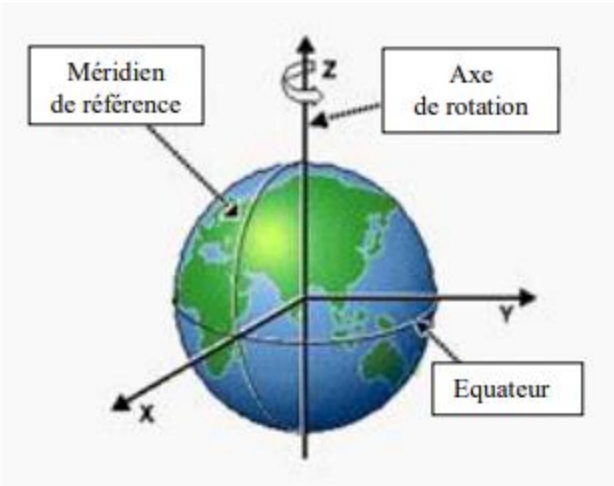


Fig. 56 Presentation of the Terrestrial Geoid (NASA's GRACE mission)

❖ *Geodetic Reference System*:It allows for the mathematical and unambiguous localization of a point within a 3D coordinate system.The geodetic reference system can be:

- ***Local***: Obtained from ground-based measurements ;
- ***Spatial***: Obtained from measurements made by satellites (GPS: Global Positioning System).



❖ *Projected Coordinates*

Mathematical transformation allowing the conversion of angular coordinates developed by the geodetic system into coordinates in a Cartesian reference frame (X and Y). Planar spatial references are more practical for measuring distance or calculating an area.

Two main criteria involved in the classification of projections:

- Types of mathematical surfaces used ;
- Type of distortion.

a. Types of mathematical surfaces used

There are several types of surfaces used in projection, the main ones being:

a.1. Cylindrical Projection (UTM)

Tangent cylinder (equator or meridian) to the ellipsoid. The central meridian and the equator are orthogonal lines (Fig. 57).

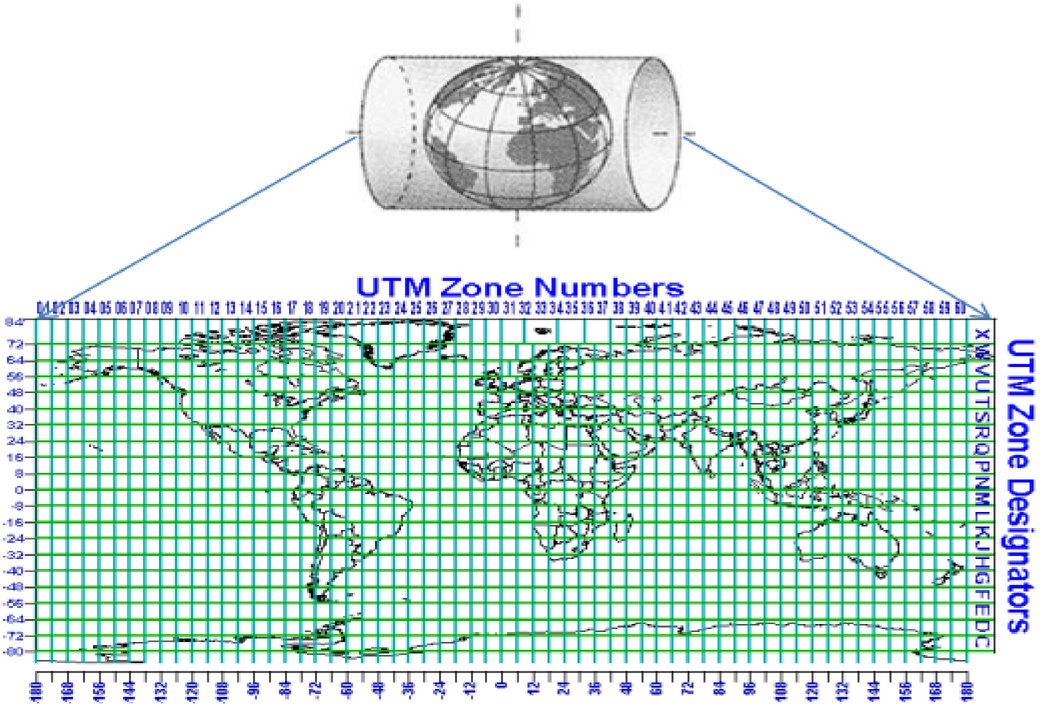


Fig. 57 The Universal Transverse Mercator projection (UTM; Peter H. Dana 97/94)

a.2. Conic (Lambert) Projection

The meridians are converging straight lines, and the parallels are arcs of circles centered on the point of convergence of the meridians (Fig. 58). It is a conic projection based on two standard parallels, which vary with the mapped region **[35]**.

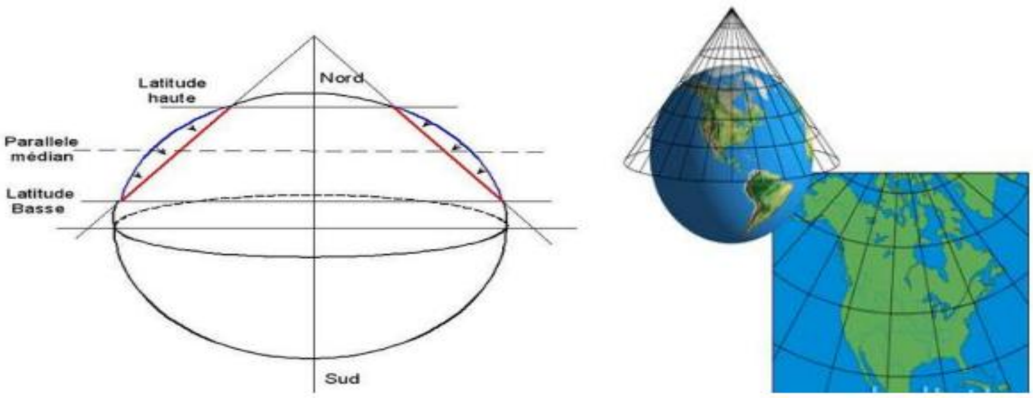


Fig. 58 A diagram explaining the Conic (Lambert) Projection
https://www.bel-horizon.eu

a.3. Azimuthal Projection

It is a planar projection, where a portion of the Earth's surface is transformed from a perspective point onto a flat surface (Fig. 59).

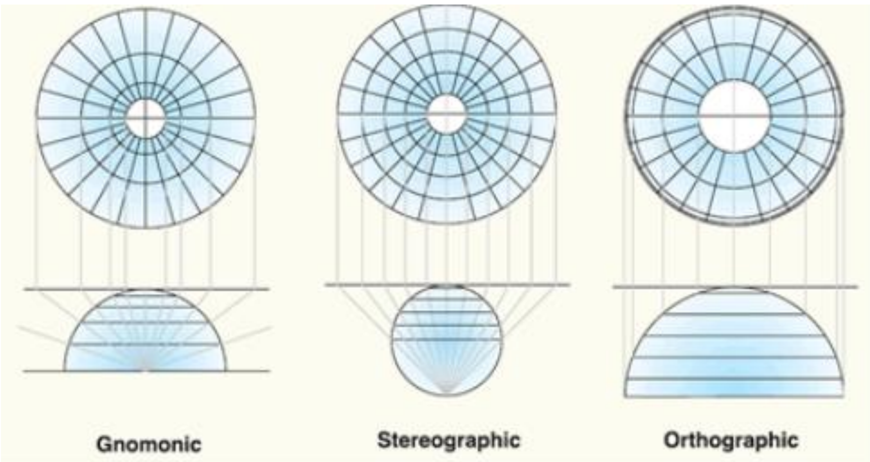


Fig. 59 Azimuthal Projection

b. Types of Distortions

The flattening of the Earth's sphere inevitably leads to distortions:

- Equivalent Projection: Preserves areas at the expense of shapes ;
- Conformal Projection: Preserves shapes at the expense of areas ;
- Compromise Projection: Attempts to find a balance, preserving both areas and shapes as well as possible.

The choice of distortion is determined by the purpose of the work. For example, if the document will be used to calculate areas, the conformal projection is preferred. For thematic maps, a compromise projection is often used.

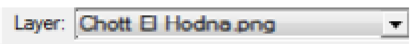
IV.3.2. Production of Georeferenced Data

Creating spatial entities in GIS largely relies on raster data (scanned maps, satellite images, orthophotos, etc.), which must be georeferenced, meaning it is associated with a coordinate system. A raster can be georeferenced:

- By entering known coordinates ;
- From a raster file ;
- From a vector file.

IV.3.2.1. Activate the Georeferencing Tool

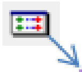
The tool used for georeferencing is called Georeferencing. It is activated via the toolbar.

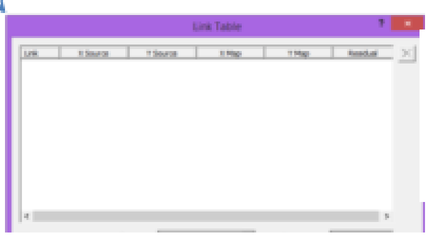


Displaying the layer to be georeferenced


Allows for the movement and rotation of the layer to be georeferenced

Production of Control Points





Link Table: In which information about the control points is displayed (old and new XY coordinates, error).

IV.3.2.2. Selection of Control Points

Control points should not be chosen randomly; there are rules to follow, and these rules are the same for all georeferencing methods. Therefore, the points should be:

- Spaced apart from each other ;
- Distributed across the entire surface of the layer ;
- Non-collinear(not aligned) ;
- It is advisable to add a sufficient number of points until residuals are displayed (at least 5 points).

IV.3.2.3. Steps for Georeferencing

A. *Georeferencing by entering known coordinates*

This involves providing the coordinates (x, y) at specific points on the map to be georeferenced (Fig. 60).

A.1. Retrieve X Y coordinates

To obtain the coordinates of a given area in advance, there are several possibilities: from a georeferenced document covering the same area, measurements on the field using a GPS, satellite data, etc. With the advent of Google Earth, this task has become extremely easy, as it covers almost the entire globe with a very acceptable level of precision**.**

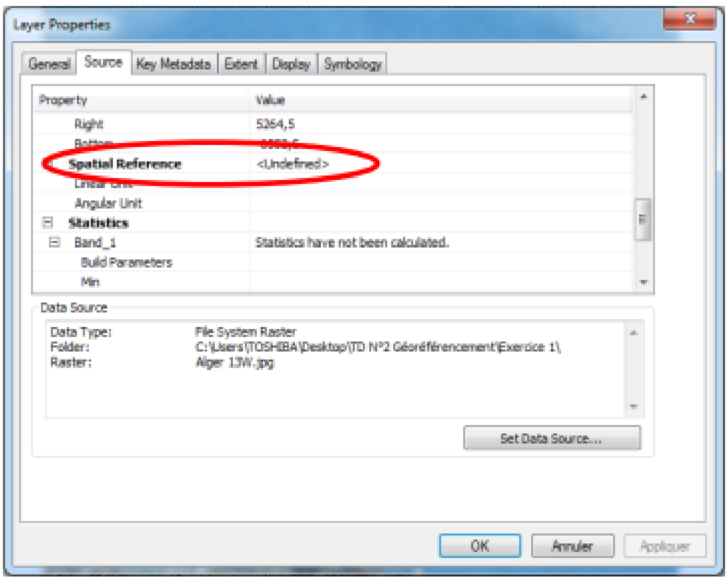
	Références X (Decimal Degrees)	Références Y (Decimal Degrees)
Point 1	487 998,714	4 068 926,285
Point 2	477 675,989	4 066 878,769
Point 3	485 218,700	4 066 869,364
Point 4	482 002,159	4 062 995,821
Point 5	477 800,997	4 054 483,100
Point 6	478 721,701	4 053 007,624
Point 7	488 723,264	4 052 988,407
Point 8	488 832,151	4 059 886,122
Point 9	486 632,131	4 062 497,502

Fig. 60 Scanned topographic map; table containing the coordinates of several points located on this map.

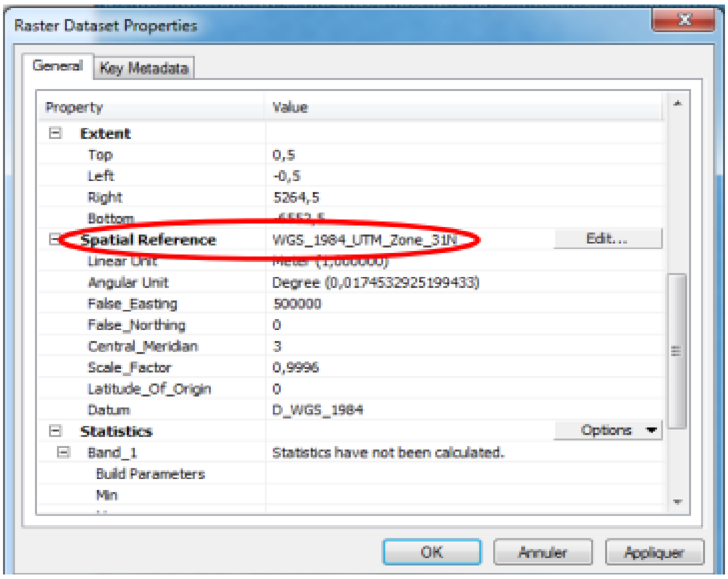
A.2. Entering Coordinates

A.2.1. Identification and Changing Projection System

In georeferencing tasks, as well as other tasks in GIS, it is essential to develop the habit of checking the projection system defined for your layers. To do this: Launch ArcMap / open the document to be georeferenced/right-click on the layer / properties / Sources, then scroll down to the Spatial Reference line. At this point, two scenarios can occur:

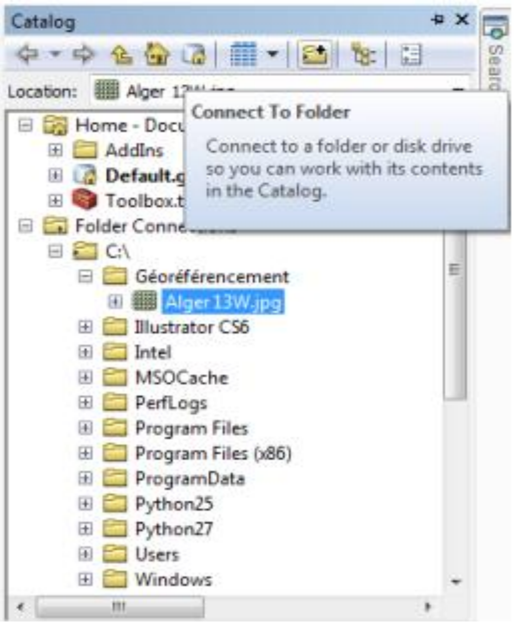


Undefined : This means that the layer lacks a projection system, and therefore, you need to assign one.

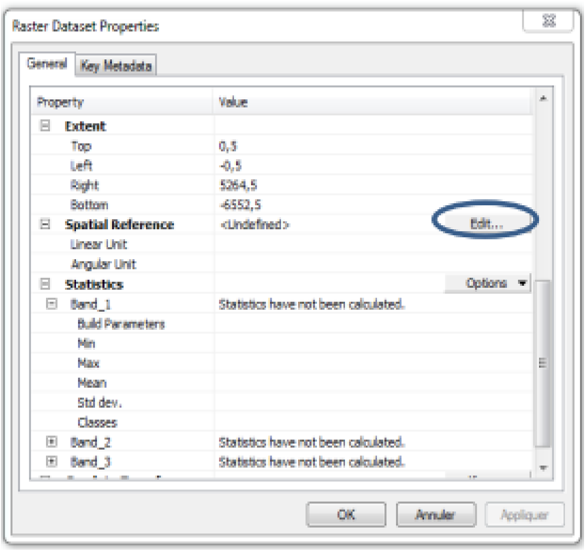


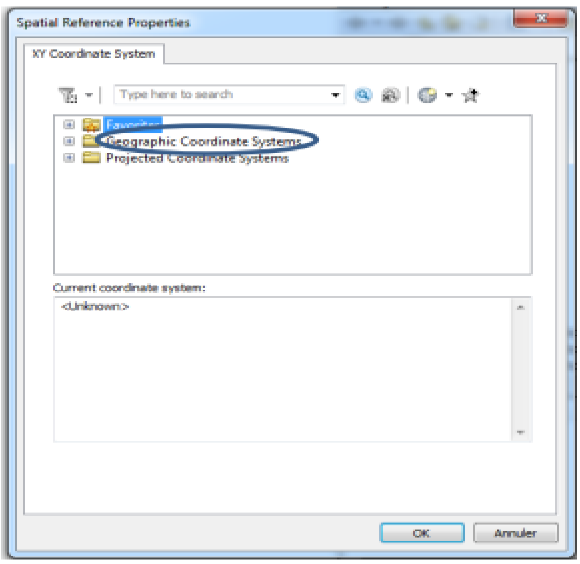
A projection system will be displayed. If the assigned system is incorrect or does not match the chosen system for your project, it needs to be changed.

To assign a projection system to a layer or change its system, follow these steps:



Launch ArcCatalog / open the layer to be georeferenced using the Connect To Folder function / right-click on the layer / Properties / scroll down to Spatial Reference / Edit / Geographic Coordinate Systems, then find the system you want to assign to your layer.





To change the projection system, you follow the same procedure. To simplify this task and avoid having to search for the projection each time you add a layer to your project, you can either - *save the used projection to the favorites list using the Add to Favorites function* (Add to Favorites) , or - *import it from a layer you've already worked on using* the Add Coordinate System (Add Coordinate System) / Import function.

A.2.2. Add Control Points

Activate the Georeferencing tool / choose the map to georeference (Fig. 61). Note that the Georeferencing tool by default uses the most recently added layer in ArcMap, so always check in the Georeferencing toolbar (Layer box) to ensure you are working with the correct layer.

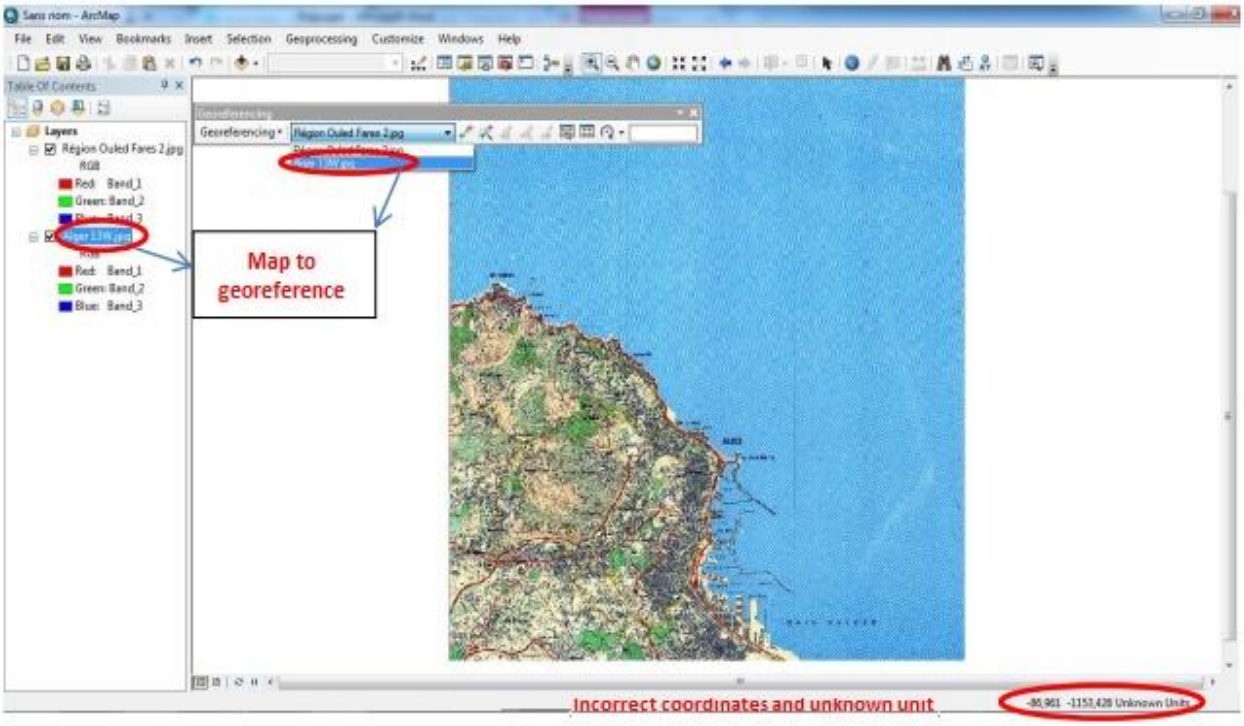
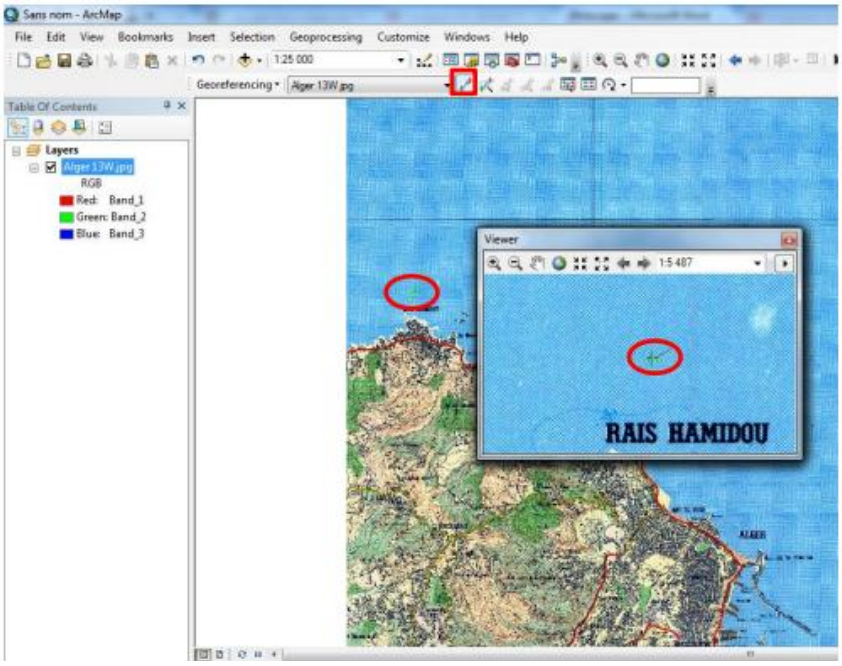


Fig. 61 Selecting the map to georeference in the Georeferencing toolbar.

Important: Before starting to add control points, it is crucial to disable the Auto Adjust function to avoid possible distortions of the map. You can disable Auto Adjust from the Georeferencing menu in the Georeferencing toolbar or from the Link Table.

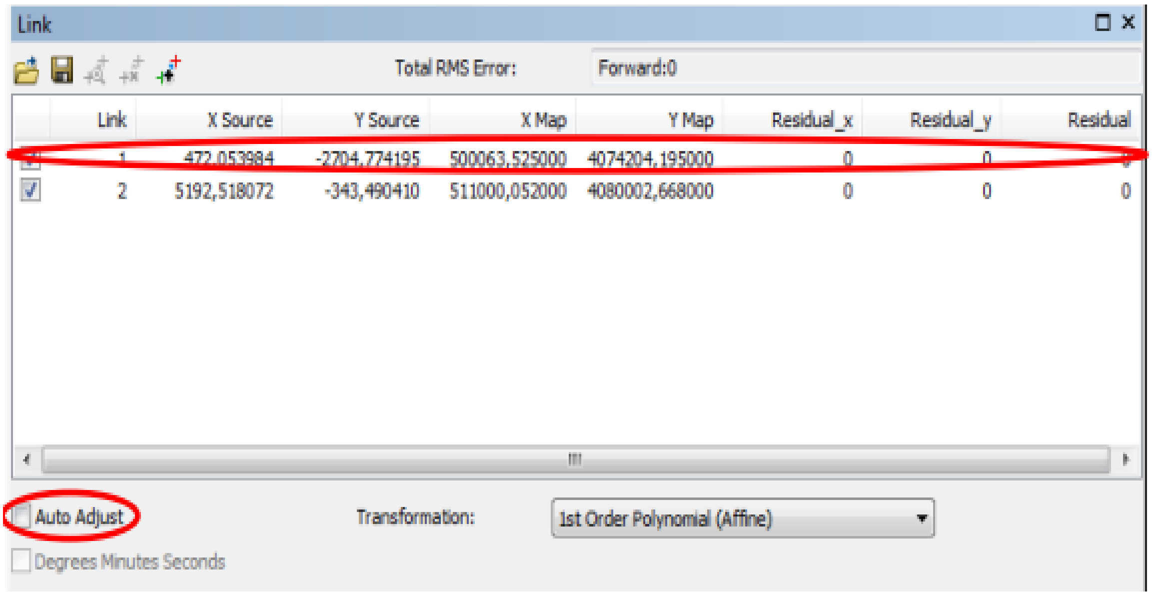
Activate the Add Control Points function / click on the location (or point) where you want to input the coordinates, so a cross appears / right-click on the same location / Input X and Y. Similarly, add all your control points.

To accurately locate the control points, it is important to zoom in sufficiently; to facilitate this task, it is recommended to use the magnifier (View/Magnifier).



Checkpoint number 5 (See Fig. 57)

Each point introduced will automatically create a line in the links table.

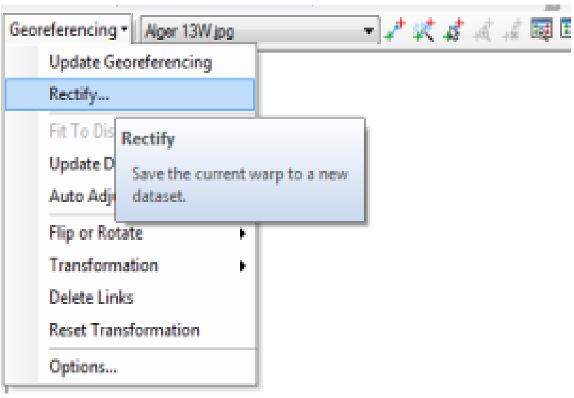


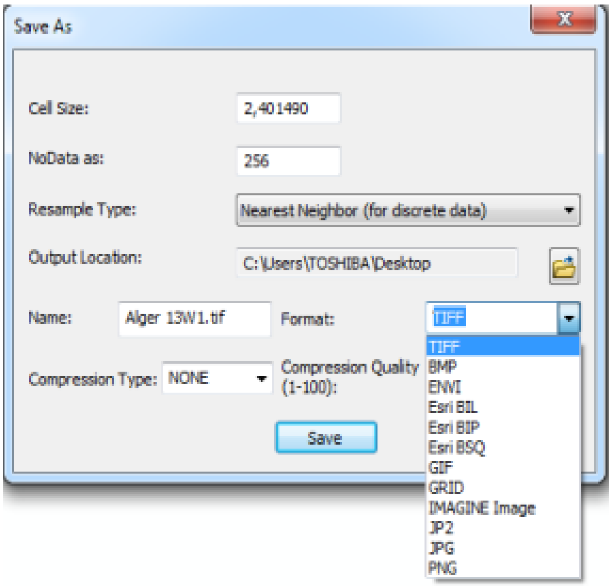
The recorded residuals should be relatively small (no more than 20; if the residual doesn't display, click on Georeferencing/Refresh Image). If not, the point should be deleted and/or replaced. It's recommended to save the links table to retain the control points, allowing you to resume the georeferencing of this layer later.

A.2.3. Creation of the New Georeferenced Map

Click on Georeferencing/Rectify: ArcGIS will create a new georeferenced image that will take the name of the original map and add the number 1. However, the name, location, and format can be defined by the user. It is always recommended to save the work in Tiff format, as it is an image file that can incorporate spatial information, unlike jpg, bmp, etc.

B. Georeferencing from a Raster (or Vector) File

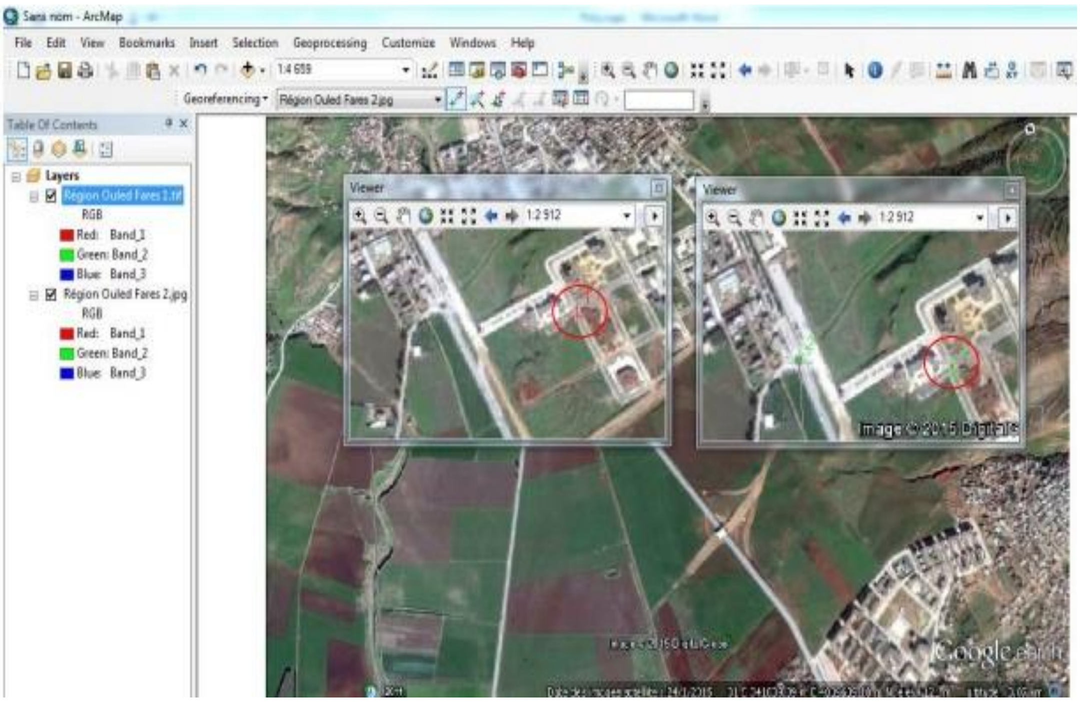




This involves georeferencing a raster map using another raster map covering a common area.

B.1. Adding the Two Maps:

It is sometimes possible to display both maps side by side, which makes it easier to select the control points. However, often the maps are very far apart in space, making it impossible to display them side by side, so you need to switch between the two maps (right-click on the layer in the Table of Contents/Zoom to Layer). In this case, it is also recommended to use the Magnifier to zoom in on both maps. By opening two magnifiers and adjusting their scales, these zoomed-in views can be displayed side by side.



B.2. Activate the Georeferencing Tool: Always ensure you are working on the correct layer, and disable Auto Adjust. Enable the Add Control Points function and start creating links between the two layers by first clicking on the layer you want to georeference. After adding a sufficient number of points, open the links table, check the residuals, and delete (or replace) the points with high residuals.

B.3. Finally, Rectify the Map: Use Georeferencing/Rectify, where ArcGIS will create a new georeferenced image, which should be saved in Tiff format (see above).

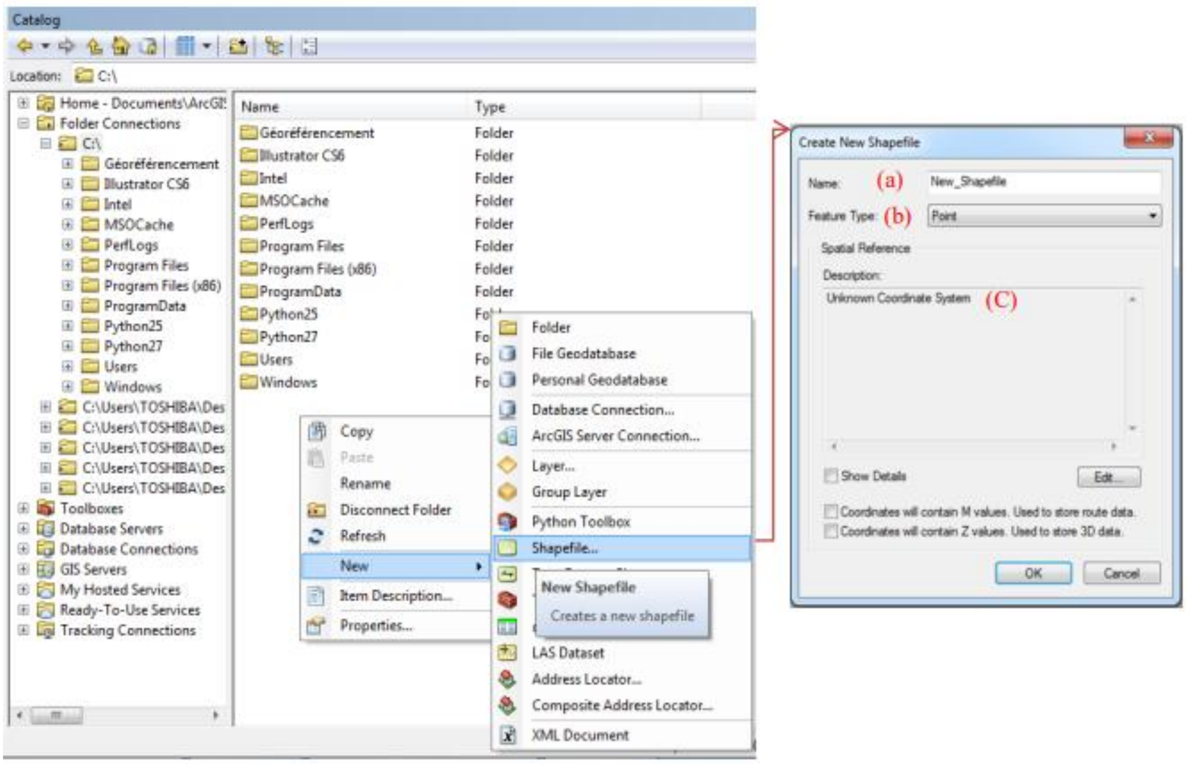
IV.4. Creation of a Shapefile Layer (Vector Mode)

As discussed in Chapter I, the vector mode represents real-world elements through points, lines (arcs), and polygons.

IV.4.1. Steps for Creating a Shapefile Layer with ArcGIS

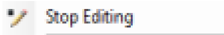
IV.4.1.1. Creating a New Shapefile Layer

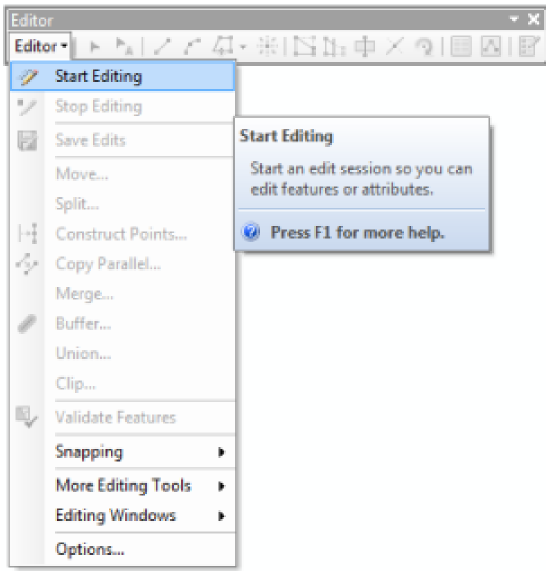
ArcCatalog / Choose the location for your layer (in our case, we'll create it in C) /Right-click and select New Shapefile… / In the Create New Shapefile window, enter the following information: a. Name of the layer (e.g., Cours digitalisation), b. Type of the layer (three types are possible: Point, Line, Polygon. In our case, it will be a Polygon), c. Coordinate System in which the layer will be defined. / Click OK to create the shapefile.

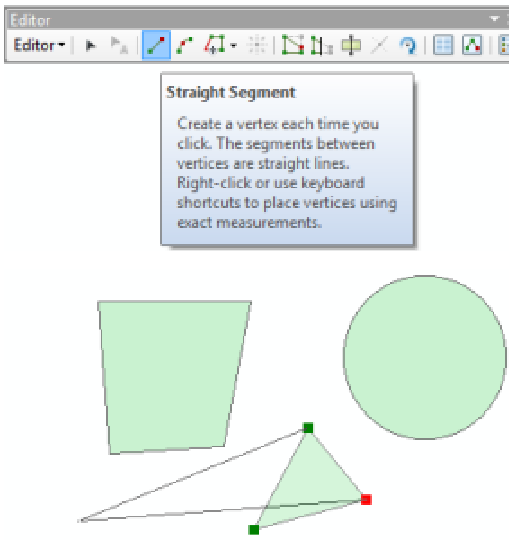


IV.4.1.2. Drawing or Digitizing

Open ArcMap / add the Digitalisation Cours layer / activate the Editor tool (Editor)

 / Editor/ Start Editing / Draw using the functions  / Editor  /] Save Edits  / Stop Editing  .

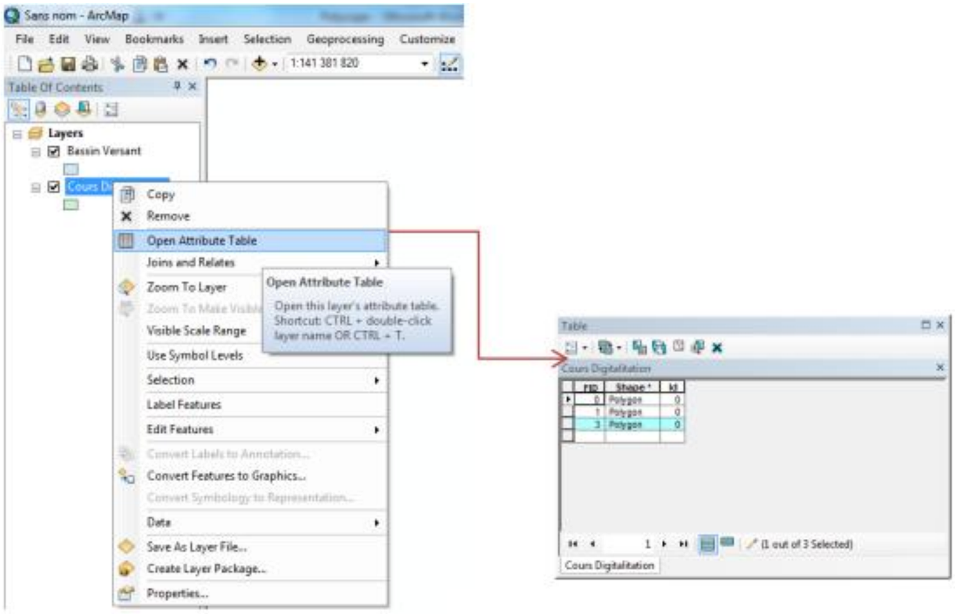




Before starting, always check if you are working on the correct layer; otherwise, you risk modifying or losing information. Generally, during digitizing, it is better to close everything and leave only the layer you are working on.

IV.4.1.3. Fill in the attribute table

To open the attribute table: right-click on the layer in the Table of Contents / Open Attribute Table.

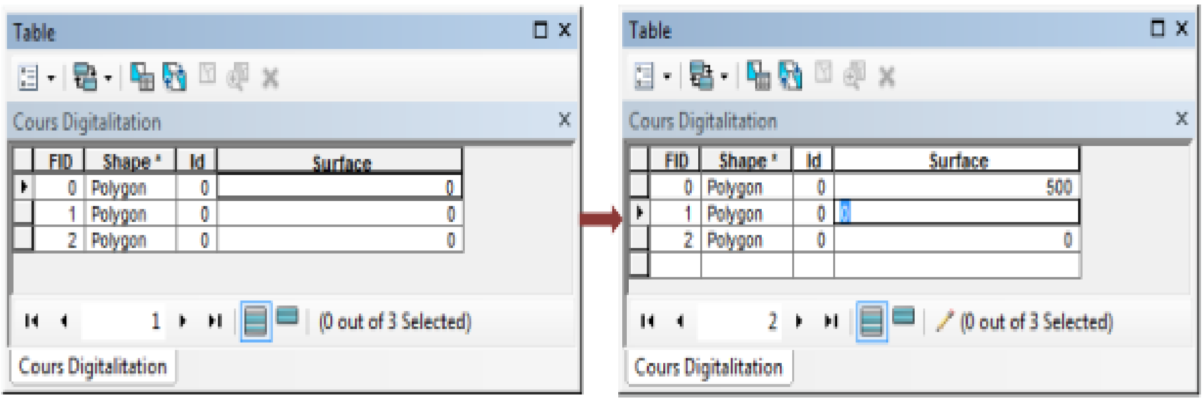


A. *Add a column to the attribute table*: Editor / Save Edits / Stop Editing. Then open the attribute

B. table / Options / Add Field: specify the Name and Type of the information you want to enter (text, numbers, dates, etc.) / OK

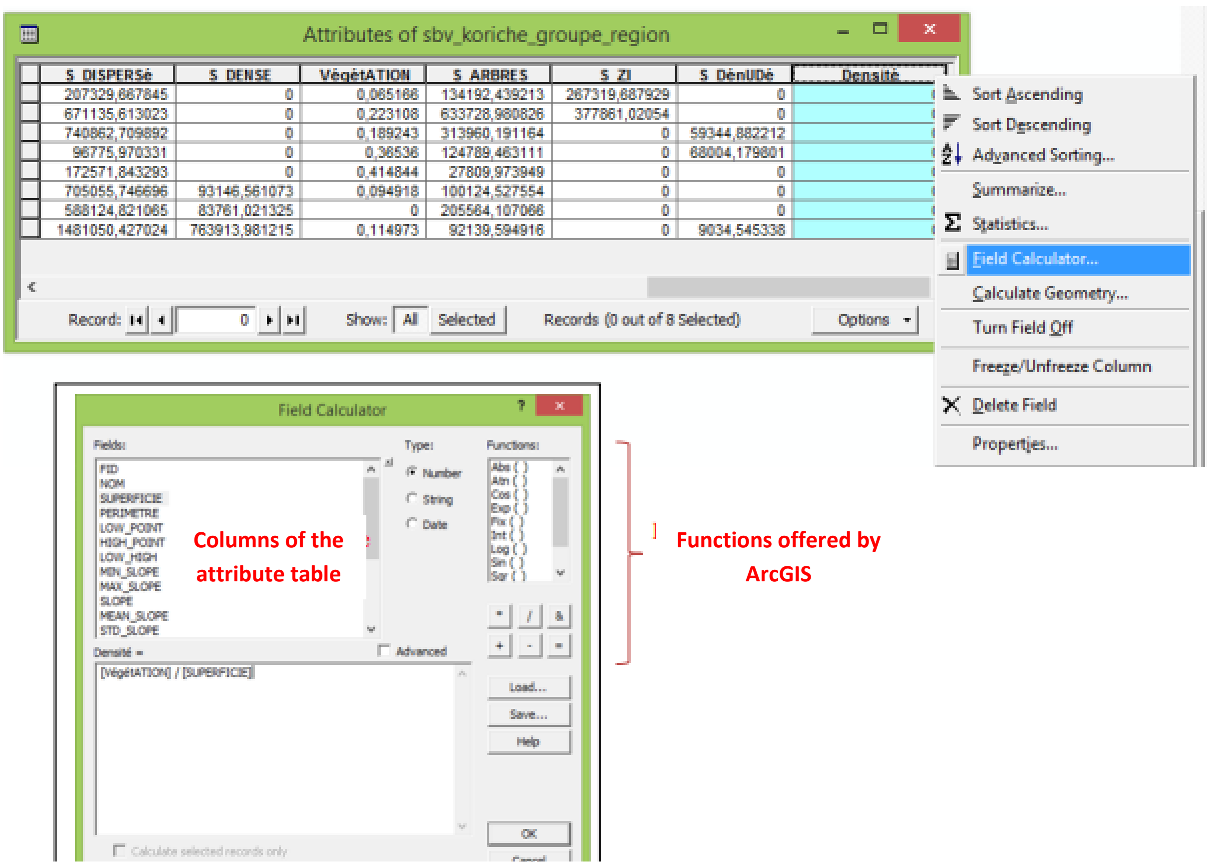
B. *Fill in the columns of the table*: *Restart Editing: Editor / Start Editing, which will enable you to write in the attribute table.*

Finally, open the attribute table and fill in the fields. The table can be filled in in two ways:
B.1. Manually



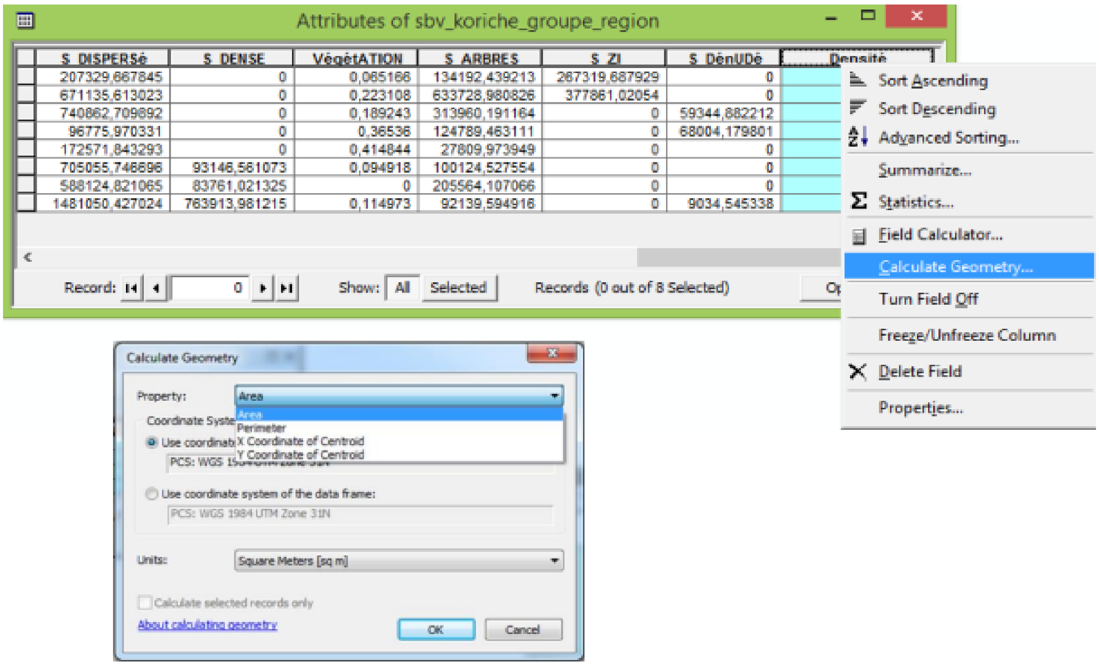
B.2. By performing calculations: several calculations are possible:

- Simple calculations such as ratios, additions, subtractions, multiplications, etc., can be performed in the attribute table. After creating a field in the attribute table to store the results / right-click on the layer name (Density) / Calculate Values (Field Calculator …) / choose the fields and the function (to calculate vegetation density, divide the Vegetation field by the Area field)

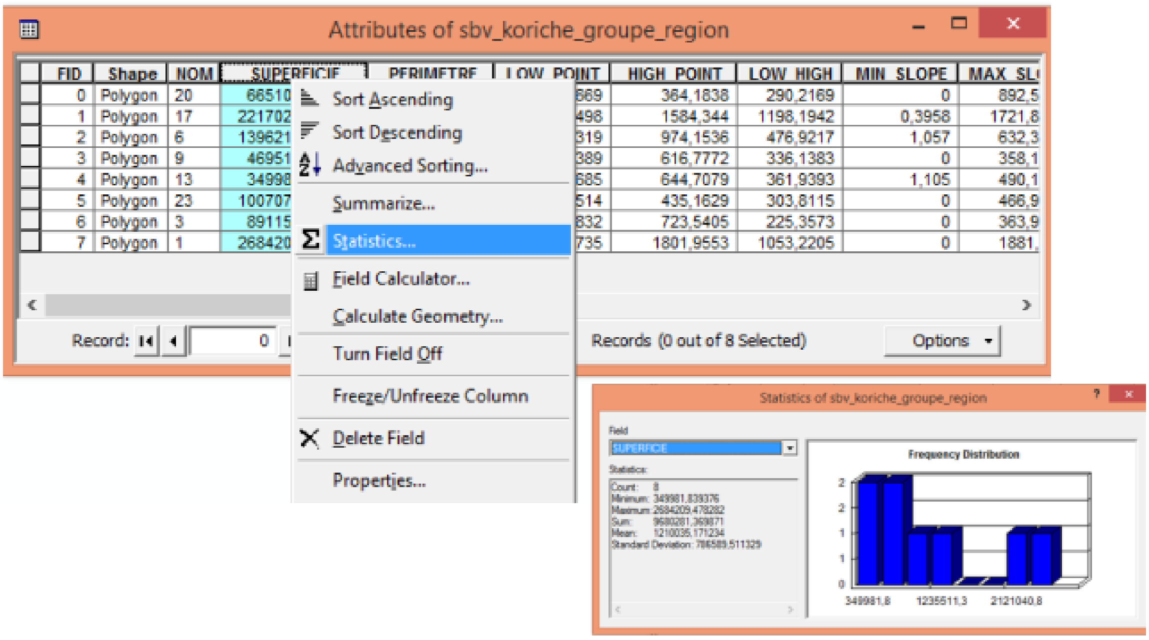


- *Calculations of areas, perimeters, lengths*

Right-click on the layer name (Density) / Calculate Geometry (Calculate Geometry …).



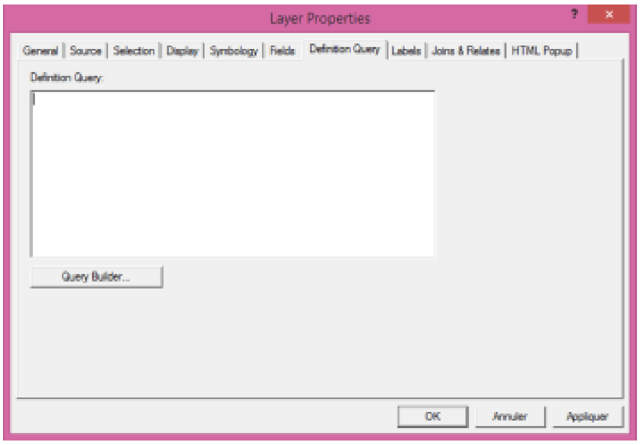
- *Other calculations:* averages, sums, standard deviation, ….

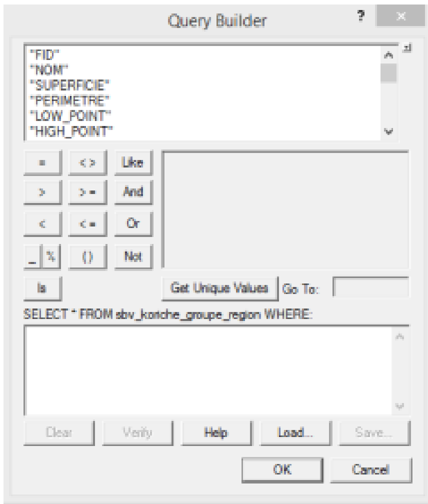


- *Making a Query:*

ArcMap provides the ability to perform search/selection queries for entities based on spatial and attribute data using an SQL-type query.

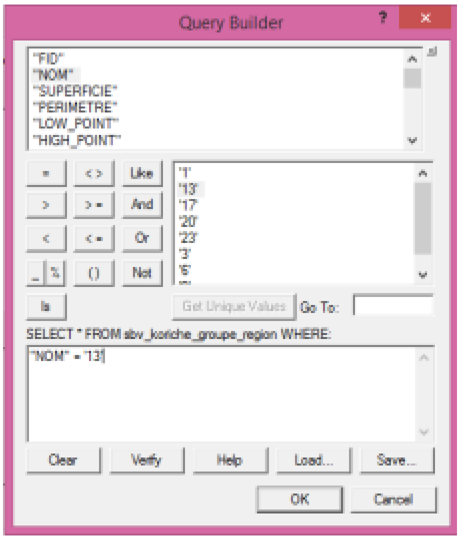
Right-click on the relevant layer / Properties / Definition Query / Query Builder.

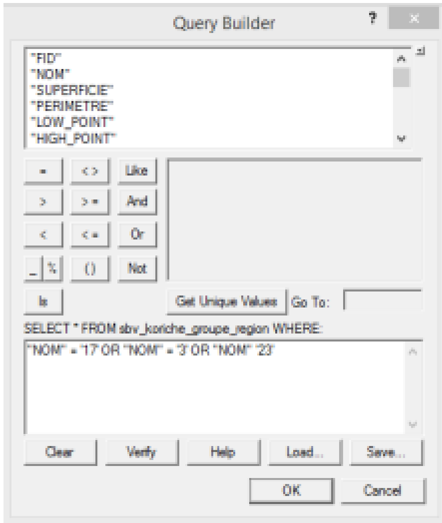




Select a Single Feature

Select Multiple Features





IV.4.2. Import/Export Data

To better understand this element and make the most of it, it is recommended to follow these links according to the specifics of each topic :

- *ArcGIS : Export and Import Data in Shapefile Format.*

https://www.youtube.com/watch?v=d-quULus7OQ

- *How to Export an Excel File to ArcGIS Using Add XY Data?*
https://www.youtube.com/watch?v=kd8MNZ5zfoI

- *How to Import an Excel File into ArcMap ?*

https://www.youtube.com/watch?v=zOYAKB7_0OI

- *How to Import Geographic Coordinates from Google Earth to Excel?*

https://www.youtube.com/watch?v=RNDzbux-FHY

- *Google Earth] Tutorial 84 : Importing KML Data*

https://www.youtube.com/watch?v=5KRBJOF6T18

IV.5.Thematic Mapping with ArcGIS

ArcGIS provides the ability to produce finished maps intended for printing.

IV.5.1. Some Concepts

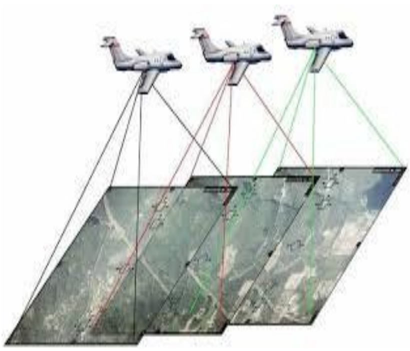
IV.5.1.1. What is Cartography?

It is the set of scientific, artistic, and technical studies and operations that involve using direct observations or documentation to create and produce maps, plans, and other forms of representation, as well as in their use: "definition adopted by the French Cartographic Committee, 1967. It is both:

- *A Science*: Because its foundations are mathematical (determination of shape and dimensions, projection systems, etc.);
- *An Art*: Because it must present aesthetic and educational qualities, be expressive and readable. This requires the designer to make choices in representation.

Venice, Italy
Urban Cartography: A Standalone Art!
Planos
Urbanos
The Editorial Staff, July 7, 2020

- *A Technique*: Uses tools (orthophotos, satellites, computers, printing, etc.)



Aerial Photography Photogrammetry Technique

IV.5.1.2. What is a Map?

According to Joly F (1977), A map is a geometric, planar, simplified, and conventional representation of all or part of the Earth's surface, with a suitable scale called 'scale.

A map is a representation, on a horizontal plane and at a reduced scale, of a given area (e.g., relief, vegetation, human activities).

According to the cartography manual, five main principles should guide a cartographer's work:

- The map is a visual representation ;
- The map is a planar representation: it is the transition from the Earth's sphere to a plane via projection ;
- The map is a reduced representation: the terrain is depicted according to a reduction ratio called scale ;
- The map is a simplified representation: choosing which objects to depict and replacing them with conventional symbols ;
- The map is a conventional representation: using cartographic language.

IV.5.1.3. Classification of Maps

The field of cartography is very broad, with an infinite number of possible themes. To study the phenomena that can be mapped, a classification of maps is necessary.

IV.5.1.3.1.Classification by Content, There are two main classes:

- ***Topographic Maps:***

These are military maps that primarily display the results of direct observations concerning planimetric (x, y) and altimetric (z) positions, the shape, dimension, and identification of concrete, fixed, and durable phenomena on the Earth's surface (descriptive aspect of the terrain's physiognomy). The scale varies from 1:5,000 to 1:100,000 depending on the country's development.

- ***Thematic Maps:***

These maps represent specific qualitative or quantitative phenomena, either concrete or abstract, on a topographic background, constrained by the choice of one or more particular themes. Among thematic maps, classifications can be made by theme, for example:

- Geological Map:Exposed rocks
- Meteorological Map: Weather phenomena
- Climatological Map: Temperature and precipitation
- Pedological Map: Soil type and nature
- Orohydrographic Map: Rivers and terrain elevation
- Marine and Bathymetric Map: Understanding the seabed
- ... etc.

IV.5.1.3.2. Classification by Medium (Mode of Expression)

Three types of maps can be defined based on the level of reading chosen to convey geographic information, corresponding to three modes of reading:

- Basic Reading: Inventory or descriptive map, allows for the extraction of information ;
- Intermediate Reading: Analytical or processing map, enables the user to analyze and process the information ;
- Advanced Reading: Synthesis or decision-making map, provides essential information for making decisions.

IV.5.1.4. Thematic Mapping

Thematic mapping is a tool for analysis, representation, decision-making, and communication used to depict variables. It enables the creation of specific graphic images that illustrate the spatial relationships of one or more phenomena or themes. Whether defined as inventory maps, analysis maps, static maps, or dynamic maps, thematic maps share common features.

A ***thematic map*** illustrates the spatial distribution of data related to one or more themes for standardized geographical regions. The map can be qualitative (e.g., main types of farms) or quantitative (e.g., percentage change in population). (*Censuses of Canada 2006 and 2011. Geography Division, Statistics 2012*).

IV.5.1.5. Elements of Thematic Map Composition

We distinguish between external and internal elements.

- External elements are related to thematic information and are linked to the characteristics of the geographic database ;
- Internal elements are connected to the features of the geographic information being represented.

IV.5.1.6. Cartographic approach

Every cartographic approach is a simplification of the real world. It serves as a tool to help solve or illustrate a problem. Before beginning the cartographic process and to optimize it, three questions should be asked:

- Why?
- What do I want to show?
- For whom?

All cartography actually follows a few very simple basic principles, rooted in common sense:

- An object (phenomenon) is represented by a single symbol;

- Variations in quantity are represented by changes in the size of the symbol.

- Variations in relative or calculated values (quantities relative to an area or unit: density, rate, GDP per capita, etc.) are represented by variations in colors or patterns, as the value is consistent across the entire surface of the geographic object.

- The stronger the value, the stronger the corresponding symbol, and vice versa.

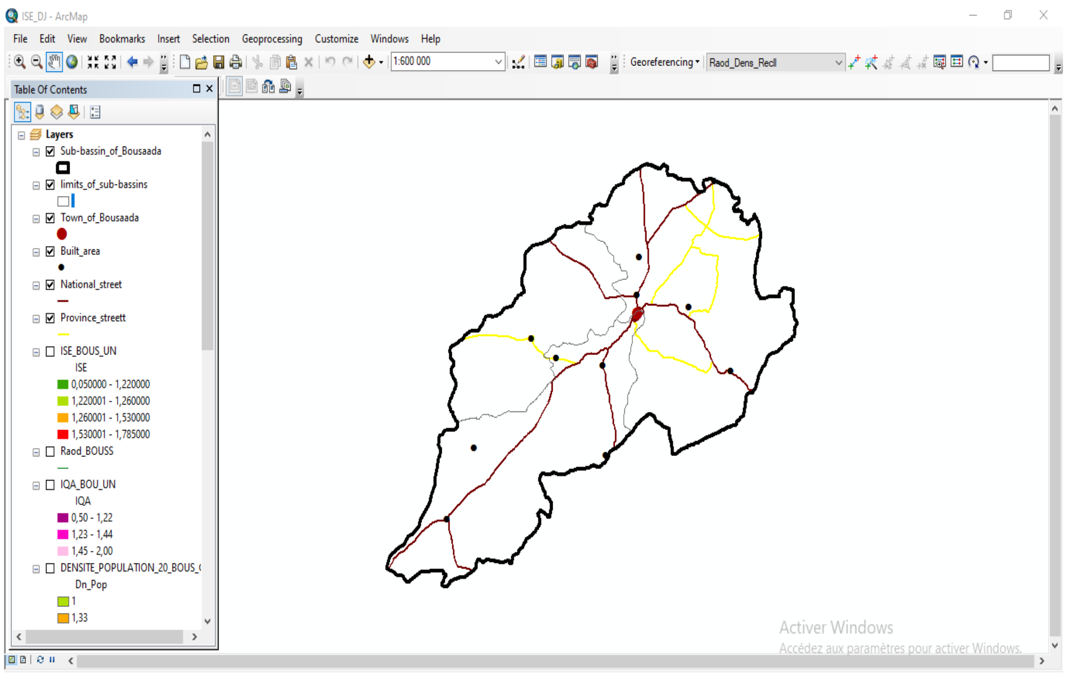
- Warmer colors are used for "positive" phenomena, while cooler colors are used for "negative" phenomena.

IV.5.2. Layout of a Map in ArcMap

In the following section, we will explore the different steps that allow us to go from a shapefile to a map ready for editing.

IV.5.2.1. Editing Classe

A shapefile (.shp) is added, composed exclusively of polygon object layers (for example, the outline of a watershed and its anthropogenic quality index, which is a combination of two factors: population density [Dp) and road density (Dr)].

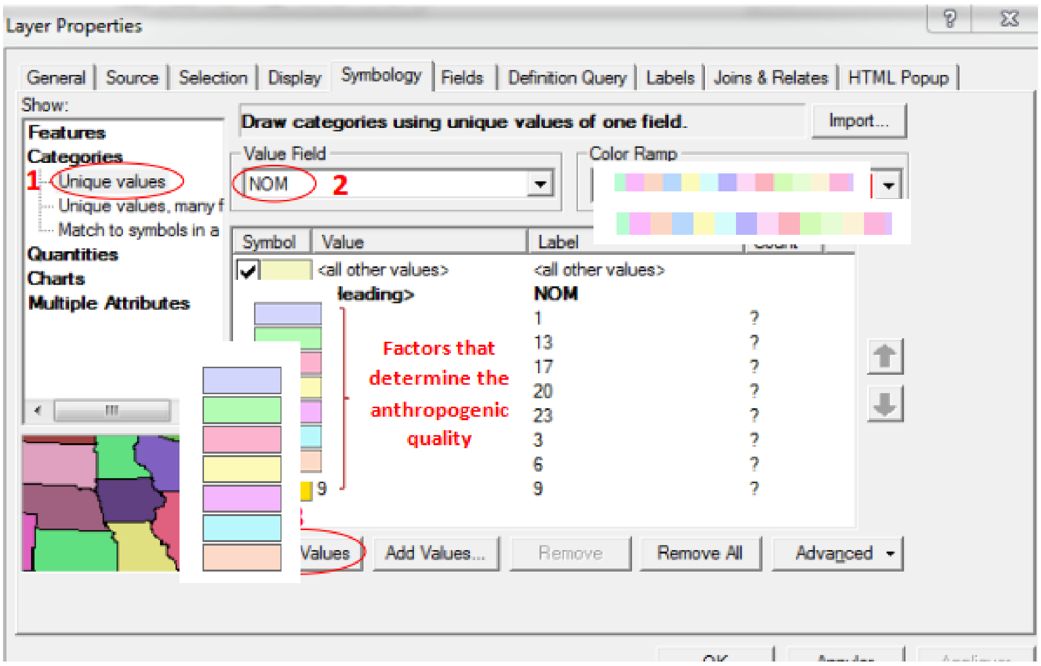


1. Right-click on the layer in the Table of Contents / Properties / Symbology tab. On the left side under the Show section, click on Categories / Unique Values.

2. In the middle section, go to Value Field and select the criterion based on which the classification will be performed.

3. At the bottom, click on Add All Values.

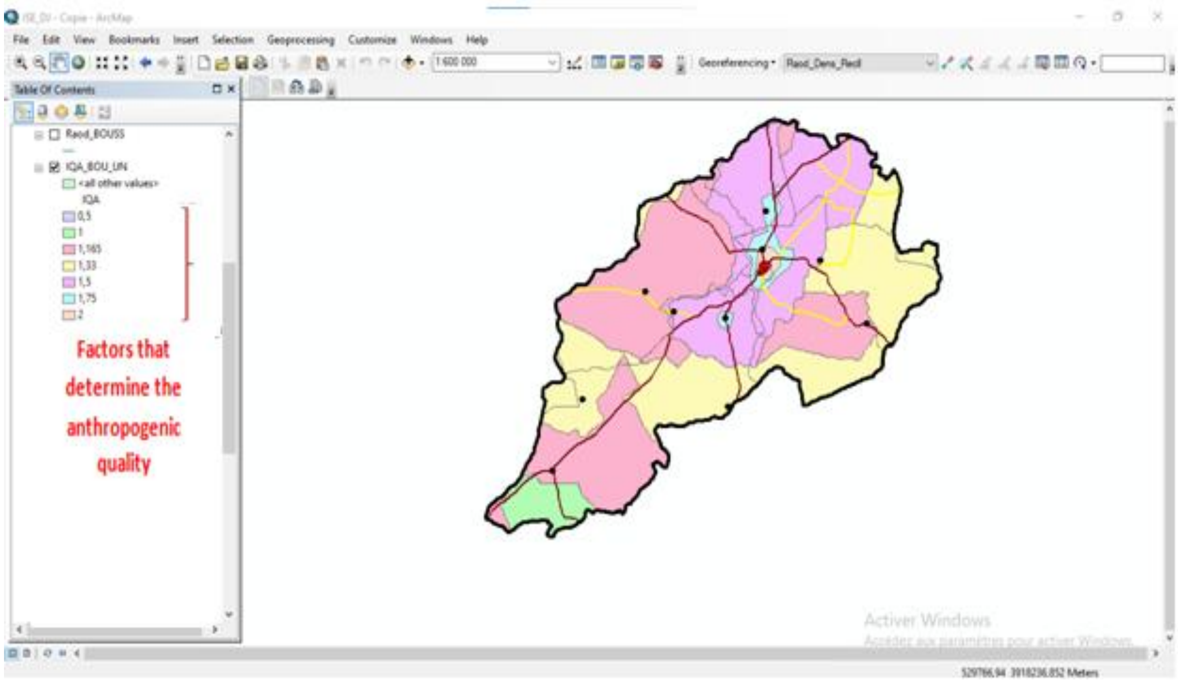
4. Click OK.



IV.5.2.2. Changing the Names of Different Defined Classes (If Needed)

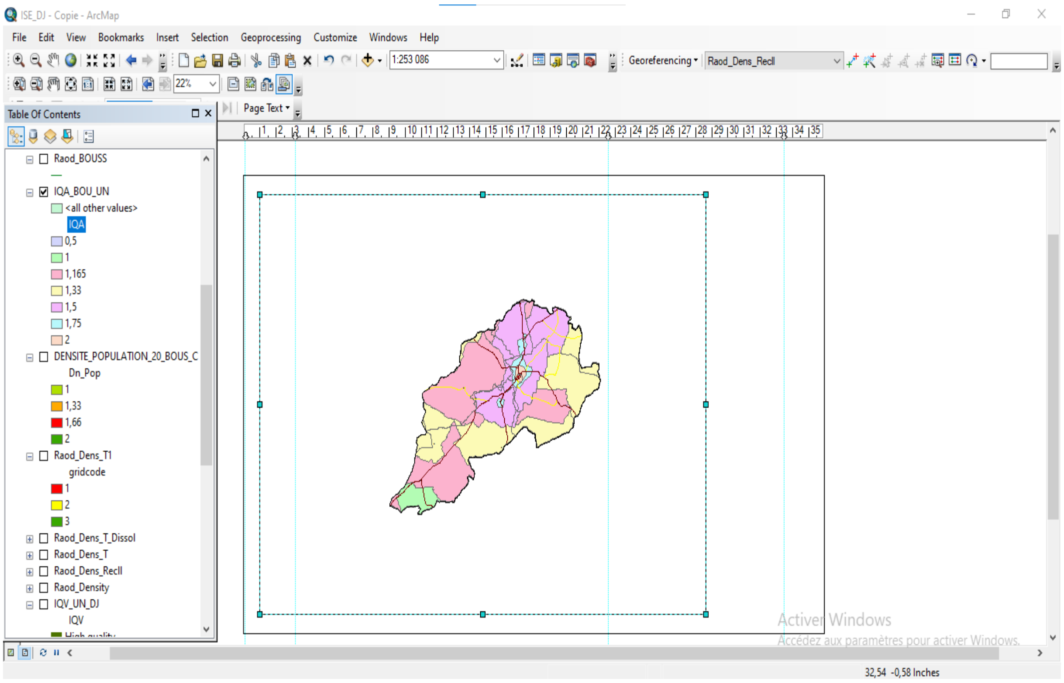
Two methods are available for changing the names of classes:

1. Change the names directly in the Table of Contents ;
2. Change the names via the Attribute Table:
    - Open the Editor toolbar / Editor / Start Editing ;
    - Open the Attribute Table, navigate to the column you want to modify, and enter the changes (for example, modify the names of sub-watersheds).



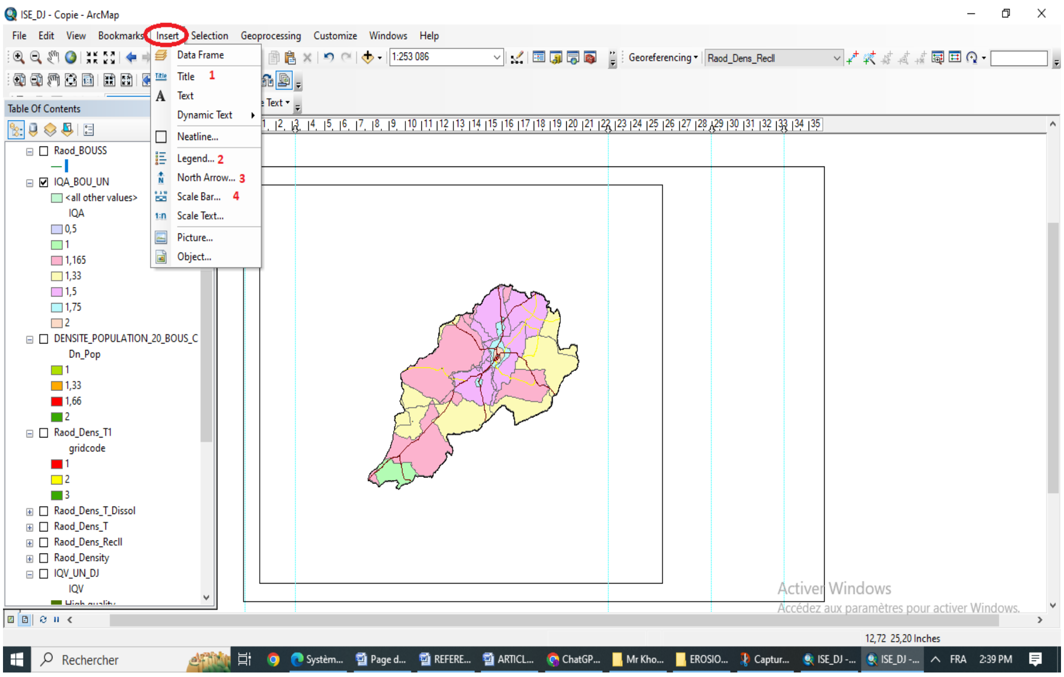
IV.5.2.3. Map Layout

1. In the menu bar, click on *View* and then select *Layout View*.

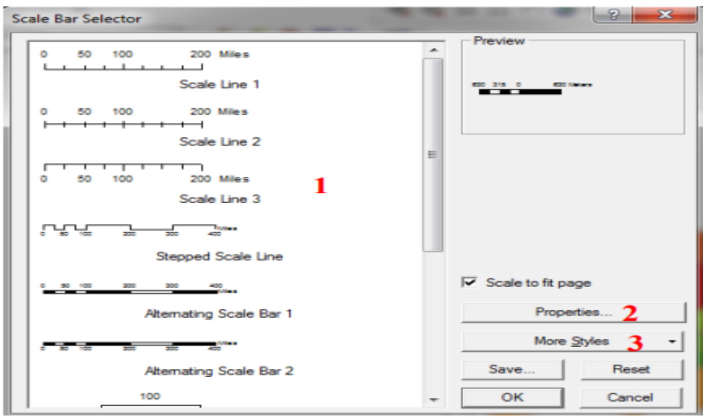


2. In the menu bar, click on *Insert* and add the following elements:

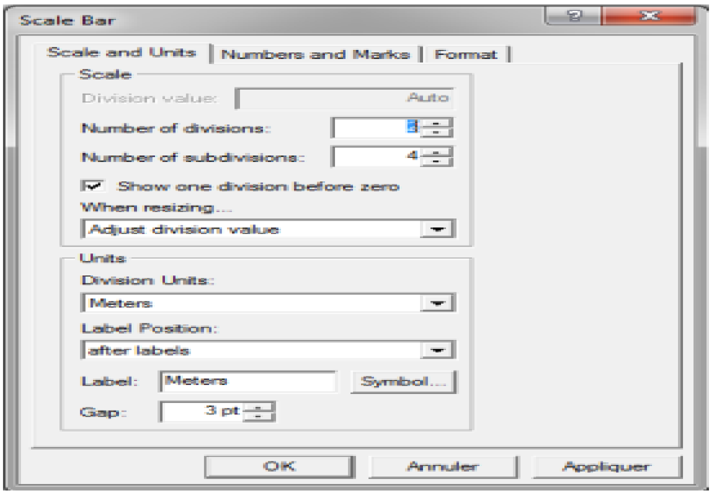
1. Title 2. Legend 3. North Arrow 4. Scale Bar



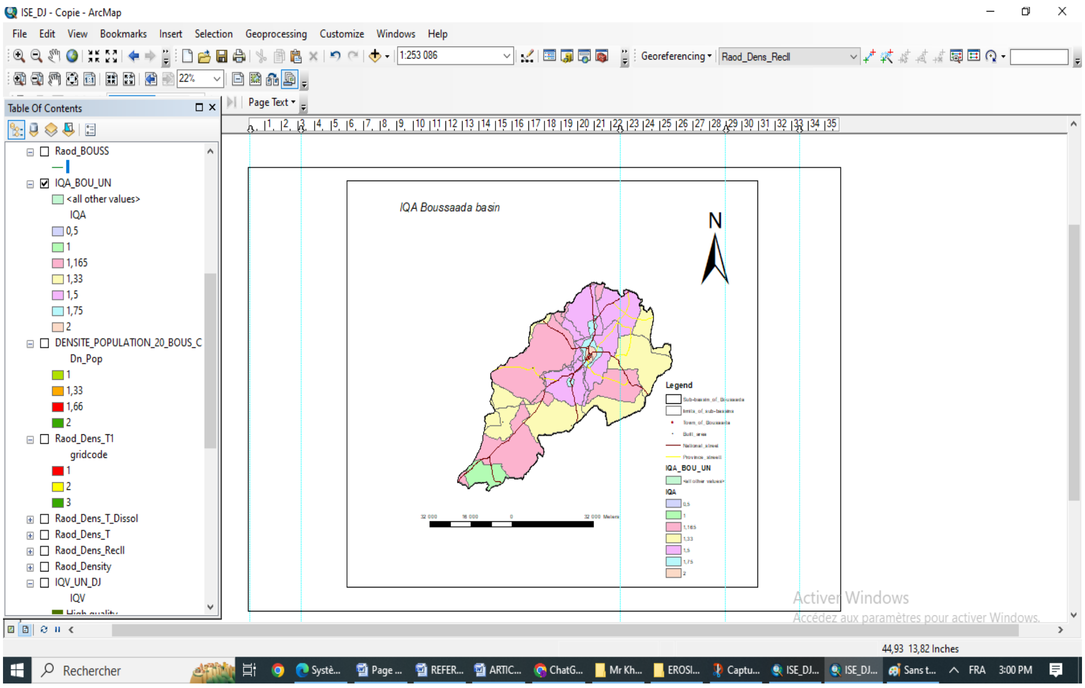
Scale



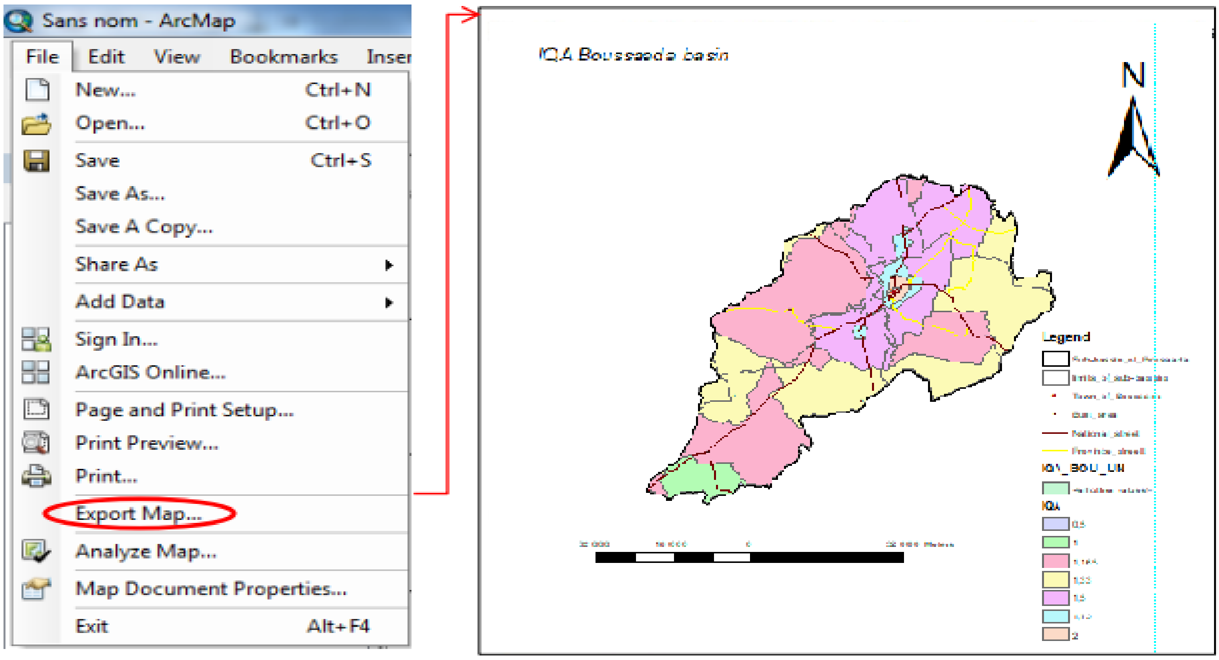
1. Choose a scale bar model from the list. For more models or to download a custom model, click on More Styles.



2. To set up the scale bar, the "Scal Bar" function offers several options: changing the number of divisions or subdivisions, selecting the unit of measurement, and adjusting the position and size of the text, etc.



3. *Editing the map*: To edit the map as an image, go to File / Export Map, then choose a location and output format for the map / Save.



Part Two: Practical work

The main objective of the practical sessions in the GIS course is to master computer-assisted cartography methods, applied to an environmental issue.

This main objective leads to three sub-goals:

- ✓ *Create thematic maps with a scientific approach* : Cartography is a scientific discipline with specific rules to follow. Students should be able to:
  - o Propose and evaluate different map alternatives;
  - o Justify map choices in relation to cartographic rules based on the intended purpose.
- ✓ *Discover the advantages and disadvantages of using computers for cartography* : The quality of maps produced has not been fundamentally improved by using computers! In fact, computers have not changed the shape of the maps. The main advantages of computers lie in the precision of contours and the speed with which a map can be created. However, the entire design process (chosen variables, calculated indices, performed classification, choice of patterns, legend) ultimately depends on the cartographer. The computer is thus a tool, albeit useful, but limited.
- ✓ *Become familiar with using ArcGIS* : This software will be used in practical sessions. It enables the development of a Geographic Information System. In terms of spatial analysis, it is more powerful than "simple" cartography software. For these practical sessions, we will primarily use this software for its "cartography" aspect (rather than its "GIS" aspect).

The digital files used in the practical exercises are presented to the students before starting, based on the requirements of the project to be completed. For example, for this assignment, we have digital files for the Boussaada Wadi Sub-watershed.

P W No. 1: Getting Started and Familiarization with ArcGIS Software

The objective of this practical session is to show students how to install the ArcGIS 10.8 software, introduce them to the software interface (ArcGIS 10.8), and teach them the main basic functions. We will also provide an overview of the software's menus and commands.%

- ***Exercise 1*: *Learning to Handle Data in ArcMap***

Add the data saved in the file: Boussaada Wadi Sub-watershed and the map of the Hydro-climatological network and water quality monitoring in NORTHERN ALGERIA.

PW. 1 / Boussaada Wadi Sub-watershed

PW.1 /Map of the Hydro-climatological network and water quality monitoring in NORTHERN ALGERIA.

1.1. Explore the various buttons in the Tools toolbar.

1.2. Change the display order by showing the map of the hydro-climatological network and water quality monitoring before the Boussaada_Wadi layer.

1.3. Rename the files: Boussaada_Wadi to Sub-watershed _OK and NORTHERN ALGERIA to Topo_Northern Algeria.

1.4. Modify the appearance (color and boundary thickness) of the Sub-watershed _OK layer.

1.5. Display the attribute tables of both layers. Select a row in the attribute table of the Sub-watershed _OK layer. Repeat the same operation with the Topo_Northern Algeria layer. What do you notice?

- ***Exercise 2: Learning to Handle Data in ArcCatalog***

Add the layers: Boussaada Wadi and NORTHERN ALGERIA

2.1. Identify the file extensions of the Boussaada_Wadi and NORTHERN ALGERIA layers.

2.2. Explore the 3 tabs in the preview window. What do you notice (types of data displayed in each tab)?

2.3. Switch the preview mode from geographic to tabular. What changes do you observe?

- ***Exercise 3: Learning to Organize a Database into Multiple Thematic Files***

Add the following layers: Boussaada Wadi , NORTHERN ALGERIA

3.1. Create two new data frames or data blocks: name the first one "Hydrology" and the second one "Topographic Map." Place the Oued Koriche layer in the "Hydrology" block and the

NORTHERN ALGERIA layer in the "Topographic Map" block.

3.2. Combine the two data blocks into a single data block called "Project."

3.3. Save the project as an ArcMap document.

P W No. 2: Georeferencing and displaying a map (Raster Image)

Georeferencing is a necessary step before any work in a GIS; it serves to establish a relationship between the entities displayed in the geographic information system and their position in the real world.

The objective of this practical session is to show students how to open and georeference an image in ArcGIS while adhering to the projection system in which it was created.

❖ The Commands Required for Georeferencing Maps

To georeference a map, follow these steps:

a. Open a Raster image in ArcGIS:

To open a Raster image file in ArcGIS, execute the following commands: ArcMap > Add Data > File > A dialog box will appear on the screen (Fig.49), Add > Ok, and the map will be displayed.

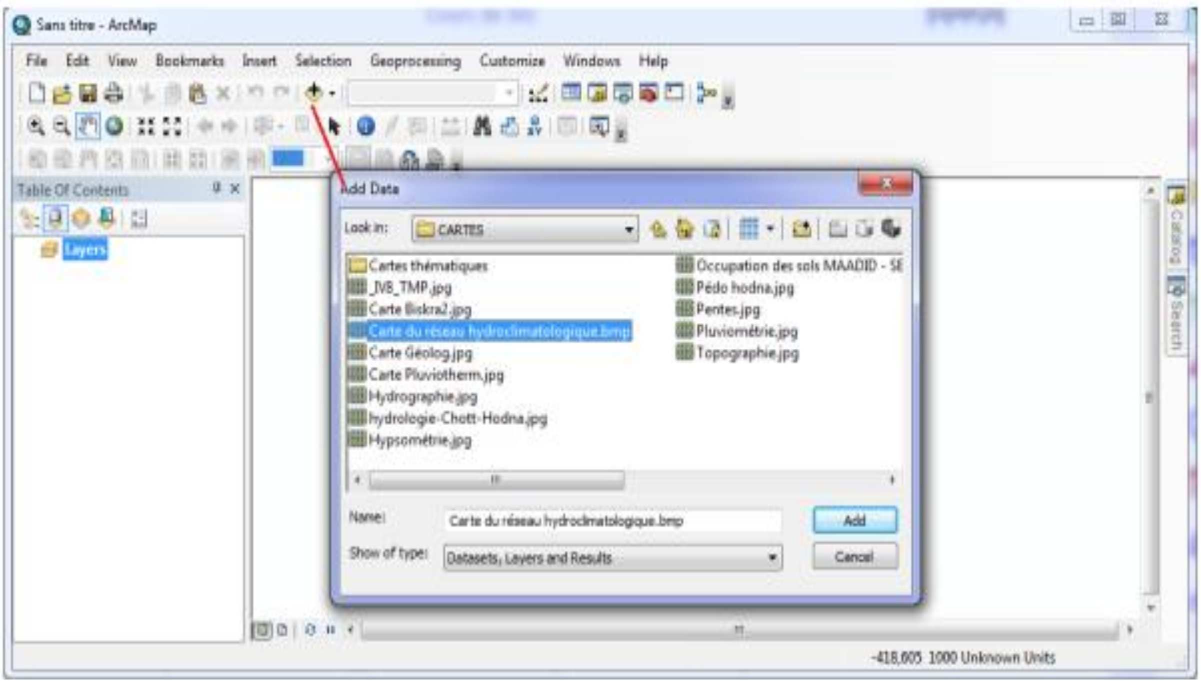
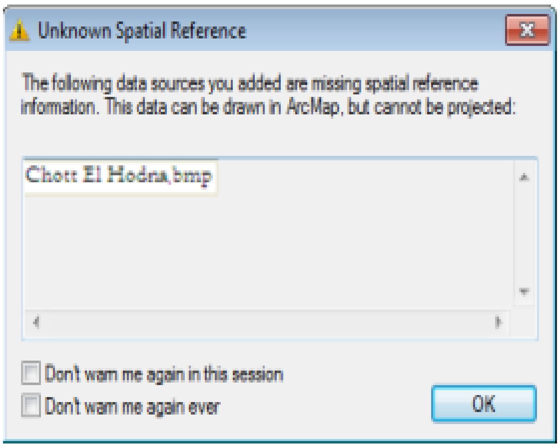


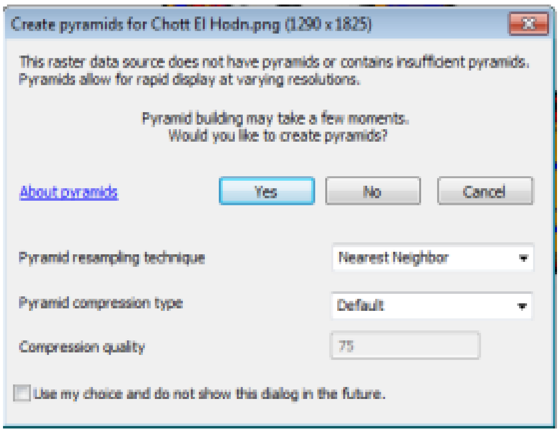
Fig.61 Selecting the file type and opening an image (map) as a Raster Image in ArcGIS

After this operation, there are two possibilities:

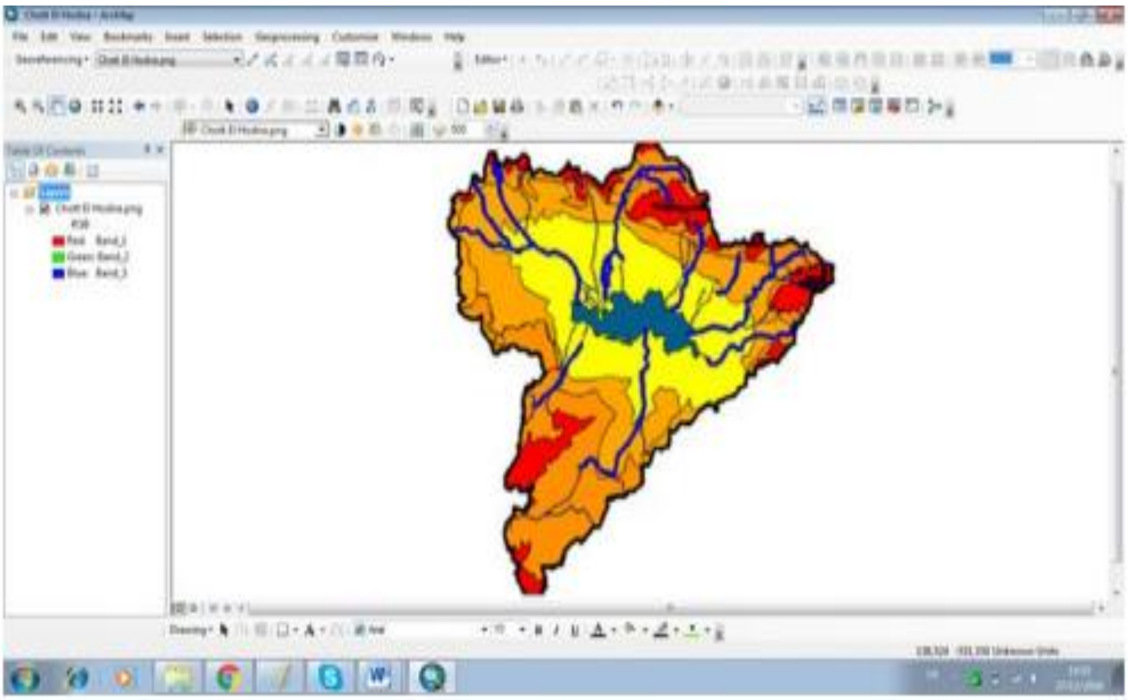
➢ A warning message (not an error) may appear indicating that one or more layers do not have a projection system. Confirm by pressing OK.



➢ Click on the Yes option to create a reduced-size file that facilitates image display.

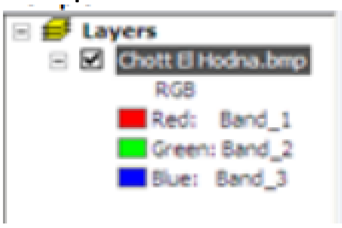


➢ After confirming the pyramid structure option (Yes), the following window will appear



➢ A first data frame is therefore created by default in each document. Each data frame in the document represents a map.

Example



In the window, the image is contained within a frame of layers:

- The image Chott El Hodna.bmp is an RGB color image.
- The three layers Red, Green, and Blue are displayed.

In the Georeferencing menu, select the image Chott El Hodna.bmp (Image to georeference).

This is also referred to as alignment or calibration.The number of points used in the alignment is 4. These points were chosen because they correspond to specific locations that are easily identifiable both in the field and on the map.

Right-click and select the option *Properties*; you will see a dialog box. Select the option: *Coordinate System*. Next:

➢ If the geographic coordinates are in *degrees /grades*, use the file :

; look for *Word* → *WGS* → *WGS 1984*.

➢ If the geographic coordinates in *meters* / *kilometers*, we use the file, use the file :

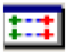
OK.

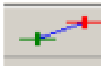
❖ **Georeferencing from known coordinates:**

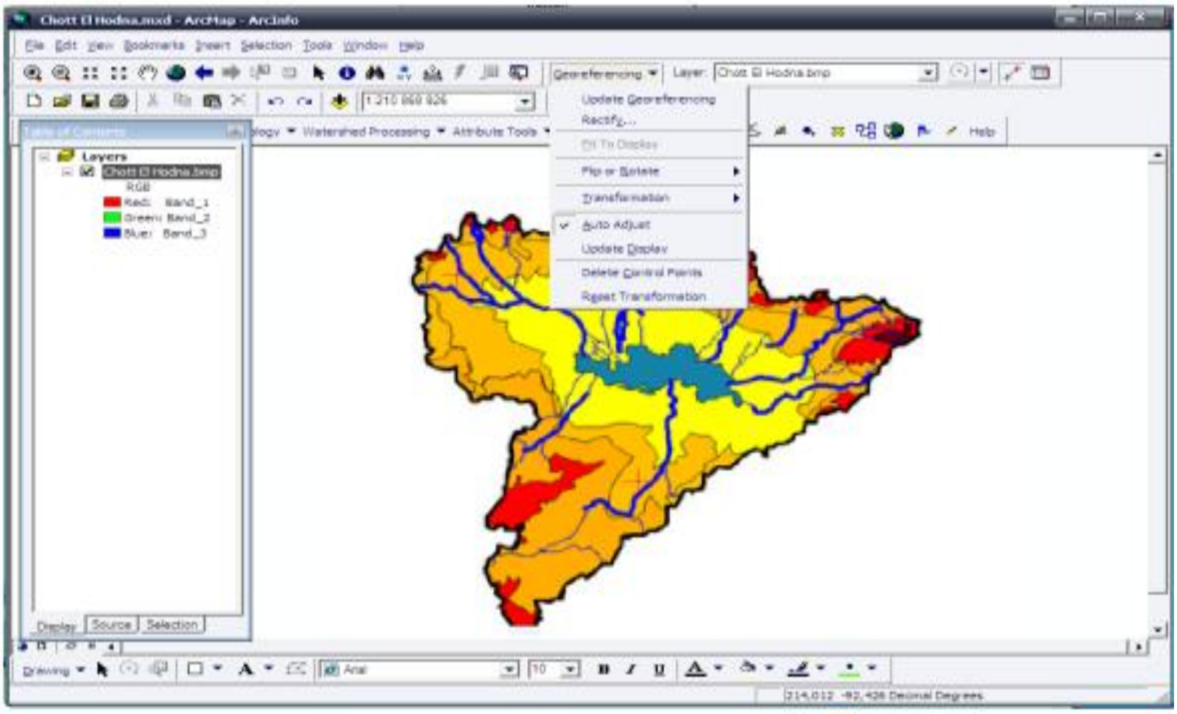
- **Input of control points**:

- Generally, this involves finding relationships between characteristic points present in the image and their actual position on the Earth's surface. These are reference points (also called "control points" or "tie points") ;
- The quality of the georeferencing will depend on the accuracy of the tie points' locations, their number, and their distribution ;
- You need to locate "remarkable" or characteristic points on the document to be georeferenced ;
- Then, you must find their location on an already georeferenced layer (raster or vector, it doesn't matter), on a paper map with coordinates, or match them with a GPS survey. You need at least four points ;
- The more points you have, the more accurate the georeferencing, but be careful: don't sacrifices the quality and confidence in the points for quantity. The farther apart these points are

and the more they cover a significant area (points close to alignment result in poor georeferencing), the closer the final image will be to the actual terrain. Input of control points is done by first clicking the point on the image to be georeferenced.

View Link Table, click this button 

*Add control points***,** then click on this button 



" Update Georeferencing " corresponds to a faster process but does not create a new image. ArcMap will use the source image and distort it in real-time (remembering the grid of points), which will require a lot of time for each map refresh.

- **To remove a control point**

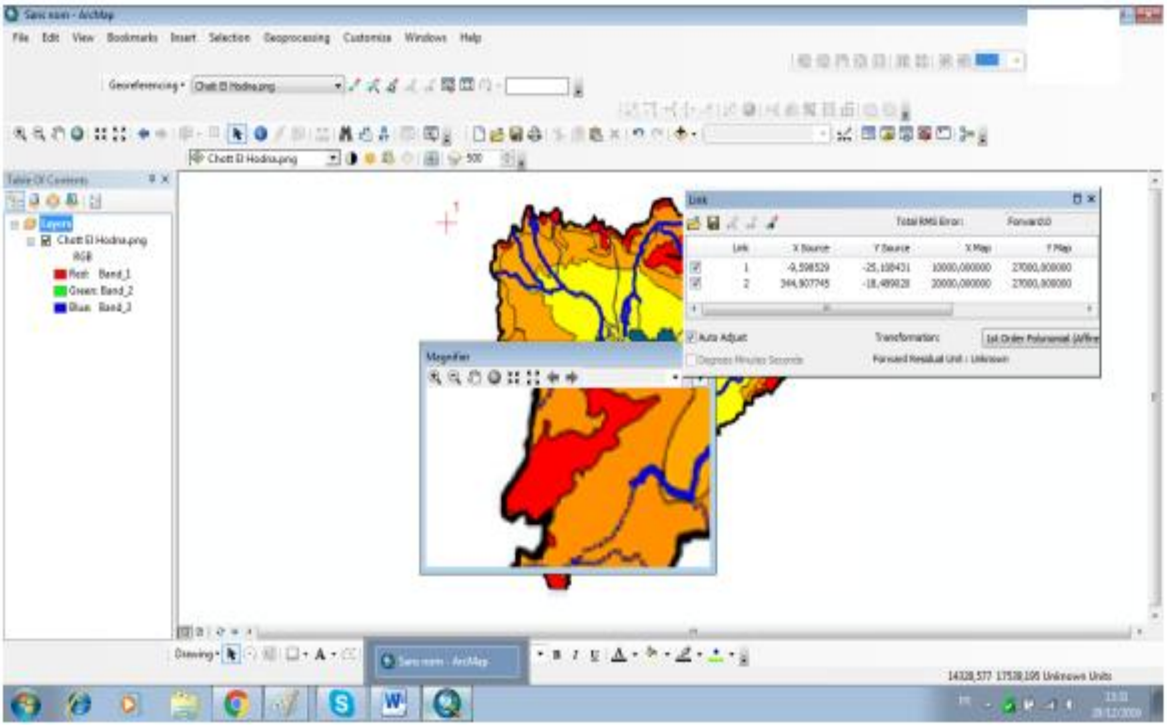
Display the list of control points, then select the point pair. The button located in the top-right corner of the dialog box allows you to delete the selected line. The link will then automatically disappear from the map.

- **To modify the coordinates of a control point**

In the list of control points, double-click the coordinate of the point you want to modify. You can then enter the desired x or y value.

- **Calculation of Root Mean Square Error (RMS)**

The mathematical function for transforming image coordinates into geographic coordinates is determined so that the control points are located, in the georeferenced map, at the geographic coordinates specified during the calibration. However, the function never allows for an exact positioning of the control points at the theoretical geographic coordinates. Therefore, georeferencing always involves some degree of error (a shift) for each control point. The average error across all control points is called the Root Mean Square Error (RMS). This error is expressed in the units of the geographic coordinate system (e.g., meters). The coordinates of each control point can be stored in an ASCII *.txt file, which allows for reuse in other calibrations. To save a calibration file, use the Save button.



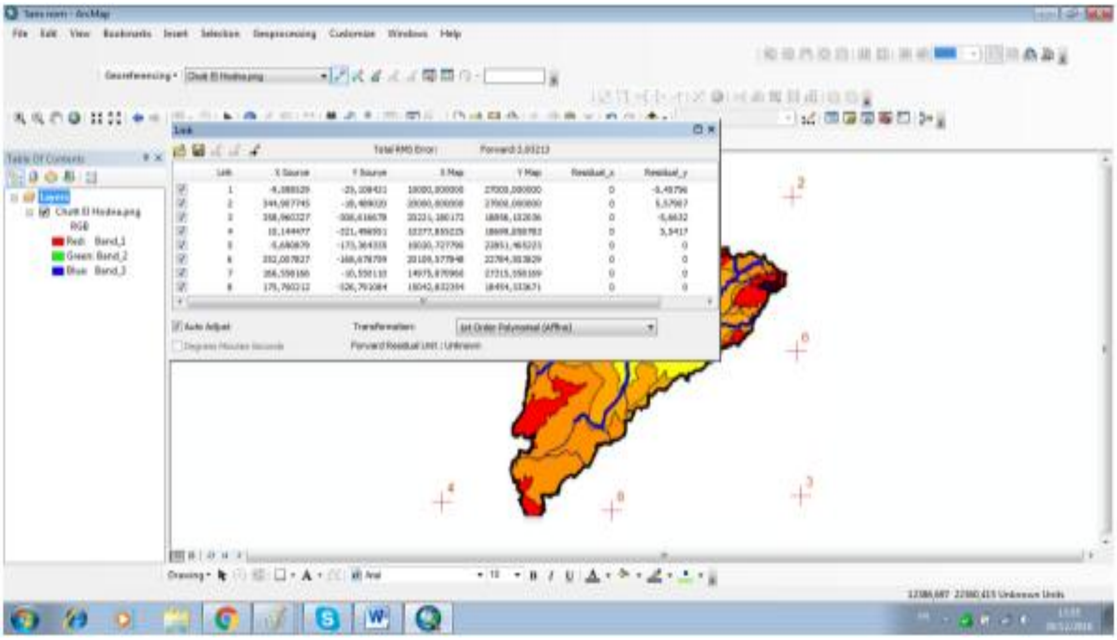
Each line corresponds to the coordinates of a point: X and Y on the source image and X and Y on the reference image, for example.

X	Y	Xmap	Ymap
1404143	-4553999	586948.1	2411389.04
753941	-9328006	586875.0	2410879.7
7724576	-7189954	587640.5	2411110.61
12908620	-1783319	588183.9	2411675.8
17424888	-3282884	588663.7	2411525.0
16727825	-5444367	588599.5	2411278.3

Under ArcGIS, the first two columns are called X Source and Y Source (image coordinates), and the other two columns are X Map and Y Map (UTM coordinates in meters East and North).

- **Validate the calibration**

Before finalizing the georeferencing, you need to check the average registration error for each control point. Click the button (***Ok / Update Georeferencing / Save***).



❖ ***Exercise***

In the digital file /Exercise / (E:/PW.2 Géoréférencement/Exercice), you will find two images: Hodna region and Hodna region 2.

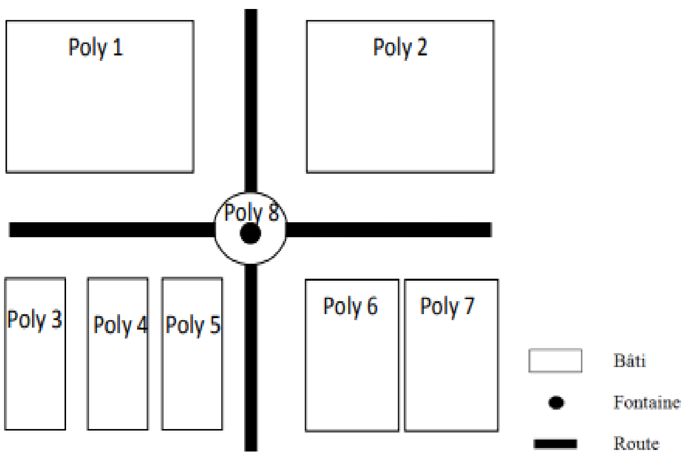
1. Georeference the non-georeferenced map.
2. Create a mosaic using the two maps.

P W No. 3: Creation of Shapefiles

Exercise 1: Creation of Vector Data

1.1. Reproduce the plan below in ArcGIS (Projection WGS_1984_UTM_Zone_31N).

1.2. Fill in the attribute table: a.Name and Type of each element ; b. Calculate the dimensions of the different graphic elements in the plan (area, perimeter, length). What do you notice?



Noms	Types
Poly 1	APC
Poly 2	Ecole
Poly 3	Commerce 1
Poly 4	Commerce 2
Poly 5	Commerce 3
Poly 6	Protection civile
Poly 7	ANRH
Poly 8	Carrefour

Exercise 2

You have the map “ Watershed and Collectors ” in JPEG format and the map “ Watershed ” in

GRID format, with the latter already georeferenced (E:/PW.3 Création de couche de forme / Exercice 2). - Digitize the map “ Watershed and Collectors ” and save your work.

P W No. 4: Map Layout

Exercise 1

Using the digital file " Wadi Boussaada sub-watershed " (E/ Bureau/ PW.4 Map layout and production / Exercice 1):

1.1. Create a map showing the density of vegetation by sub-basin.

1.2. Save the map in JPEG format.

Exercise 2

Using the mosaic of the two maps " Hodna region 1" and " Hodna region 2," created in Exercise 2 of PW 2:

2.1. Produce an administrative map of the university (following the different cartographic steps, especially the modeling phase).

2.2. Edit the map in JPEG format.

P W No. 5: GIS Applications (Ecosystem Management and Conservation).

GIS allows the creation of detailed maps of natural habitats, identifying different ecological zones and the species that inhabit them. These maps are essential for understanding species distribution and planning targeted conservation actions.

Exercise 1.

You have the "Daïras of the Wilaya of M'sila" layer. PW5: GIS Applications (Ecosystem Management and Conservation - Floristic Inventory of the M'sila Region - Medicinal Plants).

1.1. Integration and processing of collected data ;

1.2. Produce a thematic map showing the distribution of medicinal plants in each Daïra. Save the map in .shp format ;

1.3. Identify and delineate one of the Daïras in this region. Save the delineated Daïra in .shp format.

Exercise 2.

Based on the first exercise:

1. Provide the geometric spatial thematic analysis ;
2. Provide the alphanumeric (statistic) spatial thematic analysis.

Conclusion

Conclusion

A Geographic Information System (GIS) is a computer tool used to represent and analyze all elements that exist on Earth as well as all the events that occur there. A working methodology that consists of representing collected information in the form of thematic maps was carried out using the "ArcGIS" software. After defining GIS, the various functionalities of a GIS were discussed. Some are traditional to information systems: data storage, updates, consultation, and information retrieval. Others, such as spatial analysis or cartographic production, are specific to GIS.Geographic Information Systems are a science built on multidisciplinary knowledge (geography, cartography, computer science, mathematics, image processing, etc.), and they encompass several technologies. GIS relies on components like hardware, software, data, and human resources to process data (acquired in various ways) and extract information.

Geographic Information Systems (GIS) offer numerous benefits in both scientific research and professional fields. Here's a breakdown of the key advantages:

- *Data Integration and Visualization*

GIS enables the integration of diverse datasets (spatial and non-spatial), making it easier to visualize complex data in a geographic context. This ability enhances understanding and communication of patterns, trends, and relationships ;

- *Enhanced Decision-Making*

By providing a clear visualization of data and trends, GIS helps in making informed decisions across various sectors, such as urban planning, environmental management, and public health. For example, it can assist in selecting optimal locations for development or determining areas most at risk during a natural disaster ;

- *Spatial Analysis*

GIS allows for advanced spatial analyses, such as proximity, overlay, and network analyses. These tools help scientists and professionals better understand relationships between different geographical factors, leading to insights that might not be apparent from raw data alone ;

- *Improved Efficiency*

Automating tasks such as mapping, updating geographic data, and running spatial analyses saves time and resources. For example, in fields like agriculture, transportation, and logistics, GIS streamlines operations, improves route planning, and optimizes resource allocation ;

- *Collaboration and Data Sharing*

GIS facilitates collaboration by allowing multiple users to access, update, and share data in real-time. This is particularly valuable in large projects involving government agencies, research institutions, and private organizations working together across various locations ;

- *Environmental Monitoring and Management*

GIS plays a crucial role in monitoring environmental changes, such as deforestation, water quality, and wildlife habitats. It allows scientists to track, model, and predict environmental impacts, which is vital for sustainability efforts and disaster preparedness ;

- *Support for Scientific Research*

- Researchers use GIS to explore spatial relationships and generate new hypotheses in fields such as ecology, epidemiology, archaeology, and climatology. The ability to analyze spatial data alongside non-spatial data (e.g., census information or environmental variables) fosters more comprehensive scientific studies ;

- *Economic and Business Applications*

In business, GIS supports market analysis, site selection, and logistics management. By analyzing demographic, consumer, and location data, companies can optimize marketing strategies, reduce costs, and improve service delivery ;

- *Customized Solutions*

GIS platforms can be tailored to meet specific needs of different industries, allowing professionals to create specialized applications for particular projects, such as wildlife tracking, crime mapping, or infrastructure maintenance ;

- *Public Health and Epidemiology*

GIS is invaluable in tracking disease outbreaks, assessing healthcare accessibility, and identifying environmental health risks. In public health, GIS can be used to map patterns of disease spread, improve healthcare delivery, and mitigate risks in vulnerable populations. The use of GIS also enabled us to execute queries and perform geographic analyses, thereby improving information organization and facilitating quick decision-making. Our contribution is to introduce GIS as a modern and relevant management tool in cartographic evaluation.

The advantages of GIS include clear and definitive information storage, efficient management of multiple attributes on objects, better understanding of phenomena, rapid creation of thematic maps, swift analysis and processing of large volumes of data, and the user-friendliness of the ArcGIS application.

In both scientific and professional contexts, GIS serves as a critical tool for managing and analyzing spatial data, improving workflows, and enhancing decision-making processes.

In conclusion, Geographic Information Systems (GIS) offer powerful tools for capturing, storing, analyzing, and visualizing spatial data, making them indispensable for a wide range of industries, including urban planning, environmental management, transportation, and public health. GIS enables decision-makers to analyze spatial relationships, predict trends, and optimize resources by offering insights into the complex interactions between different geographic factors.

The effectiveness of a GIS depends on several components, such as data acquisition, database structure, data volume management, economic considerations, and compliance with data protection regulations. Each of these elements contributes to a system that is both technically robust and ethically responsible, ensuring data is managed efficiently and securely.

Moreover, GIS technology continues to evolve, integrating advancements like real-time data feeds, artificial intelligence, and cloud computing, which expand its capabilities and accessibility. However, as GIS grows, it also presents challenges, including the need for technical expertise, the handling of large data volumes, and the requirement to stay current with legal frameworks around data protection.

By carefully structuring databases, managing costs, and adhering to data protection standards, organizations can fully leverage GIS to enhance decision-making, improve operational efficiency, and foster a more comprehensive understanding of the spatial dimensions of their work. As GIS technology advances, its role in driving insights and shaping sustainable solutions will only grow, underscoring its importance in both current and future data-driven strategies.

Finally I want to say :

A GIS being primarily a tool, it is its use by skilled users that allows its full potential to be exploited.
Anyone may, at some point, be required to use a GIS.

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