الجمهورية الجزائرية الديمقراطية الشعبية
People's Democratic Republic of Algeria
وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
جامعة الشهيد حمه لخضر الوادي
Echahid Hamma Lakhdar University of El Oued

Faculty of Technology
Hydraulic & Civil Engineering Department

كليـــة التكنولوجيا
قســـم الري والهندسة المدنية

Course of:

Geographic Information Systems

Dr. Mega Nabil

Level 3rd Year License Sciences & Technology

Specialty: Hydraulic

Semester 5

INTRODUCTION

This course of Geographic Information Systems (G. I. S) is intended for students of 3rd year of bachelor's in fifth semester (S5) specialty "Hydraulic".

Skills pre-requisite:

The learning of the course "G. I. S" requires prior knowledge in surveying, Mathematics, and Cartography. In Fact, it is indispensable for students of this subject to have the pre-requisites for the following concepts :

- Geometry
- Topography
- Statistics
- Mapping
- Technical drawing

Course objectives :

The student will be able to know the basics of digital mapping, allowing it to perform and make decisions in terms of selection of land for construction of hydraulic structures (dams, water, wastewater Treatment plants wastewater, water towers). Of making different thematic maps (pH, Conductivity, Salinity, etc.), in order to complete the map of groundwater pollution.

Plan of the course

Chapter 1. A Geographic Information system (G.I.S)

Chapter 2. Data representation in the G.I.S

Chapter 3. The analysis in G.I.S and software

Chapter 4. Remote Sensing

Chapter 5. Examples of the application of G.I.S and remote Sensing in the field of water

- **Semester: 5**
- **Teaching unit: UDS 3.1**
- **Material 2: Geographic Information Systems**
- **HSV: 22: 30 (Lecture: 1 hour 30 minutes)**
- **Credits: 1**
- **Coefficient: 1**
- **Mode of assessment: Examination 100%.**

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Chapter II The data representation in the G. I. S

Chapter III The analysis in S. I. G and software

Chapter IV REMOTE SENSING

Chapitre I

Geographic Information Systems

1.1 Introduction

Since ancient times, humans have sought to represent their environment. Early cartography involved drawing maps on stone, parchment, and paper to navigate and mark territories. However, traditional maps are static; they cannot easily be updated or analyzed quantitatively.

The digital revolution transformed cartography into **Geographic Information Systems (GIS)**. The origins of GIS date back to the 1960s with the work of Roger Tomlinson, often called the "Father of GIS," who developed the Canada Geographic Information System (CGIS) for land inventory. Simultaneously, the Harvard Laboratory for Computer Graphics developed early mapping software.

In the following decades, the launch of satellites (Landsat), the development of GPS, and the democratization of personal computers accelerated GIS adoption. Today, GIS is ubiquitous, powering navigation apps, urban planning, disaster response, and environmental management.

1.2 What is a GIS? Formal Definition

Key Definition: GIS

A **Geographic Information System (GIS)** is a computer-based system designed to **capture, store, manipulate, analyze, manage, and display** all types of spatial or geographical data.

Unlike a simple digital map, a GIS links **location data** (where is it?) with **attribute data** (what is it?). This linkage allows users to perform complex queries and analyses, such as finding all wells within a specific aquifer that have high nitrate levels.

1.3 Core Components of a GIS

A functioning GIS is not just software; it is a system composed of five key components (Fig. 1):

1. **Hardware:** The physical equipment (computers, servers, GPS devices, scanners, printers) needed to run GIS software and capture data.
2. **Software:** The programs used to store, analyze, and display geographic data. Examples include ArcGIS (ESRI), QGIS (Open Source), and MapInfo.
3. **Data:** The fuel of GIS. This includes spatial data (maps, coordinates) and attribute data (tables, statistics). Data can be the most expensive part of a GIS.
4. **People:** The most important component. GIS requires skilled technicians, analysts, and managers to operate the system and interpret results.
5. **Methodology (Methods/Procedures):** A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

Figure 1: GIS components.

1.4 Typical Questions Answered by GIS

GIS is a decision-support tool. In the context of water resources, it helps answer questions such as:

- **Location (What is at...?):** "What water infrastructure is located at coordinate X,Y?"
- **Condition (Where is it...?):** "Where are all the reservoirs with water levels below 50%?"
- **Trends (What has changed...?):**"How has the wetland area changed over the last 20 years?"
- **Patterns (What is the spatial distribution...?):** "Is there a cluster of waterborne disease cases near a specific river segment?"
- **Modeling (What if...?):** "What areas will be flooded if the river level rises by 2 meters?"

Water Application Example: Site Selection

Scenario: A municipality needs to build a new wastewater treatment plant. **GIS Approach:** The system can overlay layers to find a site that meets all criteria:

- Outside the 100-year flood zone.
- Within 500 meters of the main sewer line.
- More than 1 km away from residential areas.
- On slope less than 5% to reduce construction costs.

1.5 Geodesy Fundamentals: Geoid, Latitude, Longitude

To map the Earth, we must understand its shape. **Geodesy** is the science of measuring the Earth's shape and size.

- **Sphere vs. Ellipsoid:** The Earth is not a perfect sphere; it is flattened at the poles. An **ellipsoid** (or spheroid) is a mathematical surface that approximates this shape (Fig. 3).
- **The Geoid:** The Earth's surface is irregular. The **geoid** is the equipotential surface of the Earth's gravity field that best fits global mean sea level. It represents the "true" physical shape of the Earth but is mathematically complex.
- **Latitude (φ) & Longitude (λ) (Fig. 4):**

- **Latitude:** Angle North or South of the Equator (-90° to +90°).
- **Longitude:** Angle East or West of the Prime Meridian (Greenwich) (-180° to +180°).

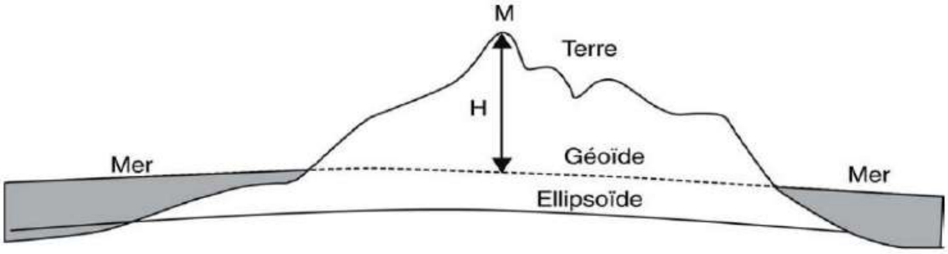

Figure 3: Geoïd form.

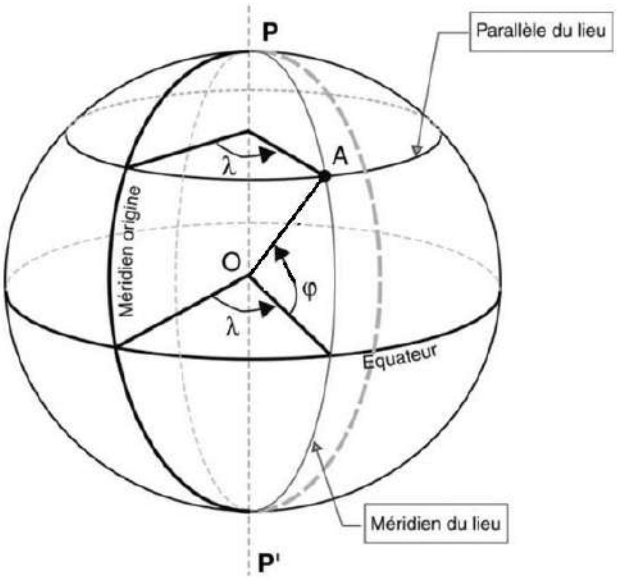

Figure 4: λ and φ Presentation.

1.6 The Challenge of Georeferencing (3D to 2D)

A fundamental challenge in GIS is transforming the 3D curved surface of the Earth onto a 2D flat map (screen or paper, Fig. 2). This process inevitably introduces **distortion**. You cannot flatten an orange peel without tearing or stretching it. Similarly, no flat map can be completely accurate in all aspects.

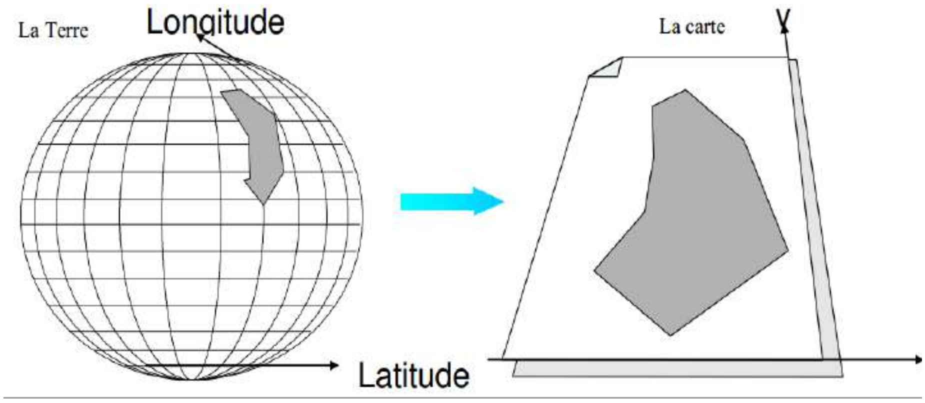

Figure 2: 3D to 2D, the paradoxe.

1.7 Map Projections

A **map projection** is a mathematical formula used to transfer points from the 3D Earth to a 2D plane. Projections are classified by the projection surface used:

1. **Cylindrical Projections:** Project the Earth onto a cylinder. Meridians and parallels cross at right angles.
   - *Example:* Mercator (good for navigation, distorts size at poles).
2. **Conic Projections:** Project the Earth onto a cone. Good for mid-latitude regions (e.g., Europe, USA).
   - *Example:* Lambert Conformal Conic.
3. **Azimuthal (Planar) Projections:** Project the Earth onto a flat plane touching a single point. Good for polar regions.

- *Example:* Stereographic.

1.8 Projection Properties

Since distortion is unavoidable, map makers choose projections based on which property they want to preserve (Fig. 5):

- **Conformal:** Preserves **angles** (shapes of small areas). Used for navigation and topographic maps (e.g., Mercator, Lambert).
- **Equal-Area (Equivalent):** Preserves **areas**. Used for thematic maps showing distribution (e.g., population density, land cover).
- **Equidistant:** Preserves **distances** from a specific point or line.
- **Aphylactic (Compromise):** Preserves no property perfectly but minimizes overall distortion (e.g., Robinson projection for world maps).

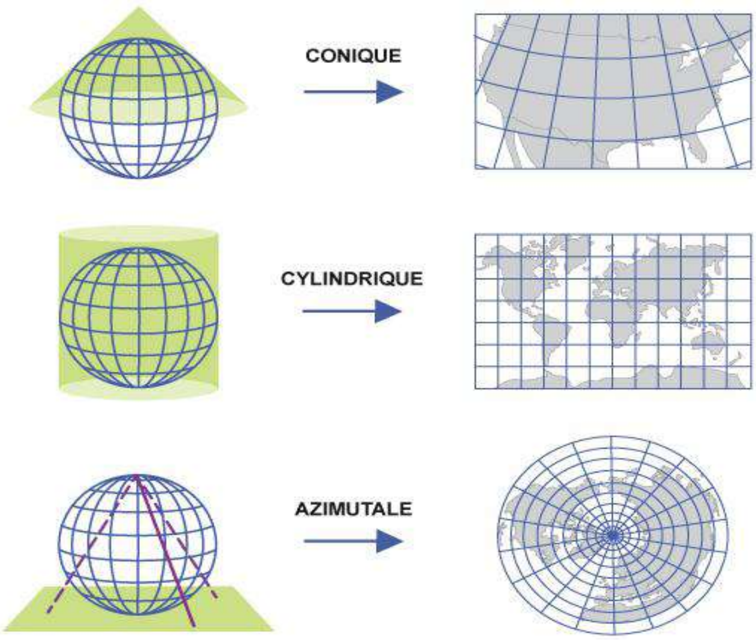

Figure 5: Map projections.

1.9 Importance of Georeferencing in GIS Workflows

Georeferencing is the process of assigning real-world coordinates to a digital dataset. In GIS, all layers (rivers, roads, satellite images) must be in the same Coordinate Reference System (CRS) to align correctly. If layers have different or undefined spatial references, they will not overlay, making analysis impossible. This is a common source of error in beginner GIS projects.

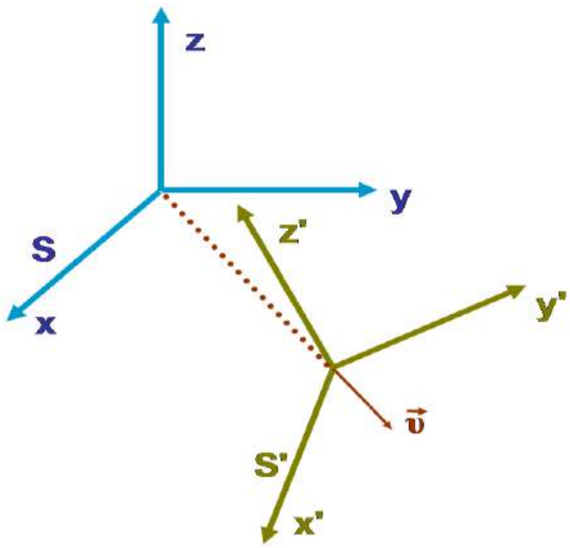

Figure 6: Georeferencing principle.

• Layer overlay is possible;

• Layer intersection is possible;

• Scanned map assembly is possible;

• Aerial photo mosaics can be created;

• Various tasks and projects can be finalized;

• Etc.

1.10 Key Concepts Summary + Review

Chapter Summary

- GIS combines hardware, software, data, people, and methods.
- GIS answers "Where", "What", and "What if" questions.
- The Earth is modeled as an ellipsoid; the geoid represents gravity/sea level.
- Projections transform 3D Earth to 2D maps, causing distortions in shape, area, distance, or direction.

Review Questions:

1. Define GIS and list its five components.
2. What is the difference between an ellipsoid and a geoid?
3. Why is it impossible to create a perfect 2D map of the Earth?
4. Which map projection property is most important for a cadastral map where calculating land area is crucial? (Answer: Equal-Area)

1.11 Data Sources

GIS utilizes a significant amount of data from various sources. These include:

- Direct topographic surveys;
- GPS point files;
- Historical maps/plans;
- Scanned documents;
- Alphanumeric data;
- Satellite imagery;
- Radar/Lidar data;
- Laser scanners;

- Photogrammetric data;
- Maritime data.

1.12 Applications

GIS is used in several fields, for example:

- Defense;
- Land registry;
- Forestry;
- Hydraulics;
- National Gendarmerie;
- Education;
- Public works;
- Agriculture;
- Telecommunications;
- Environment;
- Criminology;
- Etc.

1.13 Importance of GIS

GIS plays a significant role in the execution of various projects.

- Data is maintained in a standard format;
- Revision and updates are easier;
- Data is easy to search, extract, analyze, and visualize;
- Product value is increased;
- Data is easier to share and exchange;
- Improved staff productivity;
- Reduced time and cost; and
- Better decision-making.

Chapter II

THE DATA REPRESENTATION IN THE G. I. S

1. Introduction

How to represent the spatial information in a machine? What are the types of data to be taken into consideration? Precautions to take?

2. Definition

This is the transcript of the geographic information physical-to-digital geographic information (on a computer, tablet...).

3. Modes of representation

There are two modes of representation of geographic information (Fig. 7):

3.1. The Vector mode

The principle that is the point (defined by x and y).

- The point objects, we find: water wells, water towers, terminals, geodesic, masts, manholes,...
- The line objects: roads, wadis, railways, power lines, etc
- The surface objects: lakes, forests, sands, seas,...

Benefits

- Layering and intersection of the layers;
- Objects detachable;
- Forms quite accurate;
- Topology possible;
- File size reduced.

Disadvantages

- Low thematic resolution;
- Considerable amount of time to perform certain duties;
- Complex Structure data.

Examples of Vector data

- A topographic survey;
- A file of GPS point;
- A point file Laser scanner;
- Data layer of points, lines, or polygons;

- Etc.

3.2. The Raster mode the principle that is the pixel (n. line, n° column, dimension and value radiometric).

Benefits

- Simple Structure of the data;
- Representation of variable spatially continuous;
- Classification possible.

Disadvantages

- Large file;
- Poor print;
- Shapes at stairs
- Low spatial accuracy.

Examples of Raster data

- A scanned document
- Satellite Image;
- Aerial photography;
- Etc.

4.

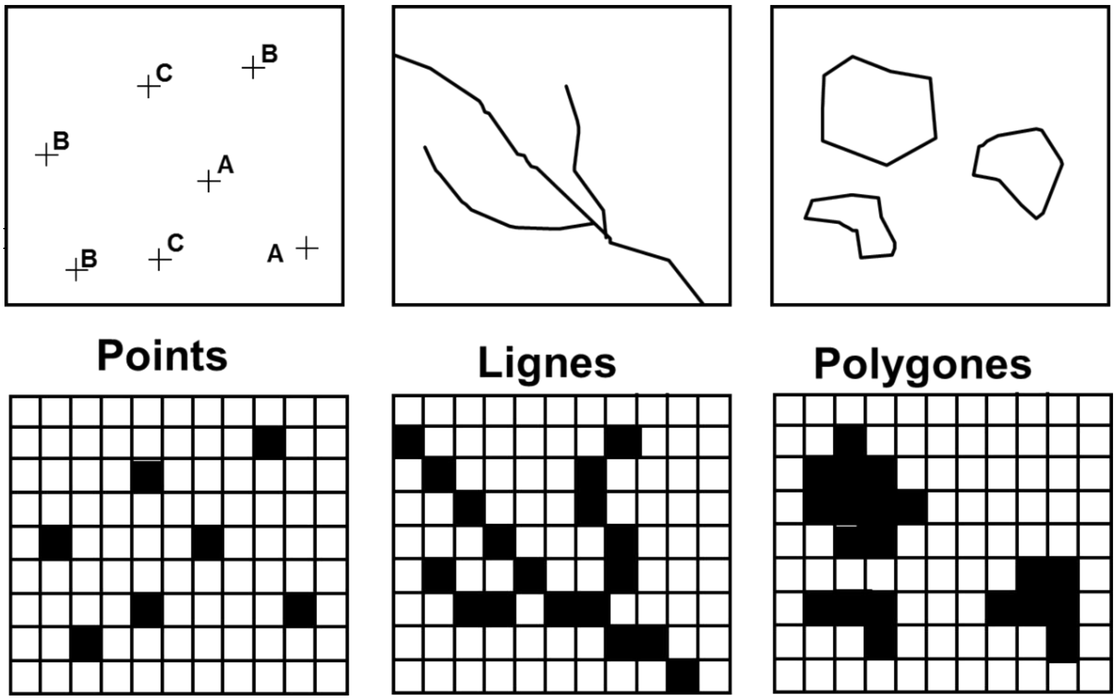

Figure 7: Vector and Raster Modes.

4. Data base definition

The concept of a database allows you to store and organize a large amount of information. The DBMS (Database Management system) Data can be used to navigate the data and extract (or update) the information required in the middle of a query.

5. Example

Table Student:

- Number
- Name
- First name
- Lieu_date_naissance
- Specialty

➢ Fixed Structure

➢ Data Volume

6. Structure of a table (Fig. 8)

1. Entity: the label of the table.
2. Attributes: elements of the table.
3. Registration: entire row of a table.
4. Identifier: single item in a table

Matricule	Nom	Prénom	L_D_N	Spécialité

Figure 8: Structure of a Table.

7. Types of databases

The evolution of systems of database management (DBMS), reflects the growing need to organise information in a way more flexible and complex. Each model responds to a logic of patterning-specific:

7.1. The Hierarchical Model (structure tree)

Appeared in the 1960s, this model organizes data in a hierarchy pyramid. Each record has only one parent but can have several "children", with the image of a family tree, or a system of records on a computer. While effective for massive volumes of data to be stable, its structure is rigid : to access an element of the lowest level, it is imperative to go through all the higher levels.

7.2. The Network Model

Designed to overcome the limitations of the hierarchical model, the network model allows a record to have multiple parents. This creates a graph complex where the links are self-explanatory. If this approach offers a greater flexibility to model complex relationships, it is still difficult to handle and maintain, as any change in the structure often requires rewriting the access programs.

7.3. The Relational Model (structure in tables)

It is the most widespread today. The data are organized in tables (or relations) that consist of rows and columns, linked by keys in common. Its strength lies in its simplicity and the use of the SQL language.

- Examples: software, such as Oracle Database (for industrial purposes), Microsoft Access (for an office), or MySQL, and PostgreSQL.

7.4. The Object-Oriented Model

Born from the need to store complex data types (images, sounds, nested structures) as the relational difficult to manage, this model treats data as objects. The data and methods to manipulate it are organized into classes, according to the principles of object-oriented programming (inheritance, encapsulation).

- Example: The system O2 is one of the representatives of this historic class, facilitating direct interaction between the application code and the database.

8. Design levels (Fig. 9)

The design of a database is a structured process that allows you to switch to a business need abstract to a technical implementation of concrete. It usually uses a life-cycle approach ANSI/SPARC, which divides the design into three distinct levels :

8.1. On the Conceptual Level (MCD)

This is the step the more abstract, often represented by the Conceptual Data Model (CDM). At this stage, we focus only on the "what" : what are the entities (ex: Customer, Order, and how are they linked to each other, without worrying about it.

- Tool : The chart Entity-Association.
- Objective : to Create a semantic representation and fair view of the reality of the business, understandable by both technicians and end users.

8.2. The Logic Level (MLD)

The logic level adapts the conceptual model to a specific storage type (usually the relational model). Here are the "how to organize" the data. The entities become tables, the properties become columns, and relationships are materialized by primary and foreign keys.

- Tool: The Logical Model of the Data (MLD).
- Objective: to Standardize the data to avoid duplication and ensure the integrity of the information. This model depends on the type of DBMS chosen (relational, object, etc), but remains independent of the specific software.

8.3. The Physical Level (MPD)

This is the final stage of the implementation on a machine. Here we define the "how to store" technically. This level takes into account the specific features of the selected software (Oracle, MySQL, PostgreSQL) and equipment.

- Elements: Definition of data types specific (VARCHAR, INTEGER), the creation of the index to speed up the research, management of the disk space and access rights.
- Objective: to Optimize the performance of the database and ensure its technical security.

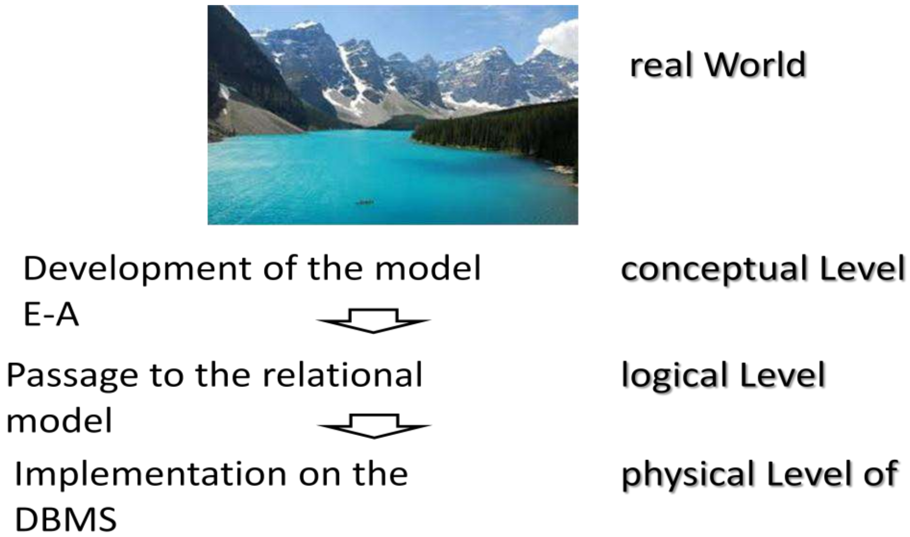

Figure 9: Levels of design of the Data Bases.

9. Cardinalities

The complete description of a relationship requires the precise definition of the participation of the entities. The cardinality is the number of an entity's interests in a relationship.

The cardinalities are numerical indicators are essential in the Conceptual Data Model (CDM), which specify the number of times an instance of one entity can participate in an association. They always look per pair (minimum, maximum) on each branch connecting one entity to another association.

9.1. The Minimum Cardinality (0 or 1)

It defines whether the participation in the relationship is optional or mandatory.

- 0: The entity can exist without being related to the association (ex: a client who has not yet passed command).
- 1: The entity must be linked to at least one instance of the association (e.g., a line of the invoice must belong to an invoice).

9.2. The Maximum Cardinality (1 or n)

It defines the upper limit for participation.

- 1: The entity can only be linked to one instance of another entity to the maximum (ex: an employee works in one department).
- n: An entity can be related to an indefinite number of occurrences (ex: a department may employ several employees).

9.3. The types of classic relationships

By combining the cardinalities maximum of two sides of an association, we obtain three main types of relationships:

- One-to-one (1:1): Each instance of A is related to one of B (e.g. a country and its capital).
- One-to-many (1:n) : An instance of A can be linked to multiple of B, but a B is linked to only one of A (ex: a class and her students).
- Many-to-many (n:n): Multiple instances of A can be related to several of B (ex: authors and books). In the logic model, this relationship generates a linking table.

Chapter III

THE ANALYSIS IN S. I. G AND SOFTWARE

1. Spatial interpolation

Due to the high cost and limited resources, data collection is usually conducted in a limited number of locations of the points selected. In GIS, spatial interpolation of these points can be applied to create a surface with estimates made for the rest of the other points.

2. Definition

The interpolation is to find, from a limited number of known points, the estimated values at each point of the area studied (fig 10).

Figure 10: Principle of interpolation.

3. Example (Fig. 11)

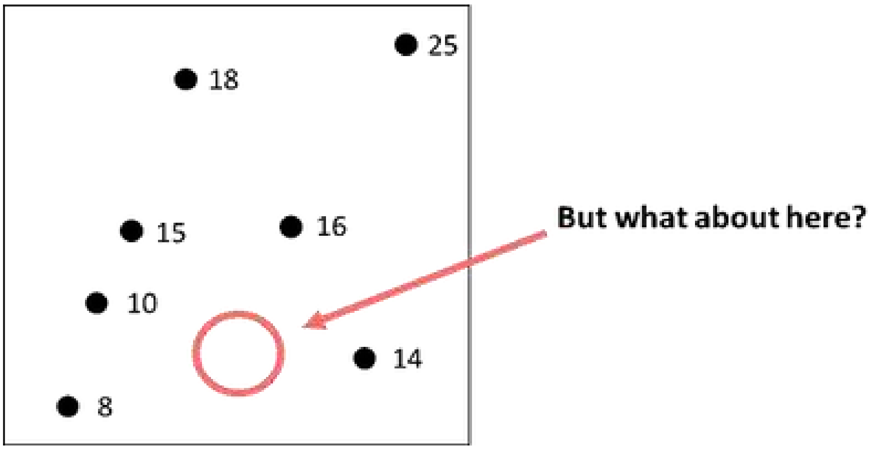

Figure 11: Object of the tween.

4. Precision

The accuracy of the interpolation dépond the number of original data used.

Données initiales $\nearrow$ $\Rightarrow$ Précision $\nearrow$

5. Interpolation methods

- Weighting by inverse Distance (IDW) ;
- Kriging ;
- Spline ;
- Other.

5.1. Weighting by Distance inverted (Inverse Distance Weighted)

The sample points are weighted during interpolation such that the influence of one point relative to other declines with distance from the unknown point you want to create (Fig. 12).

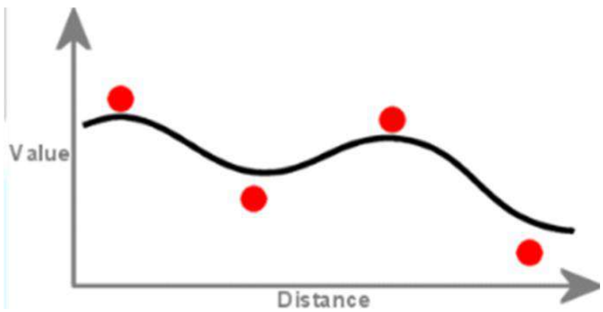

Figure 12: The IDW.

5.2. Kriging

The Kriging (Fig. 13) takes into account not only the distance between the data and the point estimate, but also the distances between the data of two-to-two.

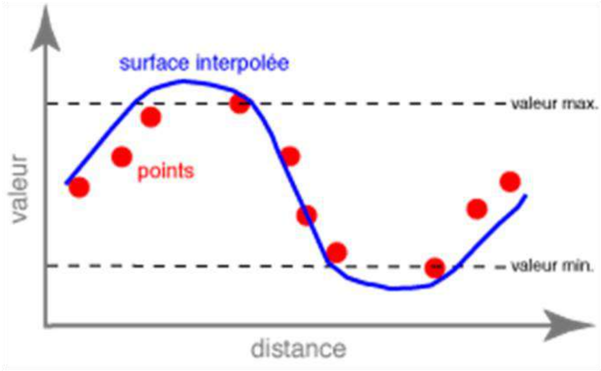

Figure 13: Kriging.

5.3. Spline

The method of Spline estimates the values interpolated from a surface that passes through the points whose value is known (curve) (Fig. 14).

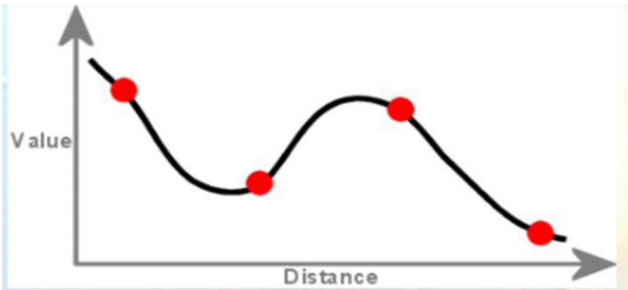

Figure 14: Spline.

6. Applications

Spatial interpolation is a fundamental technique in geomatics that is used to estimate unknown values in points not sampled from known points (control points).

- Creating continuous surfaces : It allows you to transform data isolated point (e.g. weather stations) in a layer with ongoing information about an area (ex: a map of temperature or precipitation).
- Modeling of the terrain (MNT) : It is the main tool to generate Digital Models of Terrain. From elevation points raised on the land, or of the level curves of the interpolation creates a surface topographic fluid.

- Management of data gaps: It is used to "fill the holes" in a data set where physical measurements are impossible, costly, or missing, thus providing a spatial analysis without interruption.

- Choice of the method according to the law of Tobler: The use of the interpolation is based on the principle that things that are close are more related than things far away. The choice of the method (IDW to the influence of the distance, Kriging for trends, statistics, or Spline to the curve depends on the nature of the studied phenomenon.

- Risk mapping and pollution: It is crucial to delineate areas of danger or concentration (ex: soil pollution, noise levels in the city, the spread of an epidemic by creating maps of isovalues (curves of the same intensity).

- Changing the resolution (Resampling): In the analysis raster interpolation is used to change the size of the pixels of an image in order to make it compatible with other data layers having a different resolution.

7. Spatial analysis

It is the set of operations and treatments performed on the basis of the data from a query (simple or complicated), in order to lead to a final result (semantic or spatial).

8. Examples of spatial analysis

8.1. The overlay and the crossing of layers

The overlay (the overlay) and the crossing of layers are at the heart of spatial analysis in a GIS. It is thanks to these operations that transforms raw data into strategic information for decision-making.

8.1.1. The creation of new information

The cross does not merely stack of cards ; it generates a new layer of data that did not exist initially. For example, overlaying a layer of "steep slopes", and a layer of "unstable ground", one creates a new map-specific "areas at risk of landslides".

8.1.2. The identification of spatial relationships

These techniques are used to verify the correlation between different phenomena. Thus, we can answer complex questions :

- *Is there a link between the proximity of industrial areas (layer A) and the quality of the air measured (layer B) ?*
- *What are the plots of agricultural land (layer A) located in a flood zone (layer B) ?*

8.1.3. The multi-criteria analysis to decision support

It is the preferred tool for urban planning or environmental. To establish a new hospital, you will meet several criteria: the population density, road accessibility, and the availability of land. The GIS allows you to calculate the exact spot where all of these criteria are satisfied simultaneously.

8.1.4. The integration of heterogeneous data

The overlay allows you to talk together data from different sources (from satellites, censuses, or GPS readings) by aligning on the same coordinate system. This provides a global and coherent vision of a given territory.

8.1.5. The geometric operations (Cutting and Merging)

The cross makes it possible to extract accurate statistics by geographic area :

- Intersection: in order To keep the common areas (ex: how much of the forest is located in the natural park ?).
- Union: combine all the features of the two areas.

Clipping (Clip): To extract data according to an administrative boundary, states (Fig. 15).

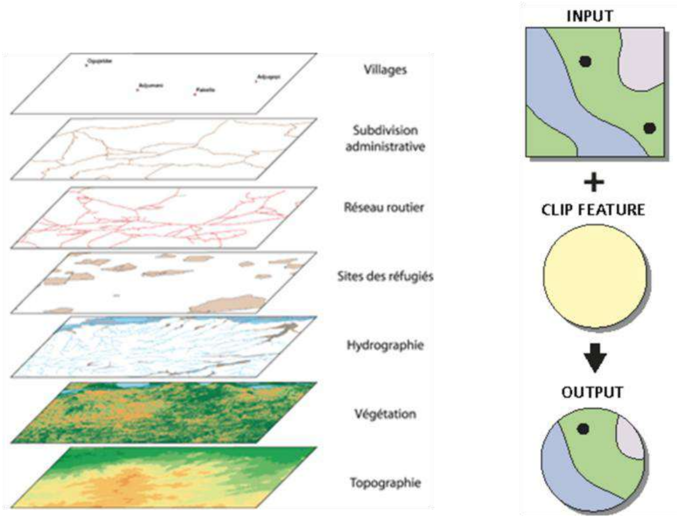

Figure 15: Layering and intersection of layers.

8.2. Buffer Zone - Buffer (Fig. 16)

The Buffer is one of the tools of spatial analysis used in the GIS. It is to generate a polygon surrounding a spatial object (point, line, or surface) at a specified distance.

Its importance lies in its ability to model the influence or the proximity of a phenomenon. Here's why it is essential :

8.2.1. Delimitation of the perimeters of protection

The most common use for the protection of the environment or public health.

- Example: Create a zone of non-treatment of 50 meters around the water course to protect the biodiversity of pesticides.

8.2.2. Analysis of the impact and noise

The buffers allow to visualize and quantify the extent of a nuisance space.

- Example: to Model the area of noise 300 metres of a highway or a railway to identify homes that require sound insulation.

8.2.3. Study of access and catchment area

For services to public and the trade, the buffer zone helps to assess the radiation of an infrastructure.

- Example : Draw a radius of 500 metres of a metro station to determine the number of residents with quick access to public transport.

8.2.4. Respect of regulatory constraints

In urban planning, it is intended to ensure that projects comply with the law (easements, setback).

- Example: ensure that no construction is planned in the area of mandatory safety 100 metres of a pipeline or high-voltage power line.

8.2.5. Preparing to cross data

The buffer zone is often an interim step prior to an overlay operation.

- Example: It first creates a buffer of 1 km around a chemical plant, and then we meet this new area with the layer "Schools" to identify schools at risk in the event of an accident.

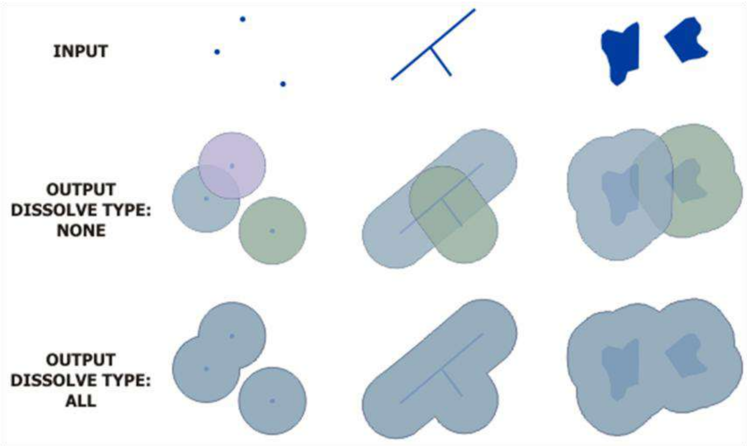

Figure 16: Buffer Zone.

8.3. Erase (Fig. 17)

The Erase operation (or *Erase* in English) is a function of cutting "negative". It allows you to remove part of a layer of data that are covered by another layer (termed layer of erasure).

Its strategic importance in a GIS is based on three pillars :

- Calculation of the surface to be useful or available: It is the essential tool to determine the real potential of a field. For example, to find the surface area of land of a plot of land, one part of the total surface area and clear the stress areas (flood zones, protected areas, easements). What remains is the area really usable.

- Update and data cleaning: The erase-allows you to avoid the overlays of information (duplicates geometric). If a new road is built through a forest, it uses the right-of-way to erase the portion of the matching forest, ensuring that the statistics of forest remain accurate.

- Analysis of exclusion: In the studies of impact or risk, this function allows you to isolate areas saved by a phenomenon. One can, for example, take the map of a city and clear all of the areas affected by flooding to immediately identify the secure area where you can install the relief centres.

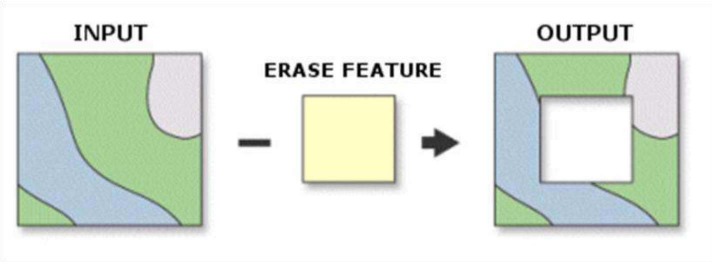

Figure 17: The erase tool.

8.4. Topology (Fig. 18)

The topology is one of the fundamental pillars of GIS. In contrast to the simple geometry that defines the position (**x,y**), the topology defines the spatial relationships between the objects (adjacency, connectivity, inclusion). It allows the software to understand that the two plots share a common limit, or that the two routes intersect actually.

8.4.1. Warranty of the integrity of the data

The topology requires consistency rules that prevent data entry errors. Without it, a card can appear correct visually, but be mathematically false. It helps avoid :

- "The Silver Polygons" (Polygons lowercase) : small empty accidental between two plots that should be close-fitting.
- Overlap: Two objects that overlap the other so that they would only have to touch.

8.4.2. Network analysis (Connectivity)

It is thanks to the topology that a GIS can calculate a route. It defines the connectivity: the software knows that a vehicle can go from one street to another because their ends (nodes) are connected. Without topology, the lines are only drawings bunk without logical connection.

8.4.3. Simplification, and simplified update

In a topological structure, if two polygons (ex: both countries share a border, this row is stored only once.

- Advantage: If you change the border, the two polygons are updated at the same time. This ensures that there is no "hole" or "duplicate" is not created when editing.

8.4.4. Spatial queries advanced

The topology allows you to perform complex analyses without geometric calculations heavy. It allows you to respond instantly to questions like :

- Adjacency: What are the neighbours of this plot ?
- Inclusion: What trees are found inside the park ?
- Adjacency: This river runs through it this protected area ?

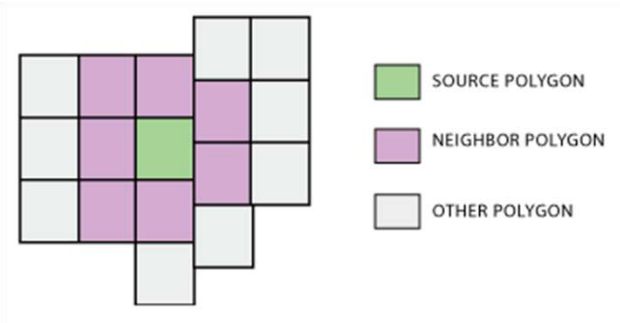

Figure 18: Example of topology.

8.5. Close (Fig. 19)

The tool Close (*Near*) is fundamental to quantify the spatial proximity between the objects of two different layers. In contrast to the buffer zone, which creates a surface, the Near tool calculates accurate measurements and adds them directly in the attribute table of your data.

- Calculation of distances accurate: It allows you to identify the entity closest to and to calculate the distance between two objects (for example, the distance between each house and the fire hydrant closest to).
- Analysis of location and accessibility: It is used to optimize the location of services. In marketing, it is used to determine which point of sale is the closest thing to a segment of customers given.
- Identification of the direction and angle: In addition to the distance, this tool can calculate the angle (azimuth) to the closest feature, which is crucial for studies on the spread of pollution or the analysis of visibility.
- Enrichment of the data (spatial Join): It allows to combine the information from one layer to another as a function of the proximity. For example, to assign to each soil sample the name of the nearest river without the need that they touch.
- Risk management and safety: It helps to check if the critical infrastructure (e.g. schools), follow the minimum safety distances when compared to sources of danger.

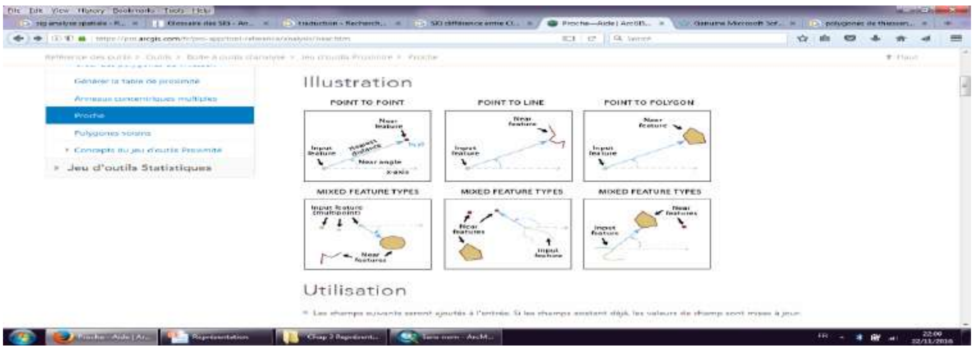

Figure 19: Example, on "The closer".

8.6. Route calculation (Fig. 20)

The tool route Calculation (or *Network Analysis*) application is the most concrete of graph theory and topology in GIS. It does not only measure distance as the crow flies, but calculates the actual experience through a structured network (roads, rails, pipelines).

8.6.1. Optimization of the time and the distance

This is its primary function: to find the shortest path or the fastest between two points. It takes into account not only the geometry of the roads, but also of the dynamic attributes such as traffic signs, speed limits, traffic signals, or plugs in real-time.

8.6.2. Logistics and fleet management

For the enterprises of delivery or collection (garbage mail), this tool allows you to organize tours to the complex including dozens of breakpoints. The aim is to reduce fuel consumption and optimize the use of vehicles (traveling salesman problem).

8.6.3. Planning aid (Emergency)

In the event of an accident, every second counts. The emergency services (ambulance, fire brigade) use the route calculation to determine which vehicle is the most "close" in real time, taking into account physical barriers or work-in-progress, ensuring a rapid response.

8.6.4. Analysis of the areas of accessibility (Isochronous)

The tool allows you to generate curves isochronous: areas representing all that is available in X minutes (for example, "what neighbourhoods are less than 10 minutes from a fire station?"). It is an aid to the major decision for the implementation of new public services.

8.6.5. Modeling of flow Networks (technical)

Beyond the road transport, this tool is used to manage networks of water or electricity. It simulates the path of a resource, and to identify which segment cut to isolate a leak while impacting less users as possible.

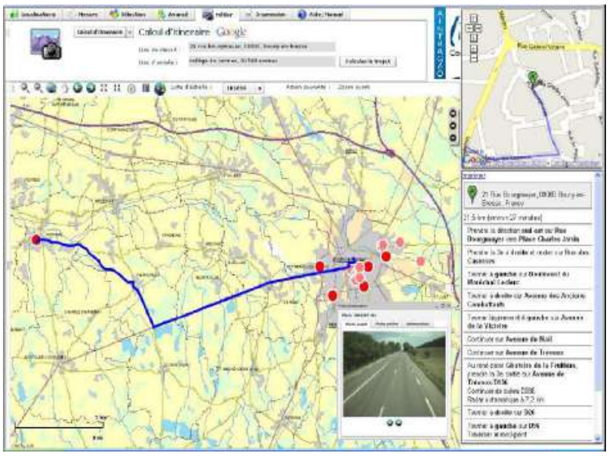

Figure 20: Route calculation.

8.7. Thiessen polygons (Fig. 21)

The Thiessen Polygons (also called Voronoi Diagrams) are a cutting tool spatial geometry which allows you to partition a territory into zones of influence from a set of given points.

The principle is simple: each polygon is generated around a point source in such a way that any location within a polygon is closer to the source point to any other point in the network.

8.7. 1. Delimitation of the areas of influence (Catchment)

It is the basic tool to define theoretically the area of coverage of a service.

- Example: If you place points for each school of a city, the Thiessen polygons will define the theoretical limits of school districts : each inhabitant is attached to the school nearest his home.

8.7. 2. Spatialization of point data (Regionalization)

It enables the transformation of measures single points in a surface coverage complete.

- Example: In meteorology, this method is used to estimate the rain fell on a station is representative of the whole area (polygon) that surrounds it. It is a simple alternative to the interpolation to calculate the spatially averaged (weighted average method of Thiessen).

8.7. 3. Analysis of the nearby without network

In contrast to the calculation of a route that follows the roads, the Thiessen polygons analyze the near absolute (bird's-eye). It is very useful for modeling of natural phenomena, or access in rural areas where transport networks are not the main constraint.

8.7. 4. Optimization of resource distribution

By observing the size and shape of the polygons, one can identify the territorial imbalances:

- A polygon huge indicates an area under-equipped (the point of service, is very far from the boundaries).
- Polygons are very small and dense indicate a strong concentration of service.

- This helps to decide where to locate a new point (for example, a new relay antenna or a charging point) to reduce the size of the largest polygons.

8.7. 5. Environmental studies and biological

In ecology, they are used to model the "territory" or the vital space of the animal species or the catchment area of the resources of a tree in the forest, starting from the principle that each individual dominates the space that is nearest to you.

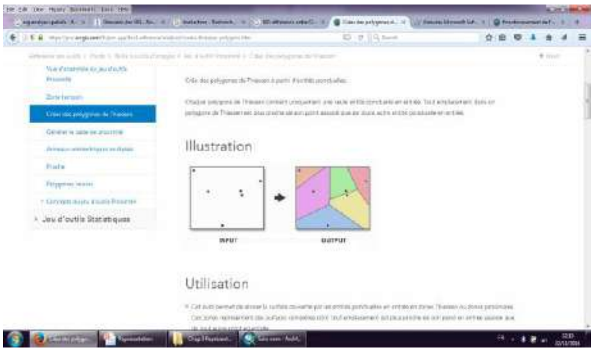

Figure 21: Thiessen Polygons.

8.8. Reclassification (Fig. 22)

The tool Reclassification is a crucial stage of the data processing, mostly in raster mode. It is to modify the initial values of a layer to replace them with new values according to a grid of a matching set.

- Simplification and readability: It allows you to transform continuous data and complex (e.g. altitudes ranging from 0 to 4810m) in thematic classes of simple (ex: 1 = Plain, 2 = Hill, 3 = Mountain). This makes the information immediately understandable for a mapping of synthesis.
- The standardization for the multi-Criteria Analysis : It is its role as the most crucial. To compare layers heterogeneous (ex: a map of slope in degrees, and a map of nearby road in meters), they are graded on a common scale, for example, from 1 (very bad) to 5 (very favorable). We can then add these layers to find the optimal site.
- Isolation of specific phenomena: The reclassification allows you to extract only what we are interested in applying to a value of "1" to the target areas, and "0" (or NoData) the rest. For example, to isolate only the areas where the slope is less than 10% for a construction project.
- Correction and cleaning of data: It is used to eliminate outliers or combine categories that are too detailed in a layer of occupation of the soil (ex: group "Oak", "Beech" and "Trees" under the single-valued "Forest").
- Preparation for the calculations of surfaces: transforming pixels to the unique values in areas grouped, the reclassification facilitates the automatic calculation of areas by category (ex: total area of the urban areas after the grouping of the different types of racks).

Figure 22: Reclassification.

8.9. Interpolation (Fig. 23)

Spatial interpolation is the tool that allows you to move from a vision of "one-off" to a "continuous" vision of the world. In GIS, its importance is critical, because it allows you to predict values (such as temperature, altitude or pollution) in places where no measurement has been performed, based on the sampling points are known.

1. Creating continuous surfaces (Grids)

Most of the geographical features do not stop at the measurement points. Interpolation allows you to generate a web of data uninterrupted.

- Example: from 10 weather stations isolated, the interpolation creates a heat map covering the entire region.

2. Modeling of the terrain (MNT)

Without interpolation, it would be impossible to create Digital Models of Terrain (MNT). It uses the altitude points (e.g. GPS or laser) to "calculate" the shape of the soil between these points, then allowing to derive slopes, exhibitions or river systems.

3. Reduction of costs and time of collection

On the field, it is often impossible or too costly to take steps around. The interpolation maximizes the value of existing data by providing statistically robust estimation for areas not visited, which optimizes the budgets of exploration.

4. To view trends and gradients

It allows you to highlight spatial structures that are invisible to the naked eye on a list of points.

- Example: See the "plume" of diffusion of a pollutant in the air or in the water table, clearly showing the direction and intensity of the spread.

5. Standardization of analyses (Resampling)

The interpolation is used to convert data of different resolutions. If you have a layer of the population that is very accurate and a layer climate coarse, you can interpolate the layer climate to match the grain of your population analysis.

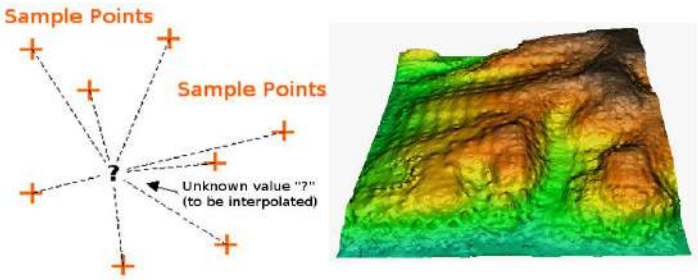

Figure 23: Interpolation.

8.10. Decision (Fig. 24)

The tool Decision (or, more broadly, the multi-criteria Analysis - CMA) represents the culmination functional GIS. This is the step where the geographic data cease to be simple maps to become arguments strategic to address a complex issue. Its significance is based on four fundamental pillars :

1. The synthesis of heterogeneous data

The decision maker is often faced with contradicting criteria (ex: environmental, economic, and technical). The decision tool allows to combine them.

- Example: For the implementation of a discharge, one crosses the permeability of the soil (geology), the distance to the housing (social), and proximity to roads (economic).

2. The prioritization and weighting

All the criteria have not the same importance. The decision tool is used to assign weights (coefficients) for each data layer.

- Application: In an urban planning project, you may decide that the protection of biodiversity has two times more than the cost of the land. The GIS system will automatically calculate the score of each plot based on this priority.

3. The comparison of scenarios ("What if?")

It is an efficient simulation tool. It allows you to test different strategies before taking action on the ground.

- Scenario A: Priority to industrial development.
- Scenario B: Priority to the conservation of wetlands.

- The GIS generates two different maps, allowing elected officials to visualize the spatial impact of their policy choices.

4. The reduction of subjectivity

Using mathematical models (such as the method of AHP - Process Analytical Hierarchy), the decision tool provides a scientific basis and objective choices that are often emotional or political. This facilitates the dialogue between the actors and justifies the decisions to the public.

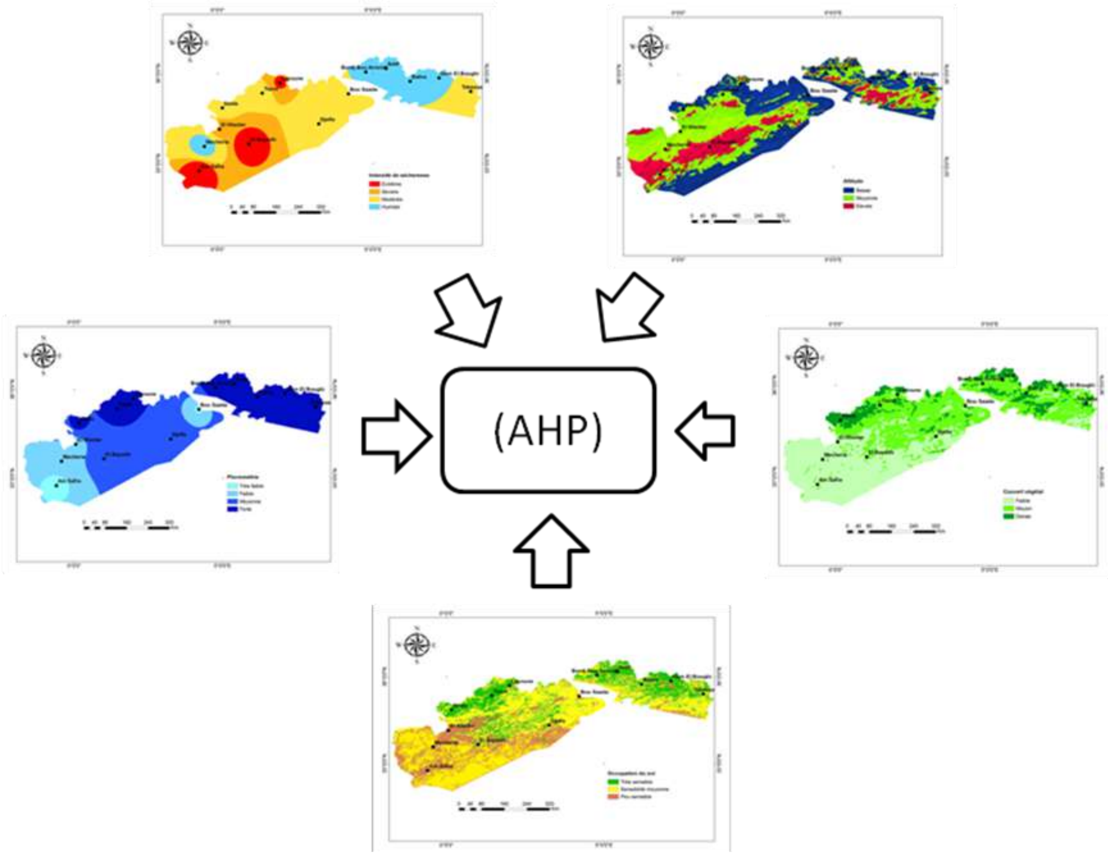

Figure 24: Example of the decision.

Chapter VI

REMOTE SENSING

1. Definition

Remote sensing is a technique of image acquisition, which allows us to obtain the digital information on the earth's surface, without physical contact with it.

2. Types of remote sensing

2.1. Remote sensing passive - Optical

The satellite receives the signal (luminance) of the objects on the surface of the Earth, following a specific wavelength. This is the principle of the human eye (Fig. 25).

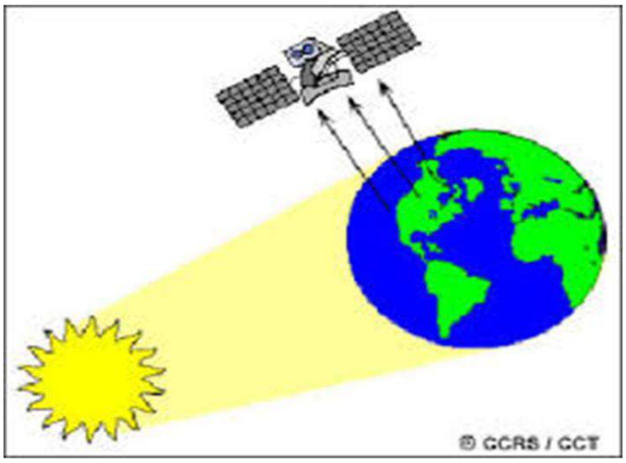

Figure 25: Principle of remote sensing

2.2. Remote sensing active - Radar

In this type, the satellite sends a signal and receiving the echo of the objects of the earth's surface (Fig. 26).

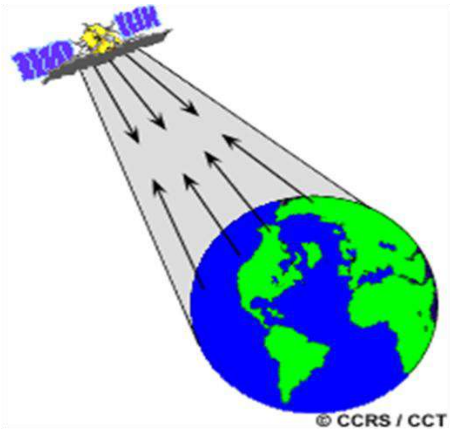

Figure 26: Principle of the active remote sensing.

2.3. Advantages of the active remote sensing

- Measurement in all weather conditions;
- Day and night;
- Penetration into the surface;
- Geometry is fairly accurate;
- The water content in the clouds;
- Movement of tectonic plates;
- Topography of surfaces;
- Topography of the oceans;
- The average level of the seas and oceans;
- Melting of the ice.

3. The electromagnetic spectrum (Fig. 27)

The electromagnetic spectrum is the foundation physics of remote sensing, because it includes all of the radiation (photons), classified by their wavelength (λ) or frequency. In remote sensing, it operates mainly three major regions of this spectrum : the visible (blue, green, red), which corresponds to what the human eye perceives ; the infrared (near -, mid-and thermal), which is essential to analyze the state of the vegetation, or the warmth of surfaces ; and microwaves, used for RADAR systems to image the Earth through the clouds or darkness. Every object on the earth's surface (water, soil, plant) has a "spectral signature" unique", that is to say that it reflects or emits the energy of the specific way in certain wavelengths. It is the analysis of these variations of energy captured by the satellite-based sensors that can identify and map to distance on the nature and status of earth's resources

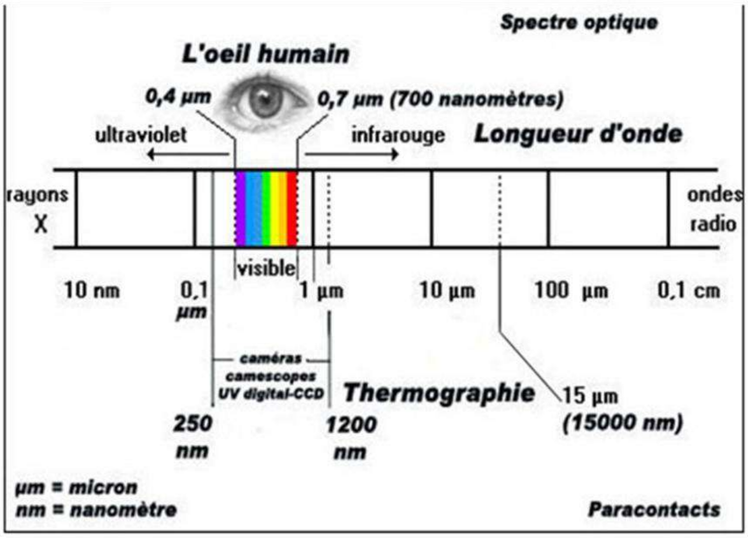

Figure 27: The electromagnetic spectrum.

4. Digital image

The principle of digital image that is the Pixel (Fig. 28). It can be defined by

- Line number;
- Column number;
- Value radiometric (digital account);
- Dimensions (spatial resolution, geometric).

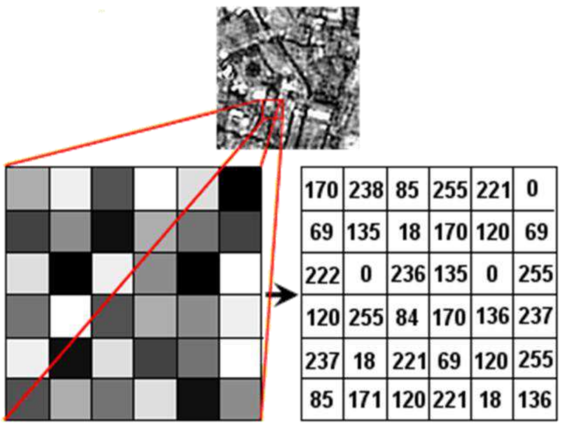

Figure 28: The Pixel in a digital image.

5. The orbits

There are three types of orbits (Fig. 29).

5.1. The geostationary orbits

- 36000 km altitude/surface to the Earth;
- Angular velocity of the Earth;
- Stationary/Earth;
- equatorial plane;
- Meteorology, telecommunications, environment,...

5.2. The polar orbits

- Meteorology (NOAA, Meteor,,...);
- Earth Observation (Spot,...)
- Telecommunications (Eutelsat,...);
- Topography and navigation (GPS, GLONAS,..).

5.3. The heliosynchronous orbits

- Moves to the same solar local time;
- Environmental studies (Landsat,...);
- Earth Observation (Alsat 1,2,...).

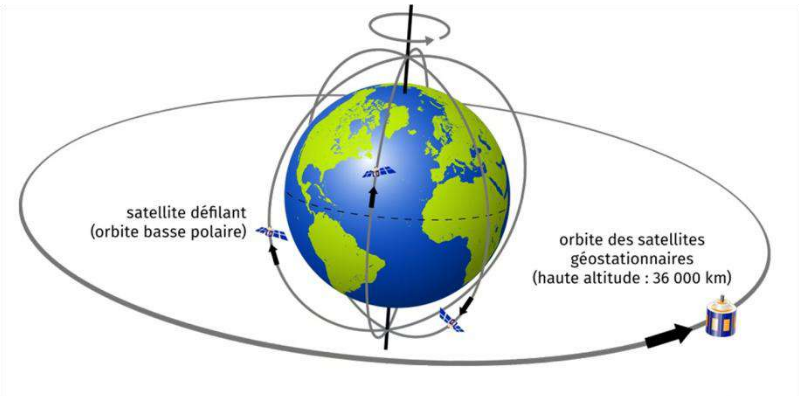

Figure 29: The different types of orbits.

6. Different resolutions

The quality and precision of a satellite image depend on four types of resolutions that define the performance of the sensor:

- Spatial resolution: It is the size of the smallest element in the soil (the pixel) that are detectable by the sensor. For example, a resolution of 10 m means that each pixel represents an area of 10x10 meters. The more it is fine (ex: 30 cm), more details are visible.
- Resolution radiometric: It refers to the sensitivity of the sensor to distinguish small changes in electromagnetic energy. It is expressed in bits (e.g. 8-bit = 256 levels of grayscale, 12-bit = 4096). The more it is, the higher the image contains shades, how to differentiate between objects with the reflectances close.
- Digital resolution: Often related to the resolution radiometric, it concerns the ability of the system to encode information in the form of numerical values (Digital Numbers) after conversion of the analog signal. It determines the accuracy of the quantification of the intensity of light received by the sensor.
- Temporal resolution : It is the frequency of passage of the satellite over the same point (the time of revisits). It varies from a few hours (weather permitting) to several days (Sentinel, Landsat). It is crucial for the monitoring of rapid changes, such as the flood or the growth of crops.

7. Products derived from satellite image

- Spatiocartes;
- Altitude, slope, aspect, aspects;
- Environmental monitoring;
- Meteorology/climatology;
- Geology;
- Public works and civil engineering;
- The maps and Plans of urban development;
- Installation of dams and river systems;
- Security and defence;
- Thematic maps (temperature, humidity, ...);

- Other.

8. Historical overview on the GPS system

- The first satellite was launched in 1978.
- In 1995, the deployment of 24 operational satellites (plus-4 in reserve) has been completed;
- In 2000, Bill Clinton authorizes an unrestricted GPS signals;
- Russia: GLONASS, 1980;
- China: Beidou, initiated in 2000;
- The european union: Galileo, expected in 2020.

8.1. Presentation

The positioning satellite (GPS), is a system put in place by the department of Defense of the United States for military purposes from 1973, the system with 24 satellites is fully operational in 1995 and opens the calendar in 2000.

The signals transmitted by the satellites can be freely received and operated by anyone. The user, whether on land, on sea or in the air, can know its position at any time and in any place on the surface of the Earth.

8.2. Applications

- Navigation maritime, land and air;
- Location of fleets commercial (boats, aircraft, trucks,..);
- Tracking and tracing of course;
- Topography and geodesy;
- study of the atmosphere and the environment;
- Defence;
- Movement of tectonic plates;
- Smartphone Applications;
- Etc.

8.3. Components

The GPS consists of three groups of elements (called segments) (Fig. 30):

The architecture of the satellite-based positioning systems (GNSS) such as GPS or Galileo, depends on the cooperation of three segments fundamental to ensure the accuracy of the geo-location :

- The space Segment consists of a constellation of satellites in orbit around the Earth (usually about 20 000 km altitude). Their main role is to continually broadcast radio signals containing the exact time of the show (thanks to the atomic clocks embedded) and their exact position in space (the ephemeris).
- The control Segment (or ground segment) : This is the "brain" of the system, consisting of stations monitoring and control spread over the globe. These stations monitor the trajectory of the satellite, check the synchronization of their clocks and transmit regular updates to correct any drift in orbit, and guaranteeing the reliability of the data disseminated.
- The user Segment : It contains the set of receivers (smartphones, enclosures, GPS, agricultural equipment or air navigation) that receives signals from at least four satellites simultaneously. By calculating the time taken by each signal to reach the receiver to deduce its exact position (a, y, z) and time by trilateration.

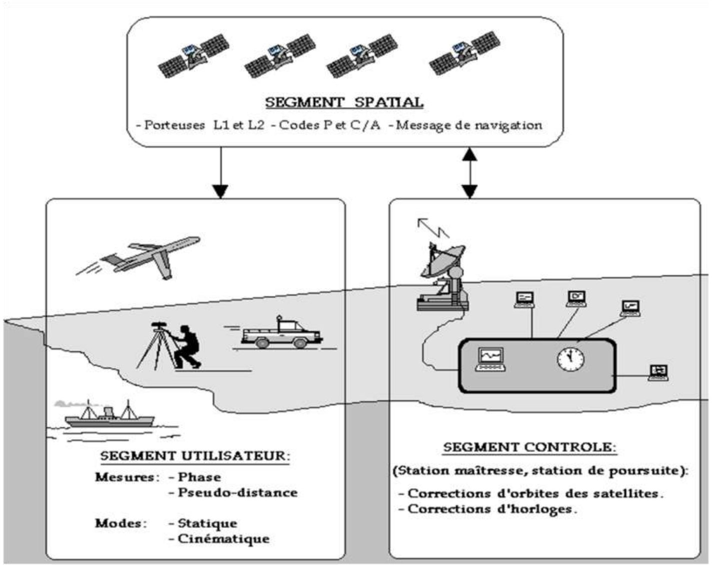

Figure 30: The three components of The GPS.

8.4. Principle of operation

The GPS works through the calculation of the distance between a GPS receiver from several satellites. The information necessary for the calculation of the position of the satellites being regularly sent to the receiver, it can, thanks to the knowledge of the distance which separates it from satellites, to know the details.

8.5. Positioning methods

8.5.1. Absolute positioning

The absolute positioning (or positioning by isolated point) is the simplest method and the most common localization GNSS, used by the majority of smartphones and enclosures navigation. It is to determine the coordinates (X,Y,Z) of a single receptor by measuring simultaneously the distance to at least four satellites are visible. This calculation is based on the principle of trilateration : the receiver measures the travel time of the signal transmitted by each satellite to deduce its distance (pseudo-distance). Although this method is autonomous and fast, its accuracy is limited (usually between 5 and 15 meters) due to various sources of errors are unavoidable, such as the crossing of theionosphere, the multi-path signals in the city or the slight offset of the clocks of the receivers general public. The measurements are made with a receiver isolated. This type of positioning is not very precise (± 50 cm to 10 m) (Fig. 31).

Figure 31: Tools of absolute positioning.

8.5.2. Relative positioning

The positioning relative (or differential) is a precision engineering that allows to achieve an accuracy of centimeter by using both receivers working at the same time. Unlike in the absolute mode, a receiver "pivot" is placed on a point whose coordinates is well-known (terminal geodesic), while the second receiver, said "mobile", and performs field surveys. The principle is based on the correction of common errors: as the two devices are similar, they are subject to the same atmospheric disturbances and errors clocks satellite. The database calculates these errors in real time and transmits corrections to the mobile (via radio or network 4G/5G), which allows you to cancel the inaccuracies of the signal. This method, often referred to as RTK (*Real Time Kinematic*), is the reference tool for surveying, precision agriculture and guidance of unmanned aerial vehicles (Fig. 32).

Figure 32: The tools of relative positioning.

9. Measurement technique

The techniques of GNSS measurement will vary depending on the duration of observation and the accuracy required, adapting to the specific needs of surveyors:

- **Static Mode**: This is the most accurate method (millimeter). Two fixed receivers record data over long periods of time (from 1 hour to several days). It is used to create networks of geodetic reference or measure the tectonic movements.
- **Static Mode fast**: optimized Version of the static, it reduces the observation time of approximately 5 to 20 minutes, thanks to the use of multiple frequencies. It is ideal for the densification of points of canvas with a centimetric precision.

- **Cinematic Mode**: The mobile receiver moves continuously after an initialization phase to the stop. This technique allows the lifting of paths or compartmental boundaries quickly, but it requires you to keep a constant contact with the satellites in order not to lose the initialization.
- **RTK (real time Kinematic)**: Often confused with the pseudo-kinematic, it allows obtaining centimetre-level accuracy instant. A base transmits corrections by radio or the internet to the mobile. The Pseudo-kinematic, meanwhile, is to occupy twice the same point, at an interval of time (approximately 1 hour) to recreate the geometry of the satellites is different and validate the measure without a radio link.

Chapter V

EXAMPLES OF THE APPLICATION OF GIS AND REMOTE SENSING IN THE FIELD OF WATER

1. Definition

This is the final phase and aesthetic of the project. Where are the details on the result obtained, in terms of the skin map and the related information.

2. Elements of the edition map

2.1. Title: the label of the card (Fig. 33).

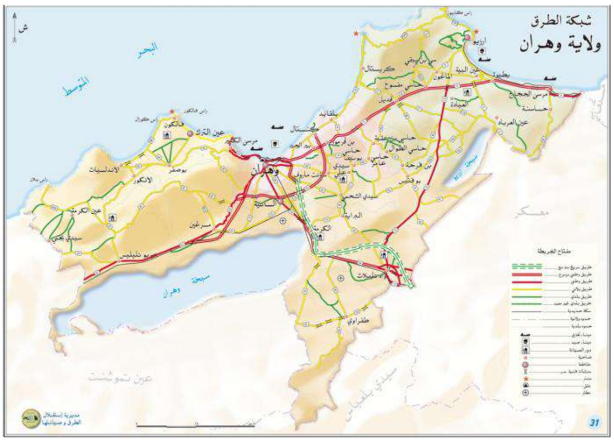

Figure 33: The title.

2.2. The legend: the key of the map (Fig. 34).

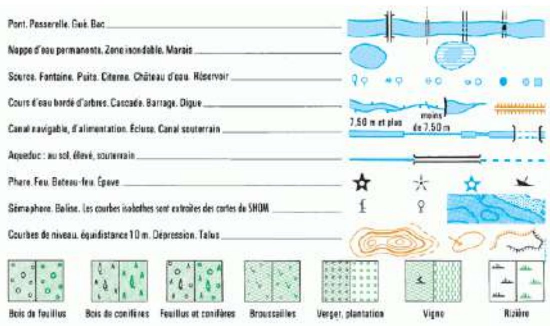

Figure 34: The legend.

2.3. Scales: numerical and graphical (Fig. 35)

1/1000, 1/2500, 1/25.000, 1/1.000.000

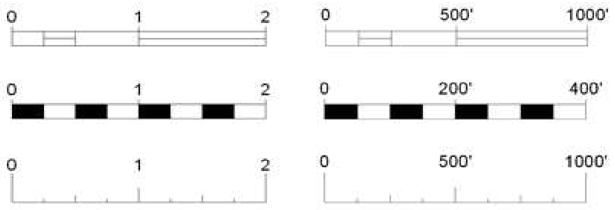

Figure 35: The graphic scale.

2.4. The orientation of the map (Fig. 36)

- The magnetic north;
- The geographic north;
- The north map.

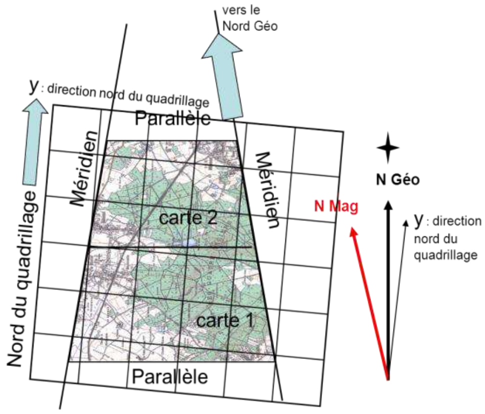

Figure 36: Map orientations.

2.5. The North arrow (Fig. 37)

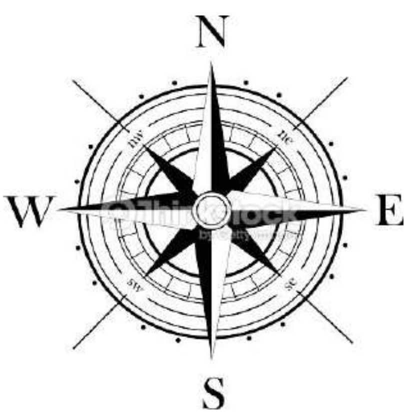

Figure 37: The North arrow.

2.6. The Datum

- WGS84 COORDINATES: UTM – WGS84
- North Sahara 1959: UTM – Clarke 1880
- ......

2.7. Grid – grid system (Fig. 38)

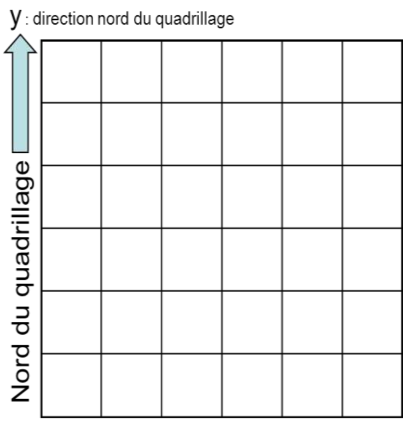

Figure 38: The grid.

2.7. Producer map – Copyright - Date

- INCT – National Institute of Cartography and remote Sensing
- ASAL – Agency Space Algerian

2.8. Source of the map

- Topographic survey;
- Satellite Image – Ortho-image.
- Radar – Lidar;
- Aerial photography – Orthophotoplan;
- Aerial photography – Restitution;
- GPS;
- ....

2.9. Visible natural items

- Orography;
- Forests;
- Wadis;
- Lakes;
- .....

2.10. Non-visible natural items

- Level curves;
- The shading;
- Points listed;
- .....

2.11. Visible anthropogenic items

- Agglomerations;
- Roads;
- Bridges;
- Airports;
- .....

2.12. Non-visible anthropogenic items

- Administrative boundaries;
- Statistics;
- Grid;
- Geodetic system;
- .....

2.13. The conventional signs (Fig. 39)

Figure 39: A few symbols.

3. Examples of the application of GIS and remote Sensing in the field of water

The integration of GIS and remote sensing has revolutionized the management of water resources by providing the ability to analyze the global and accurate. Remote sensing allows, via optical sensors and radar (such as Sentinel-2 or Landsat), to map the extent of the surfaces in water, to monitor the melting of the snow, or to estimate the soil moisture by thermal imaging. These data, once integrated in a GIS to model watersheds, to simulate scenarios of flooding due to Numerical Models (DEM) and to identify the recharge areas of the aquifers. By combining satellite data with the layers of occupation of the soil and water systems, managers can monitor the quality of the water (detection of eutrophication), optimize agricultural irrigation and planning for the protection of wetlands in the face of climate change.

3.1. Case of flooding

Let's explore the case of the mapping of flood-prone areas, since it is one of the areas where the synergy between GIS and remote sensing is the most spectacular for the public safety.

The process generally takes place in three key steps:

- Follow-up of the event by remote sensing: During a flood, the satellite Radar (SAR) as Sentinel-1 ESA is preferred because they can "see" through clouds and darkness. The water appears black on the radar images, which allows you to accurately extract the envelope of the flooded area in real-time.

- Modeling in GIS: We meet this envelope with a Digital Terrain Model (DTM) of high precision. By combining the range of observed water and altimetry, the GIS calculates the height of the water at each point, and identifies the areas of the basins where water may stagnate.
- Impact analysis (Crossover): The GIS overlays then the layer of the flood, with the layers of issues: housing, critical infrastructure (hospitals, power plants), and road networks. This allows you to instantly generate a list of buildings to be evacuated and roads were cut off.

3.2. The case of the pollution of lakes

To monitor the pollution of a lake (as eutrophication, or the presence of sediment), we use the optical remote sensing based on the reflectance properties of water. Here is a protocol technique using data from Sentinel-2 (ESA) and QGIS.

1. Acquisition and pre-processing

- Data: Download images Sentinel-2 L2A (already corrected the atmosphere).
- Masking: Use the tool Semic-Automatic Classification Plugin (SCP) to isolate only the surface water of the lake and eliminate the pixels of earth or clouds.

2. Calculation of the indices of pollution

The GIS allows you to apply mathematical formulas in the spectral bands to highlight the pollutants:

- Index of Chlorophyll (NDCI): To detect the proliferation of algae (eutrophication).

Formula: (B5 - B4) / (B5 + B4) (Band Red-Edge and Red).

- Turbidity index (NDTI): To measure the clarity of the water and the presence of sediment in suspension.

Formula: (B4 - B3) / (B4 + B3) (Bands of Red and Green).

3. Spatial analysis (GIS)

- Reclassification: Turn the results into severity classes (ex: Pollution, Low, Moderate, Critical) with the tool Reclassified by the table.
- The junction with the river Basin: Overlay the map of pollution with layers of land use (agriculture, industry).
- Objective: to test whether areas of high concentration of chlorophyll are located at the mouth of rivers flowing through agricultural areas intensive.

4. Time Tracking

Use the tool to Temporal Controller QGIS to load a series of images over several months. This helps to identify if the pollution is accidental or seasonal (related to land application of agricultural, for example).

3.3. The case of choice of site: installation of a dam of water

The implementation of a dam is a complex project that requires meeting the criteria of topography, geology, and security. The technical protocol is structured into four key phases:

3.3.1. Topographic analysis and choice of the Lock (MNT)

The objective is to identify the "Lock" (the place the narrow end of the valley) and calculate the storage capacity.

- Data: Use a DEM of high-resolution (type SRTM or ALOS PALSAR).
- Action GIS: Use the tool Profile through to find the section of the narrowest and most profound.
- Reservoir Simulation: Use the Flood Fill tool (as seen above) to delineate the influence of future man-made lake, according to the different heights of the dyke and calculate the volume of water stored using the tool Volume of a raster surface.

3.3.2. Study of the watershed and Hydrology

It is necessary to ensure that the water supply is sufficient and that the dam does ensablera not too fast.

- Action GIS: Use the tools of Hydrology (Fill sinks > Flow Management > Flow Accumulation) to delineate the watershed feeding the dam.
- Remote sensing: Analyze the land cover (Corine Land Cover), via images Sentinel-2. A strong deforestation upstream will signal a high risk of silting of the dam by soil erosion.

3.3.3. Evaluation and geological risks

The site should be stable to support the weight of the structure and the sealing of the tank must be guaranteed.

- The intersection of layers: Layer the geological map (nature of the rocks) with a layer of lineaments/faults extracted by remote sensing (imaging radar Sentinel-1 to recognize the tectonic structures).
- Exclusion: Use the tool; delete to exclude the areas at risk of landslides or the permeability is too high (the limestone rocks cracked).

3.3.4. Impact analysis and Decision-Making (AMC)

Finally, use the multi-criteria Analysis to validate the final site.

- Weighting : Give a score to each zone on the basis of :
    - The vicinity of the beneficiaries (urban/agricultural areas).
    - Minimal Impact on the populations (the number of buildings to move through OpenStreetMap).
    - Low environmental impact (absence of protected areas).
- Result : A Skill Card final designating the optimal location.

3.4. Case of Sewerage networks

The design of a Supply network Drinking Water (EPA) and Sanitation requires surgical precision to ensure gravity flow (for sanitation) and pressure (for EPA). The technical protocol is as follows:

1. Acquisition of the "Background" (remote Sensing)

Before any installation of pipes, it is necessary to a perfect knowledge of the terrain and the built environment.

- Data : Imaging very high resolution (e.g. Pleiades or statements by Drone) to identify the obstacles to the ground.
- Topography: Generation of a DEM (Digital elevation Model) by photogrammetry or LiDAR to obtain the level curves of every 50 cm. This is crucial for the consolidation in order to respect the natural slope.

2. Modeling of the application and the load (GIS)

The network must be sized according to the needs of populations.

- Coat Rack : Import the data from 'OpenStreetMap' or the land registry to locate the consumers.
- Spatial analysis: Use of a Buffer Zone (Buffer) around the future reservoirs to define the areas of pressure.
- Spatial join: Combine the data of population to the sections of the network to estimate the required flow rate (ASP) or the volumes of wastewater to be collected.

3. Path and network analysis (Route calculation)

It is here that the tool of Network Analysis comes in.

- AEP Network (under pressure): The GIS calculates the shortest path between the castle of water and subscribers, while avoiding areas of rocky ground, or unstable (identified by the intersection of geological.
- Sanitation Network (gravity): Use the tools of hydrology, GIS (Flow Direction) to ensure that the network follows the slope. The GIS identifies automatically the low points where you want to install the positions of recovery if the natural gradient is insufficient.

4. Integration Management System (CMMS)

Once the network is designed, it becomes a database alive.

- Attributes: Each section stores data key: diameter, material (PVC, HDPE), date of installation, and depth.

- Topology: The rules of connectivity to ensure that no valve is isolated and that the stream flows logically from the source to the outlets (or sewage treatment plants).

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