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وزارة التعليم العالي و البحث العلمي

Democratic and Popular Republic of Algeria
Ministry of Higher Education and Scientific Research

Ahmed Zabana Relizane University
Faculty of Natural and Life science
Department of Ecology and environment

جامعة أحمد زبانة-غليزان
Ahmed Zabana Relizane University

COURSE HANDOUT

Intended for 2 nd year Master Ecology (LMD).

Title:

Ecological Mapping

Developed by:

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The preface :

The scientific concept of ecological continuity is a tool developed in response to the international challenge of biodiversity loss. It is a complementary approach to that of protected areas, taking into account the movement of species throughout their lives. In Algeria, this concept is known as the "Trame verte et bleue", which becomes a land-use planning tool.

The ecological continuities (or ecological networks) that make up the green and blue framework include biodiversity reservoirs and ecological corridors.

Their identification and delimitation must enable plant and animal species, the preservation or restoration of which is a national or regional issue, to move around to ensure their life cycle and promote their ability to adapt. their life cycles and their ability to adapt.

The notion of continuum is used in certain ecological network design methods. A continuum is associated with a subframe. It represents a set of contiguous environments, the support environments of this subnetwork, within which the group of species associated with the subnetwork can be present or move (without prejudging their actual presence or possible obstacles). The continuum thus corresponds to a habitat approach to continuity. This term will be used more specifically for flora.

With a view to identifying and mapping a national green and blue network, regional initiatives have sought to identify the species and natural environments for which the preservation of ecological continuity is a prerequisite for the existence and maintenance of diversity. The coherence of the regional approaches is ensured by taking into account the issues and zonings reflected in the criteria presented in the framework document accompanying the national guidelines.

National guidelines for the preservation and restoration of ecological continuityWith a view to identifying and mapping a national green and blue network, regional initiatives have sought to identify the species and natural environments for which the preservation of ecological continuity is a prerequisite for the existence and maintenance of diversity. The coherence of the regional approaches is ensured by taking into account the issues and zonings reflected in the criteria presented in the framework document accompanying the national guidelines.

National guidelines for the preservation and restoration of ecological continuity

The national coherence of the Green and Blue Network is ensured in particular by taking into account, in regional ecological coherence plans, issues relating to :

- certain protected or inventoried areas (taking into account protection or knowledge zones) ;

- certain species (taking into account the connectivity needs of species sensitive to fragmentation, forming regional species lists to ensure national national consistency);

- certain habitats (taking into account the connectivity needs of habitats sensitive to fragmentation, forming national lists of habitats responsible for ensuring the national coherence of the TVB);

- ecological continuities of national importance.

It was therefore necessary, within the framework of the present study, to determine a list of habitats and a list of species to be used for the local coherence of ecological continuities and as a basis for the identification and mapping of BTV components. As these lists do not fall within the territorial framework of national coherence species and habitats, we propose to call them continuity species and habitats (or "ecological continuity indicator species").

At the end of this course, the learner will be able to :

-Understand the uses of cartography

-Use cartographic tools

-Create derived maps

- Interpret maps

-Analyse maps

-Programming an algorithm

To be able to follow this course successfully, you must have :

- An ability to determine the components of a map
- The ability to create a database

List of figures

Table of contents

Chapter I

"Ecological cartography Introduction"

I. Ecological Mapping Introduction

I.1. Typological units of vegetation

Mapping is based on the principles of phytosociology, in particular landscape phytosociology or symphytosociology.

We distinguish four nested typological vegetation units (Figure 1), ranging from plant communities to geoseries :

1-Vegetation geo-series: catenal (geoserial individual)unit of the series of a unit that is fairly homogeneous with respect to the substrate and the climate.

2-Vegetation series: a dynamic unit that groups together dynamically related plant communities within a homogeneous biotope unit.

3-Landscape cell: part of a vegetation series dominated by a plant community that gives the unit its physiognomy, associated with other plant communities of lesser importance.

4- Vegetation community: a vegetation concrete, of homogeneous floristic composition and structure, expressed in a satation of homogeneous ecology for the different parapeters of the environment.

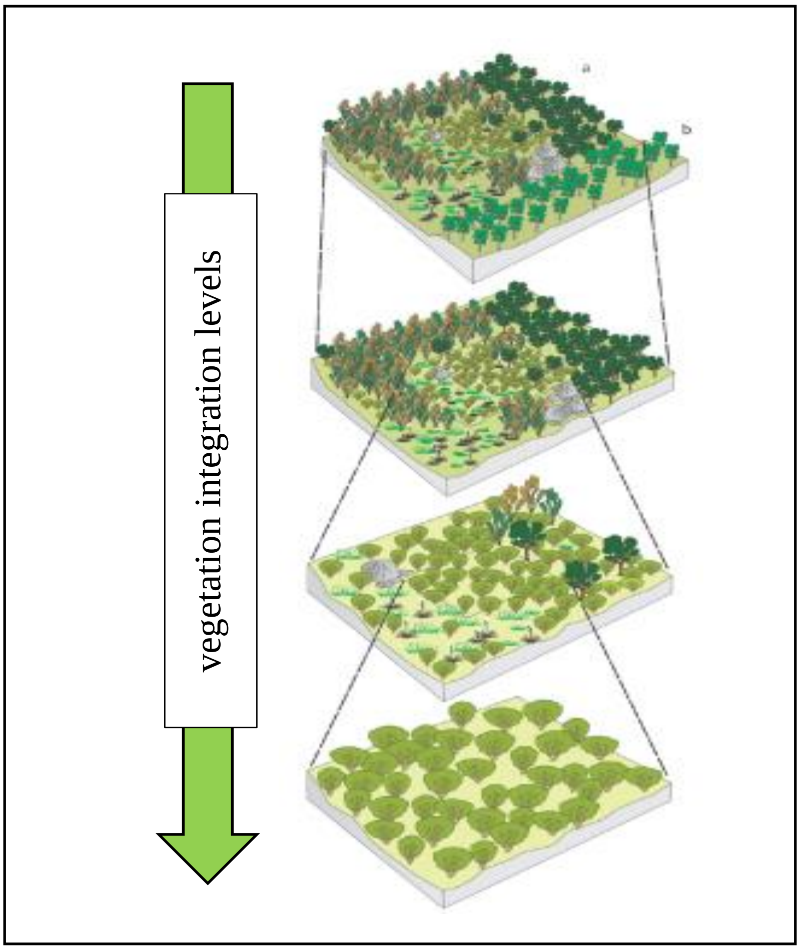

Figure 1. A nested representation of the different levels of integration of the vegetation (Lazare 2009; modified by Aouadj, 2024).

I.2. Cartographic funds

Vegetation mapping is based on a physiognomy map and an ecological envelope map. These two maps have undergone extensive technical and methodological development.

They provide the cartographic (physiognomic and ecological) background for the mapping approach presented elsewhere. They allow us to propose a spatial division on the basis of physiognomic and ecological criteria, on which the cartographer can draw and which guarantees a homogeneous segmentation of the entire territory.

I.3. The physiognomy map

The aim of the physiognomic map is to achieve a geographical division of the environments on the basis of a physiognomic approach to the vegetation (shape of the plants, dendrometry, etc.). To this end, it can be divided into three main stages (Aouadj et al., 2020a-d ; Aouadj, 2021):

1- Automatically "segmenting" infrared aerial images into spectrally homogeneous zones using specialized software;

2- The processing of this segmentation with a geometric simplification and the creation of specific masks on the basis of different sources of data;

3-The qualification of the segments for the open environment through the automatic classification of the satellite images and the spatial analysis.

I.4. The map of ecological envelopes

The goal of the ecological envelope map is the identification of distinct ecological entities that can be linked to phytosociological concepts. These ecological units are distinguished by means of a so-called unsupervised approach, i.e. they are not guided by field data. Their delimitation is obtained on the basis of a set of abiotic parameters (DTM, moisture index, bioclimatic indices, etc.) using an ascending hierarchical classification (AHC) method (Aouadj et al., 2020e-h).

The parameters are modeled as raster tiles with a resolution of 20-25 meters. The idea is to create pixel clusters based on a distance calculated from all the parameters. Once represented in geographic space, these clusters delimit polygons within which abiotic conditions are relatively homogeneous and different from those of adjacent polygons. These envelopes are then identified as spaces of succession of phytosociological series and geoseries, defined according to the degree of similarity of the pixels that constitute them. The territory must be considered in terms of a prior and ecologically relevant division in order to take into account the regionalization of environments (phyto-eco-geographical areas...). There are different types of abiotic parameters :

1-Topographic: They describe relief and morphology in various ways (slopes, topographic index, exposure, landforms, etc.). These parameters are derived from the 25 m Digital Terrain Model (DTM).

2-Climatic: Annual and monthly data on temperature and precipitation are obtained from meteorological databases.

Synthetic indices, also known as bioclimatic indices, are then created by combining these data as appropriate.

3-Geological.

4-Specific: The parameters that are qualified as such are generated in response to a specific thematic or geographic question. Regarding the thematic aspect, we can mention the layer called "Potential Wetlands and Watersheds", which reflects the probability of having wetlands. The Distance to Sea layer, which is calculated in coastal areas to estimate the impact of wind on vegetation, can be used to illustrate the geographic aspect.

II. Classic cartography

II.1. Cartography

Cartography is defined by the International Cartographic Association as follows The art, science, and technology of making maps and studying them as scientific documents and works of art. Geographic documents are representations that show the particularities of a territory and make it possible to locate elements or phenomena that take place, according to Cadène (2004).

In 1966, the Association Cartographique Internationale (ACI) and the Comité Français de Cartographie were founded: "Cartography is the totality of scientific, artistic and technical studies and activities, based on the results of direct operations or on documentation, aimed at the production of maps, plans and other representations, and at their application". The purpose of cartography is the geometric representation of the earth or another planet through the design, preparation, and production of maps.

Cartography is simultaneously a science, an art and a technique. The map, which is its ultimate purpose, tends to come closer to the truth with a certain degree of beauty (Didier & Poidevin, 2007 *in* Aouadj, 2009).

II.2. The map

The map is a pictorial means of communication in so far as the designer has taken into account the laws of visual perception, the separating power of the eye, the contrasts of colors, the contrasts of colors and the typographical rules of writing (Darteyre, 2008 *in* Aouadj, 2009).

According to F. Joly, "a map is a simplified, conventional, flat, geometric, and conventional representation of all or part of the earth's surface in an appropriate degree of similarity, called a scale". A map is a simplified, flat drawing showing the world or a part thereof. It can also be used to represent a concrete or abstract phenomenon on a cartographic background. This representation is made on paper or other support like glass, wood or computer screen. Maps can be drawn by hand or by machine. The distances on the map are always in the same proportion as on the ground (Anson & Ormeling, 2002 *in* Aouadj, 2009).

II.2.1. Map quality

1- Accuracy of the positions of the objects on the ground (for example, the road is not offset).

2- The accuracy and fidelity of the content, which has to be adapted to the terrain (e.g. paved or not paved).

3- Honesty: the information given is trustworthy.

4- Reliability: the card can be depended on (e.g. the accuracy of certain documents).

5- Readability, that is, the clarity of visual perception of content

6- Selectivity, which helps to distinguish between different categories of objects.

7- Clearness.

II.2.2. Map components

- Map scale :

Digital scale: This is the ratio of 1 cm on the map to the actual value in the field. "It is the ratio of a distance measured on the map to the same distance measured on the ground, reduced to horizon. Expressed in two ways:

1cm pour 5 km ; 1/500000

Graphic scale: Straight lines, single or double, divided into equal parts, represented by units chosen in km.

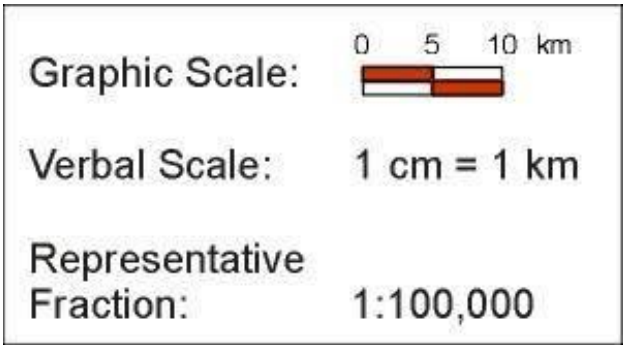

Figure 2. Types of map scale. (www.surveyinggroup.com)

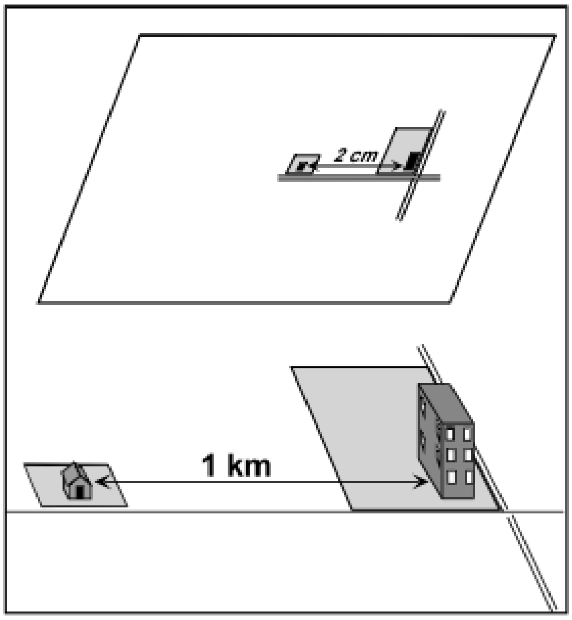

Figure 3. Types of map scale.

- Name and number of the map

The name of the most important city or village on the map.

- A legend

The legend is a description and identification of the symbols on the map. These symbols, called conventional signs, are represented by different colors:

-Blue: represents details and texts related to water: hydrographic network (rivers, wadis), lakes, sea, reservoirs, swamps, water sources...

-Green: represents all natural or cultivated vegetal cover

- Black: Represents

- ✓ anthropogenic elements such as buildings, railways, transport lines, power lines...
- ✓ toponymy (place names),

Coordinates and planimetry (exact heights, coordinates, etc.)

- ✓ Administrative boundaries (states, counties, districts)
- ✓ Bistre: representation of the orography (contour relief)

-Orientation System

Map north, denoted with "y". It is given by the gridded meridians used on the map.

o Geographic North (NG) (or Astronomical North), which is indicated by the edges of the map. By convention, the top of the map always points to NG, south to the bottom, east to the right, and west to the left (see compass rose below).

o Magnetic North (MN), which is indicated by the magnetized needle and which forms an angle (or magnetic declination) with time in relation to the geographic north. geographic north. The value of this deviation at the date of publication of the map is given for the central point of the sheet with its annual decrease in minutes centesimal.

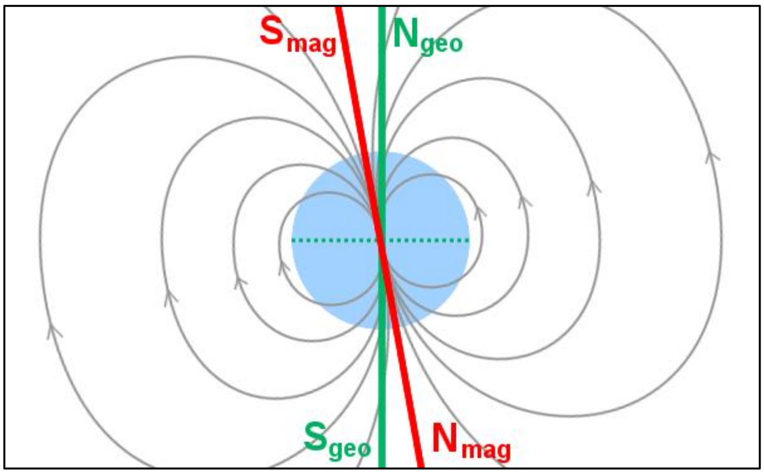

Figure 4. The magnetic poles (red line) and geographic poles (in green) are separated by about ten degrees right now. The earth spins around the geographic poles, but magnetic compasses point to the magnetic poles. (Christopher S. Baird, November 15, 2013).

-Location System

The parameters of the location of a point are as follows

o geographic coordinates or latitude and longitude o rectangular coordinates or map coordinates

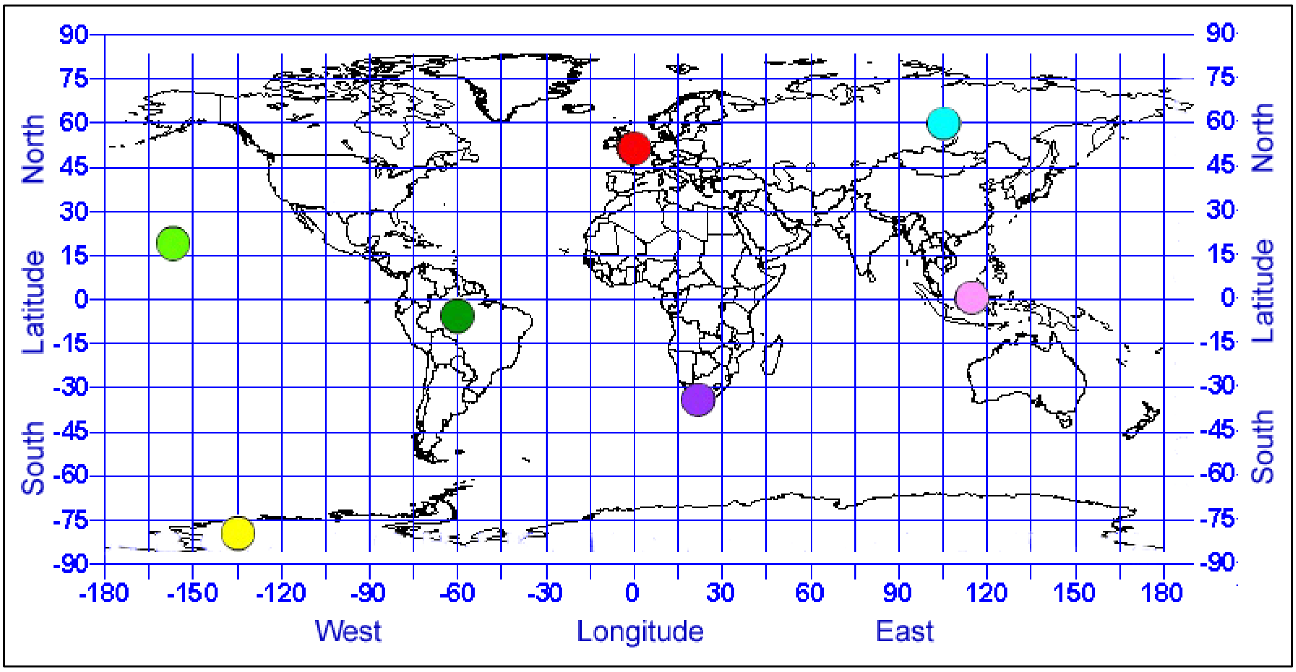

Figure 5. Geographic Grid**.**

- Map projection systems

The Earth is an ellipsoid surface. The mapping of geographic positions from a curved surface to a flat surface requires mathematical calculations called cartographic projection.

Projection of the spherical surface of the globe onto a plane involves a series of transformations which result in deformations: changing angles, changing angles, changing distances, changing distances, changing distances, changing shapes and directions. shapes and directions. There are at least three types of projections: conical, cylindrical, and planar.

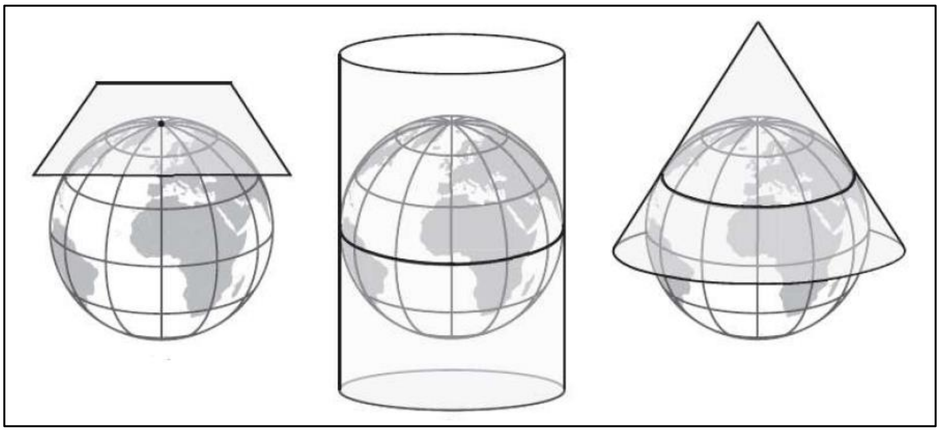

Figure 6. The different types of projection [(1): Polar stereoscopic; (2): Cylindrical; (3): Conical]. (Borden, 2009 *in* Aouadj, 2009)

-Cartographic projections used in Algeria

There are a number of series of IGN maps of Algeria, in a variety of IGN scales:

- ✓ 1 : 25 000 : These maps are in the Mercator Transverse Union (MTU) projection on the Clarke 1880 ellipsoid.
- ✓ 1 : 50 000 : These maps are drawn on the Clarke 1880 ellipsoid, in Bonne projection until 1942, then in Lambert conic projection.

- Lambert projection

This is a conformal, conical projection that was used for the mapping of Algeria at the 1:50,000 scale from 1943 to 1960. To identify planimetric and altimetric details, a red kilometer grid called "Lambert corroyage" delimits a square of 1 km.

Algeria was divided into two zones to minimize deformations (linear changes):

- A projection called "Lambert Nord" which covers northern Algeria.

- A projection called "Lambert Sud" which covers southern Algeria.

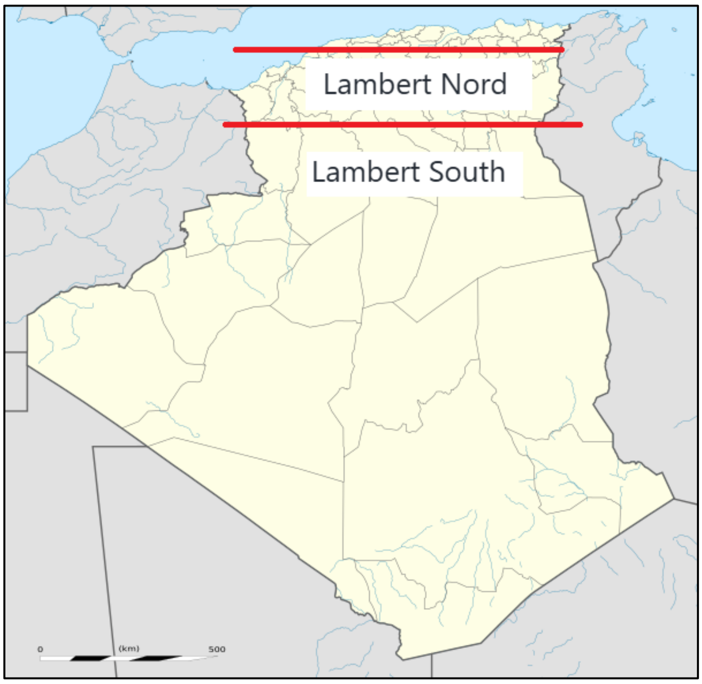

Figure 7. Projection Lambert in Algeria (Aouadj, 2024).

- UTM (Universal Transverse Mercator) map representation

The characteristics of the Mercator projection are as follows

It divides the world into 60 zones (numbered from 1 to 60). Each zone covers 6° of longitude. It is a cylindrical, transversal conformal projection, i.e. it is angular (Darteyre, 2008 *in* Aouadj, 2009).

The rectangular (Cartesian) coordinates are expressed in meters. UTM (Universal Transverse Mercator) is the current planar cartographic representation adopted by Algeria in 2003. Algeria extends from west to east over four zones 29, 30, 31 and 32, i.e. 9° west of the prime meridian and 12° east of the original meridian.

Algeria is divided into 04 zones:

- UTM North zone 29: between 8.67 degrees and 3 degrees west of Greenwich;

- UTM North zone 30: between 3 degrees west and 4 degrees east of Greenwich;
- UTM North Zone 31: between 4 degrees east and 9 degrees east of Greenwich;
- UTM North Zone 32: between 9 degrees east and 12 degrees east of Greenwich.

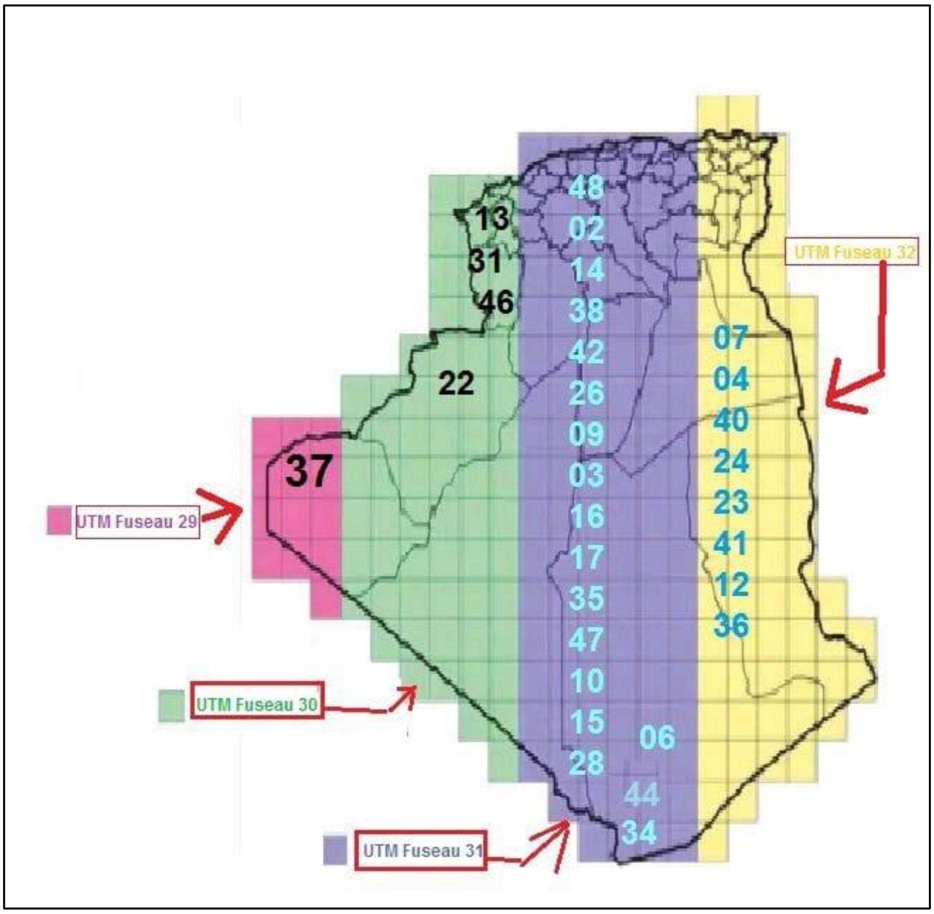

Figure 8. Mercator projection in Algeria.

II.3. The work of the cartographer

The cartographer must first grasp the reality of the terrain in order to list, organize, and arrange the geographic objects-in other words, the quantitative or qualitative data that underlie the map. It is the cartographer who decides which data to keep and which to discard. This choice is often crucial to the readability of the final document. It is also often linked to the map's theme and, where appropriate, the map's readership.

The fields of science that are directly involved are (Nabed, 2020) :

- Astronomy: includes astronomy measurements of stars (Pole Star) from fundamental points on earth, to determine positions and directions on earth.

- Geodesy: The science of the determination of the shape and dimensions of the earth. A set of techniques for determining the planimetric (X, Y) and altimetric (Z) positions of a set of geodetic points and levelling benchmarks.

- Photogrammetry: Techniques for the use of aerial photographs or satellite images for cartographic purposes (orthoimages, digital terrain models, maps, etc.).

II.4. Cartography branches

Cartography has a very wide field of application, with an infinite number of possible subjects. is infinite. To study the phenomena that can be mapped, maps get classified (Anson & Ormeling, 2002 *in* Aouadj 2009). These flat displays can be divided into two main groups:

- ✓ Thematic (Topic) maps, covering large areas at smaller scales, showing only the most important features,
- ✓ Topographic maps, on the other hand, cover only a small area and depict as many details of the terrain as possible at a large scale.

Chapter II

Physical bases of remote sensing

II. Physical bases of remote sensing

II.1. Remote sensing

Remote sensing is a tool used to collect data about an object, phenomenon or area from a distance without having to touch it. The data contained in satellite images in the form of electromagnetic radiation are used for a variety of study topics, especially agronomic or environmental phenomena, such as deforestation, desertification and pollution, and monitoring vegetation and crops and crops, etc.

Remote sensing is the set of tools and methods that are used to measure the electromagnetic waves - electromagnetic waves emitted by objects on the ground.

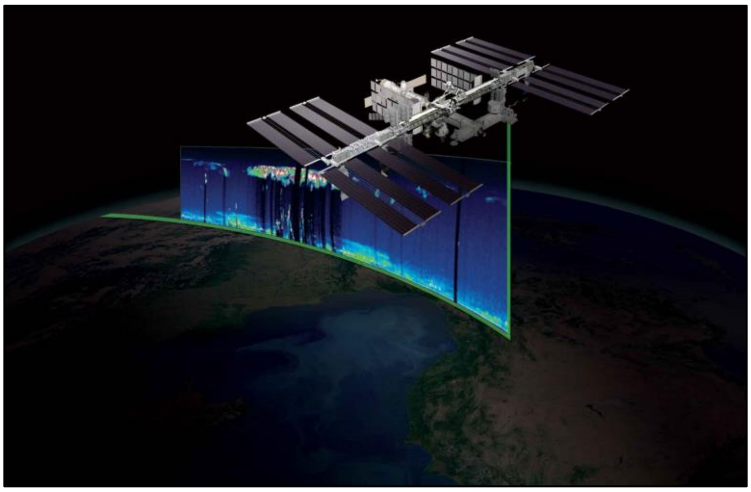

Figure 9. Remote sensing (NASA). (https://www.nasa.gov/directorates/somd/space-communications-navigation-program/remote-sensing/).

Remote sensing instruments are of two primary types—**active** and **passive**. Active sensors, provide their own source of energy to illuminate the objects they observe. An active sensor emits radiation in the direction of the target to be investigated. The sensor then detects and measures the radiation that is reflected or backscattered from the target. Passive sensors, on the other hand, detect natural energy (radiation) that is emitted or reflected by the object or scene being observed. Reflected sunlight is the most common source of radiation measured by passive sensors (NASA) :

- An active sensor is a radar instrument used for measuring signals transmitted by the sensor that were reflected, refracted or scattered by the Earth's surface or its atmosphere. Spaceborne active sensors have a variety of applications related to meteorology and observation of the Earth's surface and atmosphere. For example, precipitation radars measure the radar echo from rainfall to determine the rainfall rate over the Earth's surface; and cloud profile radars measure the radar echo return from clouds to provide a three dimensional profile of cloud reflectivity over the Earth's surface.

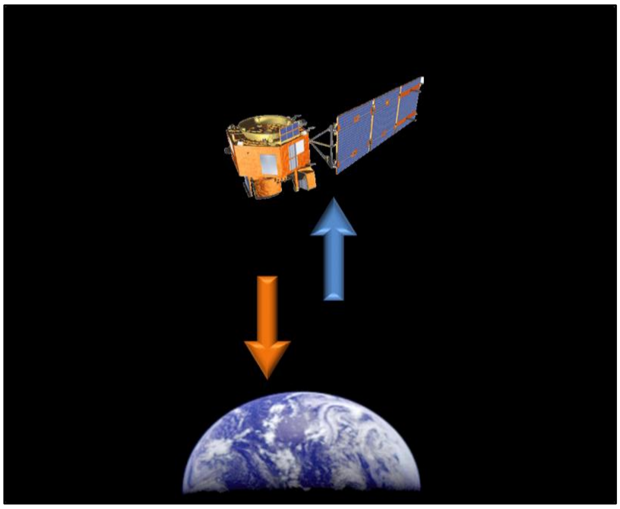

Figure 10. Remote sensing ' active sensor' (NASA). (https://www.nasa.gov/directorates/somd/space-communications-navigation-program/remote-sensing/).

- A passive sensor is a microwave instrument designed to receive and to measure natural emissions produced by constituents of the Earth's surface and its atmosphere. The power measured by passive sensors is a function of the surface composition, physical temperature, surface roughness, and other physical characteristics of the Earth. The frequency bands for passive sensor measurements are determined by fixed physical properties (molecular resonance) of the substance being measured. These frequencies do not change and information cannot be duplicated in other frequency bands.

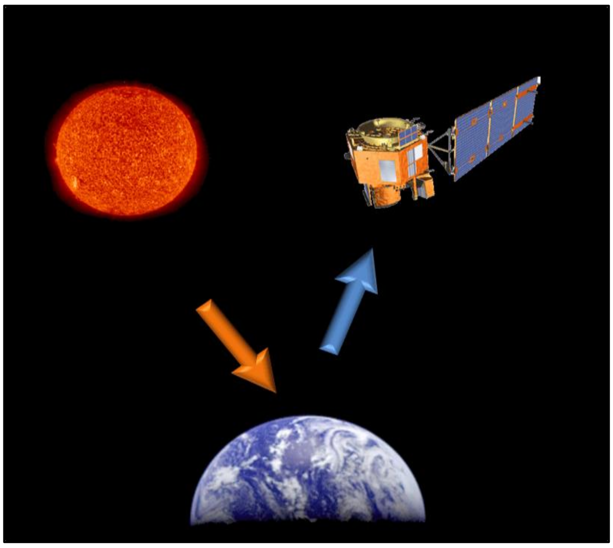

Figure 11. Remote sensing ' passive sensor' (NASA). (https://www.nasa.gov/directorates/somd/space-communications-navigation-program/remote-sensing/).

II.1.1. Aerial photography

Photo-interpretation is the act of examining an aerial photograph in order to recognize an object and make an assessment of its significance. It originated in aerial mapping, which was the primary source of remotely sensed data until the 1970s. Today, the term refers to the visual, computer-assisted or automated interpretation of remotely sensed images.

In a general sense, an aerial photograph is a photograph that is taken from the air.

Aerial photography is used in remote sensing in the visible part of the electromagnetic field and in the near infrared part (0.4µm - 0.8µm) containing the colors purple, blue, red, yellow, orange and green. It can also be panchromatic in black and white. There are two types of black-and-white film: cartographic, sensitive to all visible wavelengths, and detection, which eliminates blue to reduce atmospheric diffusion.

Figure 12. Aerial Photography.
(https://www.canon.com.au/get-inspired/aerial-photography-videography-tips).

-The Different Types of Aerial Photographs :

a- ***Simple black & white panchromatic aerial photographs***: available at low cost throughout the world. They are characterized by a good spatial resolution and are used for a variety of purposes, such as the delineation of different types of agricultural plant diseases and erosion...

b-***Black and White Infrared Aerial Imagery:*** Similar to the above except that their spectral sensitivity can go down to 1µm in the near infrared. They are characterized by their ability to penetrate fog. Water appears dark in these photos. They are used for: the study of agricultural crops, the study of diseased crops, forestry maps and soil moisture maps on agricultural land. agricultural land.

c- ***Single-color aerial photos:*** used in conventional cameras and composed of the three colors red, green and blue (RGB). They are more used in agriculture to differentiate crop types, trees, soil types and plant diseases. trees, soil types and plant diseases.

d- ***Infrared color aerial photos:*** these appear in false color, with vegetation in red and soil in green. They are used to detect agricultural plagues, as diseased plants appear in a different color from healthy ones.

e- ***Multi-spectral aerial photos:*** these are produced by using several cameras to combine different types of aerial photos, combining from 3 to 9 different

different bands. They are used to characterize various crops.

f- ***Hyper-spectral aerial photos:*** produced by combining different types of aerial photos different types of aerial photos, combining information from 10 to several hundred hundreds of different spectral bands.

g- ***Microwave and radar aerial photos:*** these are monochrome, but process radar and microwave radar and microwave wavelengths.

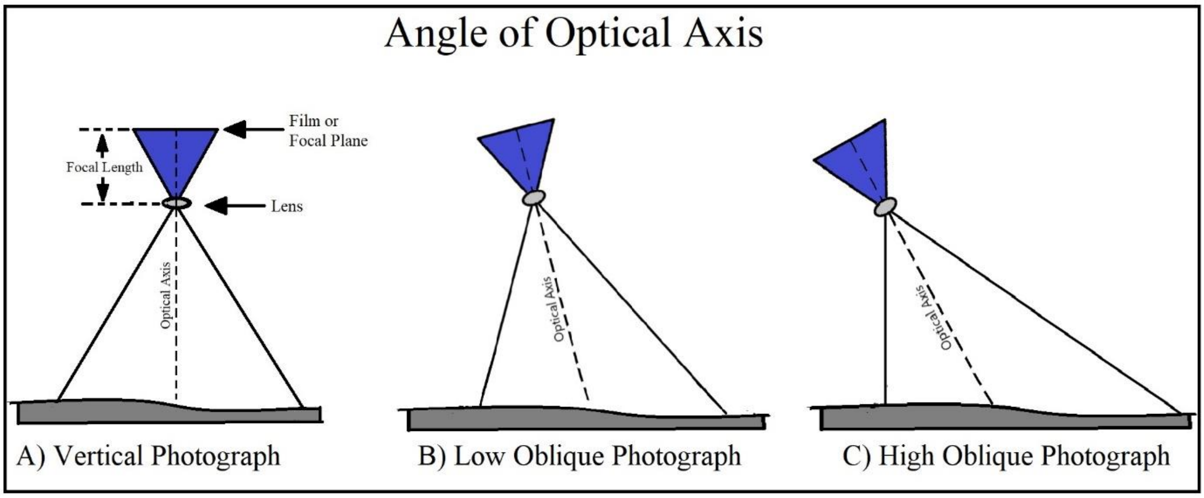

Figure 13. Types of Aerial Photography - Pan Geography. (https://pangeography.com/types-of-aerial-photography/).

-Aerial photography principle and development

Aerial photographs are taken from a vertical position, from a plane or drone, using a special camera. The photos taken by the camera respect the overlapping proportions of each two photos. The area covered by the first photo on the second photo is 60 percent in the longitudinal direction and 20 to 40 percent in the transverse direction.

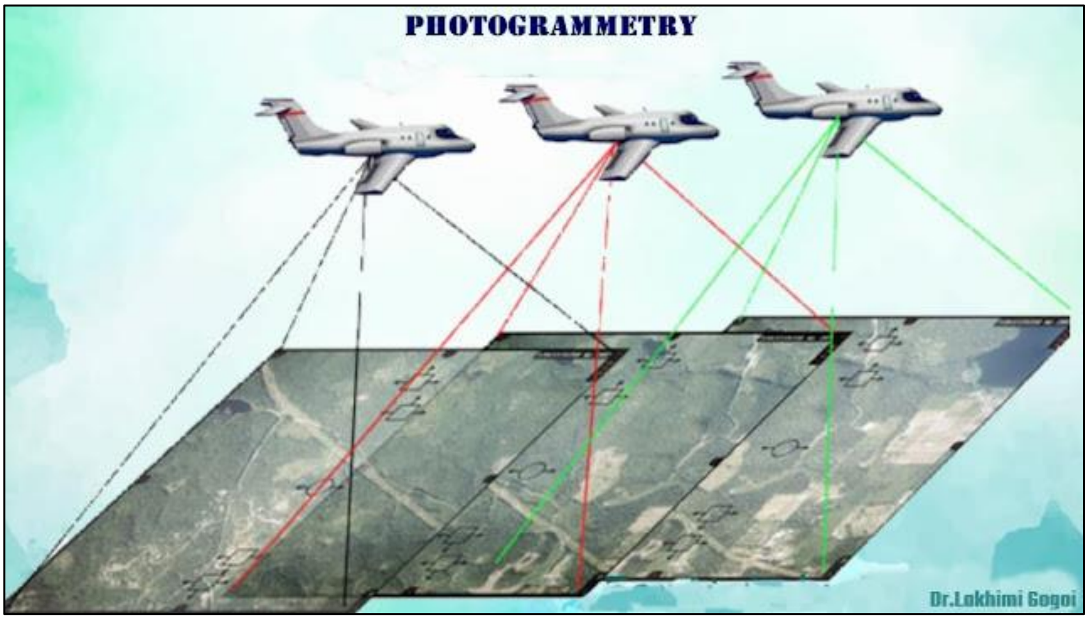

Figure 14. Photo aerial capture principles (https://lakhimi.blogspot.com/2020/05/photogrammetry-and-types-of.html).

The basic principle of photogrammetric is triangulation. "Lines of sight" can be developed from each camera to points on the object by taking photographs from at least two different locations. These "lines of sight" (sometimes referred to as "rays" due to their optical nature) are mathematically intersected to produce the 3-dimensional coordinates of the desired points. Triangulation is also the principle used by theodolites to measure coordinates.

If you are familiar with these instruments, you will find many similarities (and some differences) between photogrammetry and theodolites. Closer to home, triangulation is also the way your two eyes work together to measure distance (called depth perception).

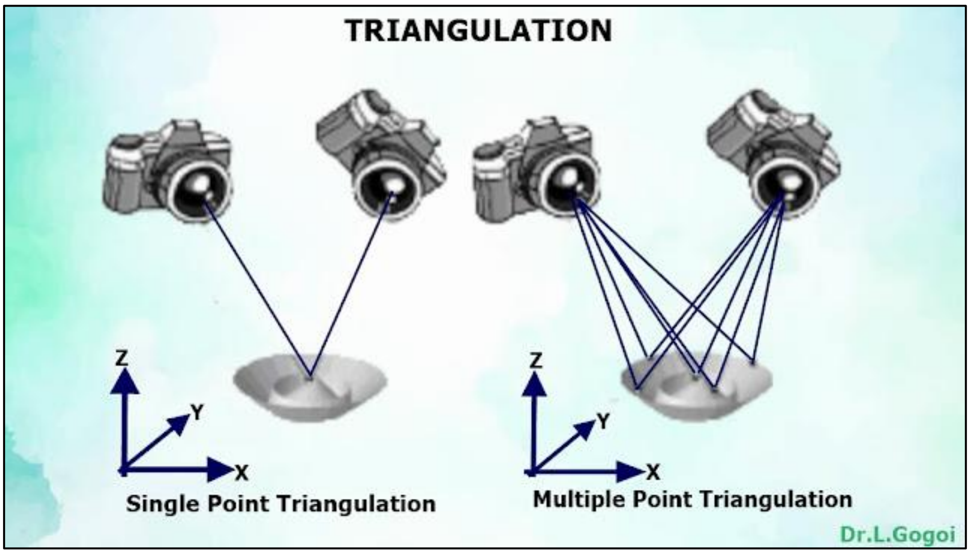

Figure 15. Triangulation. (https://lakhimi.blogspot.com/2020/05/photogrammetry-and-types-of.html).

II.1.2. Advanced remote sensing

After the launch of satellites in 1957, they orbit the surface of the Earth. The use of satellite imagery, which is less expensive than aerial photography, has been on the rise ever since. Satellite imagery is known for its rich spectral information.

II.1.2.1. Remote sensing process

Most remote sensing involves interaction between incident energy and targets. The process of remote sensing with the use of imaging systems consists of the following seven steps:

- ***Energy or Illumination:*** An energy source to illuminate the target is necessarily at the beginning of any remote sensing process.
- ***Radiation and Atmosphere:*** Radiation interacts with the atmosphere as it travels from the energy source to the target. A second interaction occurs between the target and the sensing device.
- ***The interaction with the target surface:*** The energy interacts with the surface of the target once it reaches the target. The nature of this interaction depends on the characteristics of the radiation and the surface properties.
- ***Capturing the Energy Using a Sensor:*** Once the energy has been scattered or emitted by the target, it must be captured at a distance (by a sensor that is not in contact with the target) in order to have a record of the energy.
- ***Sending, Receiving and Processing:*** The energy detected by the sensor is transmitted, often electronically, to a receiver where it is converted into digital or photographic images.
- ***Interpreting and analyzing :*** To extract the desired information about the target, visual and/or digital interpretation of the processed image is required.
- ***Application:*** The last step in the process is to use the information extracted from the image to better understand the target. The image is used to better understand the target, to help us discover new things, or to help solve a particular problem.

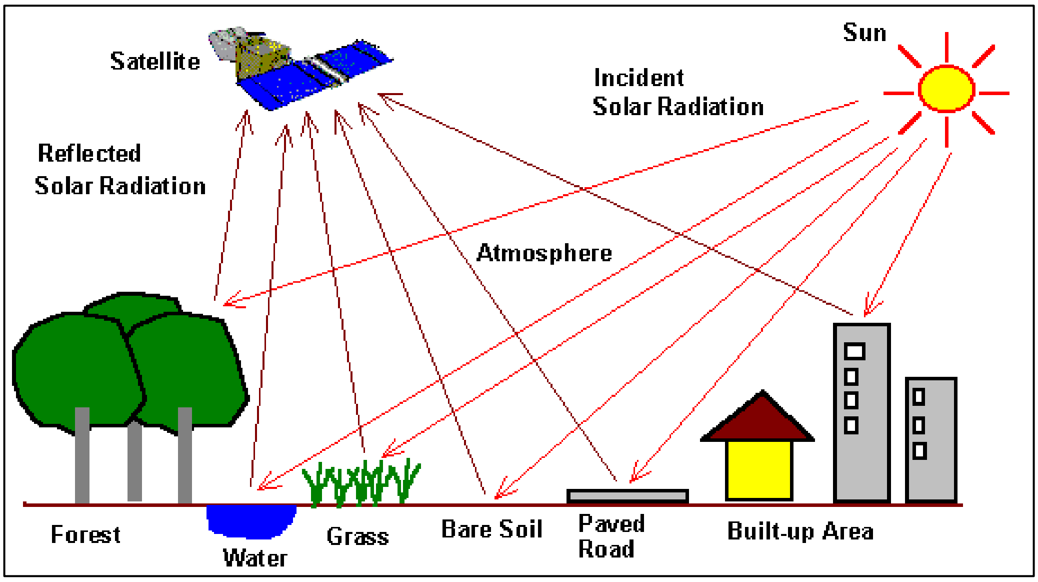

Figure 16. Remote sensing process.
(https://crisp.nus.edu.sg/~research/tutorial/optical.htm).

Remote sensing is therefore the result of the interaction between three fundamental elements: an energy source, a target and a sensor. An energy source, a target and a sensor, and consists in measuring the electromagnetic signal emitted or reflected by a target.

II.1.3. Electromagnetic radiation, interactions between radiation and matter

The biological system by which we see is a remote sensing system. The retina consists of cones and rods. These visual cells convert electromagnetic energy into sensory nerve impulses. Through a series of chemical reactions, these impulses are then transmitted to the brain via the optic nerve.

The eye sends the information to the brain. The brain splits the light into three bands of different colors and synthesizes them into a single color. Satellites, on the other hand, provide general information without increasing the amount of desired information.

In remote sensing, we use the physical properties of observed objects, particularly their optical particularly their optical properties, to acquire information about the nature of these objects. This information is transmitted to the observation system electromagnetic radiation, such as light. light.

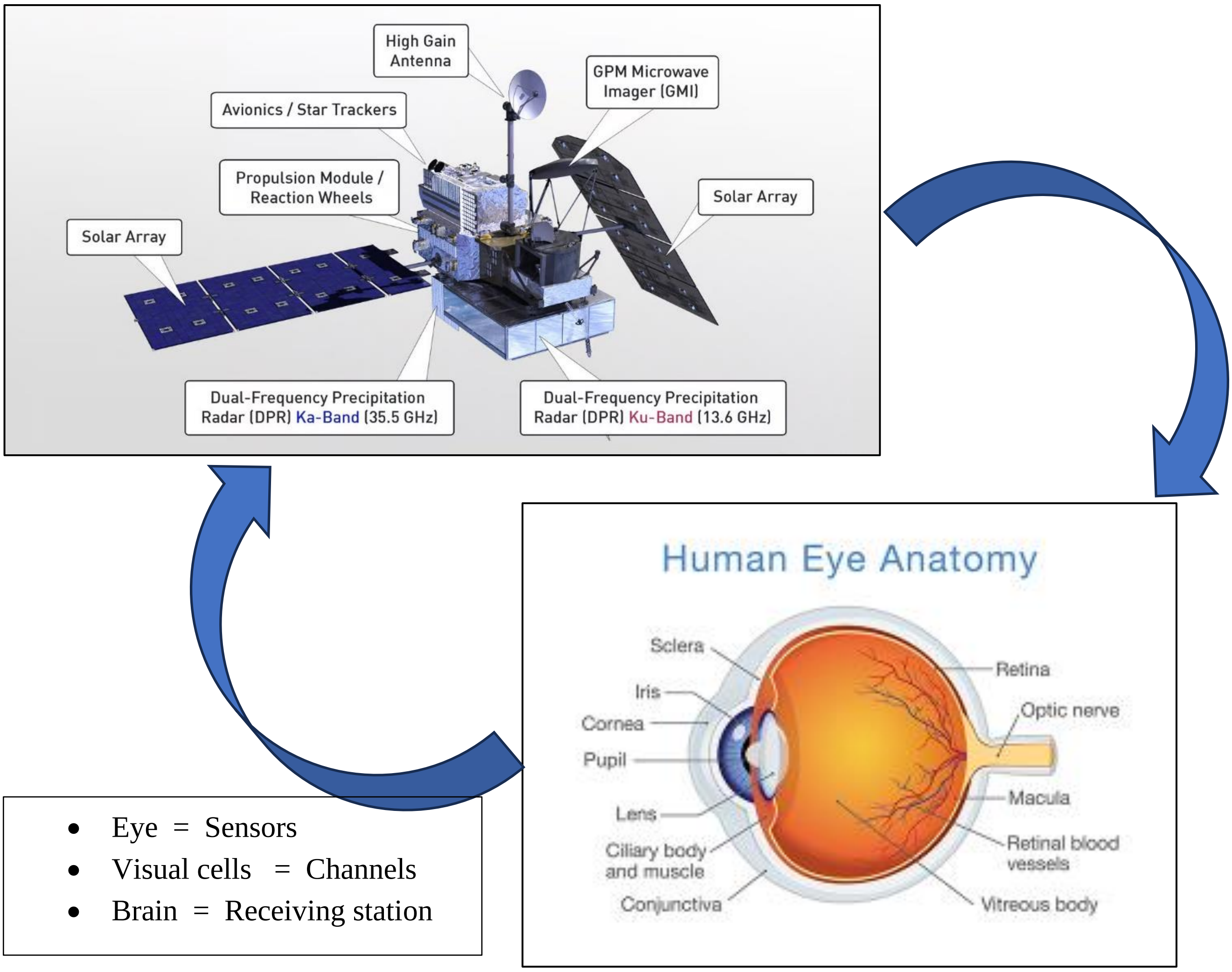

Figure 17. Comparison Eye/satellite ' the same principle'.

In remote sensing, electromagnetic radiation is used as a source of remote sensing for remote sensing. This radiation corresponds to electromagnetic waves. These waves carry energy that is more or less absorbed by various different media. The electromagnetic radiation is characterized by a wavelength and a frequency.

Electromagnetic radiation is represented by two inseparable vectors that are perpendicular to each other: the electric field E and the magnetic field H.

Electromagnetic radiation is characterized by the following :

- Wavelength λ = distance traveled by the wave at speed ν during a period T. λ is measured in meters or one of its submultiples, such as nanometers (10^{-9} meters), micrometers (10^{-6} meters), or centimeters (10^{-2} meters).
- Period T = the time T in which the wave makes one complete oscillation.
- Frequency (f) = oscillations per second with $T = 1/f$. Frequency is usually measured in Hertz (Hz), which means oscillated per second.
- $\lambda = \nu T = \nu / f$ of which :
  f = frequency
  λ = wavelength
  ν = speed of light

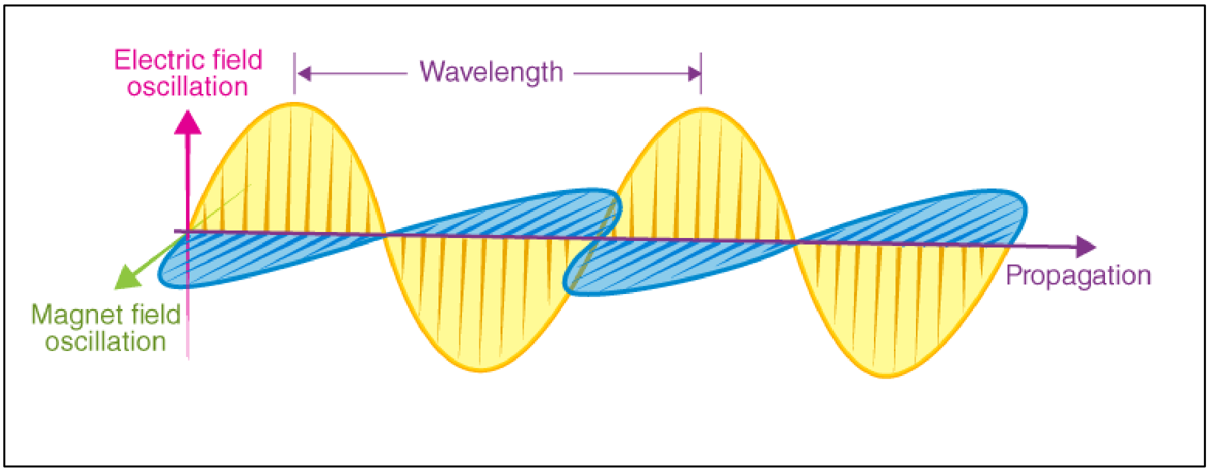

Figure 18. Electromagnetic radiation**.**

II.1.3.1. Electromagnetic Spectra

Electromagnetic radiation is a vibrational phenomenon that is made up of a series of sinusoidal waves that are called "spectral bands". Each band is characterized by a different amplitude and a different frequency, and thus by its own set of wavelengths.

The electromagnetic spectrum ranges from shortwave (including gamma rays and X-rays) to longwave (microwaves and radio waves). Several regions of the electromagnetic spectrum are used in remote sensing :

- The smallest wavelengths that are used for remote sensing are in the ultraviolet range. This radiation is beyond the range of violet. Some materials on the Earth's surface, especially rocks and minerals, fluoresce or emit visible light when illuminated by ultraviolet radiation.

- The visible (the light that can be detected by our eyes). As a matter of fact, the human eye is the primary sensor for remote sensing. Visible wavelengths range from 0.4 to 0.7 µm.

- Violet: 0.400 - 0.446 µm
- Blue: 0.446 - 0.500 µm
- Green: 0.500 - 0.578 µm
- Yellow: 0.578 - 0.592 µm
- Orange: 0.592 - 0.620 µm
- Red: 0.620 - 0.700 µm

- Infrared extends from about 0.7 to 100µm and is divided into two categories (reflected IR and emitted or thermal IR).

- The microwave region has attracted much interest in remote sensing for some time. This region includes the longest wavelengths used in remote sensing. It extends from about 1mm to 1m.

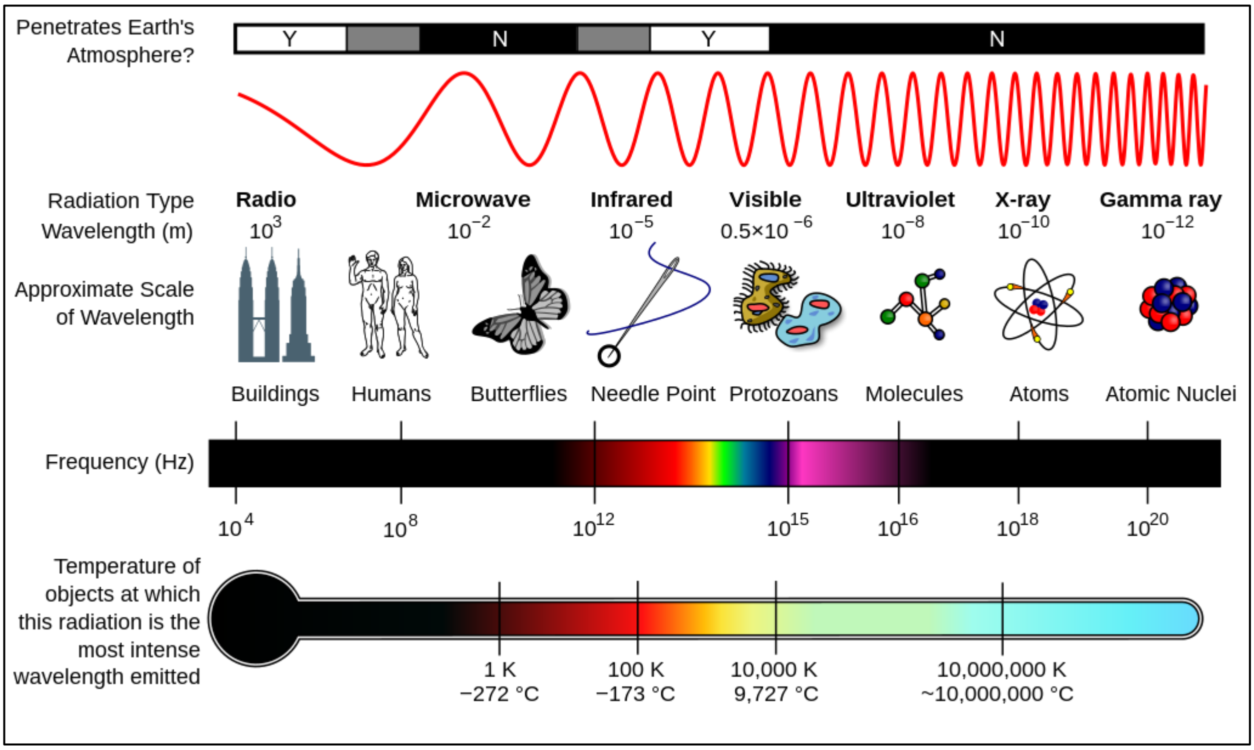

Figure 19. Electromagnetic Spectra.

II.1.3.2. Interaction between radiation and target (matter)

The energy associated with radiation is propagated in its entirety (without any loss) only in a vacuum. When exposed to radiation from an external source, matter (solid, liquid, or gaseous) absorbs a portion of this radiation, which is radiation. This radiation is converted to heat (conversion of radiant energy to thermal energy). The rest is either reflection or transmission through the body (possibly with a change in the direction of propagation, which is refraction). Each body is therefore characterized by an absorption coefficient (α), a reflectivity coefficient (ρ) and a transmittance coefficient (τ), which express the proportion of radiant energy that is absorbed, reflected or transmitted.

According to the principle of energy conservation, the sum of the coefficients is equal to 1:

$$\alpha + \rho + \tau = 1$$

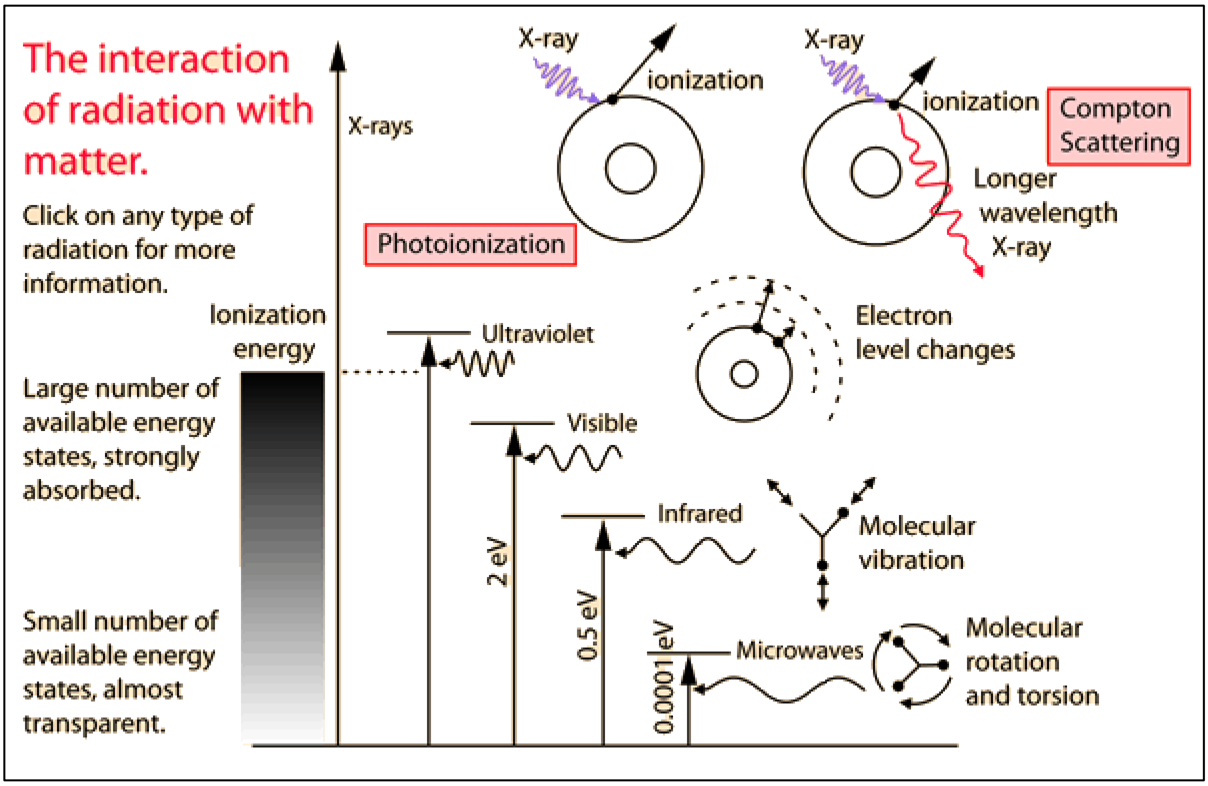

Figure 20. Interaction between radiation and target (matter). (http://hyperphysics.phy-astr.gsu.edu/hbase/mod3.html).

II.1.3.3. Visual characteristics of natural areas: plant leaf (foliage), soils, water, and other land areas

- Absorption (A) occurs when radiation energy is absorbed by the target. Transmission (T) occurs when radiation energy passes through the target, and reflection (R) occurs when radiation energy is redirected by the target.

In remote sensing, we measure the reflection of radiation from a target. There are two types of reflection depending on the target surface: specular and diffuse.

Figure 21. Interaction of incident electromagnetic radiation with plant leaf (Ebele Josephine Emengini, 2019).

- A smooth surface produces specular reflection, which means that all the energy is directed in the same direction (like a mirror). Diffuse reflection occurs when the surface is rough, redirecting energy uniformly in one direction. all directions. Most objects on Earth's surface fall between these two extremes.

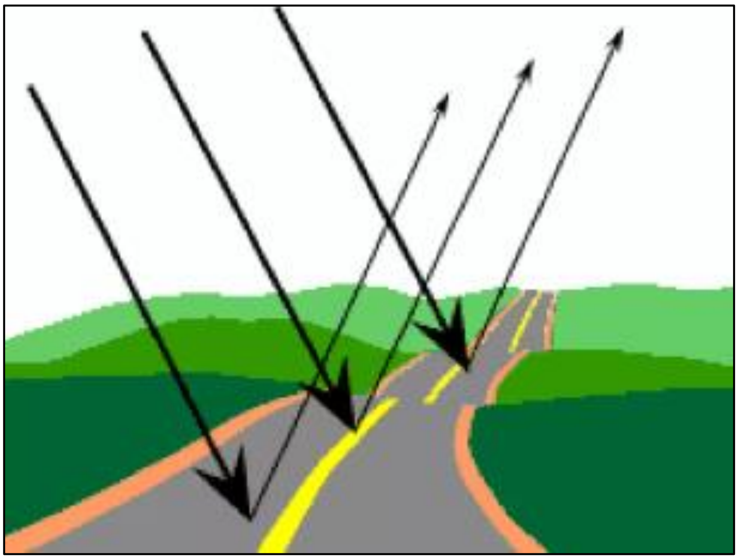

Figure 22. Specular reflection.

- Water tends to absorb more of the longer wavelengths of radiation in the visible and near-infrared ranges. As a result, water generally appears blue or blue-green in color because it is more reflective at the shorter wavelengths, and it appears even darker when viewed at the red or near-infrared wavelengths. Transmission decreases, reflectance increases, and the water appears lighter when the upper layers of the water contain suspended sediment.

The color of the water will shift slightly toward longer wavelengths. We sometimes mistake water with suspended sediment for clear, shallow water. The chlorophyll in algae absorbs more blue and reflects more green. Therefore, water that contains algae looks greener.

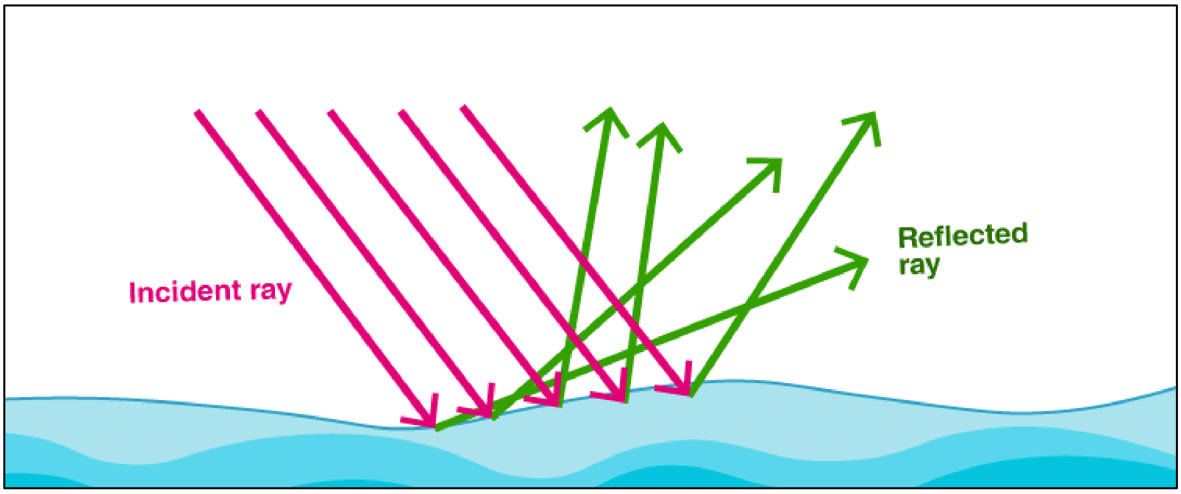

Figure 23. Reflection of Light.

Chapter III

Processing remote sensing data

(Digital image processing in remote sensing)

III. Processing remote sensing data

III.1. Pre-treatment

Pre-processing refers to the operations that are performed on images prior to any processing in order to correct or improve them in a geometric and thematic way. There are 3 types of preprocessing:

III.1.1. Atmospheric adjustment (The Atmospheric Correction Problem)

Depending on the thematic characteristics of the study area and the image processing method used, atmospheric corrections are applied to digital images. Without having data describing the meteorological conditions at the time the image was taken, it is not possible to obtain the true contribution of the atmosphere. Atmospheric corrections are therefore made by simulation in order to obtain a more accurate assessment.

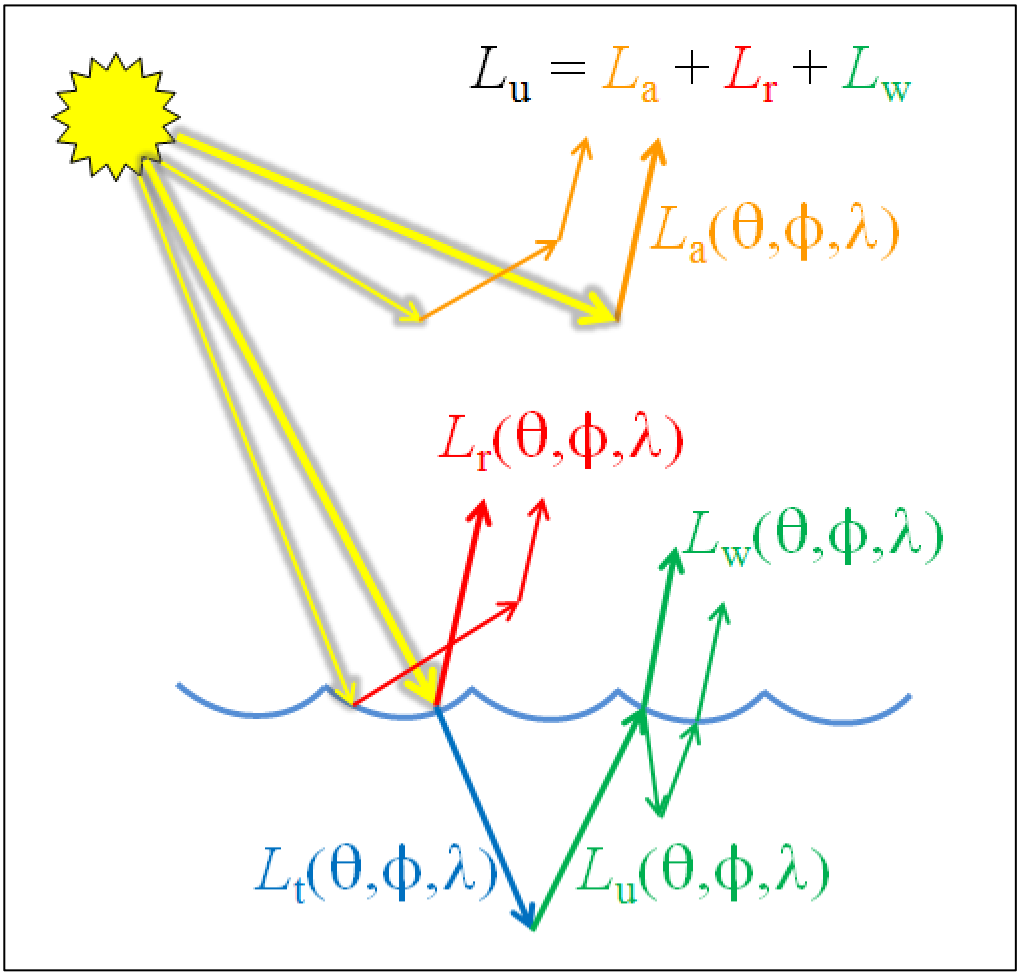

Figure 24. The Atmospheric Correction Problem.

III.1.2. Radiometric corrections

Raw remote sensing data contain radiometric errors, both point and line. These are mainly due to the sensor on board the satellite.

"The aim of the radiometric correction is the removal of these defects. It also consists of reformatting and eliminating lines in the images, including relative channel calibration".

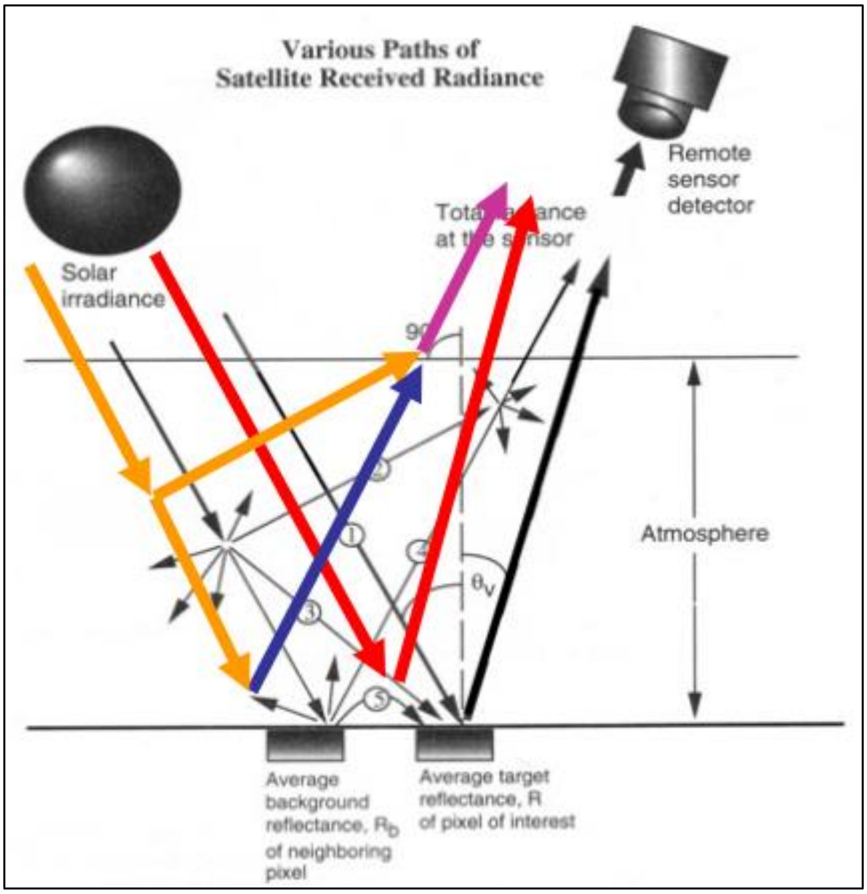

Figure 25. The Radiometric corrections problem.

III.1.3. Geometric corrections

In general terms, the geometric corrections have two objectives:

-Improvement of data quality through the reduction of noise (spatial noise); the term noise covers any distortion that may obscure the information of interest.

-Transform raw data into positional measurements of the detected objects.

Satellite imagery cannot be superimposed on topographic maps; transformation can only be achieved through the establishment of a link to a spatial reference frame (for example, a map). Images produced by sensors contain spatial deformations. They are not presented in any of the commonly used map projections.

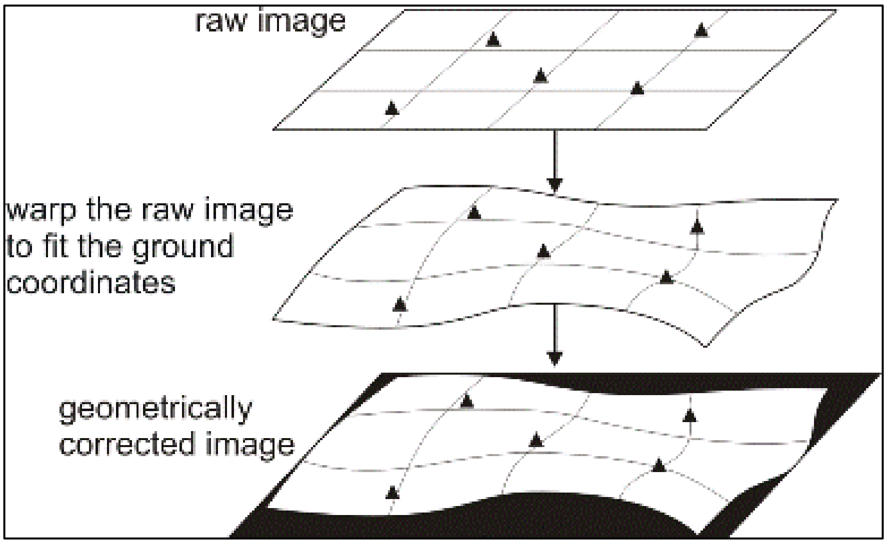

Figure 26. The Geometric corrections problem**.**

III.2. Digital processing

III.2.1. Creating colour compositions

The information provided by a single channel is not always sufficient to provide satisfactory detail that reflects what we hope to extract from remotely sensed data. The principle is simply to expose successively films corresponding to three spectral bands, each of which has a well-defined colour code. In other words, three channels are visualised, each of which is assigned to one of the three primary colours (blue, green, red). The end result is a trichromatic image, called a colour composition, in which the subjects are distinguished by different shades of these three basic colours.

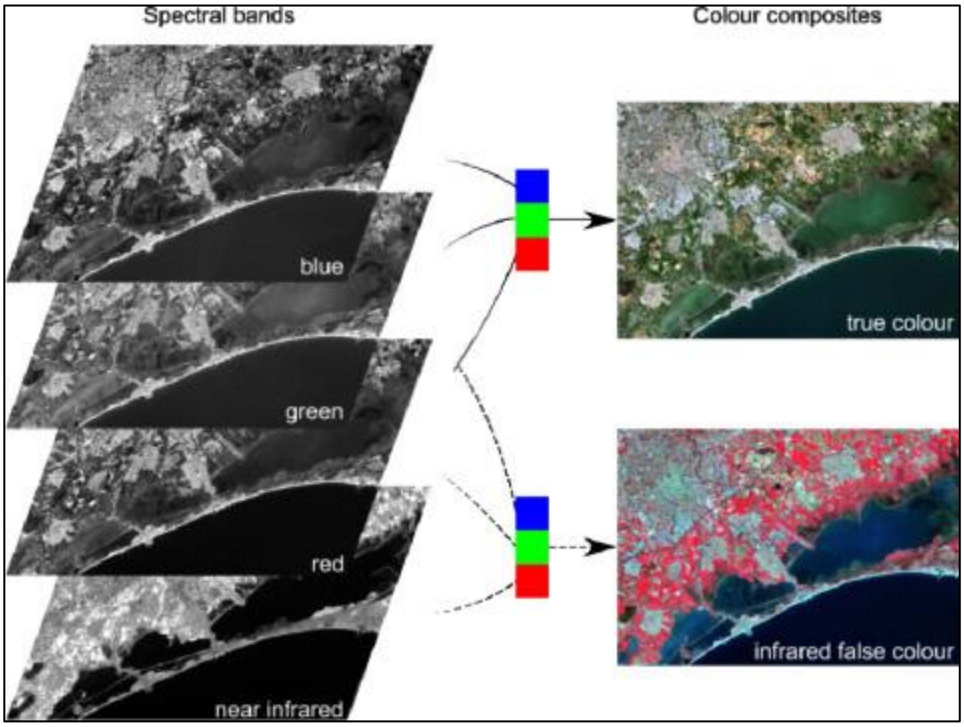

Figure 27. Creating colour compositions.

III.2.2. Creating composite color images

III.2.2.1. Diachronic compound

The diachronic study is the creation of a colour image from three multi-spectral images of the same area taken at different times.

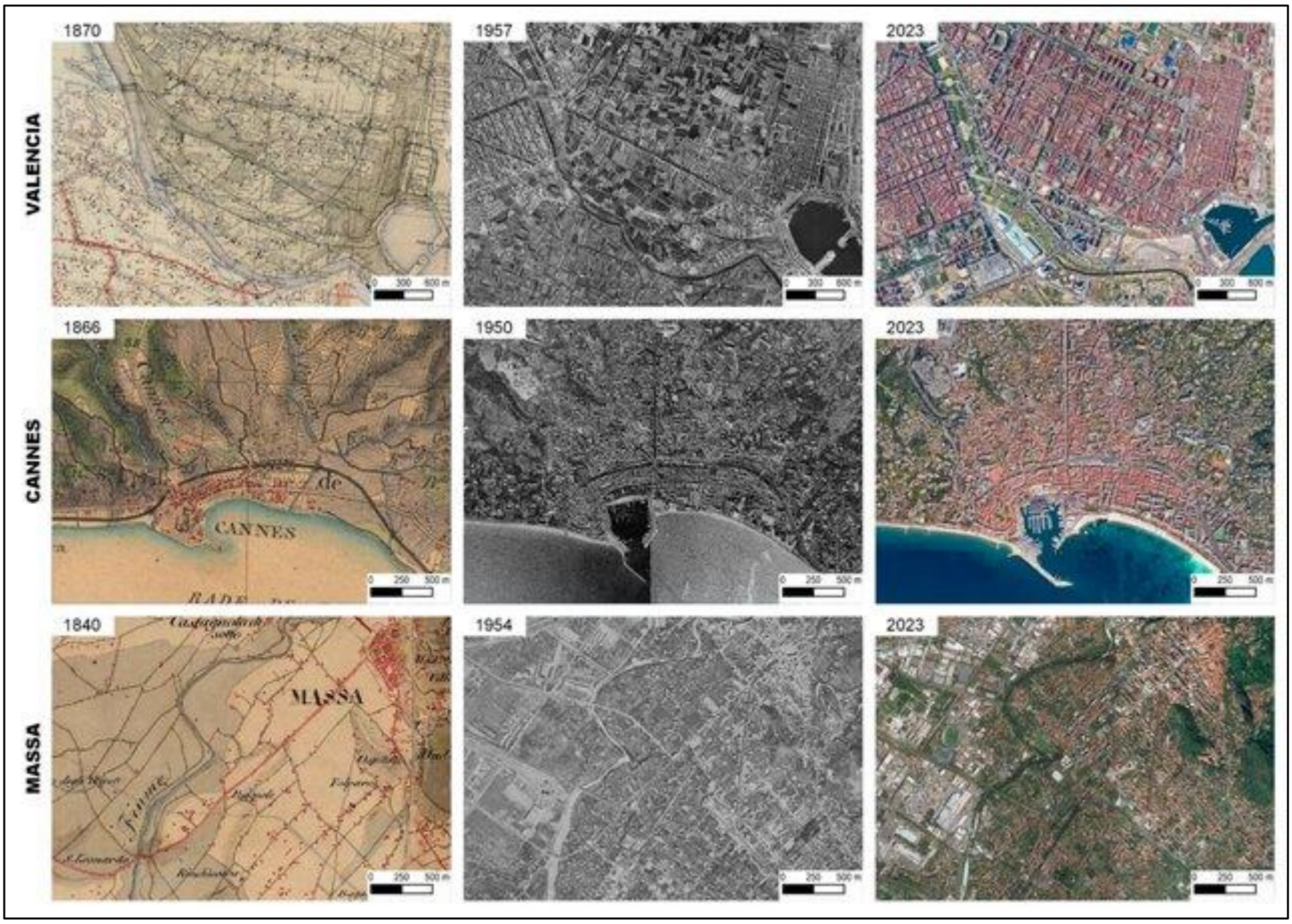

Figure 28. Examples of diachronic built-up area mapping in three representative urban contexts of the study: Valencia (Spain; Box C), Cannes (France; Box A), and Massa (Italy; Box A). Anthropic growth was reconstructed through three periods: the mid-19th century, mid-20th century, and the present.

(https://www.researchgate.net/publication/374368237_Anthropic_Constraint_Dynamics_in_European_Western_Mediterranean_Floodplains_Related_to_Floods_Events/figures?lo=1).

a-Neo channels

Consists of the creation of ratios where the value of each pixel is the result of a quotient over several spectral bands :

Vegetation Index

The vegetation index is a measure of chlorophyll activity. It is therefore a good indicator of vegetation density. It is a simple combination of channels.

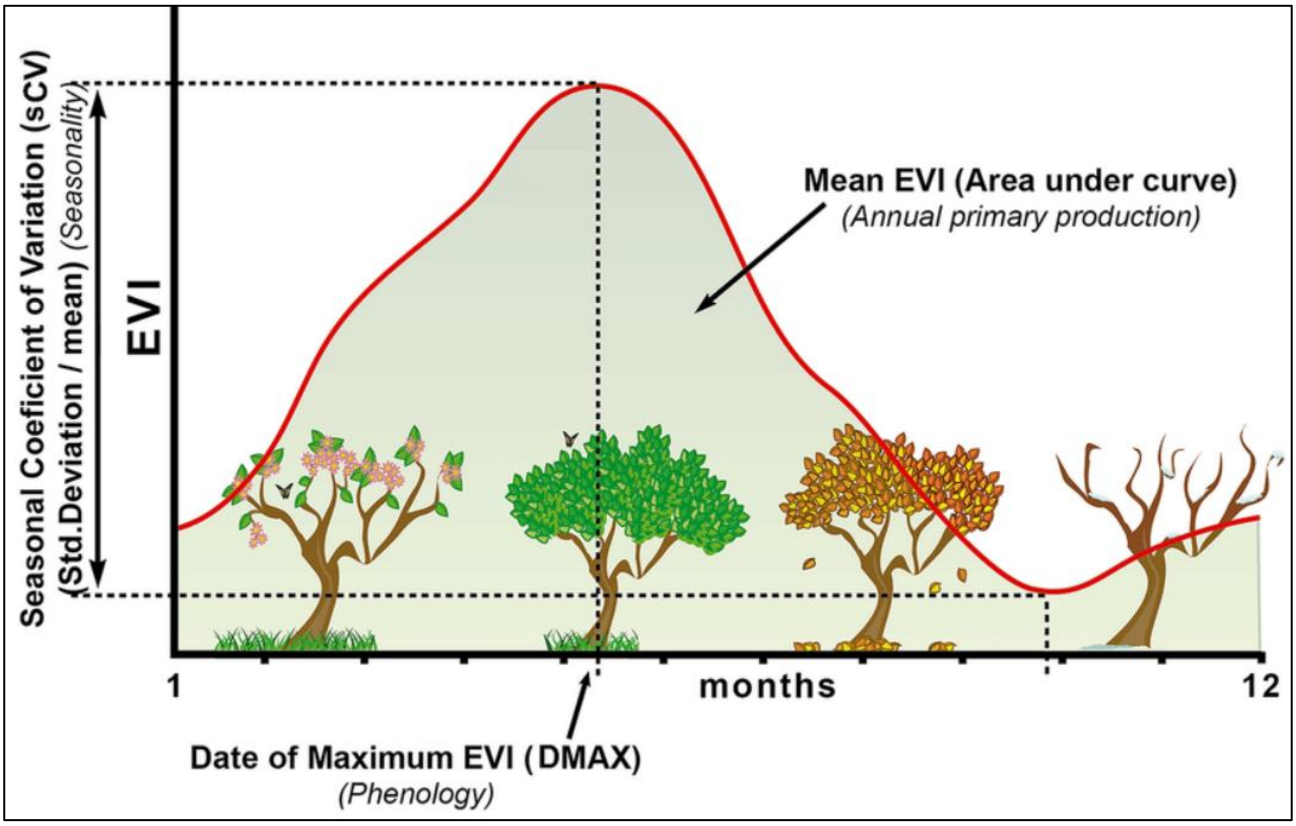

Figure 29. Vegetation Index and its uses in Precision Agriculture. (https://www.cropin.com/blogs/vegetation-index-for-precision-agriculture).

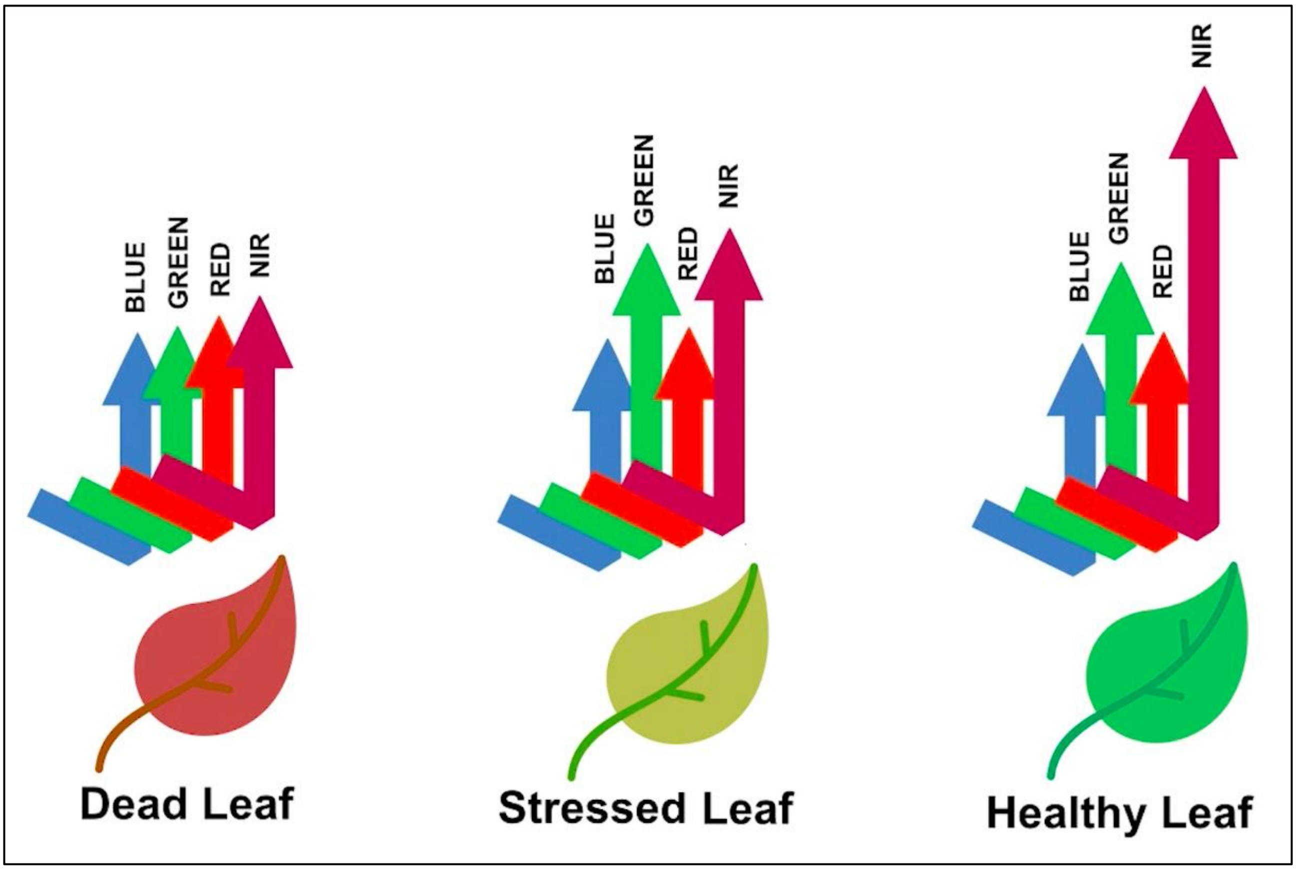

Figure 30. Vegetation Index.

Tessled Cap transformation

It's a useful tool for compressing spectral data into a few bands. These bands are related to the physical characteristics of the scene.

Three key pieces of information, namely the brightness index, the moisture index and the greenness index, are extracted from this transformation.

III.3. Remote sensing image segmentation and filtering techniques

III.3.1. Image segmentation

Image filtering is the process of modifying the appearance of an image by adjustment of the colours of its pixels. It is used to improve contrast, apply special effects and reduce noise around characters in text images to improve optical character recognition (OCR) success rates.

Thresholding is probably the simplest segmentation method. It consists of testing each pixel in theimage to see whether its value is above or below a certain threshold, and produces a binary image grouping the results.

III.3.2. Image filtering

Image filtering involves so-called neighborhood operations, in which the value of each pixel in the scene is recalculated according to the values of surrounding pixels.

III.4. Supervised and unsupervised remote sensing image classification methods

The most common methods for classifying images use radiometric information from one or more spectral bands to classify each pixel individually. This standard type of classification is known as spectral clustering detection. The image resulting from the classification is composed of pixels. Each pixel belongs to a certain theme (e.g. water, forest, buildings, etc.). When we talk about classes, we need to distinguish between information classes and spectral classes:

- Information classes are categories of interest that the analyst is trying to identify in the images, such as different types of crops, different types of trees, different types of geological features, etc.

- Spectral classes are groups of pixels with the same (or similar) spectral characteristics in terms of radiometric values in different channels.

III.4.1. Classification Objective

Mapping spectral classes to information classes is the ultimate goal of classification. In this context, the role of the analyst is to determine the usefulness of the different spectral classes and to validate their correspondence to useful information classes.

III.4.2. The classification process

The classification process consists of three basic steps:

- Creation of signature or spectral classes,
- Classification of pixels according to signature classes,

- Verifying the classification (reliability compared to the intended thematic classes). The two main approaches to digital classification are determined by the way signature classes are established (1st step) :
  - ✓ **The unsupervised approach:** there is no a priori knowledge; the classes are created automatically by the software. Classes are then named and labelled a posteriori;
  - ✓ **The supervised approach: a** priori knowledge is used for the creation of classes and input samples (training areas = test data). Pixel-based classification methods are difficult to implement because the radiometric confusion between classes increases with sensor resolution and spatial heterogeneity of the environment.

III.4.2. Classification methods

Classification is aimed at grouping (partitioning, segmenting) nn observations into a certain number of homogeneous groups or classes. There are two main types of classification:

- Supervised classification, often just called classification;
- Unsupervised classification, sometimes called partitioning, segmentation or clustering.
-

III.4.2.1. Supervised classification

Supervised classification is then the determination of a classification procedure:

- We already know how many groups there are in the population;
- We know to which group each observation in the population belongs;
- We want to classify observations into the correct groups based on different variables. A classification rule can then be used to predict the groups to which new observations belong. Typical applications include
- Determining whether a bank transaction is fraudulent or not;
- Recognising handwritten numbers;
- Identifying the type of cancer a patient has.

Let be a set of documents, each represented by an individual di and a CK class. It is defined by means of (di, CK) pairs given as examples to the system. The second matches any individual di with its description di .

$$C^f : \vec{d_i} \rightarrow C_k$$

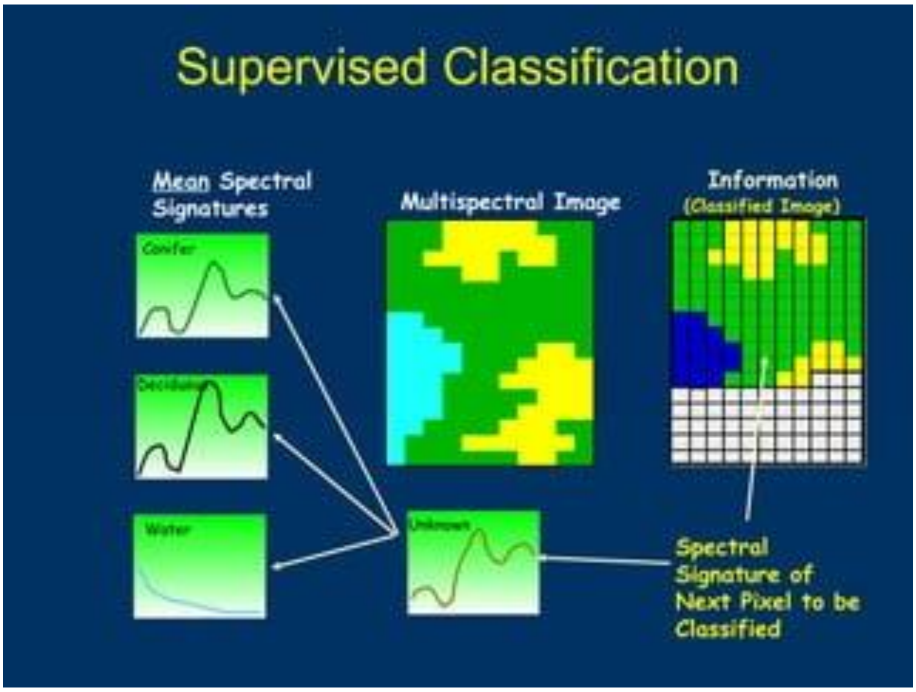

Figure 31. Supervised classification.

III.4.2.2. Unsupervised methods (unsupervised classification / clustering)

Unsupervised classification is for use when you have documents that are unclassified and do not have a classification. At the end of the unsupervised classification process, the documents must be members of one of the classification classes.

There are two types of unsupervised classification: hierarchical and non-hierarchical :

In Hierarchical Classification (HC), the subsets created are nested hierarchically. A distinction is made between top-down (or divisive) HC, which starts with the set of all individuals and divides them into a number of subsets, each subset into a number of subsets, and so on. And bottom-up (or agglomeration) CH that starts with individuals and divides them into subsets that get combined, etc. To determine which classes to merge, we use the aggregation criterion.

In non-hierarchical classification, the individuals are not in a hierarchical order. If each individual belongs to only one subset, this is called partitioning. If each individual can belong to more than one group, with a probability Pi of belonging to group i, then we speak of overlapping.

Unsupervised classification is then the determination of a classification procedure:

- The number of groups in the population is often unknown;
- The group to which each observation in the population belongs is not known;
- We want to classify observations into homogeneous groups on the basis of different

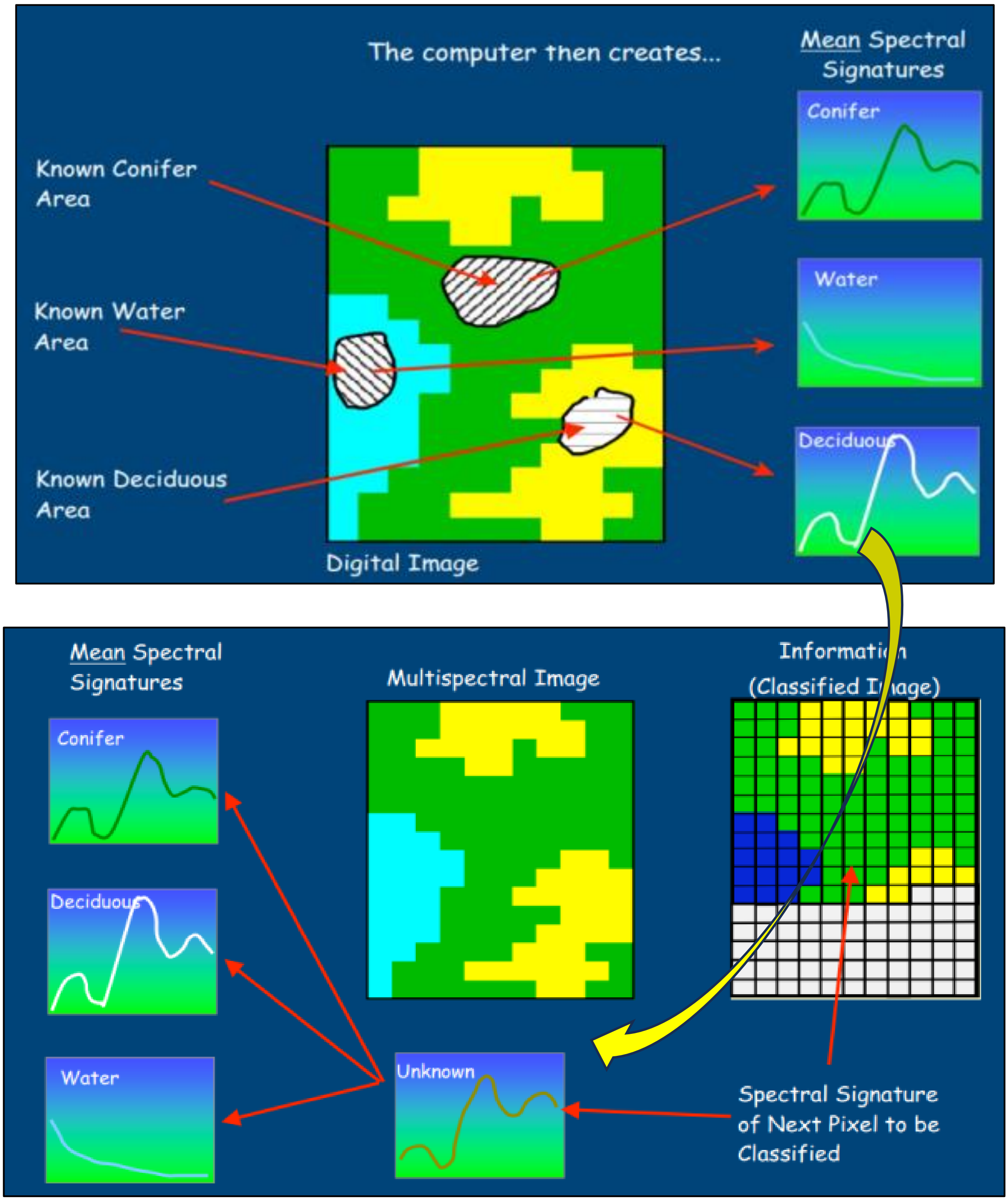

Figure 32. Unsupervised classification / clustering.

III.5. Radiometric Vegetation Indices (NDVI)

The NDVI (Normalised Difference Vegetation Index) is a standardised index used to generate an image representing vegetation cover (relative biomass). This index is based on the contrasting characteristics of two channels in a multispectral raster dataset: chlorophyll absorption in the red channel and plant reflectance in the near infrared (NIR) channel. The NDVI index is used worldwide to monitor drought, control and predict agricultural production, aid fire prevention and map desertification. Because the NDVI index compensates for changes in illumination, slope, exposure and other exogenous factors, it is the preferred index for global vegetation monitoring (Lillesand 2004).

This index produces values between -1.0 and 1.0, which mainly represent vegetation cover, with negative values mainly produced by clouds, water and snow, and near zero values mainly produced by rock and bare ground. Very low NDVI values (0.1 and below) correspond to barren rock, sand or snow surfaces. Intermediate values (0.2 to 0.3) represent shrub and grassland areas, while high values (0.6 to 0.8) indicate temperate or humid tropical forests.

The documented default NDVI equation is as follows: NDVI = ((IR - R)/(IR + R)

- IR = pixel values of the infrared channel
- R = pixel values of the red channel

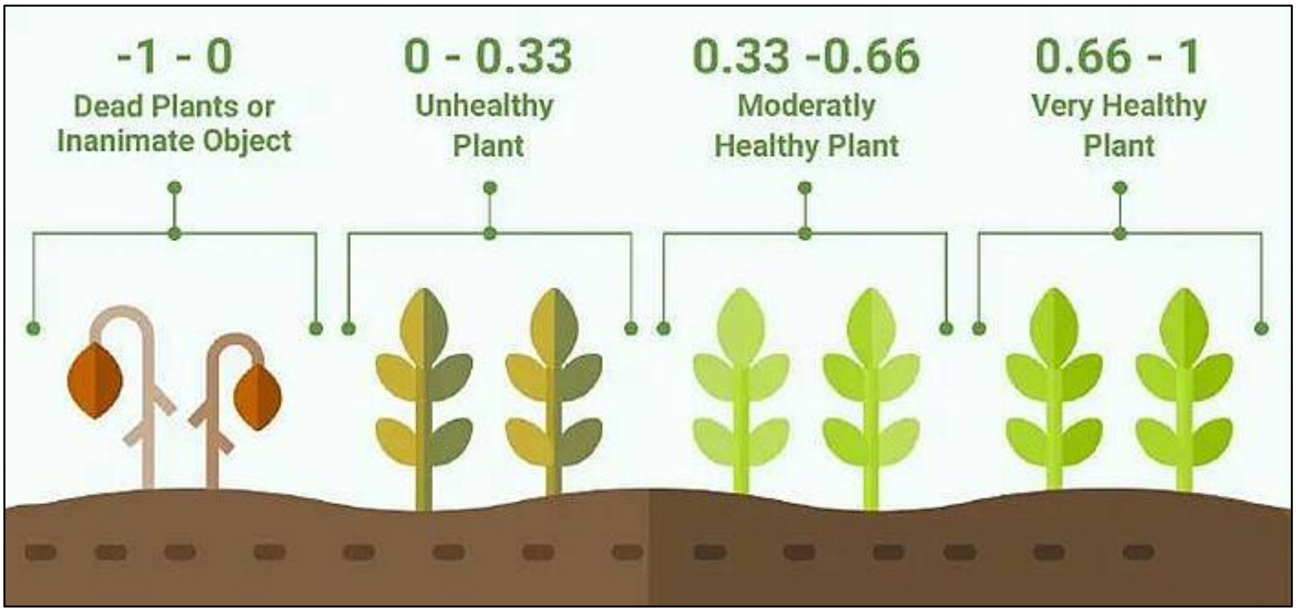

Figure 33. NDVI or Normalized Difference Vegetation Index.

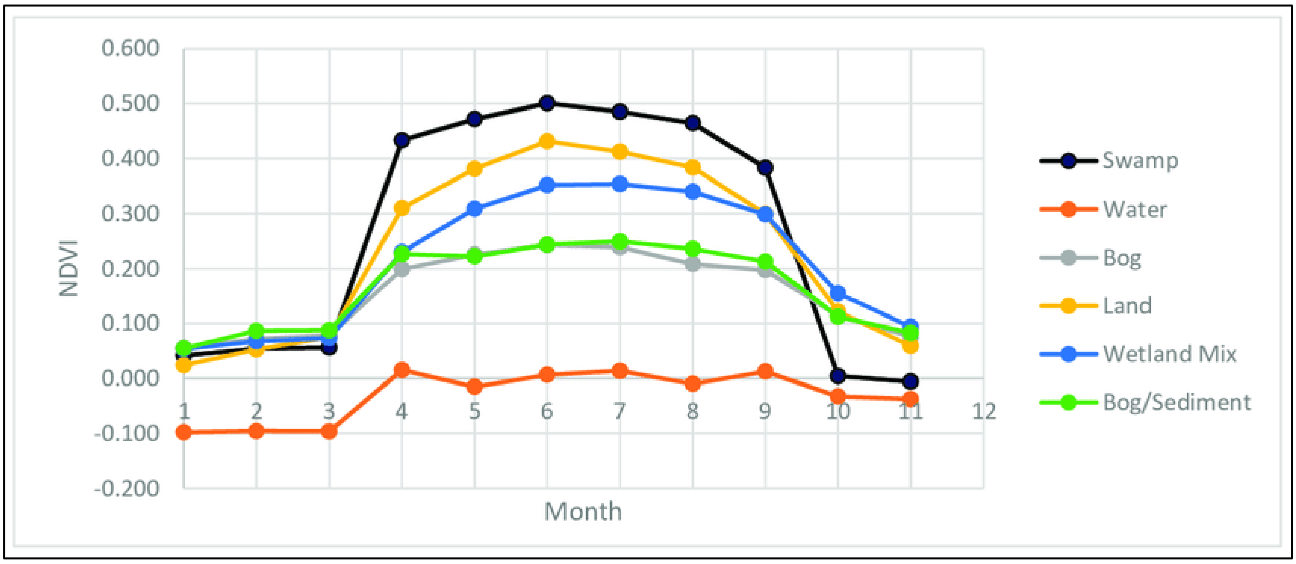

Figure 34. Normalized Difference Vegetation Index (NDVI) time series average values.

Chapter IV

Principles of ecological cartography

IV. Principles of ecological cartography

IV.1. Definition

Ecological mapping is an essential tool for visualising and analysing ecosystem and habitat distribution. It is an essential tool for the visualisation and analysis of the spatial distribution of ecosystems and habitats. It can be used for the identification of areas of critical biodiversity and for the assessment of the environmental impact of human activities. Ecological mapping enables researchers and planners to better understand and conserve natural resources.

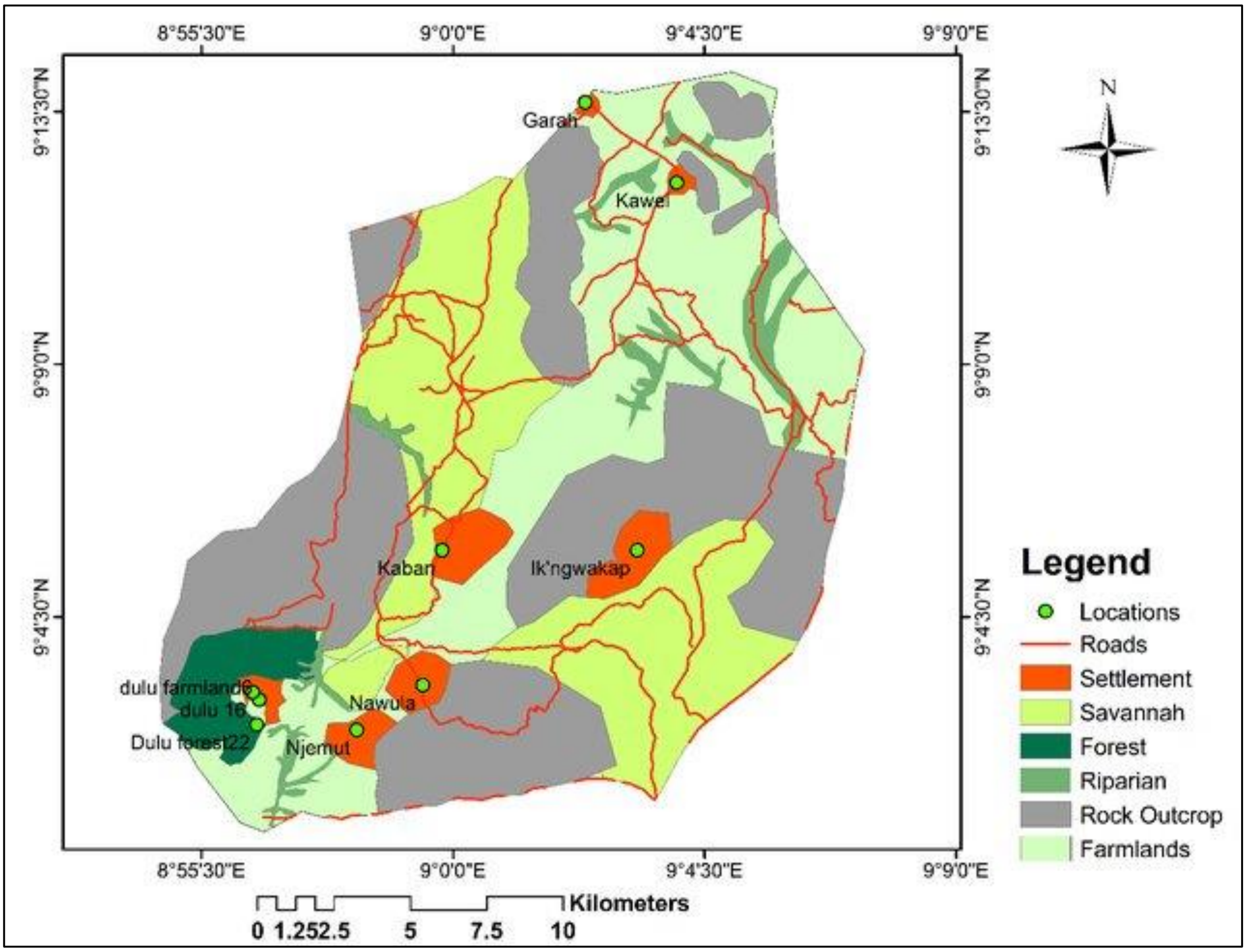

Figure 35. Ecological Map showing the study communities and the Dulu Forest (National Remote Sensing Unit, Jos).
https://www.researchgate.net/publication/325118598_Perceptions_of_the_Mushere_People_on_the_Dulu-forest_Implications_for_Conservation/figures?lo=1

IV.2. Principles of ecological cartography

The basic principles of ecological mapping are important in order to produce maps that are accurate and useful.

Here are some of these principles:

- **Data collection:** The collection of accurate information on the characteristics of the environment is crucial. These include topography, climate, vegetation and water resources.
- **Scale:** Choosing the right scale is critical. Scale has an impact on both the granularity of the information presented and the functionality of the map for different uses.
- **Symbology:** The use of a clear legend helps to understand the mapped data. Symbols should be consistent and easy to understand.
- **Geographical accuracy:** Maps need to be geographically accurate to ensure that the information they contain is reliable.

IV.3. Ecological mapping methods

Ecological mapping uses a variety of methods for the representation and analysis of ecosystem data. These methods facilitate interpretation of the complex interactions between different ecological and human components.

Through the use of specific techniques and state-of-the-art tools, it is possible to produce accurate ecological maps that can be useful for research and natural resource management. Let's take a look at the different techniques and tools used.

IV.4. Ecological mapping techniques

Ecological Mapping Techniques vary according to the aims and scale of the study undertaken. Here are some commonly used techniques:

Satellite imagery: Used to provide an overview of large natural areas and to monitor environmental change.

Geographic Information Systems (GIS): Used to collect, store, analyse and visualise geospatial data.

Photogrammetry: Technique for making precise measurements from photographs, often used for topographic surveys.

Field Surveys: These involve the collection of data in the field to validate information obtained by other means and to compile biotic and abiotic data.

Each of these techniques can be used alone or in combination to achieve the best results.

IV.5. Tools used in ecological mapping methods

Ecological mapping requires a variety of tools, both hardware and software. These tools play a crucial role in the accuracy and effectiveness of the results. Here are some commonly used tools:

- **GIS software:** ARCGIS, QGIS and GRASS GIS are among the most popular, offering a wide range of spatial analysis functions.
- **GPS (Global Positioning System):** Essential for collecting precise coordinates in the field.
- **Drones:** Used to capture aerial images and videos of hard-to-reach areas, providing valuable data for analysis.

- **Environmental sensors:** Used to monitor variables such as temperature, humidity and air quality in real time.

These tools, combined with appropriate techniques, make ecological mapping both dynamic and accurate: drone technology, for example, offers unprecedented insights with impressive precision.

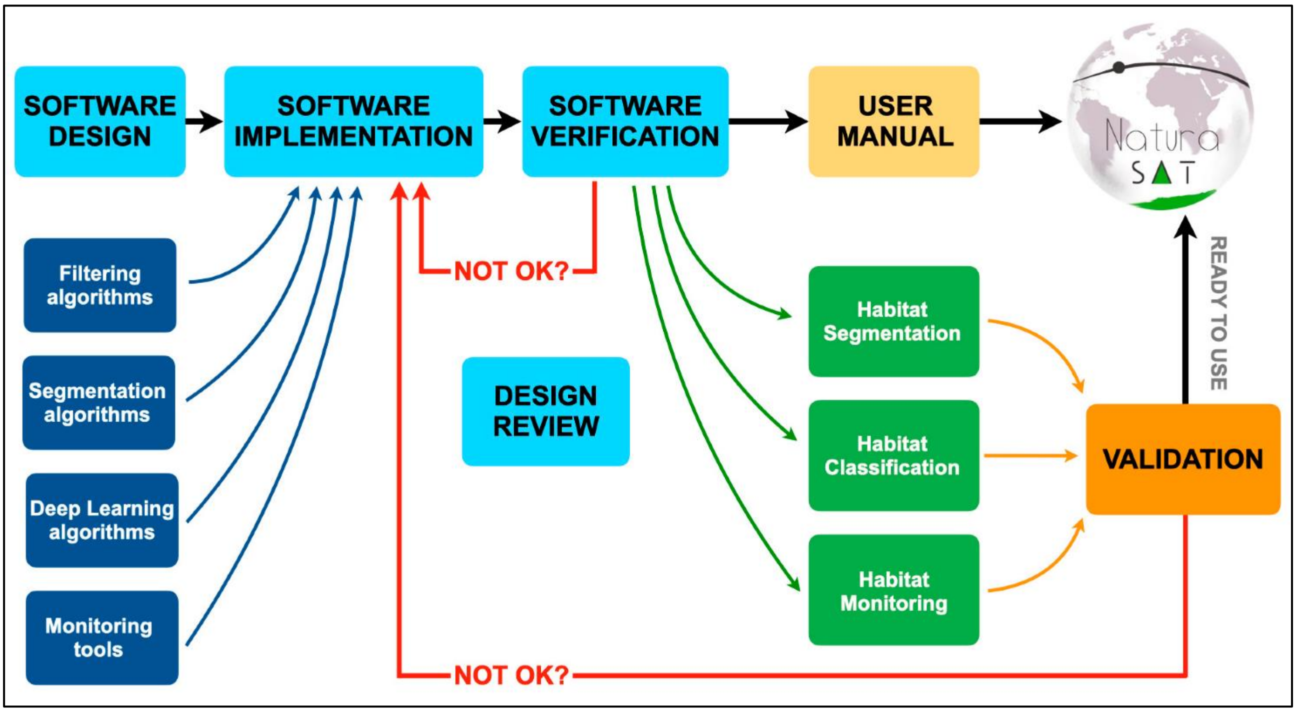

Figure 36. A Software Tool for Identification, Monitoring and Evaluation of Habitats. (https://www.mdpi.com/2072-4292/13/17/3381).

IV.6. Ecological mapping - Key points

- **Definition of ecological mapping: A** tool for visualising and analysing the distribution of habitats and ecological interactions.
- **Ecological mapping methods:** Data collection, appropriate scales, symbology and geographical accuracy.
- **Ecological mapping techniques:** Satellite imagery, Geographic Information Systems (GIS), Photogrammetry, and field surveys.
- **Ecological flow mapping: A** vital process for understanding natural movements and exchanges between ecosystems.
- **Ecological network mapping:** Identifies and analyses habitat connectivity to preserve biodiversity.
- **Examples of ecological mapping:** wildlife corridors, river networks, interconnected wetlands.

IV.7. Ecological mapping frequently asked questions

IV.7.1. What tools do we use for ecological mapping?

Ecological mapping is carried out using GIS, remote sensing technology (satellite images, drone), environmental databases and software specialized in spatial analysis and ecological modelling.

IV.7.2. What are the main steps in ecological mapping?

Collecting and analysing environmental data, identifying areas to be mapped, using GIS to process and visualise the data, and finally validating and regularly updating the maps produced are the main steps in producing ecological maps.

IV.7.3. Why is ecological mapping important?

Ecological mapping is essential for the identification and protection of natural habitats, for the assessment of the environmental impact of development projects and for the sustainable management of resources. It also helps to plan land use in a way that minimises environmental degradation and conserves biodiversity.

IV.7.4. How can ecological mapping help to conserve biodiversity?

Ecological mapping identifies critical areas for conservation by identifying and delineating natural habitats. It helps to prioritise conservation actions, monitor environmental changes and plan land use while minimising impacts on biodiversity.

IV.7.5. What is the difference between ecological mapping and a topographic map?

Ecological mapping focuses on the depiction of ecosystems, habitats and biodiversity, while a topographic map depicts the shape of the land through contour lines, indicating elevations and physical features of the landscape. The former provides an understanding of the natural environment from an ecological point of view, while the latter provides a detailed overview of the terrain and its geographical features.

IV.8. Approaches for mapping ecological flows (ecological problems)

Mapping ecological flows requires understanding the complex interactions between natural elements. Here are some approaches and tools used in this field:

Interactive maps: Often used with GIS to overlay data, these allow you to visualise ecological dynamics in real time.

Numerical models: Used to simulate how energy and matter flows through ecosystems, including models of ocean circulation or species migration.

Network analyses: These analyses describe the connectivity between habitats and are essential for visualising ecological corridors and migration routes.

An essential aspect of these approaches is the precise calculation of flows, often represented by complex formulae.

IV.8.1. Mapping ecological networks

Ecological networks play an important role in protecting biodiversity and habitat connectivity. Mapping these networks makes it possible to identify and analyse the relationships between different natural areas, facilitating their management and conservation.

These maps can reveal important ecological corridors that facilitate the movement and survival of species.

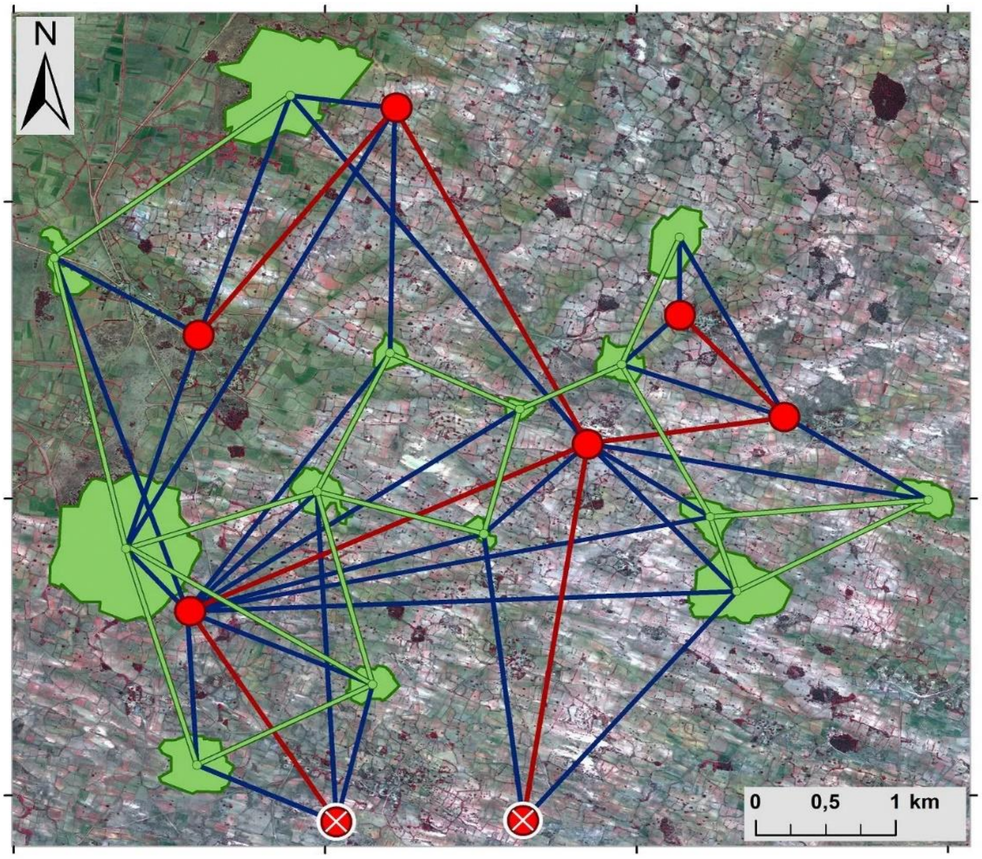

Figure 37. Ecological network of forest patches, clans, & their different interrelationships in an agricultural landscape in southern Madagascar. From Bodin and Tengö (2012): https://doi.org/10.1016/j.gloenvcha.2012.01.005).

IV.8.2. Problem environment mapping (Risk mapping)

-What is a risk map?

A map is a visual representation that can take various forms: table, flow diagram, process, mental map, etc.

It facilitates the understanding of the subject under discussion and the transfer of information between all stakeholders. A risk in a ecosystem is a more or less probable event that could cause damage and affect the smooth running of the project. Risk mapping is therefore a management tool that makes it possible to represent all the risks inherent in the ecosystem and to define their impact.

-Interest in designing a risk map

Risk mapping ensures the sustainability of the project. This representation allows the project manager to summarize all the risks linked to the project and to seek solutions to control them.

This mapping will make it possible to :

-define the strengths and weaknesses of an ecosystem's functioning

-identify opportunities and threats with the aim of:

-prevent the emergence of risk factors

-limit the impact

-The main steps in creating a risk map

The creation of a risk map is a critical step for any organisation that is in the process of strengthening risk management. The key steps in creating a risk map include :

- ✓ Identifying potential risks: Analysing the organisation's internal and external processes.
- ✓ Risk assessment: Examine risks based on their potential impact and likelihood of occurrence.
- ✓ Risk prioritisation: Prioritise risks to determine which require priority attention.
- ✓ Develop action plans: Implement controls and strategies to manage and mitigate identified risks.
- ✓ Monitoring and periodic review: Ensure that risk mapping remains relevant to changes in the organisation's internal and external environment.
- ✓ This systematic and proactive approach ensures effective risk management and improves organisational resilience.

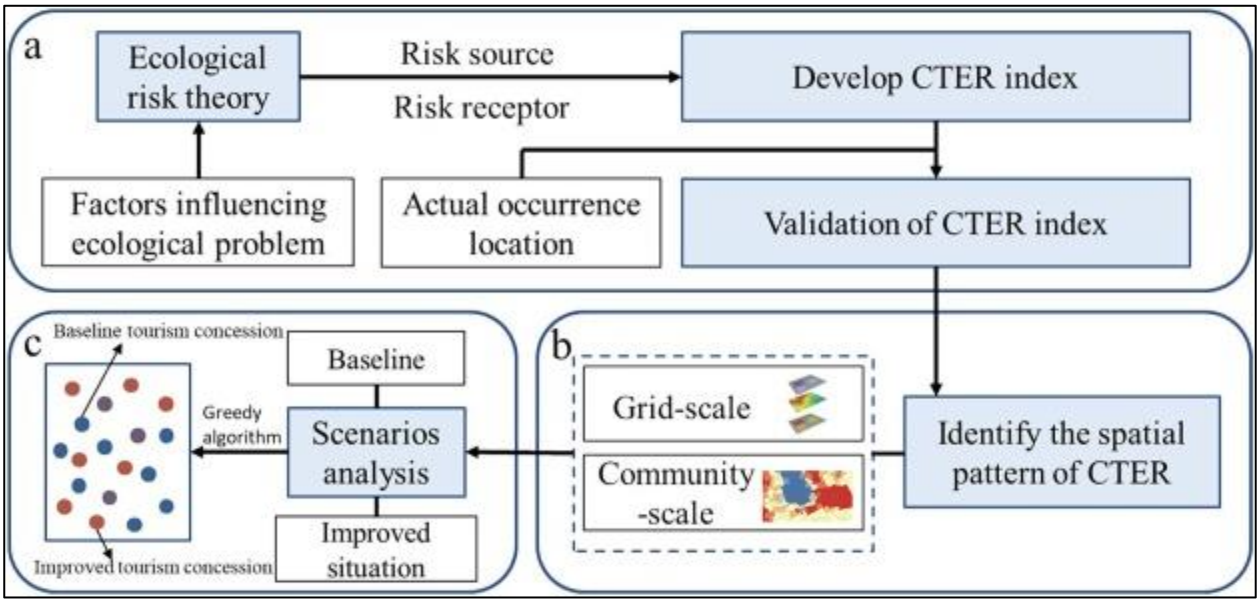

Figure 38. Measuring and reducing the ecological risk for ecosystem conservation. (https://www.sciencedirect.com/science/article/pii/S1470160X24009506).

IV.8.2. The key steps in creating a risk map

The creation of a risk map is a crucial step for any organisation that is in the process of strengthening its risk management. The key steps in building a risk map include :

- ✓ Identifying potential risks: Analyse the organisation's internal and external processes.
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- ✓ Develop action plans: Implement controls and strategies to manage and mitigate identified risks.
- ✓ Monitoring and periodic review: Ensure that risk mapping remains relevant to changes in the organisation's internal and external environment.

This systematic and proactive approach ensures effective risk management and improves organisational resilience.

IV.8.3. Geographic Information Systems for Watershed Management

Watershed management is a critical area where GIS technology excels in integrating hydrological data with land use, topography, vegetation and soil types to facilitate comprehensive watershed analysis. This integration makes it possible to identify sources of pollution, assess water quality and plan for the sustainable management of water resources.

A watershed management case study demonstrates the use of GIS to synthesise complex spatial information to address water-related challenges. For example, in river basin management, GIS can be used to model runoff patterns, predict flood areas and assess the impact of land use changes on water quality. This provides a solid basis for planning interventions such as reforestation to improve water quality and reduce erosion.

IV.8.4. GIS and modelling for the mapping of areas at risk of drought and desertification

This study monitored desertification and analyzed the spatial and temporal characteristics of desertification and its driving forces using preprocessed Landsat image data.

Organizational chart is a flowchart of our research, which can be divided into four parts: (1) data preprocessing and the extraction of desertification indicators; (2) desertification mapping; (3) analysis of temporal and spatial changes; and (4) driving force analysis.

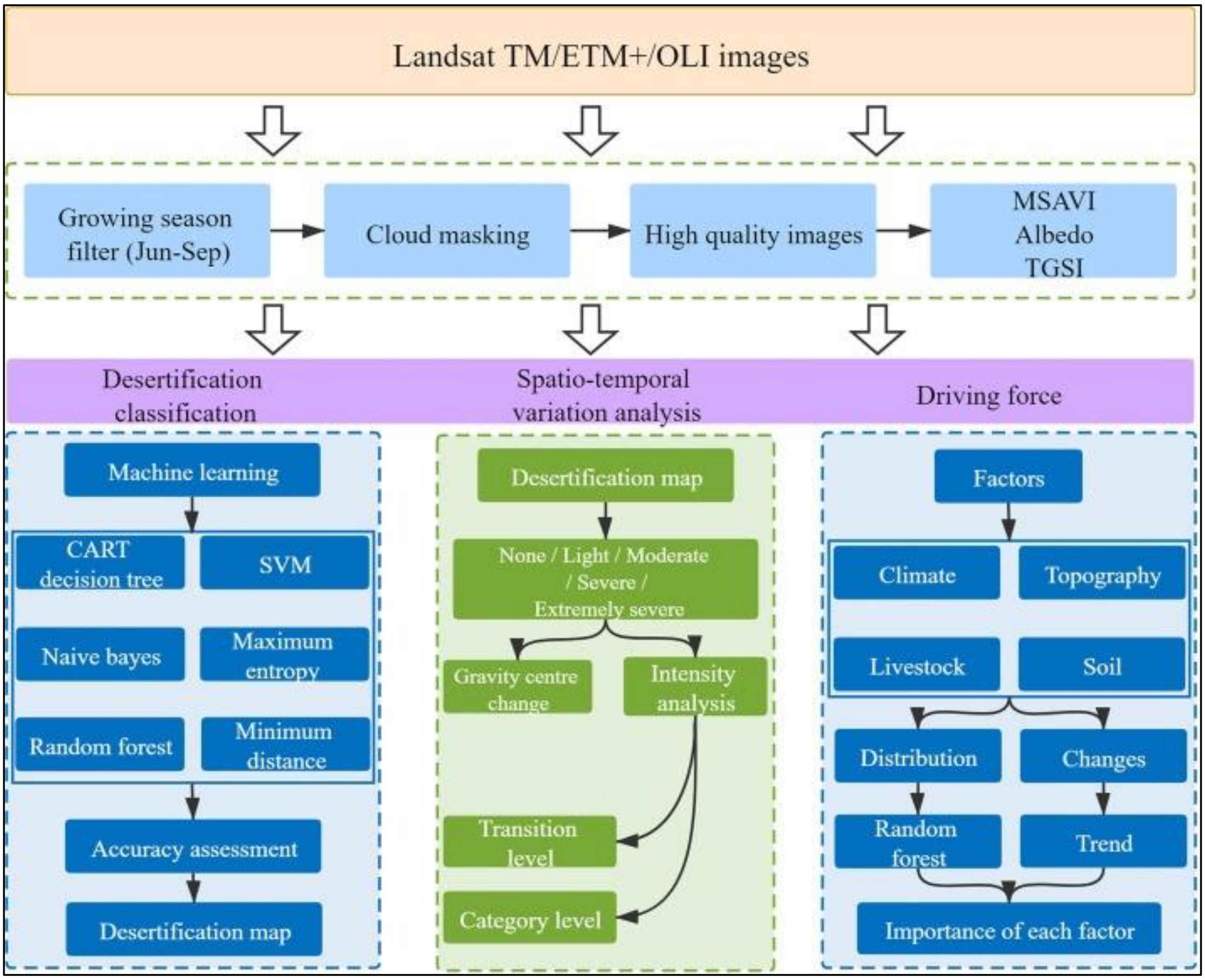

Figure 39. GIS and modelling for the mapping of areas at risk of drought and desertification.

IV.8.5. GIS and modelling for the Flood Risks

The methodology used in this study involves several steps. On the basis of the Landsat satellite image, various thematic maps will be produced using the Digital Terrain Model (DTM).

The use of empirical formulae and various applications, integrated into Geographical Information System (GIS) software, will make it possible to better understand the problem and propose development actions in such a way as to seek equilibrium, manage the impact of risks and reduce the vulnerability of the city of Meknes in order to make it resilient and sustainable.

The methodology consists first of all in integrating relevant geographical information in a GIS, such as the city map, the topographic map, aerial photographs, the digital terrain model, satellite images, etc.

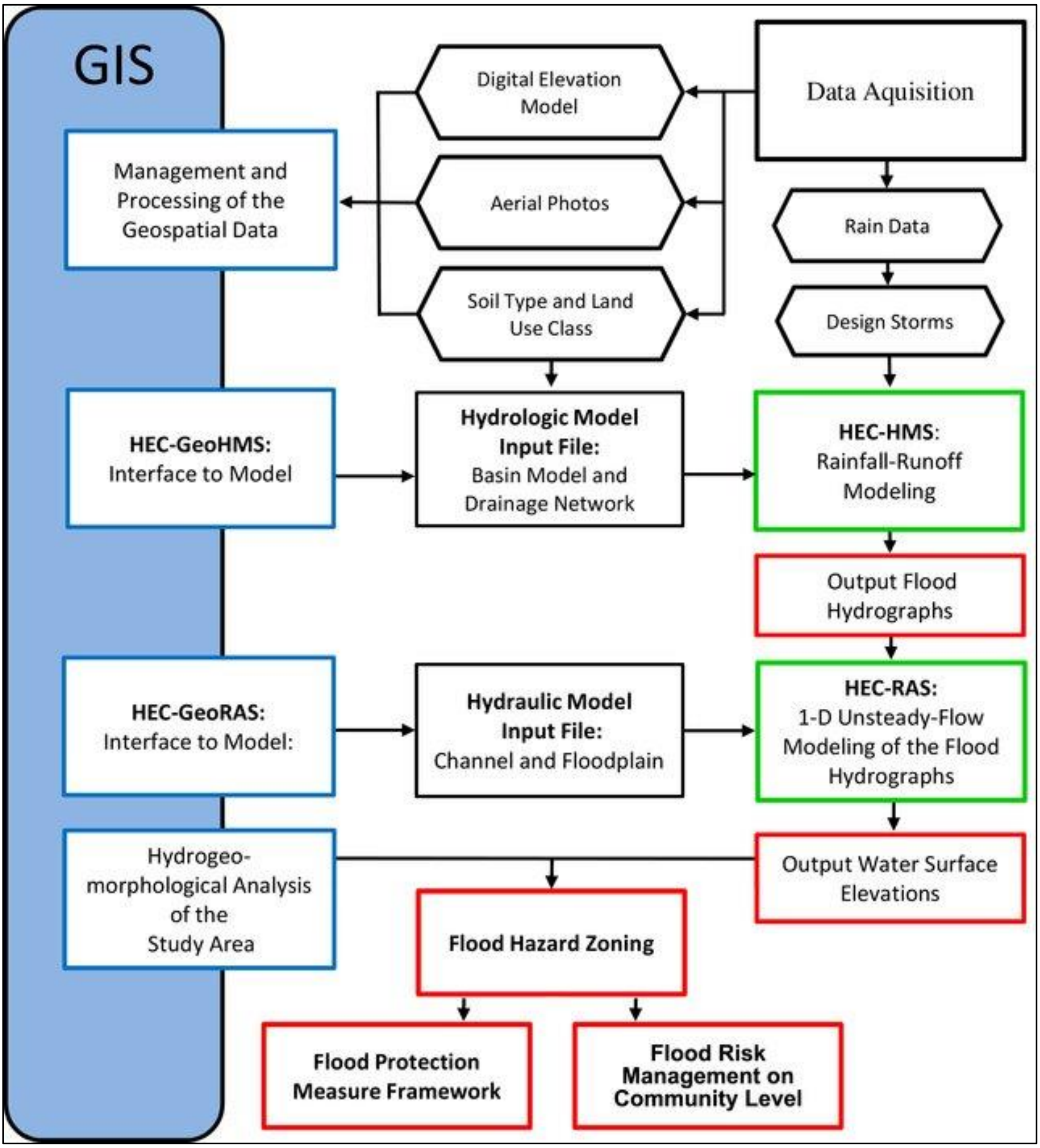

Figure 40. GIS and modelling for the Flood Risks**.**

IV.8.6. Remote sensing, GIS and water erosion modeling

The objective is to estimate the risk of soil erosion based on data collected during the analysis of remote sensing data and pedological data, and based on socio-economic elements. In order to achieve this objective, the work was carried out at different levels.

The integration of thematic maps in the GIS has made it possible to identify the impact of each factor in the estimation of soil erosion and to classify areas according to their relative importance for erosion. The approach is based on a multiplicative function of the four factors that control water erosion: soil type, slope, land use and erosion control practices. The application of this method required the evaluation of the different factors used throughout the study area, and to express them in the form of thematic maps.

The integration of these maps into a Geographical Information System is done by digitisation. The different zones obtained for each map are linked to their data bases.

data. The overlapping of the maps with the "Mapinfo" software has made it possible to develop the following map erosion risk analysis.

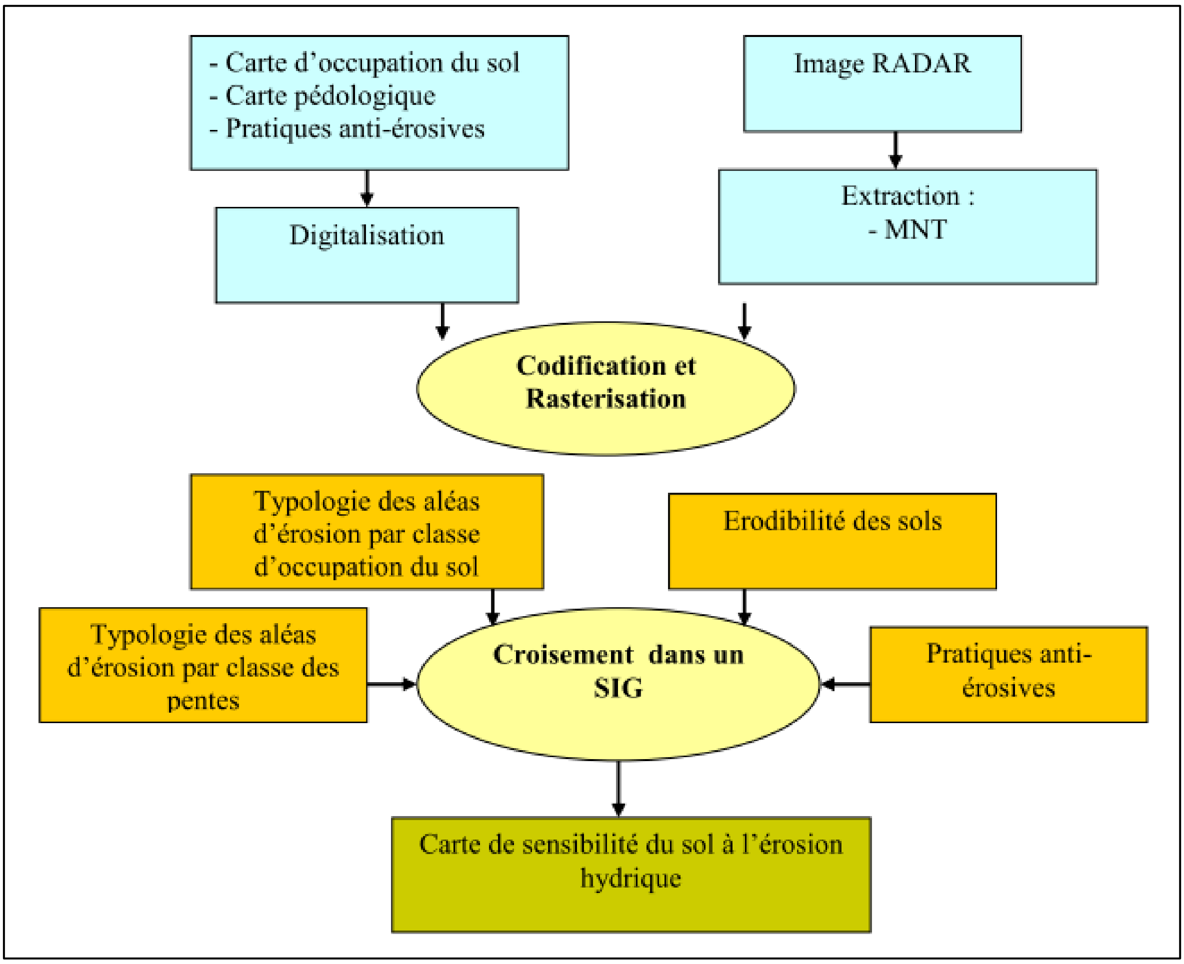

Figure 41. Remote sensing, GIS and water erosion modeling (Aouadj, 2009).

IV.8.7. Evaluating the impact of climate change on drought risk

Drought is a natural hazard that has the potential to cause significant social, economic and environmental damage. Drought risk mapping can help decision-makers identify the regions most vulnerable to drought and take proactive measures to mitigate its effects.

Analytic Hierarchy Process (AHP) is a widely used multi-criteria decision making (MCDM) technique. It can help to determine the relative importance of different factors that contribute to drought risk. Identifying the criteria that are relevant to drought risk is the first step in an AHP-based drought risk mapping methodology. This could include factors like climate, soil moisture, land use and socio-economic conditions. Each criterion is then broken down into a number of sub-criteria that can be weighted according to their relative importance. The next step is for the decision-makers to identify the alternatives that they wish to evaluate. In the context of drought risk mapping, these may include different geographical regions or areas of land use. Each alternative is then evaluated against the criteria and sub-criteria. This is done using a pairwise comparison process. During the pairwise comparison process, decision makers are asked to compare each pair of sub-criteria and find out which one is more important.

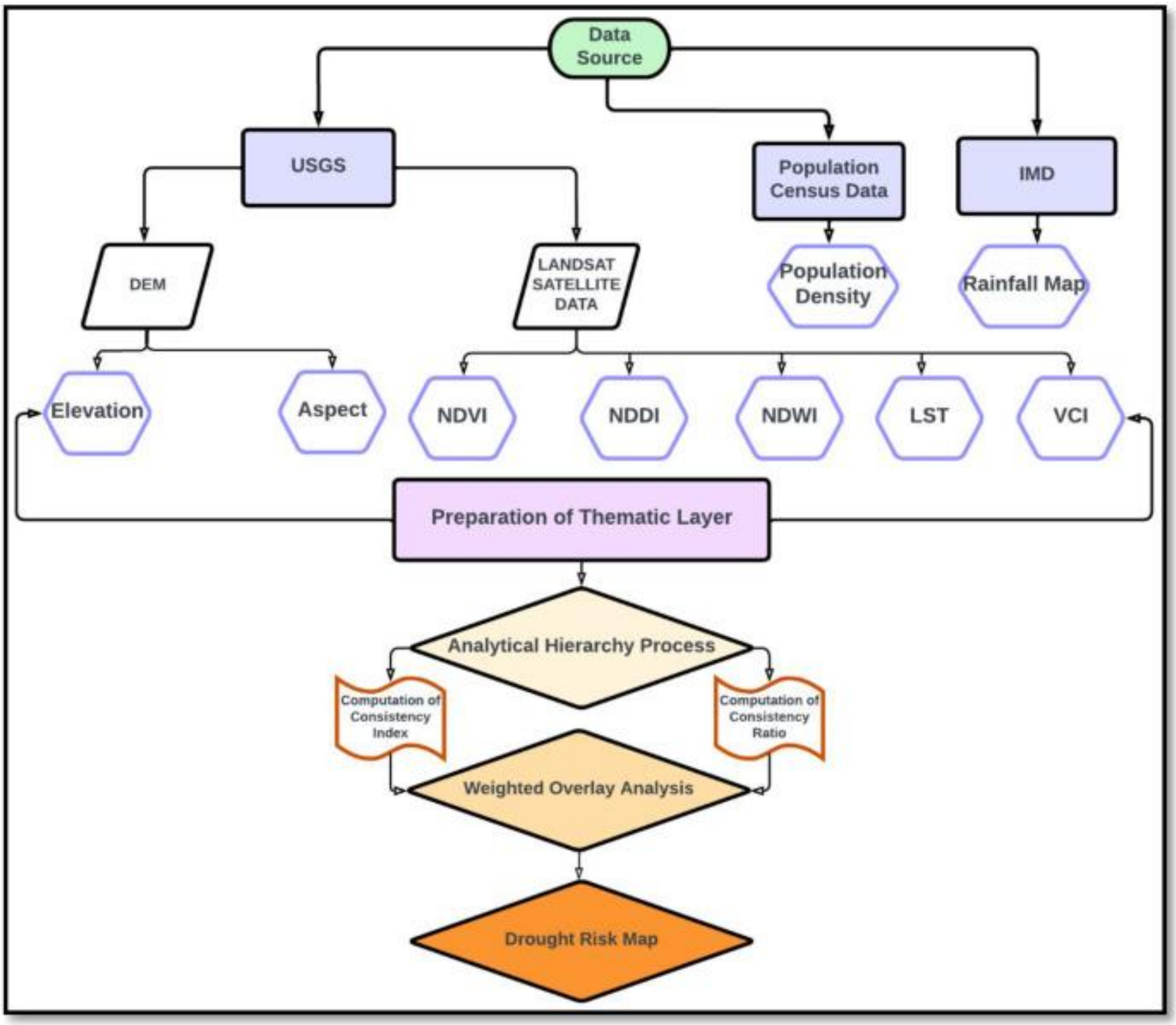

Figure 42. Shows the flowchart of the methodology.

IV.8.6. GIS-based forest fire risk assessment and mapping

The model consists of three parts: identifying hazards, analysing vulnerability and analysing response capacity. The first part focuses on several factors influencing forest fires. These include land use, topography and meteorology where the forest is located. The second part consists of population density and value of forest resources. The third part is the forest fire fighting capacity. This includes forest fire brigade, watchtower and helicopter water source.

Through GIS spatial analysis method, the forest fire risk is derived from high to low according to its fire sensitivity or fire starting capacity. With the help of the spatial analyst, a number of individual influence factors in the risk maps are combined into the overall fire risk map. The weighting of each factor is determined by Grey Relativity Analysis (GRA). This model is illustrated with a case study of the wildfire risk of an area in China. It is suggested that risk mapping is helpful for forest fire management to minimise forest fire hazard.

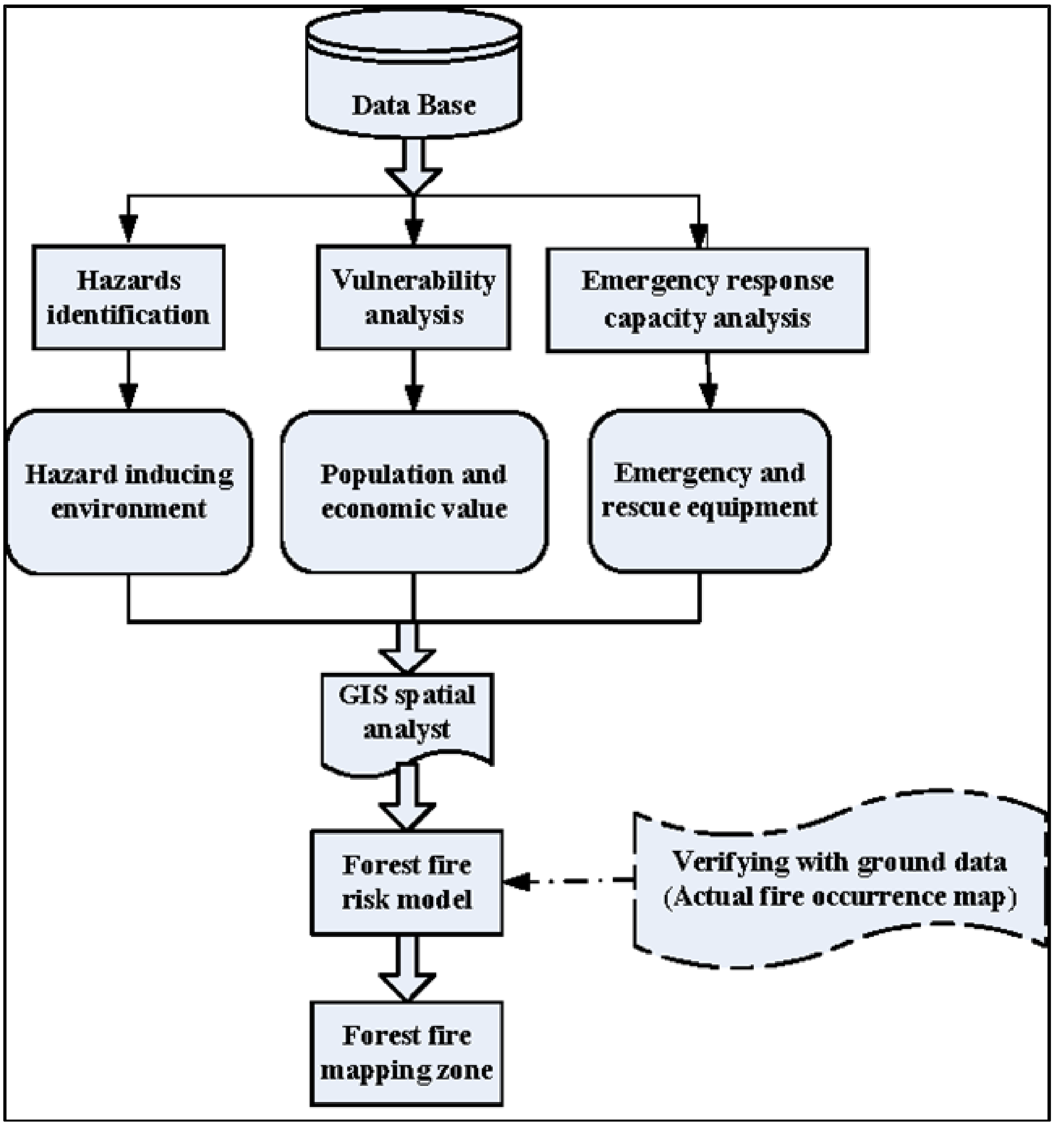

Figure 43. GIS-based forest fire risk assessment and mapping**.**

IV.8.7. The impact of GIS on the advancement of ecological conservation efforts around the world

The application of GIS to ecological conservation is revolutionising the way in which conservation strategies are planned and implemented around the world. The main impacts are :

-Protected Area Management: GIS supports the design and management of protected areas through the mapping of biodiversity hotspots and endangered species habitats.

-Wildlife corridors: GIS assists in the identification and establishment of wildlife corridors that facilitate safe animal migration, which is essential for genetic diversity and species survival.

-Environmental impact assessment: GIS tools help assess the potential environmental impact of development projects, thereby guiding sustainable development practices.

This technology not only improves the efficiency of conservation projects, but also contributes to global efforts to conserve biodiversity and promote ecosystem resilience.

Example:

Conservation efforts in the Amazon rainforest are a notable example of GIS in action. By using GIS, conservationists are able to monitor deforestation activities, map areas of high conservation value, and plan interventions to protect vulnerable ecosystems. This approach has resulted in sustainable land-use plans that balance development needs with conservation priorities.

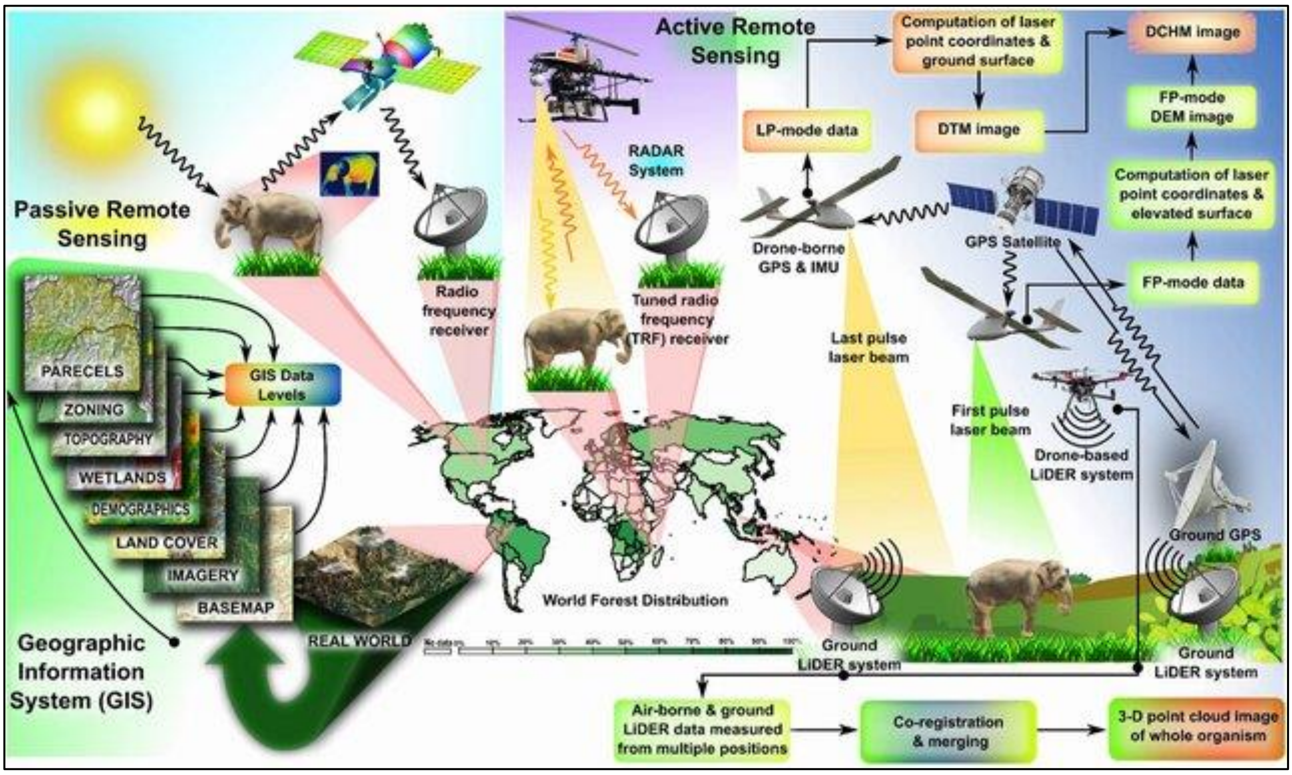

Figure 44. Application of Geographic Information Systems (GIS), remote sensing technologies like radio detection and ranging (RADAR) and satellite based light detection and ranging (LiDAR) for wildlife monitoring in the forest ecosystem.

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