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Département des Sciences Biologiques

جامعة غليزان
RELIZANE UNIVERSITY

# POLYCOPIÉ DE COURS

## Destiné aux étudiants de Master Ecologie

**Intitulé**

# Remote sensing concept and application

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**Content subject**

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## Foreword

Remote sensing and Geographic Information Systems are essential tools in geography today. This course offers an initial introduction to these two tools, with particular emphasis on the following questions: How to interpret an optical remote sensing image? How to obtain a land cover map from a remote sensing image? What is a GIS? The course also focuses on the data acquisition and interrogation (selection) methods used by GIS, and introduces students to an initial series of GIS processing operations (geoprocessing).

### I.1. Definition

Remote sensing is the technique which, through image acquisition, makes it possible to obtain information about the earth's surface without direct contact with it. Remote sensing encompasses the whole process of capturing and recording the energy of emitted or reflected electromagnetic radiation, processing and analyzing the information, and then applying that information.

Remote sensing systems, particularly those located on satellites, offer a repetitive and synoptic view of the Earth that is invaluable in monitoring and analyzing the effect of human activities on the same, as well as in environmental assessment and monitoring (urban growth, hazardous waste), detection and monitoring of global changes (atmospheric ozone depletion, deforestation, global warming), exploration, non-renewable resources (minerals, oil, natural gas) and renewable natural resources (oceans, forests, land), meteorology (weather forecasting, atmospheric dynamic processes), cartography (topography, land use, civil engineering) etc,

**Remote sensing is an essential tool for providing images from images from Earth observation satellites,**

### I.2. *Fundamental aim of remote sensing*

Expand our knowledge of our environment and facilitate interpretation of the many processes affecting the plane (Fig.1).

#### I.2.1. *Historical evolution*

- ❖ The invention of photography encouraged remote sensing.
- ❖ Remote sensing began in 1860 with a photograph of the Earth's surface taken from a balloon by Tournachon.
- ❖ First Earth observation satellite in 1960 (TIROS-I).
- ❖ Today, a number of public and private organizations and research and education centers actively working in the field of remote sensing.

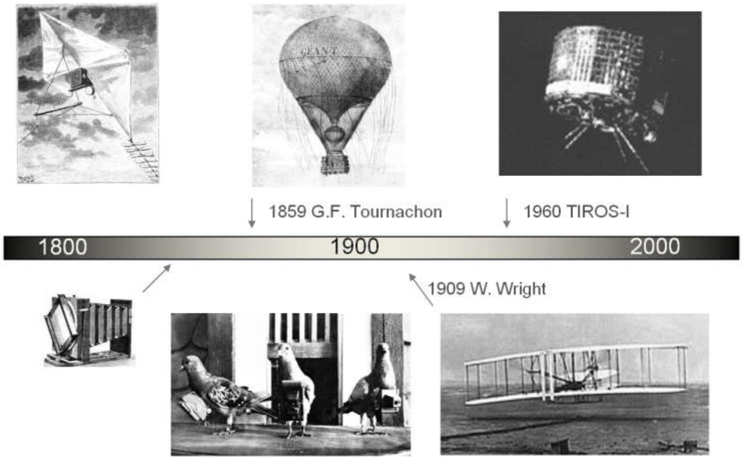



**Figure 1 : Historical event evolution of remote sensing**

### *I.2.2. The basic principle of remote sensing*

The basic principle of remote sensing is based on: target, energy source, vector. There are also many elements involved in the functioning of remote sensing, which are mentioned below:

- Source of energy (A)
- Radiation of a source of energy in the atmosphere (B)
- Interaction of radiation with the object (C)
- Recording of the energy by a sensor (D)
- Transmission, Reception, and Processing of the radiation (E)
- Interpretation and analysis of the radiation by the sensor (F)
- Application of that radiation (G)

#### I.2.2.2. Energy Source

The primary requirement for remote sensing is to have an energy service, which provides electromagnetic energy to the target of interest. The sun being a major source of energy, radiation and illumination having a sharp power allows capturing reflected light with conventional cameras and films.

Radar technology, however, requires a transmitter to be onboard the satellite, in which case the satellite itself is the source of energy. It is also possible to measure the heat emanating from the surface of the target (thermal infrared), in which case it is the target that is the source of energy (albeit stored and re-emitted solar energy) (Fig.2).

#### I.2.2.3. Radiation and the Atmosphere

The energy is required to illuminate the target. This energy is in the form of Electromagnetic radiation. Electromagnetic radiation is a dynamic form of energy that propagates as wave motion at a velocity in space.

#### I.2.2.4. Interaction with the target

The interaction of Electromagnetic radiation with the target is important to remote sensing for two main reasons. First, information carried Electromagnetic radiation reflected by the earth's surface is modified while traversing through the atmosphere. Second, the interaction of Electromagnetic radiation with the atmosphere can be used to obtain useful information about the atmosphere itself. The total energy is subjected to modification by the several physical process, scattering, absorption and refraction. Scattering is the re-direction of Electromagnetic radiation by particles suspended in the atmosphere or by large molecules of atmospheric gases. The amount of scattering depends upon the size of the particles and their abundance. The wave length of radiation, depth of the atmosphere through which the energy is travelling. Absorption is the process by which the gas molecules present in the atmosphere strongly absorb the Electromagnetic radiation through the atmosphere in certain spectral bands.

#### I.2.2.5. Recording of energy by the sensor

After the energy has been scattered by or emitted from the target, we require a sensor (remote not in contact with the target) to collect and record the electromagnetic radiation. A sensor is highly sensitive to all the wave lengths yielding spatially detailed data on absolute brightness. On the basis of the source of electromagnetic energy, the sensor can be classified into two ways. They are active sensor or passive sensor. Active sensor generates and uses its own energy to illuminate the target and records the reflected energy. It operates in the microwave regions of the electromagnetic spectrum. Their wave lengths are longer than 1 mm.

#### I.2.2.6. Transmission, Reception and Processing

The energy recorded by the sensor has to be transmitted in electronic form, to a receiving and processing station where the data processed into an image. The Image processing methods may be grouped into three functional categories such as Image Restoration, Image Enhancement and Information Extraction.

Image Restoration: Restoration processes are designed to recognize and compensate for errors, noise and geometric distortion introduced into the data during the scanning transmission and recording processes. The objective is to make the image resemble the original scene. Image restoration is relatively simple because the pixels from each band are processed separately.

Image Enhancement: Enhancement is the modification of an image, to alter its impact on viewer. General enhancement distorts the original digital values; therefore enhancement is not done until the restoration processes are completed.

Information extraction: Image restoration and enhancement process utilize computers to provide corrected and improved images for study by human interpreters. The computer makes no decision in these procedures. The human operator must instruct the computer and must evaluate the significance of the extracted information.

**I.2.2.7. Interpretation and Analysis**

Image interpretation is defined as the act of examining images to identify objects and judge their significance. An interpreter studies remotely sensed data and attempts through logical process to detect, identify, measure and evaluate the significance of environment and cultural object pattern and spatial relationship.

The quality of an image is based on the inherent characteristics of the objects. Further it depends on the following aspects.

* Sensor characteristics
* Season of the year, time of the day when the photo is taken
* Atmospheric effects
* Resolution of the image
* Image motion etc

Image interpretation is essential for the efficient and effective use of the data. The elements of image interpretation such as image tone, shape, size, pattern, image texture, shadow and association are helpful to identify the exact target and to analyse (Fig.2).

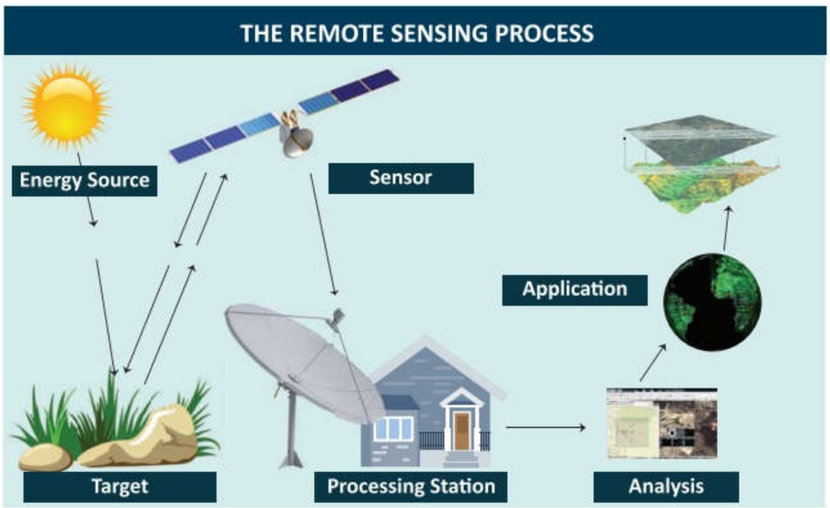



**Figure 2: functioning of remote sensing**

It is important to reiterate that visual and digital analyses of remote sensing imagery are not mutually exclusive. Both methods have their merits.

### I.3. Spatial data analysis

Spatial data analysis leverages location-based information to generate actionable insights, turning raw geographic data into valuable patterns that drive informed decision-making. This comprehensive guide explores the fundamentals of spatial data, various analysis techniques, and real-world applications of this powerful approach.

#### I.3.1. Spatial Data

Spatial data (or geospatial data) includes information with a geographic component, describing the location, shape, and relationships of objects on Earth. It is typically represented by coordinates (latitude and longitude) or topological relationships.

Types of Spatial Data:

- **Vector data —** Uses points, lines, and polygons (e.g., cities, roads, forests).
- **Raster data —** Grid-based representation (e.g., satellite imagery, elevation maps).

#### I.3.2. Importance of Spatial Data Analysis

Spatial data analysis uncovers hidden patterns by examining object relationships. Urban planners use it for infrastructure planning, while environmental scientists track land use changes and ecosystem impacts.

#### I.3.3. Spatial remote sensing applications

##### *3.3.1. Agriculture*

Remote sensing addresses many of the problems associated with agriculture, since it can be used to limit plot size, produce reliable pre-harvest agricultural statistics, diagnose the evolution of crop growth and health, and assess drought damage to improve performance and determine the most or least profitable areas of plots (Fig.3). *The remote sensing can provide the following information:*

-  *Crop extension and inventory Crop mapping*
-  *Crop production: monitoring crop phenology.*
-  *Selection and monitoring of agricultural areas*
-  *Drought and flood damage assessment flooding*
-  *Crop pest and disease control*
-  *Detection of metabolic stress (hydric or nutritional)*

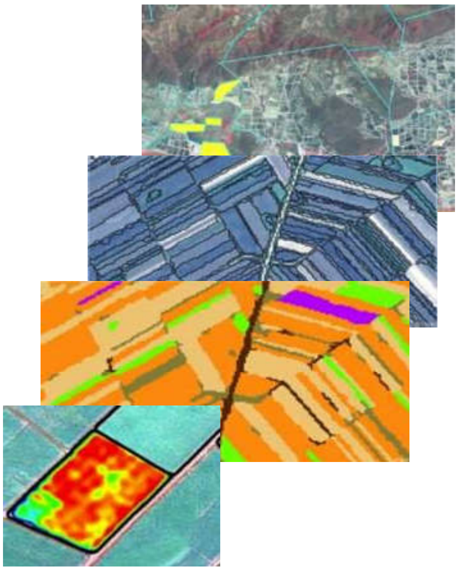


**Figure 3: Remote sensing application in agriculture**

### I.3.3.2. Remote sensing as 2D or 3D mapping

It can be used to create or update topographic maps or cadastral plans, optimize field survey campaigns, populate cartographic databases and implement sustainable development projects (Fig.4).

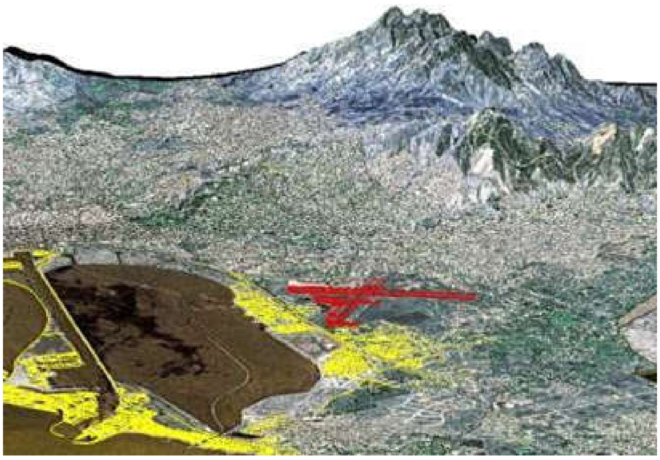


**Figure 4: Digital terrain model en 3D**

### I.3.3.3. Forestry application

Over time, there has been a major evolution in forestry management with technological improvements being crucial in improving sustainability and efficiency. Remote sensing which uses satellite and aircraft observations to collect data on the Earth's surface is one such technological miracle. Geographic Information Systems and remote sensing have become indispensable tools for managing, monitoring and conserving forest resources in the field of forestry (Fig.5).

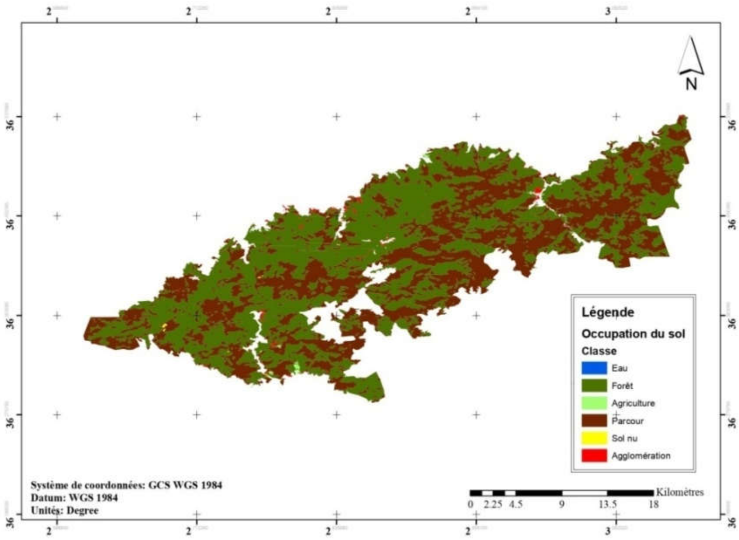



**Figure 5: Land use of Cherea Park in 2023 (Blida)**

### I.3.3.4. Spatial Mapping and Inventory

Using GIS for spatial mapping and inventory is one of the core uses in forestry management and with the use of GIS, foresters may produce precise and comprehensive maps of wooded areas that include layers of data on the species, age, density and health of the trees. A thorough understanding of the forest is provided by this spatial mapping which also makes it easier to monitor changes over time, identify possible problems and manage inventories efficiently. GIS assists in gathering real-time data using satellite imaging and remote sensing technology enabling foresters to evaluate the health of the forest, spot stressed or diseased regions and carry out prompt actions. By being proactive, this method improves the management strategy as a whole and guarantees the sustainability of forest resources over the long run.

### I.3.3.5. Forest Planning and Decision Support

The use of GIS software is essential to decision support and forest planning processes where foresters can simulate several scenarios to maximize land-use planning by combining information from multiple datasets such as topography, soil composition and climate data. Decision support models that take into account a variety of aspects including habitat protection, timber production and biodiversity conservation can be created thanks to GIS. Making difficult judgments about forestry management necessitates having a comprehensive grasp of the ecosystem. GIS tools offer a framework for weighing trade-offs, analyzing the effects of various management approaches and determining the most environmentally friendly course of action. Foresters are more equipped to make decisions that balance social, ecological and economic factors because of this integrated approach (Fig.6).

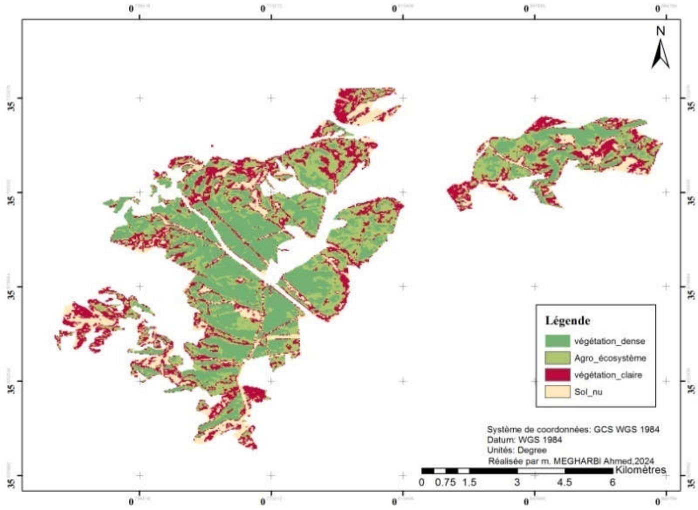



**Figure 6: Forest planning of Zemmoura forest (2024)**

**I.3.3.6. Emergency Response and Fire Management**

Communities, forests and biodiversity are all seriously threatened by wildfires where emergency response plans and fire management greatly benefit from the use of GIS tools. GIS aids in forecasting and simulating possible fire hazards by examining past fire trends, meteorological data and vegetation kinds. Rapid wildfire detection and reaction are made possible by real-time monitoring via GIS which enables the coordination of firefighting actions. Establishing firebreaks, evaluating risky regions and developing evacuation strategies are all made possible with the use of GIS. Foresters can take preventive action to lessen the impact of wildfires on ecosystems and human communities by combining weather forecasts with geographical data (Fig.7).

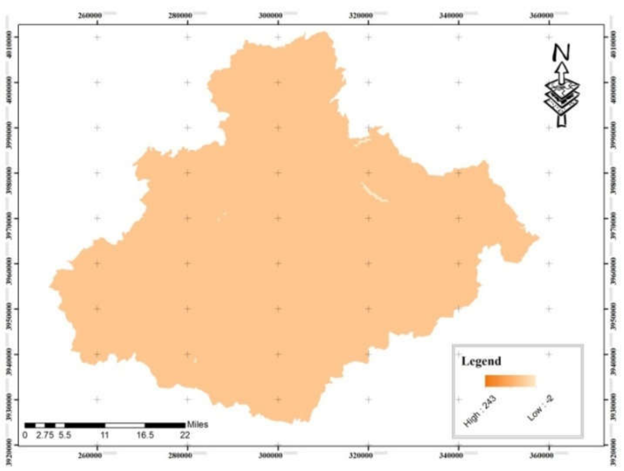



**Figure 7: Firebox map of Relizane area in 2023**

## I.4. Advantages of Remote Sensing in Forestry

### I.4.1 Accurate Forest Monitoring

With previously unheard-of accuracy, forestry professionals can now monitor large forested areas thanks to remote sensing technology like satellite imaging and aircraft surveys. The data collected is processed and analyzed with the help of GIS-based tools which offer thorough insights into the composition, density and health of the forest. Making educated judgments on the distribution of resources, conservation initiatives and sustainable forestry methods requires the use of this knowledge.

### I.4.2. Efficient Inventory and Assessment

Real-time and comprehensive data collection is difficult with traditional forestry inventory approaches since they frequently require laborious ground surveys. Remote sensing provides large-scale, quick assessments which removes this constraint where forestry professionals can produce thorough inventories that include tree species distribution, height and diameter at breast height (DBH) thanks to GIS technology which makes it easier to integrate data layers. This thorough data supports efficient forest management.

### I.4.3. Deforestation Monitoring and Prevention

Given the startling rate of deforestation occurring worldwide, proactive steps must be taken to monitor and stop more forest cover loss and a potent way to track deforestation in almost real-time is through the use of remote sensing devices. Forestry experts can spot illicit logging activities, track changes in land cover and quickly intervene to reduce deforestation by using GIS techniques. This proactive strategy aids in the preservation of important ecosystems and the protection of biodiversity.

### I.4.4. Fire Detection and Management

Forest fires are a serious hazard to wildlife, human populations and ecosystems and to promptly identify and effectively control forest fires, remote sensing is essential. By combining information on past fire trends, vegetation health and weather, GIS technology helps create maps of the risk of wildfires and with the use of this information, authorities may minimize the damage to nearby populations and forests by putting preventive measures into place and acting quickly in response to rising fire hazards (Fig.).

### I.4.5. Remote sensing urban application

Cities are unique because of the existence of dense artificial structures. The increasing urbanisation rate will eventually lead to the expedited consumption of non-renewable land resources such as water (on- and under-ground) and food [49], and energy resources such as oil, coal and gas—with environmental, social and economic impact on developing and developed countries alike. Thus, the growth of urban areas can result in substantial land-cover and land-use changes—an ideal sustainability use case for the use of remote sensing. The next sections are devoted to review of remote sensing applications within urban environments, focussing on urban growth, sprawl and change; environmental impacts of urban growth; and sustainable energy applications.

### I.4.6. Urban growth, sprawl and change

Urban growth refers to the transformation of the landscape from undeveloped to developed land. More specifically, the growth away from central urban areas into homogeneous, low-density and typically car-dependent communities is often referred to as urban/suburban sprawl. In developing countries, urban sprawl can be unplanned and uncontrolled (Fig.8).

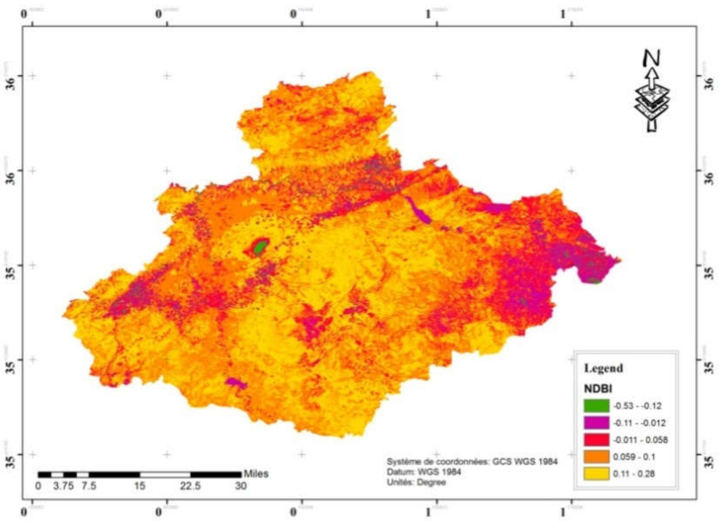



**Figure 8: Urban map of Relizane 2024**

### I.4.7. The geology

Remote sensing technology plays an important role today in the geological survey, mapping, analysis and interpretation, which provides a unique opportunity to investigate the geological characteristics of the remote areas of the earth's surface without the need to gain access to an area on the ground (Fig.9).

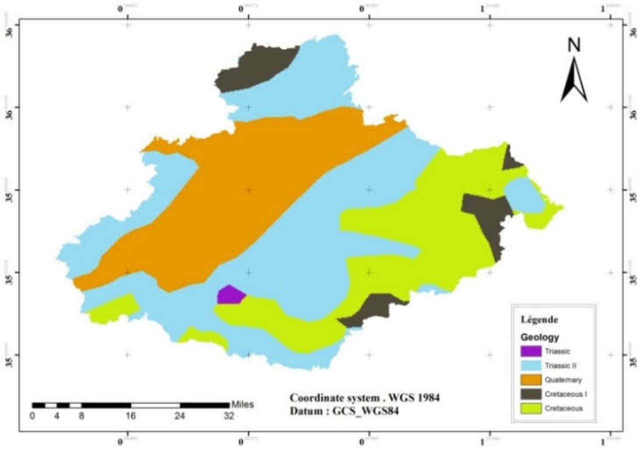



**Figure 9: Gelogical map of Relizane**

### I.4.8. Hydrology

Remote Sensing and GIS technologies are well-established tools and are routinely used in applied hydrology, forestry, land use dynamics analyses, etc. Abilities of remote sensing technology in hydrology are to measure spatial, spectral, and temporal information and provide data on the state of the earth's surface. It provides observation of changes in hydrological states, which vary over both time and space that can be used to monitor hydrological conditions and changes. Sensors used for hydrological applications cover a broad range of electromagnetic spectrum. Both active sensors that send a pulse and measure the return pulse (like radar, microwave etc.) and passive sensors that measure emissions or reflectance from natural sources (like Sun, thermal energy of the body) are used. Sensors can provide data on reflective, thermal and dielectric properties of earth's surface.

Remote sensing techniques indirectly measure hydrological variables, so the electromagnetic variables measured by remote sensing have to be related to hydrological variables empirically or with transfer functions (Fig.10).

Remote sensing applications in hydrology that are being used today are mainly in:

- Precipitation estimation
- Runoff computations
- Snow hydrology applications
- Groundwater identification and estimation
- Hydrological modelling

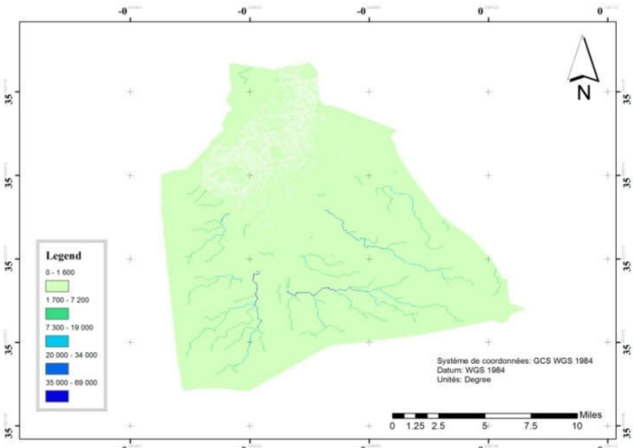



**Figure 10: water accumulation of Macta wetland**

### I.4.9. Algal cover quantification

Algal blooms are commonly quantified through the concentration of chlorophyll-a (chl-a) (Ruddick et al. Citation2008; Khan et al. Citation2021), which has the advantage of being one of the most commonly estimated parameters using remote sensing techniques since the 1970s (Gholizadeh et al. Citation2016). Although chl-a concentrations alone cannot confirm cyanobacteria dominance, remotely sensed chl-a can help detect potential cyanoHABs and their initiation, especially in zones were they are often reported, complementing other monitoring techniques. Moreover, the work of Stumpf et al. (Citation2016) points out that chl-a seems to be more sensitive in detecting changes in biomass in cyanobacterial blooms (Fig.11).

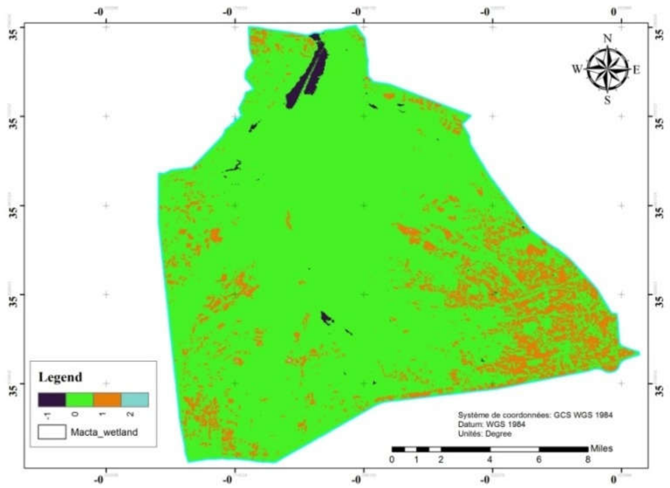



**Figure 11: Algal blooms quantification in Macta wetland**

### I.4.10. Land Use Mapping and Monitoring

Land use data represents how the landscape is being used for conservation, development, and agriculture. Remote sensing is used to map the land use pattern of large areas and monitor changes that occur over a particular period of time (Fig.12).

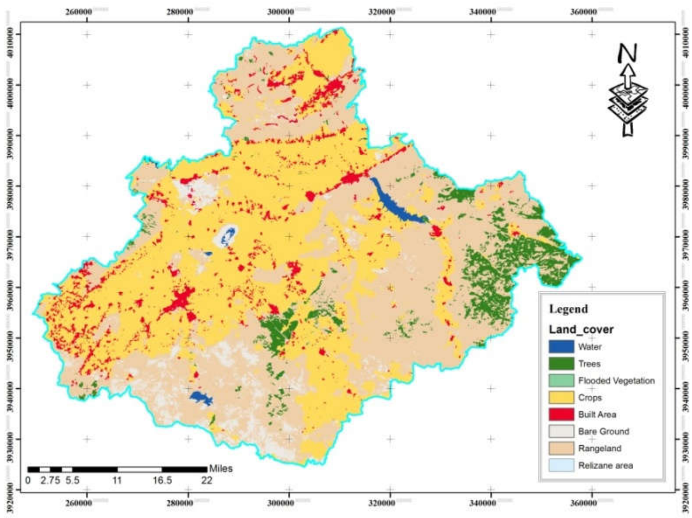



**Figure 12: Land use and land cover of Relizane area in 2024**

## I.5. Remote sensing platforms

### I.5.1. Land-based platforms

This type of platform is mainly used for experimentation and calibration.

### I.5.2.. Aerial Flatforms

- ***Balloons***: These usually consist of a very thin membrane inflated with a lighter-than-air gas, such as hot air, helium or hydrogen. They are rarely used, except in meteorology.
- ***Airplanes***: airplanes are very flexible platforms. They have three limitations: Repetitive data acquisition is not guaranteed. The territory covered in a single mission is fairly limited, and costs are relatively high.

### I.5.3. Space platforms

Space platforms, or satellites, are Earth-orbiting vessels that move along an ellipse with the center of the Earth at one of its foci. The satellite's movements are governed solely by the forces of gravity, in accordance with Kepler's laws of gravity.

$$T^2 = \frac{a^3}{K}$$

T: Period of rotation

a : is the semi-major axis of the ellipse (the radius for a circular orbit)

K : is Kepler's constant

## I.6. Types Of Satellites

Throughout the years, different types of satellites have become indispensable, supporting diverse activities ranging from broadcasting and navigation to remote sensing of the planet. They serve a variety of purposes, so it’s common to classify them depending on their functions. Several types of satellites’ orbits, each with its own unique set of characteristics, are used for different missions. At the same time, all of the different satellite types, no matter what they’re used for, help us learn more about the planet, connect people in far-flung places, mitigate human-caused and natural disasters, and open up new technological possibilities for humanity.

### I.6.1. Types Of Satellites By Orbit

In most cases, after being launched, a satellite is placed in one of several predetermined orbits around the Earth. But in some cases, it may be directed to interplanetary journey, following a path around the Sun until it reaches its ultimate destination.

Satellites are usually classified based on their orbital altitude (distance from the Earth’s surface), which directly affects their coverage and the speed at which they travel around the planet. When choosing the type of orbit, spacecraft developers should consider its intended purpose, the data it acquires, and the services it offers, as well as the cost, coverage area, and feasibility of different orbits. The 5 main types of satellites based on their orbits are:

- ✓ low Earth orbit (LEO);
- ✓ medium Earth orbit (MEO);
- ✓ geostationary orbit (GEO);
- ✓ Sun-synchronous orbit (SSO);
- ✓ geostationary transfer orbit (GTO).

**I.6.1.1. Low Earth Orbit (LEO) Satellites**

Low Earth Orbit satellites are moving at an altitude of roughly 160–1,500 kilometers above the Earth's surface. They have a short orbital period, between 90 and 120 minutes, meaning they can travel around the planet up to 16 times a day. This makes them particularly well-suited to all types of remote sensing, high-resolution earth observation, and scientific research, as data can be acquired and transmitted rapidly.

All the types of satellites in LEO can vary the angle of their plane relative to the Earth's surface. Low Earth type of orbit is very common, as it provides more potential paths for spacecraft to take. However, because of their proximity to the Earth, they have a smaller coverage area than other satellite types. Often, groups of LEO spacecraft, known as satellite constellations, are launched together to form some type of net encircling the Earth. This lets them cover huge areas simultaneously by working together.

EOS SAT, as a source for remote sensing data to feed into sustainable practices and precision agriculture, is one of the most potential LEO constellations for food producers, input suppliers, banks, governments, and others involved in the agricultural sector.

**I.6.1.2. Medium Earth Orbit (MEO) Satellites**

A Medium Earth type of orbit is located between low Earth and geostationary orbits, typically at an altitude of about 5,000 to 20,000 kilometers. Positioning and navigation services, like GPS, extensively use MEO type of satellites. Recently, high-throughput satellite (HTS) MEO constellations have been put into operation to enable low-latency data communication to service providers, commercial and government organizations.

With their longer orbital period (usually between 2 and 12 hours), this type of satellites offer a happy medium between coverage area and data transmission rates. Compared to low Earth orbit spacecraft, MEO ones require fewer devices to give worldwide coverage, but their time delay is longer and their signals are weaker.

**I.6.1.3. Geostationary Orbit (GEO) Satellites**

Spacecraft in geostationary Earth orbit are positioned 35,786 kilometers above Earth's surface, precisely over the equator. Three evenly spaced machines in GEO can give nearly worldwide coverage thanks to the huge area they cover on Earth.

Objects in GEO appear motionless from the ground because their orbital period is identical to Earth's rotation — 23 hours, 56 minutes, and 4 seconds. This allows a terrestrial antenna to always point toward the same device in space. That's why this type of satellites is perfect for always-on communication services like TV and phones. Also, this type can be used in meteorology to keep an eye on the weather in particular regions and track the development of local patterns. The downside of GEO type of spacecraft for real-time communication is the longer signal delay caused by their great distance from Earth.

**I.6.1.4. Sun-Synchronous Orbit (SSO) Satellites**

The Sun-synchronous orbit type of satellites goes from north to south across the polar regions at an altitude of 600 to 800 km above the Earth. The orbital inclination and altitude of SSO spacecraft are calibrated so that they always cross any given location at precisely the same local solar time. Thus, the lighting conditions are consistent for imaging, making this type of satellite ideal for earth observation and environmental monitoring.

This also implies that SSO's current and historical satellite images are well-suited for change detection. Scientists use these image sequences to learn about the development of weather patterns, forecast cyclones, monitor and prevent wildfires and floods, and gather information on long-term issues like deforestation and coastline changes. But because of their lower orbital altitude, SSO type of spacecraft can only cover a smaller region at once and need more machines to do so continuously.

**I.6.1.5. Geostationary Transfer Orbit (GTO) Satellites**

The most frequent type of satellite transfer orbit is a geostationary one utilized to migrate from a transition orbit to GEO. Spacecraft are not always placed directly into their ultimate orbit when propelled from Earth into space by launch vehicles such as Falcon 9. Rockets carrying payload to GEO drop it off at transfer orbits, which are halfway points on the path to its final position. Then a satellite's engine fires to reach its destination orbit and adjust its inclination

**I.7. Different Types Of Satellites By Their Functions**

Providing communication and television services is only the tip of the iceberg when it comes to the uses of space-based technology. Many types of satellites have been launched in recent years for a wide variety of scientific purposes, including Earth observation, meteorological study, navigation, studying the effects of space flight on living organisms, and gaining insight into the cosmos. Today, the most common four types of satellites based on their application are:

- communication;
- Earth observation;
- navigation;
- astronomical.

Our in-depth examination of the characteristics of different types of satellites and their functions continues below.

**I.7.1. Communication Satellites**

A communication spacecraft, usually located at GEO and equipped with a transponder — an integrated receiver and transmitter of radio signals — may receive signals from Earth and retransmit them back to the planet. As a result, it opens interaction channels between regions that were previously unable to communicate with one another due to large distances or other obstacles. Different types of communication satellites facilitate various forms of media transmissions, such as radio, TV, telephone, and the Internet.

Using the communication type of spacecraft, you can relay many signals at once. Spacecraft for broadcasting and TV signal distribution to ground-based stations typically have individual transponders for each carrier. In most cases, though, several carriers will be relayed by a single transponder. Due to its compatibility with mobile terminals, this type of satellites is ideally suited for long-distance communication.

**I.7.2. Earth Observation Satellites**

The purpose of Earth observation type of satellites is to monitor our planet from space and report back on any changes they observe. This type of space technology makes possible consistent and repeatable environmental monitoring as well as rapid analysis of events during emergencies like natural disasters and armed conflicts.

The goals of the surveillance mission determine the type of satellite sensors used for Earth observation. Information collected varies depending on the type of sensor employed and the available frequency bands.

**I.7.2.1. Navigation Satellites**

The navigation system constellations are located between 20,000 and 37,000 kilometers from Earth's surface. This type of satellite sends out signals that reveal their time, position in space, and health status. There are two major types of space navigation systems:

The spacecraft of the Global Navigation Satellite System (GNSS) broadcast signals that GNSS receivers pick up and utilize for geolocation purposes, providing global coverage. Galileo in Europe, GPS in the United States, and the BeiDou Navigation Satellite System in China are all examples of GNSS

The Regional Navigation Satellite System (RNSS) is an autonomous regional navigation system that provides coverage on a regional scale. For instance, India's IRNSS project aims to provide Indian citizens with a reliable location-based service

**I.7.2.2. Astronomical Satellites**

Basically, an astronomical satellite is a giant telescope in orbit. It is able to see well without interference from the Earth's atmosphere, and its infrared imaging technology can function normally without being fooled by the planet's surface temperature. The satellite type used for astronomy has a vision that is up to ten times better than the most powerful telescope on Earth (Fig.13).

Spacecraft used in astronomy can be broken down into several distinct types:

Astronomy satellites are used to investigate different types of celestial bodies and phenomena in space, from the creation of star and planetary surface maps and taking images of the planets in our solar system to the study of black holes.

The use of climate research satellites fitted with specific types of sensors allows scientists to gather comprehensive, multi-faceted data on the world's oceans and ice, land, biosphere, and atmosphere.

Space-based studies on plant and animal cells and structures are possible thanks to biosatellites. Because they allow scientists from different regions to work together, this type of spacecraft plays a crucial role in the progress of medicine and biology.

The vast majority of satellites can perform more than one function simultaneously. Still, it's a common recommendation that researchers diversify the types of satellites they use to obtain more comprehensive and accurate results of their studies. EOSDA LandViewer is a helpful tool for this because it aggregates space-collected imagery (including high-resolution) from multiple sources and provides a user-friendly interface for finding and downloading the images you need.

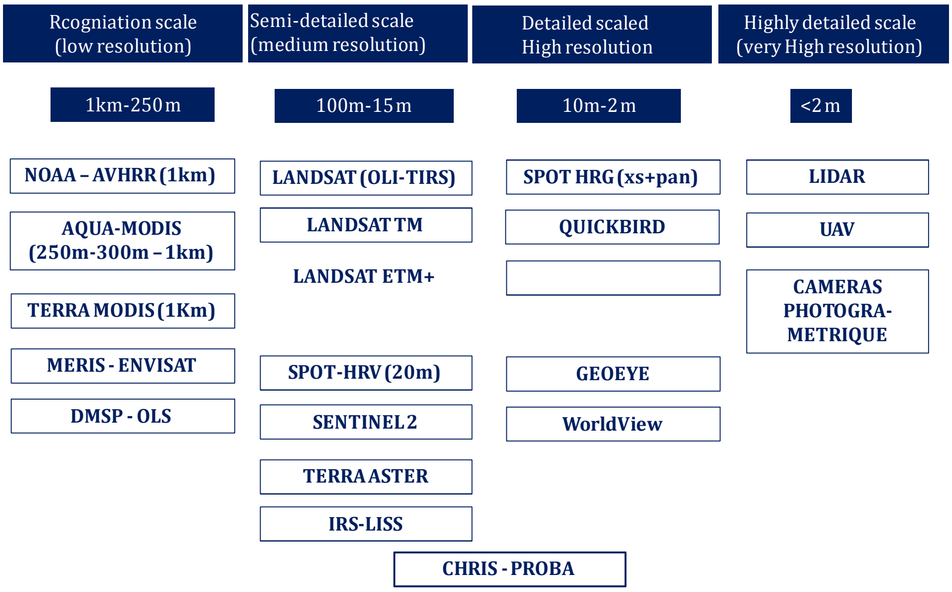



**Figure 13: Some satellites in remote sensing**

### I.7.3. Medium-resolution satellite

#### I.7.3.1. Landsat

Since 1972, the Landsat series of Earth observation+ satellites, jointly produced by NASA and the USA, has provided an uninterrupted record of spatial data on the Earth's surface to advance scientific research aimed at understanding our planet and the impact of its inhabitants on the environment. The first Landsat satellites provided a wealth of new data for improved mapping of remote areas and geological features, as well as digital analysis of vegetation. The utility of Landsat's spatial and spectral resolution has advanced its use for socially useful applications, such as global crop forecasting, forest monitoring, water use, carbon budgets and the basis of Google Maps. Landsat's long-term data is an unrivalled resource for observing land cover and land use change over several decades. Landsat's free and open data policy in 2008 was a paradigm shift for the world. Today, with improved analytical and computational capabilities, Landsat archives are poised to move to more real-time monitoring and understanding of the Earth ( pubs.er.usgs, 2019).

The LANDSAT-satellite family uses a scanning mirror system for data acquisition. The LANDSAT, launched by the USA in 1972, was the first satellite having generally available high resolution data. Geometric resolution of the first generation of Multi Spectral Scanning (MSS) data was 80 by 80 m and the sensors on board was recording radiation in four wavelength bands (Fig.14)

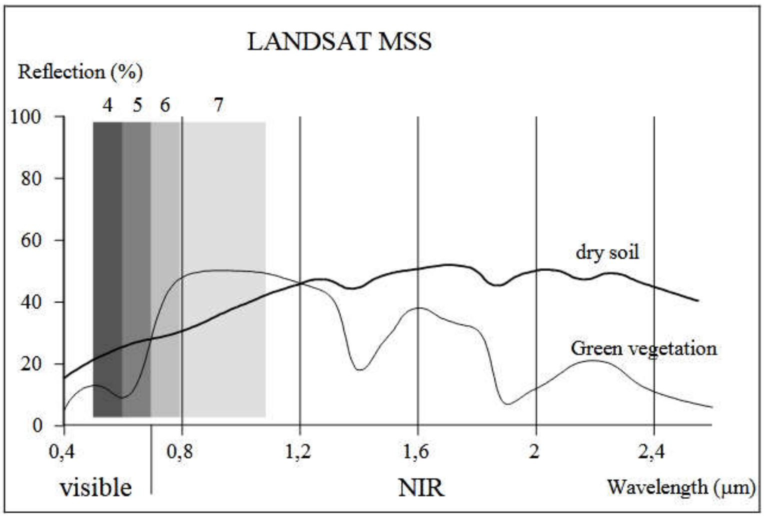



**Figure14: The LANDSAT MSS sensor.**

**I.7.3.2. Spot satellite**

The Satellite Program for Earth Observation (SPOT) had its first satellite in orbit in 1986. This program, developed by France, Belgium and Sweden, comprises five satellites. The first three satellites, launched in 1986, 1990 and 1993 respectively, are identical. They feature two high-resolution visible spectrum (HRV) sensors. These sensors provide images in four bands, one of which is panchromatic. In 1998, SPOT4 was launched into orbit. It features two high-resolution visible and infrared (HRVIR) sensors, plus a vegetation sensor. (Marie-Dominique Lancelot, trans. Robert J.1994)

The sensors retain the same spatial resolutions of 10 m for panchromatic and 20 m for the other bands as the HRV, but add an infrared band. The Vegetation sensor captures images in the following four bands: blue, red, near infrared and central infrared. It enables long-term observation of vegetation cover at a resolution of 1 km. SPOT 5 is the most recent satellite in this program, launched in 2002. It features three different sensors: high-resolution geometric sensors (HRG). A pair of high-resolution stereo sensors (HRS) is used for simultaneous acquisition of stereo pairs of the same area. This means that only one satellite is needed to obtain images for the creation of digital terrain elevation models.

The SPOT-satellite family was launched in 1986 and is based on the push-broom sensor technology. The sensor is called High Resolution Visible (HRV) and the satellite actually carries two parallel sensors capable of recording radiation either in panchromatic mode or in a three band multispectral mode (Figure 14). In the construction of the satellite sensors special attention was made to ground resolution. The pixel size in panchromatic mode is 10 by 10 m and 20 by 20 m in multispectral mode. The HRV sensors are movable, having the ability of recording data both vertically under the satellite, and oblique. The temporal resolution is 15 days.

The oblique option of the sensor makes it possible to get very frequent recordings from the same area and to assemble stereo pairs. Using photographic prints of the satellite images makes it possible to make topographic maps with the same instruments that are used in aerial photography photogrammetry. Lately the process of topographical mapping has been automated by using dedicated software on the digital satellite data (Fig.15).

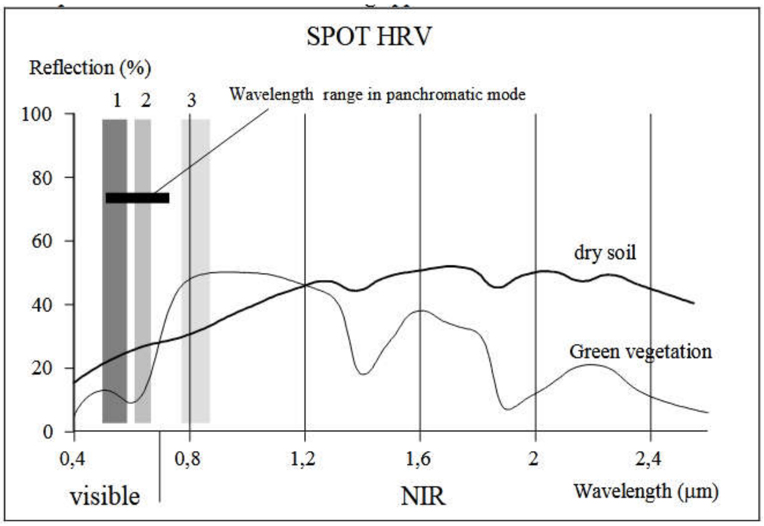



**Figure15: The SPOTSAT HRV sensor.**

### I.7.4. High resolution satellite

#### I.7.4.1. IKONOS

IKONOS is commissioned by Virginia-based GeoEye. It was commissioned in 1999. The GeoEye-1 satellite was launched into orbit in September 2008. The IKONOS satellite has a spatial resolution of 1 m in panchromatic and 4 m in multispectral. The multispectral bands captured are blue, green, red and near infrared. GeoEye offers a range of imaging options, including orthorectified and stereoscopic images.

## I.8. Types of Remote Sensing

*There are mainly two types of sensors used, which are as mentioned below:*

### **I.*8.1. Active Remote Sensing***

Active remote sensing utilizes an artificial source of radiation as an investigation, and the resulting signal, which scatters back to the sensor, depicts the Earth or the atmosphere. The Synthetic-Aperture Radar system is a type of active sensor, which can emit radiation in the form of a beam coming from a moving sensor and can also measure the backscattered components returning to the sensor from the ground in the region of the microwave.

### I.*8.2. Passive Remote Sensing*

Passive remote sensing depends only on solar radiation as its source of energy, which can be seen in multispectral, and hyperspectral sensors. It is mainly concentrated in the visible, near-infrared, and shortwave infrared spectral regions. These sensors at the satellite measure the emerging radiation from the surface of the Earth's atmosphere system in the direction of sensor observation. In a remote sensing image, a grid of pixels is located to achieve image sensing by a combination of scanning in the cross-track direction and the sensor platform movement along the in-track direction (Fig.16).

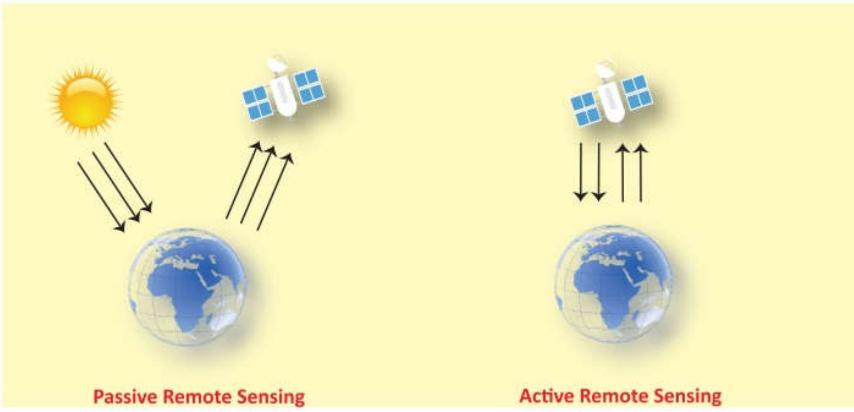



**Figure 16: Type of remote sensing**

## I.9. Electromagnetic spectrum

Electromagnetic (EM) energy includes all energy moving in a harmonic sinusoidal wave pattern with a velocity equal to that of light. Harmonic pattern means waves occurring at frequent intervals of time. Electromagnetic energy has both electric and magnetic components which oscillate perpendicular to each other and also perpendicular to the direction of energy propagation as shown in Fig.17.

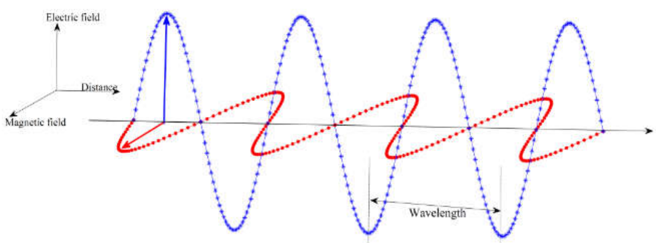



**Figure 17: Electromagnetic wave**

### I.9.1. Electro-Magnetic Radiation (EMR) spectrum

Distribution of the continuum of radiant energy can be plotted as a function of wavelength (or frequency) and is known as the electromagnetic radiation (EMR) spectrum. EMR spectrum is divided into regions or intervals of different wavelengths and such regions are denoted by different names. However, there is no strict dividing line between one spectral region and its adjacent one. Different regions in EMR spectrum are indicated in Fig. 18

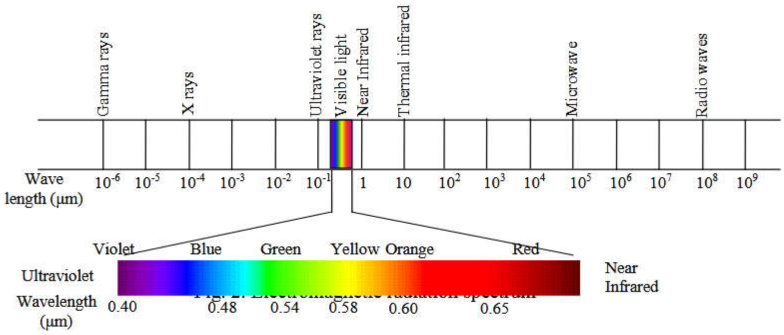



**Figure 18: Electromagnetic wave**

The EM spectrum ranges from gamma rays with very short wavelengths to radio waves with very long wavelengths. The EM spectrum is shown in a logarithmic scale in order to portray shorter wavelengths.

The visible region (human eye is sensitive to this region) occupies a very small region in the range between 0.4 and 0.7 µm. The approximate range of color "blue" is 0.4 – 0.5 µm, "green" is 0.5-0.6 µm and "red" is 0.6-0.7 µm. Ultraviolet (UV) region adjoins the blue end of the visible region and infrared (IR) region adjoins the red end.

The infrared (IR) region, spanning between 0.7 and 100 µm, has four subintervals of special interest for remote sensing.

(1) Reflected IR (0.7 - 3.0 µm)

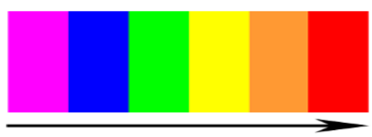
(2) Film responsive subset, the photographic IR (0.7 - 0.9 µm)

(3) and (4) Thermal bands at (3 - 5 µm) and (8 - 14 µm).

### I.9.2. The visible spectrum

represents only a small portion of the entire electromagnetic spectrum. Visible wavelengths range from 0.4 to 0.7 µm. This is the only part of the spectrum we can associate with colors.

- Violet : 0.4 - 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 - 0.7 µm

### I.9.3. Energy sources and radiation principles

#### I.9.3.1. Solar radiation

Primary source of energy that illuminates different features on the earth surface is the Sun. Solar radiation (also called insolation) arrives at the Earth at wavelengths determined by the photosphere temperature of the sun (peaking near 5,600 °C).

Although the Sun produces electromagnetic radiation in a wide range of wavelengths, the amount of energy it produces is not uniform across all wavelengths.

Fig.00. shows the solar irradiance (power of electromagnetic radiation per unit area incident on a surface) distribution of the Sun. Almost 99% of the solar energy is within the wavelength range of 0.28-4.96 µm. Within this range, 43% is radiated in the visible wavelength region between 0.4-0.7 µm. The maximum energy (E) is available at 0.48 µm wave length, which is in the visible green region (Fig.19).

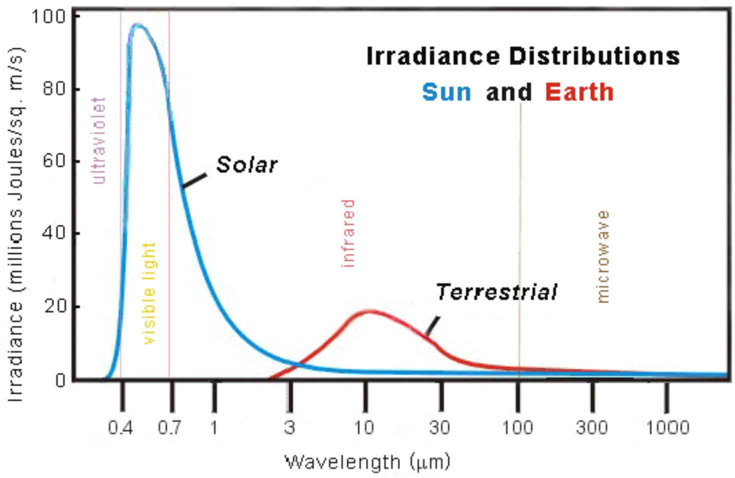



**Figure 19: Irradiance distribution of the Sun and Earth**

Using the particle theory, the energy of a quantum (Q) is considered to be proportional to the frequency. The relationship can be represented as shown below.

$$Q = h \times f \quad \textbf{(1)}$$

where h is the Plank's constant (6.626 x 10-34 J Sec) and f is the frequency.

Using the relationship between c, λ and f (Eq.1), the above equation can be written as follows:

$$Q = h * c / \lambda \quad \textbf{(2)}$$

### I.9.3.2. Properties of electromagnetic waves

reflection: a body that receives REM can reflect part of it albedo: solar energy reflected by a portion of the earth's space (% reflected) specular or diffuse.

### I.9.3.3. Radiation from the Earth

Other than the solar radiation, the Earth and the terrestrial objects also are the sources of electromagnetic radiation. All matter at temperature above absolute zero (0oK or -273oC) emits electromagnetic radiations continuously. The amount of radiation from such objects is a function of the temperature of the object as shown below.

$$M = \sigma \times T^4 \quad \textbf{(3)}$$

This is known as Stefan-Boltzmann law. M is the total radiant exitance from the source (Watts / m2), σ is the Stefan-Boltzmann constant (5.6697 x 10-8 Watts m-2k-4) and T is the absolute temperature of the emitting material in Kelvin.

Since the Earth's ambient temperature is about 300 K, it emits electromagnetic radiations, which is maximum in the wavelength region of 9.7 µm, as shown in Fig.3. This is considered as thermal IR radiation. This thermal IR emission from the Earth can be sensed using scanners and radiometers.

### I.9.4. Energy Interactions in the Atmosphere

All radiations whether from active or passive source; which is detected by remote sensors, passes through some distance (or path length) of the atmosphere. During this travel, the radiations interact with the atmosphere and undergo the process of reflection, absorption or scattering. In remote sensing, the mechanism of atmospheric scattering and absorption plays an important role (Fig.20).

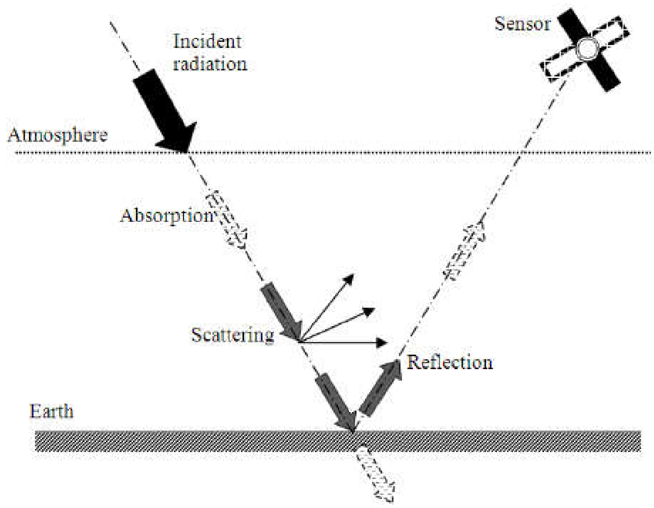



**Figure 20: Interactions in the atmosphere**

**I.9.4.1 Scattering**

Atmospheric scattering is the unpredictable diffusion of radiation by particles in the atmosphere. There are three types of Scattering :

***A. Rayleigh Scattering***

Rayleigh scattering mainly consists of scattering caused by atmospheric molecules and other tiny particles. This occurs when the particles causing the scattering are much smaller in diameter (less than one tenth) than the wavelengths of radiation interacting with them. Smaller particles present in the atmosphere scatter the shorter wavelengths more compared to the longer wavelengths.

The scattering effect or the intensity of the scattered light is inversely proportional to the fourth power of wavelength for Rayleigh scattering. Hence, the shorter wavelengths are scattered more than longer wavelengths (Fig21).

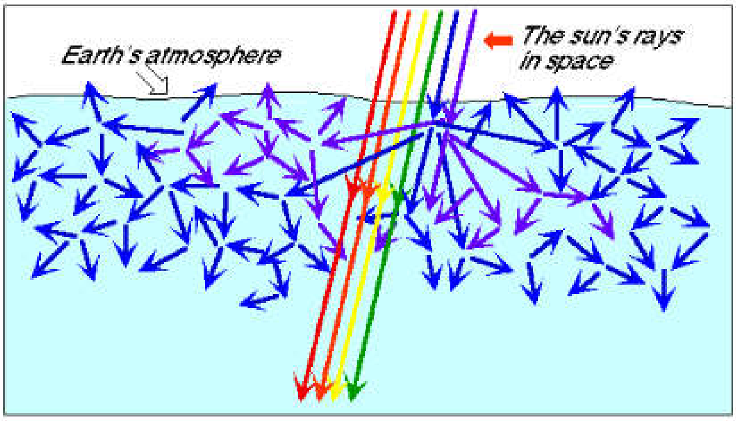



**Figure 21: Rayleigh scattering**

***B. Mie Scattering***

Another type of scattering is Mie scattering, which occurs when the wavelengths of the energy is almost equal to the diameter of the atmospheric particles. In this type of scattering longer wavelengths also get scattered compared to Rayleigh scatter (Fig. 22).

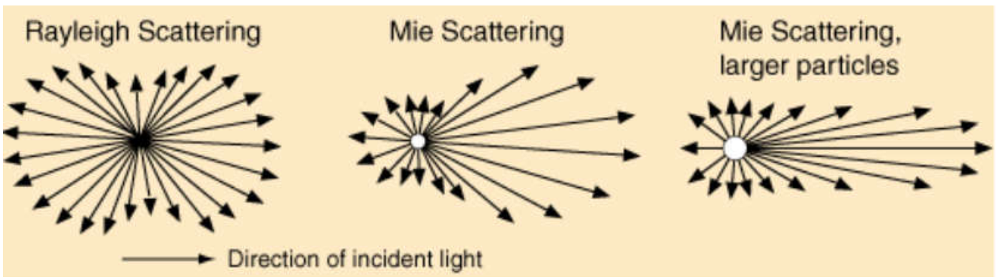



**Figure 22: Rayleigh and Mie scattering**

*C. Non-selective scattering*

A third type of scattering is nonselective scatter, which occurs when the diameters of the atmospheric particles are much larger (approximately 10 times) than the wavelengths being sensed. Particles such as pollen, cloud droplets, ice crystals and raindrops can cause nonselective scattering of the visible light.

**I.9.4.2. Absorption**

Absorption is the process in which incident energy is retained by particles in the atmosphere at a given wavelength. Unlike scattering, atmospheric absorption causes an effective loss of energy to atmospheric constituents.

The most efficient absorbers of solar radiation are water vapour, carbon dioxide, and ozone. Gaseous components of the atmosphere are selective absorbers of the electromagnetic radiation, i.e., these gases absorb electromagnetic energy in specific wavelength bands. Arrangement of the gaseous molecules and their energy levels determine the wavelengths that are absorbed.

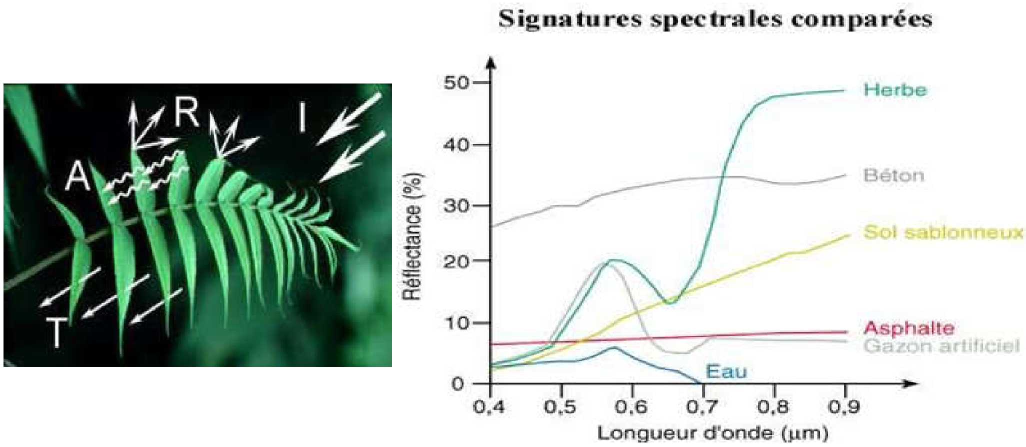



**Figure 23: Spectral characteristics of main energy sources**

**II. Spatial sampling**

Resources of spatial data: There are many resource populations may be represented as collection of points, lines, areas. For sampling purposes the major distinctions occur between finite, linear and areal population.2 Finite populations are those with discrete, identifiably distinct units that occupy fixed locations within boundary area.2

Linear resources are populations such as streams or rivers that are present only on a linear network within boundary area. Attributes are defined at all points of a stream or river network

An areal resource is a continuous population that is present everywhere with in a bounded area.2 This extends over large regions in a more or less continuous and connected manner although they may comprise disconnected polygons.2 In public health research we are dealing with areal resource data; here the population were clustered as polygons or strata.

**II.10.1. Resources of spatial data**

There are many resource populations may be represented as collection of points, lines, areas. For sampling purposes the major distinctions occur between finite, linear and areal population. Finite populations are those with discrete, identifiably distinct units that occupy fixed locations within boundary area. Linear resources are populations such as streams or rivers that are present only on a linear network within boundary area. Attributes are defined at all points of a stream or river network.

**II.10.2. Types of Spatial sampling**

There were many spatial sampling procedures established for environmental studies. The two main types were design based or traditional sampling and model based or stochastic process sampling.

**II.10.2.1. Design Based Sampling**:

It is also known as traditional sampling method which applied in random spatial fields. In this population values are unknown but fixed. This method can be used both population and super populations.

Design based sampling method classified based on three assumption sampling of independent and identically distributed populations, sampling considering spatial auto correlation, sampling considering spatial heterogeneity.

**(a) Sampling based on iid populations**

It is based on probability theory which calculate precise estimates in order to select efficient samples. In this method further classified as Simple random sampling where the sampling units chosen with equal probability, Systematic Random Sampling where first unit is drawn from population the other units are drawn in given preset order (k) relative to this first point, Stratified Random Sampling where the heterogeneous spatial data divided into homogeneous subgroups called strata which are non-overlapping, SRS then applied in each stratum, Cluster Sampling where population divided in to groups and all the observations in the selected clusters are included randomly, Two Step random and multistage sampling are extension of cluster random sampling.

**(b) Sampling based on Spatial autocorrelation**

This method consider that the geographical observations close to each other are more likely to be similar than observations further apart. The sample size should be higher than iid since the variance estimate may be inflated due to autocorrelation for super population sampling estimate where in decrease sample units for higher spatial autocorrelation for population mean estimate.

**c) Sampling Based on Spatial heterogeneity**

Spatial heterogeneity of attributes comprises two variations: population variance and population spatial auto correlation. Purposive sampling and spatial stratified sampling are appropriate techniques to deal with spatial heterogeneity in design based sampling methodology.

**II.10.2.2. Model Based Sampling**

The observations in a region are unfixed and set of values observed across the region represent a single realization of a stochastic, which called as super population.4 Here to compute an estimator weights of the sample data are determined by covariance between the observations which are given by model as function of the coordinates of the sampling locations. This method has three objectives relevant to spatial contexts: minimizing the error variance, equal spatial coverage and equal coverage in feature space. Kriging is model based spatial sampling with minimum error variance.

**II.10.2.3. Adaptive Sampling**

This is also known as Progressive sampling.3 This sampling methodology is essentially used all the information gathered during data collection process; it consists of two steps whole study area will be split as block contiguous blocks and further non overlapping plots.3 Numerical criterion is formulated, if that plot obeys, four neighbourhood plots depending only upon physical proximity will be selected as sample plots. Secondary units will be included in the sampling after selection of primary unit. Again quantitative criterion will evaluated, if its met then further neighboring plots will be added. Optimal Sampling: The variograms between current and future observation points can be used to calculate the optimal grid space for sampling, necessary to monitor each variable in the regular grid to achieve a predetermined standard deviation of prediction error. Starting with largest spacing, grid spacing reduced until the required accuracy reached.

**II.10.2.4. Spatially balanced Sampling**

This sampling procedure can be used in point line and areal resources of data. It is generalization of spatial stratification sampling, to select spatially well distributed probability samples. The spatial coordinates taken with one dimensional base map and hierarchical randomization used to randomly order the address and then apply a transformation which will produce equal probability plots. Systematic sampling along with random ordered linear structure is analogues to sampling a random tessellation of two dimensional space and results well balanced random sample

## III.Map of natural area

The natural lands map combines data collected from a variety of sources that were assessed for quality and met certain criteria. Additionally, all data – including local data sources – were subject to a visual inspection as an added assurance that the land cover classes selected matched our own understandings of these ecosystems.

### III.1. Classification in remote sensing

#### III.1.1 Concept of image classification

Classification is the process of assigning spectral classes into information classes. Spectral classes are groups of pixels that are uniform with respect to their brightness values in the different spectral channels of data. Information classes are categories of interest that an analyst attempts to identify in the image on the basis of his knowledge and experience about the area. For example, a remote sensing image contains spectral signatures of several features present on the ground in terms of pixels of different values. An interpreter or analyst identifies homogeneous groups of pixels having similar values and labels the groups as information classes such as water, agriculture, forest, etc. while generating a thematic map. When this thematic information is extracted with the help of software, it is known as digital image classification.

#### III.1.2. Approaches to Classification

Both the classification approaches differ in the way the classification is performed. In the case of supervised classification, specific land cover types are delineated based on statistical characterisation of data drawn from known examples in the image (known as training sites). In unsupervised classification, however, clustering algorithms are used to uncover the commonly occurring land cover types, with the analyst providing interpretations of those cover types at a later stage.

##### III.1.2.a. Unsupervised Classification

As the name implies, this form of classification is done without interpretive guidance from an analyst. An algorithm automatically organises similar pixel values into groups that become the basis for different classes. This is entirely based on the statistics of the image data distribution and is often called clustering.

The process is automatically optimised according to cluster statistics without the use of any knowledge-based control (i.e. ground referenced data). The method is, therefore, objective and entirely data driven. It is particularly suited to images of targets or areas where there is no ground knowledge. Even for a well-mapped area, unsupervised classification may reveal some spectral features which were not apparent beforehand. The basic steps of unsupervised classification are shown in Fig 24.

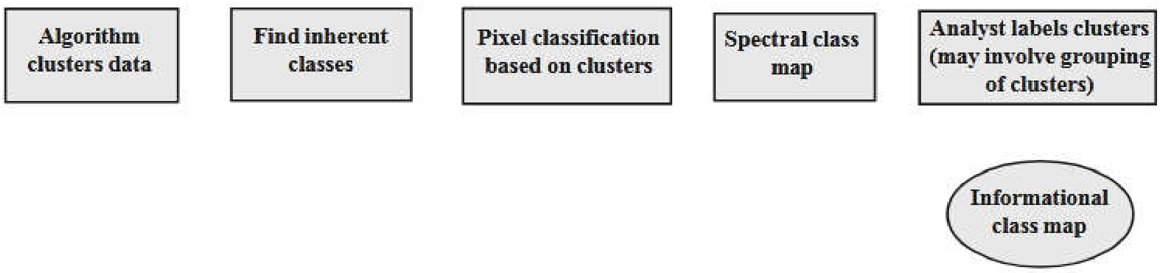



**Figure 24 : Steps of unsupervised classification**

Image Classification The result of an unsupervised classification is an image of statistical clusters, where the classified image still needs interpretation based on knowledge of thematic contents of the clusters. There are hundreds of clustering algorithms available for unsupervised classification and their use varies by the efficiency and purpose. K-means and ISODATA are the widely used algorithms which are discussed here (Fig.25)

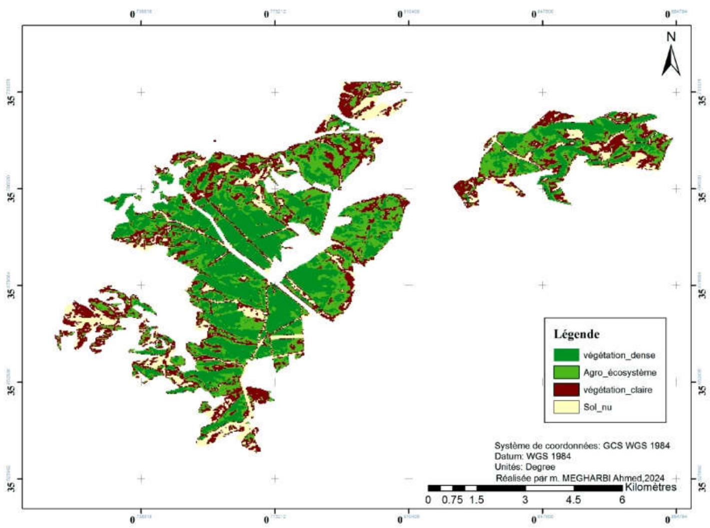



**Figure 25 : Unsupervised classification**

**III.1.2.b. Supervised Classification**

Supervised classification, as the name implies, requires human guidance. An analyst selects a group of contiguous pixels from part of an image known as a training area that defines DN values in each channel for a class. A classification algorithm computes certain properties (data

attributes) of set of training pixels, for example, mean DN for each channel (Fig. 13.3). Then, DN values of each pixel in the image are compared with the attributes of the training set.
This is based on the statistics of training areas representing different ground objects (Fig. 14) selected subjectively by users on the basis of their own knowledge or experience. Classification is controlled by users' knowledge but, on the other hand, is constrained and may even be biased by their subjective view. Classification can, therefore, be misguided by inappropriate or inaccurate training, area information and/or incomplete user knowledge. Steps involved in supervised classification are given in Fig. 26.

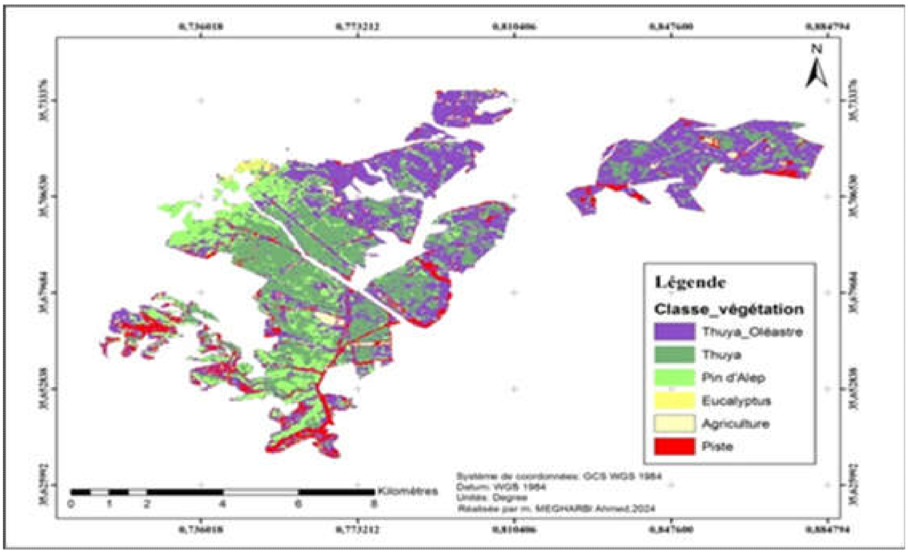



**Figure 26 : Supervised classification**

## IV. Spectral indices

### IV.1. Definition

Spectral Indices are a set of mathematical equations performed on a per-pixel basis on data coming from multispectral remote sensing (satellite) data. When looking at satellite data, you don't get a single image, you get all the red data, all the blue data, all the green data, right through infra-red up to ultraviolet. Then you apply a formula to each pixel to pull out information you want.

A spectral index is a formula that helps different phenomena on the ground be perceived. You can detect things like soil moisture, "greenness" - which can be a proxy for biomass, the composition of the land - such as ferric oxide, flooding, and even tracking seaweed in the ocean. A lot can be inferred from this data, and it is absolutely fascinating to go down rabbit holes in this area.

### IV.1.2. Vegetation Indices

### IV.1.3. Normalized Difference Vegetation Index (NDVI)

The NDVI (Normalized Difference Vegetation Index) is a normalized index used to generate an image displaying vegetation cover (relative biomass). This index is based on the contrasting characteristics of two channels in a multispectral raster dataset: the absorption of chlorophyll pigment in the red channel, and the high reflectivity of plant matter in the near-infrared (NIR) channel.

The NDVI index is used worldwide to monitor drought, control and forecast agricultural production, aid fire prevention and map desertification. The NDVI index is favored for global vegetation observation because it compensates for changes in lighting conditions, surface slope, exposure and other exogenous factors (Fig. 26).

When leaves are water-stressed, diseased or dead, they become more yellow and reflect less in the near-infrared range. Clouds, water and snow show much better reflection in the visible range than in the near-infrared range, while the difference is almost zero for rock and bare soil. The documented default NDVI equation is as follows:

$$NDVI = ((IR - R)/(IR + R))$$

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

This index generates values between -1.0 and 1.0, mainly representing vegetation cover, where negative values are mainly generated by clouds, water and snow, and near-zero values are mainly generated by rock and bare soil. 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 tropical rainforests. ArcGIS uses the following equation to generate output data:

$$NDVI = ((IR - R)/(IR + R)) * 100 + 100$$

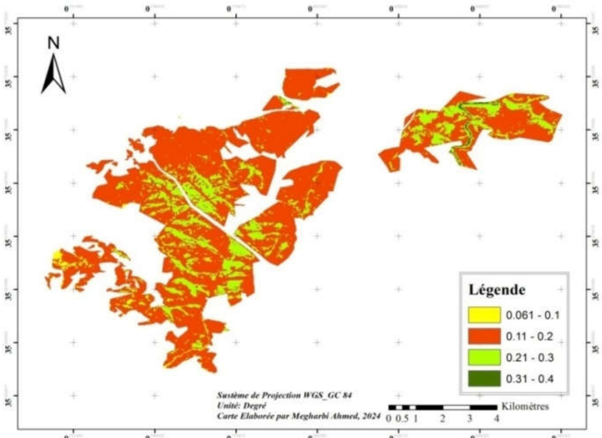



**Figure 26: NDVI map of Zemmoura forest**

### IV.2.2. Green Normalized Difference Vegetation Index (GNDVI)

GNDVI is more sensitive to chlorophyll variation in the crop than NDVI and has a higher saturation point. It can be used in crops with dense canopies or in more advanced stages of development, while NDVI is suitable for estimating crop vigor during the early stages. As with NDVI, the values given by this index also range from -1 to 1:

$$GNDVI = {(NIR - GREEN)} \big/ {(NDVI + GREEN)}$$

Values between -1 and 0: are associated with the presence of water or bare soil. It is used mainly in the crop cycle's intermediate and final stages.

Values greater than 0: the more intense the green, the more vigorous the vegetation and vegetation cover (Fig. 27).

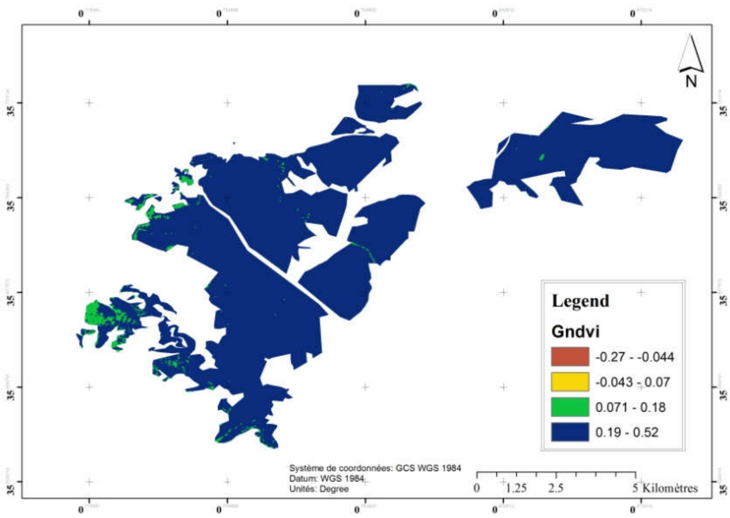



**Figure 27: GNDVI map of Zemmoura forest**

### 1V.2.3. The second Modified Soil Adjusted Vegetation Index (MSAVI2)

MSAVI2 is a vegetation index used as a variant to extend the application limits of NDVI to areas with a high presence of bare soil. It is used in areas where indices such as NDVI or NDRE provide incomplete or erroneous data, mainly due to a small amount of vegetation or lack of chlorophyll in the vegetation (e.g., in the phenological stage of emergence). In this way, it minimizes the influence of the soil background and increases the dynamic range signaled by the vegetation.

$$MSAVI2 = \frac{\left(2 * NIR + 1 - 1\sqrt{(2 * NIR + 1) - 8 * (NIR - RED))}\right)}{2}$$

MSAVI2 is most recommended for the early stages of crop development, allowing us to observe the first seedlings emerging (Fig.28).

It minimizes bare soil's influence, so it is ideal for early stages, such as crop emergence, crops that do not cover the soil in its most developed stage, or woody crops. This index allows us to be more efficient in using fertilizers during the early stages, reducing the environmental impact and increasing production significantly.

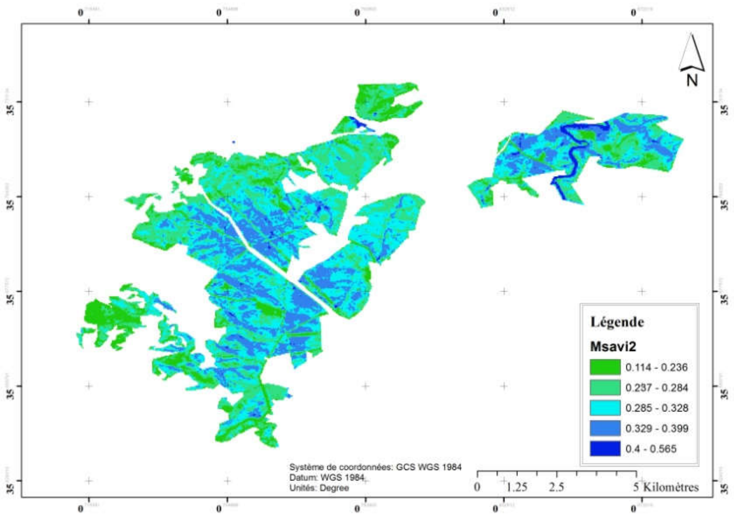



**Figure 28: MSAVI2 map of Zemmoura forest**

**1V.3.. Water Indices**

**1V.3.1. The Normalized Difference Moisture Index (NDMI)**

The Normalized Difference Moisture Index (NDMI) detects moisture levels in vegetation using a combination of near-infrared (NIR) and short-wave infrared (SWIR) spectral bands. It is a reliable indicator of crop water stress.

Severe drought conditions affect crops, but can also destroy the entire yield. NDMI can detect water stress at an early stage, before the problem gets out of hand. What's more, using NDMI to monitor irrigation, particularly in areas where crops require more water than nature can provide, helps to dramatically improve crop growth. All this makes NDMI an excellent agricultural tool. And since dry conditions in vulnerable areas increase the risk of combustion, NDMI has yet another application: monitoring areas at high risk of fire. At the same time, NDMI is often compared to NDWI, and the two should be considered as different indices. While the NDMI and Gao versions of the NDWI use the NIR-SWIR combination to detect leaf moisture content, McFeeters' NDWI uses the GREEN-NIR combination to highlight water masses and monitor their turbidity. So, to avoid confusion, the NDMI index uses a combination of NIR short-wave infrared bands and should be treated as a separate index from the NDWI, which measures the water content of bodies of water (Fig. 29).

NDMI is calculated using near-infrared (NIR) and short-wave infrared (SWIR) reflectance:

$$NDMI = (NIR - SWIR) / (NIR + SWIR)$$

NDMI is a better indicator of deforestation than NDVI thanks to a less abrupt drop in values.

The normalized difference moisture index can be used to :

- Monitor crop moisture content on a regular basis,
- Identify water-stressed fields/farms,
- Improve logistical planning of tree felling,
- Determine combustibility levels in fire-prone areas.

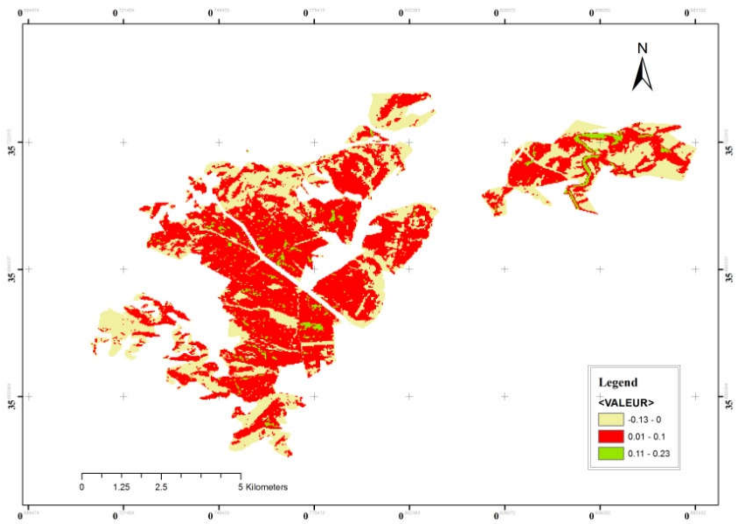



**Figure 29: NDMI map of Zemmoura forest**

Like most indices, NDMI can only have values between -1 and 1, making it very easy to interpret. Water stress would be indicated by negative values close to -1, while +1 could indicate waterlogging. Consequently, each intermediate value will correspond to a slightly different agronomic situation.

INTERPRETATION OF NDMI

- -1 - -0.8 Bare soil,
- -0.8 - -0.6 Canopy cover is almost absent,
- -0.6 - -0.4 Canopy cover is very low,
- -0.4 - -0.2 Canopy cover is low, dry or cover is very low, wet,

- -0.2 - 0 Canopy cover is medium-low, high water stress or canopy cover is low, low water stress,
- 0 - 0.2 Canopy cover is medium, high water stress or canopy cover is medium-low, low water stress,
- 0.2 - 0.4 Canopy cover is medium-high, high water stress or canopy cover is medium, low water stress,
- 0.4 - 0.6 Canopy cover is high, no water stress,
- 0.6 - 0.8 Canopy cover is very high, no water stress,
- 0.8 - 1 Total canopy coverage, no water stress/waterlogging

### 1V.3.2. The Normalized difference water index (NDWI)

The NDWI (Normalized Difference Water Index) is used to monitor crop water status. It allows us to observe the water status of the crop and identify moisture deficit and saturation in the crop. This index uses green and near-infrared bands of satellite images. NDWI can improve water information efficiently in most cases. It is sensitive to soil accumulation and results in overestimation of water bodies. NDWI values can be used with NDVI to assess the context of apparent change areas (Fig.30).

$$NDWI=(NIR-SWIR) / (NIR+SWIR)$$

As with other indices, the values obtained for NDWI range from -1 to 1, where high values correspond to high plant water content and coverage of a large part of the plant, and low values represent low vegetation water content and sparse cover.

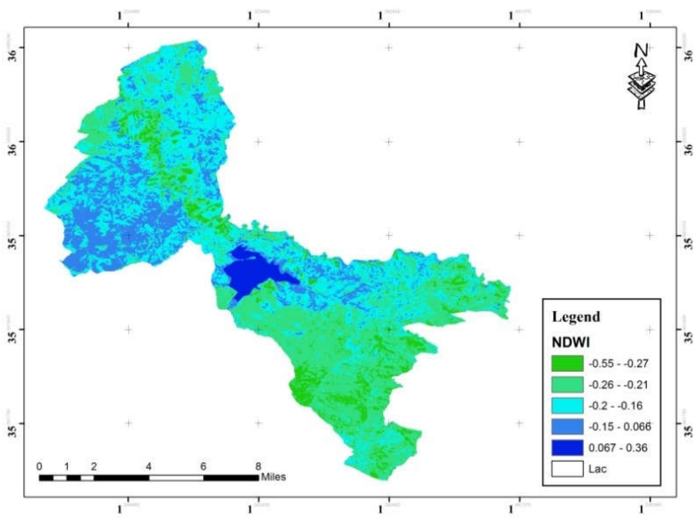



**Figure 30: NDWI map of Ouled Benabd Elkader**

The NDWI values for water basins are higher than 0.5. The NDWI for vegetation takes on much lower values, making it easier to distinguish between vegetation and water basins. The NDWI for built features takes positive values between 0 and 0.2.

NDWI values correspond to the following ranges:

- 0.2 - 1 - Water surface,
- - 0.2 - Flooding, high humidity,
- -0.3 - 0.0 - Moderate dryness, non-water surfaces,
- -1 - -0.3 - Drought, non-water surfaces

**1V.4. Soil Index**

**1V.4.1. The Bare soil index (BSI)**

Bare soil is a critical element in the urban landscape and plays an essential role in urban environments. Yet, the separation of bare soil and other land cover types using remote sensing techniques remains a significant challenge (Fig.31). There are several remote sensing-based spectral indices for barren detection, but their effectiveness varies depending on land cover patterns and climate conditions. Within this research, we introduced a modified bare soil index (MBI) using shortwave infrared (SWIR) and near-infrared (NIR) wavelengths derived from Landsat 8 (OLI – Operational Land Imager).

$$\frac{(SWIR1 + RED) - (NIR + BLUE)}{(SWIR1 + RED) + (NIR + BLUE)}$$

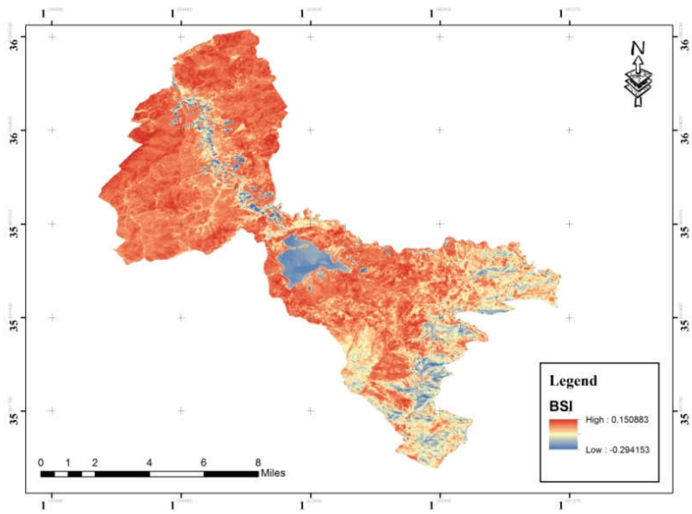



**Figure 31: BSI map of Ouled Benabd Elkader**

The BSI values for bare soil takes on much positive values. The BSI for built features takes positive values high to 0.1.

**V. Evaluation classification quality**

**V.1. Ways of Signature Evaluation**

One of the most common techniques for feature identification is spectral evaluation. Most of the image analysis software provides an interface to plot spectral signature. Fig. 32 shows an example of how a spectral image is plotted using an image analysis tool. With knowledge about the spectral profile for a given feature, we can go back and change band combinations to make that feature show up more clearly on the image

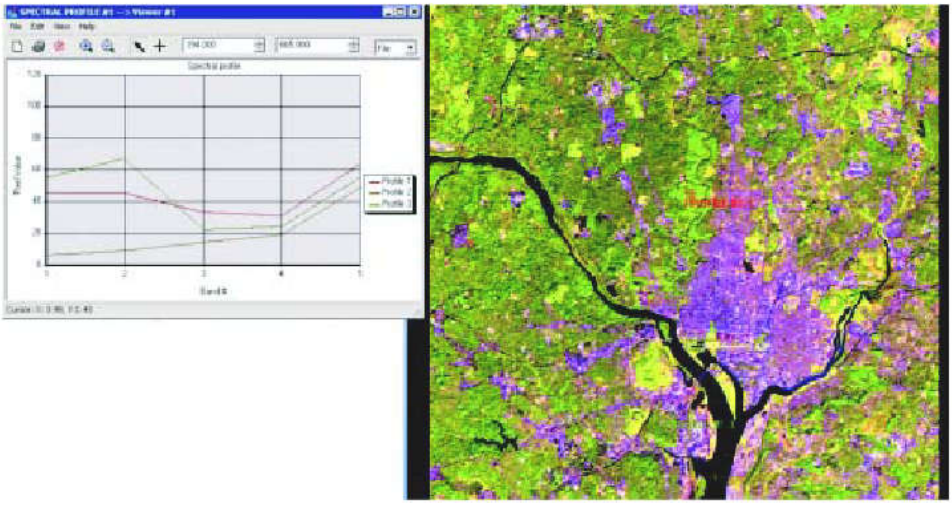


**Figure 32:** Spectral plots from a satellite image

**V.II. Spectral signatures are evaluated in the following three ways**:

• Classification is performed on the pixels within the training samples for each class and is compared with classes as recorded in the field data on those location. Ideally, all pixels in a training sample should classify correctly. However, you can expect high percentages of correctly classified pixels if the signatures taken are appropriate

• Measuering spectral distance, i.e. separability by computing divergence, transformed divergence or the Jeffries-Matusita distance. You can find mathematics behind computation of these in a book by Swain and Davis (1978). However, it is important to ensure that there is high separability between signatures from different types of training samples and low separability.

## Conclusion

Remote sensing, a powerful technology that allows us to gather information about the Earth's surface or other objects from a distance, has revolutionized various fields, from environmental monitoring to urban planning. While it offers numerous advantages, it is crucial to acknowledge there are disadvantages of remote sensing that can feel like drawbacks. In this article, we will delve into the advantages and disadvantages of remote sensing and explore the factors that can impact its effectiveness.

Remote sensing is undeniably a valuable tool for gathering spatial, spectral, and temporal information about our environment. However, it is essential to recognize its limitations and challenges. Researchers and practitioners must use remote sensing data judiciously, understanding that it is not a one-size-fits-all solution. By acknowledging the disadvantages of remote sensing and taking steps to mitigate them, we can harness the full potential of remote sensing while ensuring the accuracy and reliability of the information it provides.

## References


Broge, N.H., Leblanc, E., 2001. Comparing prediction power and stability of broadband and hyperspectral vegetation indices for estimation of green leaf area index and canopy chlorophyll density. Remote sensing of environment 76, 156–172.

Chen, J.M., 1996. Evaluation of vegetation indices and a modified simple ratio for boreal applications. Canadian Journal of Remote Sensing 22, 229–242.

Datt, B., 1998. Remote sensing of chlorophyll a, chlorophyll b, chlorophyll a+ b, and total carotenoid content in eucalyptus leaves. Remote Sensing of Environment 66, 111–121.

Gibson, P. J., 2000.Introductory Remote Sensing- Principles and Concepts, Routledge, London.

Gitelson, A.A., 2004. Wide dynamic range vegetation index for remote quantification of biophysical characteristics of vegetation. Journal of plant physiology 161, 165–173.

Gitelson, A.A., Kaufman, Y.J., Merzlyak, M.N., 1996. Use of a green channel in remote sensing of global vegetation from EOS-MODIS. Remote Sensing of Environment 58, 289–298. https://doi.org/10.1016/S0034-4257(96)00072-7

Gitelson, A.A., Merzlyak, M., Zur, Y., Stark, R., Gritz, U., 2001. Non-destructive and remote sensing techniques for estimation of vegetation status.

Guyot, G., Baret, F., 1990. Potentials and limits of vegetation indices. Presented at the Beltsville Symposium on Remote Sensing for Agriculture, pp. 16–18.

Haboudane, D., Miller, J.R., Pattey, E., Zarco-Tejada, P.J., Strachan, I.B., 2004. Hyperspectral vegetation indices and novel algorithms for predicting green LAI of crop canopies: Modeling and validation in the context of precision agriculture. Remote sensing of environment 90, 337–352.

Huete, A., Didan, K., Miura, T., Rodriguez, E.P., Gao, X., Ferreira, L.G., 2002. Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote sensing of environment 83, 195–213.

Huete, A.R., 1988. A soil-adjusted vegetation index (SAVI). Remote sensing of environment 25, 295–309.

Hunt Jr, E.R., Doraiswamy, P.C., McMurtrey, J.E., Daughtry, C.S., Perry, E.M., Akhmedov, B., 2013. A visible band index for remote sensing leaf chlorophyll content at the canopy scale. International journal of applied earth observation and Geoinformation 21, 103–112.

Jiang, Z., Huete, A.R., Didan, K., Miura, T., 2008. Development of a two-band enhanced vegetation index without a blue band. Remote sensing of Environment 112, 3833–3845.

Kaufman, Y.J., Tanre, D., 1992. Atmospherically resistant vegetation index (ARVI) for EOS-MODIS. IEEE transactions on Geoscience and Remote Sensing 30, 261–270.

Lillesand, T. M., Kiefer, R. W., Chipman, J. W., 2004. Remote sensing and image interpretation. Wiley India (P). Ltd., New Delhi

Metternicht, G., 2003. Vegetation indices derived from high-resolution airborne videography for precision crop management. International Journal of Remote Sensing 24, 2855–2877.

Miura, T., Yoshioka, H., Fujiwara, K., Yamamoto, H., 2008. Inter-comparison of ASTER and MODIS surface reflectance and vegetation index products for synergistic applications to natural resource monitoring. Sensors 8, 2480–2499.

Qi, J., Chehbouni, A., Huete, A.R., Kerr, Y.H., Sorooshian, S., 1994. A modified soil adjusted vegetation index. Remote sensing of environment 48, 119–126.

Richardson, A.J., Wiegand, C., 1977. Distinguishing vegetation from soil background information. Photogrammetric engineering and remote sensing 43, 1541–1552.

Rondeaux, G., Steven, M., Baret, F., 1996. Optimization of soil-adjusted vegetation indices. Remote Sensing of Environment 55, 95–107. https://doi.org/10.1016/0034-4257(95)00186-7

Rouse, J.W., Haas, R.H., Schell, J.A., Deering, D.W., 1974. Monitoring vegetation systems in the Great Plains with ERTS. NASA special publication 351, 309.

Tucker, C.J., 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment 8, 127–150. https://doi.org/10.1016/0034-4257(79)90013-0

Tucker, C.J., Elgin Jr, J., McMurtrey Iii, J., Fan, C., 1979. Monitoring corn and soybean crop development with hand-held radiometer spectral data. Remote Sensing of Environment 8, 237–248.

Wang, F., Huang, J., Chen, L., 2010. Development of a vegetation index for estimation of leaf area index based on simulation modeling. Journal of plant nutrition 33, 328–338.

Wang, F.-M., Huang, J.-F., Tang, Y.-L., Wang, X.-Z., 2007. New vegetation index and its application in estimating leaf area index of rice. Rice Science 14, 195–203.

Yang, C., Everitt, J.H., Bradford, J.M., 2007. Airborne hyperspectral imagery and linear spectral unmixing for mapping variation in crop yield. Precision Agriculture 8, 279–296.