MODULE 2: Introduction to RS

OBJECTIVES	✓ Reflect on Remote Sensing (RS) principles ✓ Define electromagnetic waves and their characteristics ✓ Describe the role of the Earth's atmosphere for remote sensing ✓ Satellites data ✓ Conduct simple analysis using a range of different types of optical Earth observation (EO) data
METHODS	Live session, reading material, video's, links to resources, application exercises, quizzes & discussions
DURATION	6 hours for participants

SESSION			**DURATION**	**PARTICIPANTS…**
Online	1.0	Introduction to Remote Sensing	60 min.	✓ Are exposed to the concepts of Remote Sensing
	1.1	Fundamentals of Remote Sensing	25 min.	✓ Get familiar to the fundamentals of remote sensing and the definitions of the key concepts. ✓ Learn about two types of remote sensing: active and passive.
	1.2	Electromagnetic Radiation	50 min.	✓ Explore what satellite signals are. ✓ Explore electromagnetic radiation, including wave characteristics and spectrum.
	1.3	Energy Interactions	25 min.	✓ Learn about energy interactions. ✓ Learn about the mechanisms of scattering and absorption.
	1.4	Information extraction	65 min.	✓ Get an understanding of what makes an image a quality image. ✓ Learn about what very cell (pixel) on image represents, what and how many bands makes images.
	1.5	Application and Documentation	125 min.	✓ Learn to create an overview and evaluate different RS use cases. ✓ Explore how to conduct simple analysis using a range of different types of optical Earth.

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OPEN MACHINE LEARNING FOR EARTH OBSERVATION (ML4EO)

MODULE 2: Introduction to Remote Sensing

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Before we start

- Trainers' team today

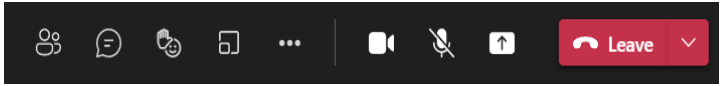
Joseph Tuyishimire
Lecturer CGIS

Clarisse Goffard
Education Expert

Joanne Schuiteman
Moodle Expert

Anselme Ndikuryyayo
Education Expert

- Communication:
  - Please mute your device if you are not speaking, and switch on the camera/video
  - Please post your questions in the chat and we will answer them on the spot, or during the Q&A session
- Material and presentation will be shared



- The presentation will be recorded, we assume your consent

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Structure of today's session

- Course overview
- Review Module 1
- Introduction to Module 2
- Q&A
- Next steps / assignments
- Closure

Course overview

The course is composed of **11 Modules**:

- Module 1: Introduction to GIS
- Module 2: Introduction to Remote Sensing
- Module 3: GIS data collection methods
- Module 4: Introduction to ML and Python
- Module 5: Data curation for ML
- Module 6: Visualization of EO data
- Module 7: Predictive modelling using local RS data
- Module 8: Deploying remote sensing-based models
- Module 9: ML workflows and best practice
- Module 10: Business model generation and value proposition design
- Module 11: Project development

Modules 1-4: online + field work

- MS Teams live sessions
- Self-learning on Moodle

Modules 5-10: face-to-face

- Block 1:April 2023
- Block 2: May 2023

Module 11: online & face-to-face

- Project development
- Pitch event

Review of Module 1 FORUM

DEADLINE EXTENDED TO <u>TUESDAY 28.02</u>

?? QUESTIONS ??

Experience	Features/Interface	Challenges
It was so amazing to create my first map using QGIS but it takes a lot of attention and critical thinking.	The features in QGIS are great as it is an open source application that can be expanded and adjusted with respect to the needs.	The interface was new and I have to find out everything which takes some of my time in completing the exercise.
The instructions were clear	This software is actually full of powerful functionalities	Performance issues
It was very clear to create first map by following the given steps.	user friendliness and navigability of the interface	another challenge i faced was to add a layer of lenth in Km for that i tried to get an extra tutorial
I did a lot of documentation as well, finally i did it and I am proud of the work thank you everyone for the encouragement	QGIS has many features, after sometime using it, it's faster to get familiar to them.	one challenge was that some of the instructions given were not exactly the same in QGIS software mainly due to the version used.
My first map on QGIS was an exciting and rewarding experience	QGIS has many features, after sometime using it, it's faster to get familiar to them.	one I face during the application exercise is how to allocate some tools

Structure of the Live Session

- Course Overview
- Review Module 1
- Module 2: Introduction to Remote Sensing
  - WHAT is Remote Sensing?
  - WHY is Remote Sensing relevant/useful?
  - WHO uses Remote Sensing?
  - FOR WHAT purpose or FOR WHOM is Remote Sensing used?
  - Examples of real-life applications of Remote Sensing
- Q&A
- Next steps / assignments
- Closure

What do you know about RS ?

We will collect your current ideas via Mentimeter.

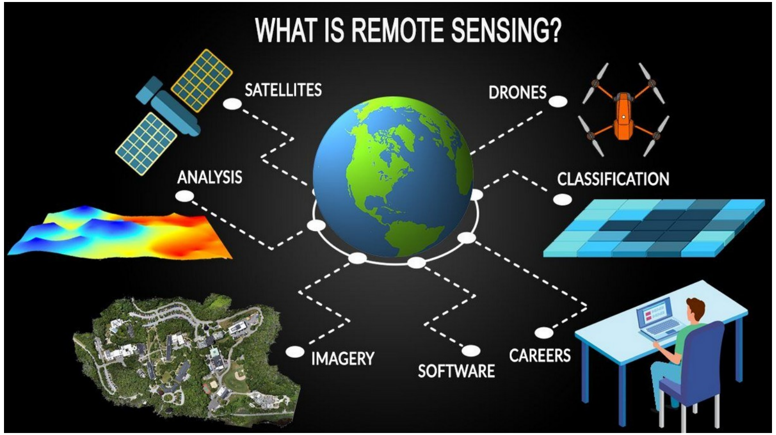
Follow the steps:

- ➢ Either: Click on the link in the chat
- ➢ Or: go to www.menti.com + submit the code (given in the chat)
- ➢ THEN participate by answering the questions

MODULE 2: Introduction to Remote Sensing

Digital Transformation Center Rwanda

WHAT is Remote Sensing?



1. Gothering information about the earth system
2. No physical contact
3. Principles of electromagnetic enegy
4. Features reflect differebtly

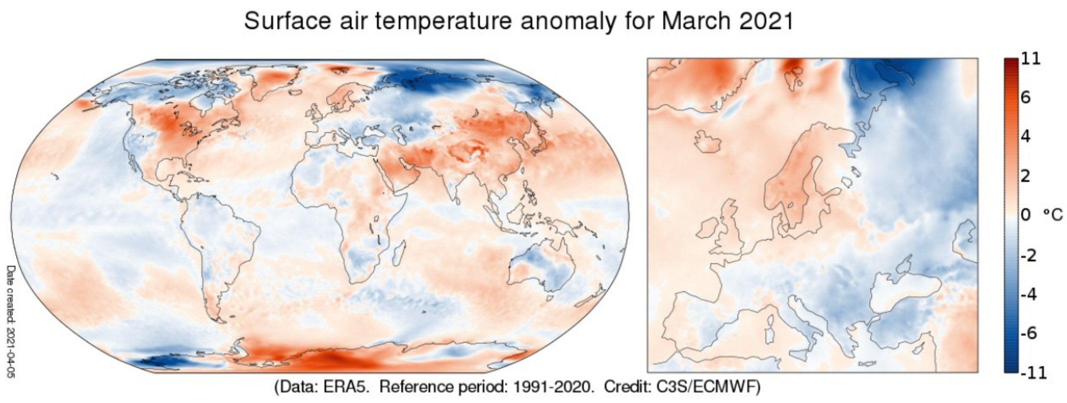
Target

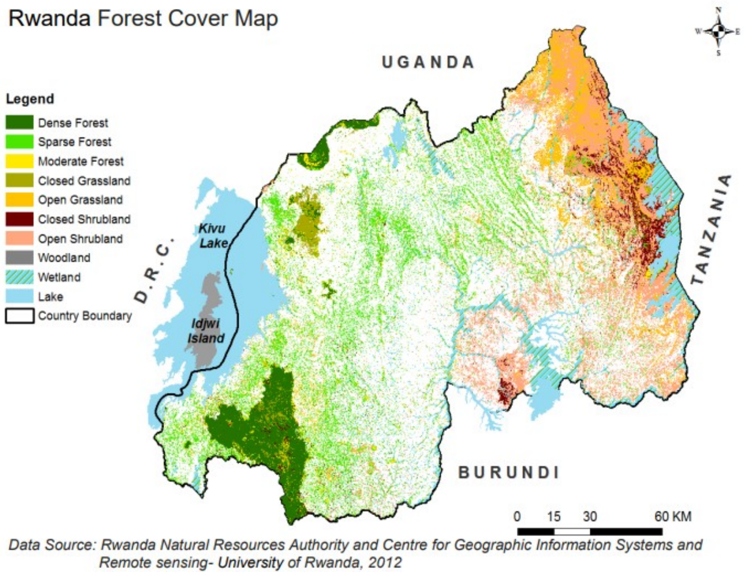
Transmission

Sensor

Energy Source

WHY is Remote Sensing relevant/useful?





Data Source: Rwanda Natural Resources Authority and Centre for Geographic Information Systems and Remote sensing- University of Rwanda, 2012

- Monitoring from small to global scale
- One image, different uses
- inaccessible areas
- Time-series
- Freely available to commercial
- Coarse to high-resolution
- Cost
- Replicability of methodology

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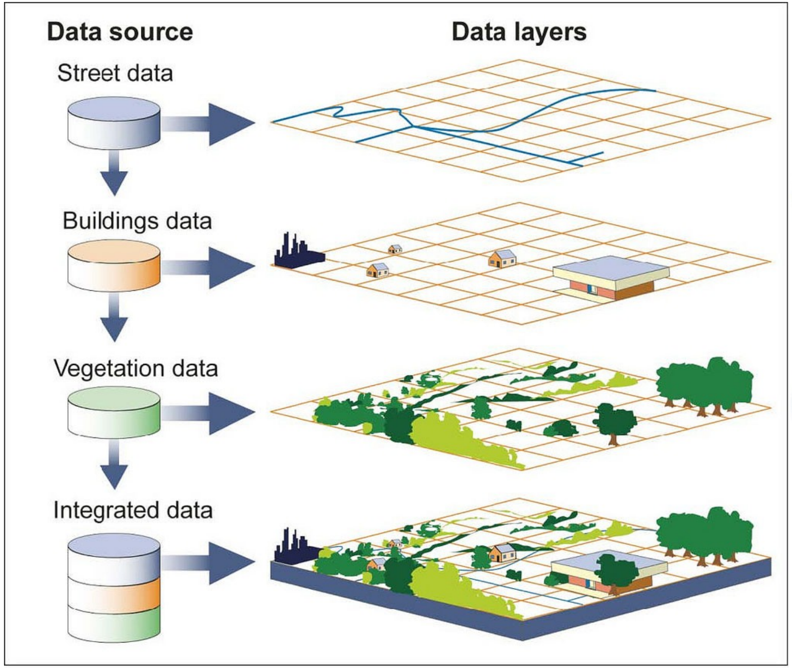
WHO uses Remote Sensing?

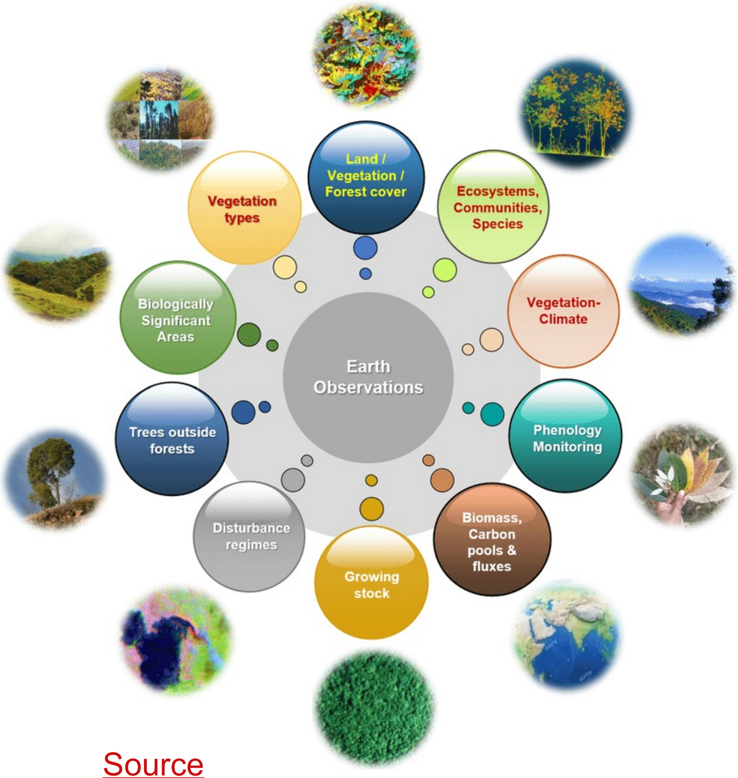
- *Land Managers*
- *Environmentalists*
- *Natural resource managers*
- *Mineral experts*
- *Hazards and Disaster Managers*
- *Geologists*
- *Security agents*
- *Climatologists*
- *Conservationists*
- *Retailers*
- *Urban Managers/Planners*
- *Agronomists*
- *Marine Scientist*
- *Water Engineers*
- *Health Planners*
- *Soil Scientists…etc.*

FOR WHAT purpose or FOR WHOM is Remote Sensing used?



Source: GAO.

Source

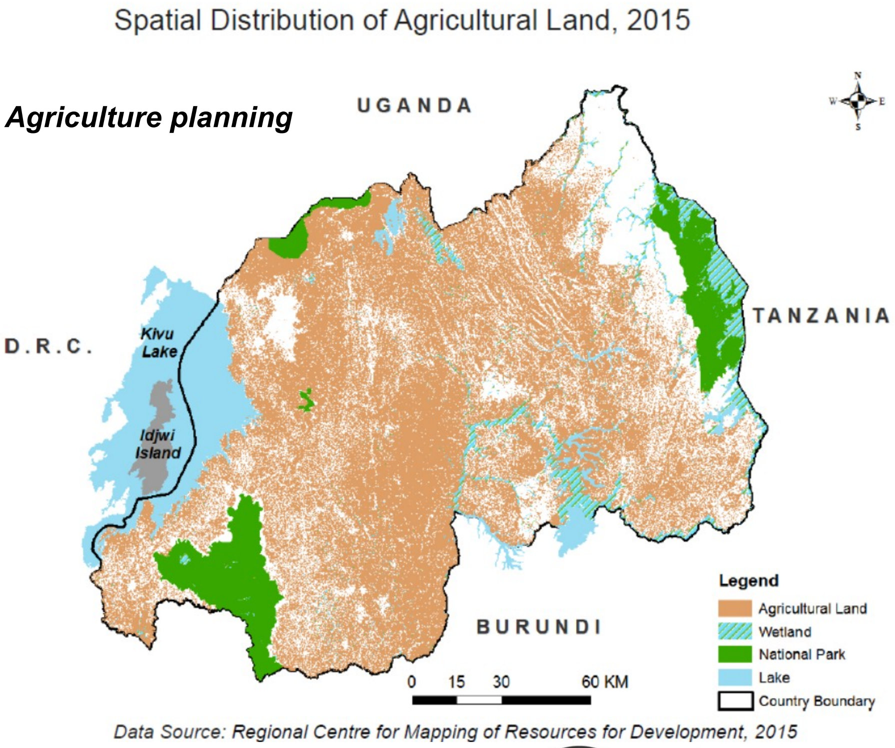


Source

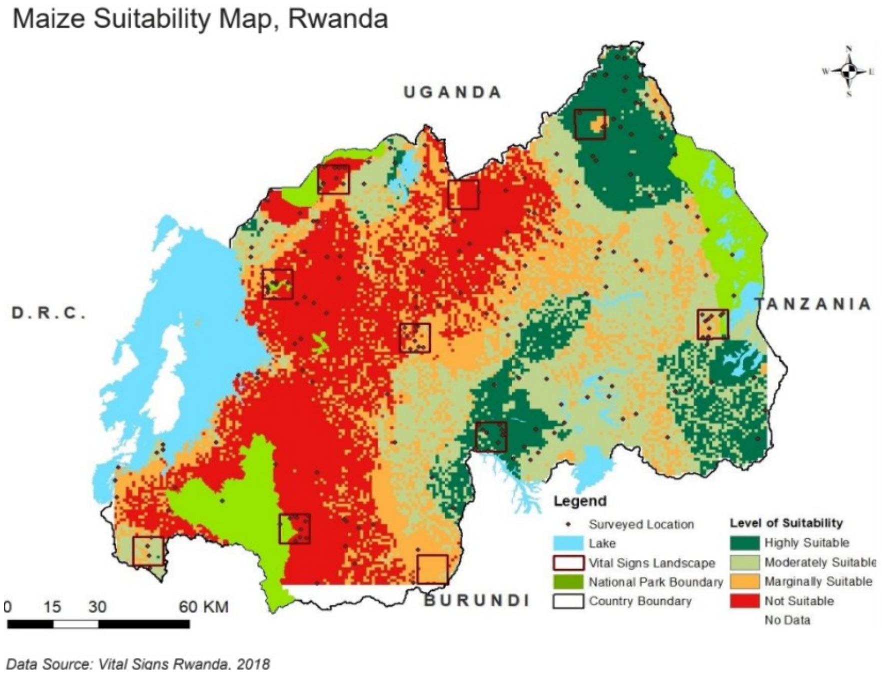
- Clear models
- Replicability
- Data availability
- Evidence-based decision
- Improved livelihood

Examples of real-life applications of Remote Sensing

Agriculture planning

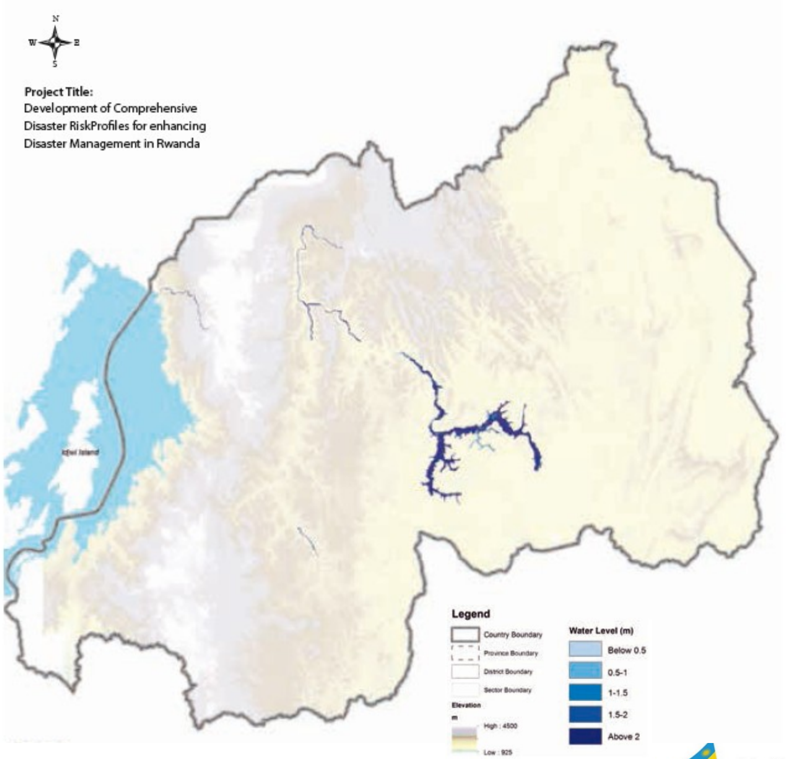


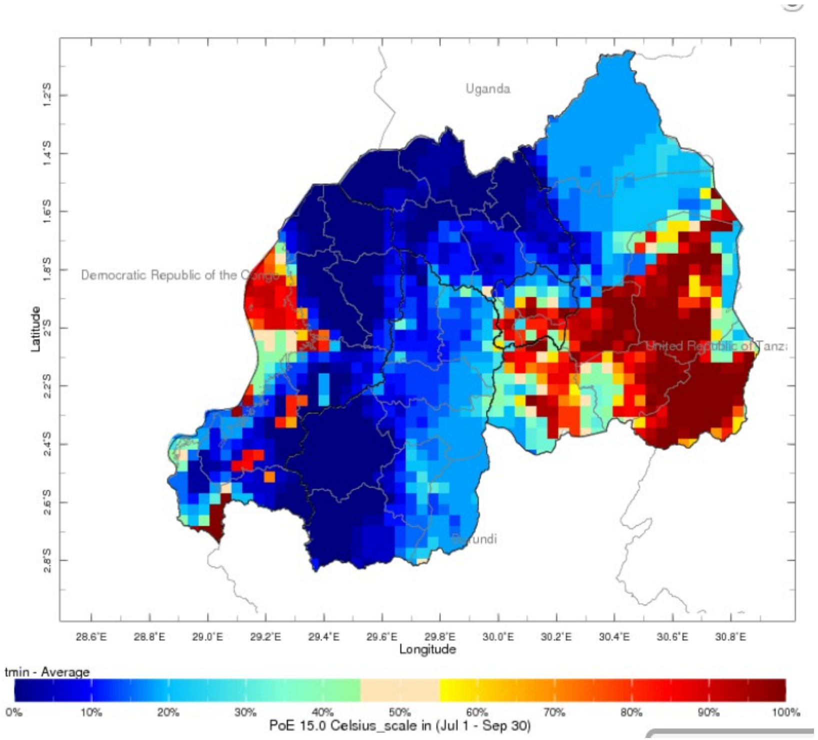
Crop types mapping



Examples of real-life applications of Remote Sensing

Figure 35. National flood hazard map of Rwanda





- Disaster Risk management
- Weather/ climate
- Etc..

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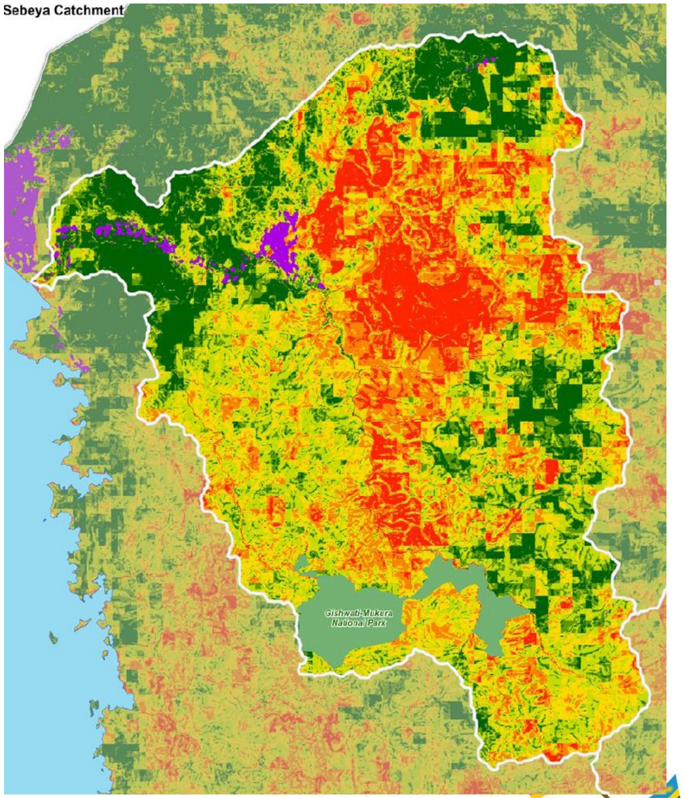
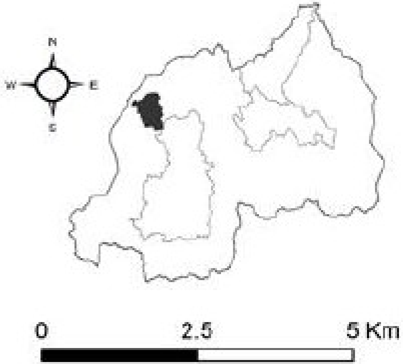
Examples of real-life applications of Remote Sensing





1. Soil erosion risks

Methodology: Revised Universal Soil Loss Equation (RUSLE)

- Demonstration Catchment
- Settlements
- Lakes
- National Parks
- Country

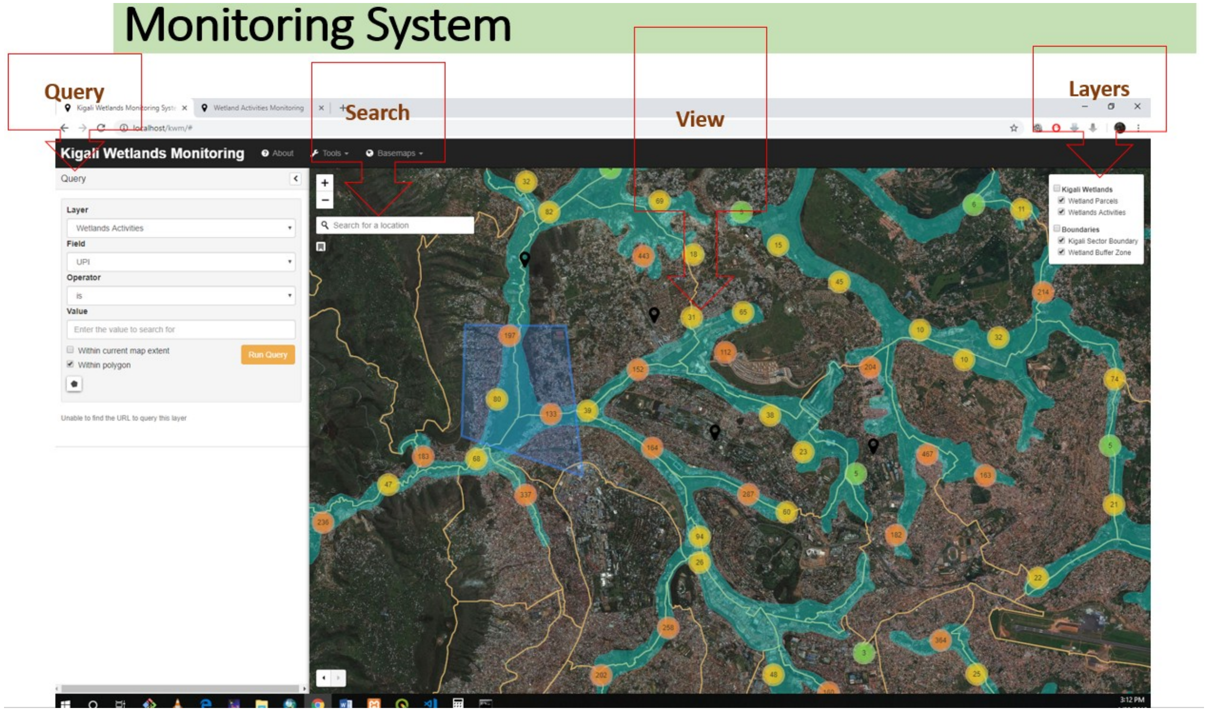
Potential Soil Erosion Risk in Rwanda

Risk (t/ha/year)

- Very low (0 - 5)
- Low (5 - 10)
- Moderate (10 - 25)
- High (25 - 50)
- Very high (50 - 100)
- Extremely high (>100)

- Mapping soil erosion
- Planning for key restoration measures
- Prioritization
- Stakeholders involvement

Examples of real-life applications of Remote Sensing



- Monitoring of critical ecosystems encroachment
- Informed decision making-relocation
- Sustainable management-Restoration

Q & A

DO YOU HAVE ANY QUESTIONS?

Please raise your hand

or write your questions into the chat box!

Structure of today’s session

- Course overview
- Review Module 1
- Introduction to Module 2
- Q&A
- Next steps / assignments
- Closure

Self-study part Moodle – Module 2

➢ To be completed by Sunday **05.03.2023**

- Read all contents of all sessions
- Watch all videos
- answer all quiz questions after each session (3 attempts)
- Perform the application exercise

Group Assignment on Moodle – Module 2

➢ To be completed by Sunday **05.03.2023**

Contribution to the Forum:

- Post your results of the application exercise and your answers to the questions in the forum
- Read the contributions of the other group members
- Answer any question you got in response to your own post

Evaluation of the Live Session

- Before we close… please do a short evaluation of our live session
- Either: Click on the link in the chat
- Or: go to www.menti.com + submit the code (given in the chat)
- THEN participate by answering the questions

CLOSING

THANK YOU

for sharing this time with us!

See you next time (Monday, 06.03, 3pm):

Module 3: GIS data collection methods

2.2 Fundamentals of Remote Sensing

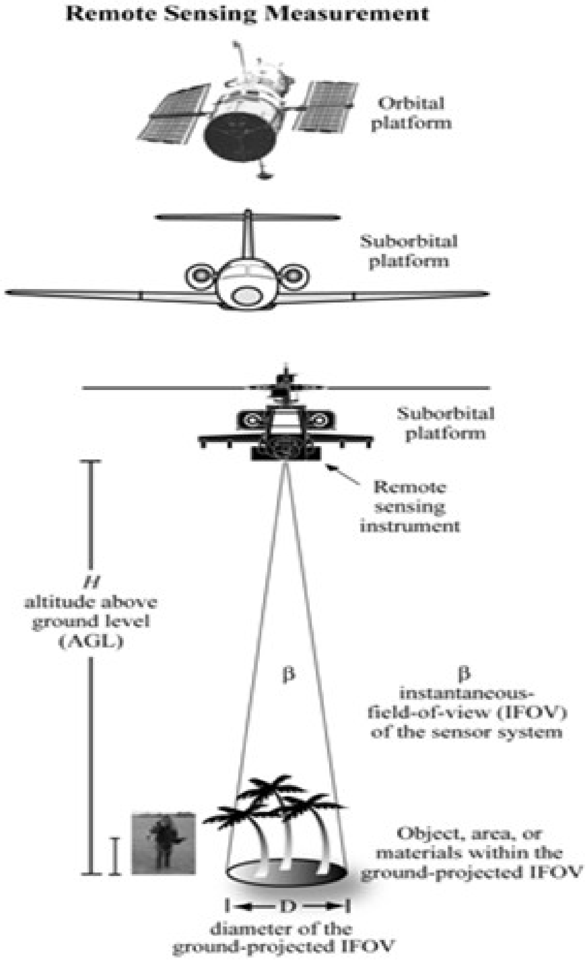
Reading material

In the first session, you will get familiar to the fundamentals of remote sensing and the definitions of key concepts. After that you'll be presented with two types of remote sensing: active and passive.

Remote sensing is the art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring and interpreting imagery and digital representation of energy patterns derived from noncontact sensor systems (adopted by the ASPRS in 1988; in Colwell, 1997).

- A remote sensing instrument collects information about an object or phenomenon within the instantaneous field- of-view (IFOV)
- The remote sensing instrument may be located just a few meters above the ground and/or onboard an aircraft or satellite platform

In remote sensing, many different instruments that detect and record electromagnetic radiation (EM)exist. Those instruments are called **sensors**. Sensors differ one from another in terms of their sensitivity to radiation at different wavelengths but also in terms of how they register electromagnetic radiation. Two main categories of Earth Observation systems can be differentiated – **passive and active**.



Source: John R. Jensen (2014): Remote Sensing of the Environment: An Earth Resource Perspective

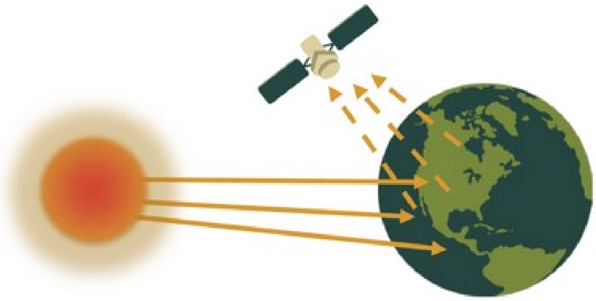
Passive Remote Sensing

Sensors that use external sources of electromagnetic radiation to “observe” an object, so usually rely on the Sun but also the Earth or atmosphere radiation are called passive sensors.

Passive sensors record electromagnetic energy that is reflected (e.g., blue, green, red, and infrared light) or emitted (e.g., thermal infrared radiation) from the surface of the Earth.

What is important to remember is that this kind of Earth Observation will not work at night when no reflected energy coming from the Sun. Only energy that is naturally emitted (for example thermal infrared) can be detected both at night and during the day, only if the amount of energy to register is large enough to be recorded. So, briefly speaking the passive sensors can detect naturally occurring radiation only.

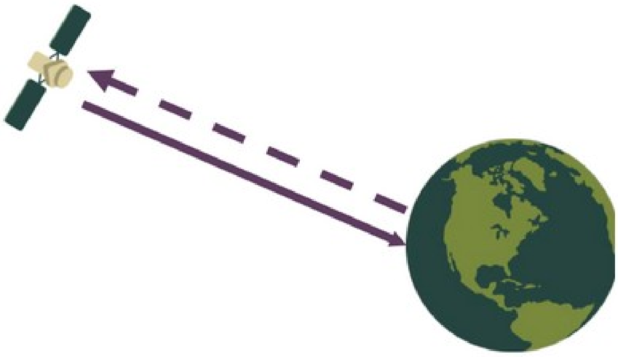
Passive Earth Observation employs multispectral or hyperspectral sensors. They can measure the acquired quantity of radiation with multiple band combinations. These band combinations differ by the number of channels, they consist of more than two wavelengths. These bands register spectra which are not visible bands only, but also the ones beyond human vision (IR, NIR, TIR, microwave).



Credits: NASA Applied Sciences Remote Sensing Training Program. Remote Sensors | Earthdata (nasa.gov)

Active Remote Sensing

On the other hand, active remote sensing is based on the sensor's own energy of light (illumination). The sensor itself emits radiation which is directed toward the target and then reflected back to the sensor to be recorded. So, this type of sensing and observing the Earth does not require the sunlight to measure and detect the radiation. Lidar and radar technologies are example of active sensors.



Credits: NASA Applied Sciences Remote Sensing Training Program. Remote Sensors | Earthdata (nasa.gov)

Active or Passive Remote Sensing - what does it mean?

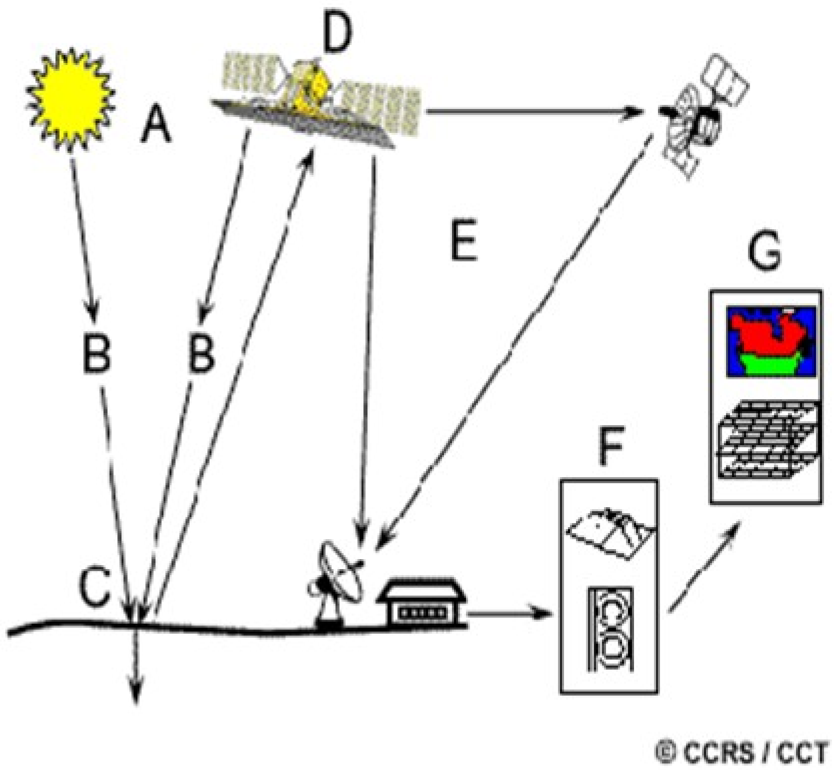
To get a grasp on how satellite data collection works, watch this video

What is Active and Passive Remote Sensing? - YouTube (time duration 2:51)

https://www.youtube.com/watch?v=vzfGMMEEz5w

Remote sensing process

On the image below, you can see the process of remote sensing. Below you will find the explanation of what the different points correspond to.



Source of picture: Canada Centre for Remote Sensing (CCRS)

1. **Energy Source or Illumination (A)** - the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest. In case of passive satellites that is the Sun, in case of a actives satellites that is the satellites itself.
2. **Radiation and the Atmosphere (B)** - as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.
3. **Interaction with the Target (C)** - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
4. **Recording of Energy by the Sensor (D)** - 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.
5. **Transmission, Reception, and Processing (E)** - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).
6. **Interpretation and Analysis (F)** - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.
7. **Application (G)** - the final element of the remote sensing process is achieved when we apply the information, we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

Exercise materials and tasks

Quiz questions

Instructions: As a recap and deepening of this session's content, we have prepared the following quiz Have fun!

1. Which satellites are daytime dependent?

   a. Active satellites
   b. Passive satellites

2. When considering our eyes to be remote sensors, which of the following statements are false?

   a. Our eyes detect radiation from the sun
   b. Our eyes detect energy in the form of visible light from the sun allowing us to see
   c. Light energy occupies a wide portion of the electromagnetic spectrum
   d. Other types of light energy are invisible to our eyes

3. Which of the following satellites are active satellites?

   a. LiDAR
   b. Radar
   c. Optical

2.3 Electromagnetic Radiation

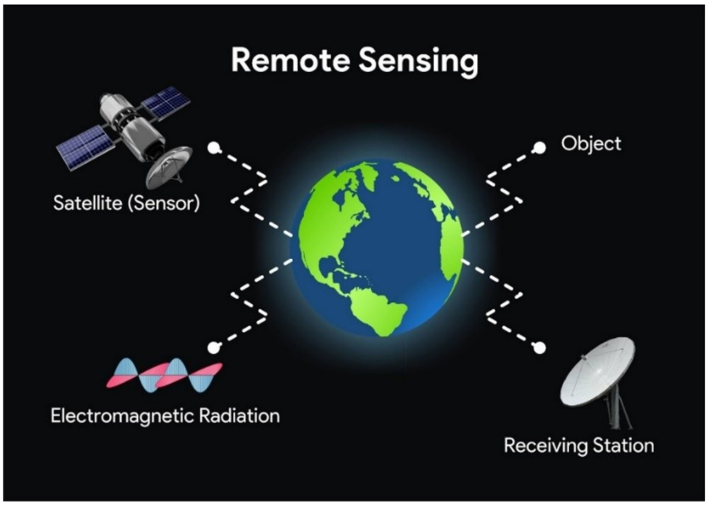
Reading material

Now that you know about the basic principles of remote sensing and how they are applied, in this second session, we will briefly touch upon the physics and show what satellite signals are.

In this session you will explore electromagnetic radiation, including wave characteristics and spectrum.

The concept of remote sensing

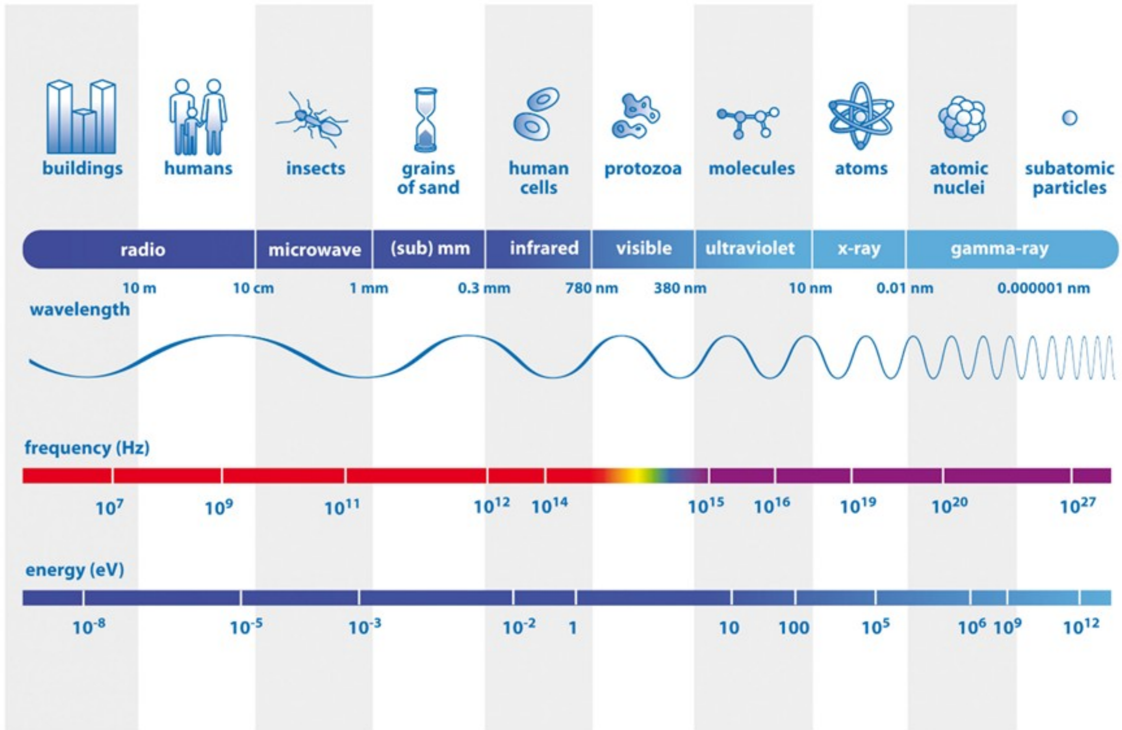
Electro-magnetic radiation which is reflected or emitted from an object is the usual source of remote sensing data. Satellites or spacecrafts always consists of sensors which, therefore, capture and record that emitted or reflected radiation.



Source : https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing

Electromagnetic radiation or **EMR** is a key component in the process of remote sensing. Remote sensing works depending on about four types of radiating features of EMR– absorption, transmission, reflection, and emission.

While electromagnetic radiation falls upon any object surface, it might be absorbed by the object or transmitted, reflected, or sometimes the object emit might radiation from itself (such as in the form of heat).

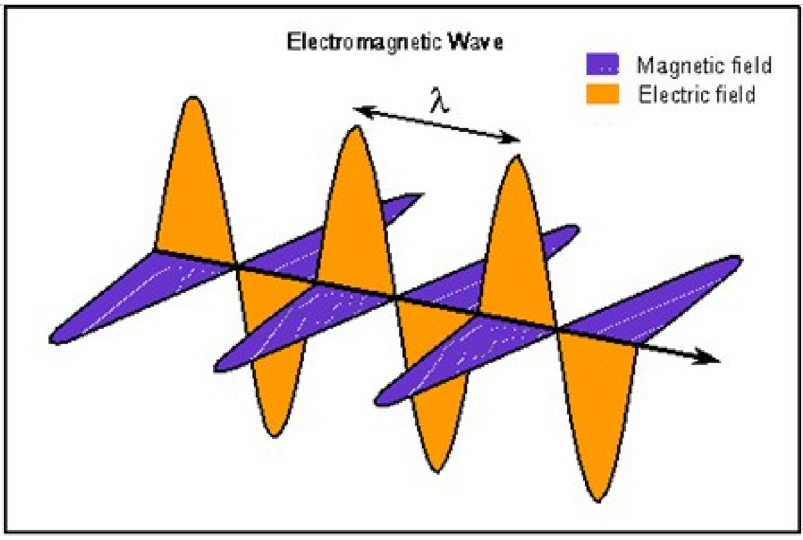


Source: https://eo-college.org

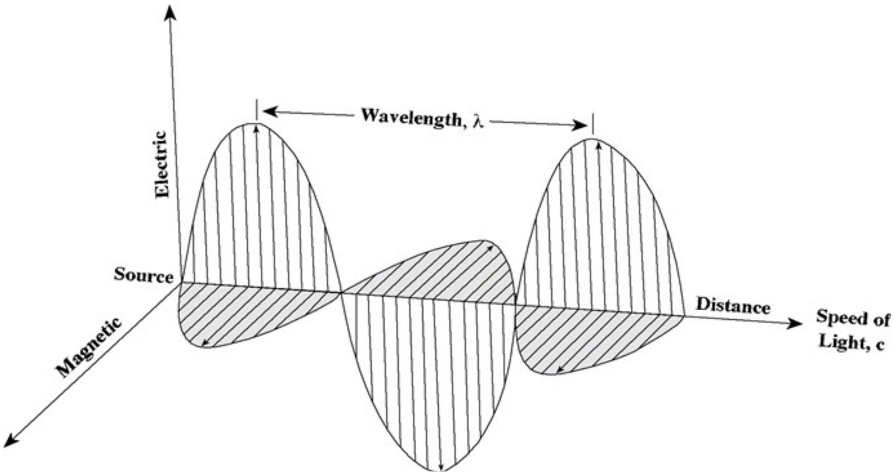
EMR waves characteristics

All types of EMR are transmitted, or propagated, as waves. In common with all waves, the two most fundamental properties of electromagnetic waves are length and frequency. The longer the wave length the lower the frequency and vice versa.

Electromagnetic wave consists of an **electrical field (E)** which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a **magnetic field (M)** oriented at right angles to the electrical field. Both these fields travel at the **speed of light (c).**



Source: John R. Jensen (2014): Remote Sensing of the Environment: An Earth Resource Perspective



Source: John R. Jensen (2014): Remote Sensing of the Environment: An Earth Resource Perspective

- velocity is the speed of light, c=3 x 108 m/s
- wavelength (ʎ) is the length of one wave cycle, is measured in metres (m) or some factor of metres such as
    - centimeters (cm) 10-2 m
    - micrometers (µm) 10-6 m
    - nanometers (nm) 10-9 m
- frequency (v) refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in hertz (Hz), equivalent to one cycle per second, and various multiples of hertz.
- unlike c and ʎ changing as propagated through media of different densities, v remains constant.

$$c = \lambda \nu$$

where:

λ = wavelength (m)
ν= frequency (cycles per second, Hz)
c =speed of light (3×10^8 m/s)

The **amplitude** of an electromagnetic wave is the height of the wave crest above the undisturbed position.

The **electromagnetic spectrum** may be defined as the entire range of radiation wave lengths.

A simple explanation of electromagnetic spectrum and how does it affect us in our everyday life.

What is Light? Maxwell and the Electromagnetic Spectrum - YouTube (time duration 3:55)

https://www.youtube.com/watch?v=pj_ya0e20vE

Exercise materials and tasks

Quiz questions

Instructions: As a recap of this session's content, we have prepared the following quiz. Enjoy!

1. Which statements are true?

   a. The distance between the peak and trough of a wave is called 'amplitude'.
   b. The distance between two following peak is referred to as 'wavelength'.
   c. The vectors describing an electromagnetic wave travel at the speed of light.

2. We see different colours because they have different frequencies.

   a. True
   b. False

3. The percentage of energy reflected by a particular type of surface at its various constituent wavelengths is termed its 'spectral signature'.

   a. True
   b. False

4. In which unit is frequency normally measured in?

   a. Meters/seconds (m/s)
   b. Hertz (Hz)
   c. Meters (m)

2.4 Energy Interactions

Reading material

We know that when light comes into contact with an object it scatters. In the previous session, we learned that a signal from a satellite is part of an electromagnetic wave, and this scattering also applies to a signal from satellites.

In this third session, you will learn about energy interactions, and the mechanisms of scattering and absorption.

Interactions with the Atmosphere

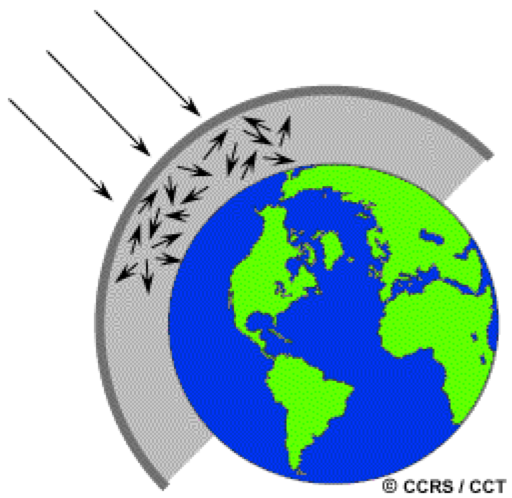
Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of scattering and absorption.

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path.

How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere.

There are three (3) types of scattering which take place:

- Rayleigh scattering
- Mie scattering
- Nonselective scattering



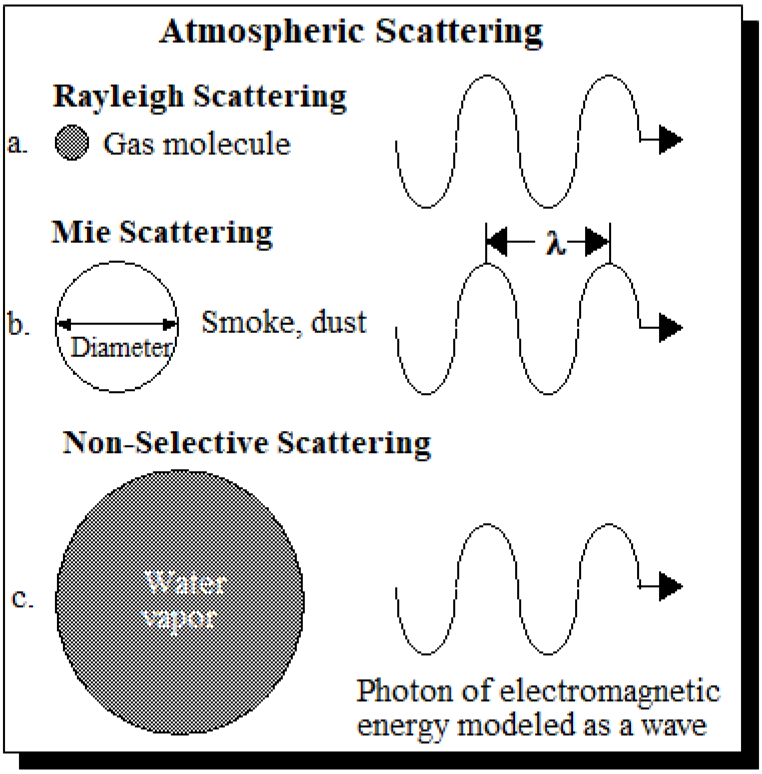
Source: Canada Centre for Remote Sensing (CCRS)

Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. These could be particles such as small specks of dust or nitrogen and oxygen molecules.

Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day is because of this phenomenon. As sunlight passes through the atmosphere, the shorter wavelengths (i.e., blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At sunrise and sunset, the light has to travel farther through the atmosphere than at midday and the scattering of the shorter wavelengths is more complete; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.

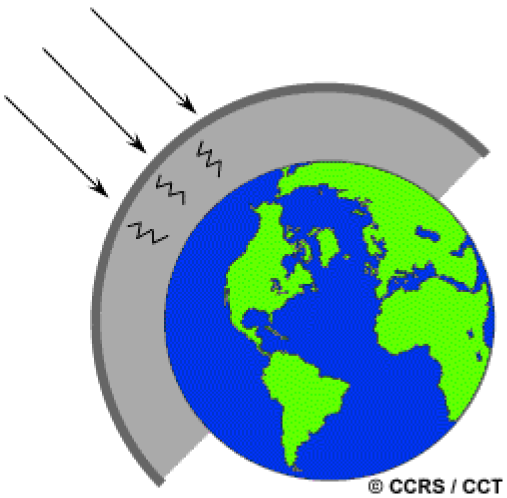
Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud conditions are overcast.

The final scattering mechanism of importance is called **nonselective scattering**. This occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering. Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally. This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities (blue + green + red light = white light).



Source: John R. Jensen (2014): Remote Sensing of the Environment: An Earth Resource Perspective

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents which absorb radiation.

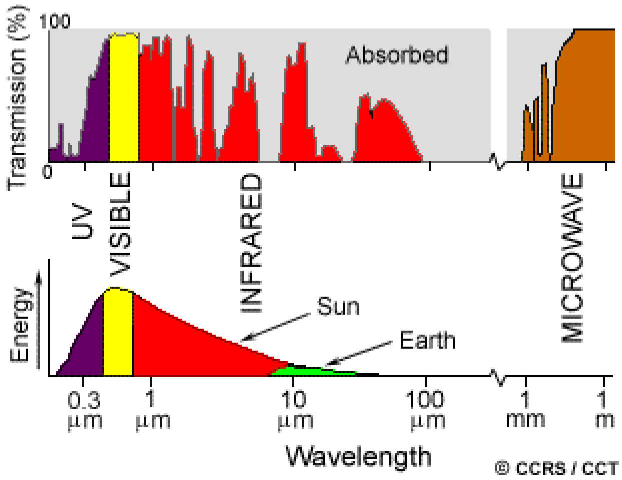


Source: Canada Centre for Remote Sensing (CCRS)

Ozone serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight.

You may have heard carbon dioxide referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere. Water vapour in the atmosphere absorbs much of the incoming longwave infrared and shortwave microwave radiation (between 22µm and 1m). The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e., high humidity).

Because these gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can "look" for remote sensing purposes. Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called atmospheric windows. By comparing the characteristics of the two most common energy/radiation sources (the sun and the earth) with the **atmospheric windows** available to us, we can define those wavelengths that we can use most effectively for remote sensing. The visible portion of the spectrum, to which our eyes are most sensitive, corresponds to both an atmospheric window and the peak energy level of the sun. Note also that heat energy emitted by the Earth corresponds to a window around 10 µm in the thermal IR portion of the spectrum, while the large window at wavelengths beyond 1 mm is associated with the microwave region.



Source: Canada Centre for Remote Sensing (CCRS)

Energy-Matter interactions with the terrain:

- **Radiant flux** (Φ, in Watts): the amount of radiant energy onto, off of, or through a surface per unit time.
- **Radiation budget equation:**

$$\Phi_{i\lambda} = \Phi r_{\lambda} + \Phi \tau_{\lambda} + \Phi \alpha_{\lambda},,$$

reflectance: $r_{\lambda} = \Phi r_{\lambda} / \Phi_{i\lambda}$

transmittance: $\tau_{\lambda} = \Phi \tau_{\lambda} / \Phi_{i\lambda}$

absorptance: $\alpha_{\lambda} = \Phi \alpha_{\lambda} / \Phi_{i\lambda}$

$$1 = r_{\lambda} + \tau_{\lambda} + \alpha_{\lambda}$$

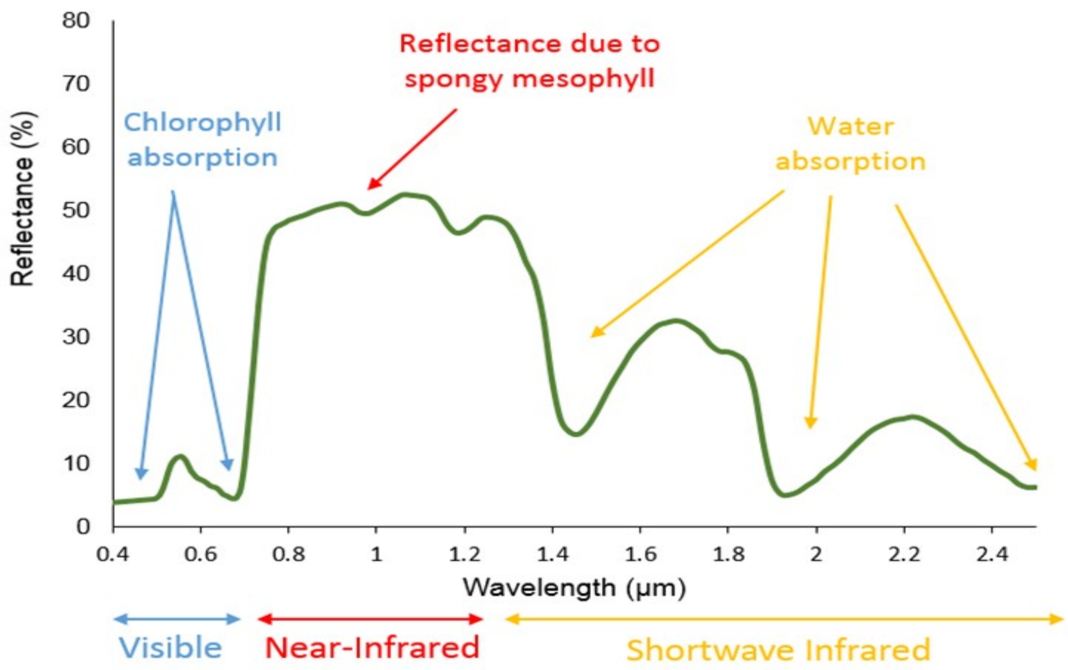
they are based on a hemisphere. Clear glass has high τ_{λ}, so the r_{λ} and α_{λ} should be low; fresh snow has high r_{λ}, so τ_{λ} and α_{λ} are low; fresh asphalt has high α_{λ}, so ….

$R_{\lambda} = (\Phi r_{\lambda} / \Phi_{i\lambda}) \times 100$, this is **spectral reflectance** (reflectance at specified wavelength intervals)

- **Albedo** is ratio of the amount of EMR reflected by a surface to the amount of incident radiation on the surface. Fresh Snow has high albedo of 0.8-0.95, old snow 0.5-0.6, forest 0.1-0.2, Earth system 0.35

Spectral Reflectance

The wavelengths of EMR always vary based on the nature of distant objects, and thus create different spectral signatures. Remote sensing sensors play important roles to identify these spectral signatures. The recorded radiation (or datasets) is then used to analyse the object (e.g., features of Earth's surface) and for mapping purposes.

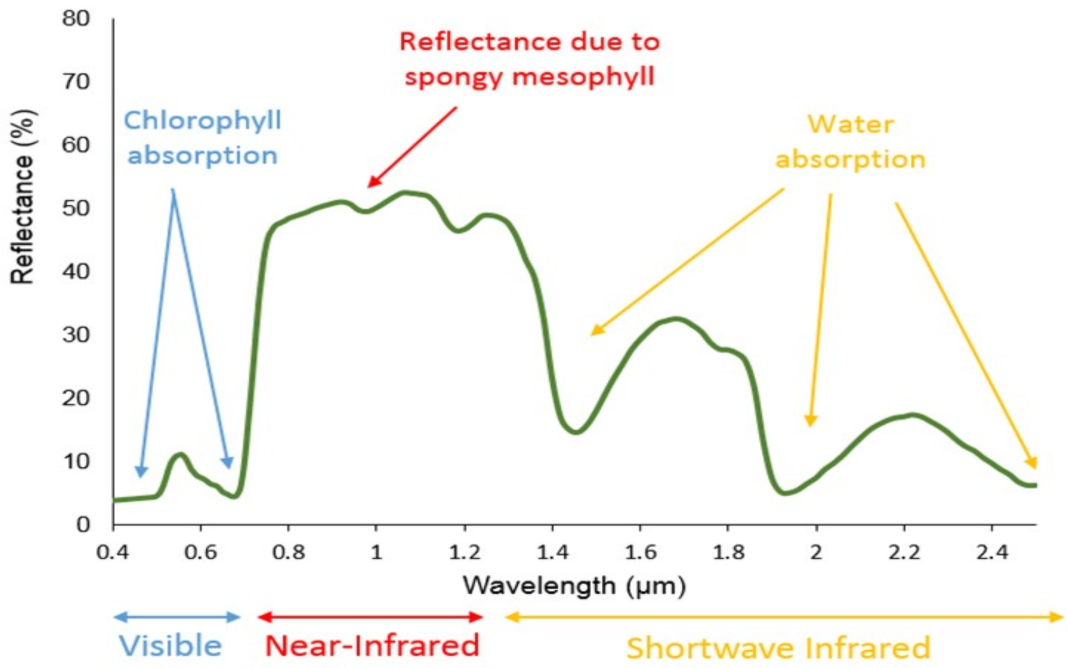


Source: YouTube video: Spectral Reflectance Curves - What is Remote Sensing? (8/9) - YouTube

Different surface features reflect and absorb the sun's electromagnetic radiation in different ways. The reflectance properties of an object depend on the material and its physical and chemical state, the surface roughness as well as the angle of the sunlight. The reflectance of a material also varies with the wavelength of the electromagnetic energy. The amount of reflectance from a surface can be measured as a function of wavelength, this is referred to as spectral reflectance.

Spectral Reflectance is a measure of how much energy (as a percent) a surface reflects at a specific wavelength. Many surfaces reflect different amount of energy in different portions of the spectrum. These differences in reflectance make it possible to identify different earth surface features or materials by analysing their spectral reflectance signatures.

Spectral reflectance curves graph the reflectance (in percent) of objects as a function of wavelengths.



Source: YouTube video: Spectral Reflectance Curves - What is Remote Sensing? (8/9) - YouTube

* Mesophiyll is the soft chlorophyll-containing tissue of a leaf between the upper and lower layers of epidermis: involved in photosynthesis

Exercise materials and tasks

Quiz questions

Instructions: As a recap and deepening of the previous session's content, we have prepared this quiz. Have fun!

1. Impact of the atmosphere – which statement is correct?
   a. All parts of electromagnetic radiation are affected by the atmosphere in the same strength.
   b. Increasing portions of water vapor increase the transmissivity in the atmosphere.
   c. Where the atmosphere exhibits high transmissivity for specific wavelength, atmospheric windows can be found.

2. Scattering mechanisms – which image represents Mie scattering?
   a. red sunset
   b. white clouds
   c. blue sky

3. Scattering mechanisms – which image represents Rayleight scattering?
   a. red sunset
   b. white clouds
   c. blue sky

4. Which part of electromagnetic radiation (EMR) is absorbed the most?
   a. Visible
   b. Near-infrared (IR)
   c. Shortwave infrared (SWIR)

2.5 Information Extraction

Reading material

In this session, you will find out what makes image a quality image. You'll learn what very cell (pixel) on image represents, what and how many bands makes images.

Images Resolutions – Dimensions of Remote Sensing:

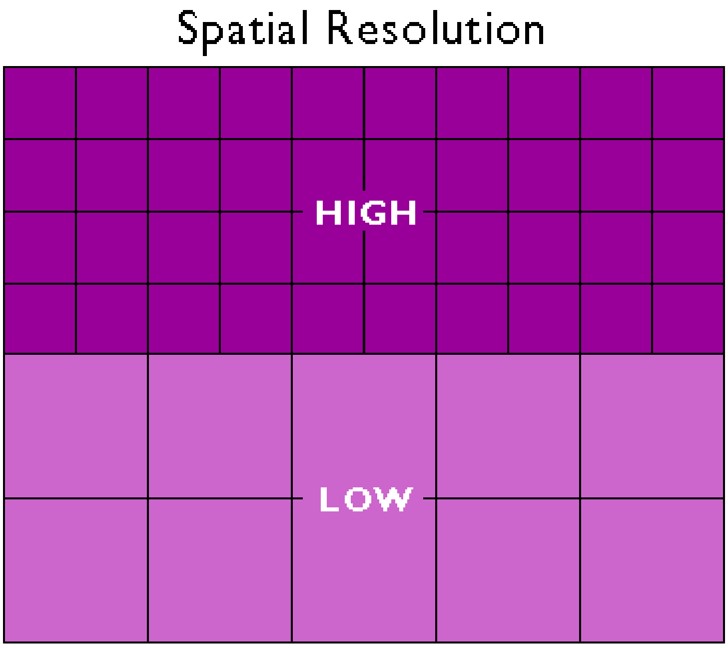
For earth observation, image resolutions have to be taken into consideration. The quality of remote sensing data consists of its

- Spectral resolutions
- Radiometric resolutions
- Spatial resolutions
- temporal resolutions

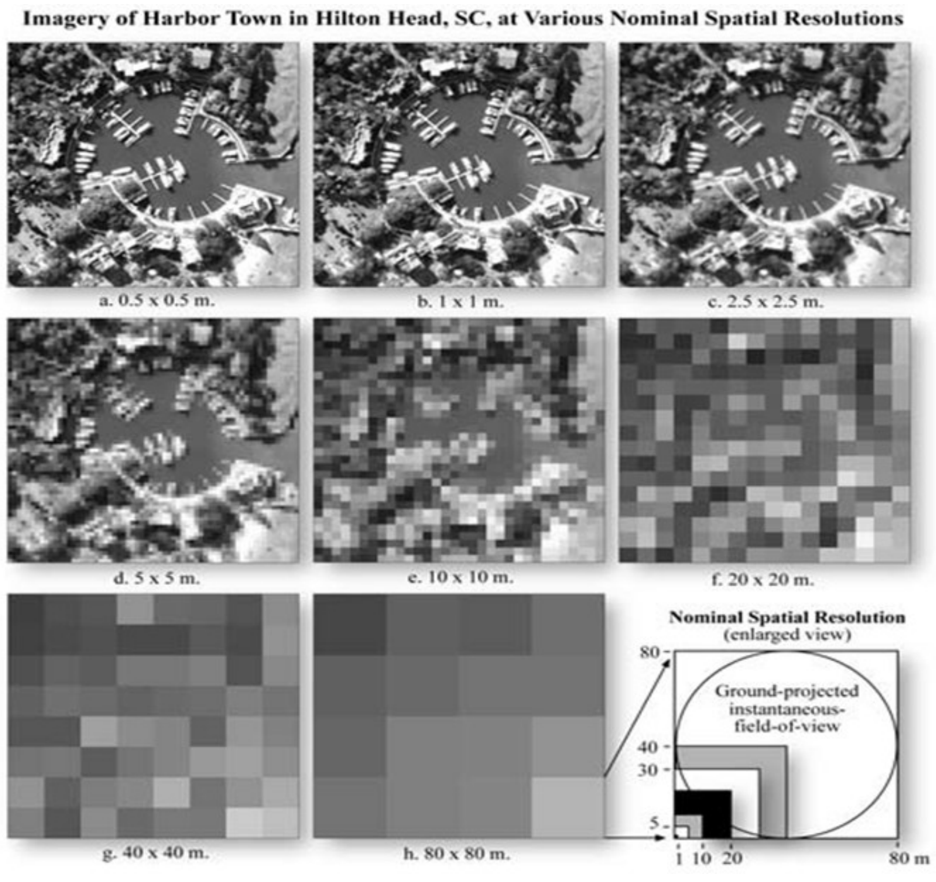
1. Spatial Resolution

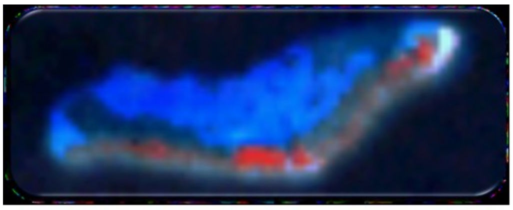
Spatial resolution refers to the size of the smallest object that can be resolved on the ground. In a digital image, the resolution is limited by the pixel size, i.e., the smallest resolvable object cannot be smaller than the pixel size. The intrinsic resolution of an imaging system is determined primarily by the instantaneous field of view (IFOV) of the sensor, which is a measure of the ground area viewed by a single detector element in a given instant in time. However, this intrinsic resolution can often be degraded by other factors which introduce blurring of the image, such as improper focusing, atmospheric scattering and target motion. The pixel size is determined by the sampling distance.

A "**High Resolution**" image refers to one with a **small Pixel size**. Fine details can be seen in a high-resolution image. On the other hand, a "**Low Resolution**" image is one with a **large Pixel size**, i.e., only coarse features can be observed in the image.

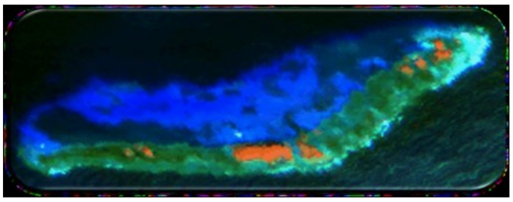


Source: https://www.e-education.psu.edu/geog160/node/1959

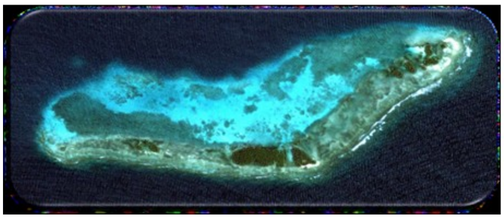




Spectrographic Imager Satellite SPOT- 20m



Compact Airborne Spectrographic Imager CASI- 5m



IKONOS -1m

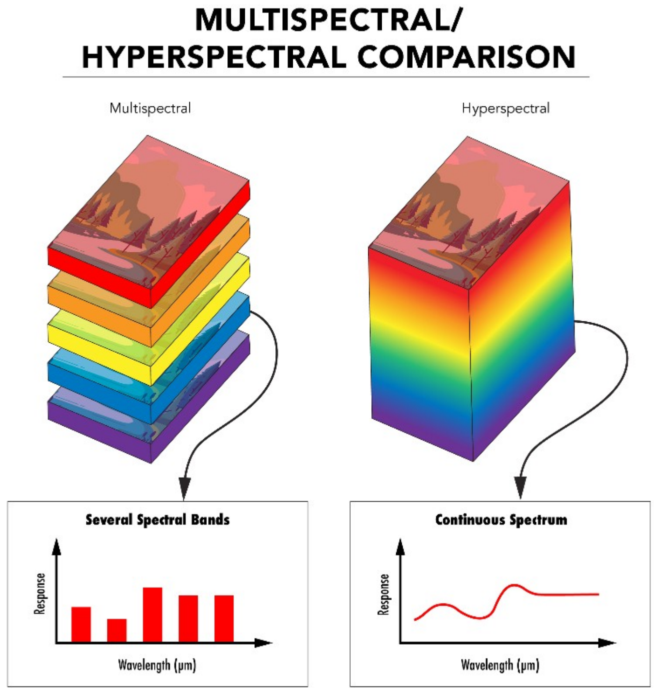
Source: Remote Sensing of the Environment: An Earth Resource Perspective, Book by John R. Jensen (2014)

2. Spectral resolution

Spectral resolution refers to the ability of a satellite sensor to measure specific wavelengths of the electromagnetic spectrum. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. Wide intervals in the electromagnetic spectrum are referred to as Low spectral resolution, and narrow intervals are referred to as High spectral resolution. For example, a multispectral image breaks light into 4 to 36 bands.

Then, it assigns those bands names such as red, green, blue, and near-infrared. Each band may span 0.05 um in the electromagnetic spectrum. Similarly, hyperspectral imaging captures a spectrum of light. But it divides the light into hundreds of narrow spectral bands.

For hyperspectral images, spectral resolution is very high. Remember that every channel or band (colour) of electromagnetic spectrum contains specific information, it is always better to combine different to have maximum of information about features to be analysed.



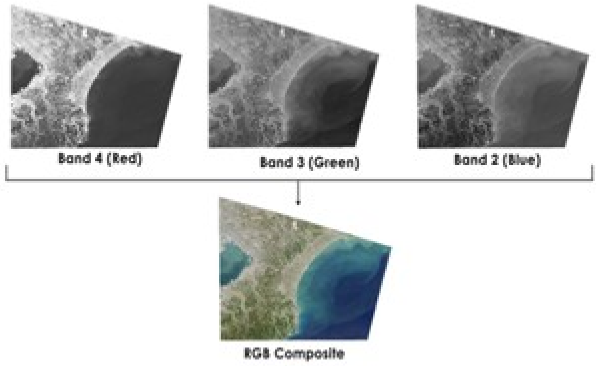
Source: https://cdn.eo-college.org/2021/01/figure4.jpg

Besides Multispectral bands, a satellite dataset contains grayscale band with a high spatial resolution named panchromatic image. A panchromatic image uses a single band that combines Red, Green and Blue bands, allowing for a greater spatial resolution. The resulting image does not contain any wavelength-specific information.

Panchromatic images are produced by the same satellites that produce multispectral images. Since a panchromatic image is a combination of all three visible bands (red + green + blue), the total intensity of solar radiation is much higher in every pixel compared to a multispectral image. The use of the RGB bands sacrifices color for brightness which explains why all panchromatic images are greyscale images.

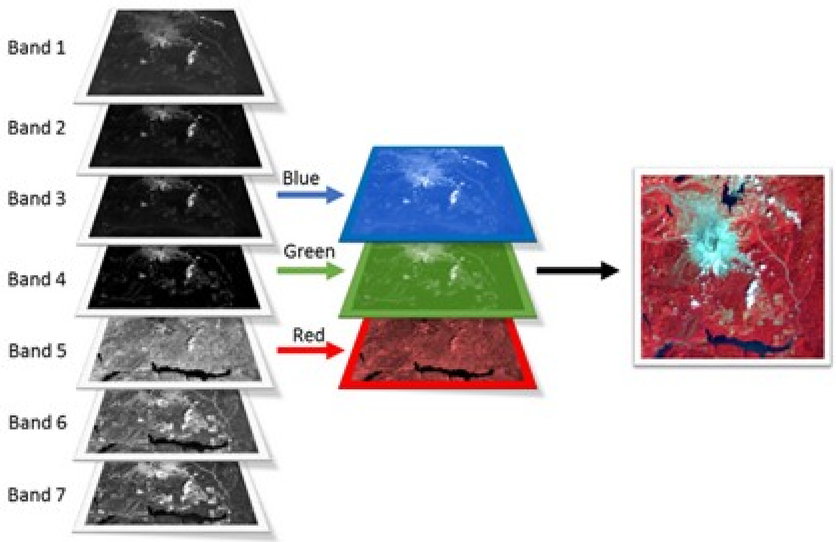
Two main types of band s combination are mostly known in remote sensing:

Natural or True Colour Composites: A natural or true colour composite is an image displaying a combination of visible red, green and blue bands. The resulting composite resembles what would be observed naturally by the human eye, many people prefer true colour composites, as colours appear natural to our eyes, but often subtle differences in features are difficult to recognize.



Source: https://gisgeography.com/remote-sensing-earth-observation-guide/

False Colour Composites: False colour images are a representation of a multi-spectral image produced using bands other than visible red, green and blue as the red, green and blue components of an image display. False colour composites allow us to visualize wavelengths that the human eye cannot see (i.e., near-infrared).



Source: https://gsp.humboldt.edu/olm/Courses/GSP_216/sessions/composites.html

Using bands such as near infra-red increases the spectral separation and often increases the interpretability of the data. There are many different false coloured composites which can highlight many different features. For examples (see the table below for Landast8 dataset)

Band Combinations for Landsat 8

Natural Color	4 3 2
False Color (urban)	7 6 4
Color Infrared (vegetation)	5 4 3
Agriculture	6 5 2
Healthy Vegetation	5 6 2
Land/Water	5 6 4
Natural With Atmospheric Removal	7 5 3
Shortwave Infrared	7 5 4
Vegetation Analysis	6 5 4

Source: https://www.esri.com/arcgis-blog/products/product/imagery/band-combinations-for-landsat-8/

3. Radiometric resolution

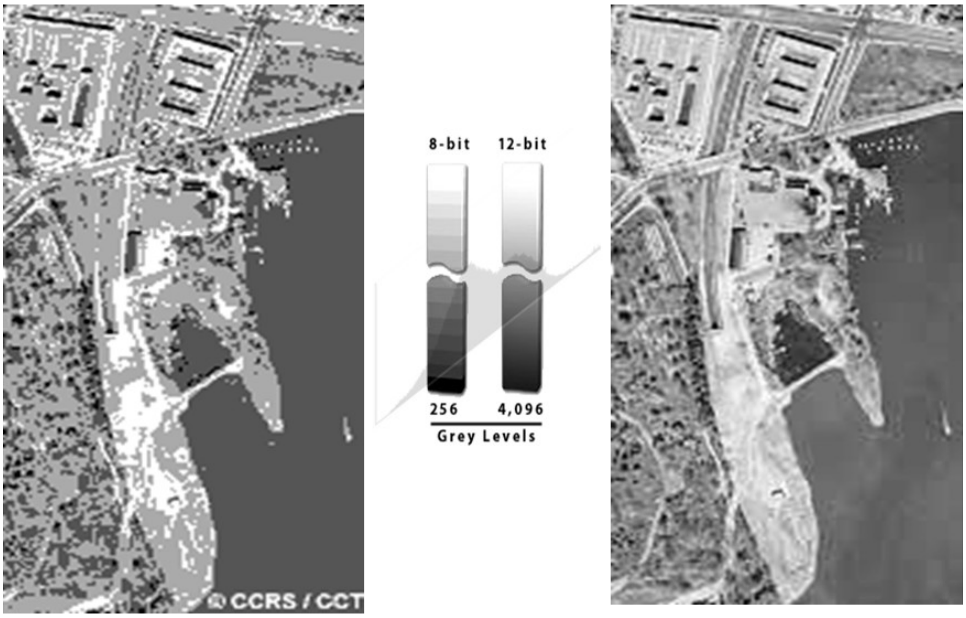
Radiometric resolution refers to the smallest change in intensity level that can be detected by the sensing system. Sensor's sensitivity to the magnitude of the electromagnetic energy. The intrinsic radiometric resolution of a sensing system depends on the signal to noise ratio of the detector.

In a digital image, the radiometric resolution is limited by the number of discrete quantization levels used to digitize the continuous intensity value. This quantization is expressed in number of bits, it is the one defining the radiometric coverage too.

The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in energy.

bits	Max. num
1	2
2	4
3	8
6	64
8	256
11	2048
12	4096

Resolution: 12 bits   Coverage: 0 - 4095



Source of picture: Canada Centre for Remote Sensing (CCRS)

We said that radiometric resolution characterizes how finely a given sensor can receive and divide the radiance between the different bands. In the picture above, we can see the difference between lower (8-bit) and higher (12-bit) radiometric at comparable spatial resolution. A greater resolution increases the range of intensities that a sensor can distinguish.

4. Temporal resolution

Temporal resolution refers to the frequency at which imagery is recorded for a particular geographic area. It is most relevant in time-series studies or phenomena monitoring. A major difference to the spatial domain is that the temporal resolution is not solely dependent on the sensor, but on the satellite platform that the sensor is mounted on.

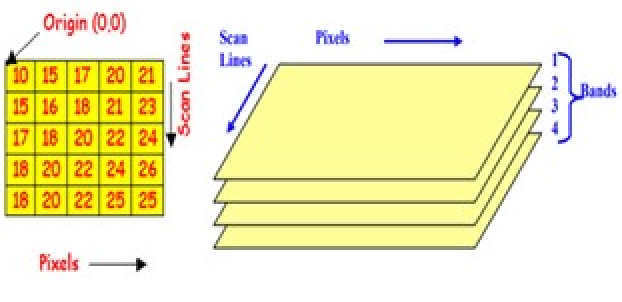
https://cdn.eo-college.org/2021/03/S2L2A-timelapse_SaudiArabia.gif

Now that you know what parts an image is made of, it's time to dive into how the image can be further processed.

Digital Image processing in Remote sensing

Remote sensing data are recorded in digital format, mainly as images or pictures, as you know a picture is worth a thousand words, Pictures concisely convey information about positions, sizes and inter-relationships between objects. They portray spatial information that we can recognize as objects.

As consequence, all image interpretation and analysis involve some levels of digital processing. A digital remotely sensed image is typically composed of picture elements (pixels) located at the intersection of each row i and column j in each K bands of imagery. Associated with each pixels a number known as Digital Number (DN) or Brightness value (BV) that depicts the average radiance of a relatively small area within a scene. A smaller number indicates low average radiance from the area and the high number is an indicator of high radiant properties of the area.



Structure of a Digital Image and Multispectral Image

Source: Photogrammetry and Remote Sensing Division, Indian Institute of Remote Sensing
In remote sensing, most common image processing functions are grouped into the four categories: 1. Image Pre-processing 2. Image Enhancement 3. Image Transformation 4. Image Classification and Analysis
1. **Image Pre-processing**: it involves those operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as ***radiometric or geometric corrections.*** • ***Radiometric corrections*** include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor. Radiometric correction is done to reduce or correct errors in the digital numbers of images. Done to improve interpretability and analysis of images and to standardize images. • ***Geometric corrections*** include correcting for geometric distortions due to sensor-Earth geometry variations, and conversion of the data to real world coordinates (e.g., latitude and longitude) on the Earth's surface.
2. **Image Enhancement**: it is normally performed to improve the appearance/visibility /quality of the imagery to assist in visual interpretation and analysis. Examples of enhancement functions include contrast stretching to increase the tonal distinction between various features in a scene, and spatial filtering to enhance (or suppress) specific spatial patterns in an image. There are also some other Image quality enhancement such as **Pansharpening**, which aims at increasing the resolution of satellite images: Pansharpening (short for panchromatic sharpening) is a fusion technique to combine a panchromatic image of high spatial resolution with multispectral image data of lower spatial resolution to obtain a high-resolution multispectral image. In other words, we use panchromatic image details to 'sharpen' the multispectral imagery while simultaneously preserving spectral information.
3. Image Transformation: this refers to operations performed to combine data from multiple spectral bands. Arithmetic operations (i.e., subtraction, addition, multiplication, division) are performed to combine and transform the original bands into "new" images which better display or highlight certain features in the scene. For example, the computation of different Indices (NDVI, VCI, NDWI, NDBI, NSMI, NDDI, NDI) • ***Normalized Difference Vegetation Index (NDVI)*** describes the vegetation density and assessing changes in plant health. NDVI is calculated as a ratio between the ***Red (R)*** and ***Near-infrared (NIR)***. In this tutorial learn how to apply the NDVI formula and calculate vegetation patterns. **NDVI = (NIR – R) / (NIR + R)** NDVI values always range from **-1 to +1** • ***Normalized Difference Built-up Index (NDBI)*** describes the Built-up density of any Geographic area. NDBI is calculated as a ratio between the ***short-wave infrared (SWIR)*** and ***Near-infrared (NIR).***

NDBI = (SWIR – NIR) / (SWIR + NIR)

NDBI values range from **-1 to +1**

- ***Soil Adjusted Vegetation Index (SAVI)*** is similar to NDVI, these enhancements to NDVI are useful because SAVI accounts for variations in soils. SAVI is calculated as a ratio between the **near-infrared (NIR), red (RED)**, and ***L (Vegetation cover current factor).***

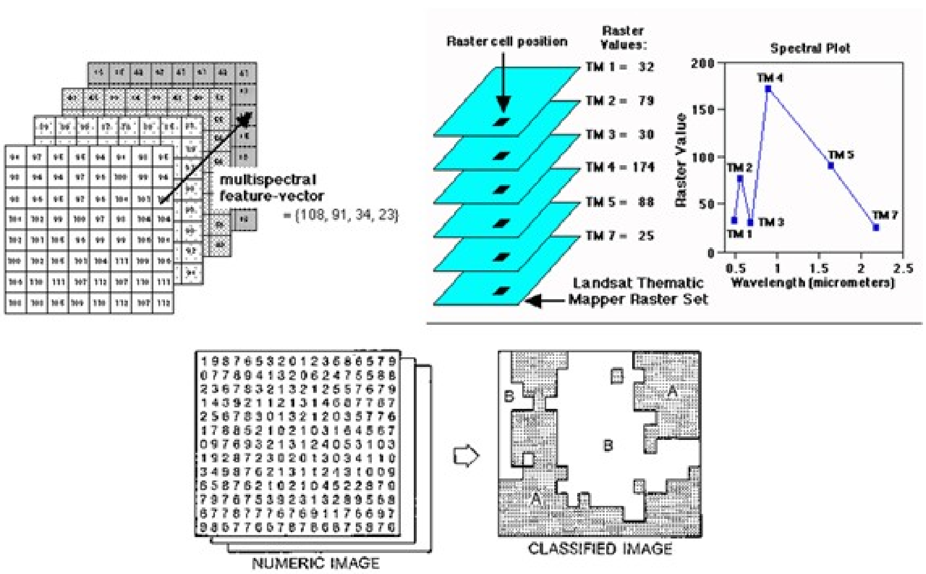
SAVI = (NIR– RED) * (1+L) / (NIR+ RED+L)

SDVI values range from **-1 to +1**

4. **Image classification**: it is the process of reducing images to information classes. Classification divides the spectral or spatial feature space into several classes based on a decision rule to create one layer (thematic layer).

General Procedures:

- *Feature Extraction*: Transform the multispectral image by a spatial or spectral transform to a feature image (e.g. choice of some classes such as built up, forest, water bodies, agriculture land, bare soil, etc.). Alternatively, you can always look up for the established FAO land cover classification scheme as inspiration: https://www.fao.org/3/x0596e/X0596e02a.htm#P1974_116516
- *Training:* Extract the pixels to be used for training the classifier to recognize certain categories, or classes.
- Determine the discriminant functions in the feature space. Supervised or unsupervised
- *Labeling*: Apply the discriminant functions to the entire feature image and label all pixels. The output consists of one label for each pixel.



Source of Picture: Remote Sensing of the Environment: An Earth Resource Perspective, Book by John R. Jensen (2014)

Two major categories of image classification techniques include unsupervised a supervised classification:

Unsupervised classification is where the outcomes (groupings of pixels with common characteristics) are based on the software analysis of an image without the user providing sample classes. The computer uses techniques to determine which pixels are related and groups them into classes. The user can specify which algorism the software will use and the desired number of output classes but otherwise does not aid in the classification process. However, the user must have knowledge of the area being classified when the groupings of pixels with common characteristics produced by the computer have to be related to actual features on the ground (such as wetlands, developed areas, coniferous forests, etc.).

Supervised classification is based on the idea that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. Training sites (also known as testing sets or input classes) are selected based on the knowledge of the user. The user also sets the bounds for how similar other pixels must be to group them together. These bounds are often set based on the spectral characteristics of the training area, plus or minus a certain increment (often based on “brightness” or strength of reflection in specific spectral bands). The user also designates the number of classes that the image is classified into. Many analysts use a combination of supervised and unsupervised classification processes to develop final output analysis and classified maps.

Data processing levels

Recently, operational processing of remote sensing data has led to multiple processing levels.

“Standard” types of pre-processing:

- Radiometric calibration
- Geometric calibration
- Noise removal
- Formatting

Generic description:

- Level 0: raw, unprocessed sensor data
- Level 1: radiometric (1R or 1B) or geometric processing (1G)
- Level 2: derived product, e.g., vegetation index

Exercise materials and tasks

Quiz questions

Instructions: As a recap and deepening of the previous session's content, we have prepared this quiz. Please answer the following three questions to test your knowledge retention:

1. What is spatial resolution?
   - **a. It describes the smallest angular (horizontal) separation between two objects**
   - b. It describes the ability of sensors to detect grey values
   - c. It describes the number of bands, that a sensor provides

2. What is the maximum value of the digital number which could be represented for an image with a radiometric resolution of 6 bits?
   - a. 256
   - b. 8
   - **c. 64**
   - d. 2048

3. Temporal resolution – pick the right answer(s)!
   - **a. Temporal resolution describes the time interval between two overpasses at given point**
   - b. Temporal signatures of two different land cover types are the same
   - c. Remote sensing instruments with high temporal repetition are less suited for disaster monitoring

4. Which two of the following are correct statements with respect to sensor design?
   - **a. For high spatial resolution, the sensor has to have a small IFOV**
   - **b. A small IFOV increases the amount of energy that can be detected within the IFOV**
   - c. Narrowing the wavelength range detected for a particular channel or band increases the amount of energy detected without reducing spatial resolution but this reduces the spectral resolution of the sensor
   - d. Coarser spatial resolution reduces radiometric and/or spectral resolution

2.6 Application and documentation

Exercise materials and tasks

Congrats! You made it through the theory part of Remote Sensing!

Let´s now do a practical exercise on this topic:

From *USGS earth explorer website*, download one tile of Landsat 8 (choose any Image of a period between May and September 2022) covering the Eastern part of Rwanda and perform following tasks of Image processing:

1. Click on the following link https://gisgeography.com/usgs-earth-explorer-download-free-landsat-imagery/, it will guide on how to download Landsat 8 images.

2. Layer stack of Multispectral bands.
   Layer stacking is a process of combining multiple separate bands in order to produce a new multi band image. This type of multi band images is useful in visualizing and identifying the available Land Use Land Cover classes
   For additional steps of layer stacking of Multi-spectral Landsat bands in QGIS, follow instructions in this video: https://www.youtube.com/watch?v=zq6XbuIkk-s

3. **Subset the image of Nyagatare District (use district shapefile from the GIS dataset).**
   Refer to this link https://www.youtube.com/watch?v=yKNSIRrX28g
   Satellite data downloaded usually cover more area than you are interested in and near 1 GB in size, it always better to select a portion of the larger image to work with, A subset is a section of a larger downloaded image

4. Create a Pansharpened Image of Nyagatare district Image
   To perform this step, refer to https://www.youtube.com/watch?v=UpFNgWqAN_U

5. Perform Image classification (supervised one) to create a Land use /land cover map of Nyagatare district.
   Supervised classification is mainly performed through the following 3 steps:
   a. Selection training areas (according the number of desired or identified classes)
   b. Generate signature file
   c. Classify (selection a classification method. the following are the most commonly known method for supervised classification: Maximum likelihood, Iso cluster, Class probabi**lity, Principal components and** Support vector machine (SVM)

   To preform image classification step in this exercise, please follow instruction on this link: https://www.youtube.com/watch?v=HKNS-wsc7lo

6. Compute NDVI and NDBI indices variation across Nyagatare district
   This exercises consists of band ratio:
   The NDVI is a band ratioing involving visible red and near-infrared bands of satellite images and determines the vegetation cover over a particular area

Normalized Difference Built-up Index (NDBI) describes the Built-up density of any Geographic area. NDBI is calculated as a ratio between the short-wave infrared (SWIR) and near-infrared (NIR).

Follow the steps in this video on how to Calculate NDVI from Sentinel 2 in QGIS: https://www.youtube.com/watch?v=EaC5sQpExjg

Tutorial is for Sentinel 2 band so instead of band 8 use band 5 of Landsat 8.

Repeat the steps using the raster calculator to Calculate NDBI from Landsat 8 in QGIS: https://www.youtube.com/watch?v=cx8w5QsnvRY

Quiz questions

Instructions: Answer the following questions about the exercise you just performed:

1. When you downloaded Landsat8 file from USGS, in which format was the data saved?
    - **a. .tiff**
    - b. .shp
    - c. .png

2. When we layer stack in QGIS, which operation do we use?
    - a. Clipper
    - b. Rasterize
    - **c. Merge**

3. When calculating NDVI indices of Nyagatare district, values range from?
    - a. 0 to 1
    - **b. -1 to 1**
    - c. -1 to 0

Additional Resources and Links

- *Electromagnetic spectrum and remote sensing: https://youtu.be/US8RHxQ_-qQ*
- *Spatial resolution: https://www.youtube.com/watch?v=HyWcbUbEqaE*
- *More on basic of remote sensing: Rees, W.G. (2010). Physical Principles of Remote Sensing. Cambridge, USA: Cambridge University Press.*

In Rwanda, ArcGIS and Erdas Imagine software are the most used. These softwares are commercial, but most public, educational or non-profit organisations provide licences as the government has signed a memorandum of understanding with ESRI Rwanda to provide licences.