Introduction to Remote Sensing and GIS Techniques and Applications

20 January 2025

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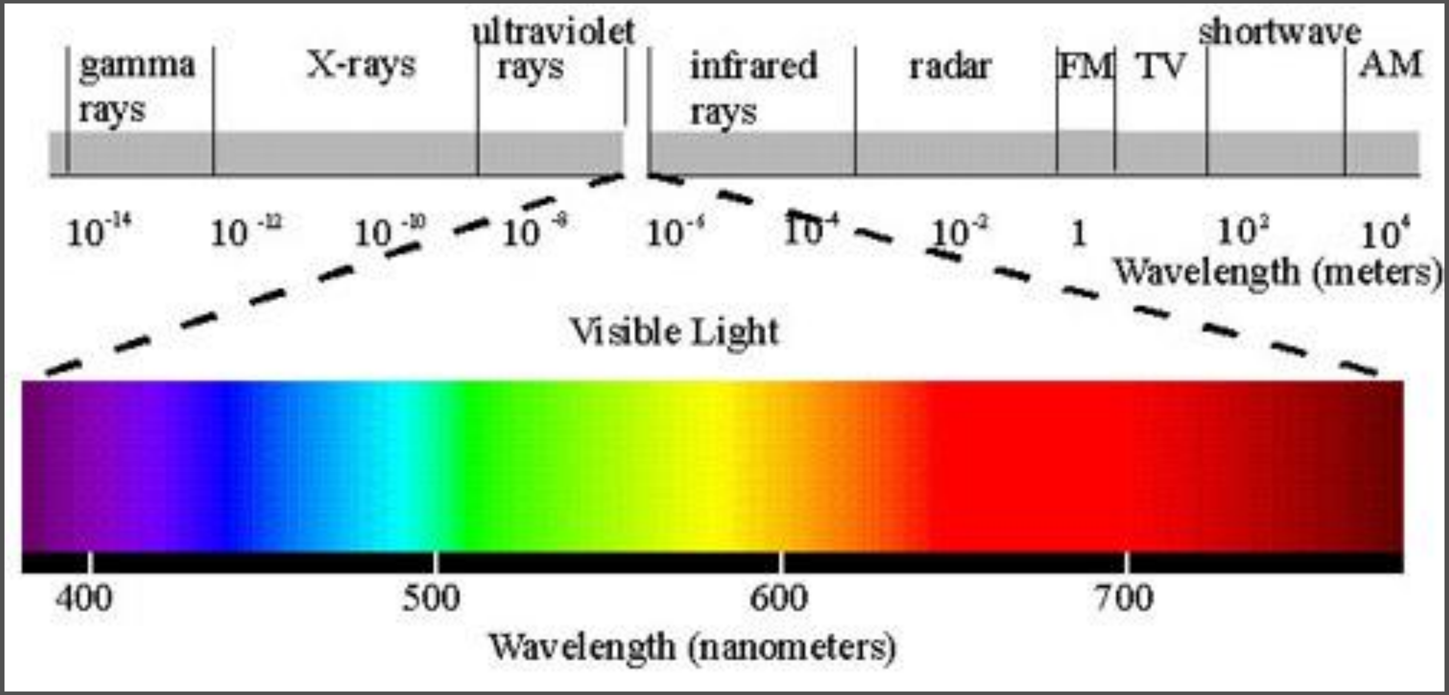
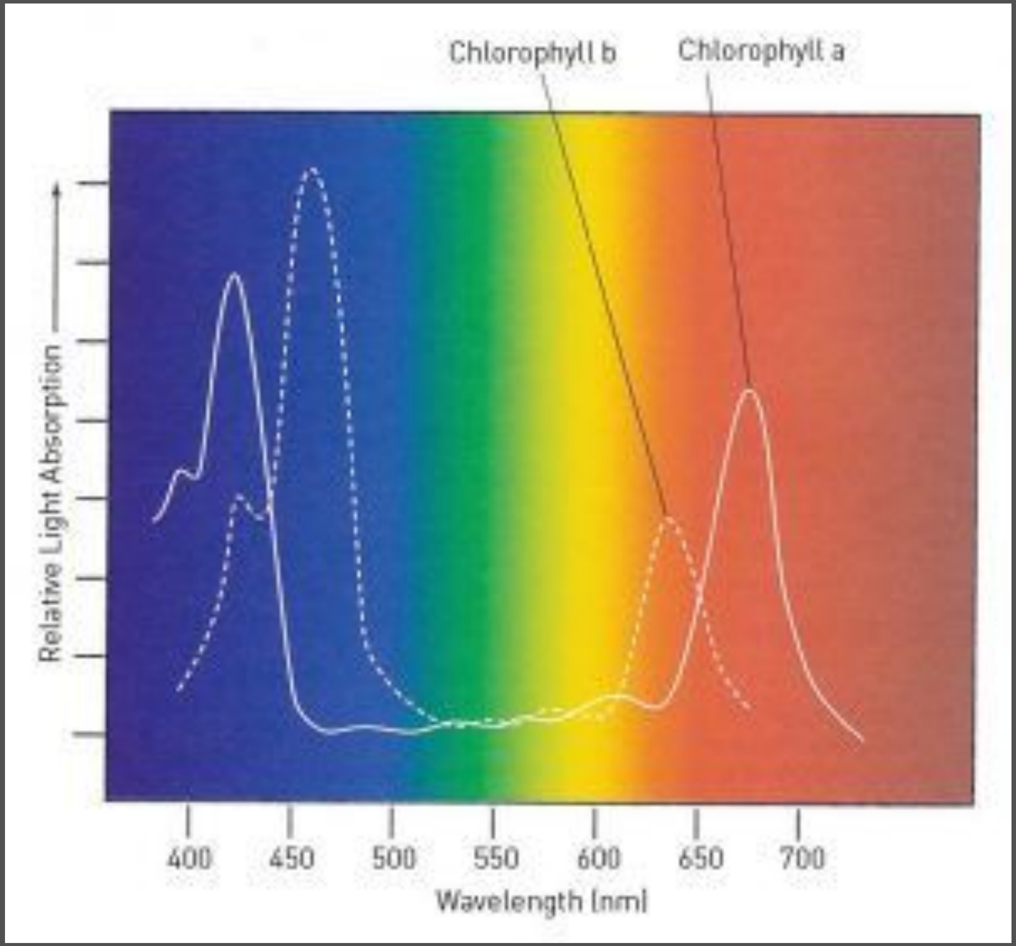
How do we see?



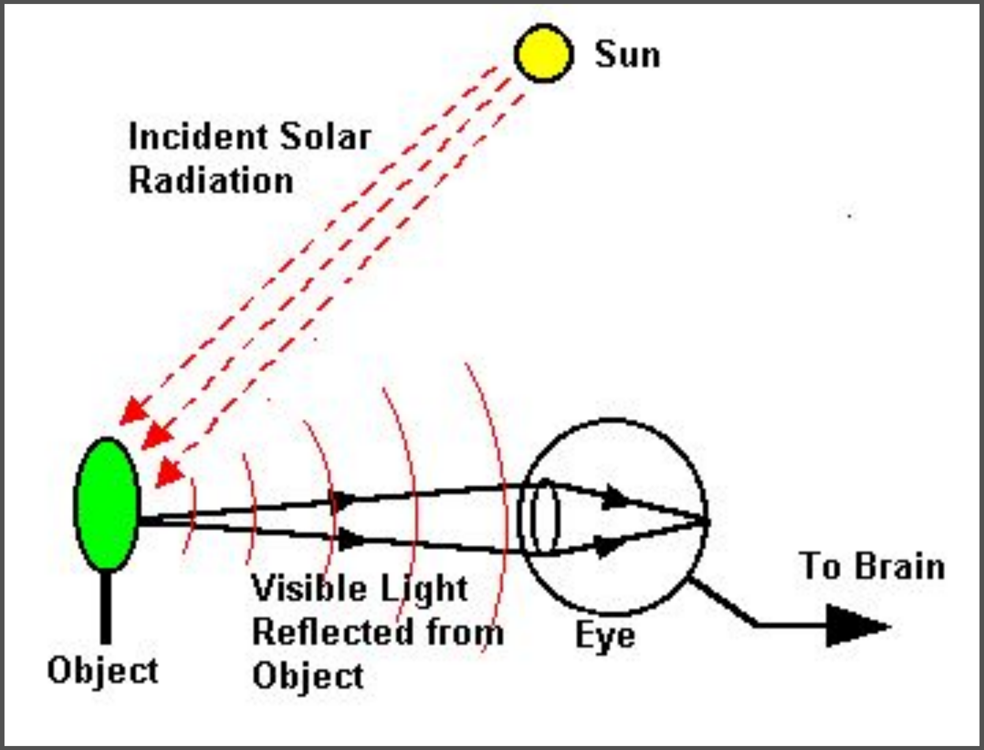
Materials respond differently to different regions of the electromagnetic spectrum. Some portions are reflected and others are absorbed. A graphical representation is what we call the spectrum of the material.

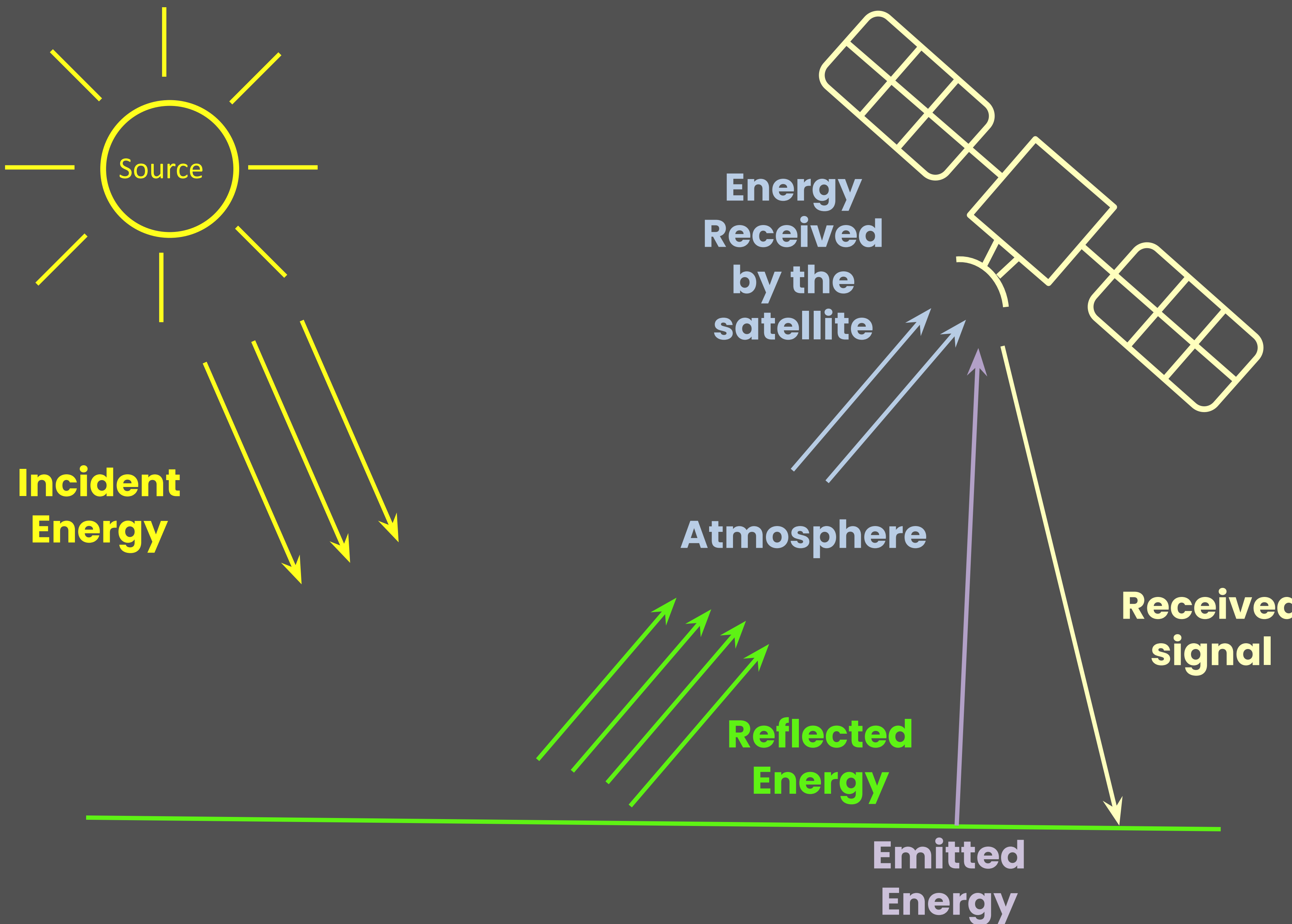
Specific Example of Vegetation



Chlorophyll absorptions are maximum in blue and red with least near green. So there is a high reflection of green

A Remote Sensing Camera. How does it look? What are its components?



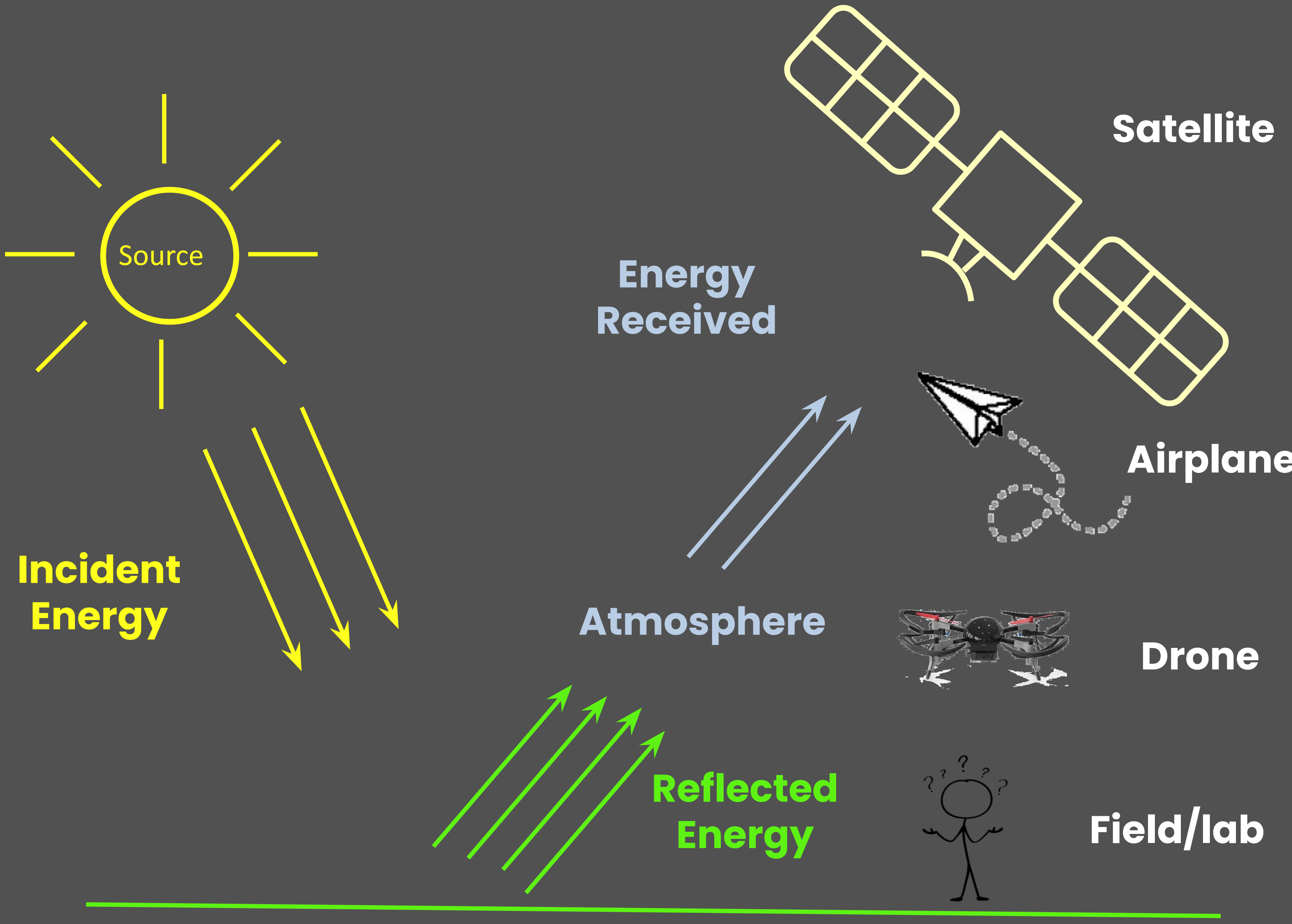

Source
Incident Energy
Energy Received by the satellite
Atmosphere
Reflected Energy
Received signal
Emitted Energy

Some Terms

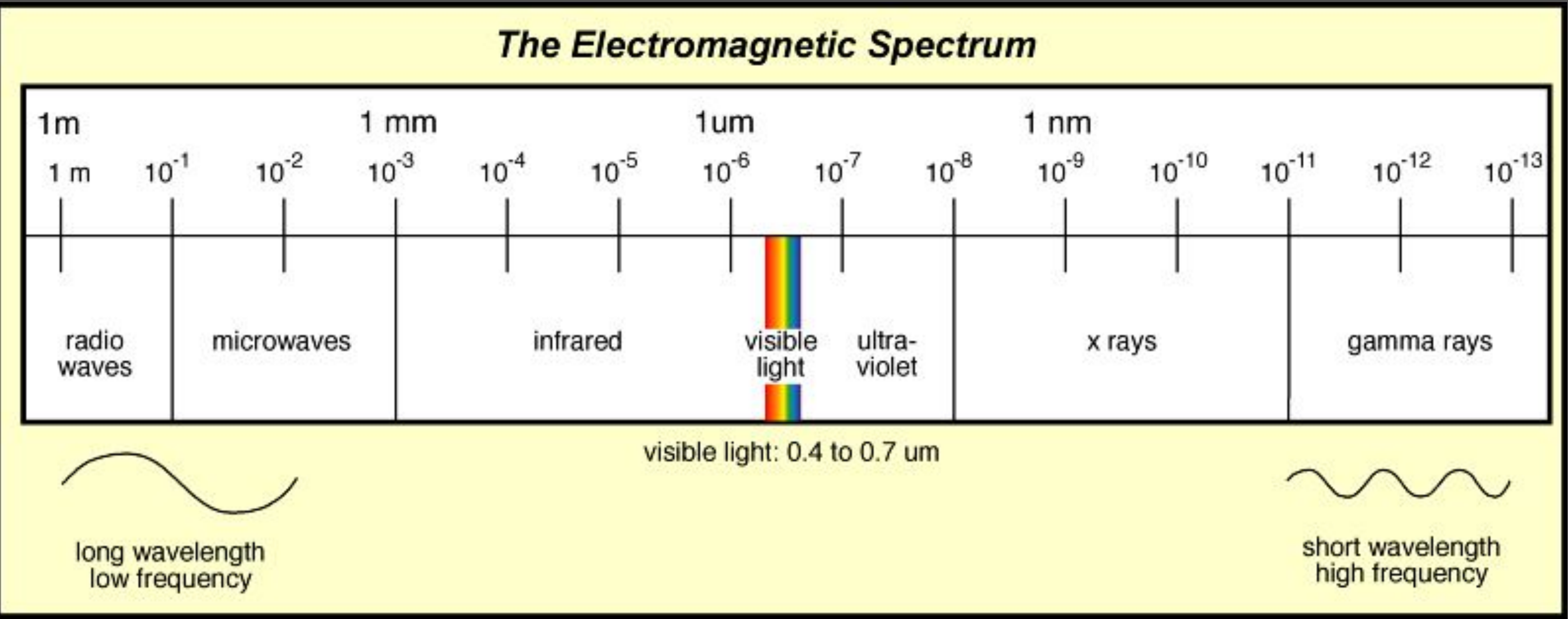
- Remote Sensing: obtaining info without direct contact
- DN: electron count recorded by the sensor
- Radiance: energy received by the sensor
- We are interested in energy reflected by surface.
- Surface reflectance is the ratio of the energy leaving the target and the energy received by the target. It includes corrections for atmospheric effects, sun angle corrections etc.

Platforms in Remote Sensing

- Ground based spectroradiometers for labs/field
- Unmanned aerial vehicles
- Airborne sensors
- Space-borne sensors


Source
Satellite
Energy Received
Airplane
Incident Energy
Atmosphere
Drone
Reflected Energy
Field/lab

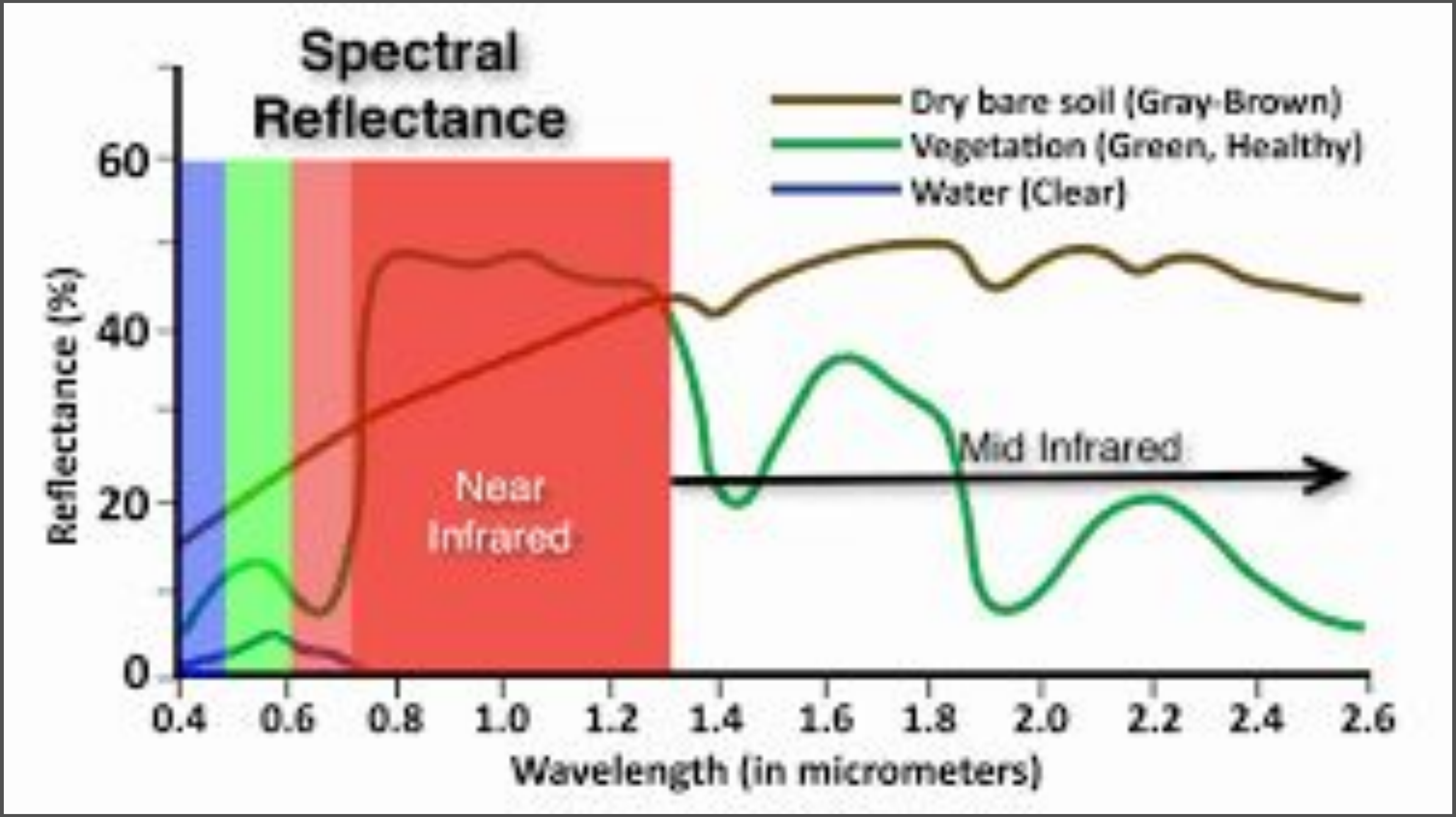
Does all light behave the same way?



Visible and portion of IR is optical based
Long wave IR is emission based
Microwave is back scatter based

FOCUS OF THIS CLASS: OPTICAL

Spectral Reflectance Curve

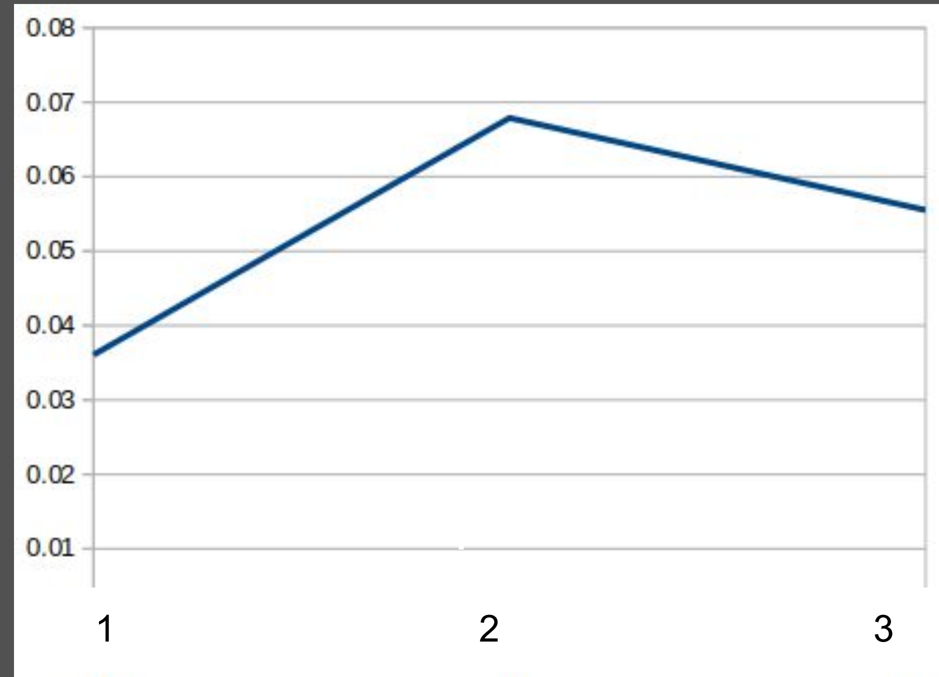


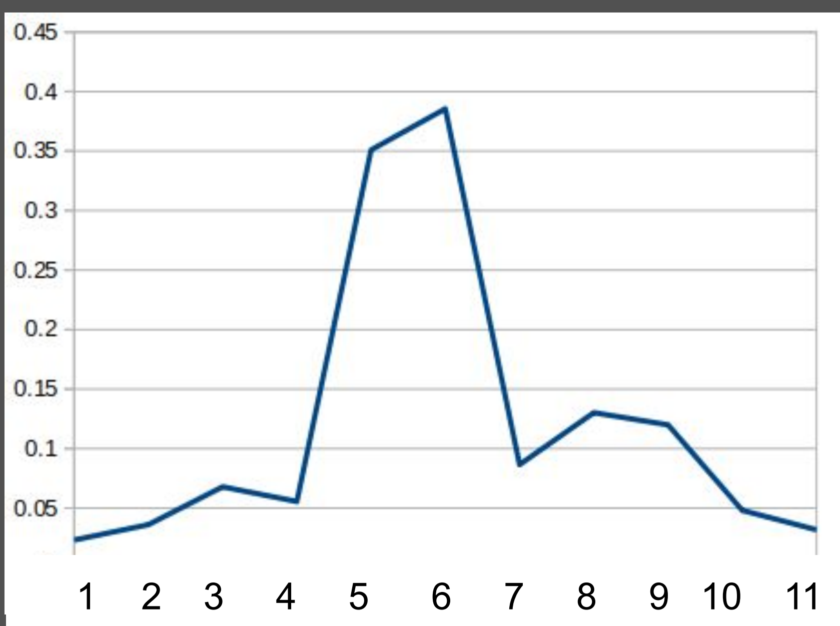
Different land cover types depict different spectrum.

Image source: Boldbayer R 2020

Why do these absorptions occur?

Satellite Bands and the Spectral Response Curve





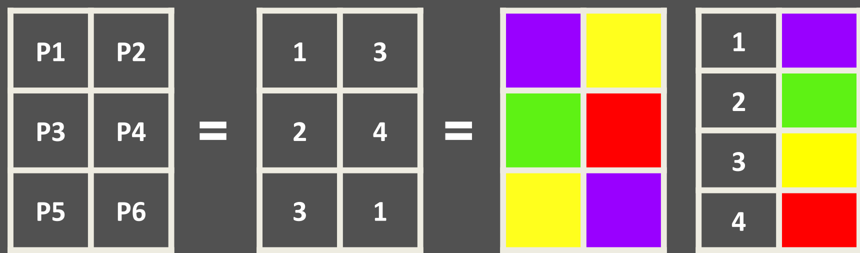
Let's Recap

- We have understood how imaging of satellite data is undertaken
- Spectral bands as representation of wavelength
- Spectral profile
- Matrix representation of satellite data

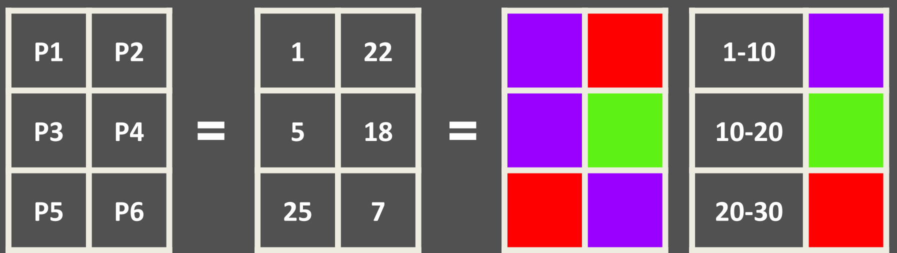
Question: How do we visualize the data?

Single Band Visualization

Single band pseudocolor representation

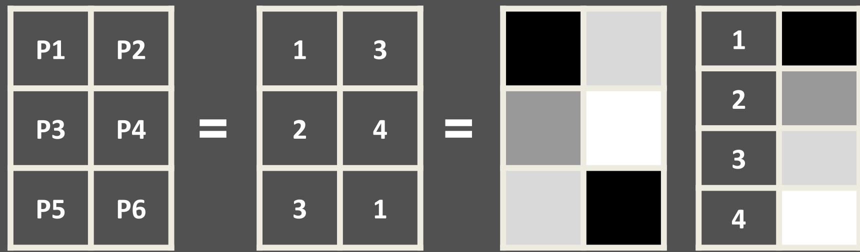


Case 1 : Give each unique value one color



Case 2: Give a range of values one color

Single band grayscale representation



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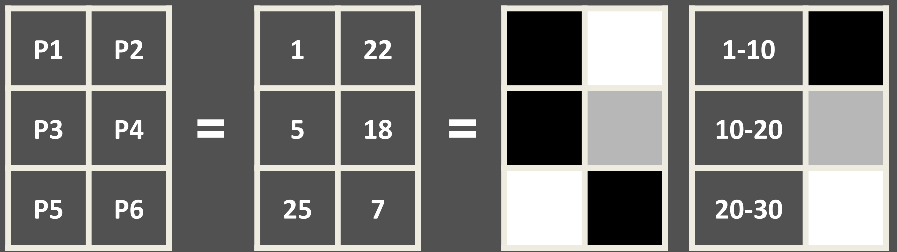
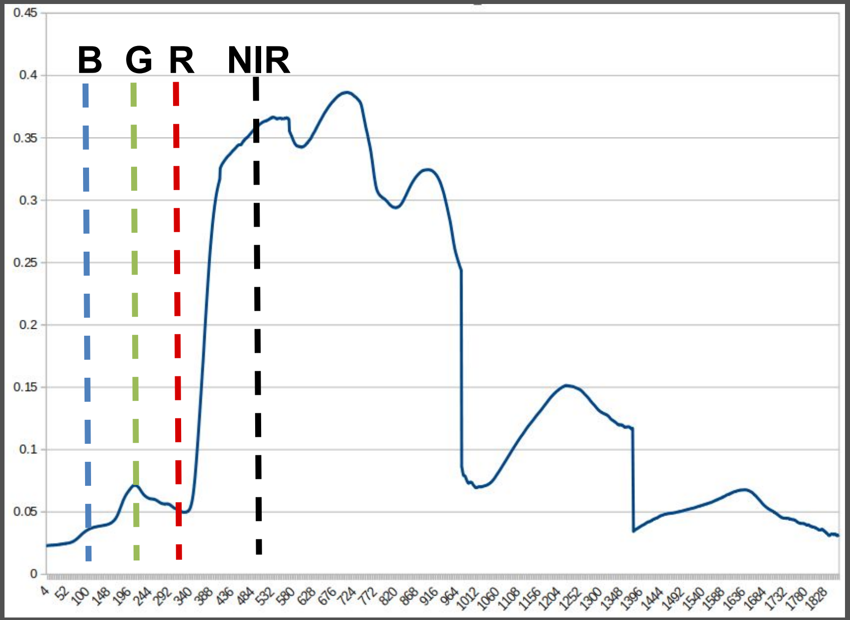


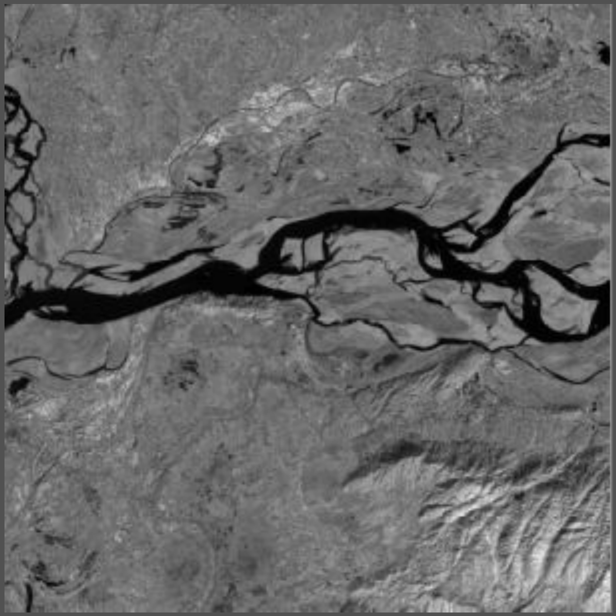
Case 2: Give a range of values one color

This can be thought as a special case of pseudocolor with the colorbar in shades of gray

Color Composites

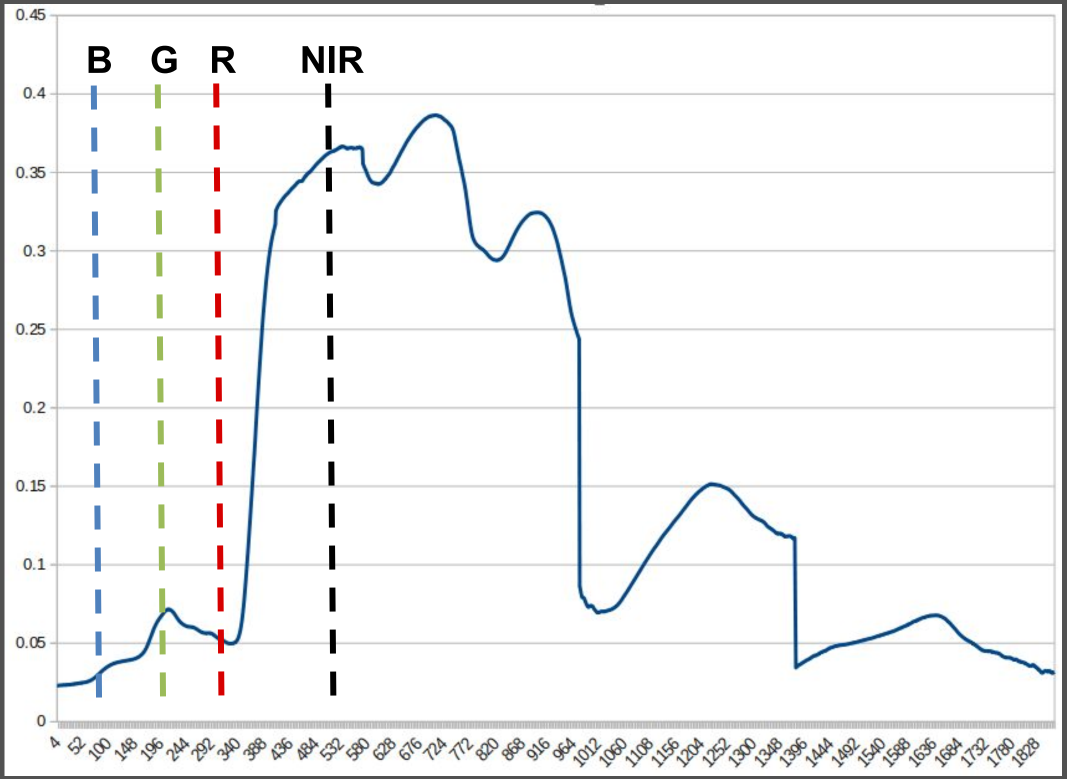
Software Visualization Channel	Satellite Band True Color	Satellite Band Standard False Color
Red	700	1100
Green	550	700
Blue	400	550





Band Ratios and Spectral Indices

- Based on the spectral profile of the target, some ratios can result in exaggerated values that simplify identifying the target. Eg NIR/Red for veg
- High NIR and low red results in large values for the ratios.
- Normalization to ensure values fall in a specific range helps generalize. Eg NDVI



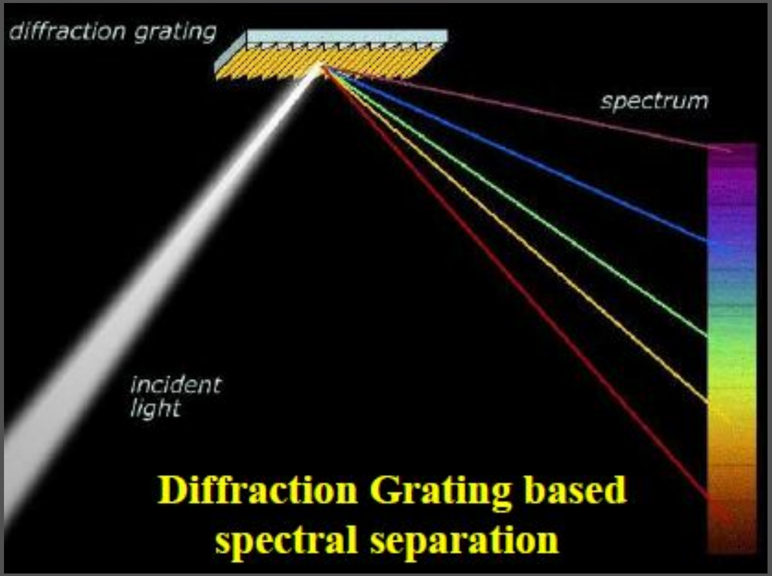
NDVI=(NIR - Red) / (NIR + Red)

For veg: High NIR, low Red. So values will be high and close to 1

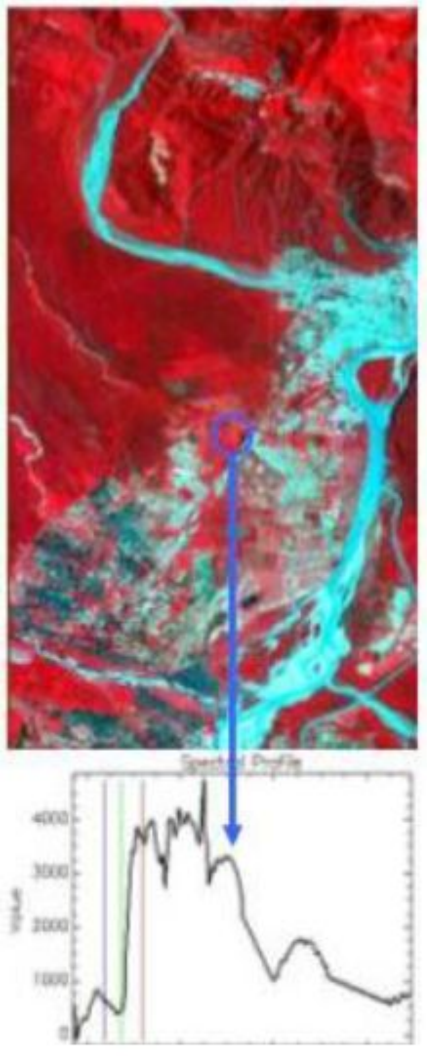
Urban: close to 0 as both NIR and Red is high

Water: Negative as NIR is lower than Red

Spectral Resolution



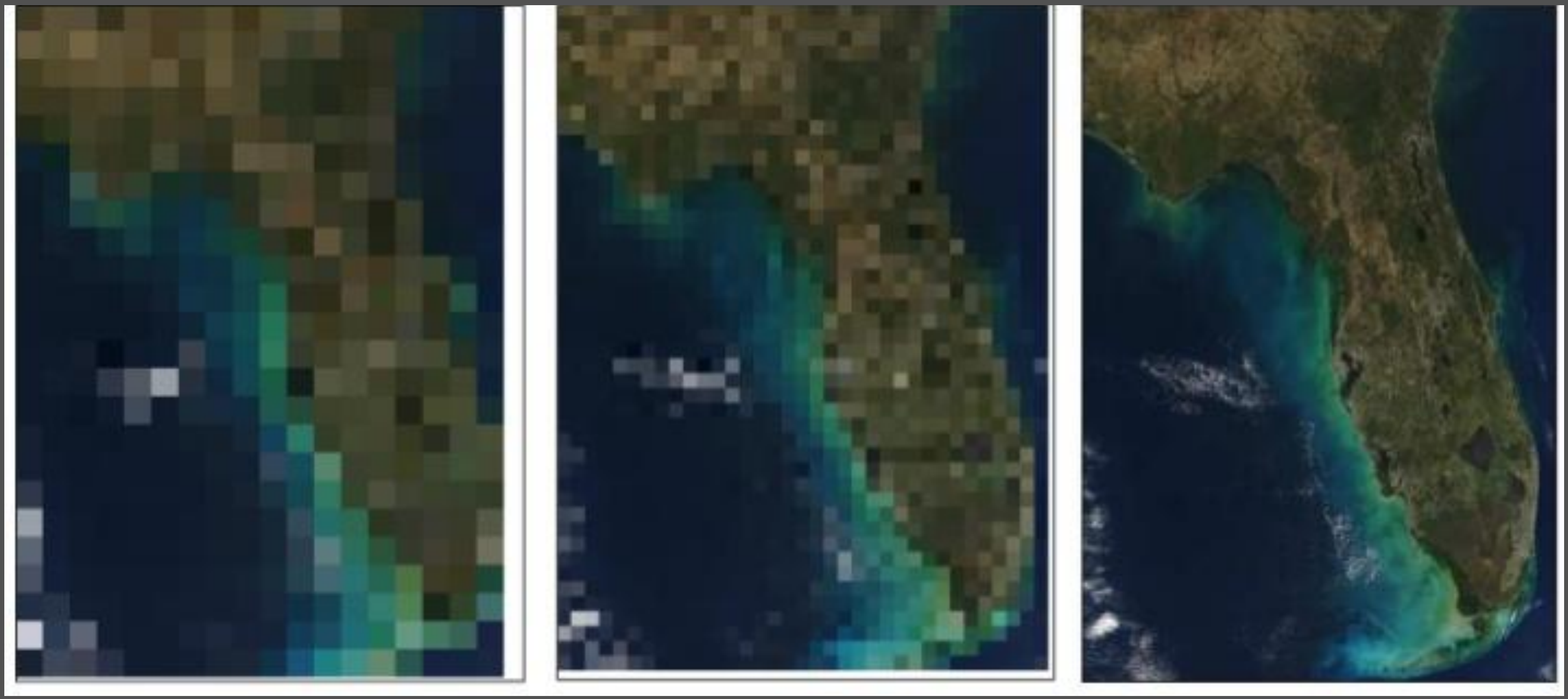
- Incident light is divided into the spectral components which are detected by the detector.
- Depending upon sampling and whether broad band or narrow bandwidth is taken, we have **multispectral** or **hyperspectral.**



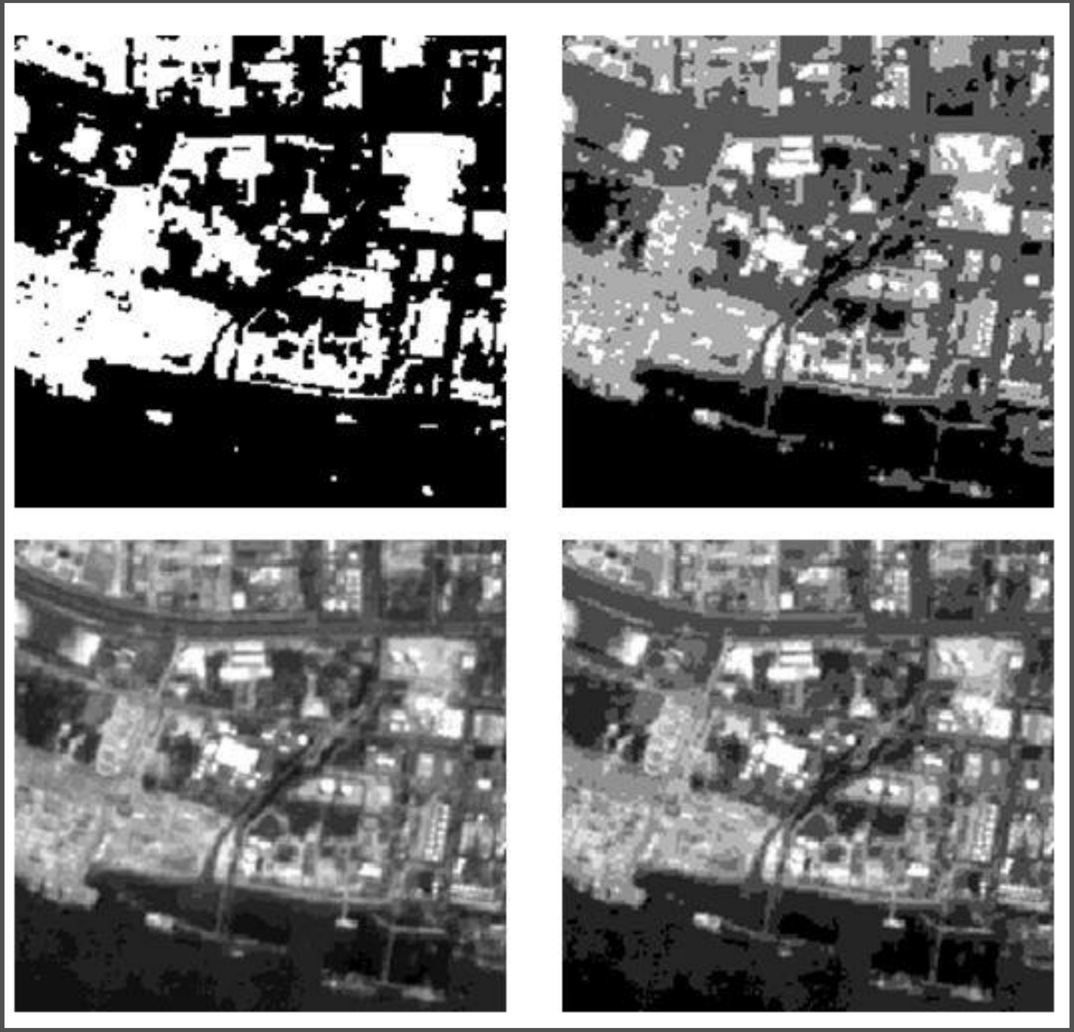
EO-1 Hyperion
Bands-140

Landsat-7 ETM+
Bands-6

Spatial Resolution



Changing Grey Levels: Radiometric Resolution



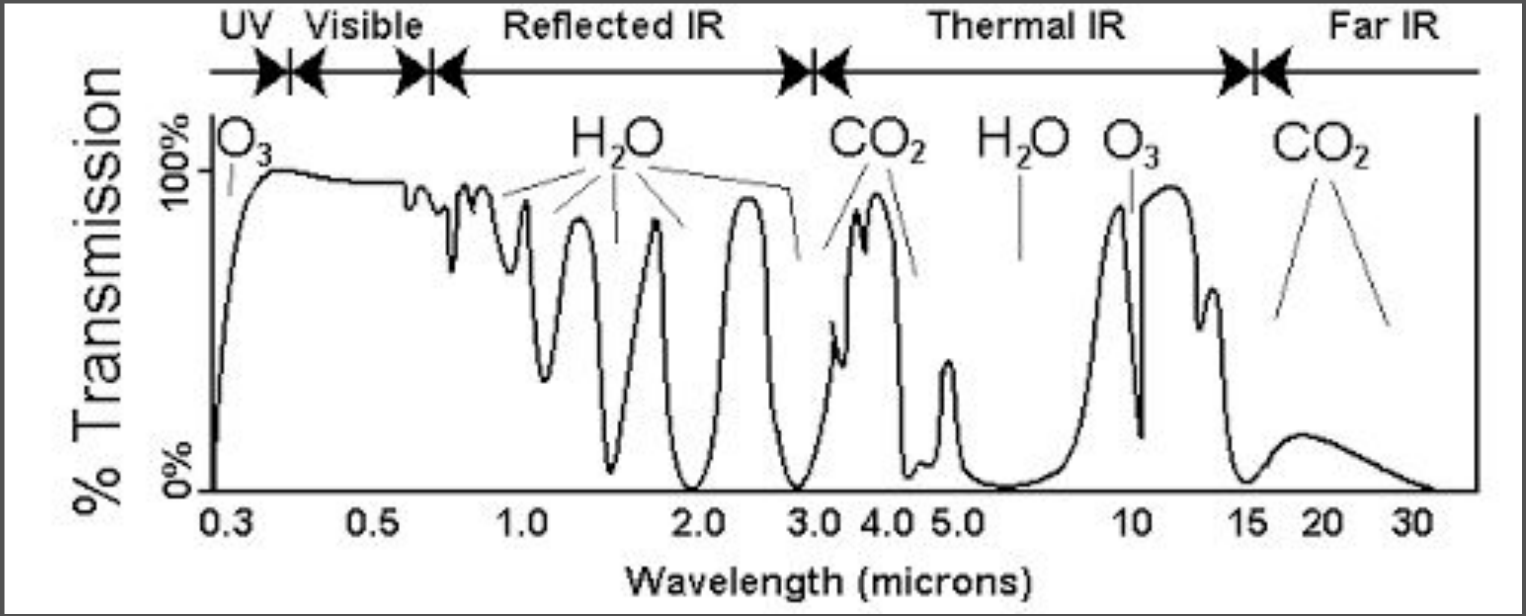
Errors in Remotely Sensed Data

- Geometric Error: Error in the form of distortions in shape and size. This is rectified using georeferencing and ground control points.
- Radiometric Error: Errors in the data values. Can be of various types as explained below.

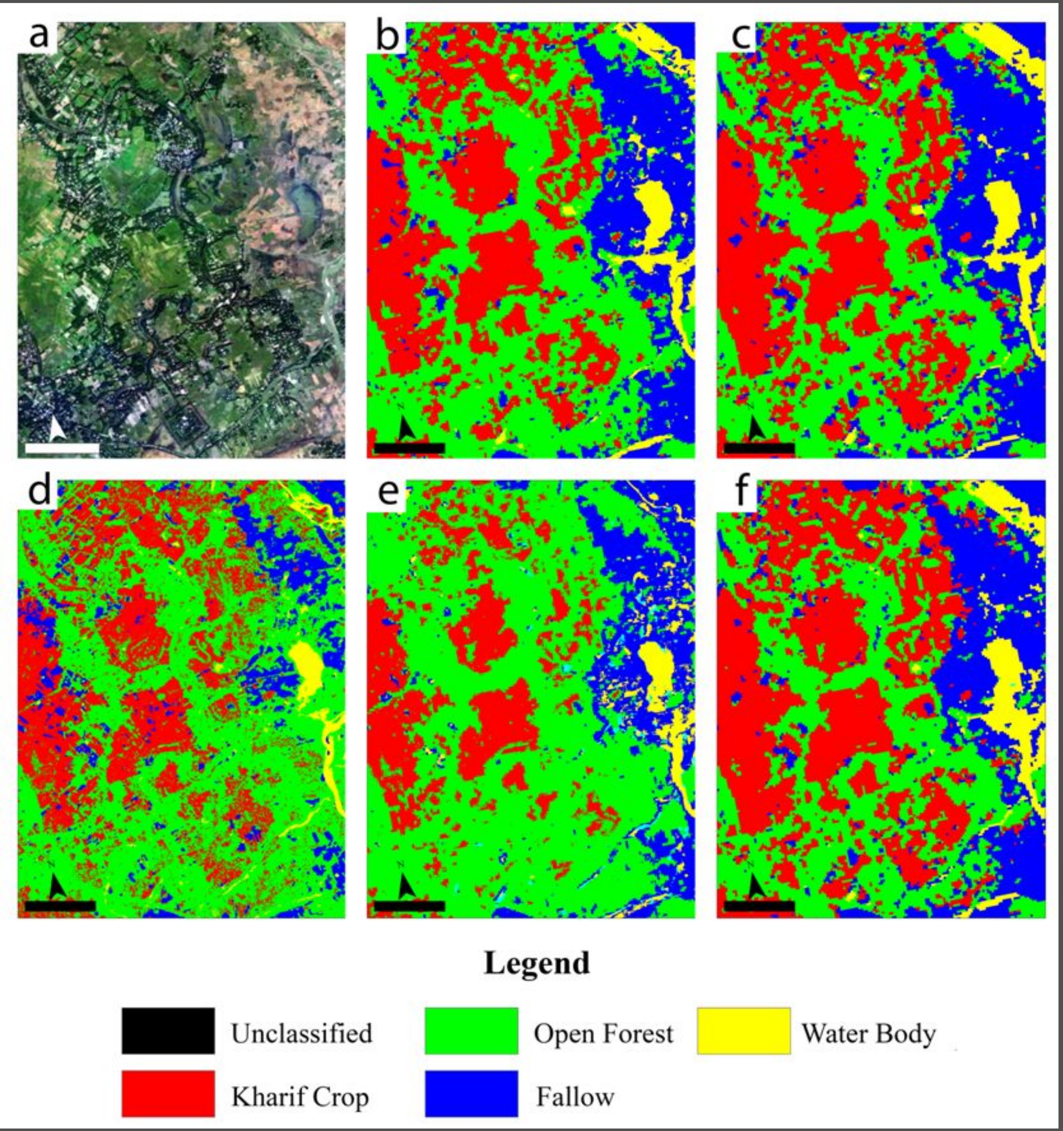
Question: What is the role of the atmosphere?

Do you think a Martian atmosphere can have the same characteristics?

Atmospheric Windows



Classification

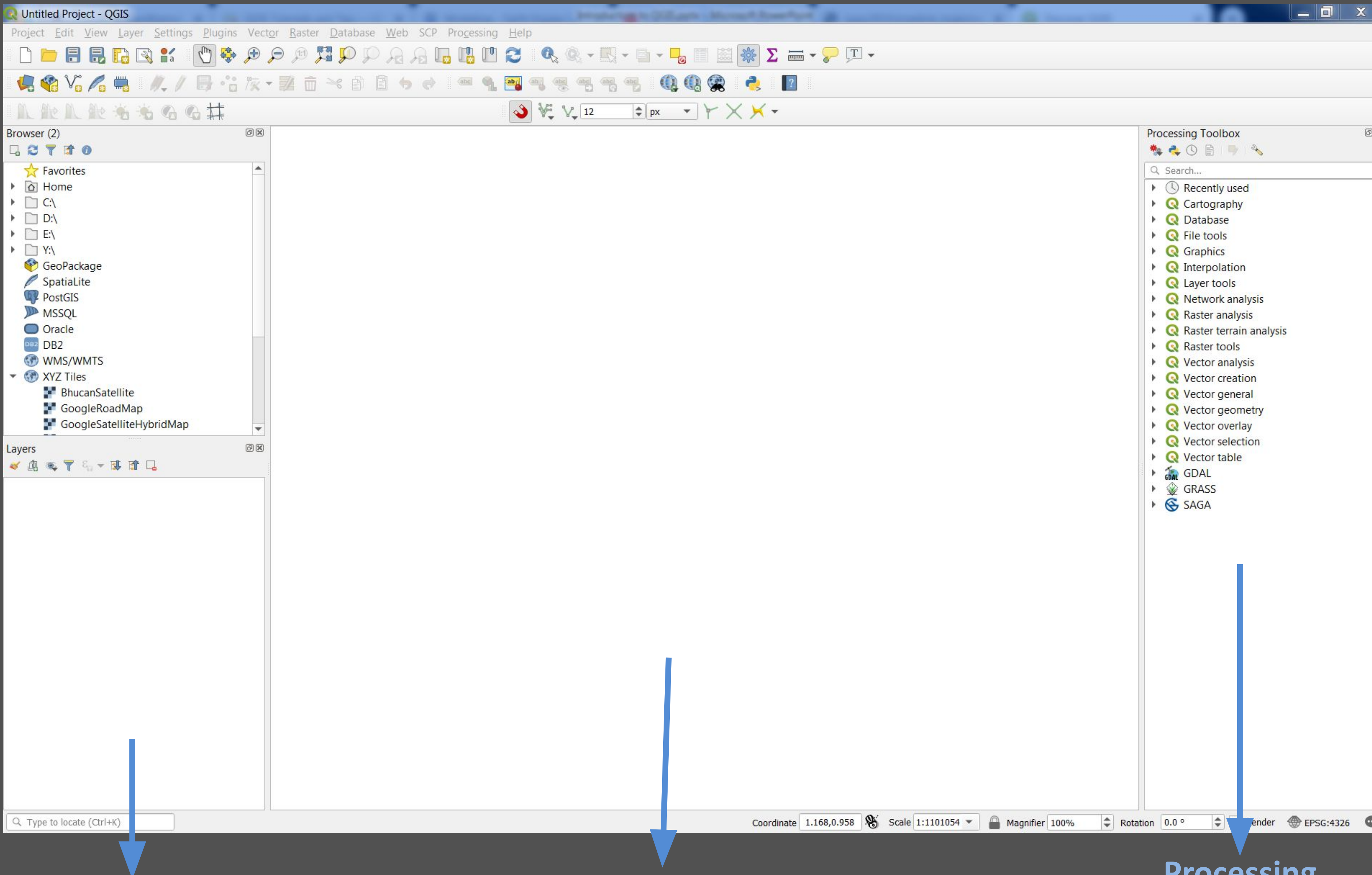


- There are two major types: Supervised and Unsupervised
- Essential idea is clustering based on similarity indices
- Different algorithms based on the measure of similarity

What software can handle geospatial data?

- ENVI
- ErDAS
- ArcGIS
- QGIS
- Google Earth Engine
- Other open source options through Python scripts and libraries

QGIS Window



Layer Panel

Map Window

Processing Toolbox

Why Spatial Analysis?

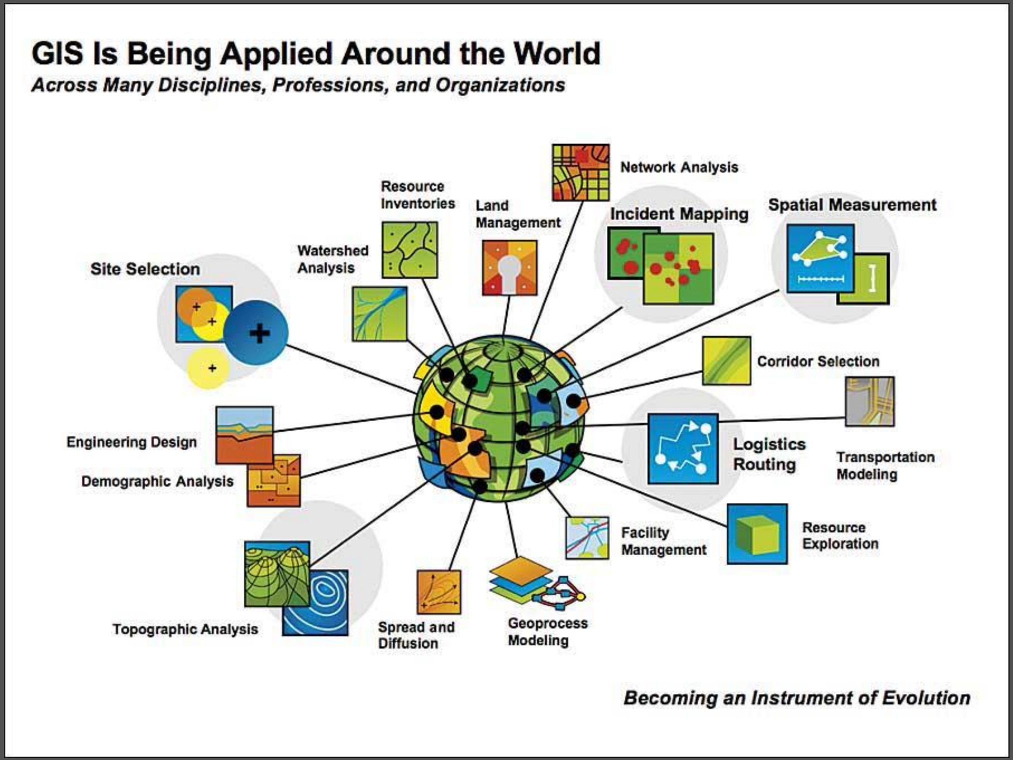
- To study and understand the real world processes by developing and applying manipulation and analysis criteria.
- To reveal new or previously unidentified information
- To visualize over the spatial domain via maps to aide planning and research.

GIS and it's Components: Hardware and Software

"GIS is a system comprising of computer hardware, software, geospatial data, and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information."

Some of the applications of GIS

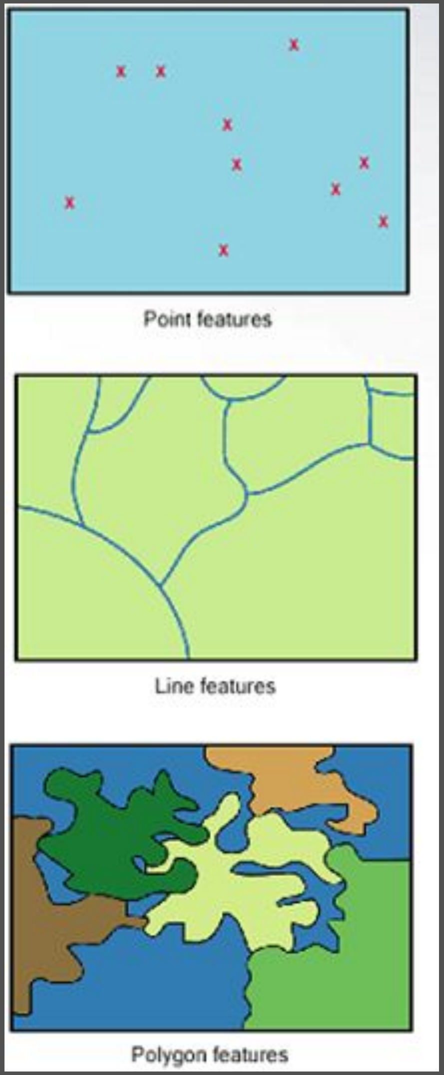
- Routing and traffic management
- Land-cover mapping
- Disaster risk reduction
- Site suitability analysis
- Medical: Checking the spread of diseases
- Site suitability analysis for urban and rural facilities

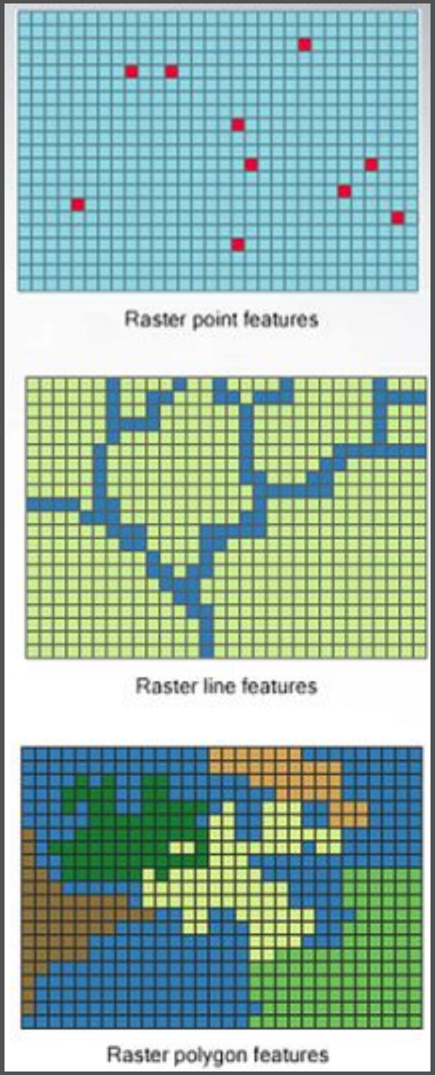


- Agricultural yield forecasting using agricultural and meteorological information

Vector and Raster Spatial Data model

Vector
In the form of discrete points, lines & polygons.





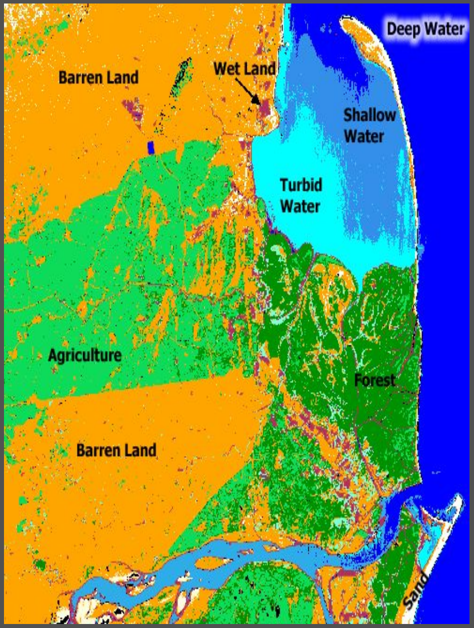
Raster
Continuous data given by pixels.

Vector

Raster

Raster data structure

In a raster model of geospatial data, the basic unit is a pixel. The pixel values can be whole numbers or floating point integers. The geographic coordinates are known.



In this thematic layer, the pixel values are whole numbers. One value represents infomation about what class it is

In this continuous layer, the pixel values denote the radiance or reflectance and will have a value for each band.

Exercise 1:

Download data from the folder basicData at:

https://github.com/RituAnilkumar/nnrms/

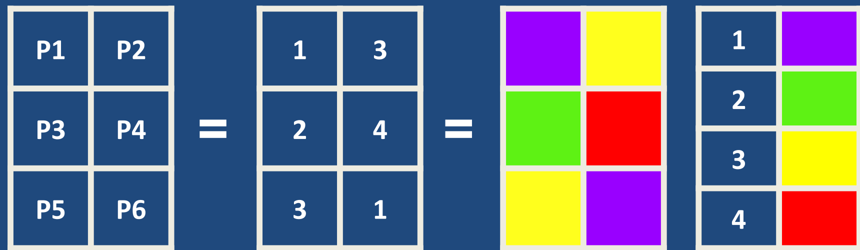
Exercise 2:

Opn and visualize raster images with:

1. Single band pseudocolor
2. Single band grayscale
3. Multiband true color
4. Multiband false color

Single Band Visualization

Single band pseudocolor representation



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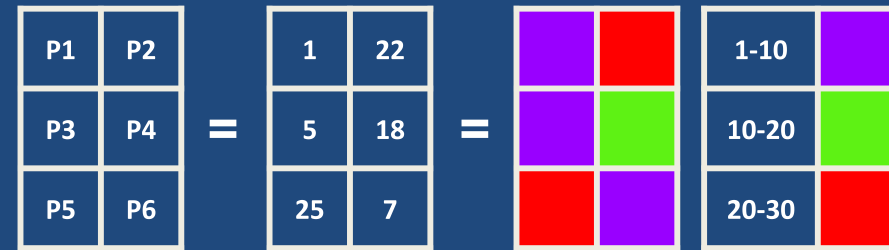
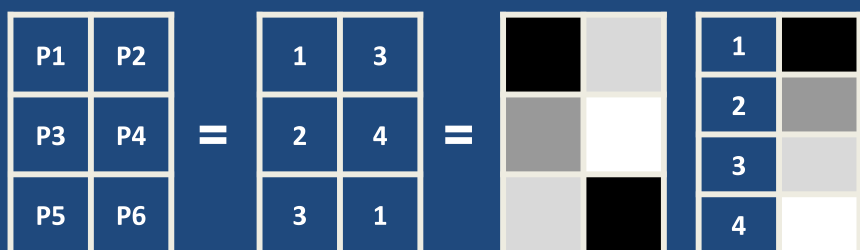
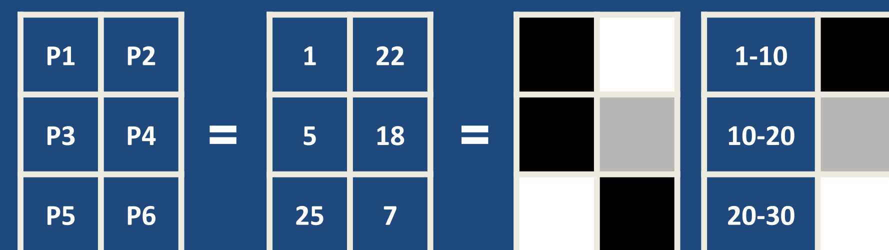


Case 2: Give a range of values one color

Single band grayscale representation



Case 1 : Give each unique value one color

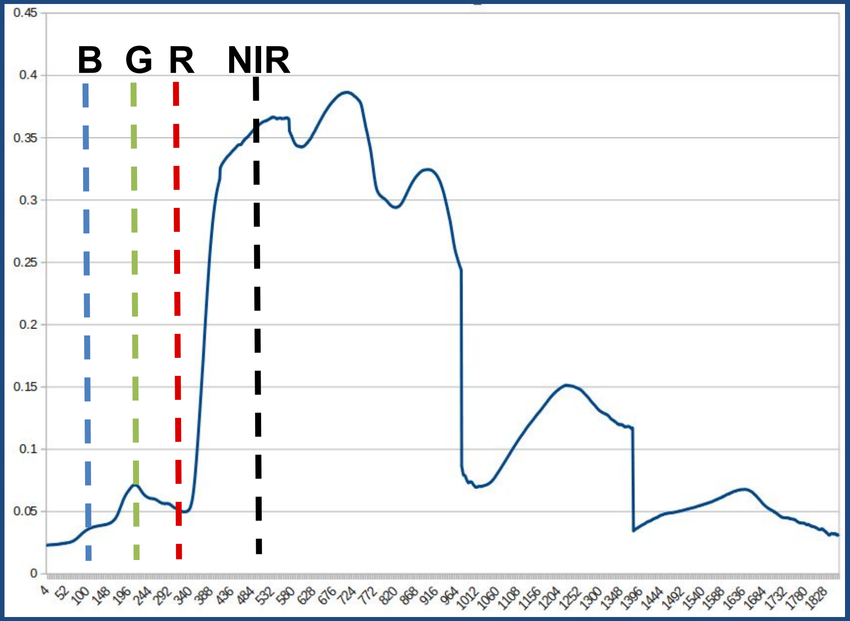


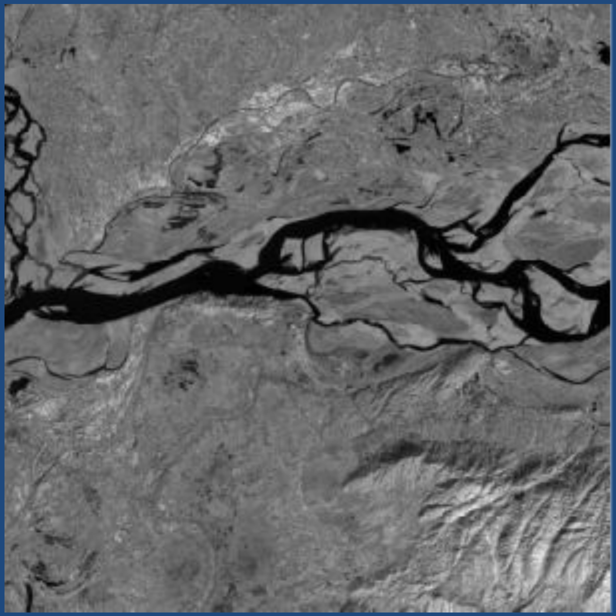
Case 2: Give a range of values one color

This can be thought as a special case of pseudocolor with the colorbar in shades of gray

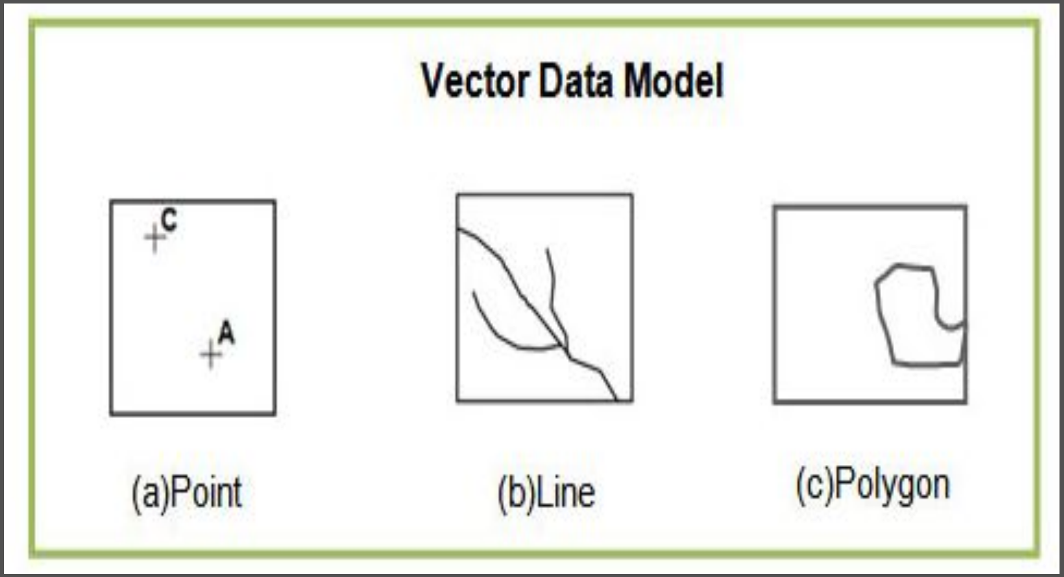
Color Composites

Software Visualization Channel	Satellite Band True Color	Satellite Band Standard False Color
Red	Red	NIR
Green	Green	Red
Blue	Blue	Green





Vector data structure



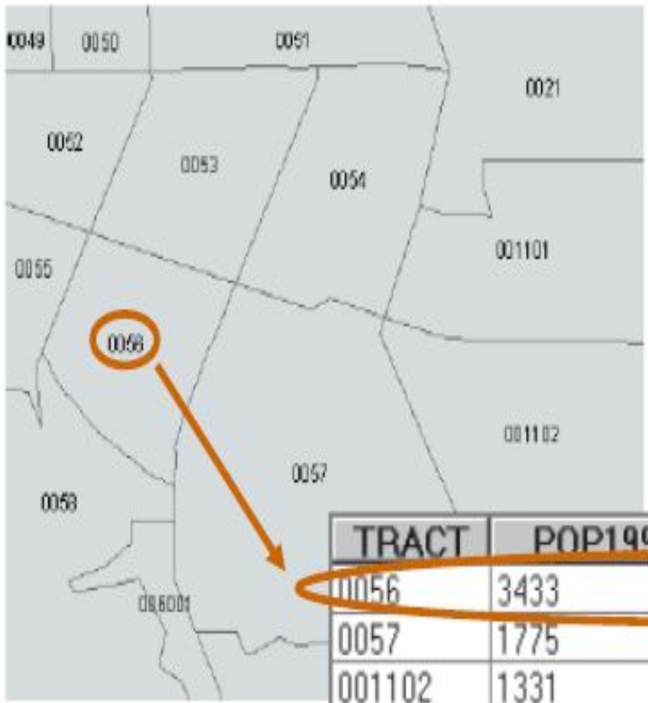
- Points are pairs of x, y coordinates
- Lines are sets of coordinates that define a shape
- Polygons are sets of coordinates defining boundaries that enclose areas

Raster and Vector Data model

Data Model	Advantages	Disadvantages
Raster	Simple data structure	Cell size determines the resolution at which the data is represented
	Compatible with remote sensing or scanned data	Requires a lot of storage space
	Spatial analysis is easier	Projection transformations are time consuming
	Simulation is easy because each unit has the same size and shape	Network linkages are difficult to establish
Vector	Data is represented at its original resolution and form without generalization	The location of each vertex is to be stored explicitly
	Require less storage space	Overlay based on criteria is difficult
	Editing is faster and convenient	Spatial analysis is cumbersome
	Network analysis is fast	Simulation is difficult because each unit has a different topological form
	Projection transformations are easier	

Vector data structure

- In vector data layers, the feature layer is linked to an attribute table.
- Every individual feature corresponds to one record (row) in the attribute table.



TRACT	POP1990	AREA	PERIMETER
0056	3433	5205890	9508.022
0057	1775	17330714	17017.602
001102	1331	13391034	15832.158
001202	3245	10129278	12933.502
001302	2839	8228478	11483.996

Exercise 3:

Open and Visualize vector files:

1. Point shapefile
2. Visualize the attribute table
3. Line shapefile
4. Polygon shapefile

Exercise 4:

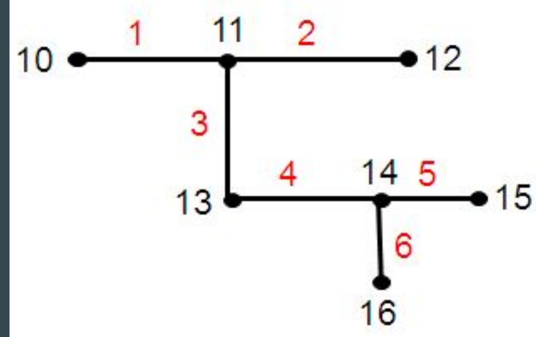
Create vector files by digitization:

Type of Topology

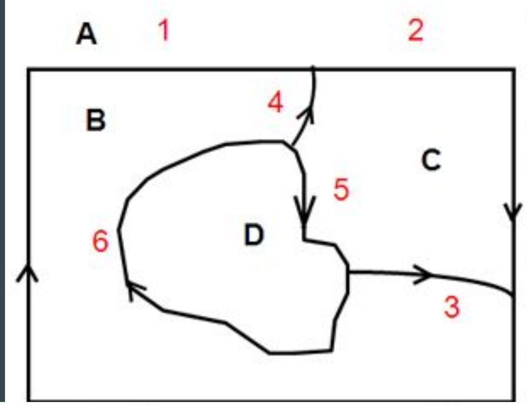
A topology is a mathematical procedure that describes how features are spatially related and ensures data quality of the spatial relationships.

Types of Topology

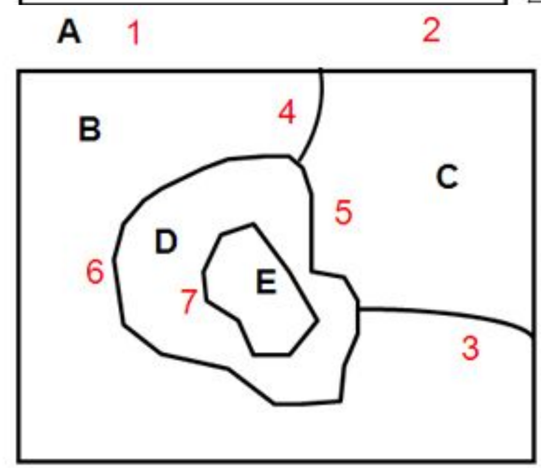
- Connectivity
- Adjacency
- Containment



Arc-Node List		
Arc	*From node*	*To node*
1	10	11
2	11	12
3	11	13
4	13	14
5	14	15
6	14	16



Left-Right Topology		
Arc	**Left Polygon**	**Right Polygon**
1	A	B
2	A	C
3	C	B
4	B	C
5	C	D
6	B	D



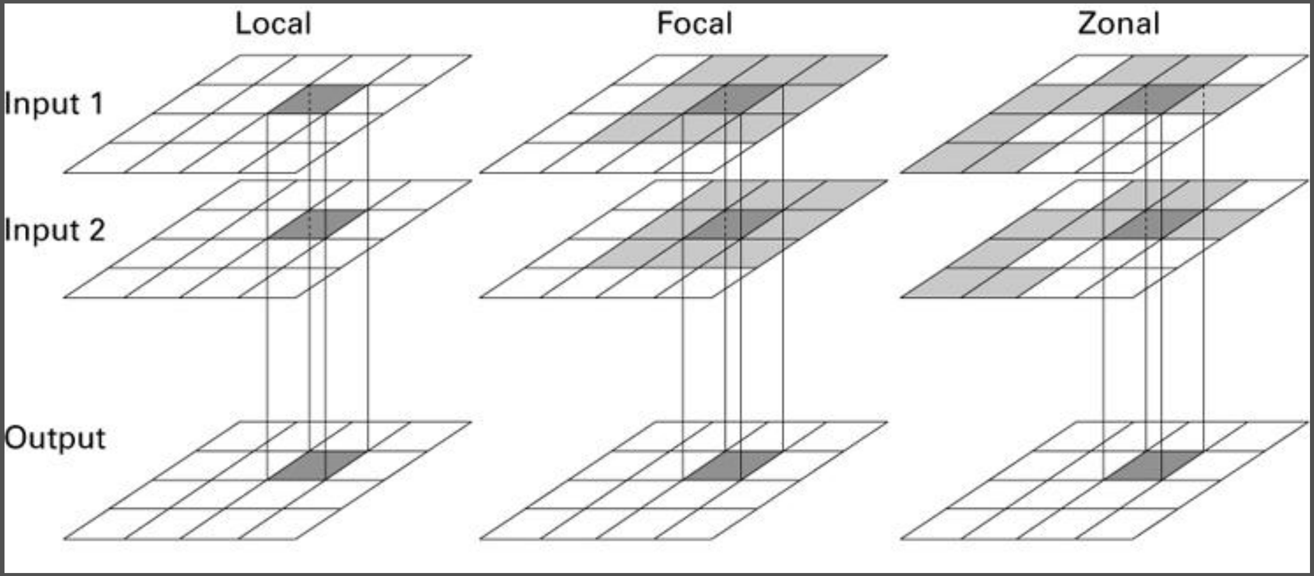
Polygon arc topology	
Polygon	**Arc List**
B	1, 4, 6, 3
C	2, 3, 5, 4
D	5, 6, 0, 7
E	7

GIS Operations

Raster Operations

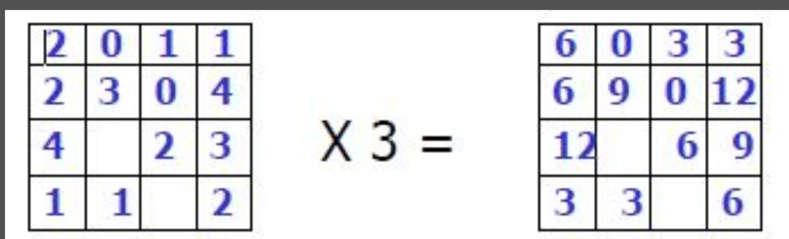
Raster operations can be of four types depending upon the operand.

1. Local Operations or point operations
2. Focal Operations or neighbourhood operations
3. Zonal Operations or area operations
4. Global Operations or map operations

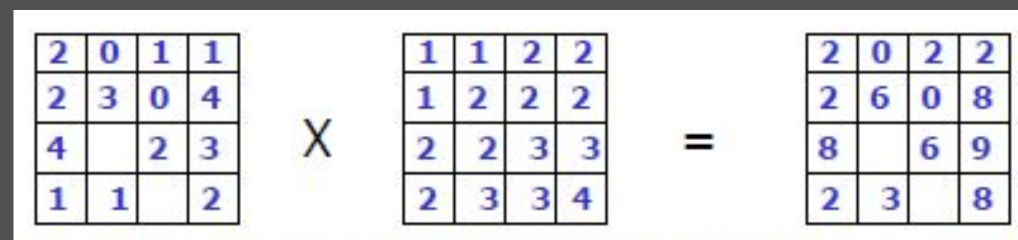


Raster Local Operations

- Independent of any other pixel.
- Element wise operations occur.
- New map is generated on a pixel by pixel basis.
- Eg: Arithmetic, relational and logical operations of raster.



Here, each element is multiplied by the scalar 3.



Here, each element of Raster 1 is multiplied by the corresponding element in Raster 2.

Raster Focal Operations

- The result is dependent on neighbouring pixels.
- For eg: mean operation where a kernel is applied on a raster.

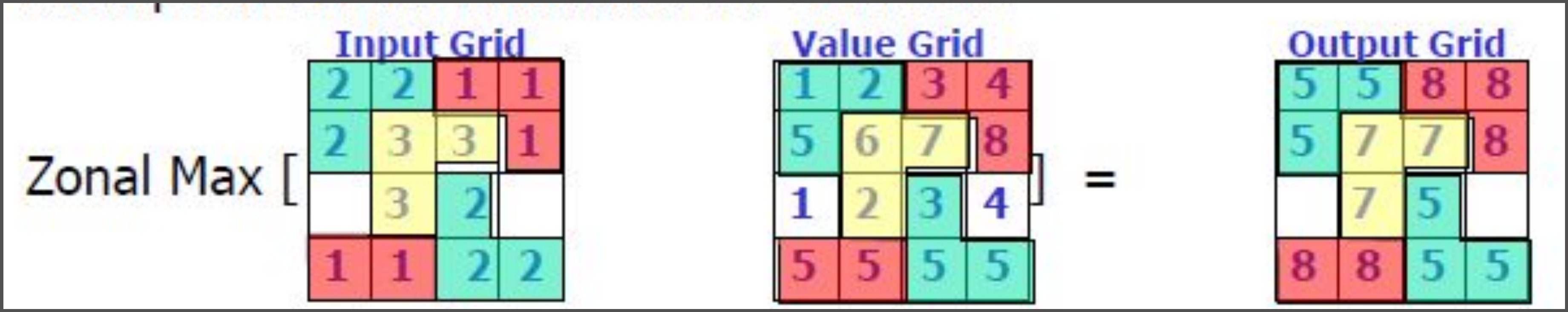
1	1	1	0	2
2	1	2	3	1
0	0	4	1	1
0	3	2	2	1
1	4	3	2	0

$\rightarrow$ **2**

Consider the above case where a raster is applied with a mean operation using a 3X3 kernel (red). The central value is substituted with the mean of neighbouring 9 pixels given by (1+2+3+1+4+2+2+3+0)/9=18/9=2. This is iterated for all the pixels in the raster.

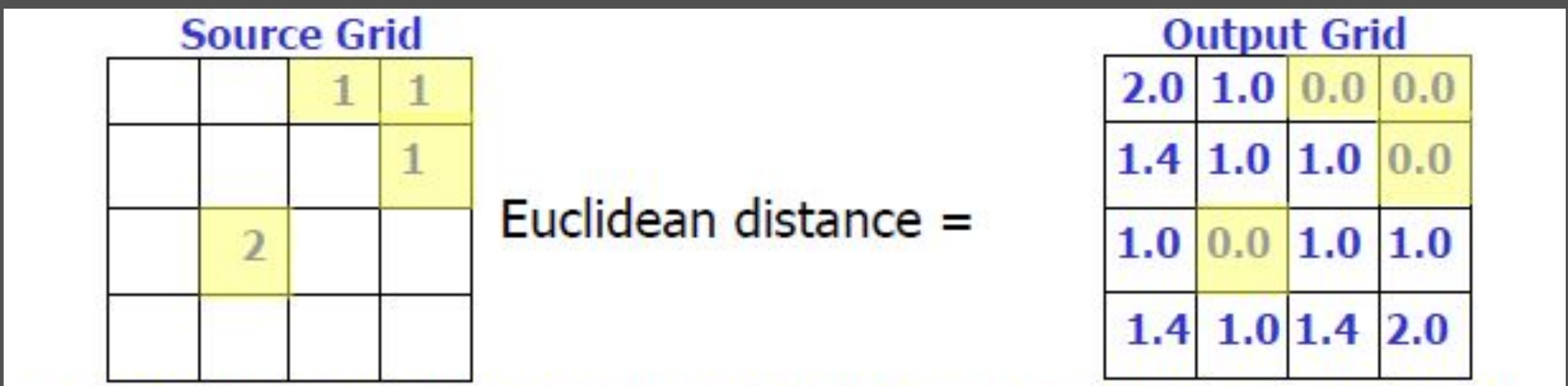
Zonal Functions

- We have two inputs for suchfunctions, the zone and the raster. Statistics of any operation performed on the raster is applied to all pixels falling within the zone.
- Consider the following example. The input grid is the zone. There are 3 zones: 1,2 and 3.
- We perform a zonal maximum which checks for the maximum pixel value in each zone and replaces the value of each pixel with that maximum value.
- This is useful in



Global Functions

- Output value of each cell is a function of the entire grid. For example, the total population is give by the population map total.
- Another standard example is the Euclidean distance
- Distance between non-adjacent cells can be computed according to their row and column addresses.
- For any other cell, the output value is the distance from its nearest source cell. Below, the source cells are given in yellow.



A Euclidean distance function computes the distance from the nearest source cell

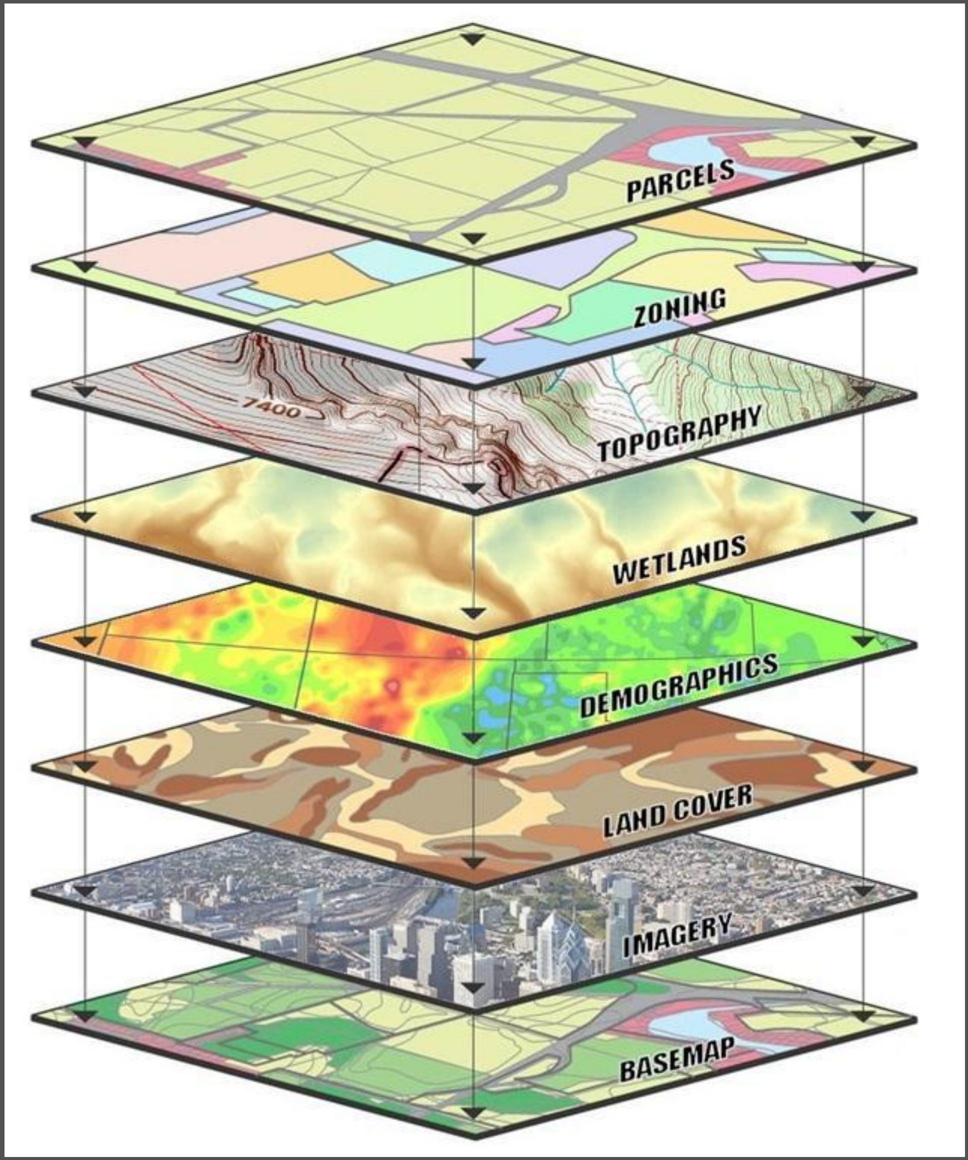
GIS Overlay Analysis

Raster Overlays

Raster overlay analysis allows us to perform an integrated analysis of multiple datasets and is particularly useful for site suitability studies, habitat analysis etc.

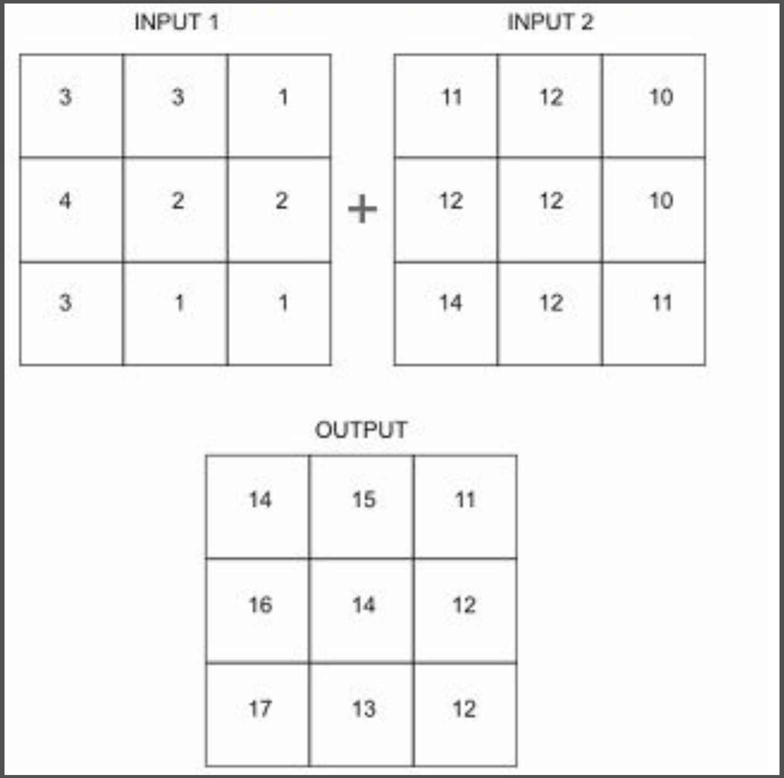
Types of raster overlays:

- Arithmetic
- Conditional
- Logical



Arithmetic Overlay

- Addition, subtraction, multiplication, division, modulo
- sin, cos, tan, asin, acos, atan.
- Eg Raster2 := Raster1 * 5
- Similar to elementwise matrix operations



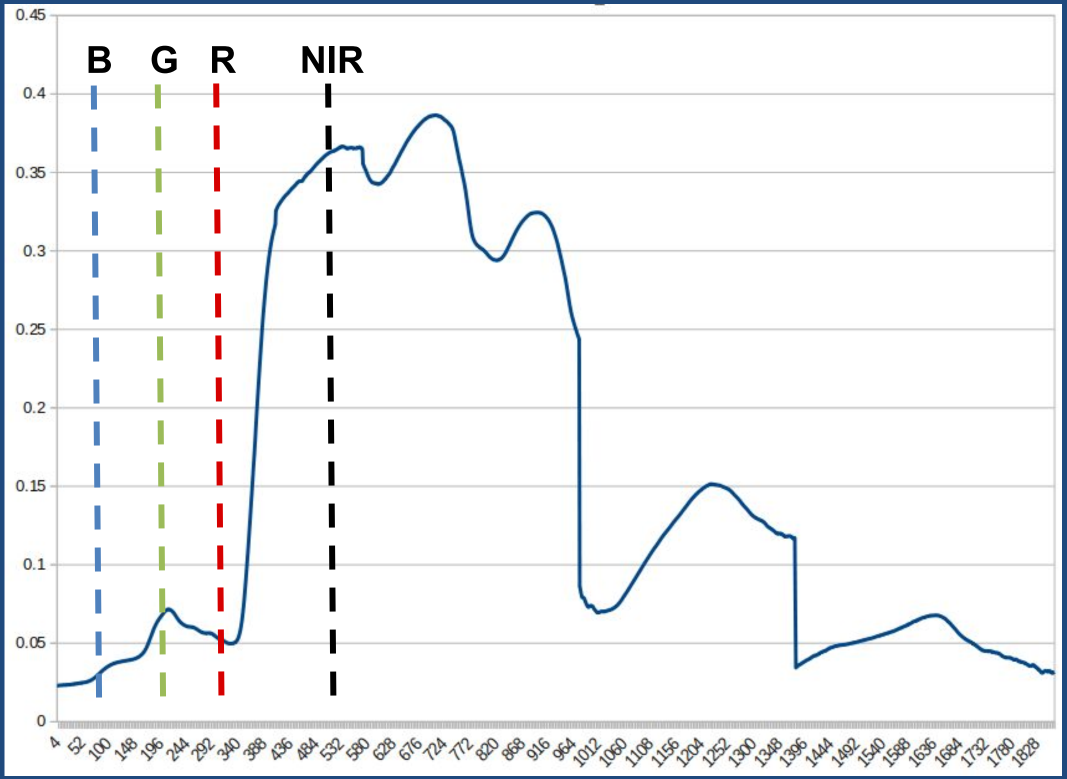
$$\mathbf{a} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix} \qquad \mathbf{5a} = \begin{pmatrix} 5 & 10 & 15 \\ 20 & 25 & 30 \\ 35 & 40 & 45 \end{pmatrix}$$

Exercise 5:

Perform raster arithmetic operations to generate
$NDVI = (NIR-RED)/(NIR+RED)$

Band Ratios and Spectral Indices

- Based on the spectral profile of the target, some ratios can result in exaggerated values that simplify identifying the target. Eg NIR/Red for veg
- High NIR and low red results in large values for the ratios.
- Normalization to ensure values fall in a specific range helps generalize. Eg NDVI



NDVI=(NIR - Red) / (NIR + Red)

For veg: High NIR, low Red. So values will be high and close to 1

Urban: close to 0 as both NIR and Red is high

Water: Negative as NIR is lower than Red

Relational Overlay

- These check for the condition.
- Equal to ==
- Greater than >
- Less than <
- Greater than or equal to >=
- Less than or equal to <=
- Not equal to !

This provides Boolean Output of 1 for true and 0 for false.

Exercise 6:

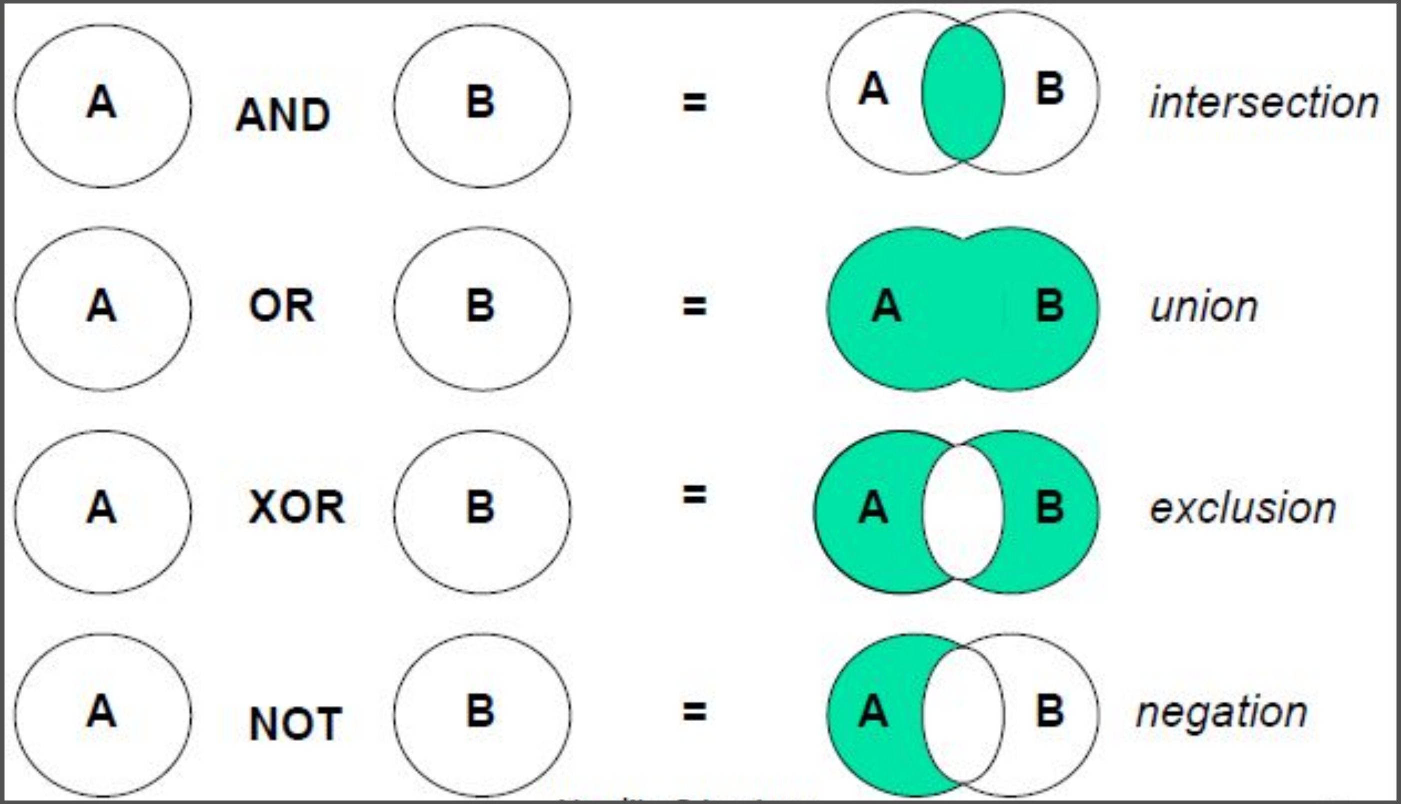
Check NDVI<0 values

Check NDVI>0.3 values

Logical Overlays

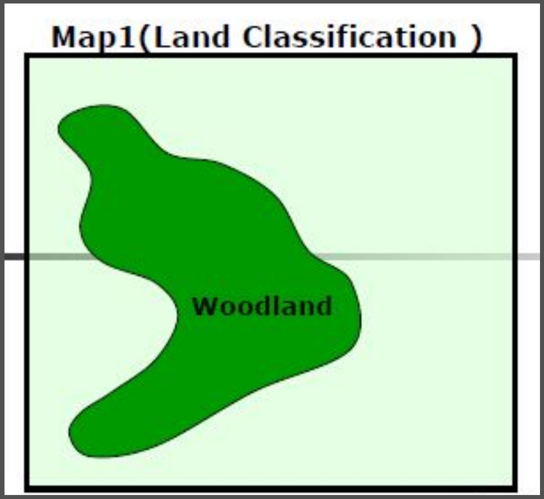
Logical conditions are specified with

- Operands(Data Elements)
- Operators (Relationships among data elements
- The cell values of output is either true or false

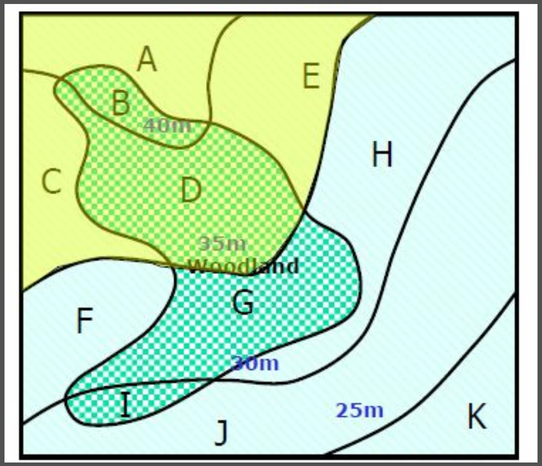


Types of Logical Operators

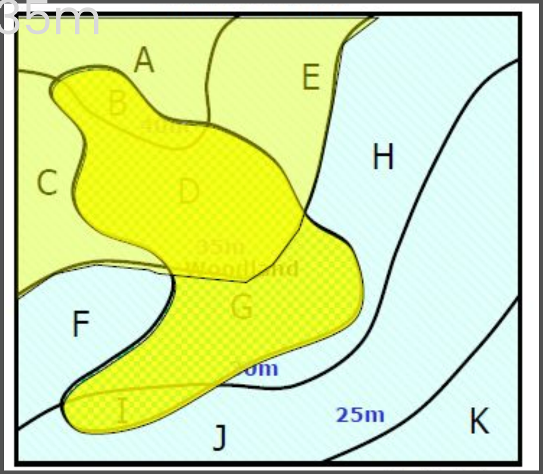
Examples of Logical Operation

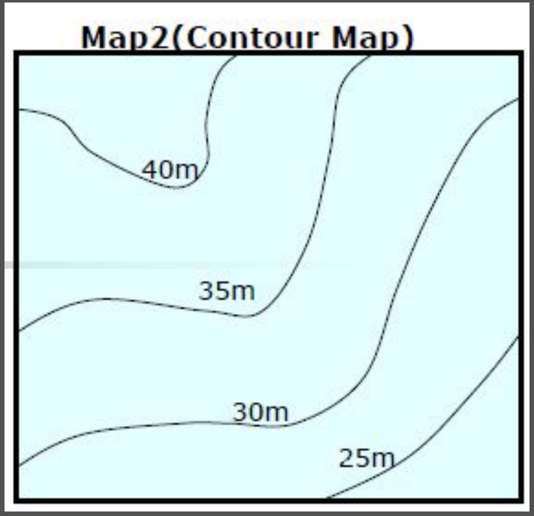


Land over 35 meters

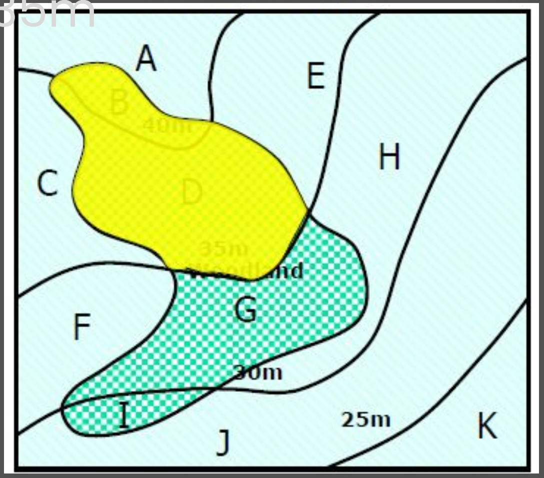


Woodland OR Over 35m

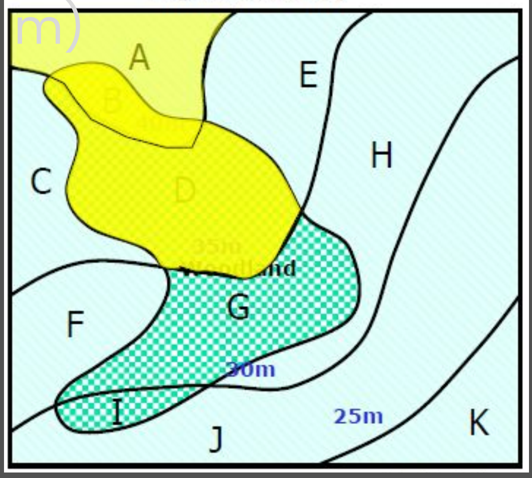




Woodland AND over 35m



(Woodland AND Over 35 m) OR (Over 40 m)



Exercise 7:

Apply NDVI<0 values

OR

NDVI>0.3 values

Topological Overlays for feature extraction

PRIMARY OPERATION RESULT

CLIP

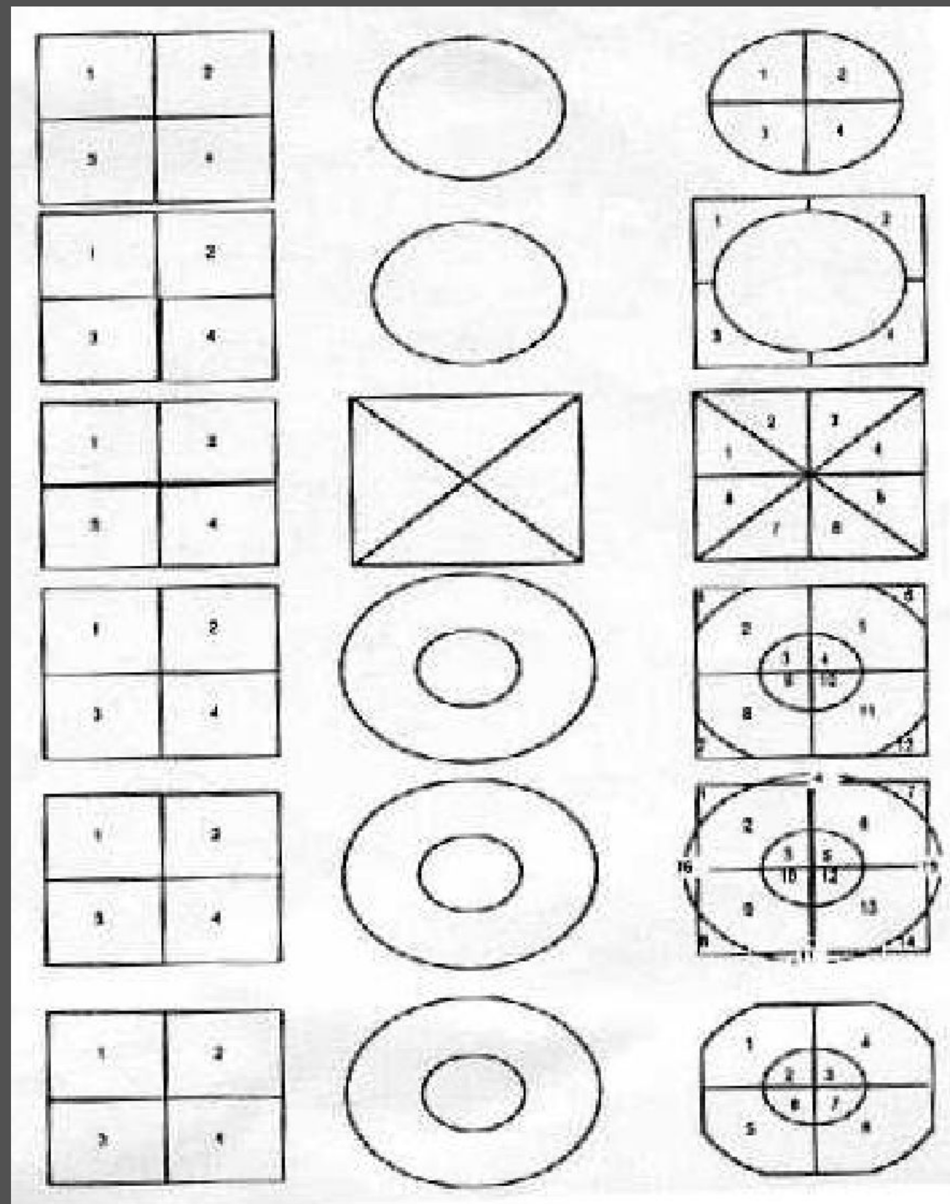
ERASE

SPLIT

IDENTITY

UNION

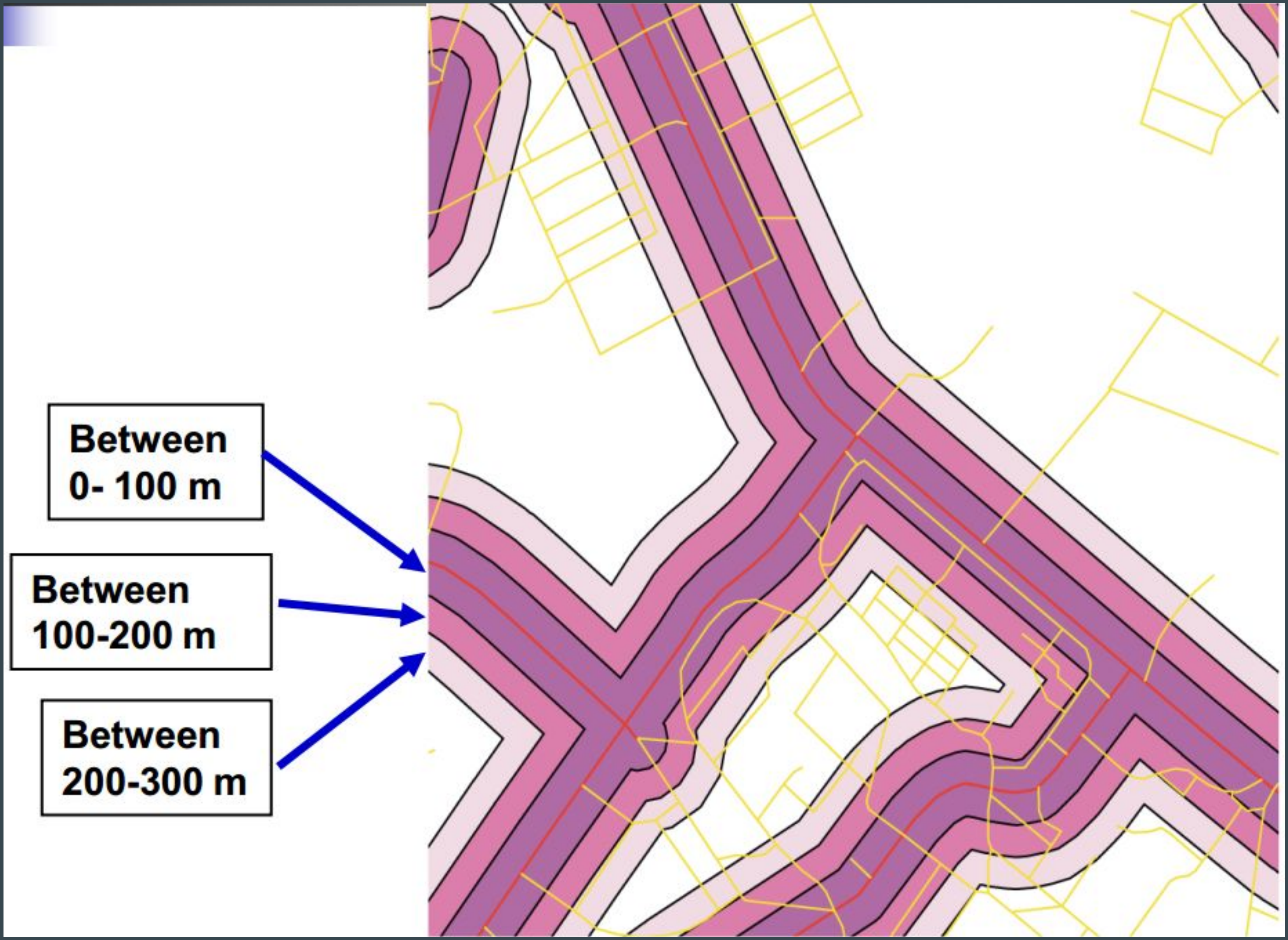
INTERSECT



Exercise 8:

Clip raster using polygon

Neighborhood Operations: Multiple Ring Buffer



Exercise 9:

Apply a buffer to a shapefile

Applications

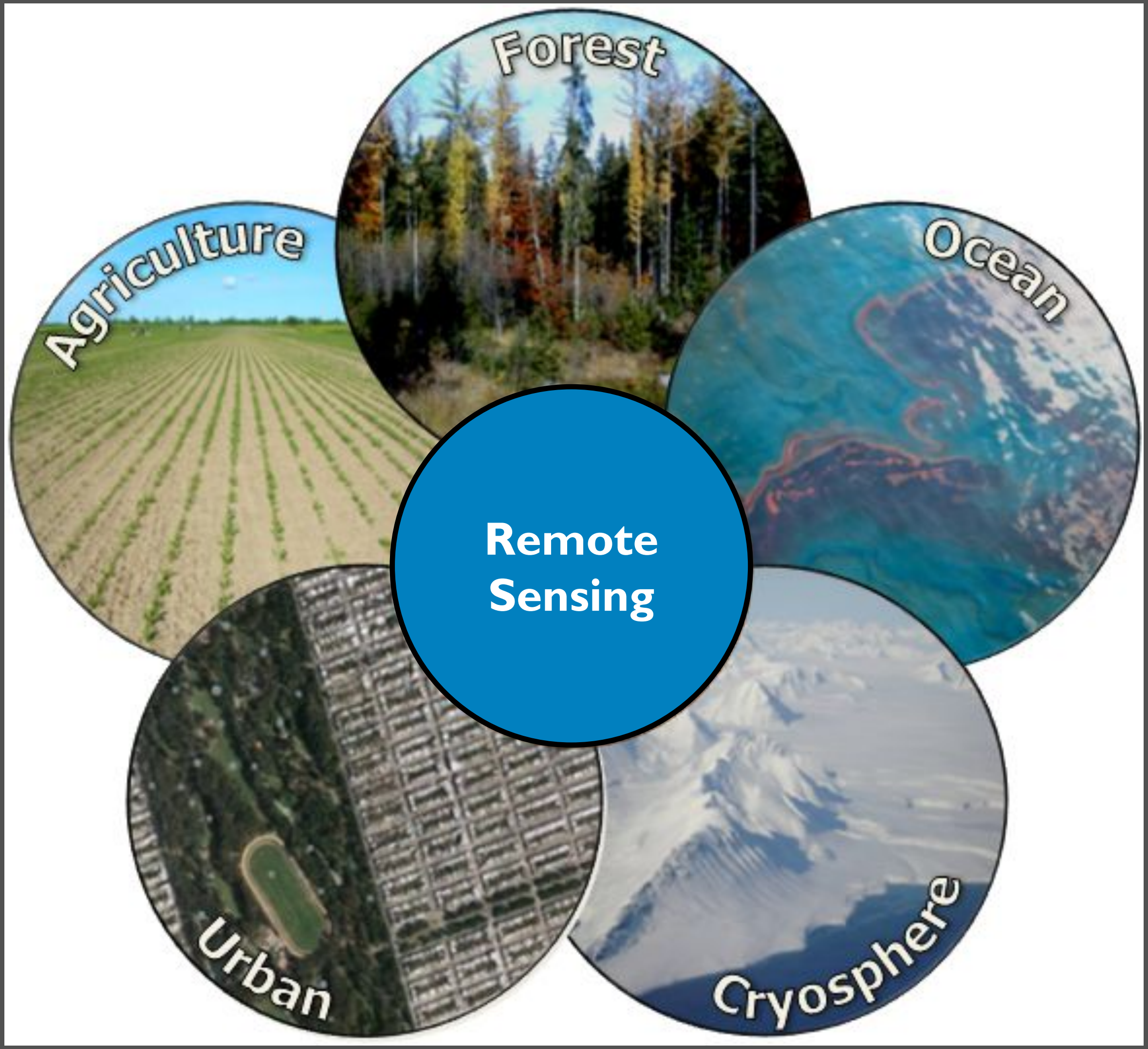
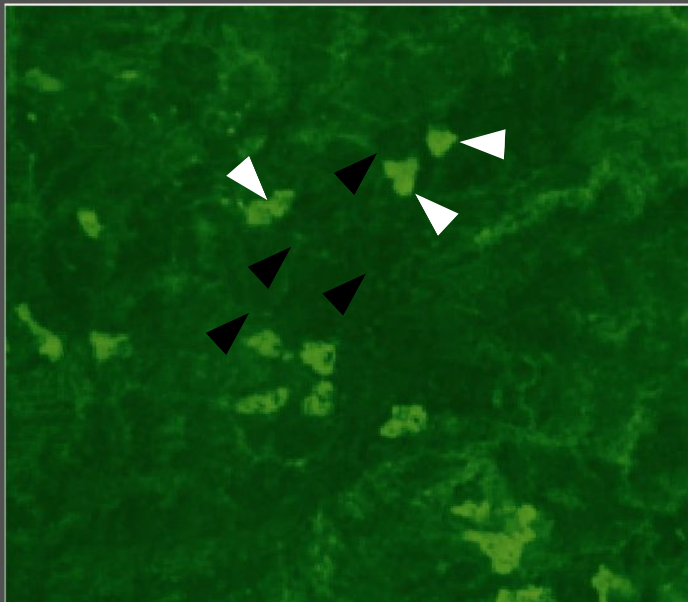
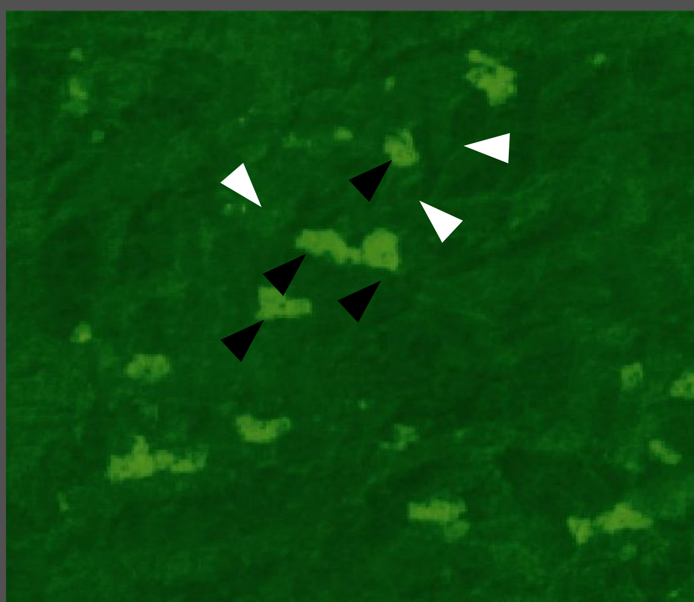


Image source: ESA PolSAR

Forest Cover Changes, Species Identification



2019 February



2020 February

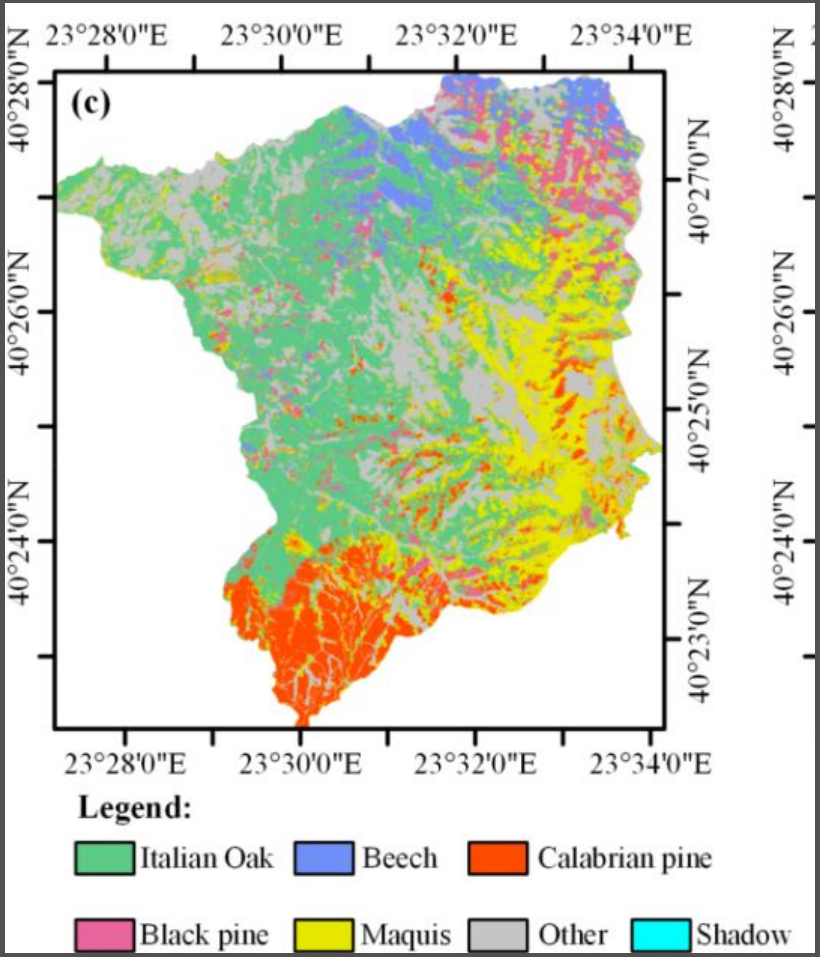


Image Source: Stavrakoudis et al, 2014

Forest inventory and biodiversity studies can be performed by species identification due to the unique spectrum of the different species.

Crop Monitoring

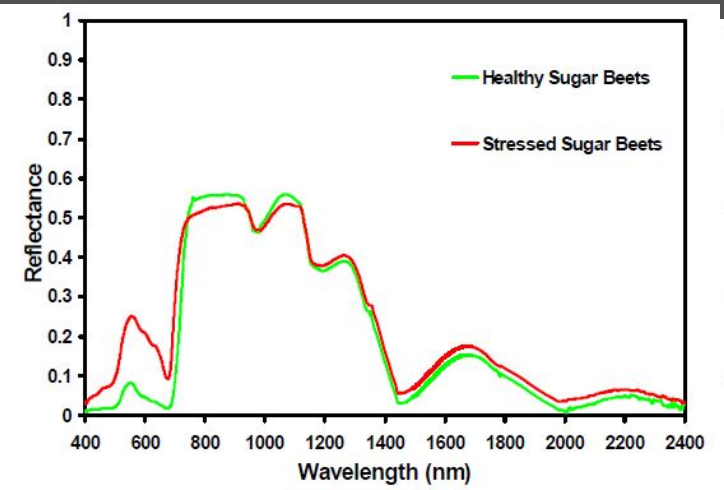
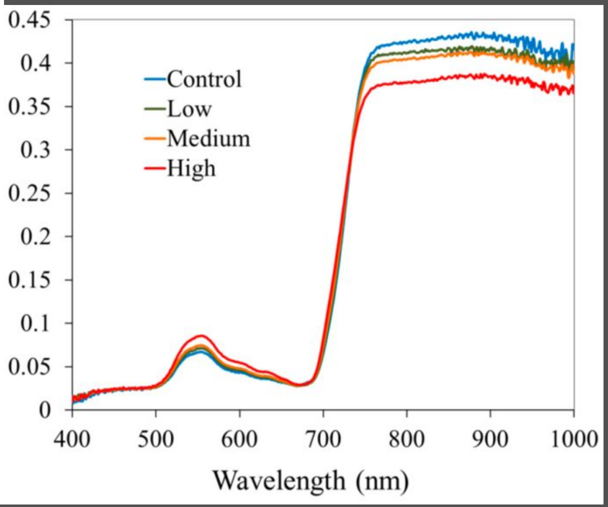
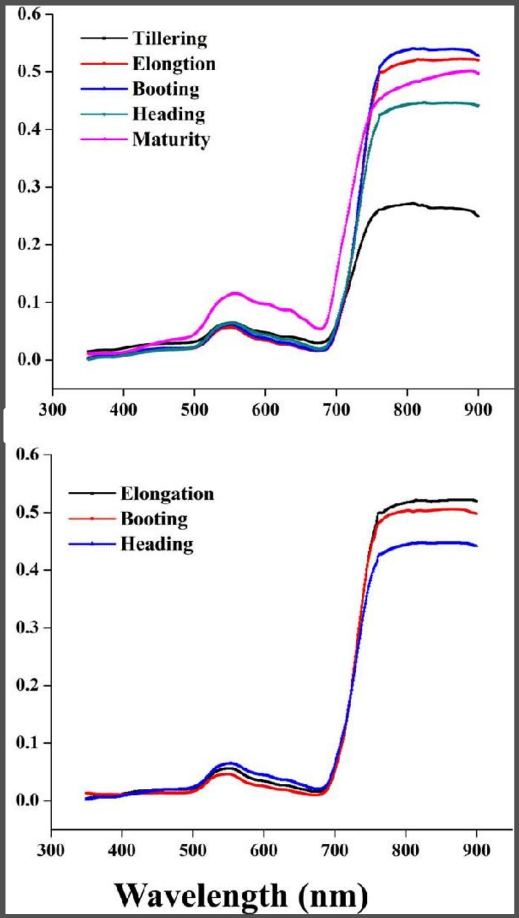


Image Source: North Dakota State University. Variation in spectrum between stressed and healthy crop visible.

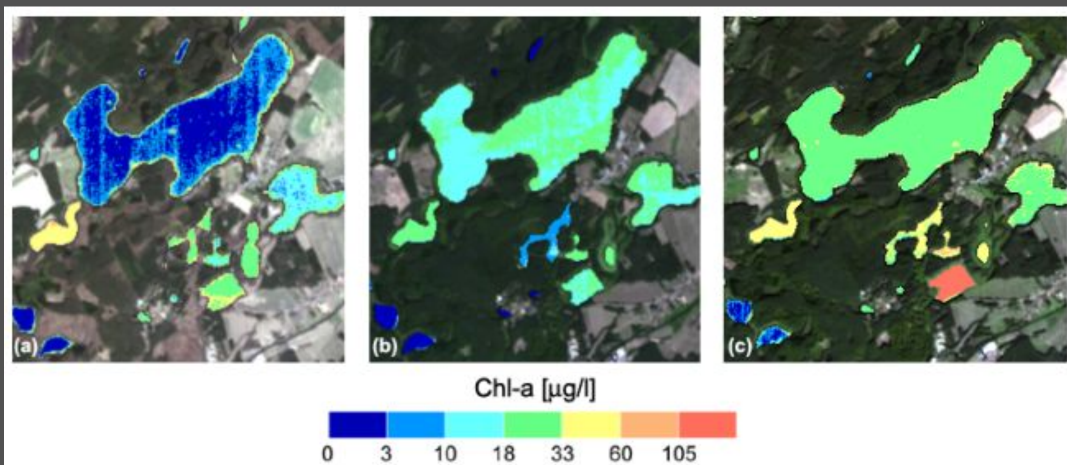


Bandaru et al, 2016: Variation of Rice Spectrum due to differing levels of arsenic contamination.

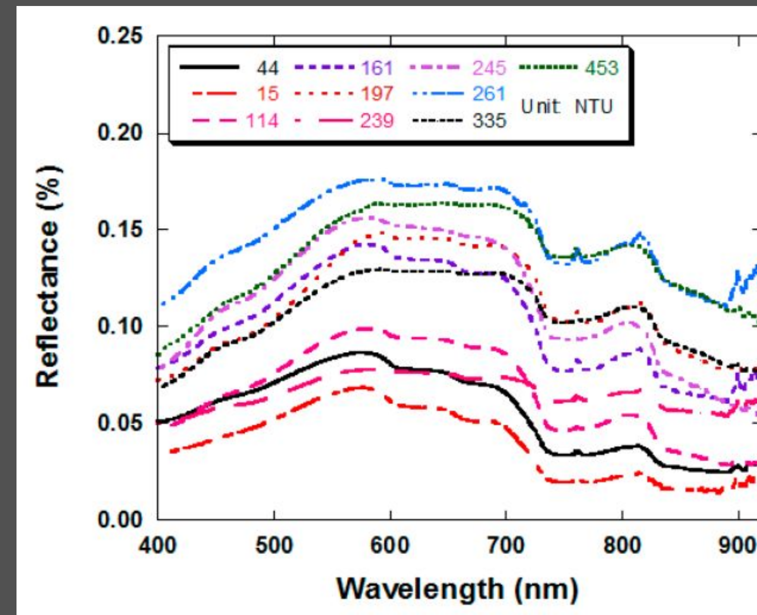


Din et al, 2017: Variation of Spectrum over different growth stages

Water Quality Monitoring

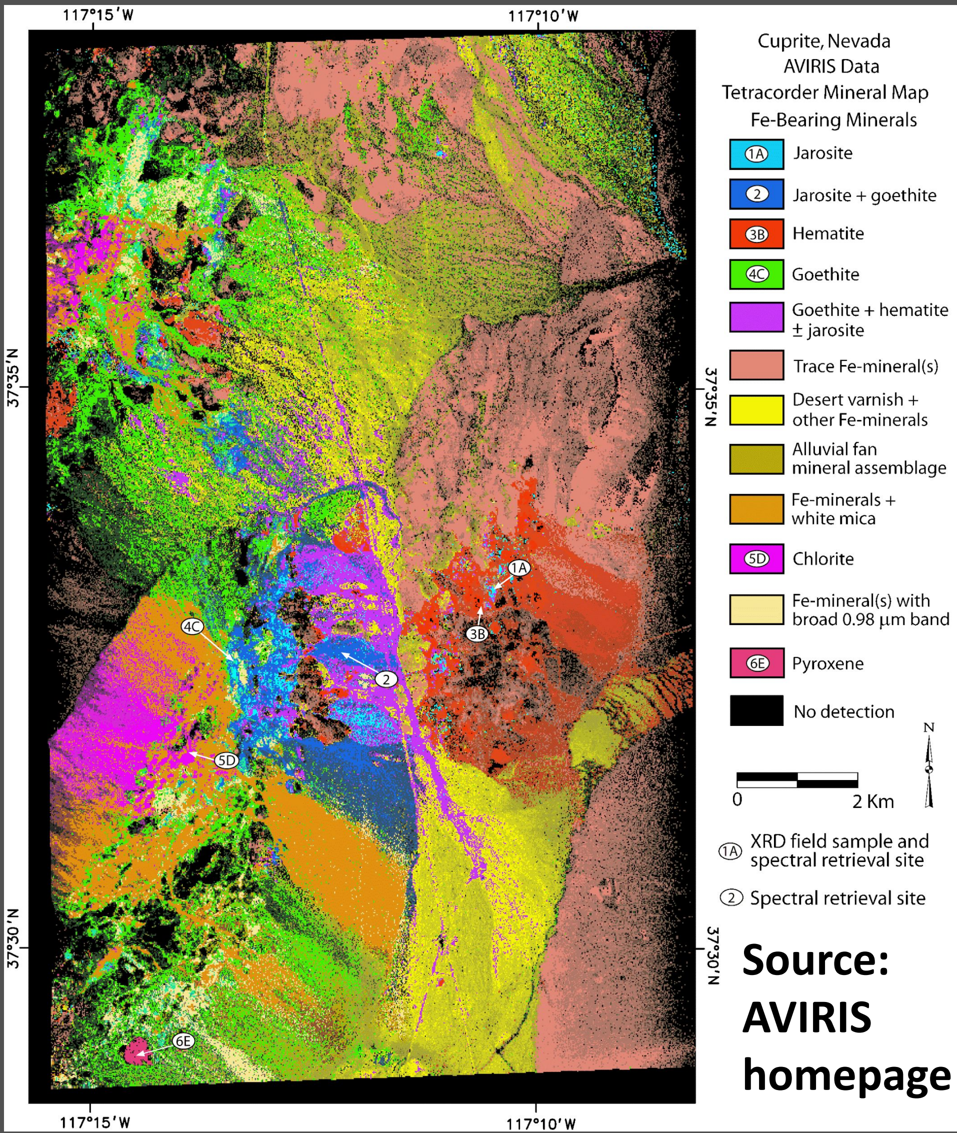


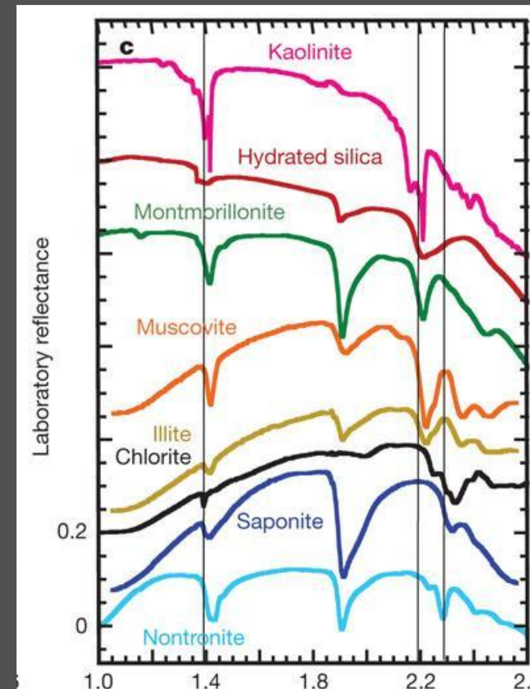
Source: Mannheim et al, 2004 where chlorophyll a quantity in the water body has been established based on CHRIS PROBA data. A seasonal variation is depicted above depicting temporal monitoring of the quality.



Source: Wu et al, 2014. The turbidity in the water body has been studied and measured.

Mineral Mapping





Source: Ehlmann et al, 2009

Mineral mapping in the Nevada region for Cuprite deposits is displayed. Similar mapping can be done in Jaintia, Digboi etc

Extra-terrestrial Mineral Mapping

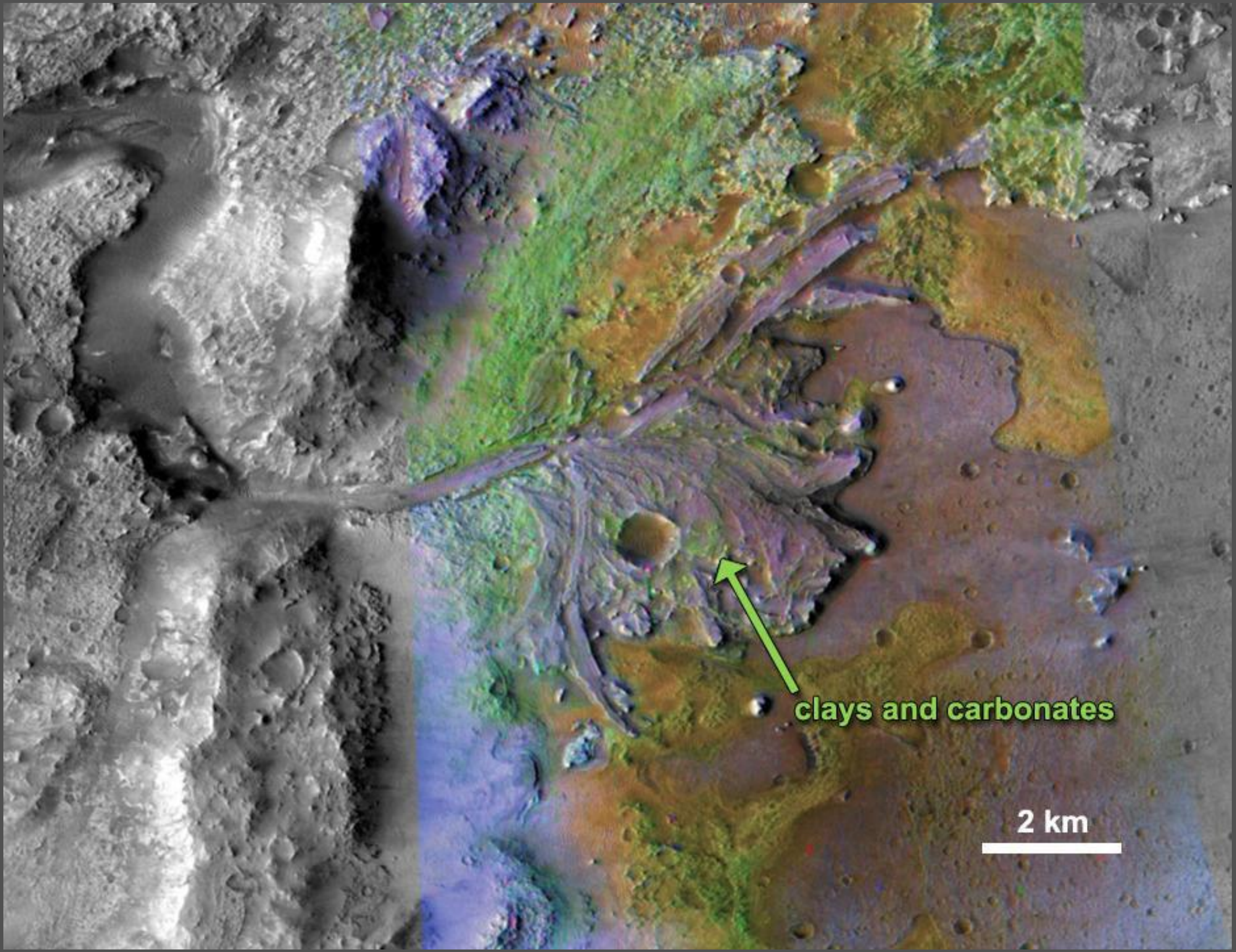


Photo Courtesy: Jet Propulsion Laboratory

Clays and carbonates detected on Mars using the hyperspectral sensor CRISM inside the Jazero crater. Clays require water and carbonates require water in neutral conditions.

Data Download

- USGS Earth Explorer: https://earthexplorer.usgs.gov/
- ESA/Copernicus: https://scihub.copernicus.eu/dhus/#/home
- ISRO/Bhuvan: https://bhuvan-app3.nrsc.gov.in/data/download/index.php
- Private Players: Eg https://www.planet.com/get-started/
- Spectral library: https://crustal.usgs.gov/speclab/QueryAll07a.php

Alternately, access data through other options:

- Google Earth engine
- Microsoft Planetary Computer
- Amazon Web Services

THANK YOU FOR YOUR PATIENCE

Any Doubts?

In case of any queries, drop me a line on

ritu.anilkumar@nesac.gov.in