

# **COURSE: SATELLITE IMAGE PROCESSING**

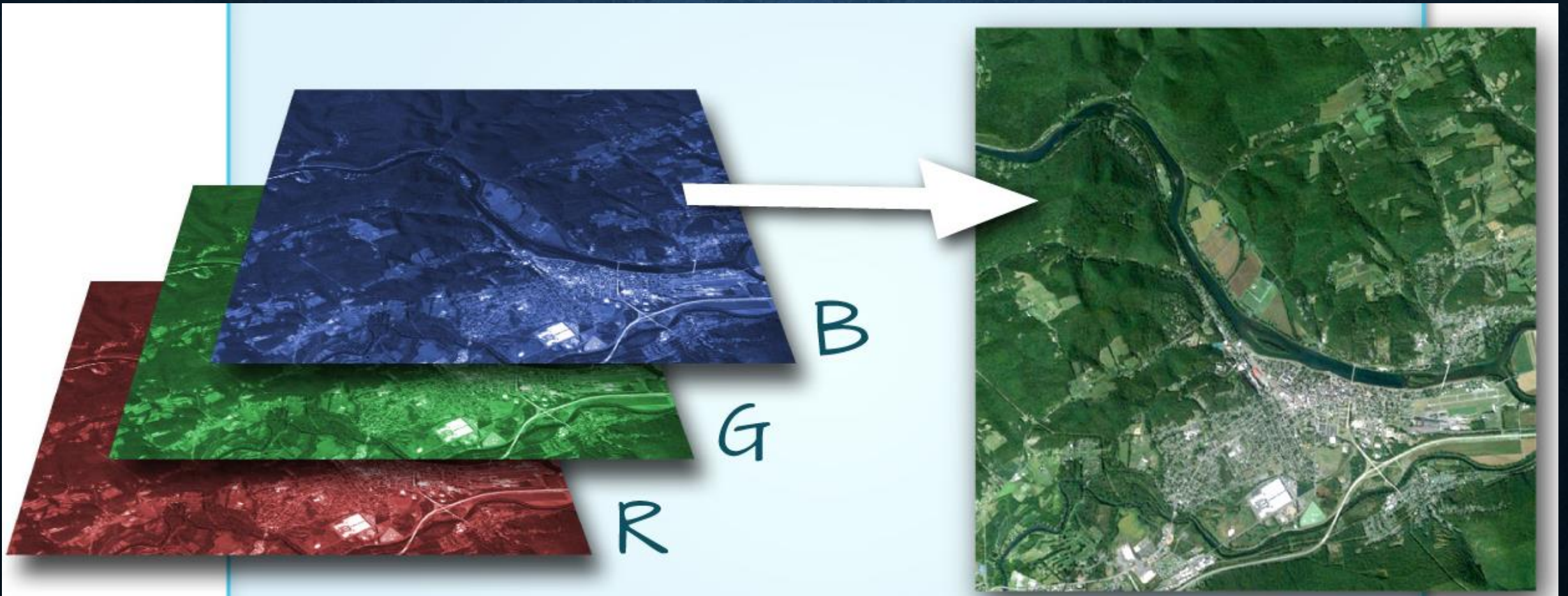
## **LECTURE 8 – Image Spectral Resolution and Enhancement**

Lecturer: Dr. Tingneyuc Sekac, Ph.D. PNG University of Technology

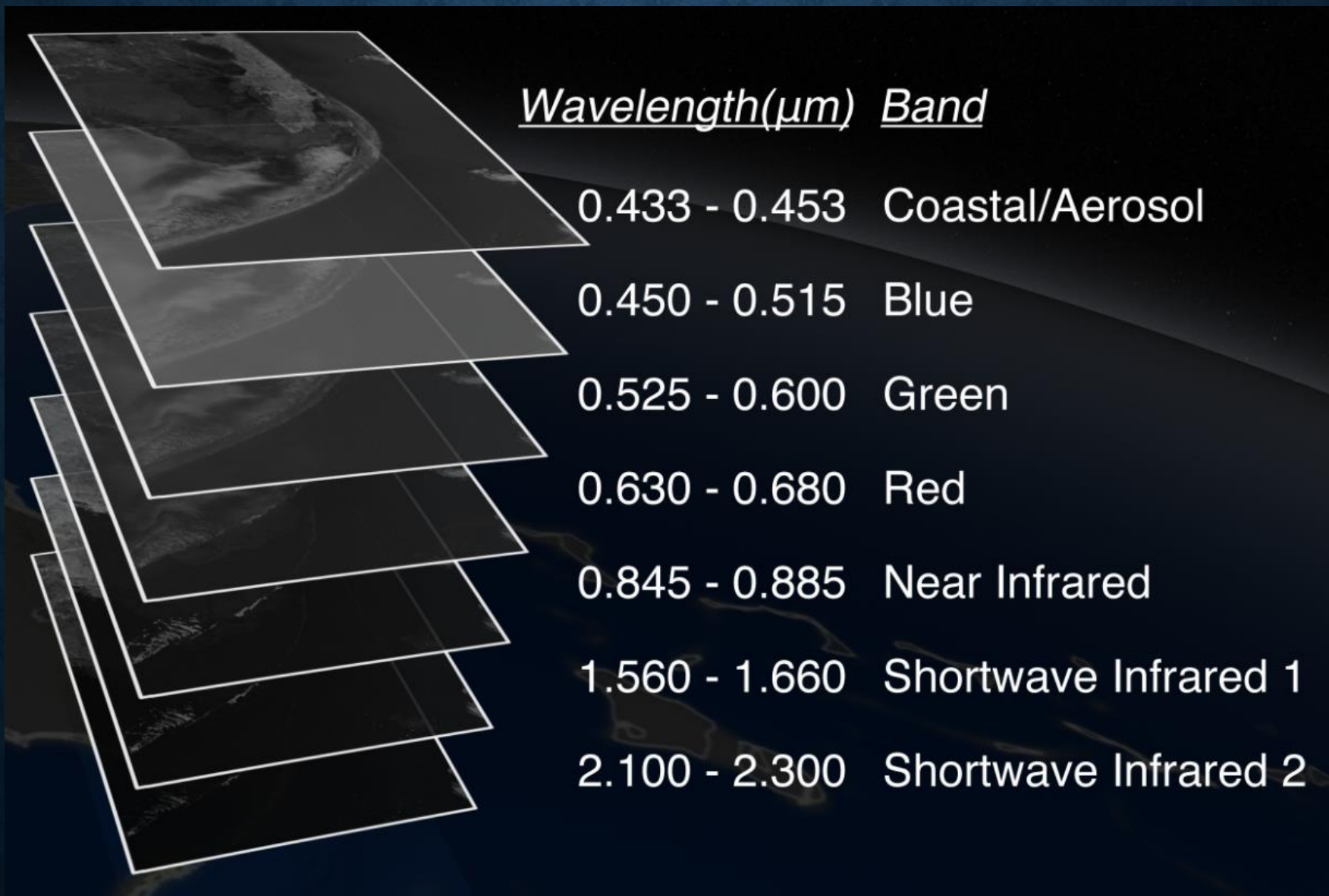
# Understanding Spectral Resolution

Spectral Bands

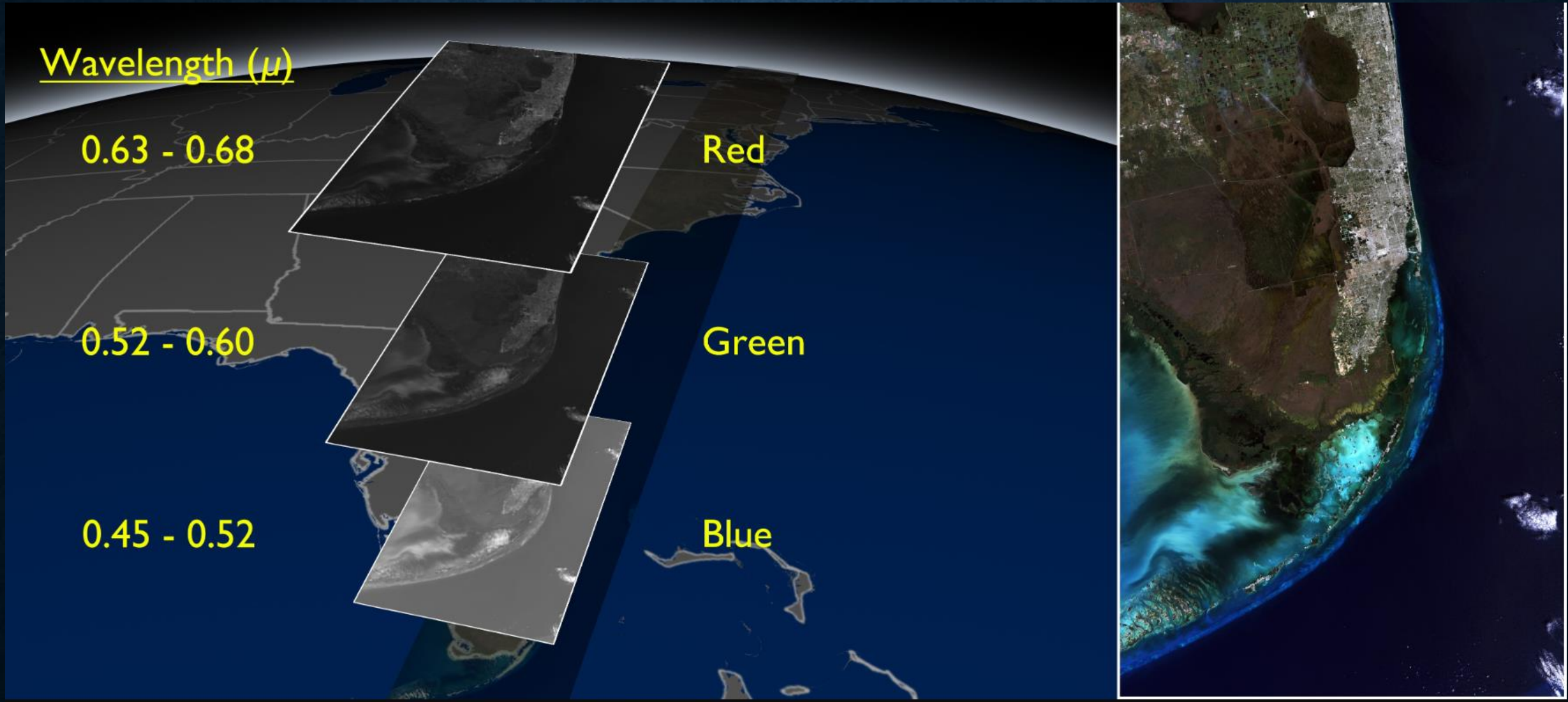
Layer Stack Raster



# Understanding Spectral Resolution



# Spectral Resolution



# Definition of Spectral Resolution

**Spectral resolution** is the number and dimension (size) of wavelength intervals (referred to as bands or channels) in the electromagnetic spectrum to which a remote sensing instrument is sensitive.

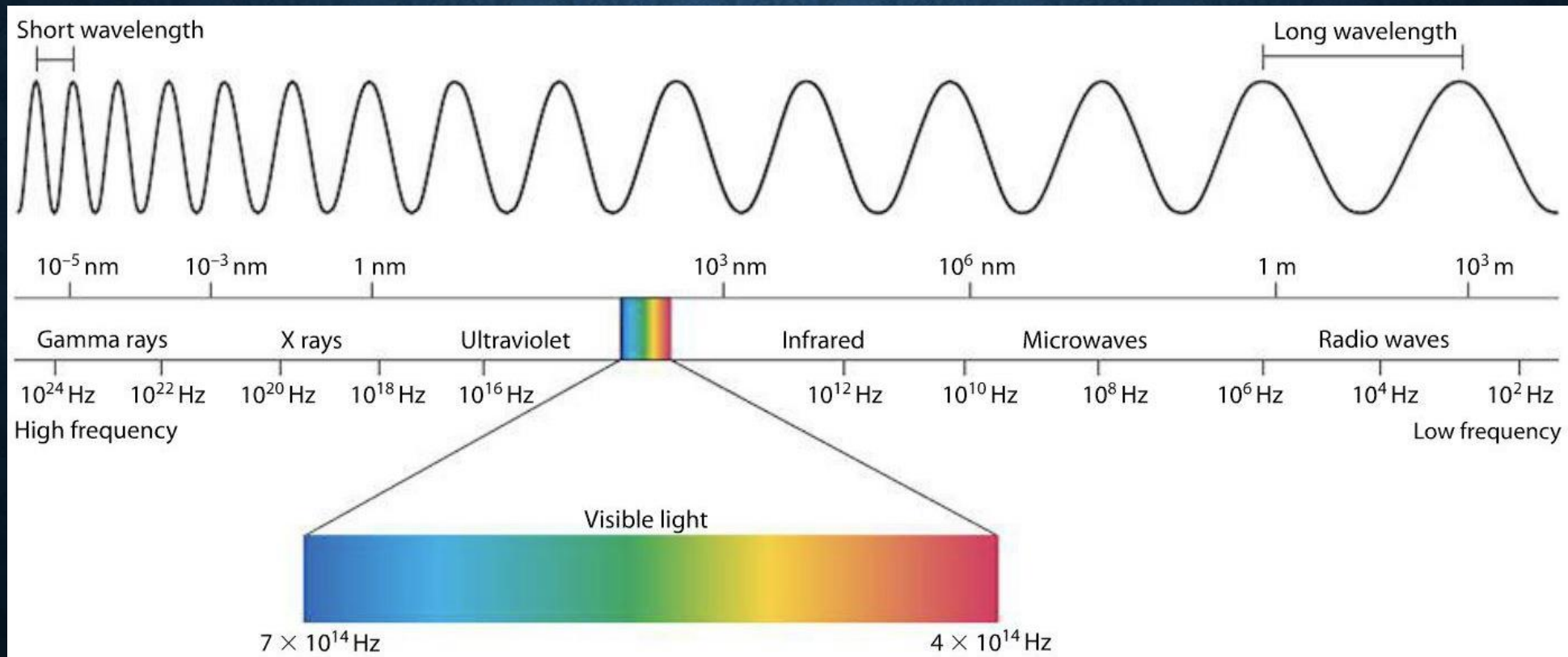


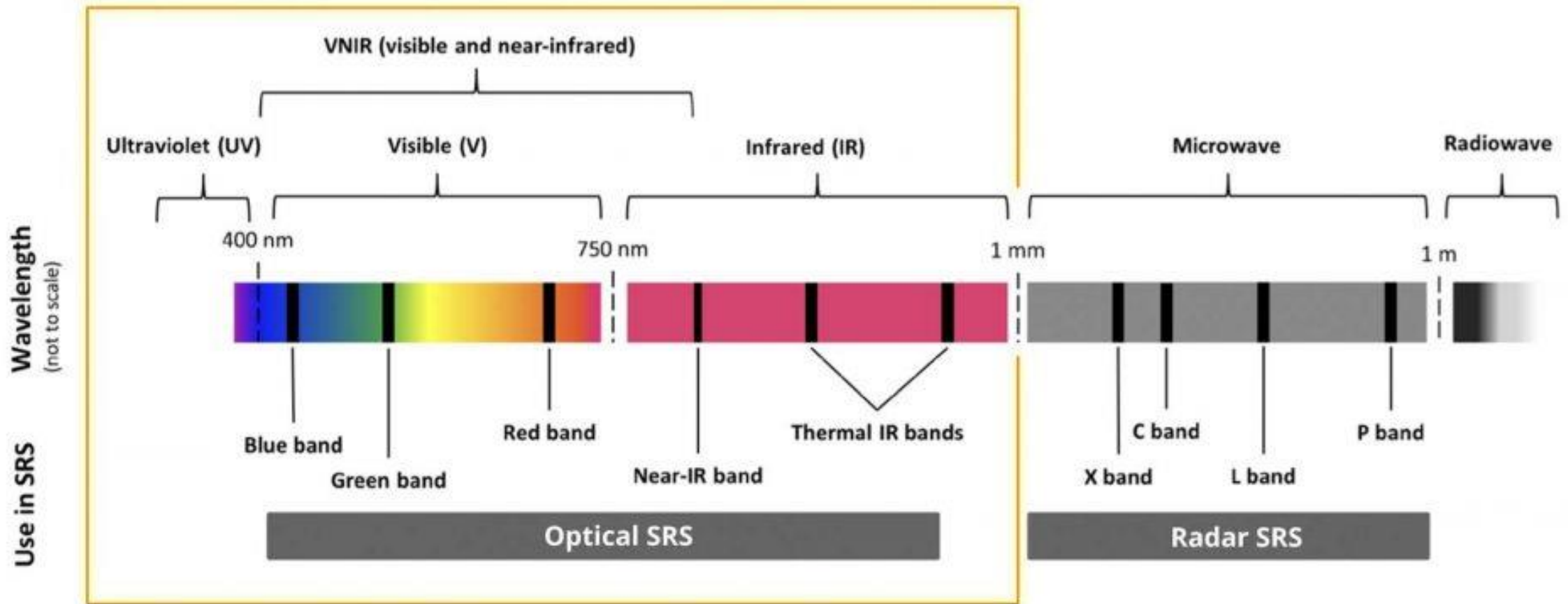
Image credit: Miniphysics

# Definition of Spectral Resolution

- ❑ Satellite sensors capture electromagnetic radiation across multiple spectral bands, ranging from visible light to infrared and beyond.
- ❑ The spectral resolution of an image is determined by the number and width of these bands.
- ❑ Sensors with higher spectral resolution have more bands with narrower bandwidths, allowing them to capture more detailed information about the reflectance properties of Earth's surface.

# Electromagnetic Spectrum

The electromagnetic spectrum, and its use in satellite remote sensing (SRS).



# Range of EMS and Practical Application

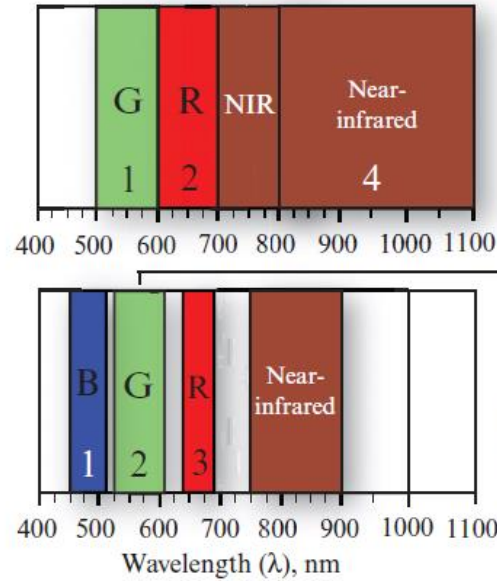
Example;

A satellite sensor with low spectral resolution might capture data in just a few broad bands, such as red, green, and blue (RGB).

In contrast, a sensor with higher spectral resolution might have additional bands in the near-infrared (NIR), shortwave infrared (SWIR), and other regions of the spectrum, enabling more detailed analysis of;

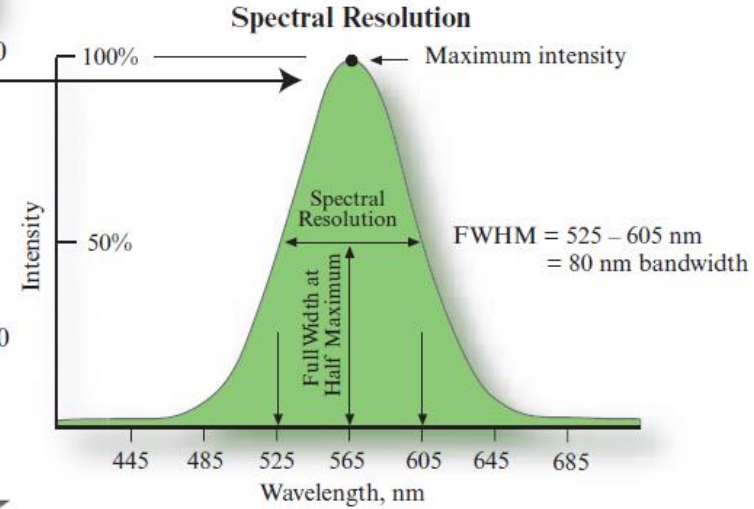
- vegetation health,
- soil composition, and
- other surface properties

# Spectral Resolution Characteristics

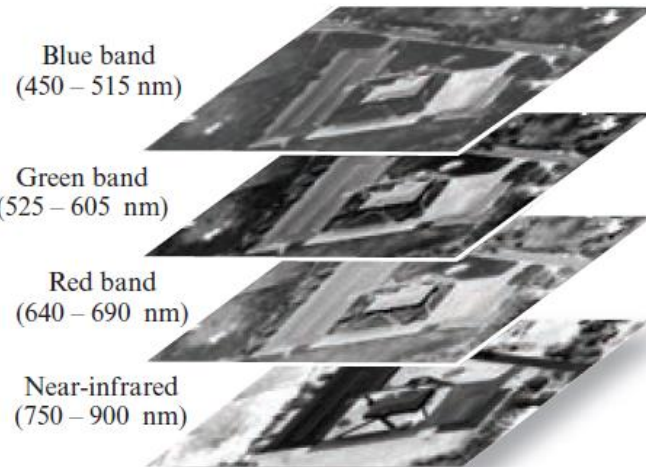


a. Spectral bandwidths.

## Spectral Resolution Characteristics



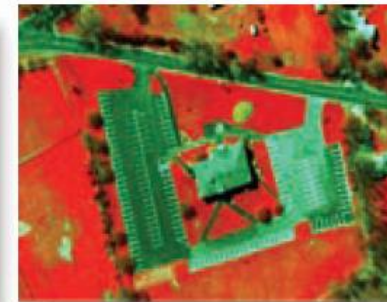
b. Precise bandpass measurement of a detector based on Full Width at Half Maximum (FWHM) criteria.



c. Individual multispectral band images.



d. Natural color-composite created using blue, green, and red bands.



e. Color-infrared color-composite created using green, red, and near-infrared bands.

# Landsat Spectral Band Combination

## Natural Color



Landsat 8/9 OLI	4,3,2
Landsat 7 ETM+	3,2,1
Landsat 4-5 TM	3,2,1
Landsat 4-5 MSS	N/A
Landsat 1-3 MSS	N/A

## Color Infrared (CIR)



Landsat 8/9 OLI	5,4,3
Landsat 7 ETM+	4,3,2
Landsat 4-5 TM	4,3,2
Landsat 4-5 MSS	3,2,1
Landsat 1-3 MSS	6,5,4

## False Color (Urban)



Landsat 8/9 OLI	7,6,4
Landsat 7 ETM+	7,5,3
Landsat 4-5 TM	7,5,3
Landsat 4-5 MSS	N/A
Landsat 1-3 MSS	N/A

# Landsat Spectral Band Combination

## False Color (Vegetative Analysis)



Landsat 8/9 OLI	6,5,4
Landsat 7 ETM+	5,4,3
Landsat 4-5 TM	5,4,3
Landsat 4-5 MSS	4,3,2
Landsat 1-3 MSS	7,6,5

## Shortwave Infrared



Landsat 8/9 OLI	7,5,4
Landsat 7 ETM+	7,4,3
Landsat 4-5 TM	7,4,3
Landsat 4-5 MSS	N/A
Landsat 1-3 MSS	N/A

# Summary: Spatial Resolution Vs Spectral Resolution

Difference between spatial resolution and spectral resolution

- ❑ The difference between spatial resolution and spectral resolution is from pixel size and spectral detail.
- ❑ Spatial resolution is a measurement of how detailed objects are in an image based on pixels.
- ❑ Whereas spectral resolution is the amount of spectral detail in a band based on the number and width of spectral bands.

# Summary: Spatial Resolution Vs Spectral Resolution

□ Landsat-8 produces 11 images and each band consists of the following spectral resolution:

Band Number	Description	Wavelength	Resolution
Band 1	Coastal / Aerosol	0.433 to 0.453 $\mu\text{m}$	30 meter
Band 2	Visible blue	0.450 to 0.515 $\mu\text{m}$	30 meter
Band 3	Visible green	0.525 to 0.600 $\mu\text{m}$	30 meter
Band 4	Visible red	0.630 to 0.680 $\mu\text{m}$	30 meter
Band 5	Near-infrared	0.845 to 0.885 $\mu\text{m}$	30 meter
Band 6	Short wavelength infrared	1.56 to 1.66 $\mu\text{m}$	30 meter
Band 7	Short wavelength infrared	2.10 to 2.30 $\mu\text{m}$	60 meter
Band 8	Panchromatic	0.50 to 0.68 $\mu\text{m}$	15 meter
Band 9	Cirrus	1.36 to 1.39 $\mu\text{m}$	30 meter
Band 10	Long wavelength infrared	10.3 to 11.3 $\mu\text{m}$	100 meter
Band 11	Long wavelength infrared	11.5 to 12.5 $\mu\text{m}$	100 meter

# Summary: Spatial Resolution Vs Spectral Resolution

- ❑ Each band has a spatial resolution of 30 meters except for bands 8, 10, and 11.
- ❑ While the panchromatic band has a spatial resolution of 15 meters, its thermal bands have a 100-meter pixel size.

Band Number	Description	Wavelength	Resolution
Band 1	Coastal / Aerosol	0.433 to 0.453 $\mu\text{m}$	30 meter
Band 2	Visible blue	0.450 to 0.515 $\mu\text{m}$	30 meter
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# Spectral Enhancement

- ❑ Spectral enhancement is the process of refining new spectral data from available bands.
- ❑ This process relies on the spectral signatures of individual features on the Earth's surface.
- ❑ Spectral signatures are the distinctive qualities that denote the range of different features' reflected radiation wavelengths collected by satellite sensors.
- ❑ For example, spectral signatures can distinguish man-made objects from types of vegetation.

# Spectral Enhancement

- ❑ New data are created on a pixel-by-pixel basis.
- ❑ Spectral enhancement applies an operation such as subtraction or division to corresponding pixels between two or more bands and creates a new image that may enhance the original image's features.

# Spectral Enhancement

The technique of spectral enhancement can be used to:

- ❑ Extract new bands of data that are more easily interpreted by the eye,
- ❑ Diminish redundancy in a multi-spectral dataset by merging bands of data that convey similar information,
- ❑ Display a wider variety of data in the visible RGB spectrum.

# Spectral Enhancement Techniques

The most commonly used spectral enhancement techniques are:

## 1. Spectral Ratios and Indices:

band ratios commonly used in vegetation and geologic studies.

## 2. Principal Components Analysis (PCA):

Compresses redundant data values into fewer bands, which are often more concise and powerful.

PCA is used to support image;

- extraction,
- classification, and
- change detection analysis.

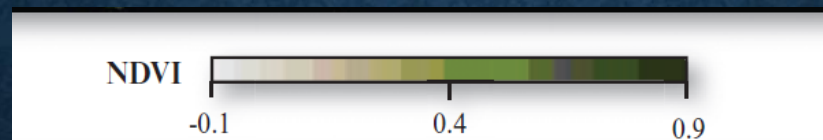
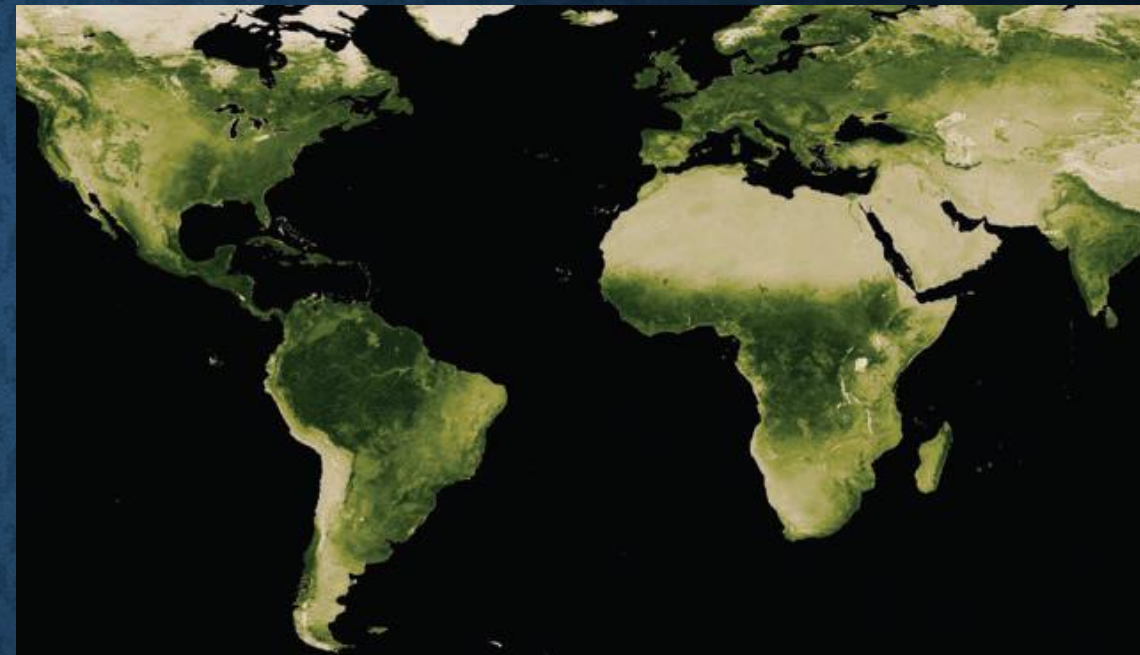
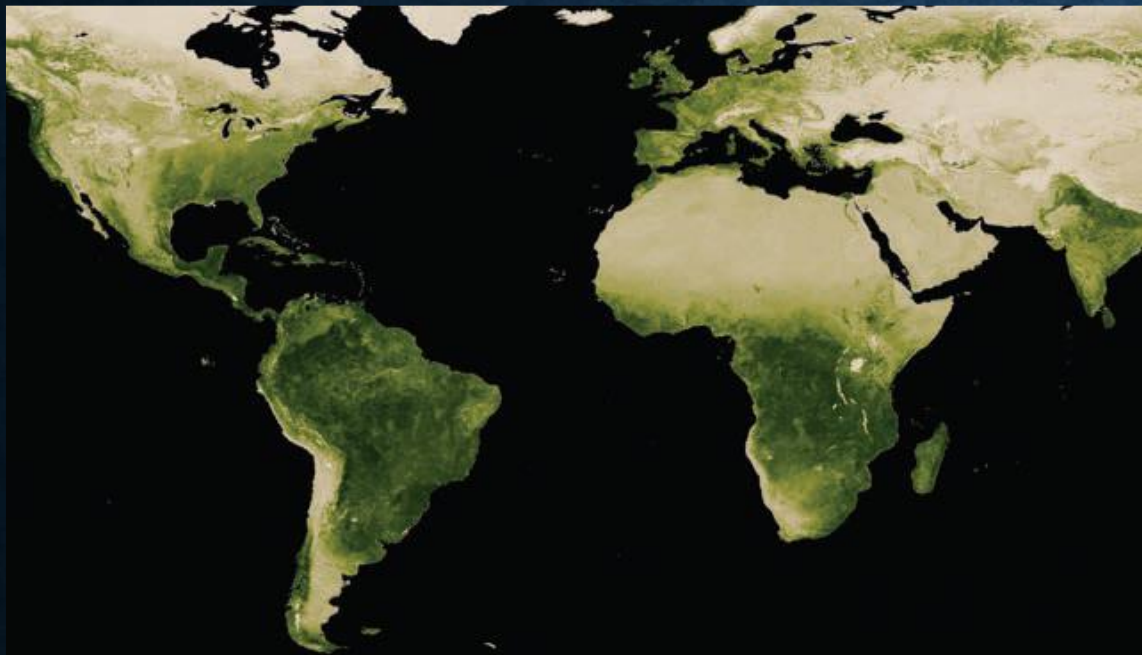
# Spectral Enhancement Techniques

## 3. Tasseled Cap:

Transforms and rotates the data structure axes to optimize data display for vegetation studies.

Tasseled Cap transformation can also be formed within ArcGIS Pro, but this book does not provide instructions.

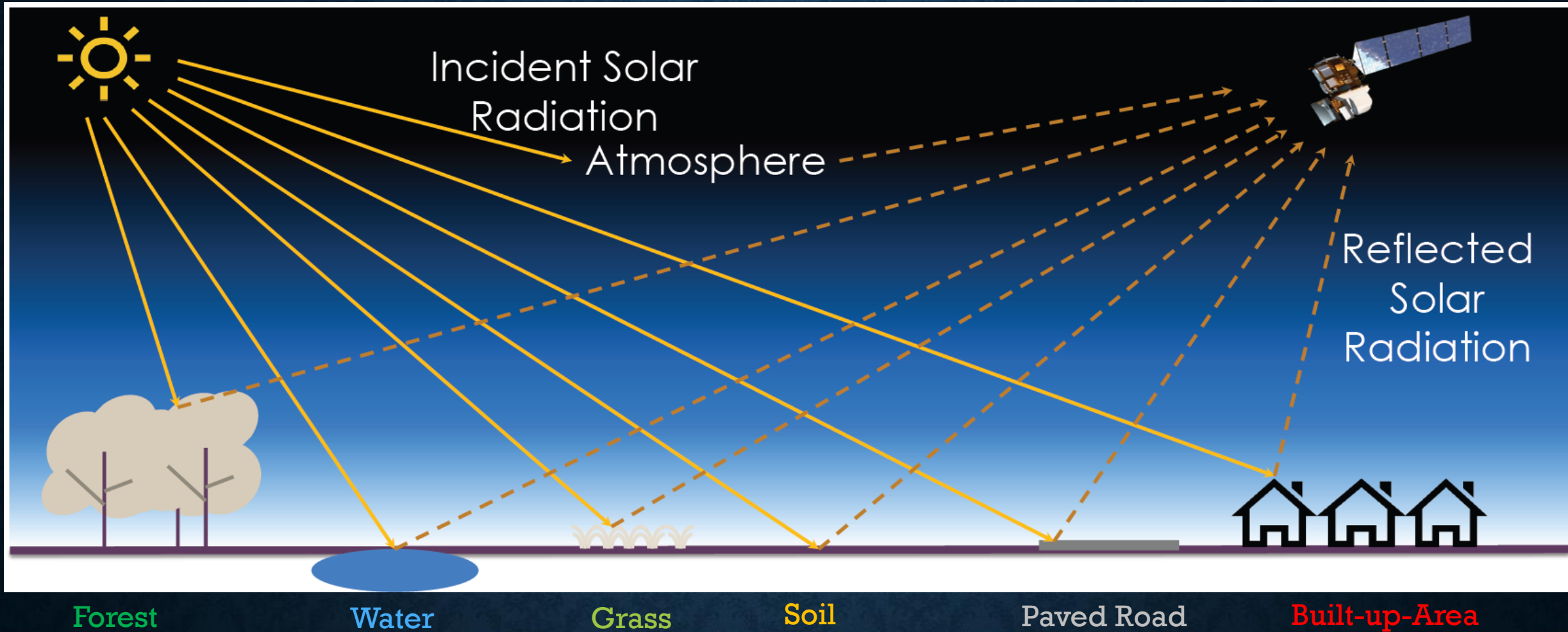
# Spectral Ratios and Indices:



a. NDVI composite derived from MODIS images collected from February 1, 2012, to March 1, 2012.

b. NDVI composite derived from MODIS images collected from October 1, 2012, to November 1, 2012.

# What is Measured

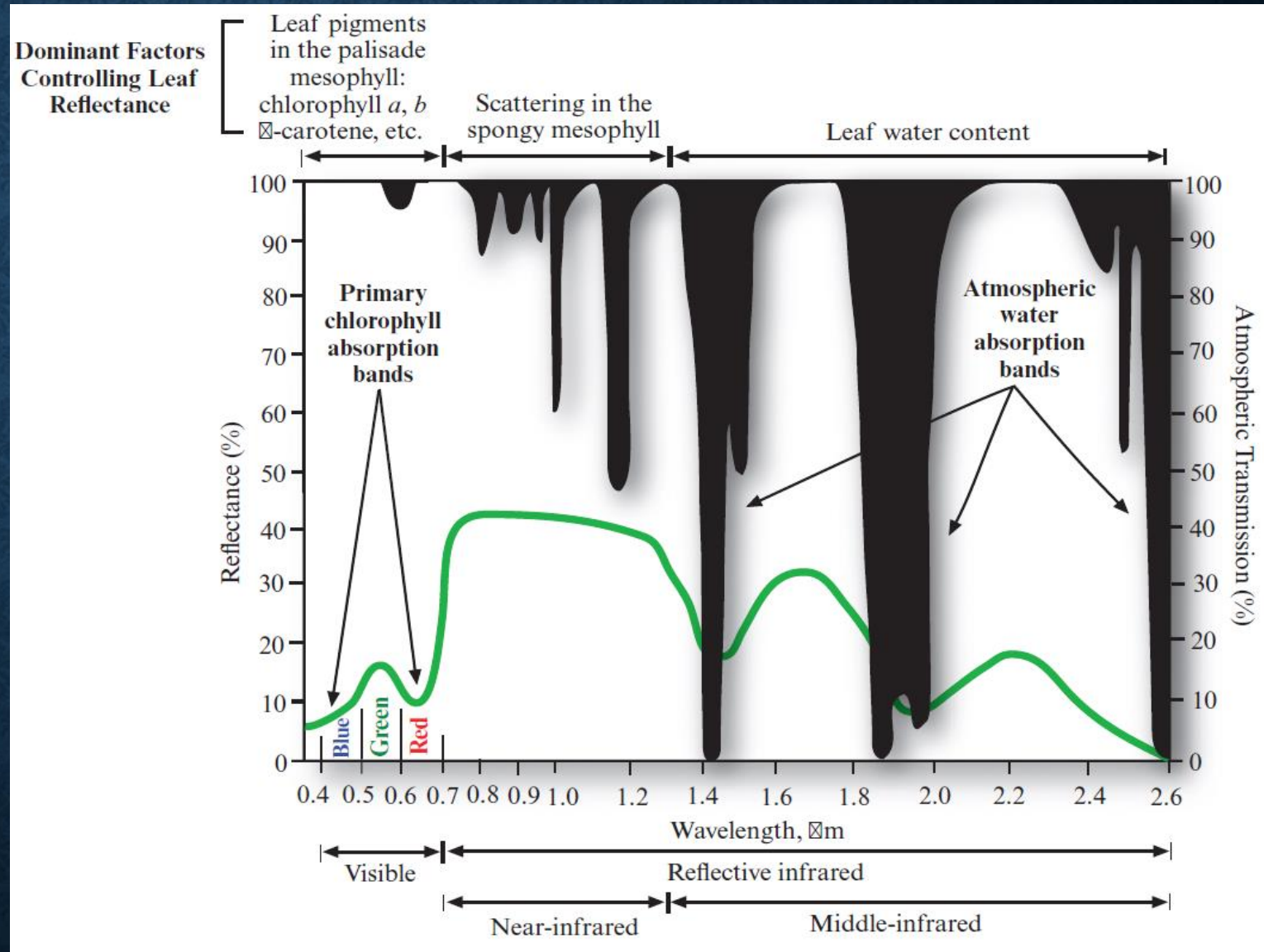


# Vegetation Interaction and Reflection

- ❑ Healthy, green vegetation absorbs Blue and Red wavelengths (used by chlorophyll for photosynthesis) and reflects Green and Infrared.
- ❑ Since we cannot see infrared radiation, we see healthy vegetation as green.
- ❑ The amount of reflected energy is dependent on the health of the vegetation, water content, and phenological stage.

# Spectral Signatures – Spectral Characteristics of Healthy Green Vegetation

□ Difference of Reflection between Water Soil and Vegetation.

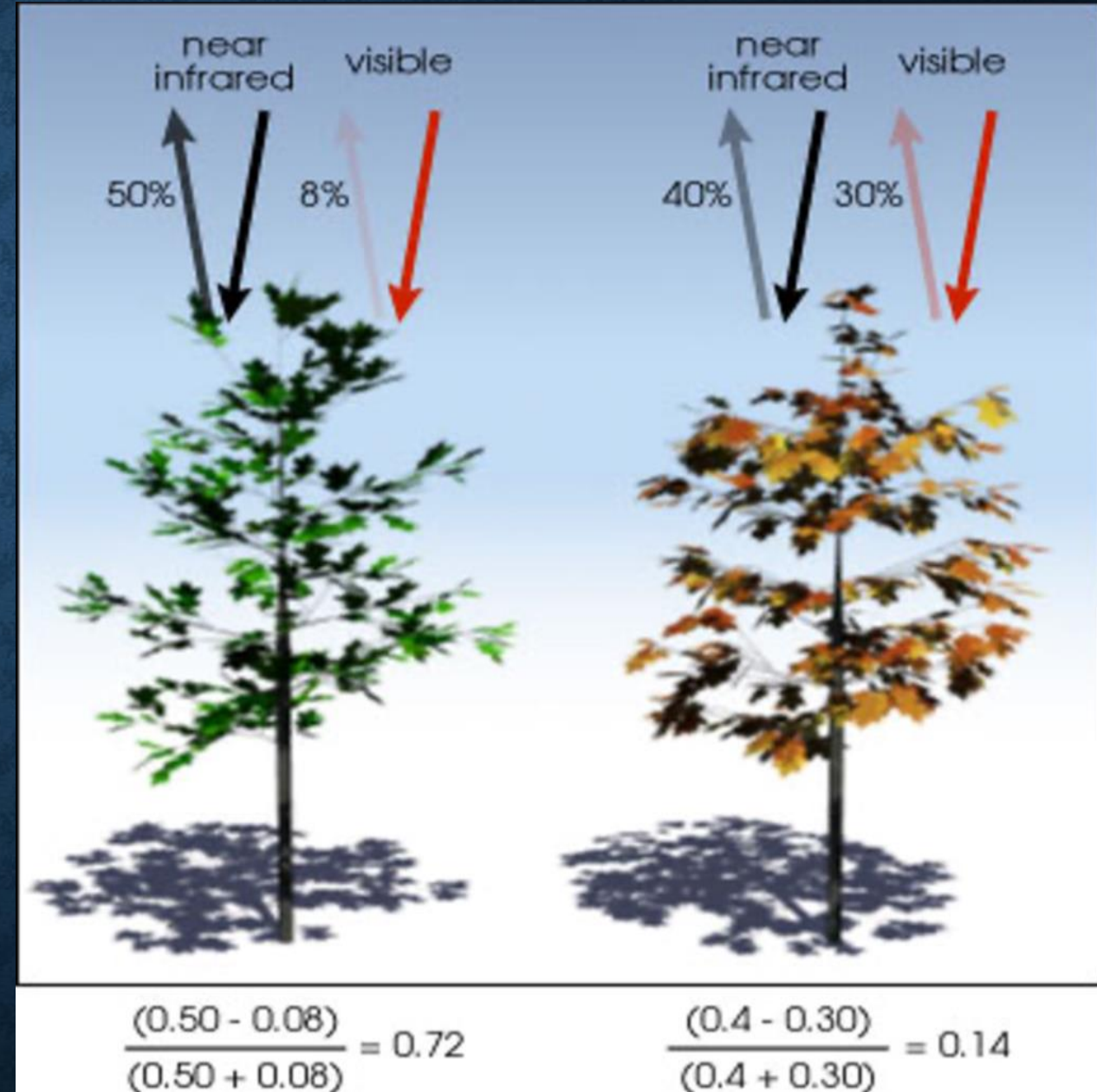


# Natural Differential Vegetation Index (NDVI)

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$

NDVI Values range from -1.0 to 1.0.

- Negative values to 0 mean no green leaves or vegetation/unhealthy vegetation growth.
- Values close to 1 indicate the highest possible density of green leaves/vegetation/Healthy grown vegetation.





# Spectral Band Ratio and Indices

## Normalize Differential Moisture Index (NDMI):

- ❑ The Normalized Difference Moisture Index (NDMI) is sensitive to the moisture levels in vegetation/leaves.
- ❑ It is used to monitor droughts as well as monitor fuel levels in fire-prone areas.
- ❑ It uses NIR and SWIR bands to create a ratio designed to mitigate illumination and atmospheric effects.

$$\text{NDMI} = (\text{NIR} - \text{SWIR1}) / (\text{NIR} + \text{SWIR1})$$

# Spectral Band Ratio and Indices

## Normalized Differential Built-up Index (NDBI):

- ❑ NDBI uses the NIR and SWIR bands to emphasize manufactured built-up areas.
- ❑ It is ratio based to mitigate the effects of terrain illumination differences as well as atmospheric effects.

$$\text{NDBI} = (\text{SWIR} - \text{NIR}) / (\text{SWIR} + \text{NIR})$$

# Spectral Band Ratio and Indices

## Normalize Differential Water Index (NDWI)

- ❑ NDWI method is an index for delineating and monitoring content changes in surface water/water bodies.
- ❑ It is computed with the NIR and green bands.

$$\text{NDWI} = (\text{Green} - \text{NIR}) / (\text{Green} + \text{NIR})$$

# Landsat Bands

Landsat 8 & 9 OLI and TIRS Bands ( $\mu\text{m}$ )			Landsat 7 ETM+ Bands ( $\mu\text{m}$ )		
Band 1	30 m Coastal/Aerosol	0.43-0.45			
Band 2	30 m Blue	0.45-0.51	Band 1	30 m Blue	0.44-0.51
Band 3	30 m Green	0.53-0.60	Band 2	30 m Green	0.52-0.60
Band 4	30 m Red	0.63-0.68	Band 3	30 m Red	0.63-0.69
Band 5	30 m NIR	0.85-0.88	Band 4	30 m NIR	0.77-0.90
Band 6	30 m SWIR-1	1.57-1.65	Band 5	30 m SWIR-1	1.55-1.75
Band 10	100 m TIR-1	10.60-11.19	Band 6	60 m TIR	10.40-12.50
Band 11	100 m TIR-2	11.50-12.51			
Band 7	30 m SWIR-2	2.11-2.29	Band 7	30 m SWIR-2	2.08-2.35
Band 8	15 m Pan	0.5-0.68	Band 8	15 m Pan	0.52-0.90
Band 9	30 m Cirrus	1.36-1.38			

# Spectral Band Ratio and Indices

ASI - Artificial Surface Index, (Yongquan Zhao & Zhe Zhu 2022)

AWEI\_ns (Automated Water Extraction Index,no shadows, Feyisa 2014)

AWEI\_sh (Automated Water Extraction Index,shadows, Feyisa 2014)

BAEI (Built-Up Area Extraction Index, Bouzekri et al. 2015)

BAI (Burn Area Index, Martin 1998)

BSI (Bare Soil Index, Rikimaru et al. 2002)

BUI (Built-Up Index, He et al. 2010)

CMR (Clay Minerals Ratio, Drury 1987)

ENDISI (Enhanced Normalised Difference for Impervious Surfaces Index, Chen et al. 2019)

EVI (Enhanced Vegetation Index, Huete 2002)

FMR (Ferrous Minerals Ratio, Segal 1982)

IOR (Iron Oxide Ratio, Segal 1982)

LAI (Leaf Area Index, Boegh 2002)

MBI (Modified Bare Soil Index, Nguyen et al. 2021)

MNDWI (Modified Normalised Difference Water Index, Xu 1996)

MSAVI (Modified Soil Adjusted Vegetation Index, Qi et al. 1994)

# References:

Jensen, John R., 2015- Introductory digital image processing : a remote sensing perspective / John R. Jensen, University of South Carolina.  
pages cm. -- (Pearson series in geographic information science) 4<sup>th</sup> ed.