Sensors and Electronics

Remote Sensing

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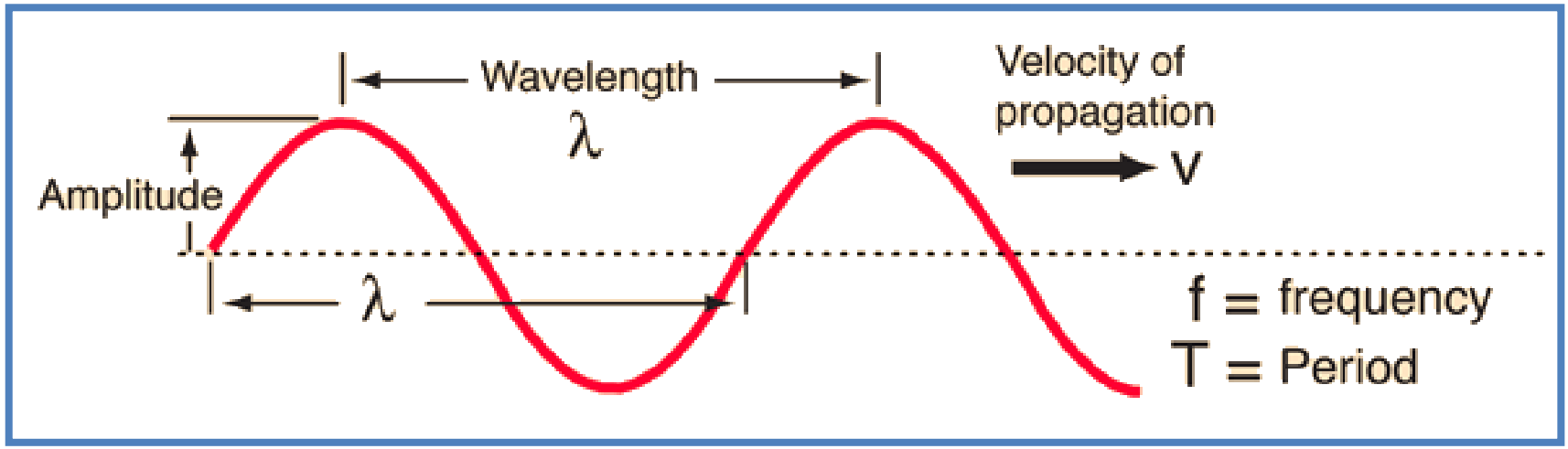
Introduction to Remote Sensing

- Remote Sensing is the ability to measure certain attributes of an object without direct contact with the object itself.
- “Sense” an object’s characteristics from a distance.
- Human eyesight is a form of Remote Sensing. We can obtain information about an object like its color and size without touching it.

Introduction to Remote Sensing

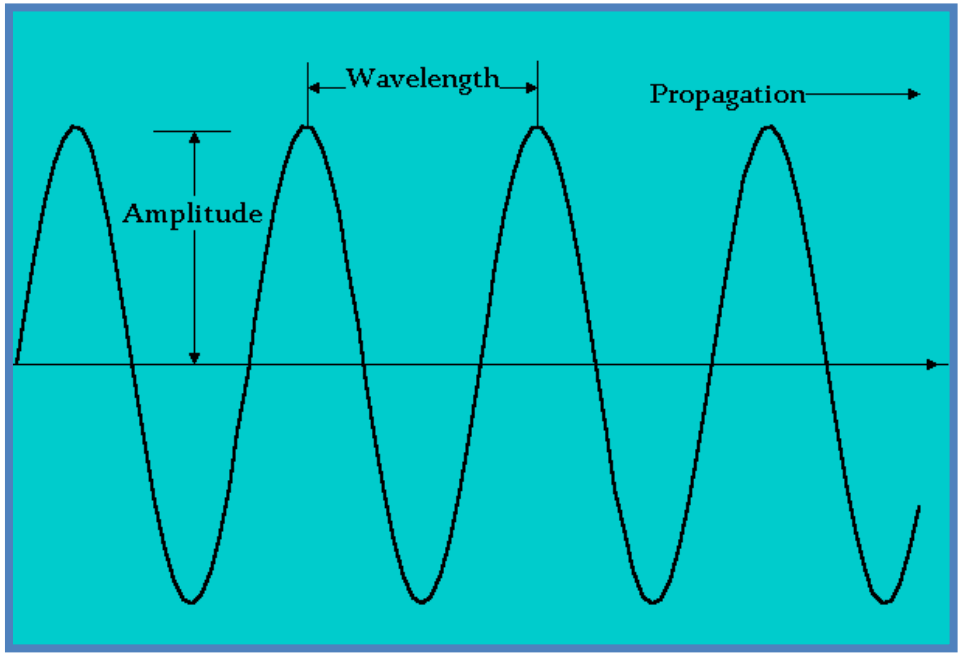
- A wave is a form of disturbance from an equilibrium (resting/balance).
- It is the mean with which light travels.



Source: hyperphysics.phy-astr.gsu.edu

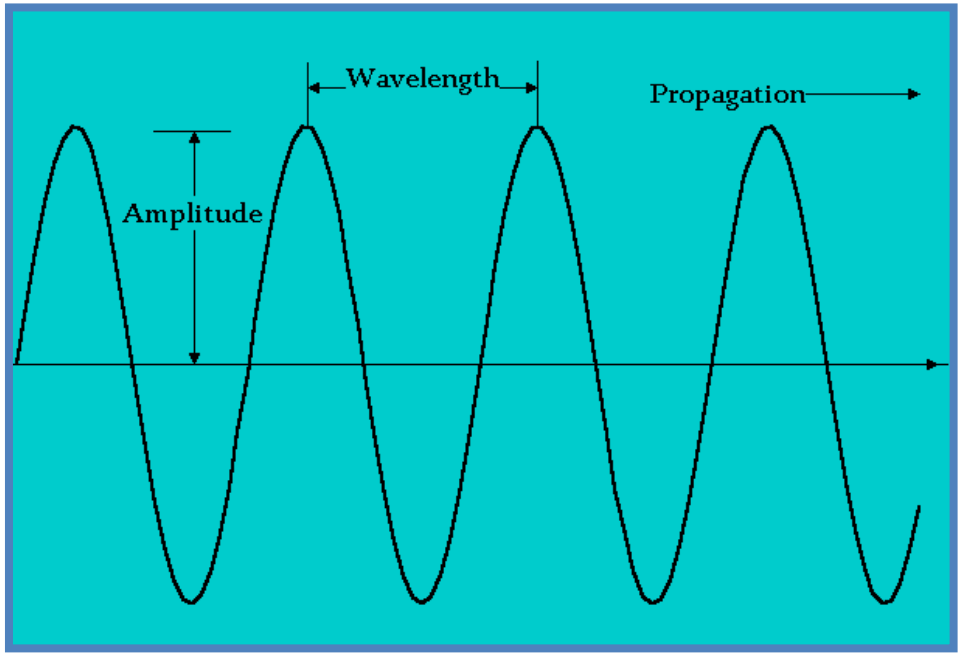
Properties of Wave?

- Wavelength is the distance between adjacent peaks in a series of periodic waves, measured in meters.
- Amplitude is the distance from the wave's maximum height to its resting point (y=0, when the wave function hits the x axis).



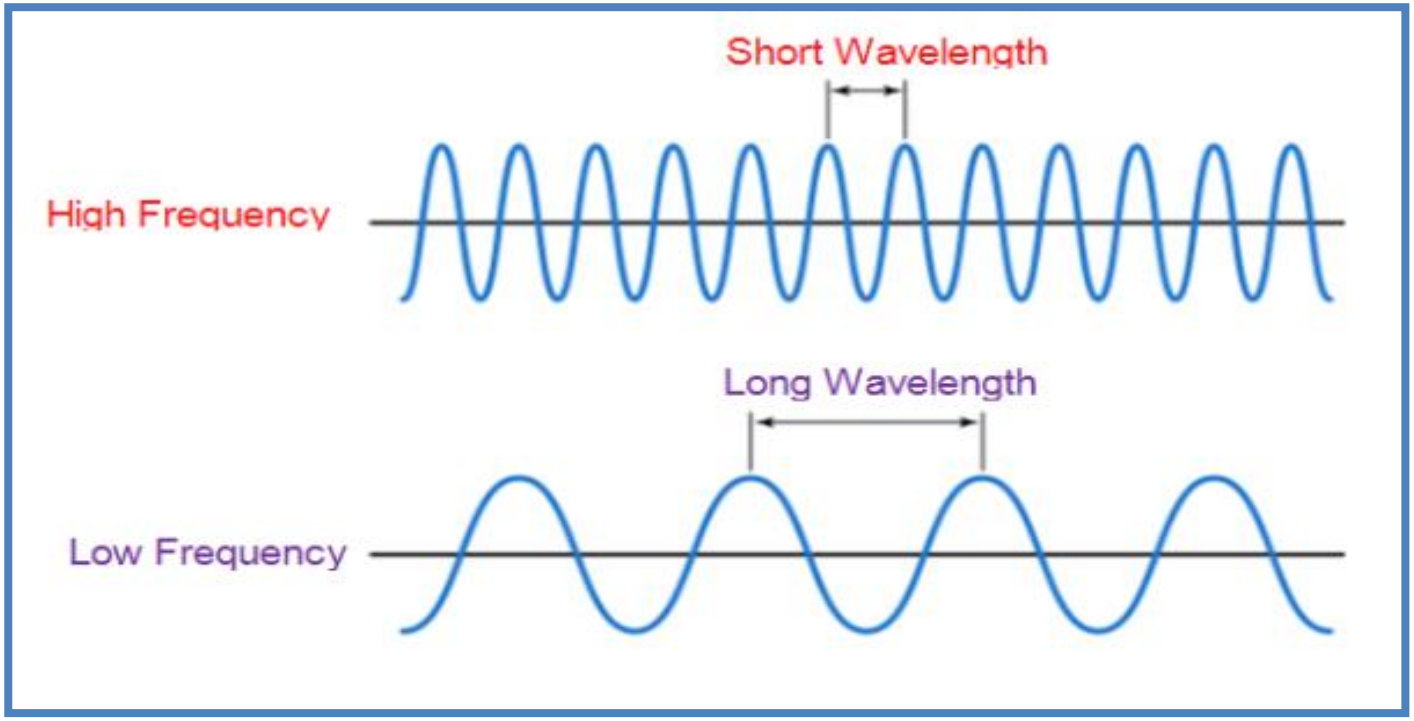
Properties of Wave?

- Frequency is a property of a wave that describes how many wave cycles happen during a given period of time. Frequency is often measured in Hertz (Hz), and a wave with a frequency of 1 Hz will make 1 full cycle per second.



Introduction to Remote Sensing

- Wavelength and therefore frequency characterize all waves and their properties



Source: techplayon.com

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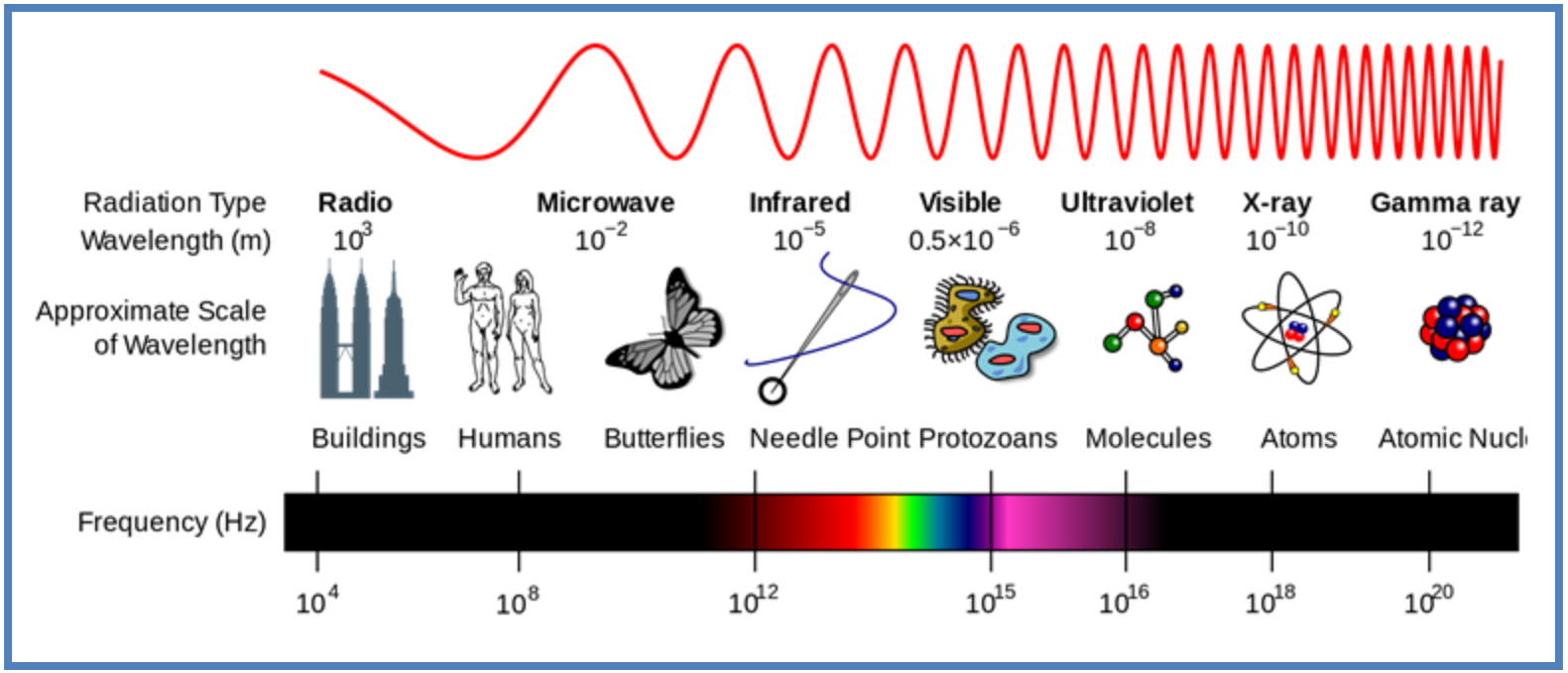
Introduction to Remote Sensing

- Each object is characterized by different absorption and reflectance rates across the electromagnetic spectrum (wavelengths).
- The wavelength of Electromagnetic waves can vary from thousands of kilometers down to a fraction of the size of an atomic nucleus.

Introduction to Remote Sensing



Source: nasa.gov (NASA)

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Properties of the EMR Spectrum

Spectrum of Electromagnetic Radiation				
Region	Wavelength (Angstroms) (10^{-10} m)	Wavelength (meters)	Frequency (Hz)	Energy (eV)
Radio	$> 10^{9}$	> 0.1	$< 3 \times 10^{9}$	$< 10^{-5}$
Microwave	$10^{9} - 10^{6}$	$0.1 - 10^{-4}$	$3 \times 10^{9} - 3 \times 10^{12}$	$10^{-5} - 0.01$
Infrared	$10^{6} - 7000$	$10^{-4} - 7 \times 10^{-7}$	$3 \times 10^{12} - 4.3 \times 10^{14}$	$0.01 - 2$
Visible	$7000 - 4000$	$7 \times 10^{-7} - 4 \times 10^{-7}$	$4.3 \times 10^{14} - 7.5 \times 10^{14}$	$2 - 3$
Ultraviolet	$4000 - 10$	$4 \times 10^{-7} - 10^{-9}$	$7.5 \times 10^{14} - 3 \times 10^{17}$	$3 - 10^{3}$
X-Rays	$10 - 0.1$	$10^{-9} - 10^{-11}$	$3 \times 10^{17} - 3 \times 10^{19}$	$10^{3} - 10^{5}$
Gamma Rays	< 0.1	$< 10^{-11}$	$> 3 \times 10^{19}$	$> 10^{5}$

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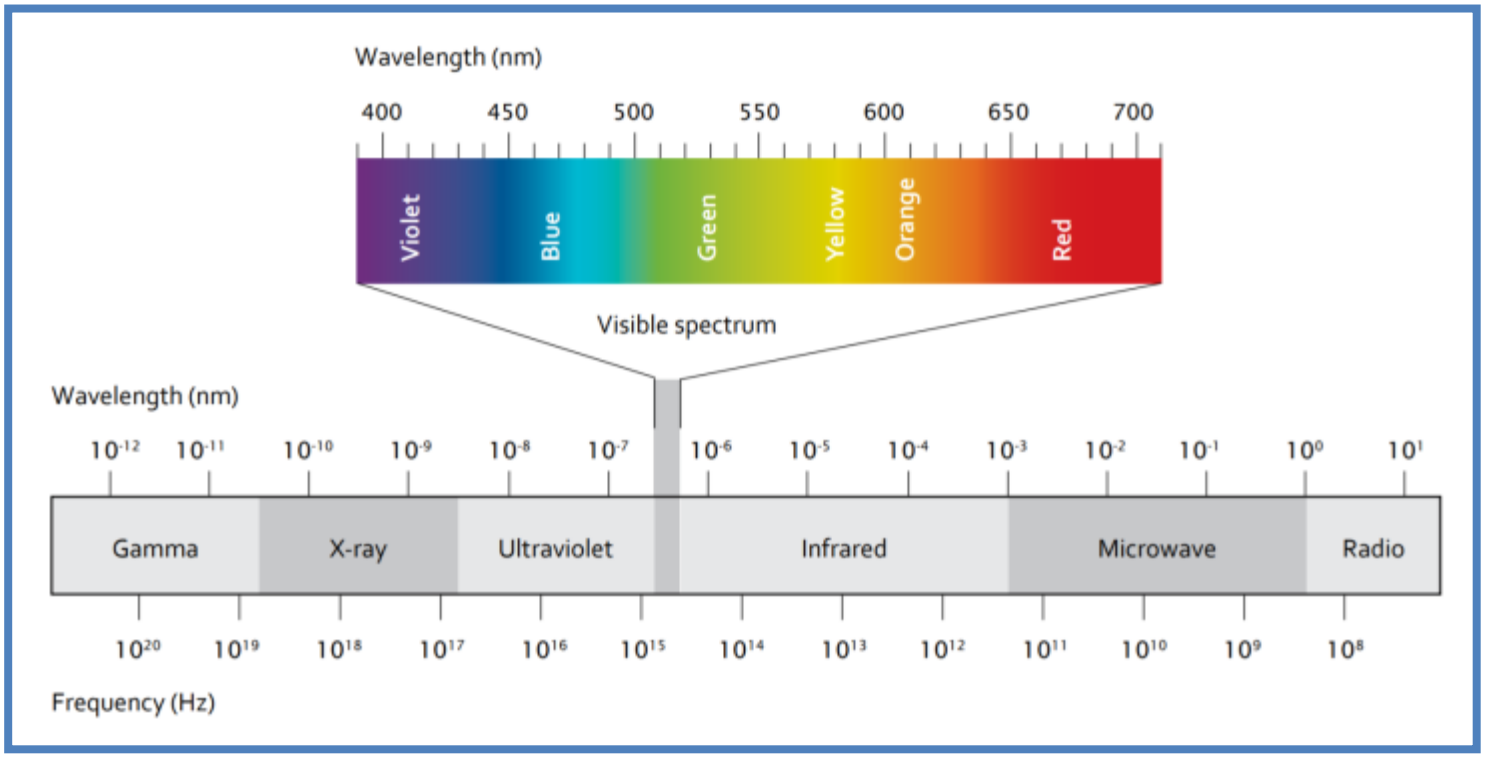
Introduction to Remote Sensing

- The human eye is capable of sensing only a very small fraction of the spectrum, from 350-700 nm.
- This is known as the “visible spectrum”, and is the range in which humans can perceive and “see” the colors of the objects around them, based on the reflected light that reaches our eyes.

Introduction to Remote Sensing



Source: chem.libretexts.org

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Introduction to Remote Sensing

- If an object changes color, this phenomena is perceived by us because essentially the change in reflection occurred within the visible spectrum.
- For example, a raw, previously green tomato has now matured and appears red to us, because it now reflects more light in the 650-730 nm spectrum, which corresponds to the red color.
- To put it simply, all objects have high reflectance in the spectrum that we see as its colour.

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Introduction to Remote Sensing

- Such observations led to the following question: since changes in the visible spectrum can be conceived by us and have a direct effect on the properties of the object, what happens to spectral changes that we cannot see with our own eyes
- “What kind of information can we obtain if we can measure these invisible changes?”

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Remote Sensing Applications

- Plants, and more specifically, photosynthetically-active tissues, demonstrate high absorption in the Red spectrum, while reflecting the largest portion of Green light - and therefore appear green to us.
- Photosynthetically active radiation (PAR) is the spectral range of solar radiation from 400 to 700 nm that photosynthetic organisms are able to use in the process of photosynthesis.

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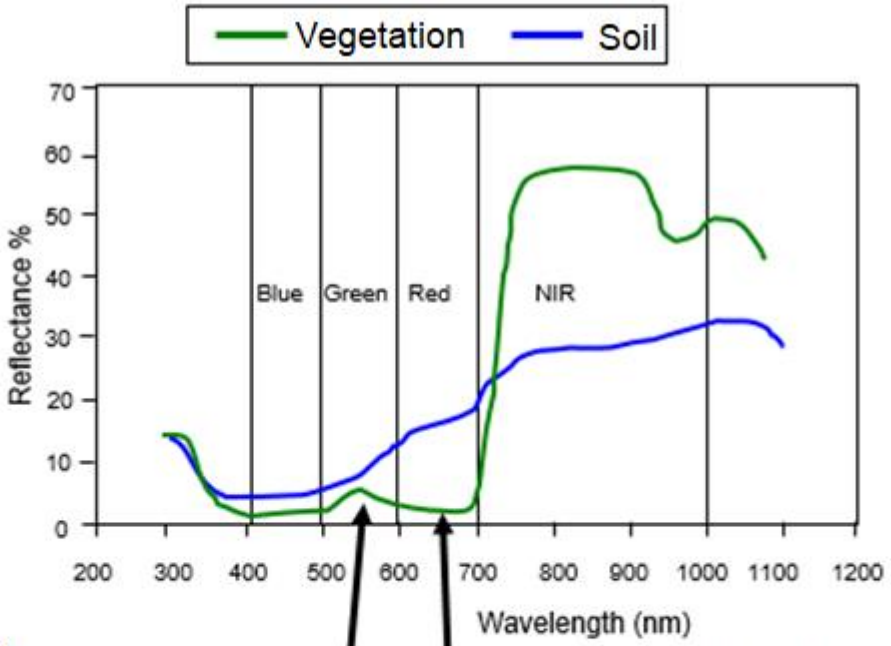
Remote Sensing Applications



High Reflectance at 550nm, characteristic of vegetation, thus green colour

Low Reflectance at 650nm means red light absorbtion by the photosynthetic tissue

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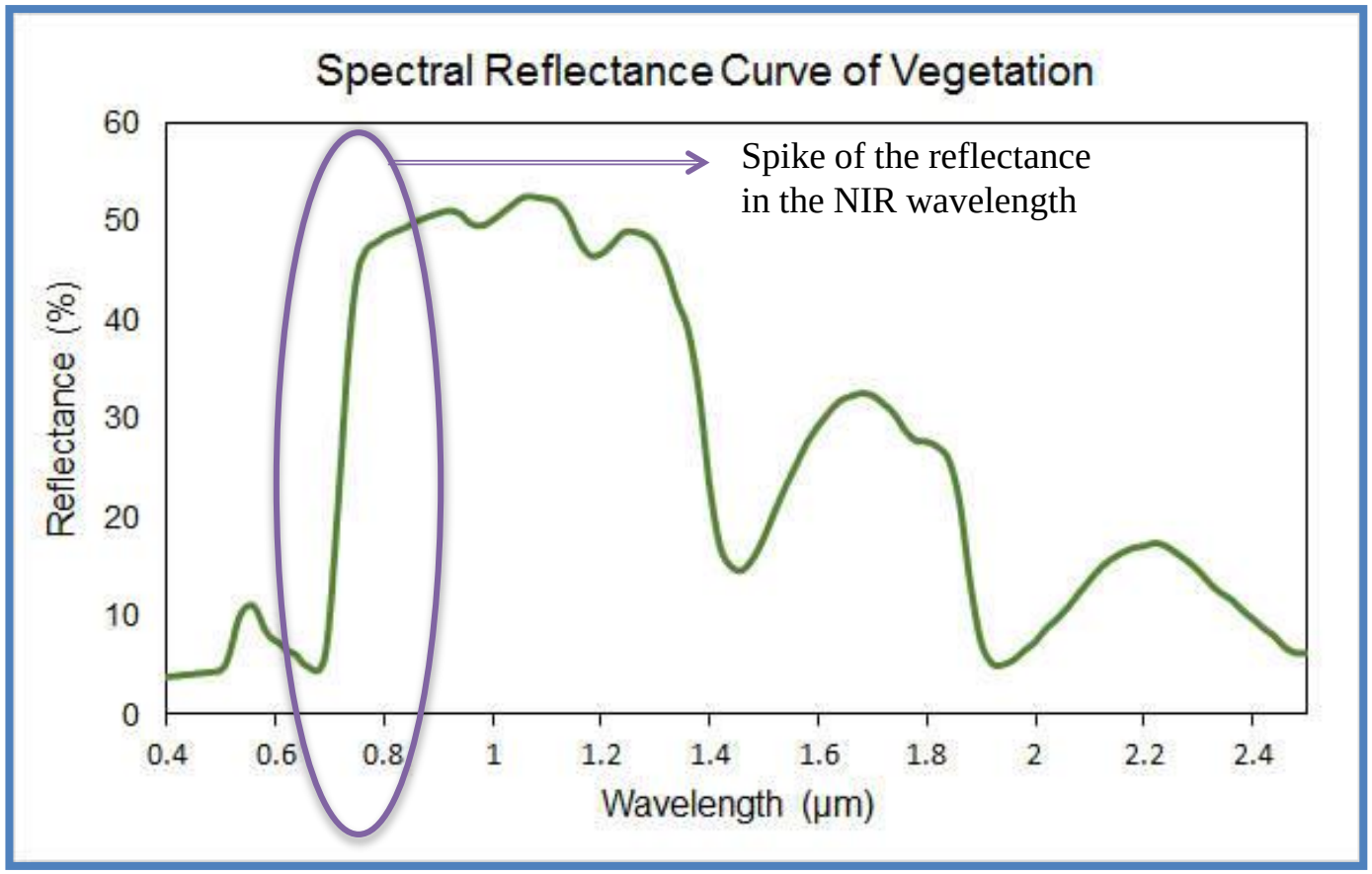
Remote Sensing Applications

- However, there is another unique ability of vegetation: it also reflects most of the Near-Infrared (NIR) light that hits it, due to the spongy mesophyll.
- NIR is placed outside the visible spectrum, and therefore, is not visible by the human eye.

Remote Sensing Applications



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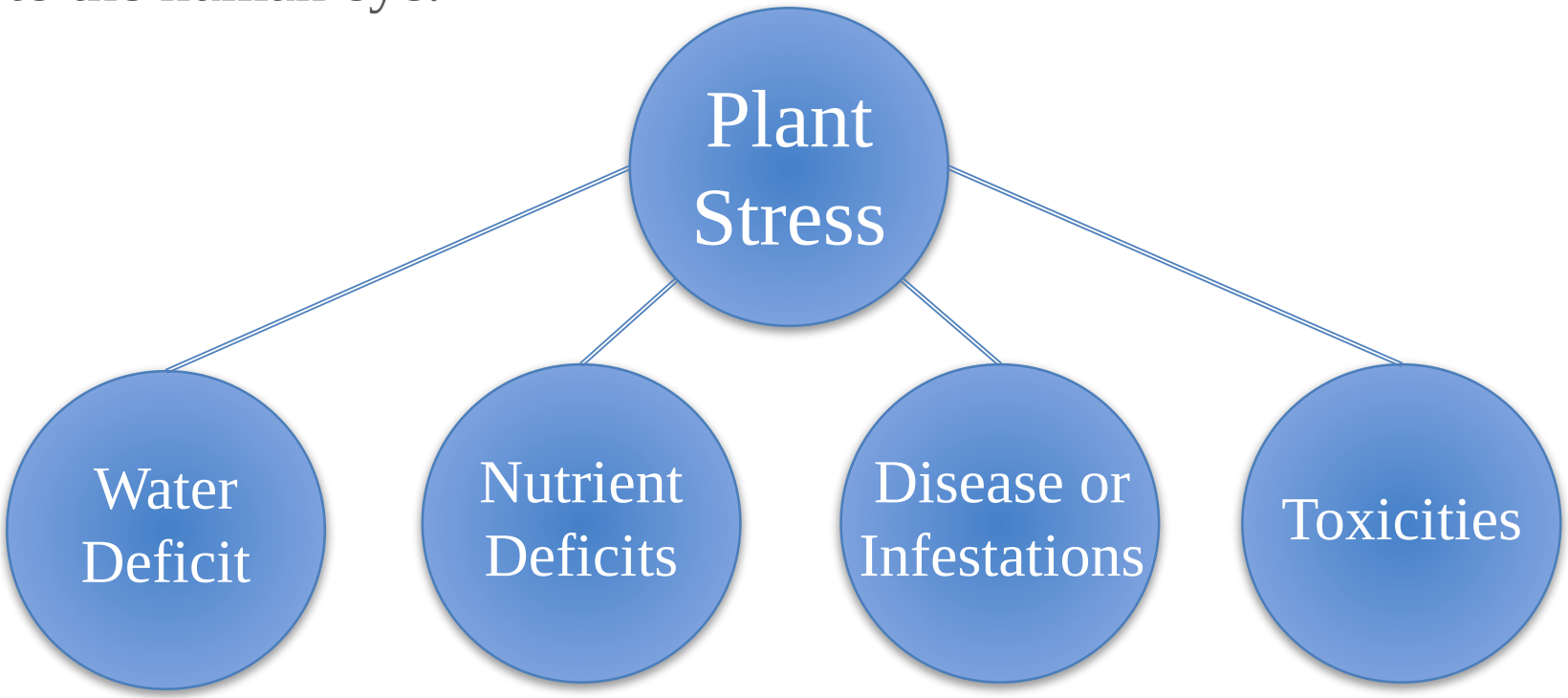
Remote Sensing Applications

- To sum up, plants normally reflect most of the NIR light that hits their leaves (700-800 nm), while they absorb most of the Red one (630-670 nm).
- If this is not the case, it is an indicator that something prevents the plants from performing their biological functions properly.

Remote Sensing Applications

- Such factors can vary, from a source of stress, to a disease infestation. These abnormalities can be detected **quicker** by identifying variations in reflectance, before they become visible to the human eye.



Remote Sensing Applications

Healthy Vegetation

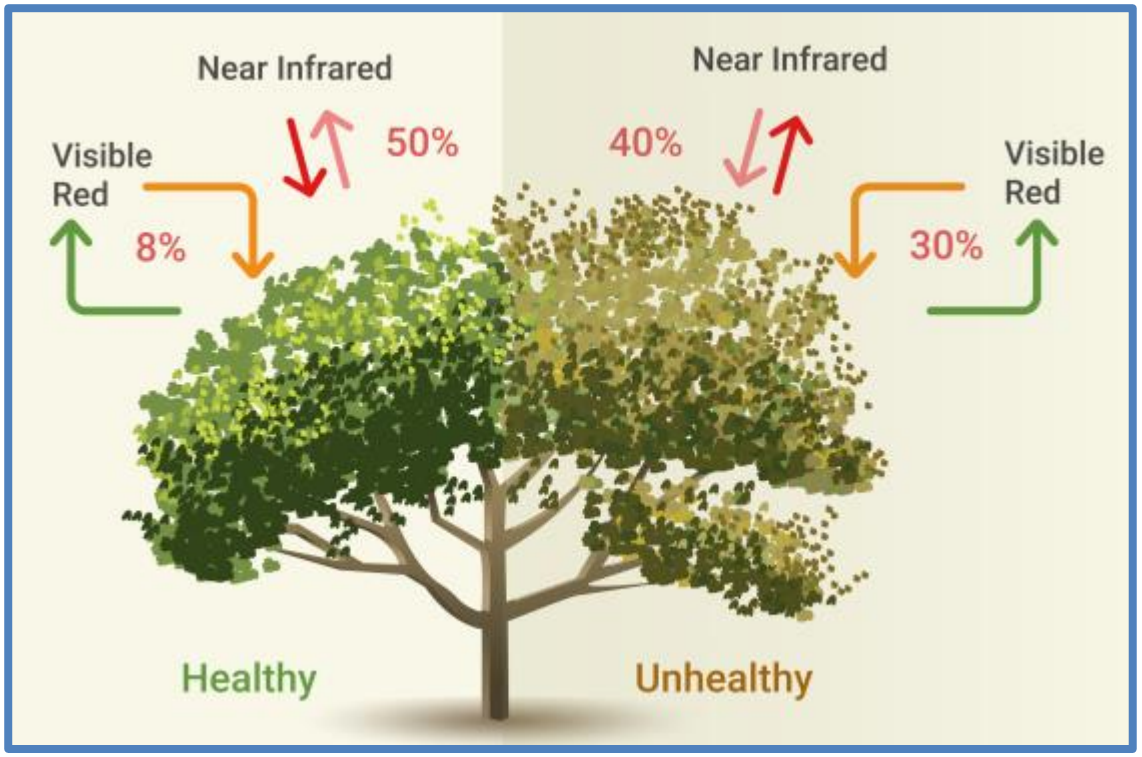
- High Reflectance in Near-InfraRed
- Low Reflectance in Red

Source: Agricolus.com

Remote Sensing Applications

Non-healthy Vegetation

- Low Reflectance in Near-InfraRed
- High Reflectance in Red



Source: Eos.com

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Vegetation Indices

- This knowledge led to the development of mathematical formulas that express the vigor and overall health of vegetation based on the reflectance ratios of different spectra.
- This formulas are known as “Vegetation Indices” and are the core of Remote Sensing in Precision Agriculture.

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Vegetation Indices

- Vegetation Indices provide a simple yet elegant method for measuring plant response throughout the season.
- Most of them are computed as some type of relationship between reflected light in the visible and NIR wavelengths

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Vegetation Indices

- The most widely used VI is the **Normalized Difference Vegetation Index** or **NDVI**.
- It quantifies vegetation very effectively by measuring the difference between near-infrared and red light reflection. NDVI is very good at detecting uneven patterns of growth within a field.
- NDVI ranges from [-1 to +1], but in vegetation it takes values from [0.2 to 1].

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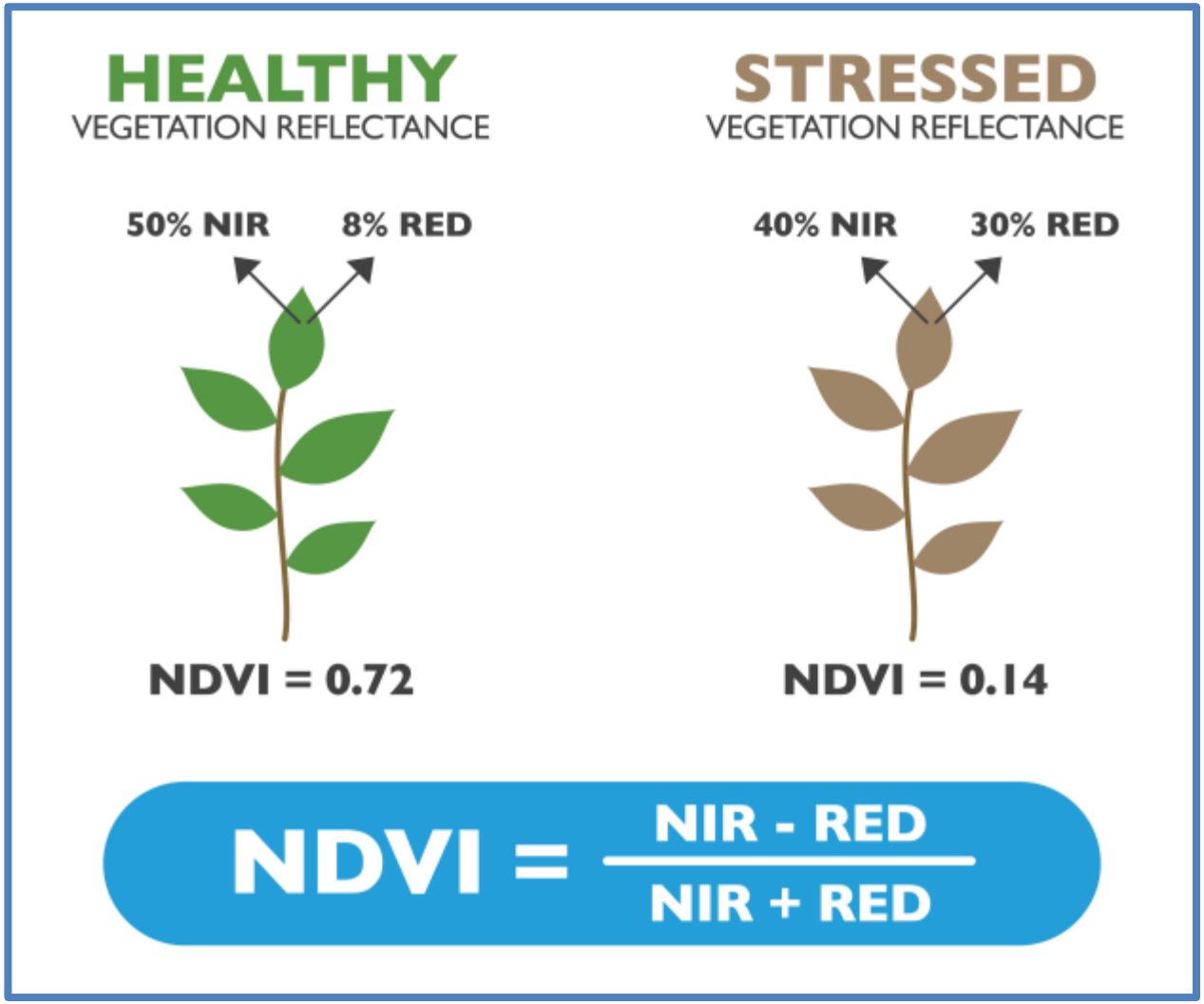
Vegetation Indices



Source: Agricolus.com

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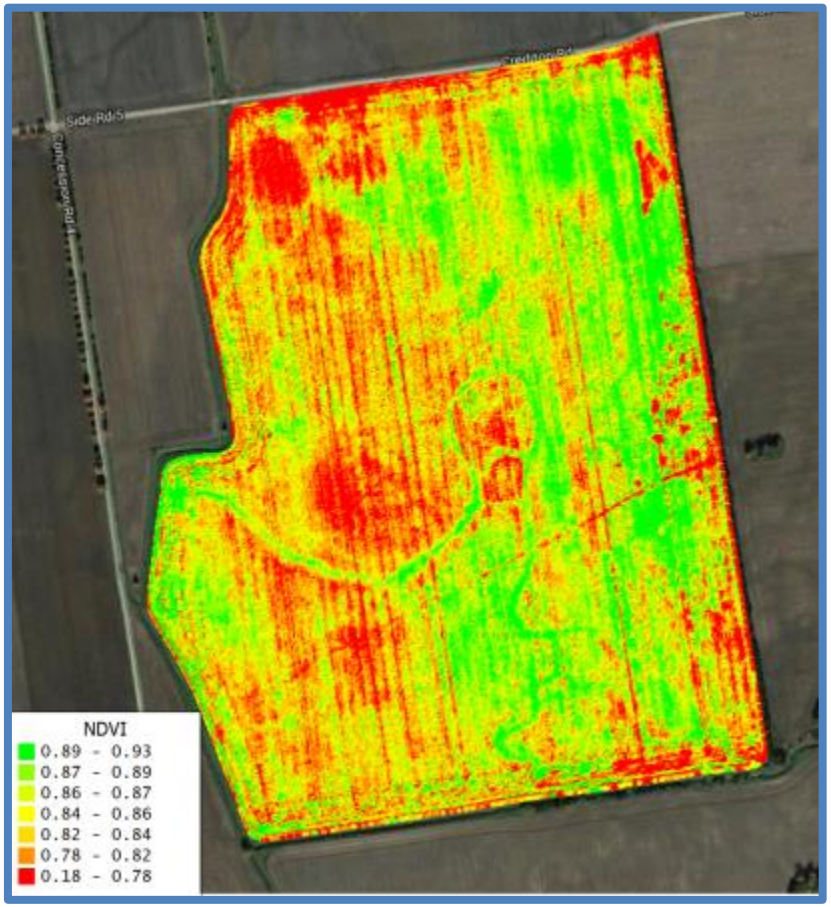
Vegetation Indices

- The map on the right is an NDVI map
- It demonstrates which areas have more dense and healthy vegetation.
- Based on the vegetation indices' values, different treatments can be applied according to each zones needs.



Source: Pix4d.com

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Vegetation Indices

- Although NDVI is an excellent tool to identify problematic zones within a field, its abilities can often be misleading, because it simply lacks diagnostic capability
  - "NDVI is not good for identifying the cause of an observed agronomical problem, but rather powerful for indicating where and when there is a problem".

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Vegetation Indices

- Specialized Indices have been developed for specific applications, on certain phenomena and can identify accurately occurrences such as disease outbreaks and nutrient deficits.
  - Narrow-band indices are designed to address specific stress factors.
  - Show promise for diagnosing water and nutrient stress.

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Remote Sensing Data

- Remote sensing data collection is based on the principle of 'isolating' specific spectral reflection wavelengths, resulting in **multispectral imagery**, images in which each pixel represents a reflectance value of the respective channel/band.

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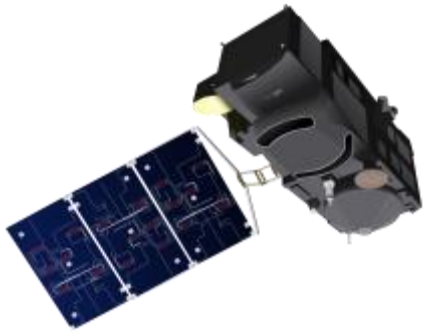
Reflectance Data

- Spectral Reflectance data acquisition can be performed in 3 “layers”.
- Each datasource differs in accuracy and ease of data collection.



Satellites

Several hundreds kms

Drones

20-150 m

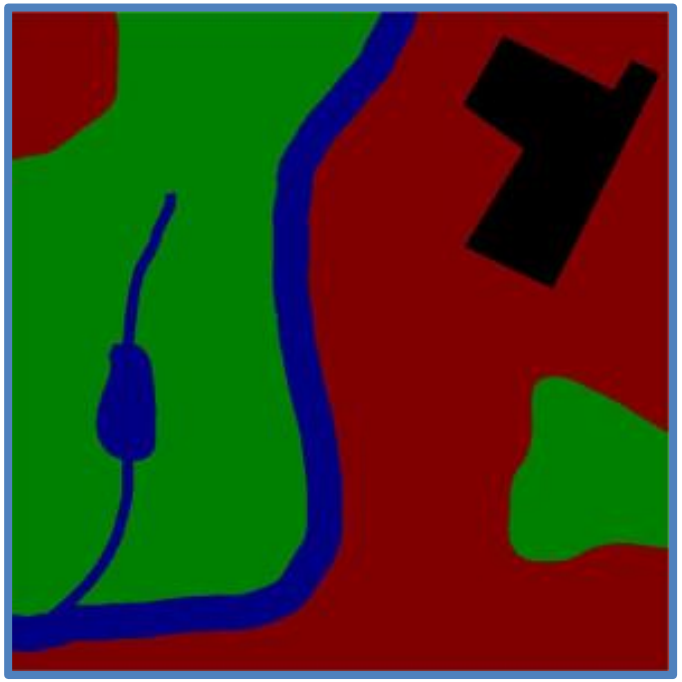
Handheld

Ground Level

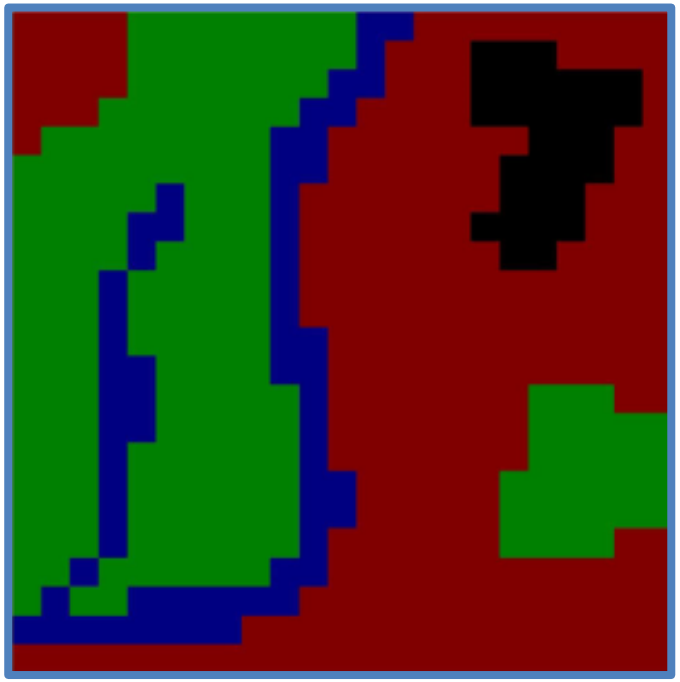
Reflectance Data

- Two main data structures:

Vector Data
mainly proximal sources



Raster Data
mainly remote sources



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Raster Data

- **Imagery Data**
- Red-Green-Blue (RGB) is imagery in the visible spectra.
- Similar to normal photography.
- Each pixel has a unique value for each of the three colors (red, green and blue) that create the image as we see it

RGB
Red: Band_1
Green: Band_2
Blue: Band_3

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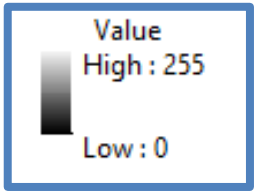
Raster Data

- Multispectral imagery contains data of a **single band** (NIR in this image), and each pixel represents the reflectance value of that point.
- The grayscale tone of the pixel indicates the reflectance value.



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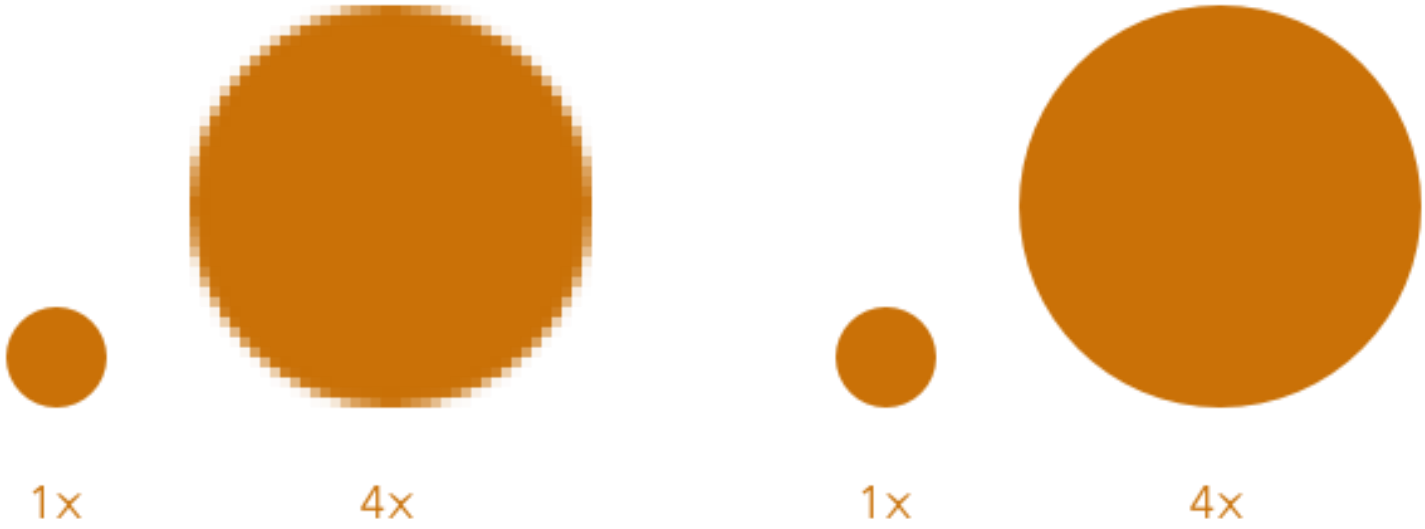
Raster Data

- Sensor Resolution in Remote Sensing:
  - **Spectral**: number of bands measured by sensor
  - **Radiometric**: sensitivity of sensor to detect differences in signal strength
  - **Spatial**: ability of sensor to distinguish small objects; defines PIXEL size
  - **Temporal**: frequency of revisit time (in satellites)

Vector Data

- Vector files are made up of **points, lines and polygons** to create paths.
- Vectors can be scaled up and down **without losing quality** (pixelate).



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Satellites in Agriculture

- The sensors that are carried by satellites usually measure energy.
- Based on that attribute, they can be divided into passive and active sensors.
- Active (or optical) satellites help us with canopy, while passive (or radar) satellites help us with structure.

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Satellites in Agriculture

- The **active** sensors have their own energy source, projecting it towards the objects that occupy the surface of the globe and then measure the energy that is returned. An example of radar satellite sensor is the Sentinel 1 from ESA.
- By the ratios between the energy emitted and reflected we can study the type of objects and their structure.
- Active sensors are used to study soil texture, soil-water-plant interaction, yield prediction, different species detection and plant structure.

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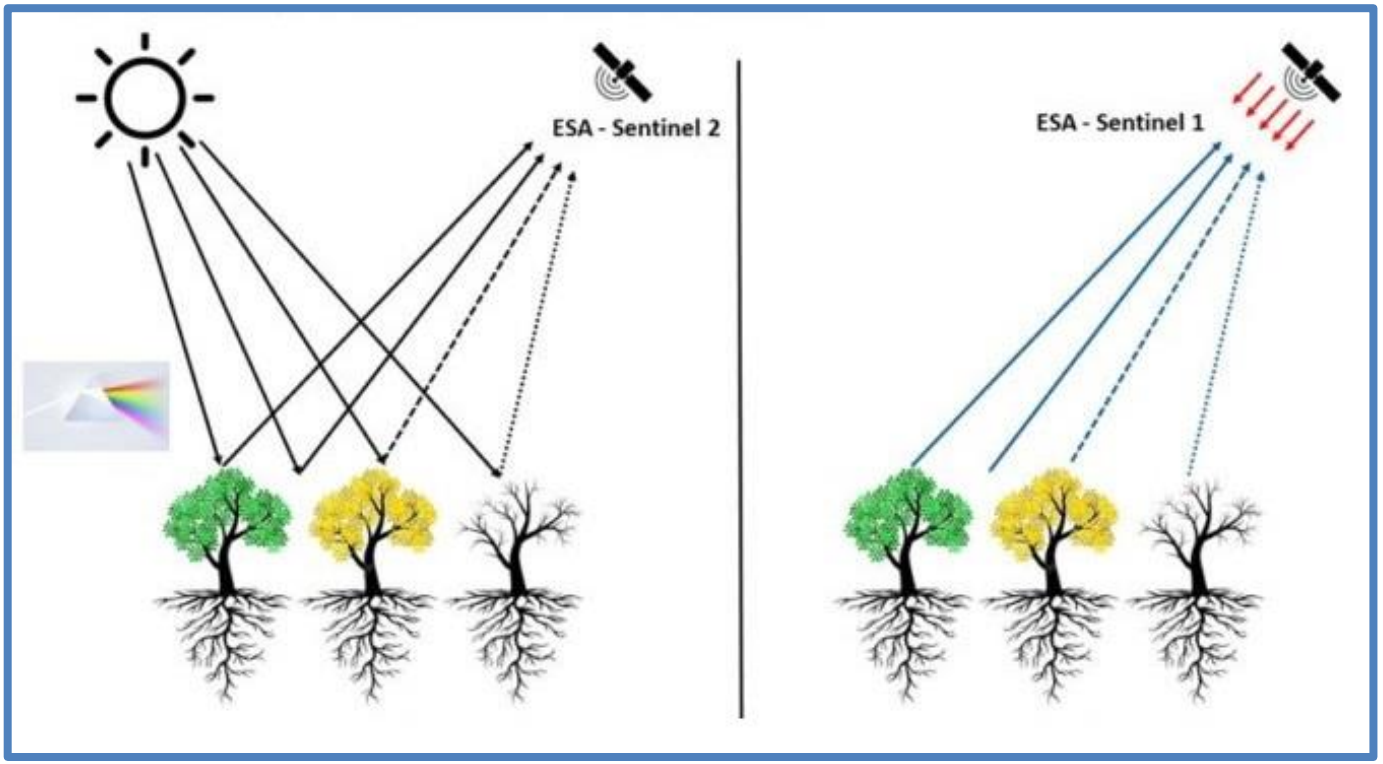
Satellites in Agriculture

Example of **passive (left)** and **active (right)** satellite sensors



source: Sparkle Project

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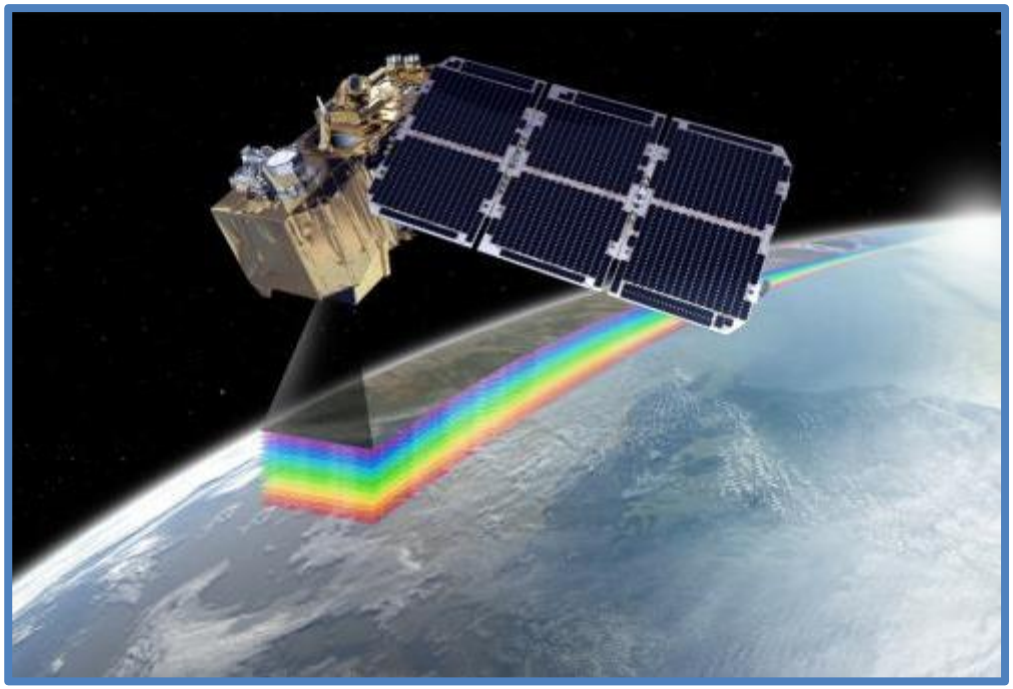
Satellites in Agriculture

- **Passive** sensors measure reflected energy, and therefore do not need to project any energy source of their own towards the target area or object. Such sensors are the Sentinel 2 from ESA and Landsat 8 from NASA.

- Sensors of this type have the most applications in agriculture, since they measure spectral reflectance.



Source: ESA

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LandSAT Platforms

- MSS
  - 80 m resolution

- TM
  - 30 m resolution
  - 120m for channel 6

LandSAT Thematic Mapper (TM) Characteristics

Band	Wavelength	Response	Resolution
1	0.45 - 0.52	Blue-Green	30
2	0.52 - 0.60	Green	30
3	0.63 - 0.69	Red	30
4	0.76 - 0.90	Near IR	30
5	1.55 - 1.75	Mid-IR	30
6	10.40 - 12.50	Thermal IR	120
7	2.08 - 2.35	Mid-IR	30

LandSAT Multispectral Scanner (MSS) Characteristics

LandSATs 1-3	LandSATs 4-5	Wavelength (micrometers)
Band 4	Band 1	0.5 - 0.6
Band 5	Band 2	0.6 - 0.7
Band 6	Band 3	0.7 - 0.8
Band 7	Band 4	0.8 - 1.1
Band 8		10.4 - 12.6

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Satellites in Agriculture

- For satellite data, although very high resolution has been achieved (i.e. 10x10 m^2 / pixel) for **open data**, problems such as cloud coverage and the visiting frequency, during which the satellite is above an area in every orbital and only then can collect data remain without any substantial answer.

Proximal Reflectance Sensors

- Sensors that collect data at ground level are called proximal reflectance sensors.
- These type of sensors obviously offer the highest possible accuracy, but data acquisition is several times more time consuming and requires physical presence inside the field.
- This type of data is often used as **Ground Truth** for remote datasets – Measurements that are used to evaluate the accuracy and validity of the Remote measurement.

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Proximal Reflectance Sensors

Agricultural vehicles mounted with reflectance sensors.

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Drones in Agriculture

- At the last datasource level we come across a new technology, Unmanned Aerial Vehicles (UAVs, or simply Drones), which deliver high quality data quickly and effectively.

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Drones in Agriculture

- Drones have all the advantages of satellites, with almost no drawback.

  - Can cover large areas quickly.
  - No physical presence is required inside the field.
  - Can perform data collection any time.
  - Not affected by cloud coverage.
  - High quality imagery, flights are often lower than 100m altitude.

Drones in Agriculture

- Satellites, however, maintain advantages such as:

  - There are historical data from previous periods always available.
  - Imagery of sufficient accuracy for most agricultural applications is open data and therefore free.
  - They do not require specialized personnel to perform data collection.

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Thermal InfraRed

- Another wavelength band that interests agricultural science is that of the Thermal Infrared.
- This band is fundamentally unlike any other, because it is **not reflected**, but **emitted**.

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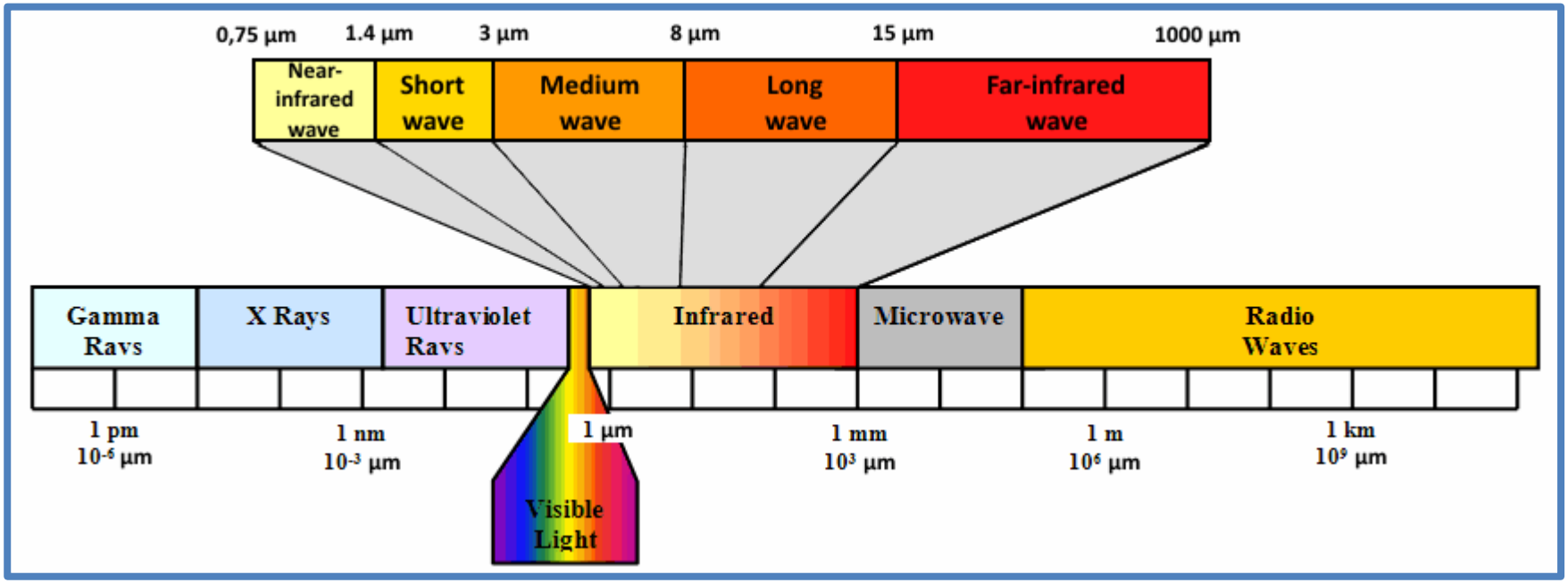
Thermal InfraRed



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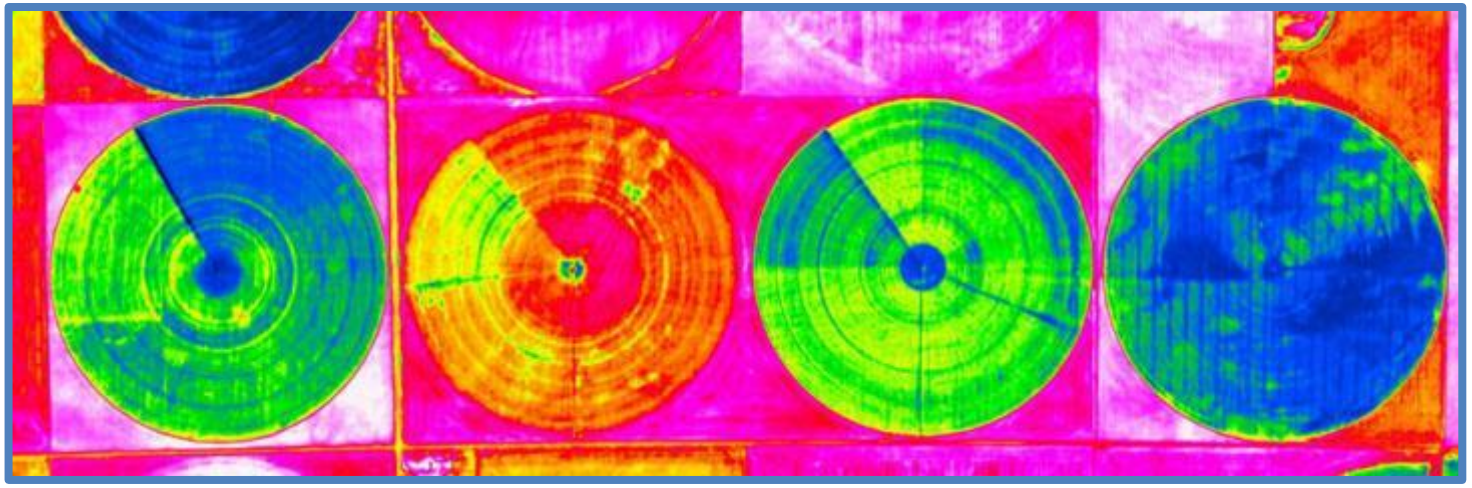
Thermal InfraRed

- Every object absorbs and emits thermal energy differently, based on its thermochemical attributes, and most importantly its thermal capacity.
- Water has high thermal capacity, and therefore high moisture content keeps the plants at low temperature.



source: Cornerstone Mapping

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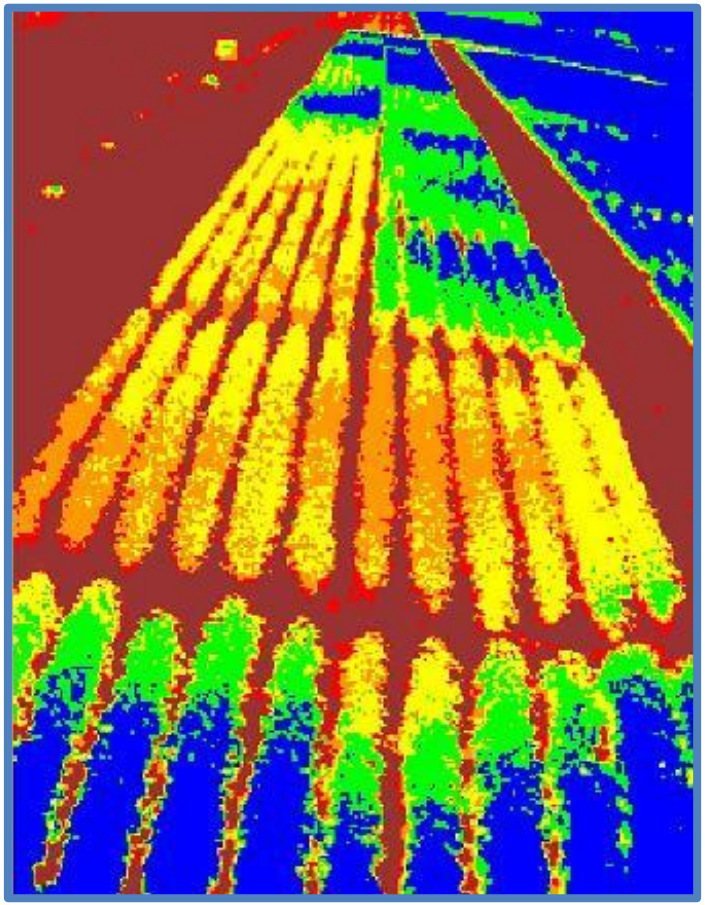
Thermal InfraRed

- TIR is more sensitive to water stress.
- Thermal plant water stress indices typically provide adequate lead time for scheduling irrigations.
- Satellites such as Lansdast also cover the TIR spectrum, but with very low reliability (resolution of 120mx120m).



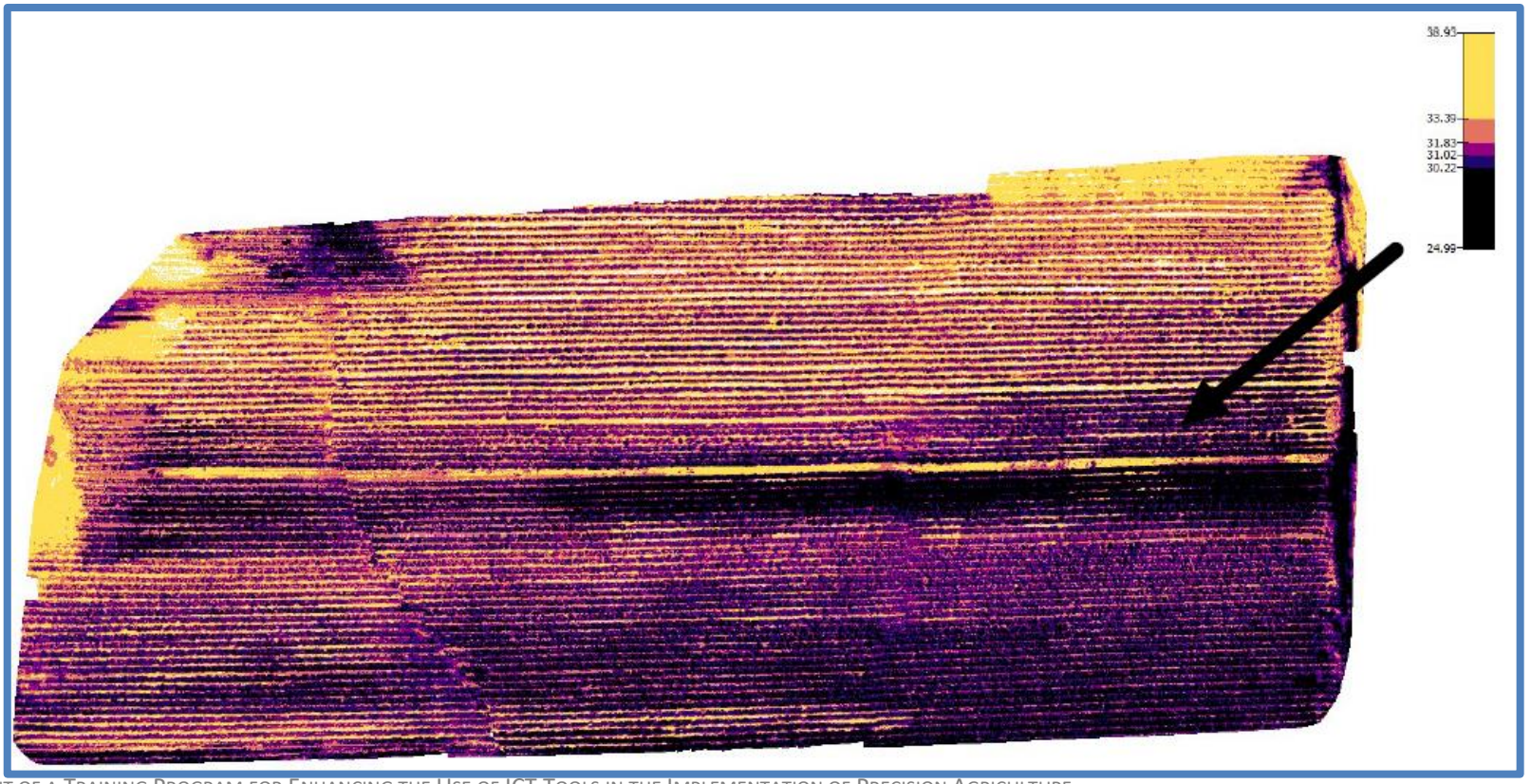
source: IsraelAgri

Thermal InfraRed

- Drones mounted with thermal sensors are capable of collecting higher resolution data, similar to the reflected bands.

Thermal InfraRed

- Soil properties and structure can also be studied, since soils retain water differently as well.



DEVELOPMENT OF A TRAINING PROGRAM FOR ENHANCING THE USE OF ICT TOOLS IN THE IMPLEMENTATION OF PRECISION AGRICULTURE

Project coordinator

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Partners

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