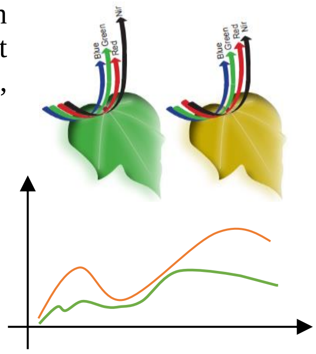
B1.5 Spectral monitoring and indices

Sensors – how does a sensor work?

The ***sensors*** can detect very subtle differences in vegetation that would remain hidden under normal observation. **Satellites** or **drones make** it possible to install remote sensors that monitor differences in vegetation from a long distance, quickly, in short intervals and with high accuracy. There are sensors that can collect data even when the sky is covered with clouds.

The sensors use light in the range of 200-2000 nanometers, the human eye can distinguish between roughly 200-700 nanometers. The *light reflection*[1] that the sensor captures (the so-called spectral band) is dependent on the chlorophyll content and therefore also on the health of the plants. The most useful satellites are *Sentinel-1 backscatter* and *Sentinel-2 NDVI* (Copernicus). Since 2014, the Sentinel satellites have been the main satellites of the Copernicus remote sensing program managed by the European Union in cooperation with the European Space Agency.

1) Example: A green leaf reflects more light in the infrared and green wavelengths, a leaf full of water reflects less light; this will make it possible to distinguish between soil, green vegetation, dry vegetation, etc.



What sensors to use?

The *spatial resolution* of the sensor is important for agricultural practice. It is expressed in a unit called a *pixel*. A pixel is the smallest possible element or area that a sensor can record as a separate unit. Sensors with high (or fine) resolution display both large and very small objects. For farmers, a resolution of 0.5 pixels per meter or less is suitable, which is sufficient to distinguish the variability in the field.

Another important characteristic of the sensor is *radiometric resolution*[2]: the sensitivity of the sensor to detect colours. The finer the radiometric resolution, the more sensitive the sensor is to detecting differences in the amount of reflected or emitted energy. The brightness of the image depends on the number of bits used to represent the sensed energy. Image brightness values in a black and white image are often represented by grey levels ranging from 0 (white) to 255 (black) (referred to as 8 bits).

Types of sensors

Remote sensors are classified as passive or active depending on the light source. ***Passive sensors*** measure the amount of solar energy reflected from objects. Because these sensors rely on sunlight, data can only be recorded when the sun is shining on the target area and cloud cover is minimal.

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[1] Reflection is when light bounces off an object. If the surface is smooth and shiny, like glass, water or polished metal, the light will reflect at the same angle as it hit the surface. This is called specular reflection. Light reflects from a smooth surface at the same angle as it hits the surface. For a smooth surface, reflected light rays travel in the same direction. This is called specular reflection. For a rough surface, reflected light rays scatter in all directions. This is called diffuse reflection

[2]3 The radiometric resolution specifies how well the differences in brightness in an image can be perceived; this is measured through the number of the grey value levels, measured in bits. An 8-bit representation has 256 grey values, a 16-bit (ERS satellites) representation 65.536 grey values.

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These limitations often limit data collection around midday to maximise available sunlight. Passive sensors are sensors mounted on satellites (for example Landsat or QuickBird) or aircraft.

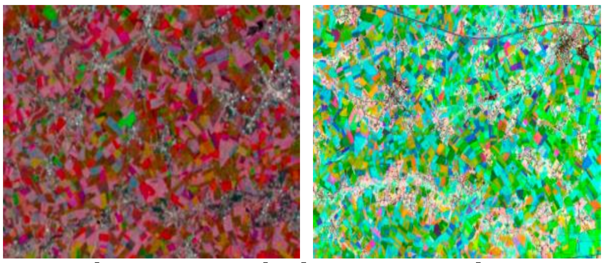
Active sensors use their own modulated light at defined or fixed wavelengths. The sensor illuminates the object and uses photodiodes to measure the part of the light that is reflected. One of the primary advantages of active sensors over passive sensors is their ability to obtain measurements at any time, regardless of time of day or season, while eliminating the influence of sun angle and cloud cover. Active sensors include sensors mounted on satellites are, for example, Radarsat, Ikonos, QuickBird, Landsat, Spot, Rapideye, EO-1 Hyperion etc.

From the values of the reflected spectral bands, the so-called *vegetation indices* are calculated for crop evaluation as reflectance ratios between two spectral bands. Vegetation indices are used to assess vegetation condition, cover and growth, as well as attributes such as *leaf area index* (LAI) and *plant height*.

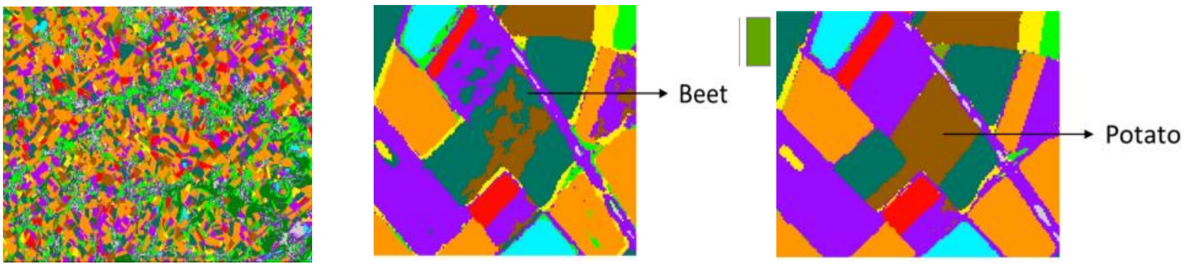
The data is scanned in time intervals, processed and the result displayed in ***symbolic maps***. The processing is demanding, but automated, so that the user receives it in an understandable form.

2) Example: The identification of crops in fields on a landscape image is based on the analysis of the colour's spectrum. The rich information on agricultural land that is presented in *synthetic aperture radar* (SAR) backscatter observations.

And the same area, after evaluation taken by *Sentinel-2 NDVI*, demonstrates the difference in temporal NDVI mosaic across different agricultural parcels. Final result after complete evaluation, based on Sentinel-1 and -2 inputs, shows a detailed view on the classification results in a highly diverse arable landscape.



The colors in the boxes represent individual crops: Winter wheat - Winter barley – Rapeseed – Maize – Potato -Beet - Flax Grassland -Forest - Built-up – Water – Other



In the near future, all areas of agricultural crops in the EU will be under the surveillance of Sentinel satellites. In real time, the State will be able to control almost all the production areas of farmers, determine subsidies, and control production.

Properly chosen colour synthesis can point to possible plant stress or soil erosion based on different colour shades – in addition to the monitoring of healthy and prosperous growth of the plant. For example:

– Blue: differentiating vegetation from bare soil.

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- Green: vegetation characteristics, local maximum of reflectiveness.
- Red: differentiating vegetation from bare soil, absorption band.
- Vegetation Red Edge: increase in reflectiveness from vegetation, determining vegetation health etc.

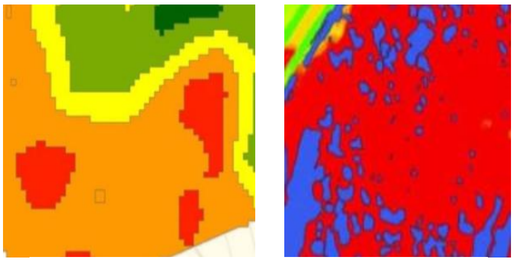
The remote sensor's ability to detect subtle differences in vegetation makes it a useful tool for *quantifying within-field variability*, *assessing crop growth*, and *managing fields* based on current conditions that may be missed using typical ground-based visual survey methods. Remote sensing technology has a number of applications, including *environmental monitoring*, *site-specific agronomic management*, *land cover classification*, *climate and land use change detection*, and *drought monitoring*.

3) Example: a) Spreading dose of fertilising winter wheat with NPK fertilisers on a plot of 25 ha. Doses in kg per ha: red 80 kg, beige 90 kg, yellow 100 kg, dark green 120 kg. A higher level of nutrition is provided to locations with a higher expected yield.

4) Example: b) Targeted intervention with herbicide according to the map from the detailed monitoring of weeding on a plot of 36 ha (creeping thistle); 39% of the area was treated.

Satellites can assist growers in areas of:

- Detecting and controlling pests and disease.
- Understanding water and nutrient status.
- Planning crop nutrition programmes.
- Informing in-season irrigation.
- Predicting yields.
- Estimating harvest timing.



a) b)
Source: https://ahdb.org.uk

Be careful when dealing with service providers. It is best to procure as an advisor an educated practitioner who can see under the hands of the service providers: what data they use, what properties they have, what methods are used and why. The guaranteed "*Relative income potential*" must be verified, all relevant documents must be documented. It should include as many entries as possible describing the monitored location.

It is also possible to use the Free Images service - as part of the Copernicus (Sentinel) program or *Landsat series images*, where each interested party can check how the data collection works on their property and its reflectivity in individual bands of the spectral curve.

Summary

The sensors can detect very subtle differences in vegetation that would remain hidden under normal observation. Satellite devices, or drones, make it possible to install remote sensors that monitor differences in vegetation from a long distance, quickly in short intervals and with high accuracy. Remote sensors are classified as passive or active depending on the light source. Passive sensors measure the amount of solar energy reflected from objects. Because these sensors rely on sunlight, data can only be recorded when the sun is shining on the target area and cloud cover is minimal. Active sensors use their own modulated light at defined or fixed wavelengths. The active sensor illuminates the object and uses photodiodes to measure the part of the light that is reflected at any

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time, regardless of time of day or season, while eliminating the influence of sun angle and cloud cover. The data is scanned in time intervals, processed and the result displayed in symbolic maps. The processing is demanding, but automated, so that the user receives it in an understandable form. The remote sensor's ability to detect subtle differences in vegetation makes it a useful tool for quantifying within-field variability, assessing crop growth, and managing fields based on current conditions that may be missed using typical ground-based visual survey methods. Remote sensing technology has a number of applications, including environmental monitoring, site-specific agronomic management, land cover classification, climate and land use change detection, and drought monitoring.

Links to relevant topics

A more detailed description of the issue, with many pictures, recommended:

https://ahdb.org.uk/knowledge-library/satellites-for-agriculture

Land set images:

https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/satellite-description/orbit

https://ahdb.org.uk/knowledge-library/satellites-for-agriculture

Key words

light reflection
Sentinel-1 backscatter
Sentinel-2 NDVI
chlorophyll content
spatial resolution
pixel
radiometric resolution
passive sensors
active sensors
vegetation indices
leaf area index
plant height
symbolic maps
quantifying within-field variability
assessing crop growth
managing fields
environmental monitoring
site-specific agronomic management
land cover classification
climate and land use change detection
synthetic aperture radar
drought monitoring
relative income potential
land sat series images

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