esa space solutions

Copernicus Academy

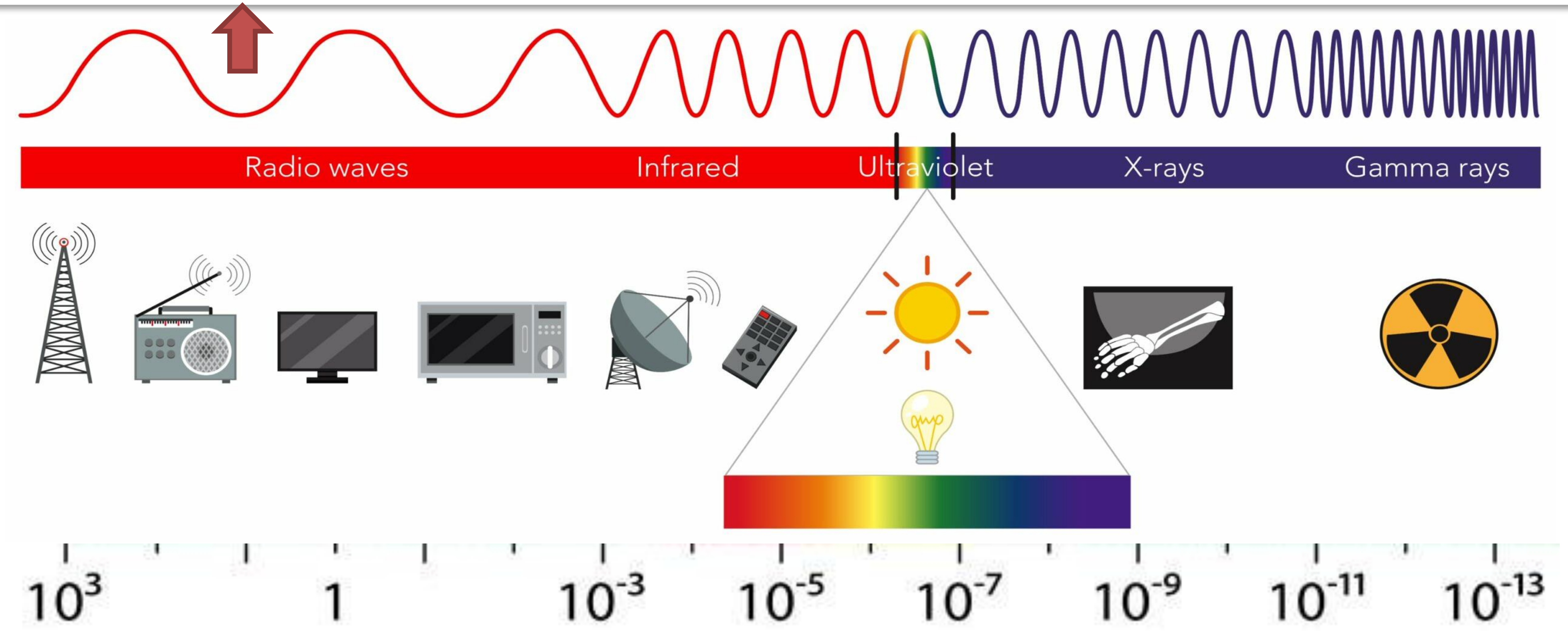
ÚSTAV GEOGRAFIE
Prírodovedecká fakulta UPJŠ v Košiciach

6. SAR and optical remote sensing for precision agriculture 2

SAR and optical for precise agriculture

RADAR SATELLITES
Weather & illumination independence
Penetration through cloud cover

Use: information about the vegetation structure and moisture content



OPTICAL SATELLITES
Weather & illumination dependence
No penetration through cloud cover

Use: spectral (and chemical) properties of vegetation

Source:https://cthrumetals.com/emi-shielding/

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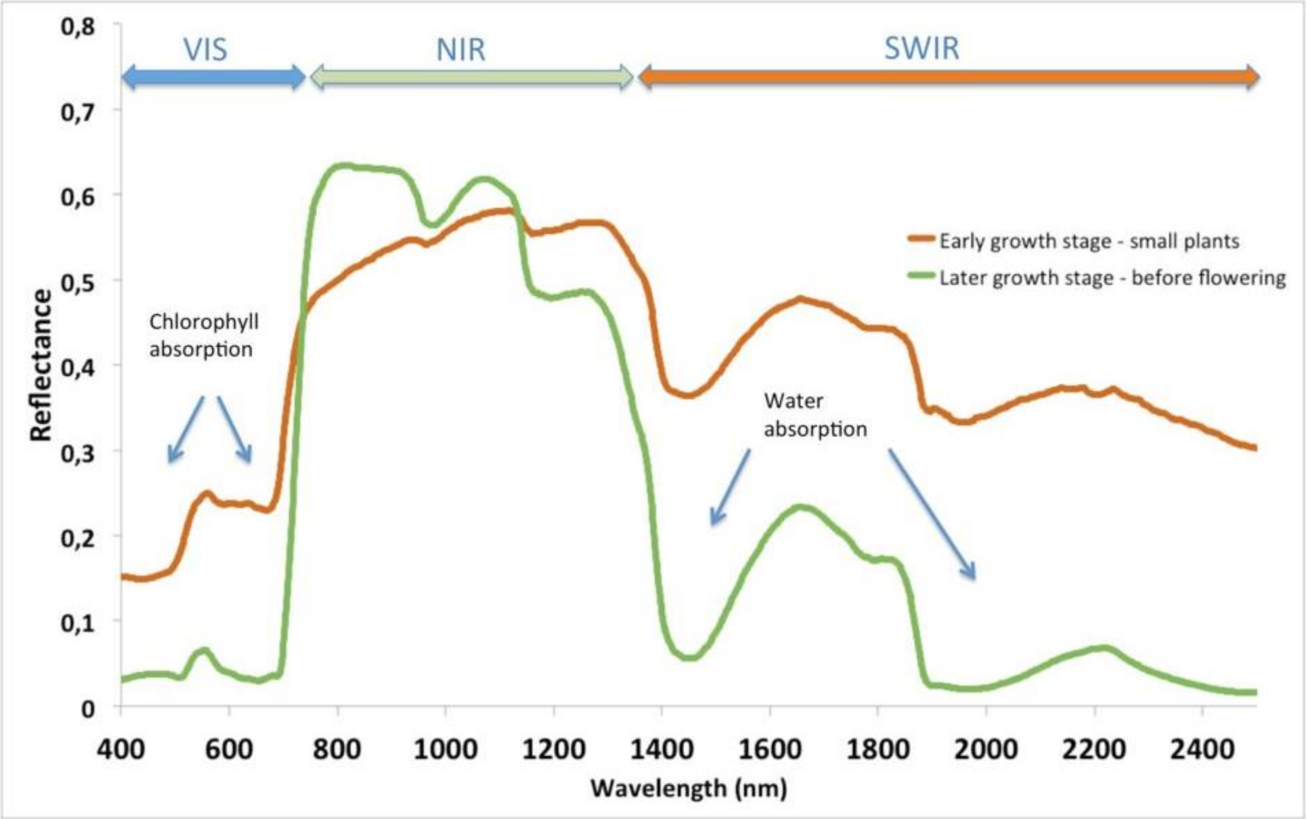
Optical Sensors: Spectral indices - to extract specific signal from spectral signature

- Particular wavelengths are sensitive to particular chemicals and compounds
- Indices take advantage of these wavelength features



Vegetation indices:

- VI - Vegetation Index
- NDVI - Normalized Difference Vegetation Index
- EVI - Enhanced Vegetation Index
- SAVI - Soil Adjusted NDVI
- AVI - Advanced Vegetation Index
- NDMI - Normalized Difference Moisture Index
- …

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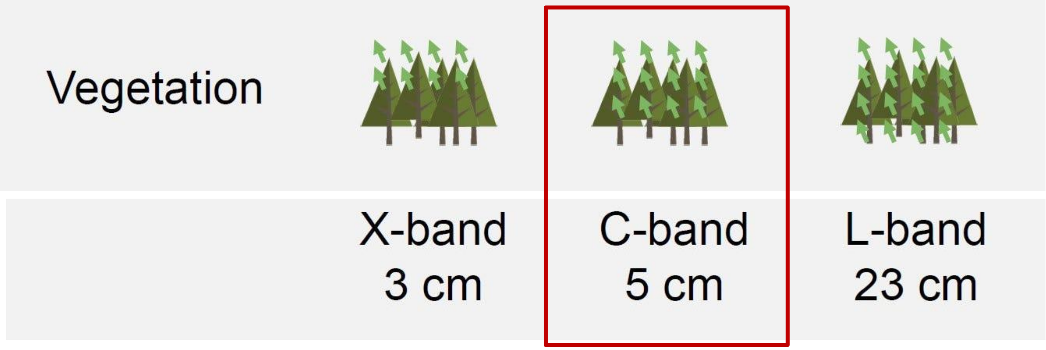
Penetration through vegetation as a Function of Wavelength and dielectric characteristics

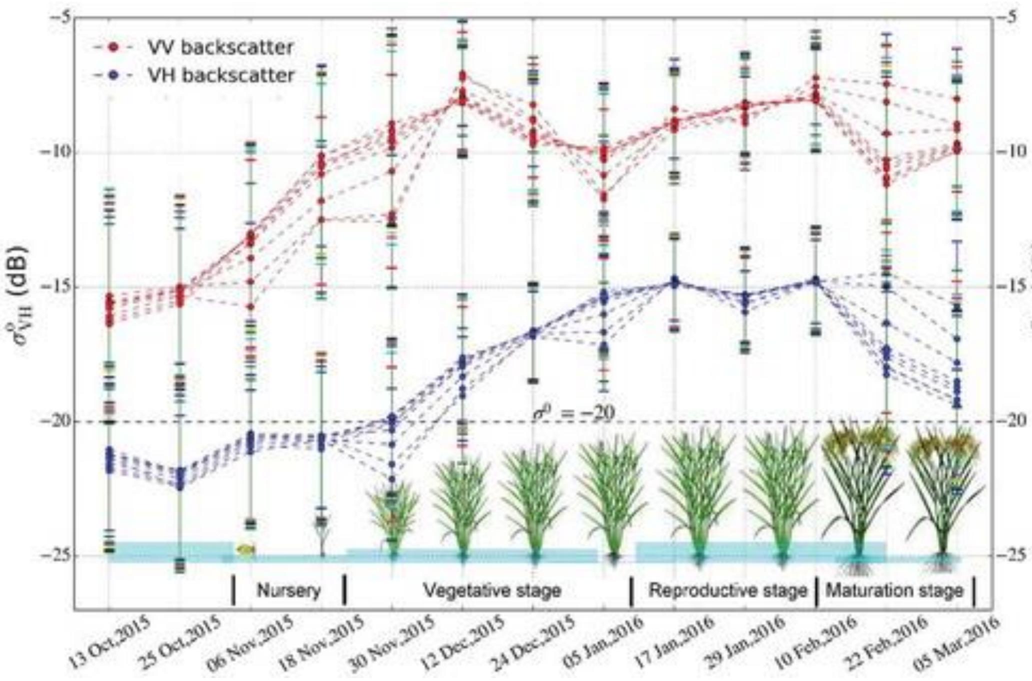
- The penetration depth is depending on **wavelength** and **dielectric characteristics** of objects

Agricultural monitoring

- For agricultural monitoring we need enough penetration into canopy (L- or C-band), but not to deep so that we have soil interference (C- or X-band for lower biomass)
- information about the vegetation structure, moisture content, spatio-temporal changes, harvest time

Source:https://medium.com/@preet.balaji20/decoding-synthetic-aperture-radar-sar-remote-sensing-sar-series-part-1-getting-started-d3409eb3b2e3





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Biophysical variables estimation for agriculture applications

Biophysical variables are plant traits or characteristics of interest which can be measured on the ground and possibly estimate by remote sensing at various scales depending of the sensor spatial resolution

Crop processes	LAI	FAPAR	FCOVER	Albedo	Chlorophyll	Water-content	SLA	soil brightness	Temperature
Photosynthesis	+++	+++			+++		++		
Evapotranspiration	++	+++	+++	++		++			+++
Respiration	++								
Nitrogen	+++				+++				
Phenology	+++	++	++						
Lodging									
Impact of pests	+++								
Soil permanent charac.								+++	
Residues									

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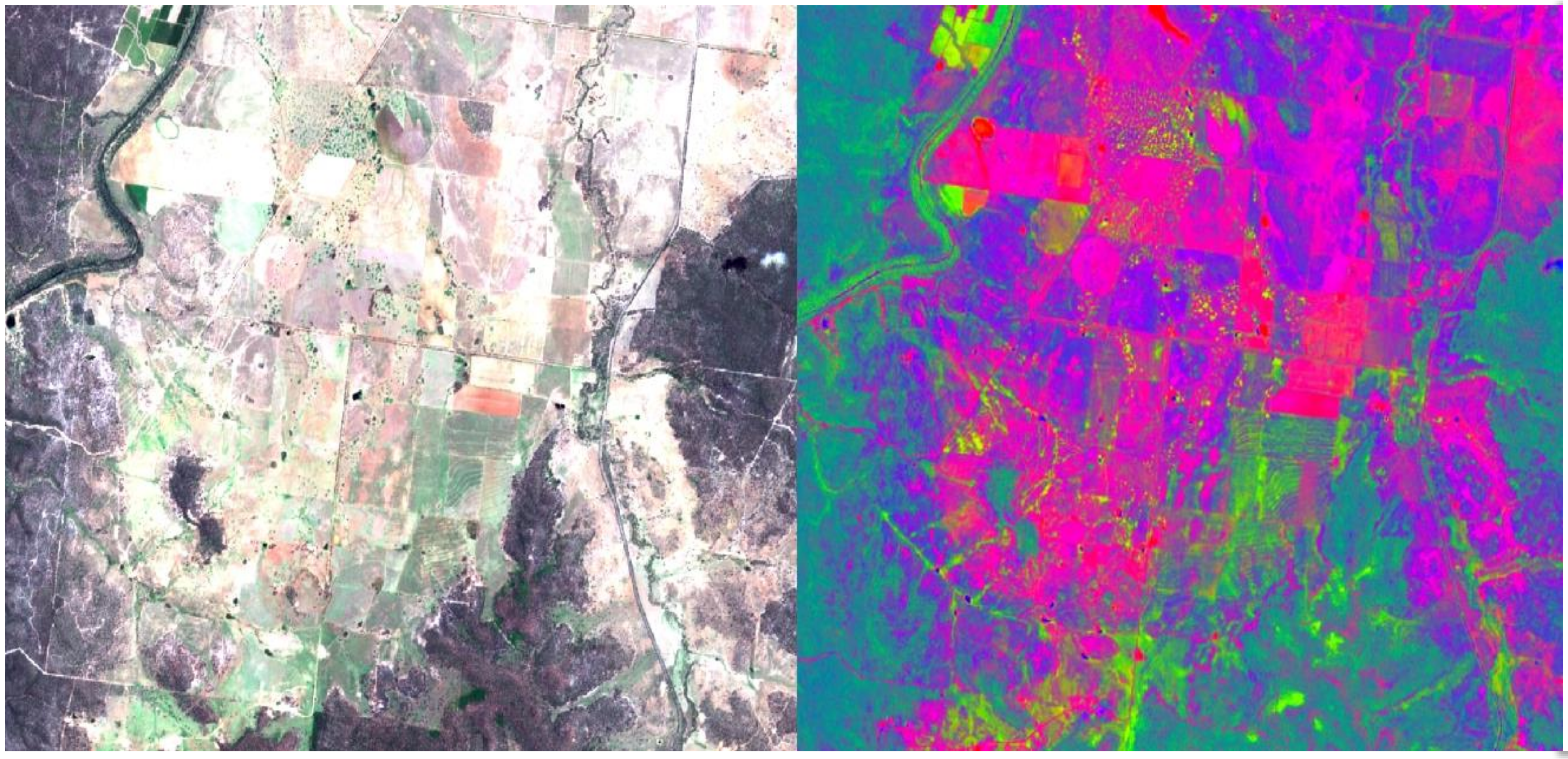
Fraction of green Vegetation Cover – FCover

- Corresponds to the fraction of ground covered by green vegetation
- Quantifies the spatial extent of the vegetation
- Independent of the geometry of illumination (unlike FAPAR)



The image on the left is a true-colour (red, green, blue) Sentinel-2 reflectance image. The darker areas are woodlands. The image on the right shows the same imagery, transformed using a model originally developed for Landsat which estimates fractional vegetation cover from the reflectance values. On each pixel, the proportions of red, green and blue represent the proportion of bare ground, live vegetation and dead vegetation respectively.

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Fraction of Absorbed Photosynthetically Active Radiation - FAPAR

- Quantifies the fraction of the solar radiation absorbed by live leaves for the photosynthesis activity.
- It refers only to the green and alive elements of the canopy
- Depends on the canopy structure, vegetation element optical properties, atmospheric conditions, and angular configuration

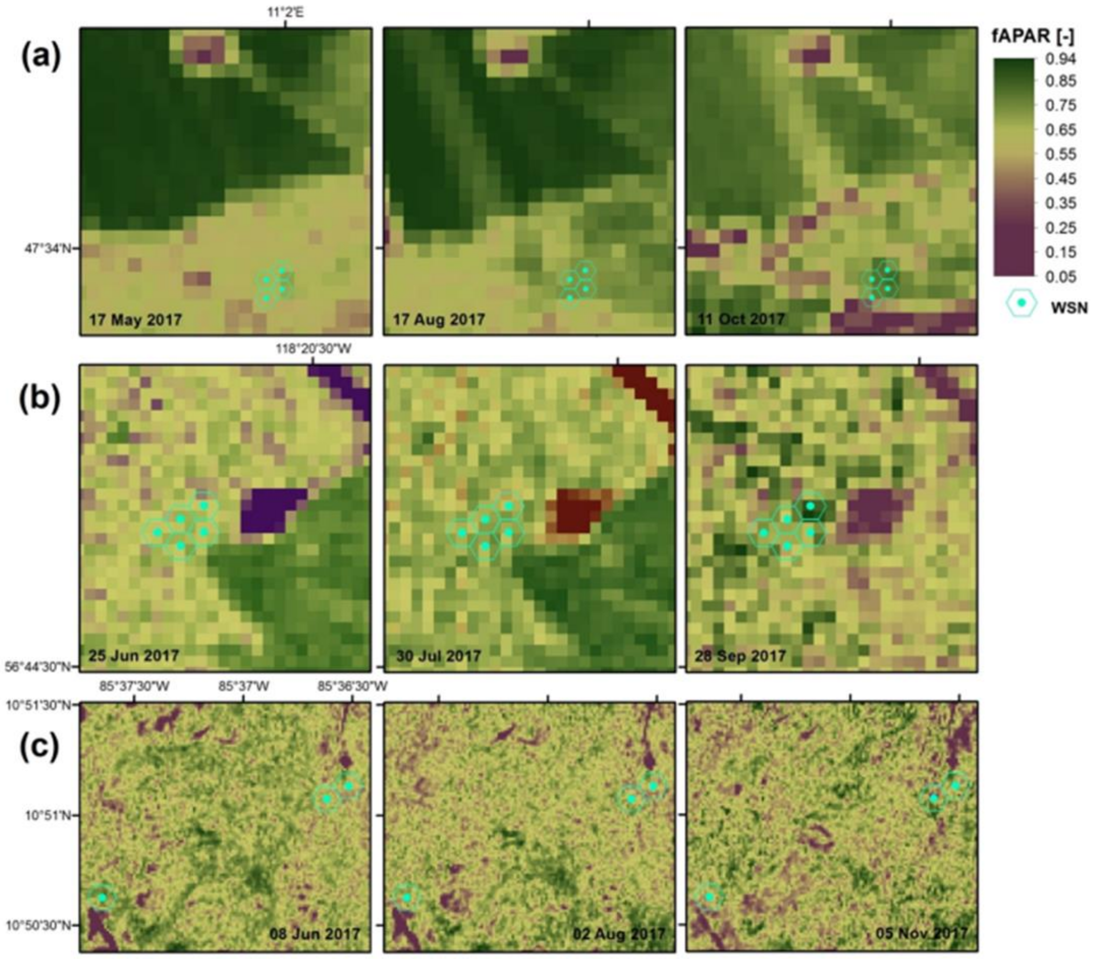

Fig. 7. The S2 fAPAR products at (a) Graswang, (b) Peace River and (c) Santa Rosa for several dates, representing early, peak and end of vegetation periods.

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Canopy Chlorophyll Content (CCC)

The **total amount of chlorophyll a and b pigments** in a contiguous group of plants per unit ground area (in g/m²)

- Closely related to the plant nitrogen content (fertilization)
- Absorption at 675 nm very sensitive to changes in chlorophyll content but only for low CCC values
- Lower chlorophyll absorption at 550 nm, sensitive to a greater range of CCC , not easily saturated but less sensitive to chlorophyll changes

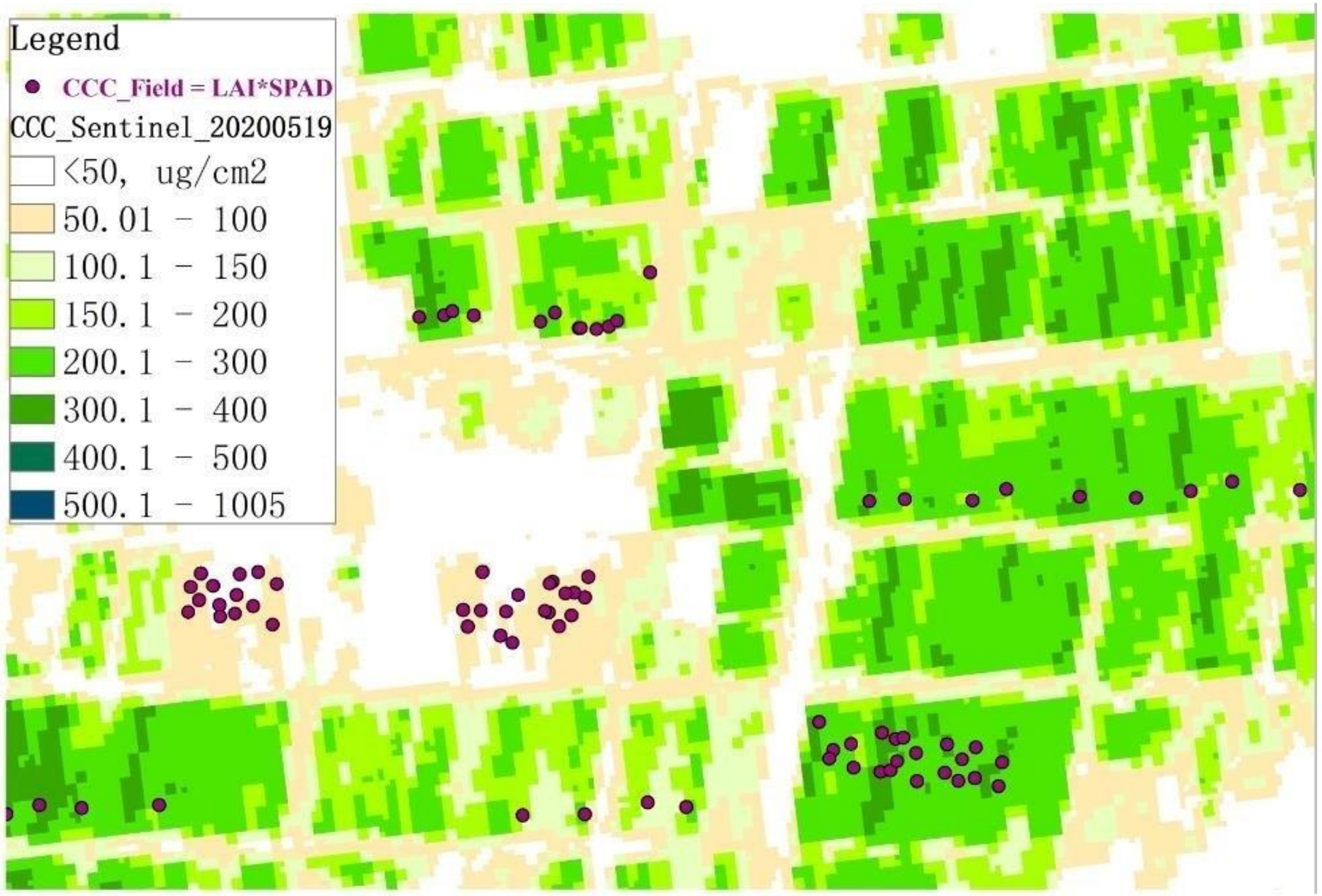

Figure 1 Winter wheat Crown Chlorophyll Content and sample sites in Yucheng, Shandong Province

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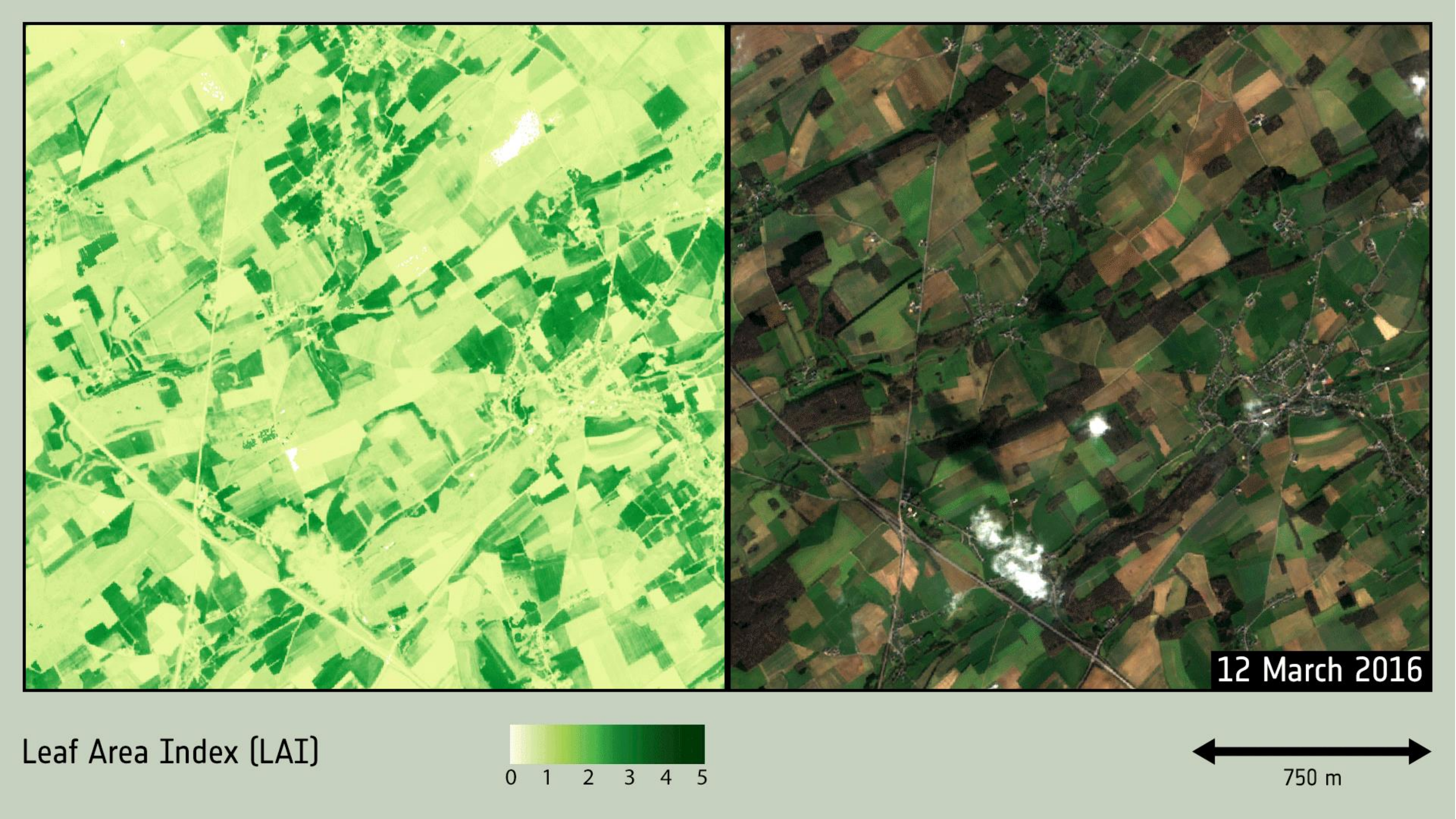
LEAF AREA INDEX (LAI)

LAI is a dimensionless index measuring the one-sided green leaf area over a unit of land (m^2 / m^2).



Data from the Copernicus Sentinel-2 mission can be used to measure the ‘leaf area index’ of vegetation (left). This information can, in turn, be used to monitor crop growth and agricultural practices like harvesting. The animation shows the development of crop fields in Belgium between March and October 2016.

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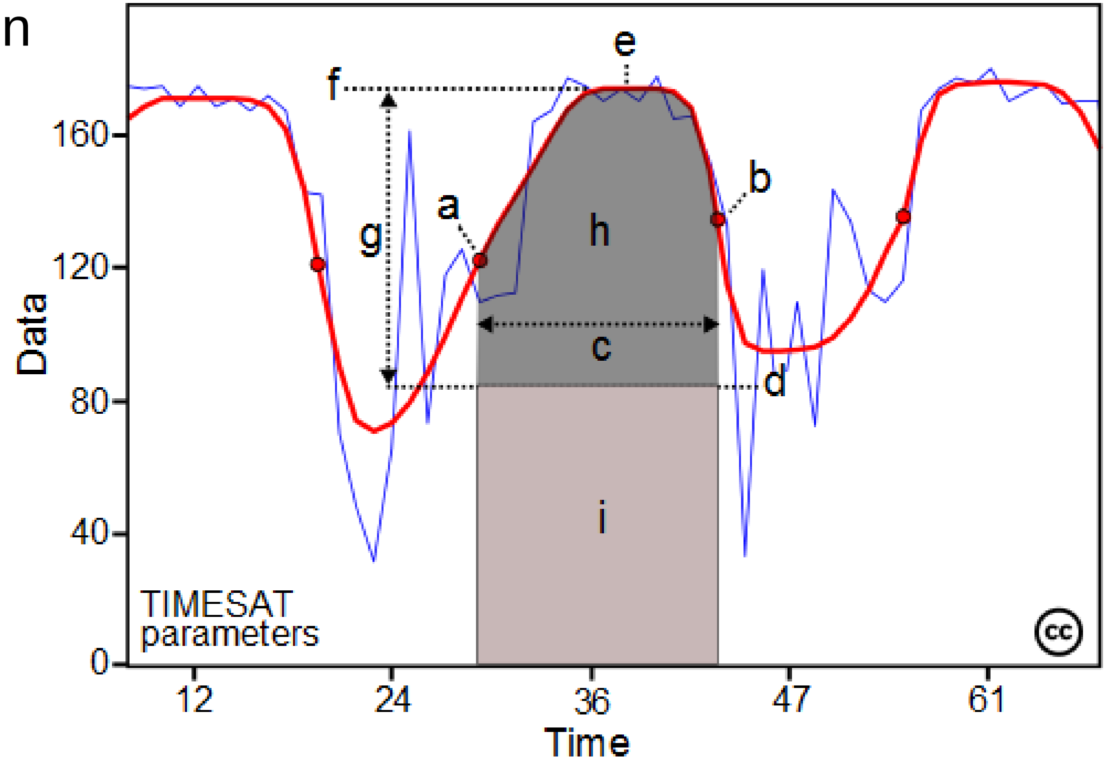
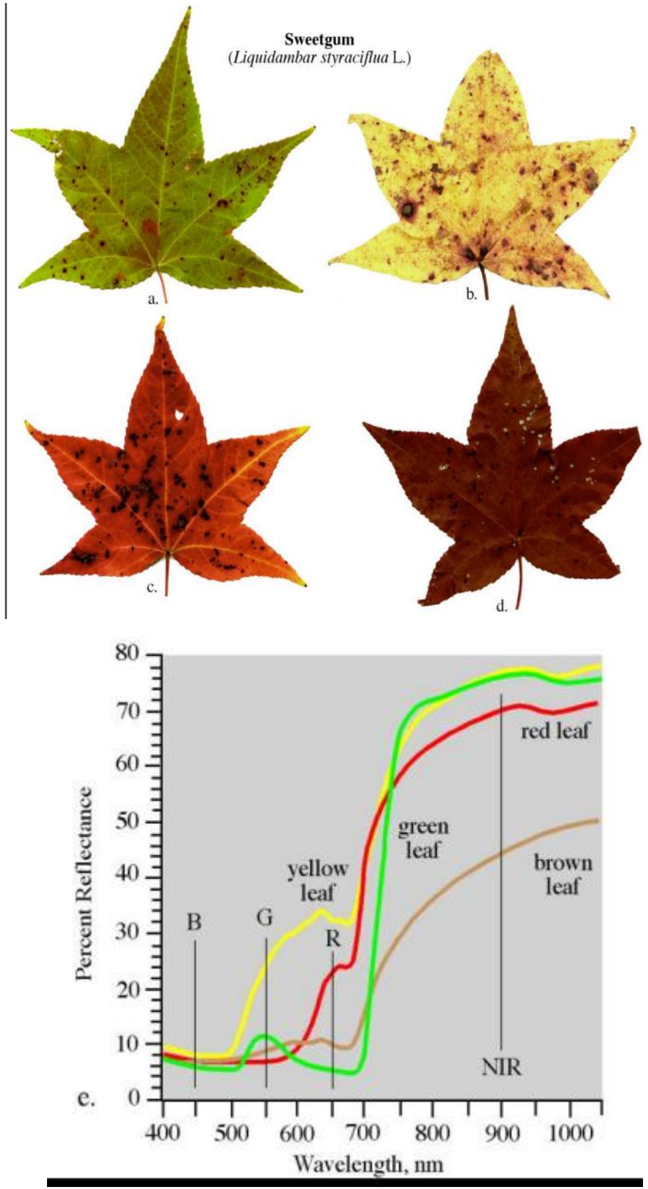
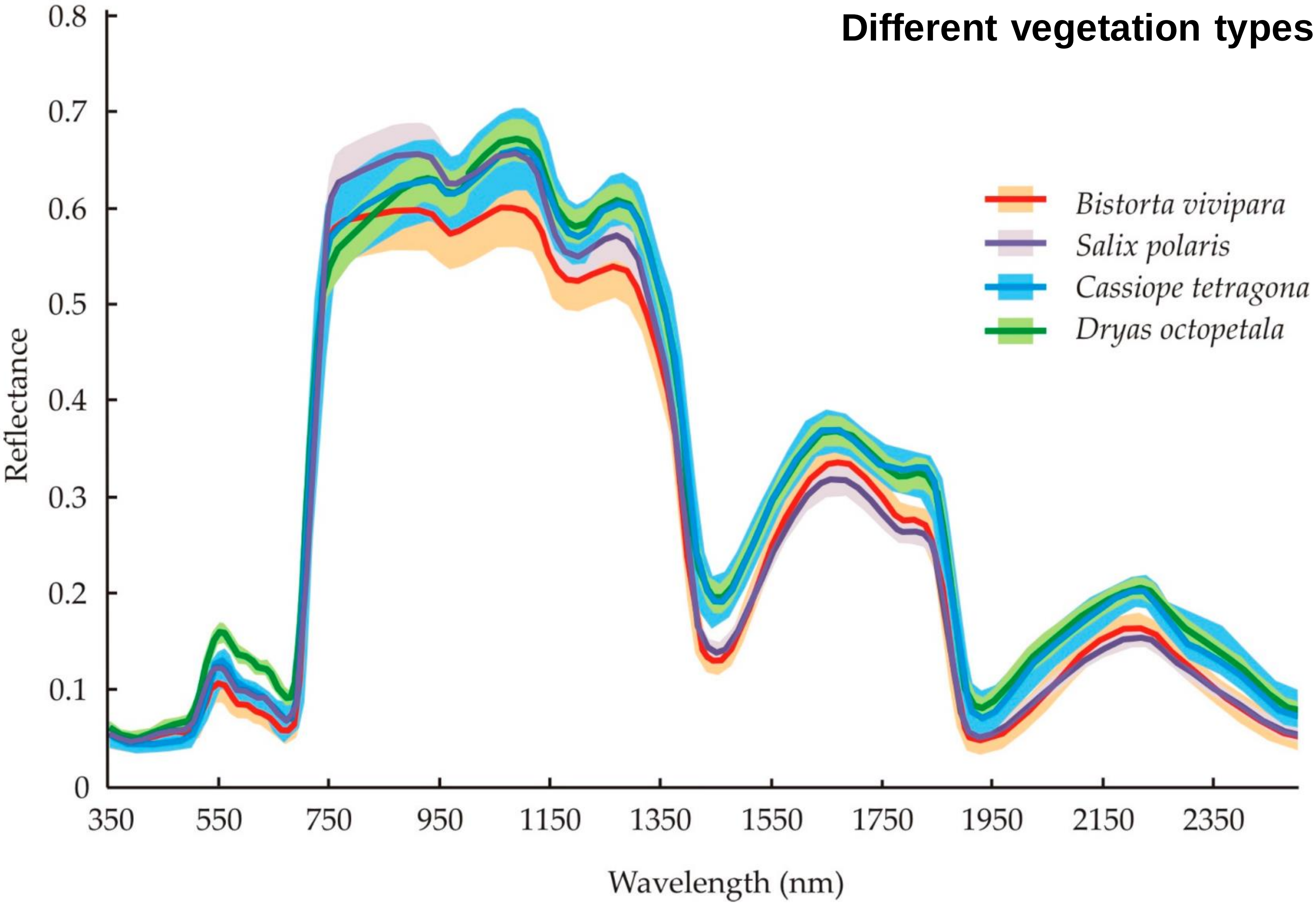
Temporal development of vegetation

(a) beginning of season
(b) end of season
(c) length of season
(d) base value
(e) middle of season
(f) maximum value
(g) amplitude

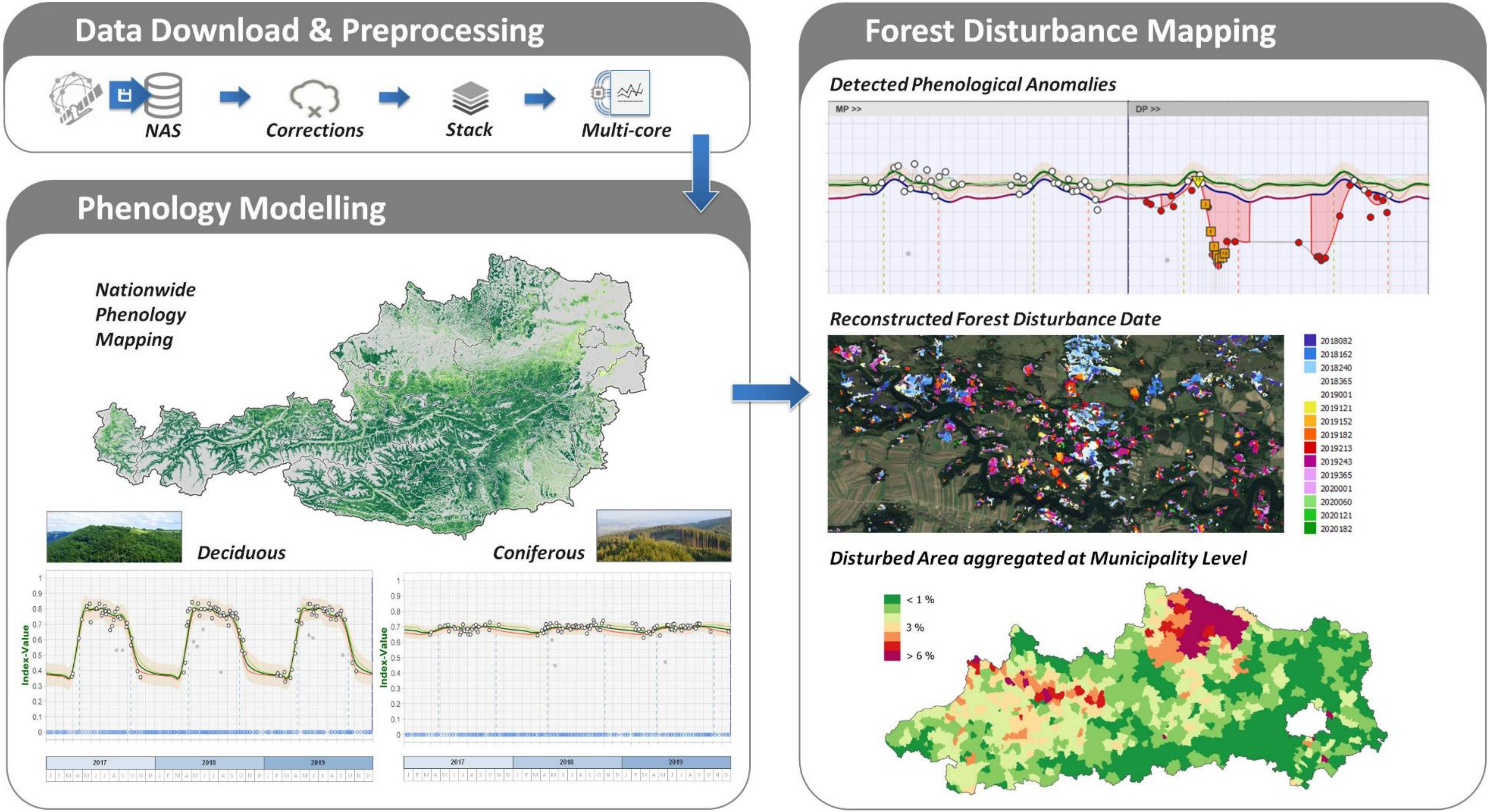




Different vegetation types



Phenology and disturbances

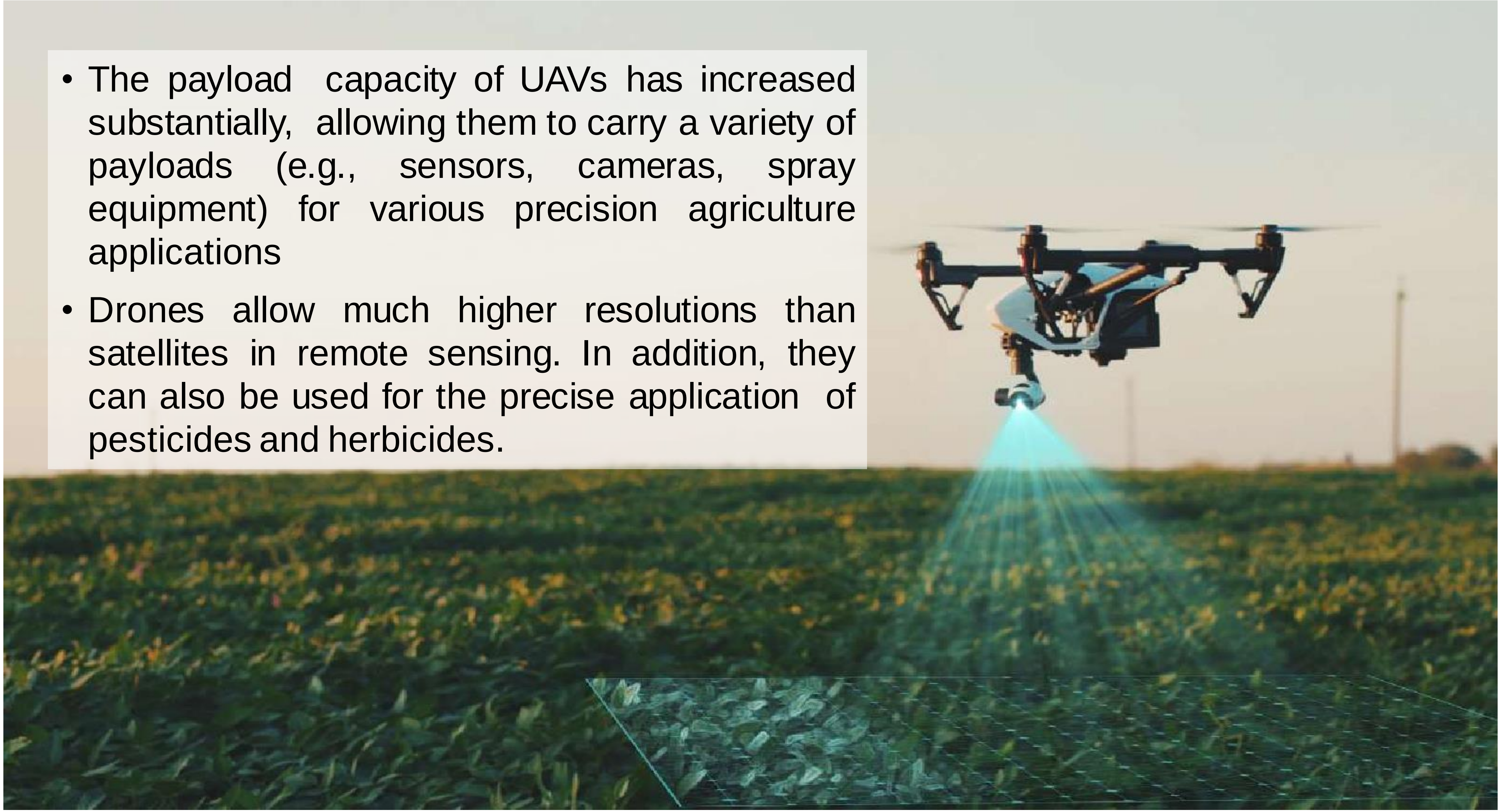


Sentinel-based markers for CAP Monitoring

https://dataspace.copernicus.eu/news/2023-10-19-cap-monitoring-national-scale-slovenia-based-copernicus-data

UAV sensors and platforms

Unmanned Aerial Vehicles (UAVs)



- The payload capacity of UAVs has increased substantially, allowing them to carry a variety of payloads (e.g., sensors, cameras, spray equipment) for various precision agriculture applications
- Drones allow much higher resolutions than satellites in remote sensing. In addition, they can also be used for the precise application of pesticides and herbicides.

Various Drone Payloads and Their Applications[69]

RGB Camera
Only able to capture the wavelengths of the visible spectrum.

- Monitoring plants outer defects, greenness and growth
- Calculating a range of vegetation indices
- Creating high-resolution digital elevation models (DEMs)
- Mapping vegetation height

Multispectral Camera
Able to capture wavelengths beyond the visible spectral range, usually through 3-15 bands.[70]

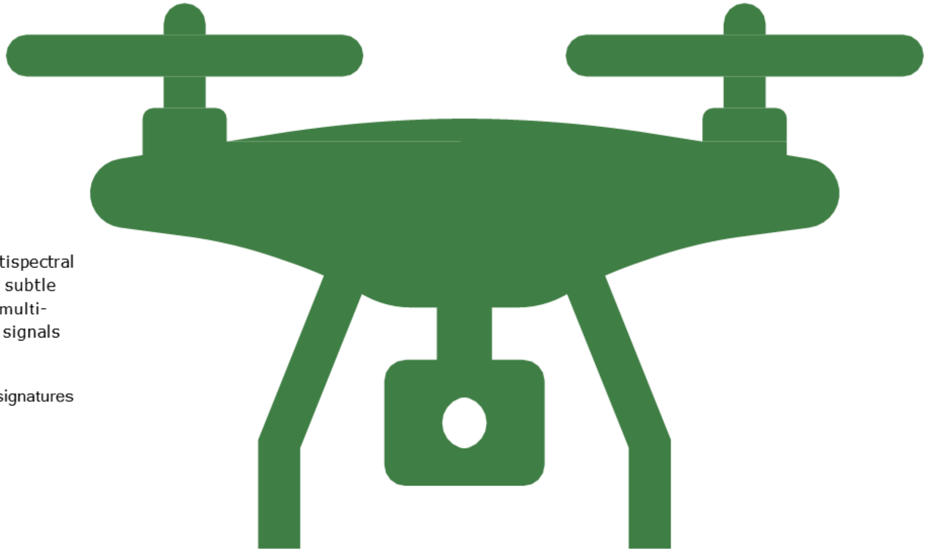
- Monitoring and mapping crop diseases and weeds
- Estimating the vegetation state
- Detecting nutrient deficiency
- Mapping vegetation height

Hyperspectral Camera
Has more and narrower spectral bands compared to multispectral (They are most suitable when there is a need to identify subtle differences in signal along a continuous spectrum. Since multi-spectral cameras sample larger wavebands, these small signals may not be detected)[71]

- Distinguishing different plant species with similar spectral signatures
- Identifying plant biochemical composition
- Quantifying soil vegetation
- Calculating chemical attributes

Thermal Camera
Infrared radiation to form a heat zone image, operating at wavelengths of ~14,000 nm

- Evaluating water stress and assessing irrigation uniformity
- Calculating vegetation indices
- Calculating chemical attributes



Lidar (Light Detection and Ranging)
Uses laser beams to create a 3D representation of the surveyed environment

- Creating high-resolution digital surface models of terrain and elevation
- Measuring canopy heights, coverage, tree density, location and height of individual trees

Position Sensors
Includes inertial navigation systems, GPS, magnetometer

- Finding the physical location of the UAV

Chemical Sensors
- Measuring and detecting quantities of various chemical agents

Biological Sensors
- Identifying various forms of microorganisms

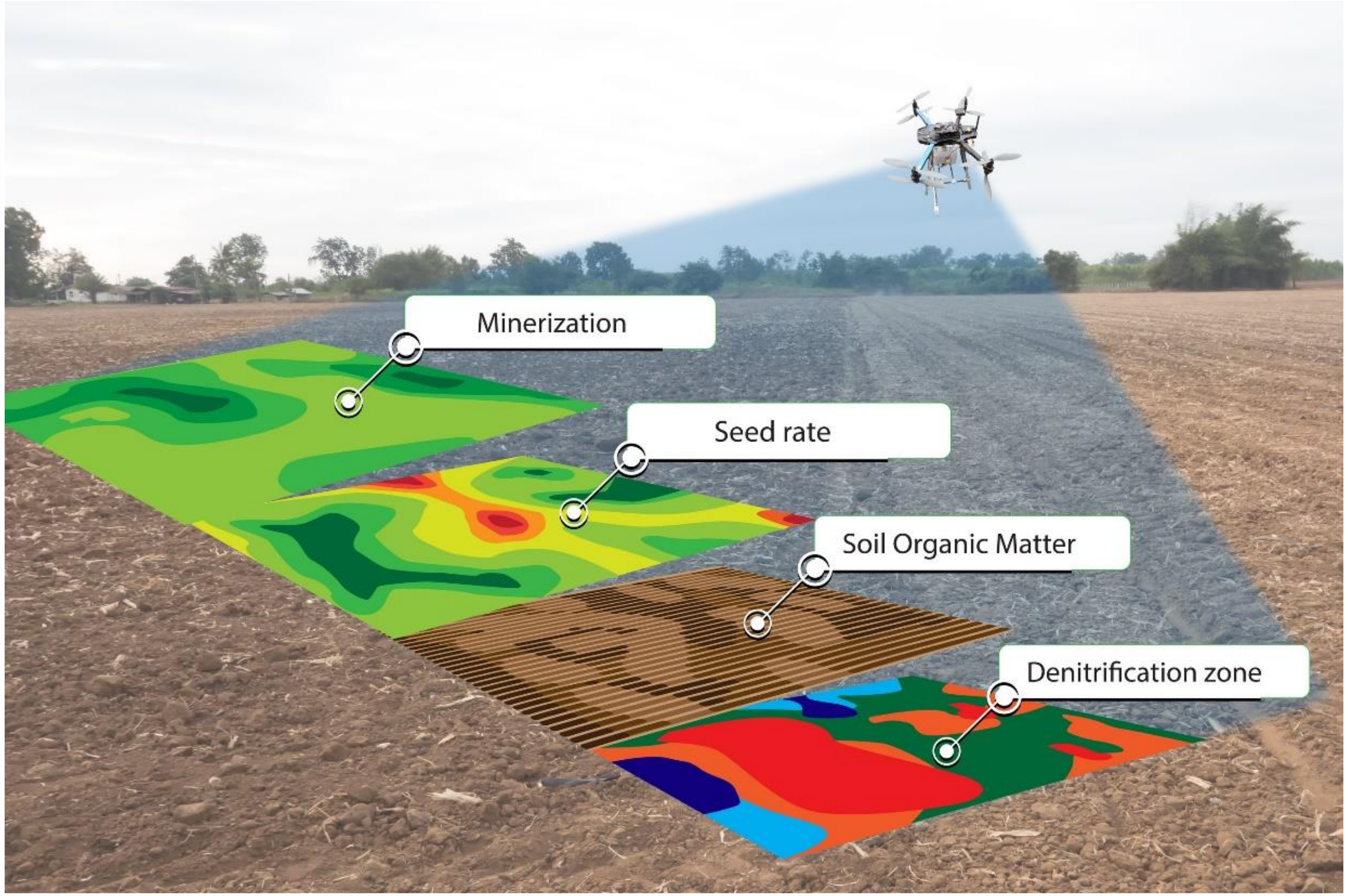
Meteorological Sensors
- Measuring weather-related indicators such as wind speed, temperature and humidity

Spraying System or Similarpayloads
- System consisting of pumps and sprinklers for spraying chemical inputs

Common Benefits Of Using UAVs In Agriculture

- Increased Mapping Accuracy
- Reduced Crop Survey Cost
- Increased Efficiency
- Reduced CO_2 Emissions
- Increased Crop Yields
- 3D mapping of land
- Save money on crop surveys
- Save money on insurance

https://www.skydatausa.com/skydata-s-fleet/mavic-3m-crops-and-natural-resources-hide-no-secrets



On-site sensors

On-site sensors measure field and crop characteristics with high accuracy, which growers can use to make farming decisions. Sensors are used in pest monitoring, soil monitoring, smart irrigation, yield monitoring, weather monitoring, and precision planting and spraying applications. The most commonly used sensors are listed in the table below.

Table 4: Types of on-site sensors for precision agriculture

Group	Sensors
Soil	Moisture, temperature, nitrogen, phosphorous, potassium, carbon, pH
Plants	NDVI, chlorophyll, plant health, plant water demands, sugar content
Atmospheric	Temperature, humidity, wind speed, rainfall, pressure, precipitation
Water	pH, temperature, turbidity, water depth, conductivity, dissolved O_2

Satellites and UAVs in Precise Agriculture - Applications

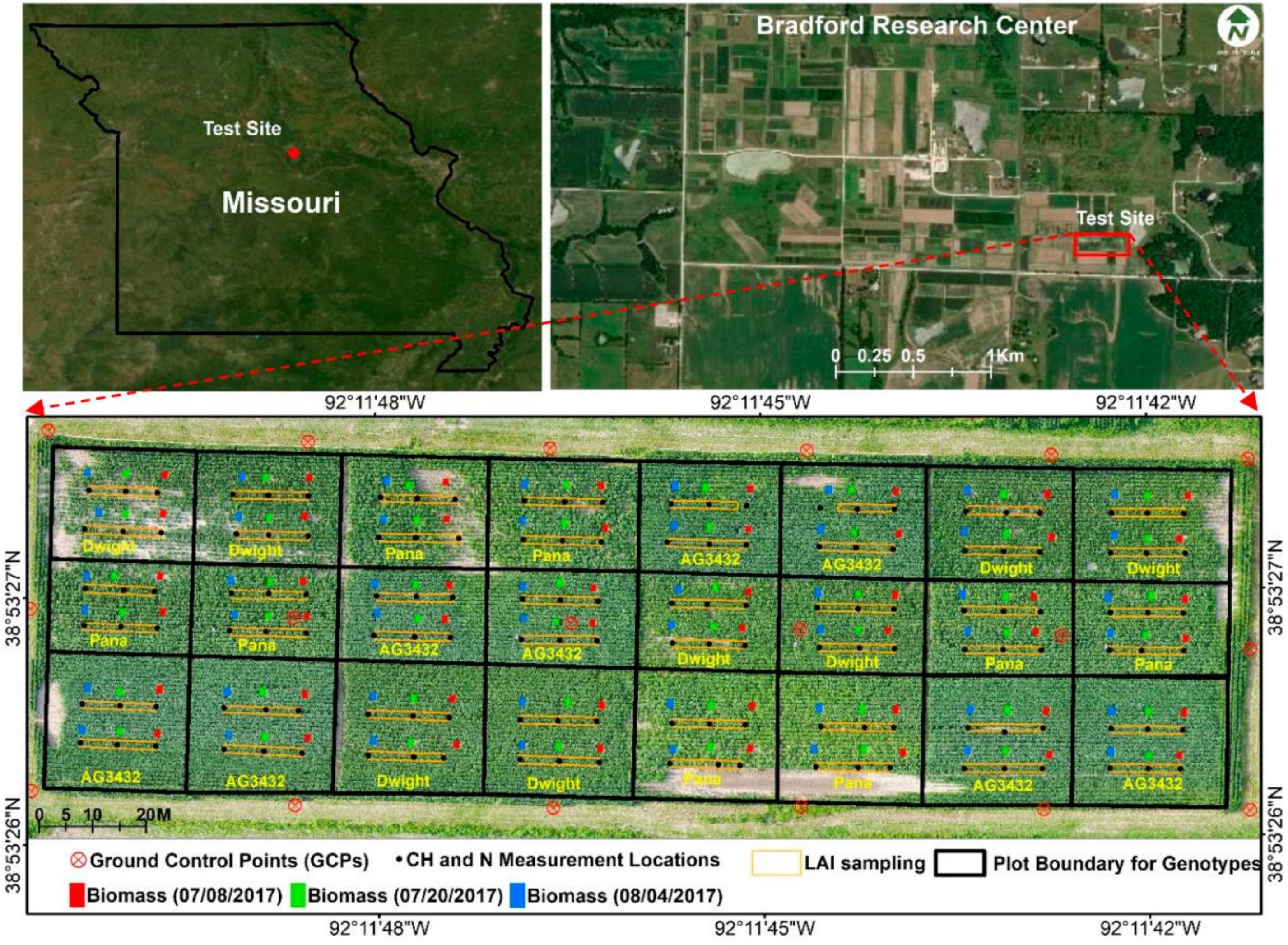
Comparing Satellite Imagery To UAV Data

Feature	Drone	Satellites
Autonomy	Needs an operator	Fully autonomous
Accessibility	Suits for flat and easy-to-reach areas	Doesn’t depend on relief specifics
Scalability	Typically used for small fields	Covers large and small areas
Limitations	Prohibited in certain areas	No field data restrictions*
Dependence on weather conditions	Can’t be operated in heavy rains and strong winds	Partial data loss due to cloud cover
Price of use	Correlates with operating time	Correlates with the captured territory
Complexity of interpretation	Requires additional analysis by a GIS specialist	Usually processed on online farming platforms

https://eos.com/blog/drones-vs-satellites/

Satellites and UAVs in Precise Agriculture - Applications

Crop Monitoring Using Satellite/UAV Data Fusion



https://www.mdpi.com/2072-4292/12/9/1357

For more information, see the tutorial:

[6. Crop Classification with S1 time series data using the SNAP software]

Thank you for the attention