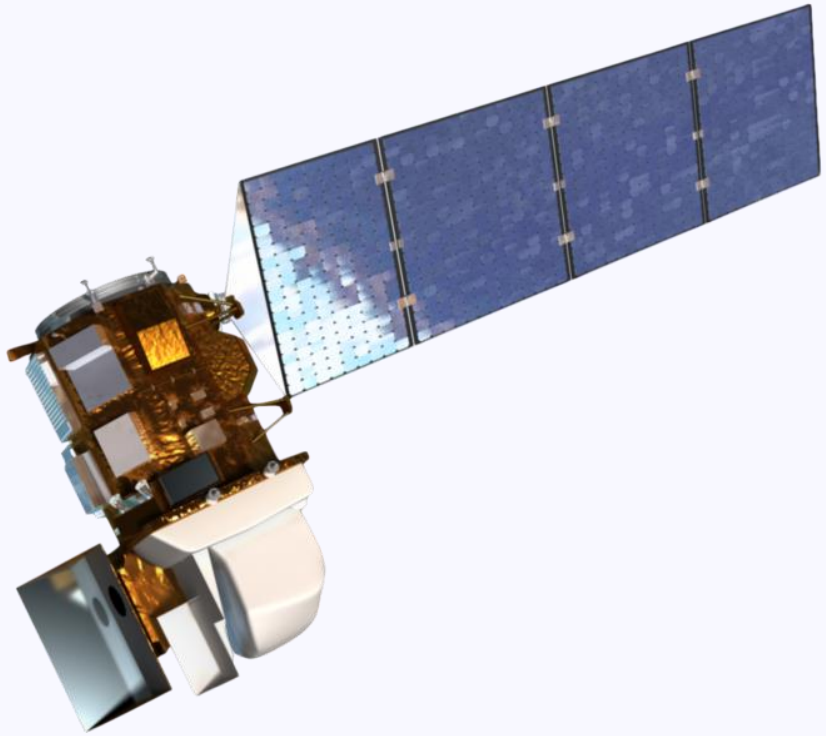
Introduction to Agricultural Monitoring

12 October 2021



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What is an important application of remote sensing change detection?

Mentimeter

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What is an important application of remote sensing change detection?

Mentimeter

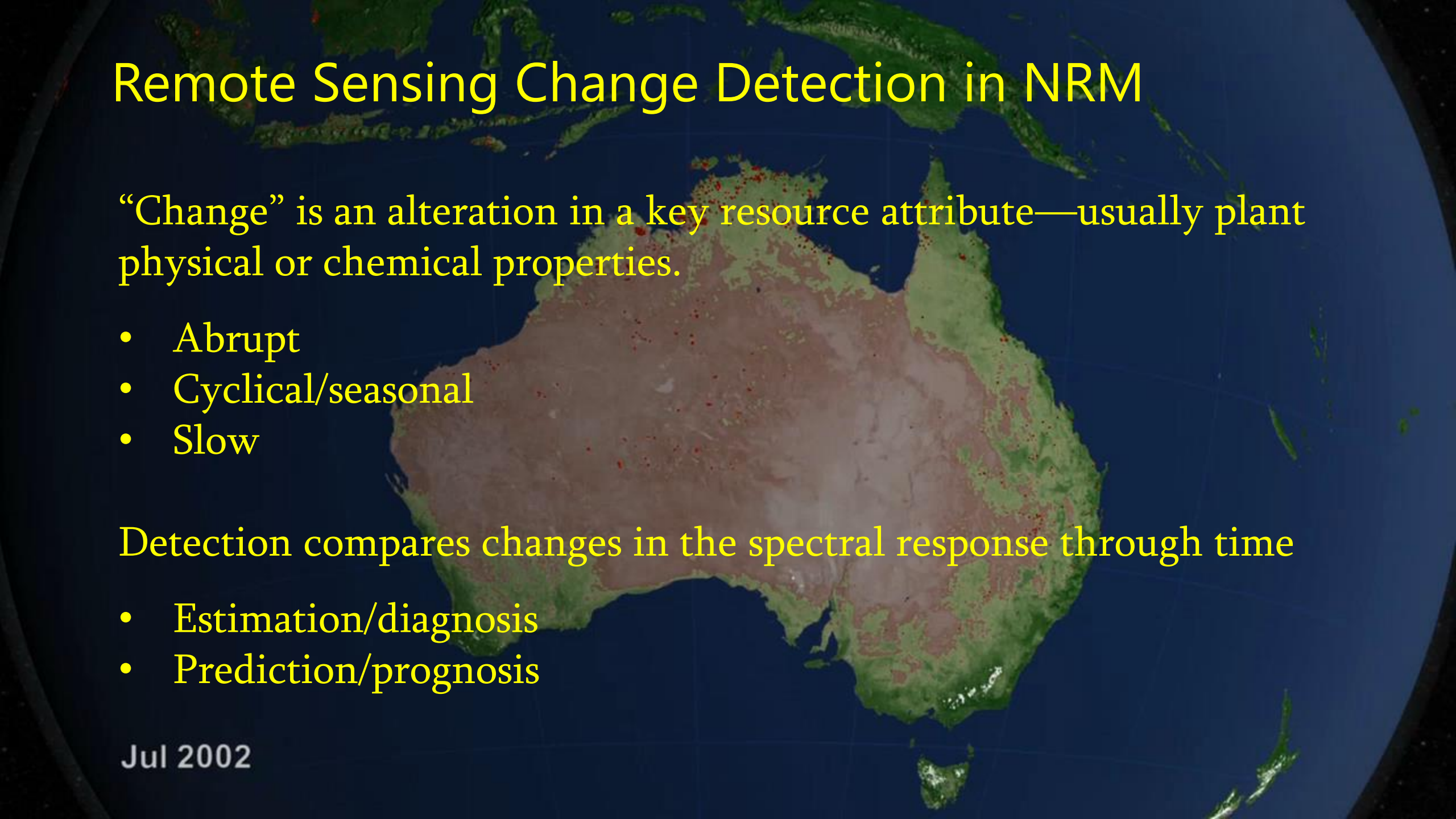
Remote Sensing Change Detection in NRM

"Change" is an alteration in a key resource attribute—usually plant physical or chemical properties.

- Abrupt
- Cyclical/seasonal
- Slow

Detection compares changes in the spectral response through time

- Estimation/diagnosis
- Prediction/prognosis

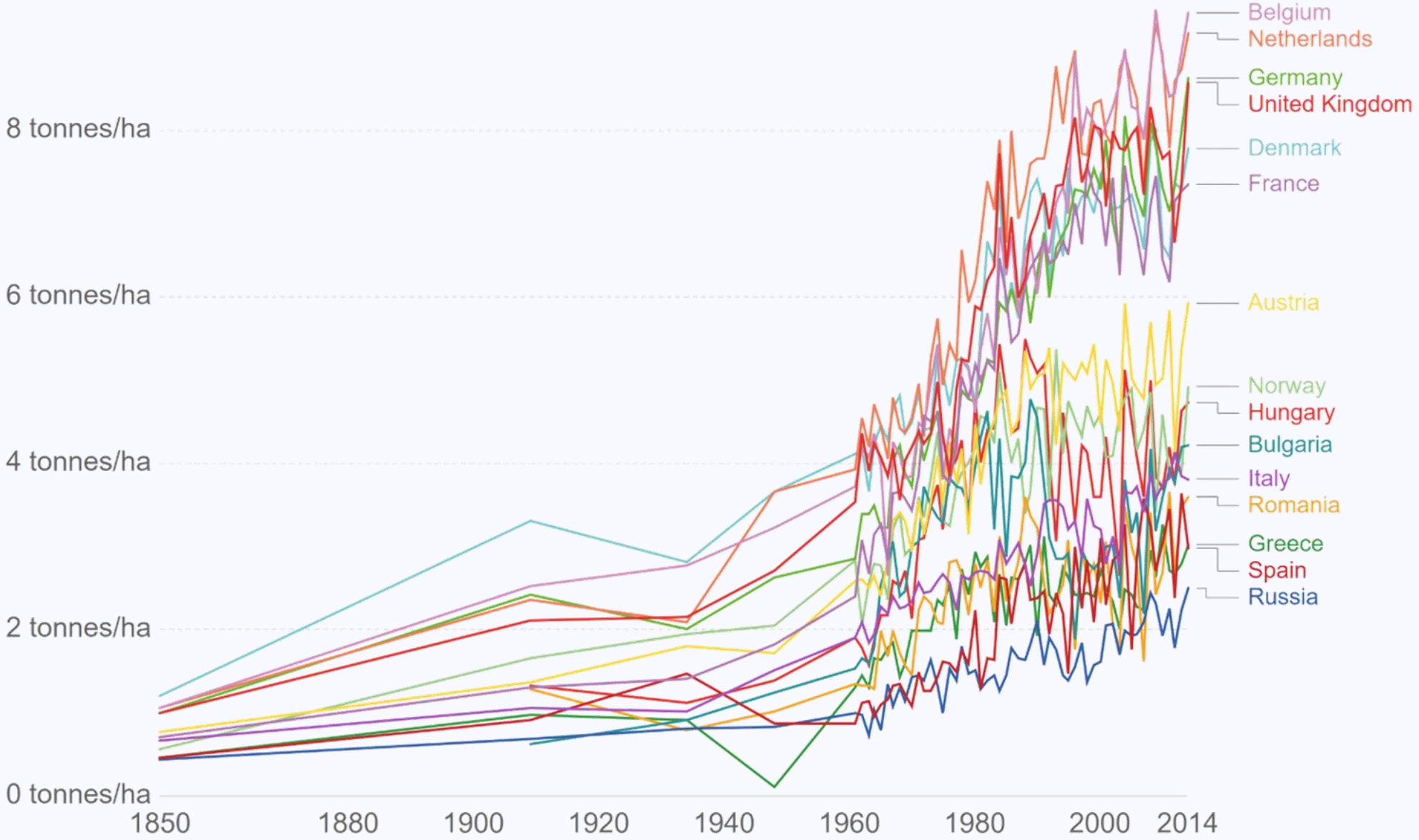


Learning Objectives of this Course

- Interpret problems in agricultural monitoring considering the scale of observation and information requirements
- Compare observation and remote sensing-based estimates of crop yield
- Analyze observation and remote sensing-based estimates of evapotranspiration

Long-term wheat yields in Europe

Wheat yields across selected countries in Europe, measured in tonnes per hectare.



Source: Long-term wheat yields - FAO (2017) & Bayliss-Smith (1984)

OurWorldInData.org/yields-and-land-use-in-agriculture/ • CC BY-SA

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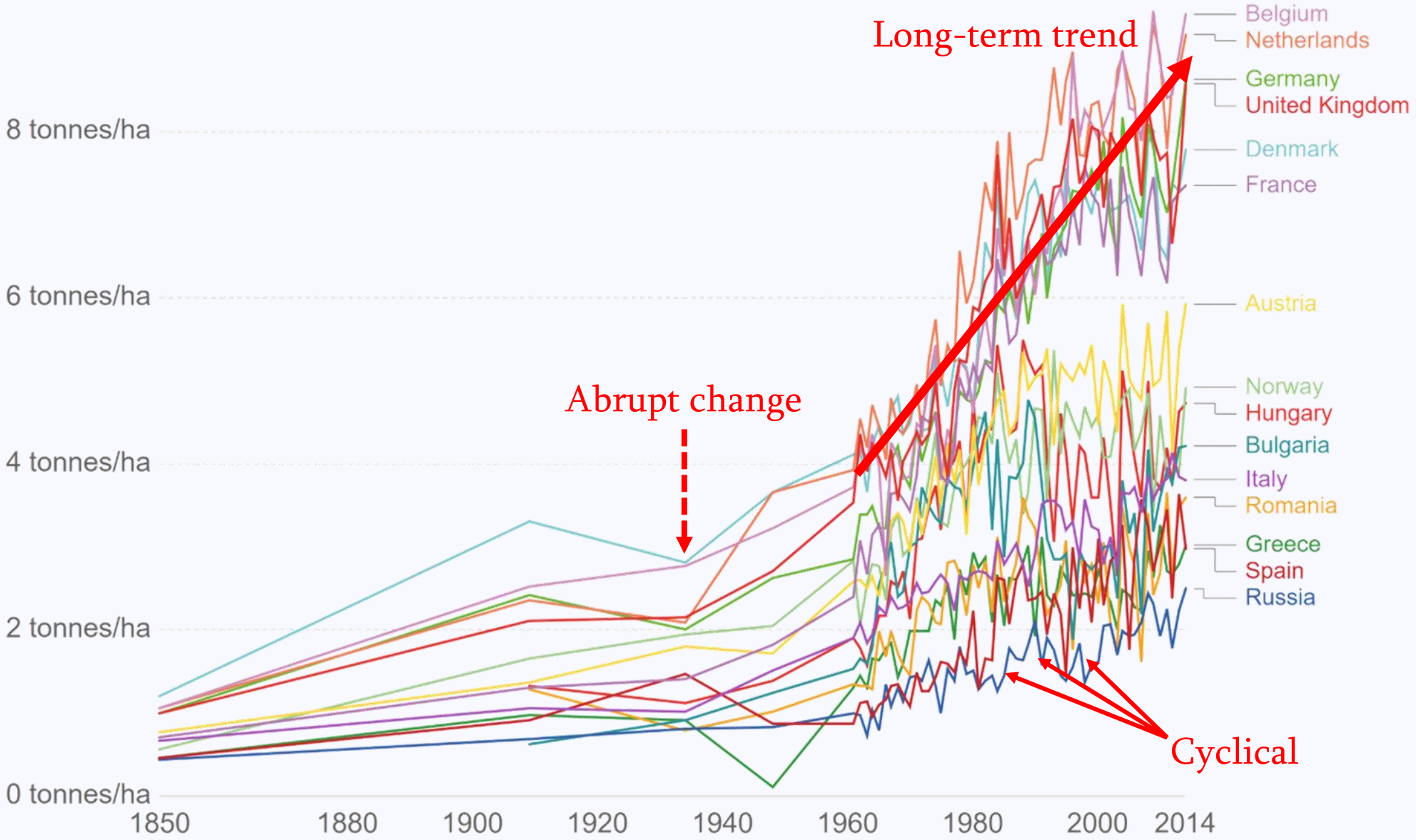

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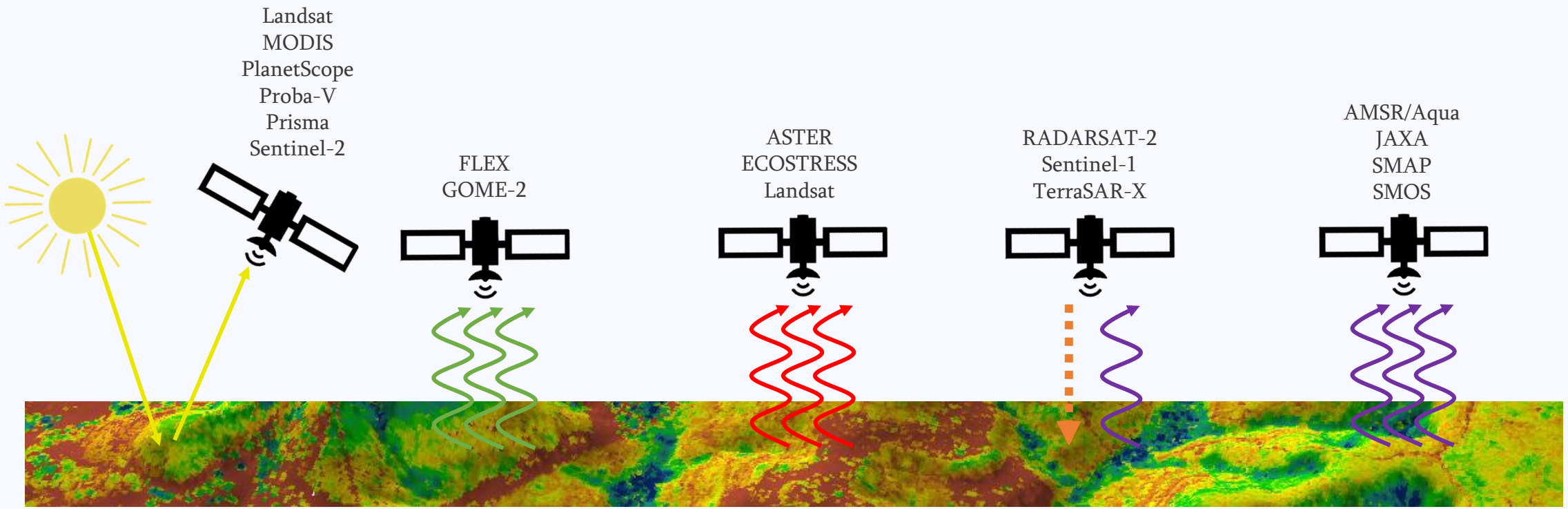
OurWorldInData.org/yields-and-land-use-in-agriculture/ • CC BY-SA

Physical and chemical properties

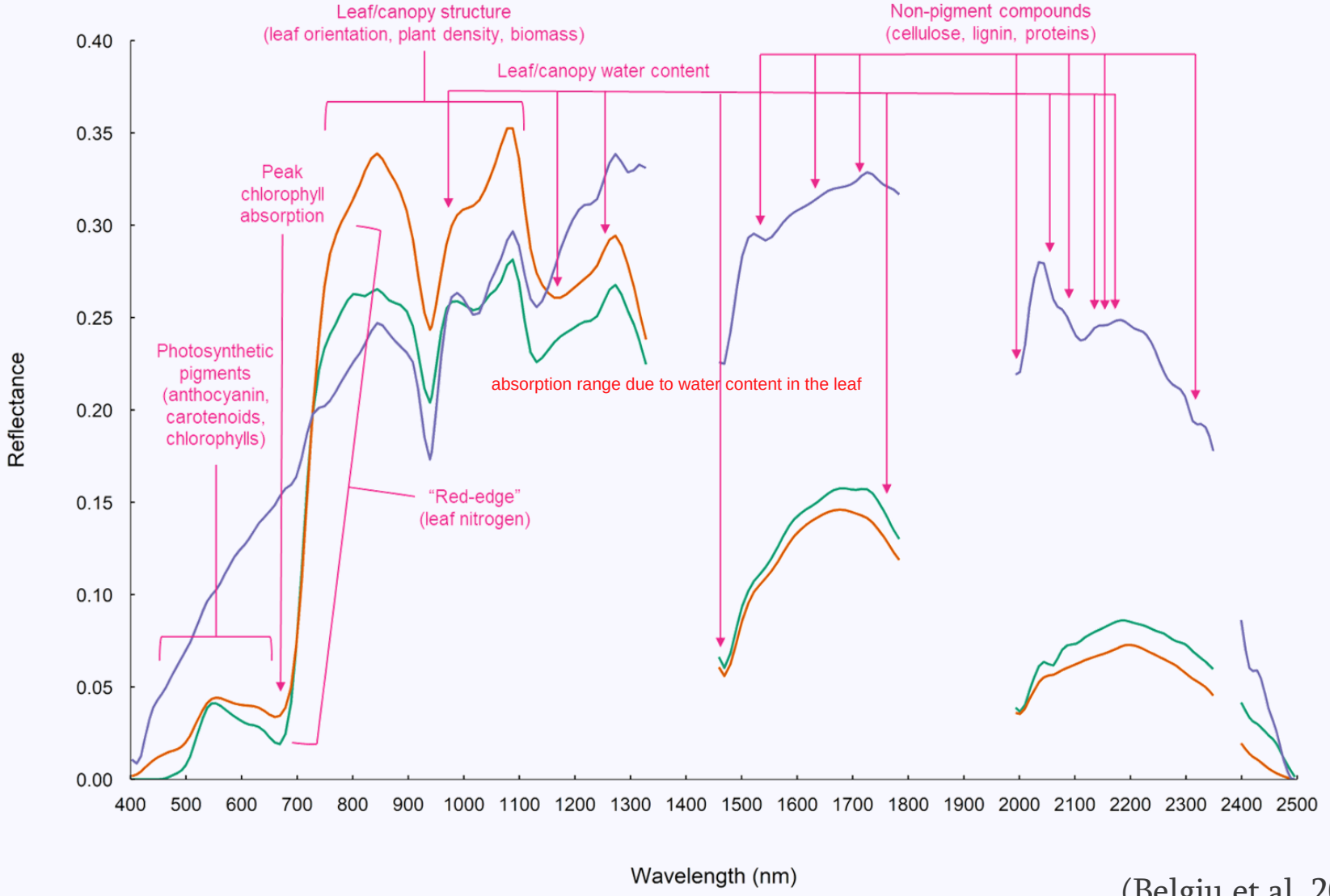
- Leaf constituents (concentrations)
  - Chlorophyll a+b, accessory pigments, nitrogen
  - Leaf water
  - Wet and dry matter
- Radiation
  - Fraction of absorbed photosynthetically active radiation (fAPAR)
- Canopy structure
  - Leaf Area Index (0-8 m^2 m^{-2})
  - Leaf angle (0-90 deg)
  - Canopy cover or fractional vegetation cover (0-100 %)
  - Canopy height (0.1-50 m)
  - Tree density (100-4000 trees per ha)
  - Crown diameter (0.5-15 m)
  - Stem diameter (0.1-2 m)

Spectral response (broad definition)



Passive: optical Passive: fluorescence Passive: thermal Active: microwave Passive: microwave

Optical remote sensing (0.4-3µm)



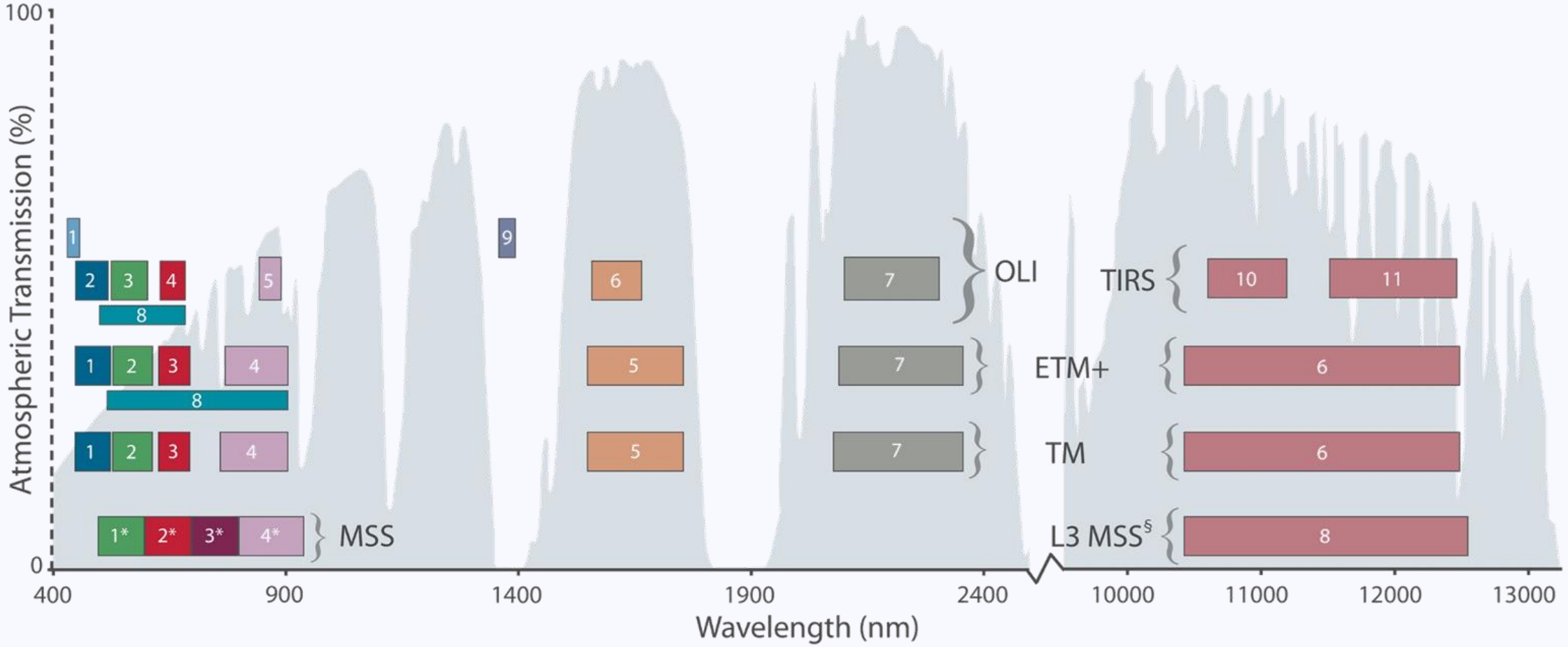
Vegetative

Reproductive

Maturity

(Belgiu et al. 2021)

Multispectral broadbands



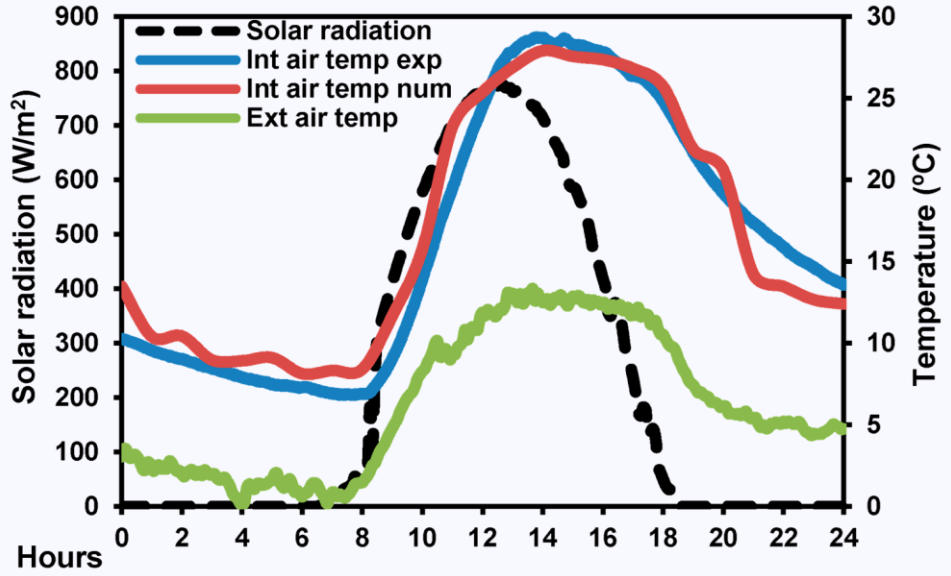
* MSS bands 1–4 were known as bands 4–7, respectively, on Landsats 1–3

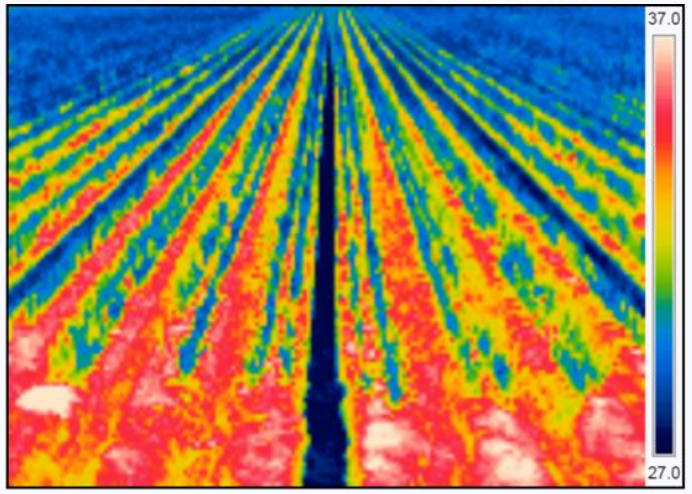
§ The 240 m thermal band on Landsat 3 was out of spec within three weeks of launch and turned off in March 1979

(Wulder et al., 2012)

Thermal remote sensing (3-15µm)

- Objects absorb energy and reradiate at specific wavelengths
- Colder objects =longer wavelengths
- Warmer objects = shorter wavelengths
- Water use efficiency
- Sensitive to atmospheric moisture

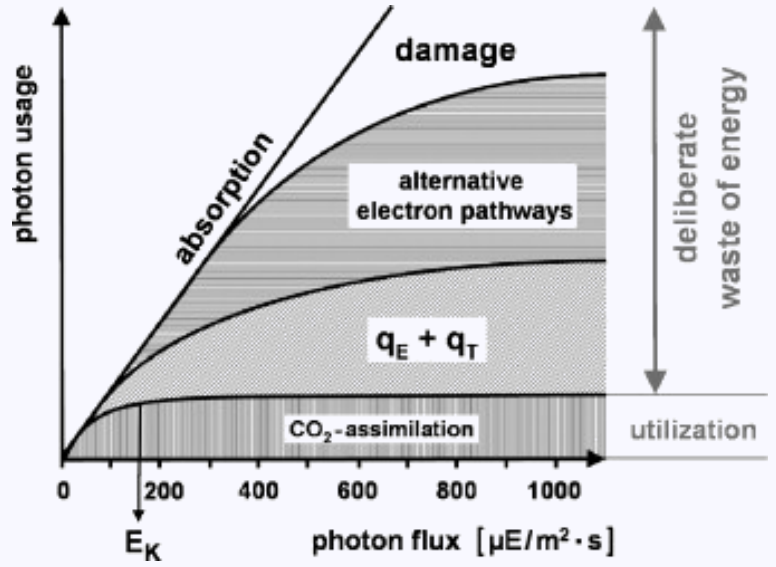




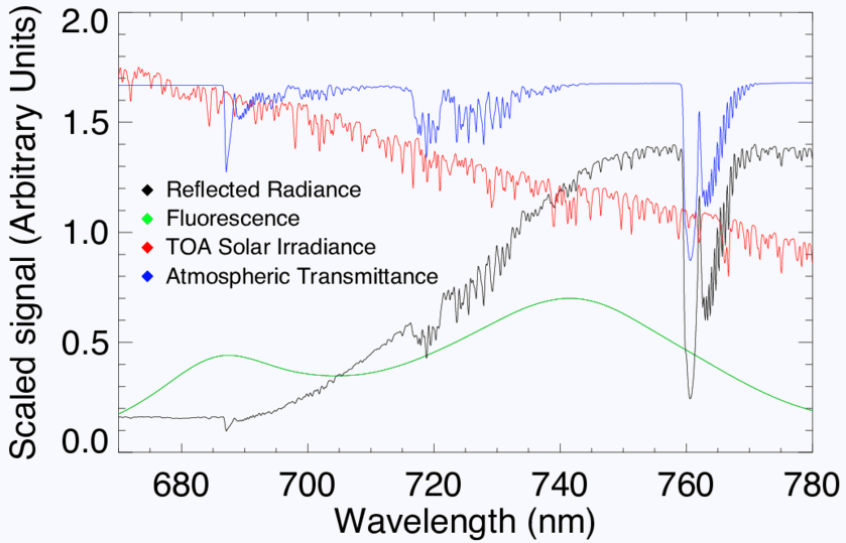
Solar-induced fluorescence (0.65-0.80µm)

- Solar energy dissipated by the leaf/canopy is handled in one of three ways:
  - Used for growth and maintenance
  - Non-photochemical quenching (heat dissipation)
  - Fluorescence
- Good for detecting carbon assimilation and biomass accumulation (GPP/NPP)
- Weak single compared to reflectance

reflected radiance not atmospherically correcteed



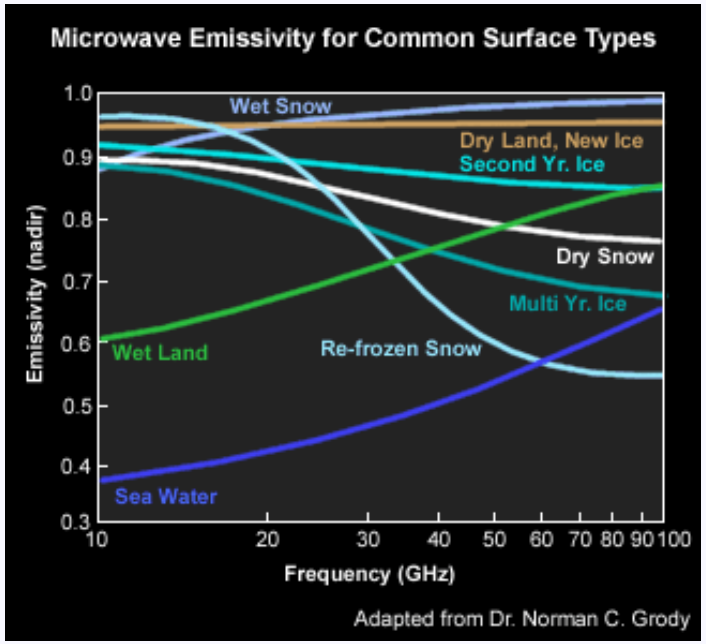
(Wilhelm and Selmar 2011)

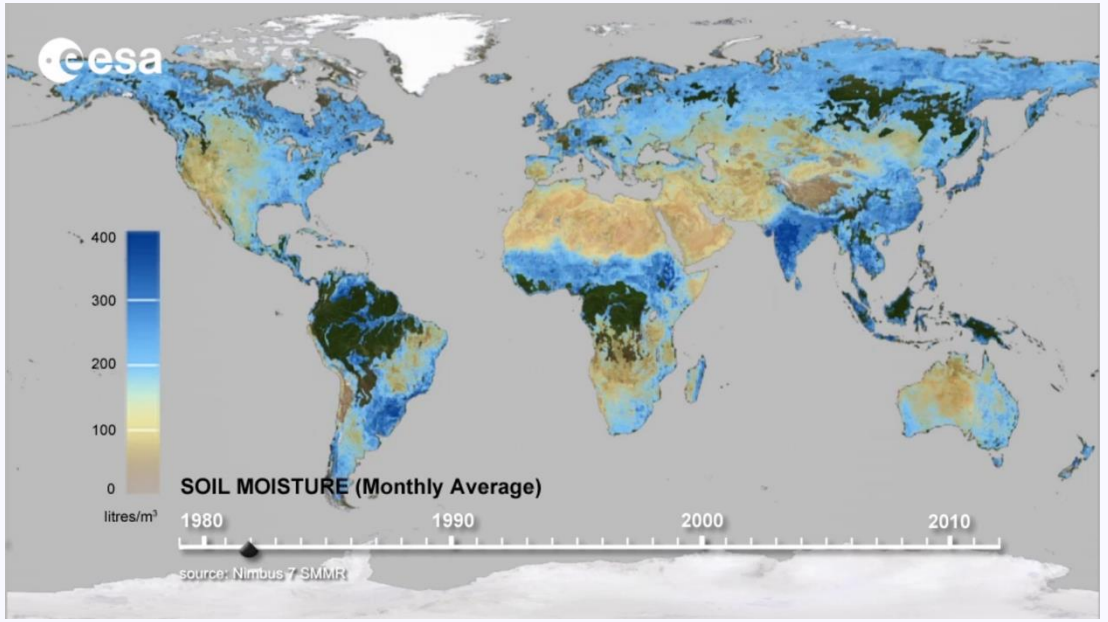


(Joiner et al., 2013)

Passive microwave (3-30cm)

- Similar to thermal infrared
- Brightness temperature is a function of radiance
- Physical properties of object more important than object temperature
- Atmosphere largely transparent to microwaves
- Microwaves “visible” day or night
- Requires a large field-of-view





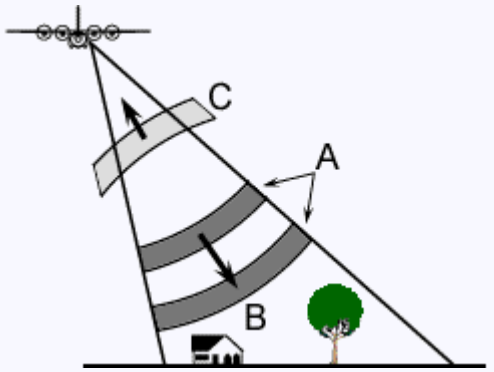
Active microwave: RADAR (3-30cm)

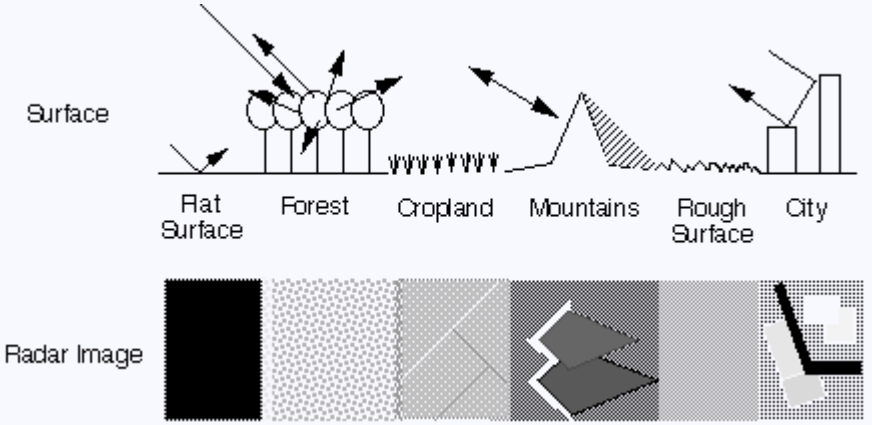
- Fundamentally different from active sensors
  - Antennae, receiver and transmitter
  - Off nadir
  - Backscatter and range

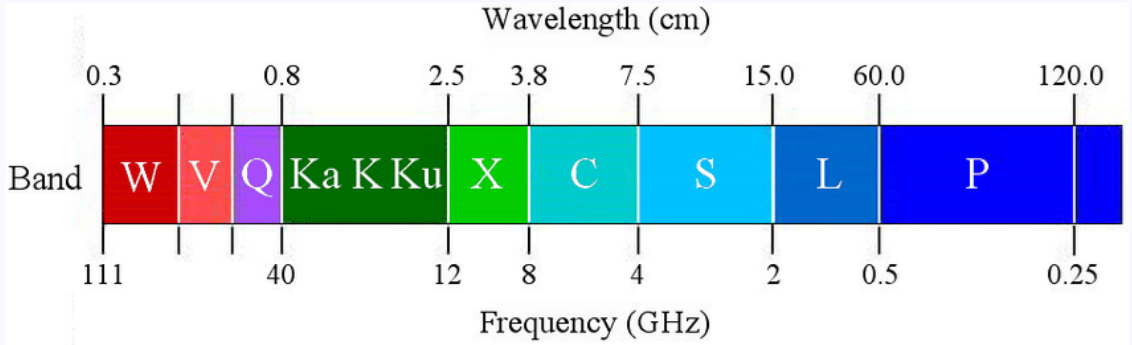
- Surface roughness, geometry and dielectric properties

- Polarization: HH,VV,HV,VH

- Lower frequency (longer wavelength)=deeper penetration







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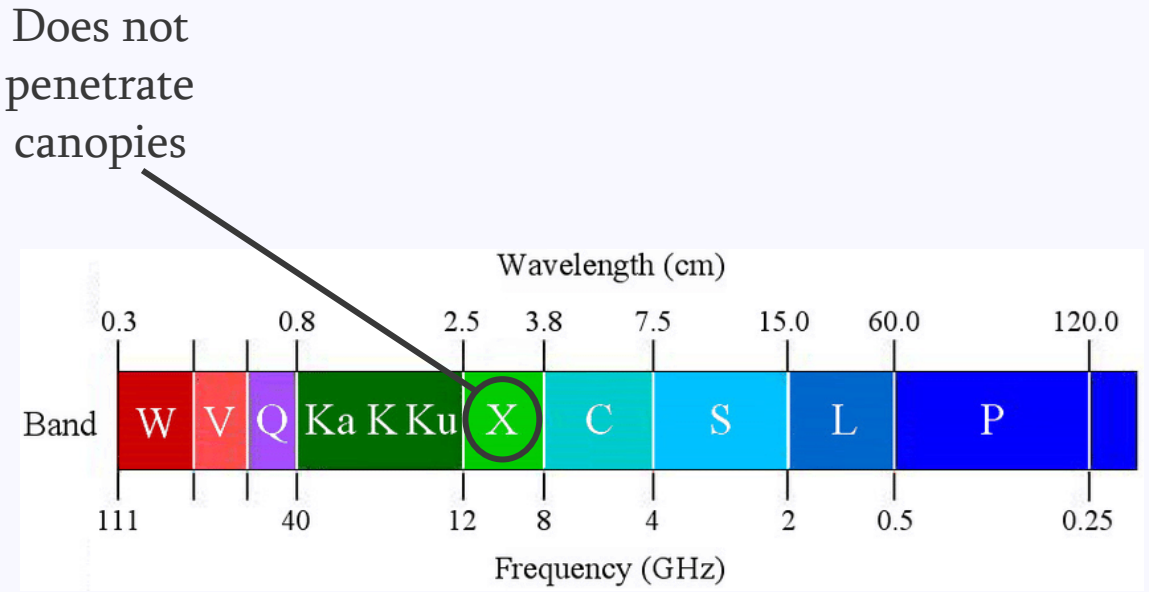

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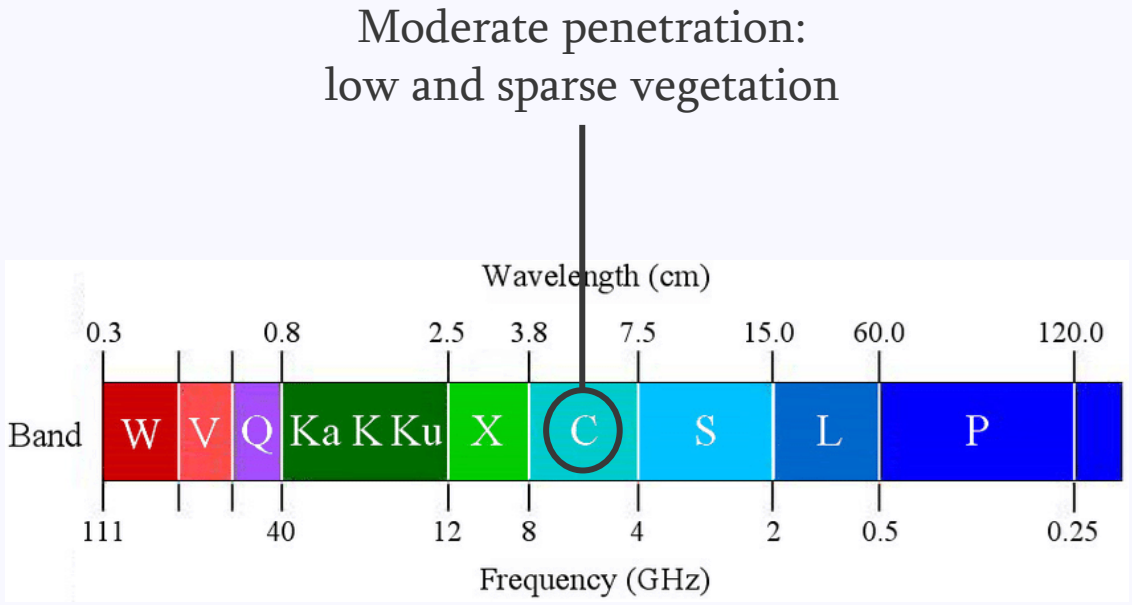

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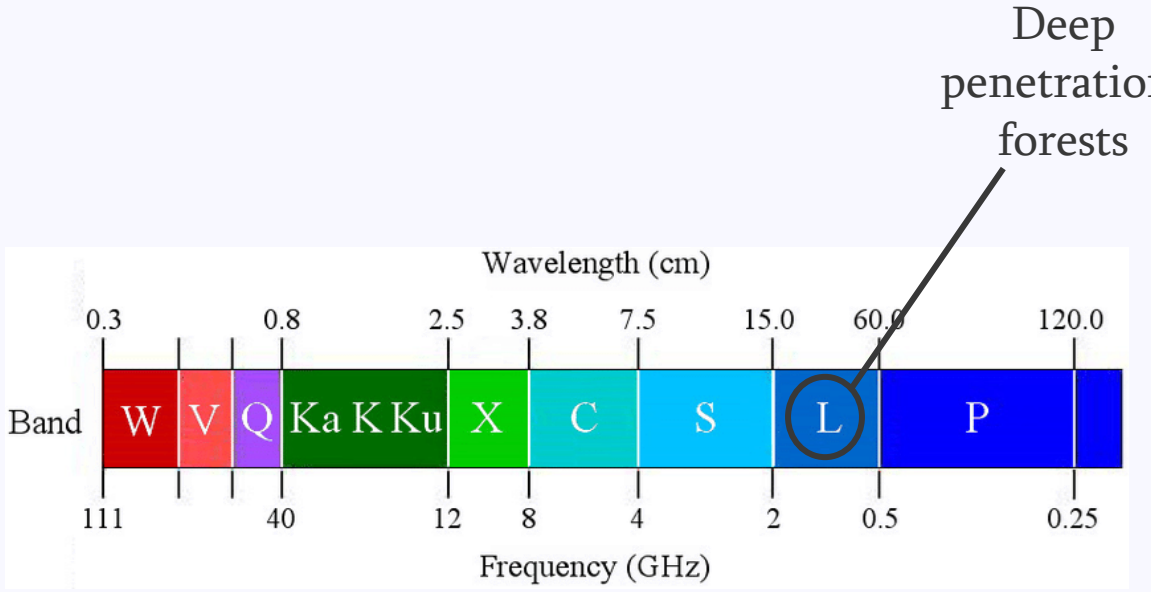
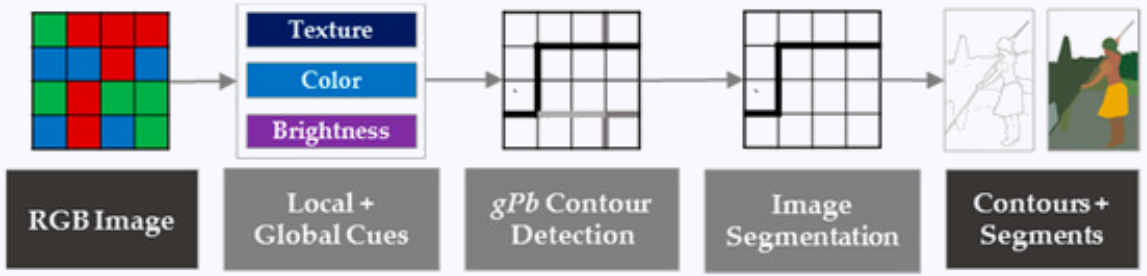


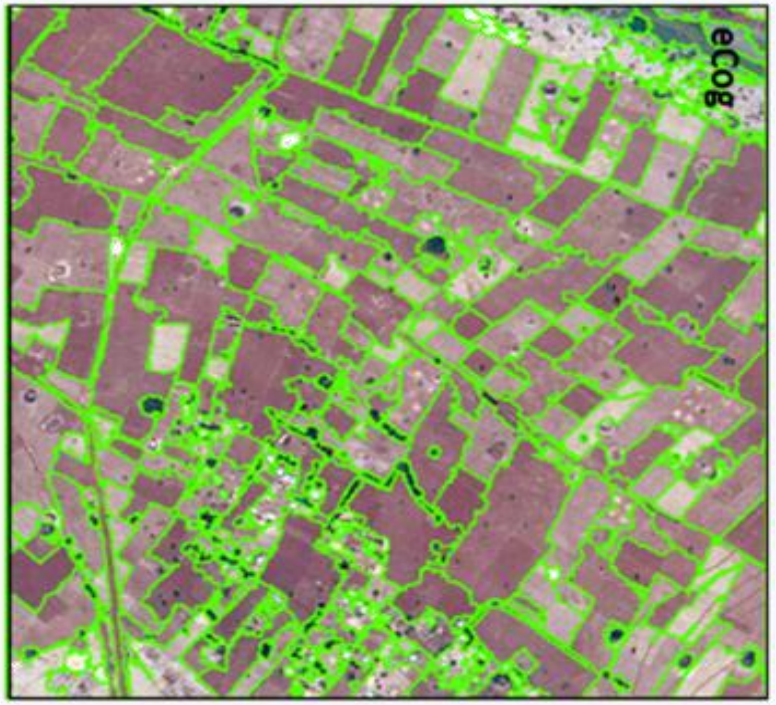
What about changes in space?

Change detection of categorical data (e.g., land cover map) concerns the location and extent of a feature



(Crommelinck et al., 2017)

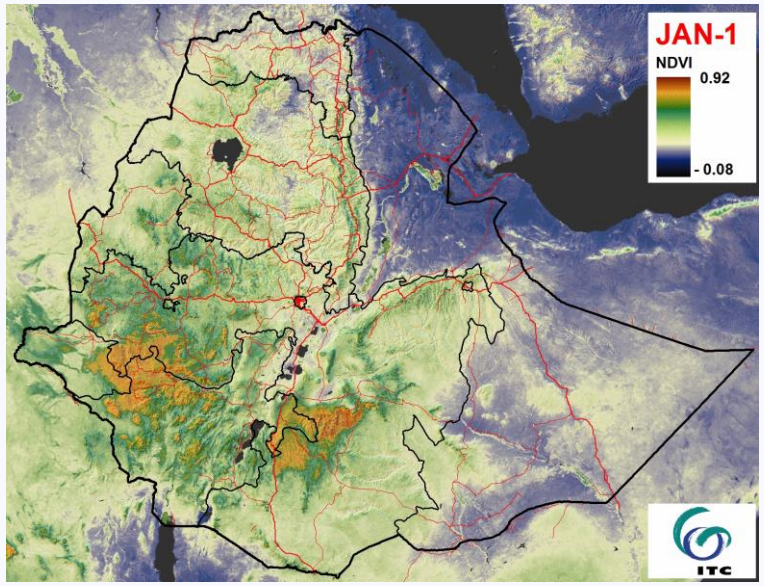
At the core of the mapping process however are spectra…

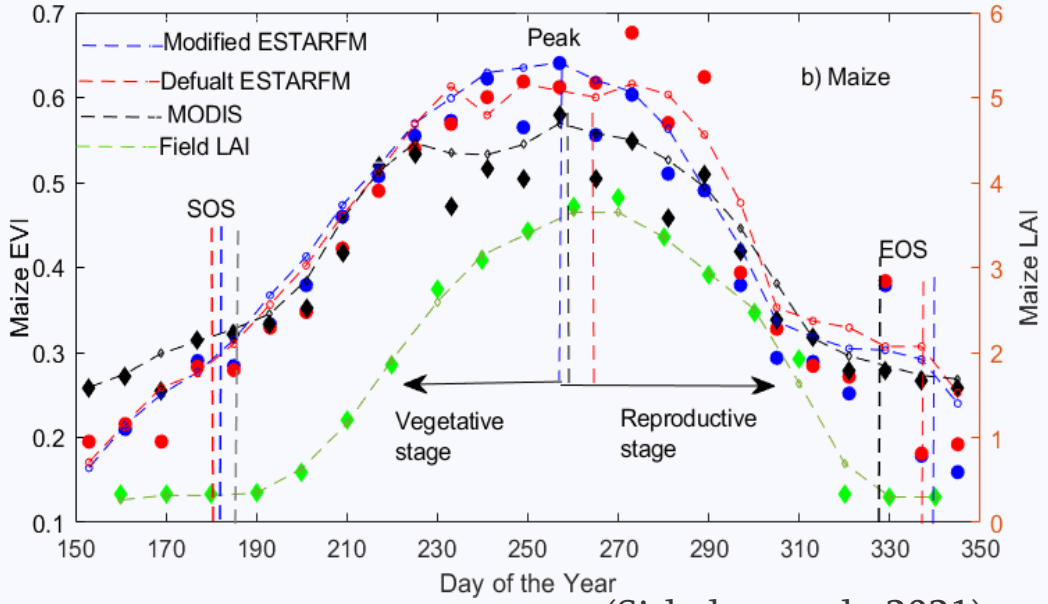


Monitoring

Most of what we do…

- Occurrence/no occurrence
- Seasonality
- Magnitude and direction of trend
- Tipping points
- Weather extremes



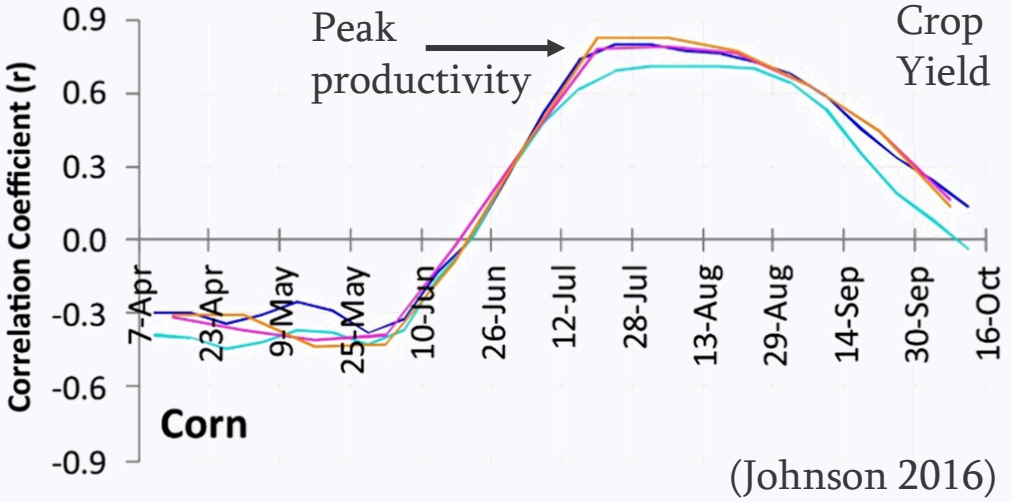


(Sisheber et al., 2021)

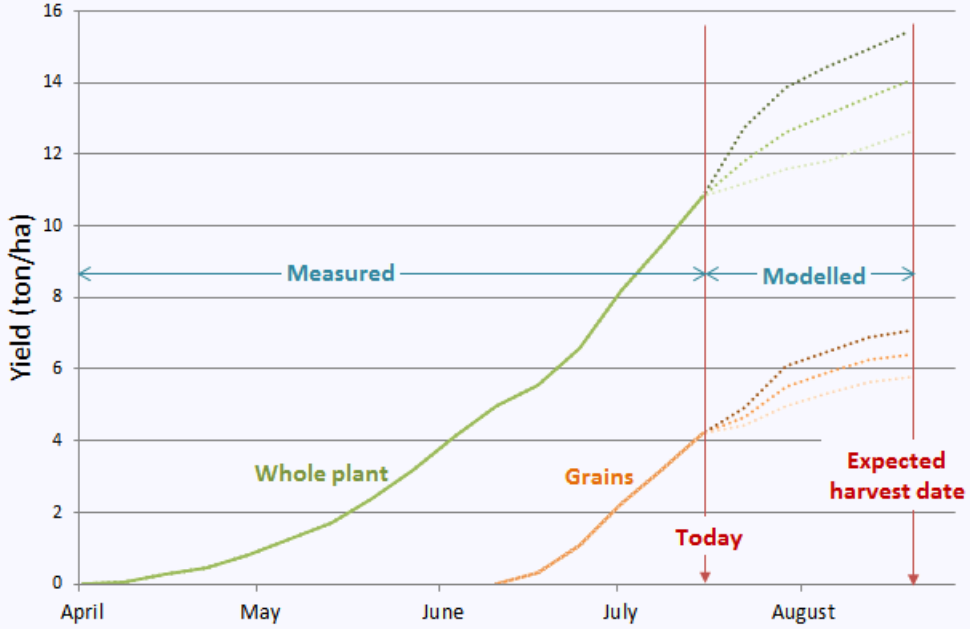
Within-season forecasting

- Data driven methods
  - Linear regression → machine learning
  - Vegetation + weather index
    - NDVI, LAI, fAPAR
    - Temperature, precipitation
  - Reproductive-targeted/cumulative

- Process-based models
  - Potential: CO_2, radiation, physiology
  - Stresses: moisture, temperature, nutrients
  - Aberrations: pests, disease
  - Calibration period



(Johnson 2016)



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Spectral properties of sensors

Strongly disagree

NIR bands (700–1300 nm) detect changes in biomass

Water emits thermal radiation at shorter wavelengths because it is colder

More radiation is dissipated by plants as fluorescence than is used for growth

Cross-polarization is good for targets that scatter microwaves

Strongly agree

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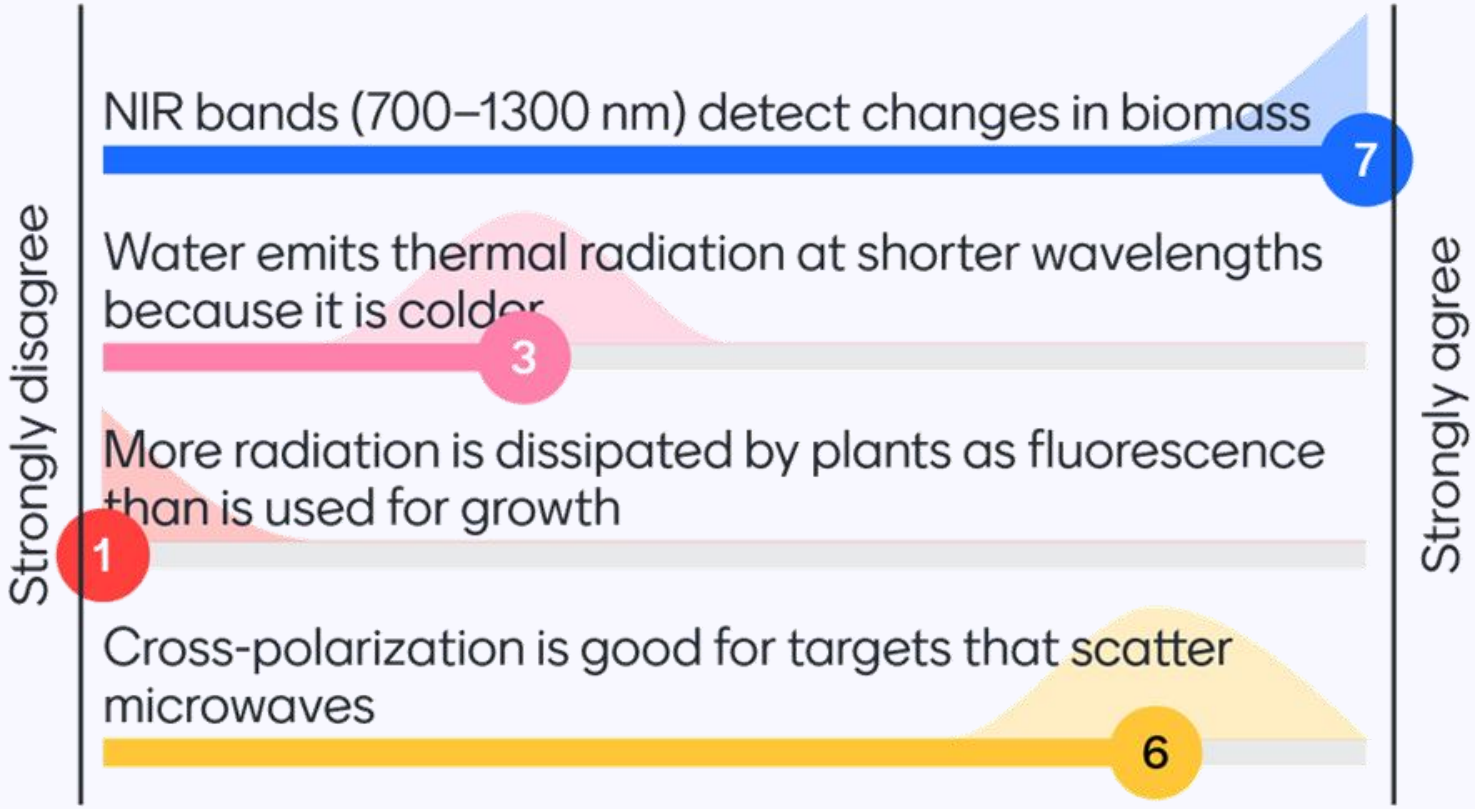
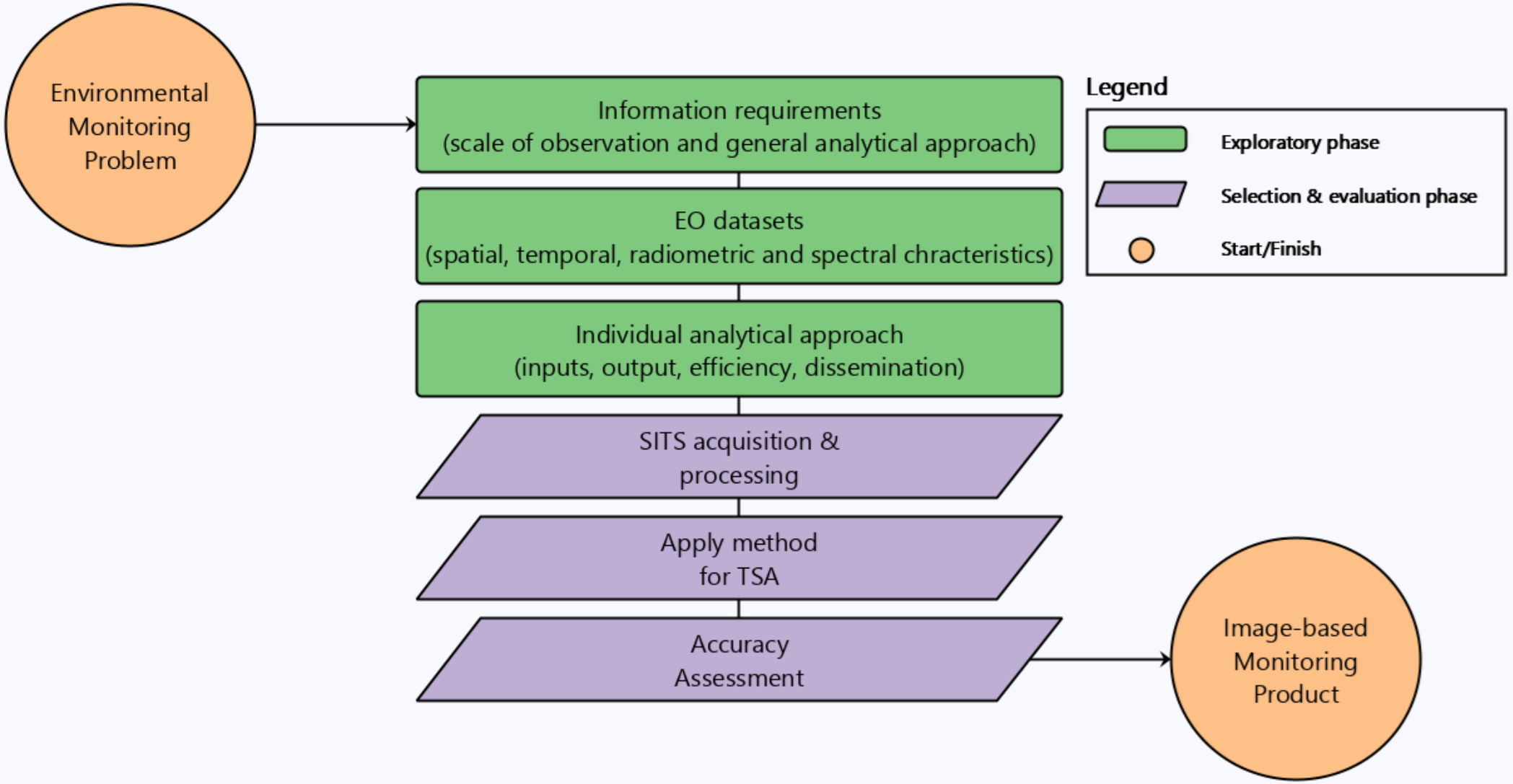


Steps in remote sensing monitoring



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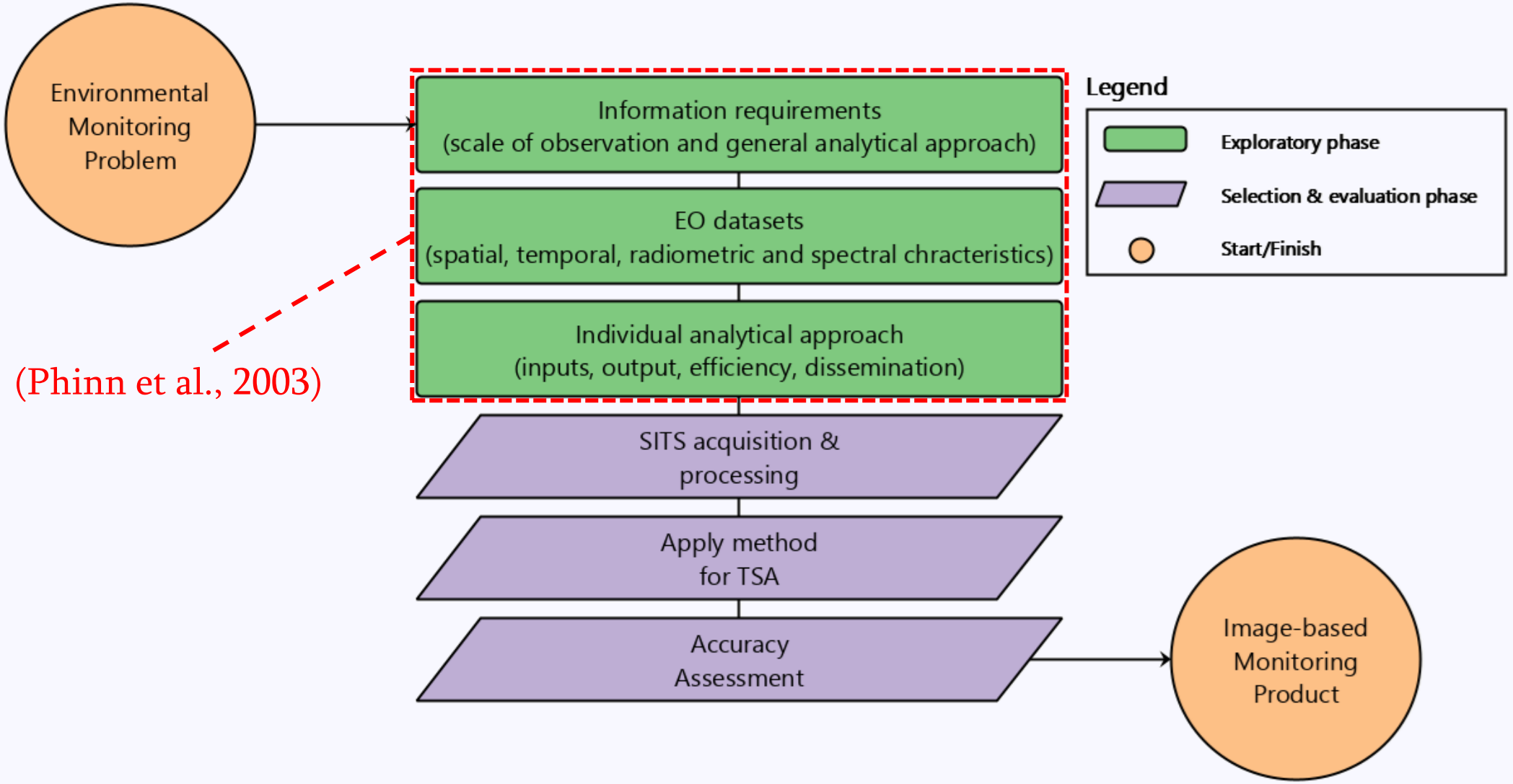
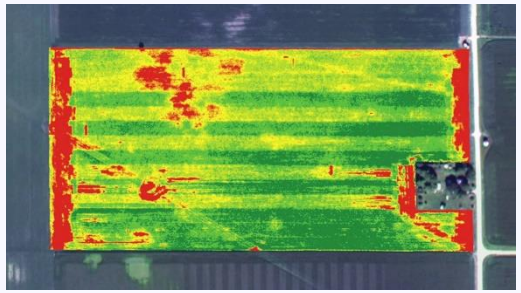


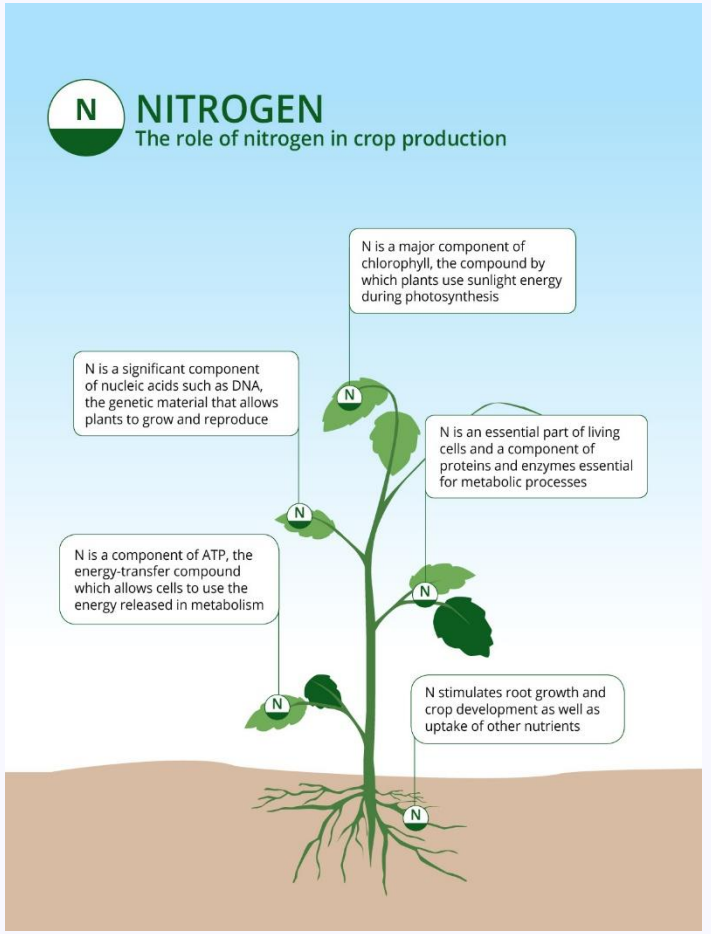
What problem do you want to address?



Driving factors
(abiotic & disturbance)

Landscape patterns
(composition & configuration)

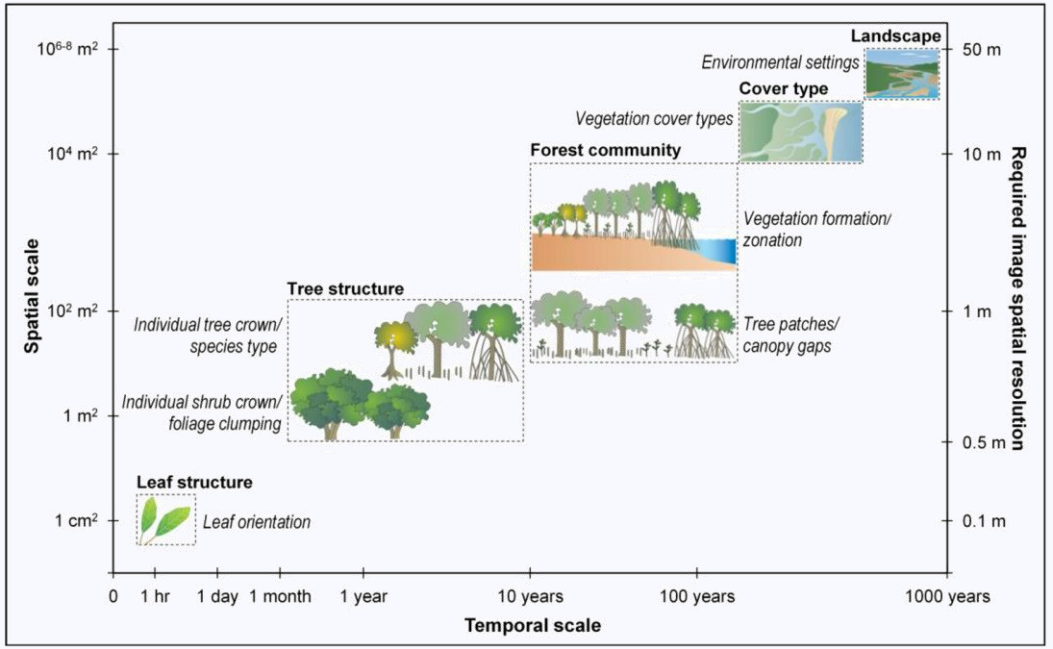
Ecosystem processes
(vertical & lateral fluxes)



Positive/negative feedback

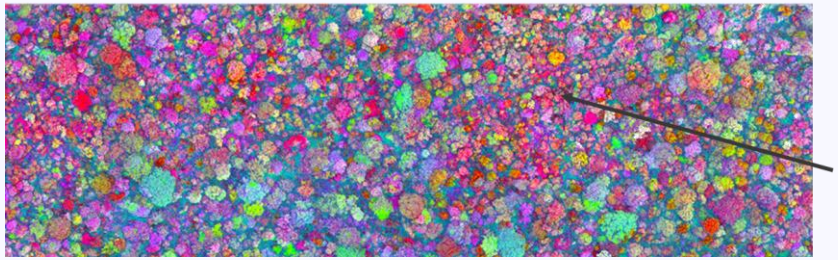
Scale of Observation

- Extent
- Minimum mapping unit (MPU)/Ground resolution element (GRE)
- Grain/target



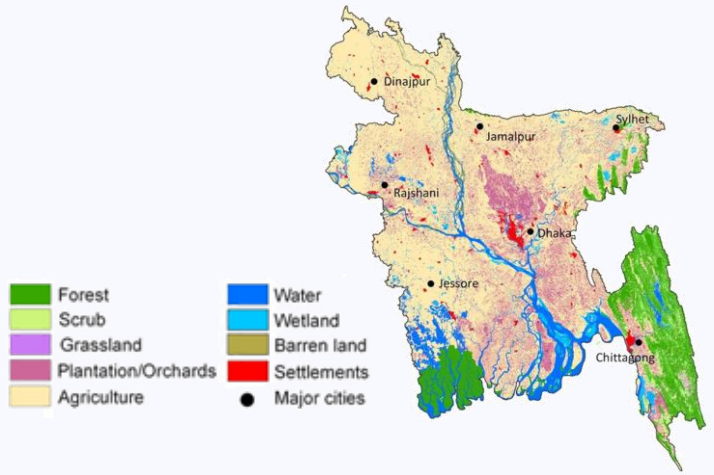
True Color Composite

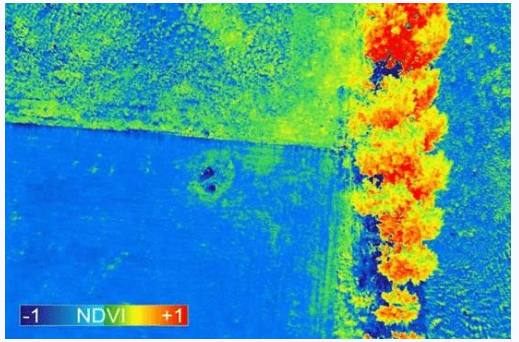
Tree Species derived from hyperspectral EO

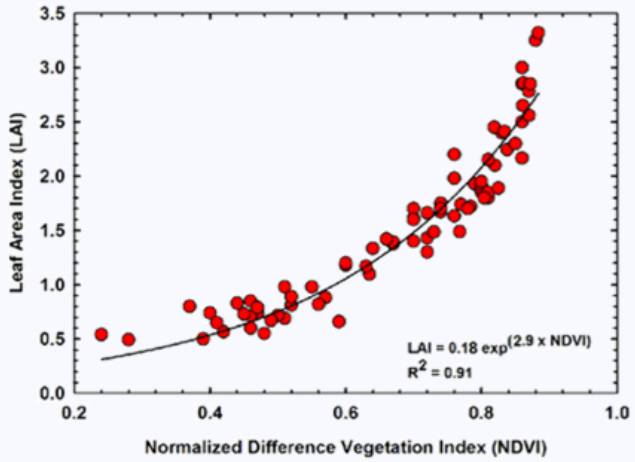


General Analytical Approaches

- Landscape element pattern ("conversion") analysis
  - Categorical (PV, NPV, soil)
  - "Fuzzy"
- Quantification and mapping of biophysical patterns ("modification")
  - Continuous (spatial structure)
  - Empirical
  - Deterministic or mechanistic

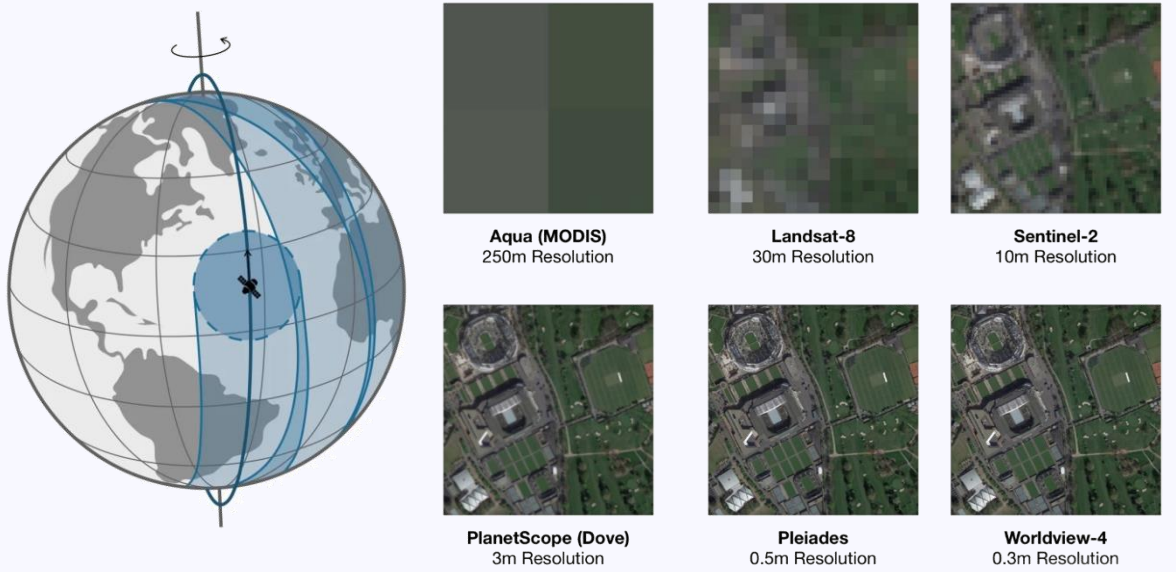






Types of Resolution

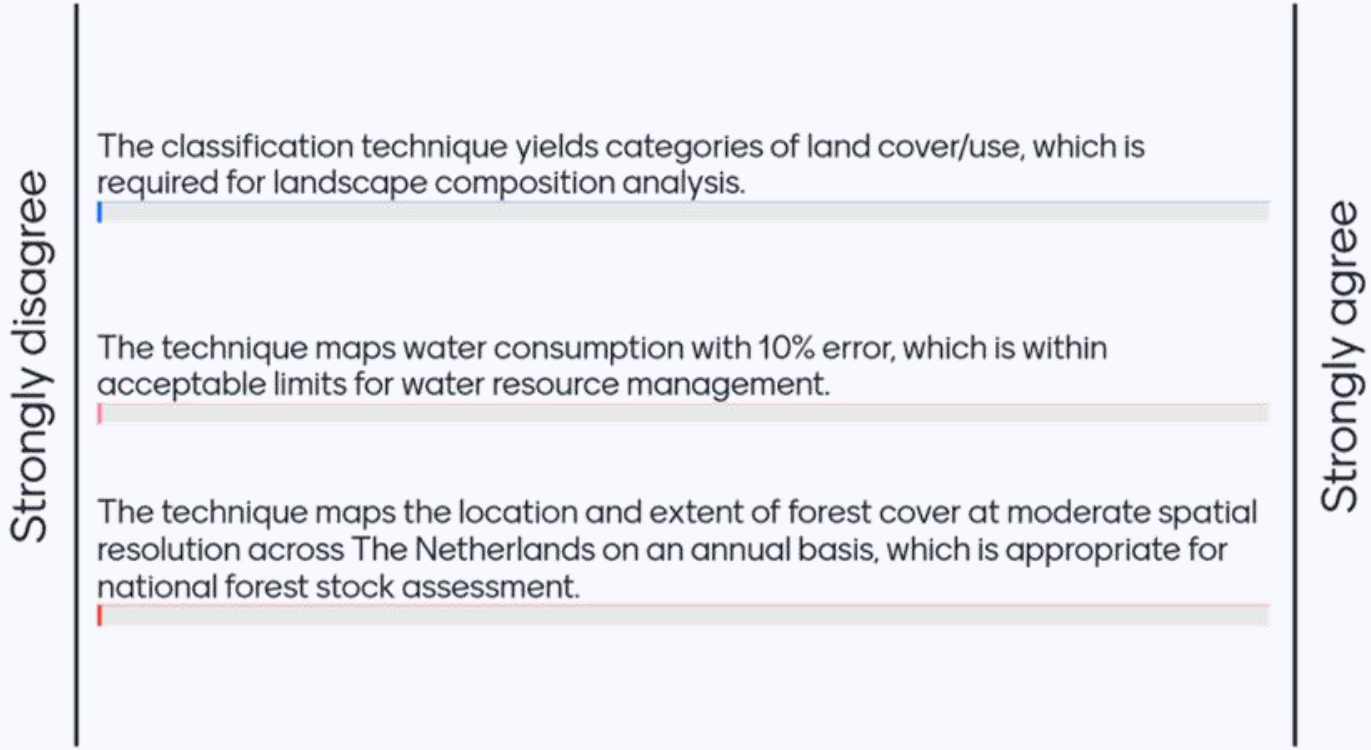
- Spectral resolution
  - Number of bands and width
- Temporal resolution
  - Return frequency
- Spatial resolution
  - Size of smallest object visible
- Radiometric resolution
  - # of bits / shades of grey
- Tradeoffs



Selection Criteria for an Analytical Method

Does the EO data meet method assumptions and input requirements?	Effective
Is the output within “acceptable” error levels for the mapping problem?	Reliable
Does the output match the spatio-temporal characteristics of the problem?	Valid
Can the method be implemented within a specified time horizon given the costs of labor, computer processing, etc.?	Efficient
Is the output format acceptable for use by target knowledge users?	Usable

Which condition of an Earth observation analytical technique fulfills the "reliability" criteria?



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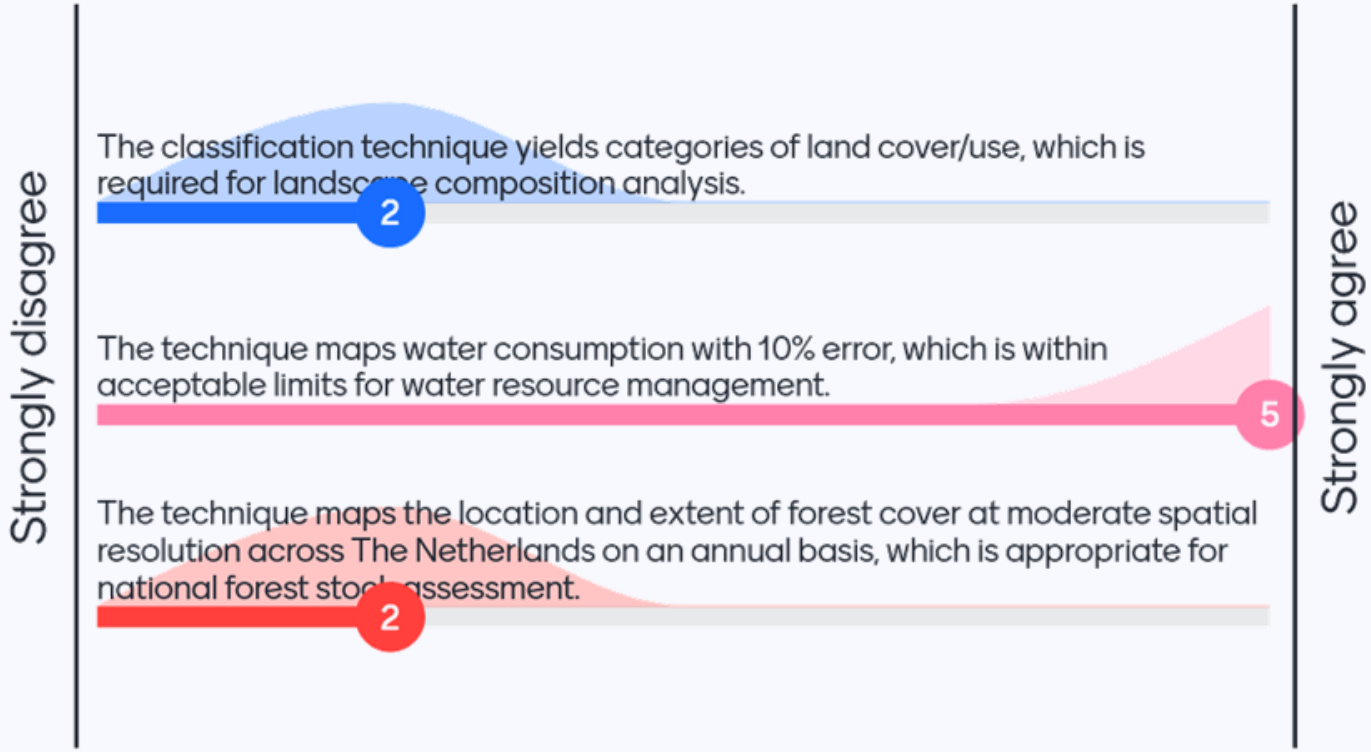

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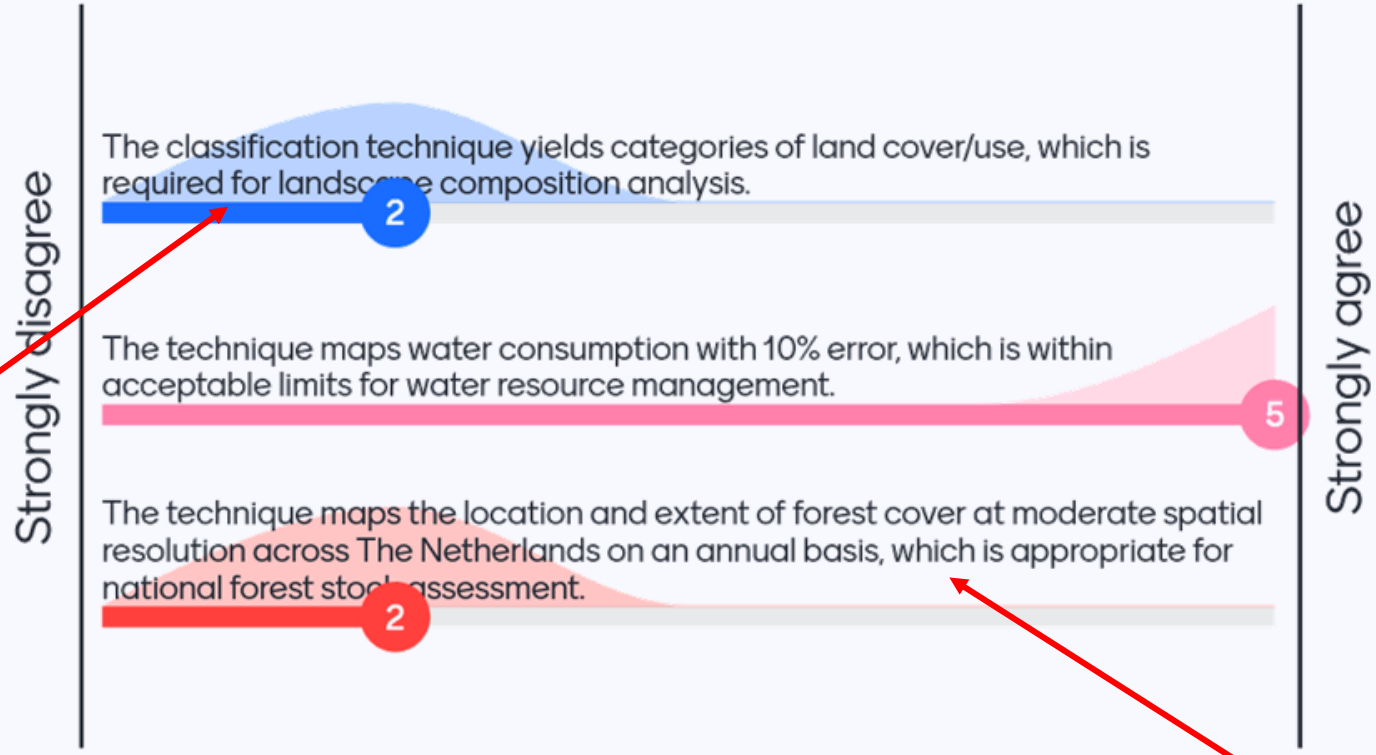


Effective

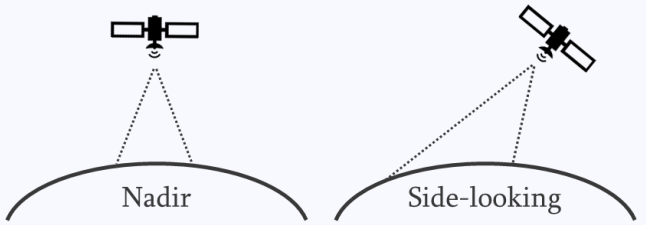
Valid

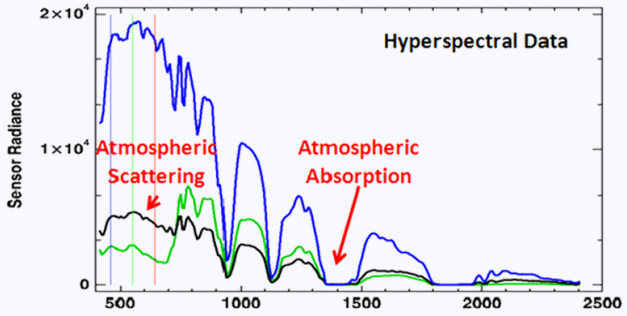
Data Acquisition

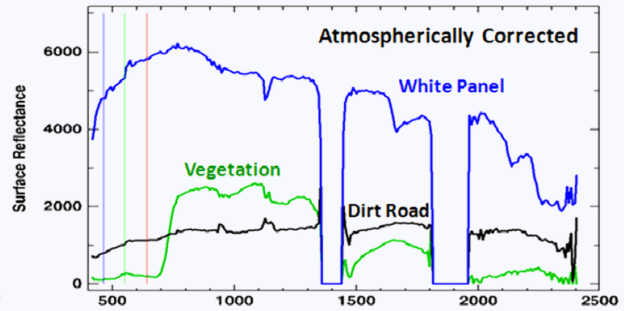
- ESA Copernicus Open Access Hub (https://scihub.copernicus.eu/)
- Google Earth Engine (https://earthengine.google.com/)
- NASA Earth Data (https://search.earthdata.nasa.gov/)
- NASA/USGS AppEEARS (https://lpdaac.usgs.gov/tools/appeears/)
- USGS GloVis (https://glovis.usgs.gov/)
- USGS Earth Explorer (https://earthexplorer.usgs.gov/)
- VITO Vision (http://www.vito-eodata.be)

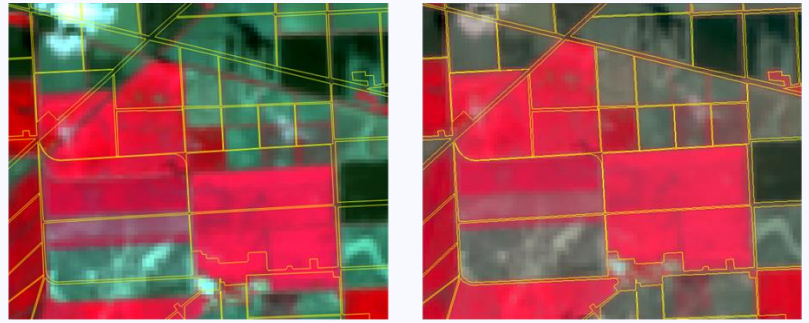
Preprocessing

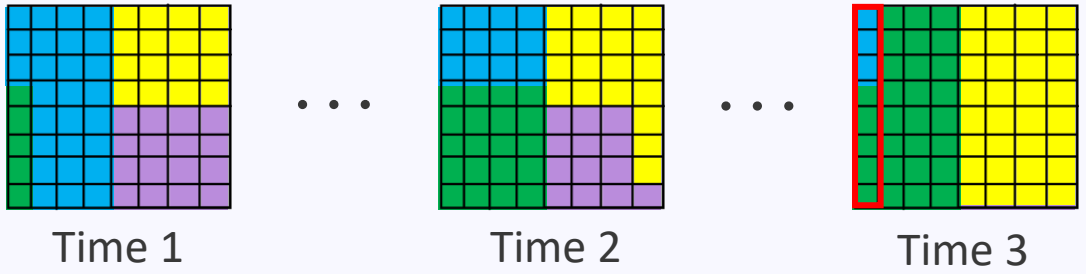
- View/sun angle
- Atmospheric correction
  - Dark-object subtraction
  - Radiative transfer
  - Cloud/cloud shadow masking
- Geometric correction
  - Ground control points
  - Othrorectification
- Radiometric normalization
  - Pseudo-invariant features





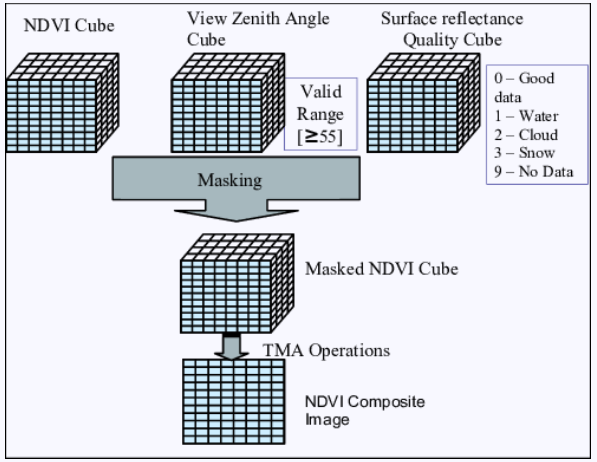




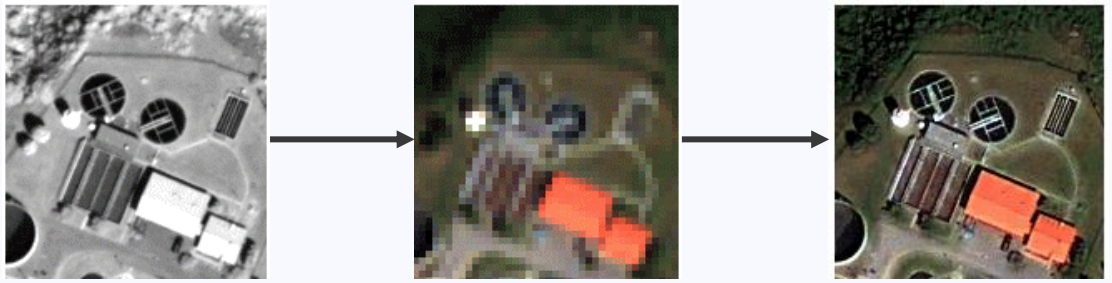


Enhancement

- Composites MODIS
- Metrics (e.g., NDVI)
- Mosaics UAV image
- Multi-sensor data fusion Landsat + Modis for phenology study
- Pan-sharpening (single source) earlier it used to use



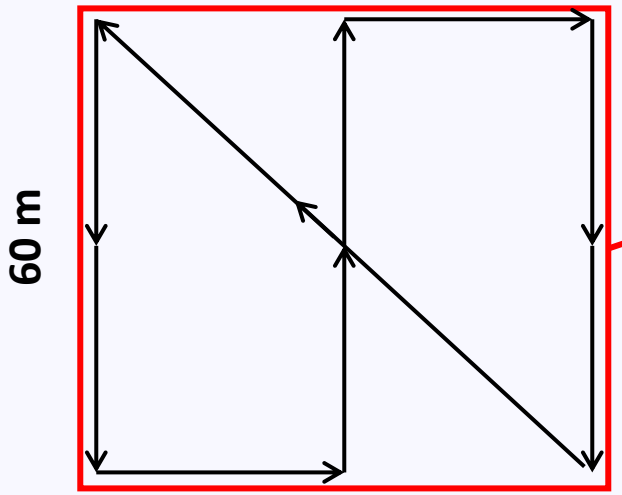
Processing changes the values but enhancement does not. It is for visibility

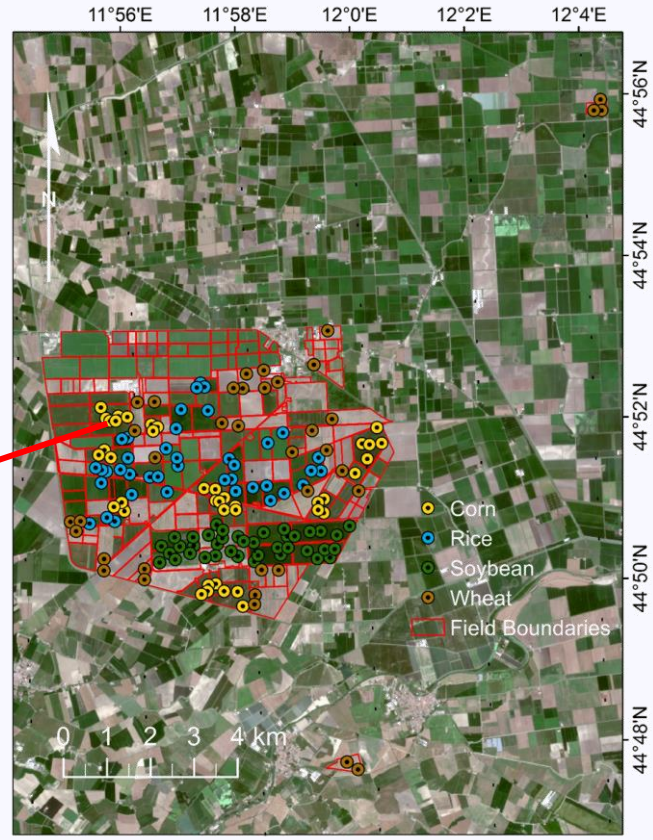


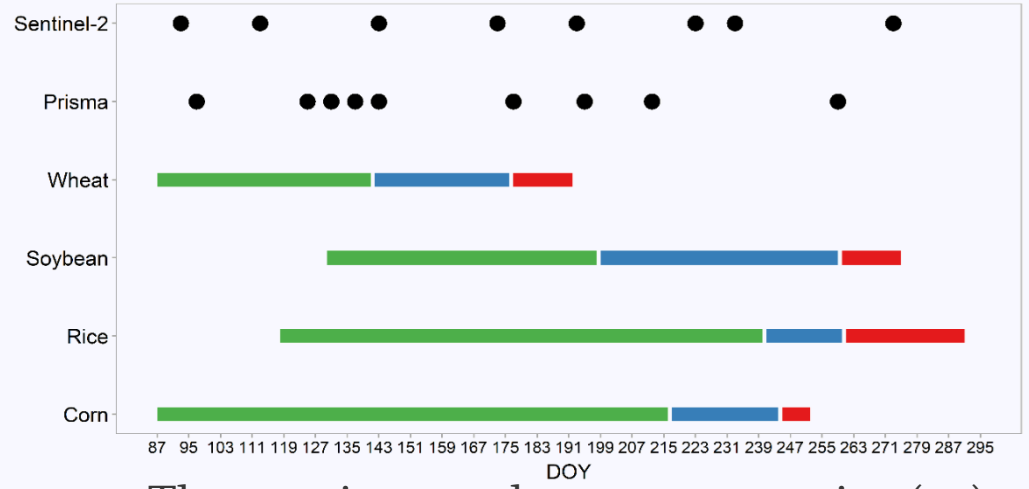
Reference Data

- Objective of field work
- Timing of observations
- Sampling design random or stratified
- # of samples 40 samples/crop

  Follow books
- Size of sample sites



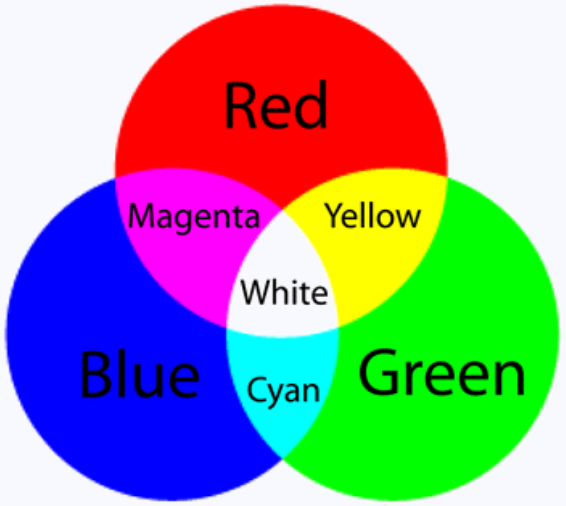


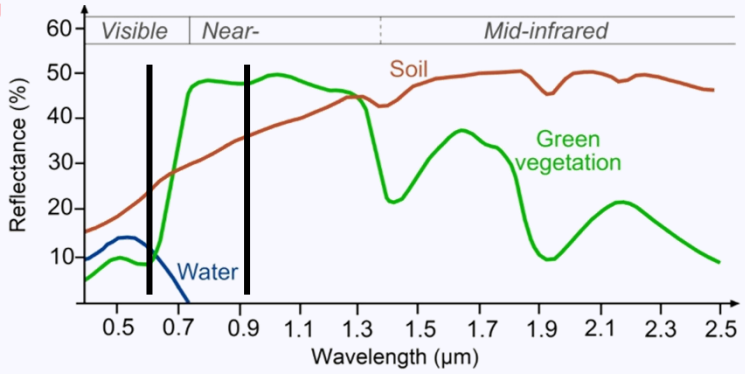


Three main growth stages: vegetative (—), reproductive (—), and maturity (—)

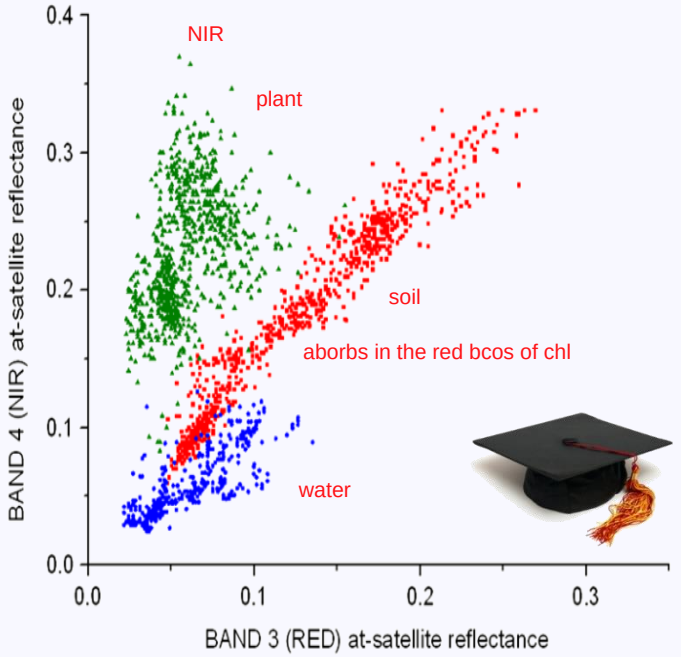
Extracting Information
Change Index

- Raw spectra
- Brightness temperature
- Backscattering coefficients
- Vegetation indices are more popular than transformation
- Principle components Preprocessing
- Tasseled cap transformation
- Spectral mixture analysis





Refelect



Extracting Information
Continuous methods

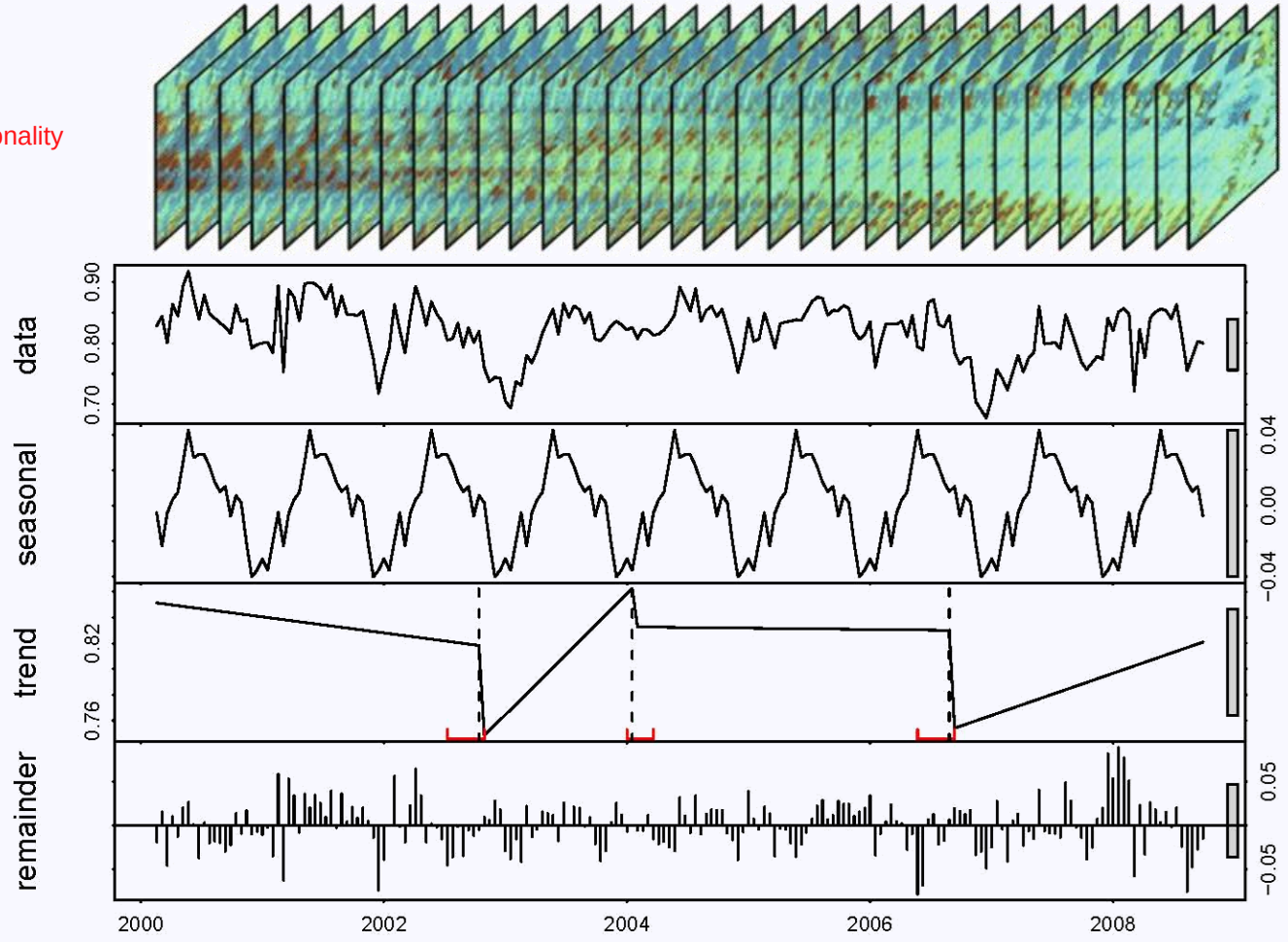
We focus mainly on analyzing continuous data

- Categorical approach: subtle changes missed and susceptible to "edge-effects" land cover classification
- Fuzzy approach : accounts for deficiencies in categorical approach, but non-intuitive

Extracting Information
Continuous methods

we will use correlation methods

- Abrupt change/recover
  - Landtrendr used for detecting trends not seasonality
- Within-season forecasting
  - Correlation analysis
- Seasonality/trend
  - BFAST
  - Box-Jenkins
  - Spectral analysis
- Drought/floods
  - Anomalies



BFAST: Verbesselt et al. (2010)

Accuracy Assessment

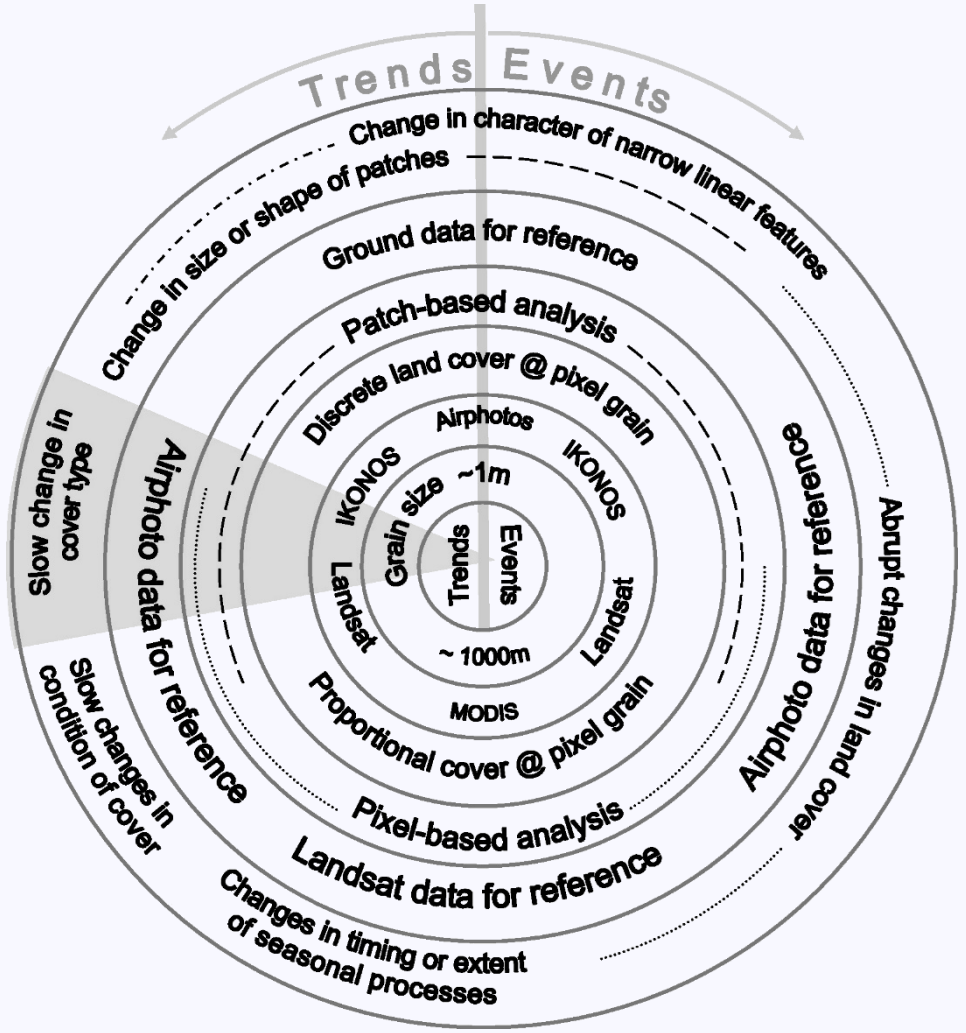
- Independent reference data
  - Accuracy level >> map product
  - Samples (“points”)
  - Elementary sampling units (samples within a frame)
  - Vectors from HR imagery

- Error statistics
  - Confusion matrix (categorical data) categorical data are not important for monitoring
  - R^2, RMSE, MAE, bias (continuous data)

- Sample size
  - Cross-validation, bootstrapping, jackknifing for samll sample size
  - Over- and under-sampling problematic in ML
  - Split sample

Conclusion

- Identify imagery appropriate to detect changes in resource attributes/indicators
- Identify potential imagery of appropriate grain and extent
- Estimate costs of pre-processing and analysis
- Evaluate the availability and cost of appropriate reference data
- Characterize performance of different options in terms of cost, confidence in map product, and utility of the map product



Kennedy et al. (2009)

Agricultural Monitoring Feasibility Assessment

Hierarchy Theory in Phinn et al. (2003) is applied to habitat mapping in a restored wetland environment. It is used to select “optimal” EO data and analytical techniques.

In the courses’ first practical, you will apply Hierarchy Theory and concepts elaborated upon in Kennedy et al. (2009) to select EO data and an analytical technique to monitor various patterns in an important agroecosystem of the USA.

We will use the jigsaw cooperative teaching technique to increase efficiency and individual responsibility in the decision-making process.