Hyperspectral imagery applications for agricultural and environmental monitoring

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Context

- Sustainable agriculture and new EU regulations (Cross compliance, GAEC, FAS,...).
  - Monitoring agriculture and environment is closely linked to the knowledge of **agricultural management systems** combined with **physico-chemical and environmental** crop characteristics at different **spatial levels** (from sub-parcel to regional levels)

- From Hyperspectral imagery to Hyperspectral remote sensing.
  - **Hyperspectral imagery**, also known as imaging spectroscopy is widely used in the laboratory by physicists and chemists.
  - More recently (in the mid-80's), with advancing technology, imaging spectroscopy also focused on the Earth surface introducing the concept of **hyperspectral remote sensing.**

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Presentation

- Context
- Hyperspectral remote sensing
  - Hyperspectral image characteristics from air- and space-borne sensors
  - Hyperspectral Data acquisition and processing
- Hyperspectral imagery potentialities
- Hyperspectral-based characterization of grassland at local and regional level
  - Inventory of forage production & quality
  - For controlling GAEC and AEM applications

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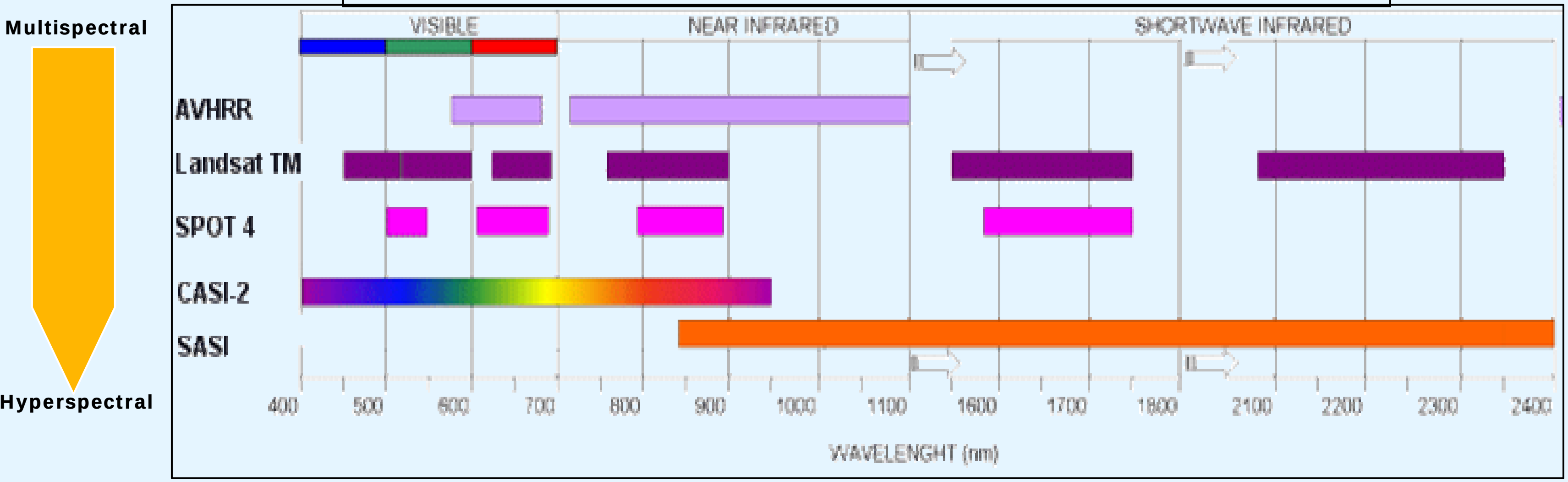
Hyperspectral remote sensing

- Combines spectral & spatial information
  - Broad-wavebands (separated by spectral segments) *vs.* narrow-wavebands (> hundred of bands, narrowness & contiguous)

Multispectral & hyperspectral sensors bandwidth comparison



- **CASI-2** (Compact Airborne Spectrographic Imager)
  - VIS-NIR (400-950 nm)
  - # spectral bands: 96 bands
  - Spectral resolution: 5.7 nm
  - Spatial resolution: 2.5 x 2.5 m
  - Swath width: 303 pixels
- **SASI** (Shortwave Infrared Airborne Spectrographic Imager)
  - SWIR (850-2450 nm)
  - # spectral bands: 160 bands
  - Spectral resolution: 10 nm
  - Spatial resolution: 2 x 2 m
  - Swath width: 600 pixels

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Hyperspectral remote sensing

- Combines spectral & spatial information
  - Broad-wavebands (separated by spectral segments) *vs.* narrow-wavebands (> hundred of bands, narrowness & contiguous).
  - Hyperspectral imagers produce a stack of images of an object (scene) where each image is acquired at each narrow spectral band forming the familiar “image cube” (2 spatial dimensions + 1 spectral dimension).
  - A temporal dimension can be added.

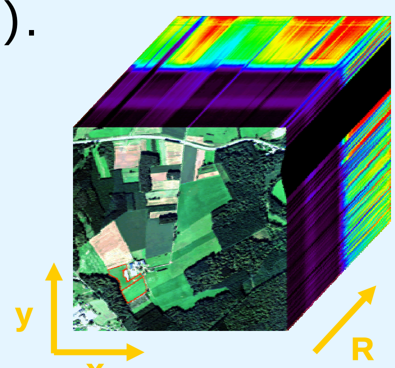

Image analysis combined spectral & spatial analysis
Based on spatial image analysis, chemometrics and spectroscopy analyses.

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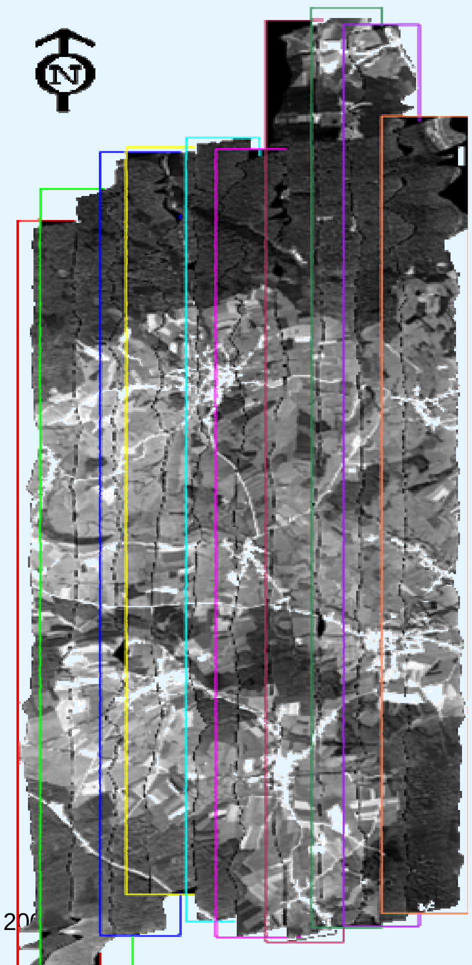
Hyperspectral remote sensing

- Data acquisition
  - Variable atmospheric & climatic conditions between scenes:
    (aerosol, cloud, brightness…)
  - Sensor problems:
    pixels with outlier values
    (difficult to repeat the acquisition campaign)



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Hyperspectral remote sensing

- Data acquisition

- Material
  - Not pure pixel (Pixel Purity Index)
  - Not homogeneous scene
  - Background reflectance (soils…)
  - Canopy architecture (texture…)
  - …

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Hyperspectral remote sensing

- Data acquisition
- Material
- Geometric aspects
  - Georeferenced & Orthorectified image

Geometric distortion

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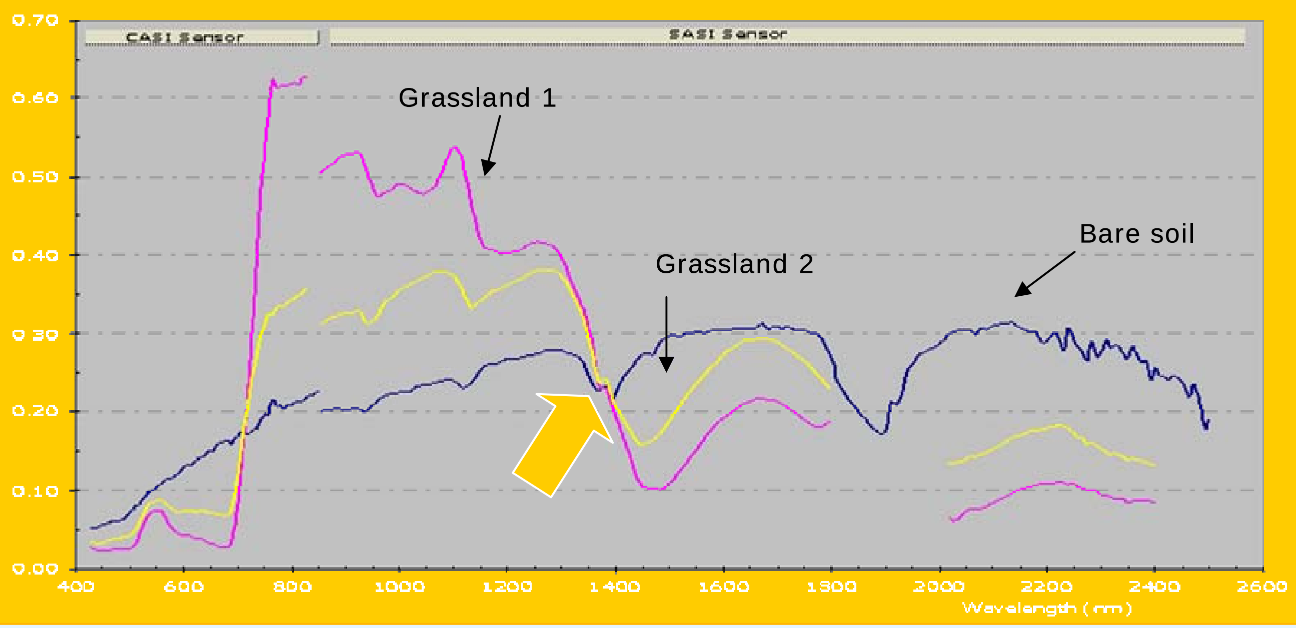
Hyperspectral imagery potentialities

- Provide sufficient details for target identification.

Spectral analysis at pixel level to identify specific targets (e.g. grassland)



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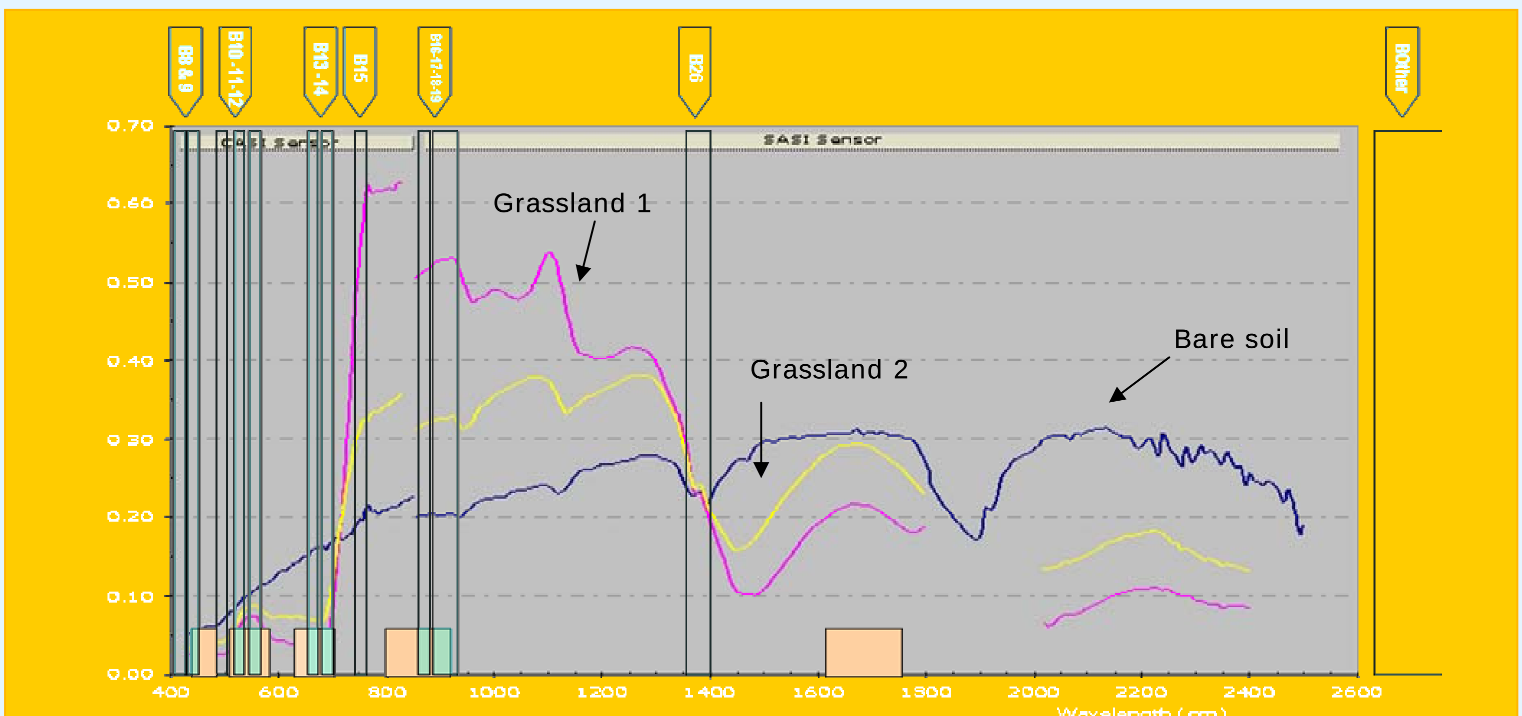
Hyperspectral imagery potentialities

- Provide sufficient details to distinguish spectrally similar materials.
  - Multispectral sensors provide an average reflectance for a spectral segment (region) with 1 channel.
  - Hyperspectral sensors provide several reflectance values for this spectral segment.



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Hyperspectral imagery potentialities

- Provide sufficient details to distinguish spectrally similar materials.
  - Multispectral sensors provide an average reflectance for a spectral segment (region) with 1 channel.
  - Hyperspectral sensors provide several reflectance values for this spectral segment.

To distinguish spectrally similar materials like vegetation types, vegetation conditions (stress, disease…)

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Hyperspectral imagery potentialities

- Provide sufficient spectral details to predict physico-chemical properties.

To estimate biophysical parameters (wet matter, biomass, grass height…) & biochemical parameters (protein, VEM, DVE…)

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Hyperspectral imagery potentialities

- Provide sufficient spectral **and** spatial information to detect spatial discrepancies.
  - A spatial discrepancy is defined as a pixel or small group of pixels that differ in reflectance from surrounding pixels inside a given target.

Spectral analysis at Parcel level
To classify agricultural practices

(haying grasslands, grazing grasslands, neither haying nor grazing grasslands…)

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Hyperspectral imagery applications for grassland

- Spectral analysis at pixel level
  - To identify grassland (land use)
  - To characterize grass canopy with quantitative information (biophysical and biochemical).
- Spectral analysis at parcel level
  - To discriminate/classify grassland management practices in relation with GAEC en AEM.

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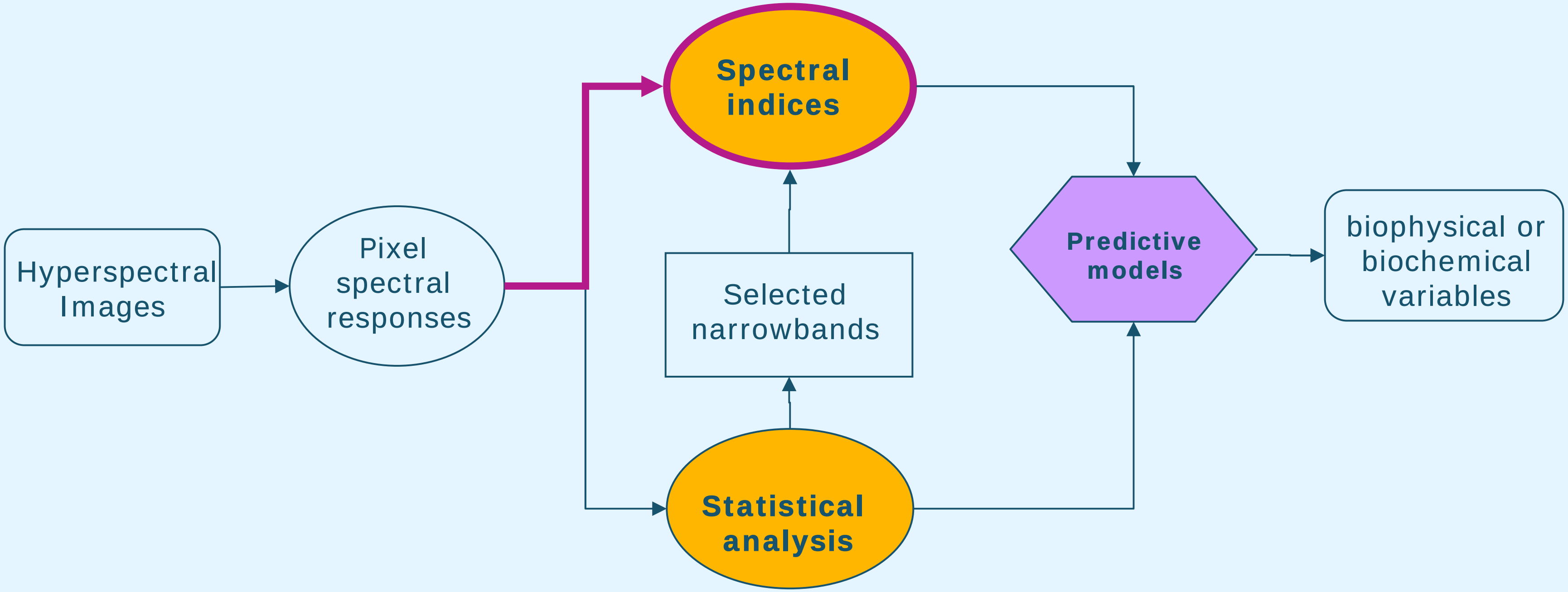
Spectral analysis at pixel level

- Vegetation Indices (VI)
  - Spectrally derived broad-waveband VI have been widely used to quantify crop parameters (such as wet biomass, LAI, plant height…)



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Spectral analysis at pixel level

- Vegetation Indices (VI)
  - These indices derived from narrow-waveband give better estimations of biophysical variables.
    - Indices from multispectral sensors use average spectral information over broad-waveband widths (e.g. TM band 3 [red]: 0.63 to 0.69, TM band 4 [NIR]: 0.76 to 0.90) resulting in loss of critical information.
  - However the large number of bands is not fully exploited
    - **Optimal combination** of specific narrow-wavebands for specific material.
    - **New indices** computed using wavebands other than Red or NIR (e.g. green vegetation indices)
    - **Spectral profile characteristics** in particular spectral regions (red-edge and green-edge narrowband): Amplitude, slope, maximum slope wavelength…

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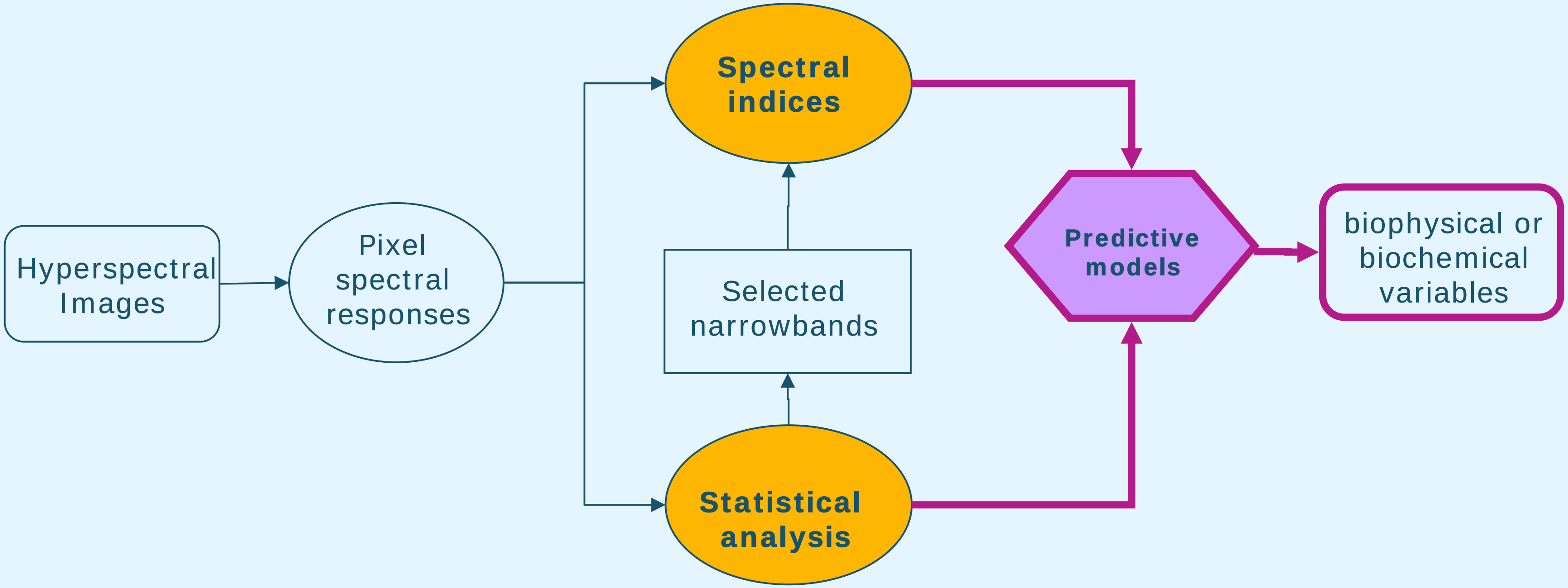
Spectral analysis at pixel level

- Optimum multiple narrow-waveband regression models
  - Multiple linear regression using several bands or band ratios.



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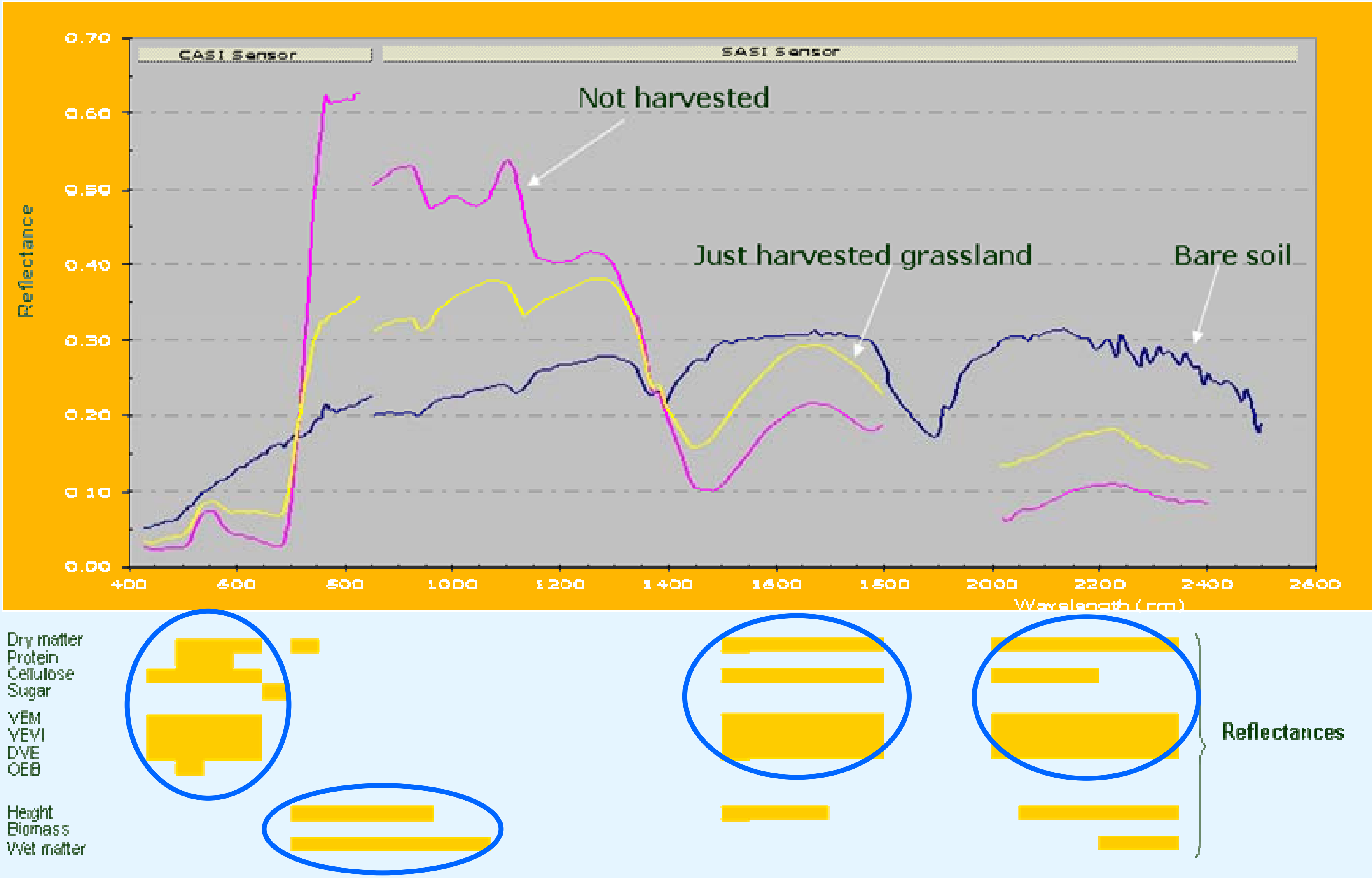
Spectral analysis at pixel level (grassland analysis)



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Spectral analysis at parcel level

- Study the possibility to classify grassland in **management classes**
  - Haying grasslands (P)
  - Grazing grasslands (F)
  - Neither haying nor grazing grasslands (NP NF)

- Grassland classification based on the hypothesis that management practices can be identified by the combination of
  - **Vegetation indicators** (quantitative parameters) selected at the pixel level
  - **Textural indicators** (qualitative parameters)

- Different textural approaches
  - Global approach (global variance)
  - Local approach (moving windows of 3x3 pixels)

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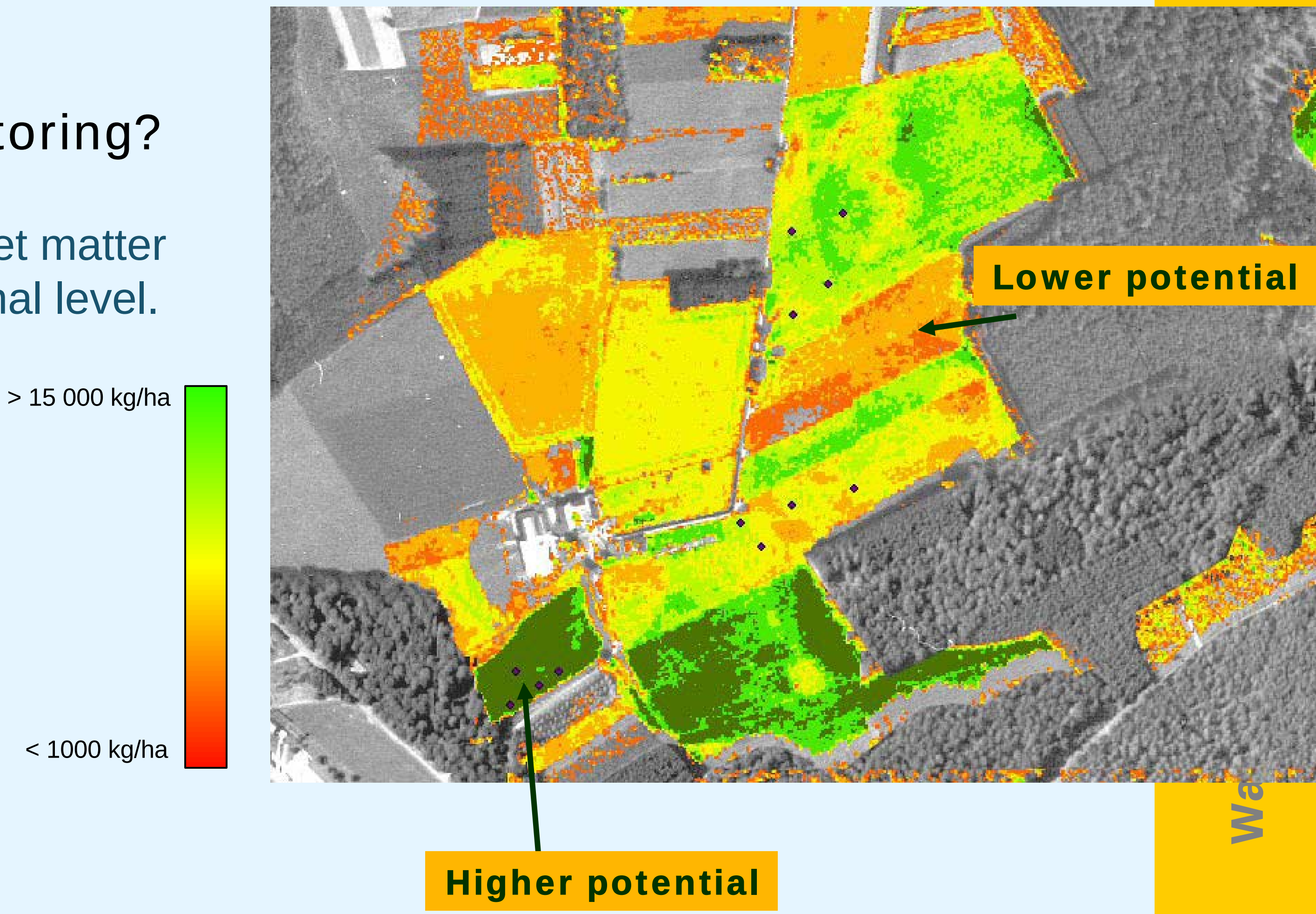
Regional mapping

- Question 1:
  Regional monitoring?

Estimation of the wet matter production at regional level.



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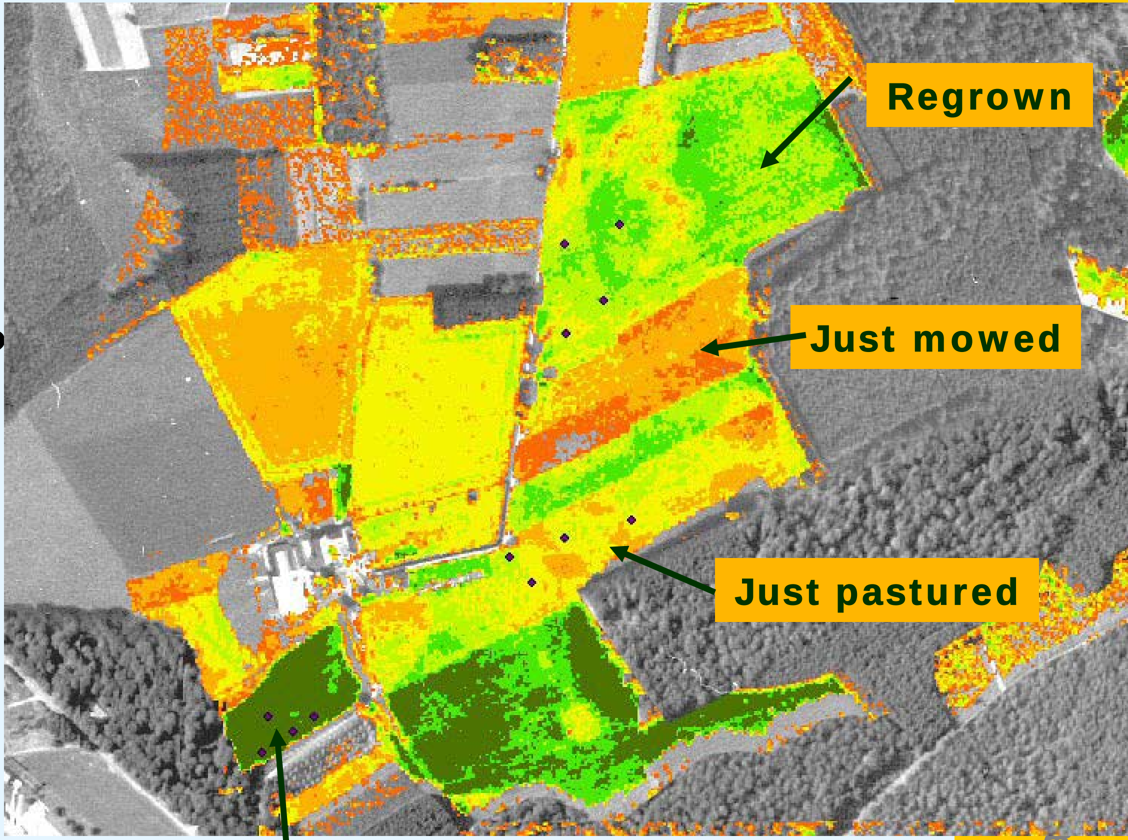
Regional mapping

- Question 1:
  Regional monitoring.

- Question 2:
  Grassland discrimination?



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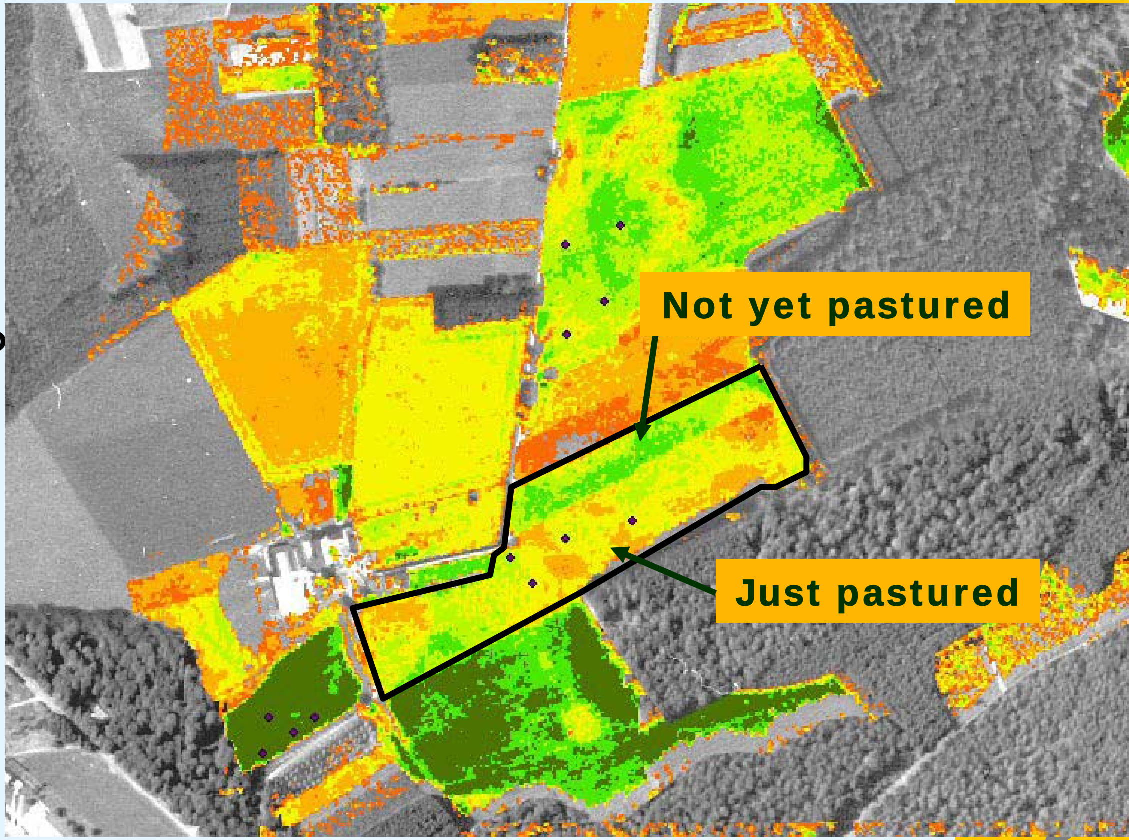
Regional mapping

- Question 1:
  Regional monitoring.
- Question 2:
  Grassland discrimination?
- Question n°3:
  Management practices?



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Conclusion

- Growing area of interest in the RS community is the use of measurements made at multiple wavebands to increase the acquisition and detection of low contrasted targets.

- For applications in agriculture and environment monitoring, both high spatial resolution and high temporal frequency are necessary.

- The future:
  - Sensor providing High resolution data (spatial and spectral resolution) with low temporal frequency.
  - Panchromatic -> Multispectral -> Hyperspectral -> Ultraspectral

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