AST 426 :Sensing Technologies for Precision Farming II

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Recap from Previous Lecture

Soil Available Water (AW)

- The amount of water in the soil that is available for plant uptake, typically measured as the difference between the soil water content at field capacity and the permanent wilting point.

$$AW = FC - PWP$$

Available Water Depletion Percentage (AWD%)

$$\boldsymbol{AWD\%} = \left(\frac{FC - \theta}{FC - PWP}\right) \times 100 = \left(\frac{\boldsymbol{FC - \theta}}{\boldsymbol{AW}}\right) \times \mathbf{100}$$

θ : Current VWC (%) in soil

Recap from Previous Lecture

Example: Let us say, you have sandy loam soil that has field capacity (FC) of 30%, PWP of 15% and your soil moisture sensor reads its current VWC (θ)as 22%. Then what is the AWD% of your soil?

Solution:

$$AWD\% = \left(\frac{FC - \theta}{FC - PWC}\right) \times 100 = \left(\frac{30-22}{30-15}\right) \times 100 = \mathbf{53.33\%}$$

Soil Moisture Sensor for Irrigation Scheduling

Irrigation Trigger Point/Management Allowable Depletion (MAD)

- Farmers typically aim to irrigate when a certain percentage of available water has been depleted, often referred to as the **Management Allowable Depletion (MAD)**
- This threshold can vary based on the **crop, soil type, and environmental conditions**.

Soil Moisture Sensor for Irrigation Scheduling

Quiz

The field capacity (FC) of a soil is 30%, the permanent wilting point (PWP) is 15%, and the current volumetric water content (VWC) is 18%. The MAD value for the crop is set at 40%. Should irrigation be applied?

We know that : AW=FC-PWP=30%-15%=**15%**

This means that available water in the soil is 15%.

Given, MAD=40%

MAD threshold = 40% of AW = $\left(\frac{40}{100}\right) \times 15 = \mathbf{6}\%$

Therefore, Soil Moisture Threshold to trigger irrigation = 30%-6% = **24%.**

But current VWC is 18% which is below 24%, **therefore irrigation should be applied**.

Soil Moisture Sensor for Irrigation Scheduling

Quiz **You are managing two different crops in the same field. Crop A has a MAD value of 40%, and Crop B has a MAD value of 60%. The field capacity is 30%, and the permanent wilting point is 10%. The current volumetric water content is 22%. For which crop (A or B) should irrigation be applied first?**

Crop A

We know that : AW=FC-PWP=30%-10%=**20%**

This means that available water in the soil is 20%.

Given, For **crop A** MAD=40%

MAD threshold = 40% of AW = $\left(\frac{40}{100}\right) \times 20 = 8\%$

Therefore, Soil Moisture (SM) Threshold to trigger irrigation = FC-MAD threshold=30%-8% = **22%.**

But current VWC is 22% which is at the same point as SM threshold of 22%, **therefore irrigation should NOT be applied quiet yet**.

Crop B

We know that : AW=FC-PWP=30%-10%=**20%**

This means that available water in the soil is 20%.

Given, For **crop B** MAD=60%

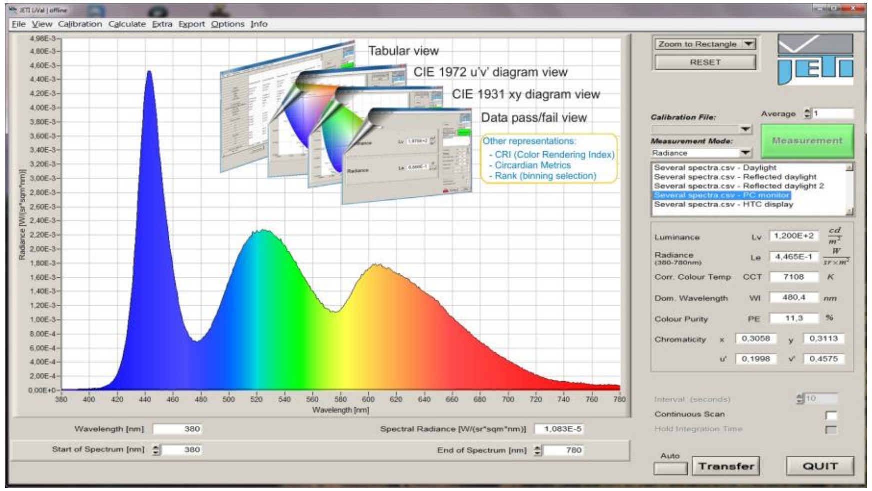
MAD threshold = 60% of AW = $\left(\frac{60}{100}\right) \times 20 = 12\%$

Therefore, Soil Moisture (SM) Threshold to trigger irrigation = FC-MAD threshold=30%-12% = **18%.**

But current VWC is 22% which is above the SM threshold of 18%, **therefore irrigation should NOT be applied**.

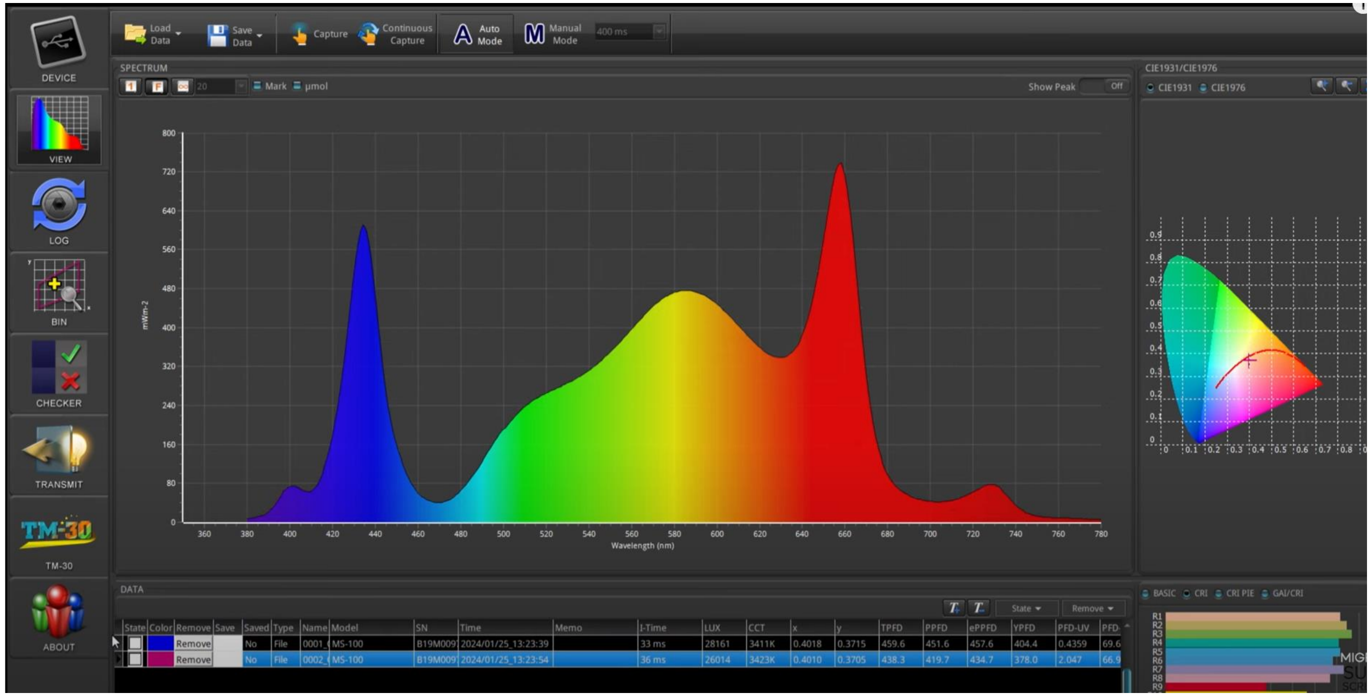
Proximal Sensing: Spectroradiometer

- Spectroradiometer is a device that measures the spectral power distribution of light across various wavelengths
- Captures spectral reflectance and absorbance data, helping to identify different materials based on how they reflect or absorb light.
- When used in **proximity to crops**, it collects detailed spectral data that can be used to **monitor plant health, stress, and growth**



Proximal Sensing: Spectroradiometer

- Spectroradiometer emits light onto a target (e.g., crop canopy) and measures the reflected light across a wide range of wavelengths, from visible light (400–700 nm) to near-infrared (700–2500 nm).



[Apogee M100 spectroradiometer | Grow Light spectrum analyser (youtube.com)]

Proximal Sensing: Spectroradiometer

Key Applications in Precision Agriculture

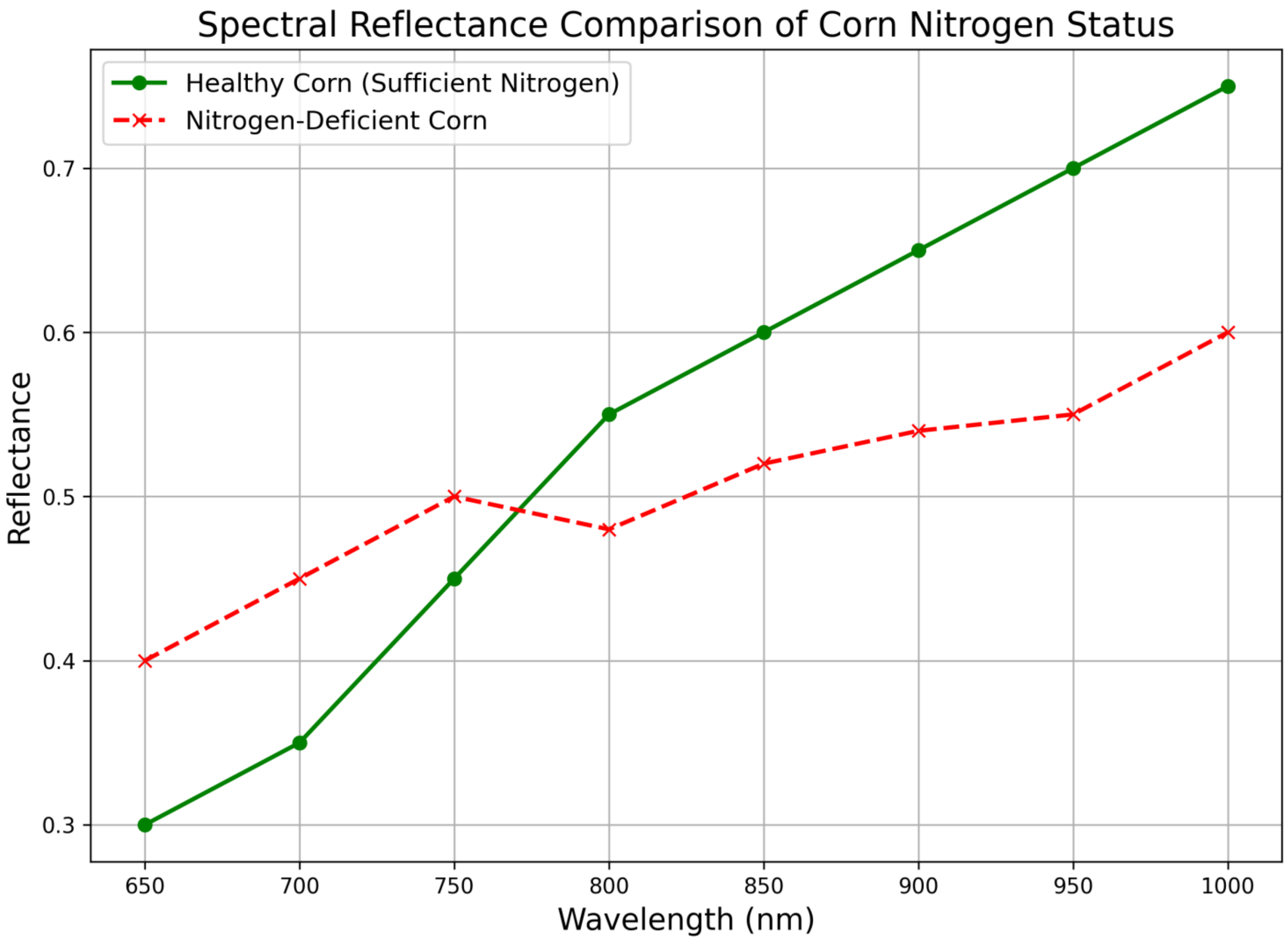
- Crop Health Monitoring
- Nutrient Management
- Water Stress Detection
- Yield Prediction

Case Study: Detect nitrogen deficiency in corn using a spectroradiometer to guide variable-rate nitrogen fertilization

- Spectroradiometers work by **measuring light reflectance** in different wavelengths, particularly in the **visible** and **near-infrared (NIR)** ranges.
- Nitrogen deficiency **reduces chlorophyll content** in plants, leading to **changes in reflectance**.
- **Nitrogen-deficient corn** shows **lower reflectance in the NIR region** and **higher reflectance in the visible (red) region**
- Chlorophyll content (an indicator of nitrogen levels) is strongly related to the **Normalized Difference Vegetation Index (NDVI)**, which is calculated from the red and NIR reflectance

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Case Study: Detect nitrogen deficiency in corn using a spectroradiometer to guide variable-rate nitrogen fertilization



Case Study: Detect nitrogen deficiency in corn using a spectroradiometer to guide variable-rate nitrogen fertilization

Quiz

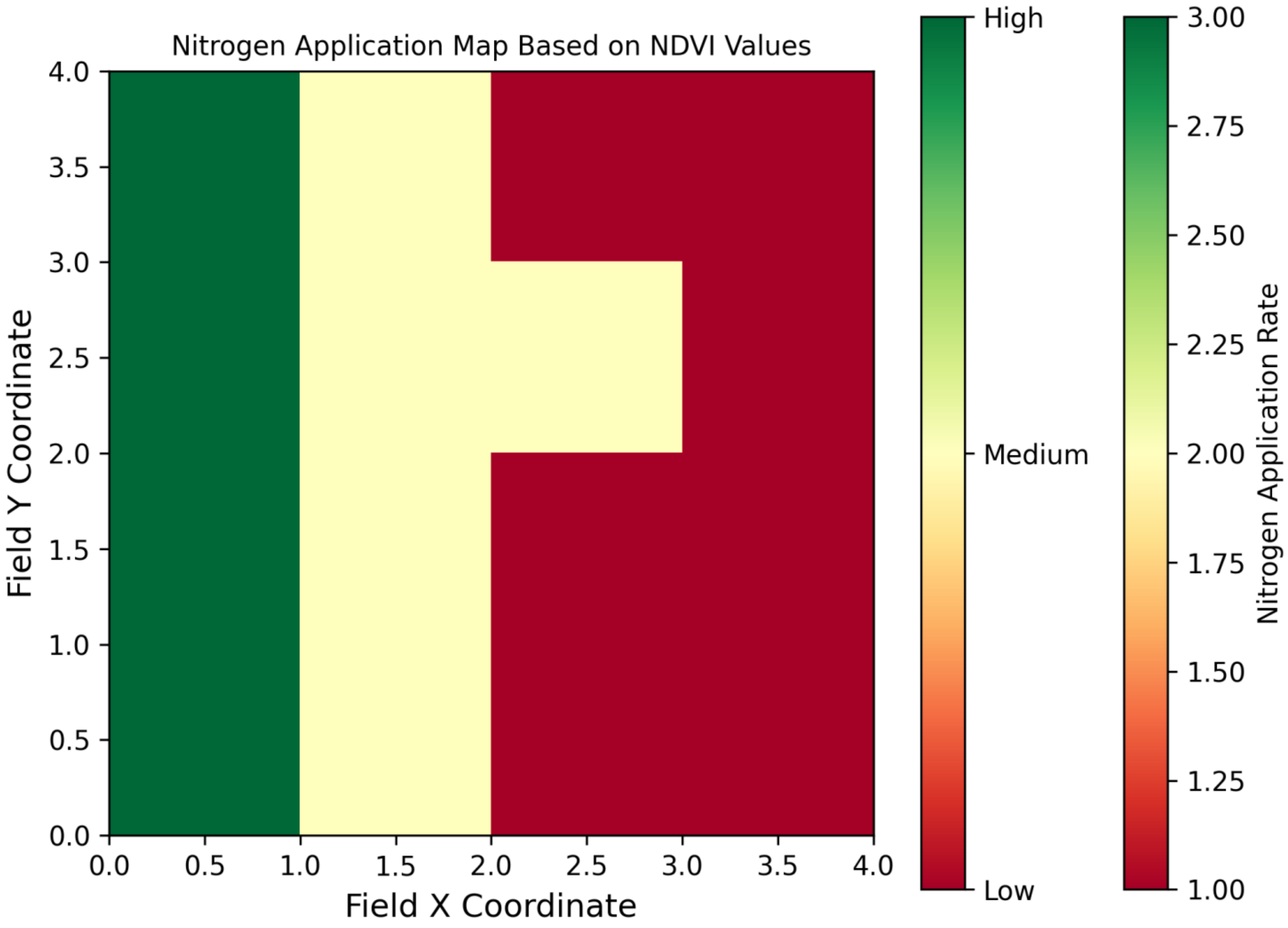
Determine the NDVI values for healthy and Nitrogen-deficient corn plants and interpret the results.

Corn Type	Red Reflectance (600-700 nm)	NIR Reflectance (700-1300 nm)
Healthy Corn	0.30	0.70
Nitrogen-Deficient Corn	0.45	0.55

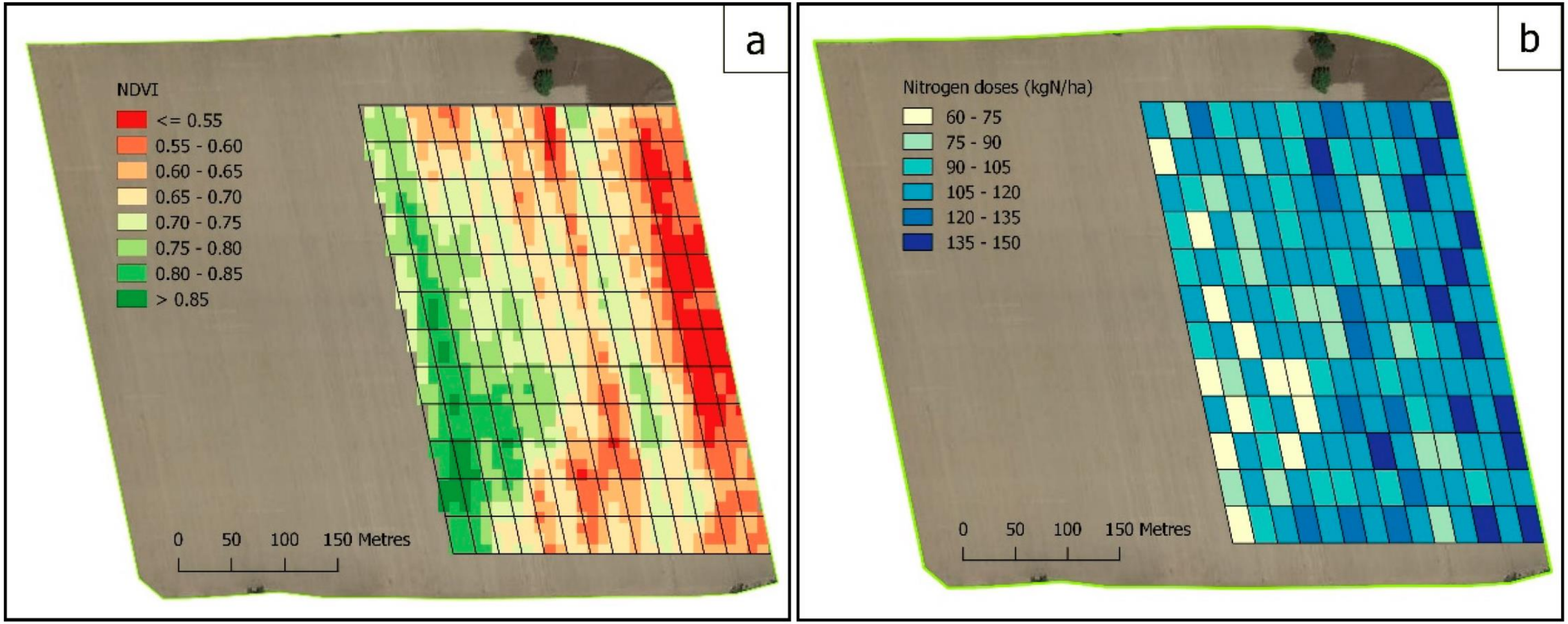
$$NDVI_{Healthy} = \frac{(0.70 - 0.30)}{(0.70 + 0.30)} = \frac{0.40}{1.00} = 0.40$$

$$NDVI_{Deficient} = \frac{(0.55 - 0.45)}{(0.55 + 0.45)} = \frac{0.10}{1.00} = 0.10$$

Case Study: Detect nitrogen deficiency in corn using a spectroradiometer to guide variable-rate nitrogen fertilization



NDVI-based Nitrogen Application Map



Vizzari, M., Santaga, F., & Benincasa, P. (2019). Sentinel 2-based nitrogen VRT fertilization in wheat: Comparison between traditional and simple precision practices. Agronomy, 9(6), 278.

Remote Sensing : Multispectral Sensors

- Multispectral sensors capture data at specific wavelengths across the electromagnetic spectrum, typically in the visible and near-infrared (NIR) ranges.
- Typically consists of **3 to 10 bands** (sometimes up to **20 bands**)
- Used to assess crop health, monitor soil conditions, and optimize resource management by detecting variations in light reflectance.

Types of Multispectral Sensors

i. **Handheld Multispectral Sensors**: Portable devices used for on-the-ground data collection.
ii. **Drone-Mounted Sensors**: Capture high-resolution, large-scale data over fields.
iii. **Satellite-Based Sensors**: Cover large geographic areas for long-term monitoring.

Remote Sensing : Drone-based Multispectral Sensors

**SPECIFICATIONS

WEIGHT	350 g (12.3 oz.) RedEdge-P + DLS 2
DIMENSIONS	8.9 x 7.0 x 6.7 cm (3.5in x 2.8in x 2.6in)
RGB OUTPUT*	5.1 MP (global shutter, aligned with all bands)
SENSOR RESOLUTION	1456 x 1088 (1.6MP per MS band) 2464 x 2056 (5.1MP panchromatic band)
GROUND SAMPLE DISTANCE	7.7 cm per pixel (per MS band) at 120m (~400 ft) AGL 3.98 cm per pixel (panchromatic band) at 120m (~400 ft) AGL
FIELD OF VIEW	50° HFOV x 38° VFOV (MS) 44° HFOV x 38° VFOV (PAN)
EXTERNAL POWER	7.0 V - 25.2 V
POWER INPUT	5.5/7.0/10W (standby, average, peak)

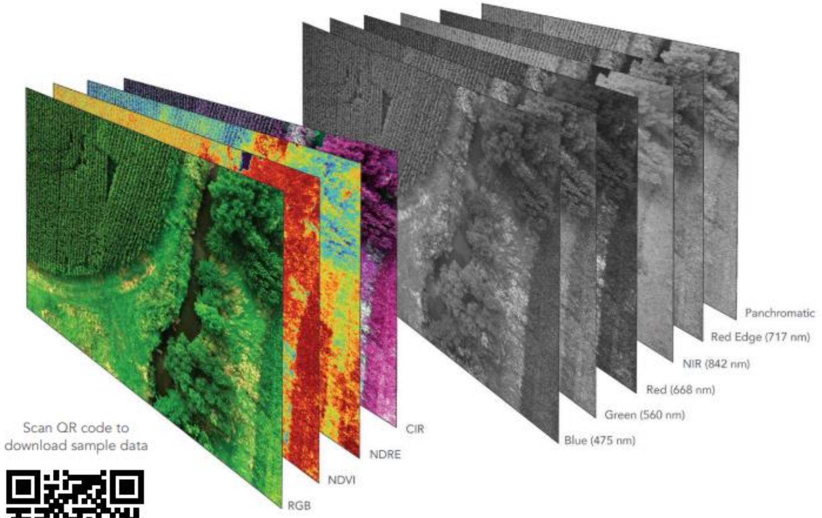
AgEagle MicaSense Altum-PT

AgEagle MicaSense RedEdge-P

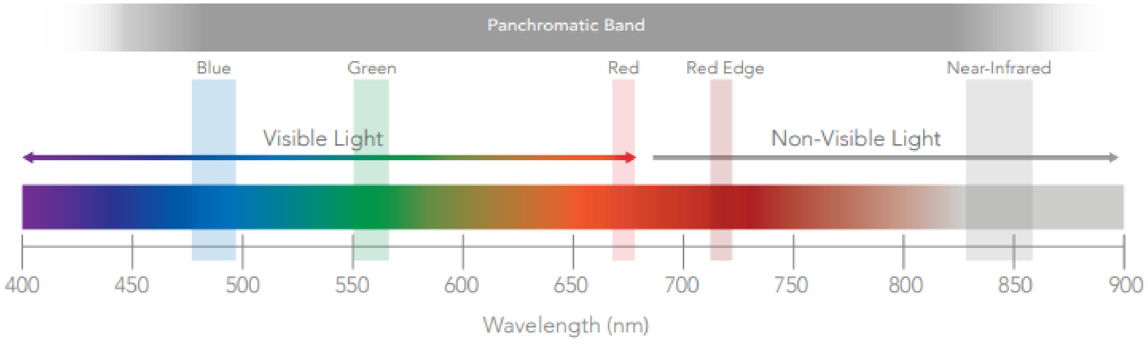
Panday, U. S., Pratihast, A. K., Aryal, J., & Kayastha, R. B. (2020). A review on drone-based data solutions for cereal crops. Drones, 4(3), 41.

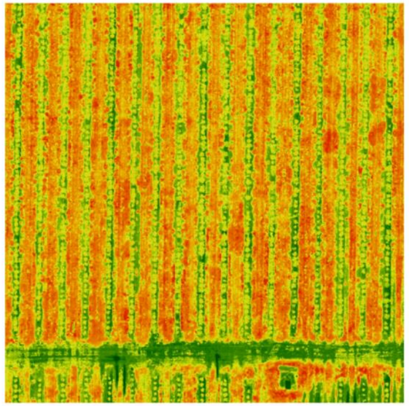
https://ageagle.com/wp-content/uploads/2022/08/AgEagle-RedEdge-P-Brochure-EN.pdf

Remote Sensing : Drone-Mounted Multispectral Sensors

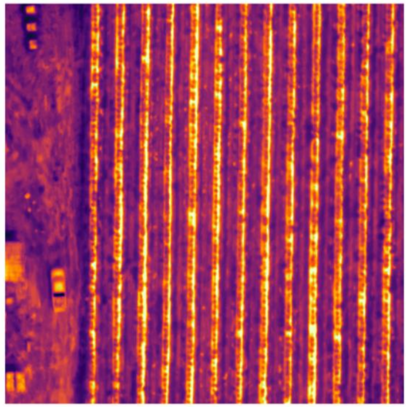


Scan QR code to
download sample data





NDVI

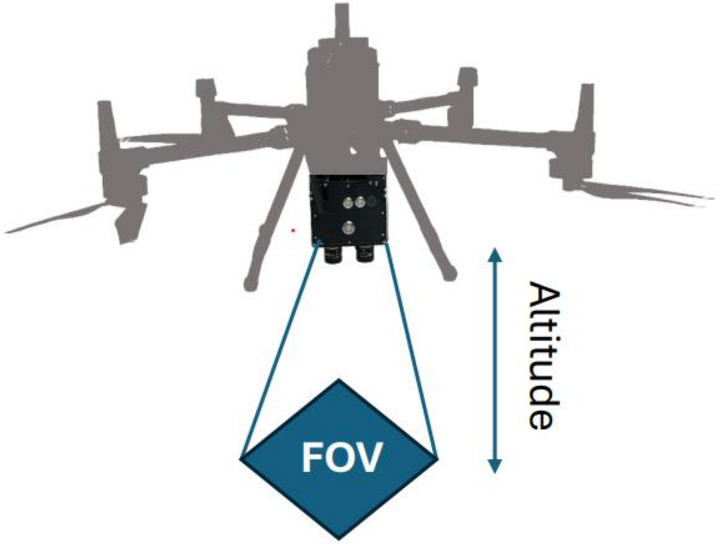


THERMAL

https://ageagle.com/wp-content/uploads/2022/08/AgEagle-RedEdge-P-Brochure-EN.pdf

https://coptrz.com/blog/top-5-multispectral-drones-in-2024/

Remote Sensing : Drone-Mounted Multispectral Sensors



50 m Altitude

Lens	Camera	GSD, [cm]	FOV, [m]
12 mm	5MP	1.4	35x29
	1.3MP	2.1	27x21
25 mm	5MP	0.7	17x14
	1.3MP	1	13x10

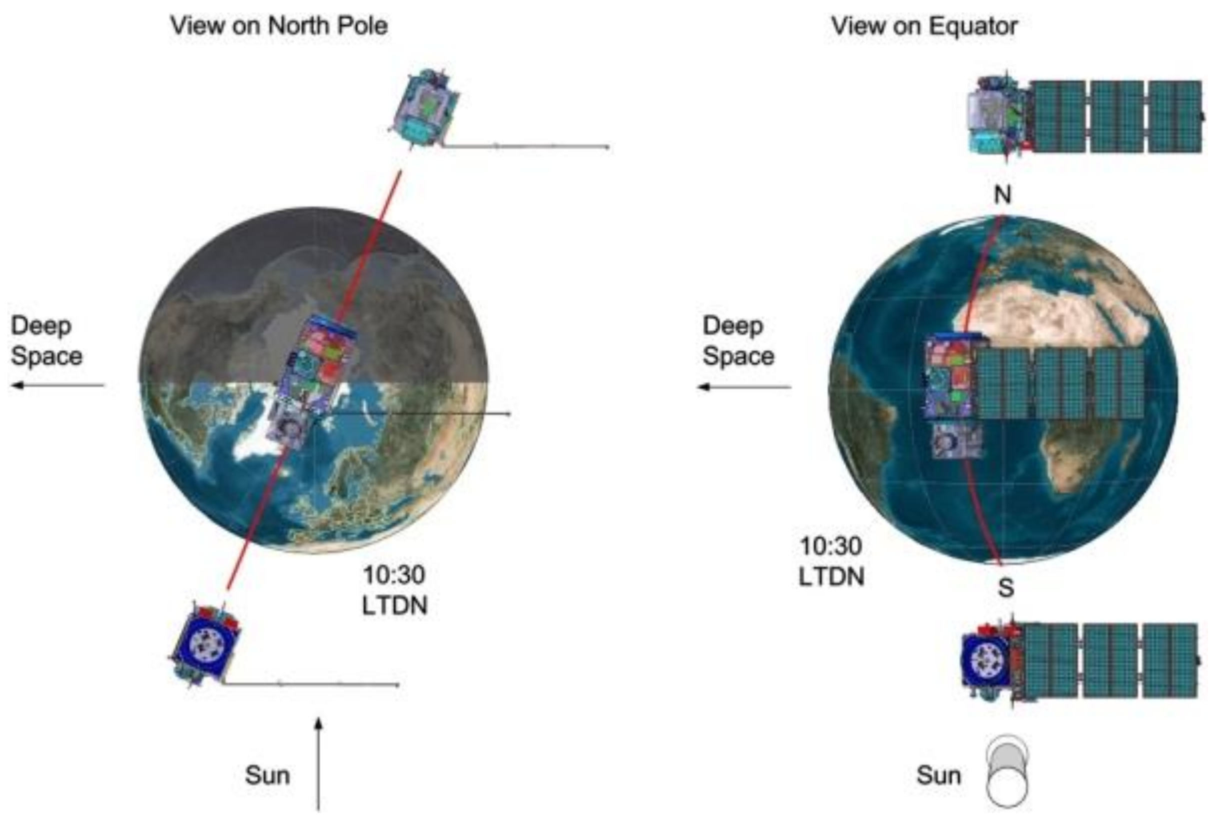
100 m Altitude

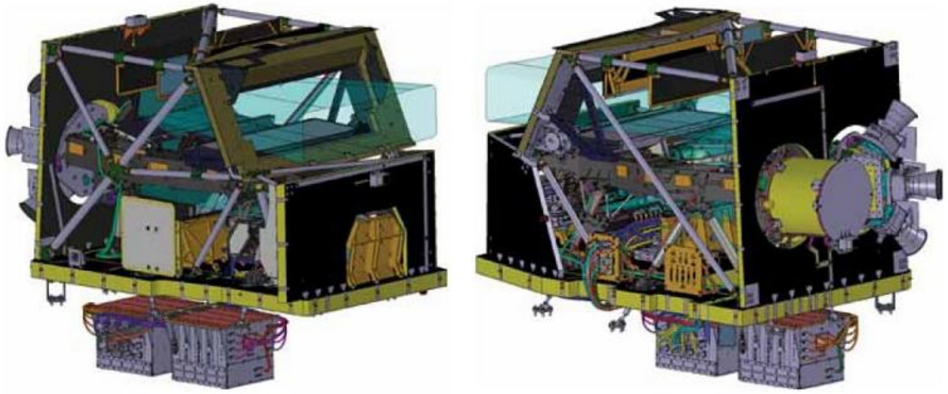
Lens	Camera	GSD, [cm]	FOV, [m]
12 mm	5MP	2.9	70x59
	1.3MP	4.1	53x43
25 mm	5MP	1.4	34x28
	1.3MP	2	26x20

Feature	Description
# of bands	6
Band Locations	440 (±55) nm, 510 (±65) nm, 600 (±40) nm, 725 (±12) nm, 800 (±25) nm, 1500 (±25) nm
Pixels/band	NIR, Red Edge, Color: 2448x2048px, SWIR: 640x480px

https://spectraldevices.com/cdn/shop/files/MSDC-2-4_AGRI_short_product_sheet_v2.pdf?v=9086298096293143126

Remote Sensing : Satellite-Mounted Multispectral Sensors





The MultiSpectral Instrument [Credits: Airbus Defense and Space]

Band	Band range (nm)/band center (nm)	Spatial resolution (m)	Purpose in L2 processing context
B1	433–453/443	60	Atmospheric correction
B2	458–523/490	10	Sensitive to vegetation aerosol scattering, iron oxides/hydroxides detection
B3	543–578/560	10	Green peak, sensitive to total chlorophyll in vegetation
B4	650–680/665	10	Max chlorophyll absorption, iron oxides/hydroxides detection
B5	698–713/705	20	Not used in L2A context
B6	734–748/740	20	Not used in L2A context
B7	765–785/783	20	Not used in L2A context
B8	785–900/842	10	LAI
B8a	855–875/865	20	Used for water vapor absorption reference
B9	930–950/945	60	Water vapor absorption atmospheric correction
B10	1365–1385/1375	60	Detection of thin cirrus for atmospheric correction
B11	1565–1655/1610	20	Soils detection, OH-mineral alteration mapping
B12	2100–2280/2190	20	AOT determination, OH-mineral alteration mapping

https://sentiwiki.copernicus.eu/web/s2-mission#S2-Mission-MSI-Instrument

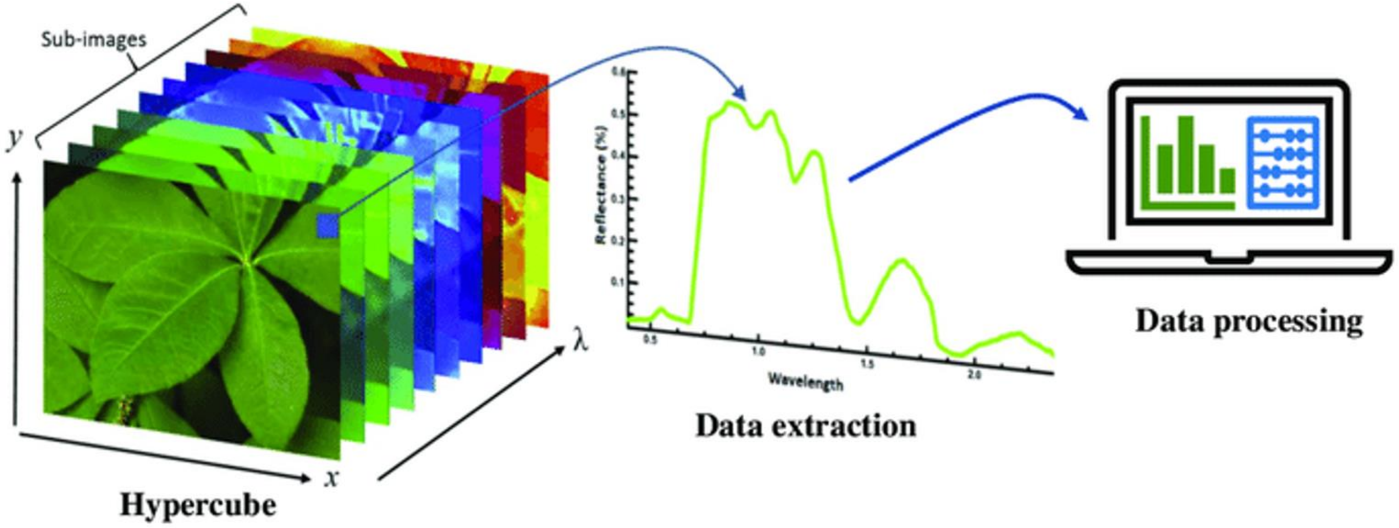
Remote Sensing : Hyperspectral Sensors

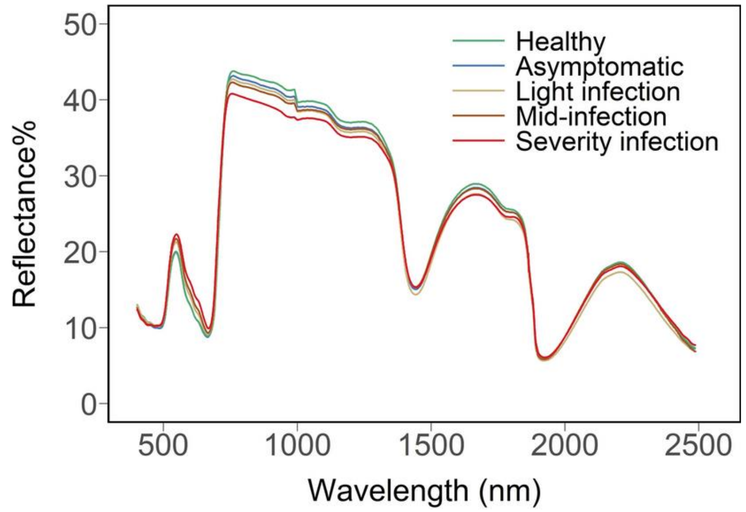
- Hyperspectral sensors capture data across hundreds of narrow, contiguous spectral bands in the electromagnetic spectrum
- Typically consists of **hundreds to thousands of bands** (commonly **100-300+ bands**)
- Offer detailed insights into crop health, soil properties, and plant stress, allowing for more precise and targeted farming decisions
- More sensitive to subtle changes in plant and soil characteristics due to high spectral resolution

Drone-mounted hyperspectral sensor

Headwall Nano HP hyperspectral payload with LiDAR on the DJI Matrice 350 (youtube.com)

Remote Sensing : Hyperspectral Sensors





Lv, Z., Meng, R., Chen, G., Zhao, F., Xu, B., Zhao, Y., ... & Yan, J. (2023). Combining multiple spectral enhancement features for improving spectroscopic asymptomatic detection and symptomatic severity classification of southern corn leaf blight. Precision agriculture, 24(4), 1593-1618.

Kashyap, B., & Kumar, R. (2021). Sensing methodologies in agriculture for monitoring biotic stress in plants due to pathogens and pests. Inventions, 6(2), 29.

Remote Sensing : Hyperspectral Sensors

SPECIM AFX10

VNIR (400 – 1000 nm)

Specim AFX10 is a VNIR hyperspectral imaging solution with a hyperspectral camera, a small and powerful computer, and a high-end GNSS/IMU unit in a compact enclosure that can be installed on multiple drone types.

Specim AFX10 is best suited for:

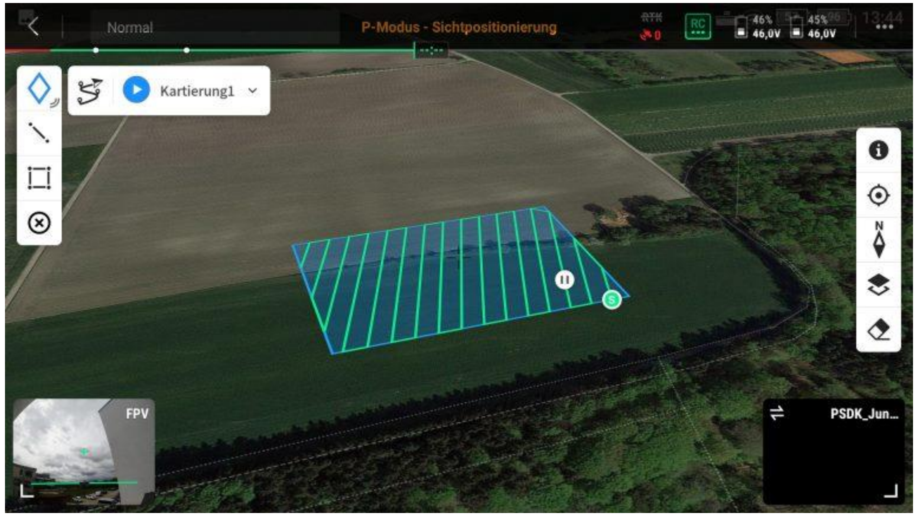
- Vegetation classification and species identification
- Water quality analysis
- Wetlands monitoring
- Wildlife population study

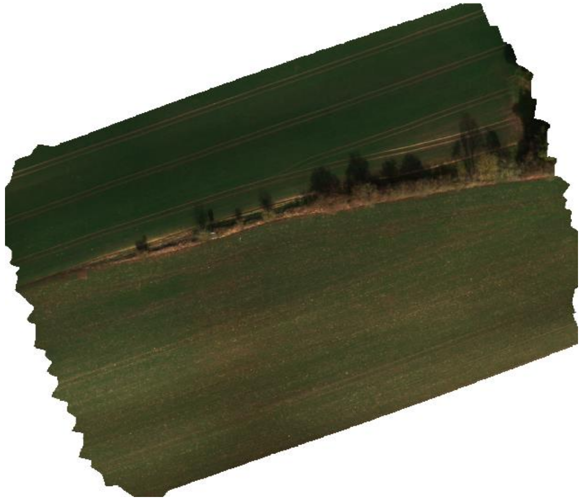
FEATURES

- All in one HSI solution for UAVs
- Spectral range VNIR from 400 to 1000 nm
- Supports gimballed or gimballess mounting
- Multiple spectral ROI enables both hyperspectral and application-specific multispectral configurations
- Fore lens aberrations are fully characterized
- Significantly less smile and keystone
- Ability to collect more light
- Full real-time and post-mission position and orientation solution for direct georeferencing

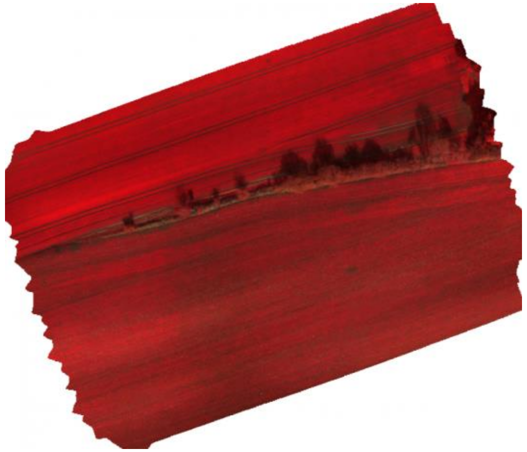
https://www.specim.com/afx/?gad_source=1&gclid=Cj0KCQjwlvW2BhDyARIsADnIe-LD31TiRlFS9oAUVRVNnJZauuJXos1R5hCX66g0irliGRVUHmHhbxcaAqWzEALw_wcB

Remote Sensing : Hyperspectral Sensors

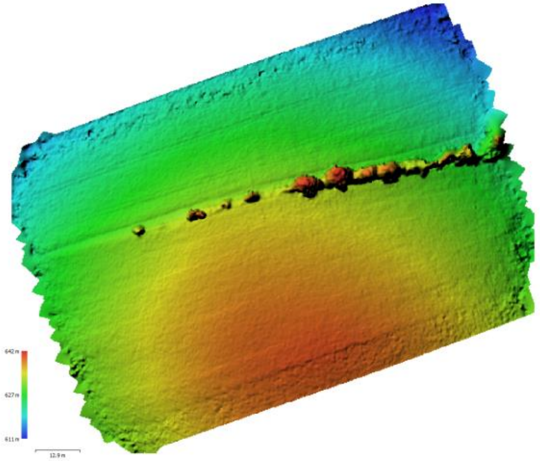




RGB



Color Infra Red (CIR)



Digital Elevation Model (DEM)

NDVI

https://www.cubert-hyperspectral.com/knowledge-base/uav-hyperspectral-mapping

Next Lecture

Remote Sensing in Agriculture I