AST 426 :Soil and Crop Health Monitoring II

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Overview of Indices used In Precision Agriculture

Vegetation Indices (Vis)

- VIs are derived from spectral data captured by remote sensing technologies
- Useful for quantifying vegetation health, soil conditions, and crop yield

Types of Indices

a. **Spectral Indices**: Focus on vegetation health and chlorophyll content
b. **Biophysical Indices**: Assess biophysical properties like leaf area index (LAI)
c. **Thermal Indices**: Monitor temperature-related stresses

Biophysical Indices

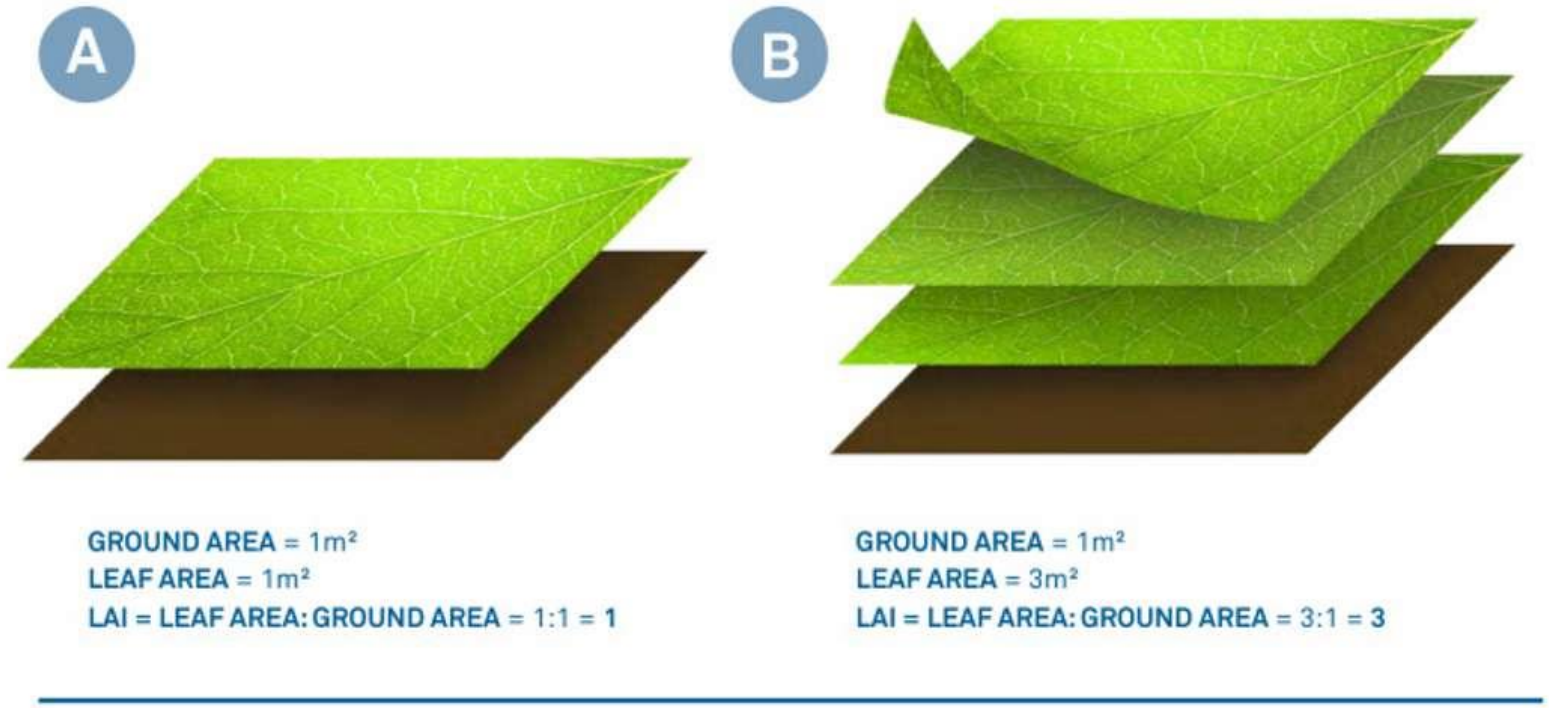
- Biophysical indices focus on quantifying physical and biological characteristics of crops and vegetation

1. **Leaf Area Index (LAI)**

   - Measures the **total leaf area per unit ground area**
   - Indicates canopy density and biomass
   - Quantifies the **amount of leaf material in a canopy**
   - One of the most widely used measurements for **describing plant canopy structure**
   - **Crop growth monitoring, yield prediction**
   - **Multispectral or hyperspectral data**

Biophysical Indices

1. Leaf Area Index (LAI)



https://metergroup.com/education-guides/the-researchers-complete-guide-to-leaf-area-index-lai/

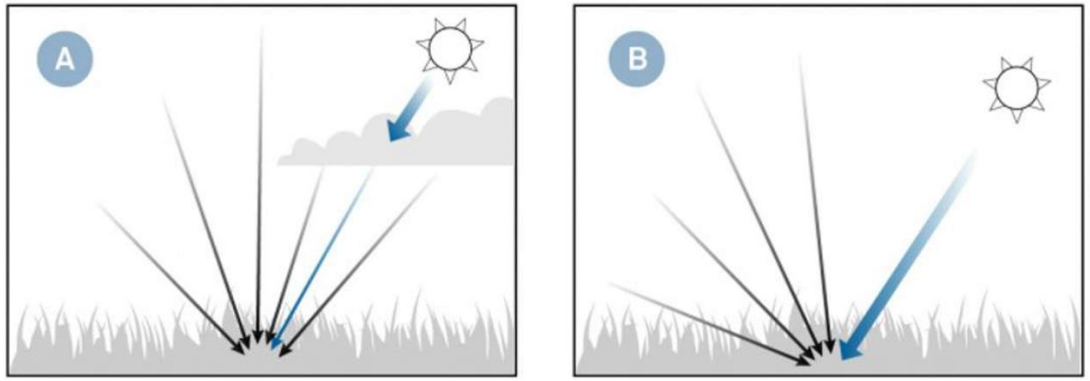
Biophysical Indices

1. Leaf Area Index (LAI)

$$L = \frac{[(1-\frac{1}{2K})\, f_b - 1)]\ \ln \tau}{A(1-0.47 f_b)}$$

$$K = \frac{\sqrt{\chi^2+\tan\theta^2}}{\chi+1.744\ (\chi+1.182)^{-0.733}}$$

χ = leaf angle distribution
f_b = beam fraction
θ = solar angle
ζ =ratio of transmitted and incident photosynthetically active radiation (PAR)
K= extinction coefficient
A= leaf area absorptivity



https://metergroup.com/education-guides/the-researchers-complete-guide-to-leaf-area-index-lai/

Biophysical Indices

1. Leaf Area Index (LAI)

LAI-2200C
Plant Canopy Analyzer
Non-destructive leaf area index measurements in plant canopies.

LI-3000C
Portable Leaf Area Meter
Fast, non-destructive leaf area measurements in the field.

LI-3100C
Leaf Area Meter
Rapid measurements of large numbers of harvested leaves.

[Leaf Area: LI-3000C Portable Area Meter]

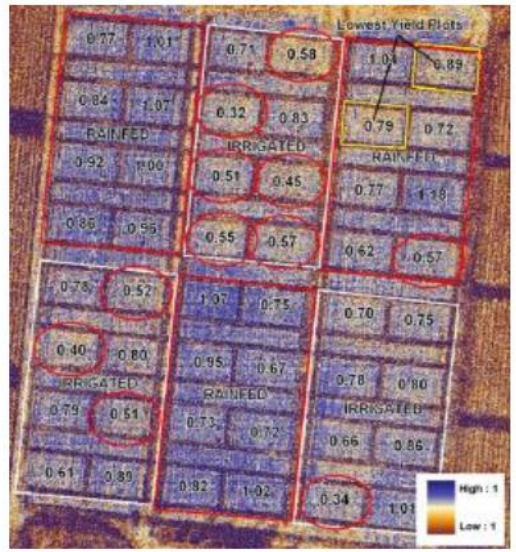
https://www.licor.com/env/products/leaf-area/

Biophysical Indices

2. Canopy Chlorophyll Content Index (CCCI)/Leaf Chlorophyll Content

- Measures the chlorophyll content in the canopy
- Indicates the nitrogen status and overall health of the crop
- Nitrogen management, early detection of nutrient stress
- Derived from Red and NIR bands

[CL-01 Chlorophyll Content Meter | Hansatech Instruments Ltd]



Example of Airborne images of Canopy Chlorophyll Content Index (CCCI) derived using a 3-band multispectral camera (670, 720, 790-nm)

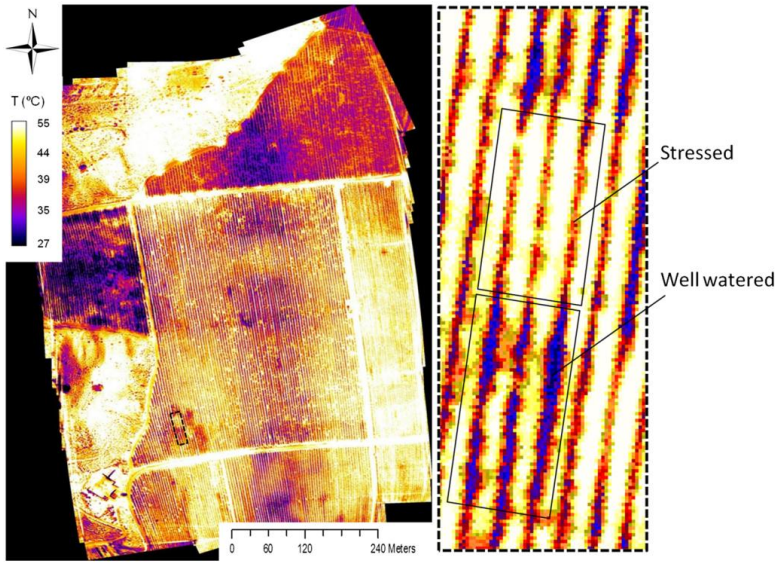
https://ppsystems.com/chlorophyll-content/

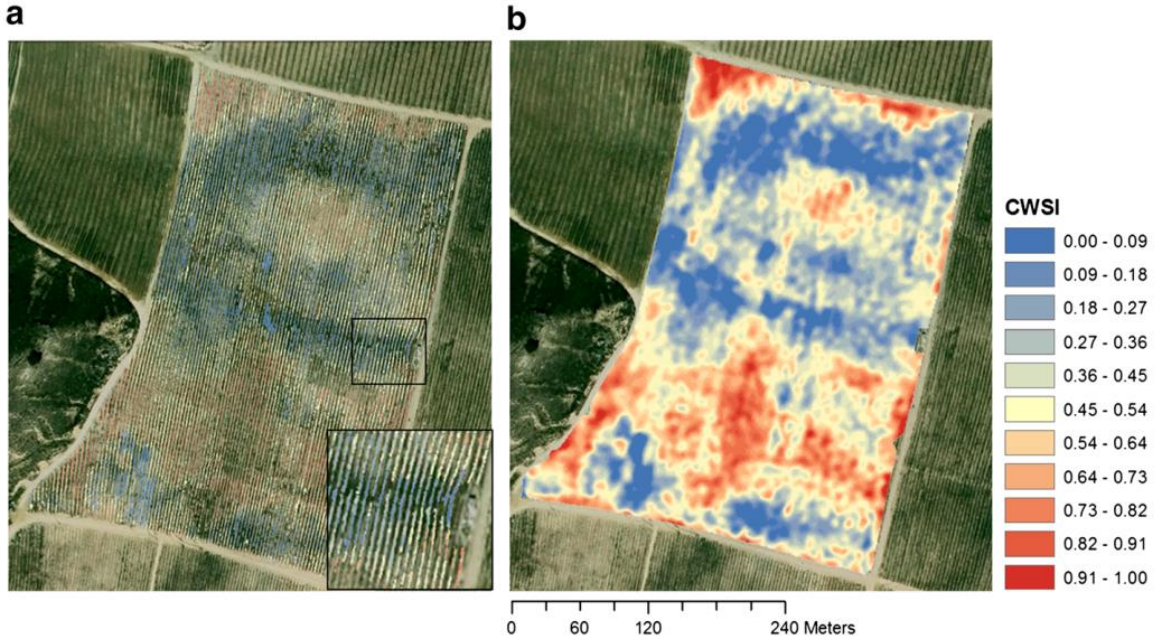
Antille, D. L., Lobsey, C. R., McCarthy, C. L., Thomasson, J. A., & Baillie, C. P. (2018). A review of the state of the art in agricultural automation. Part IV: Sensor-based nitrogen management technologies. In 2018 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers.

Thermal Indices

1. Crop Water Stress Index (CWSI)

- Compares canopy temperature to a non-stressed baseline temperature
- Indicates water stress and helps optimize irrigation
- Drought monitoring, irrigation scheduling
- Derived from thermal infrared data





Bellvert, J., Zarco-Tejada, P. J., Girona, J., & Fereres, E. J. P. A. (2014). Mapping crop water stress index in a 'Pinot-noir'vineyard: comparing ground measurements with thermal remote sensing imagery from an unmanned aerial vehicle. Precision agriculture, 15, 361-376.

Thermal Indices

2. Normalized Difference Temperature Index (NDTI)

- Differentiates between soil and canopy temperatures to assess water stress
- Calculated from land surface temperature
- Useful for monitoring crop water status
- Irrigation scheduling, drought impact analysis
- Derived from thermal infrared data

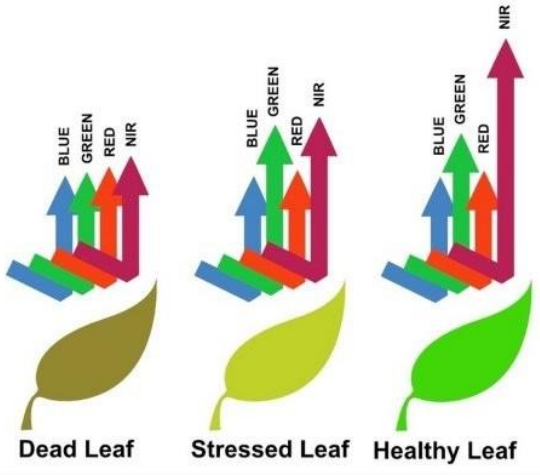
$$NDTI = \frac{(T_{soil} - T_{canopy})}{(T_{soil} + T_{canopy})}$$

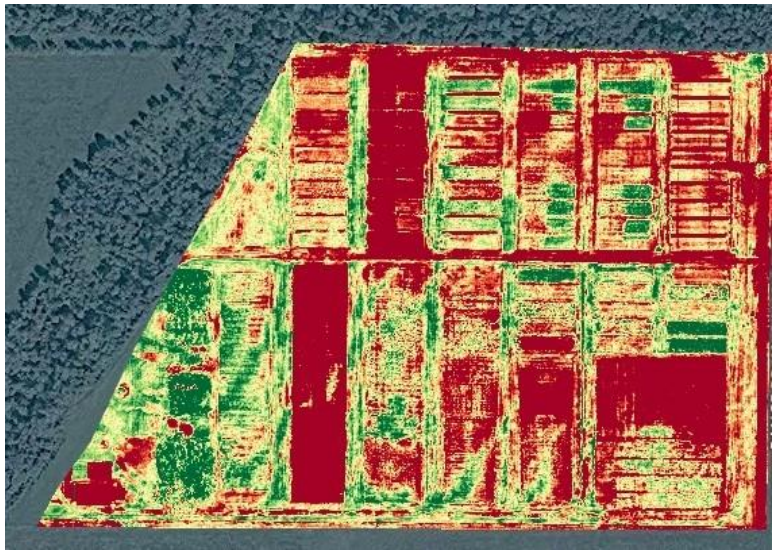
Vegetation Indices

1. Normalized Difference Vegetation Index (NDVI)

- Measures vegetation health and vigor by assessing chlorophyll content
- Indicates plant health, biomass, and canopy cover
- Drought monitoring, crop yield estimation, land cover classification
- Derived from Near-Infrared (NIR) and Red bands

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

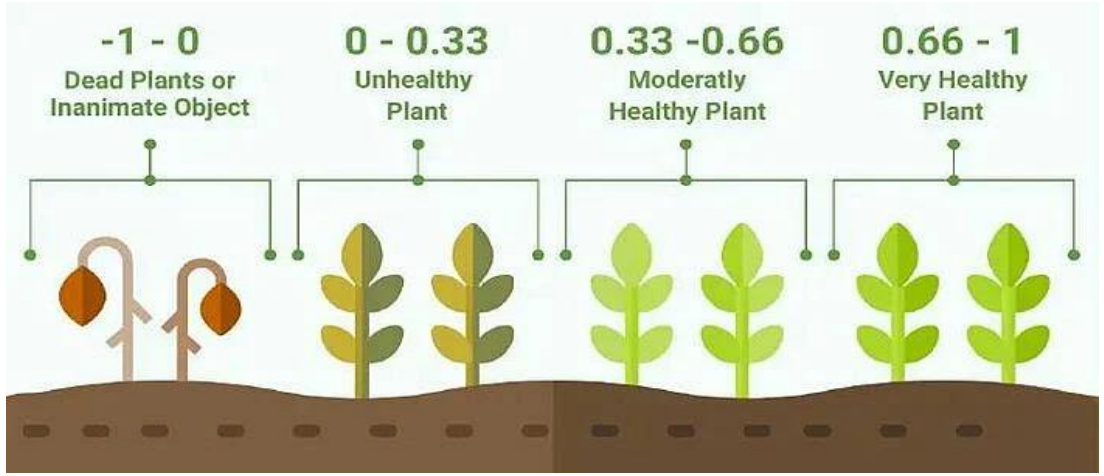


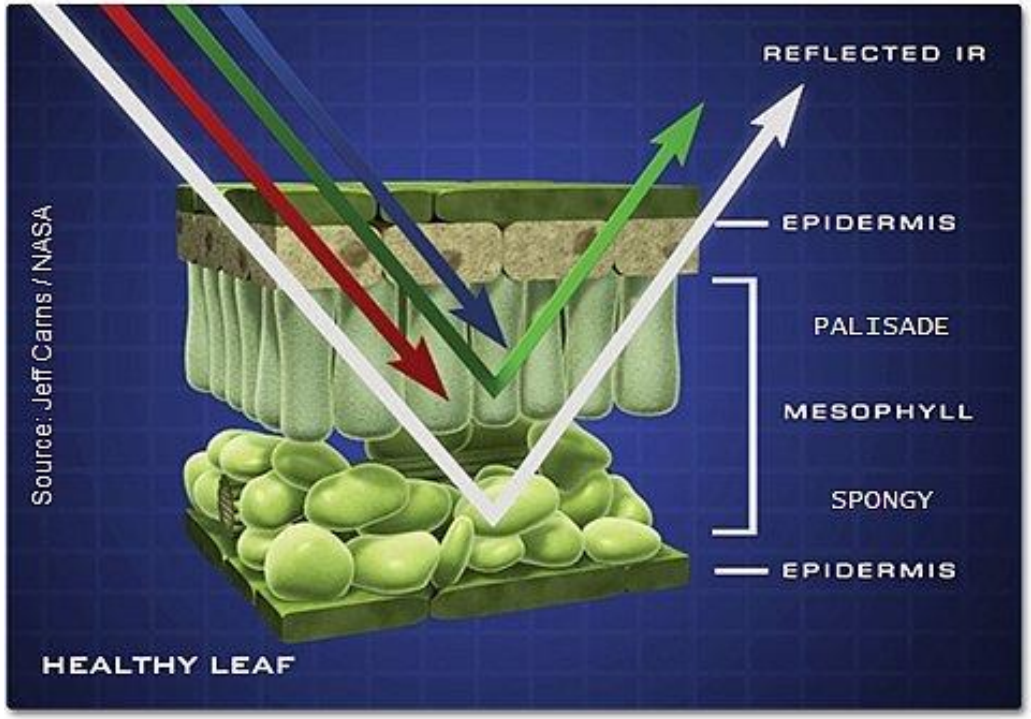


https://www.linkedin.com/pulse/value-near-infrared-debunking-myth-false-ndvi-kyle-miller

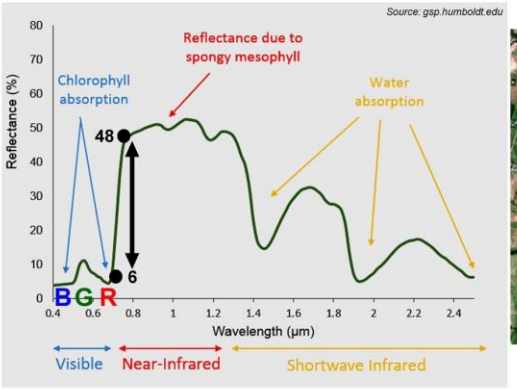
Vegetation Indices

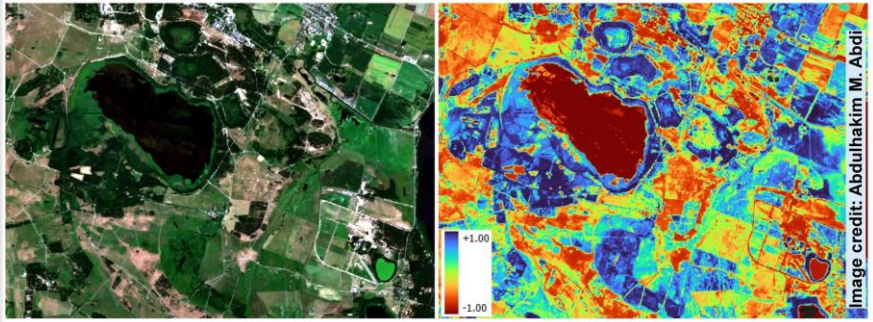
1. Normalized Difference Vegetation Index (NDVI)





$$\text{Normalized Difference Vegetation Index (NDVI)} = \frac{NIR-RED}{NIR+RED} = \frac{48-6}{48+6} = 0.77$$





Original RGB Image

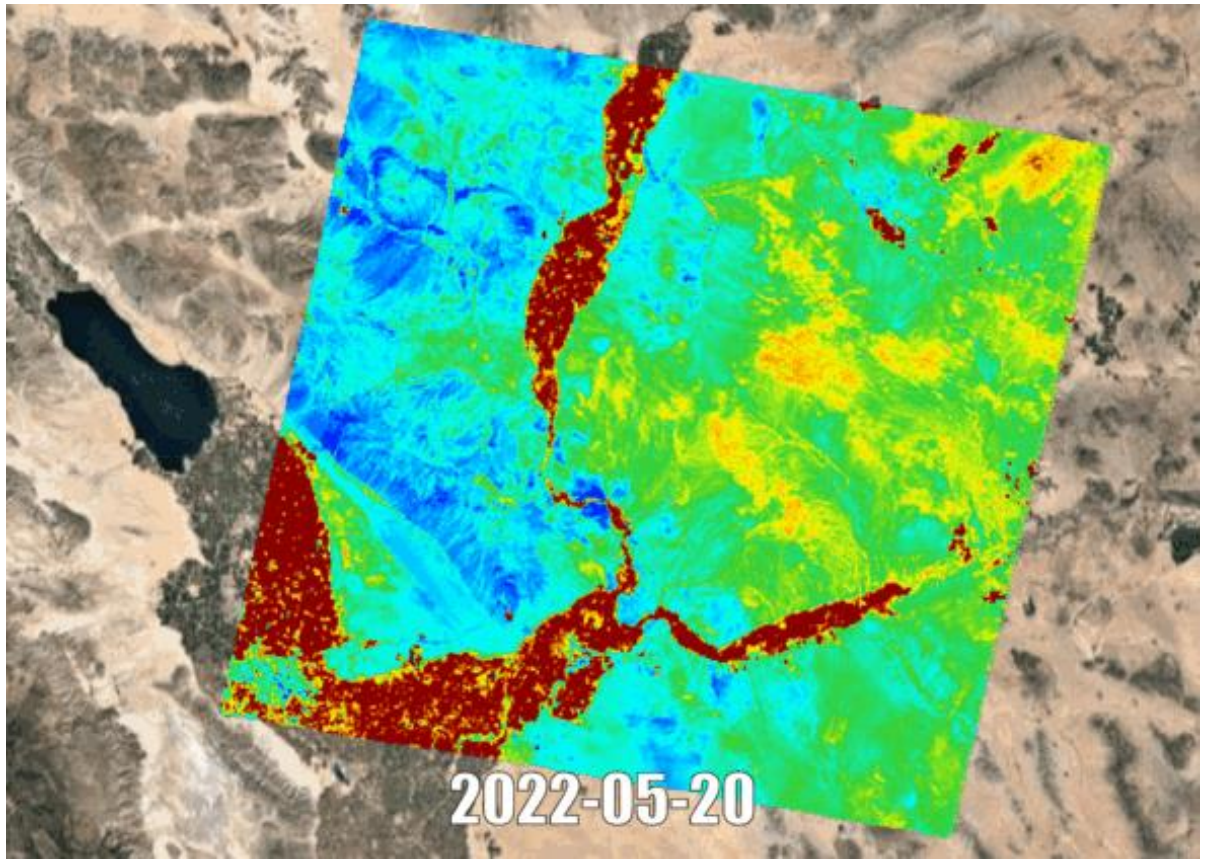
NDVI Applied

https://www.cropin.com/blogs/ndvi-normalized-difference-vegetation-index

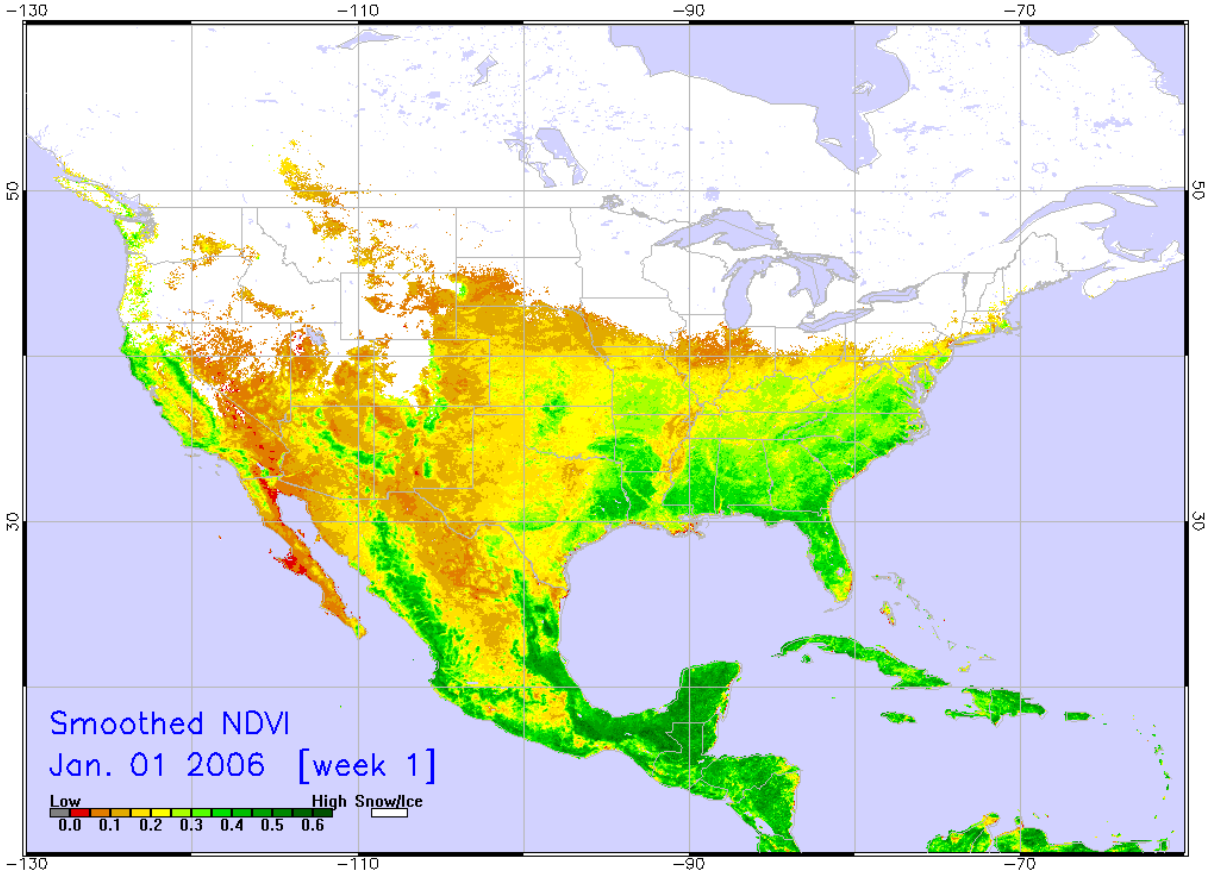
https://hakimabdi.com/blog/birth-of-the-normalized-difference-vegetation-index-and-the-paradigm-shift-in-satellite-remote-sensing-of-the-environment

Vegetation Indices

1. Normalized Difference Vegetation Index (NDVI)



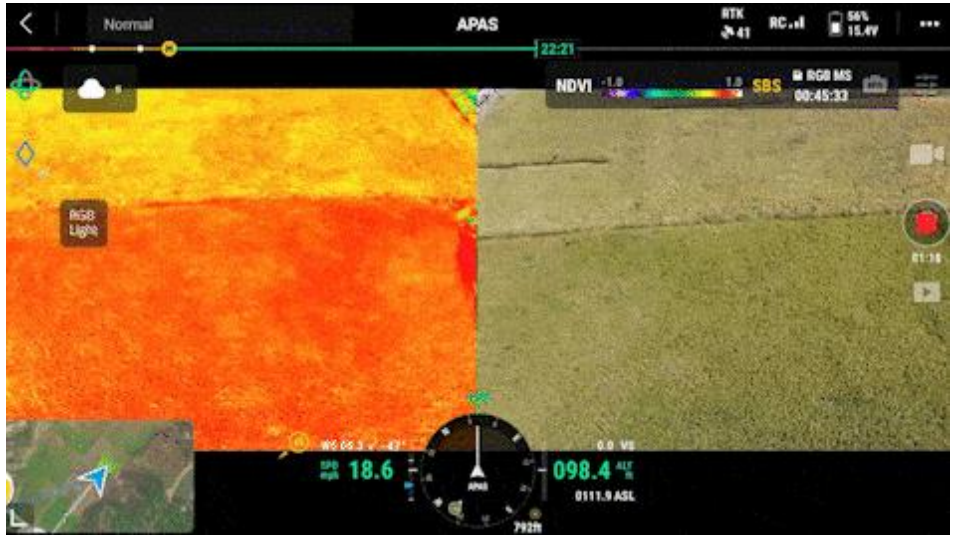
https://www.usgs.gov/media/images/landsat-7-extended-science-mission-ndvi-animation

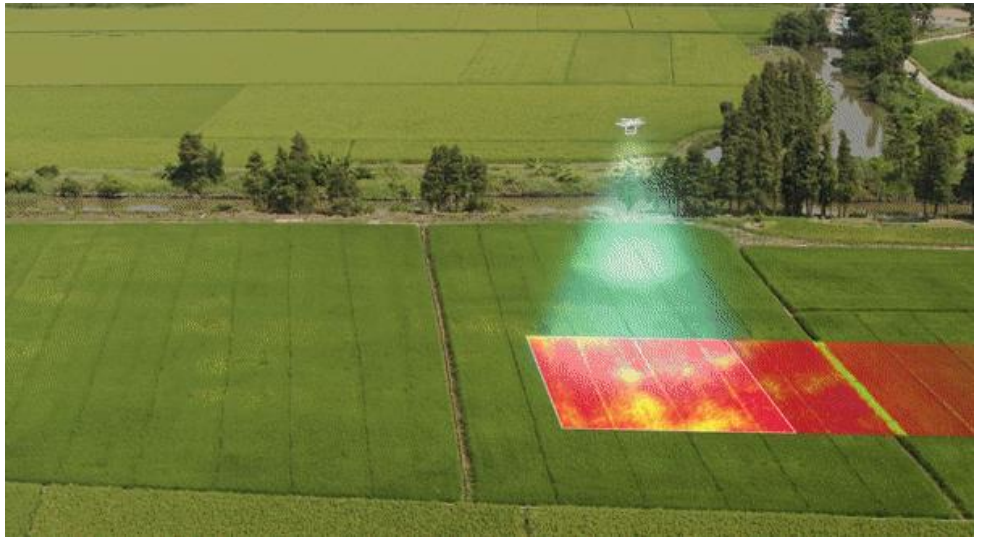


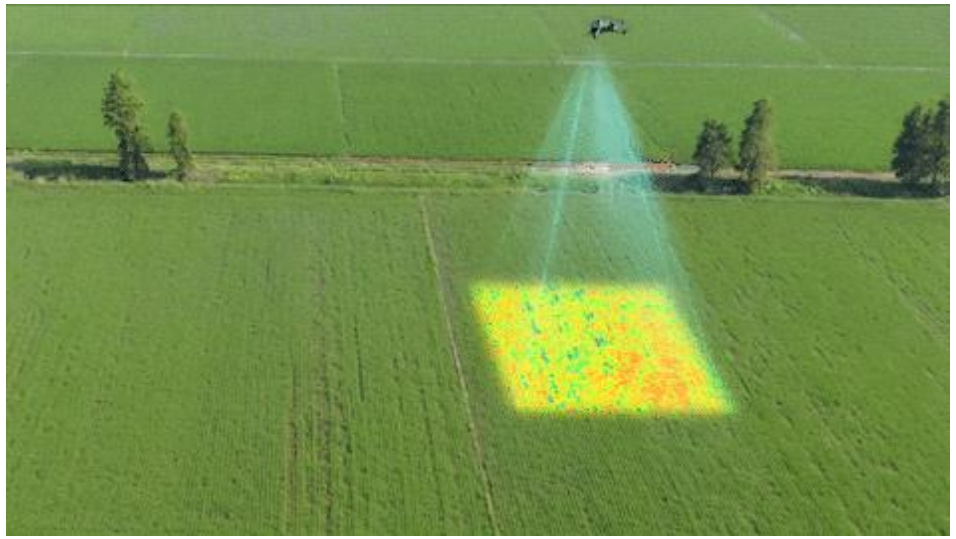
https://feww.wordpress.com/vegetation/

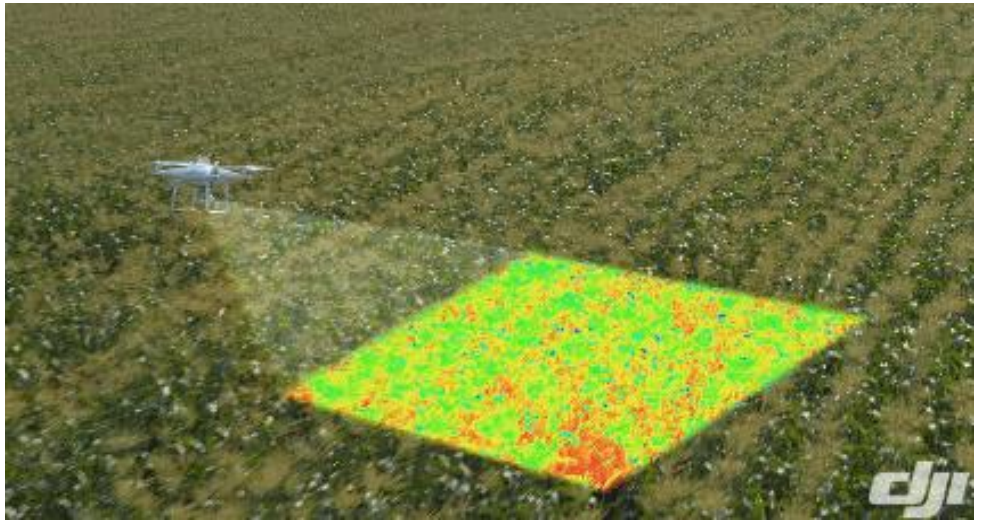
Vegetation Indices

1. Normalized Difference Vegetation Index (NDVI)









Vegetation Indices

2. Enhanced Vegetation Index (EVI)

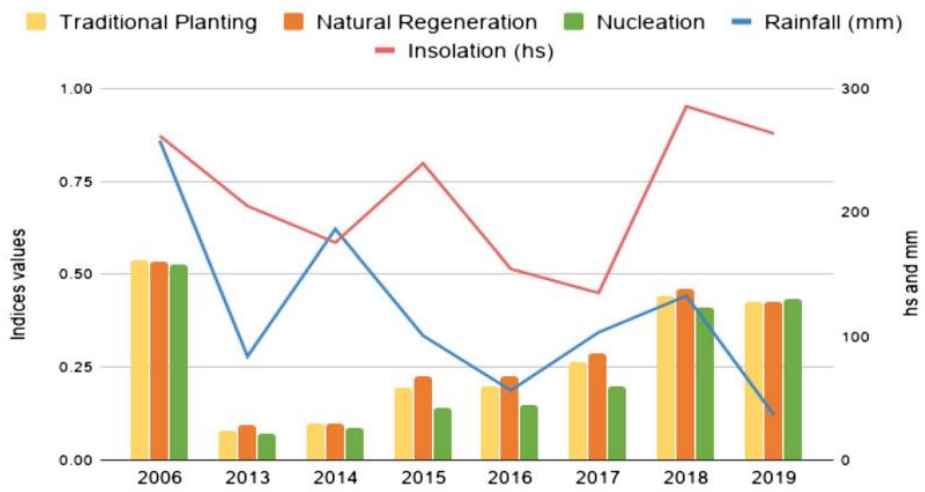
- **Improves NDVI by reducing the influence of soil and atmospheric effects**
- More sensitive to areas with dense vegetation.
- Monitoring dense forest canopies, precision agriculture, and land use studies.
- Derived from NIR, Red, and Blue bands.

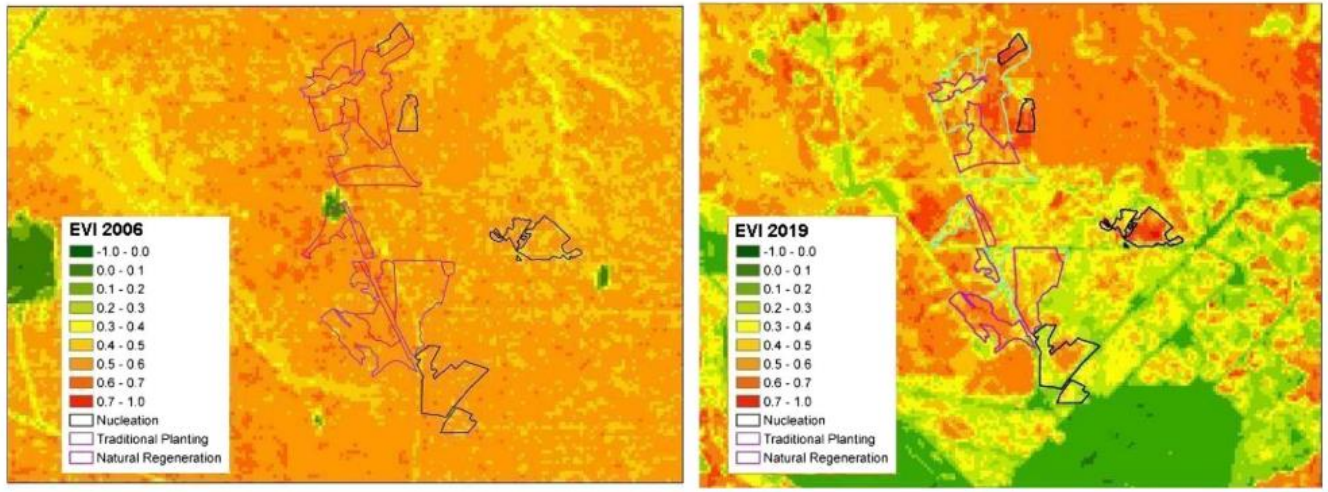
$$\mathrm{EVI} = G \times \frac{(\mathrm{NIR} - \mathrm{Red})}{(\mathrm{NIR} + C1 \times \mathrm{Red} - C2 \times \mathrm{Blue} + L)}$$

G = Gain factor (typically 2.5)
C1 (typically 6) , C2 (typically 7.5) = Coefficients for atmospheric resistance
L (typically 1)= Canopy background adjustment factor

Vegetation Indices

2. Enhanced Vegetation Index (EVI)





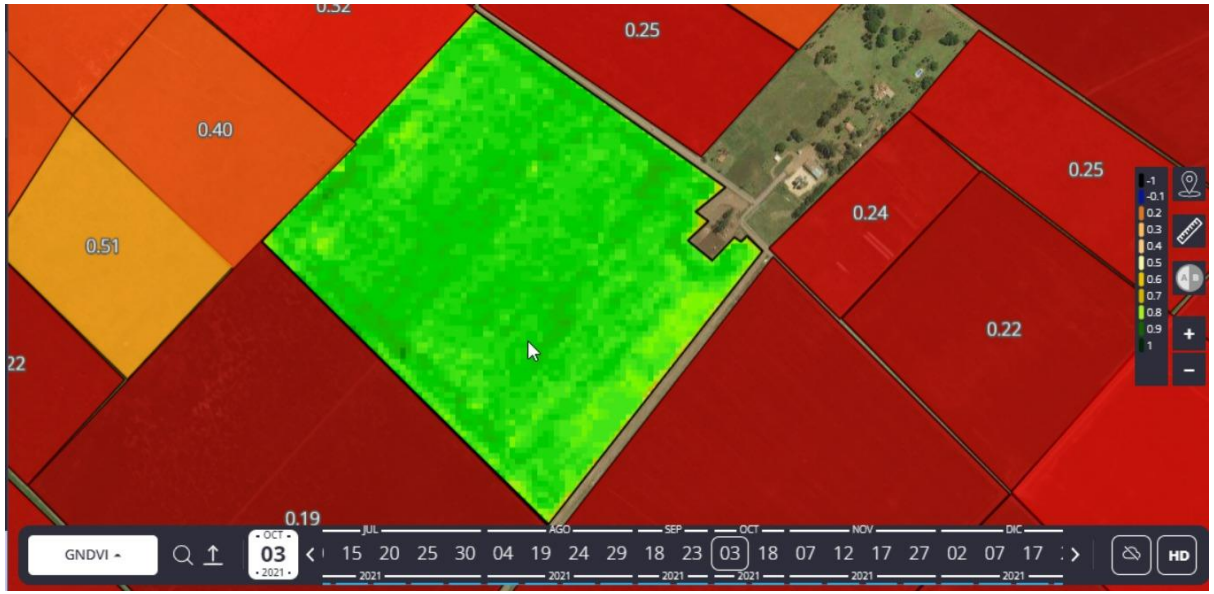
de Araujo, R. A., Silva, J. L. D. S., Cugula, J. D. S., Paschoal, J. P., Esteves, V. P. P., & Morgado, C. D. R. V. (2021). Assessment of vegetation recomposition methods in a tropical forest using satellite images. Clean Technologies and Environmental Policy, 23, 797-810.

Vegetation Indices

3 . Green Normalized Difference Vegetation Index (GNDVI)

- Assesses chlorophyll content and photosynthetic activity
- Sensitive to nitrogen content in crops
- Nitrogen management, early stress detection, yield prediction
- Derived from NIR and Green bands
- Mainly used in the **intermediate and final stage** of the crop cycle

$$GNDVI = \frac{(NIR - Green)}{(NIR + Green)}$$



https://www.auravant.com/en/help-en/imagery-and-layers/3636624-what-is-the-gndvi/

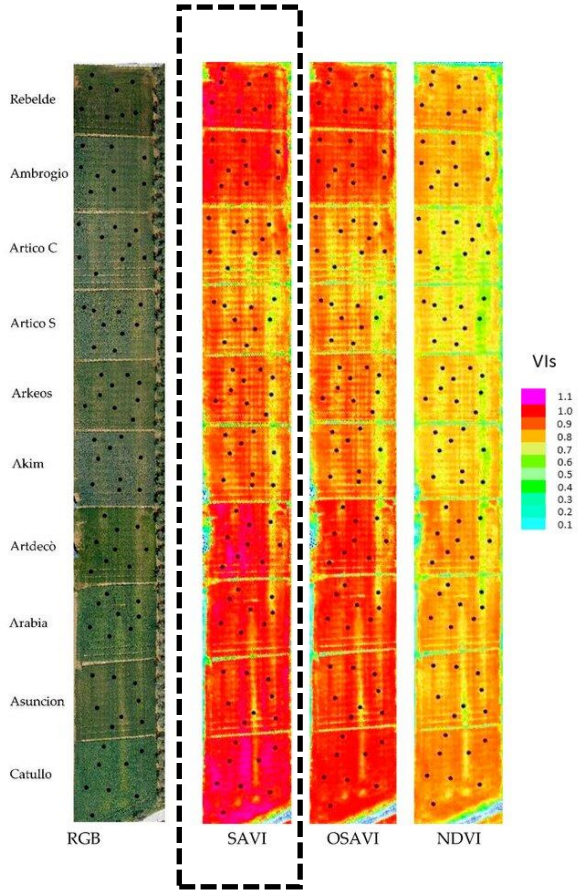
Vegetation Indices

4 . Soil Adjusted Vegetation Index (SAVI)

- Reduces the influence of soil brightness in sparse vegetation areas.
- Effective in regions with partial canopy cover.
- Early growth stage monitoring, soil moisture assessment.
- Derived from NIR and Red bands.

$$\mathrm{SAVI} = \frac{(\mathrm{NIR}-\mathrm{Red})\times(1+L)}{(\mathrm{NIR}+\mathrm{Red}+L)}$$

L = Soil adjustment factor (commonly 0.5)



Marino, S., & Alvino, A. (2020). Agronomic traits analysis of ten winter wheat cultivars clustered by UAV-derived vegetation indices. Remote Sensing, 12(2), 249.

Vegetation Indices

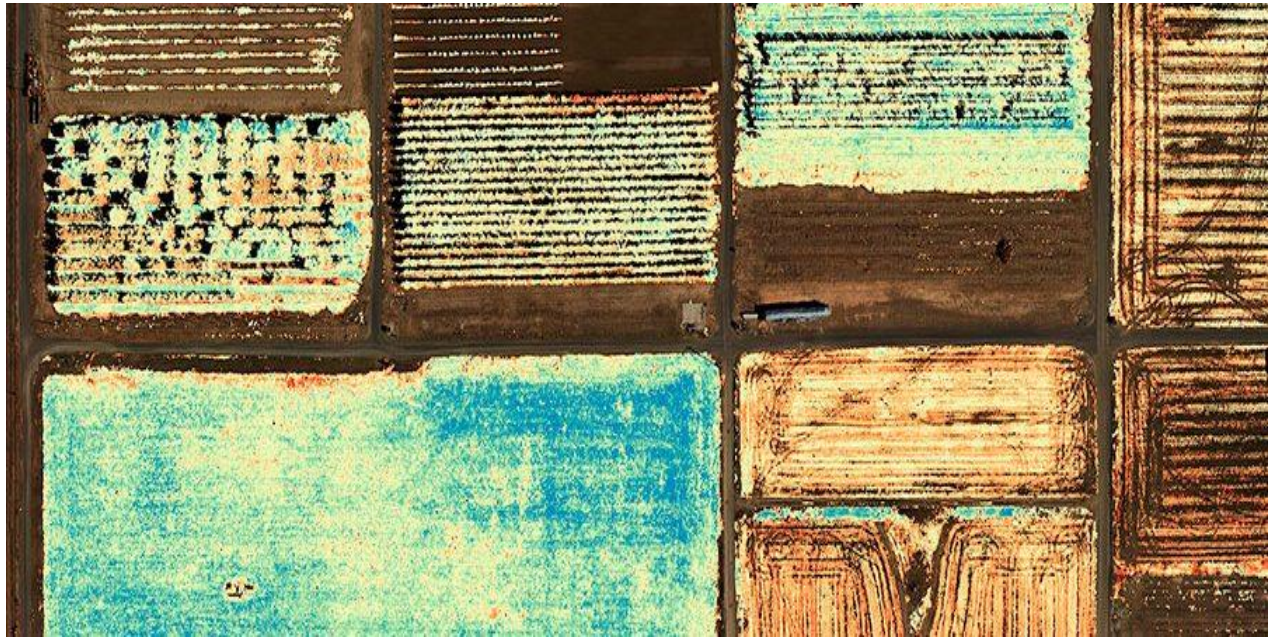
5 . Normalized Difference RedEdge Index (NDRE)

- NDRE is a vegetation index designed to assess chlorophyll content and plant health, particularly in the later stages of crop growth.
- It utilizes the red-edge band, which is sensitive to changes in chlorophyll concentration.
- Detects subtle changes in chlorophyll content.
- Monitors plant health **beyond the canopy closure phase**.
- Effective in detecting nitrogen deficiencies and stress in crops.
- More sensitive to chlorophyll variations than NDVI
- NDRE is crucial for advanced monitoring of crop health, particularly in detecting stress and nutrient deficiencies when traditional indices become less effective.

$$NDRE = \frac{(NIR - RedEdge)}{(NIR + RedEdge)}$$

Vegetation Indices

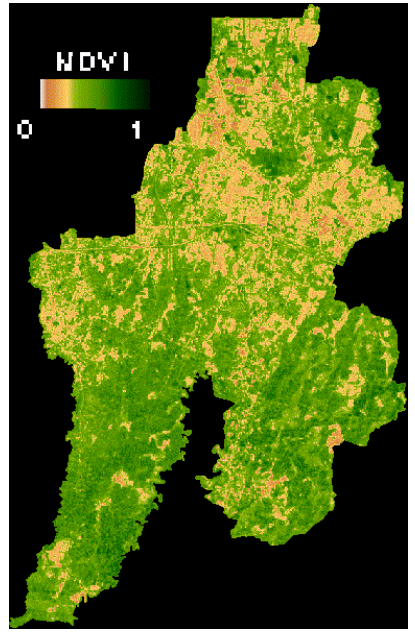
5 . Normalized Difference RedEdge Index (NDRE)



Which Indices to Use and When?

Early Growth Phase Indices

- NDVI, SAVI
- Early detection of plant vigor, nitrogen status, and initial stress signs



Mid to Late Growth Phase Indices

- GNDVI, NDRE, CWSI, Thermal Indices
- Monitor biomass accumulation, water stress, and disease progression
- Adjust irrigation schedules, manage nutrient applications, predict yield
- NDRE is a powerful tool for late-stage crop monitoring, offering deeper insights into crop health and aiding in precise agricultural management

Optimal Usage

- By combining indices such as NDVI for early growth stage and NDRE for later growth stages

Quiz

1. Why might NDVI be less effective in the later stages of crop growth?

- NDVI can become less effective in later stages because it tends to saturate in dense vegetation. As crops mature and develop multiple canopy layers, NDVI primarily captures data from the upper canopy, missing information from the lower layers. This leads to a reduced ability to detect subtle variations in plant health.

2. What are the typical NDRE value ranges, and what do they indicate about crop health?

-1 to 0.2: Indicates bare soil or a developing crop.
0.2 to 0.6: May indicate an unhealthy plant or a crop that is not mature yet.
0.6 to 1.0: Represents healthy, mature, ripening crops.

Next Lecture

- Precision Water and Nutrient Management I