Hyperspectral Remote Sensing in Detection of Biotic and Abiotic Stresses in Plants for Precision Agriculture

Keshav D Singh (Postdoc);
Christian Nansen (P.I.);
Robert Starnes (Pilot);
Elvira De Lange (Postdoc);
UC Davis, CA
Infestation/Disease/Wilt

Biotic/Abiotic Stress

Vegetation starts Damaging

Agriculture Plants/Trees

Change in Spectral Signature

Hyperspectral Imaging

Pest Management

Pesticides Spray

Crops Management/Precision Agriculture
Hyperspectral Imaging (HSI):
- Imaging and Spectroscopy
- Hundreds of narrow spectral bands to address subtle information

Imaging Spectroscopy: Interaction between the electromagnetic radiation and contact material

Advantages:
- Non-destructive
- Low cost
- Less time

Ref: @Basics of Crop Sensing, ANR-1398
Plant-Biotic Interaction:

- Infestation/Pests
- Fertilizers/Nutrients

Infestation causes:
- Bacteria
- Fungus
- Virus
- Insect pests: Whiteflys, Mealybugs, Aphids, Spidermites, Nematodes

Fertilizer/Nutrients:
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)

Ref: @Estación Experimental del Zaidín (CSIC), Spain
Plant-Abiotic Interaction:
- Drought (water deficit),
- Excessive watering (water-logging/flooding),
- Extreme temperatures (cold, frost and heat)
- Salinity (sodicity)
- Mineral (metal and metalloid) toxicity
Combined biotic and abiotic environmental stress factors:

Healthy  Stressed
Crop health via Reflectance profiling:
• Vegetation stress identification and monitoring
• Detection of crop responses to biotic and abiotic stressors

Ref: @Basics of Crop Sensing, ANR-1398
Reflectance profiling: Healthy vs. Unhealthy/Stressed Plants (chlorophyll content or plant health)

Plants reflect **Green** light and absorb all other colors (**Blue**, **Red** etc.)
Processing and Analysis Steps:

Raw HRS Data → Data Calibration → Hypercube → Spectral Profile (Reflectance) → Bioassay → Data Analysis/ Solution

- Performance
- Preference
- LICOR
- Nutrition Analysis
- Root Analysis
Benchtop Hyperspectral Camera:
Sensor Type: Push-broom line scanning
Spectral bands: 240
Range: 380-1035nm
Spectral resolution: 2.75 nm

Ref: @Nansen Lab., UC Davis
Soybean Plant: Non-Infested vs. Infested

REFLECTANCE

WAVELENGTH (NM)

Soybean Non-Infested
Soybean Infested
Unmanned Aircraft Systems (UAS) overview:
Drone/UAV: S1000 Premium Octocopter
Hyperspectral Imager: OCI-D1000 (Push-broom frame scanning)
Wavelength: 470-980nm
Spectral bands: 116
Almond Trees Field Study using UAS

Field Trip-1

Nichols Farm, CA
UAV Images Affect:
- Multiple scattering ground reflectance
- Atmospheric conditions
Field Flight with UAV:

- Healthy spots
- Potential disease hotspots
Hyperspectral images of Almond trees subjected to different levels of “K” fertilization.
Mite three-choice bioassay: $b > a \approx c$

Ref: @Nansen Lab., UC Davis
Macro-elements Analysis:

![Graph showing N (%) for different almond varieties and dilutions](image1)

![Graph showing K (%) for different almond varieties and dilutions](image2)

Ref: @Nansen Lab., UC Davis
Field Infrared Data:

Unhealthy (NW)

Healthy (MID)

Courtesy: Nichols Farm, CA
Reflectance variation in Non-Pareil/Red (Clark-NW vs. Clark-MID):

![Graph showing reflectance variation](image_url)
Reflectance variation in Wood (Clark-NW and Clark-MID):

[Graph showing reflectance variation for Clark Wood WRC, Clark-NW Wood WRC, and Clark-MID Wood WRC.]
Mite two-choice bioassays:

- Average mites (%): 
  - Red: MID > NW
  - Wood: MID > NW

- Average mites (no.): 
  - Red: MID > NW
  - Wood: MID > NW

Mite performance bioassay:

- Average eggs (%): 
  - Red: MID > NW
  - Wood: MID > NW

- Average eggs (no.): 
  - Red: MID > NW
  - Wood: MID > NW

Ref: @Nansen Lab., UC Davis
Leaf toughness Non-Pareil

Ref: @Nansen Lab., UC Davis

Leaf toughness Wood Colony

Ref: @Nansen Lab., UC Davis
Macro-elements Analysis:

![Graph showing K (%) for Red and Wood Almond varieties]

**Minerals Composition**

- N (%): 127.9166667
- S (%): 76.75
- P (%): 59.41666667
- K (%): 4.055833333
- Mg (%): 0.01
- Ca (%): 33.83333333
- Na (%): 5.650833333
- B (ppm): 2.826666667
- Zn (ppm): 0.2075
- Mn (ppm): 0.1675
- Fe (ppm): 2.280833333
- Cu (ppm): 3.0275
- Al (ppm): 6.833333333

Ref: @Nansen Lab., UC Davis
Strawberry Field Trip-1
Strawberry hypercube (without-mites):
Strawberry hypercube (with-mites):
Reflectance variation in Strawberry Field:

Reflectance Spectra

- Straw-FirstSite (Without-Mites)
- Straw-SecondSite (With-Mites)
Rice field treatment plots: Rice varieties (M-202 & M-206)

Four Weevils' Density treatment (Control, Low, Medium, High)

First 8 rows

Last 8 rows

Yuba City, CA
Reflectance variation w.r.t. weevils’ density within M-202 rice variety:

The two factors analysis of variance (ANOVA) with replication (two) was used to evaluate whether significant differences exist between treatments.
Reflectance variation w.r.t. weevils’ density within M-206 rice variety:

The Reflectance differences are due to variation in weevils’ density over each treatment.
Red-Edge Positions (REPs) of M-202 rice variety:

\[
\text{REP} = [700 + 40(RRE - R700)/(R740 - R700)] \text{ nm;}
\]

where, \( RRE = (R670 + R780)/2 \)

Red-Edge Positions (REPs) of M-206 rice variety:

Changes in leaf chlorophyll content cause shifts in the REP to shorter and longer wavelengths for low and high chlorophyll contents, respectively.
10 different treatments with sterile/non-sterile soil types:

- **Sterilized** (Orange, Blue, Green, Brown, Red)
- **Non-sterilized** (Red/gray, Brown/gray, Green/gray, Orange/gray, Blue/gray)
Reflectance variation within all treatments without infestation:

Date_07/25/2016 (Without Infestation)
Reflectance variation within all treatments after infestation:

Date_08/03/2016 (With Leafhoppers Infestation)
Reflectance comparison before and after infestation (Date_07/25/2016 vs. Date_08/03/2016):

- Narrowband hyperspectral vegetation indices are used to get chlorophyll content and carotenoids concentration.
- The reflectance variation between the two dates as a consequence of exposure to leafhoppers (non-infected vs. infected)
- It estimates smaller changes in vegetation health to differentiate sterile/non-sterile treatments of with and without infestation.
The REPs are sensitive to changes in chlorophyll concentration.

Green treatment is highly preferred by leafhopper followed by Orange, Orange-gray, Blue-gray, Red gray, Brown-gray, Red, Blue, Green-gray to Brown treatment, as least preferred.
Conclusions:

- Reflectance spectra indicate significant differences
- Early detection of infection & diseases, before wilt or pest outbreaks
- Field area covered by stress plants
- Yield and seed quality of crops

**Advantages:**
It reduces,

- Fertilization and Pesticide spray time
- Cost of spray
- Poisonousness in our biosphere (organic farming)
- Crops destruction

**Hyperspectral Remote Sensing:** “A way to sustainable agroecosystem study for precision agriculture”
References:


Thank you