Continuing Project

# Characterizing abiotic and biotic tree stress using hyperspectral information

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## Reflectance spectroscopy can capture tree stress responses

- **Rapid and accurate** observation of forest traits is necessary for effective monitoring of forest health

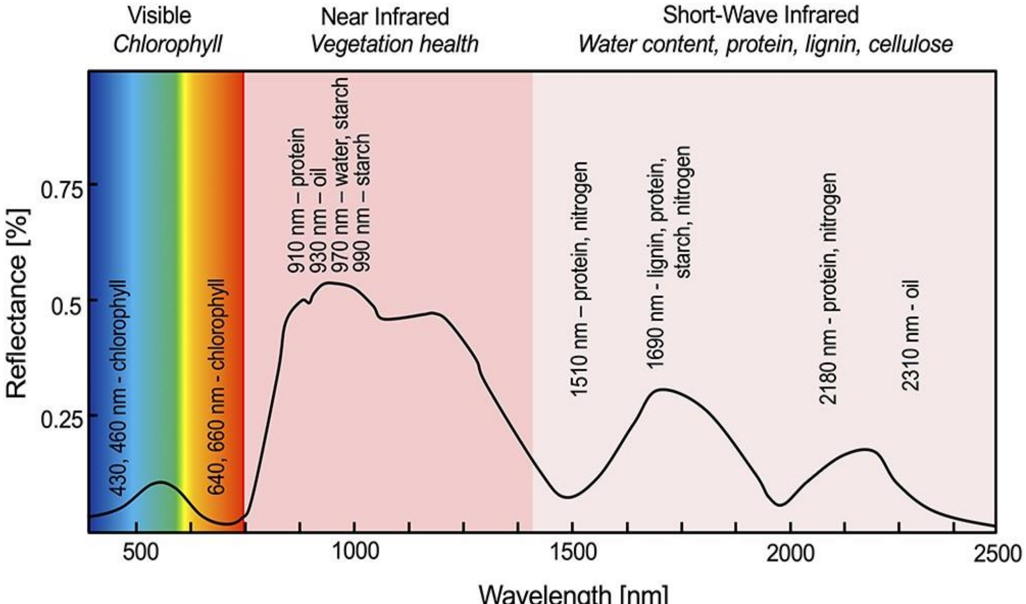
- **Leaf spectral reflectance** has been used to investigate functional traits and to detect **diverse forest issues** (e.g., drought, air pollution, fire, diseases, invasive species, etc.) **at different spatial scales**

Rapid ‘Ohi’a Death, Hawaii (Greg Asner)

# Reflectance spectroscopy can capture tree stress responses

- **Retrieving foliar traits** relevant to specific stress response mechanisms from hyperspectral data helps identify different stressors

- Understanding **the link between physiochemical responses and spectral changes** is crucial to increase the potential for extracting a wider range of functional traits from leaf spectral profiles




(Ensminger 2020)

## To test different spectral regions to investigate their influences on model performance estimating key leaf functional traits

- Functional traits can provide information on tree health status

  *Growth & Survival*

  (e.g., the photosynthetic rate, water content, specific leaf area, foliar N, sugars)

  *Defense & Stress response*

  (e.g., phenolic compounds)

- Various wavelength ranges of a leaf spectral profile contain absorption features related to specific substances in leaves

  (e.g., chlorophylls, water, cellulose, proteins, nitrogen)

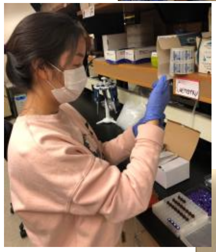
## Methods

Abiotic and biotic stress

| | |
|---|---|
| Fungal infection + Soil quality | Nitrogen deficiency + Drought |
| Fungal infection + Drought | Nitrogen deficiency + Salt deposition |

Black walnut (*Juglans nigra* L.)
Red oak (*Quercus rubra* L.)

Stress response measurement



**Trait data collection**

Leaf functional traits
- Gas-exchange
- Water
- Biochemical

**Spectral data collection**

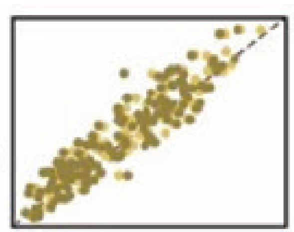
Leaf reflectance spectra (400−2400 nm)

Spectroradiometer
(SVC HR-1024i)

## Partial Least Squares Regression (PLSR)

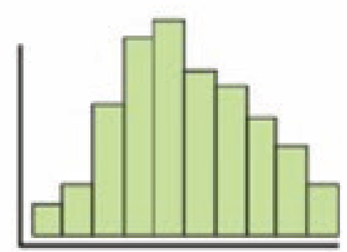
- Multivariate statistical approach
- Train PLSR models on leaf reflectance spectra and six key leaf traits measured
    - The maximum photosynthetic rate ($A_{max}$)
    - Leaf water content (LWC)
    - Specific leaf area (SLA)
    - Nitrogen (N)
    - Sugars
    - Gallic acid (Gal)
- Validate models and get leaf trait estimates

### Trait retrievals



Build & Validate model

Apply →



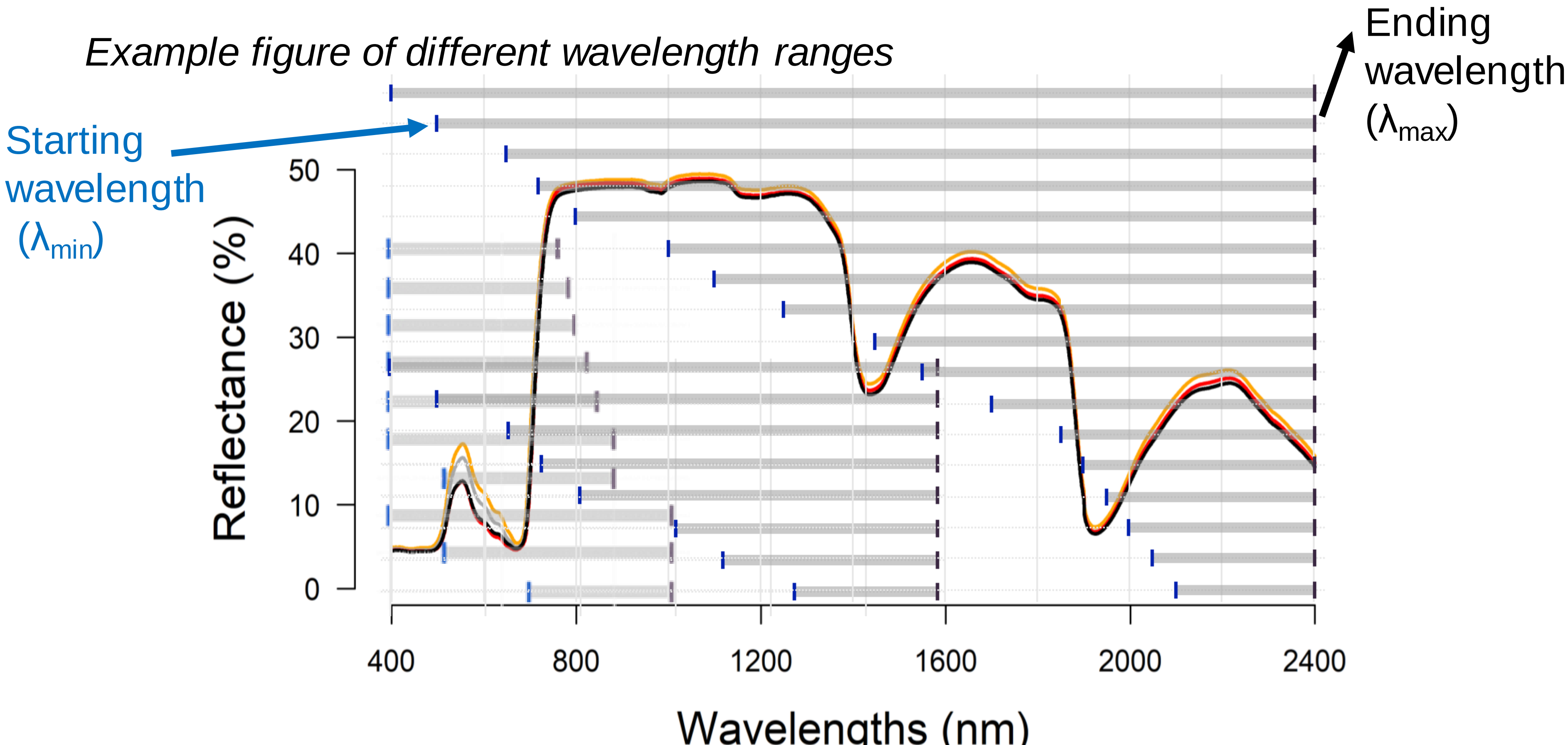
Predicted traits

(Burnett et al., 2021)

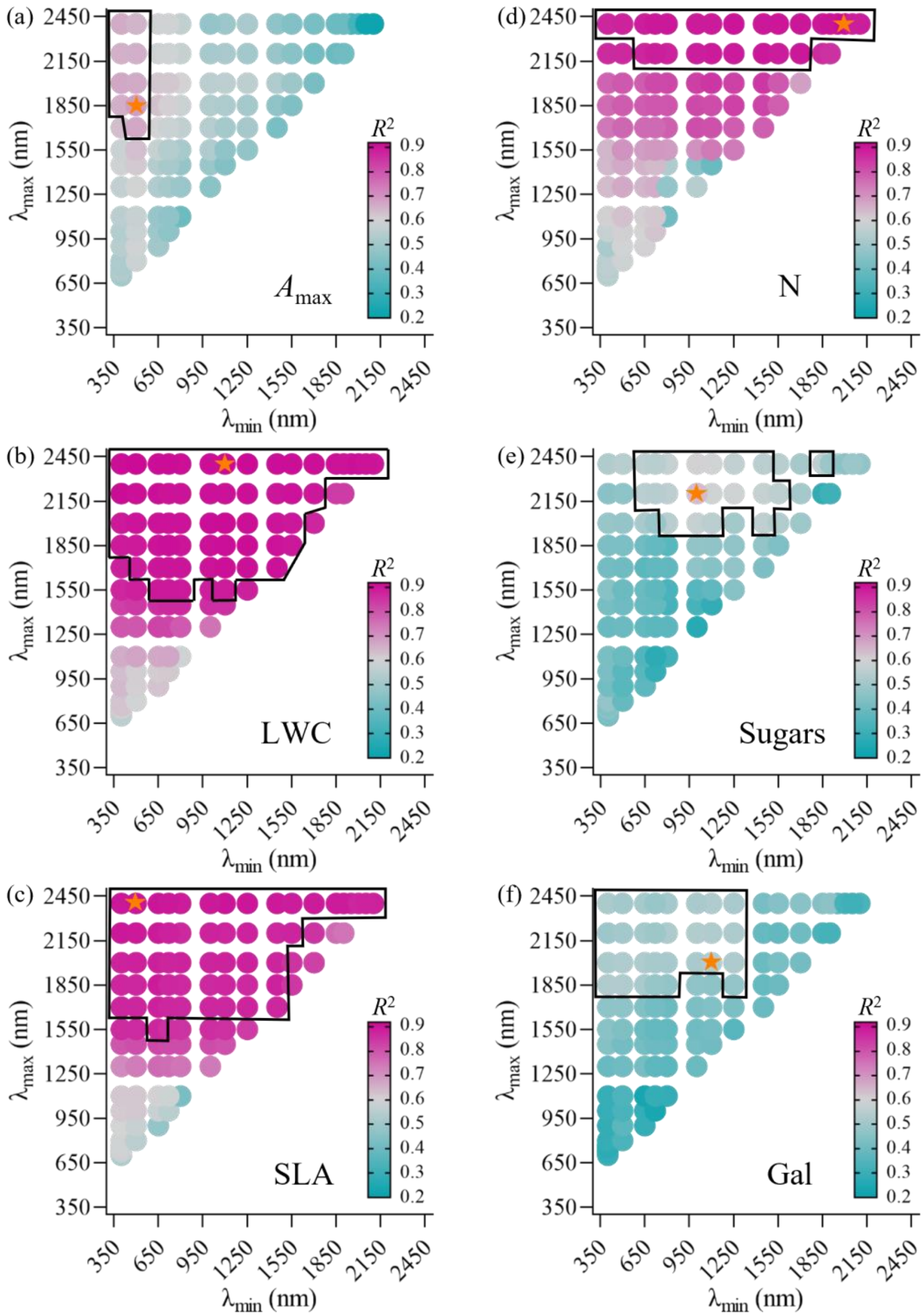
## Partial Least Squares Regression (PLSR)

- Build predictive models by relating wavelengths to leaf traits measured
- Test model performances with 100 different wavelength ranges
- Model performance parameters: $R^2$, normalized RMSE

*Example figure of different wavelength ranges*



## Major Findings

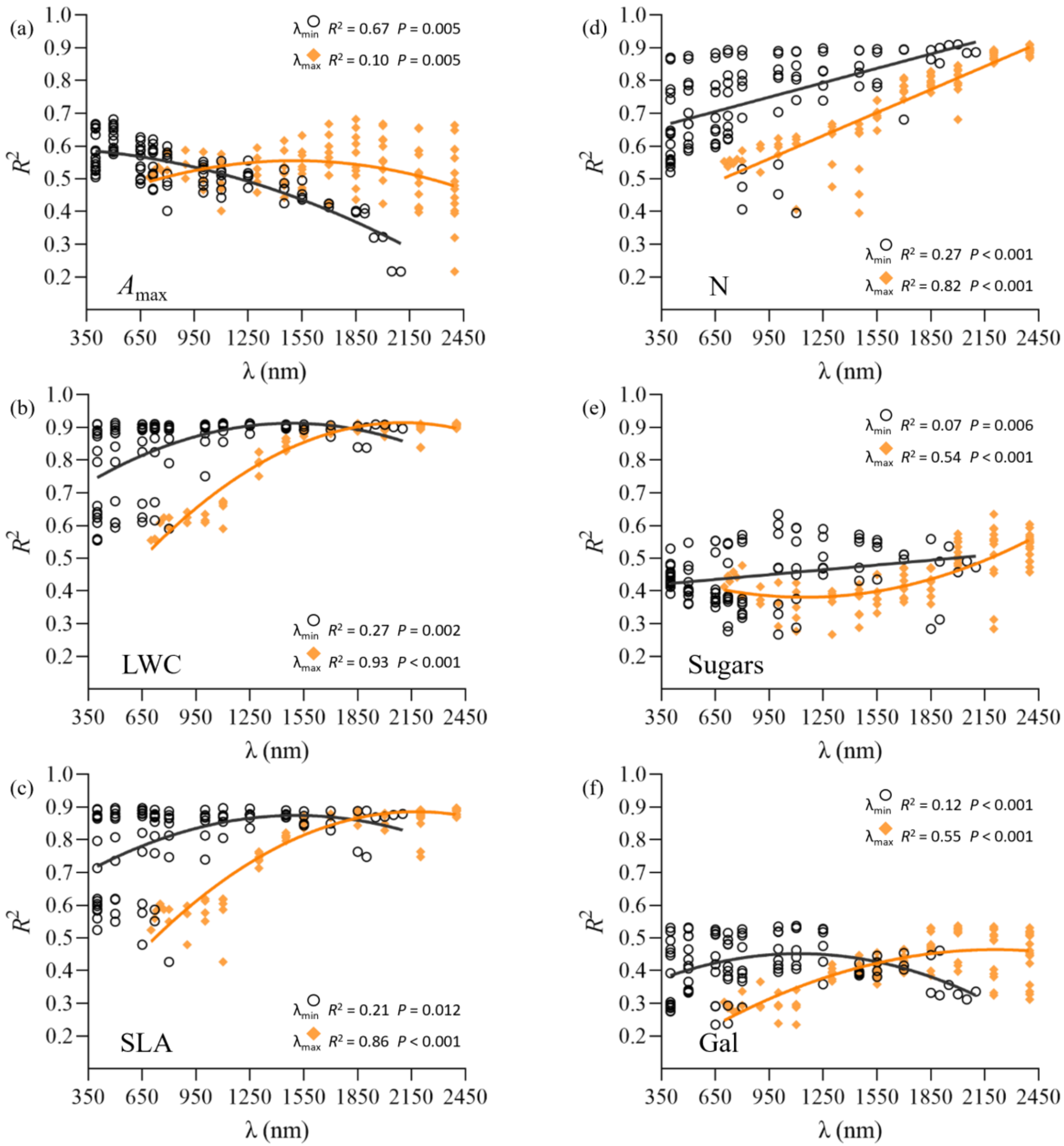



- Wavelength ranges including the SWIR regions (1300−2400 nm) produced enhanced model performances for six traits

- The full spectral range was not always the most optimal range

Wavelength ranges [$\lambda_{min}$, $\lambda_{max}$]

## Major Findings

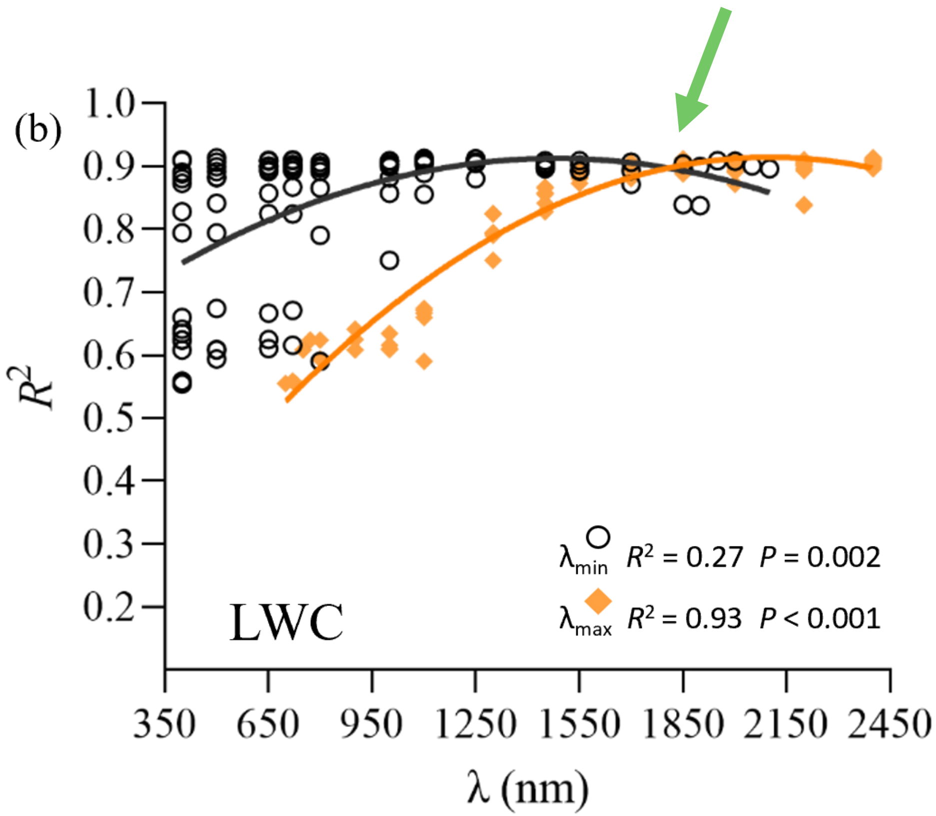



- PLSR model performance was significantly associated with both the starting or ending wavelengths

- The importance of starting or ending wavelength ranges differs depending on leaf traits

Wavelength ranges
[$\lambda_{min}$, $\lambda_{max}$]

# Major Findings

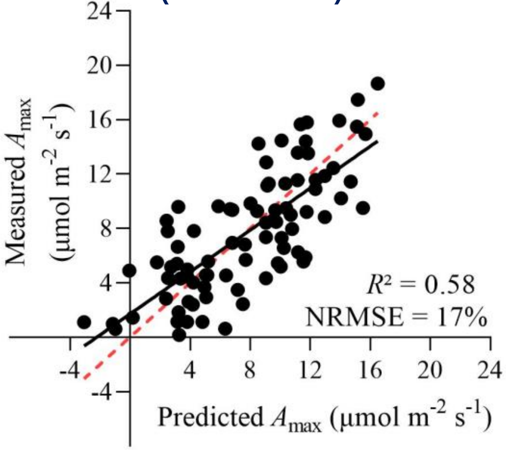



- The modeling performance ($R^2$) shows a convergence in the effects of starting and ending wavelengths, particularly at the wavelengths corresponding to known absorption features

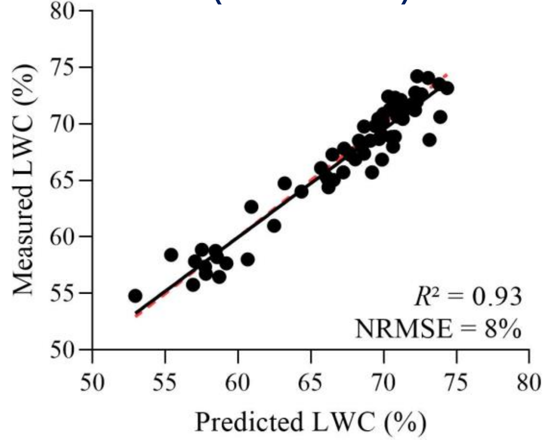
# Final trait models using the most optimal spectral regions

## Major Findings

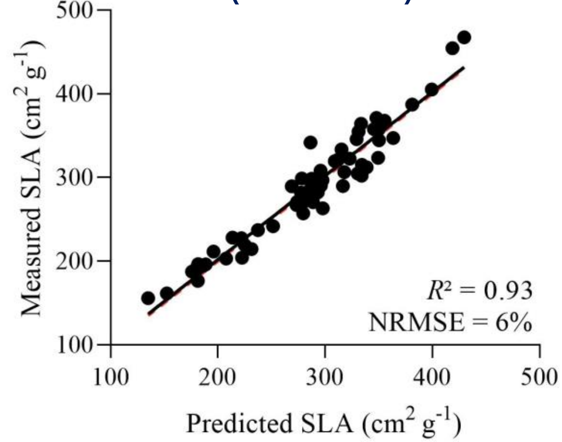
**The maximum photosynthesis rate (500–1850 nm)**



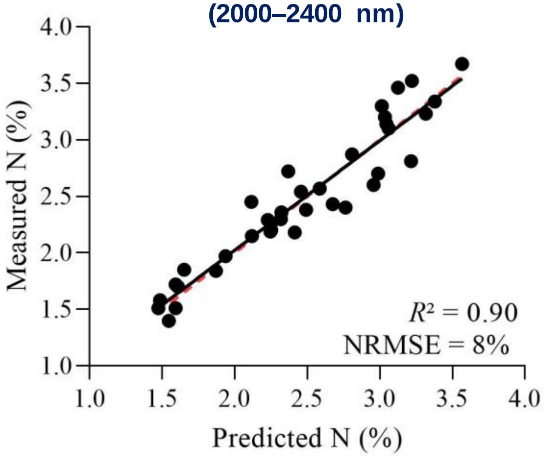

**Leaf water content (1100–2400 nm)**



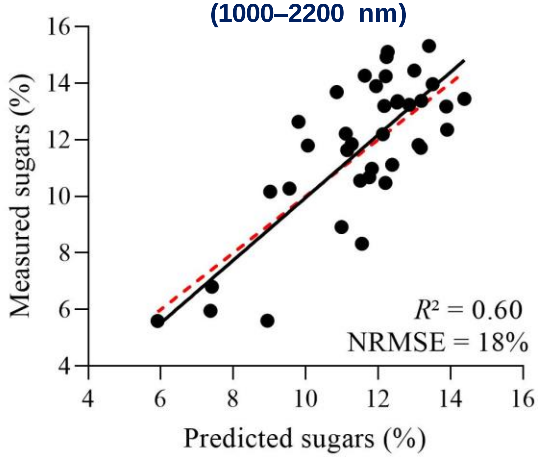

**Specific leaf area (500–2400 nm)**



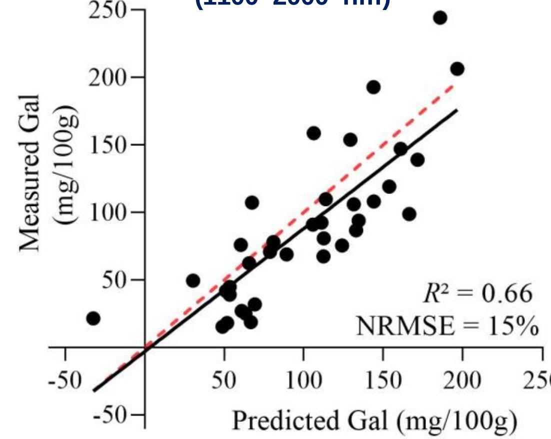

**Nitrogen (2000–2400 nm)**




**Sugars (1000–2200 nm)**




**Gallic acid (1100–2000 nm)**

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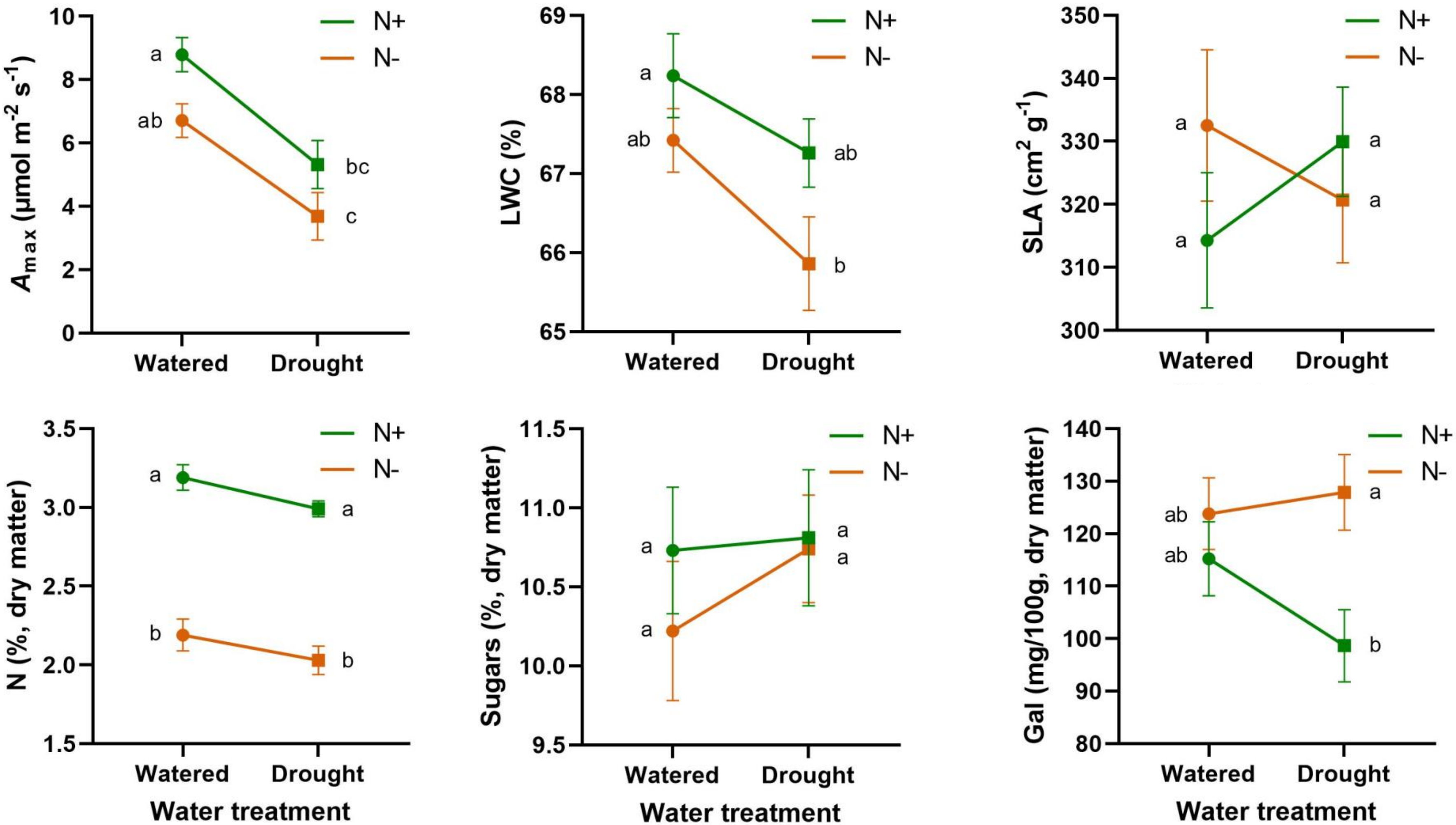
Trait retrievals + Spectral phenotyping (Water & Nutrient stress) **Major Findings**




Leaf functional traits predicted from spectral data show responses to stress treatment provide detailed information on shifts in tree health status

- Standardized analyses, spectral measurements, and robust statistical modeling allow us to build trait models to retrieve relevant foliar traits for stress monitoring
- The inclusion of short infrared wavelength ranges (1300−2400 nm) was essential in enhancing the prediction of all six leaf traits using PLSR
- Future research finding the most optimal spectral regions to improve predictions of important traits in other species and conditions are needed

- Report with predictive models predicting leaf functional traits related to growth, nutritional status, defense
- Public presentation of findings at HTIRC and Digital Forestry meetings at Purdue, CAFS annual meeting, and international conferences (ESA and AGU)
- A manuscript for peer-reviewed journal *in preparation* (*Methods in Ecology and Evolution*)

- Generate outcomes that can directly inform potential management decisions involving forest plantation management through more efficient and specific characterization of tree health using RS data

- This project will be at a national-scale and relevant for all industry members

# Acknowledgements

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**Mickelbart lab**