Scaling, propagating and mapping uncertainty in spectroscopy-derived foliar traits from the leaf to the image

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Major Themes

- Leaf traits & spectroscopy
- Image processing & scaling
- Spatial predictions
- Applications

Coachella Valley, California
Data from Green et al., (2003). *Ag. For. Met.*

\[ \text{ANPP} = \text{LUE} \times \text{APAR} \]
\[ \text{LUE}_{\text{area}} = [\text{N}_{\text{canopy}}/\text{FPAR}] / \text{M}_{\text{area}} \]

\[ L\text{UE (g M}^{-1}) = \text{N}_{\text{mass (mg g}^{-1})} \]

\[ r = 0.39 \]
\[ r = 0.56 \]
\[ r = 0.85 \]

\[ r = -0.48 \]
\[ r = 0.72 \]
\[ r = 0.79 \]
Singh et al. [in prep] Eco. Apps

AVIRIS Imagery

Atmospheric Correction

BRDF Correction

Normalized image

Predicted trait means + uncertainties

Cross-validation

Image-level calibration

PLSR

Canopy spectra

Topographic normalization

Leaf-level calibration

PLSR

Cross-validation

Plot-level traits

Field sampling

Species, basal area

Cloud/Shadow mask

Leaf-level traits

Leaf spectra

Foliar Samples

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165 Plots  120+ AVIRIS Scenes

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Where we are today:

Standardized equations to predict foliar constituents using leaf-level spectroscopy.

Also: cardenolides, condensed tannins, phenolic glycosides

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Standardized equations to predict foliar constituents using leaf-level spectroscopy.

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LMA (g m⁻²)

Wavelength (nm)

PLSR Coefficients

-30

0.2

0.6

−

0

10

500

1000

1500

2000

2400

95% CI

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Here we see a series of scatter plots for various plant parts and isotopic measurements. The plots are labeled as follows:

- **%N**: Percent Nitrogen (N) against Mass (%)
- **%C**: Percent Carbon (C) against Mass (%)
- **Fiber**: Fiber content against ADF (%)
- **Lignin**: Lignin content against ADL (%)
- **Cellulose**: Cellulose content against Cell (%)
- **δ¹⁵N**: δ¹⁵ Nitrogen isotopes against ADL (%)
- **LMA**: Leaf Mass Area against M_area (gm^-2)

Each scatter plot contains data points color-coded by species, with species abbreviations specified in the legend:

- ABBA
- PIST
- PIRE
- THOC
- TSCA
- PIBA
- PIMA
- LALA
- ACSM
- ACRU
- TIAM
- QURU
- QUAL
- OSVI
- FRAM
- POTR

*Residuals by species

Serbin, Singh, Kingdon, McNeil, Townsend [in prep] *Eco. Apps*
Scaling: Imaging Spectroscopy

Twin Otter

ER-2

[Graph with wavelengths and spectra]

[Images of aircraft and payload equipment]
Leaf Nitrogen Conc. (%)
Leaf Mass per Area (LMA, g m\(^{-2}\))

PVSS

NIR

Leaf Canopy

NIR

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Lignin (% DW)

Singh et al. [in prep] Eco. Apps
Legend

- Plots

AVIRIS Swaths

- Green: 2008
- Green: 2009
- Yellow: 2010
- Red: 2011

Legend:

- Plots

AVIRIS Swaths

- Green: 2008
- Green: 2009
- Yellow: 2010
- Red: 2011

Map showing regions A, B, C, D, and F with labeled states: MI, IL, OH, WV, PA, NY, CT, VT, MA, NJ, DE.
Singh et al. [in prep] Eco. Apps
A: Baraboo Hills, WI (Hickory/Oak/Pine)

Legend
- Plots
- AVIRIS Swaths
  - 2008
  - 2009
  - 2010
  - 2011

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Spatial Variation in LMA

A: Porcupine Mountains, MI (OG Hem/Hdw)
B: Ottawa NF, MI (OG Hem/Hardwood)
C: Flambeau River SF, WI (N. Hardwood)
D: Baraboo Hills, WI (Hickory/Oak/Pine)
E: Fernow Exp. Forest, WV (Mixed Hdw)
F: Green Ridge SF, MD (Mixed Oak)

Missing (urban/cloud)

Singh et al. [in prep] Eco. Apps
Spatial Variation in LMA

NLCD Land Cover Classification Legend

- 11 Open Water
- 12 Perennial Ice/Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land (Rock/Sand/Clay)
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 72 Sedge/Herbaceous*
- 73 Lichens*
- 74 Moss*
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska only
R: ADL
G: Nitrogen
B: LMA

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Singh et al. [in prep] Eco. Apps
Model-data Assimilation: AVIRIS

Willow Creek EC Tower Site, Wisconsin

Serbin et al. (in prep)
Dietze et al., (in review). JGR-Biogeosciences

www.pecanproject.org
Model-data Assimilation: AVIRIS

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Next Steps

• Application of PLSR algorithms to new sites
  – Eastern US; NEON
  – HyspIRI California Campaign (cal/val)

• Synthesize spatial predictions within ecosystem models
  – Upper Midwest, HyspIRI California Campaign Leaf morphology, phenology, chemistry, etc
Funding: NASA Terrestrial Ecology, NASA Earth & Space Science Fellowship, Wisconsin Space Grant Consortium, McIntire-Stennis
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NASA AVIRIS / MASTER teams; NEON airborne group

San Joaquin Exp. Range, California