Foliar Traits from Imaging Spectroscopy: What Foliar Traits Tell Us and How We Get There

Philip Townsend, University of Wisconsin Madison

Contributors:
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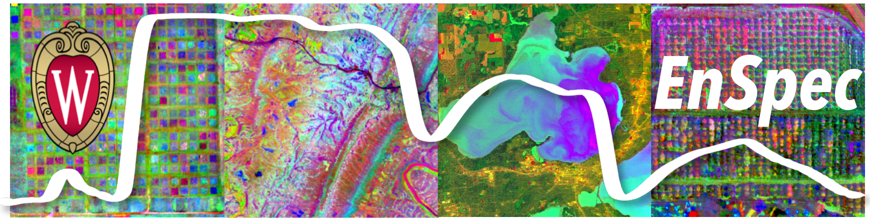
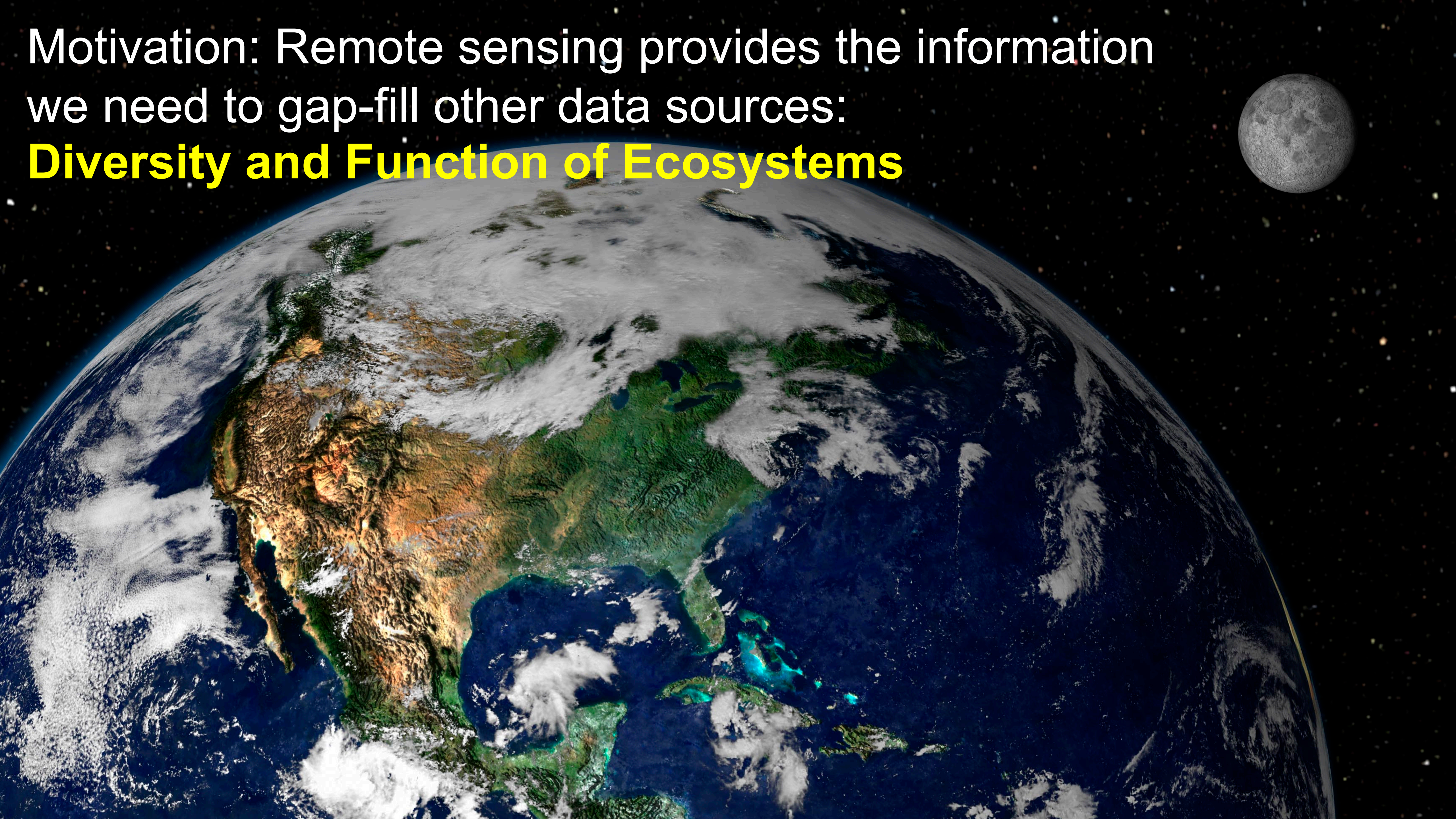
Erin Hokanson Wagner, Justin Merz, Clayton Kingdon, John Chapman
Ankur Desai, Eric Kruger, Jeannine Cavender-Bares, José Mereiles, Mike Madritch
Fabian Schneider, Ryan Pavlick, Natasha Stavros, David R. Thompson, David Schimel



Jet Propulsion Laboratory
California Institute of Technology

Motivation: Remote sensing provides the information we need to gap-fill other data sources:

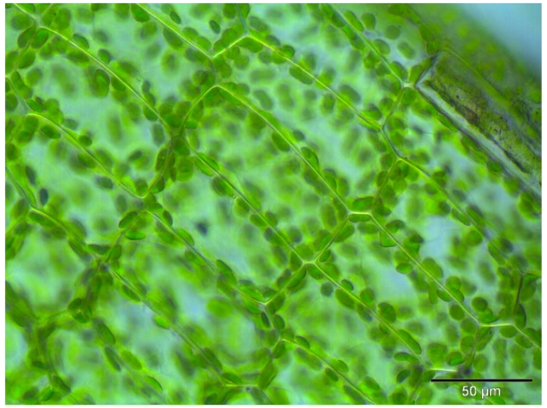
Diversity and Function of Ecosystems

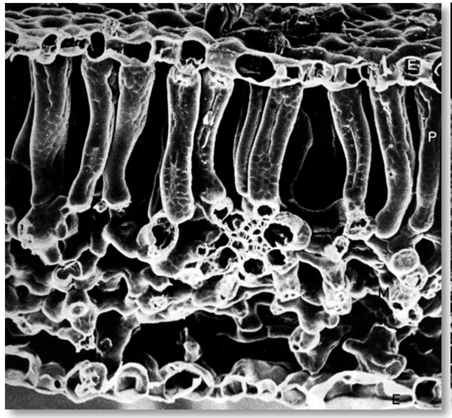


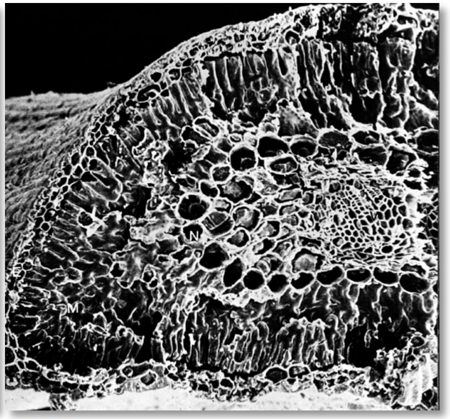

Censuses

Traits, Fluxes

What are plants doing?
What's different among plants?







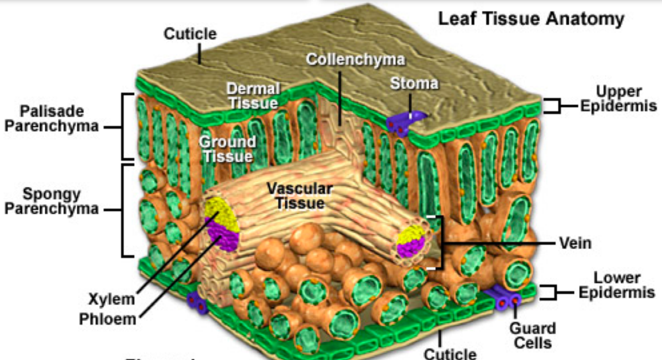
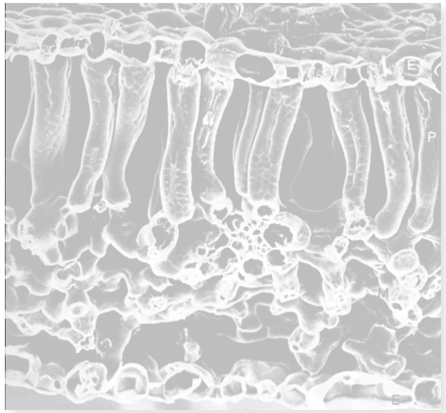
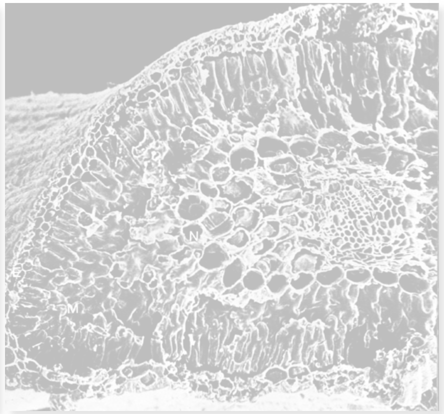
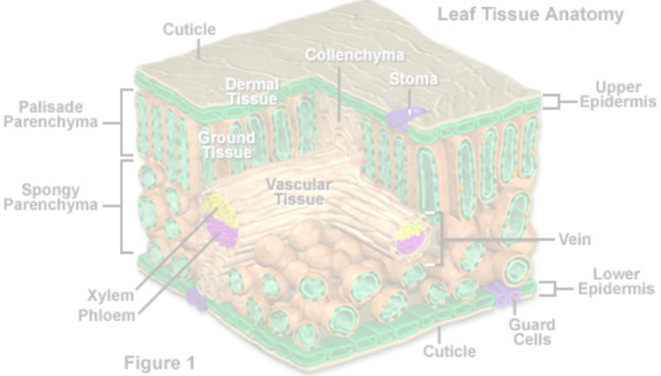


Figure 1

What are plants doing?
What's different among plants?

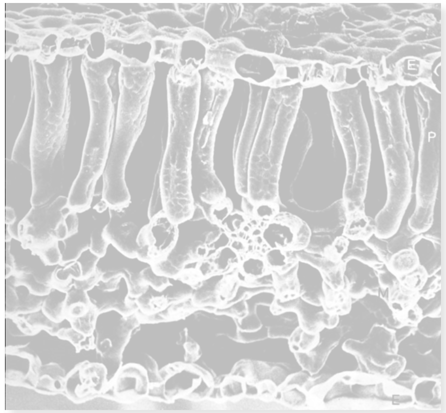


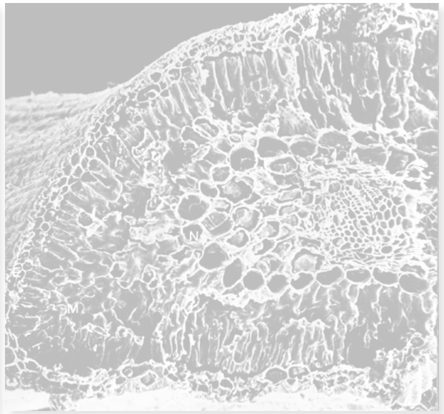


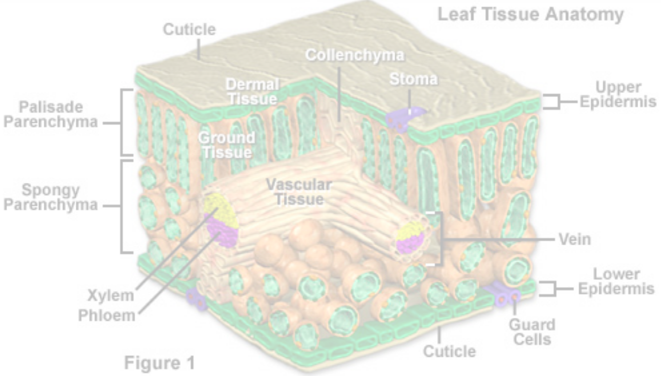


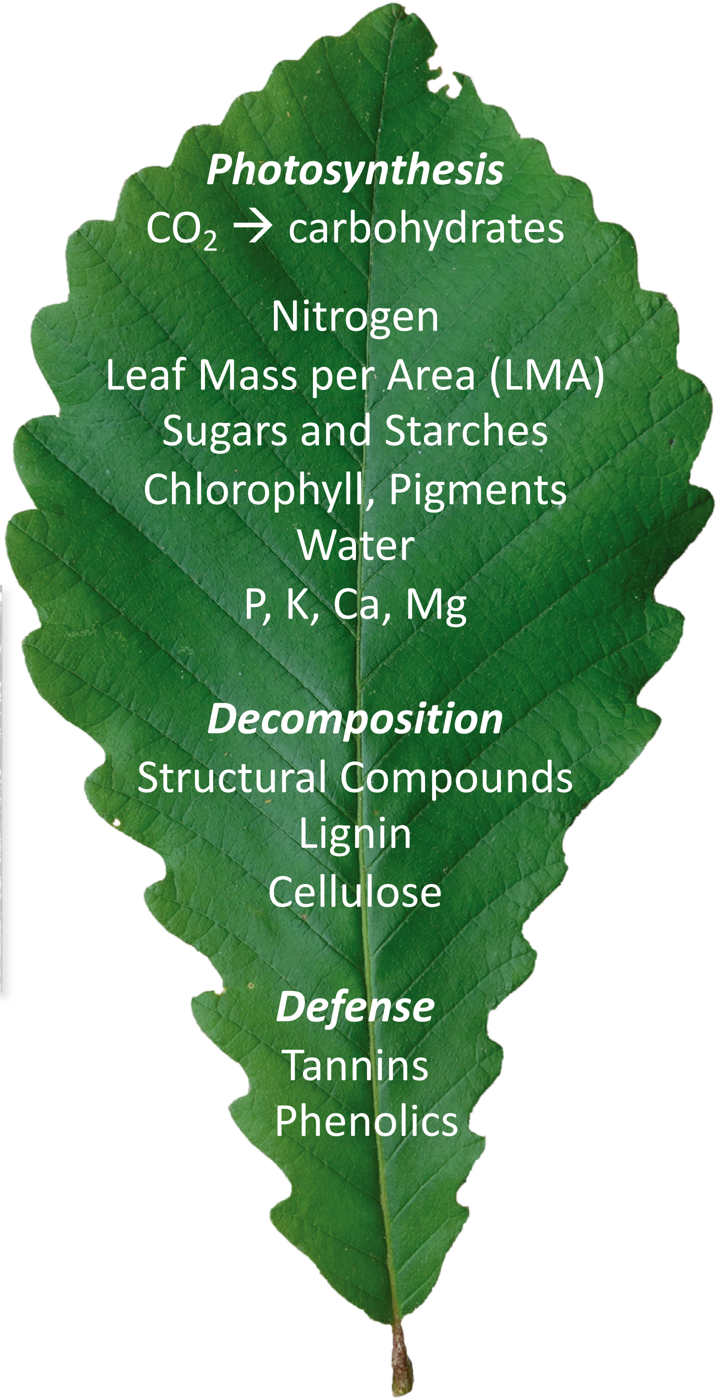
What are foliar functional traits
and why do we care?

What are plants doing?
What's different among plants?









What are foliar functional traits
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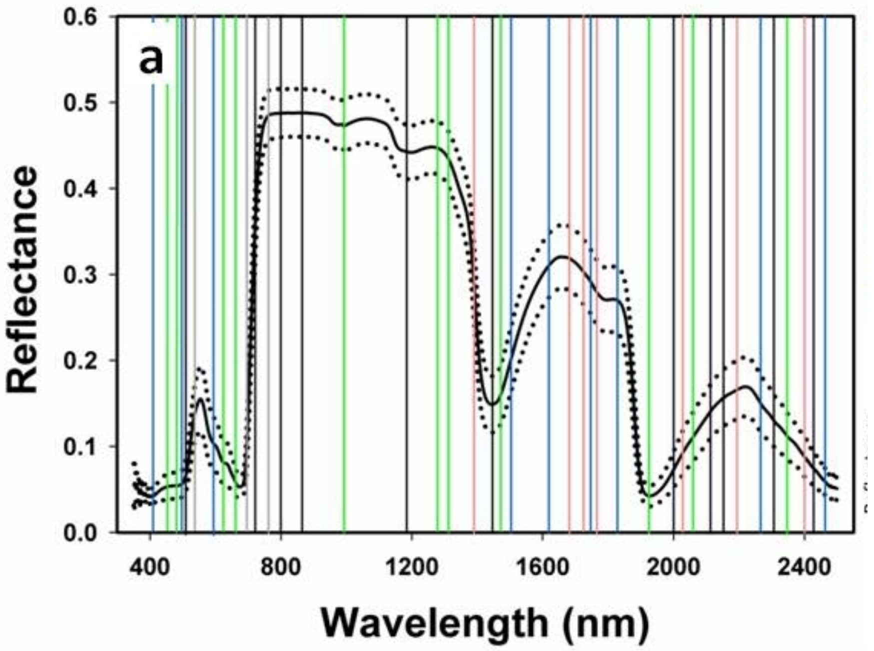
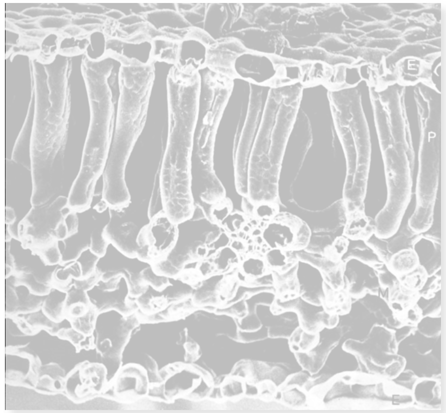
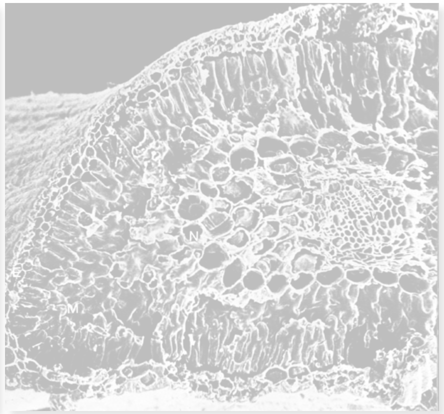
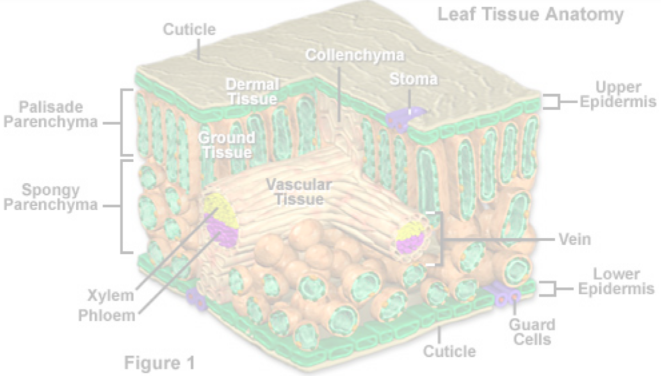


What are plants doing?
What's different among plants?







Photosynthesis

$CO_2 \rightarrow$ carbohydrates

Nitrogen
Leaf Mass per Area (LMA)
Sugars and Starches
Chlorophyll, Pigments
Water
P, K, Ca, Mg

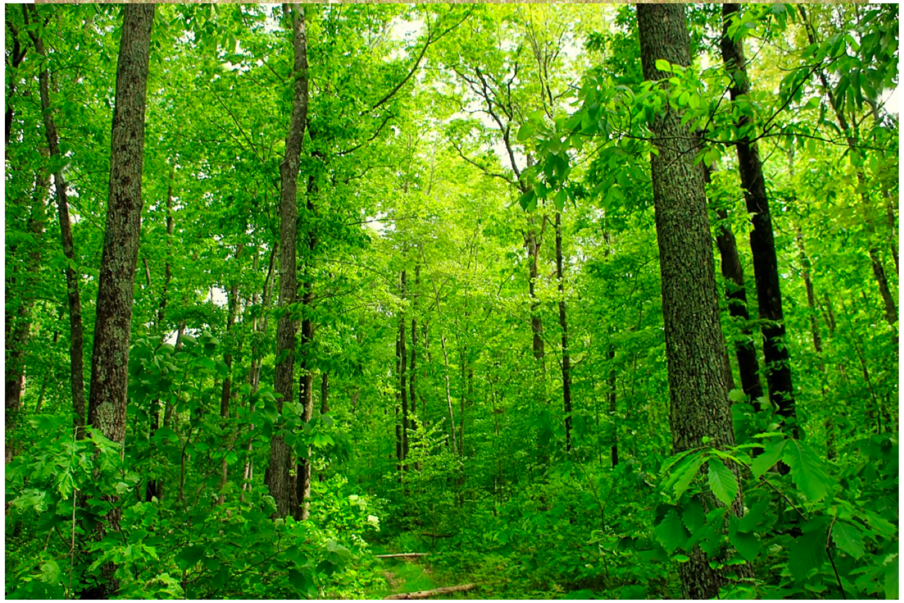
Decomposition

Structural Compounds
Lignin

Defense

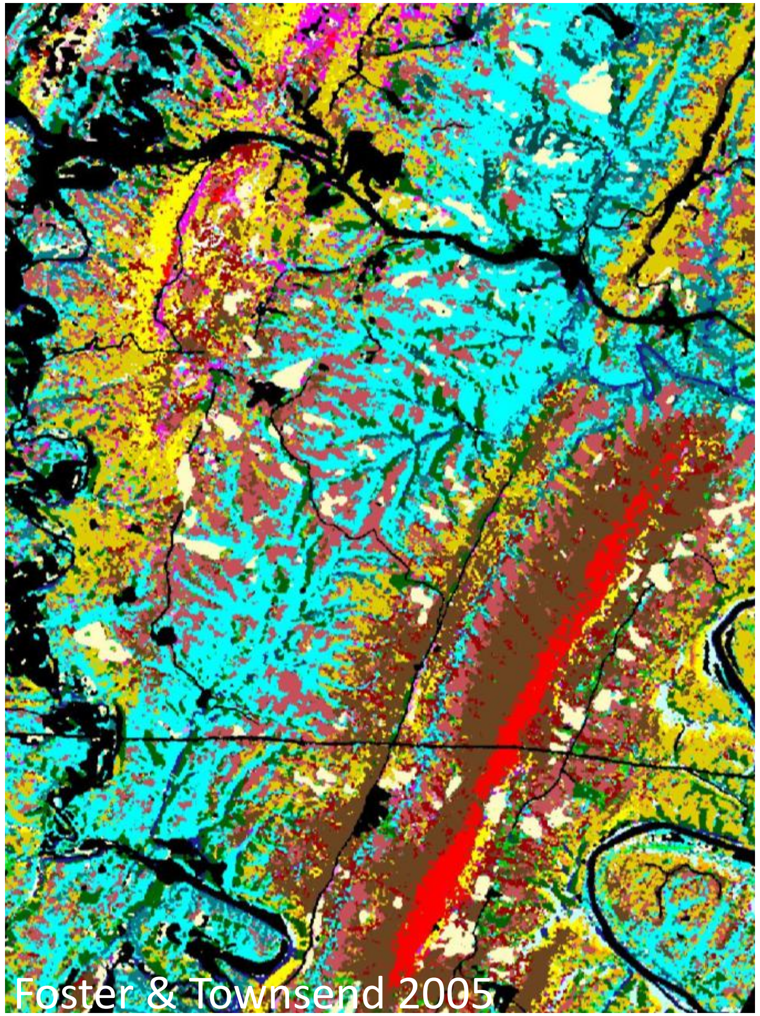
Tannins
Phenolics

What are foliar functional traits and why do we care?



What are plants doing?
What's different among plants?

What are the causes?
How will plants respond to change?



Species

Diversity

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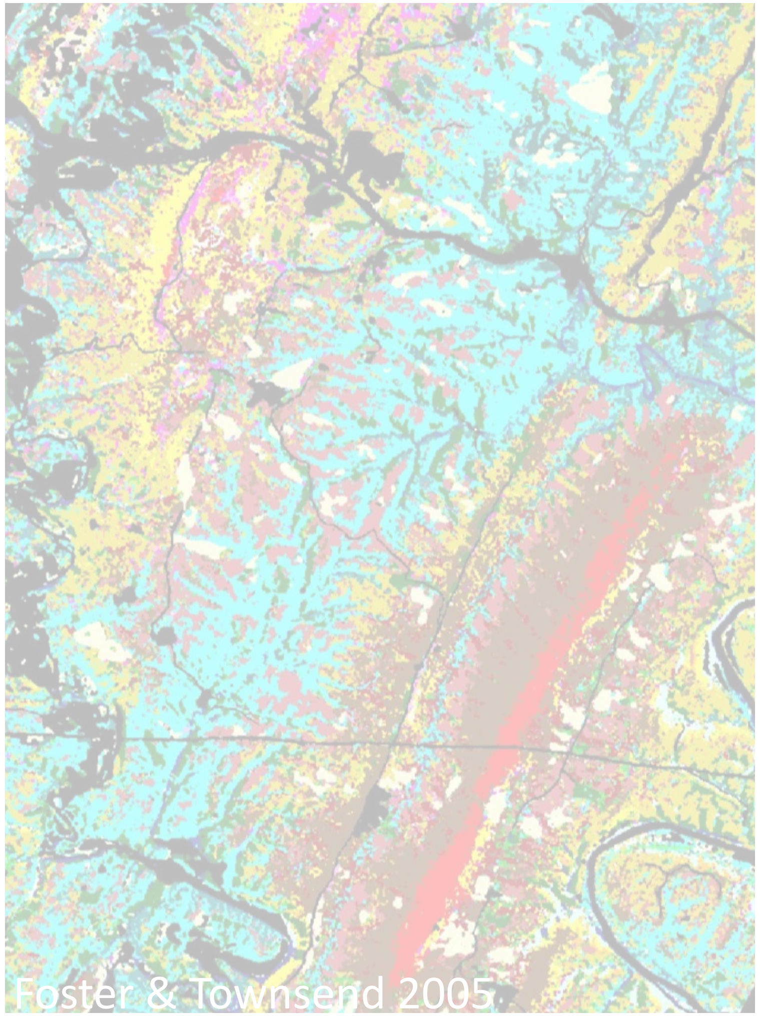
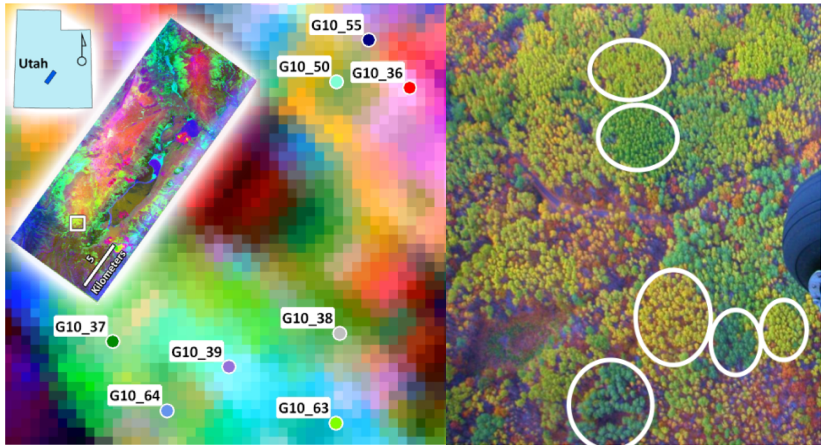
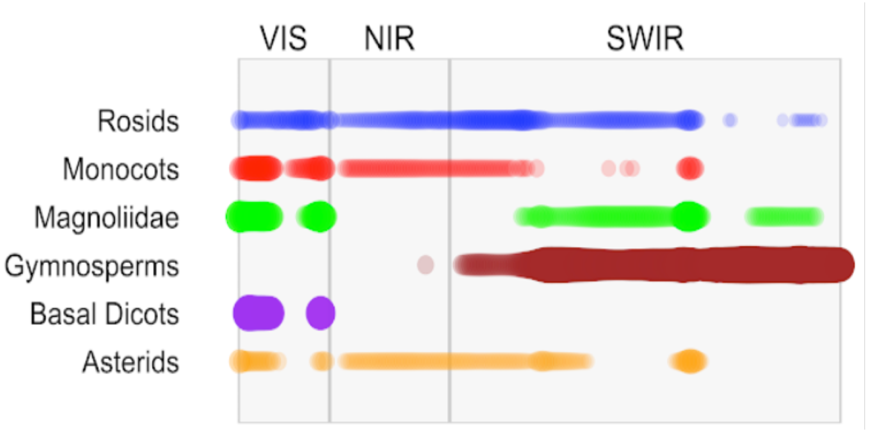
How will plants respond to change?



Foster & Townsend 2005



Madritch et al. 2014



Mereiles, Cavender-Bares et al.

Species

Diversity

Genotype

Evolutionary Drivers (selection & phylogeny)

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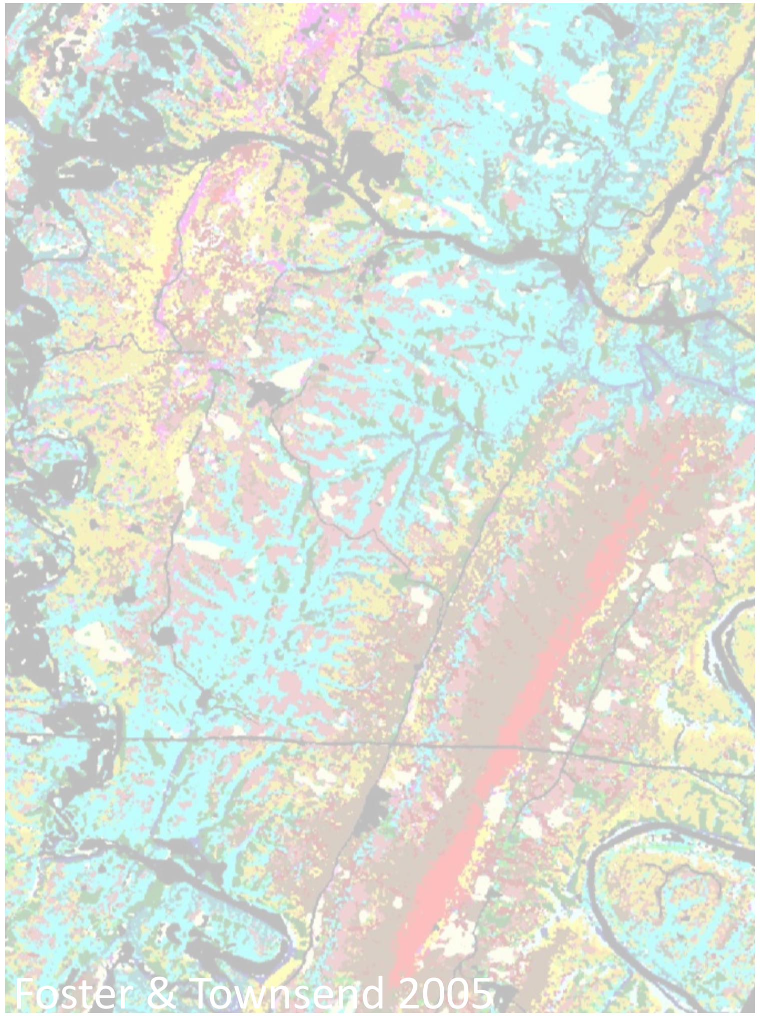
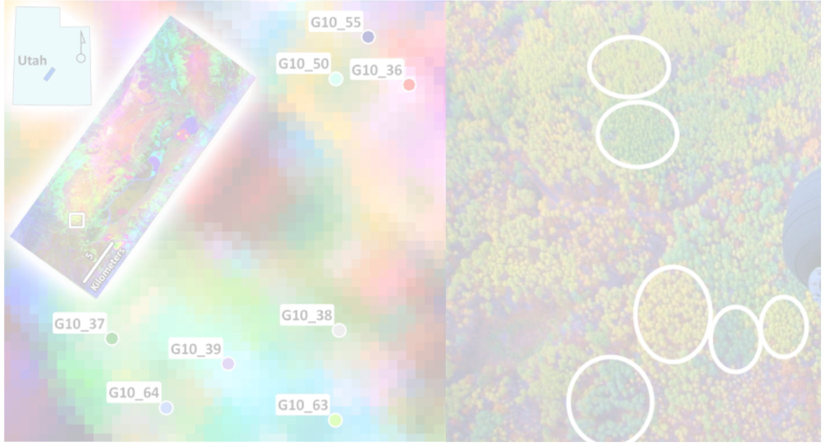
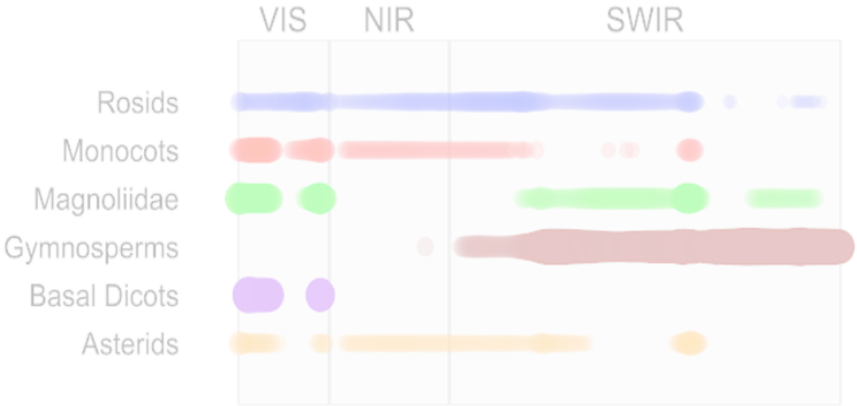




Madritch et al. 2014



Mereiles, Cavender-Bares et al.

Species
Diversity

Genotype
Evolutionary Drivers (selection & phylogeny)

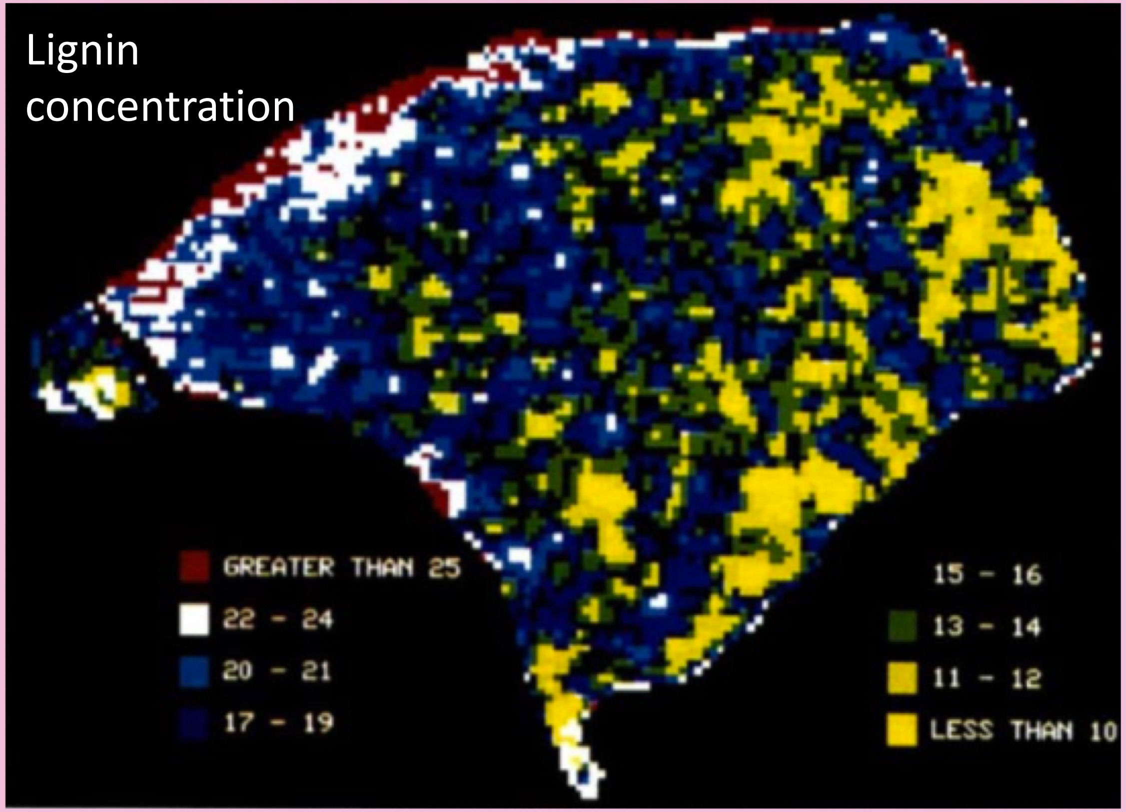
Phenotype
Environment

NATURE NATURE VOL. 335 8 SEPTEMBER 1988

Remote sensing of canopy chemistry and nitrogen cycling in temperate forest ecosystems

Carol A. Wessman*‖, John D. Aber†¶, David L. Peterson‡ & Jerry M. Melillo§

* Department of Forestry and the Environmental Remote Sensing Center, University of Wisconsin, Madison, Wisconsin 53706, USA
† Department of Forestry, University of Wisconsin, Madison, Wisconsin 53706, USA
‡ Ames Research Center, National Aeronautics and Space Administration, Moffett Field, California 94035, USA
§ Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts 02543, USA



Wessman et al. 1988

1980s 1990s 2000s 2010s Now

NATURE
NATURE VOL. 335 8 SEPTEMBER 1988

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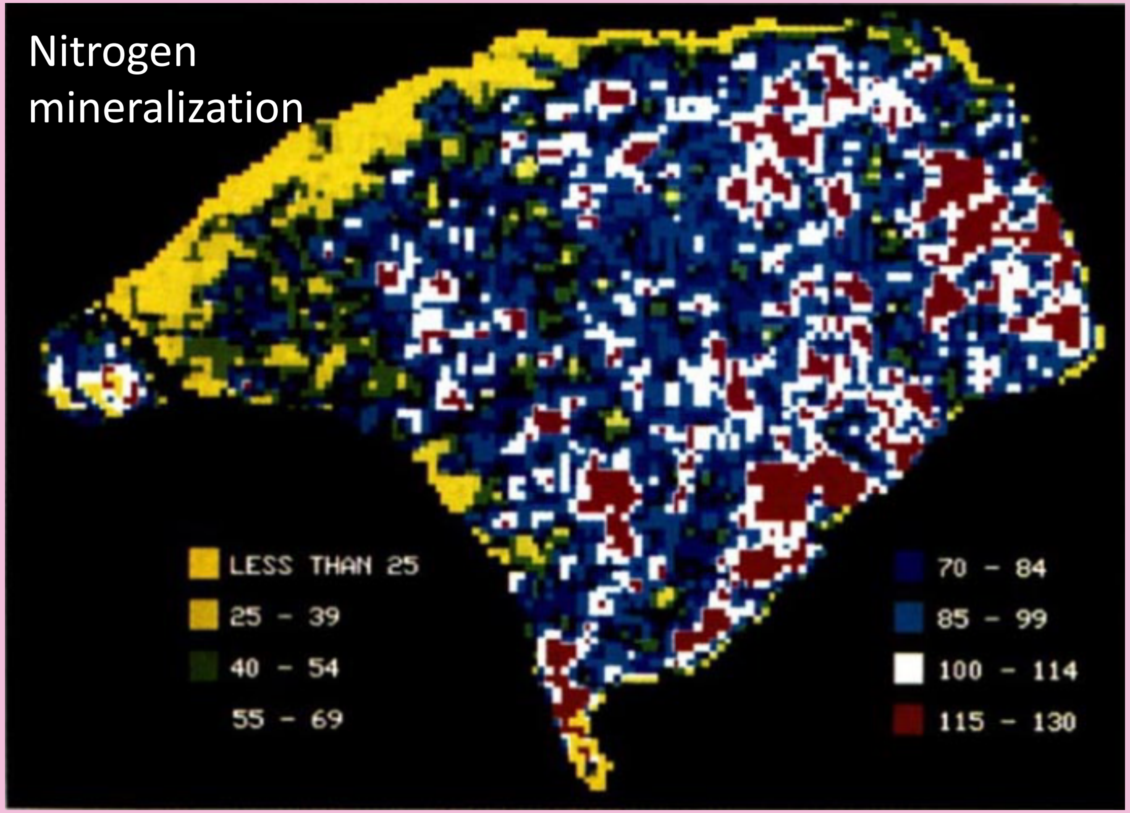
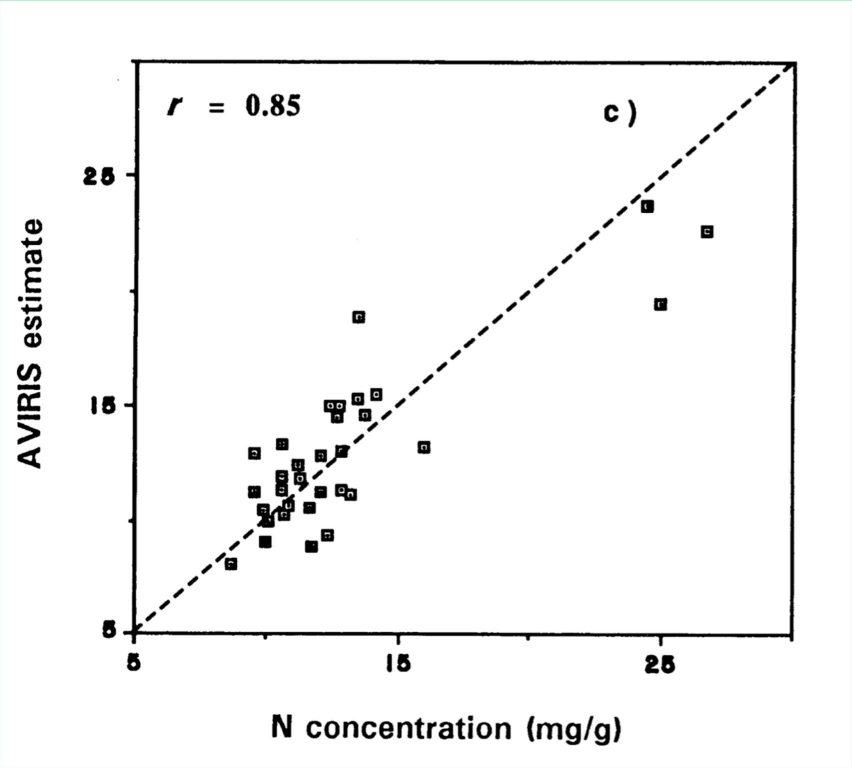
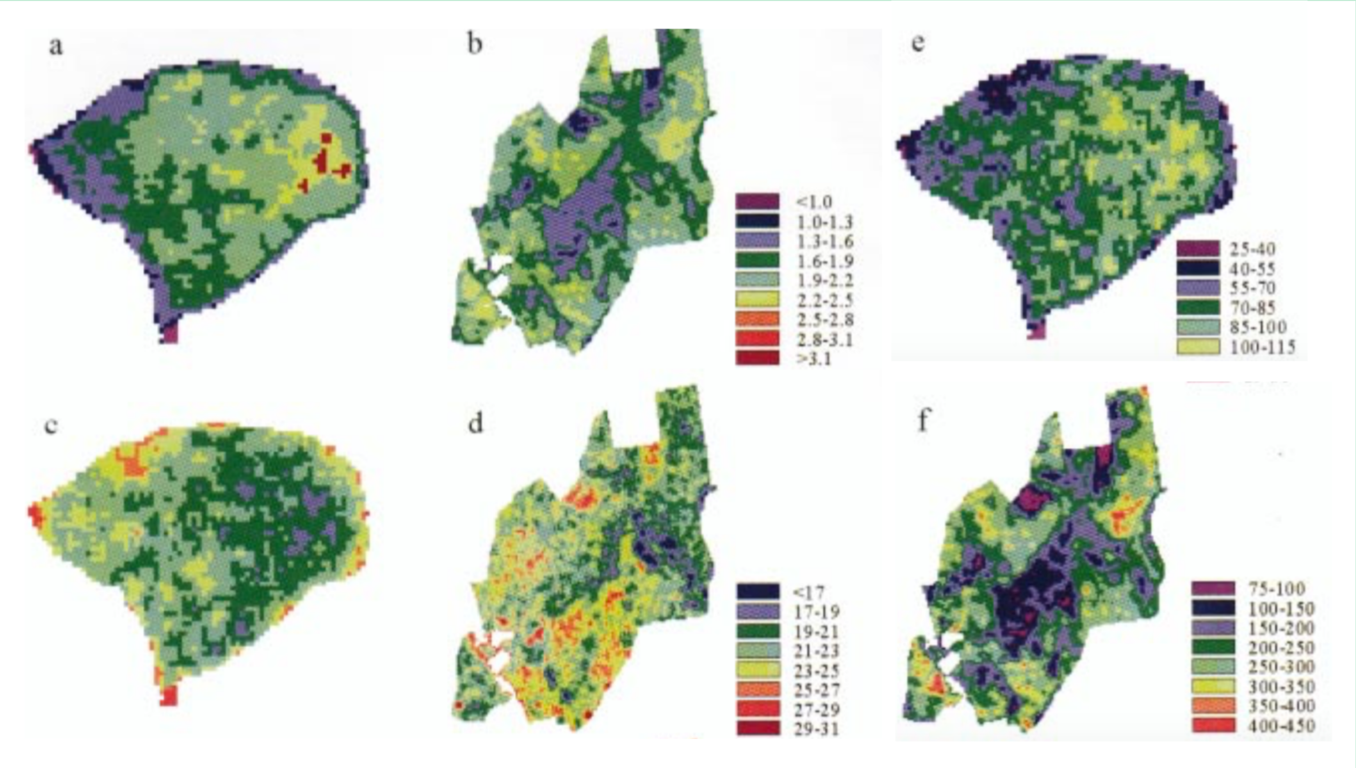


Wessman et al. 1988

1980s → 1990s → 2000s → 2010s → Now





Matson et al. 1994

Martin and Aber 1997

1980s → 1990s → 2000s → 2010s → Now

Botanical Gazette, Vol. 87, No. 5 (Jun., 1929), pp. 583-607

A SPECTROPHOTOMETRIC STUDY OF REFLECTION OF LIGHT FROM LEAF SURFACES

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY

CHARLES A. SHULL

January 1965 / Vol. 4, No. 1 / APPLIED OPTICS

Spectral Properties of Plants

David M. Gates, Harry J. Keegan, John C. Schleter, and Victor R. Weidner

American Journal of Botany, Vol. 38, No. 5 (May, 1951), pp. 327-331

REFLECTION OF VISIBLE AND INFRARED RADIATION FROM LEAVES OF DIFFERENT ECOLOGICAL GROUPS [1]

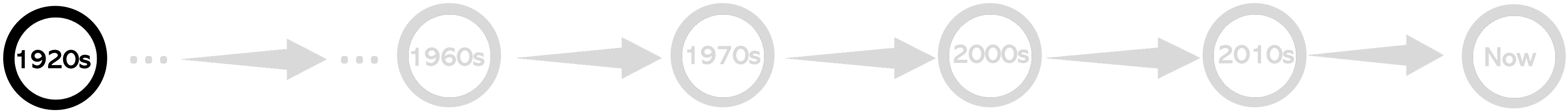
W. D. Billings and Robert J. Morris

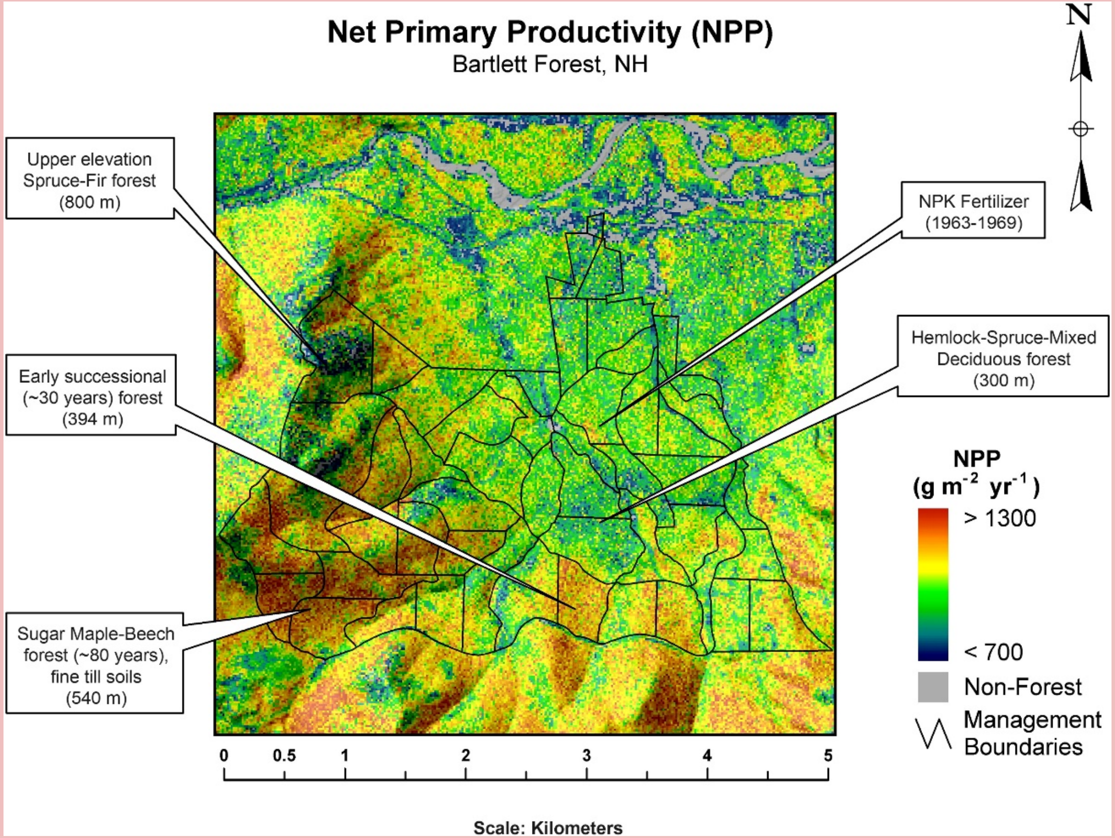
JOURNAL OF ANIMAL SCIENCE, Vol. 43, No. 4 (1976)

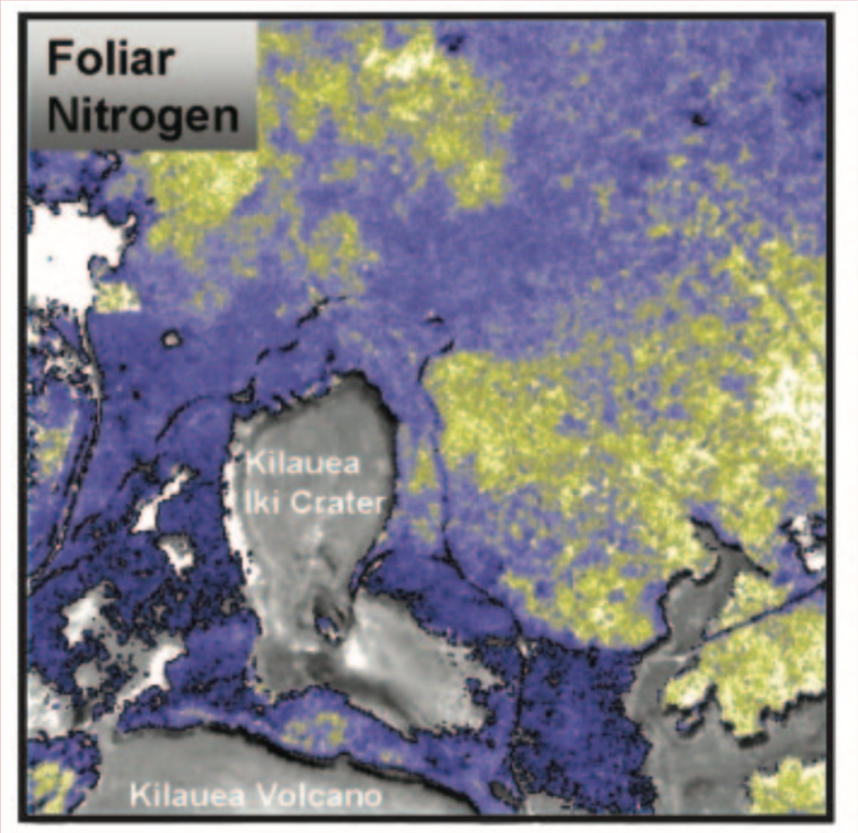
PREDICTING FORAGE QUALITY BY INFRARED REFLECTANCE SPECTROSCOPY[1]

K. H. Norris[2], R. F. Barnes[3], J. E. Moore[4] and J. S. Shenk[5,6]

Agricultural Research Service, U.S. Department of Agriculture
Beltsville, Maryland 20705 and University Park, Pennsylvania 16802;
The University of Florida, Gainesville 32611; and
The Pennsylvania State University, University Park 16802



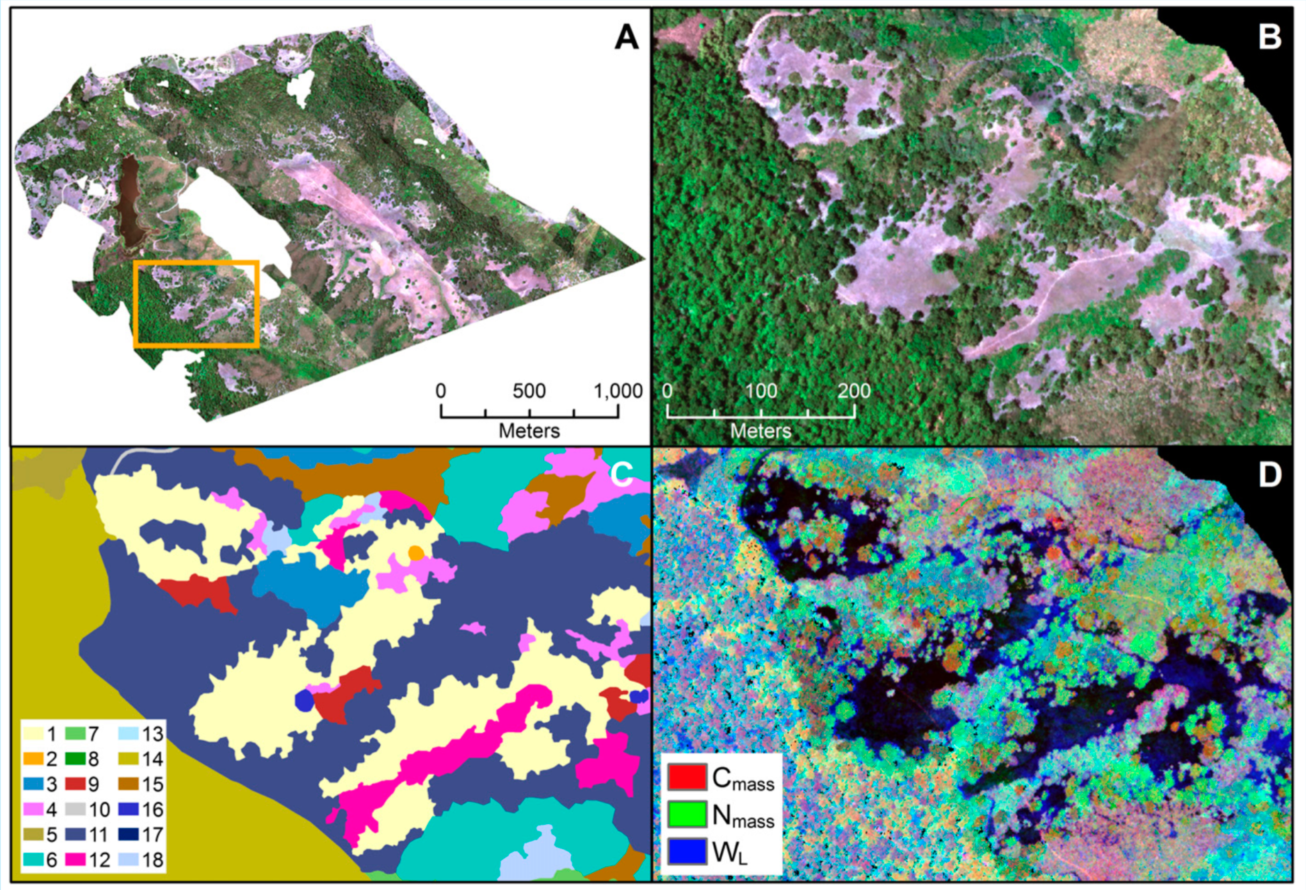




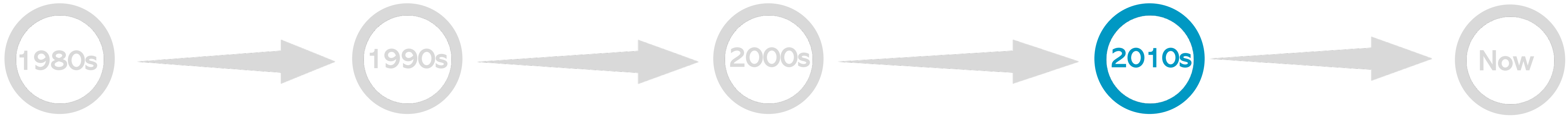
Smith et al. 2002; Ollinger et al. 2005

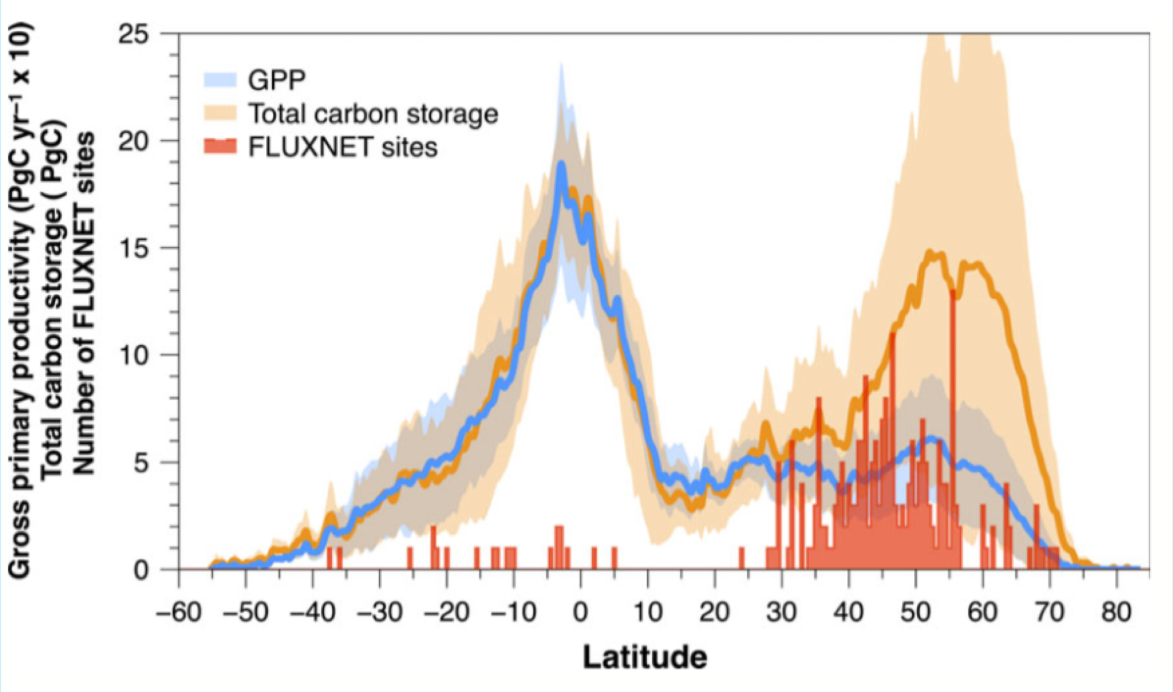
Asner and Vitousek 2005

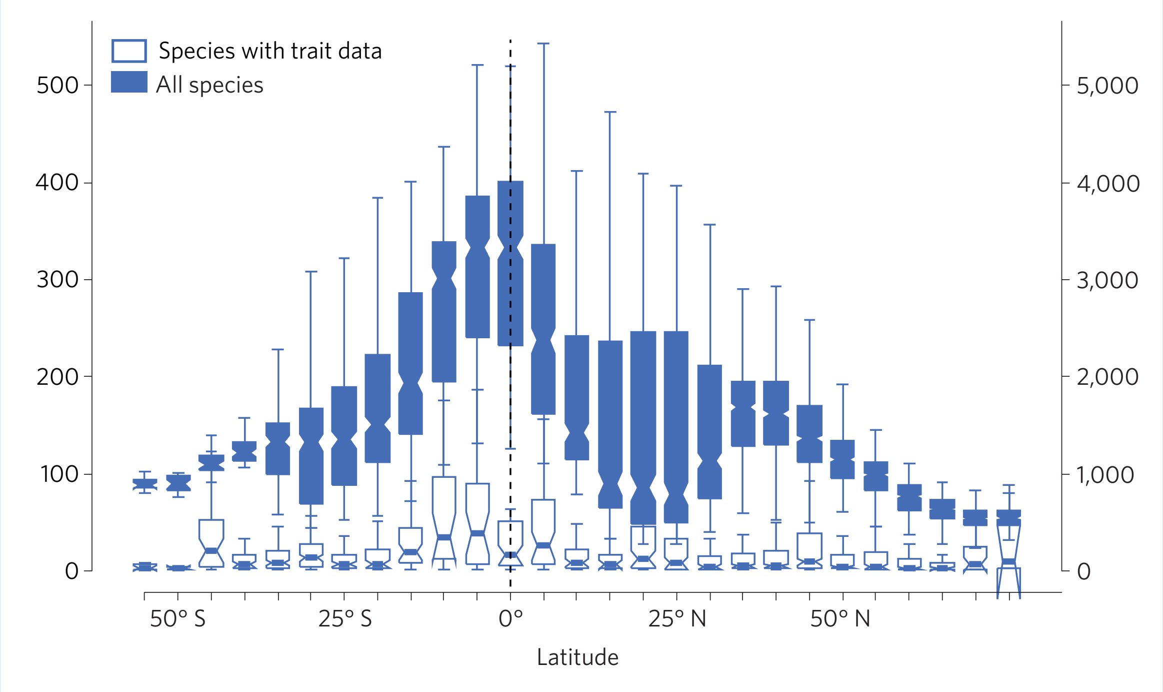
1980s → 1990s → **2000s** → 2010s → Now



Dahlin et al. 2013

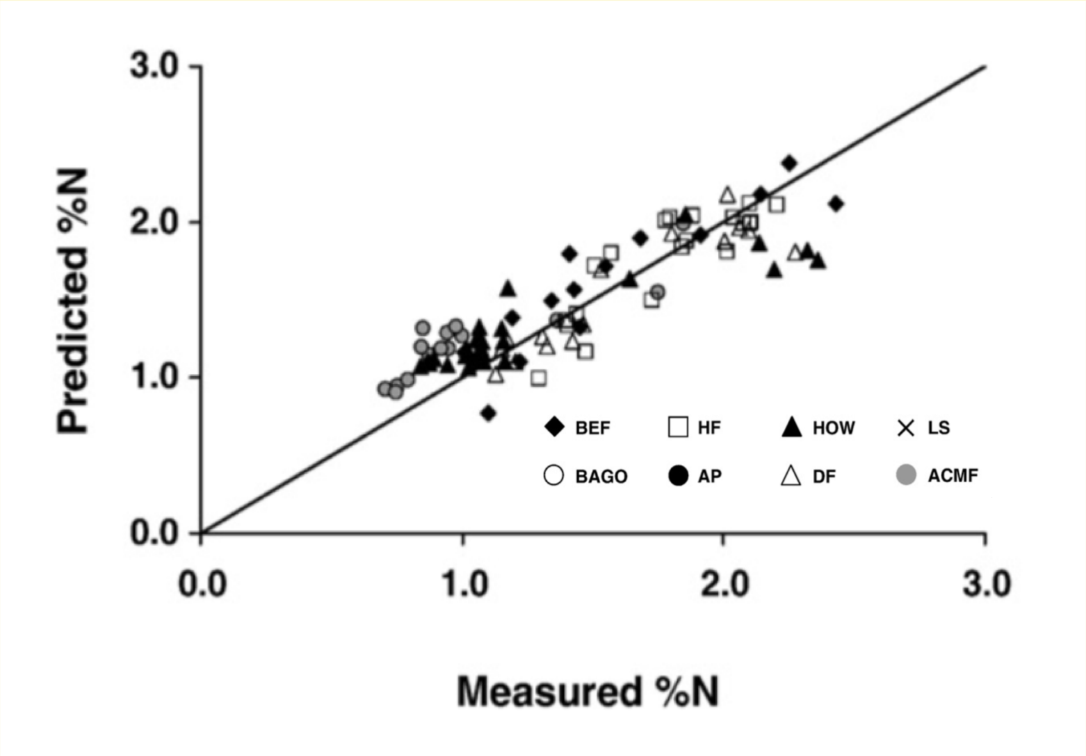


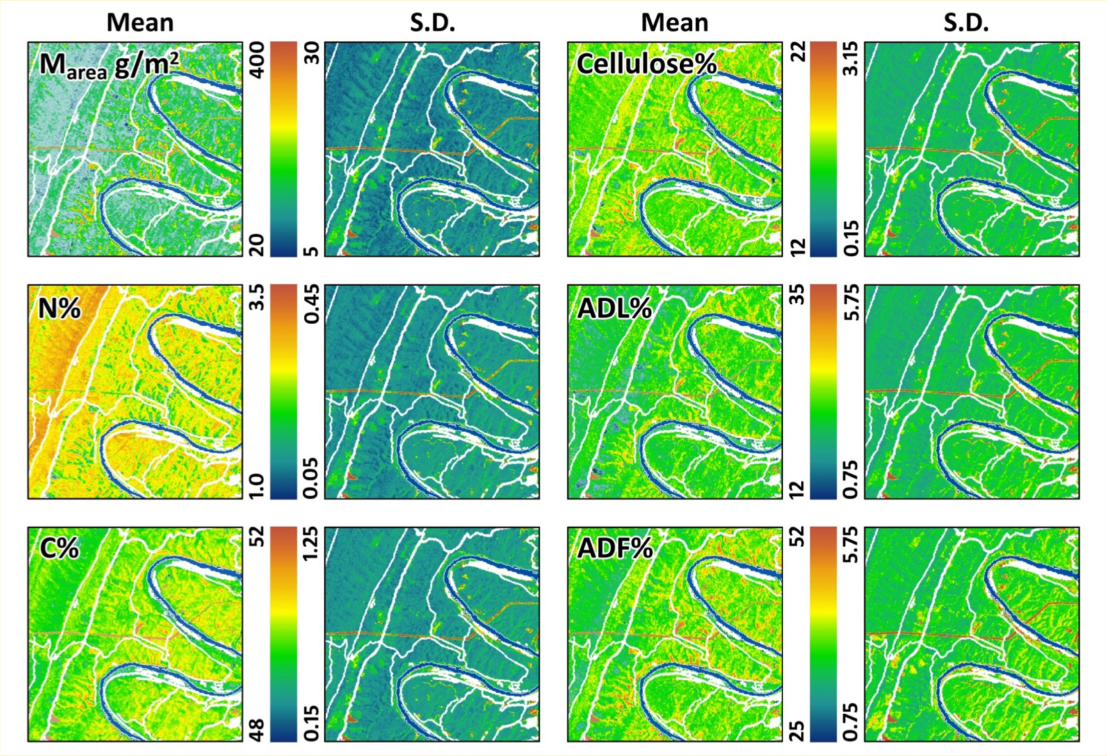




Schimel et al. 2015

Jetz et al. 2016

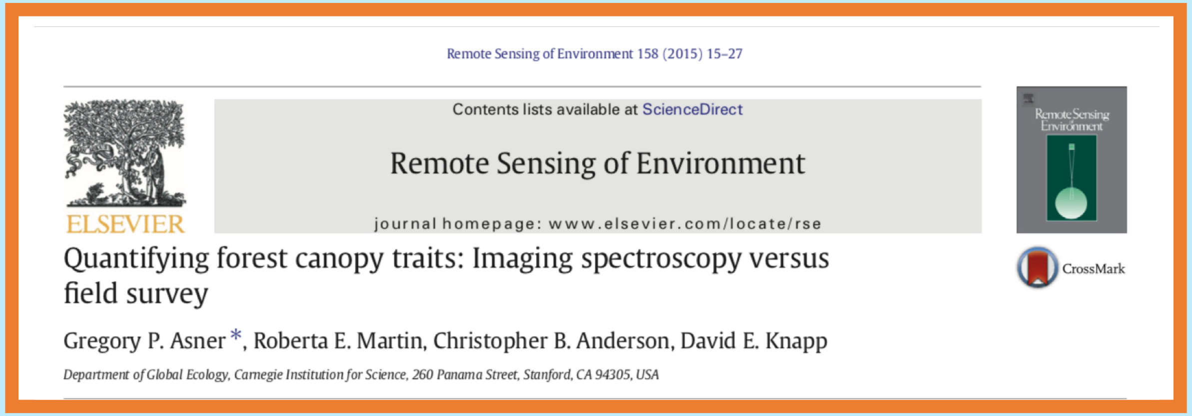




Martin et al. 2008

Singh et al. 2015

1980s → 1990s → 2000s → 2010s → Now



Remote Sensing of Environment 158 (2015) 15–27

Contents lists available at ScienceDirect

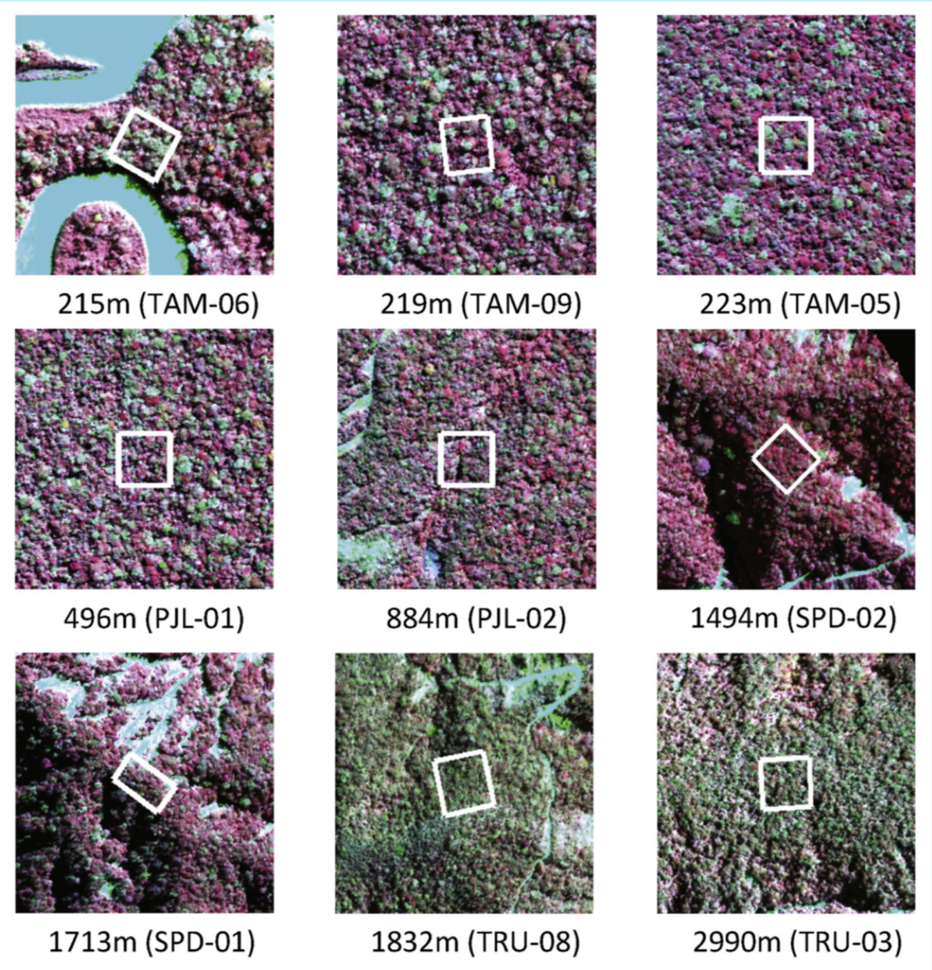
Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

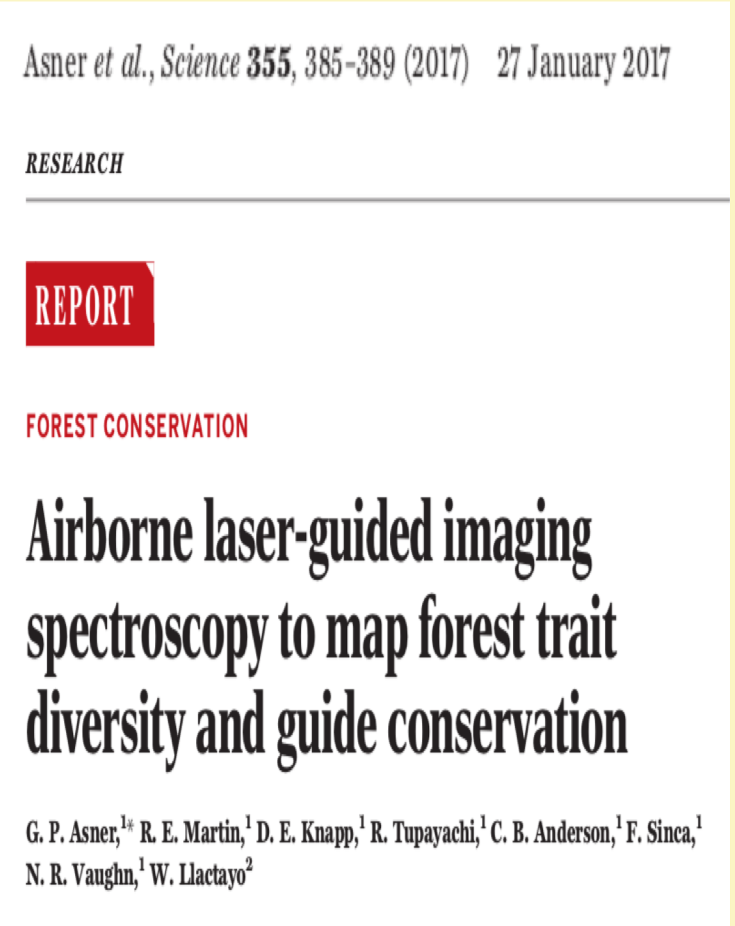
Quantifying forest canopy traits: Imaging spectroscopy versus field survey

Gregory P. Asner *, Roberta E. Martin, Christopher B. Anderson, David E. Knapp

Department of Global Ecology, Carnegie Institution for Science, 260 Panama Street, Stanford, CA 94305, USA



1980s → 1990s → 2000s → **2010s** → Now



Asner *et al.*, *Science* **355**, 385-389 (2017) 27 January 2017

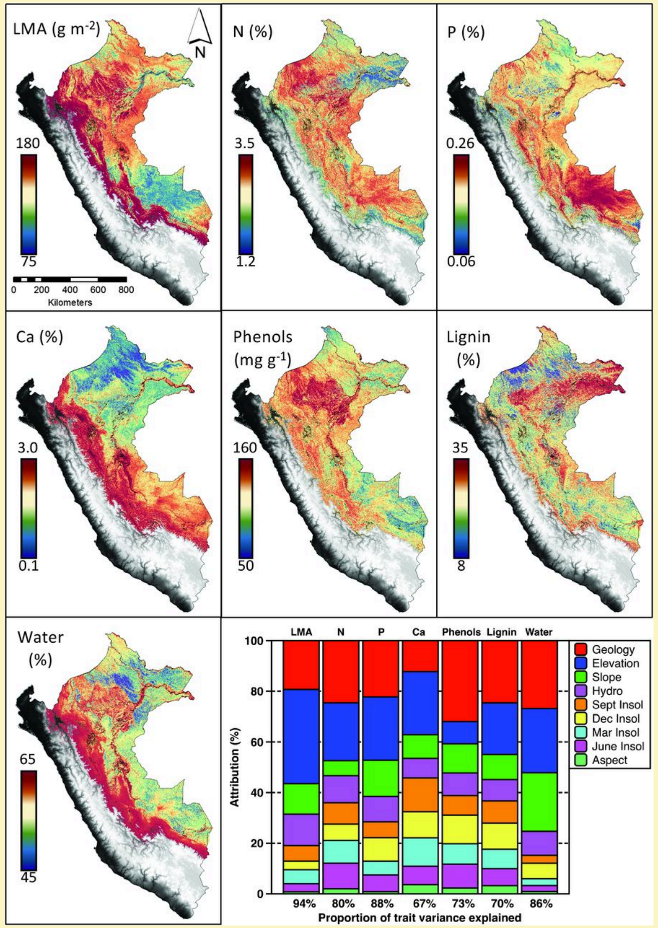
RESEARCH

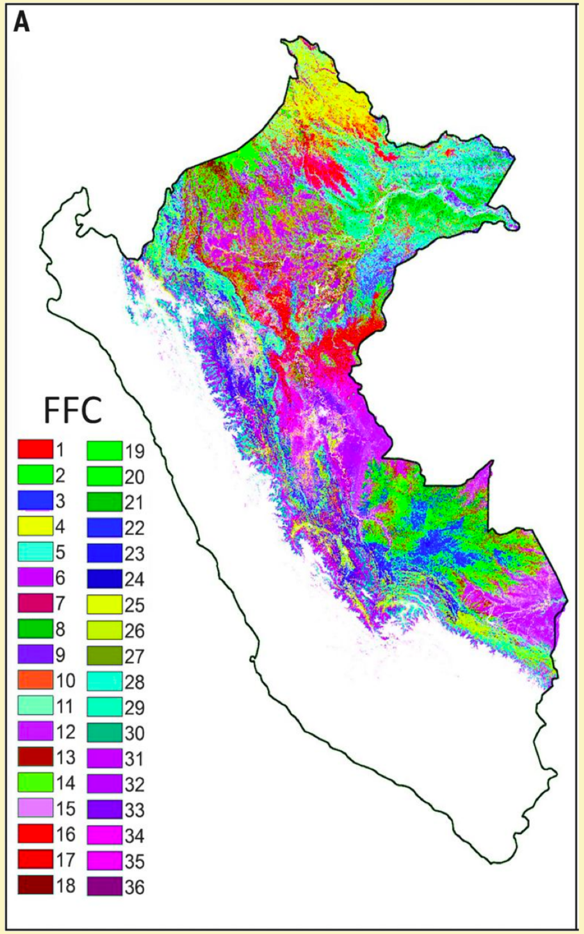
REPORT

FOREST CONSERVATION

Airborne laser-guided imaging spectroscopy to map forest trait diversity and guide conservation

G. P. Asner,[1*] R. E. Martin,[1] D. E. Knapp,[1] R. Tupayachi,[1] C. B. Anderson,[1] F. Sinca,[1] N. R. Vaughn,[1] W. Llactayo[2]





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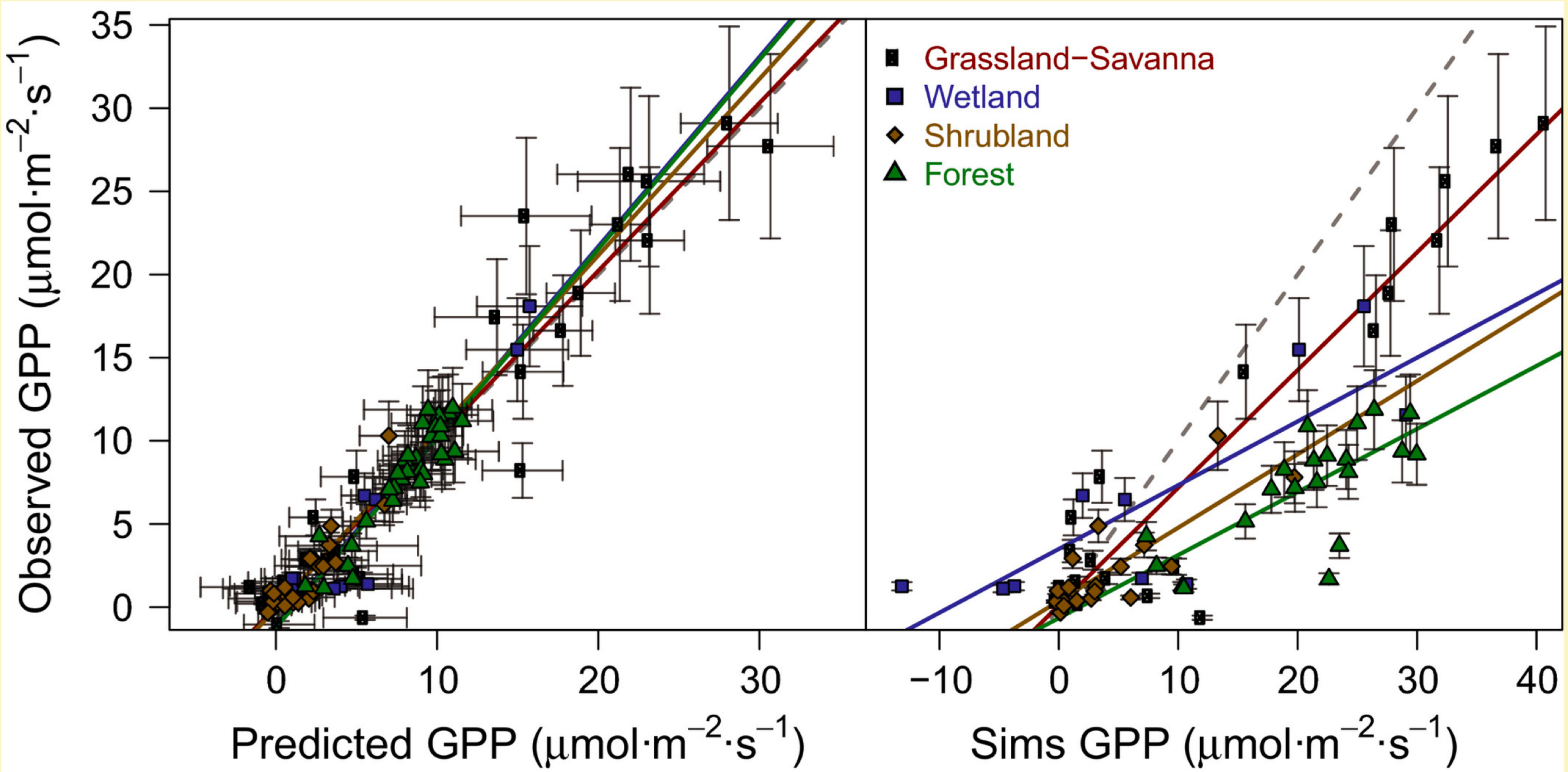
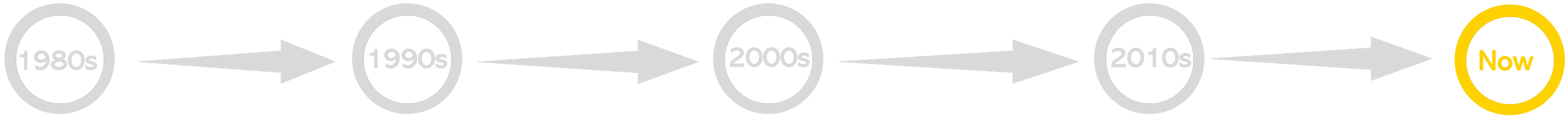
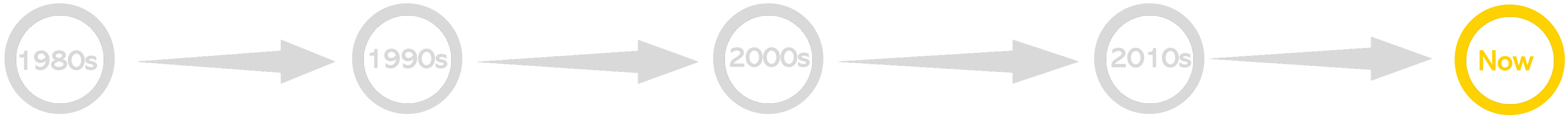


Dubois et al. 2018



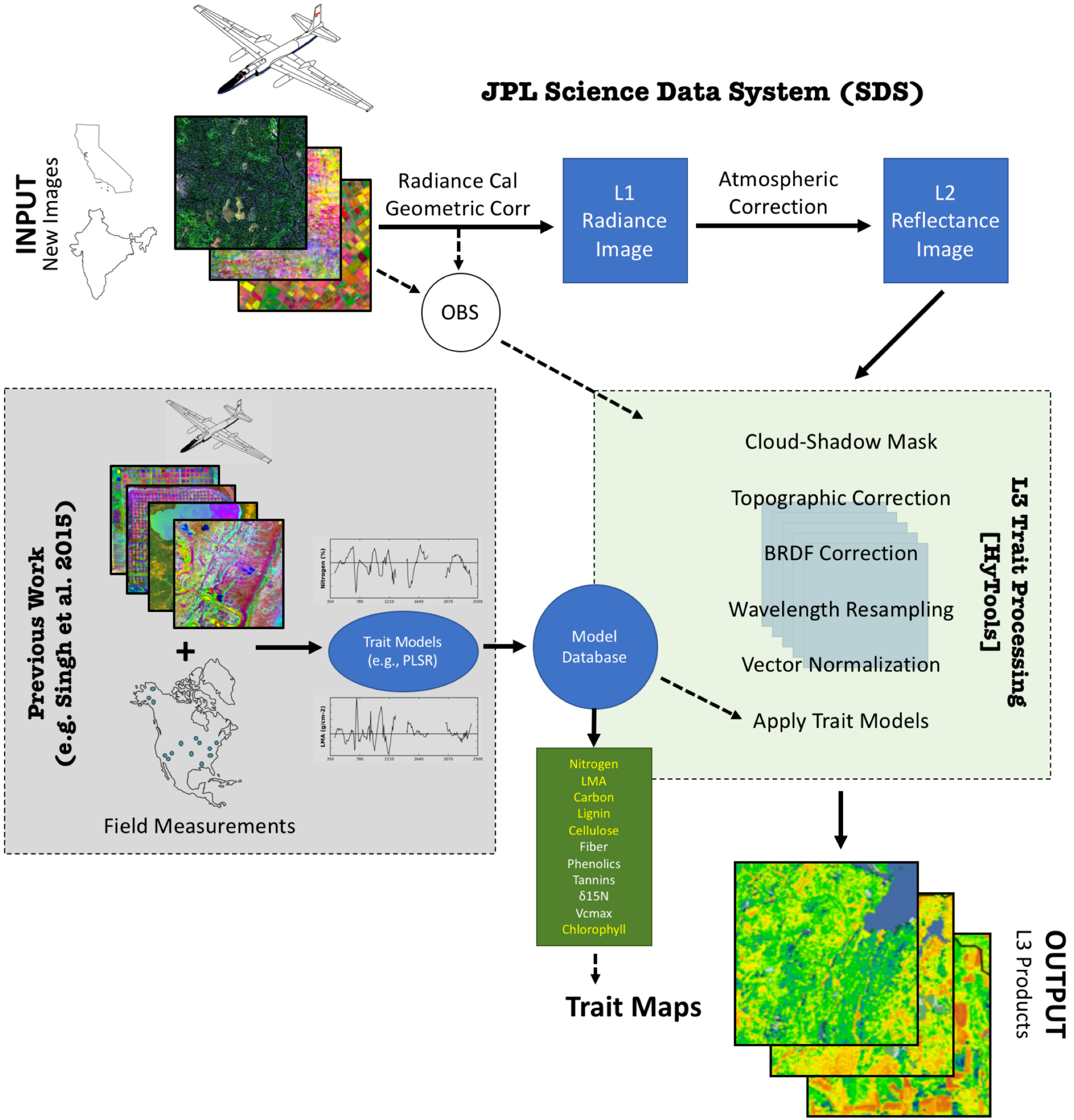
Where are we now?

- Strong foundation of science and application make SBG/HyspIRI a low risk/high reward mission
- Spatial, temporal, spectral resolution → functional resolution
- Address urgent questions about Earth's biosphere, and model phenotypic, genotypic, and ecological community response to environmental / climate change
- Are we ready?



Draft Workflow

Operational with AVIRIS

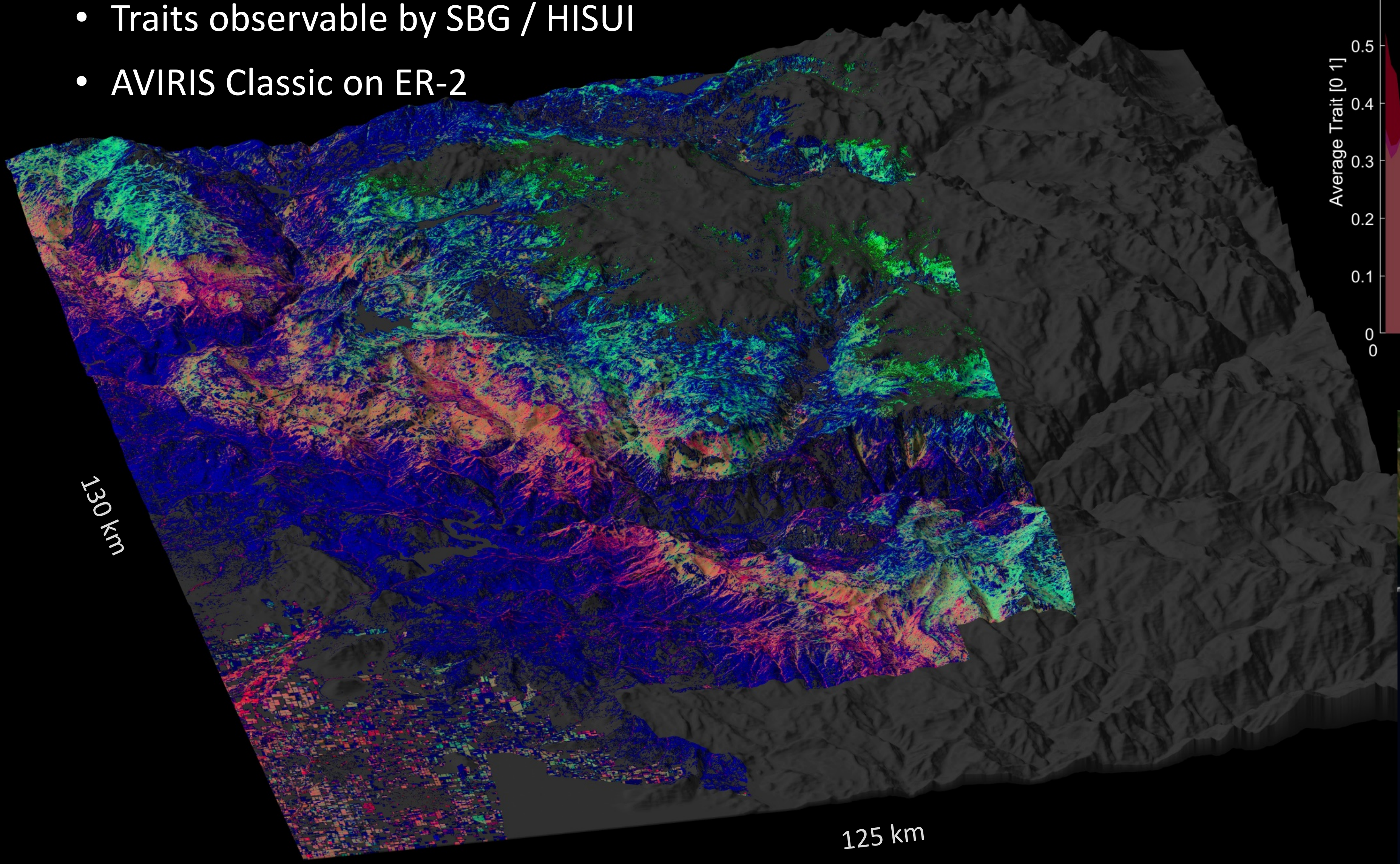


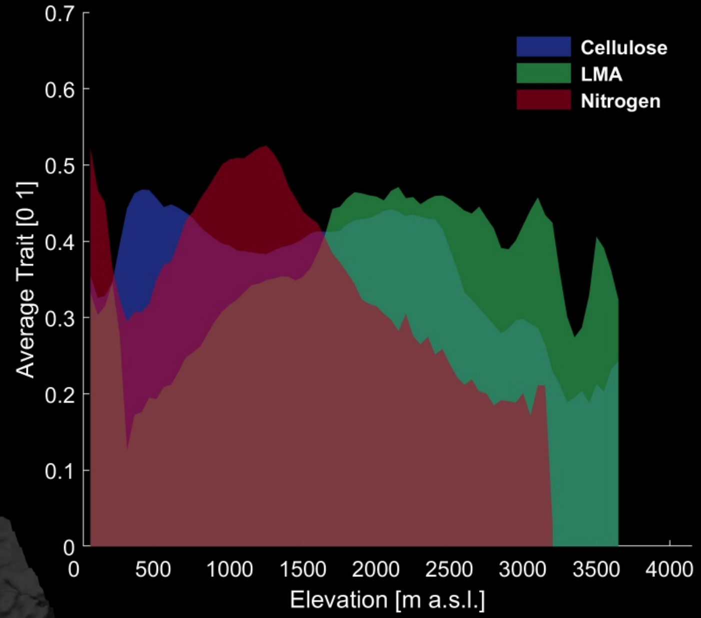
Jet Propulsion Laboratory
California Institute of Technology

National Ecological Observatory Network

Preliminary Results

- Traits observable by SBG / HISUI
- AVIRIS Classic on ER-2



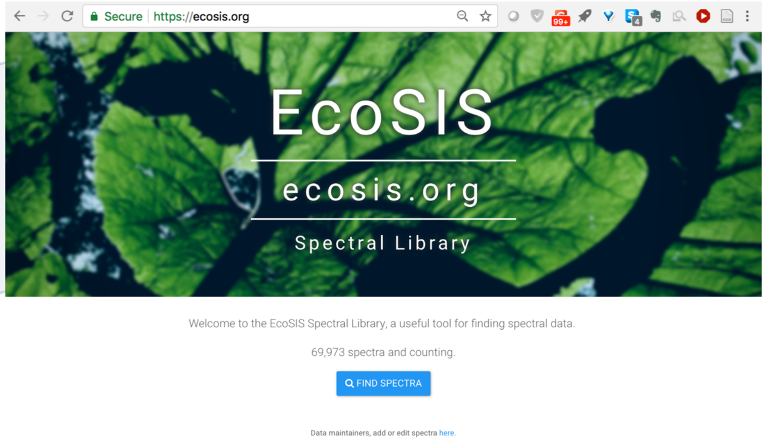


Townsend et al. in prep., Singh et al. 2015; figure by Fabian Schneider

Emerging tools for synthesis and implementation

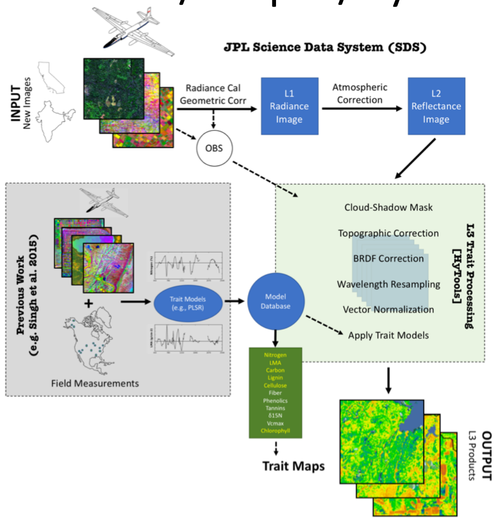
Data Life Cycle

EcoSIS.org – get your DOI, archive spectral data and measurements



HyTools **workflow**

https://github.com/EnSpec/HyTools-sandbox



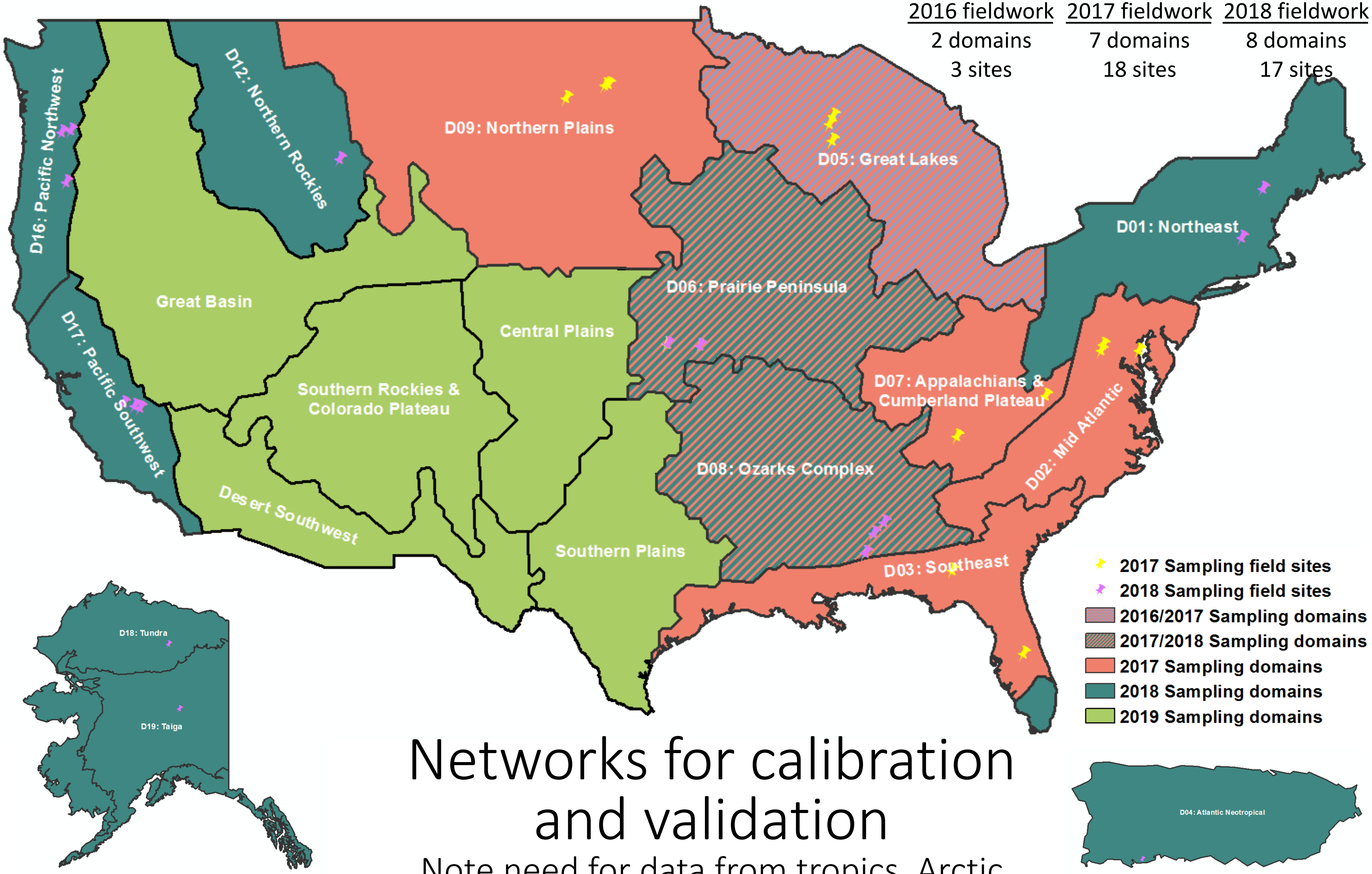
EcoSML.org

Spectral Model Library

ESTO Earth Science Technology Office

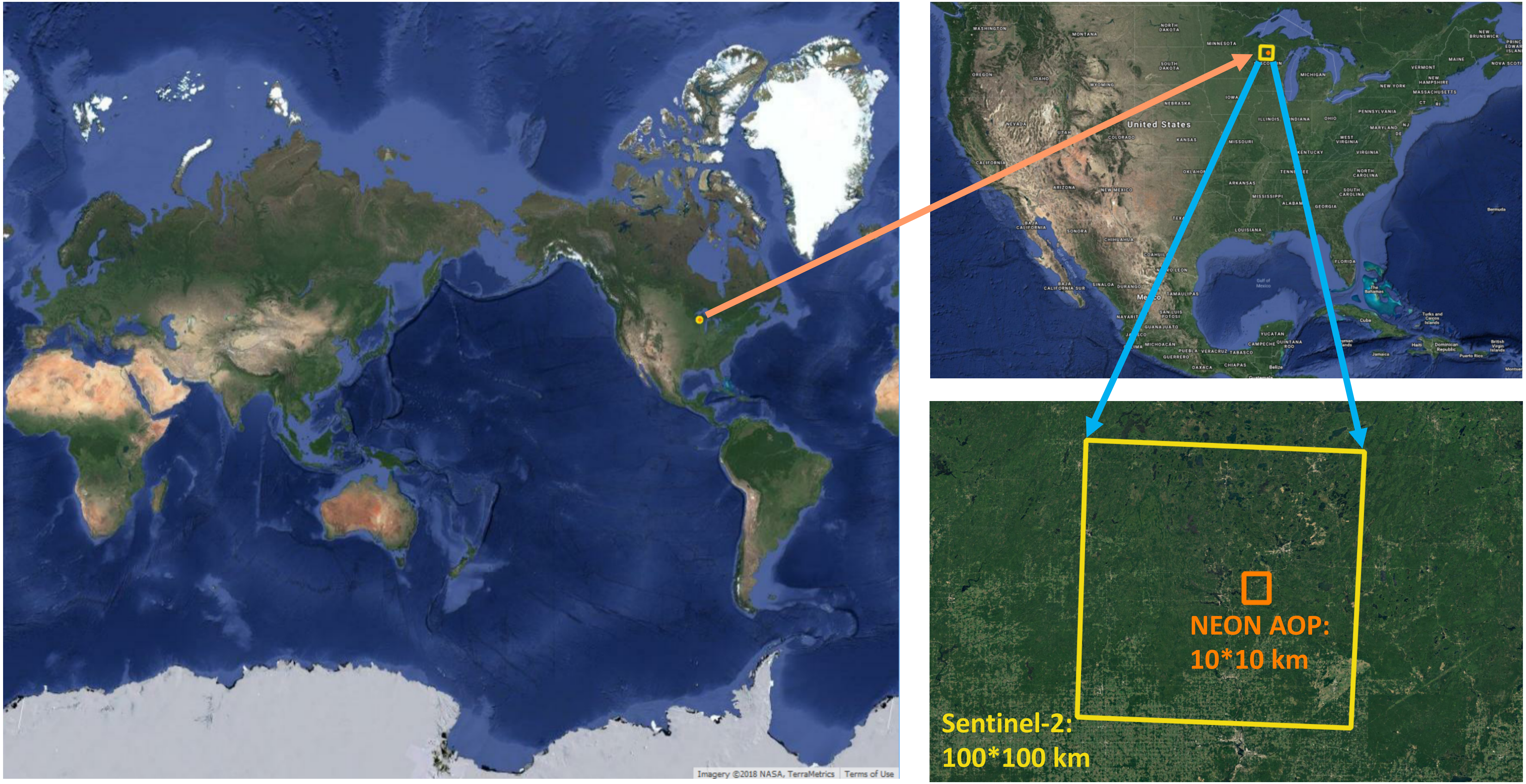
NASA

2016 fieldwork	2017 fieldwork	2018 fieldwork
2 domains	7 domains	8 domains
3 sites	18 sites	17 sites



Networks for calibration and validation

Note need for data from tropics, Arctic


Imagery ©2018 NASA, TerraMetrics
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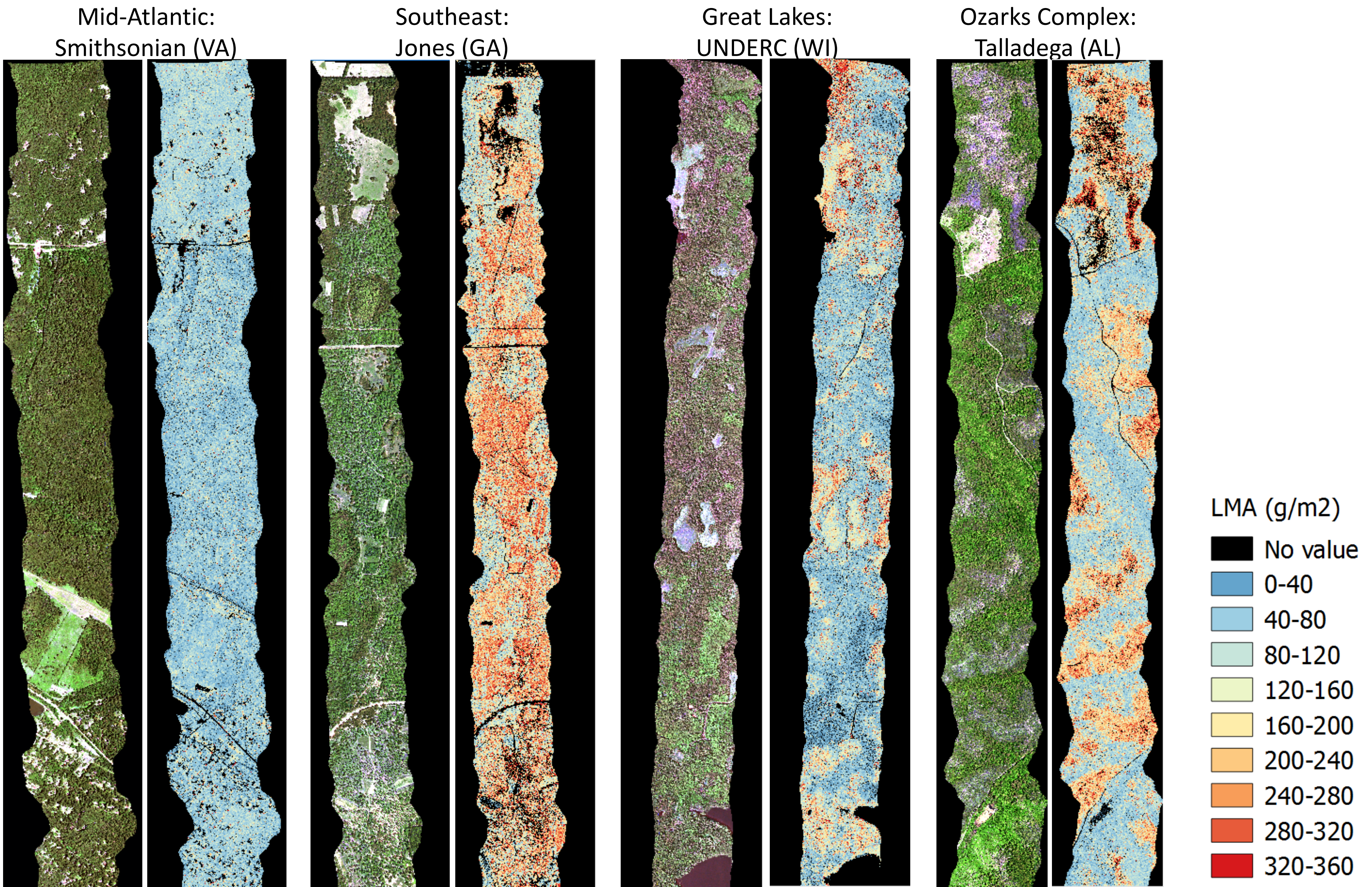
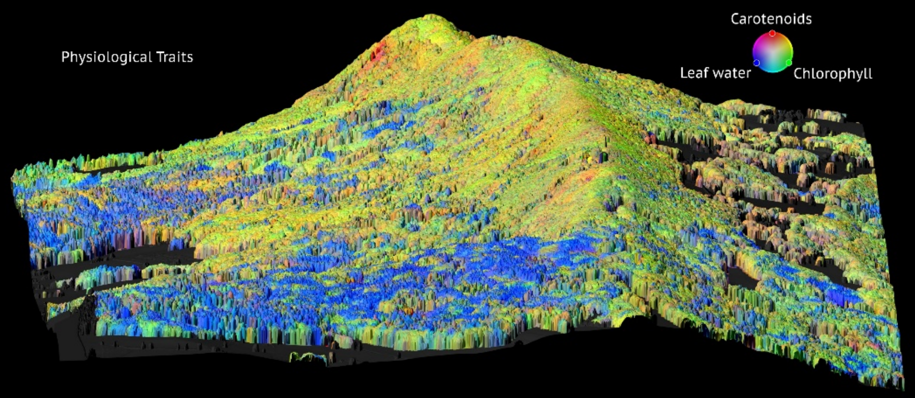
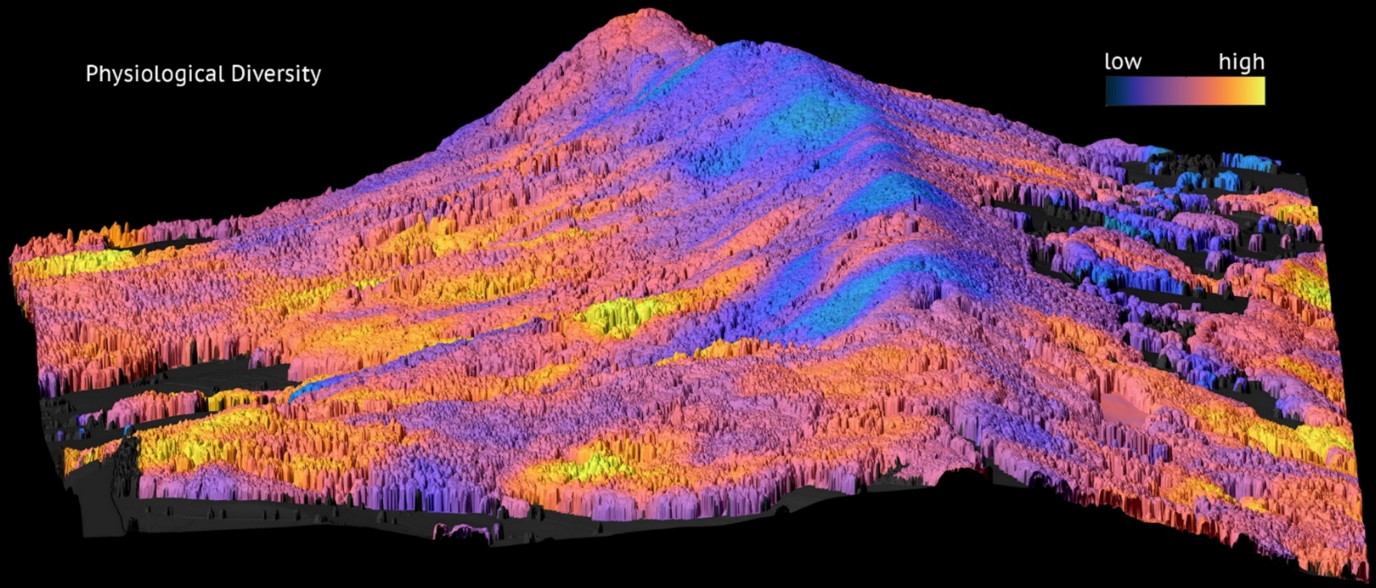
United States
NEON AOP:
10*10 km
Sentinel-2:
100*100 km


Mid-Atlantic:
Smithsonian (VA)
Southeast:
Jones (GA)
Great Lakes:
UNDERC (WI)
Ozarks Complex:
Talladega (AL)
LMA (g/m2)
No value
0-40
40-80
80-120
120-160
160-200
200-240
240-280
280-320
320-360

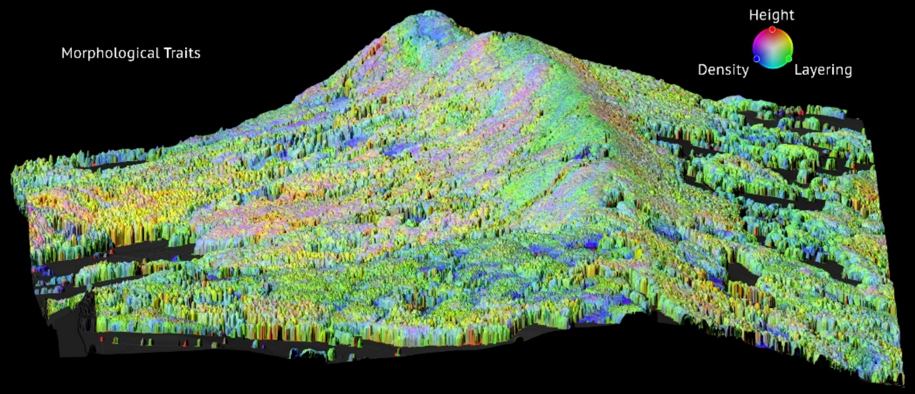
Mapping of Plant Functional Diversity

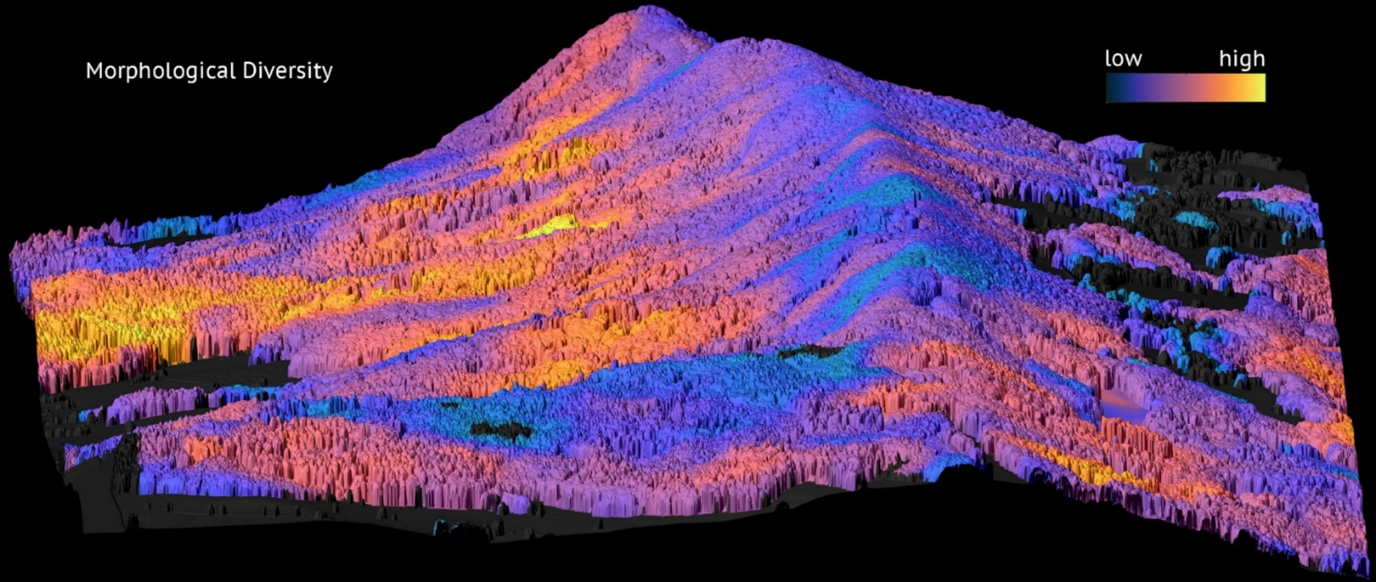
Leaf Biochemistry from Spectroscopy





Canopy Structure from LiDAR





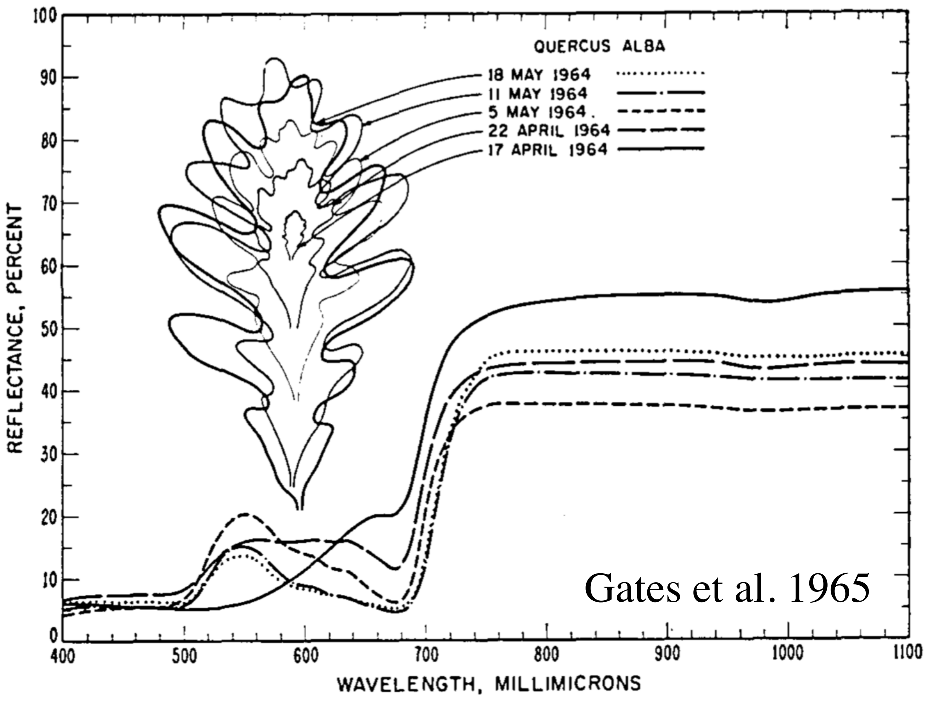
Schneider, et al. (2017) Nature Communications

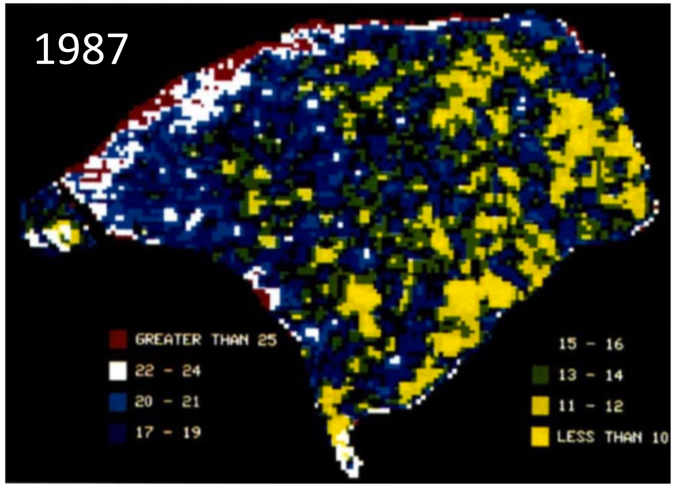
Botanical Gazette, Vol. 87, No. 5 (Jun., 1929), pp. 583-607

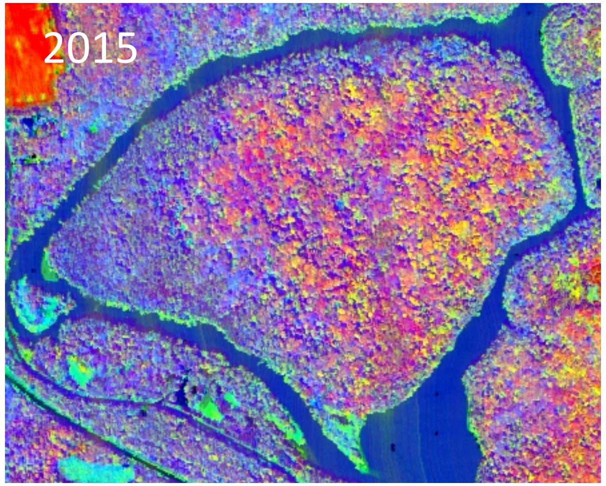
A SPECTROPHOTOMETRIC STUDY OF REFLECTION OF LIGHT FROM LEAF SURFACES

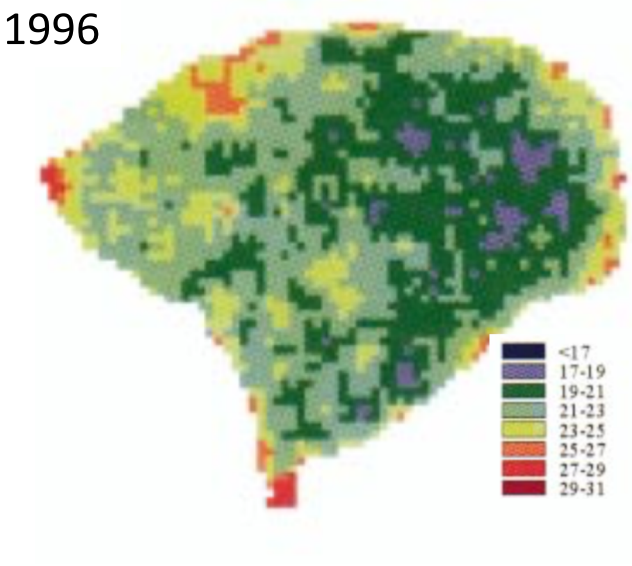
CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY

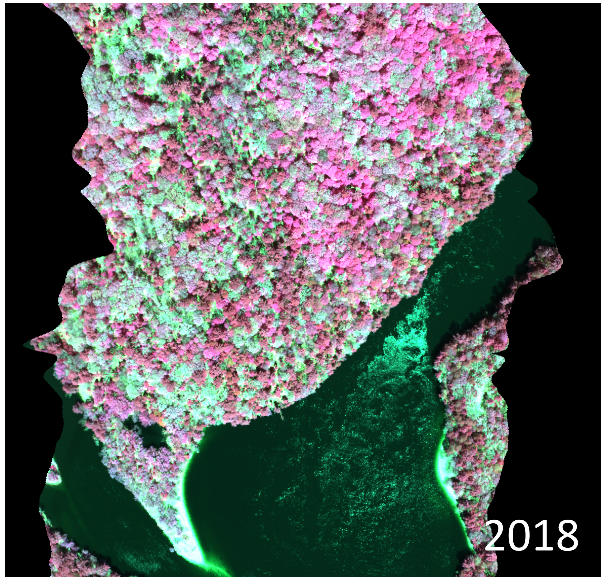
CHARLES A. SHULL







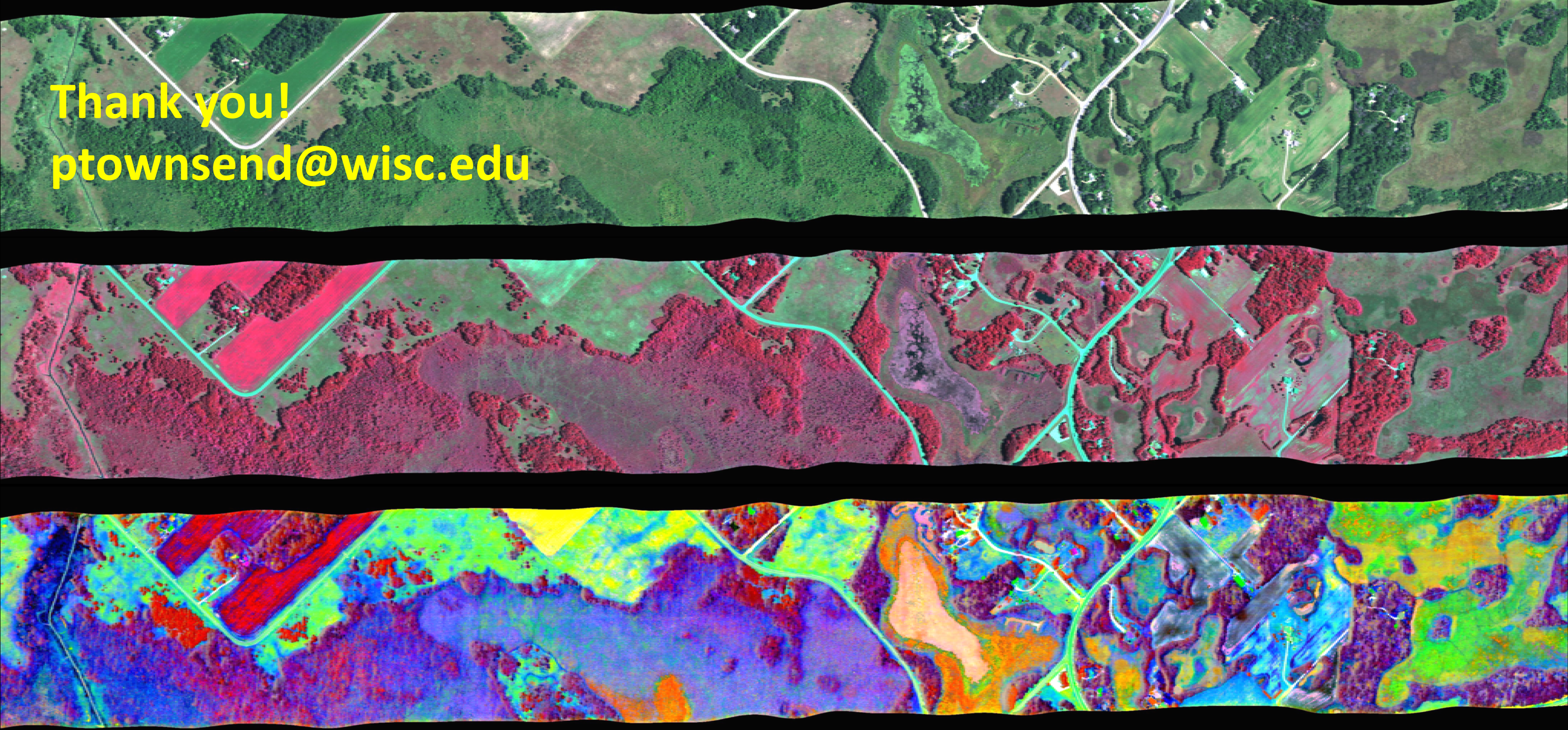




We've come a long way. Its time to use this information globally, and to have time series, look at phenology.
We can measure vegetation function and its variation.
The community will use these data.

Thank you!

ptownsend@wisc.edu



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