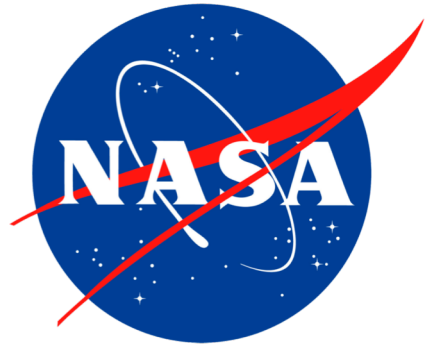
Imaging Spectroscopy from Space

1 October 2018

Phil Townsend

University of Wisconsin



Contributors:

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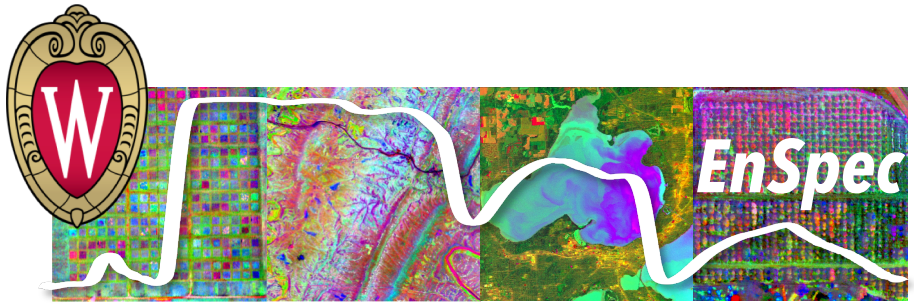
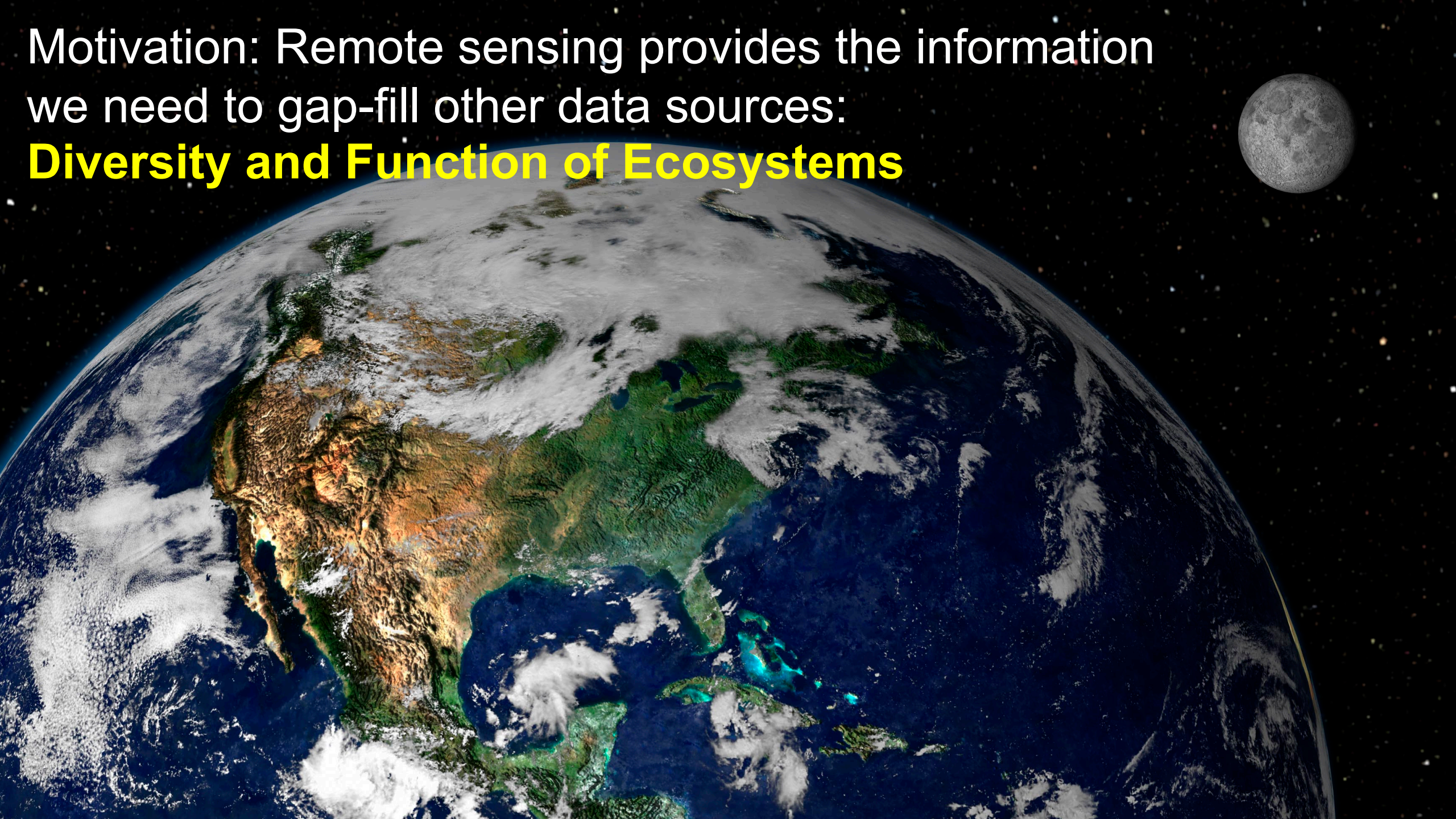
Ankur Desai, Eric Kruger, Jeannine Cavender-Bares, José Mereiles, Mike Madritch
Fabian Schneider, Ryan Pavlick, Natasha Stavros, David Thompson, David Schimel

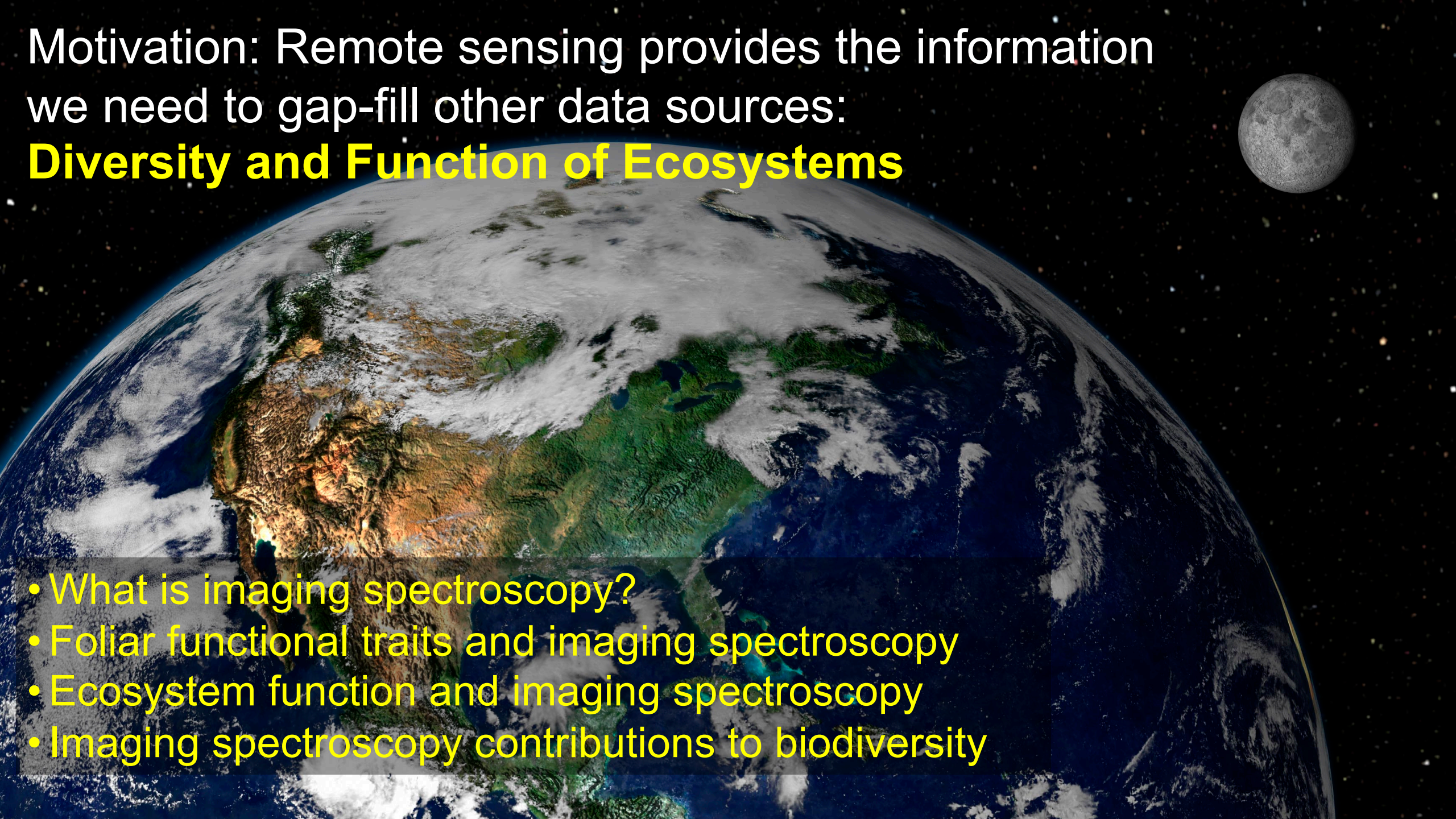


Jet Propulsion Laboratory
California Institute of Technology

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

Diversity and Function of Ecosystems



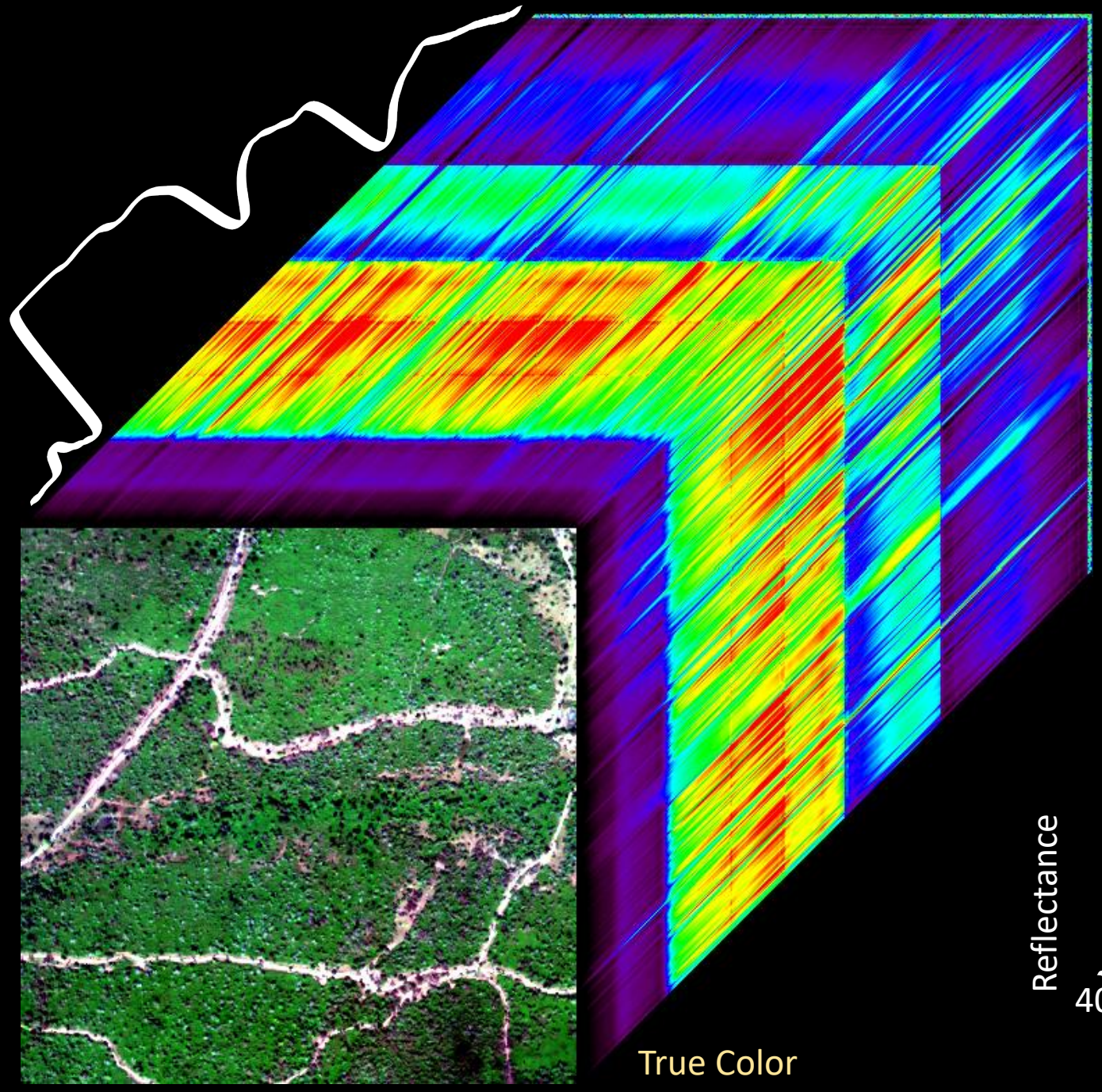


Motivation: Remote sensing provides the information we need to gap-fill other data sources:

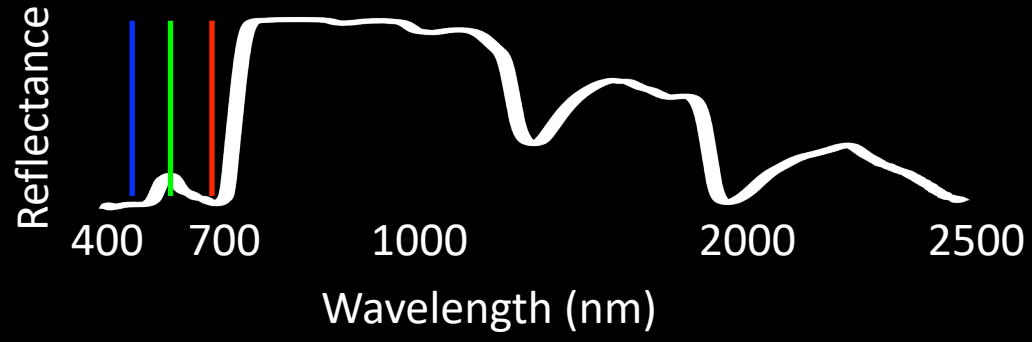
Diversity and Function of Ecosystems

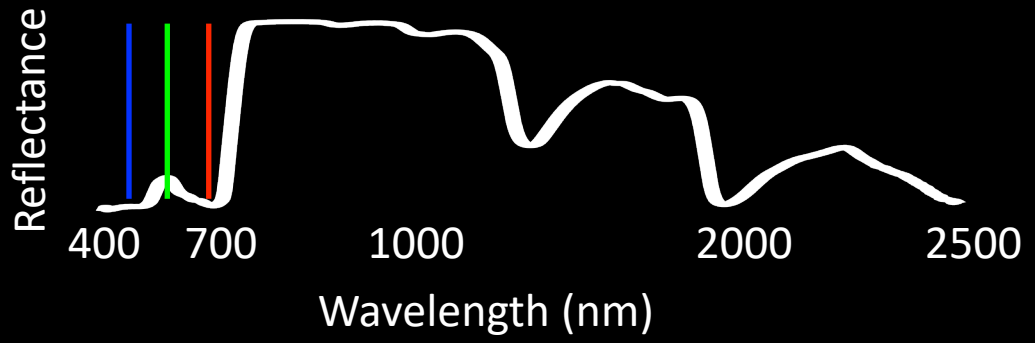
- What is imaging spectroscopy?
- Foliar functional traits and imaging spectroscopy
- Ecosystem function and imaging spectroscopy
- Imaging spectroscopy contributions to biodiversity

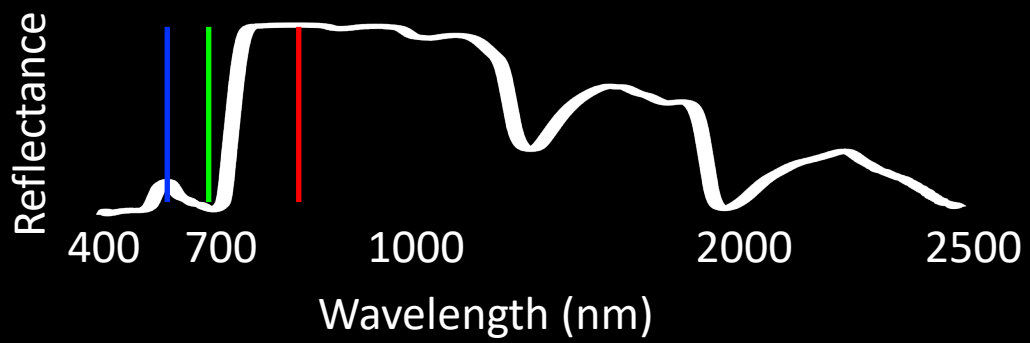
Representing Imaging Spectroscopy ("Hyperspectral") Data

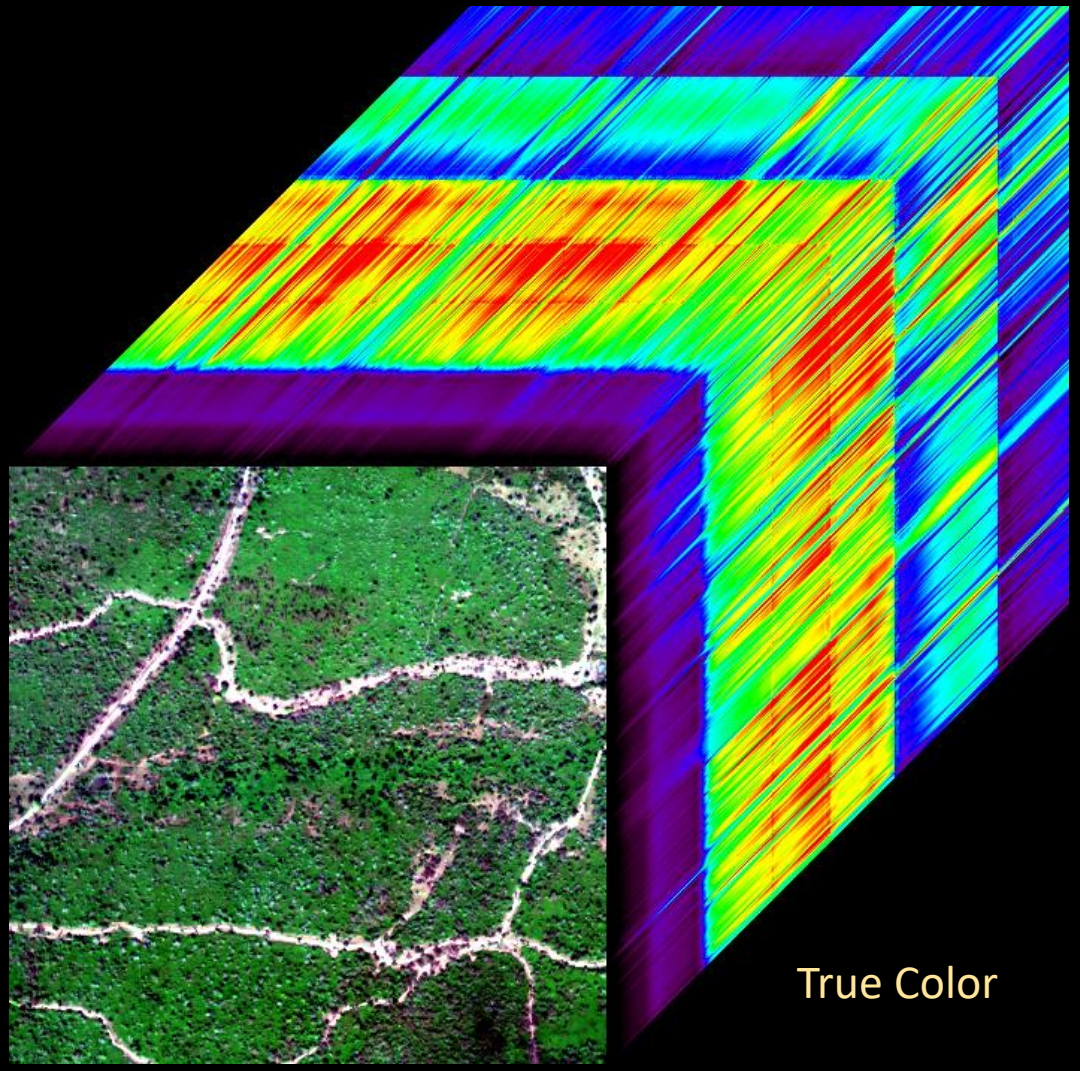


True Color









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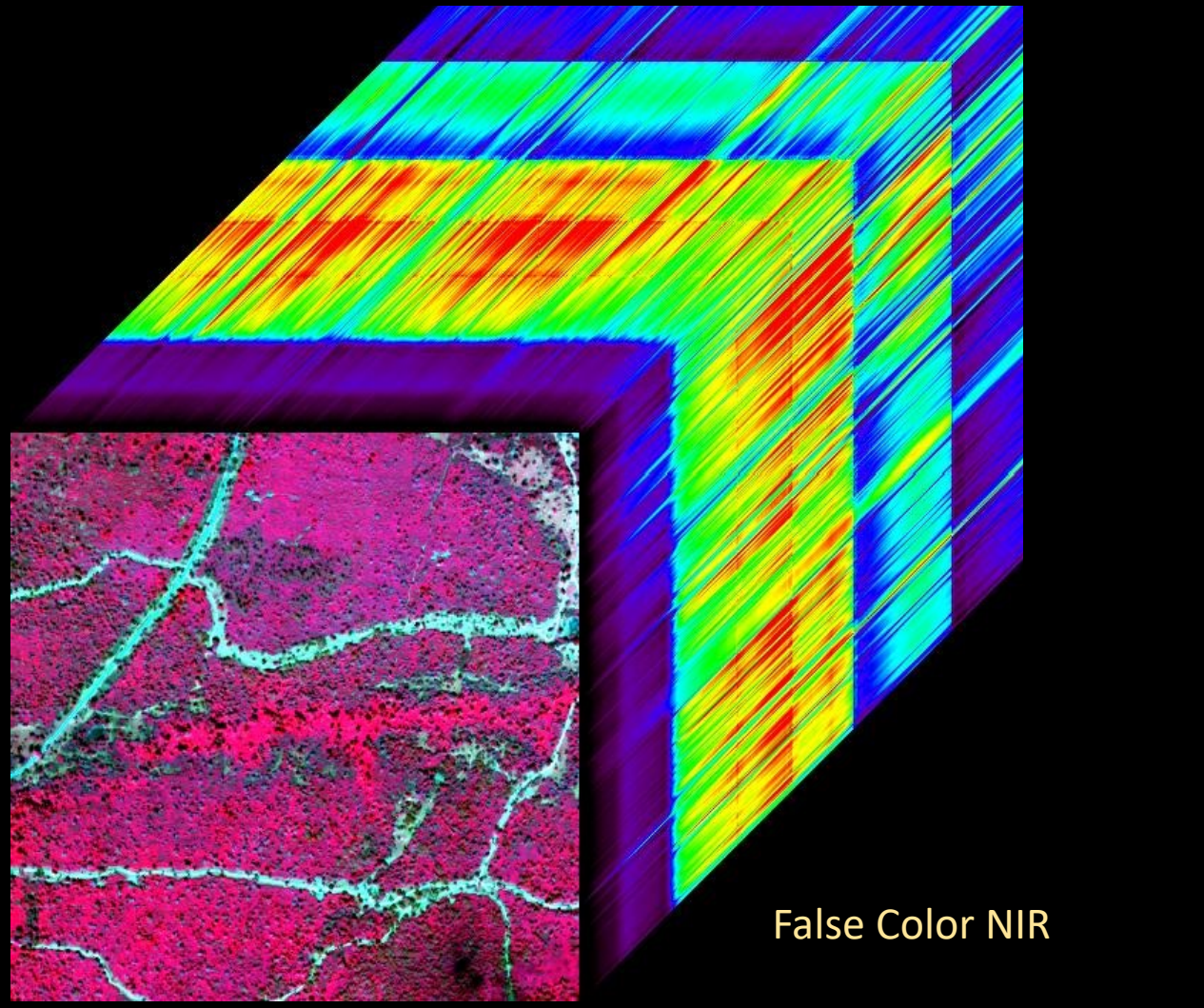

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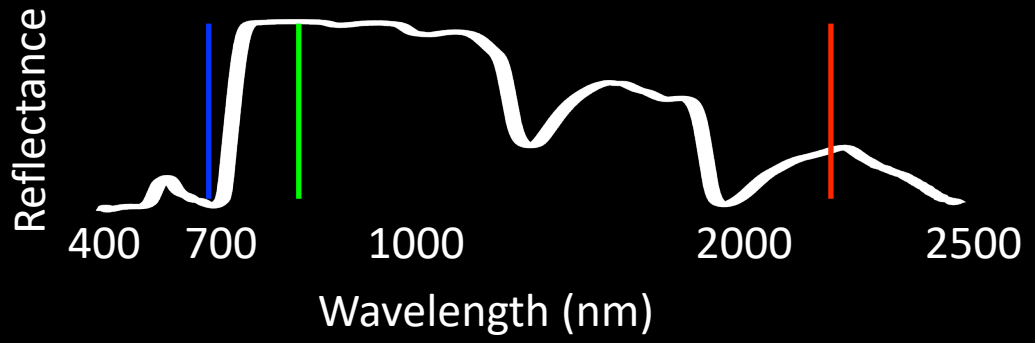
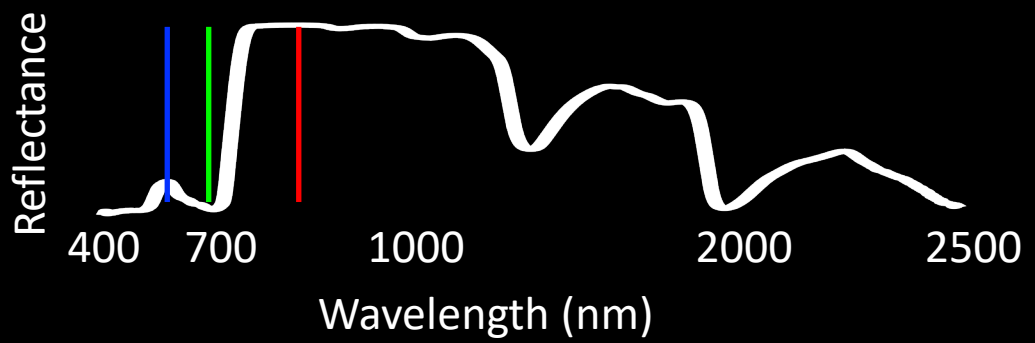
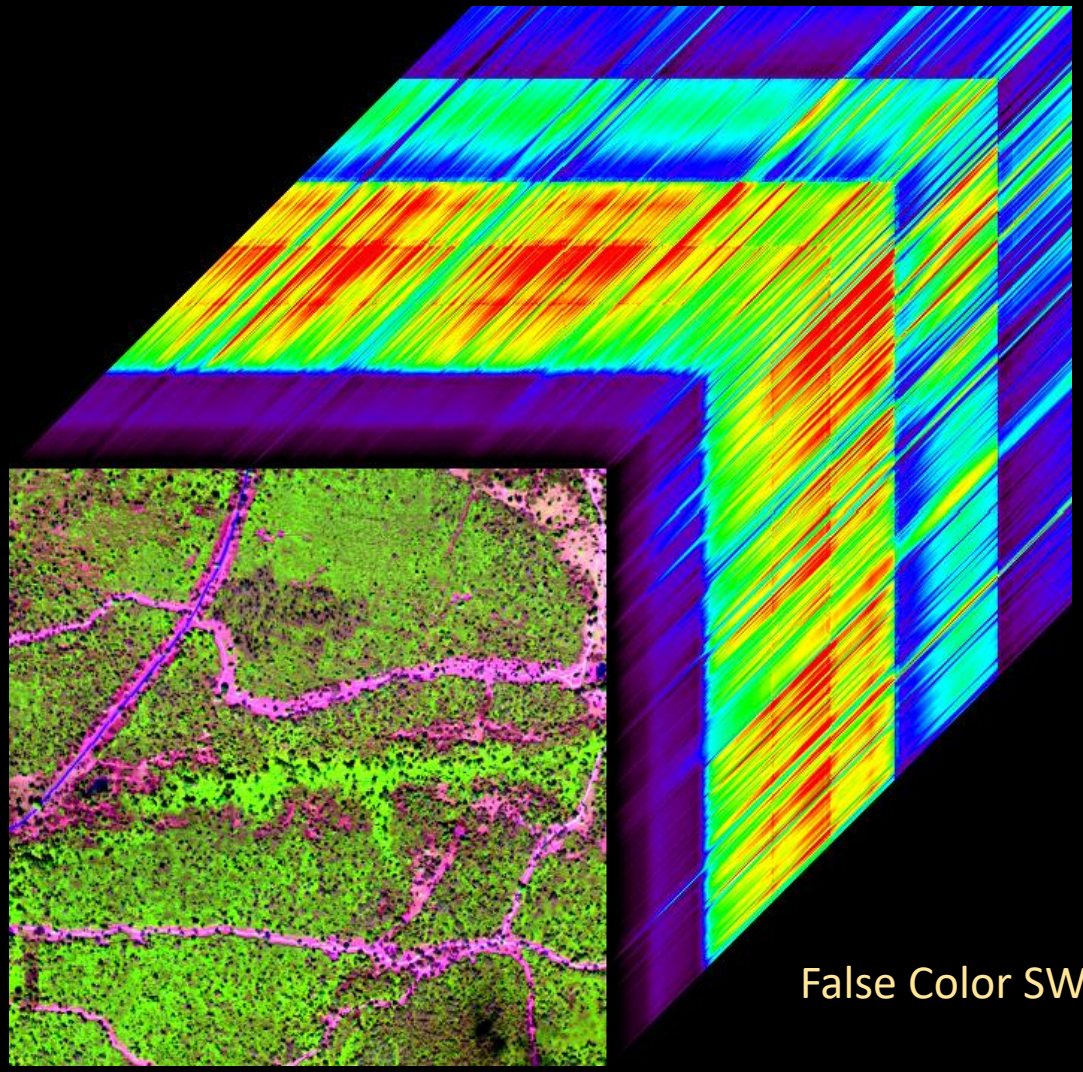
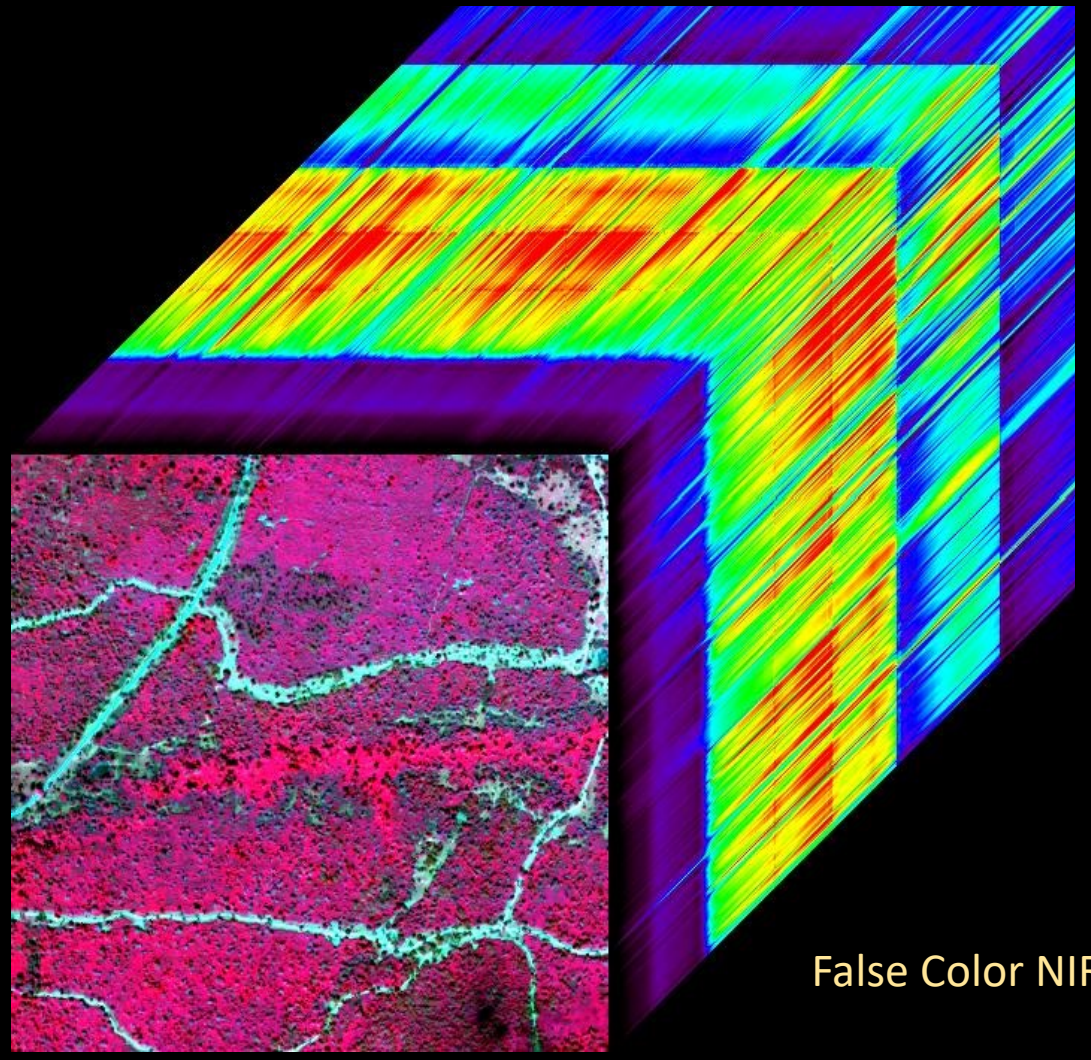






False Color SWIR



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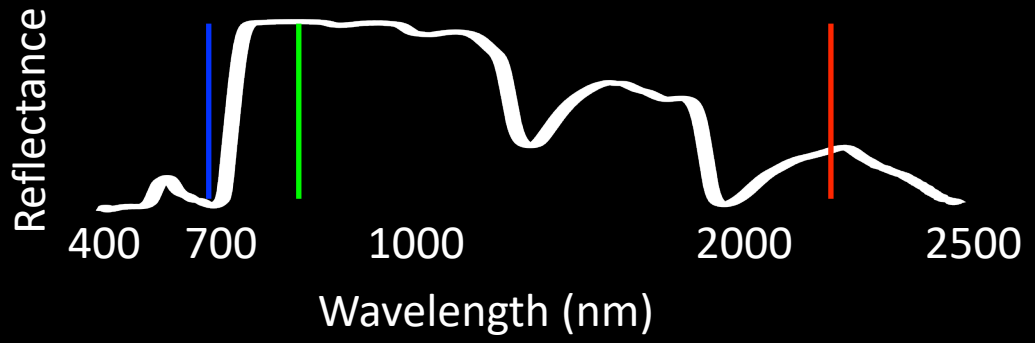
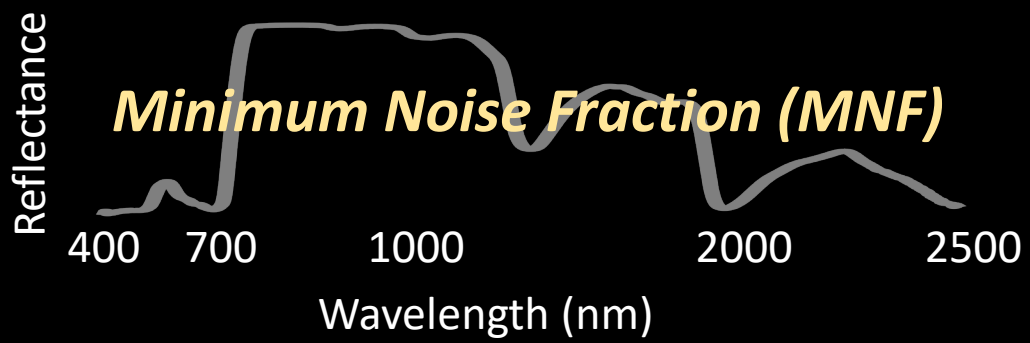
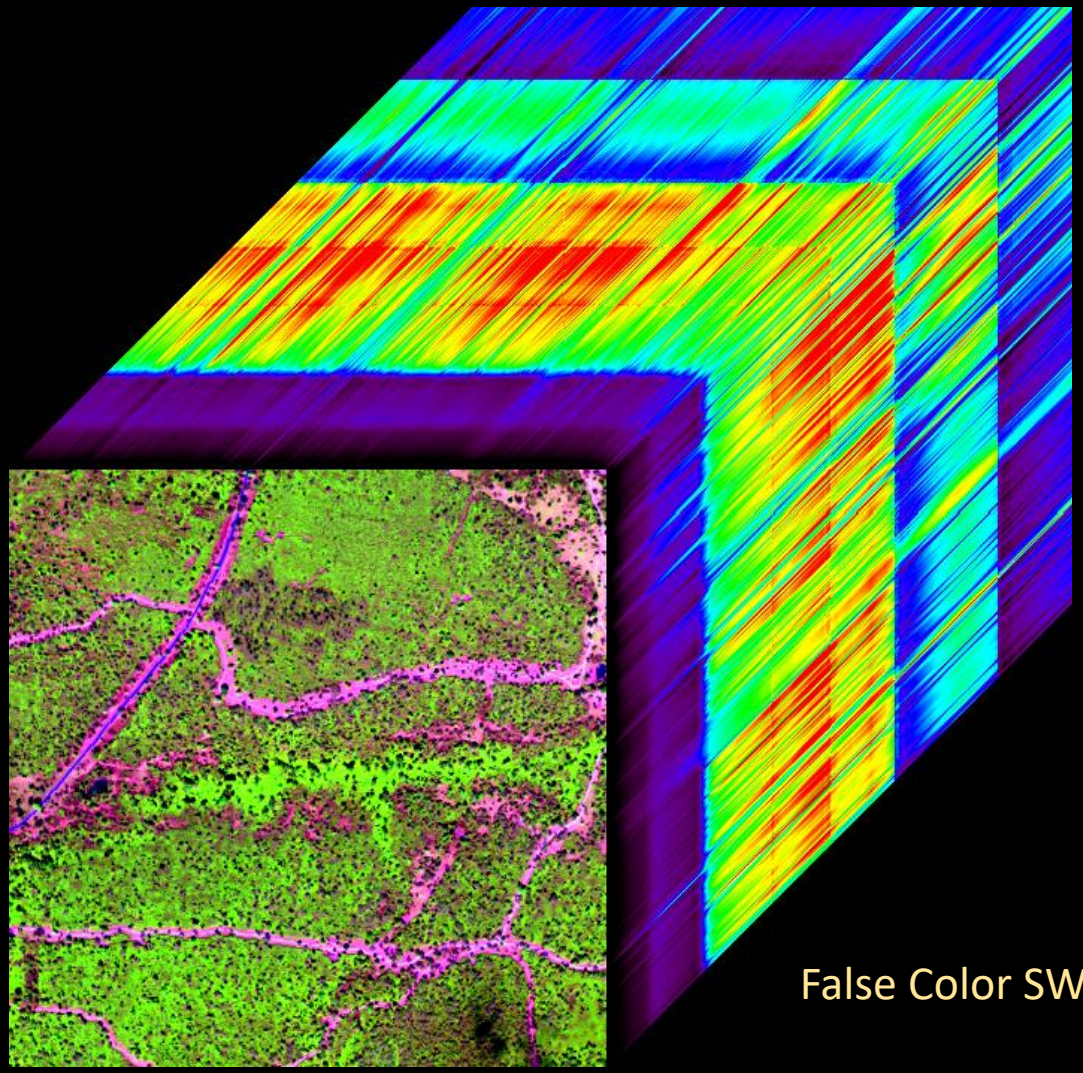




Minimum Noise Fraction (MNF)



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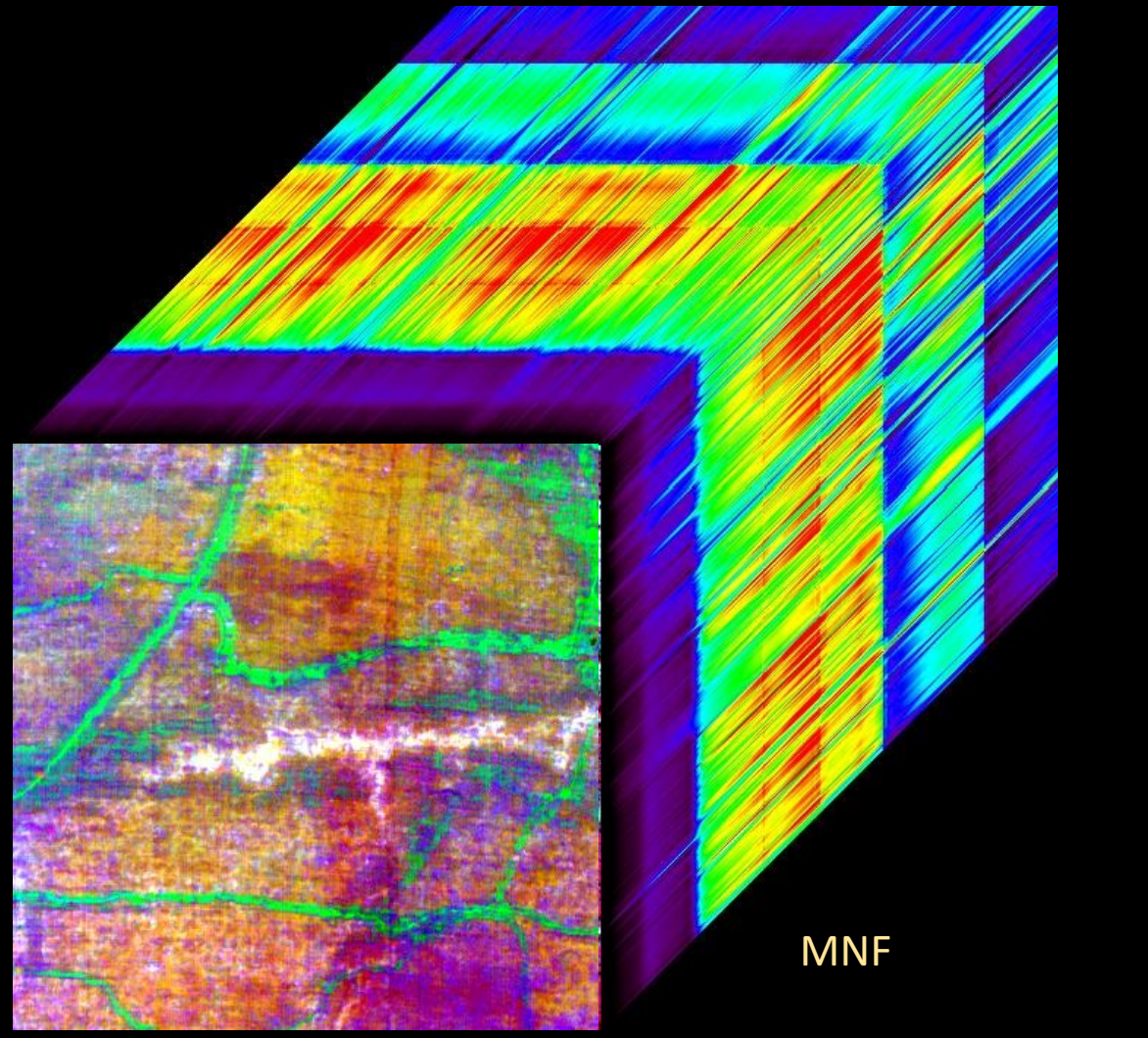
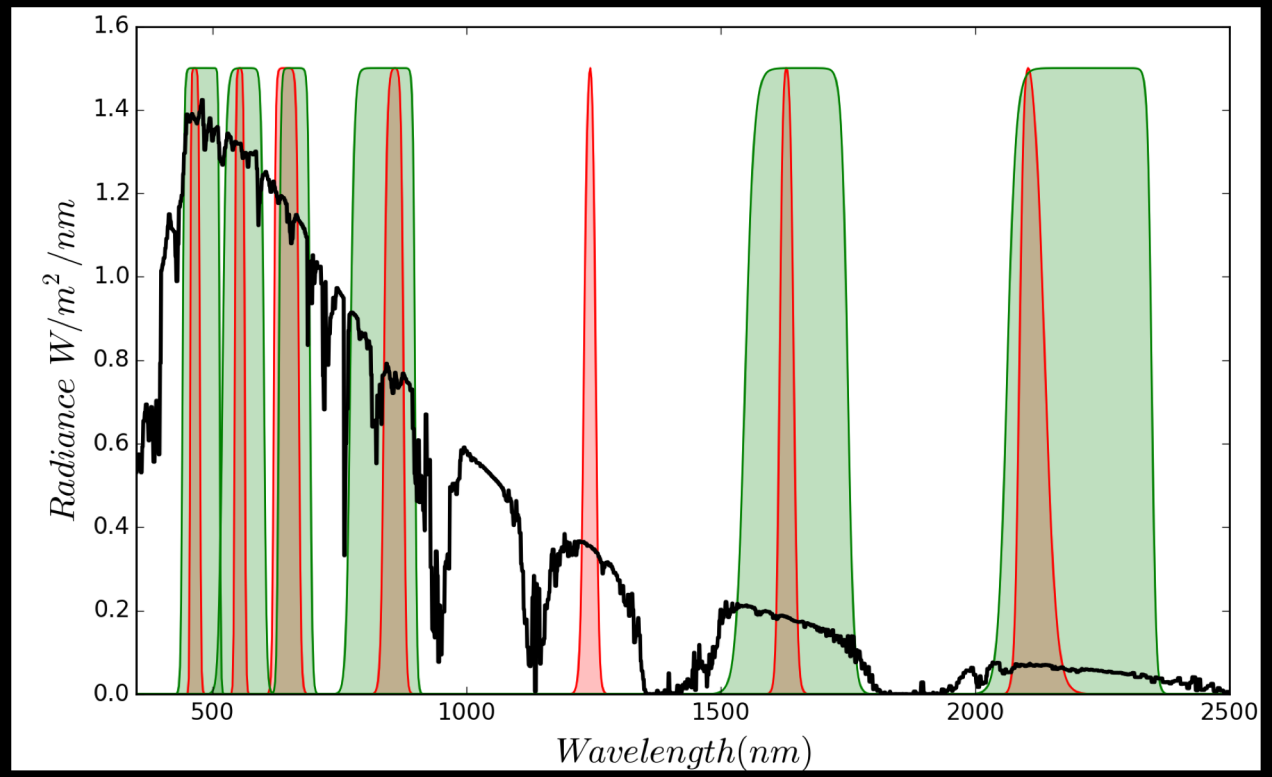
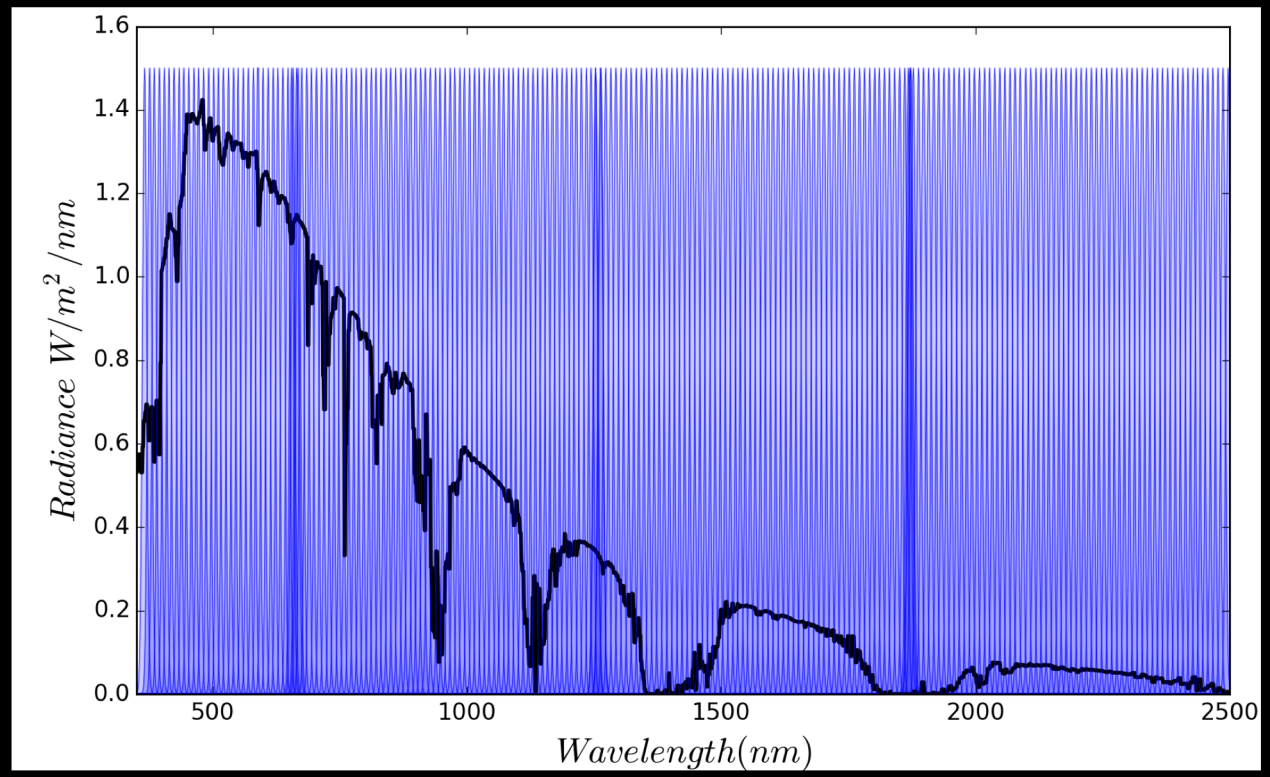


MNF



Multispectral



“Hyperspectral”

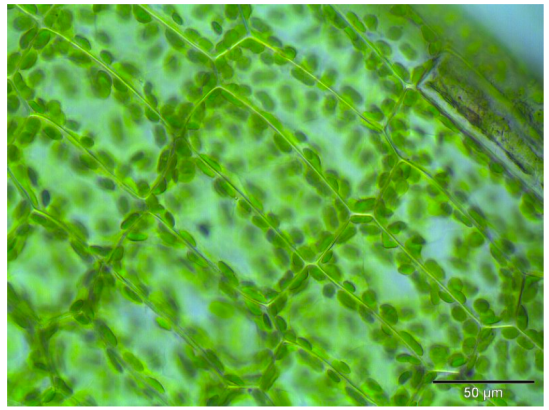

Censuses

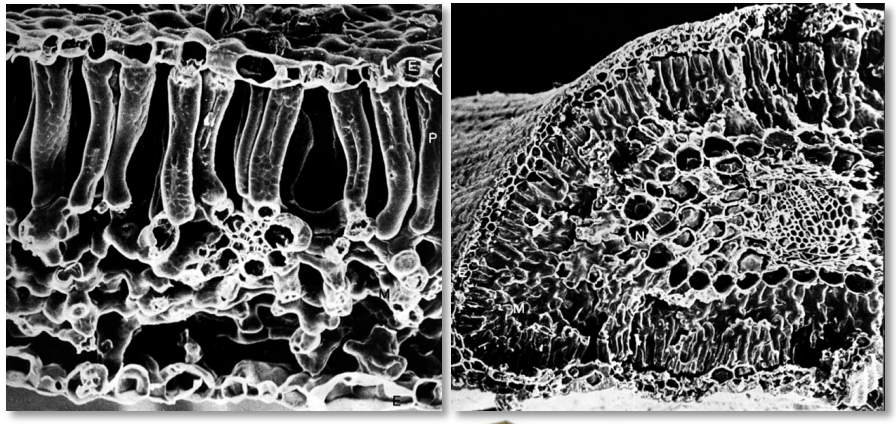

Traits, Fluxes


Censuses


Traits, Fluxes

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





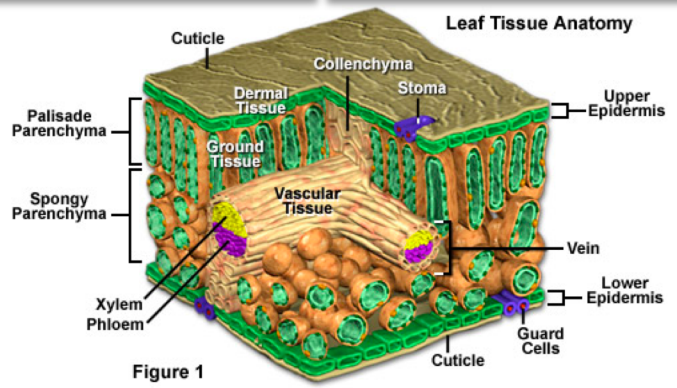


Figure 1

What are plants doing?
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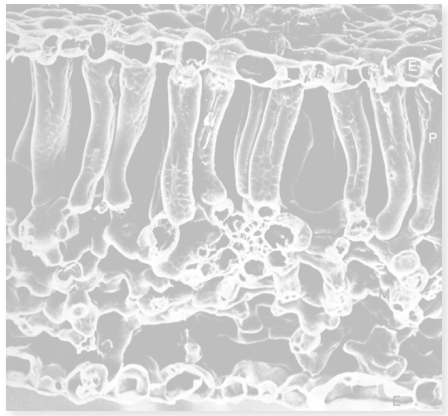

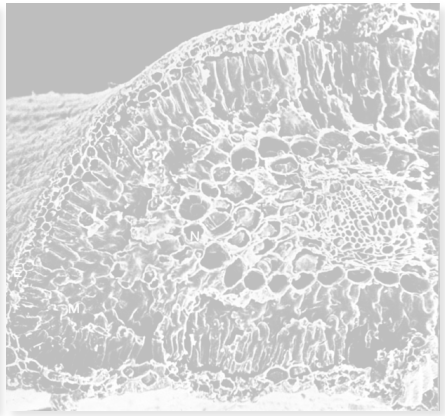

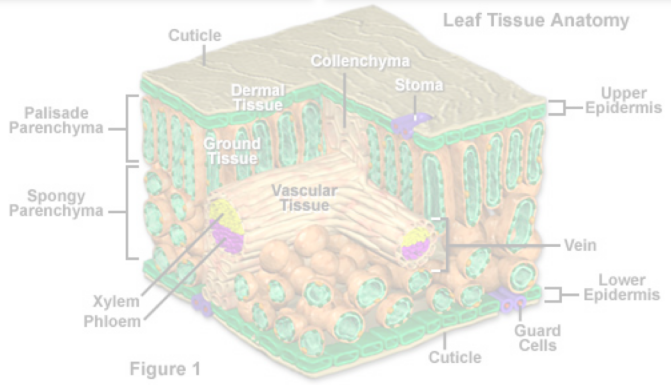

What are foliar functional traits and why do we care?

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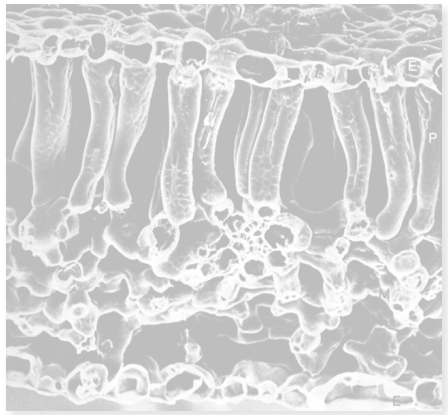

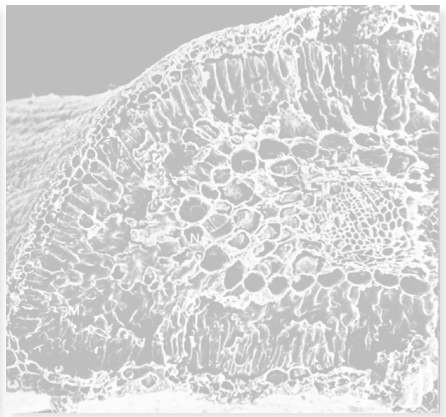

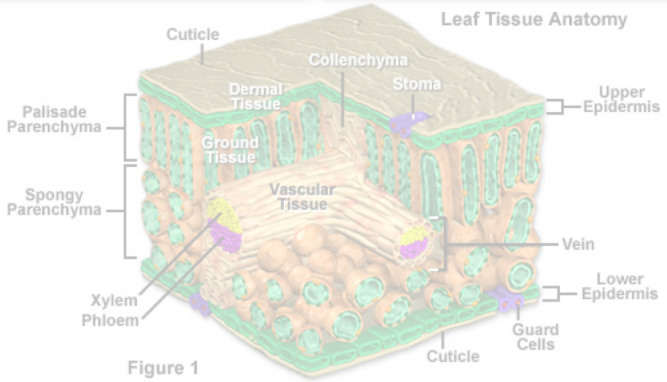

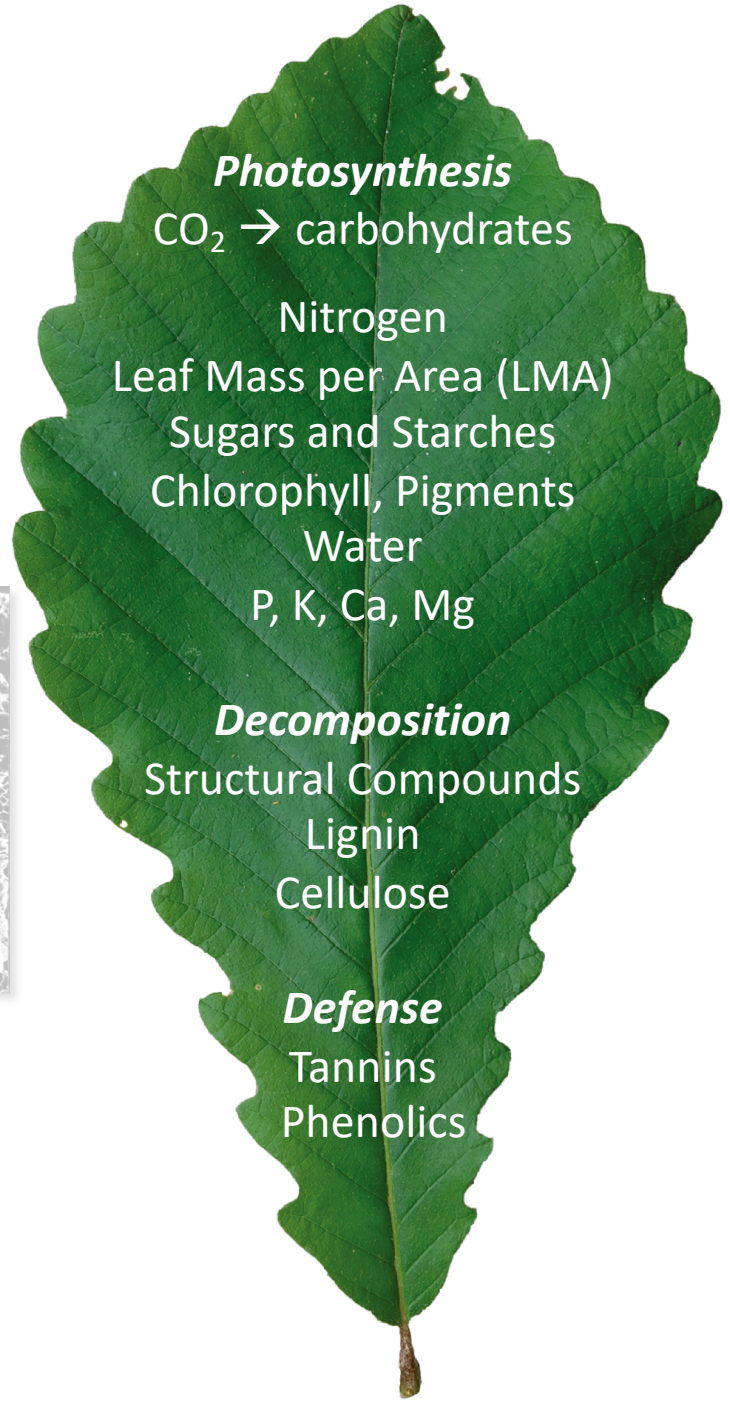

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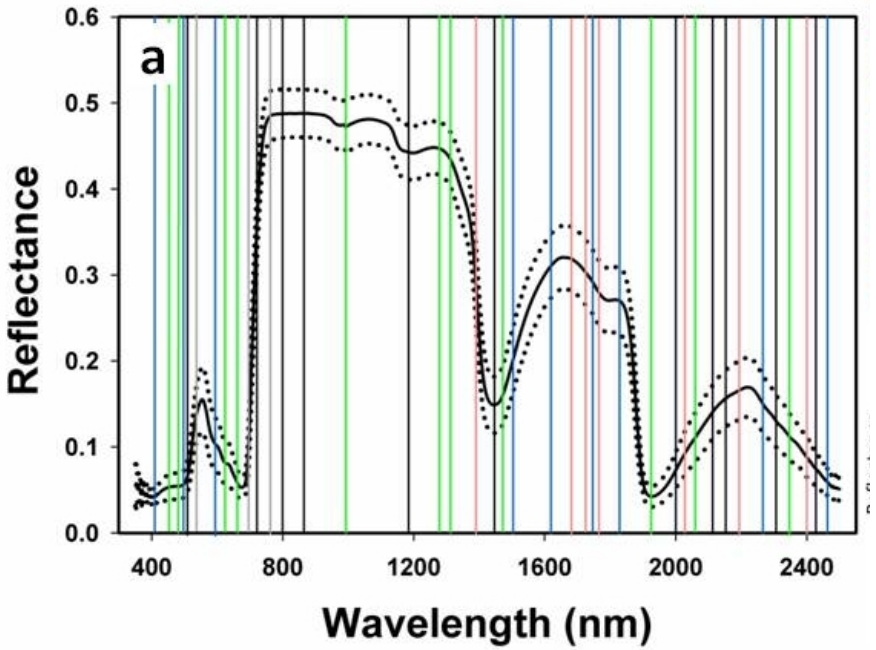

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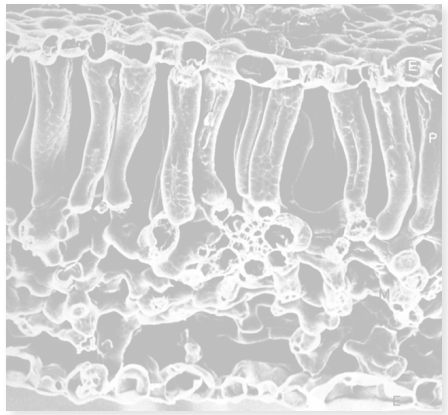
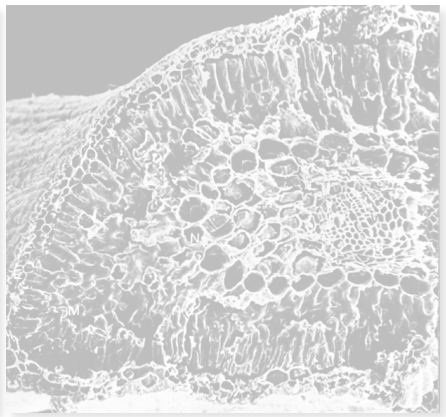




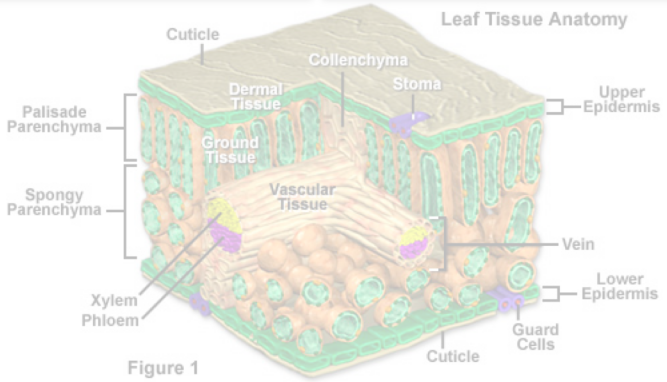
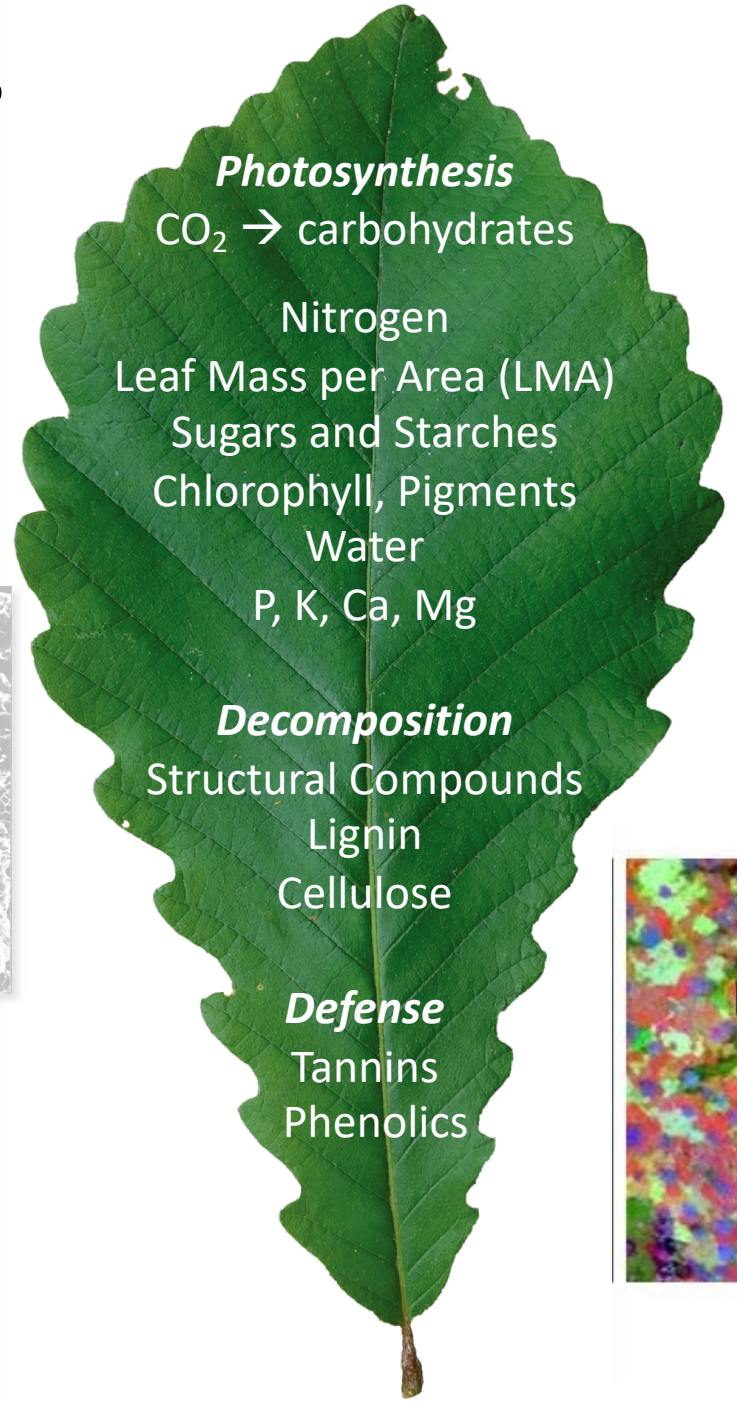


Figure 1



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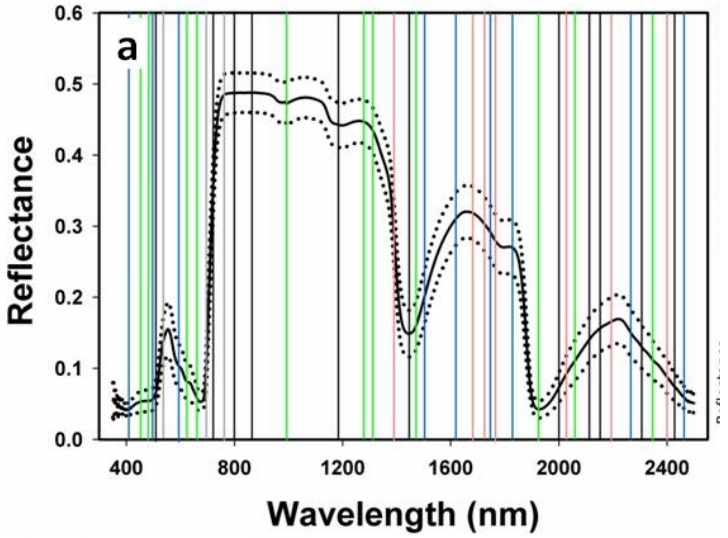

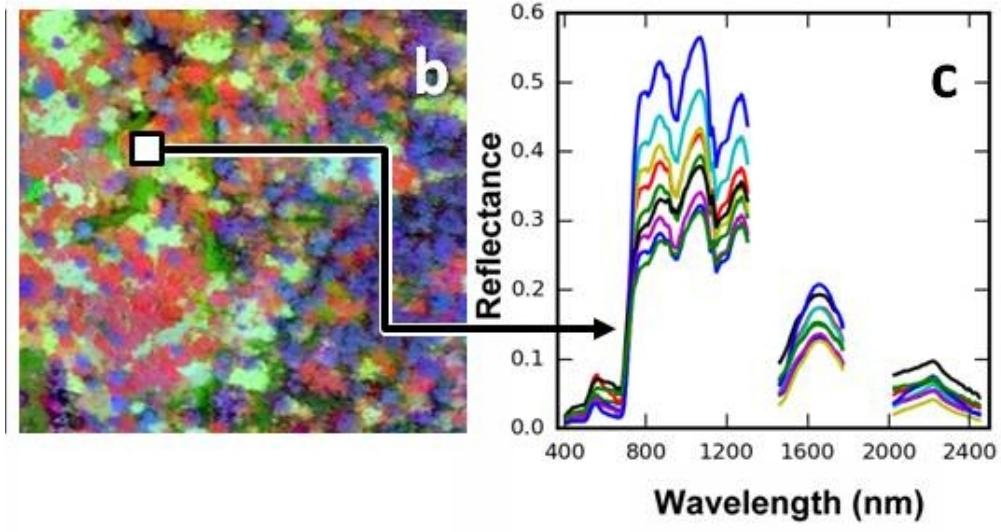

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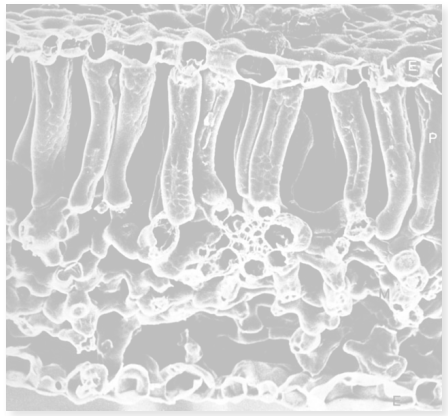

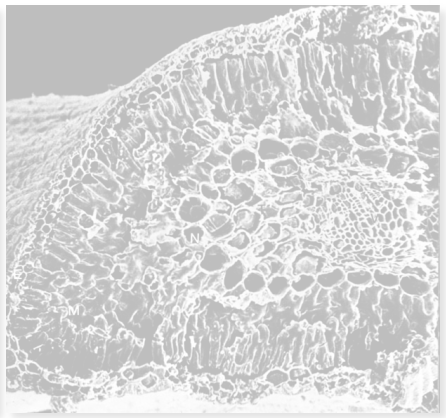

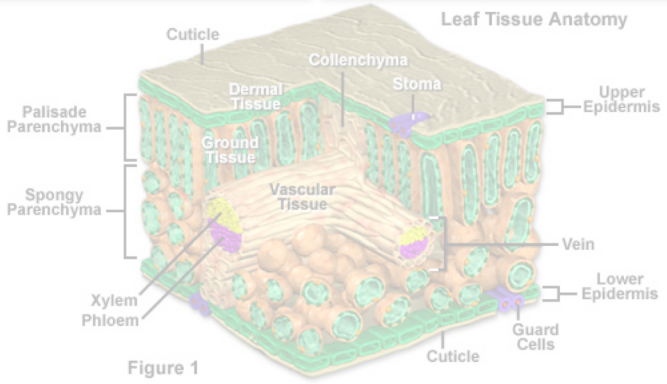

Photosynthesis

CO_2 → carbohydrates

Nitrogen

Leaf Mass per Area (LMA)

Sugars and Starches

Chlorophyll, Pigments

Water

P, K, Ca, Mg

Decomposition

. Structural Compounds

Lignin

Defense

Tannins

Phenolics

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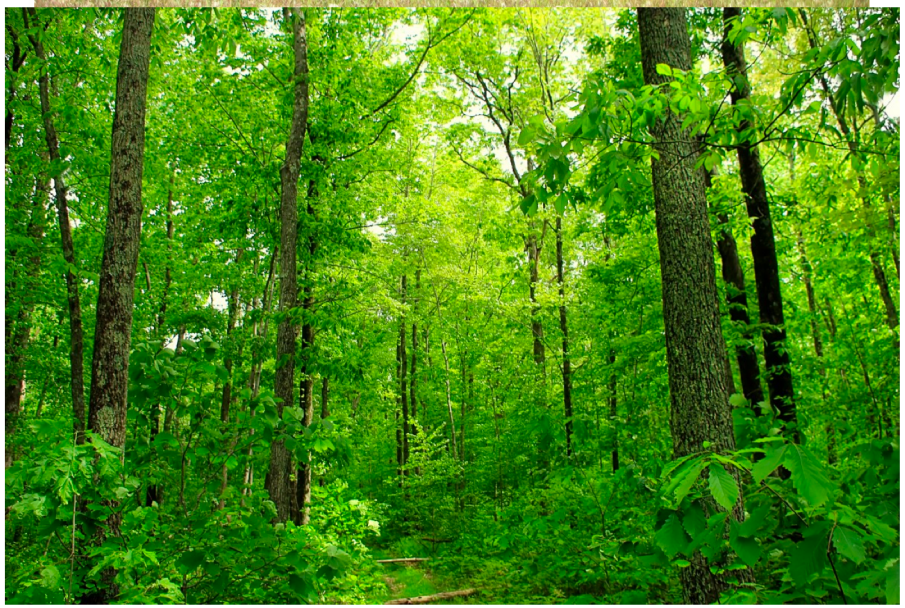
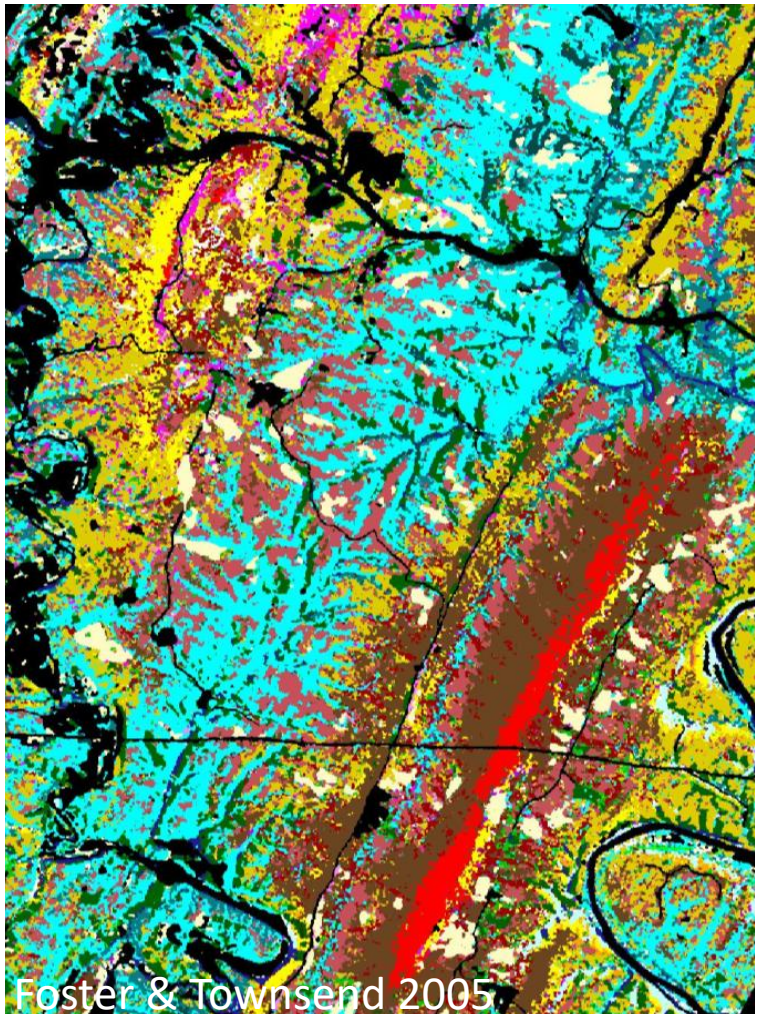


What are plants doing?
What's different among plants?

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



Species

Diversity

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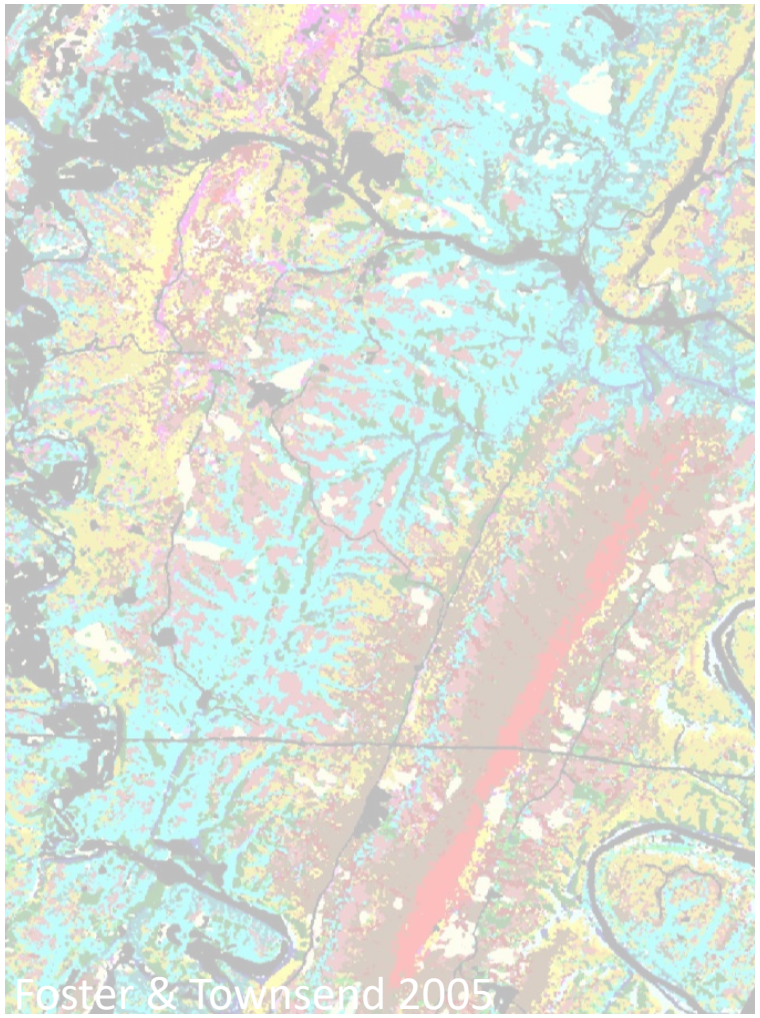
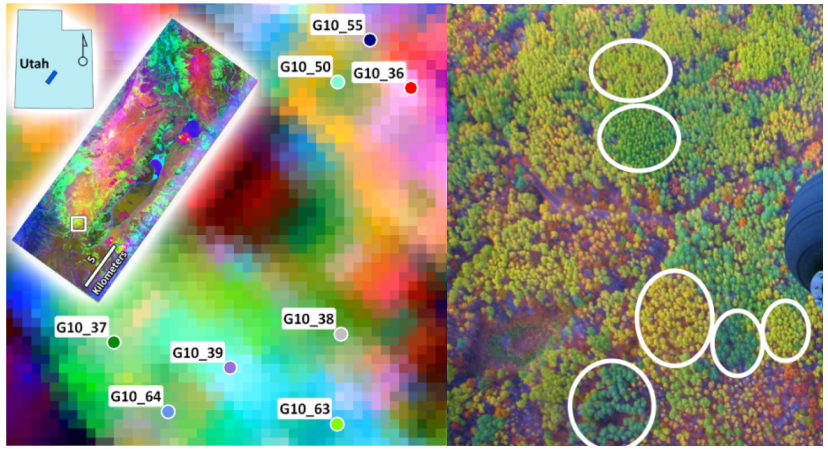
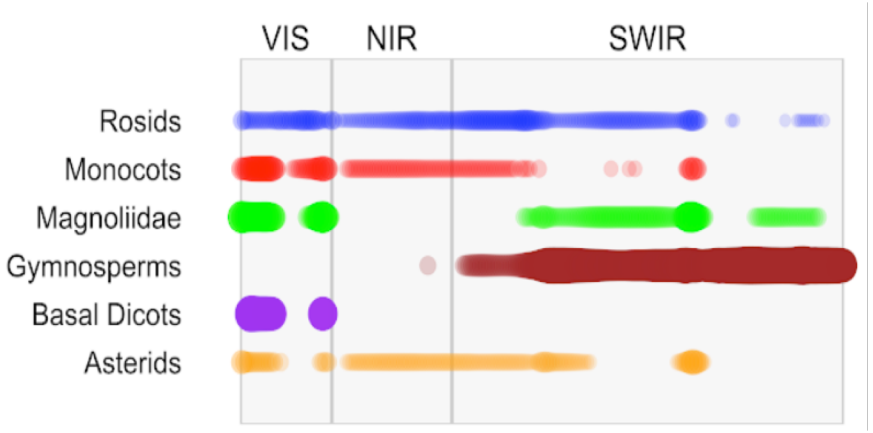


Foster & Townsend 2005



Madritch et al. 2014



Mereiles, Cavender-Bares et al.

Species

Diversity

Genotype

Evolutionary Drivers (selection & phylogeny)

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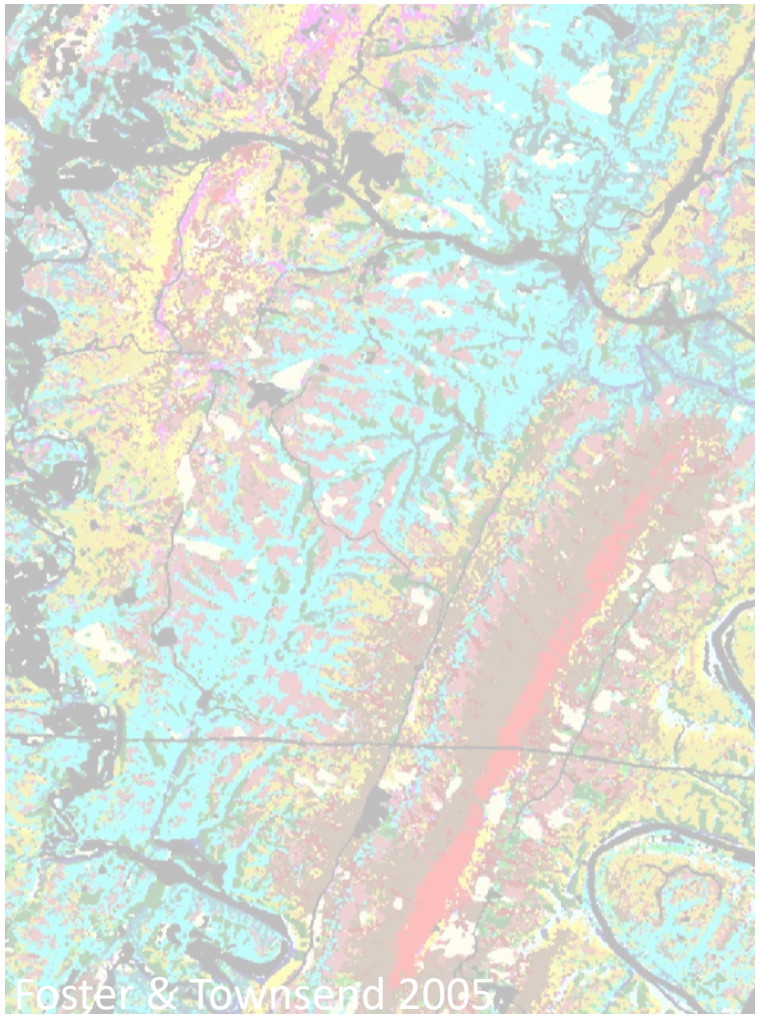
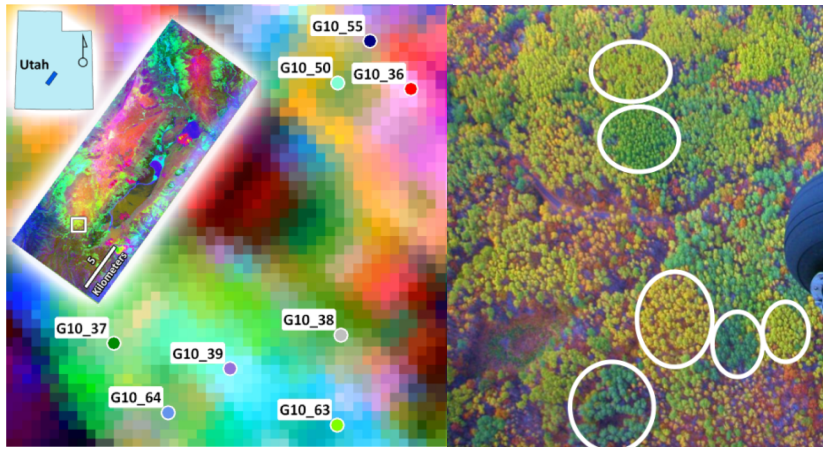
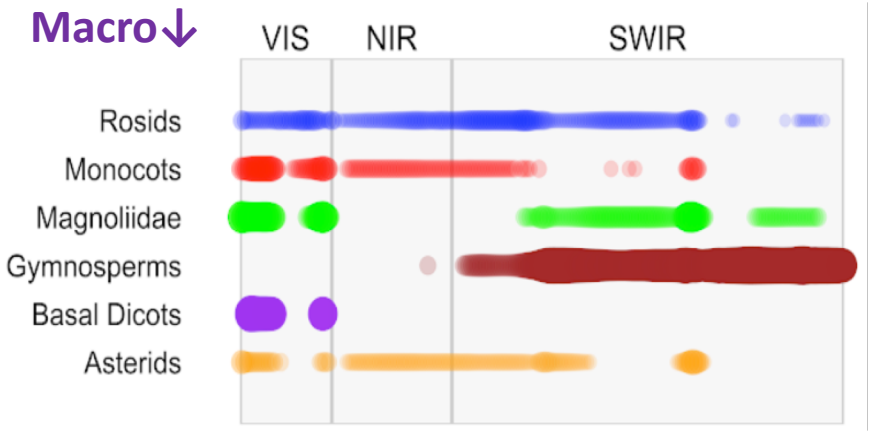




Micro ↑ Madritch et al. 2014
Macro↓



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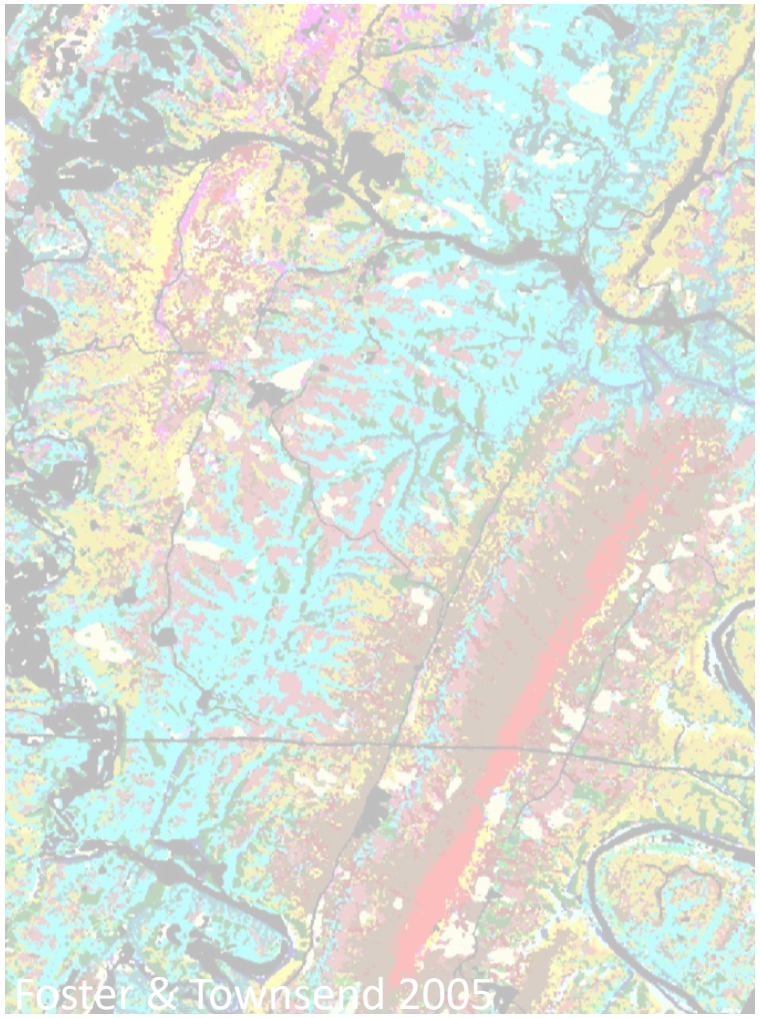

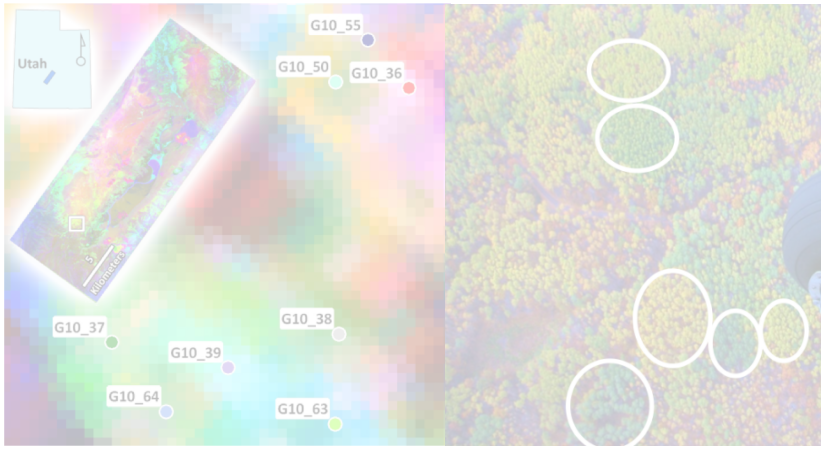

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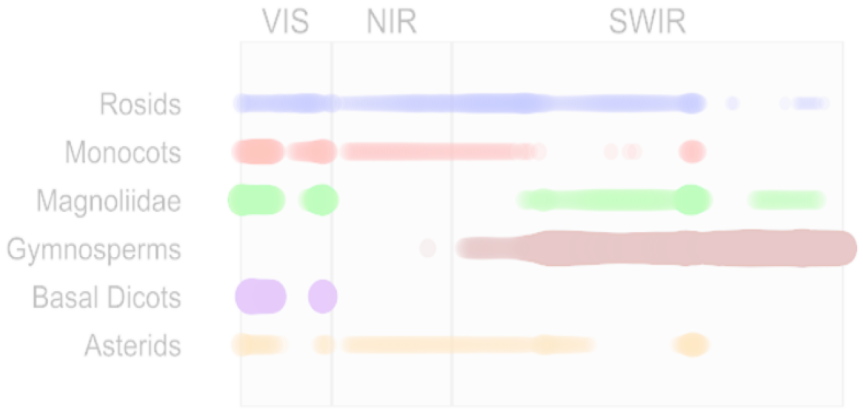


Mereiles, Cavender-Bares et al.

Species
Diversity

Genotype
Evolutionary Drivers (selection & phylogeny)

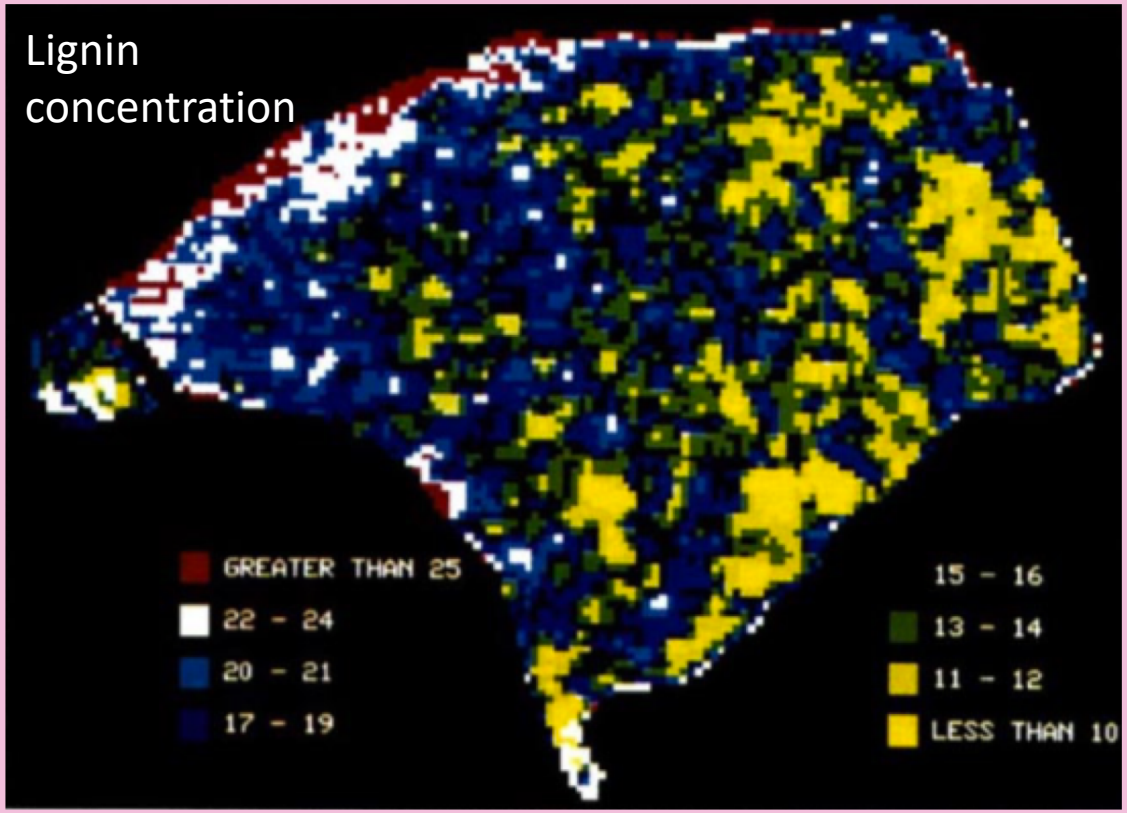
Phenotype
Environment

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

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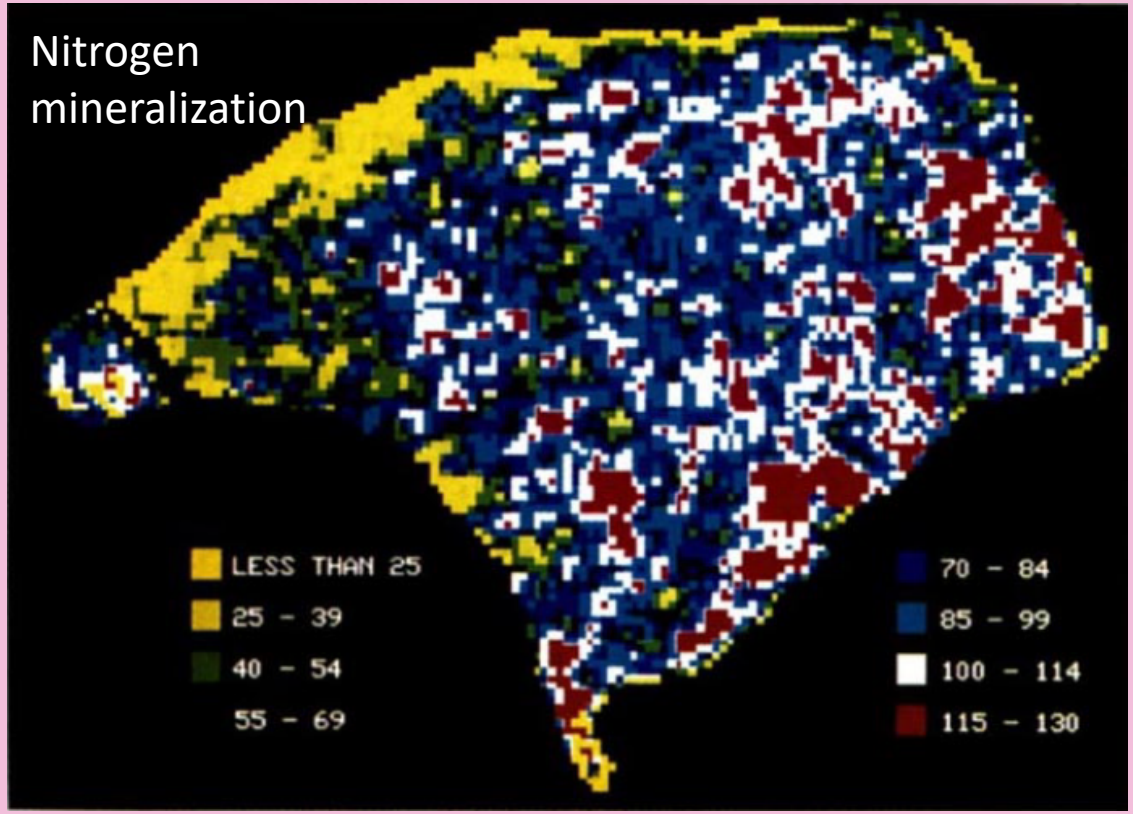
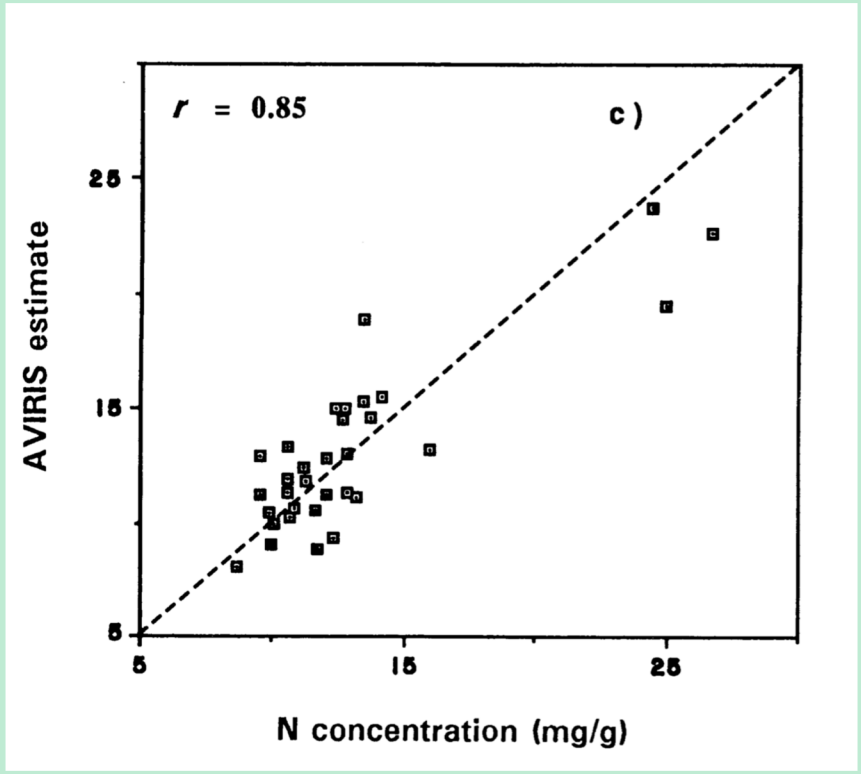
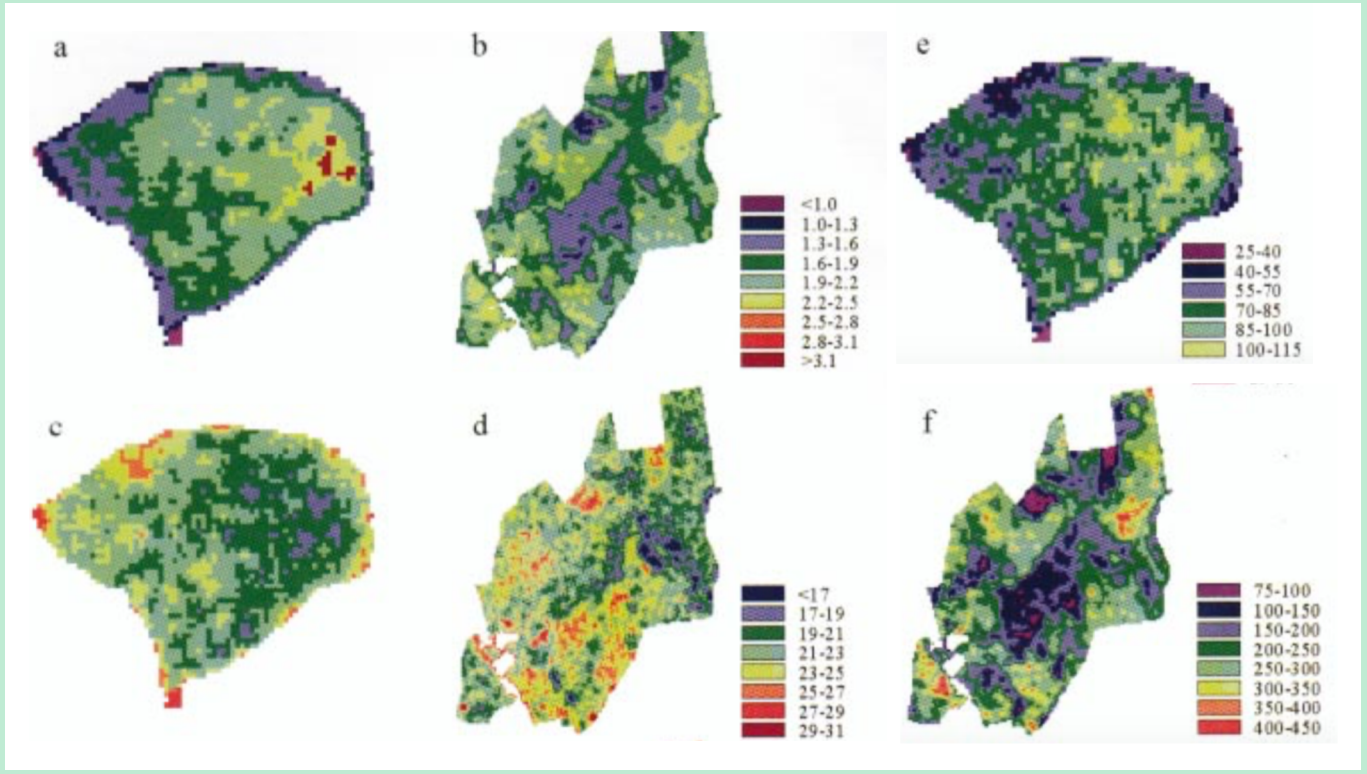


Wessman et al. 1988

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

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

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

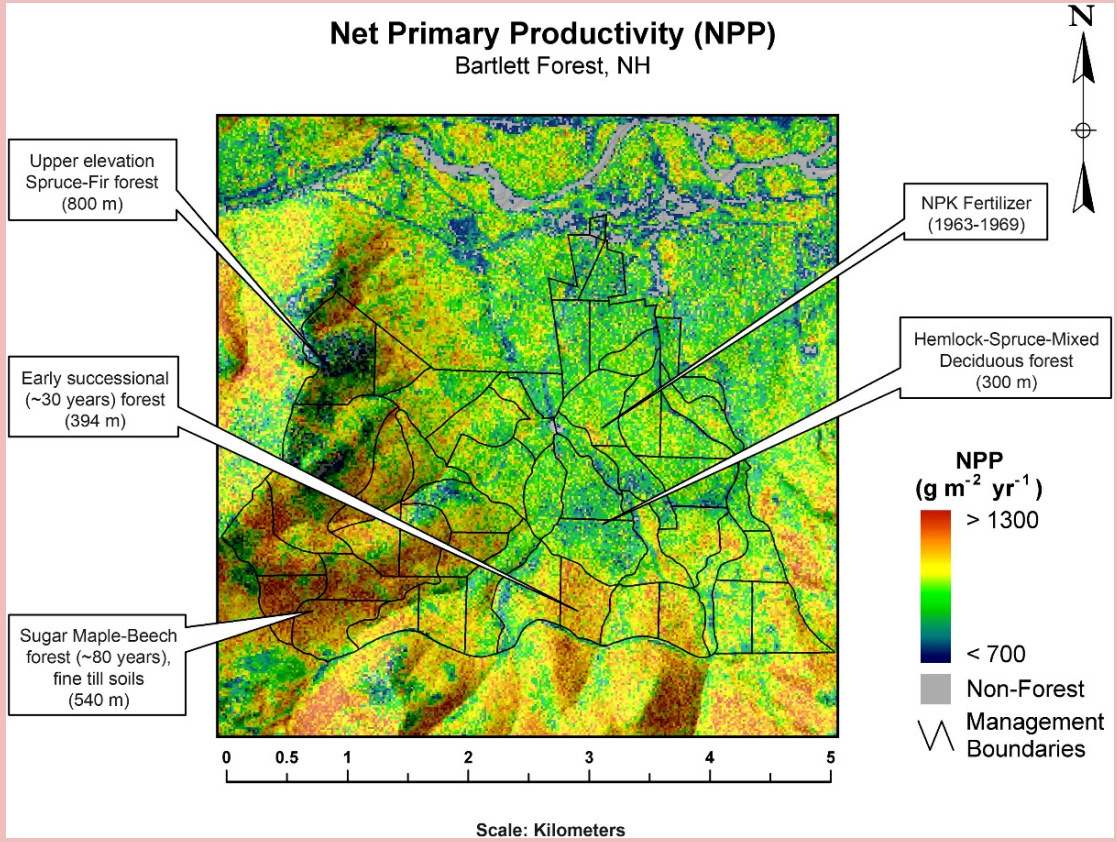
JOURNAL OF ANIMAL SCIENCE, Vol. 43, No. 4 (1976)

PREDICTING FORAGE QUALITY BY INFRARED REFLECTANCE SPECTROSCOPY[1]

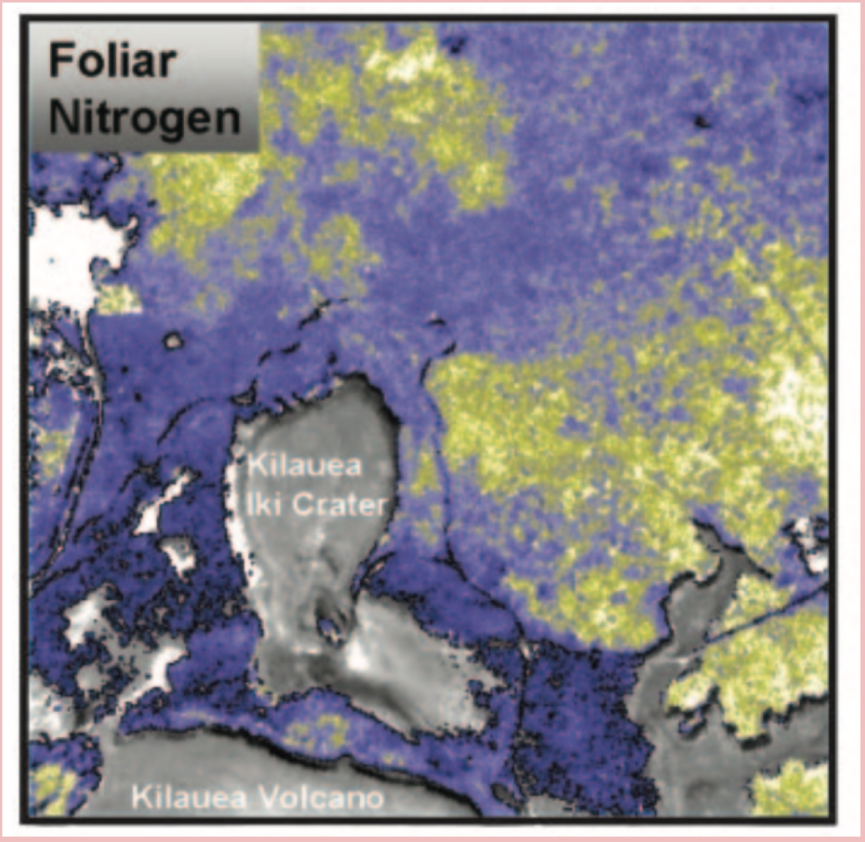
K. H. Norris[2], R. F. Barnes[3], J. E. Moore[4] and J. S. Shenk[5,6]

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

1920s ... 1960s 1970s 2000s 2010s Now

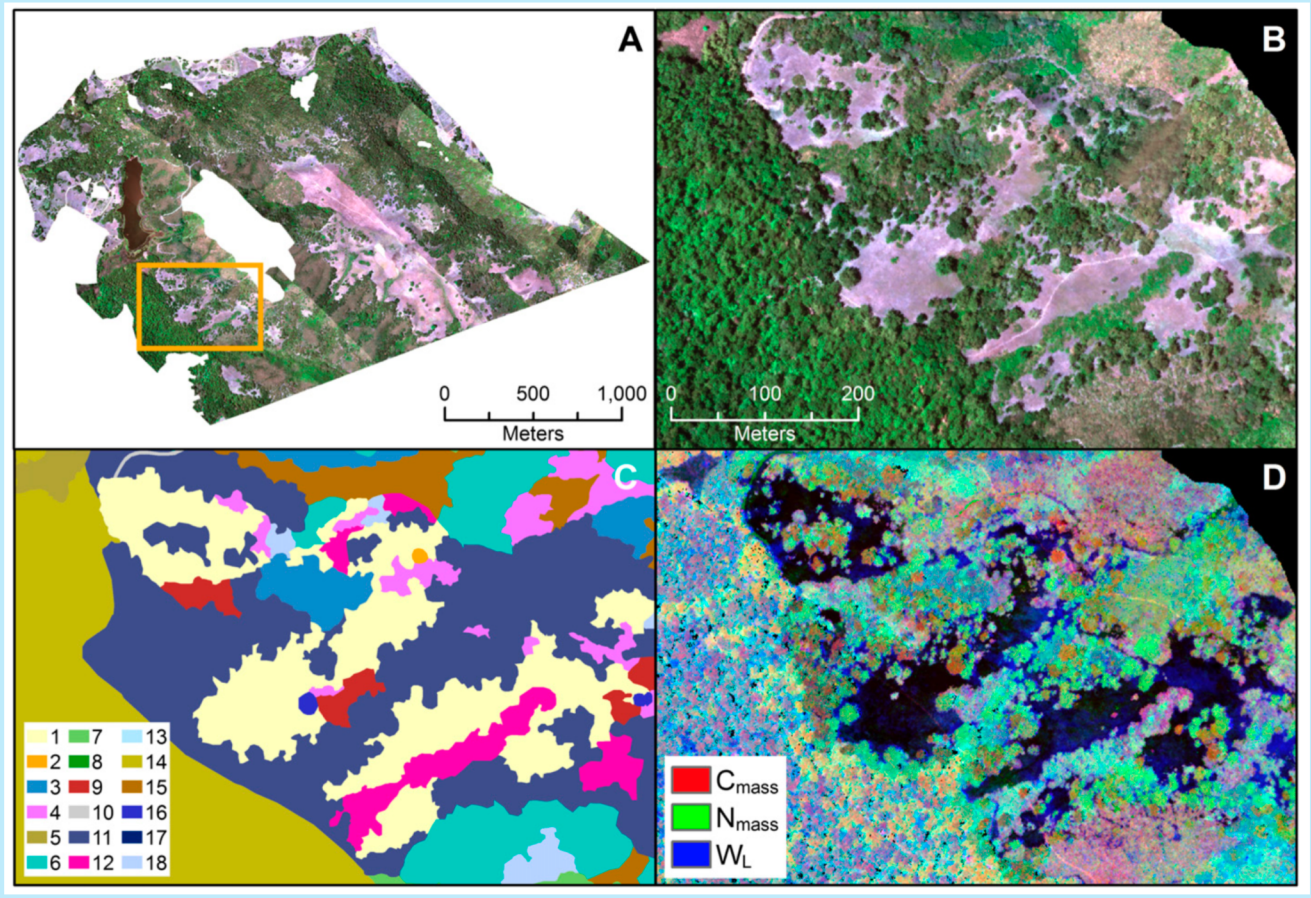


Smith et al. 2002; Ollinger et al. 2005



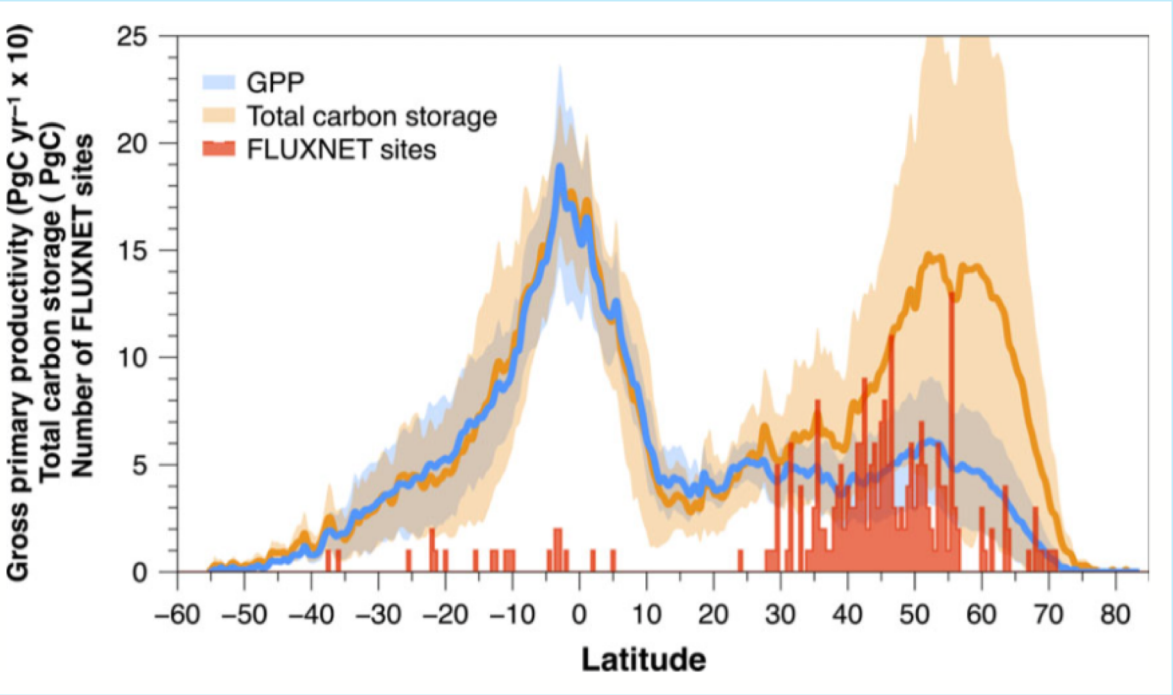
Asner and Vitousek 2005

1980s → 1990s → 2000s → 2010s → Now

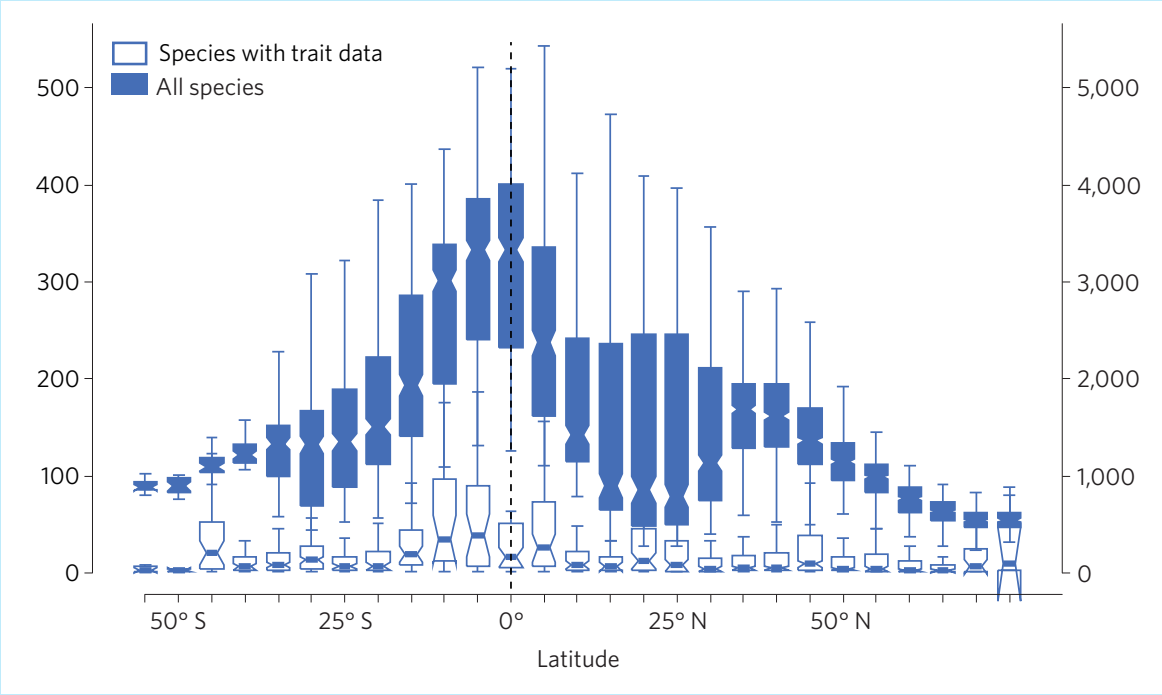


Dahlin et al. 2013

1980s → 1990s → 2000s → 2010s → Now

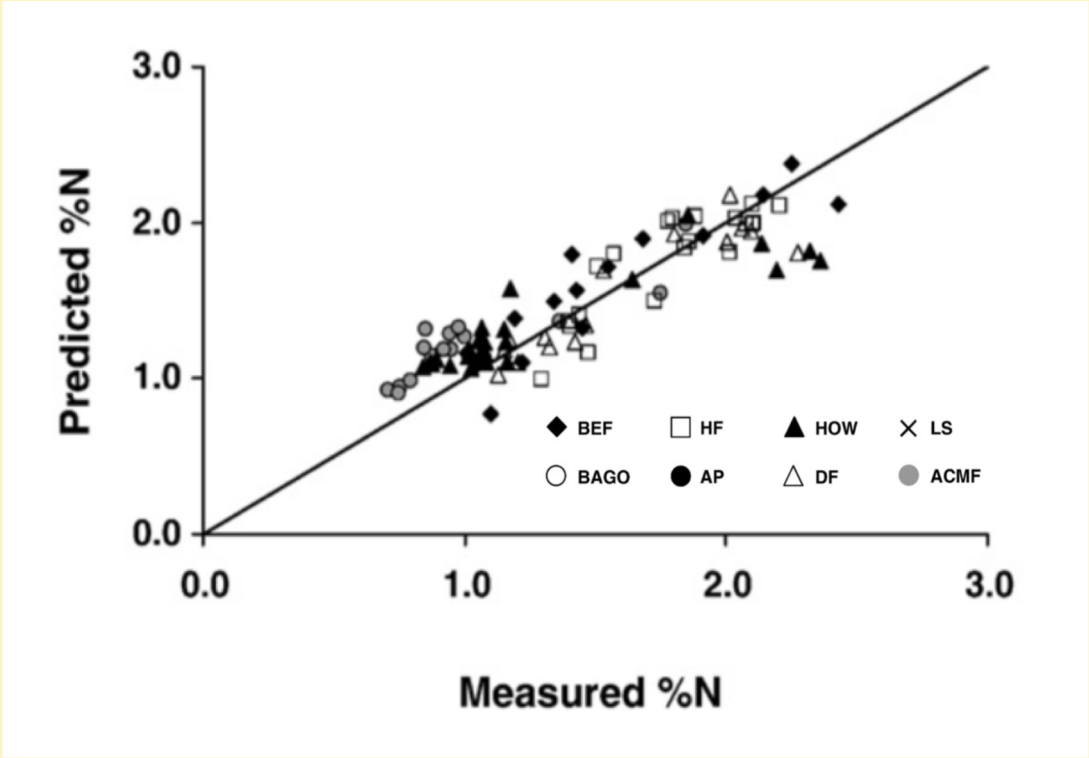


Schimel et al. 2015

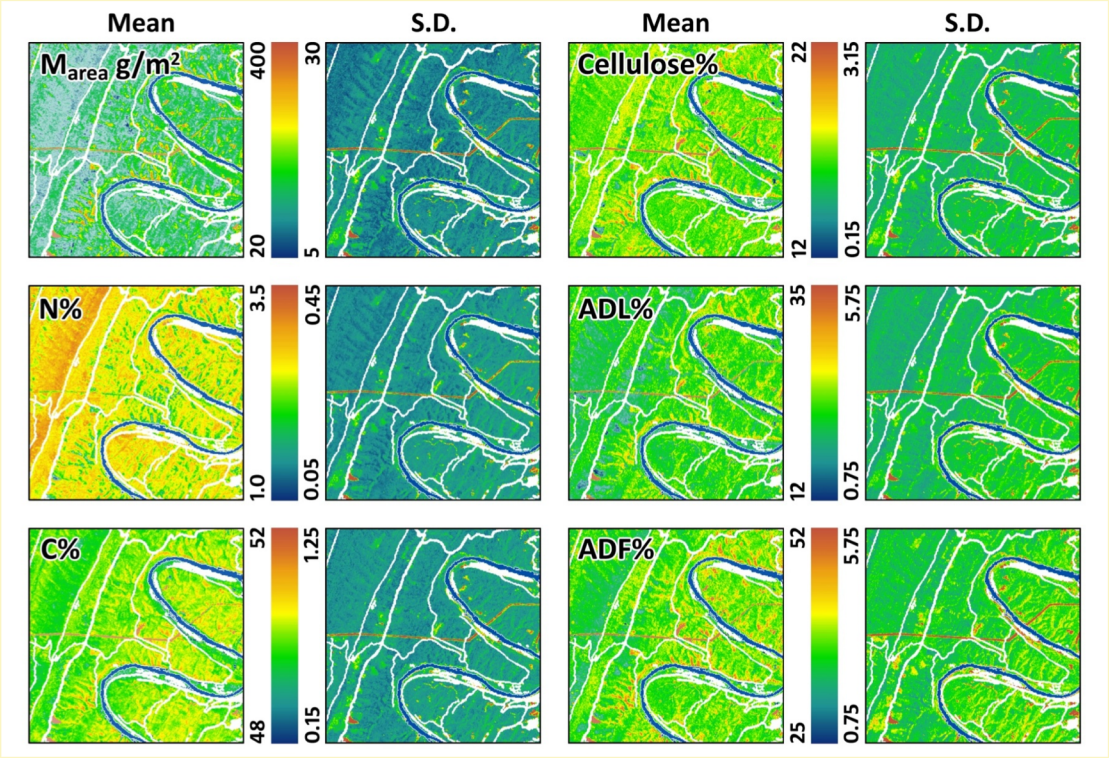


Jetz et al. 2016

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



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

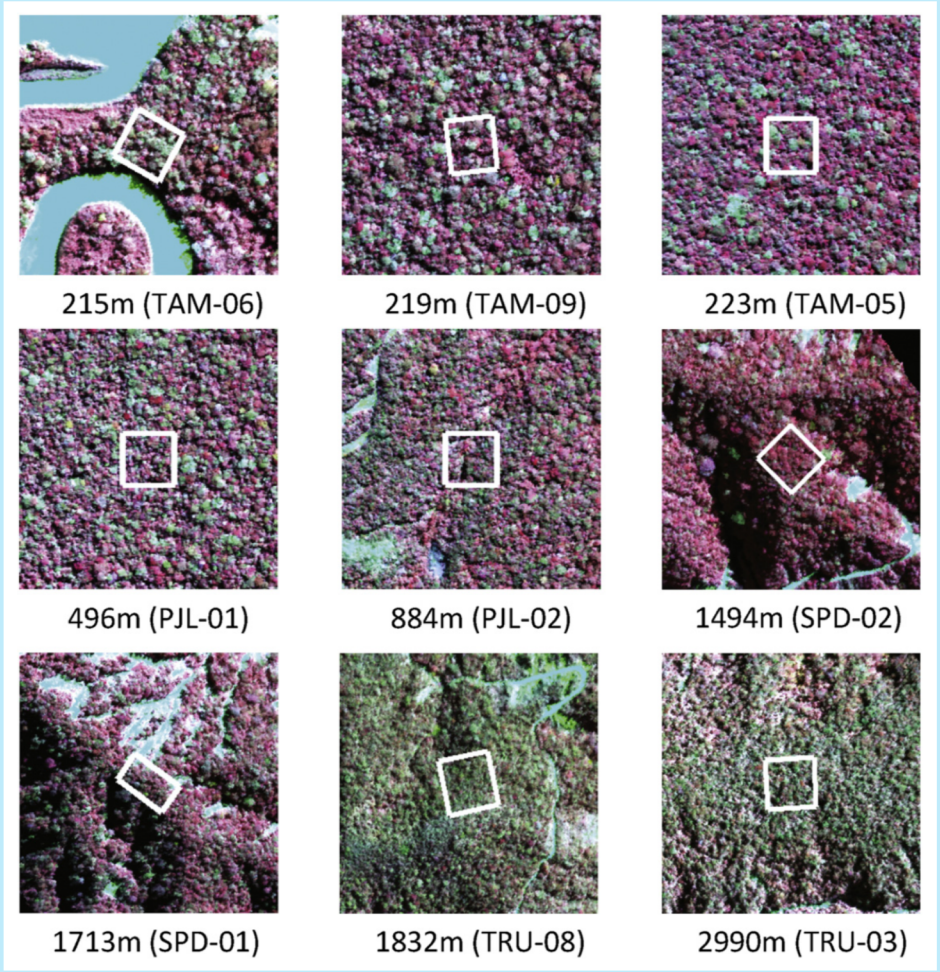
Remote Sensing of Environment

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

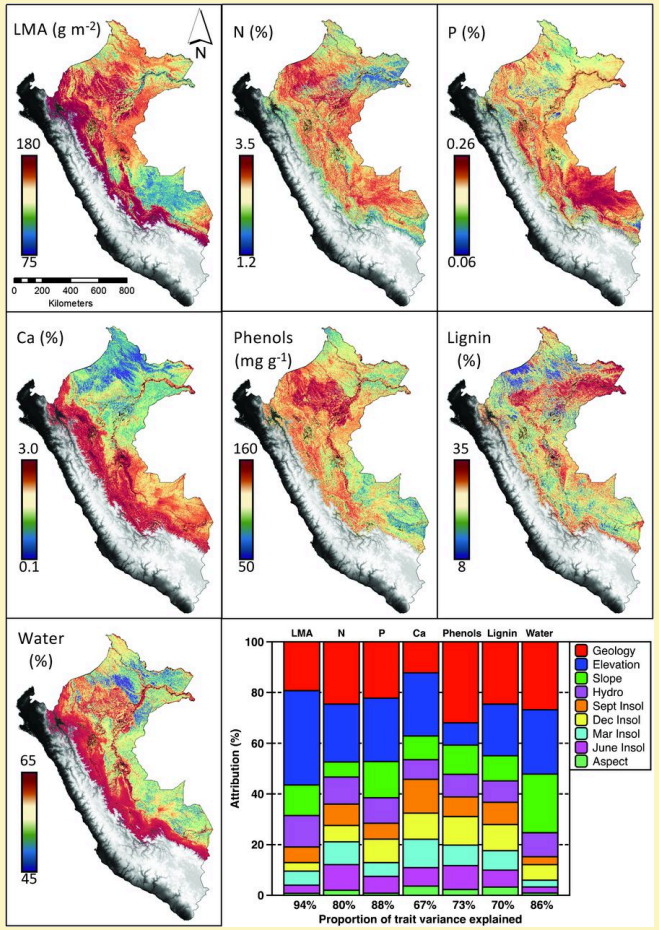
RESEARCH

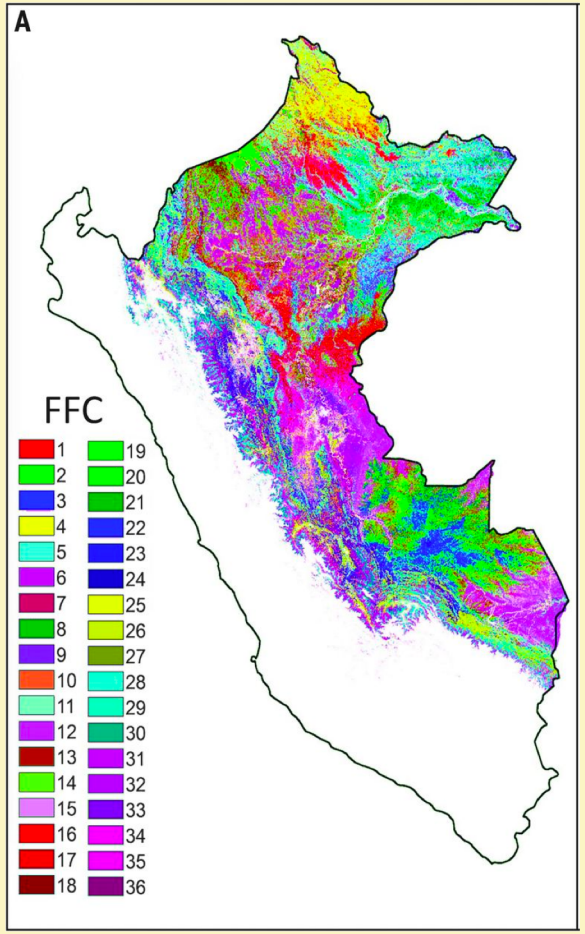
REPORT

FOREST CONSERVATION

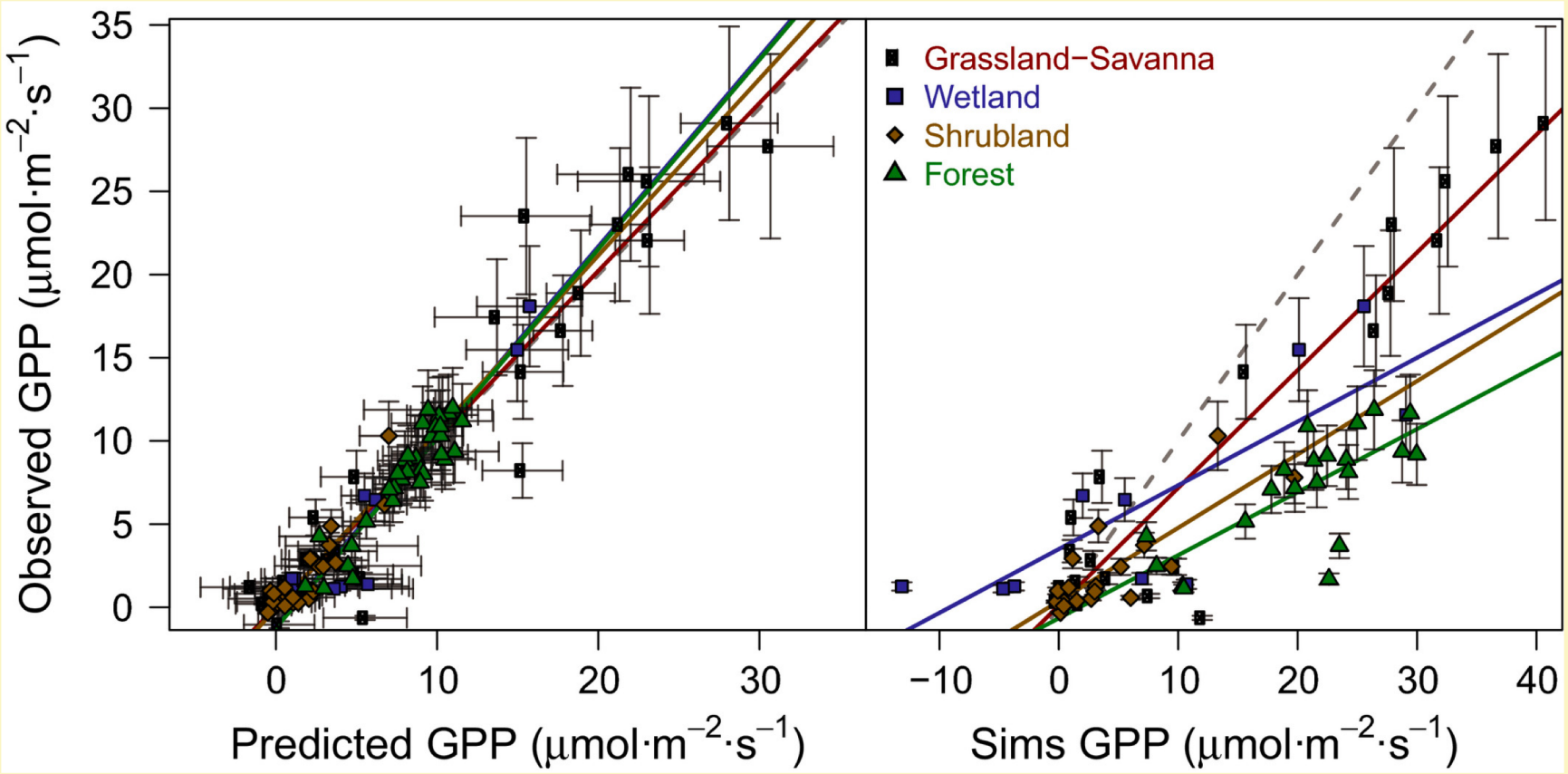
Airborne laser-guided imaging spectroscopy to map forest trait diversity and guide conservation

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]





1980s → 1990s → 2000s → 2010s → Now

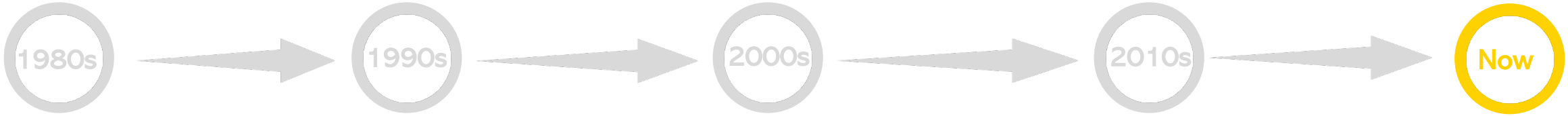


Dubois et al. 2018

1980s → 1990s → 2000s → 2010s → Now

Where are we now?

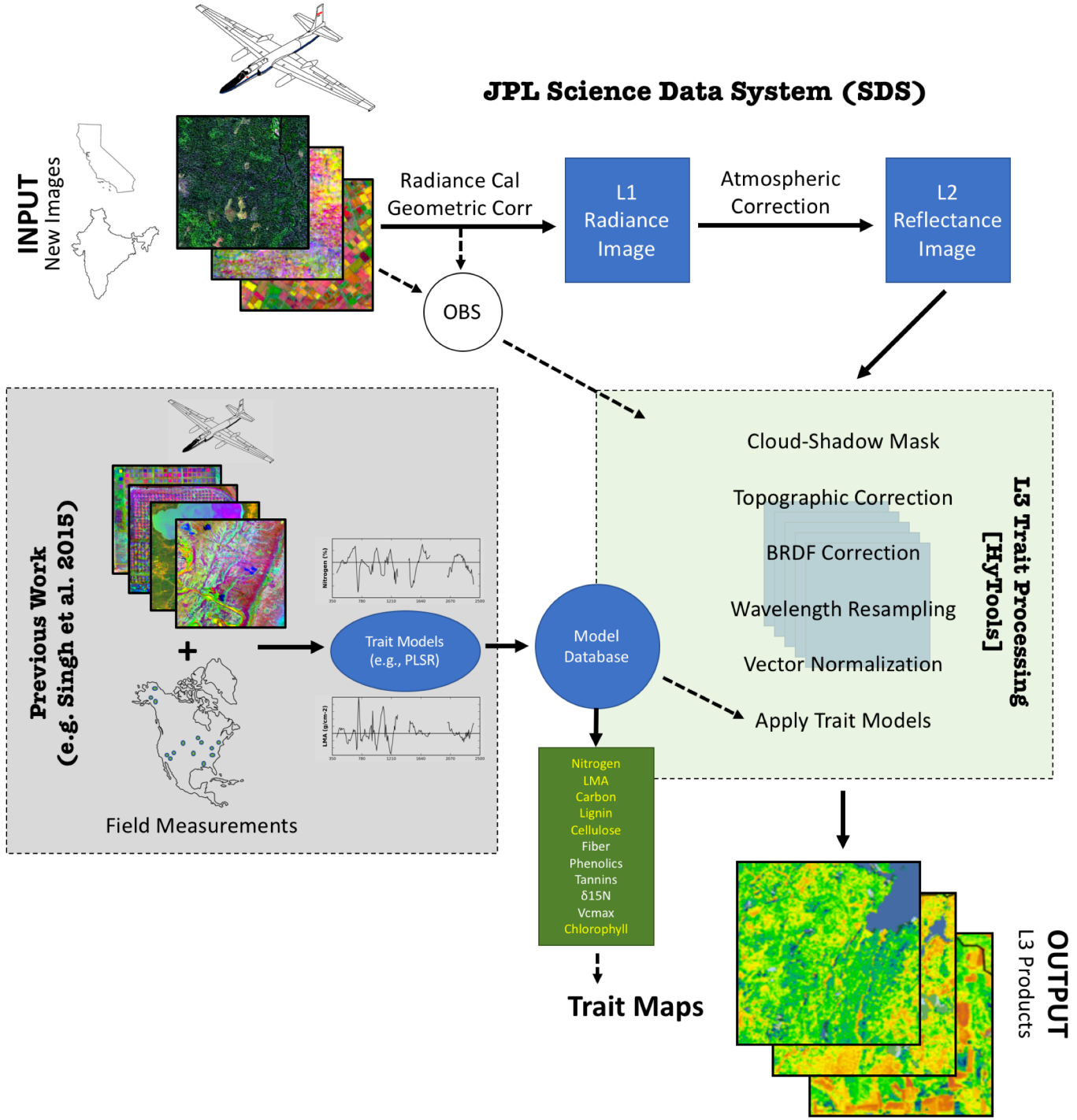
- Strong foundation of science and application for imaging spectroscopy from space
- Spatial, temporal, spectral resolution → functional resolution
- Address urgent questions about Earth's biosphere, and model phenotypic, genotypic, and ecological community response to environmental / climate change



Barriers to entry:

Workflow

Operational with AVIRIS

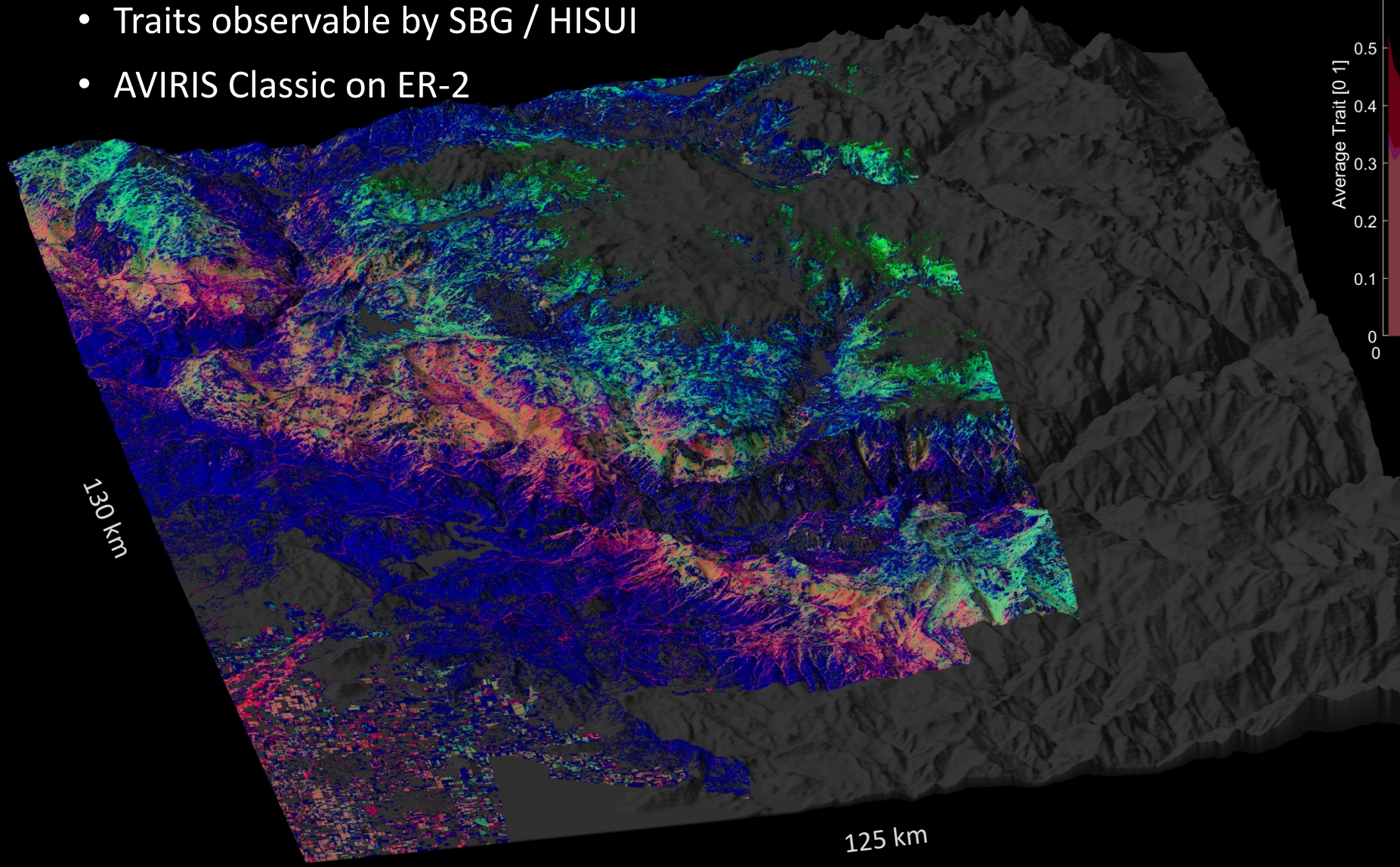


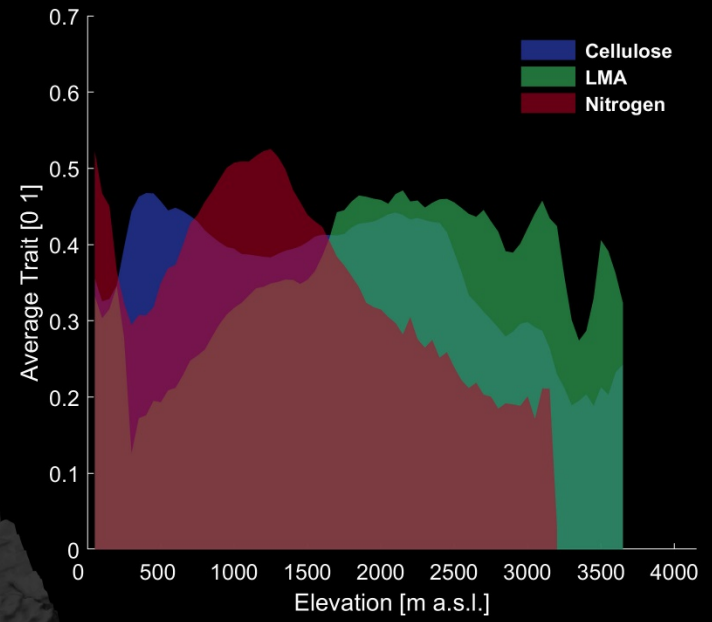
Jet Propulsion Laboratory
California Institute of Technology

National Ecological Observatory Network

Preliminary Results

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



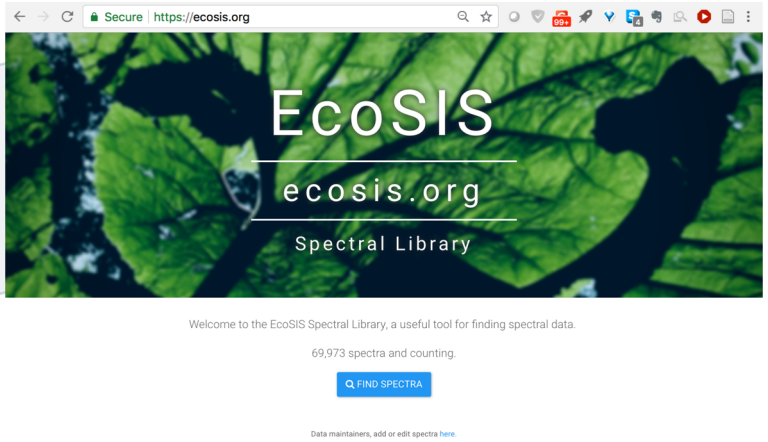


Townsend et al. in prep., Singh et al. 2015; figure by Fabian Schneider

Emerging tools for synthesis and implementation

Data Life Cycle

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



EcoSML.org

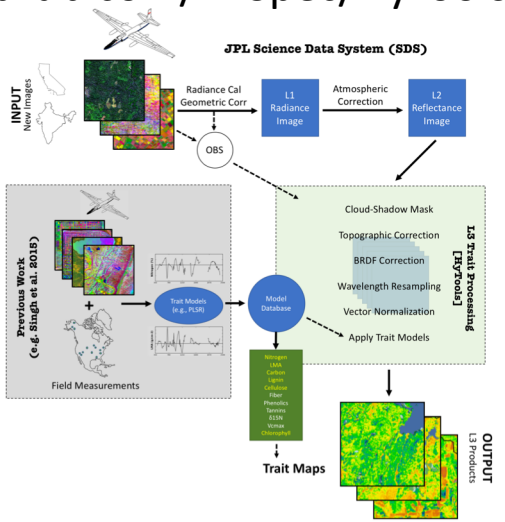
Spectral Model Library

ESTO Earth Science Technology Office

NASA

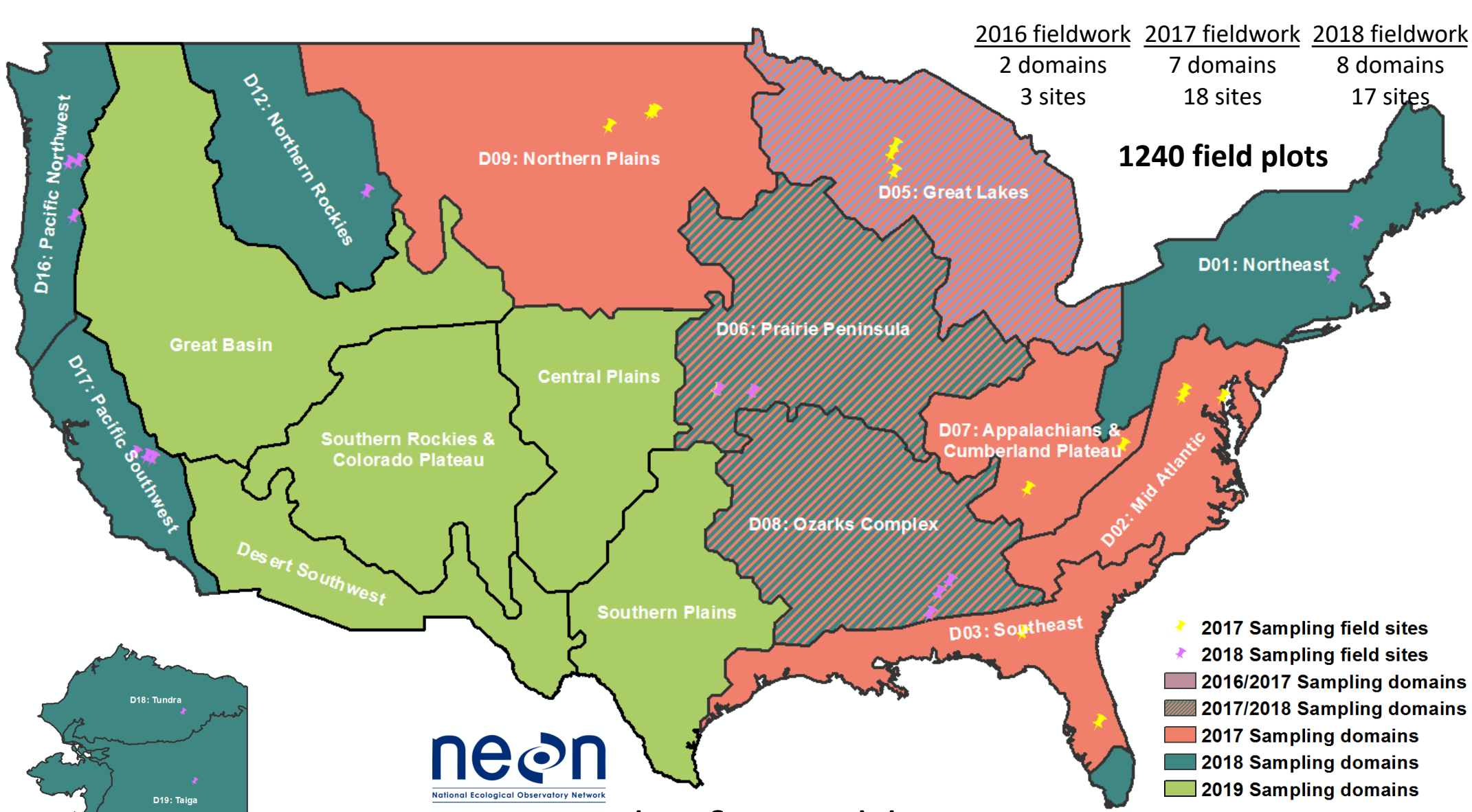
HyTools workflow

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



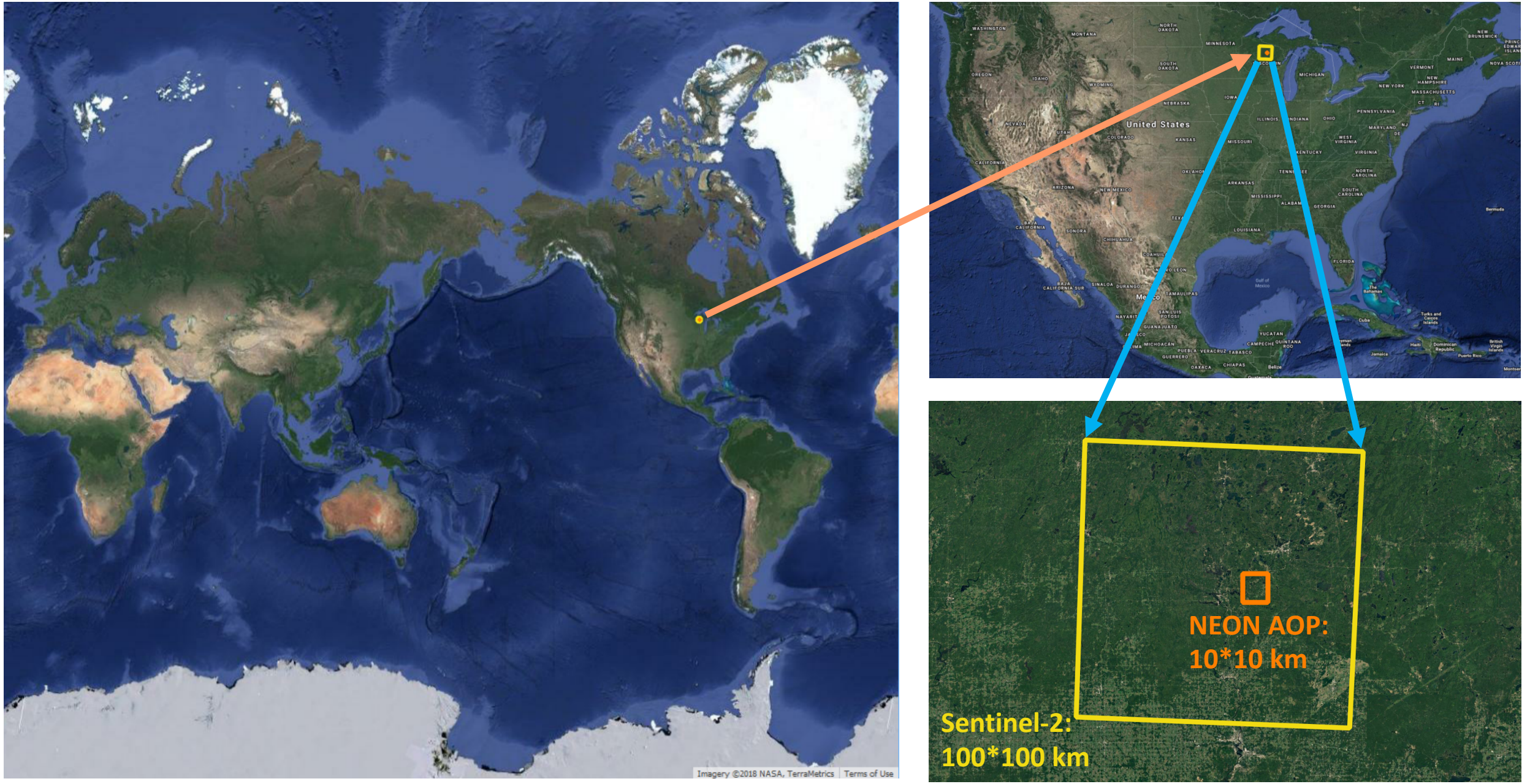
2016 fieldwork	2017 fieldwork	2018 fieldwork
2 domains	7 domains	8 domains
3 sites	18 sites	17 sites

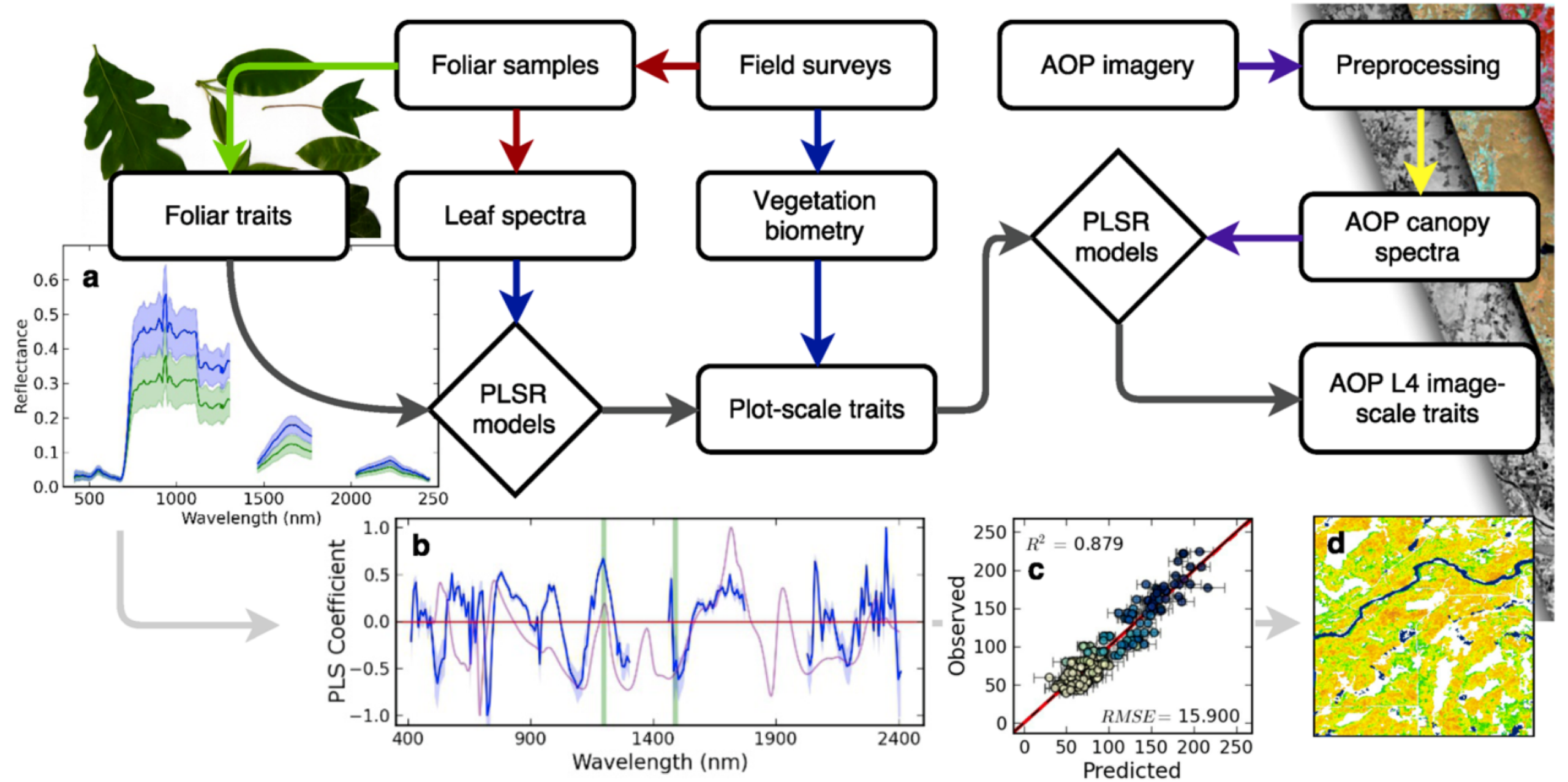
1240 field plots



Networks for calibration and validation

Note need for data from tropics, Arctic


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



Trait mapping workflow using field data and AOP images, (a) canopy reflectance, (b) PLSR coefficients, (c) model validation, (d) trait map (Singh et al. 2015).

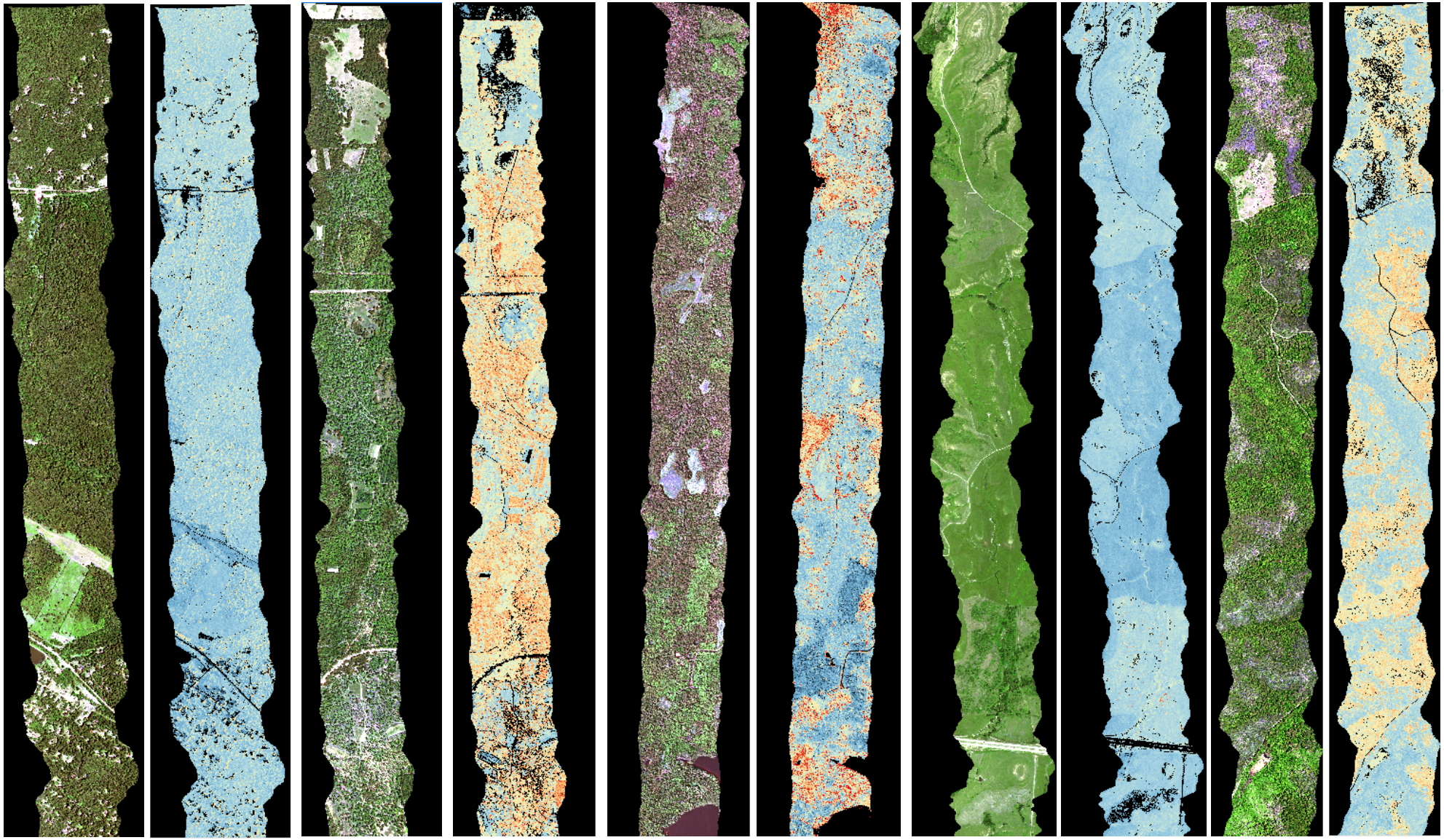
Mid-Atlantic (D02): Smithsonian (VA)

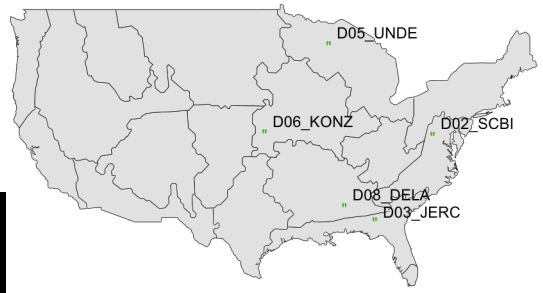
Southeast (D03): Jones (GA)

Great Lakes (D05): UNDERC (WI)

Prairie Peninsula (D06): Konza (KS)

Ozarks Complex (D08): Talladega (AL)



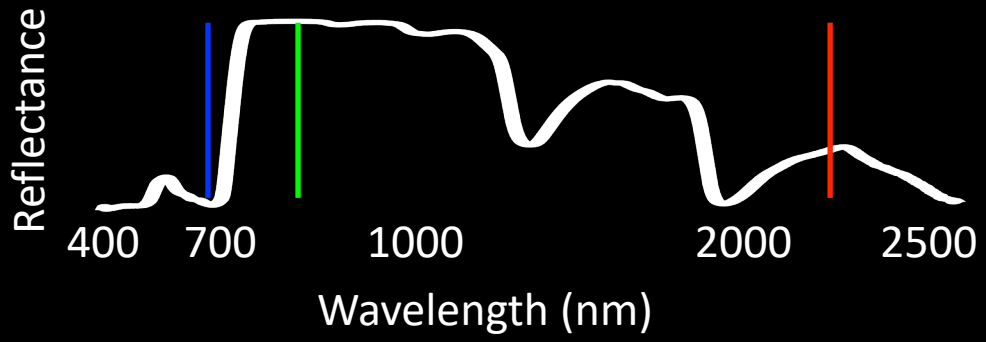


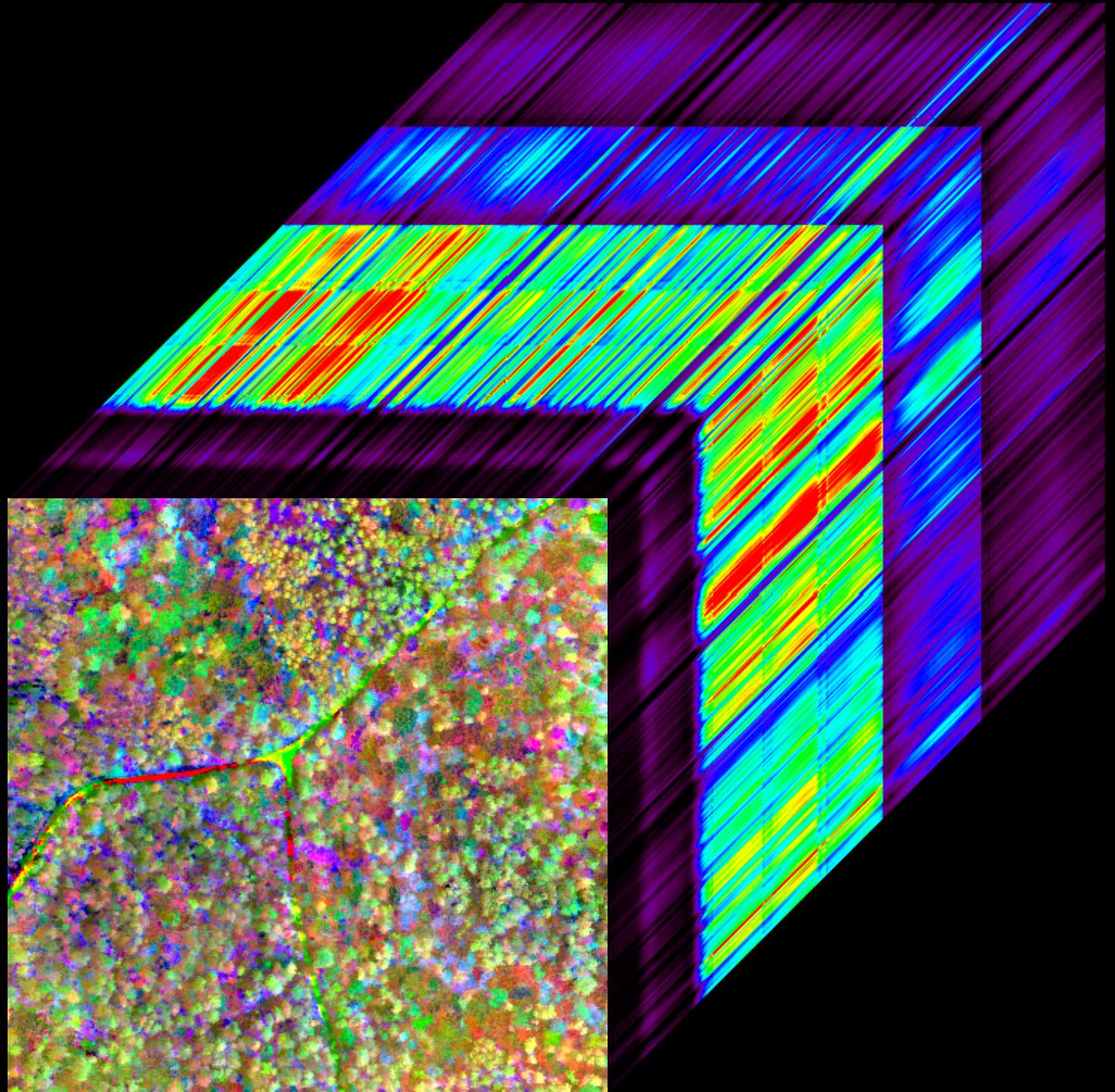
LMA (g/m2)

- No value
- 0-40
- 40-80
- 80-120
- 120-160
- 160-200
- 200-240
- 240-280
- 280-320
- 320-360

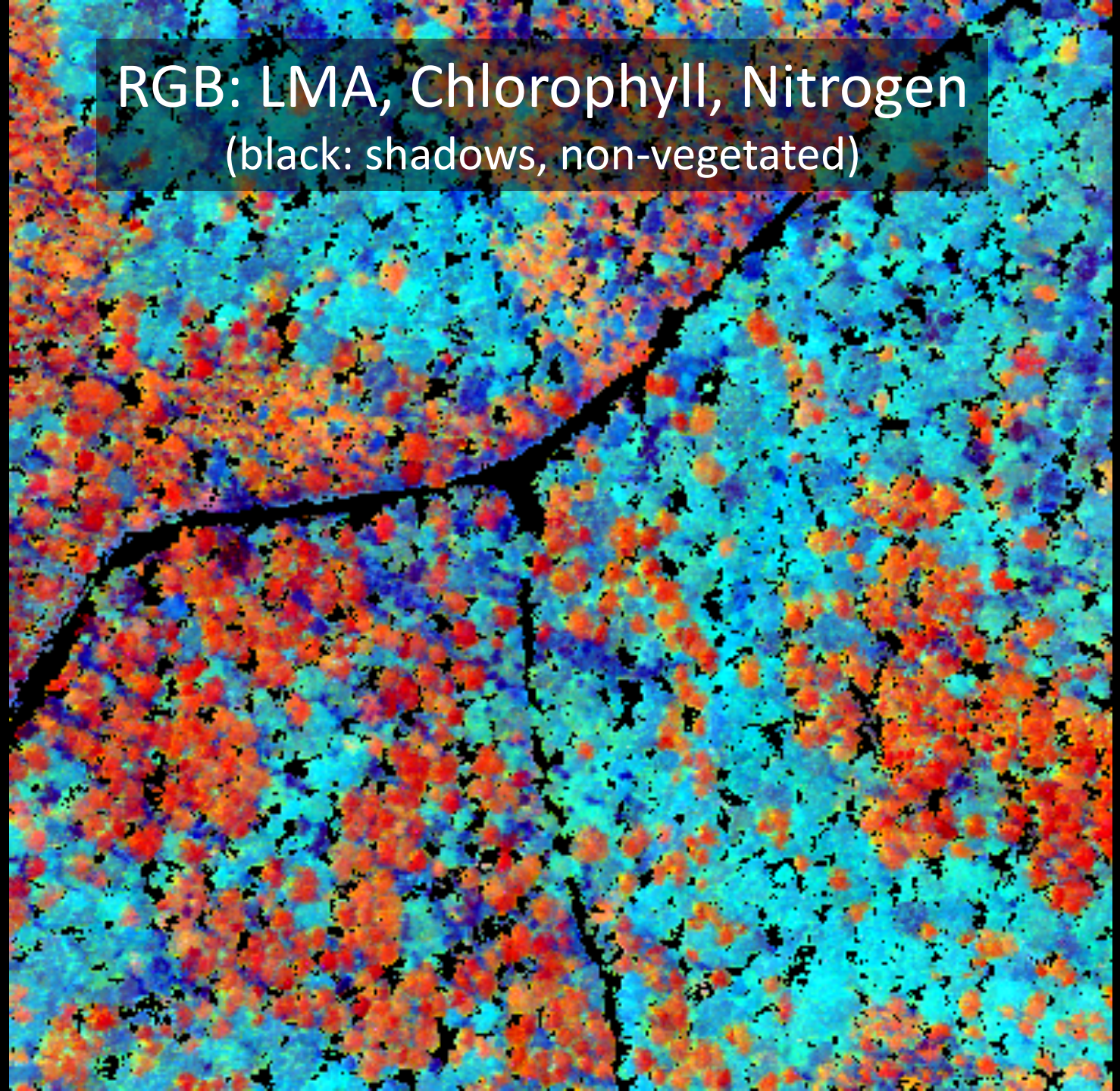
Foliar Traits in NEON Domains

Domain 6 – Talladega National Forest





Traits	R^2 (val)	% RMSE
%C	0.63	13.06
Aluminum	0.55	10.4
Carotenoids_area	0.57	11.92
Carotenoids_area	0.59	13.3
Cellulose_DS	0.6	12.11
Chlorophyll_area	0.64	11.14
Chlorophyll_mass	0.58	13.85
d13C	0.63	13.12
EWT	0.62	14.13
Flavonoids	0.53	14.5
Iron	0.51	15.03
Lignin	0.57	13.37
LMA	0.78	10.2
Manganese	0.62	12.99
Nitrogen	0.55	13.44
Phosphorous	0.5	12.93
Potassium	0.66	10.74
Starch	0.61	12.73
Sugar	0.45	16.37
TotPhen	0.82	8.4
Water_percent	0.58	11.86
Zinc	0.54	16.12



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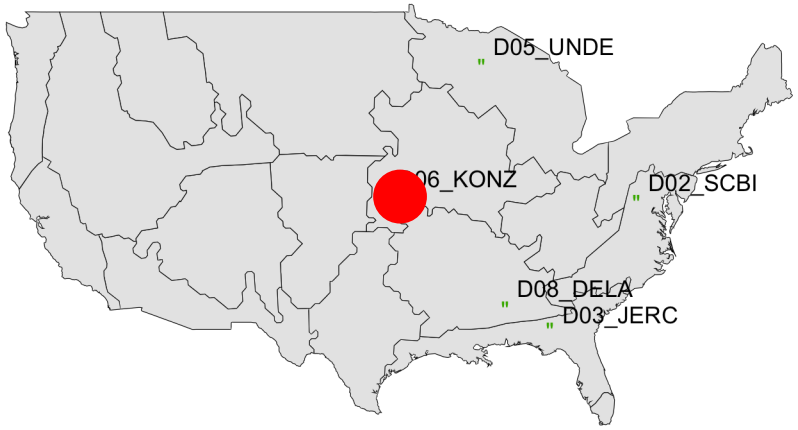
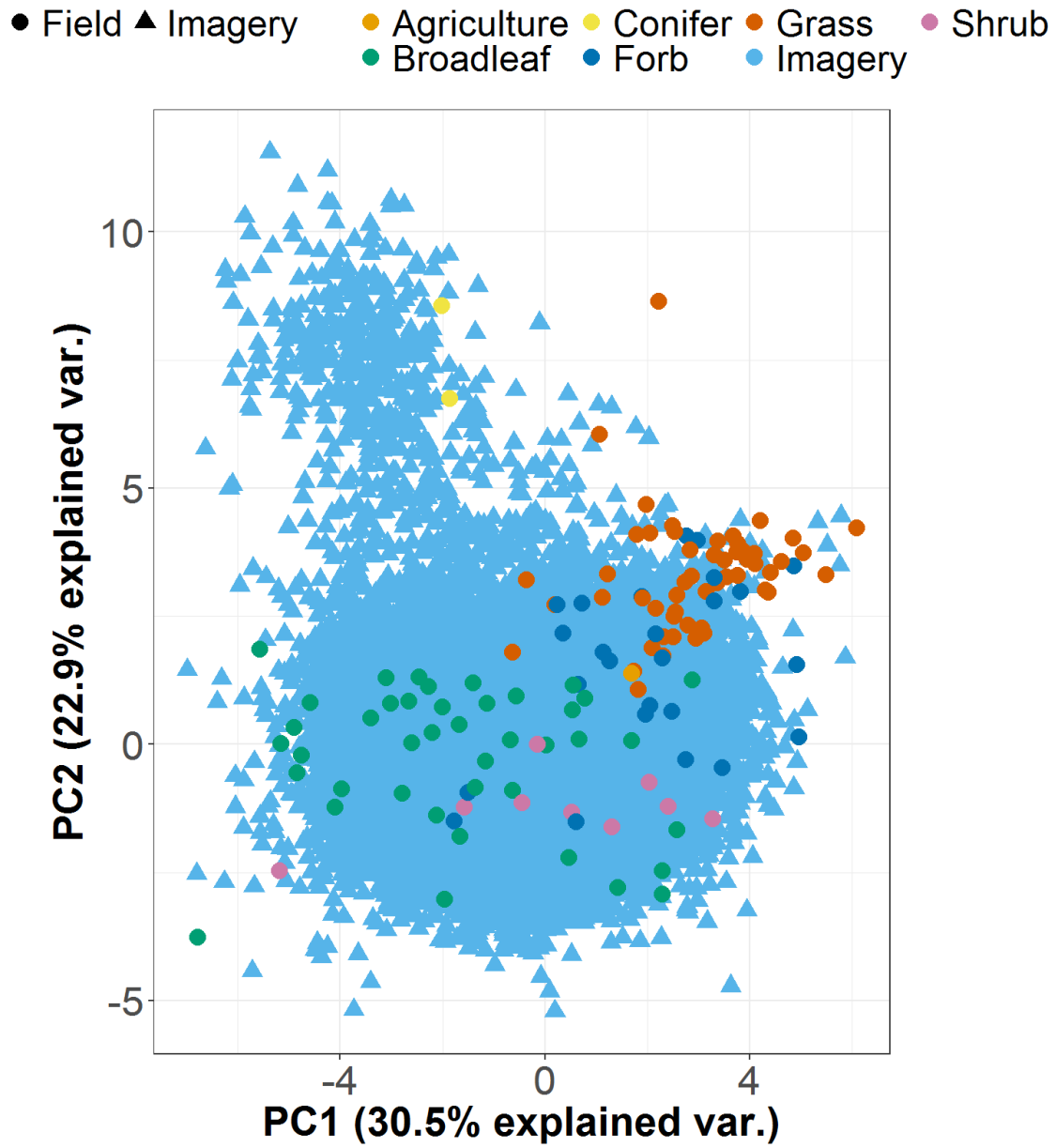
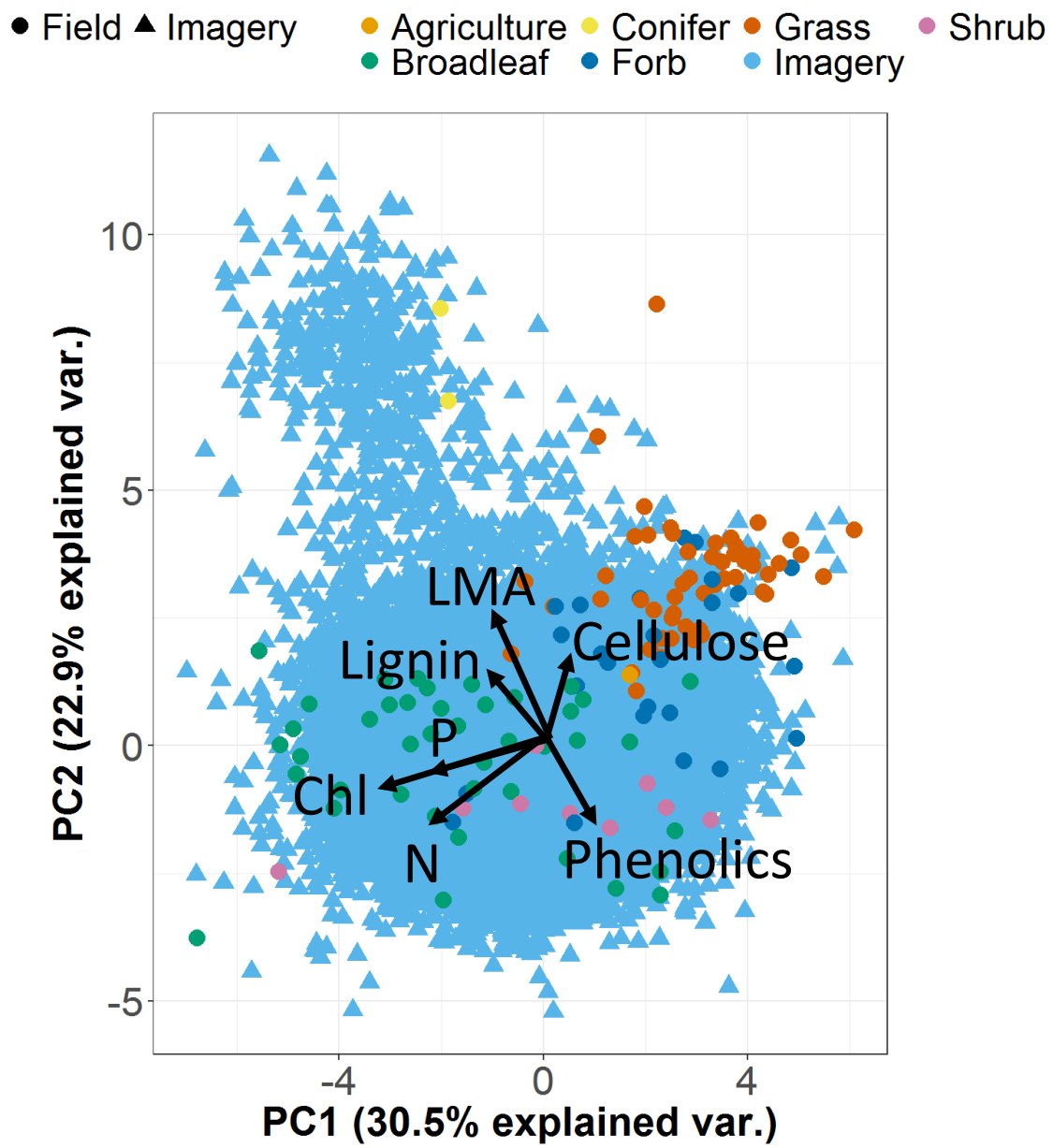
Domain 06: Prairie Peninsula



Visualizing “Trait Space”



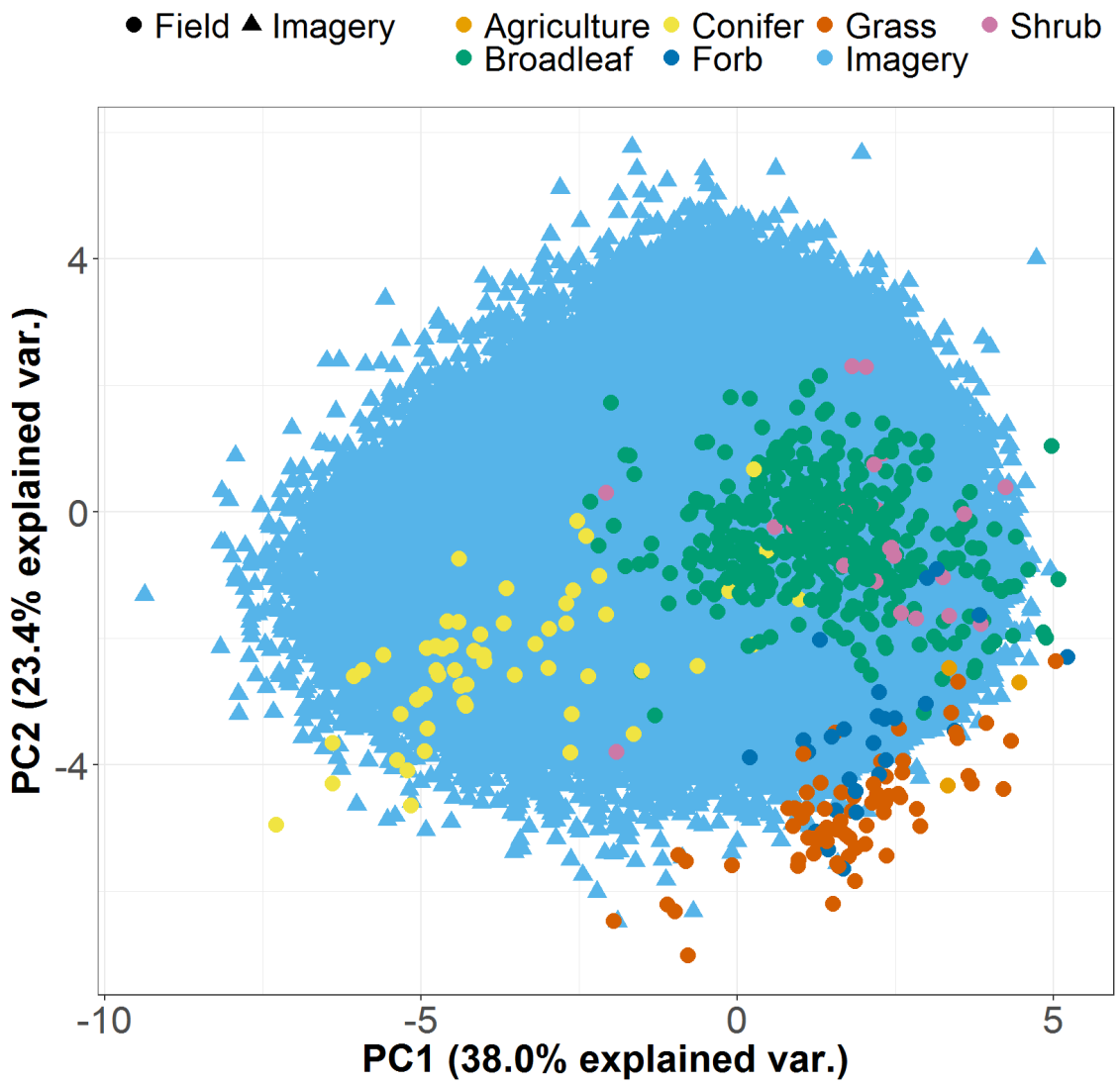
Domain 06: Prairie Peninsula



All domains:

Physiognomic types

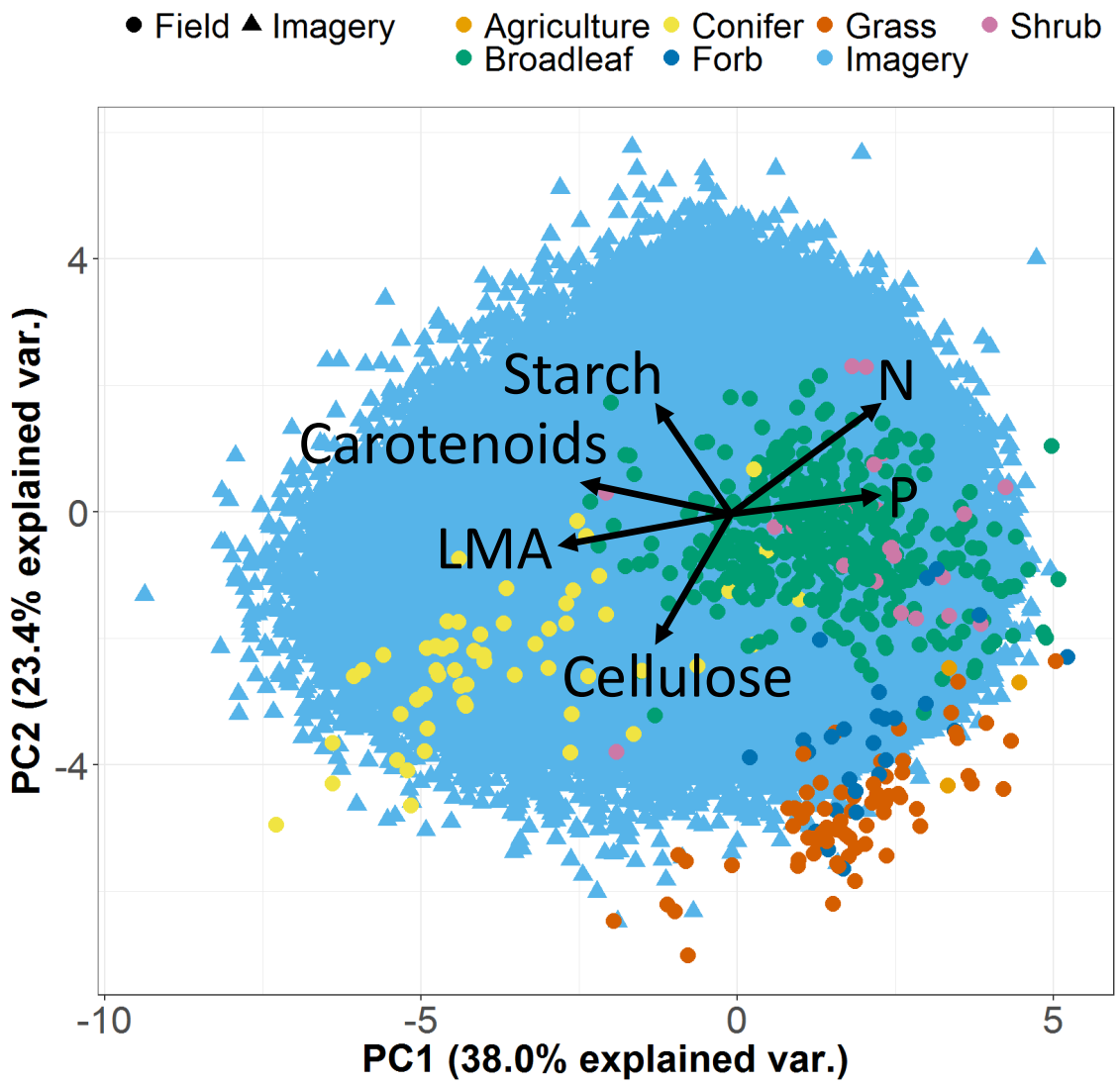
Key Species



All domains:

Physiognomic types

Key Species



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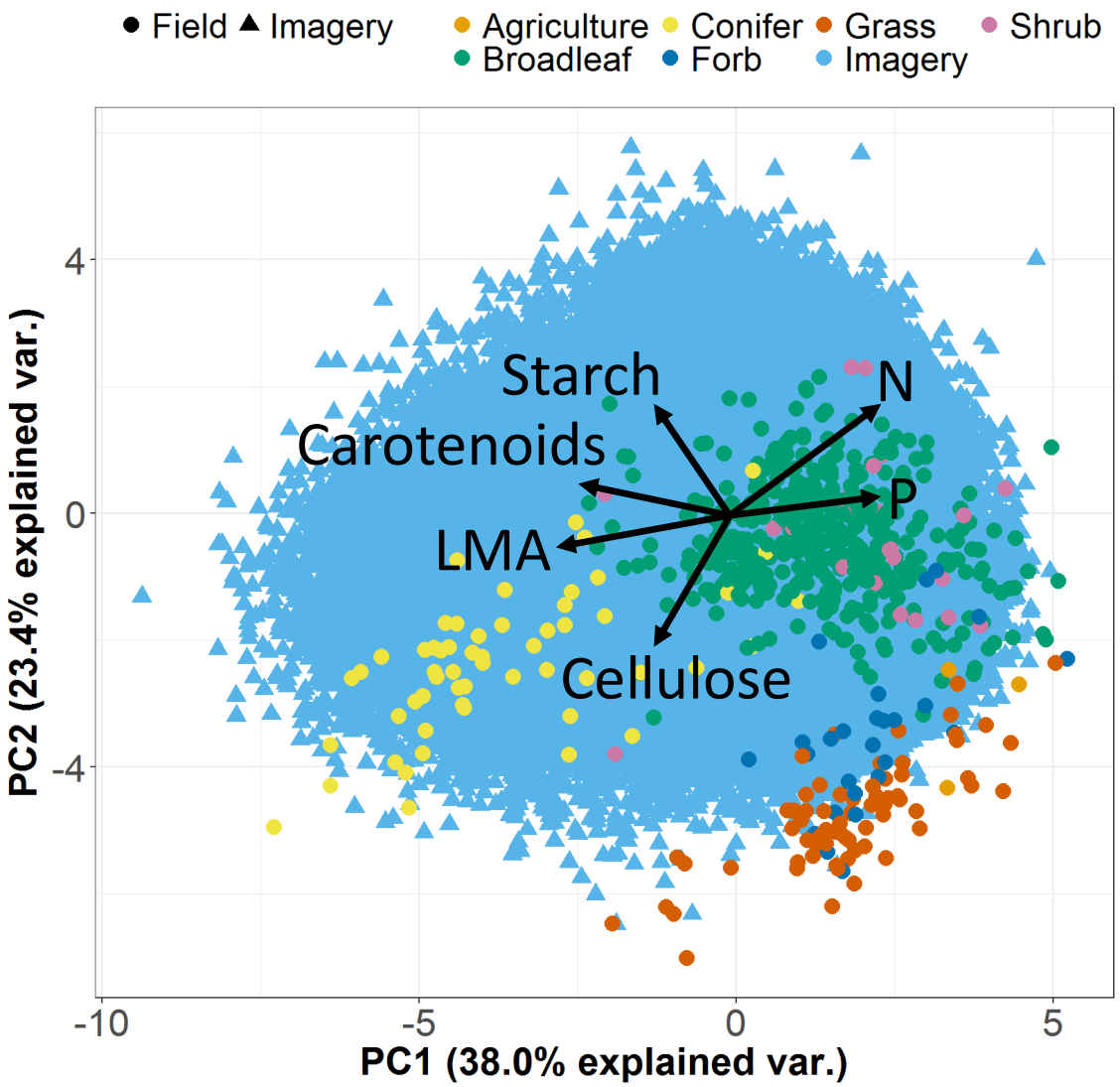
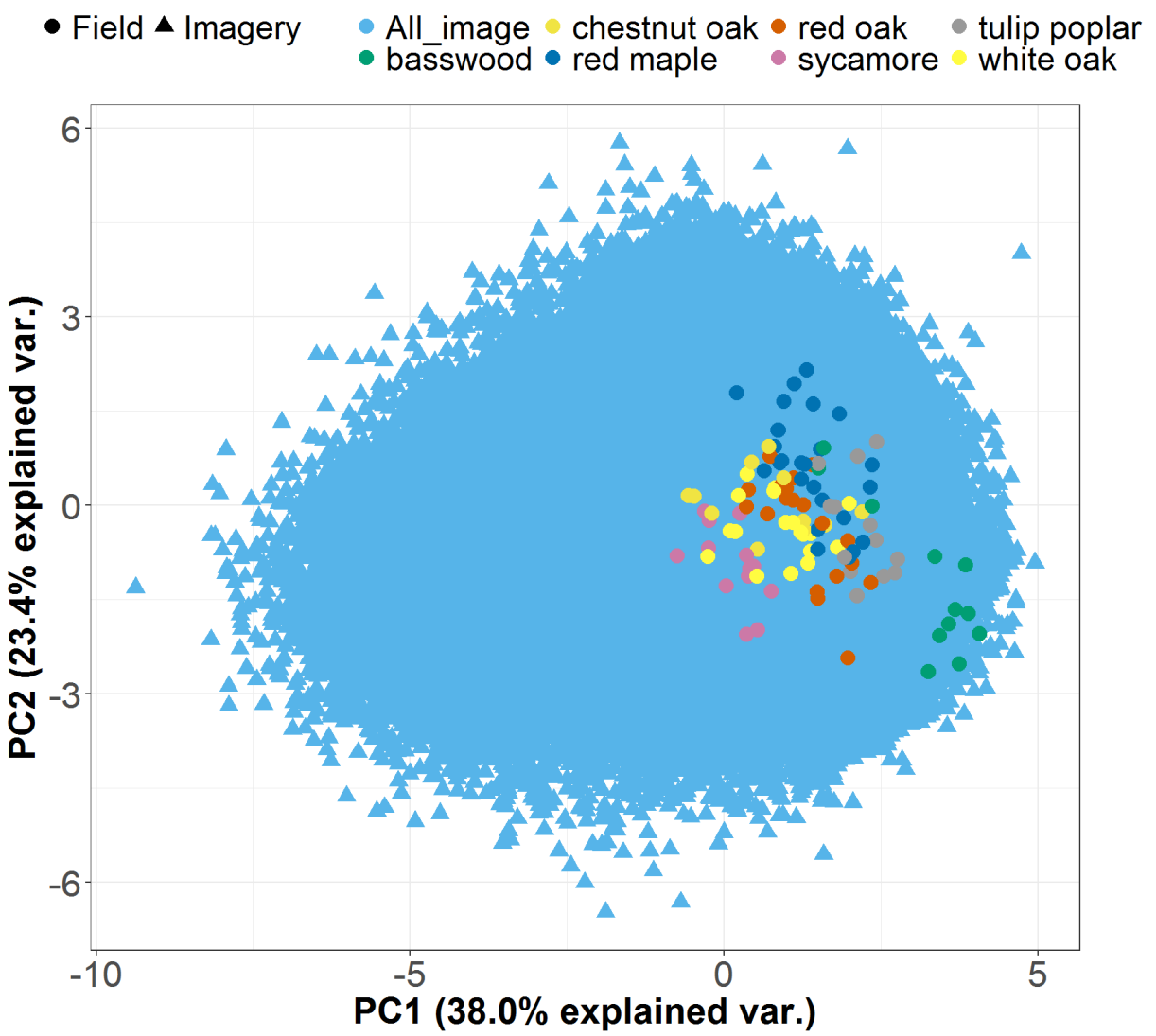
Physiognomic types

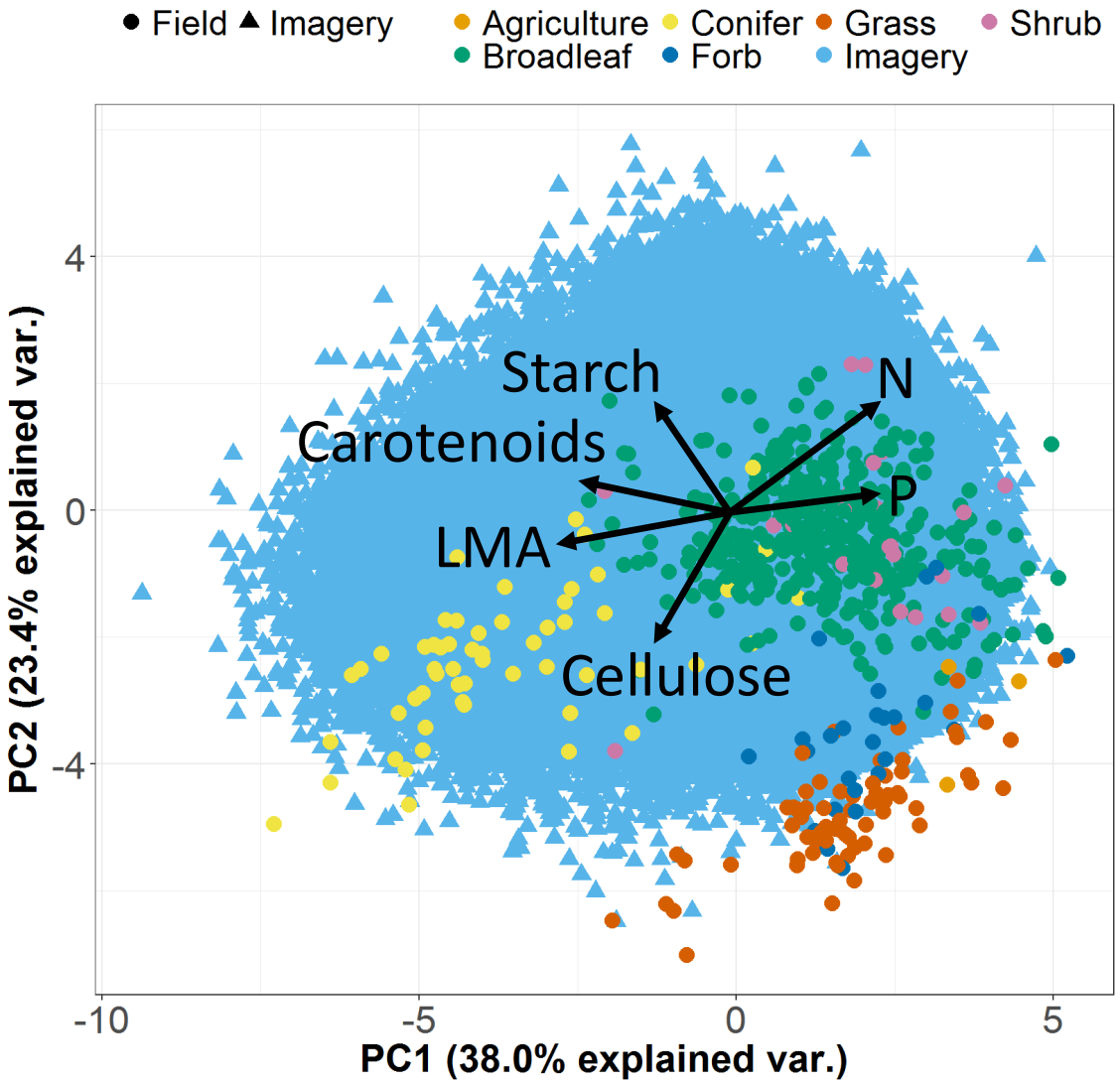


Key Species

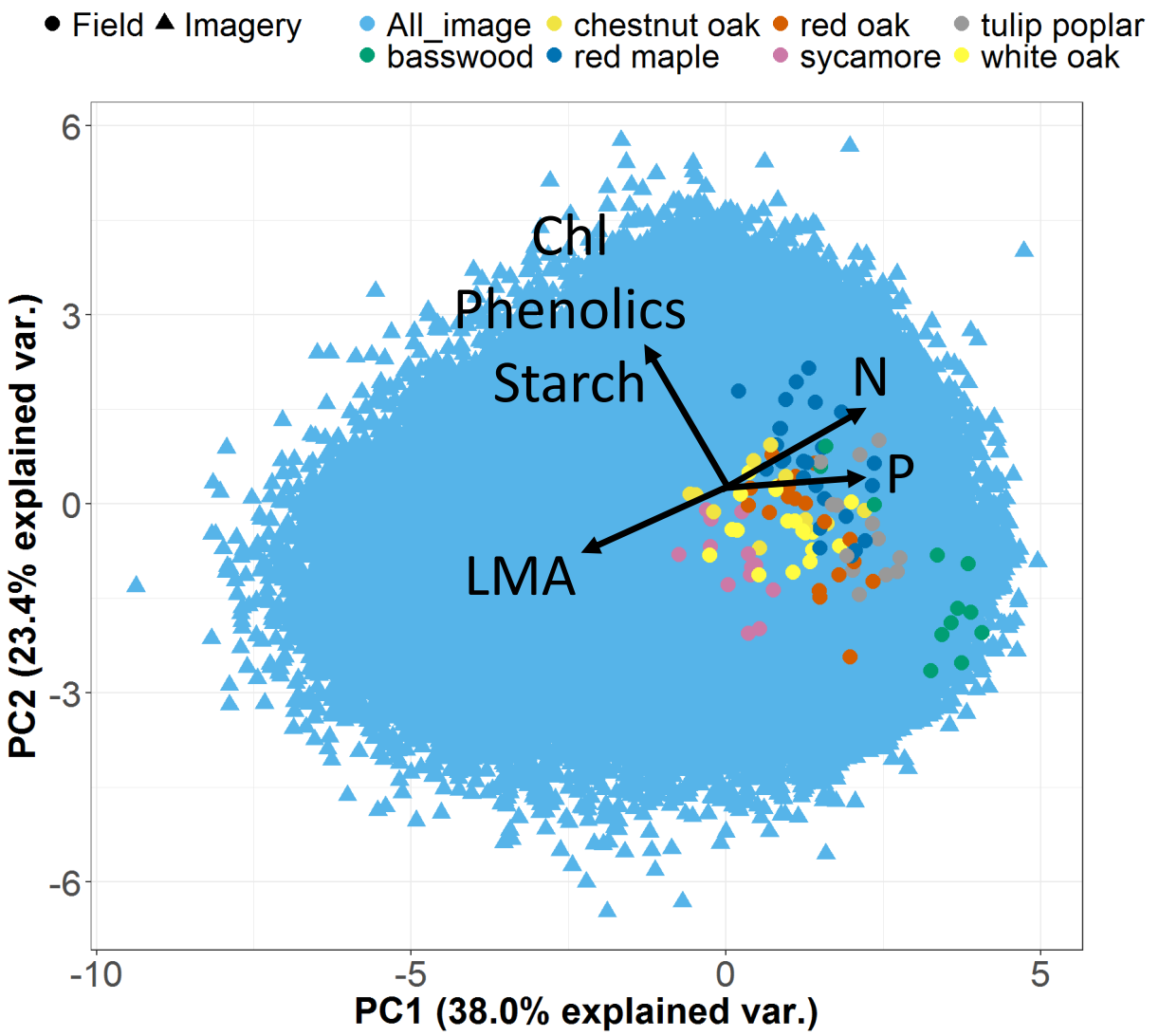


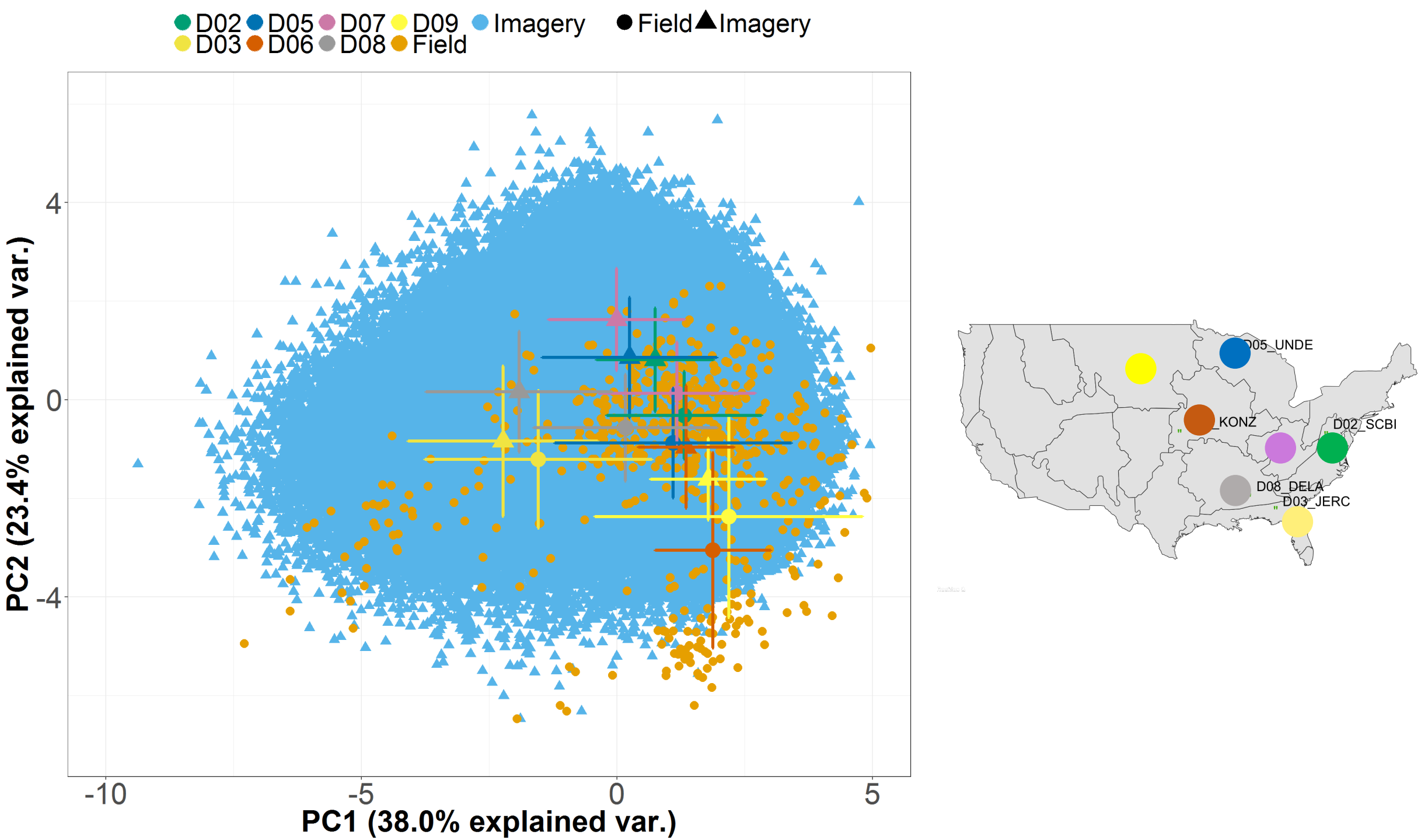
All domains:

Physiognomic types



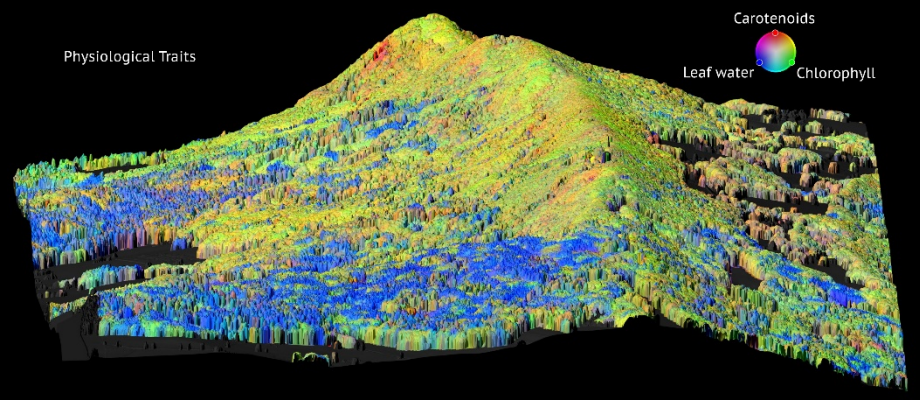
Key Species

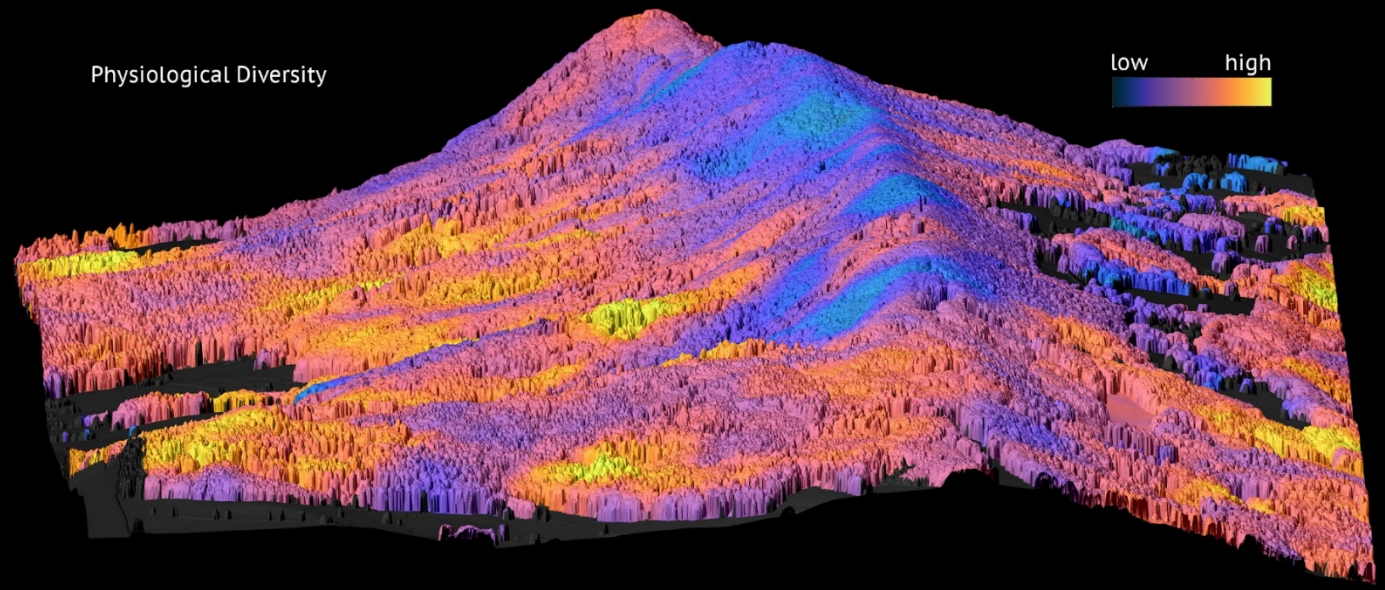



D02
D05
D07
D09
Imagery
Field
Imagery
D03
D06
D08
Field
4
0
-4
PC2 (23.4% explained var.)
-10
-5
0
5
PC1 (38.0% explained var.)
D05_UNDE
_KONZ
D02_SCBI
D08_DELA
D03_JERC

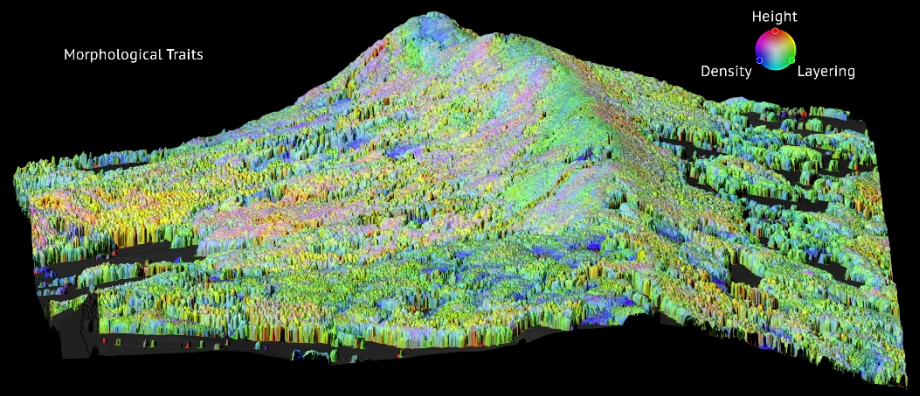
Mapping of Plant Functional Diversity

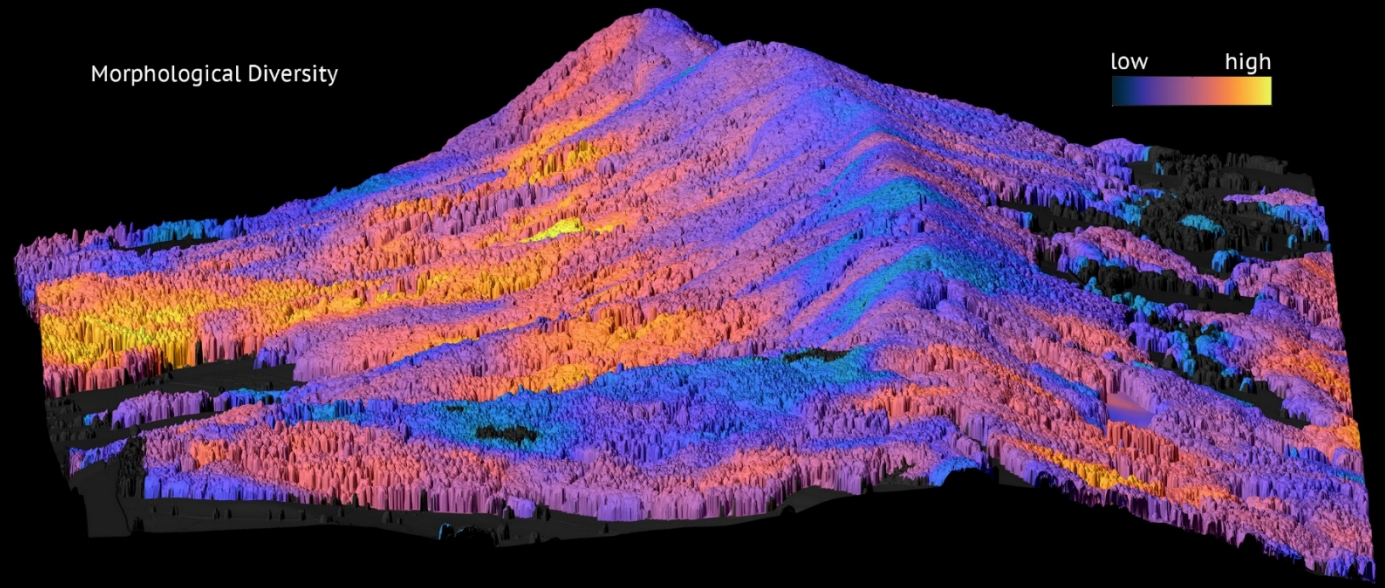
Leaf Biochemistry from Spectroscopy





Canopy Structure from LiDAR





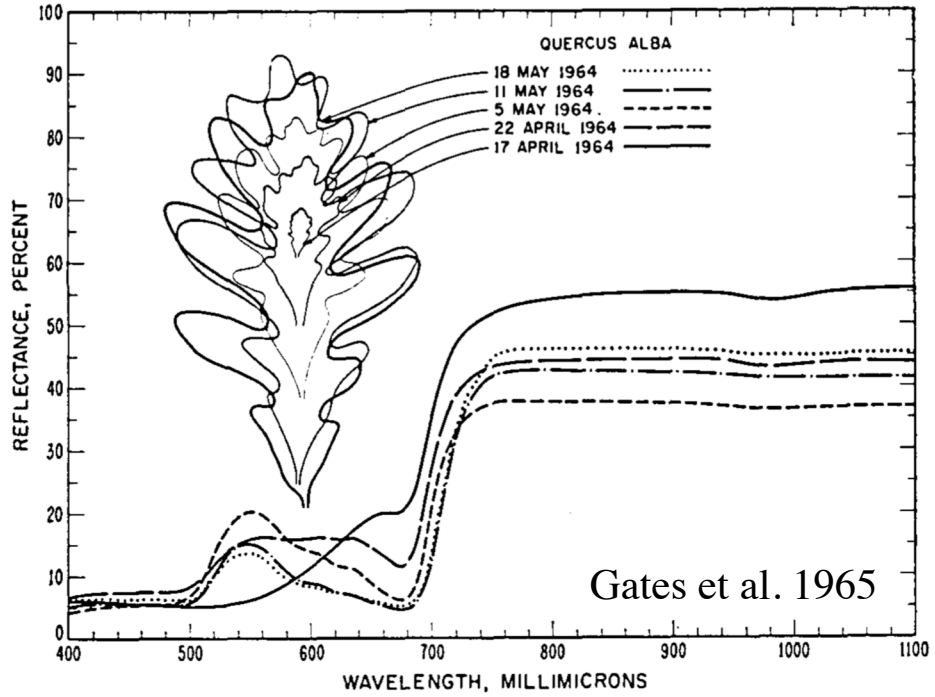
Schneider, et al. (2017) Nature Communications

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

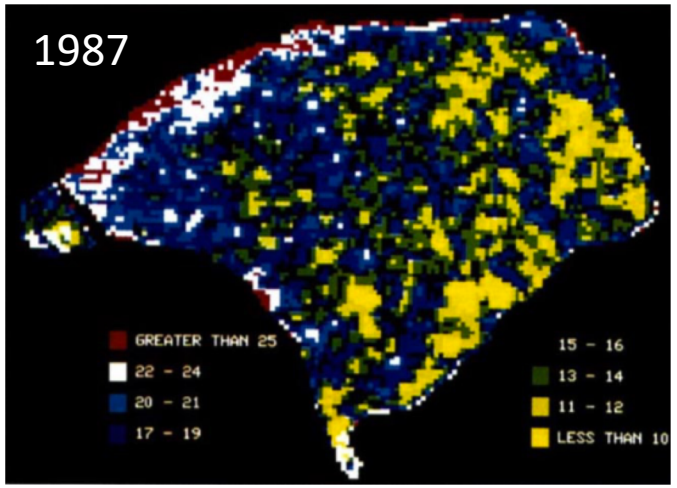
A SPECTROPHOTOMETRIC STUDY OF REFLECTION OF LIGHT FROM LEAF SURFACES

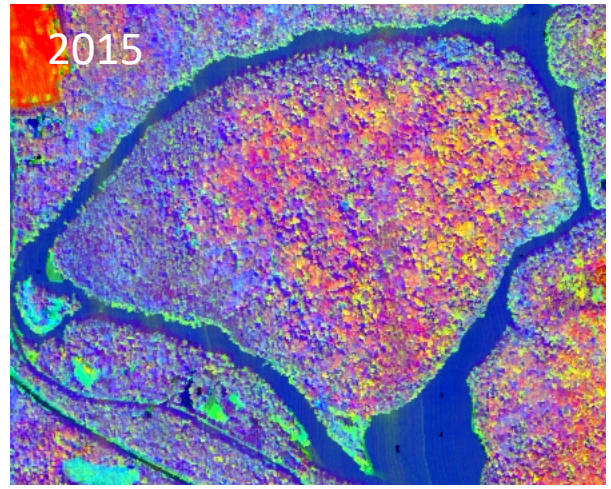
CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY

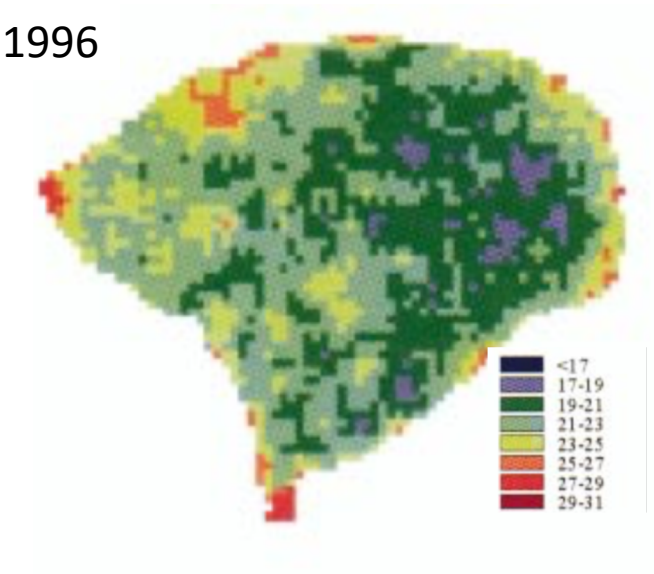
CHARLES A. SHULL

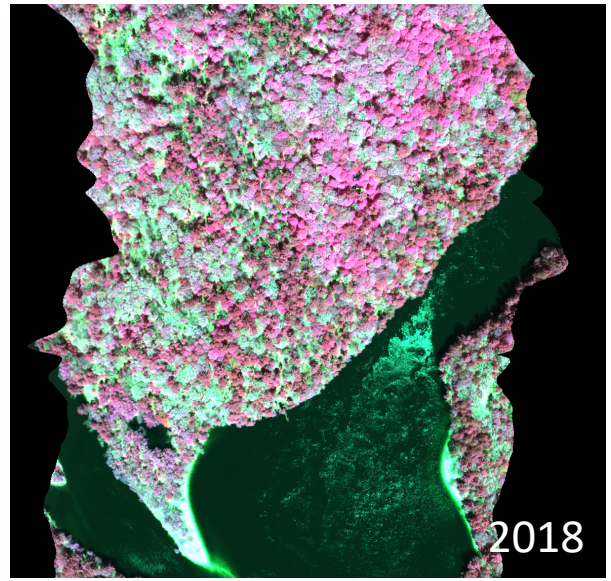


Gates et al. 1965









We've come a long way. With spaceborne imaging spectroscopy, we will be able to measure vegetation function and its variability globally, and through time.

Thank you!

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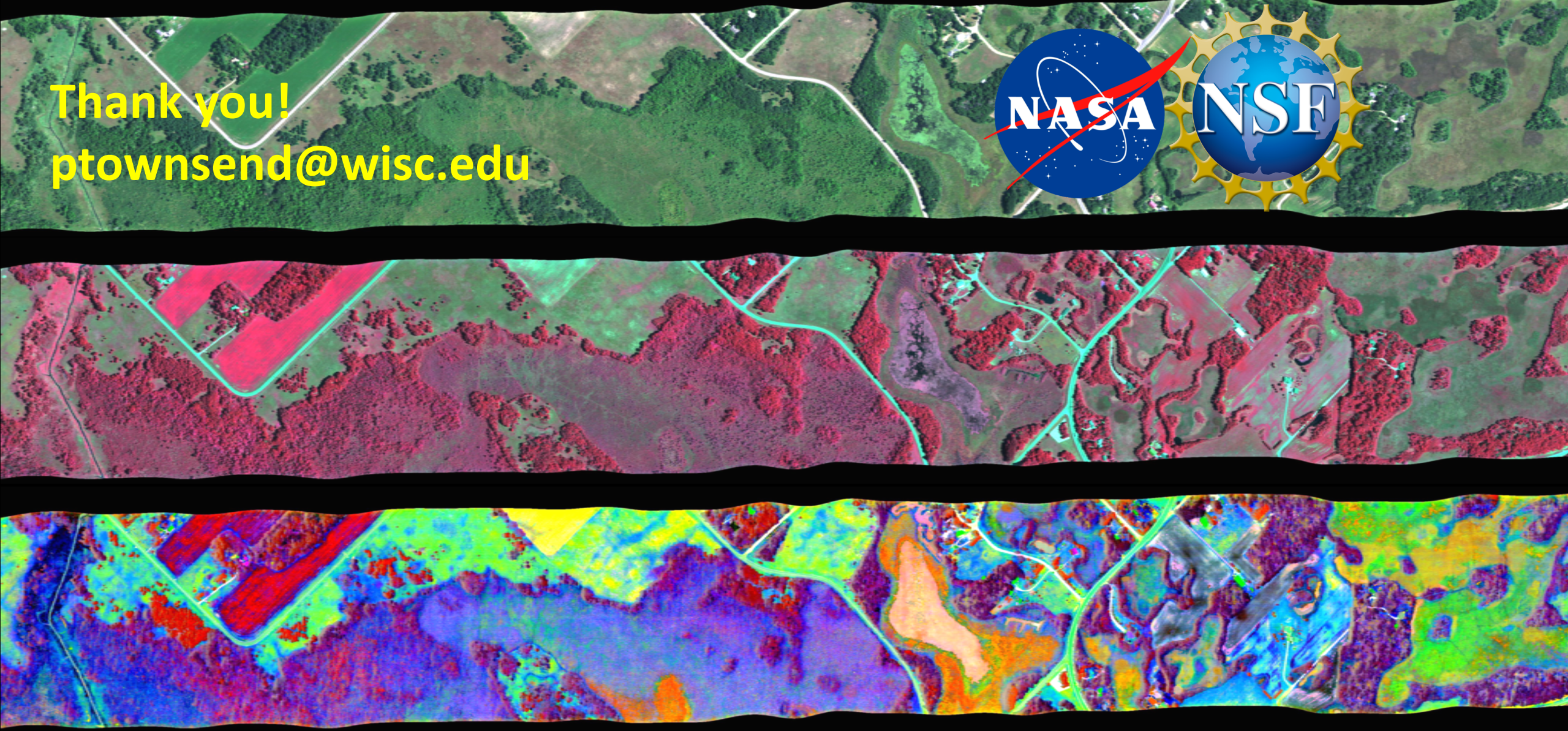

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