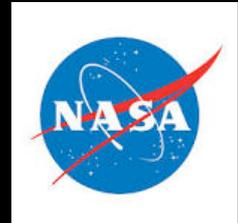
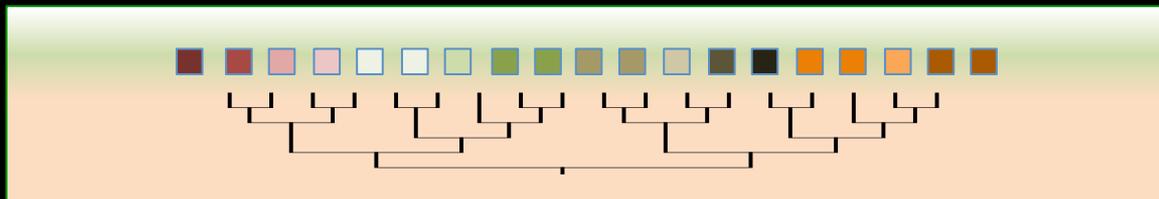
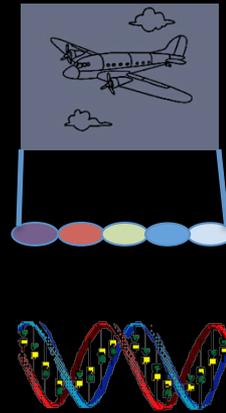


Linking remotely sensed optical diversity to genetic, phylogenetic and functional diversity to predict ecosystem processes

Dimensions of Biodiversity Team PIs



DEB
1342872

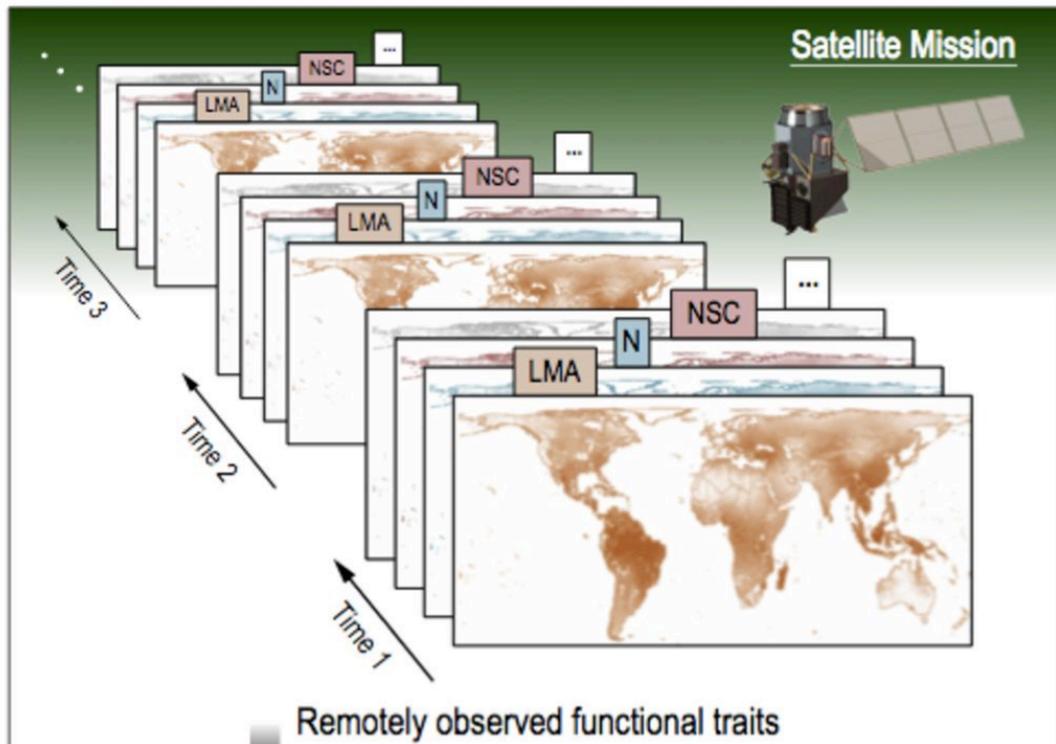


How well can we remotely and spectrally detect the diversity of plants on Earth?



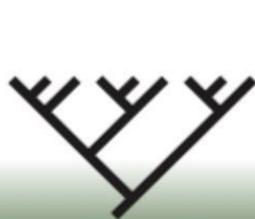
Needed: Integration of remote and in situ biodiversity measurements

Global Biodiversity Observatory



Integration

In-situ biodiversity observations



Phylogenies

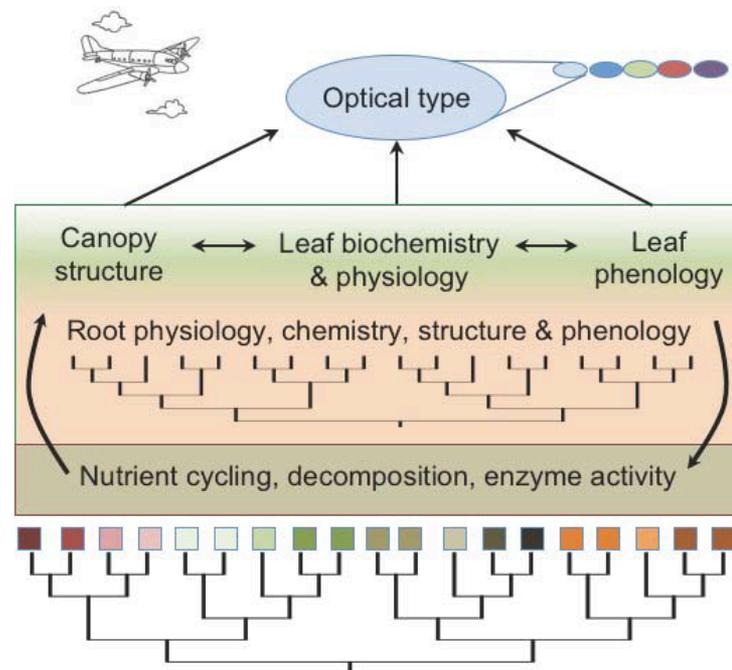


Trait measurements



Species distributions

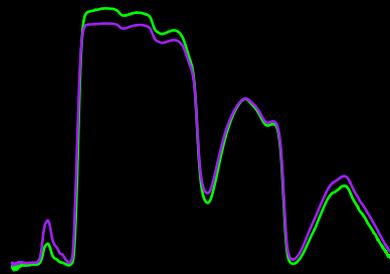
NCEAS Working Group "Observing Biodiversity from Space," Jetz, et al 2016



- Detecting plant diversity, chemistry and function in terrestrial systems
 - Diversity experiments
 - Naturally assembled communities



- Locating plant taxa in the tree of life using hyperspectral data



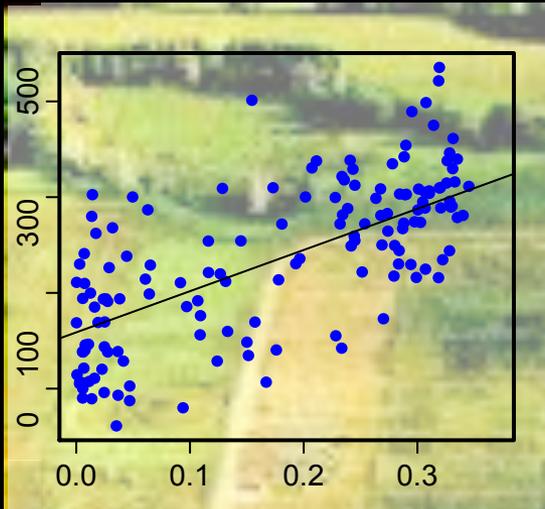
Start with manipulated diversity experiments in prairie and forest



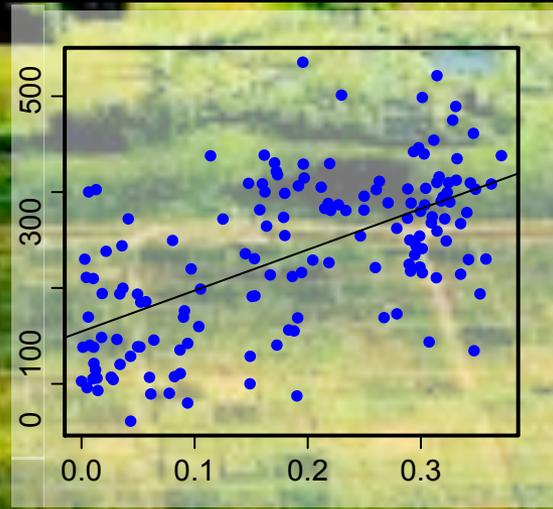
Diversity begets productivity

Productivity ($\text{g m}^{-2} \text{yr}^{-1}$)

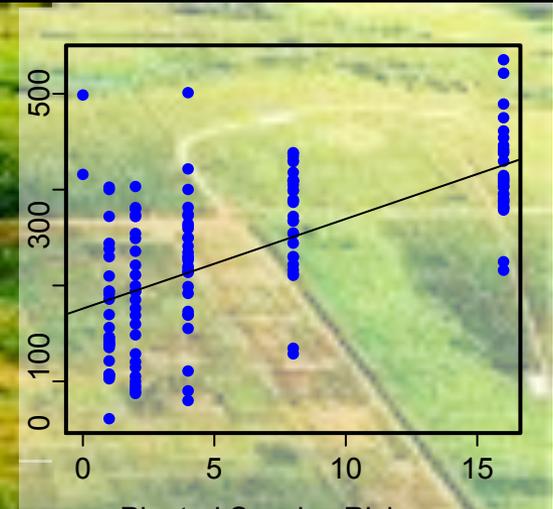
Phylogenetic Evenness



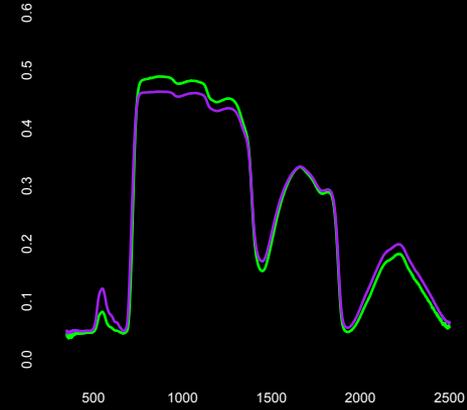
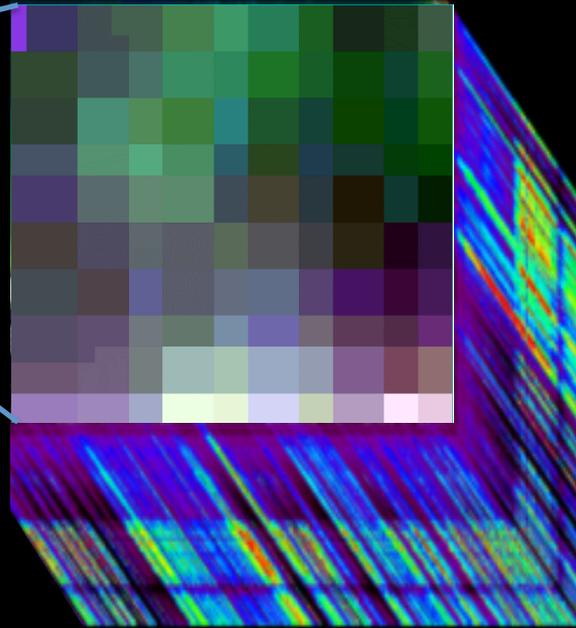
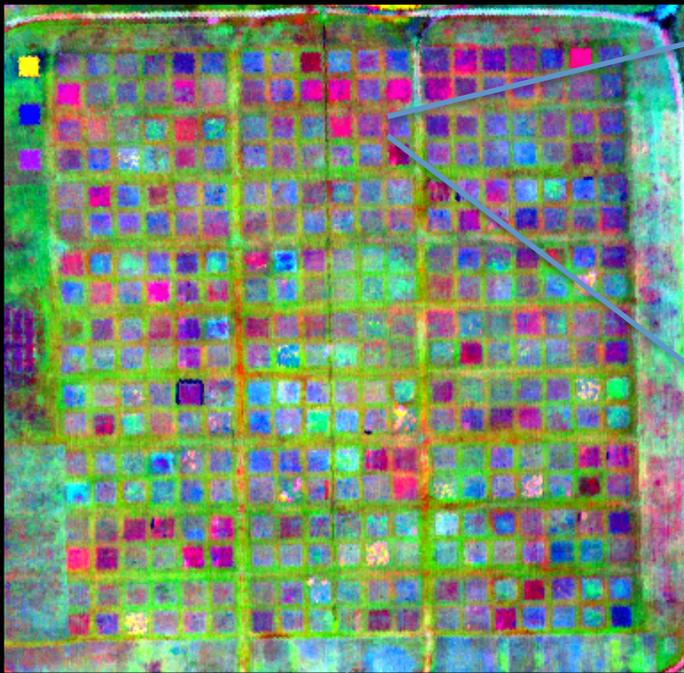
Functional Evenness



Species Richness



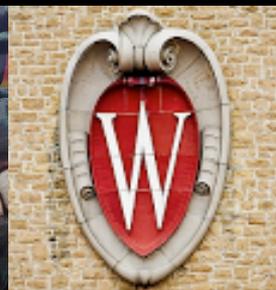
20 year Biodiversity (BioDIV) Experiment - Cedar Creek LTER



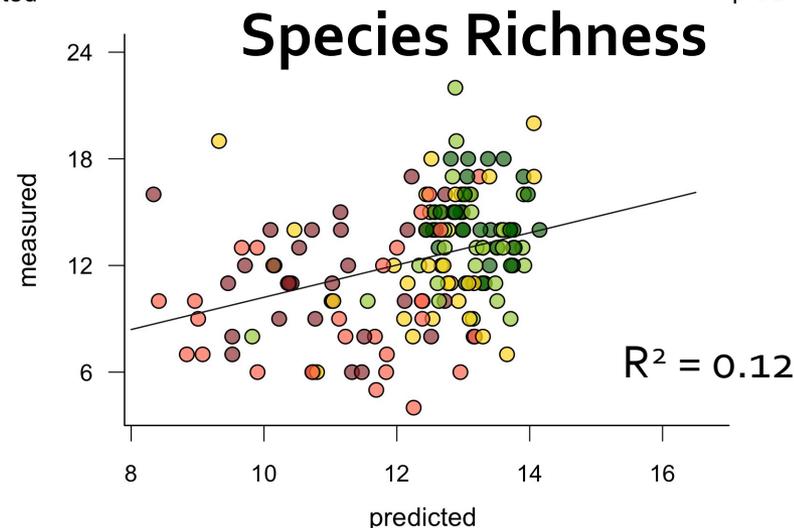
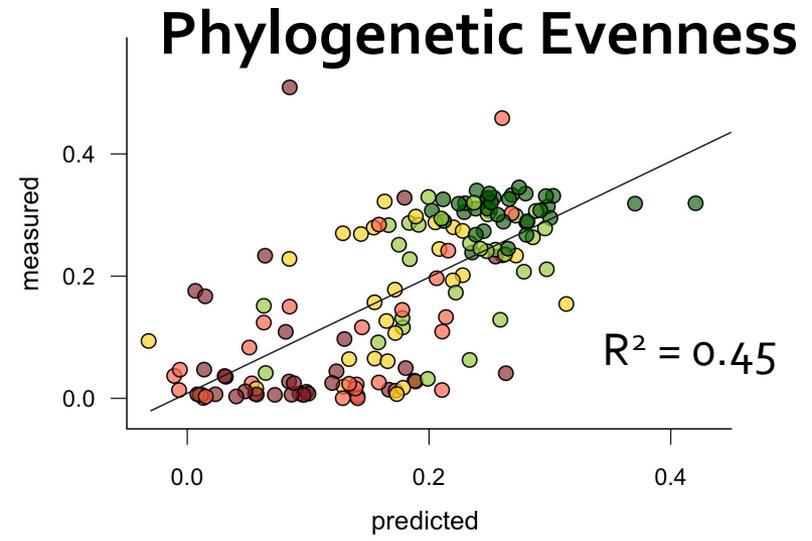
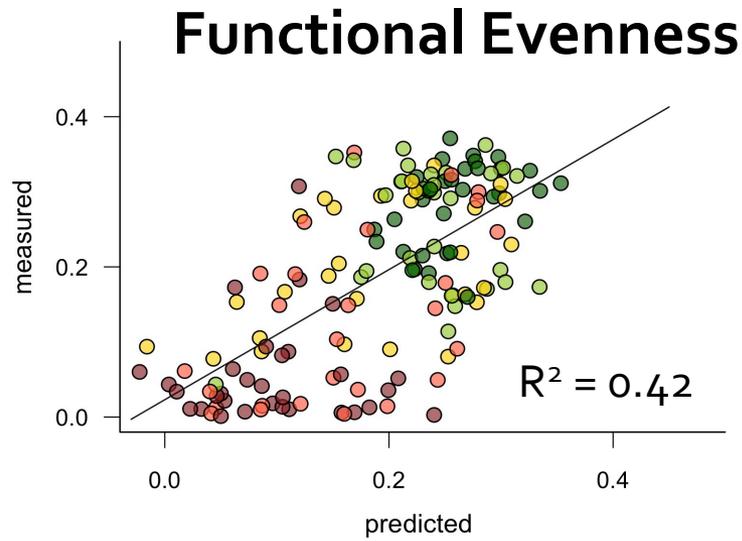
AVIRIS

Airborne Visible / Infrared Imaging Spectrometer

upwelling spectral radiance in 224 contiguous spectral channels, 400 to 2500 nanometers (nm)



We can significantly predict diversity from AVIRIS data using PLSR
...but functional and phylogenetic diversity are better predicted than species richness



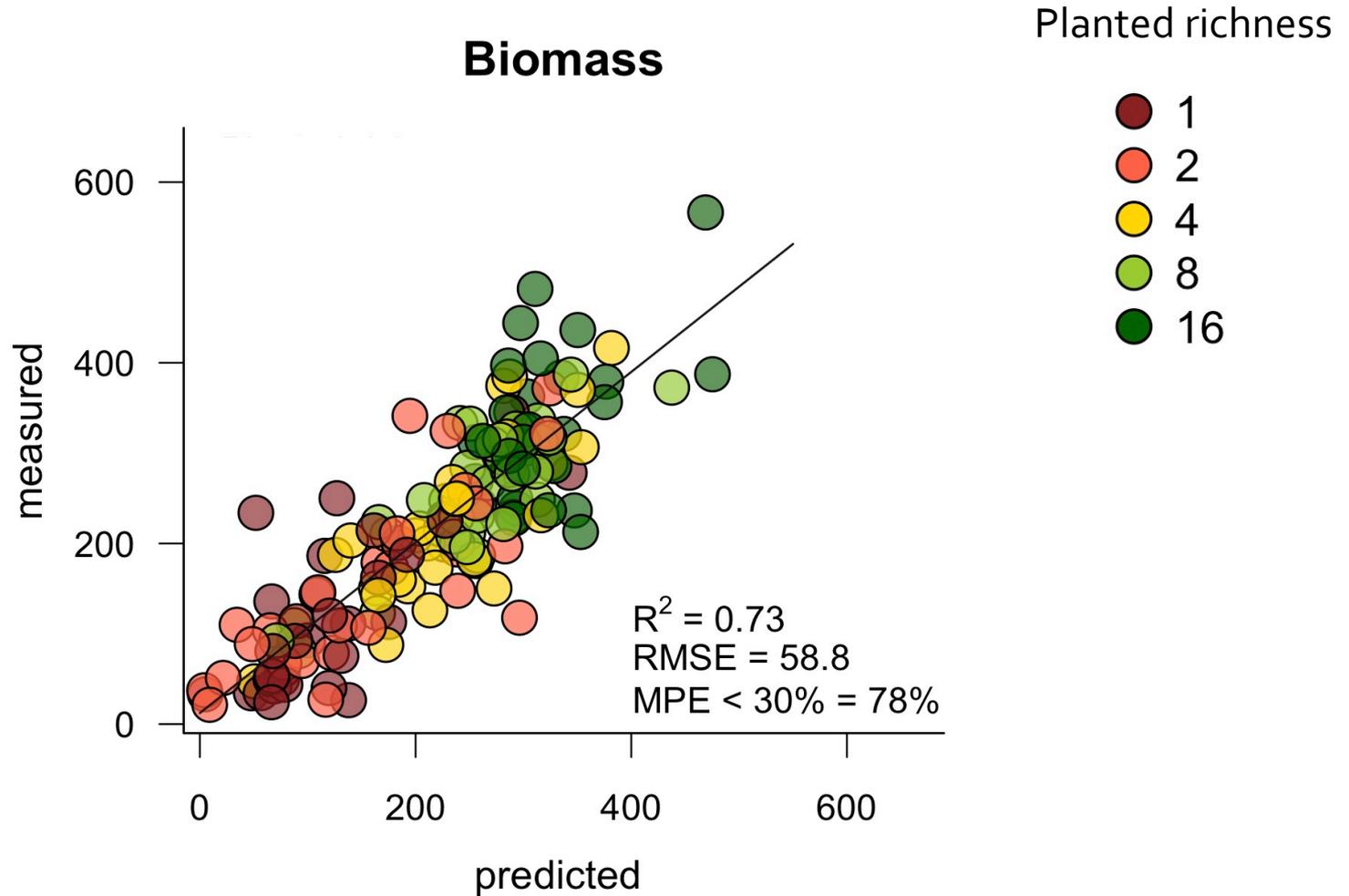
Planted richness

- 1
- 2
- 4
- 8
- 16

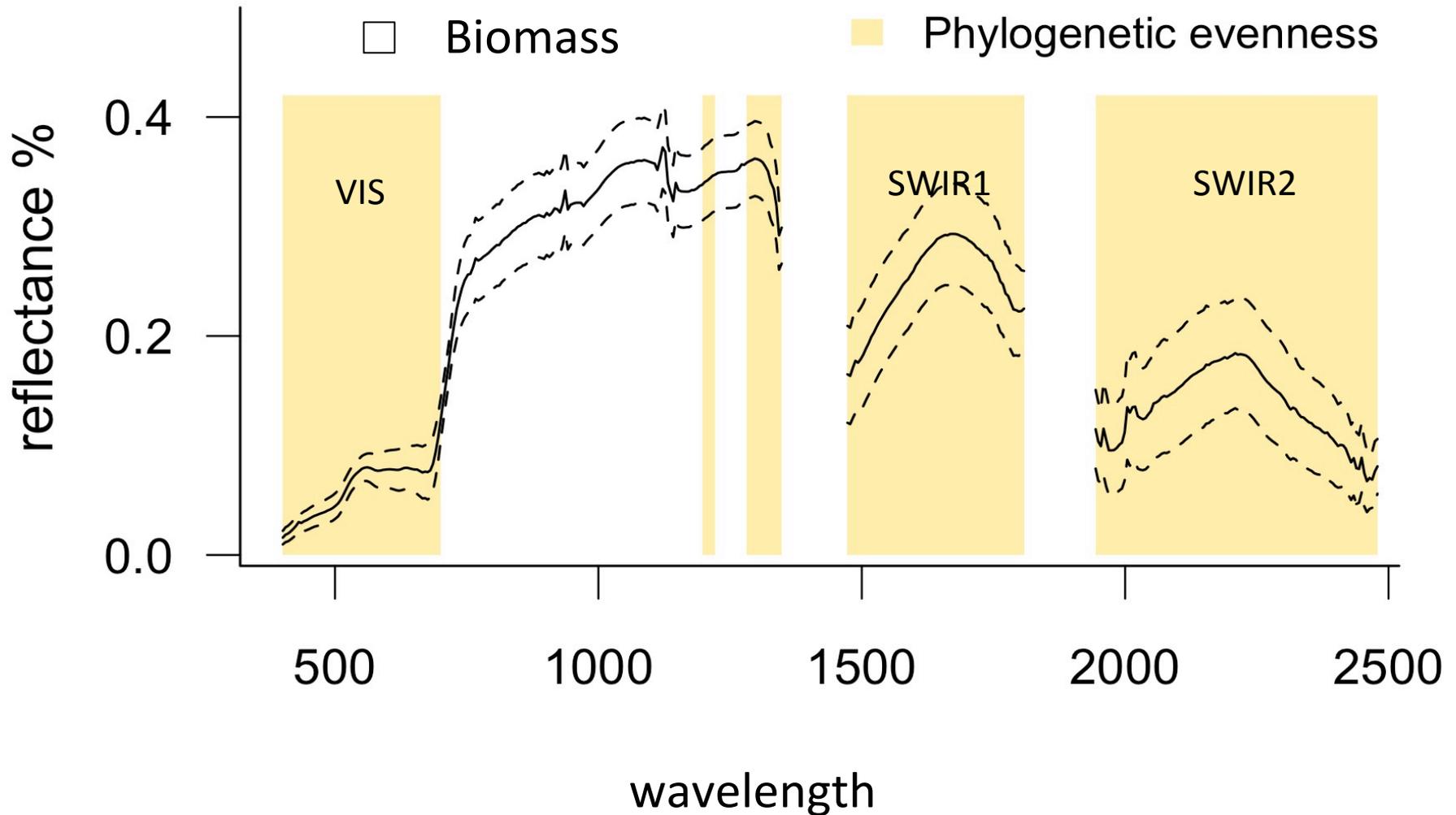


Anna Schweiger

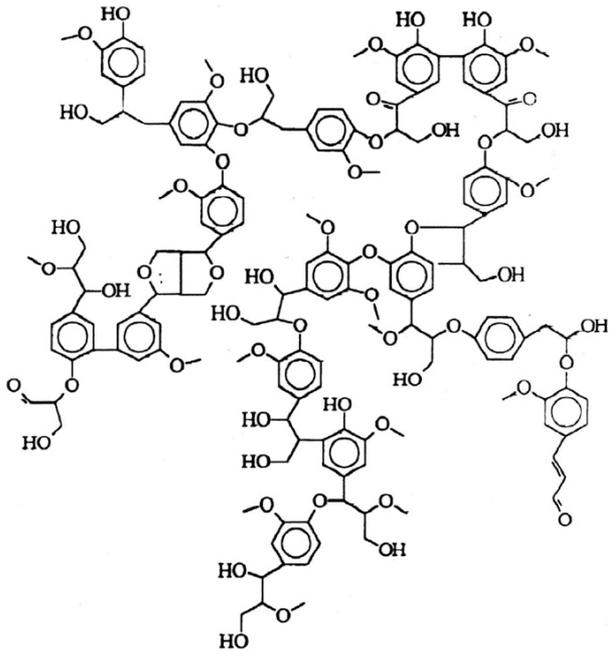
Biomass is predicted better than diversity in this system



Multilevel models show biomass and diversity are most strongly detected in different parts of the spectrum

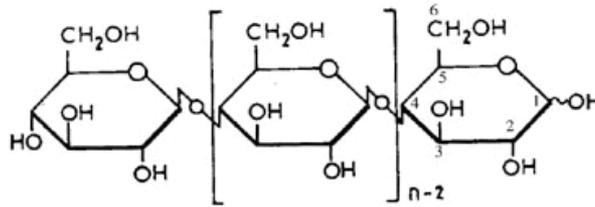


Leaf chemistry influences root and litter chemistry -> affects ease of degradation and consumption by microbes

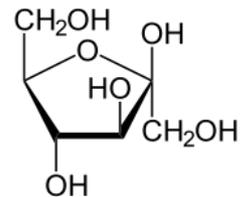
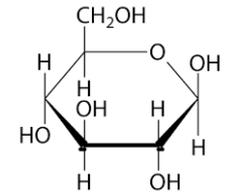


Lignin

Hard to degrade



Cellulose



Soluble sugars

Readily consumable



Remote Detection



Vegetation chemistry

Diversity (SR, PE, FE)
Composition

Productivity

aboveground

Plant community structure and function

belowground

Root Chemistry

Productivity

Soil Organic Matter Quantity and Quality

Diversity and Composition

Biomass and enzyme activity

microbial community structure and function

Remotely sensed above ground traits/ chemistry predicts below ground processes

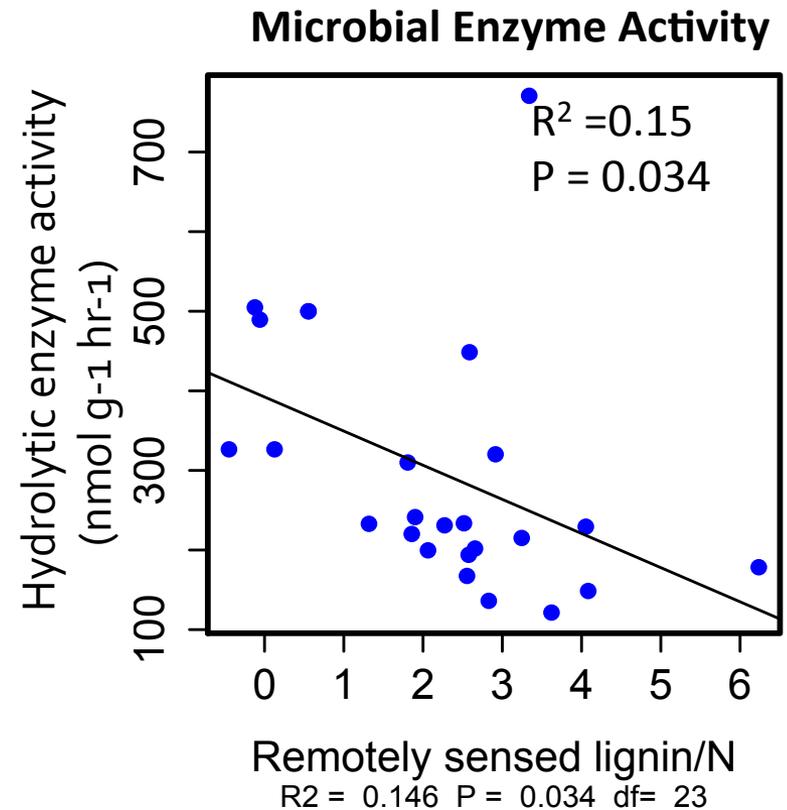
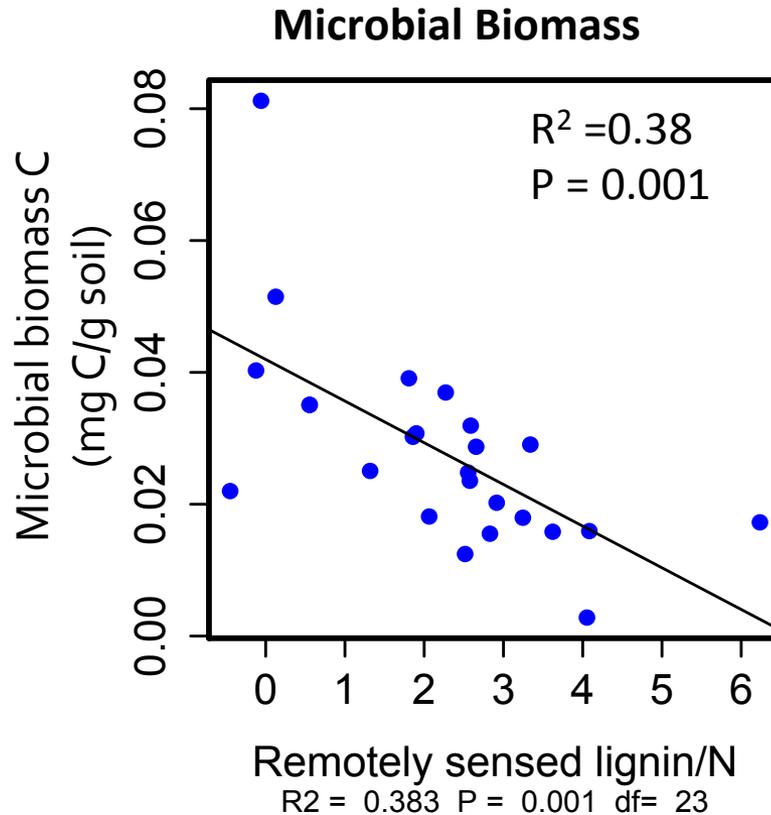
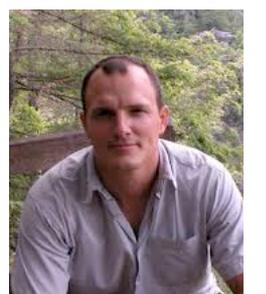
Sarah Hobbie



John Couture



M. Madritch



Lignin/N

Remotely sensed above ground traits/ chemistry predicts below ground processes

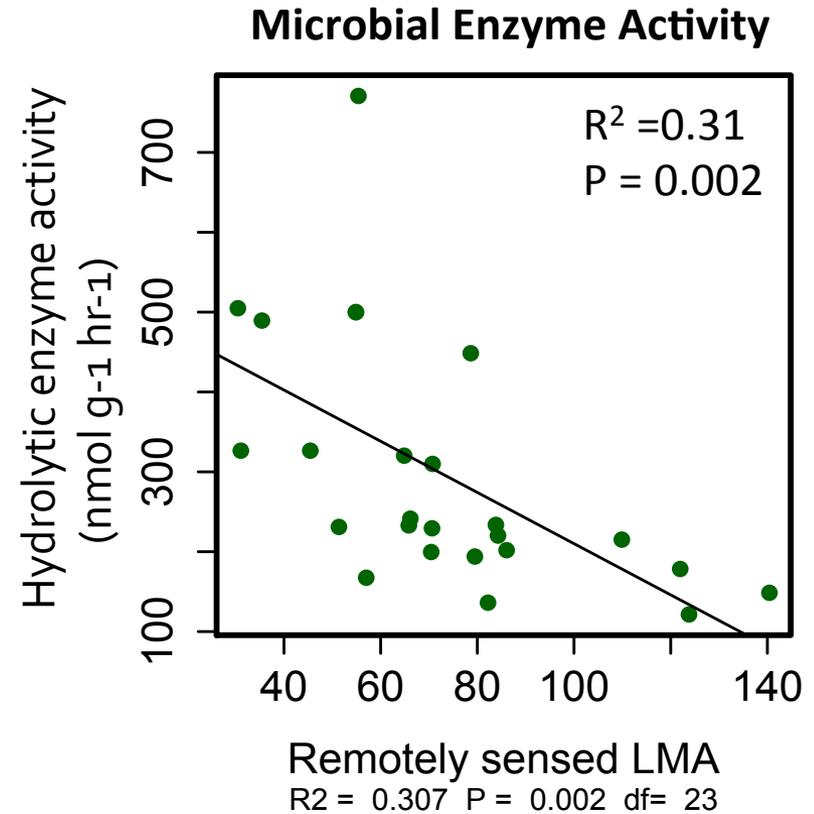
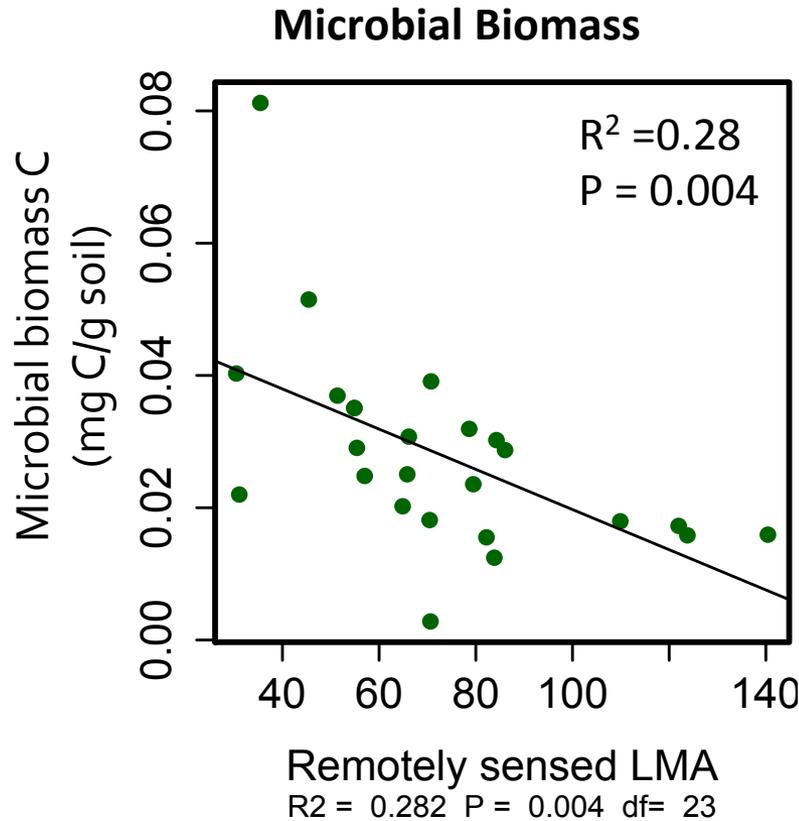
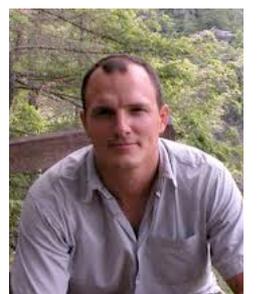
Sarah Hobbie



John Couture

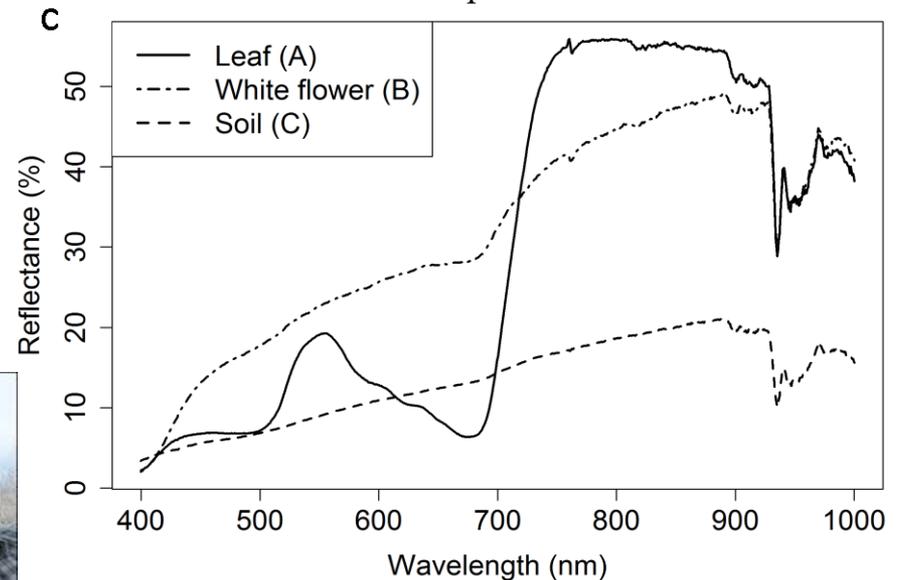
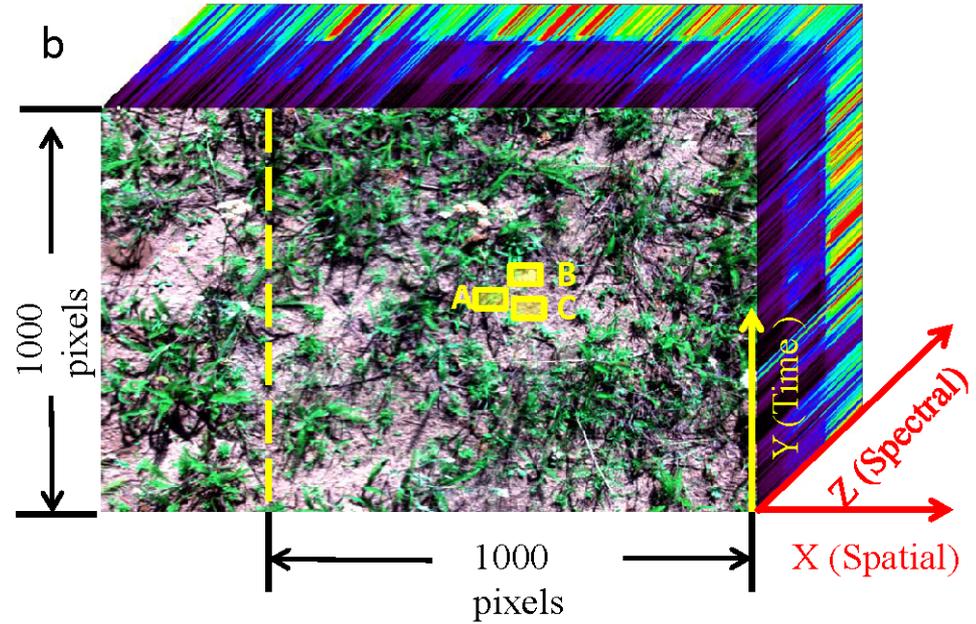
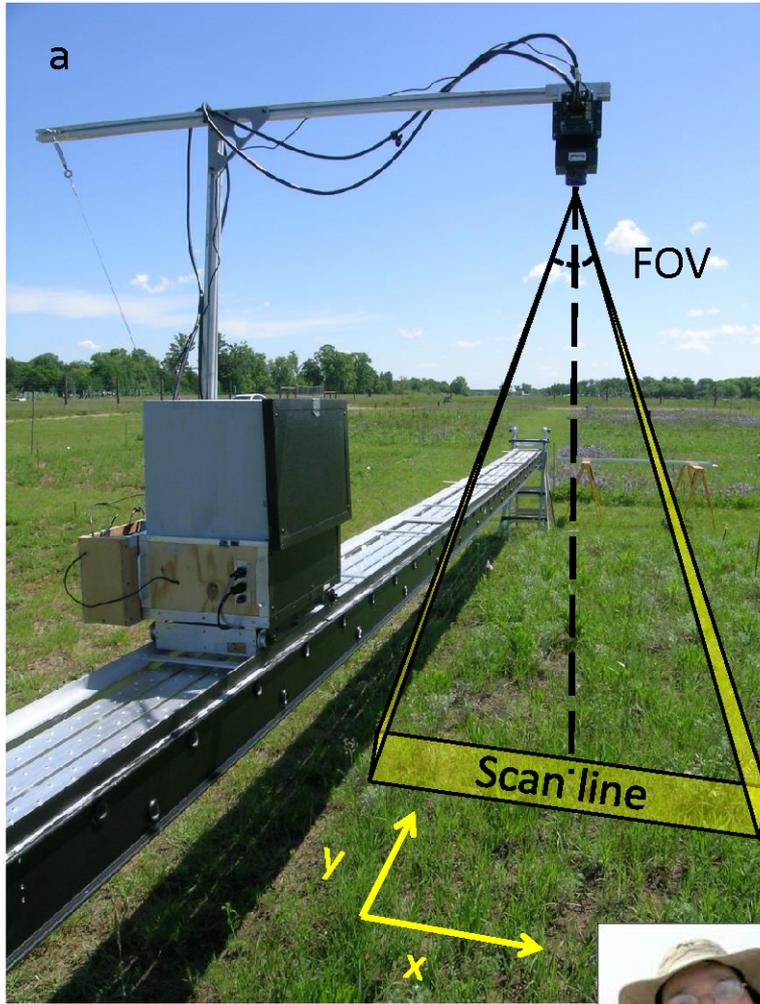


M. Madritch



Leaf mass per area

How well can we simulate the community from leaves?

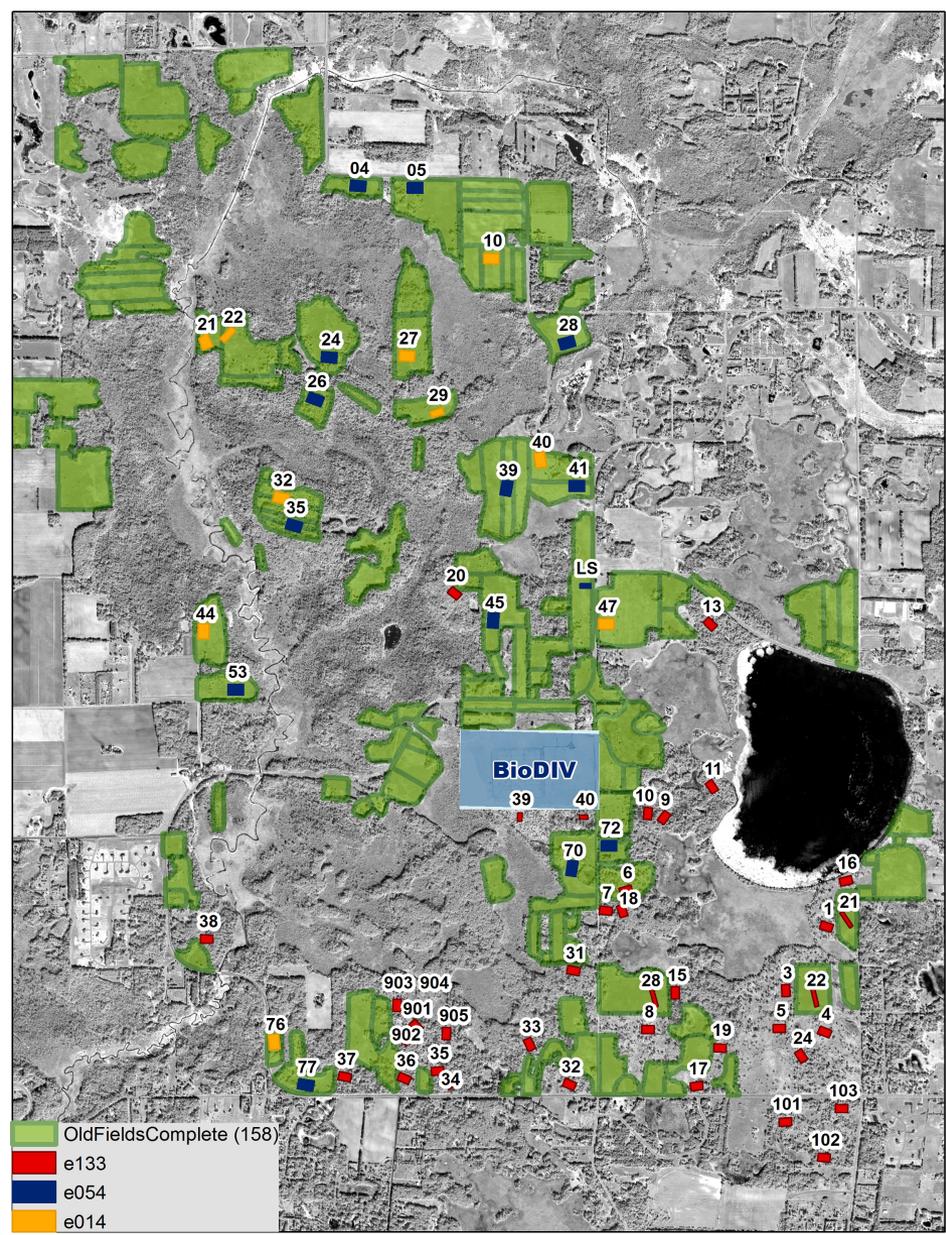


Wang, Gamon et al in prep

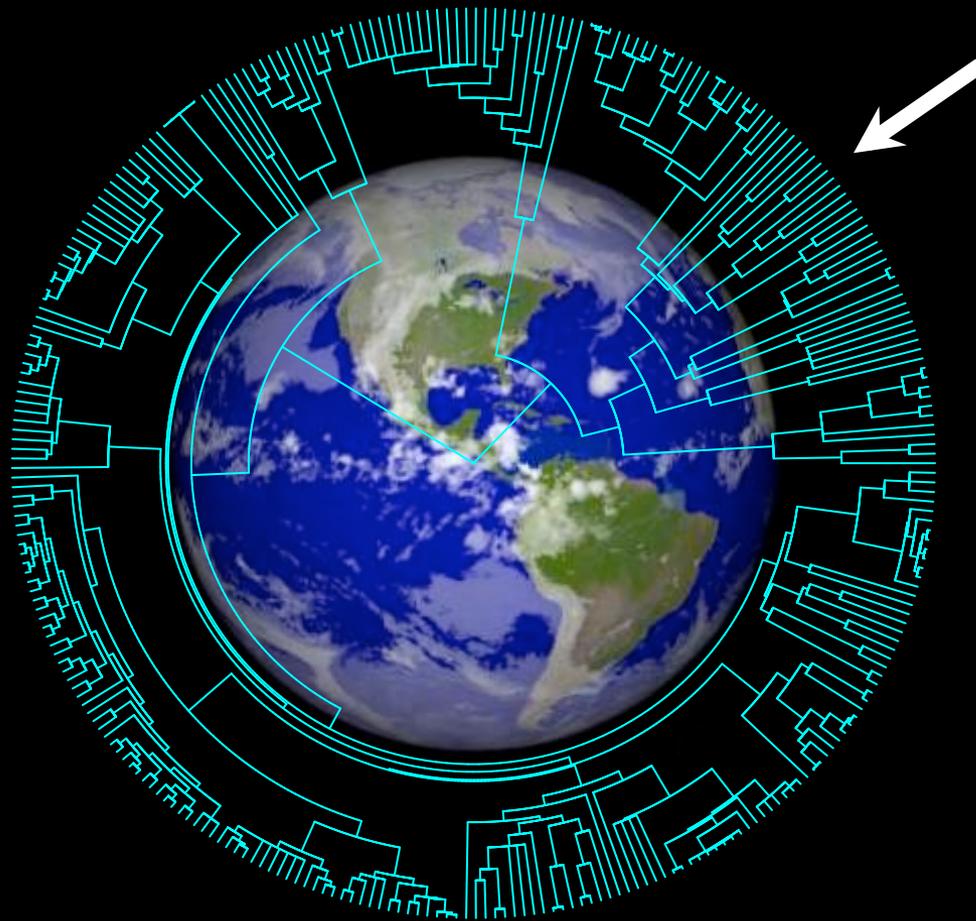


Testing models in naturally assembled grasslands

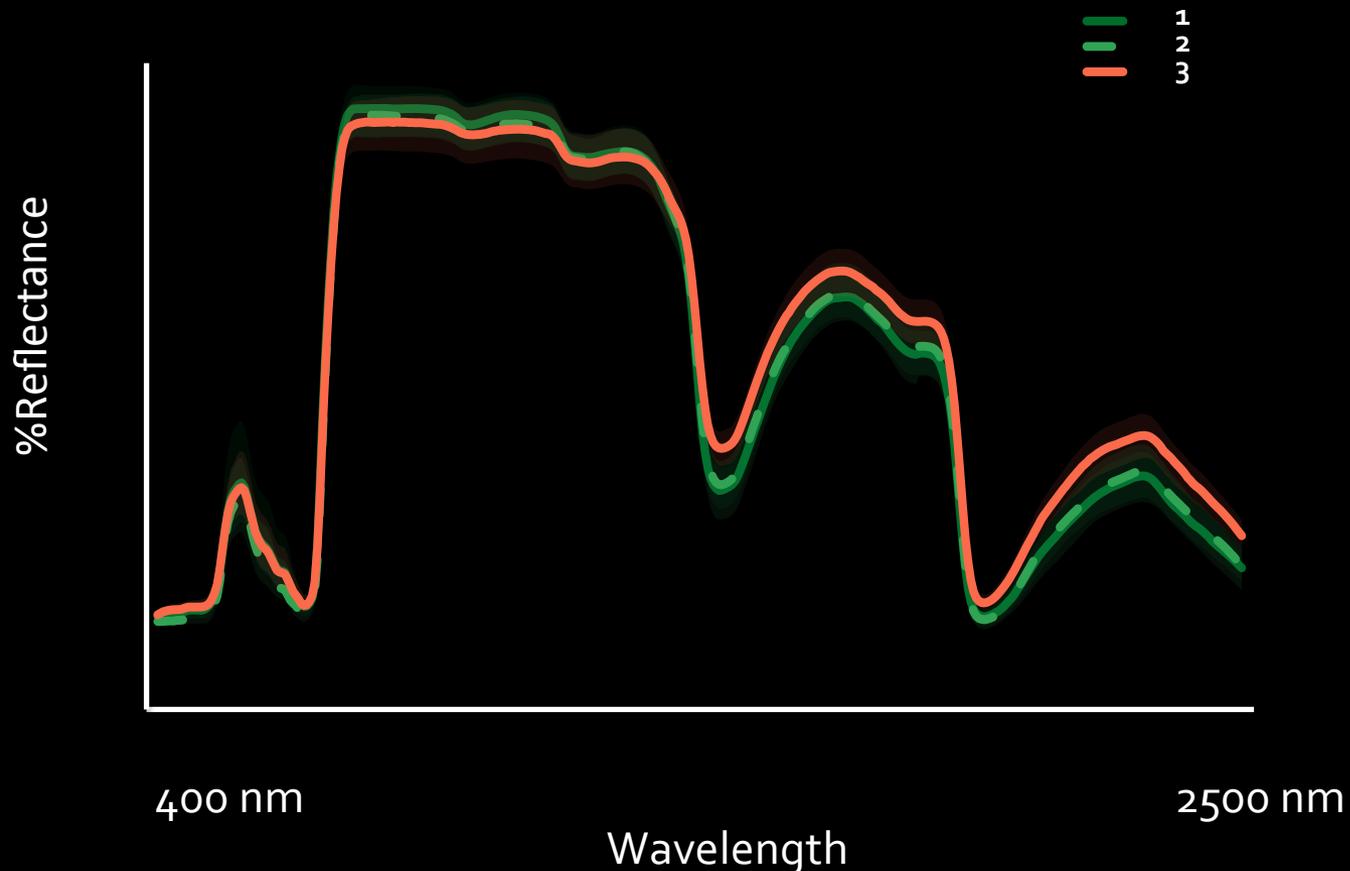




Locating taxa in the tree of life using spectra

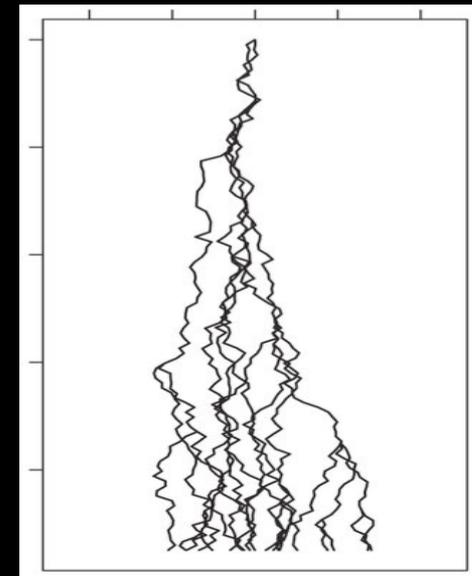
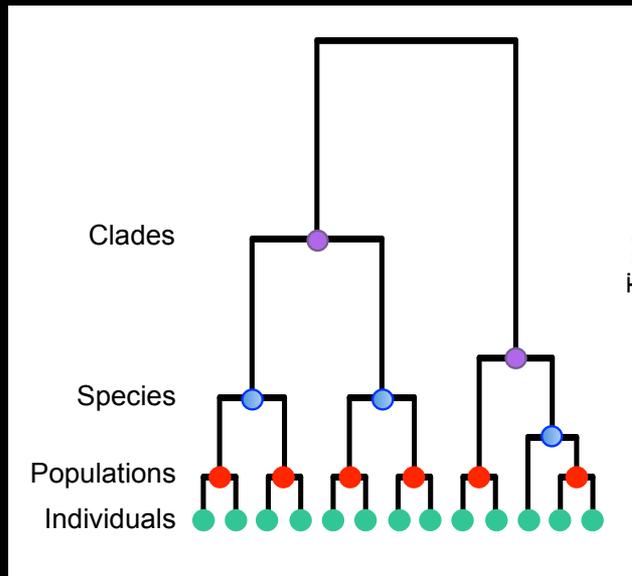


Spectral properties differ among taxa -
We suspect that even small differences can differentiate
taxa given the high dimensionality of the data



Hypothesis

The hierarchical organization of plant diversity that results from evolutionary history provides a framework for predicting spectral similarity of organisms.



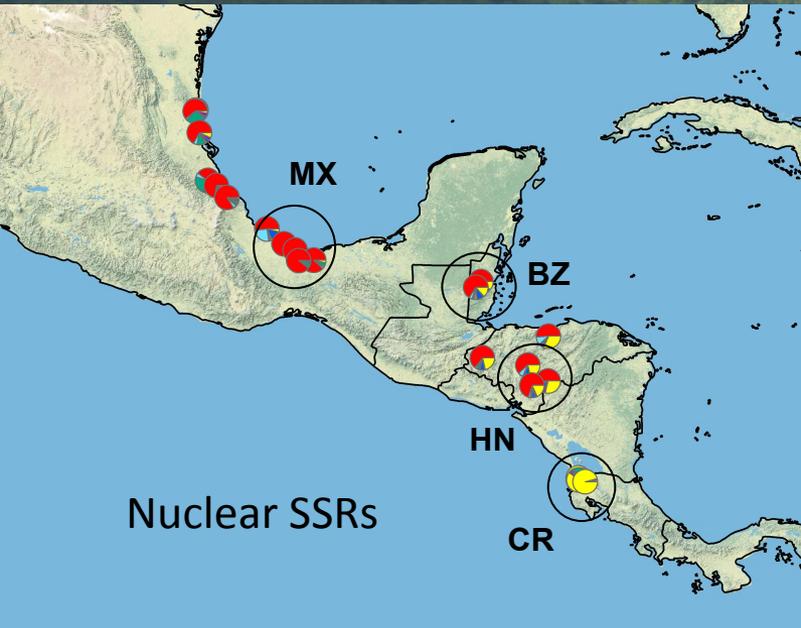
Four populations planted in common gardens in Honduras and Costa Rica

Mexico (MX)

Belize (BZ)

Honduras (HN)

Costa Rica (CR)



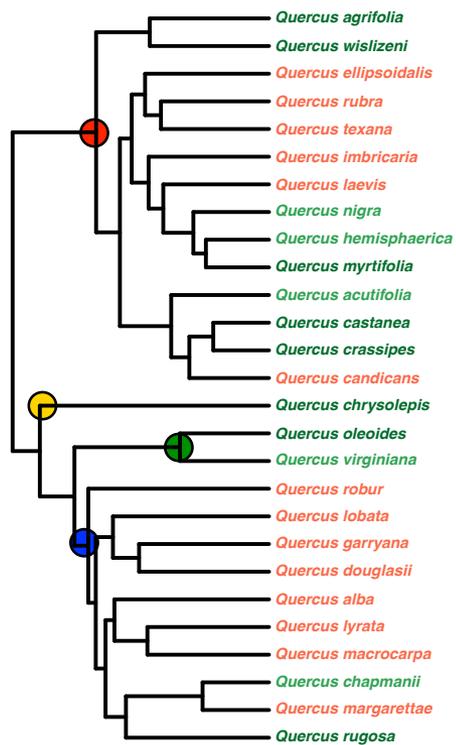
Many species within the oak genus grown in a common greenhouse environment



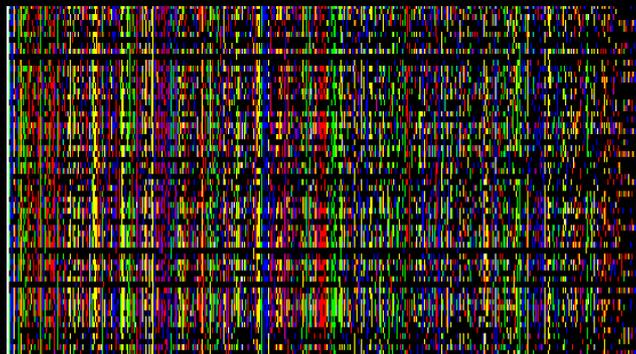
Matt Kaproth
UMN



RADseq phylogeny

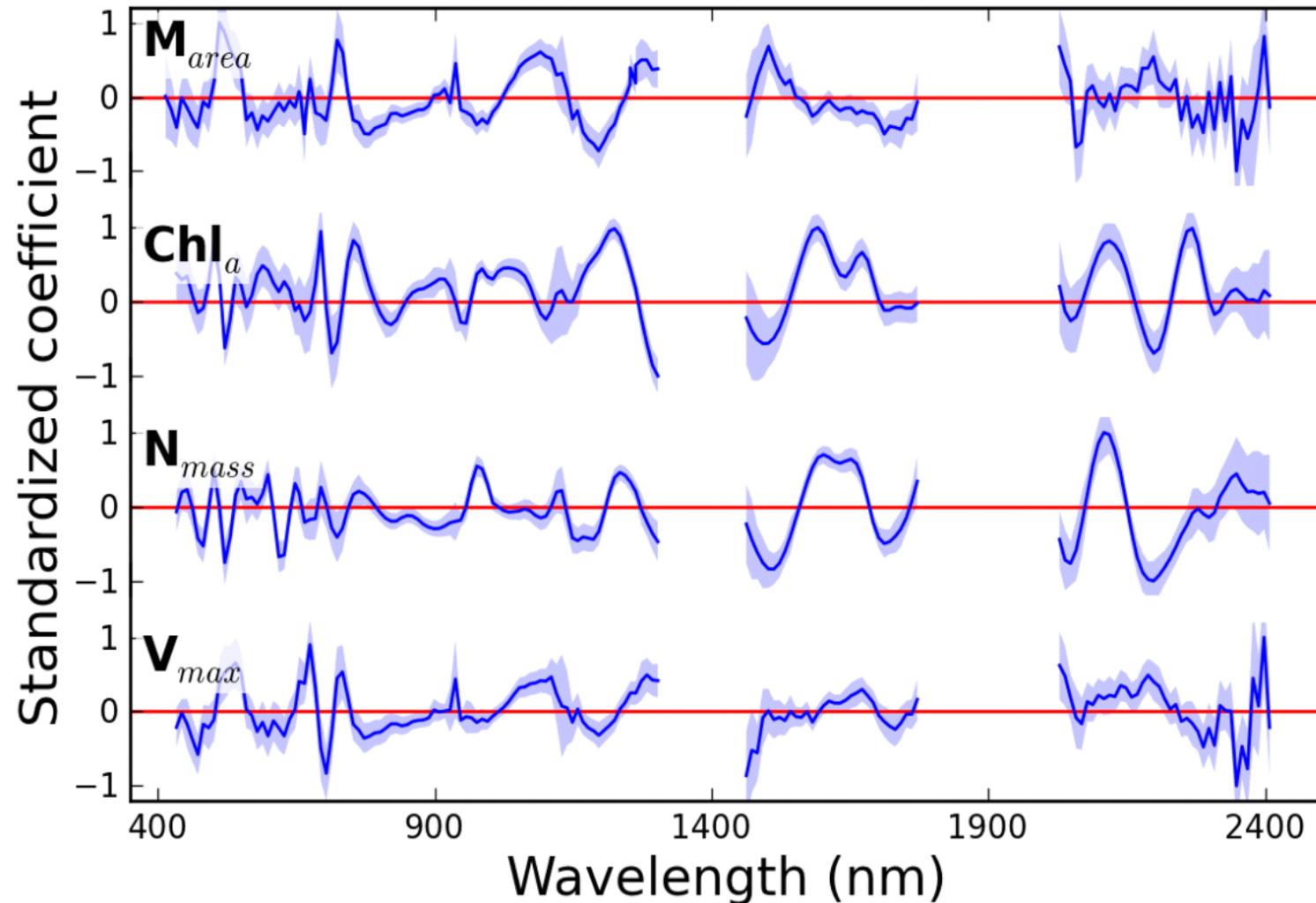
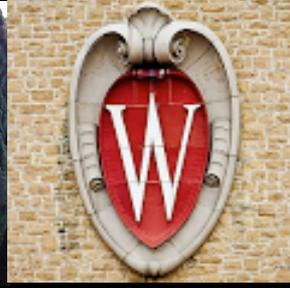


José Meireles

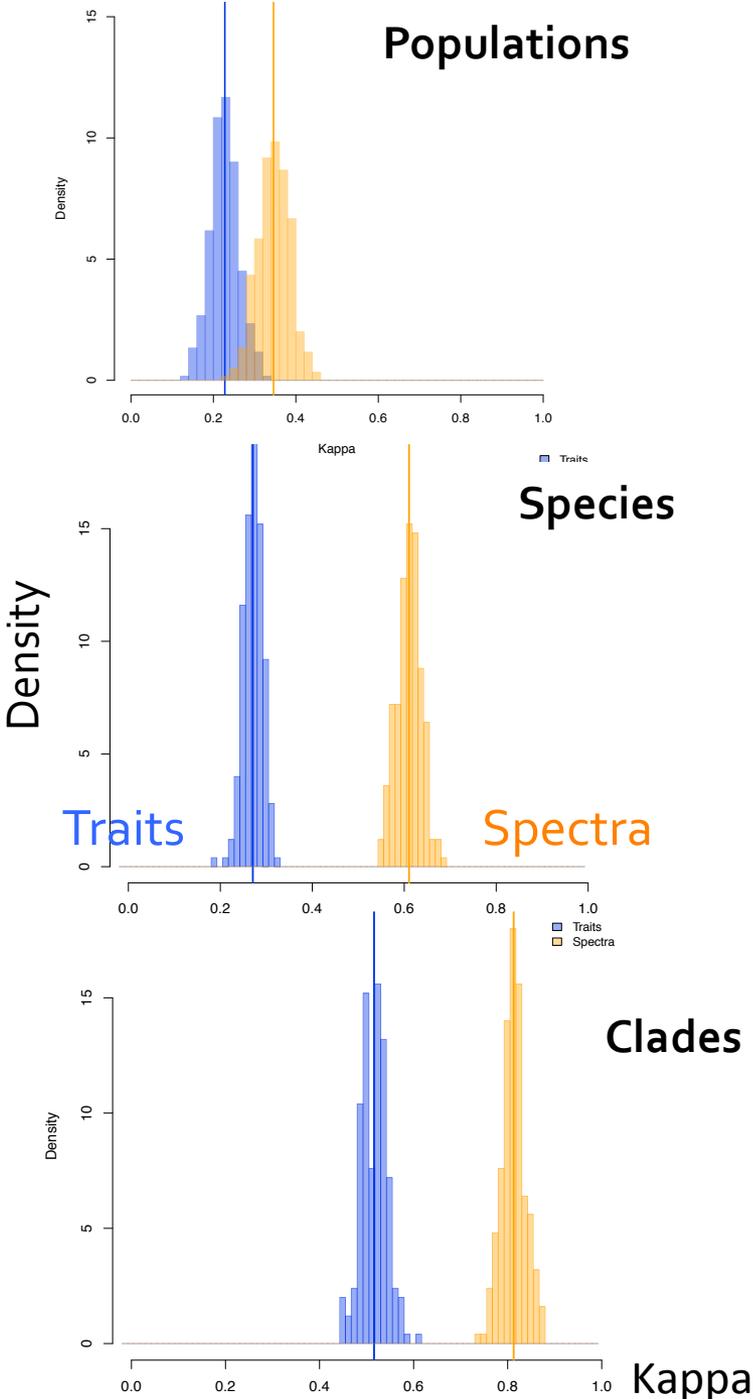


Optical and remote detection of functional traits

Phil
Townsend



PLS-DA validation models for traits and spectra

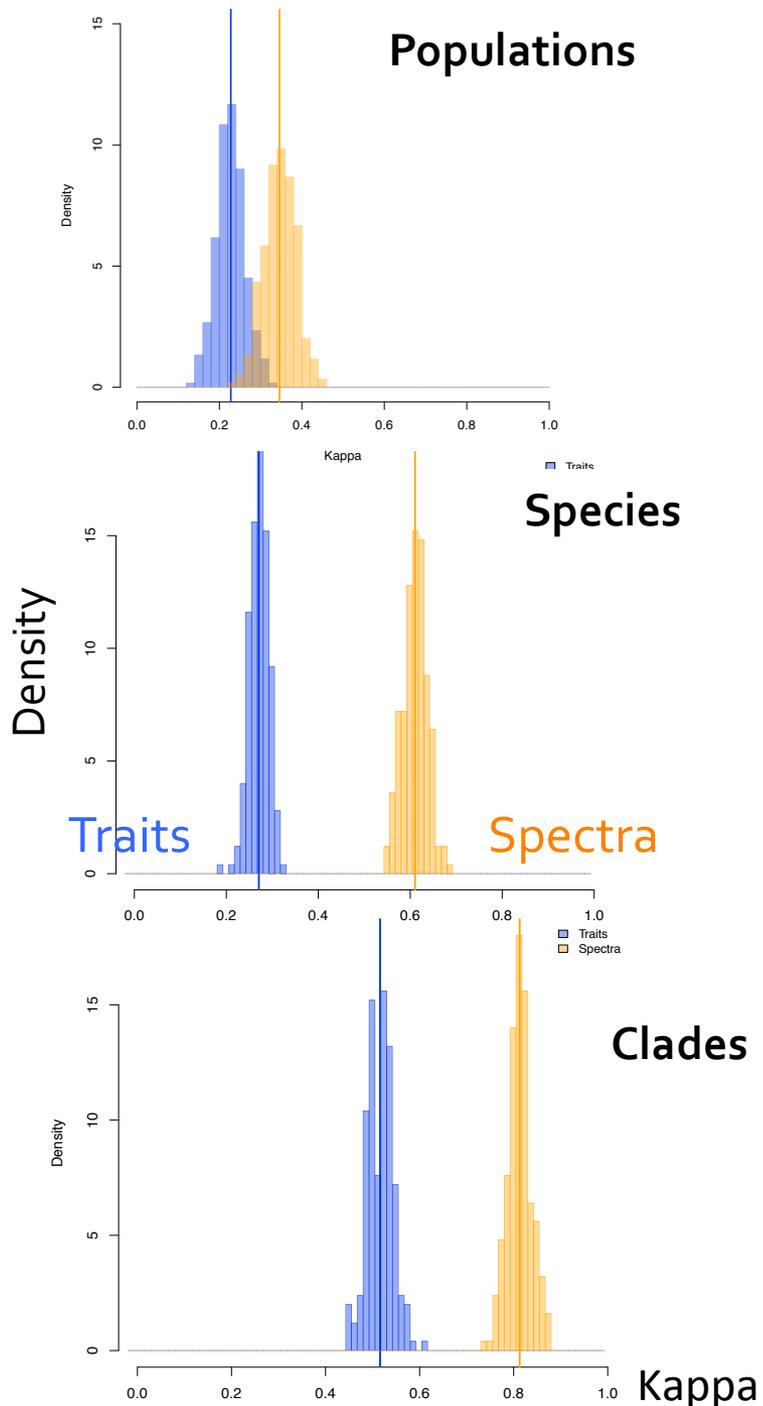


greater accuracy in classification with increasing hierarchical levels of biological organization

Assignment accuracy →



PLS-DA validation models for traits and spectra



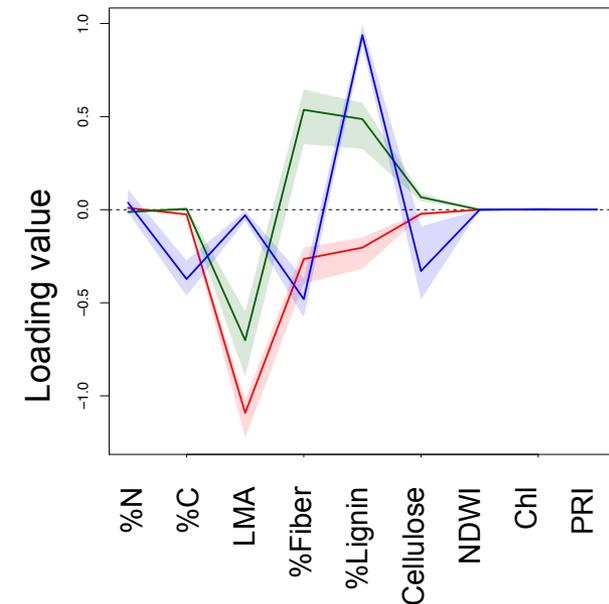
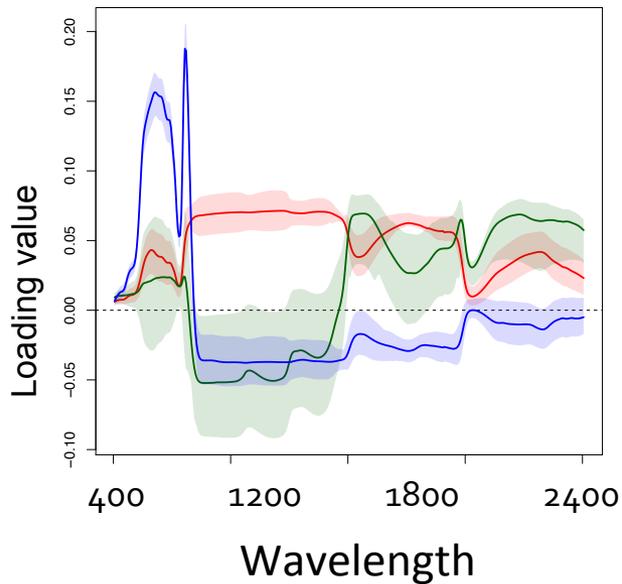
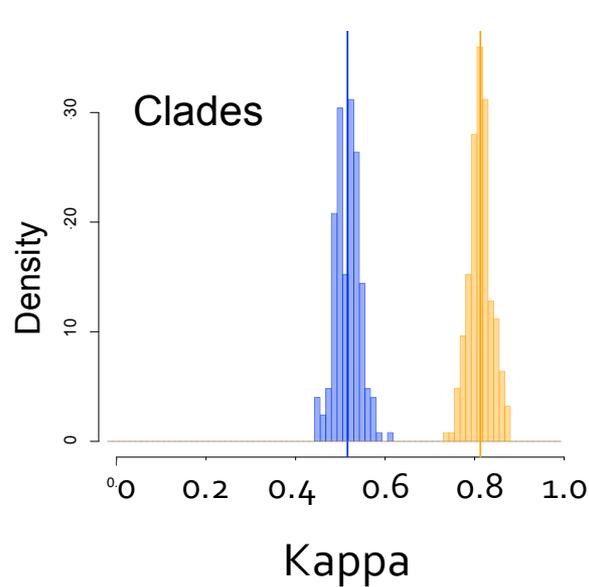
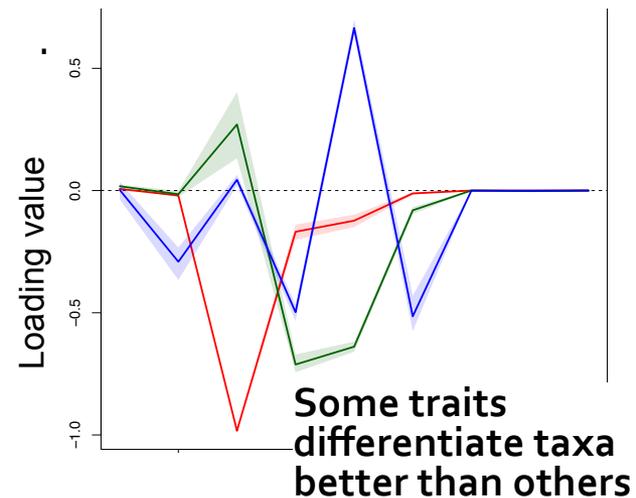
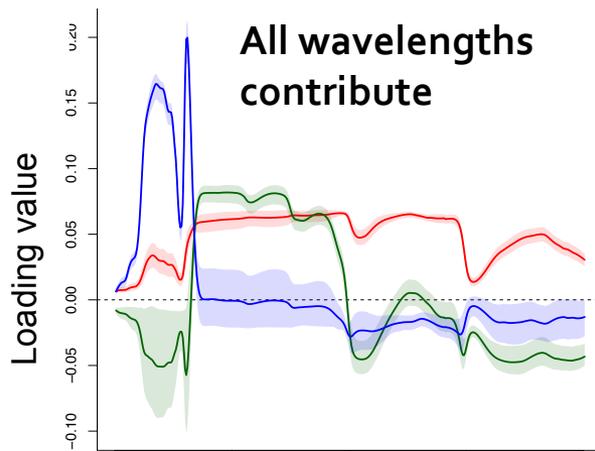
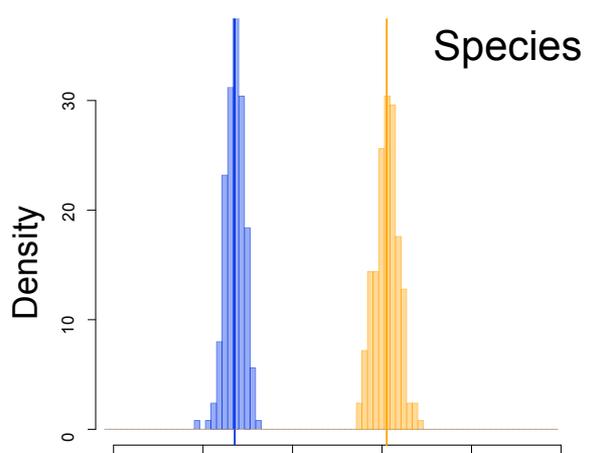
Spectra always discriminate taxa with higher accuracy than **traits**

Assignment accuracy →

Here is why....

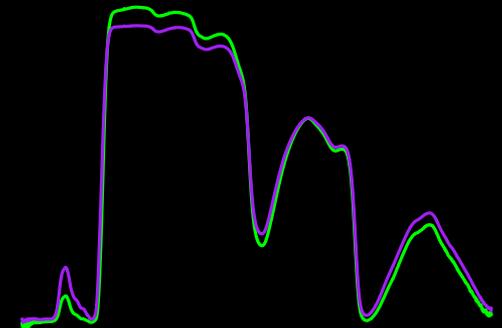
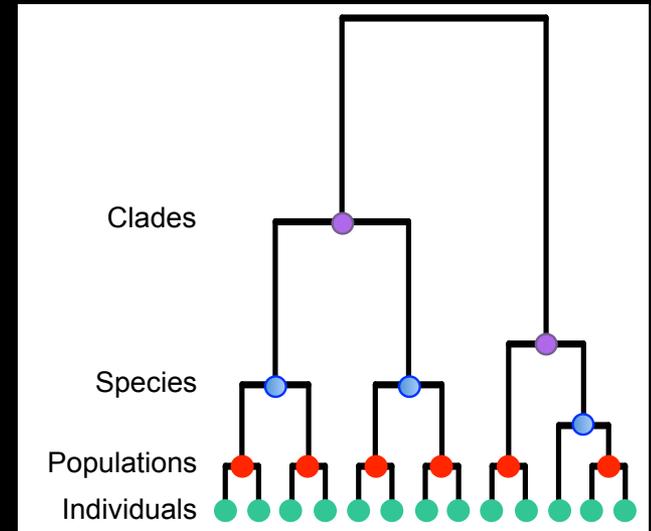
Spectra

Traits



PLS-DA loadings for first 3 components

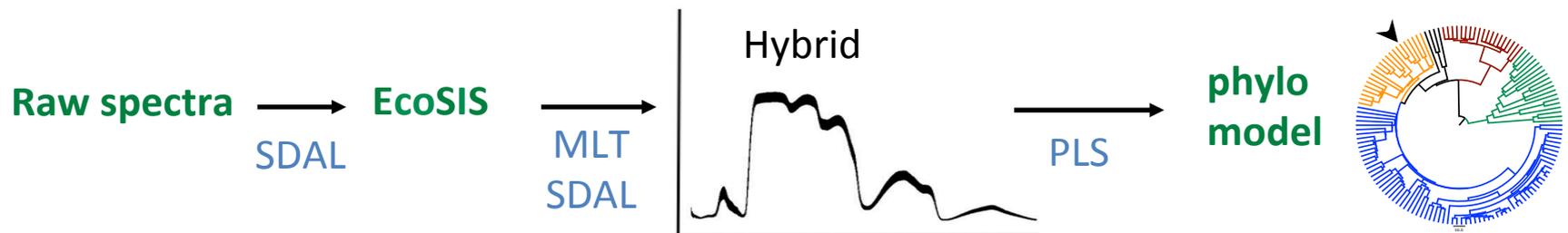
- Accuracy of classifying biological units increases through the hierarchy of plant diversity from *populations* < *species* < *clades* (.... in this system)
- *Full spectra* provide greater accuracy than *traits* derived from spectra for classifying taxa
- demonstrates potential to use the tree of life to remotely detect taxa

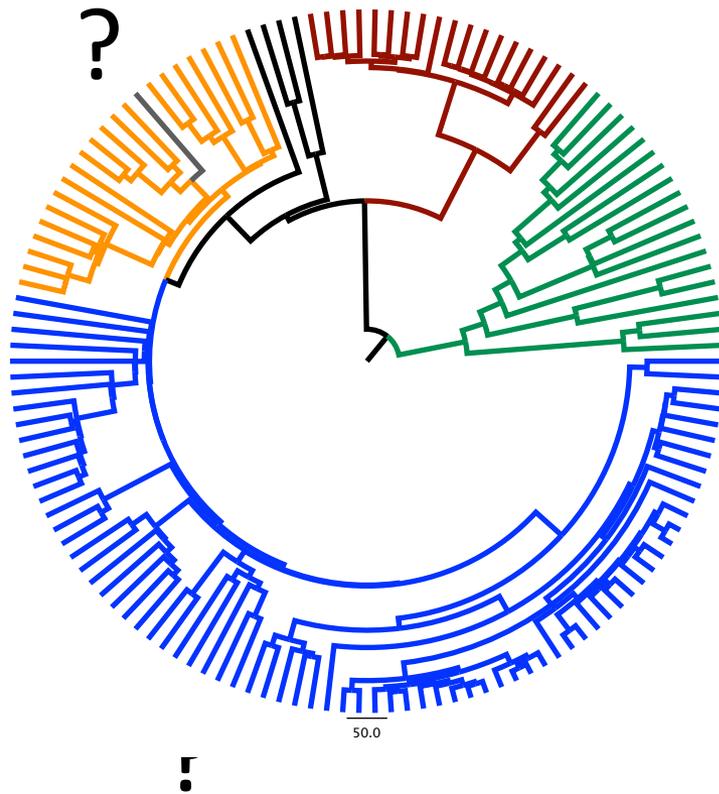


NIMBioS Working Group: Remotely Sensing Biodiversity

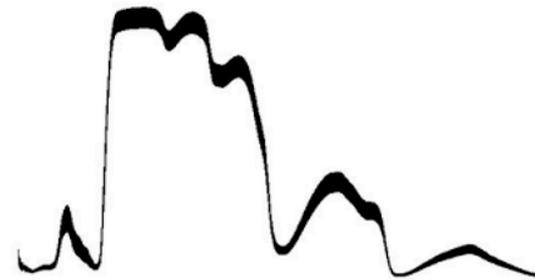


NIMBioS



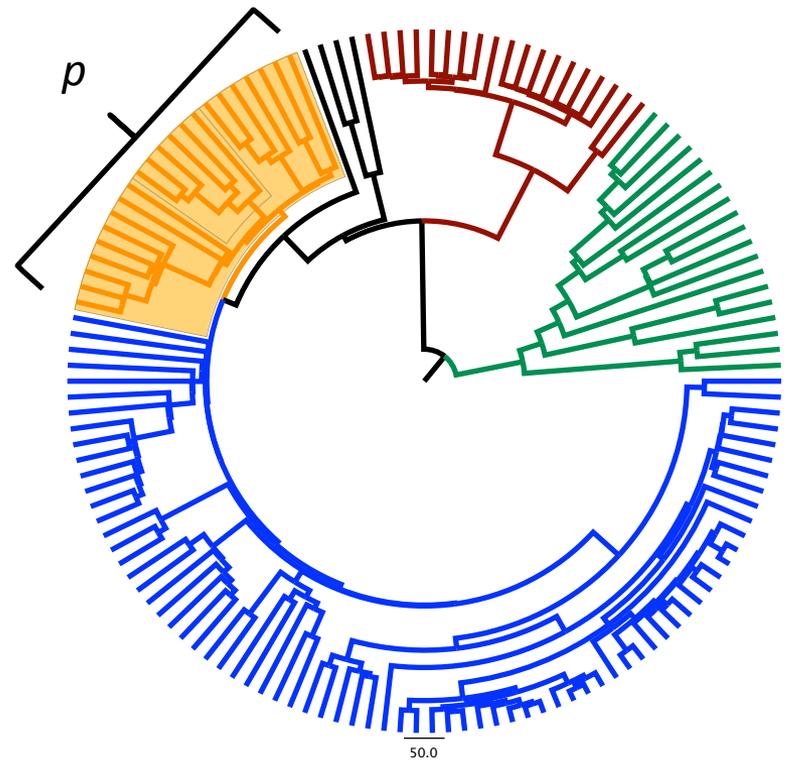
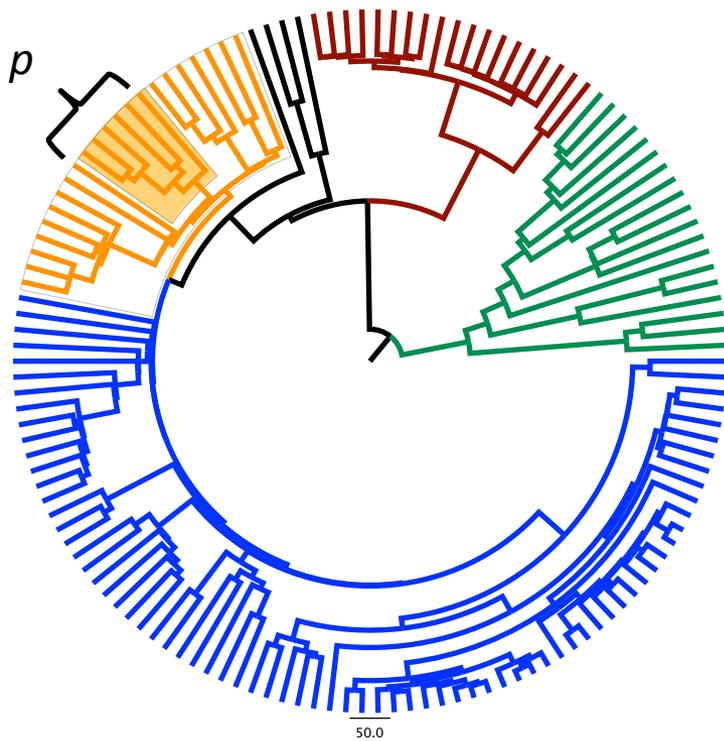


Place an unknown leaf spectrum within the plant tree of life



$$Pr \left(\{s, a_i\} | \sigma^2, t_{\{s,a\}}, y, \mu_i \right) \propto \exp \frac{-(y - \mu_i)^2}{2\sigma^2 t_{\{s,a\}}}$$

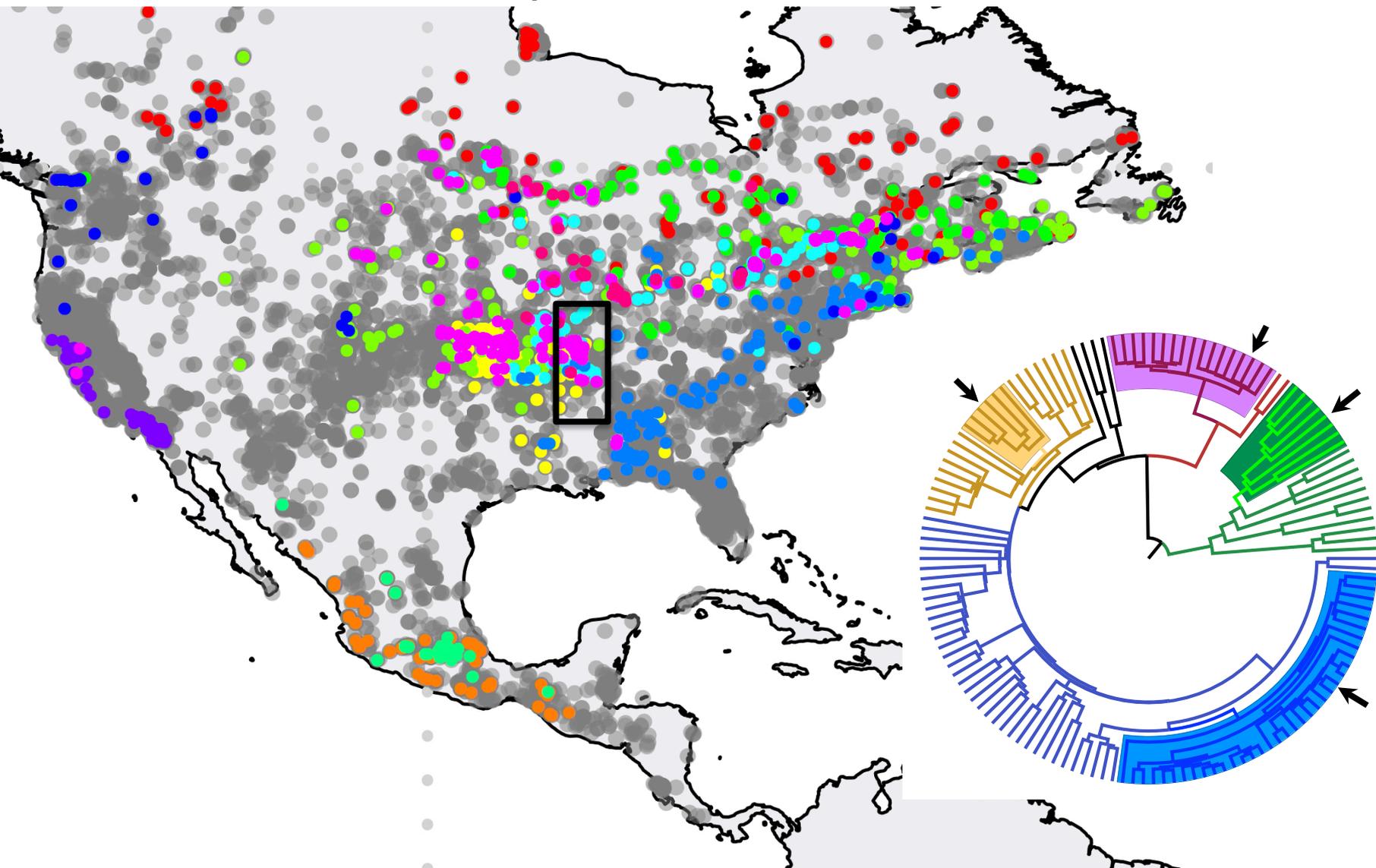
The probability of adding new tip \mathbf{s} to an ancestral node \mathbf{a}_i is given by a gaussian where: The data \mathbf{y} is the new tip's spectrum, the mean is the ancestral spectrum μ_i , and the variance is given by the brownian motion rate σ^2 times the time of divergence $t_{\{s,a\}}$.



What is the probability that an unknown spectrum falls within a given clade?

$$\frac{\sum_j^K Pr(j, \sigma^2, \beta | \tau_{N-1}, Y)}{\sum_i^T Pr(i, \sigma^2, \beta | \tau_{N-1}, Y)}$$

Once we know where a spectrum fits in the tree of life, the taxonomic deciphering can be further circumscribed with species distribution data



Dimensions of Biodiversity Team

- John Gamon
- Phil Townsend
- Sarah Hobbie
- Anna Schweiger
- Mike Madritch
- Art Zygielbaum
- John Couture
- Rebecca Montgomery
- Ran Wang
- Shan Kothari
- Peter Reich
- Dave Tilman

NIMBioS Remote Sensing of Biodiversity Working Group

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- Aditya Singh
- Phil Townsend
- Michael Schaepman
- Susan Ustin
- Anna Schweiger
- Aditya Singh
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- Robert Guralnick
- Jens Kattge
- Andrew Latimer
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- Mark Schildauer
- Franziska Schrodtt
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