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

Dimensions of Biodiversity Team PIs

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Linking plant spectra and spectral diversity to plant function, phylogeny and diversity
A. Linking spectra to functional and phylogenetic diversity

B. Spectral diversity at different spatial scales

Cavender-Bares et al AJB 2017
Spectral diversity
Spectral diversity – plant diversity relationship depends on spatial resolution

Spectral diversity – plant diversity relationship factoring out soil fraction (0.75 m² resolution)
RS trait diversity (LMA) – species diversity (AVIRIS 1m²)

Townsend et al
Spectral distance is associated with functional and phylogenetic distance between species.
Spectral diversity predicts productivity

Figure 2 | Spectral profiles, their coefficient of variation, and local maxima of the coefficient of variation.

The range of vector normalized spectra of all species ($n = 17$) is shown in red. The black line is the coefficient of variation of vector normalized reflectance values for each spectral band ($n = 2,000$). The blue vertical lines indicate five local maxima of the coefficient of variation (at 429 nm, 675 nm, 1451 nm, 1981 nm, and 2360 nm) and the location of known absorption features of chemical leaf traits.

Figure 3 | Relationship between spectral diversity and productivity.

Aboveground productivity ($g \text{ m}^{-2}$) increased with spectral diversity of plant communities calculated from a, species' mean leaf level spectra ($n = 35$, $r^2 = 0.51$, $b = 94.92$, $t = 5.90$, $P < 0.001$) and b, 1,000 randomly selected image pixels per plot acquired by an imaging spectrometer mounted on an automated tram ($n = 27$, $r^2 = 0.41$, $b = 3.81$, $t = 4.14$, $P < 0.001$). Each point here and in similar subsequent figures represents a single plot in the Cedar Creek biodiversity experiment.

Anna Schweiger
Spectral diversity using only local maxima of the coefficient of variation also predict productivity.
Spectra predict functional traits with high accuracy

Anna Schweiger

Chlorophyll A
Chlorophyll B
Lutein
Violaxanthin
Antherixanthin
Zeaxanthin
Beta Carotene
Anthocyanins
Solubles
Hemicellulose

Schweiger, Cavender-Bares et al, Nature EE 2018
Trait maps of the BioDIV experiment at Cedar Creek

Wang/Townsend
Productivity

Root Chemistry

Soil Organic Matter Quantity and Quality

Plant community structure and function

Diversity (SR, PE, FE) Composition

Vegetation chemistry

Productivity

Biomass and enzyme activity

Diversity and Composition

microbial community structure and function

aboveground

belowground

Remote Detection
Remotely sensed vegetation chemistry predicts root chemistry

PLSR models of vegetation chemistry

Root soluble fraction:
sugars, organic acids and amino acids

\[ R^2 = 0.43^{***} \]

Sarah Hobbie
Remotely sensed above ground chemistry predicts below ground processes

**Microbial Biomass**

- Remotely sensed lignin/N vs. Microbial biomass C
  - \( R^2 = 0.38 \)
  - \( P = 0.001 \)

**Microbial Enzyme Activity**

- Remotely sensed lignin/N vs. Hydrolytic enzyme activity
  - \( R^2 = 0.15 \)
  - \( P = 0.034 \)

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**Dimensions of Biodiversity Team, unpublished**
Remotely sensed vegetation cover predicts aboveground plant biomass and soil microbial biomass belowground.

Vegetation cover was estimated for every 1m² pixel, and averaged per 9x9 m² plot, by building a logistic model using ground cover measurements and soil angle (Serbin et al. 2015).
Remotely sensed vegetation cover predicts fungal and bacterial diversity and composition

**Bacterial diversity**

- $R^2 = 0.05 \ast P = 0.016$

**Bacterial composition NMDS1**

- $R^2 = 0.49 \ast \ast \ast$

**Fungal diversity**

- $R^2 = 0.15 \ast \ast \ast$

**Fungal composition NMDS1**

- $R^2 = 0.35 \ast \ast \ast$

Vegetation Cover (proportion)
Phylogeny meets Spectra

Evolutionary Model

Spectral Model

$dX_t = \alpha(\theta - X_t)dt + \sigma dB_t$

Leaf layers, Chlorophyll, Carotenoids, H2O, LMA

Drift

Constrained

Convergent

Meireles, Schweiger, Cavender-Bares 2017 — www.github.com/meireles/spectrolab
Phylogeny meets Spectra

Evolutionary Model

Spectral Model

Leaf layers, Chlorophyll, Carotenoids, H2O, LMA

Meireles et al. 2017; — www.github.com/meireles/spectrolab
Spectra detect phylogenetic lineages better than species; spectra are more informative than traits.
Spectra are phylogenetically conserved EXCEPT in the visible range associated with pigments for light harvesting and photoprotection.

NIMBioS working group
Meireles and NIMBioS working group

Phylogenetic Signal

Rosids
Monocots
Magnoliidae
Gymnosperms
Basal dicots
Asterids

A

B

Reflectance

0.1 0.2 0.3 0.4 0.5

Wavelength

500 1000 1500 2000
Constrain RS data using species distribution models

Place an unknown leaf spectrum within the plant tree of life and derive the probability that it falls within a given clade

NIMBioS working group on Remote Sensing of Biodiversity