Forest Mosaics: Spatial Vegetation Diversity Patterns from Stands to Regional Scales Incorporating Airborne Observatory Platform (AOP) Datasets with Satellite Data in Northeastern U.S

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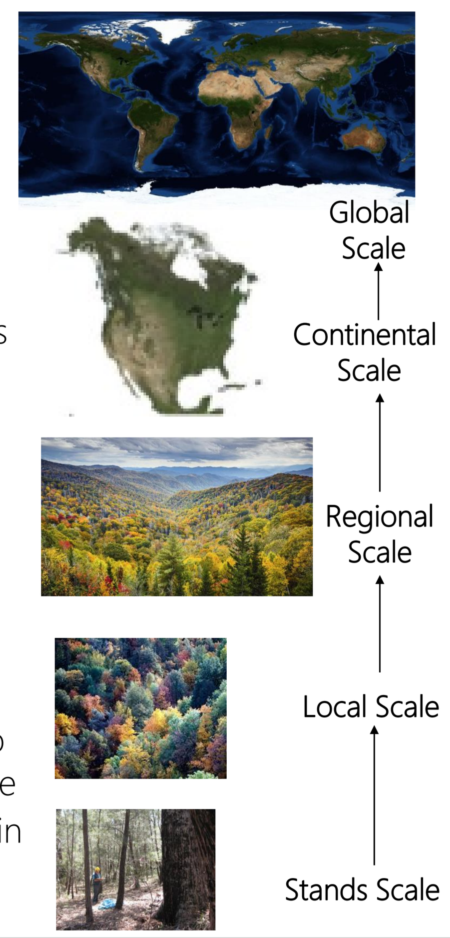
INTRODUCTION

Motivations:

- Human activities are impacting the species diversity at an unprecedented rate (Sala et al, 2000)
- Global biodiversity trends can be collected from satellites, but finer scale processes cannot be studied without an expanded network of repeat ground and airborne observations over short-term intervals (every 1 to 5 years).
- *In situ* biodiversity measurements can reflect where fine-scale patterns of species diversity are mechanistically related to broad scale on ecological processes.

Research Questions:

- What are the spatial and spectral detection limits for species diversity mapping with AOP datasets and by extension, what are the upscaling constraints?
- What coarser scale natural and human variables are driving species diversity patterns at the site level and where are local diversity hotspots predicted to occur?



Objectives:

- Detect one or more biodiversity indicators using a combination of NEON field and Airborne Observatory Platform (AOP) datasets
- Upscale local biodiversity patterns across sites to identify hotspots and drivers at the regional scale
- Synthesize biodiversity measurements together in a relational database with links to national and international databases (NEON- Geo BON)

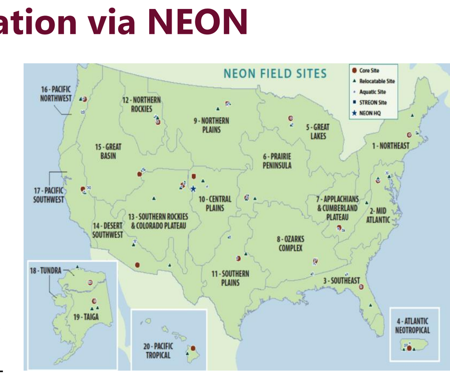
NEON DATA

Remote Sensing via NEON:

- NEON collects ecological data from 106 locations around the US that support ecological studies at regional to continental scales.
- NEON AOP provides three major high-resolution products: Lidar, hyperspectral and digital images

Regional & Continental Ecological Observation via NEON

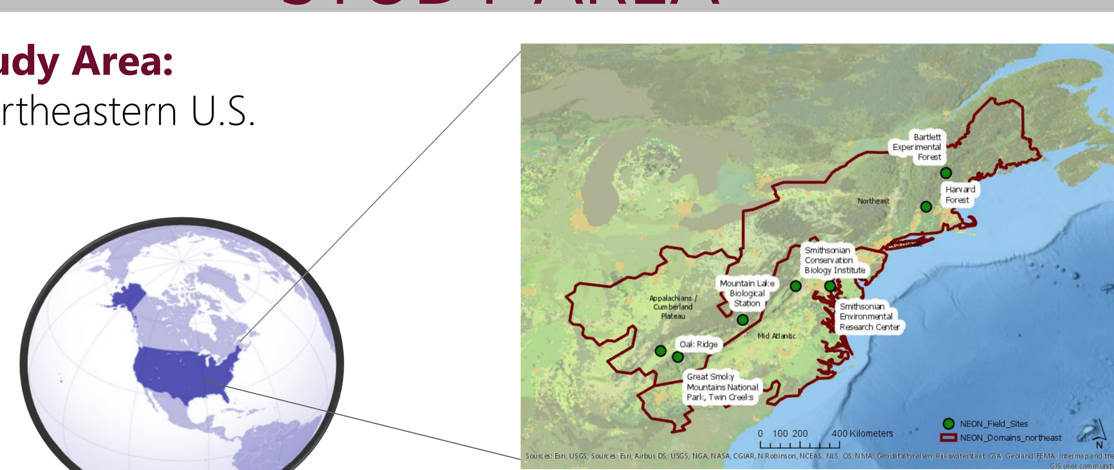
- Standardized and integrated source of ecological field data
- Georeferenced NEON field measurement collection from diverse locations can enable scientists the ability to sense large scale problems in US ecosystems
- NEON Data Theme for vegetation biodiversity mapping: plant phenology observations, plant presence and percent cover (PPPC) and Woody Plant Vegetation Structure (WVPS)



Freely Available

STUDY AREA

Study Area:
Northeastern U.S.



Study Area Map of Northeast United States(NEUS)

The study area covers six NEON core sites and one relocatable site:

Mapping Biodiversity Patterns

Biodiversity patterns are mapped by combining biodiversity metrics calculated from NEON field data with variables derived from Lidar and hyperspectral acquisitions.

Calculating Biodiversity Matrix

Species Richness (variety) = Species richness is a measure of the number of kinds of species

Simpson's Diversity Index $D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$

n = the number of individuals, N= total number of individuals, s = number of species

Simpson's diversity index (D) is a measure of biodiversity that takes into account richness and evenness. A high value of D means the habitat or landscape is diverse, species rich, and able to withstand more environmental impact with more resilience.

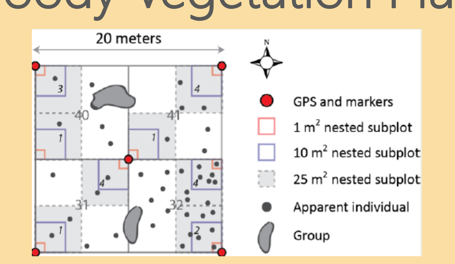
α – diversity (Alpha diversity) = the number of species in a local area
β – diversity (Beta diversity) = the turn-over rate of species in a local area(or habitat)
γ – diversity(Gamma diversity) t = the number of species in a region

Spatial Biodiversity derived from remote sensing images →
- Spectral Diversity → Vegetation Indices; Spectral information content
- Functional Diversity → Plant functional traits
- Species Diversity → Spatial species distribution

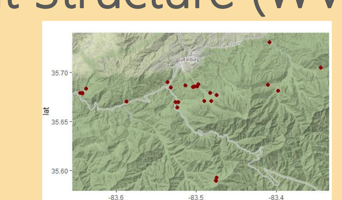
NEON Terrestrial Observation Systems (TOS)

We expanded NEON code into an R workflow that calculates biodiversity indices from NEON field data, extracts the geolocation of field observations, matches field datasets with AOP datasets, and downloads related AOP data.

Woody Vegetation Plant Structure (WVPS)



NEON field measurement framework. Nested subplot size in a 20 m x 20 m base plot with heterogeneously distributed vegetation.



WVPS is sampled every few years and includes species and abundance data from a sensor perspective. The design supported α diversity calculations such as species

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NEON AOP Datasets

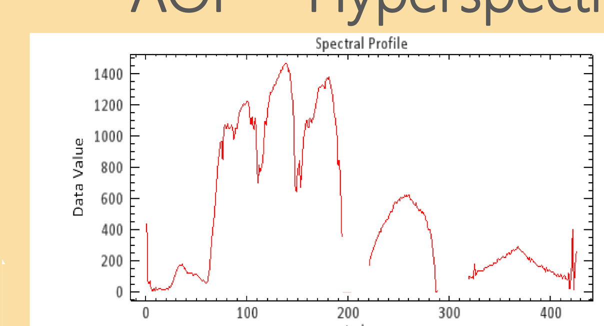
We worked with Woody Vegetation Plant Structure (WVPS) field data to generate diversity metrics that the sampling designs could support (e.g., species richness, beta diversity, Simpson's Index).

AOP - Lidar

Slope and Aspect (DP3.30025)
Elevation (DP3. 30024)
Ecosystem Structure – CHM (DP3.30015)

NEON Flightline

AOP – Hyperspectral



Example of spectral information (426 bands) extracted from one pixel of a NEON hyperspectral reflectance tile 1000m × 1000 m

Vegetation Indices (DP3.30026) includes NDVI, SAVI, ARVI, NDNI, NDLI, EVI
Total Biomass (DP3.30016)
Surface Reflectance (DP3.30006)
LAI (DP3.30012)
Spectral Variability

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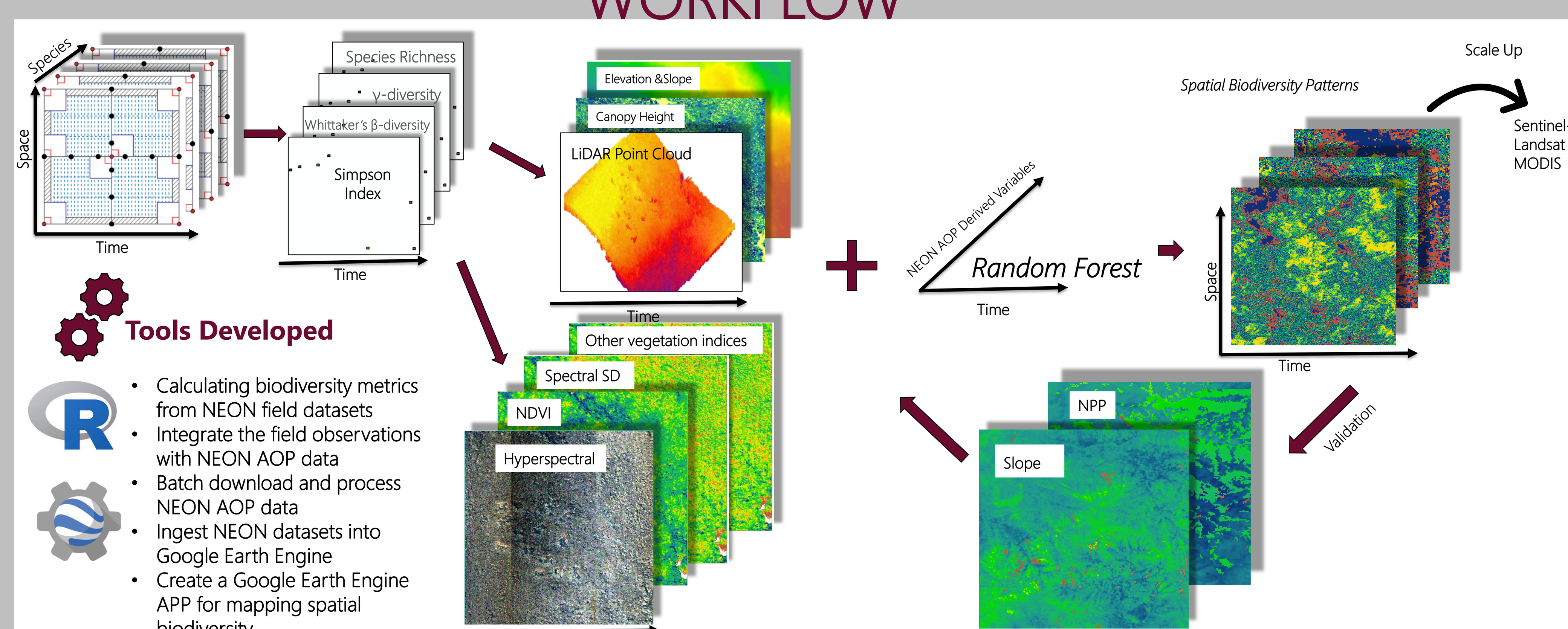
Human Activities -> Land-use legacy

Scaling: Sentinel-2, Landsat, MODIS

WORKFLOW

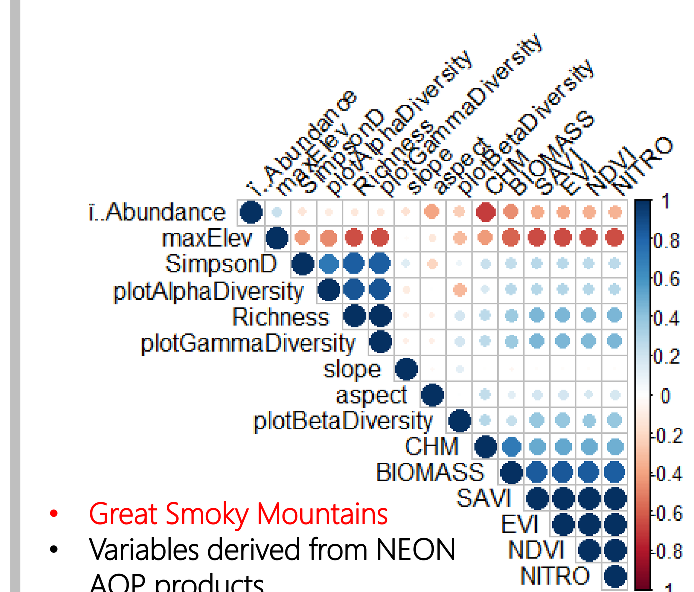


Tools Developed

- Calculating biodiversity metrics from NEON field datasets
- Integrate the field observations with NEON AOP data
- Batch download and process NEON AOP data
- Ingest NEON datasets into Google Earth Engine
- Create a Google Earth Engine APP for mapping spatial biodiversity

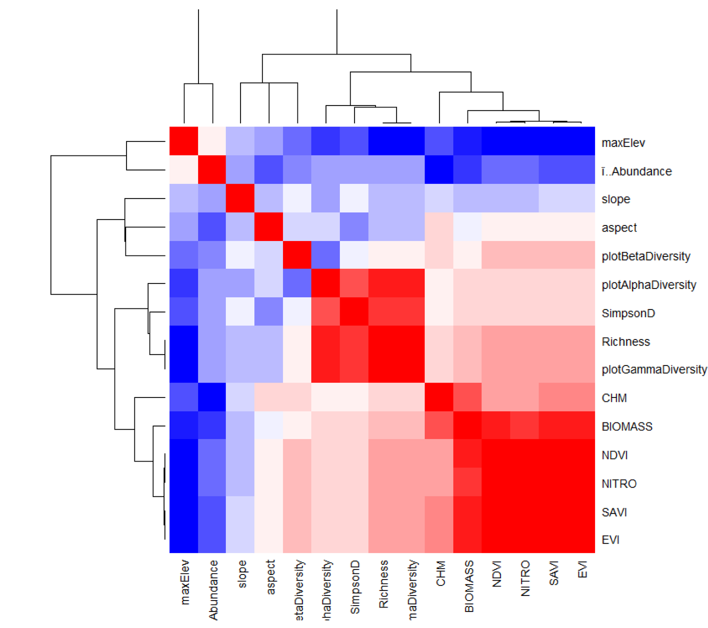
RESULTS

1. NEON Derived Variables Performance Analytics



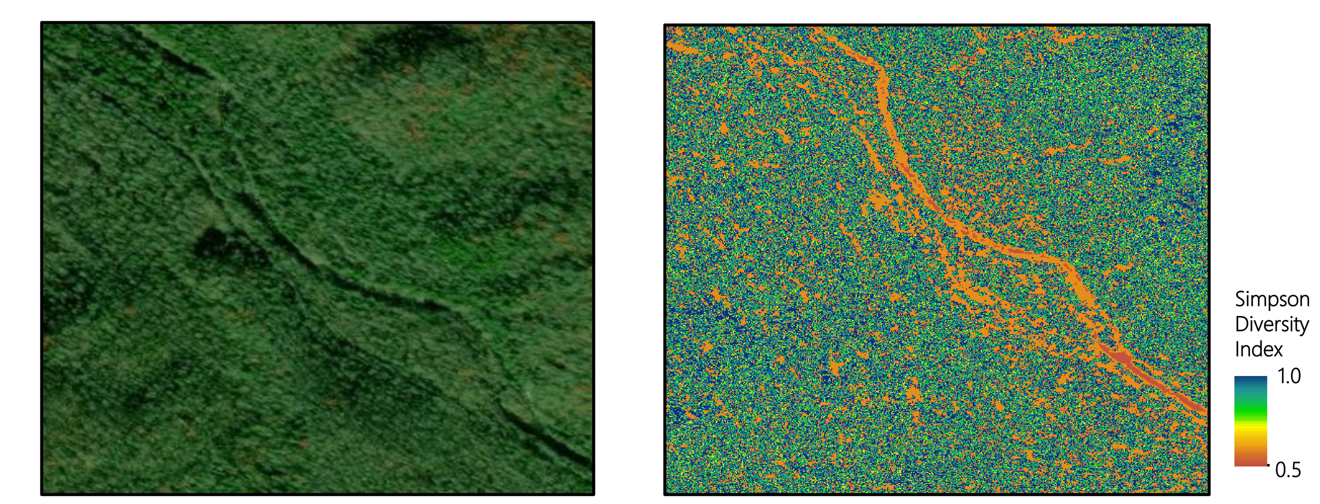
- Great Smoky Mountains
- Variables derived from NEON AOP products

Correlation matrix of NEON derived variables for biodiversity mapping



Heatmap of NEON derived variables for biodiversity mapping

2. Spatial Biodiversity Map



Spatial Biodiversity Map of Great Smoky Mountains in 2017

- Location: 2016 Great Smoky Mountains NEON site
- One scene of NEON Level 3 scene 1000m × 1000 m, spatial resolution: 1m
- The training accuracy is 90.9% and the validation overall accuracy is 84.7%

Conclusions:

- The tool developed in R for calculating biodiversity indices is robust and can be extended to additional NEON sites to automate the workflow for mapping biodiversity patterns
- Environmental variables of NEON are highly related with biodiversity.
- We produced the correlation matrix and the spatial biodiversity map (represented as Simpson's Diversity Index) and found great potential for scaling up to continental scales.

Future Work:

- Add the other six NEON sites to expand the study to continental level
- Scale up by incorporating Sentinel-2, Landsat, and MODIS database
- Expand analysis to regional scale of NE US
- spectral variability, specific vegetation products (such as surface roughness) from lidar by using BCAL lidar tools will be examined and put into the variables

References:

- Sala, Osvaldo E., et al. "Global biodiversity scenarios for the year 2100." science 287.5459 (2000): 1770-1774.
- Asner, Gregory P., and Roberta E. Martin. "Spectranomics: Emerging science and conservation opportunities at the interface of biodiversity and remote sensing." Global Ecology and Conservation 8 (2016): 212-219.

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