

Mapping Stable Nitrogen Isotopes Using Hyperspectral Imagery

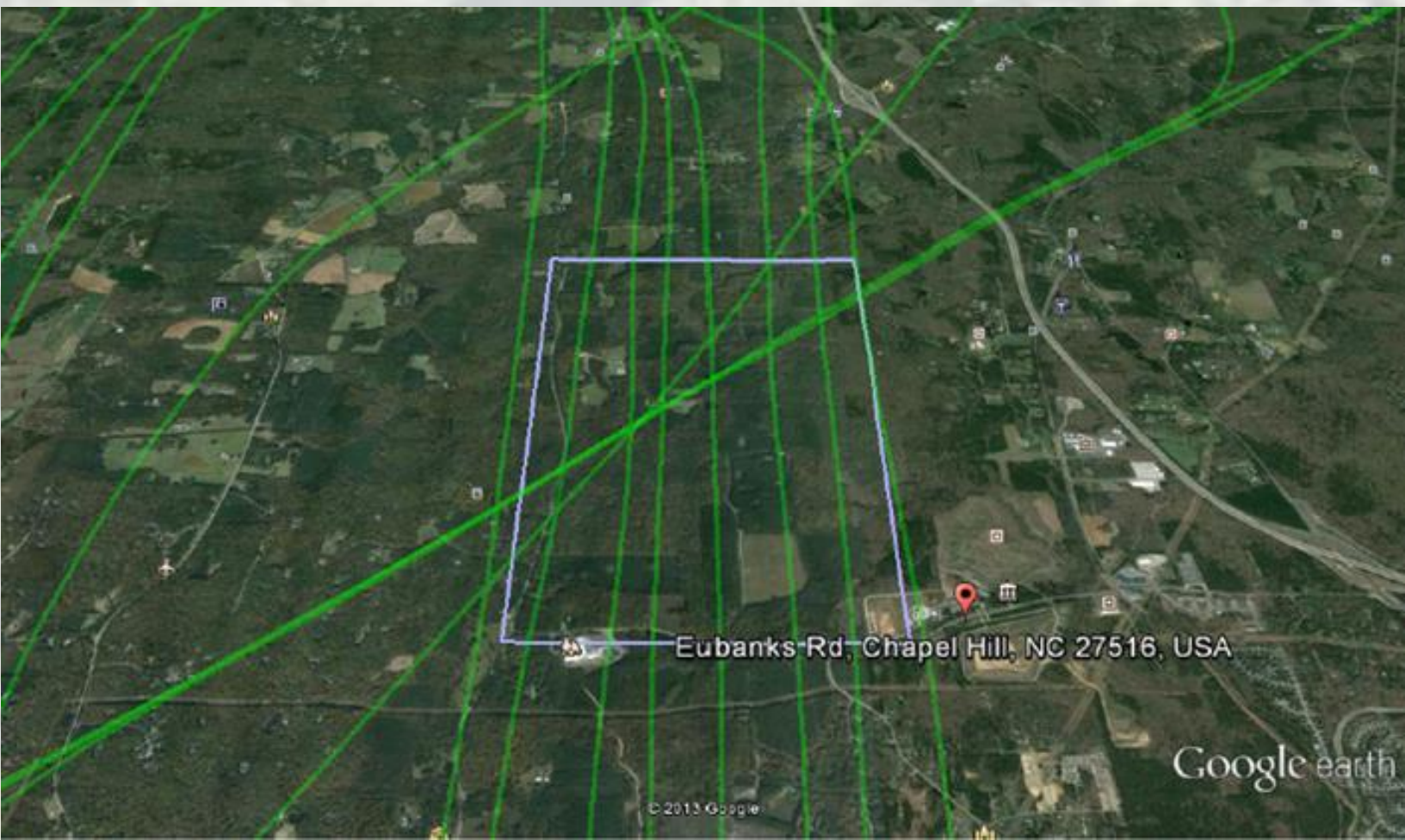
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ABSTRACT

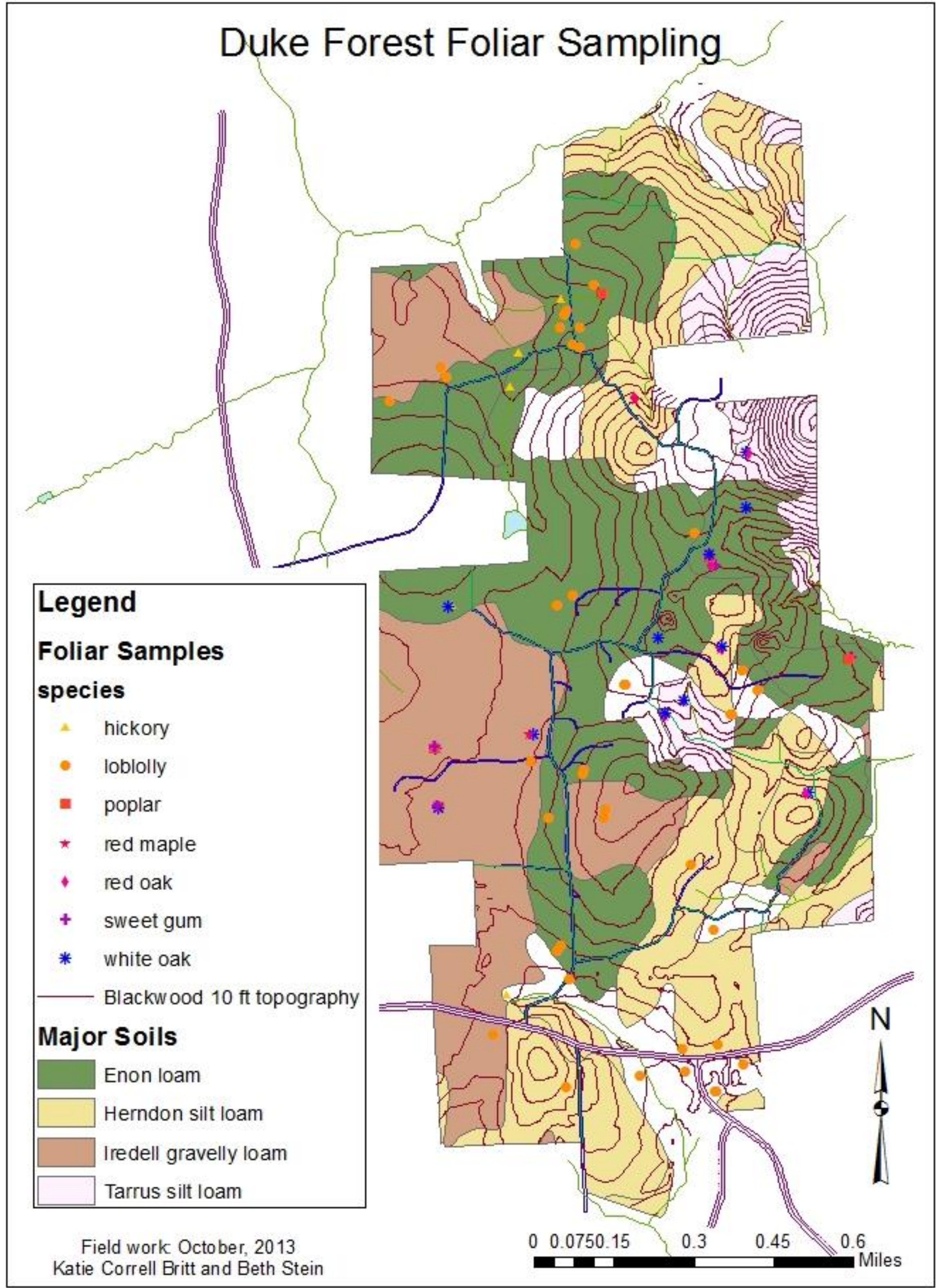
As nitrogen deposition increases globally, ecosystem changes will occur. It is important to understand the growth response of different ecosystems and where nitrogen retention will occur. Stable isotopes of foliar nitrogen can provide insight into how this process is occurring in the soil. Previous studies have found links between foliar nitrogen and optical properties. This study focuses on the Southern Piedmont Forests. A study at the Duke Forest's Blackwood Division in Chapel Hill, North Carolina, allowed for foliar sampling across various soil types, elevations, and species. Concurrent hyperspectral imagery was taken, allowing for the relationship between environmental drivers, optical properties, and nitrogen content to be identified. These relationships will be used to map nitrogen content at the canopy level. Foliar sampling was performed in species identified as major contributors to the canopy. Major canopy contributors were oak, hickory, poplar, sweetgum, and pine. Foliar samples were analyzed for chlorophyll, macronutrients, carbon, nitrogen, and stable isotope N15. The relationship of these characteristics, as well as elevation, soil type, species, and optical properties, were input to predict the spectral signature associated with the N15 content. Ancillary data on elevation, soil type, and species, coupled with hyperspectral imagery, will use the relationships to predict canopy level nitrogen at the image scale.

STUDY AREA

Field work was conducted in the Blackwood Division of the Duke Forest, in Chapel Hill, North Carolina. The Duke Forest is a research forest in the Piedmont region. The site has mixed hardwood and loblolly pine. It was previously farmland. Sampling was conducted within one week for pine and three days for hardwood of NASA's G-LiHT flight. Plots were established along environmental gradients of soil type and topography. Trees were selected within plots to maximize the number of species that contributed significantly to the canopy.



Duke Forest G-LiHT flight lines, September 30, 2013.



Loblolly pine, older stand (above)



Loblolly pine, younger stand (above)



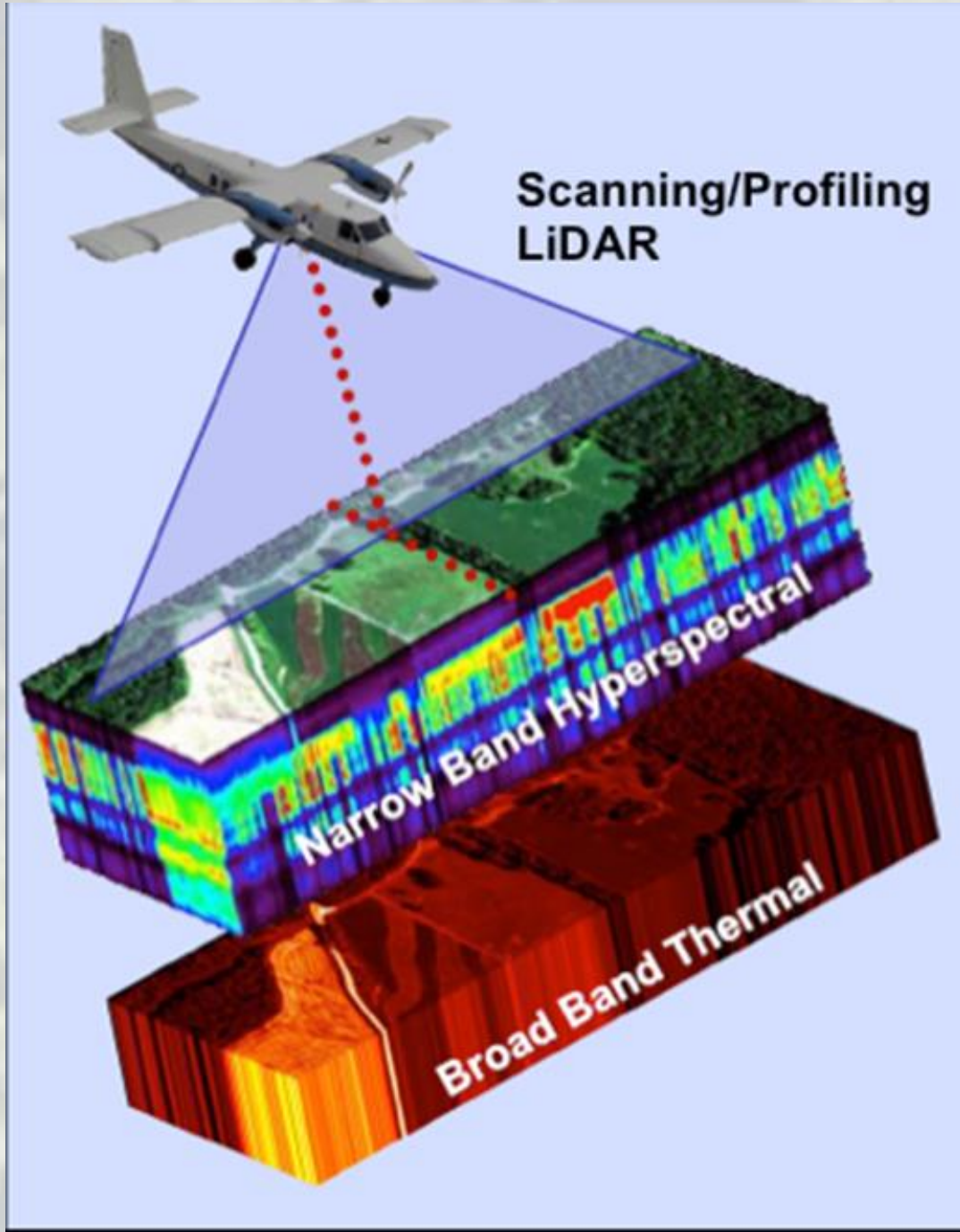
Hardwood, wetland (above)



Hardwood, upland (above)

BACKGROUND

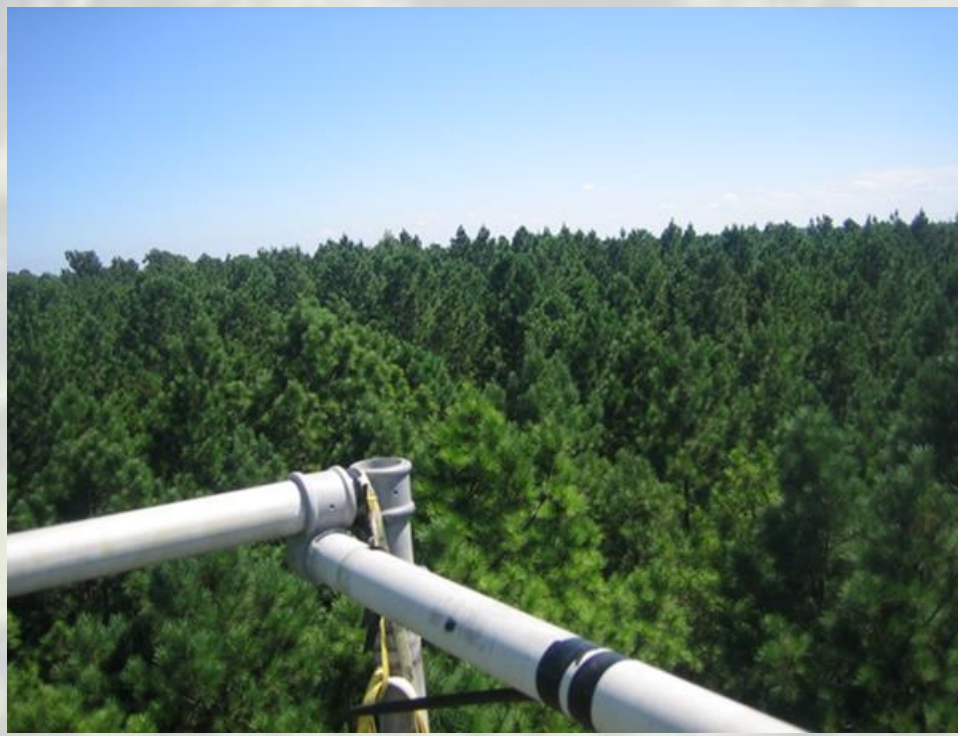
- Atmospheric deposition of nitrogen is increasing globally and terrestrial inputs have nearly doubled because of anthropogenic activities
- Nitrogen is typically a limiting nutrient for plants, and it is unclear how different ecosystems will respond to increased inputs.
- A rapid method is needed for assessment of ecosystem responses.
- $\delta^{15}\text{N}$, a heavier, stable isotope, is a useful indicator of the nitrogen cycles as it is preferentially left during fractionation and can be used to identify nitrogen cycle dynamics.
- Optical properties have been found to be correlated with plant properties such as cell structure, water content, physiology, and foliar biochemistry.
- Leaf level relationships have been established between reflectance and $\delta^{15}\text{N}$.
- Canopy level relationships have been established between reflectance and canopy %N, but there is debate about whether %N or species and canopy distribution are being predicted.



G-LiHT Sensor: Lidar, Hyperspectral, and Thermal Image: NASA G-LiHT <http://gliht.gsfc.nasa.gov/>

OBJECTIVES

- Prediction of canopy $\delta^{15}\text{N}$ from hyperspectral imagery to identify nitrogen cycling dynamics
 - Rapid assessment of ecosystem dynamics and response to increased nitrogen deposition
- Are there environmental, phenological, or physiological drivers of the relationship of $\delta^{15}\text{N}$ and reflectance?
 - Successional stage, chlorophyll coupling and the red edge?
 - Does species/canopy distribution drive the relationship?
 - Significant differences within and/or between species?
- Inclusion of heterogeneous landscapes?



Goal: Prediction of nitrogen cycle dynamics at the canopy level.

DATA

FIELD WORK

- Foliar Sampling
- Shotgun sampling
 - Nutrient analysis
 - Chlorophyll
 - Optical properties (ASD)
- Measurements
- DBH
 - Temperature
 - Crown width
 - LAI (Pine)
 - Stand characteristics
- Location
- GPS
 - Differential post processing
 - Tree and plot location

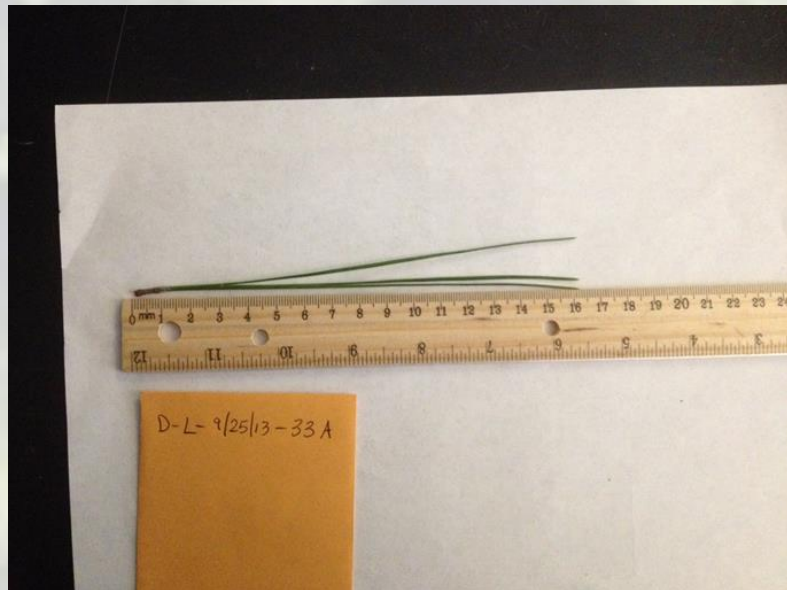
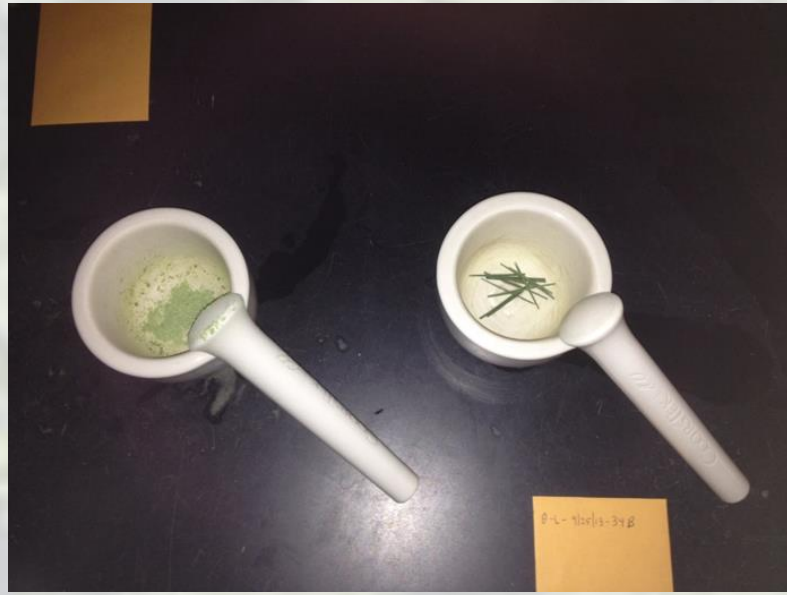
LAB WORK

- Frozen Needles
- Length, width, and weight
 - Chlorophyll extraction
 - Total carotenoids
- Fresh Hardwood Leaves
- Optical properties
 - Fluorescence
 - Chlorophyll
 - Leaf area and weight
- Dry Needles and Leaves
- C and N analysis
 - Isotope analysis
 - Nutrient analysis



LAB PROCEDURES

- Chlorophyll Analysis (loblolly)
- Fresh needles frozen, ground in liquid nitrogen
 - Measurements for indirect specific leaf area
- Dry Analysis for Dry Foliar Samples (both loblolly and hardwood)
- Carbon and Nitrogen (C N Analysis)
 - Nitrogen Isotopes ($\delta^{15}\text{N}$ by IRMS)
 - Nutrient analysis (dry ash for Al, B, Ca, Fe, K, Mg, Mn, Na, P, and Zn)



CONTINUING WORK

Samples are being processed in the lab. Imagery is being processed. Once lab work is complete, spectral signature will be extracted for each point from the imagery. Ancillary data on soil, topography, age class, and metrics from lidar will be included. This data will help determine underlying drivers of the relationship of reflectance and nitrogen. Regressions predicting $\delta^{15}\text{N}$ will be built and applied to the imagery. Ability to predict $\delta^{15}\text{N}$ within and between species will help determine whether relationships with reflectance indicate nitrogen content or canopy distribution, potentially driven by species.

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