Leaf functional diversity is not equivalent to canopy functional diversity: Mapping whole canopy traits with imaging spectroscopy and lidar fusion

Aaron Kamoske¹, Kyla Dahlin¹, Shawn Serbin², and Scott Stark³

¹Michigan State University, Geography, Environment, and Spatial Sciences, East Lansing, MI, USA
²Brookhaven National Laboratory, Environmental and Climate Sciences Department, Upton, NY, USA
³Michigan State University, Department of Forestry, East Lansing, MI, USA

Foliar nitrogen concentration (foliar N) and leaf mass per area (LMA) have been identified as key drivers of plant functional diversity and are strongly correlated with photosynthetic carbon assimilation in terrestrial ecosystems. However, these traits are not static between and among species, instead tradeoffs between light interception, photosynthetic capacity, and construction costs (e.g. leaf economics spectrum) lead to significant variation across landscapes. This diversity in leaf traits can lead to considerable differences in carbon assimilation rates at the leaf level, which is difficult to quantify at ecosystem scales without advanced technologies. Much of our current understanding of landscape-scale heterogeneity in functional traits has come from airborne imaging spectroscopy, which can be linked with foliar trait data to map functional diversity across entire ecosystems. Yet, these remote sensing platforms primarily measure processes occurring in leaves at the top of the canopy, thus ignoring critical information about the three-dimensional structure of forest canopies. Moreover, there is a critical relationship between forest structure and function which drives ecological processes such as carbon assimilation, resource use and efficiency, and woody growth. With traditional remote sensing platforms assuming a 2D world, this leads to an important question in ecosystem functioning: Do total canopy foliar N patterns match top of canopy N concentrations, or are these patterns different? In the United States, the National Ecological Observatory Network's Airborne Observation Platform (NEON AOP) provides a unique opportunity to address this question by collecting airborne lidar and hyperspectral data in unison across a variety of ecoregions. With a fusion of hyperspectral and lidar data from the NEON AOP and field collected foliar trait data, we show that top of canopy leaf-level and whole canopy foliar N represent fundamentally different measurements regardless of spatial resolution, which could have critical impacts when scaled to landscape, continental, and global models. In addition, we examine the influence of topography, geology, and management regimes on these two measurements of functional diversity at a NEON site consisting of patches of open longleaf pine and dense broadleaf deciduous forests. By understanding how these measurements are linked to abiotic gradients and management regimes, we show that top of canopy functional diversity is more closely related to environmental gradients, reflecting species differences, while whole canopy functional diversity is more evenly distributed, which is a
reflection of N availability and utilization across this ecosystem.