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ECOSYSTEMS IN FOUR DIMENSIONS:

Measuring changes to forest structure and function in the Anthropocene

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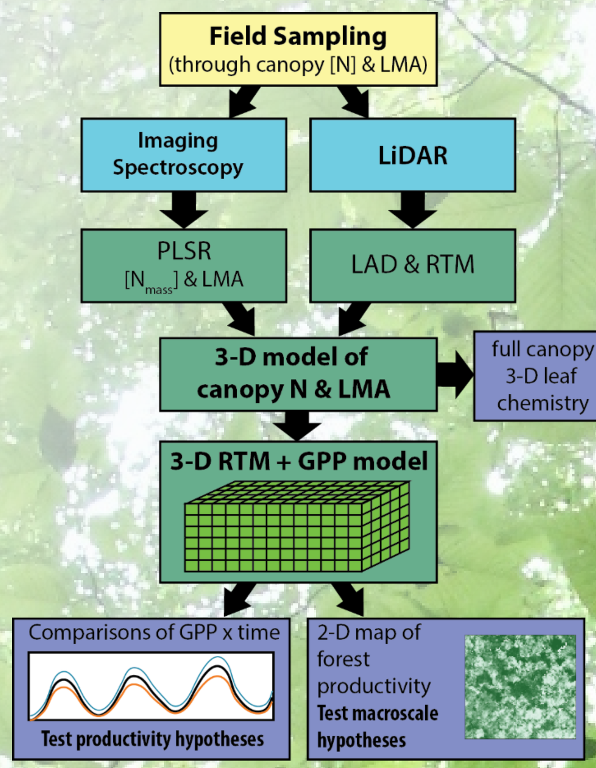
http://www.neonscience.org/data-collection/airborne-remote-sensing

INTRODUCTION

How do we scale up detailed ecological knowledge of essential features of the biosphere to continental and global models? We know that for forests, measuring and understanding productivity is essential because the terrestrial biosphere stores approximately 11 gigatonnes of CO_2 per year (Le Quere et al. 2015), a third of anthropogenic emissions, yet the magnitude of the terrestrial land sink is also the most uncertain component of the global CO_2 budget. We also know that an ecosystem's productivity is related to is structural (Hardiman et al. 2014) and functional (Tilman et al. 1997) diversity. However, it is not clear which ecological factors of terrestrial plant communities are most critical when modeling and scaling up fine scaled knowledge to macroscales.

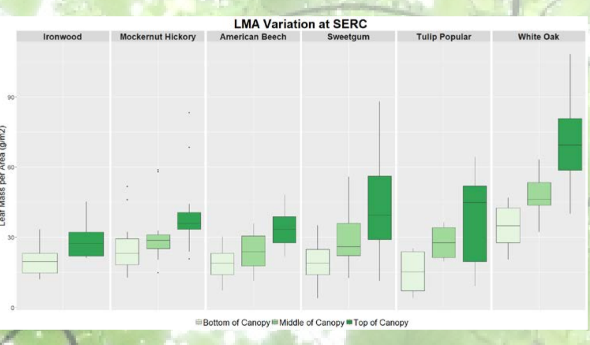
The overarching goal of this project is to test two of the critical questions in ecology – first, does higher functional diversity lead to higher productivity at the regional scale? And, second, is information about structural and functional diversity necessary to accurately predict current and future productivity in global ecosystem models?



Project design.

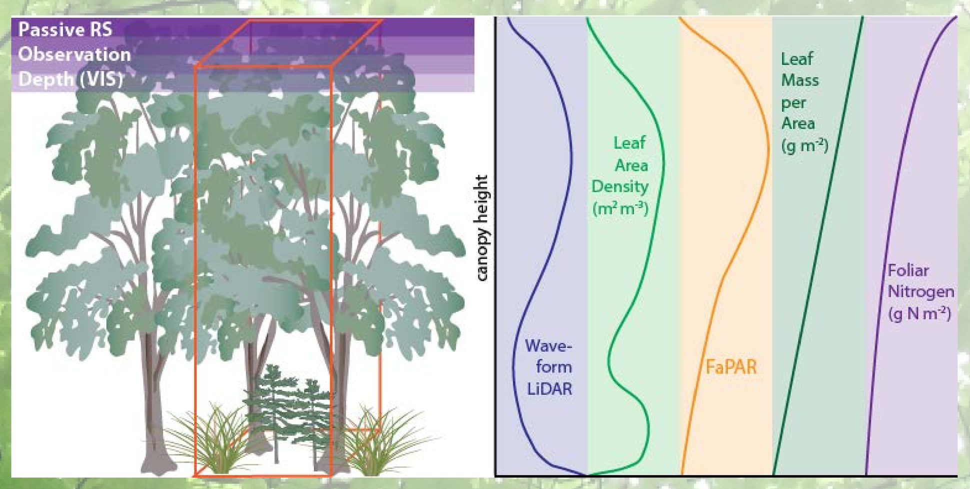
LEAF TRAITS & THE FOREST LIGHT ENVIRONMENT

Within a forest canopy, plant productivity depends on two suites of factors: 1) the functional diversity of plants at the level of functional type, species, individual, or leaf, and, 2) the physical structure, and therefore the within-canopy light environment, of the forest. Predictive models of plant productivity, from 'green slime' to 'big leaf' to multilayer and even demographically structured models all assume that photosynthetic rates can be lumped into generalized classes ('plant functional types') and that explicit handling of the three-dimensional structure of the forest is not essential to estimating its productivity. Yet we know these assumptions are inadequate – important plant functional traits like foliar nitrogen concentrations ($[N]_L$) and leaf mass per area (LMA) can vary substantially within a single species and through a canopy (Serbin et al. 2014, Niinemets et al. 2015), and the amount of light a leaf receives is not due to its general canopy position but is due to the locations of the leaves and branches that surround it.



Preliminary leaf mass per area (LMA) data from SERC broken down by canopy position.

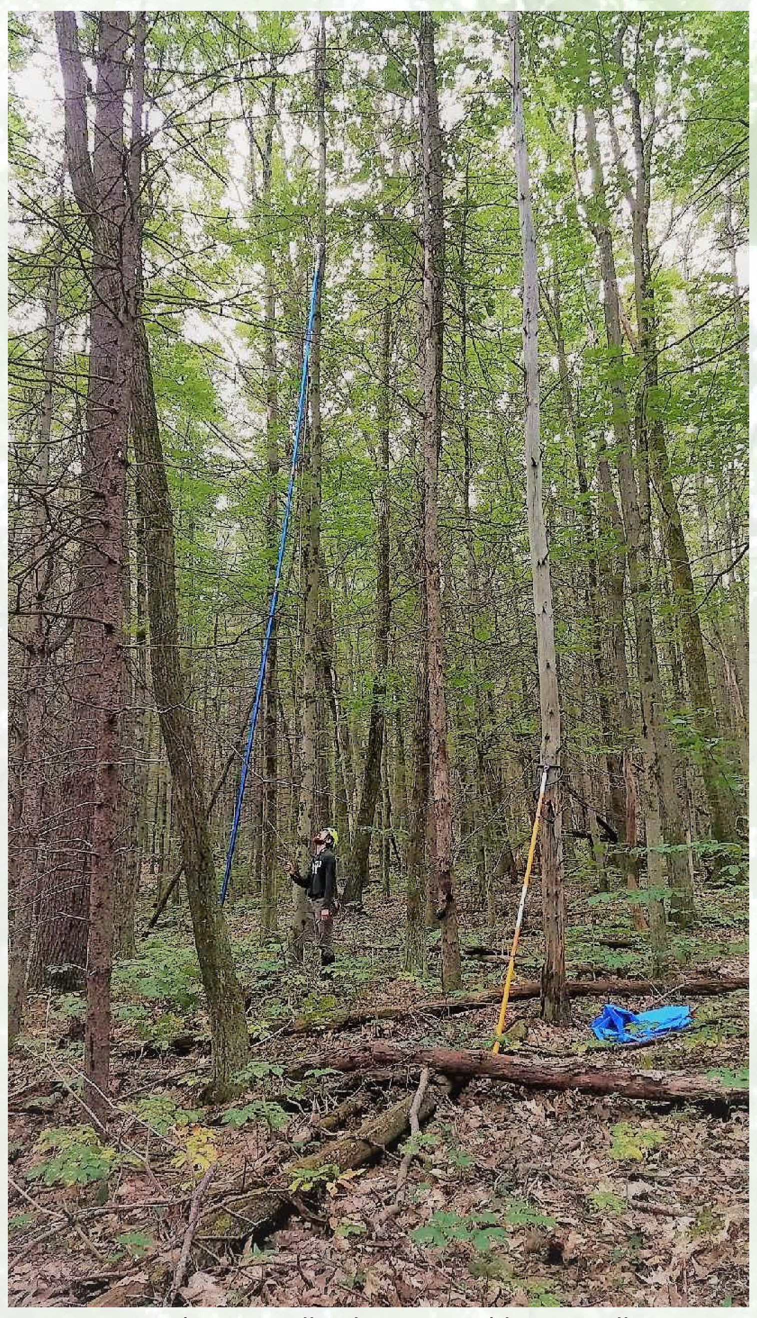
By combining forest structural and functional diversity into one synthetic model of ecosystem productivity, we aim to bridge the gap between methods that rely on traditional 2-D passive remote sensing and emerging active sensing of structural properties. In recent forest model development, improving representations of functional diversity has been a key focus (e.g. Medvigy et al. 2009) while structural diversity has received less attention. Assuming that plants optimize for light access may be sufficient in mesic forests under ideal, static conditions, but in real forests trees fall or drop branches due to storm impacts, insect infestations, and drought in ways that create complex, heterogeneous canopies that change the canopy light environment and, therefore, a forest's productivity.



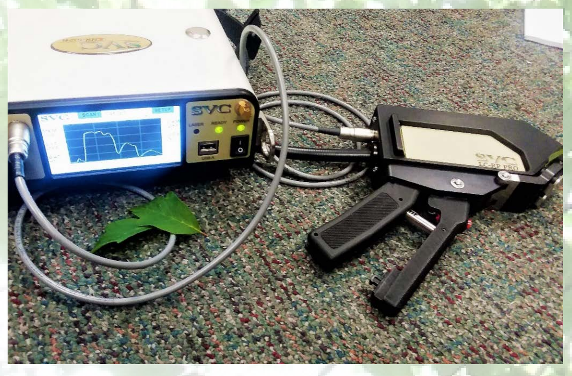
Conceptual figure showing the distribution of information, light, and leaf traits through a canopy.

COLLECTING LEAVES FROM THE TOPS OF TREES

In the summer of 2017, MSU graduate student, Aaron Kamoske, and undergraduate, Logan Brissette, started a pilot project to inform our macrosystems program. They travelled to two NEON sites – the Smithsonian Environmental Research Center (SERC) and Harvard Forest (HF). At each site they collected leaves from the top 5+ most common tree species throughout the forest canopy using a combination of slingshot, pole pruners (lower left image), and hand pruners. Each sample was then packed in a cooler and brought back to the lab (equipment in center image). In the lab spectral samples were taken using an SVC spectroradiometer, then leaf punches were collected, weighed, and dried to measure leaf water content and leaf mass per area (lower right image). Back at MSU a subset of the samples were analyzed for C and N – the rest will be estimated based on empirical relationships between the leaf spectra and the samples.



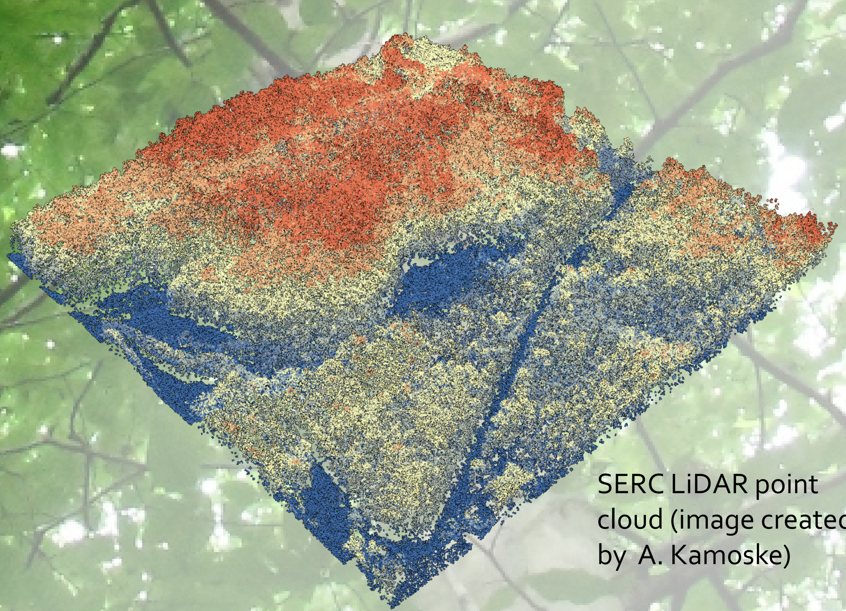
Aaron using the very tall pole pruners (blue) to collect leaves at HF. (photo credit: L. Brissette)



SVC spectroradiometer collecting a sample (photo credit: A. Kamoske)

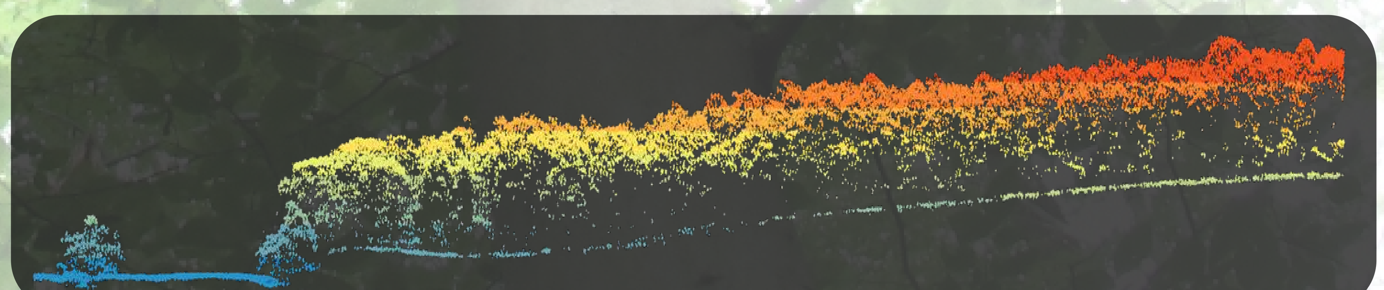
Logan collecting tulip tree leaf punches (photo credit: A. Kamoske)

LiDAR + IMAGING SPECTROSCOPY



SERC LiDAR point cloud (image created by A. Kamoske)

To measure leaf level nitrogen and LMA we are using a hybrid approach, doing lab chemistry on about 25% of the samples then using the relationship between leaf spectra and leaf traits to estimate the N and LMA values for the rest of the samples. To map leaf traits across the landscape and through the canopy we are using fused hyperspectral imagery (imaging spectroscopy) and LiDAR data collected by the NEON Airborne Observation Platform (AOP). The hyperspectral imagery will be used to map top of canopy leaf N and LMA, then the LiDAR point clouds will be used to calculate leaf area density (like leaf area index but divided vertically through the canopy) and to model the light environment. We will then 'project' the top of canopy values down through the forest to make a 3D map of leaf N and LMA.



SERC LiDAR cross section (image created by A. Kamoske)

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