LEAF AREA DENSITY FROM AIRBORNE LiDAR:
COMPARING SENSORS AND RESOLUTIONS IN A TEMPERATE BROADLEAF FOREST ECOSYSTEM

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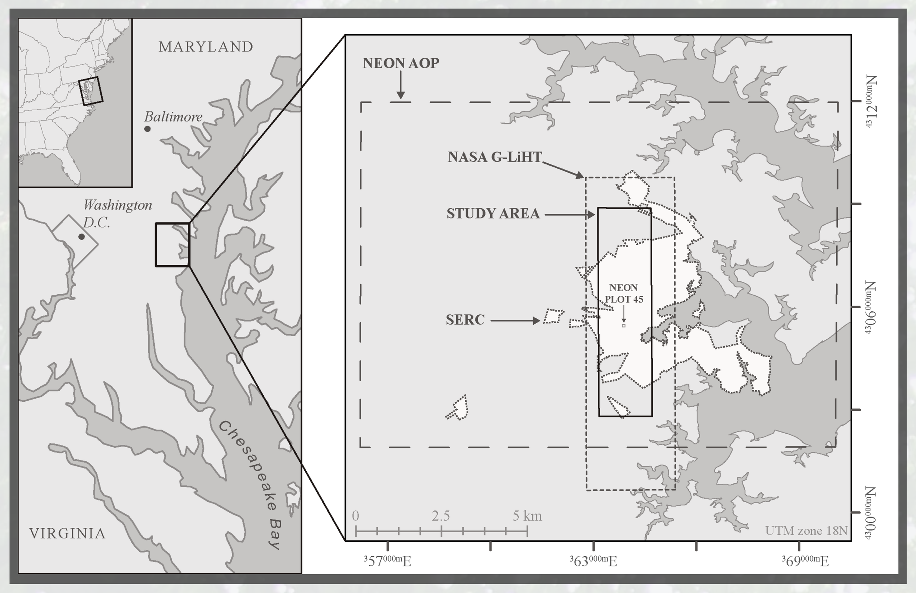
INTRODUCTION



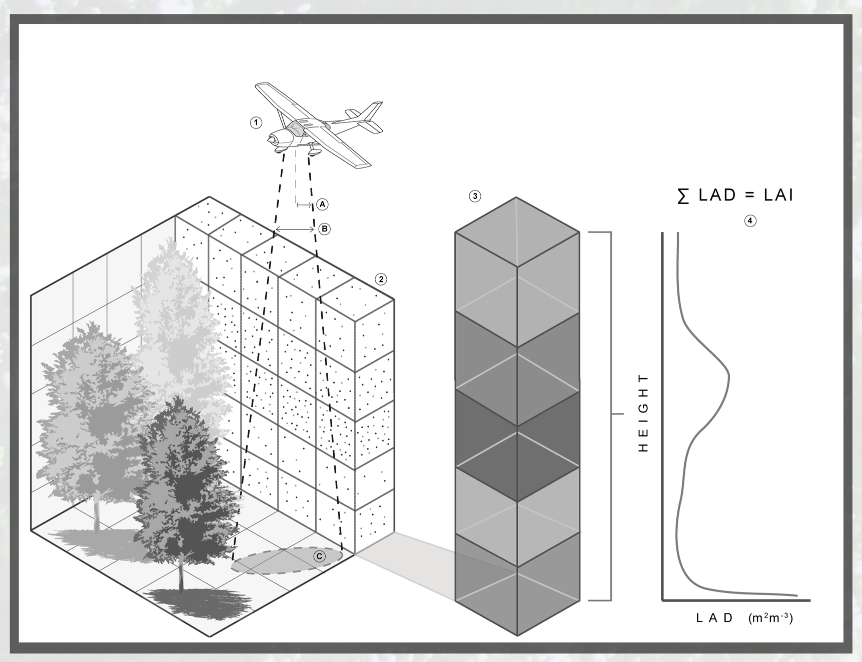
- Forest processes that play an esstial role in carbon sequestration are closely tied to the three-dimensional structure of forest canopies (Parker et al. 2004; Hardiman et al. 2011).

- Leaves at varying vertical positions within the canopy are physiologically unique (Poorter et al. 2009), which leads to higher carbon storage than if light conditions were constant (Niinemets et al 2015).

- Due to this within-canopy variation, three-dimensional structural traits are critical to improving carbon storage estimates by Earth system models (Bonan et al 2012).

- We compare leaf area density and LAI estimates at the Smithsonian Environmental Research Center in Maryland, USA, from two airborne LiDAR systems, NEON AOP and NASA G-LiHT, while addressing the spatial scale of analysis, as well as differences in canopy penetration and pulse density of these estimates.

METHODS



LiDAR pulses penetrate the forest canopy and reflect off leaf and woody material, or hit the ground, and return to the plane (1). Height measurements are voxelized (2). The MacArthur and Horn method is applied to the voxelized data (3) returning a leaf area density profile (4). The sum of the leaf area density estimates in a column of voxels is equal to the LAI of that vertical column. Columns without a ground return are not used in further calculations.

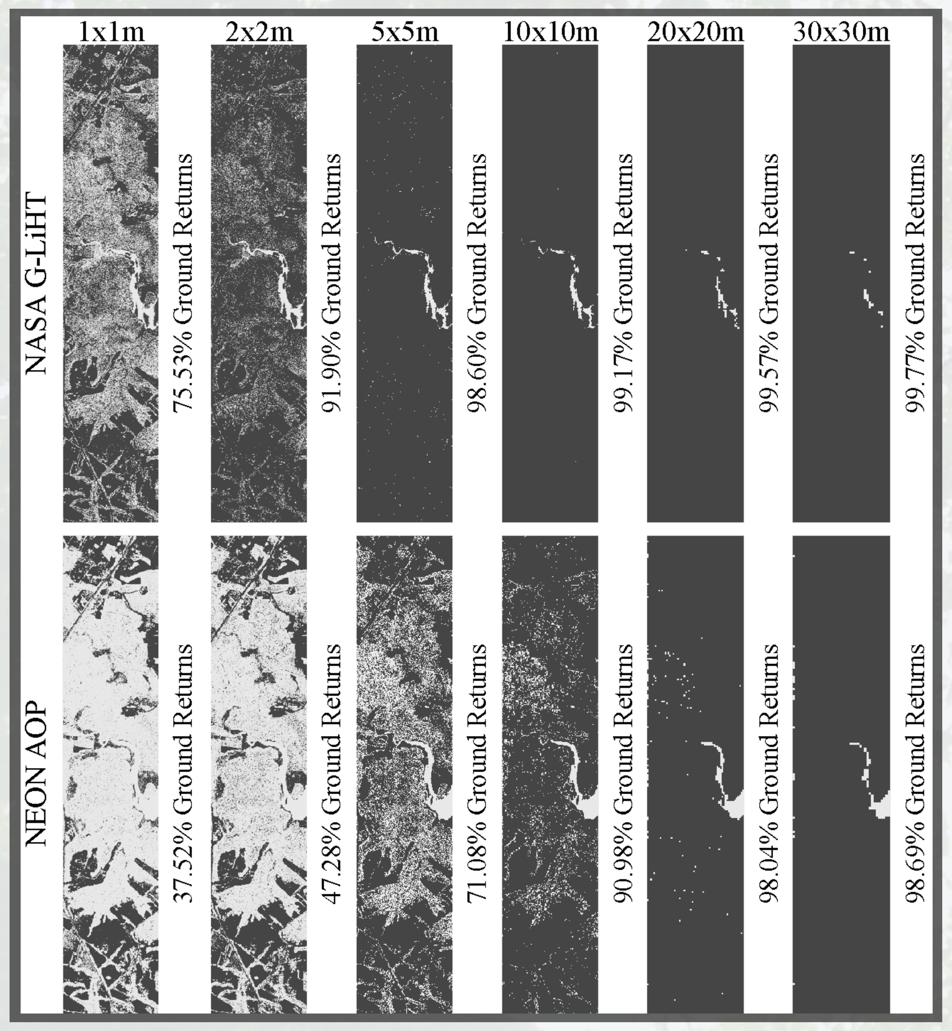
MacArthur and Horn Method

Within each voxel, leaf area density is estimated as:

$$LAD_{i-1,i} = \ln(S_e/S_t)(1/k\Delta z)$$

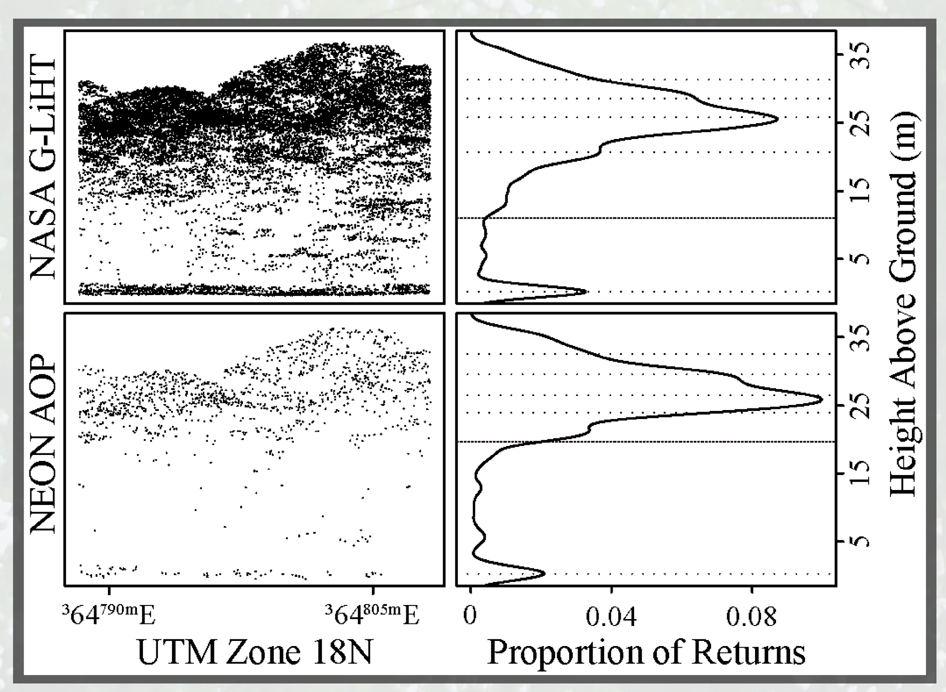
where for each vertical column of voxels, *i* is a voxel in a sequetially ordered vertical column of the canopy, S_e is the number of pulses entering the given voxel, S_t is the number of pulses exiting the same voxel, *k* is an extinction coefficient, and *z* represents theheight of a voxel. Together, the term $1/k\Delta z$ represents the Beer-Lambert Law extinction coefficient. The slope of a regression between LAI derived from hemispherical photographs and LiDAR estimated LAI is used as *k*.

COMPARING NASA G-LiHT AND NEON AOP LiDAR DATA



- Ground returns are critical to calculating leaf area density. Without a ground return, all pulses passing through a voxel are not accounted for.

- While differences persist, both sensors are within 10% of each other at a 10x10 meter resolution.

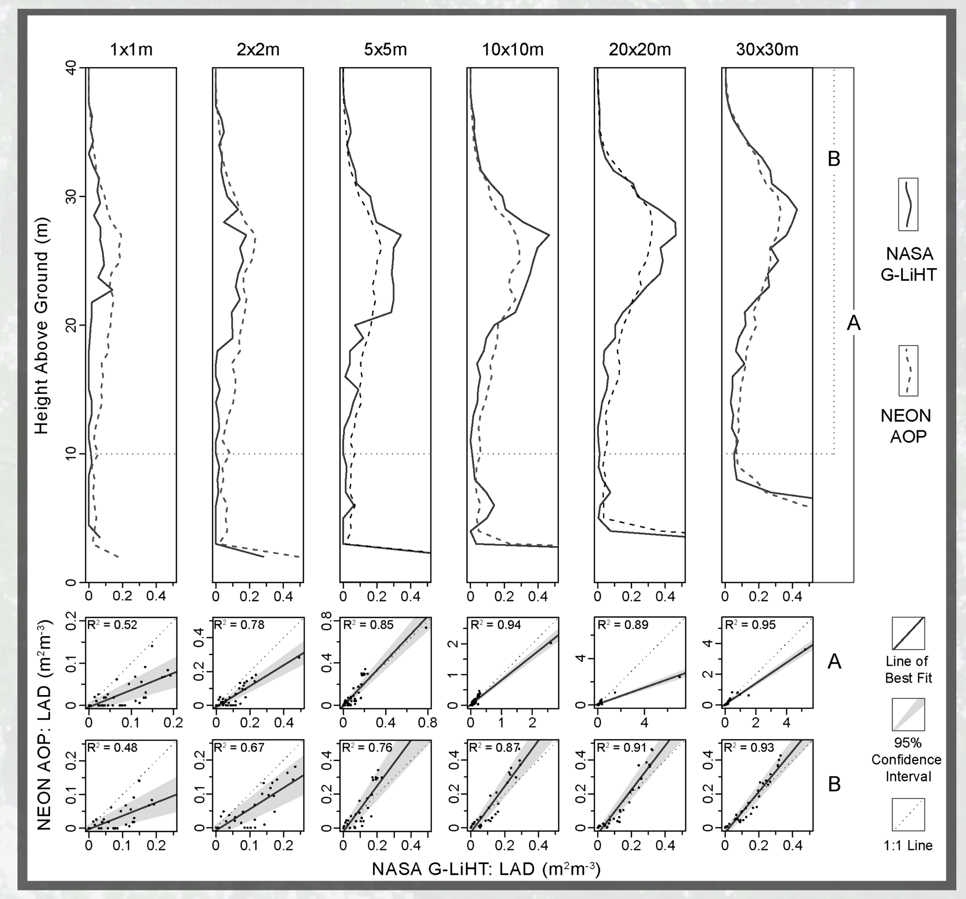


- Within NEON plot 45, a 20x20 meter vegetation plot, NASA G-LiHT has 20,475 LiDAR returns while NEON AOP has 1,299, or 94% less returns.

- When we binned these returns by height, the 25th, 50th, 75th, and 90th percentiles occur at similar heights above ground.

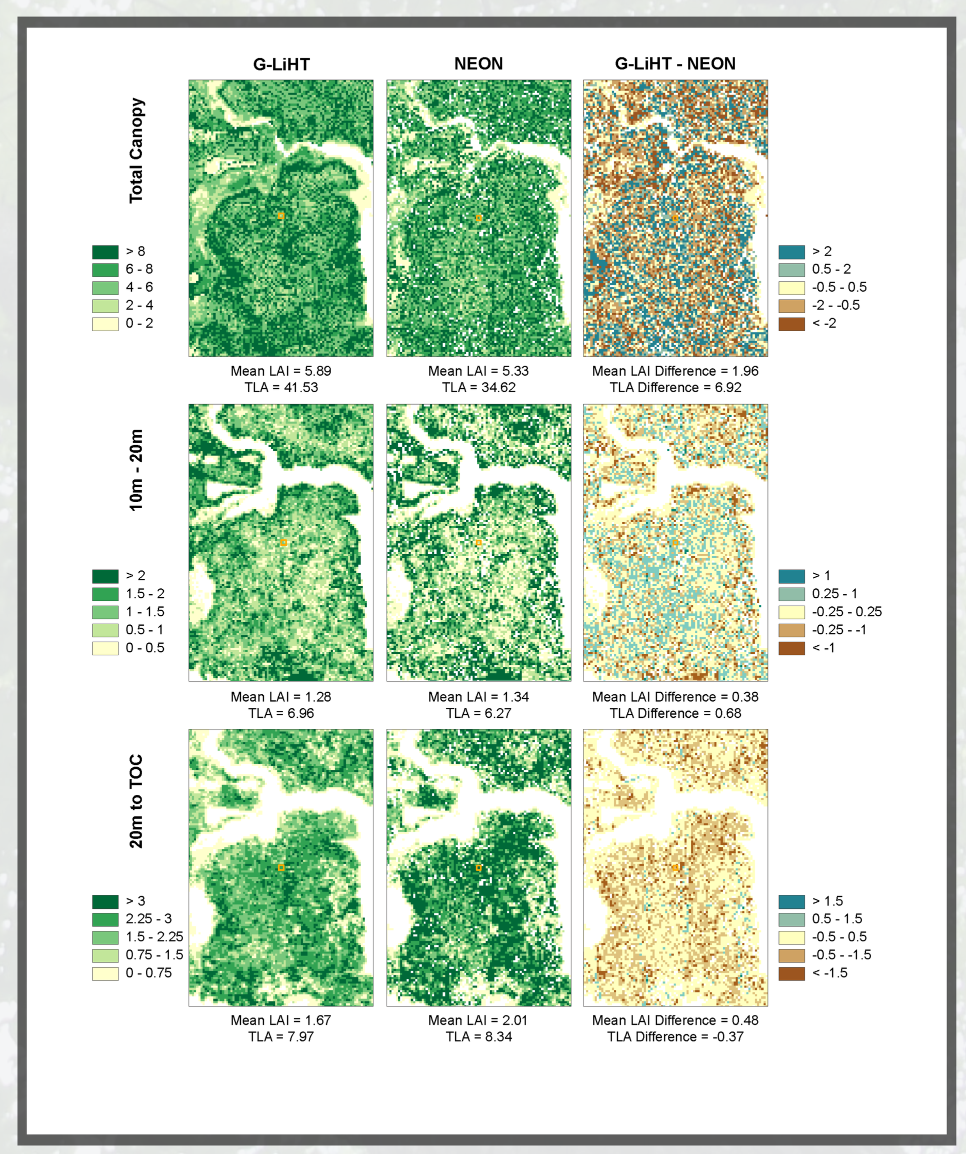
- However, the 10th percentile (dark dotted line) of returns for NASA G-LiHT occurs much deeper in the canopy at 11.5 meters above the ground, while the 10th percentile of returns for NEON AOP occurs at 20.3 meters above the ground.

COMPARING LAD, LAI, AND TOTAL LEAF AREA ESTIMATES



- Row A shows all data from ground to the top of canopy, while row B shows data from 10 meters above the ground to the top of canopy. All extracted data is from NEON Plot 45.

- The tightening of the relationship between the two sensors begins to occur at a 10-meter spatial resolution, which is also where over 90% of cells have a ground return value in both datasets.



- Total leaf area (sum of all LAI estimates; km2) at the 10x10 meter resolution across the entire study area. A subset is shown for visualization purposes. Mean LAI differences were calculated as the mean of the absolute values of the differences.

- When 10 meters above the ground to the top of canopy is considered, there is a 2% difference in TLA estimates.

- When the ground to top of canopy is considered, there is a 17% difference in TLA estimates.

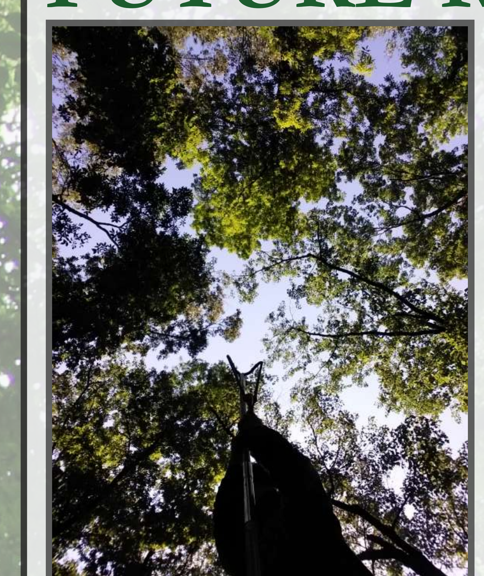
KEY FINDINGS

-We show that lower pulse density NEON AOP LiDAR data can be used to accurately estimate leaf area density and LAI

-There are minimal differences between NASA G-LiHT and NEON AOP leaf area density and LAI estimates at coarser spatial resolutions (10x10 meters and greater)

-Our leaf area density and LAI estimates are within the ranges found by other research using field-based techniques at SERC

FUTURE RESEARCH



- Upscaling field collected leaf traits using LiDAR and imaging spectroscopy from the NEON AOP at sites across the Eastern U.S.

- Modeling the within canopy variation of canopy function and structural traits in 3D.

ACKNOWLEDGEMENTS

This work is supported in part by NSF Macrosystems Biology award #1702379. Many thanks to Logan Brissette for help in the field and to the Smithsonian Environmental Research Center for site access.

Smithsonian Environmental Research Center

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