Project Summary and Proposed Modification

A Neural Network Approach to Generating Leaf Area Index Estimates Using the Sentinel-2 Satellite Record → Leaf Area Index Estimates to Inform Midrotation Treatments

Co-PIs: Rachel L. Cook, NCSU (lead), Aaron Weiskittel, UMaine, Mark Kimsey, U Idaho, Alicia Peduzzi, UGA
Project Code CAFS.21.87

Rachel Cook presenting

Original Objectives

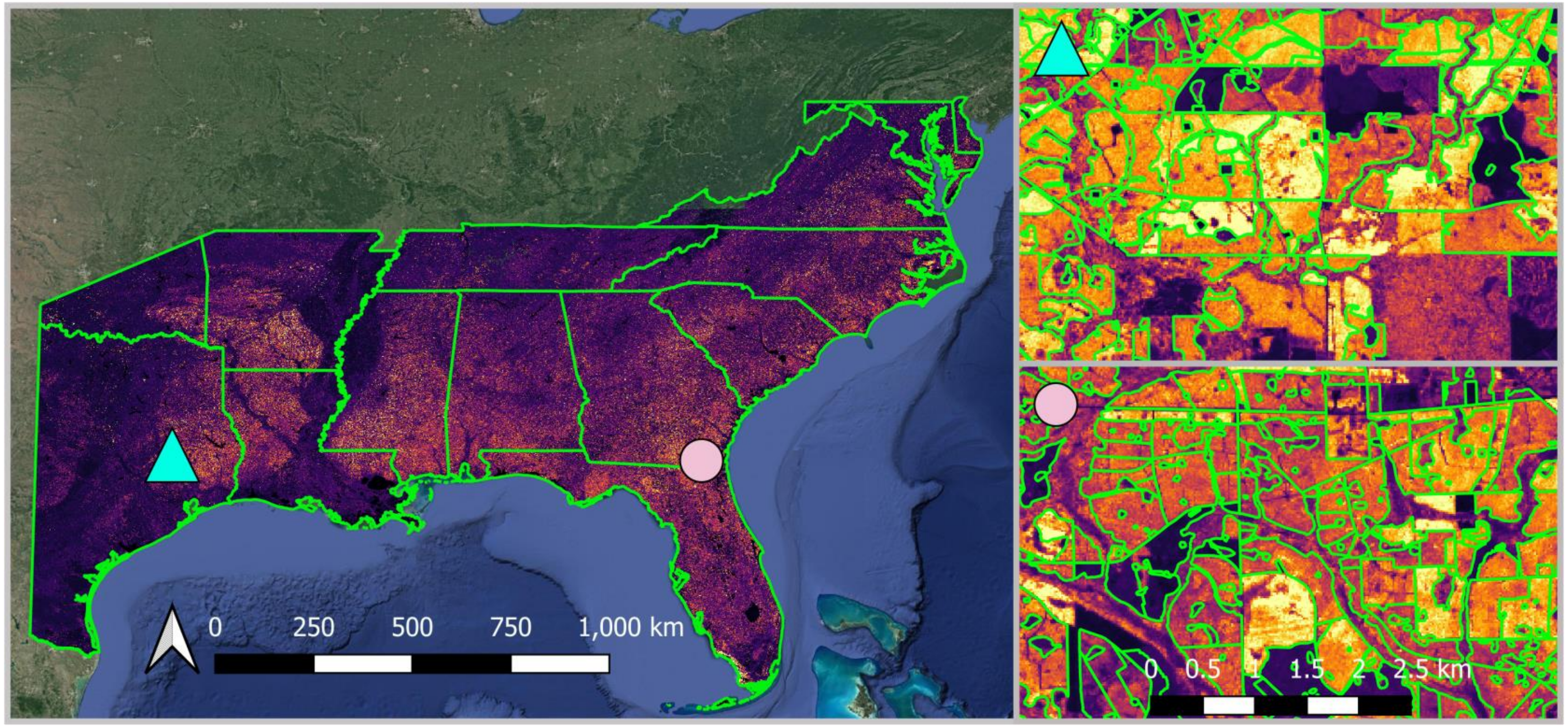
- Operationalize web interface with loblolly pine canopy “machine-learning” LAI model (MLAI)

- Expand to other regions and species for a national level LAI model for production forests

- Develop understory model to run in parallel with overstory model

- Use LAI model to develop potential productivity and response maps in conjunction with soils and climate data

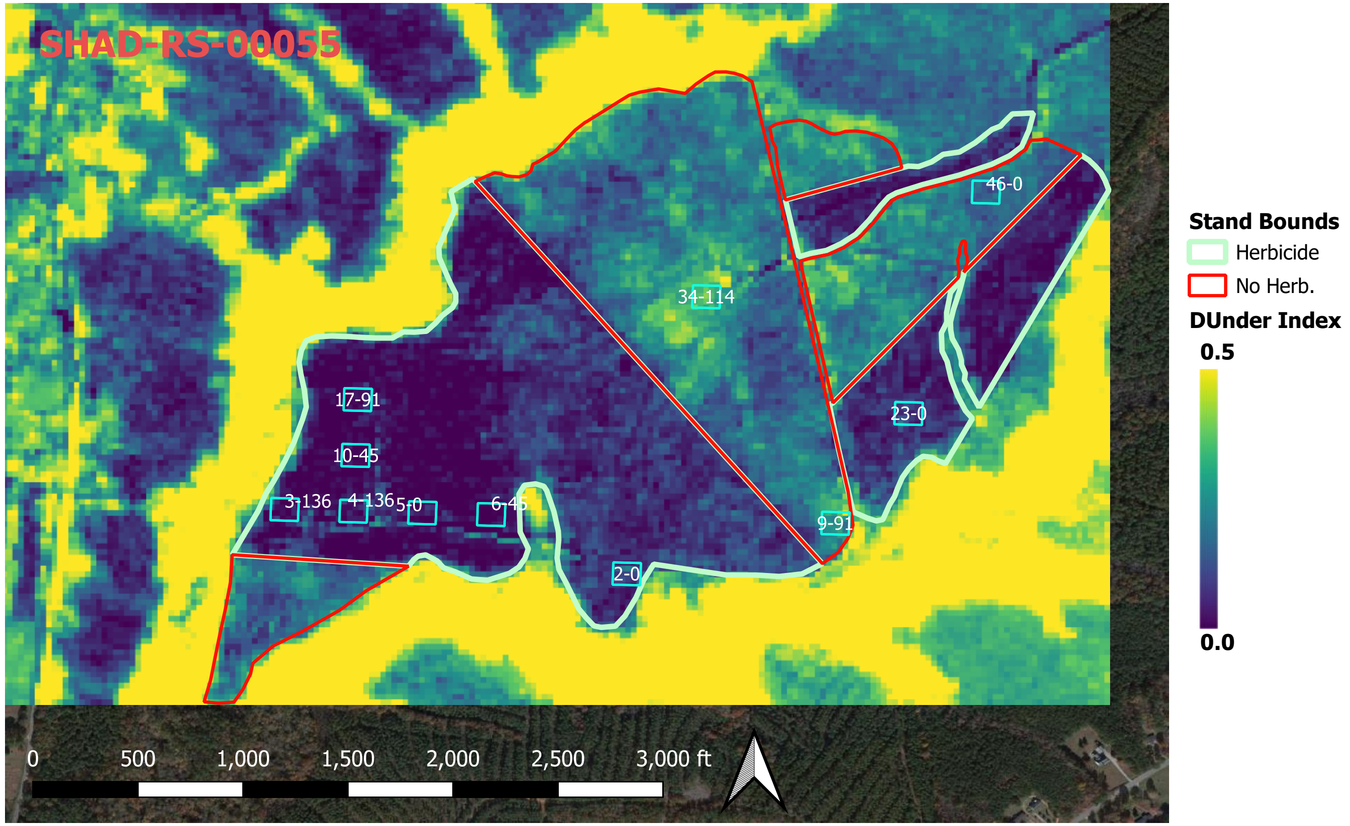
Canopy LAI in Loblolly



- Sentinel-2 based, 10-20 m entire SEUS
- Also now adapted for Landsat archive (‘84-present)
- Annual LAI layers now in database
- Currently working with Okan to deploy in ArcGIS online

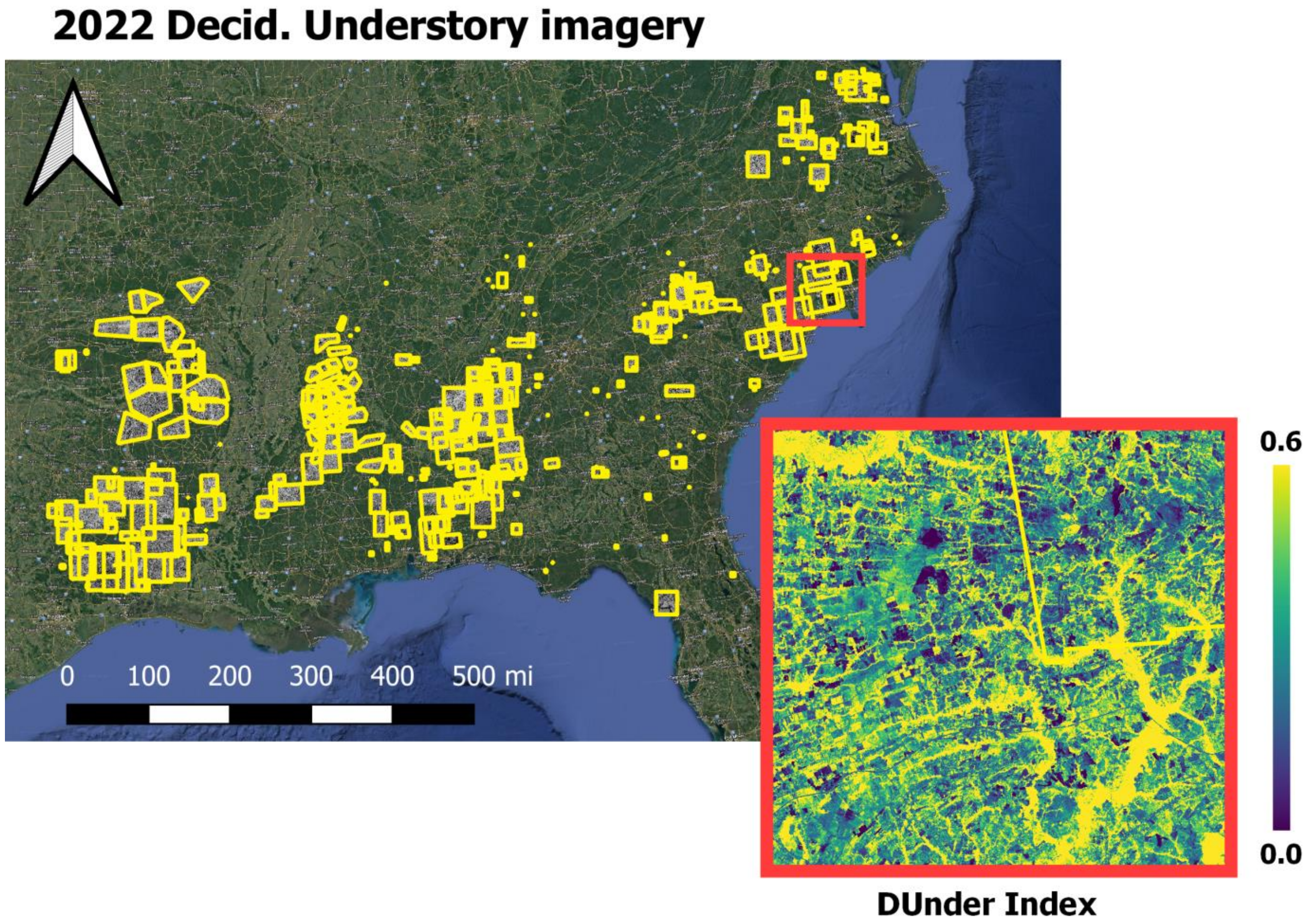
- Recent research (publishing 2023) w/ LiDAR ground truth suggests we could improve on performance of established linear models (e.g. neural networks, different veg. indices)

Deciduous Understory Quantification (Loblolly)



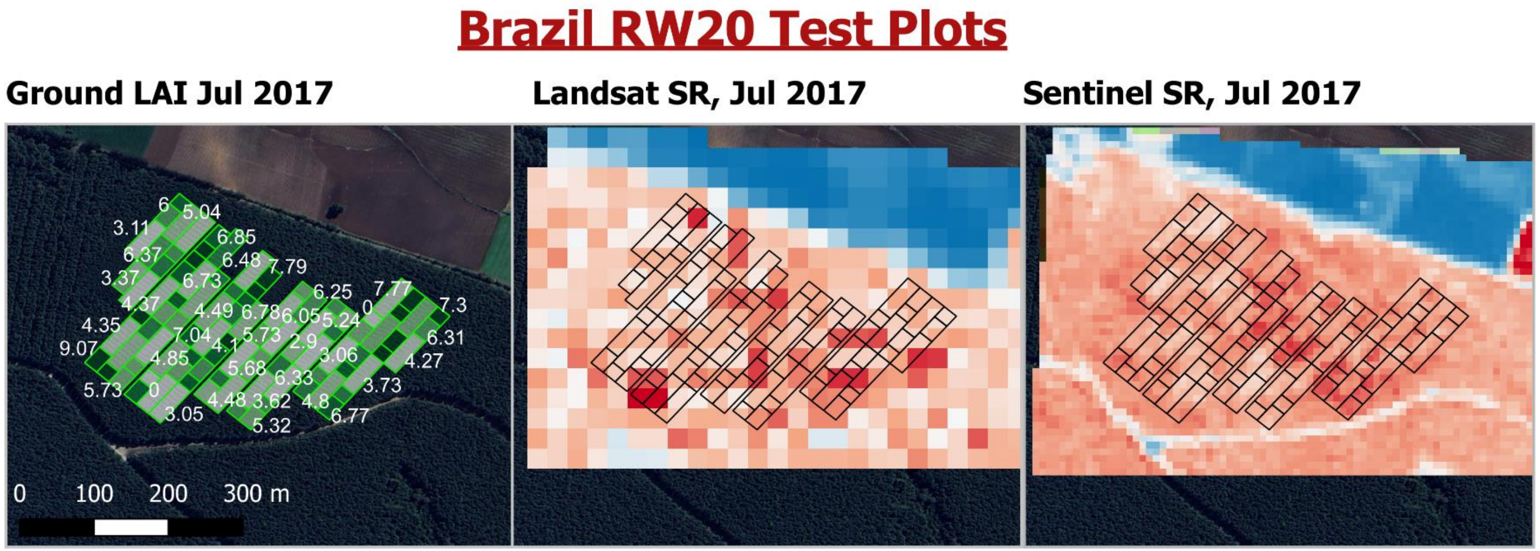
- Test plots in NC Herb/noHerb
- Uses seasonal differences in green-up timing
- Implemented in Google Earth Engine via Sentinel-2 and Landsat

Deciduous Understory at Continental Scale



- Test production run for 3M ac in 2022
- Automated scene selection and local phenology optimization
- Ground truth program with partner Member orgs is ongoing

Loblolly LAI in Latin America



Ground LAI values vs. Landsat + S2 ‘Simple Ratio’

- Ground LAI taken from *P. taeda* measurement plots in Brazil+Argentina
- Other LA crops to try (e.g. *Eucalyptus*) but ground data currently too sparse.

LAI in other North American forests

- Success in adapting spruce/fir LAI model to Earth Engine
  - Can replicate Bhattarai et al. (2022) operationally
- Interest in second attempt at Pacific Northwest Douglas Fir, pending ground LAI data.
- (Results scattered after a series of hard drive failures)

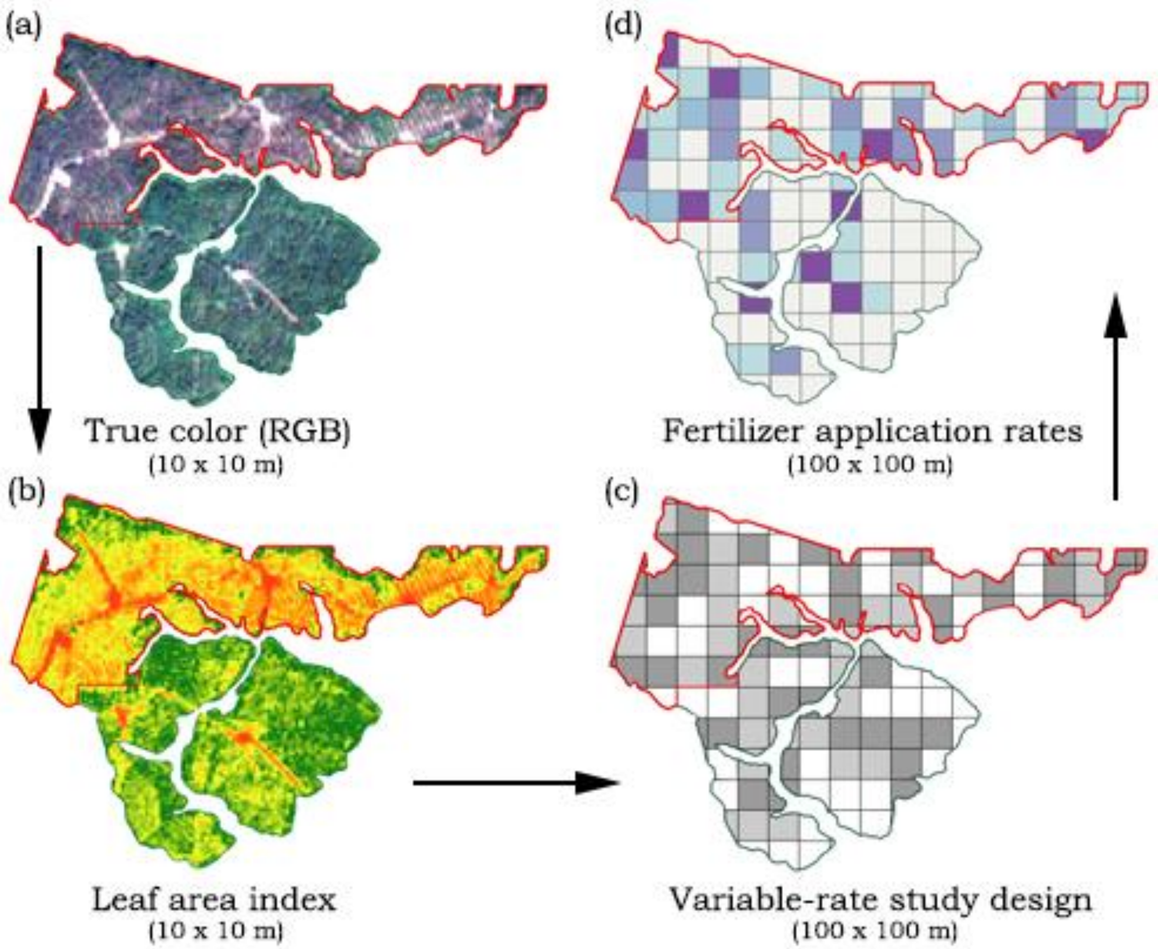
Proposed Modifications – Experimental Plan

- Use LAI model to develop potential productivity and response maps in conjunction with soils and climate data (Continuted)
- Apply LAI tools to Midrotation silvicultural decisions
- Assess operational level response to herbicide and/or variable rate fertilization
- Use canopy LAI to make Fertilizer Rate decisions (vs Random rate)
- Assess response in canopy LAI due to changes in understory LAI
- Use repeat LiDAR flights (and ground truth data) to assess individual tree height and volume response to treatments

Experimental Design

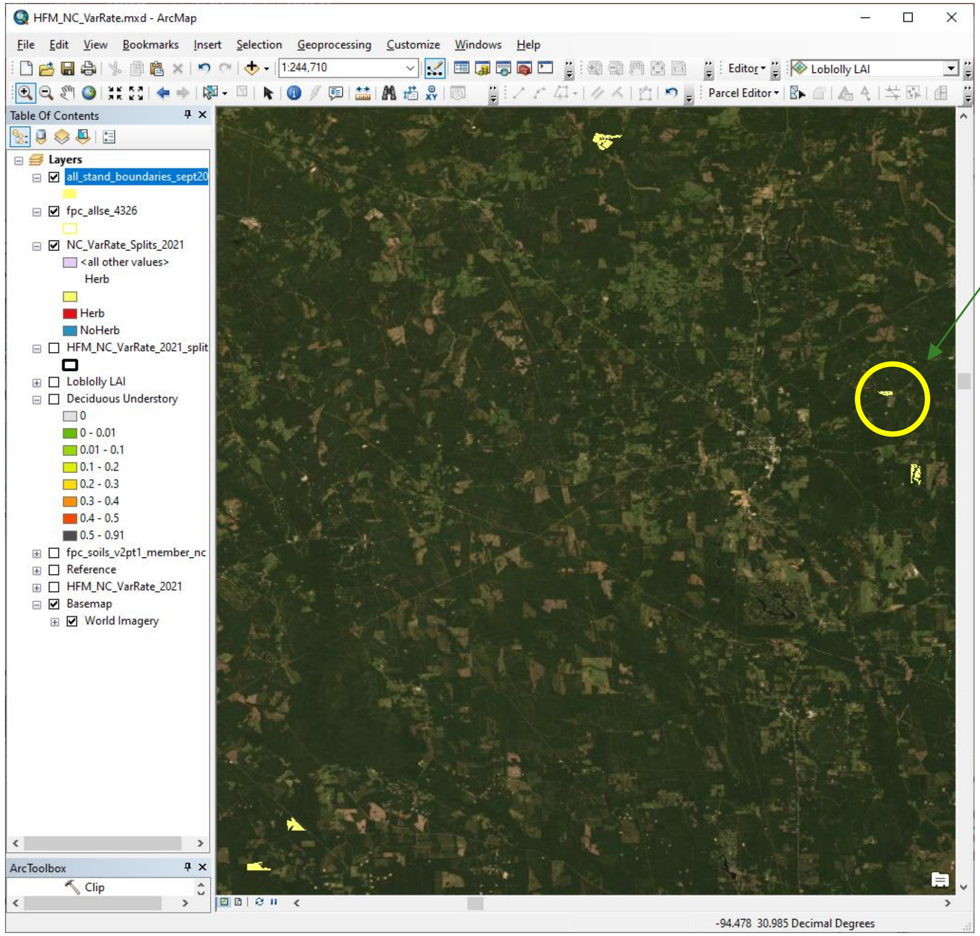
- Herbicide vs No Herbicide
  - Random application N (lb) + 10% P
    - 100
    - 200
    - 300
  - LAI-based rates of elemental N (lb/ac) + 10% elemental P
    - 0
    - 100
    - 150
    - 200
    - 250
    - 300

LAI	N Rate lb/ac
>3.5	0
3.0-3.5	100
2.5-3.0	150
2.0-2.5	200
1.5-2.0	250
1.0-1.5	300

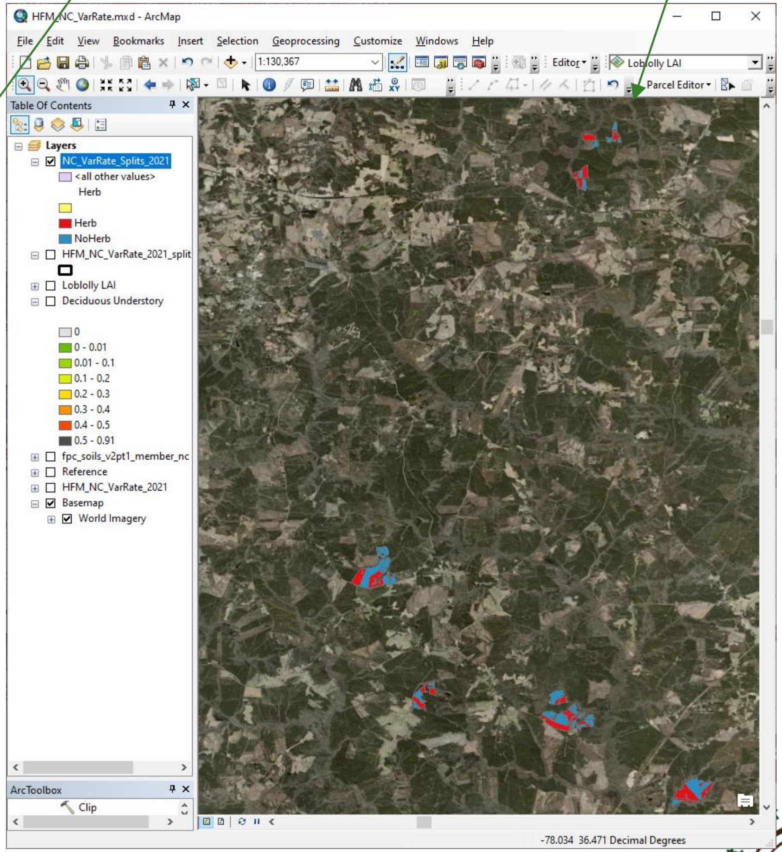


Treatments based on 1 ha grid

Study Locations



630 acres

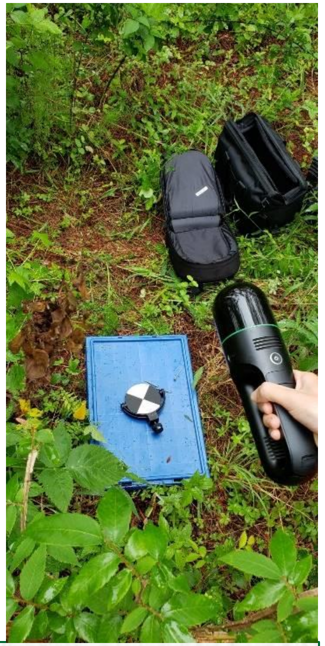


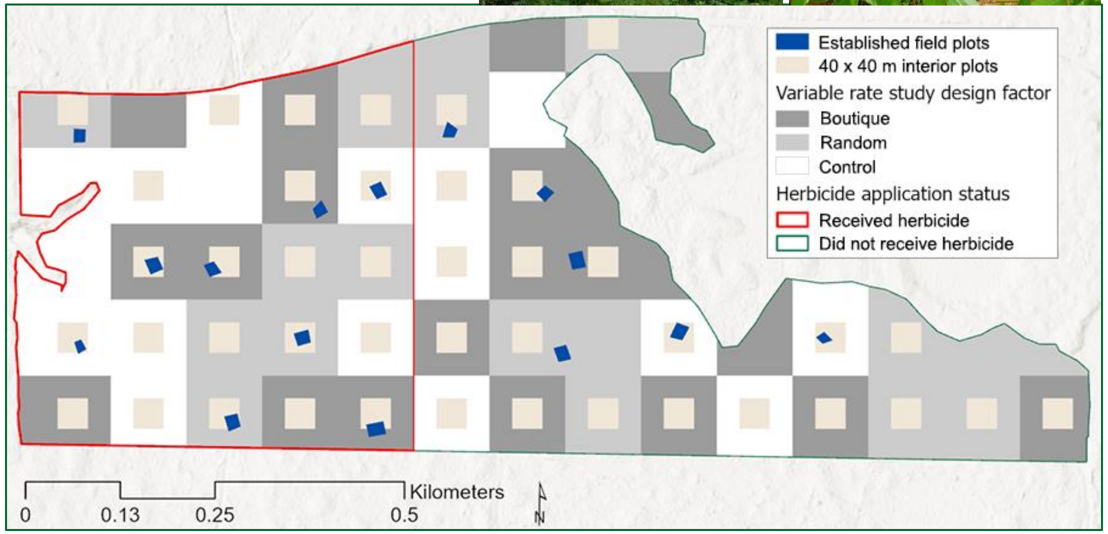
1500 acres

Field data collection

Measurements taken:

- Diameter
- Height
- Height to live crown
- Understory metrics
  - total percentage of ground cover occupied by understory with living foliage
  - fraction evergreen and/or deciduous
  - max & mean heights

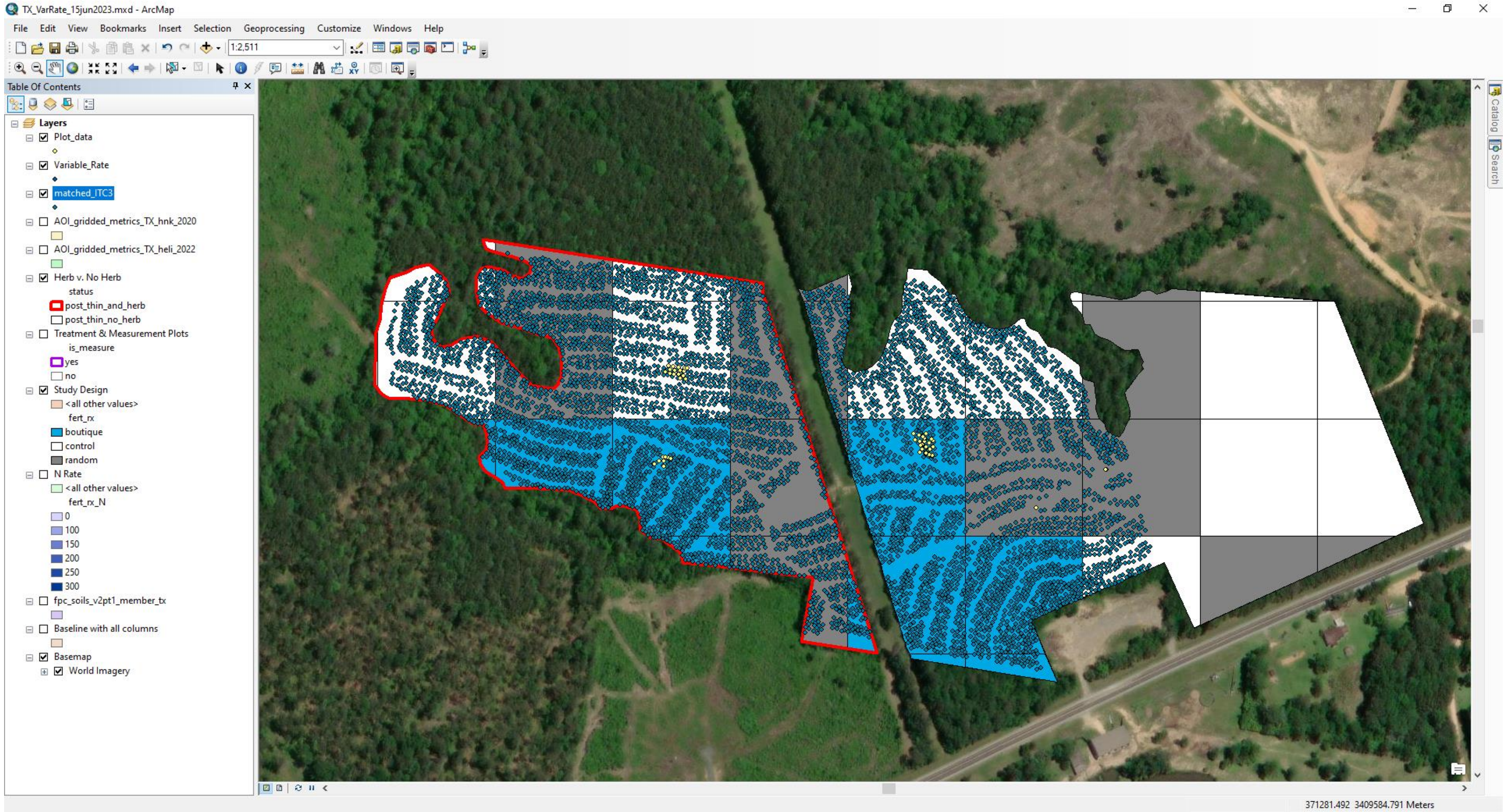




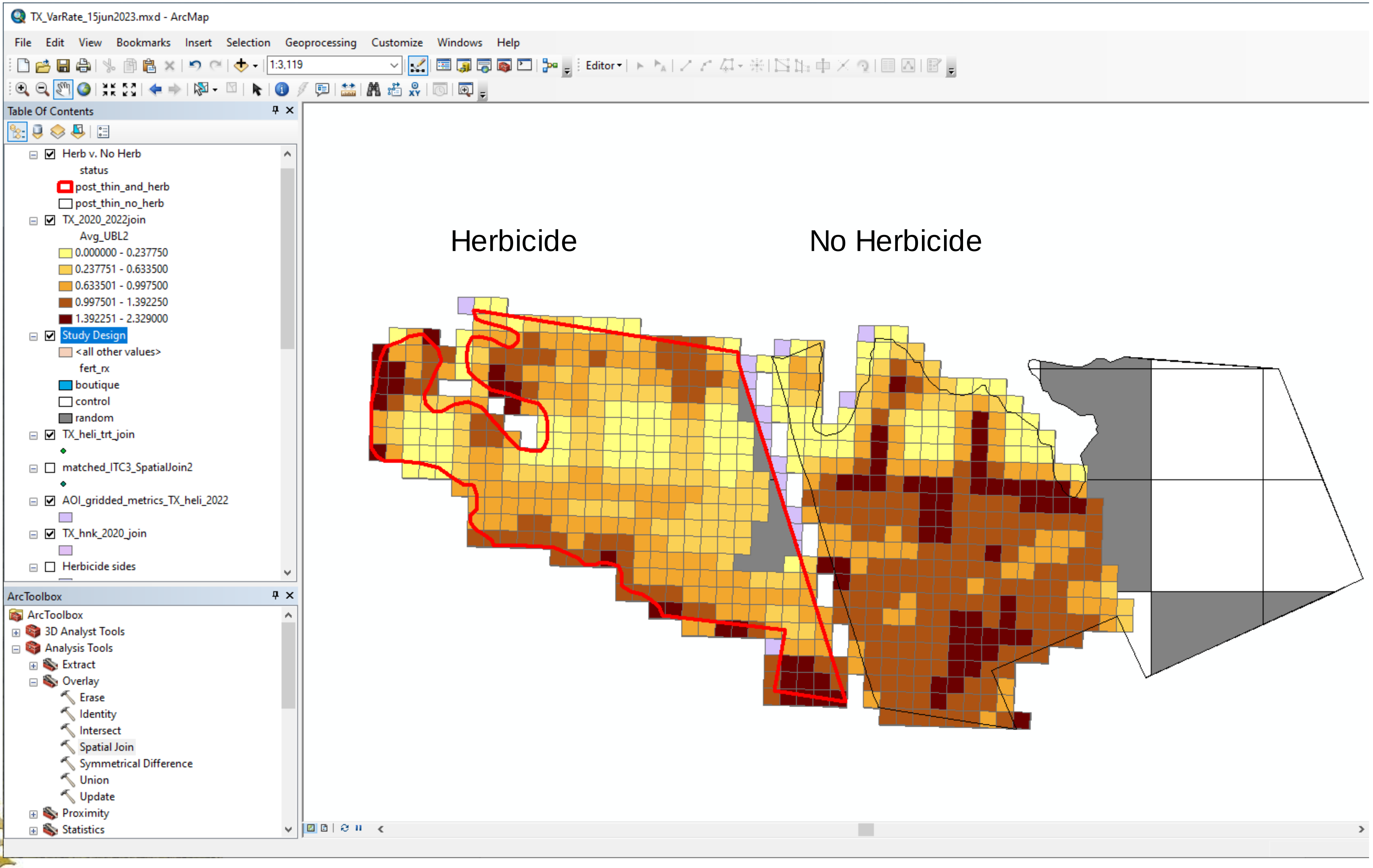
TX: 77 plots established pre-fertilization (Dec 2020)

Re-measured one and two growing seasons post-fertilization (Dec 2021, Jan 2023)

2 years of growing season – Helicopter LiDAR acquisition



Understory LAI 2022



Preliminary Results 2020-2022 from LiDAR

- Where there was no herbicide, more fertilizer fed the competition

Initial LAI was related to Ht growth (ft)

Level				Least Sq Mean
greater than 3.5	A			4.1346407
3.0 to 3.5	A	B		3.7642473
2.5 to 3.0		B		3.6896007
2.0 to 2.5		B		3.5482759
1.5 to 2.0			C	3.0415821
1 to 1.5			C	3.0046219

No Herbicide

Height growth (ft) per N rate

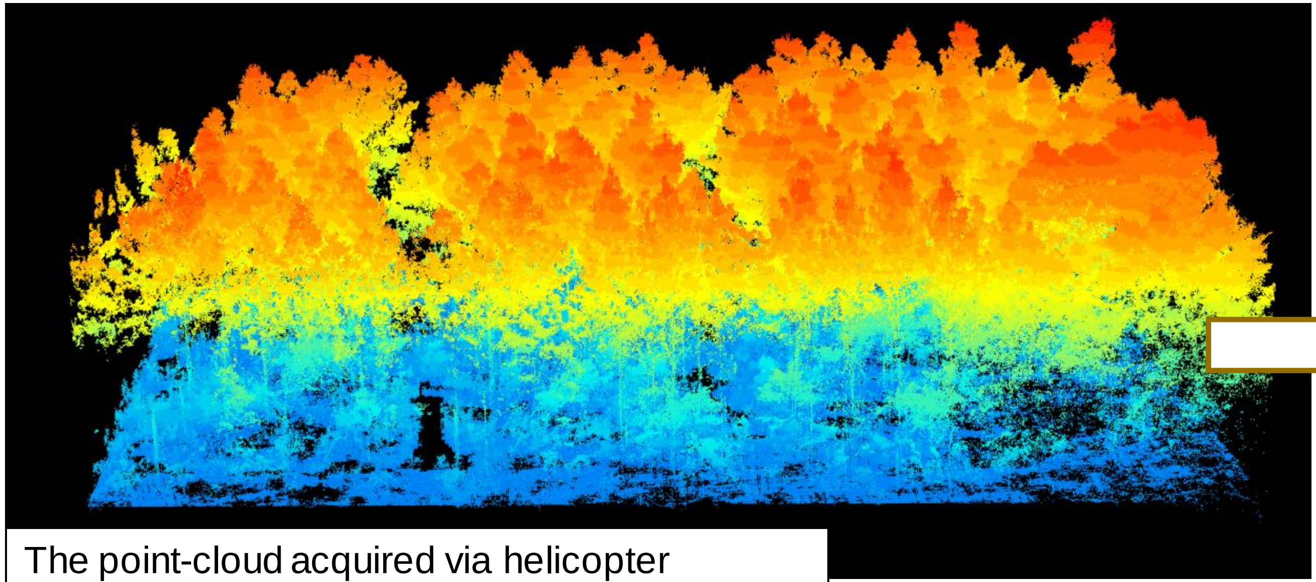
Level					Least Sq Mean
0	A				4.1605562
150		B			3.7106436
200		B	C		3.4603196
300			C	D	3.1935305
250				D	3.0157738

Dbh per N rate

Level					Least Sq Mean
300	A				9.3378484
250		B			8.6624108
200		B			8.6623012
150			C		8.1287476
0				D	7.5439520

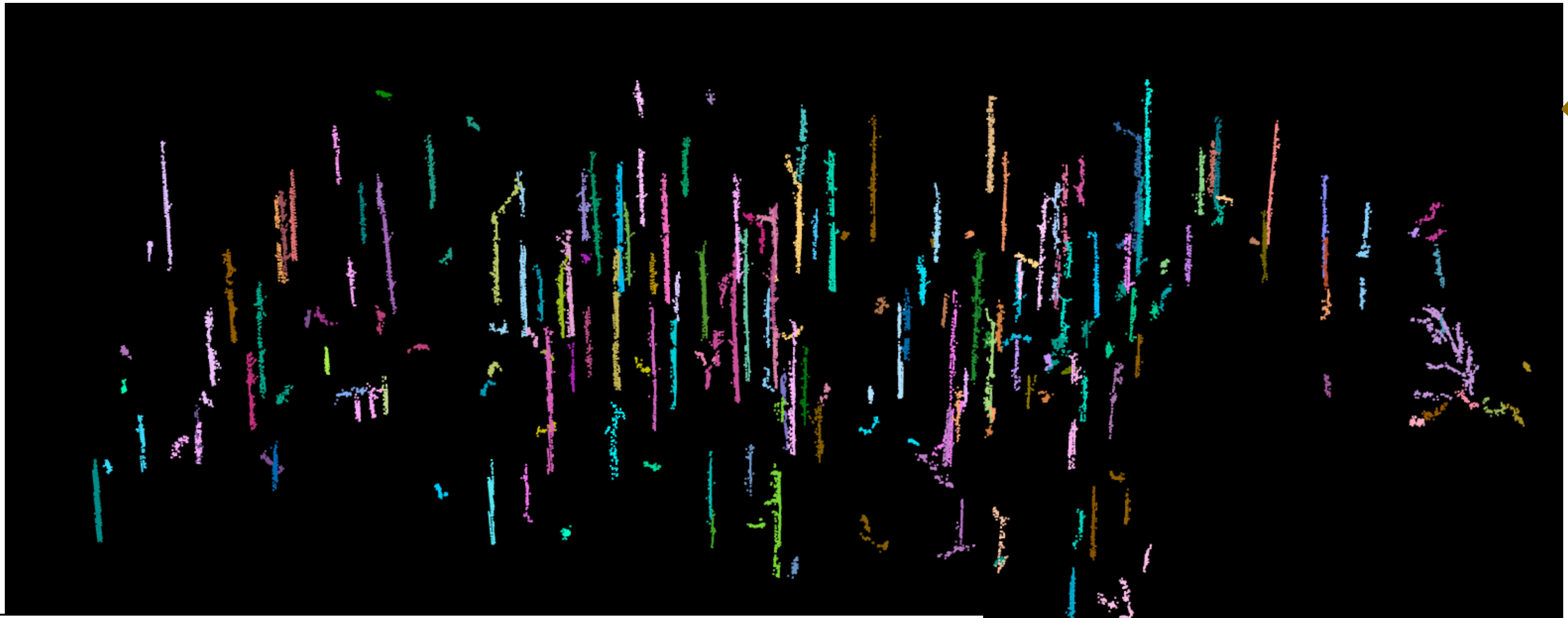
DBH (in) per Fert App

Level				Least Sq Mean
random	A			8.9993612
boutique		B		8.3461038
control			C	7.5439520



The point-cloud acquired via helicopter

The point-cloud classified into individual trees



The point-cloud analyzed* to classify the location of tree stems.

Company Benefits

- Accessibility to LAI canopy layers
- Operational scale results from mid-rotation fertilization vs herbicide across soils and geology
- With time, ability to assess return on investment for: rates of fertilization and/or herbicide
- Determination of when/where LAI-based, variable rate fertilizer application can be beneficial.