Forest Productivity Cooperative Research Overview

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NC STATE UNIVERSITY · VIRGINIA TECH · Universidad de Concepción · UFLA UNIVERSIDADE FEDERAL DE LAVRAS

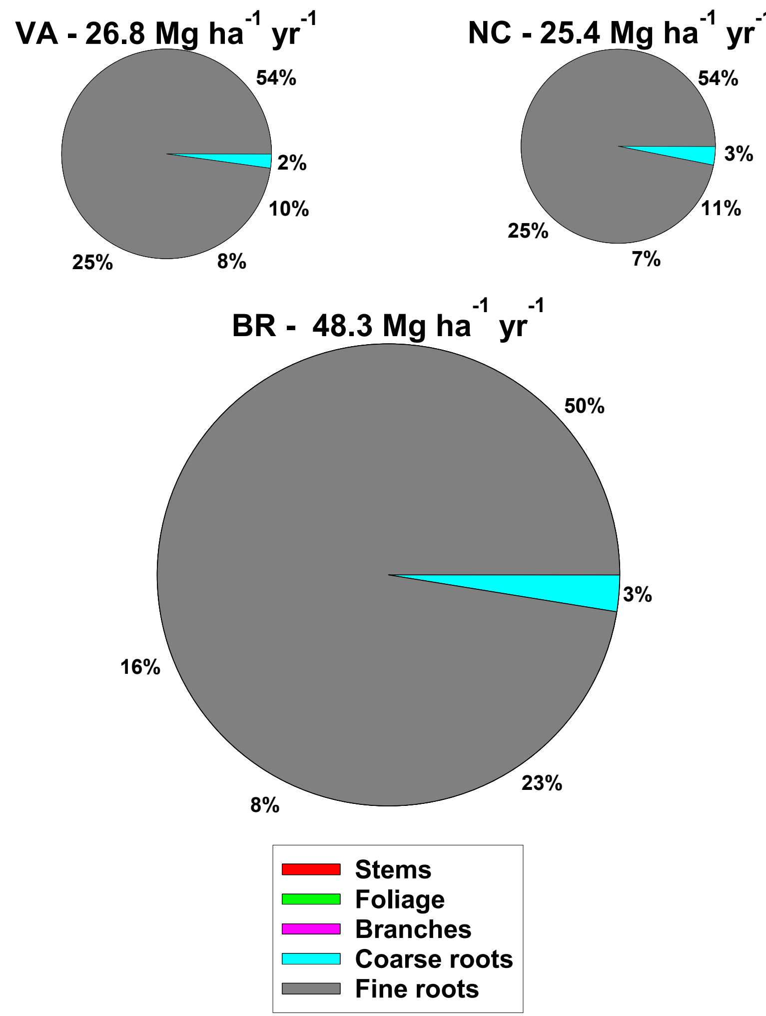
CAFS Phase I: Silviculture x Spacing x Genetics

Forest Ecology and Management

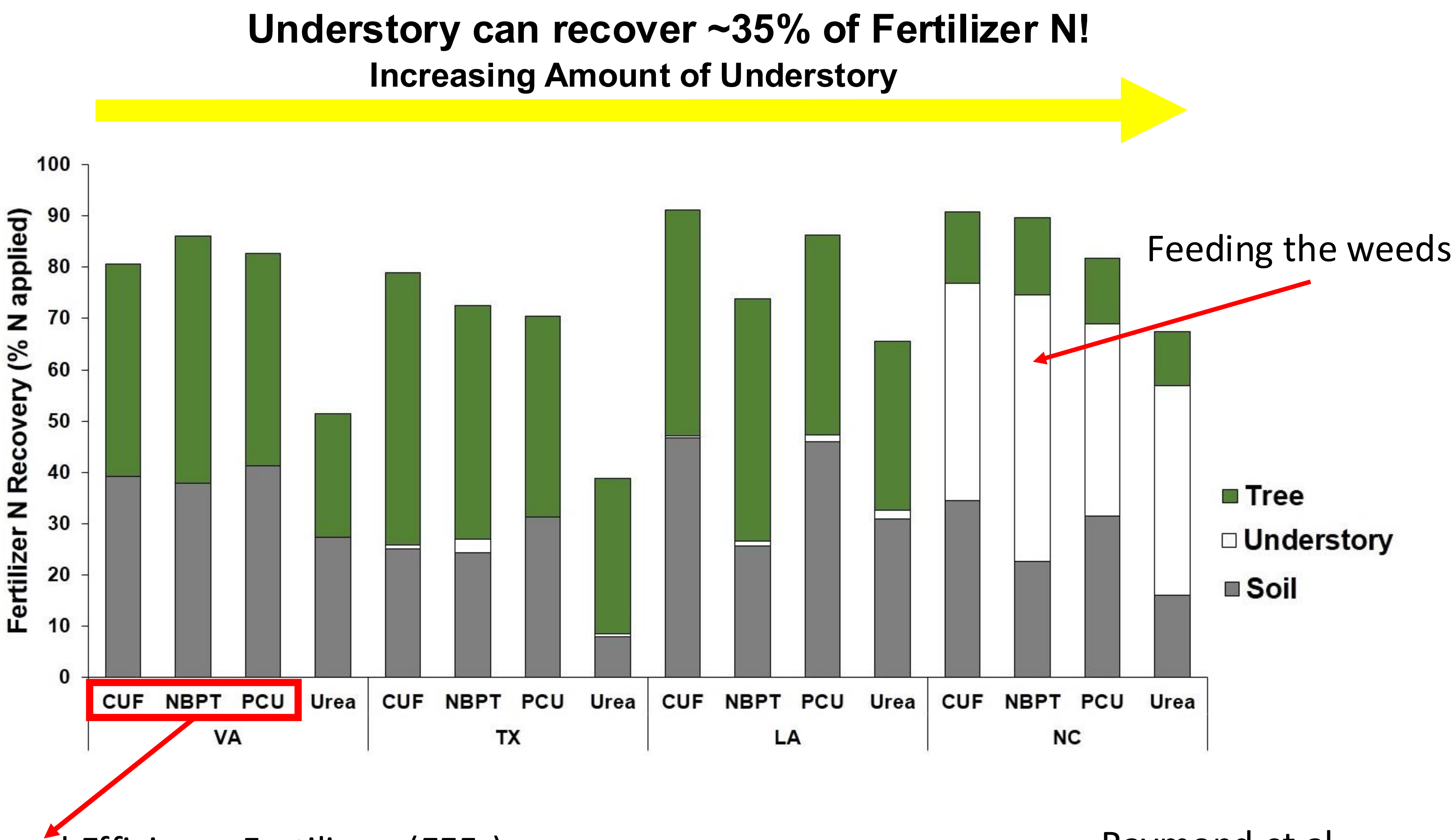
Quantifying above- and belowground biomass improved our understanding of site differences and demonstrated the importance of management decisions in sequestering carbon in Pinus taeda

--Manuscript Draft--

Increased above ground growth in BR not related to changes in above-below ground allocation



^{15}N Fertilizer from CAFS

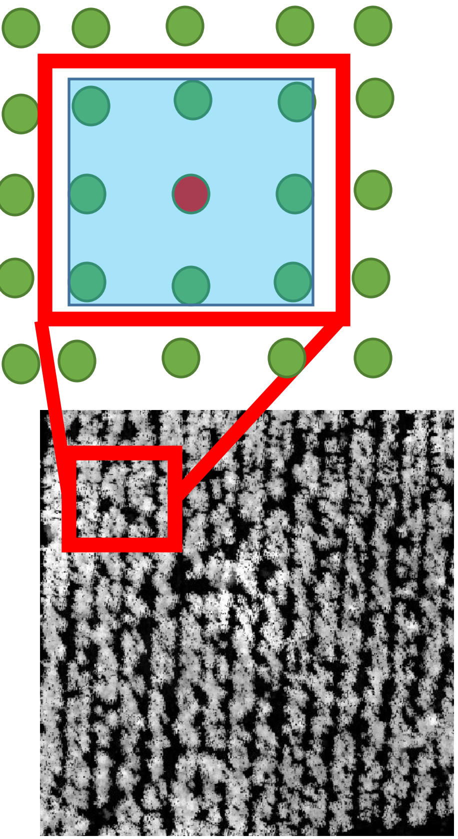


Enhanced Efficiency Fertilizers (EEFs)

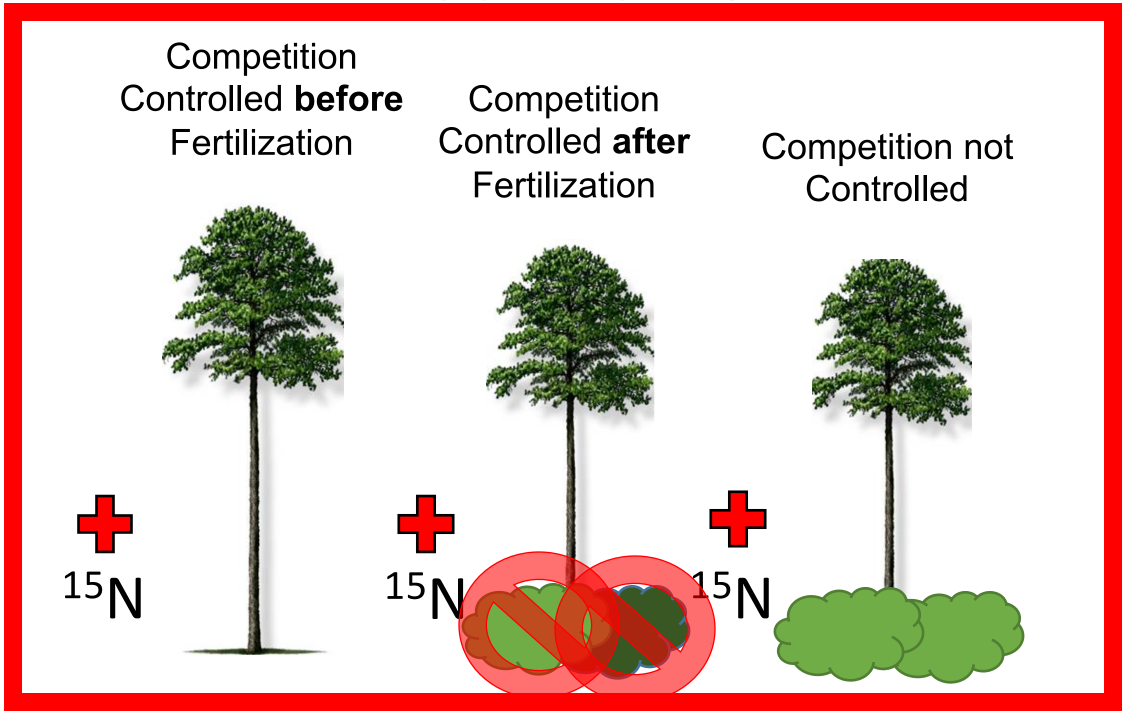
Raymond et al.

What should come first? Fertilizer or Competing Veg Control?

Aerial View of Measurement Plot

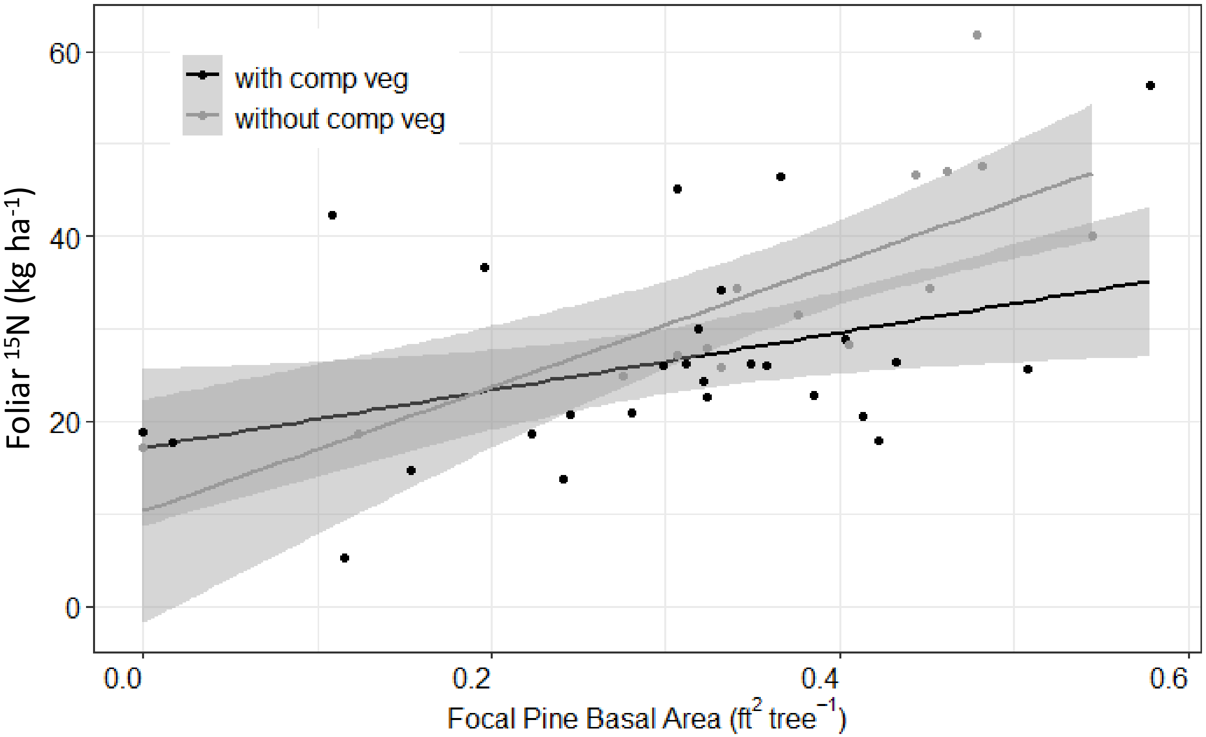


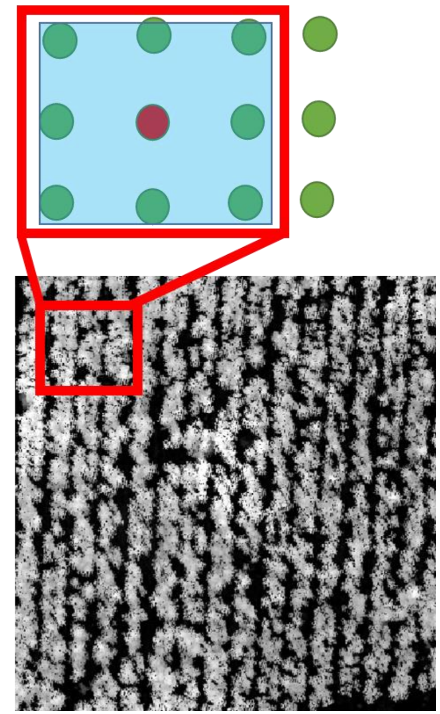
Treatments



Everything is fertilized at the same time.
Veg control is what differs among treatments.

Big trees capture more fertilizer and they capture more yet when the competition is gone





US FPC NCSU Grad Students

Ben Rose,
PhD NCSU

Vicent Ribas-Costa,
PhD with Univ
Madrid

Travis Howell,
PhD

Maria Higuita,
PhD NCSU

Drew Martin,
MS NCSU

Sarah Puls,
MS NCSU

TJ Queck
MS at NCSU
with Bayer

Jacob Bost,
MS NCSU

Iván Raigosa-Garcia,
PhD NCSU

Strategic Priorities 2020-2025

Nutrition and Site-Specific Resource Supply

- Soil mapping for fertilization response and potential productivity
- Long-term nutrient availability
- Mid-rotation fertilization: Crown recession & potential response

Vegetation Control vs Fertilization

- Midrotation Release
- Timing during Rotation
- Herbicide updates

Remote Sensing

- Satellite and LiDAR: Competing vegetation LAI
- Lidar: stand inventory

1. Nutrition and Site-Specific Resource Supply

- Soil mapping for fertilization response and potential productivity

- Long-term nutrient availability
  - RW28 & USDA Long-term P Carryover
  - Fungal microbiome

- Mid-rotation fertilization: Crown recession & potential response
  - RW19 data analysis

Major Soil Group	
A	Clay
B	Fine Loamy
C	Coarse Loamy
D	Spodic
E	Silty
F	Deep Subsoil (Grossarenic, > 40 in)
G	Deep Sand (> 80 in)
H	Histosol/ Organic

Depth Code (inches)	
0	unknown (0-20)
1	0 – 5
2	5 – 10
3	10 – 20
4	20 – 40
5	40 – 80
6	None within 80 in

Drainage	
E	Excessively Drained
D	Somewhat Excessively Drained
W	Well Drained
M	Moderately Well Drained
S	Somewhat Poorly Drained
P	Poorly Drained
V	Very Poorly Drained

Modifier 1: Nature of Surface	
d	Dark surface
y	Silty
e	Eroded
g	Gullied
r	Rocky
o	Other or NA

Modifier 2: Nature of Subsoil	
a	Alfic
m	Mica
x	Mixed
k	Kaolinitic
p	Plastic/ smectitic/ vertic
i	Siliceous (sandy)
o	Other or NA

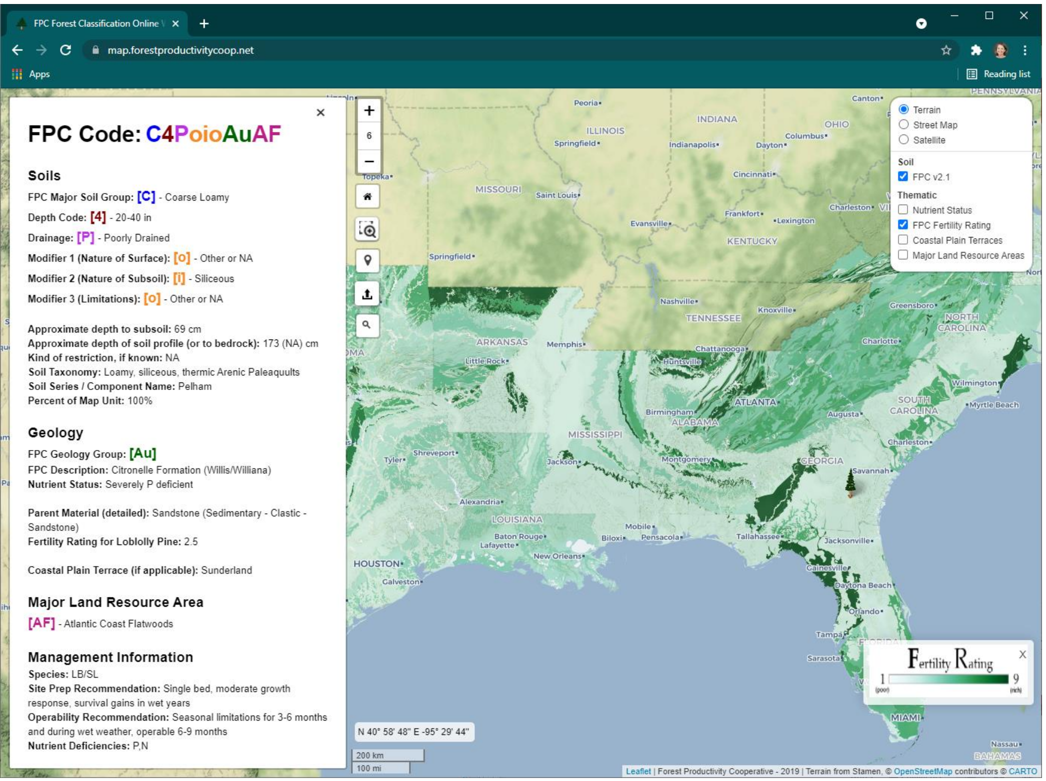
Modifier 3: Limitations (A or B Horizon)	
w	Ponded Water
f	Floods (fluvic)
l	Lamella
s t u	Root limited (densic, lithic, paralithic) (<10, 10-20, 20-40 in)
v	Root limited 40-80 in
q	Restrictions within 40 inches (fragic, cemented, plinthic)
c	Alkaline, calcareous
n	Salt affected (natric)
o	Other or NA

Geo Code
Pa
Al
Dw
Lb
Ws
Am
Au
Ct
Fl
Ch
Vk
Yg
Jk
Cb
Wx
Md
Bb
Ba
Av
Sa
Cs
Ms
Fs
Lo
Gg
Le
Sh
St
Lm
Sc
Bg
Um
Sr
Mr
Ui

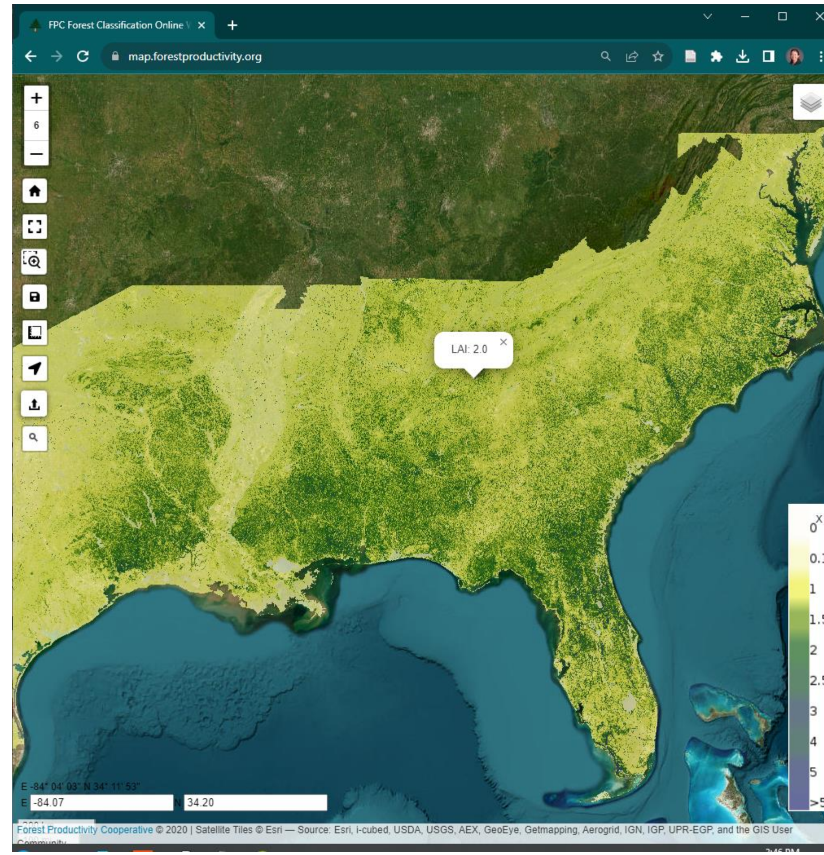
Physiographic Province	
AF	Atlantic Coastal Plain Flatwoods
GF	Gulf Coastal Plain Flatwoods
SC	Southern Coastal Plain
WG	Western Gulf Coastal Plain
LP	Mississippi Valley Loess Plain
BP	Blackland Prairie
SH	Sandhills
PD	Piedmont
MT	Mountains
AA	Alluvium

Classification based on:
Site Productivity Optimization of Trees “SPOT” system

FPC Soil Webmap & GIS



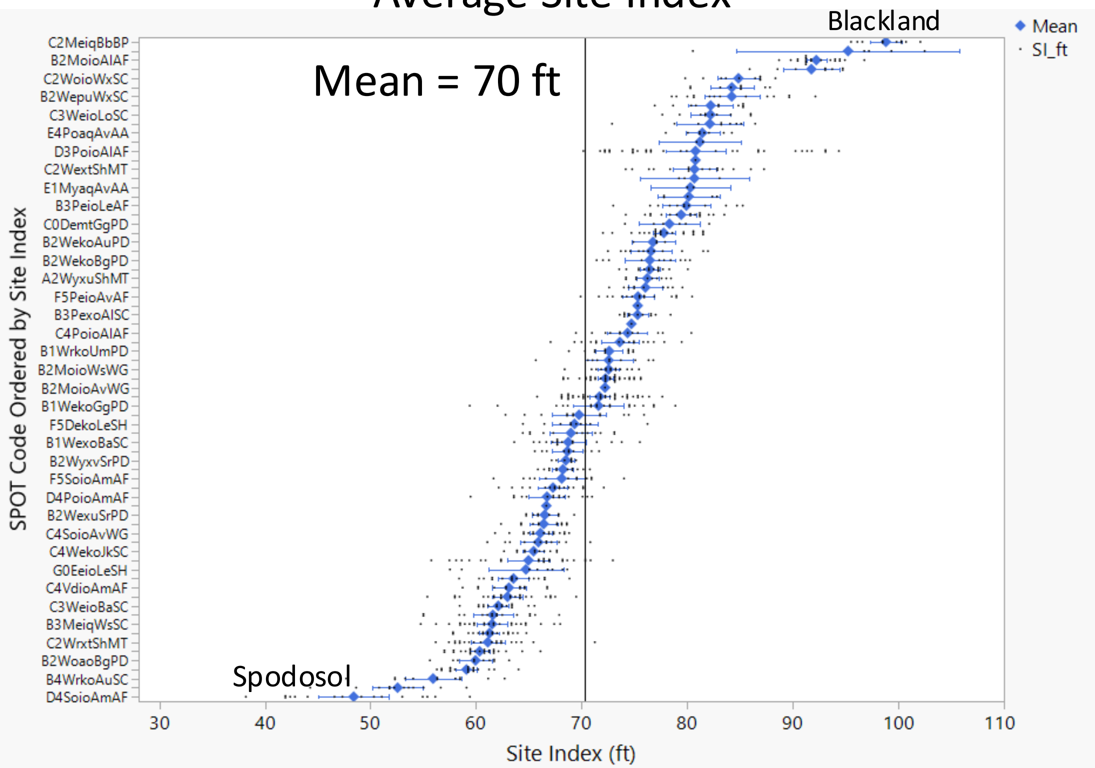
Soils, Geology, and Physiographic Province



Satellite-based LAI

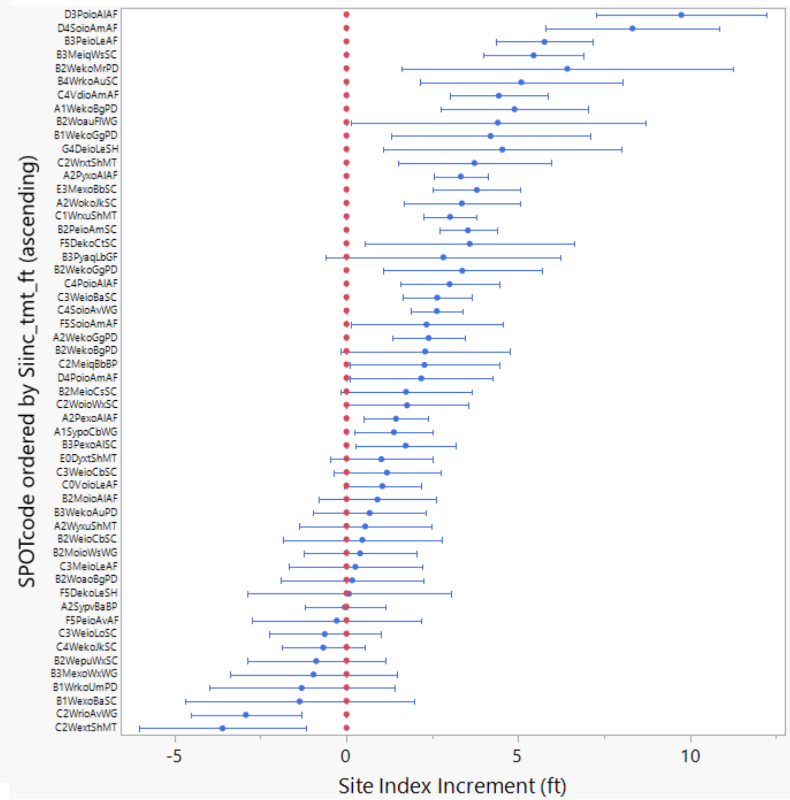
Site Index by SPOT code (ft)

Average Site Index

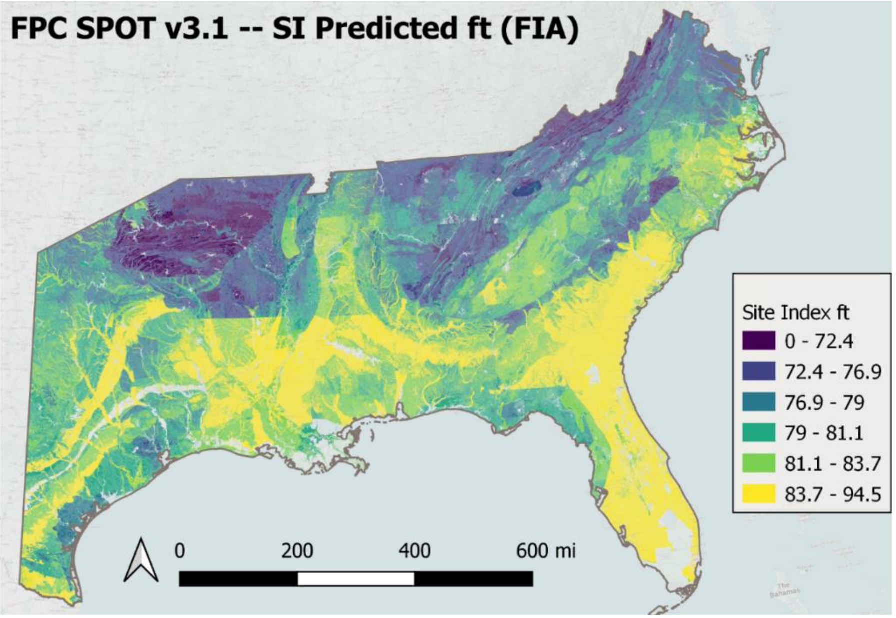


Each error bar is constructed using a 95% confidence interval of the mean.

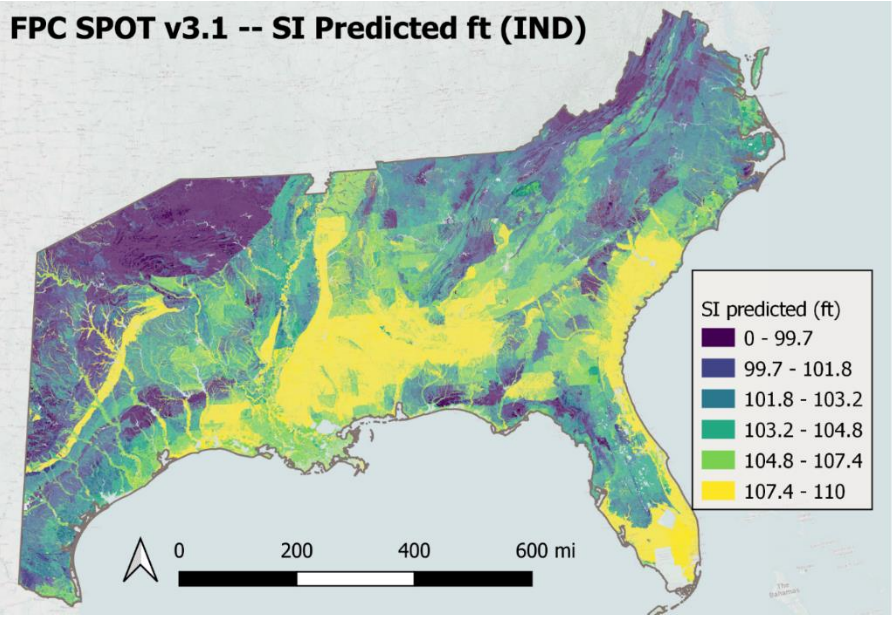
Response to N+P



Predicted Site Index

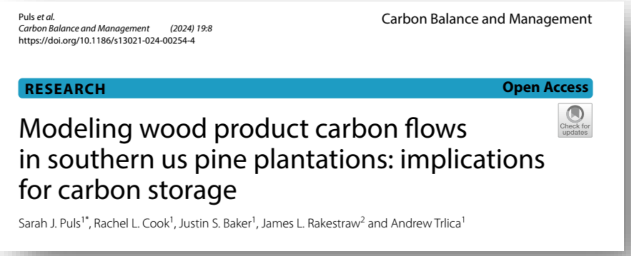


- Planting Year Basis: 2020
- Regeneration: Planted



- Planting Year Basis: 2020
- Management Basis: Chem+Fert+Thin

Site Index Important for Forest Carbon Modeling


Puls et al.
Carbon Balance and Management (2024) 19:8
https://doi.org/10.1186/s13021-024-00254-4

Carbon Balance and Management

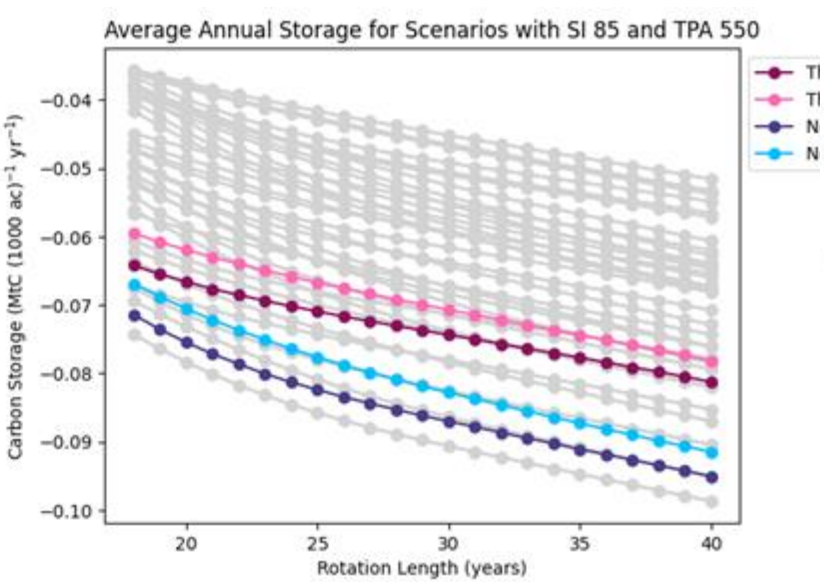
RESEARCH Open Access

Modeling wood product carbon flows in southern us pine plantations: implications for carbon storage

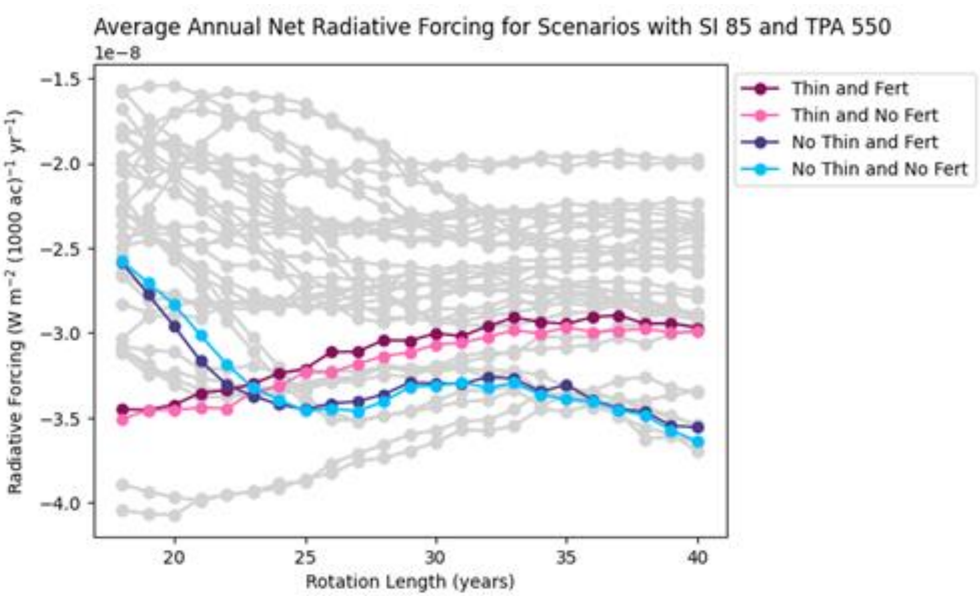
Sarah J. Puls[1*], Rachel L. Cook[1], Justin S. Baker[1], James L. Rakestraw[2] and Andrew Trlica[1]

- Need recognition of ways to improve carbon in industrial forestry
- Dynamic Life Cycle Assessment Approach
    - Puls et al. A Range of Management Strategies for Planted Pine Systems Yields Net Climate Benefits. Revisions submitted to Mitigation and Adaptation Strategies for Global Change.

carbon storage

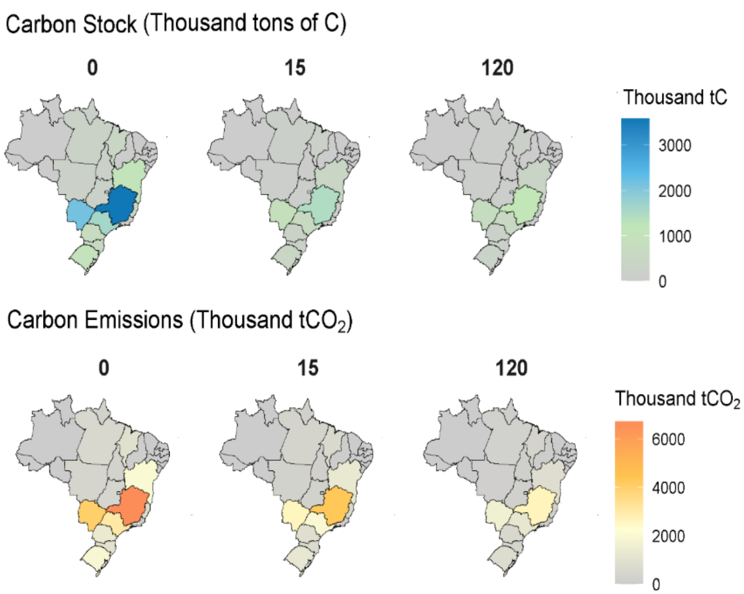


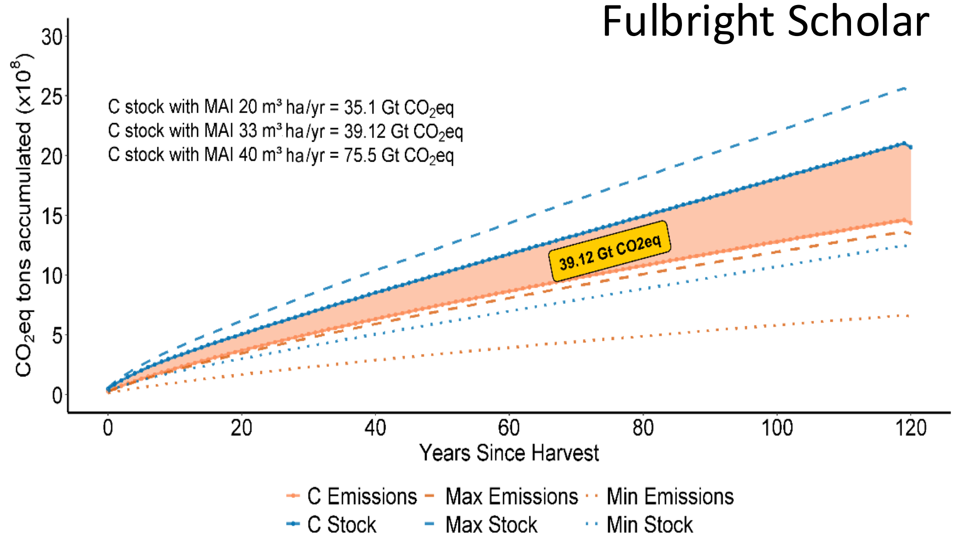
net radiative forcing



Adapting Harvested Wood Products Carbon Model for Brazil

Fernanda Leite Cunha
Fulbright Scholar

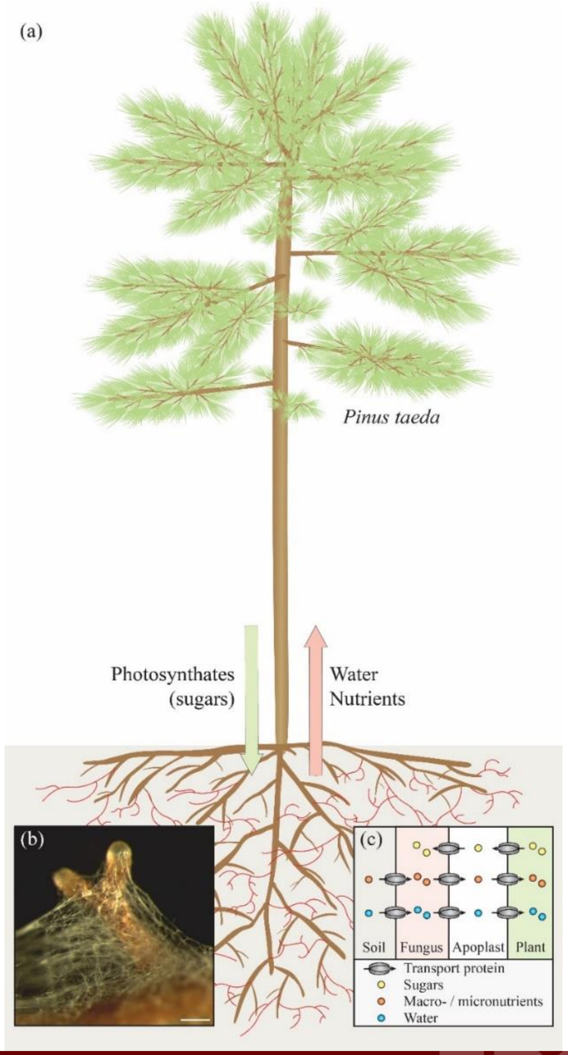




$650k over 4 years NCSU+VT

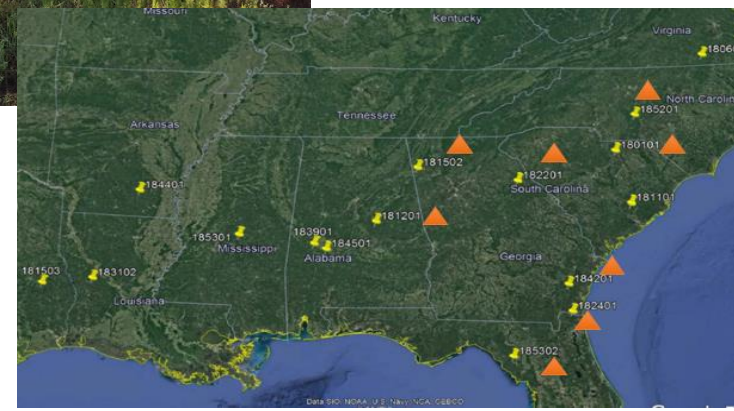
USDA Long-term P Carryover

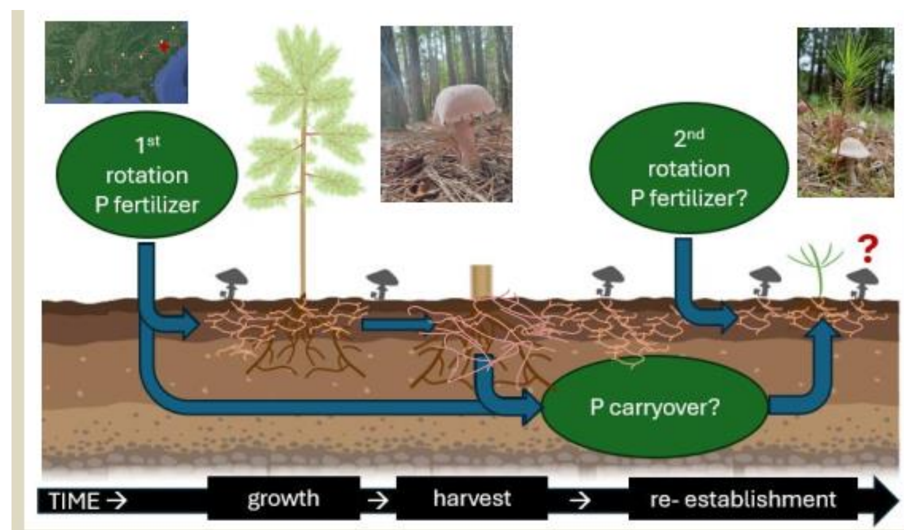
- Evaluate soil P carryover from previous fertilizer inputs
- How does the fungal microbiome influence nutrient uptake and productivity?
- How does fertilization influence the fungal microbiome?



RW28 Grad Student Projects

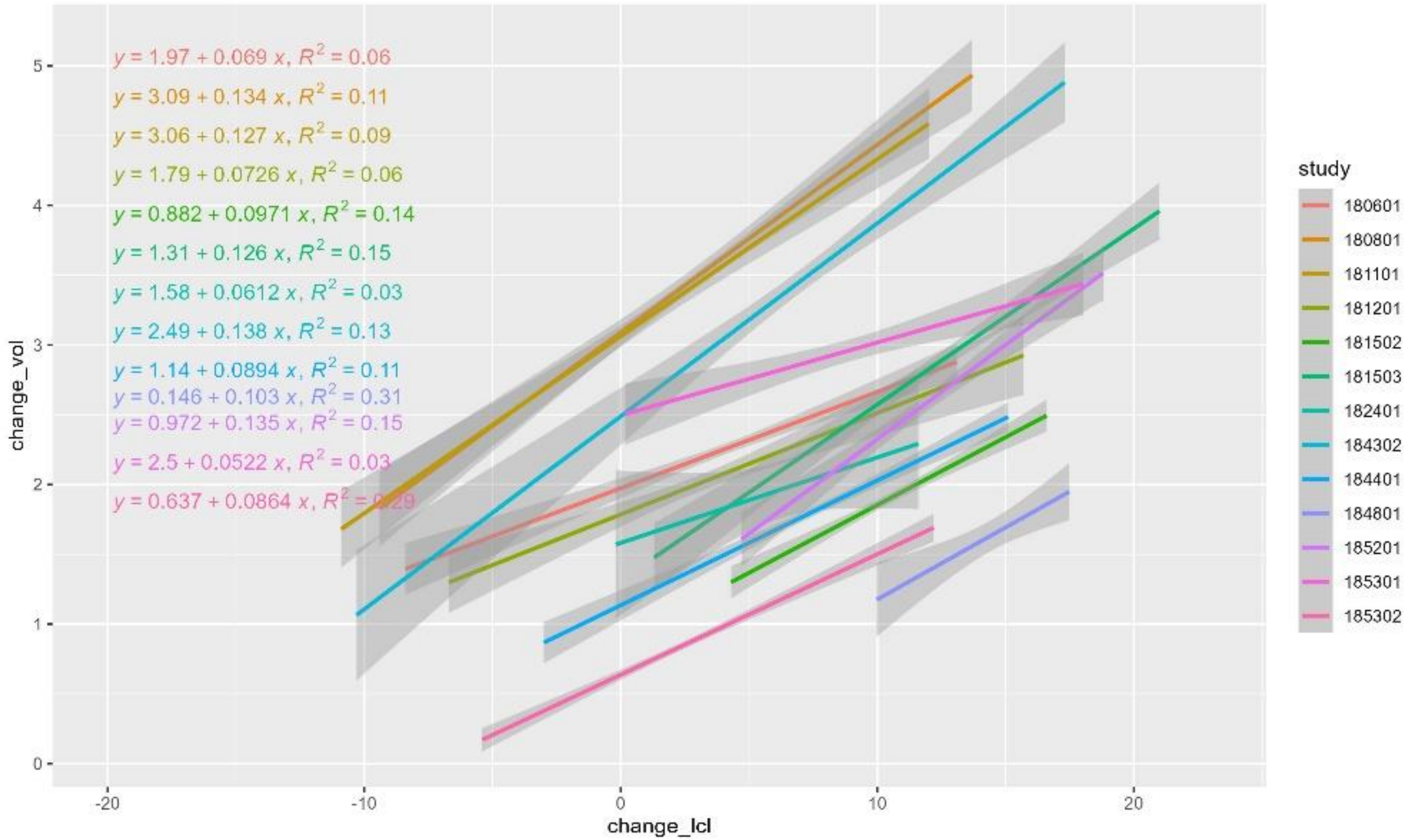
- Daniel Hong
  - Effects of substrate quality and nutrient amendments on decomposition rate and nutrient release.
- David Enemo
  - P chemical availability due to soil and management history
- Ben Rose
  - Fungal microbiome across sites as affected by soils and fert
- Maria Higuita
  - Selecting fungal communities to improve P acquisition





Mid-rotation fertilization: Crown recession & potential response

RW18 Relationship between live crown length
and volume growth in response to juvenile fertilization



Greater increases in live crown length four years post-fertilization = greater volume increases

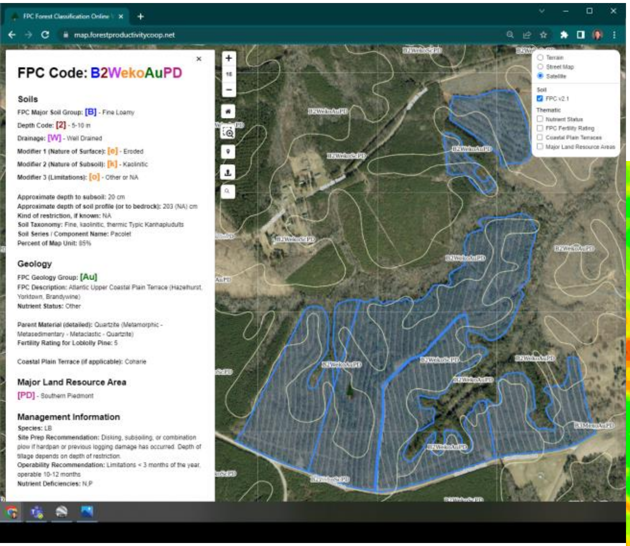
2. Vegetation Control vs Fertilization

- Midrotation Release
  - Timing during Rotation
    - ^{15}N Veg Control & Fertilization
  - Variable Rate Trial

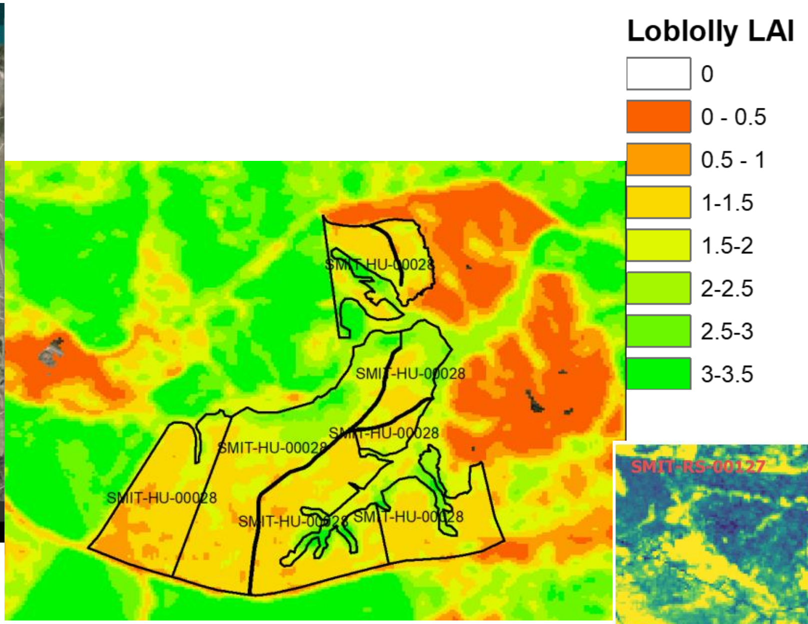
- Herbicide Trials

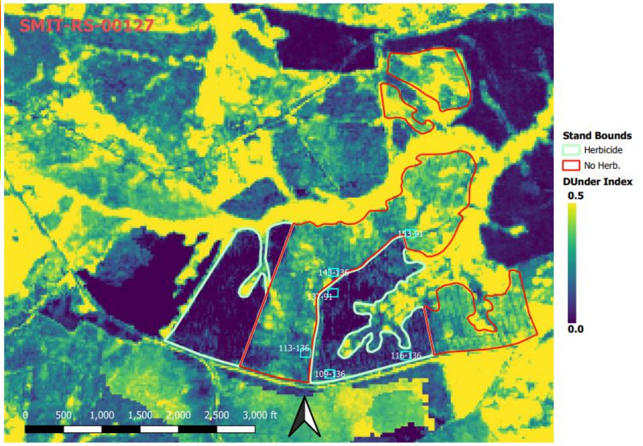
How to know what stands to fertilize vs herbicide?

Likely soil response + Leaf Area Index + Understory Assessment



Likely responsive to N+P





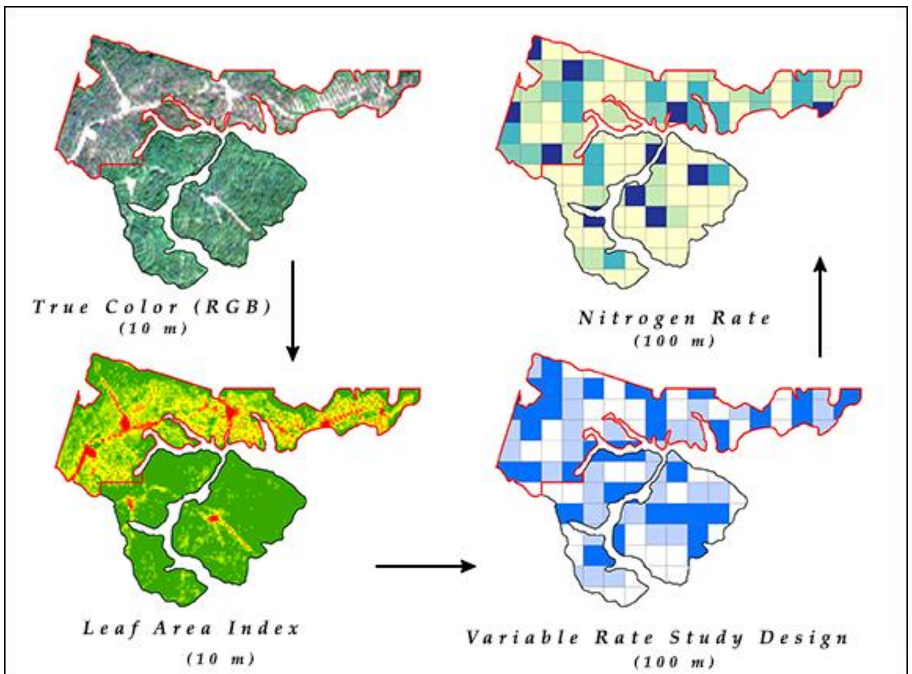
Manulife

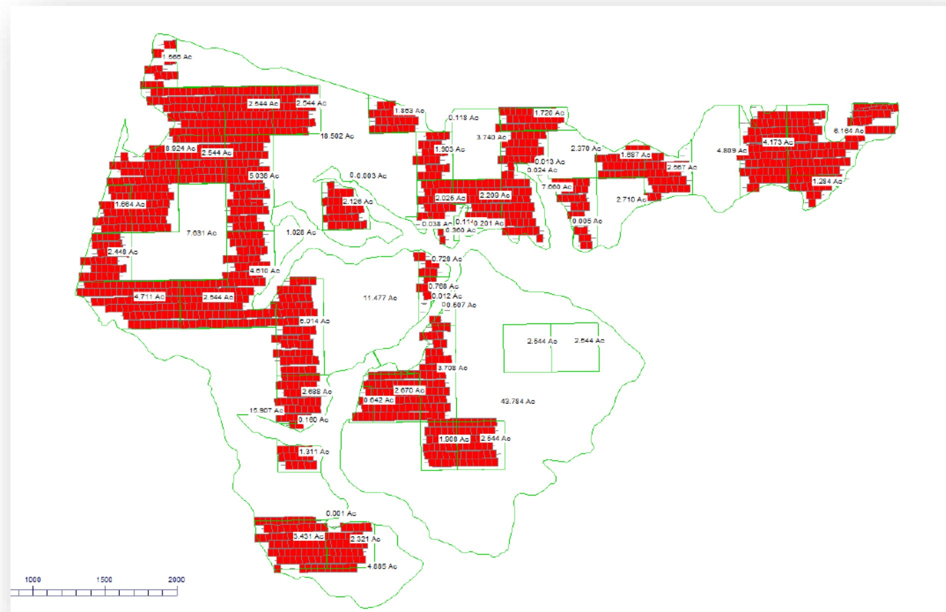
WIN Only What Is Needed By Lesco Aviation

CHEM AIR Shreveport, Louisiana LLC

Precision Forestry

- Variable Rate Fertilization
- With and without Understory Control





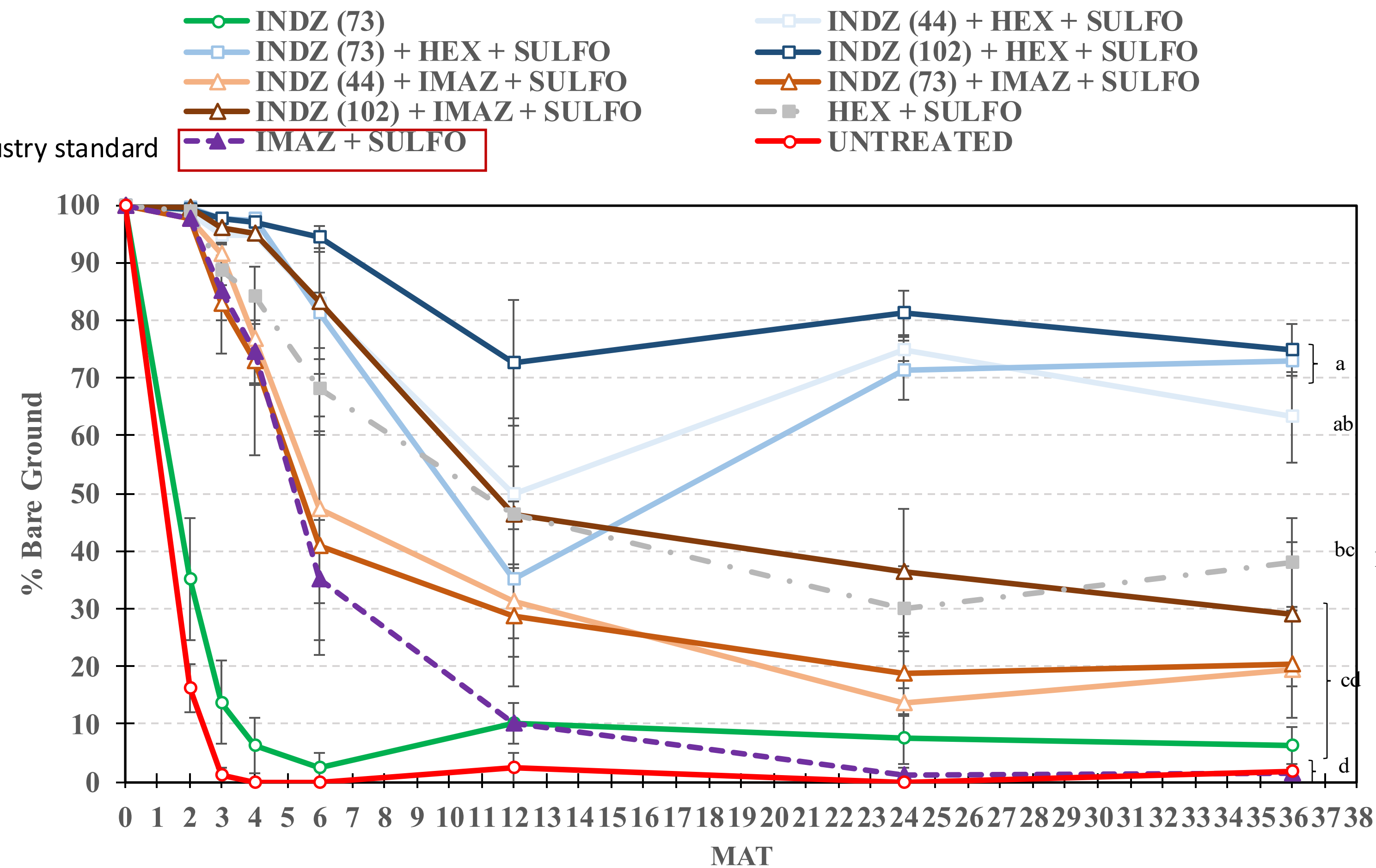
As Applied Fertilizer Map
0, 100, 200, 300 lbs of N

Resource Management
Veg Control

HEX + SULFO

IMAZ + SULFO

Industry standard



INDZ + HEX + SULFO

HEX + SULFO

INDZ + IMAZ + SULFO

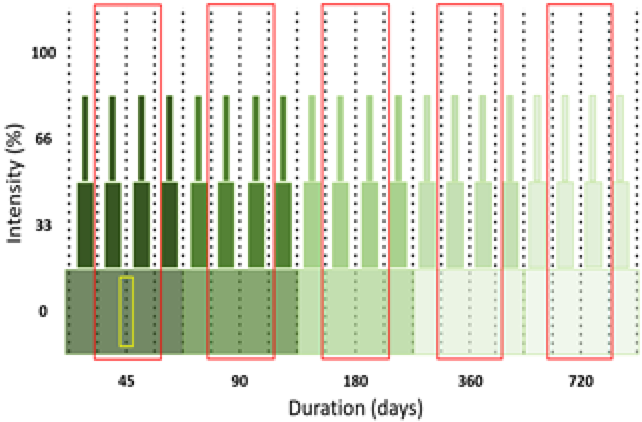
INDZ
IMAZ + SULFO
UNTREATED

MAT: Months After Treatment
LS Means Tukey HSD; α = 0.050; P ≤ 0.0001 (36 MAT)

envu

Brazil: RW23 Intensity and Duration of Weed Control

- Sites installed in Paraná with pine
  - Klabin
  - FIA-NGB
- ^{15}N Application
  - Klabin
    - Pine: 1 yr after planting (Mar 2022)
  - FIA-NGB
    - Pine: 2 year after planting (Oct 2022)



$25,000/yr for 4 year for PhD student in Brazil

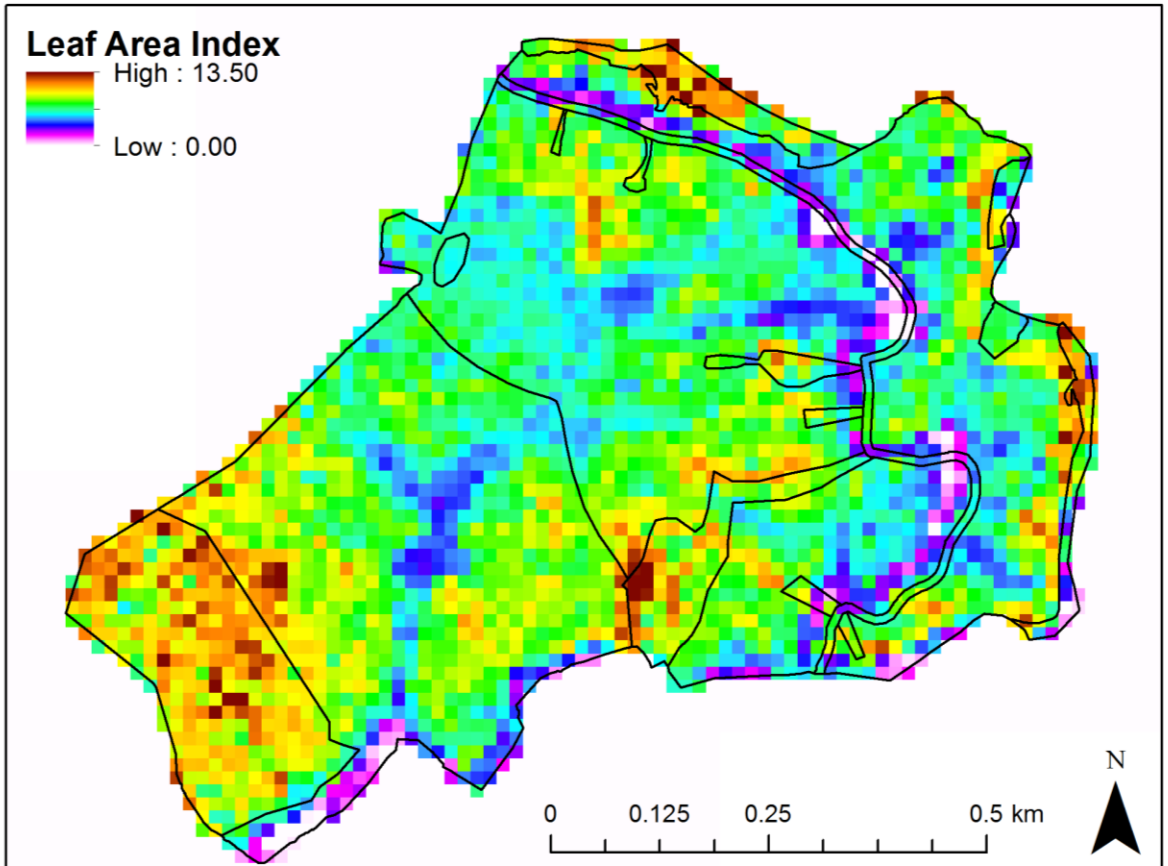
+$50k for ^{15}N work 2022-2023

3. Remote Sensing

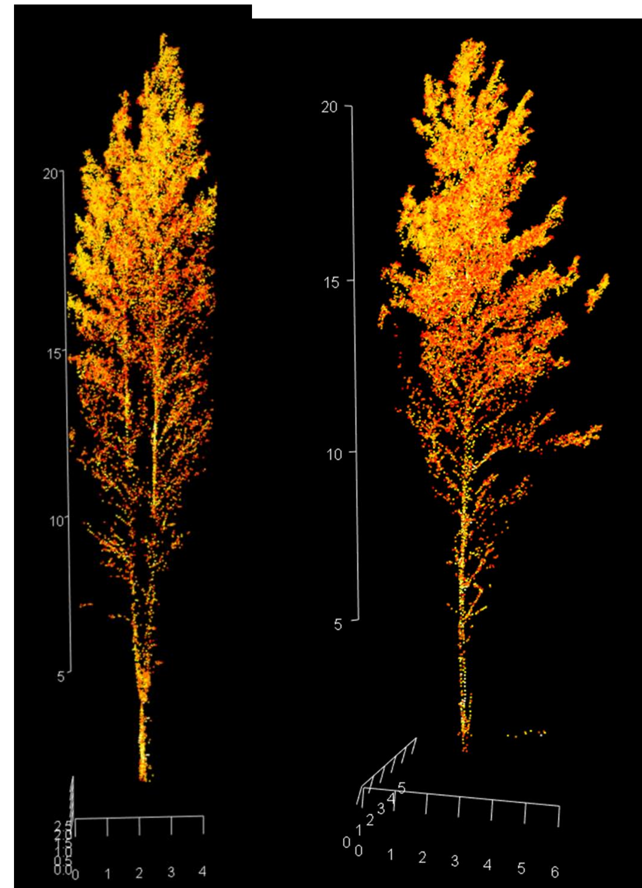
- Satellite and LiDAR: LAI mapping
  - Crop trees
  - Competing vegetation
- Lidar: stand inventory
  - Merchandising
  - Volume equations from LiDAR

Long History of LiDAR

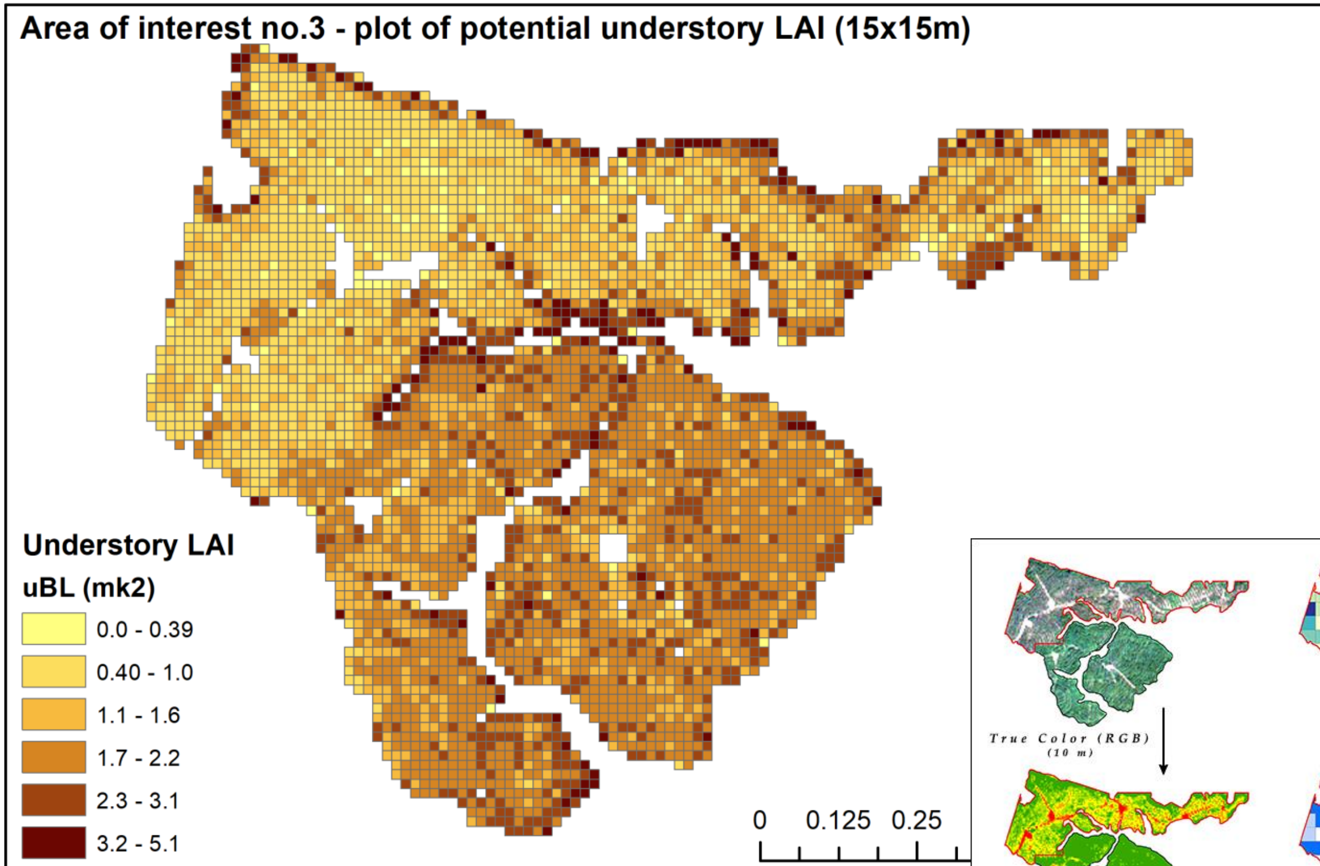
Not that many years ago

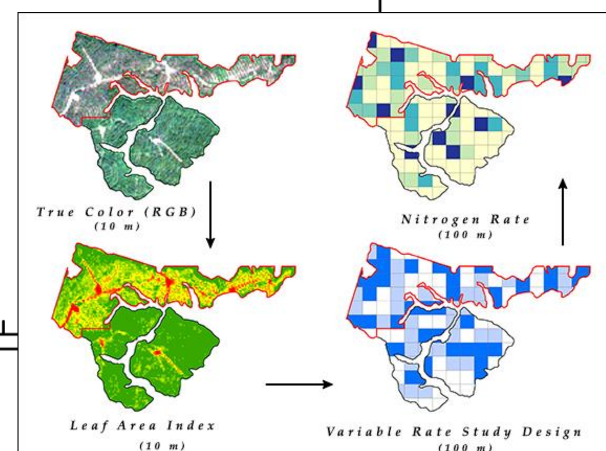


Today



Can we ID Evergreen Understory from Space if trained on LiDAR?





LiDAR Inventory: What Does Site Index Even Mean Now?

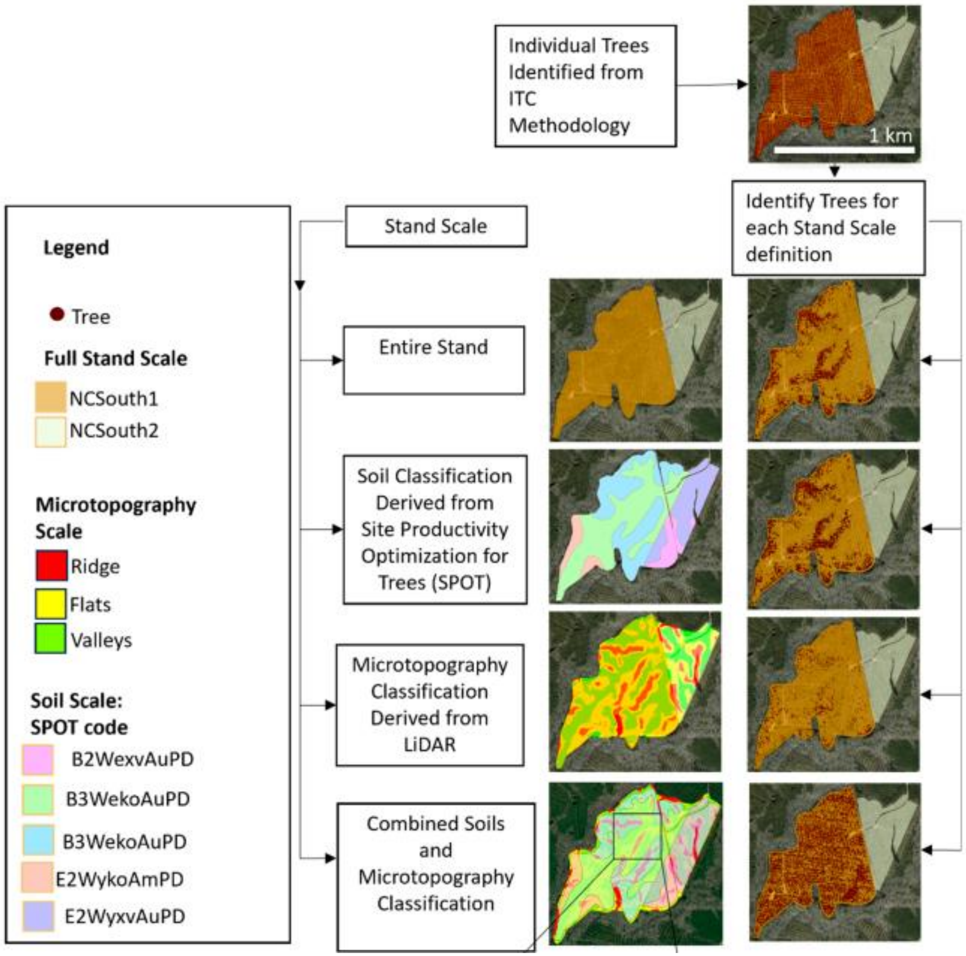
forests MDPI

Article

Rethinking Productivity Evaluation in Precision Forestry through Dominant Height and Site Index Measurements Using Aerial Laser Scanning LiDAR Data

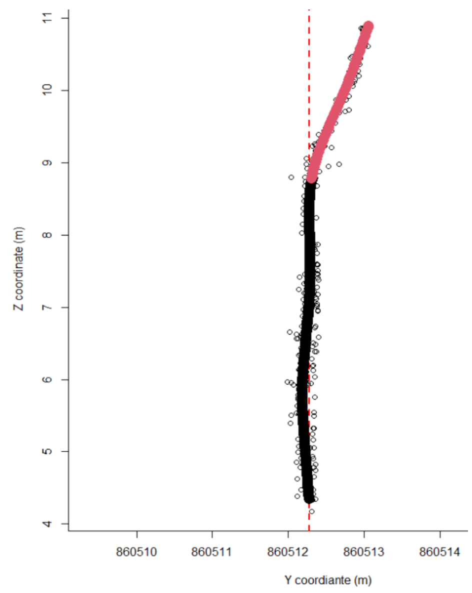
Iván Raigosa-García [1], Leah C. Rathbun [2], Rachel L. Cook [1,*], Justin S. Baker [1], Mark V. Corrao [3,4] and Matthew J. Sumnall [5]

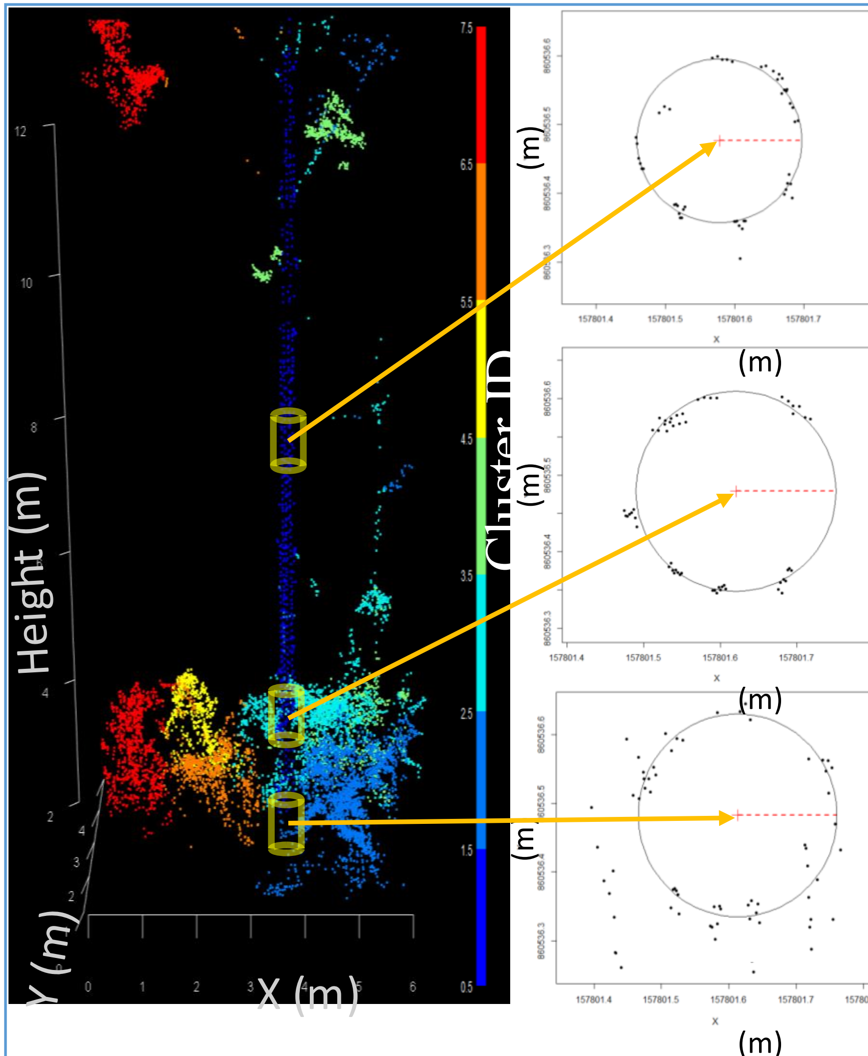
- Dominant Height of:
  - 100 tph
  - 40 tph
  - 85th percentile
- Segregated by:
  - Stand
  - Plots
  - Soils
  - Topography
  - Soils+Topography



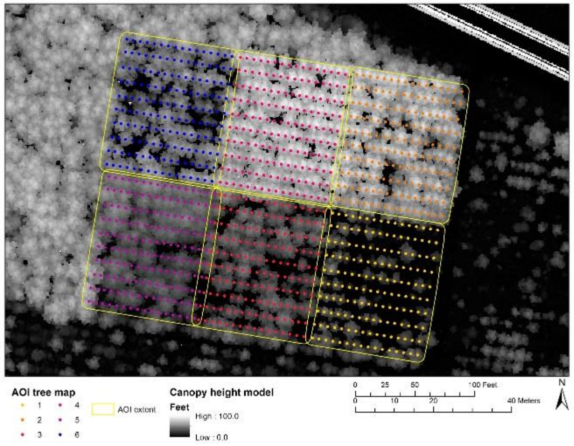
Hyperdense Helicopter LiDAR

- Data will inform tree level volume prediction equations from LiDAR
- Stem quality (sweep, forks, stops, crooks)
- Taper

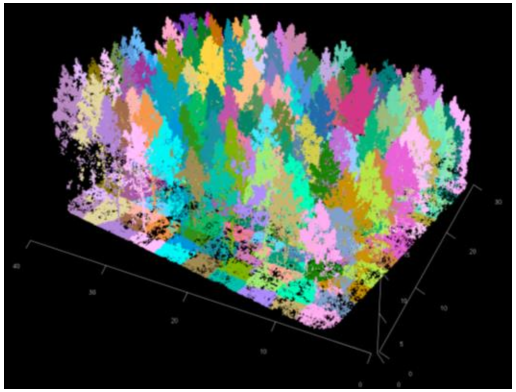


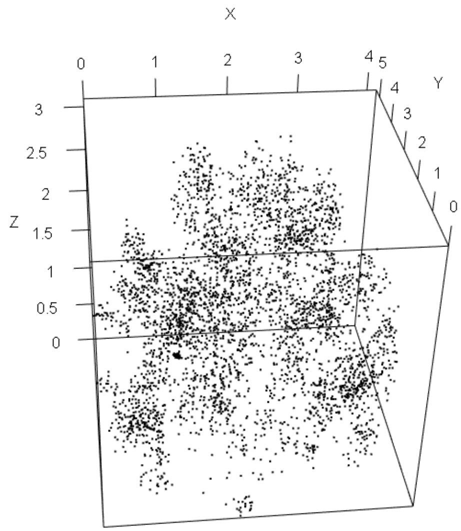


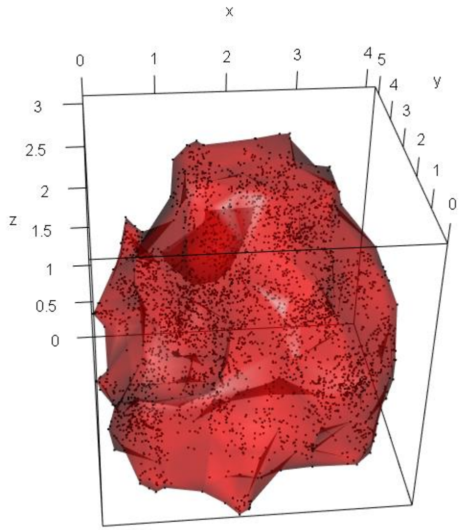
New Projects: 5 pines LiDAR study



- How light capture compares with water used to generate carbon
- Can we detect differences in structure and therefore function?
- Take tree scale knowledge and extrapolate

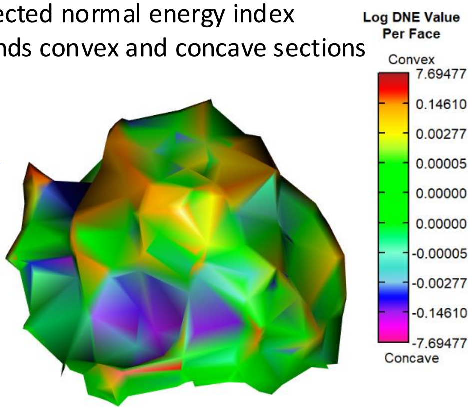




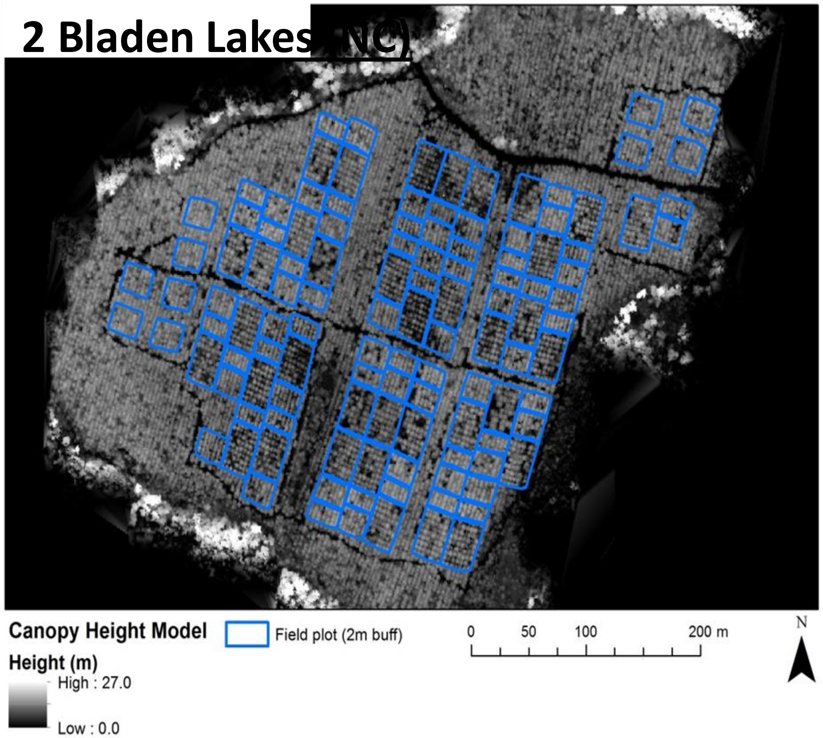


DNE

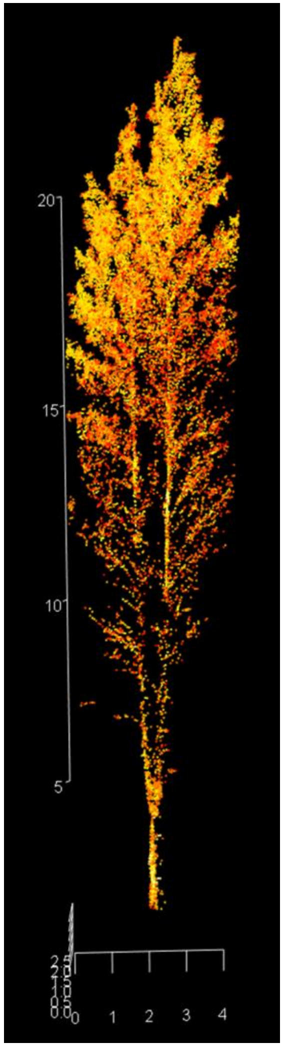
Directed normal energy index – finds convex and concave sections

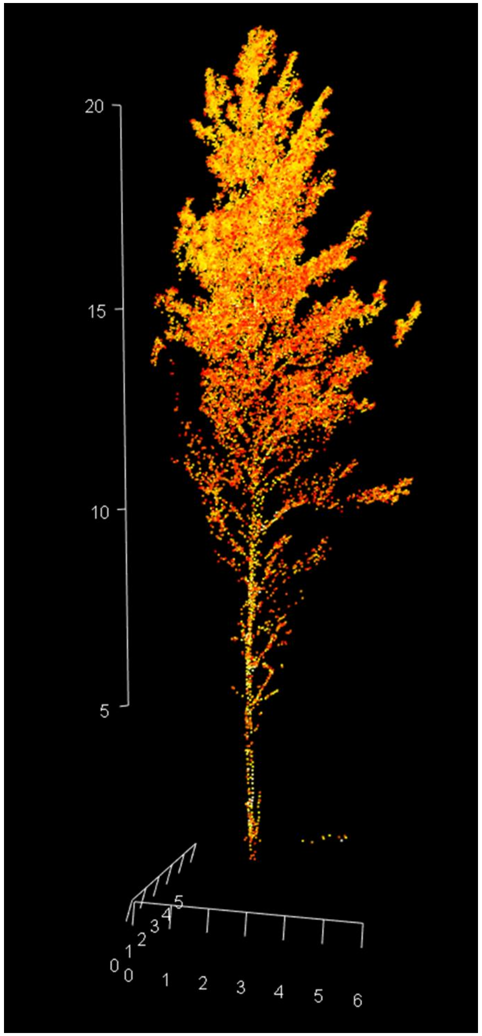


High point cloud density



Even forked stems are visible →

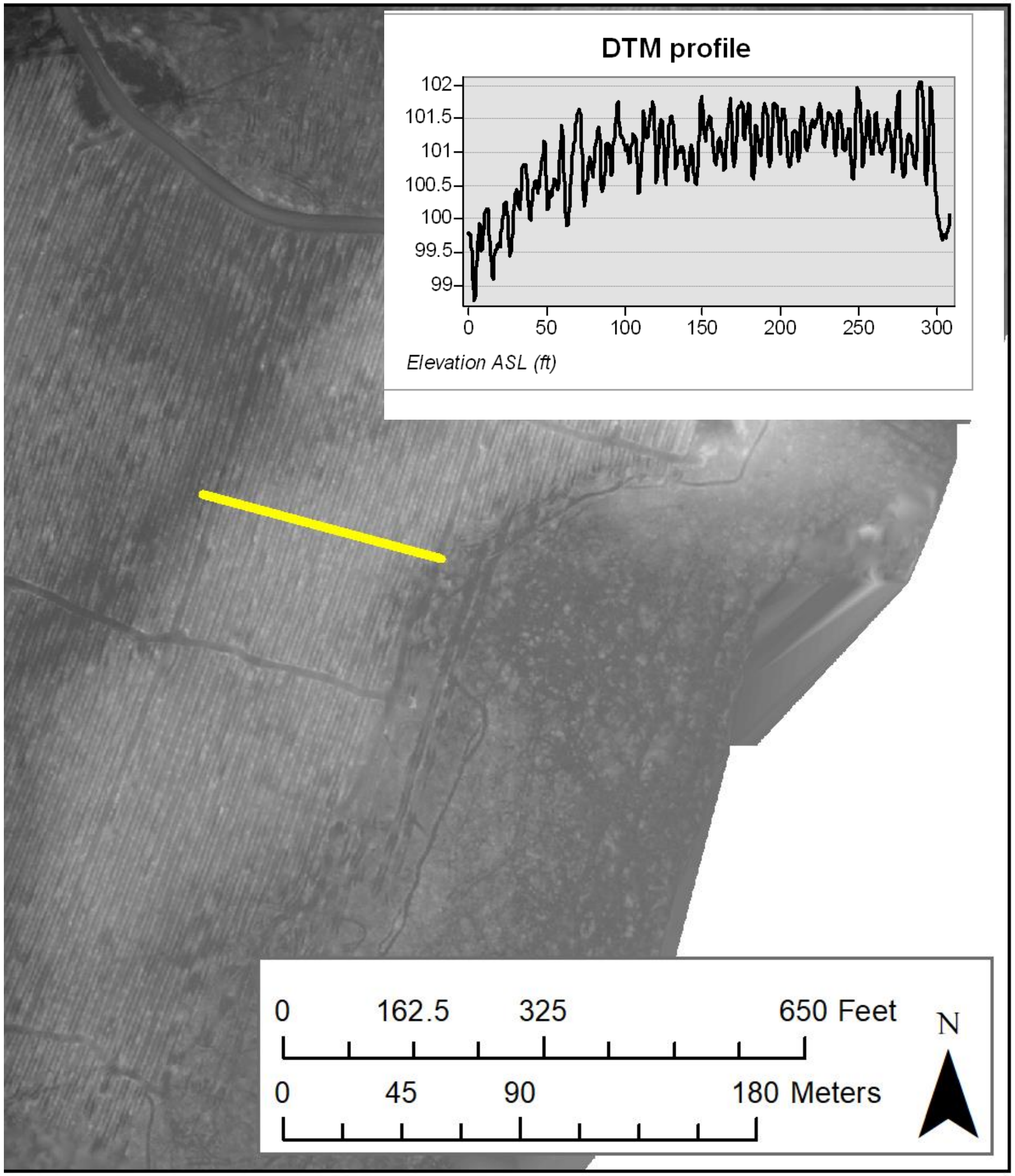




- ~2200 pulses/m^2

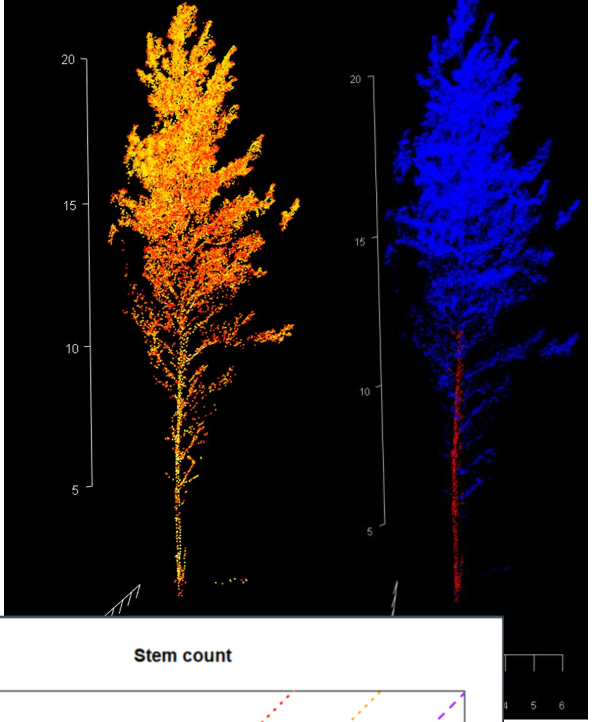
Digital terrain model

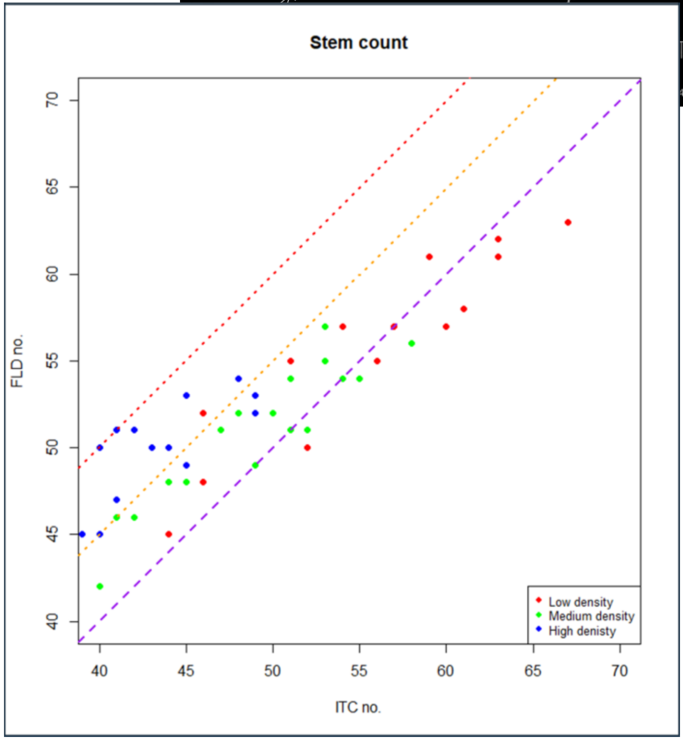
- High resolution terrain information;
  - Here 0.5x0.5m ->
- Can see tree row bedding and tracks below canopy;



Stem detection

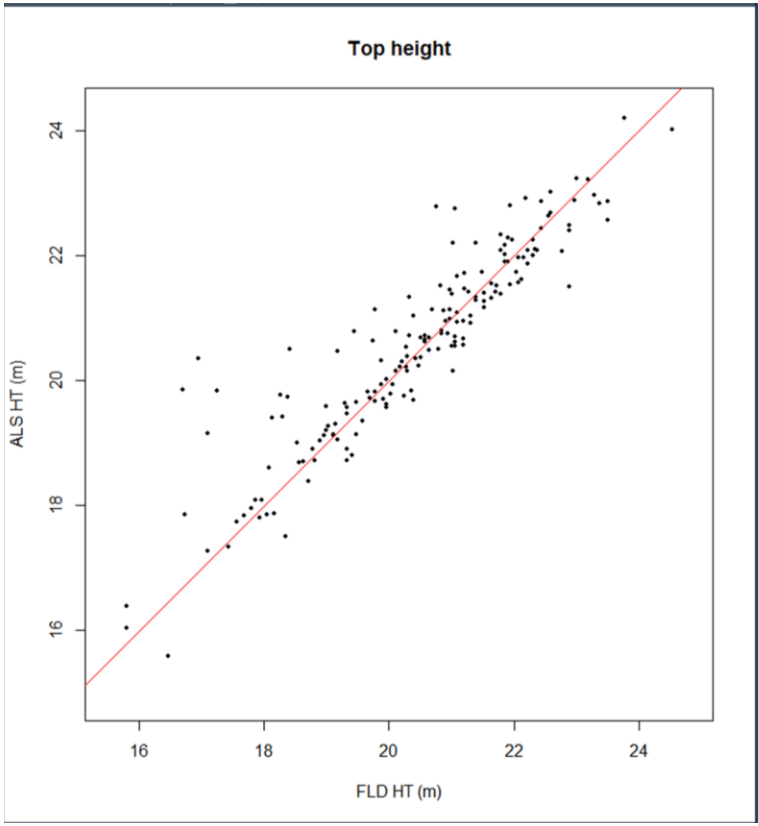
- Originally 63 tree per plot;
  - Not all trees survived;
- Stem detection best in low density plots;
- Medium density within 5 trees of correct;
- High density within 10 trees of correct;
- Note: some commission due to volunteers.





Estimating tree top height

- Individual tree height for central 5x5 stems in each plot;



Metric	R-sq	RMSE	RMSE%	Bias	bias%
DBH MLR (cm)	0.414	1.751	0.138	0.203	0.016
DBH RF (cm)	0.331	2.283	0.18	-1.273	-0.1
SV MLR (ft^3)	0.462	7.429	0.161	-3.59	-0.078
SV RF (ft^3)	0.354	7.351	0.159	-2.127	-0.046
Height (m)	0.84	0.694	0.079	0.144	0.016
HTLC (m)	0.11	2.708	0.257	0.202	0.019

Height to the live crown

- Individual tree height to the live crown for central 5x5 stems in each plot;
- *May not be actual HTLC – variable more akin to height of foliage rather*

Metric	R-sq	RMSE	RMSE%	Bias	bias%
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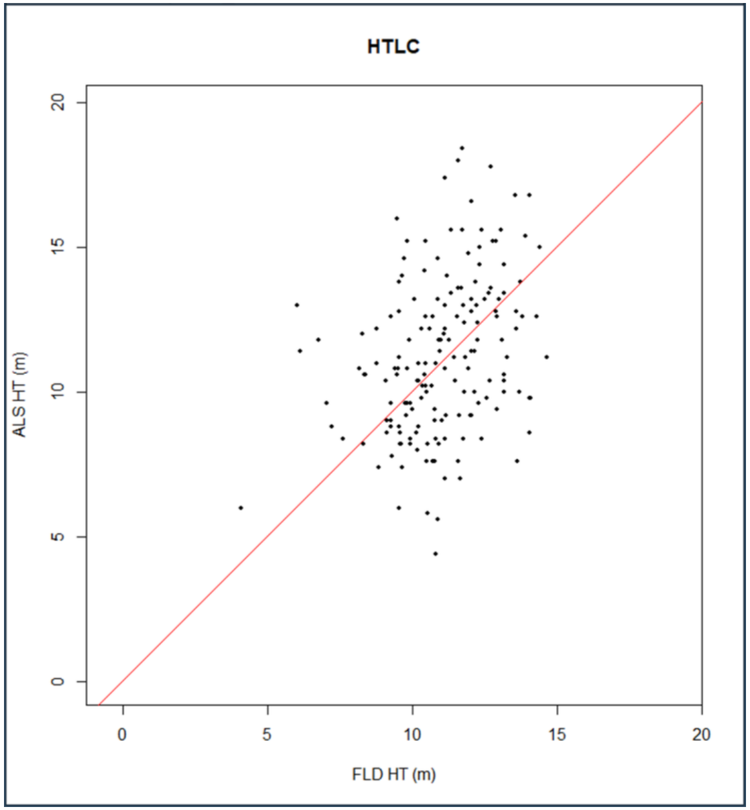
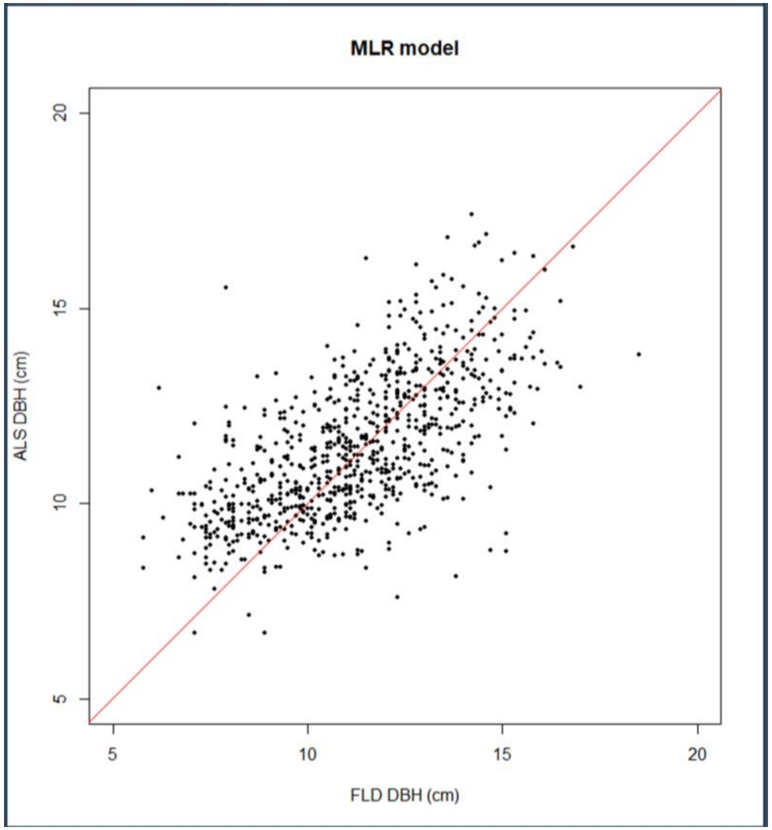
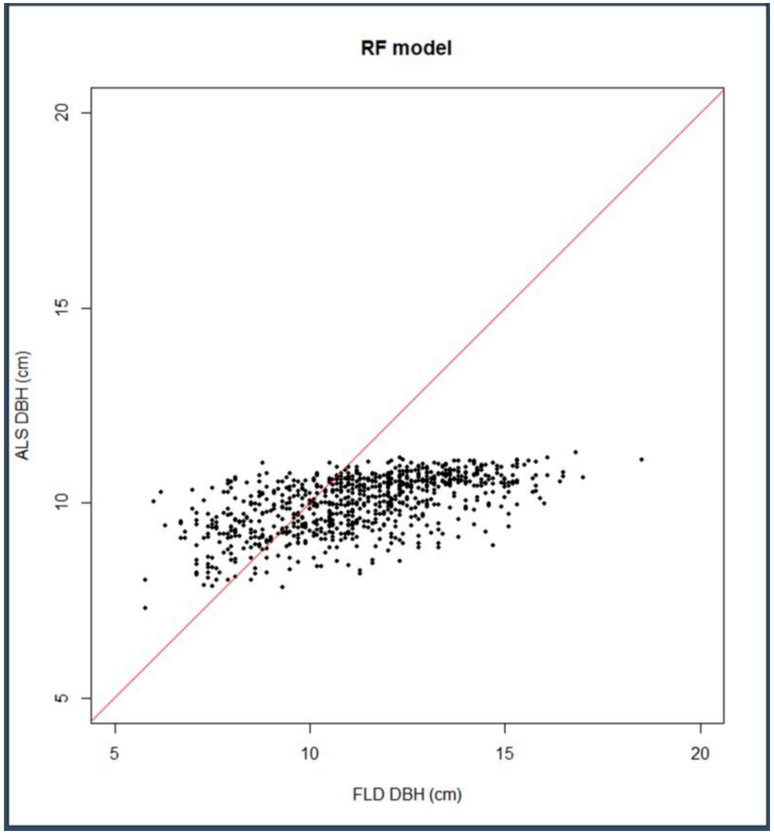
Height (m)	0.84	0.694	0.079	0.144	0.016
HTLC (m)	0.11	2.508	0.257	0.202	0.019



Estimates of DBH

Metric	R-sq	RMSE	RMSE%	Bias	Bias%
DBH MLR (cm)	0.414	1.751	0.138	0.203	0.016
DBH RF (cm)	0.331	2.283	0.18	-1.273	-0.1
SV MLR (ft^3)	0.462	7.429	0.161	-3.59	-0.078
SV RF (ft^3)	0.354	7.351	0.159	-2.127	-0.046
Height (m)	0.84	0.694	0.079	0.144	0.016
HTLC (m)	0.11	2.708	0.257	0.202	0.019





Thanks!

Competing veg BA was negatively related to pine volume