The forest and the trees:

A look at how ecosystem complexity is shaped by landscape and disturbance

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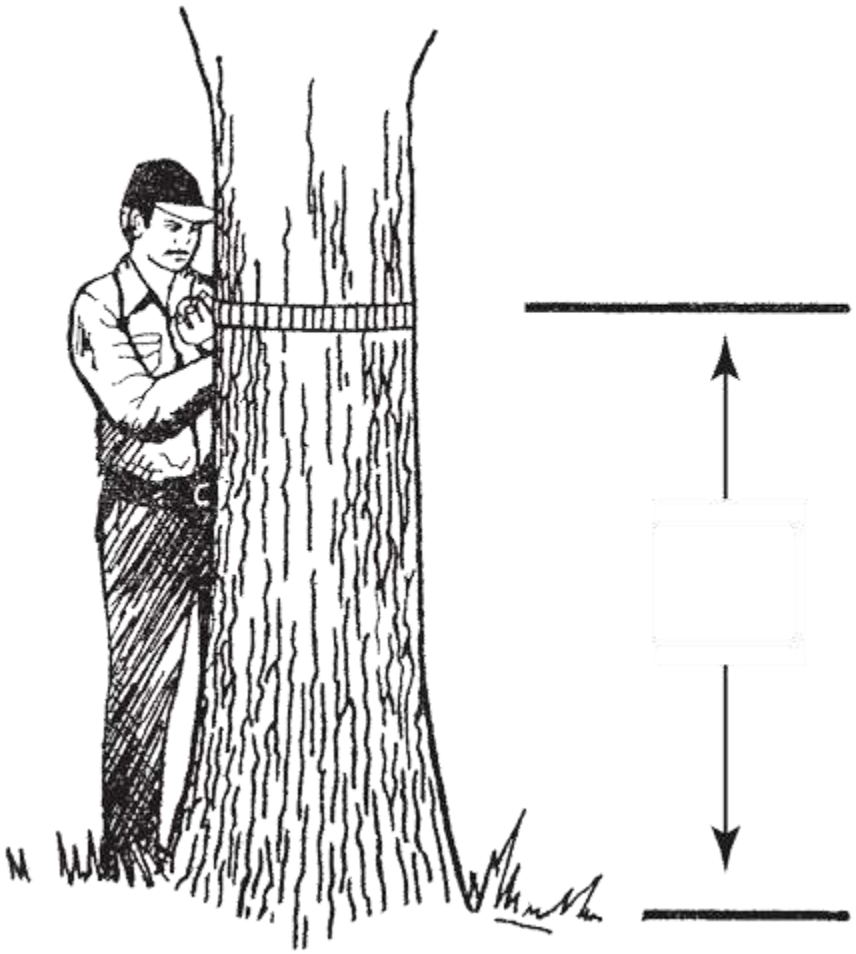
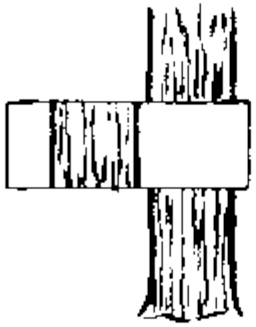
@atkinsjeff

Award No. 1550657

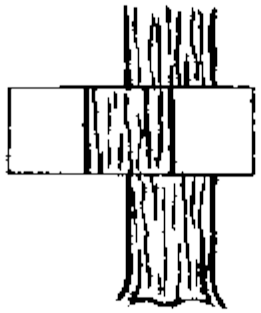
Image by the amazing Catherine McGuigan

By understanding how a system is put together, can we better understand how it works?

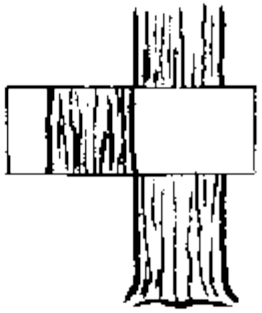




Don't Talley



Talley



Borderline
Talley Every Other One

$$biomass = e^{(\beta_0 + \beta_1 ln(dbh))}$$

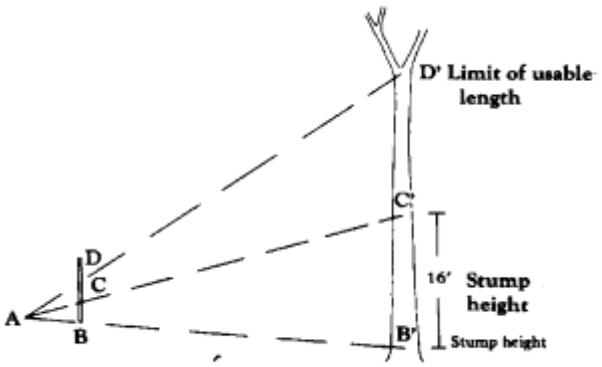
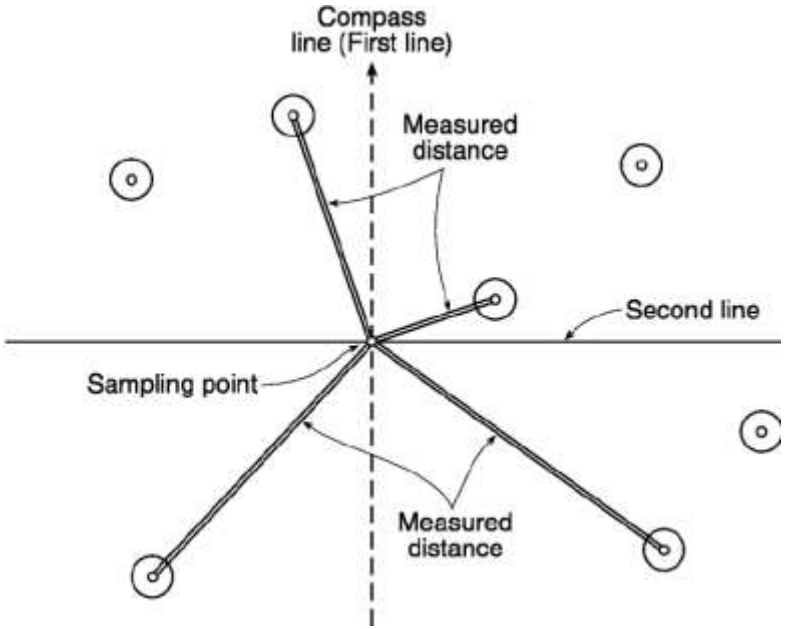
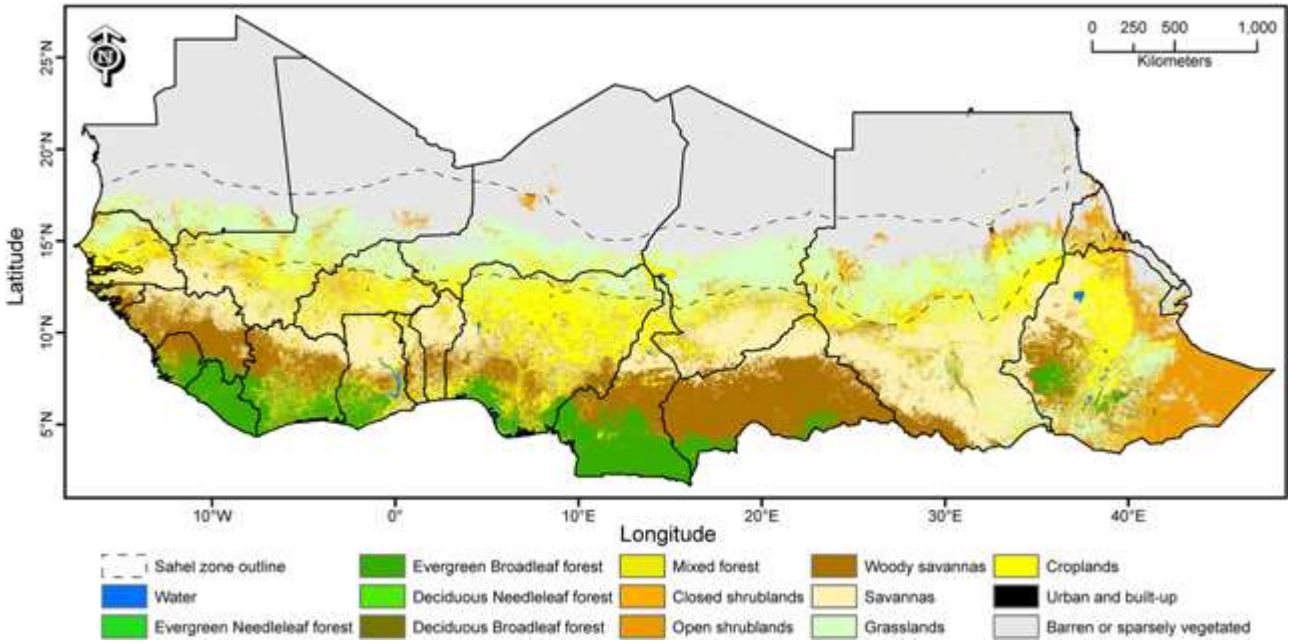


Figure 13.—Measuring Heights, Method 2.



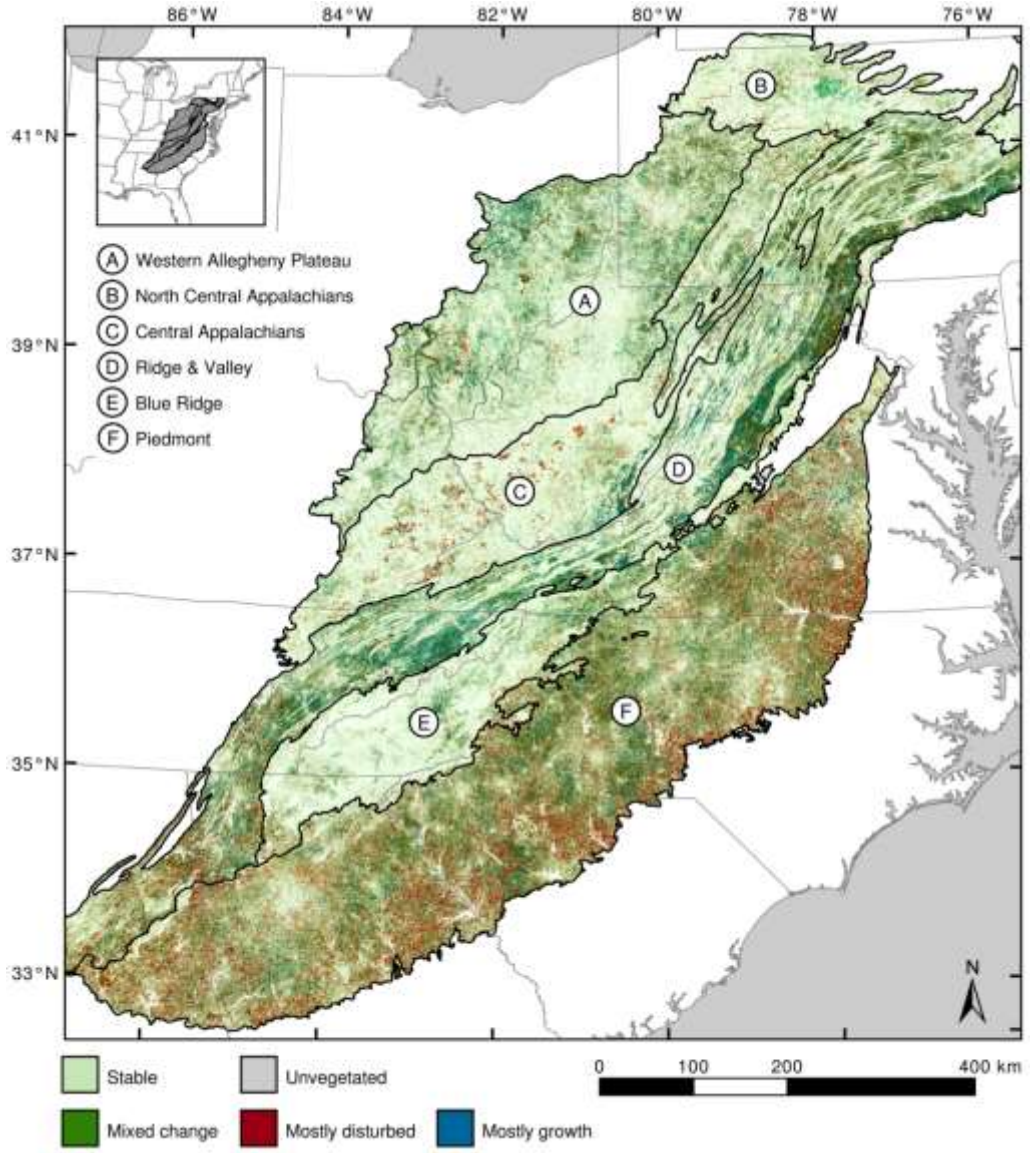

MAKE A BETTER PLACE FOR YOU AND

The Satellite Age



Tracking net primary productivity in the Sahel with MODIS data

Abdi et al. (2014)



Changescape map by physiographic area, compiled from 28 years of Landsat data

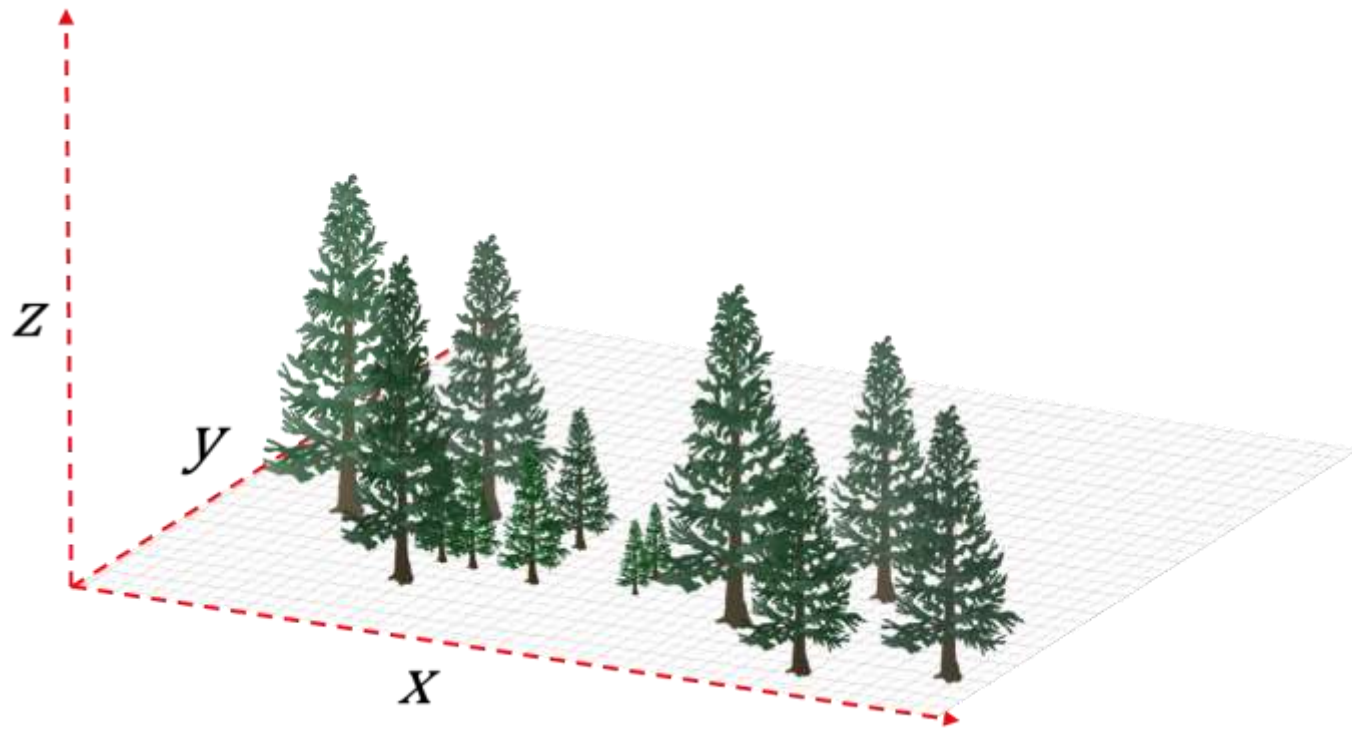
Hughes et al. (2017)

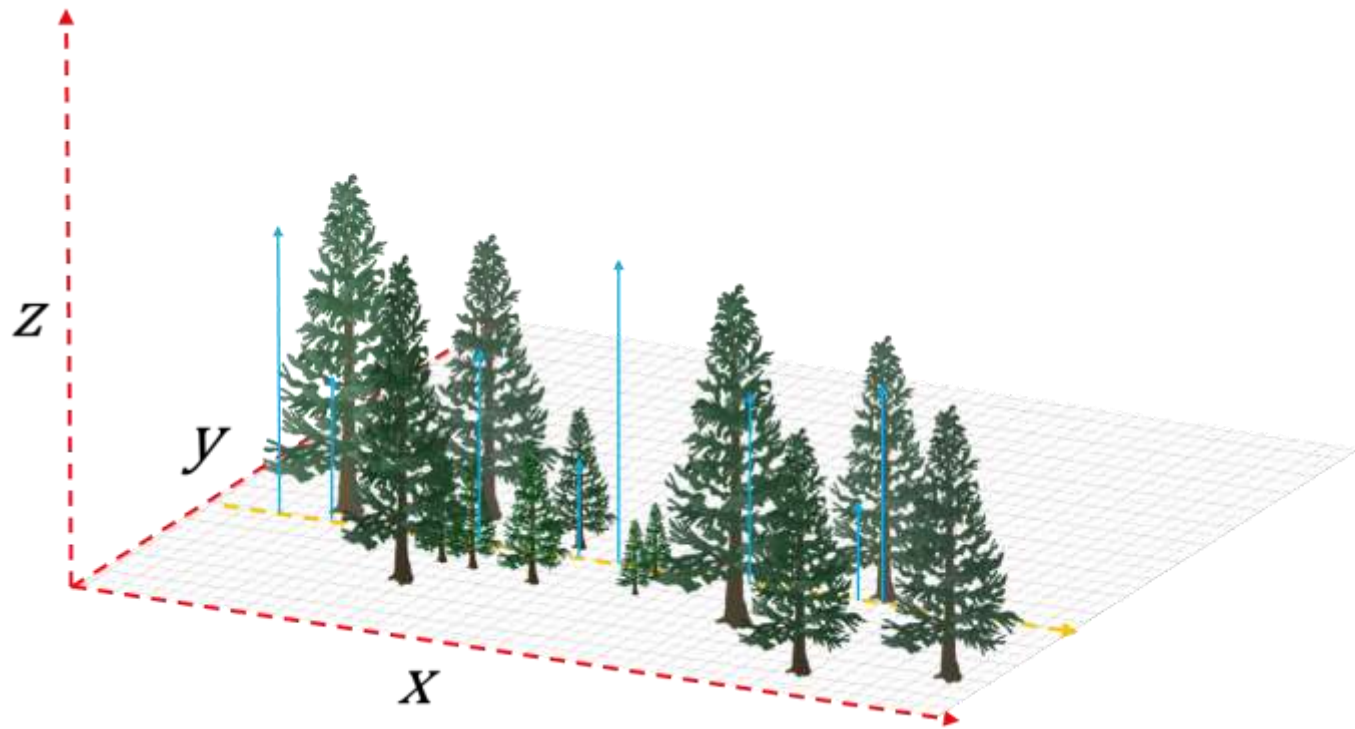
The Satellite Age

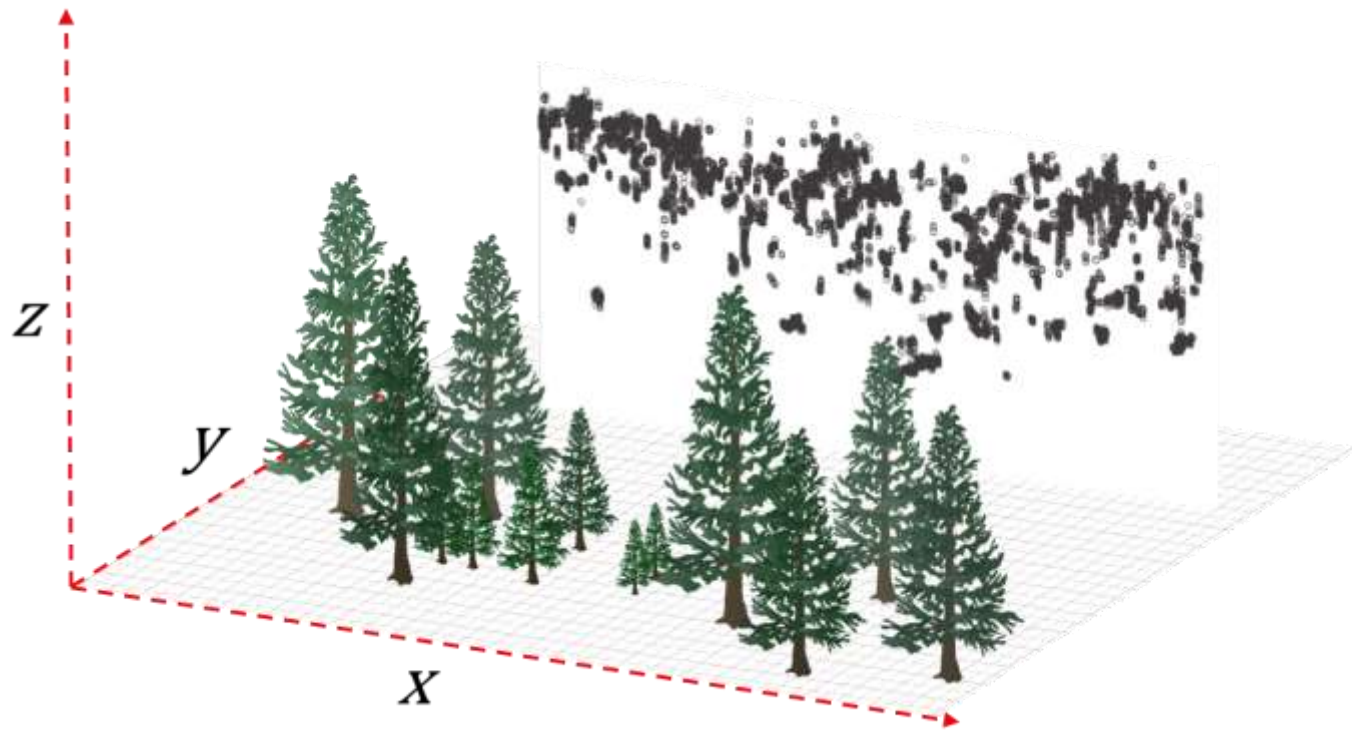
2-D Terrestrial LiDAR

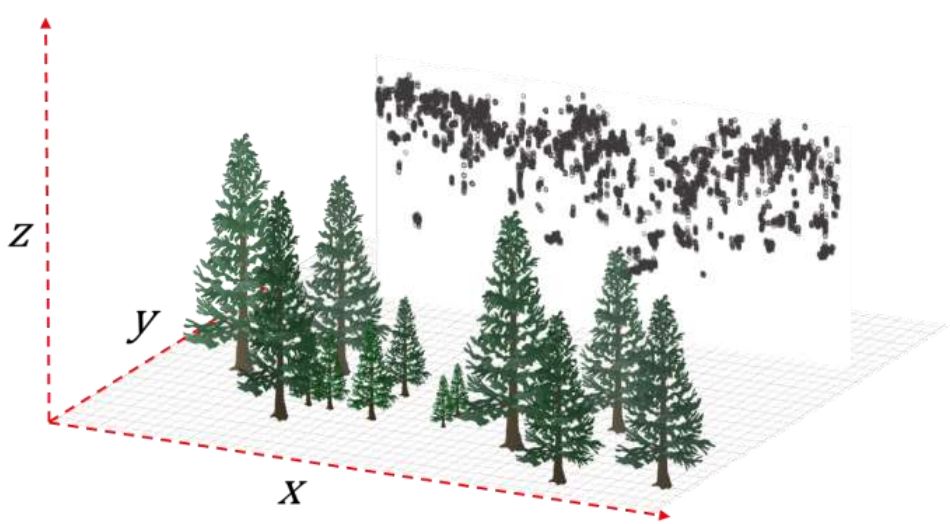
- Portable Canopy LiDAR (PCL)
  Upwardly facing
- Produces a 2D point cloud in a vertical slice through the canopy
- Can get at canopy structural complexity, e.g. position and arrangement

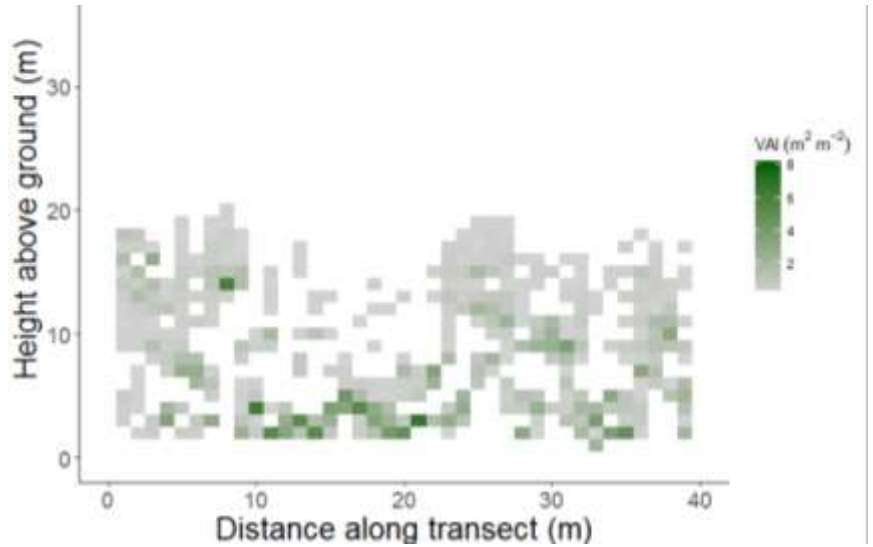
Hardiman et al. 2013; Parker et al. 2004

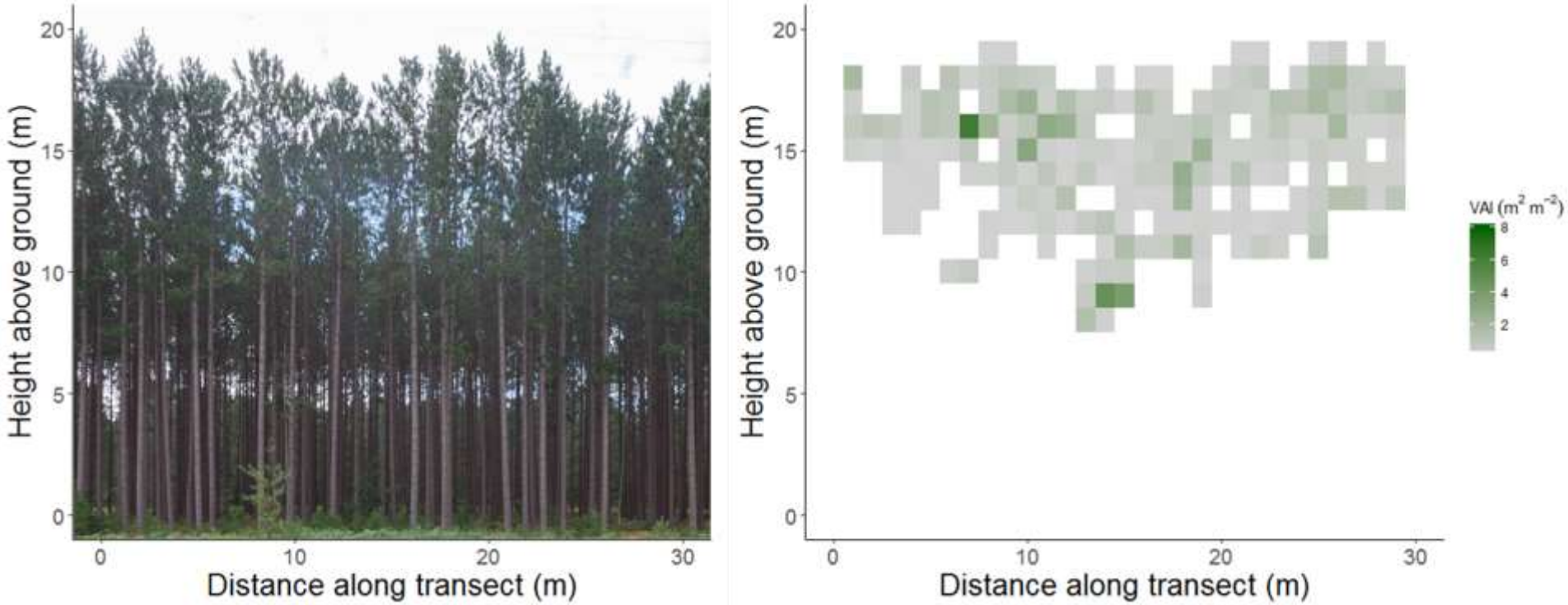

z
y
x


Z
y
X


z
y
x


z
y
x

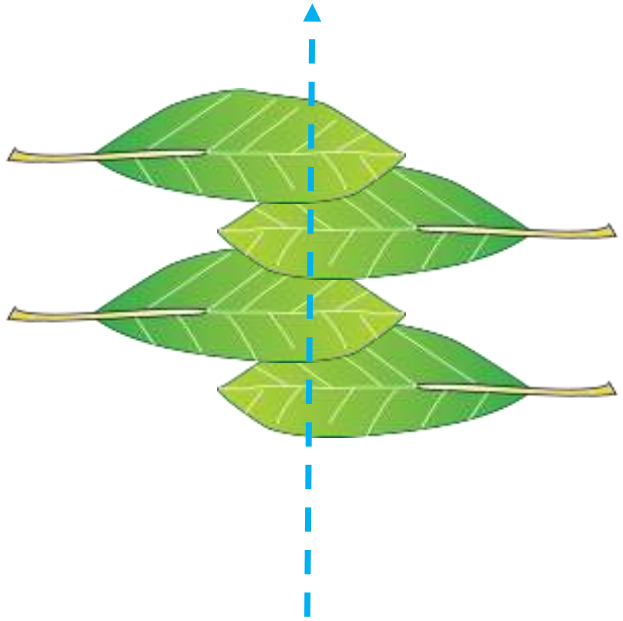

Height above ground (m)
0
10
20
30
0
10
20
30
40
Distance along transect (m)
VAI (m² m⁻²)
6
5
4
2


Height above ground (m)
20
15
10
5
0
0
10
20
30
Distance along transect (m)
Height above ground (m)
20
15
10
5
0
0
10
20
30
Distance along transect (m)
VAI (m² m⁻²)
8
6
4
2

What is canopy structural complexity (CSC)?

Canopy Structural Complexity

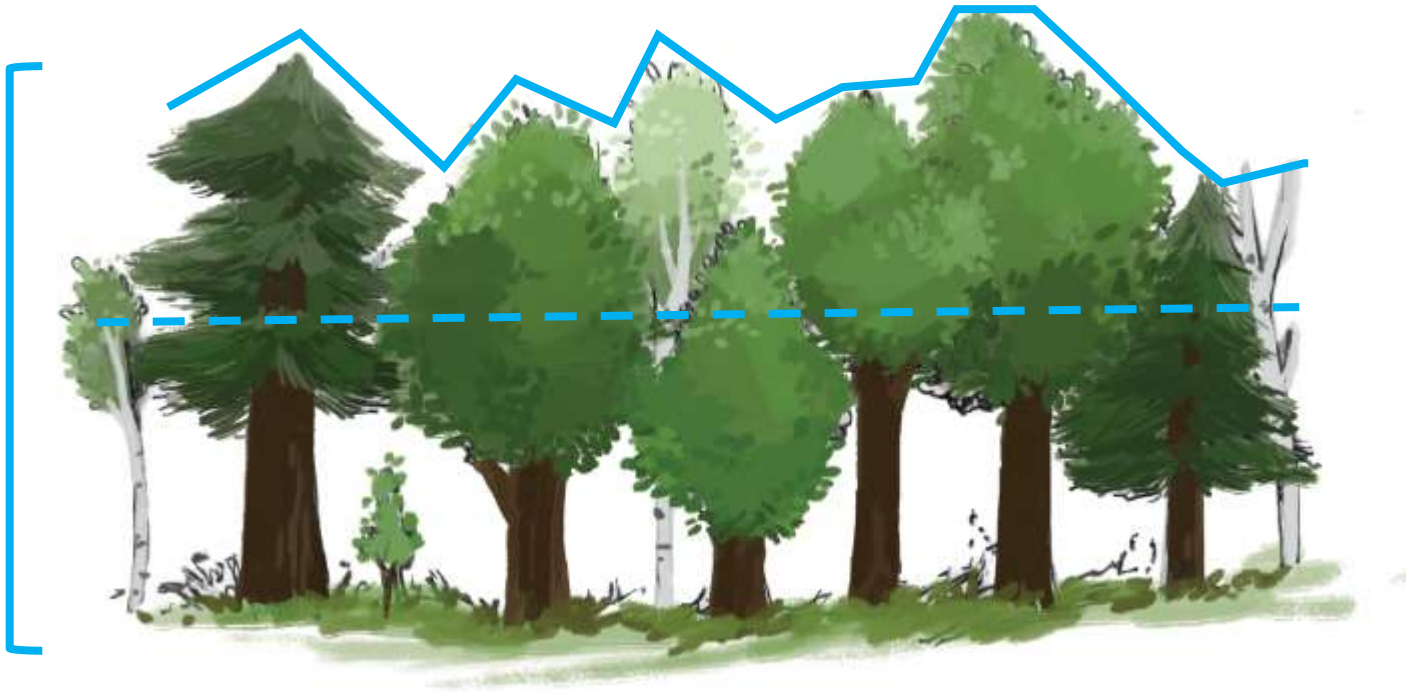
- Density/Quantity



Atkins et al. *In Review*

Canopy Structural Complexity

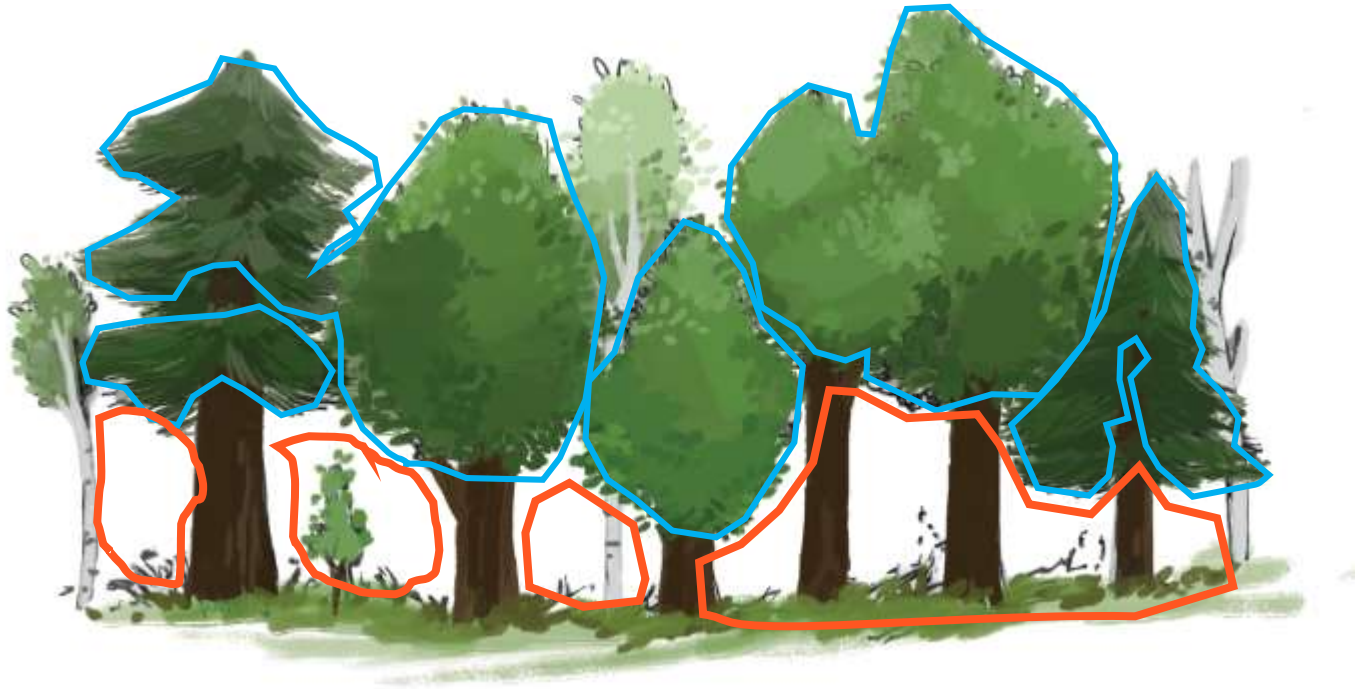
- Density/Quantity
- Height



Atkins et al. *In Review*

Canopy Structural Complexity

- Density/Quantity
- Height
- Arrangement



Atkins et al. *In Review*

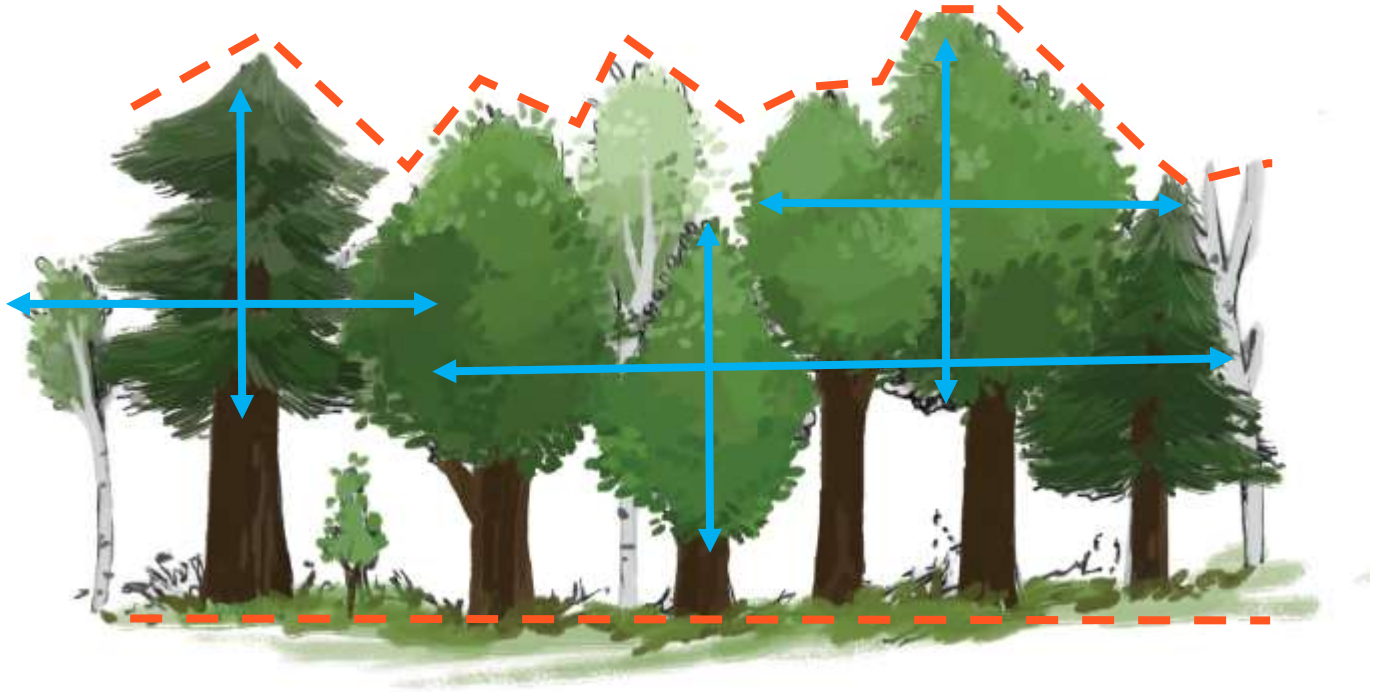
Canopy Structural Complexity

- Density/Quantity
- Height
- Arrangement
- Openness

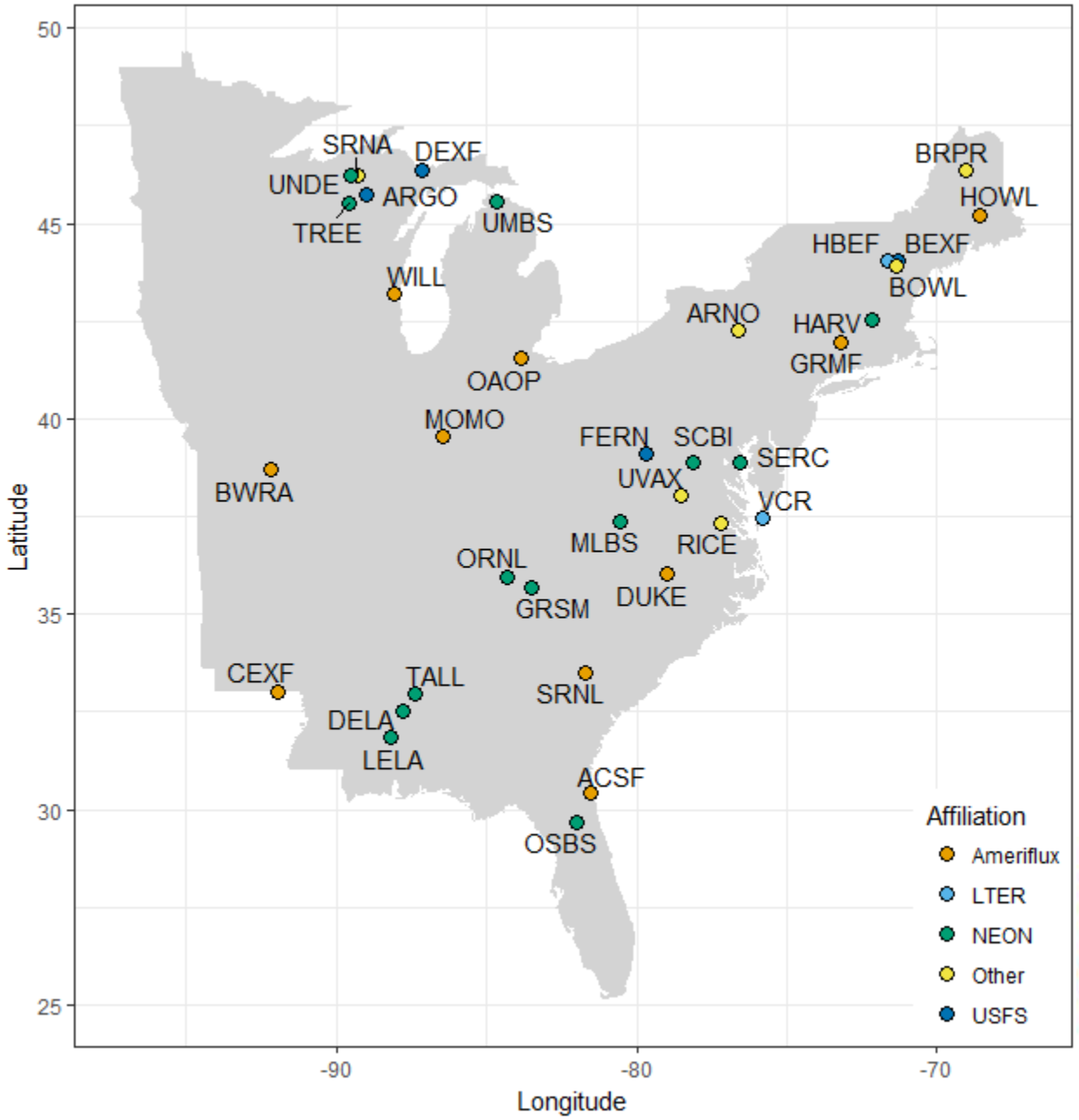
Atkins et al. *In Review*

Canopy Structural Complexity

- Density/Quantity
- Height
- Arrangement
- Openness
- Variability



Atkins et al. *In Review*



Where we have been. . .

- Project started in 2016
- Over 20 sites sampled (portable canopy LiDAR)
- New ways to look at forest and canopy structure
- Fundamental structure/function relationships

AMERIFLUX

neon
National Ecological Observatory Network, Inc.

CORNELL UNIVERSITY FOUNDED A.D. 1865

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

USDA

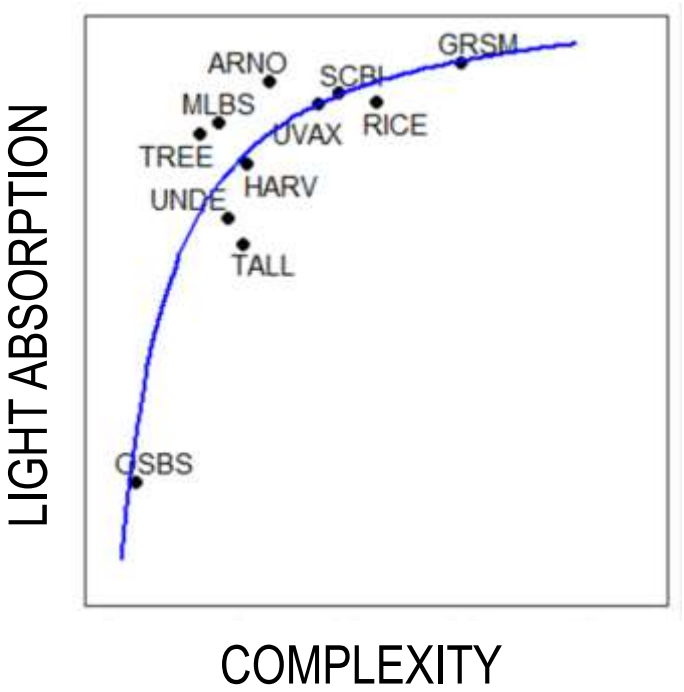
LTER

UNIVERSITY of VIRGINIA

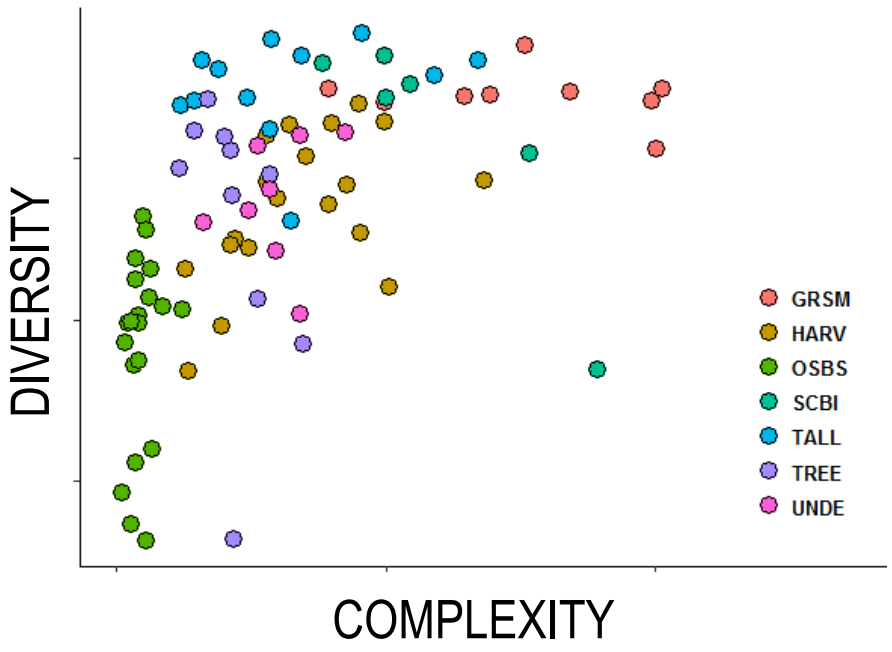
VIRGINIA COMMONWEALTH UNIVERSITY MCV RPI 1838

What we have found...

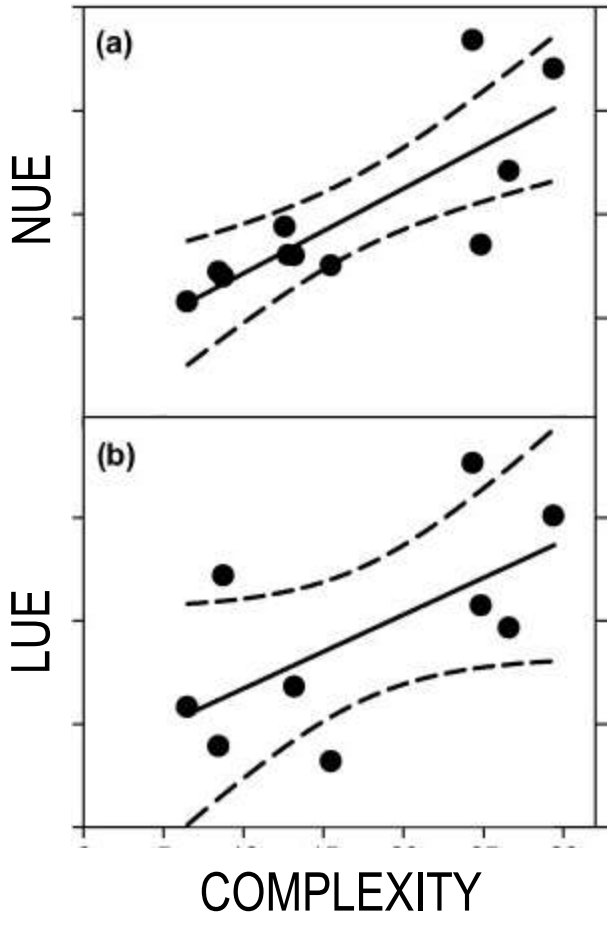
- Measures of canopy structural complexity (CSC) describe arrangement and position of vegetation
- Beyond LAI
- Improved prediction of ecosystem functioning (e.g. light absorption, LUE, NUE, etc.)
- Connections with diversity, richness
- Differences within and among sites



Atkins et al. (In Review)



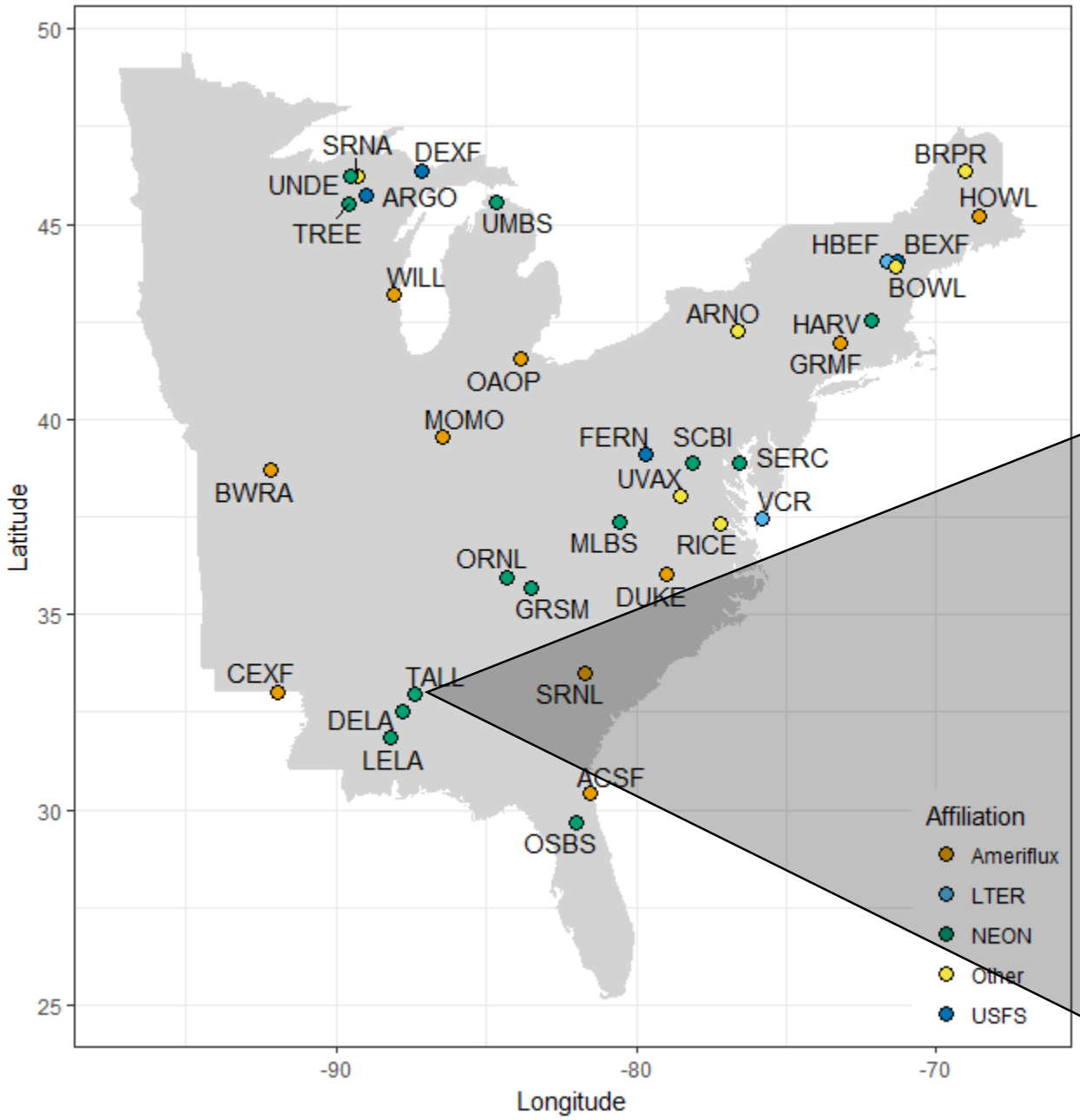
Gough et al. (In Prep)



Hardiman et al. (2013)

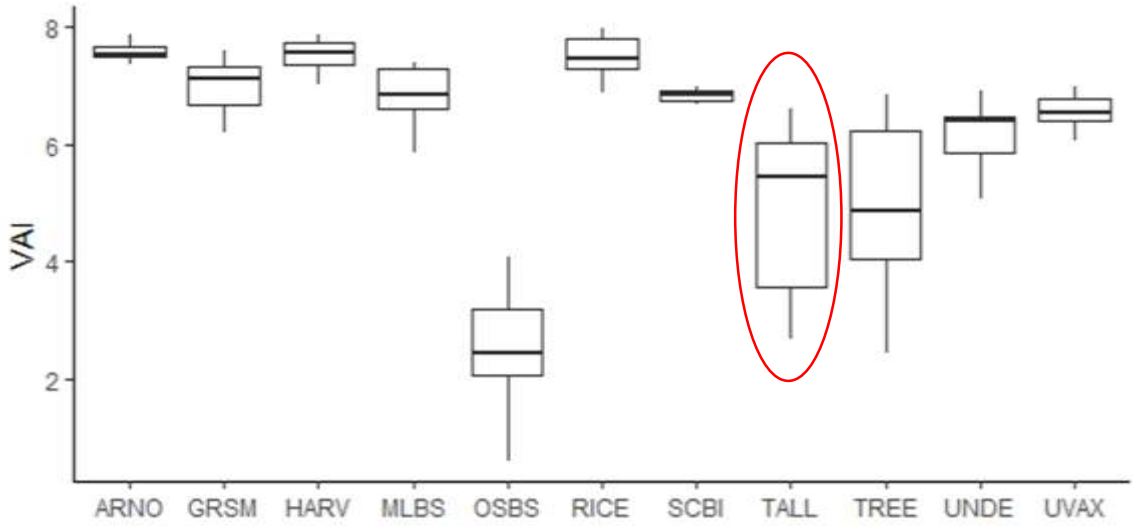
Talladega National Forest

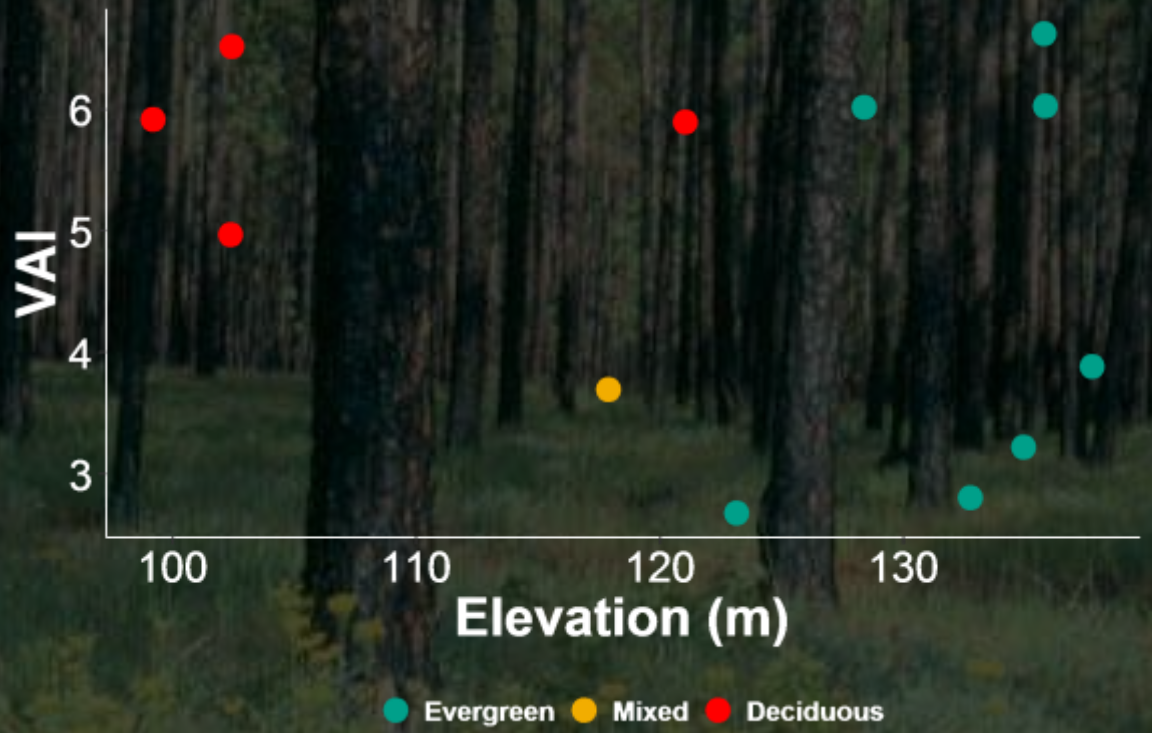
- NEON site (TALL) covers 5300 ha
- Rolling hills creates a mosaic of forest
- Hardwoods in the bottoms, longleaf pines upland
- Logged in the 1930s
- Frequent, prescribed burning
- Site elevation gradient of only ~40 m

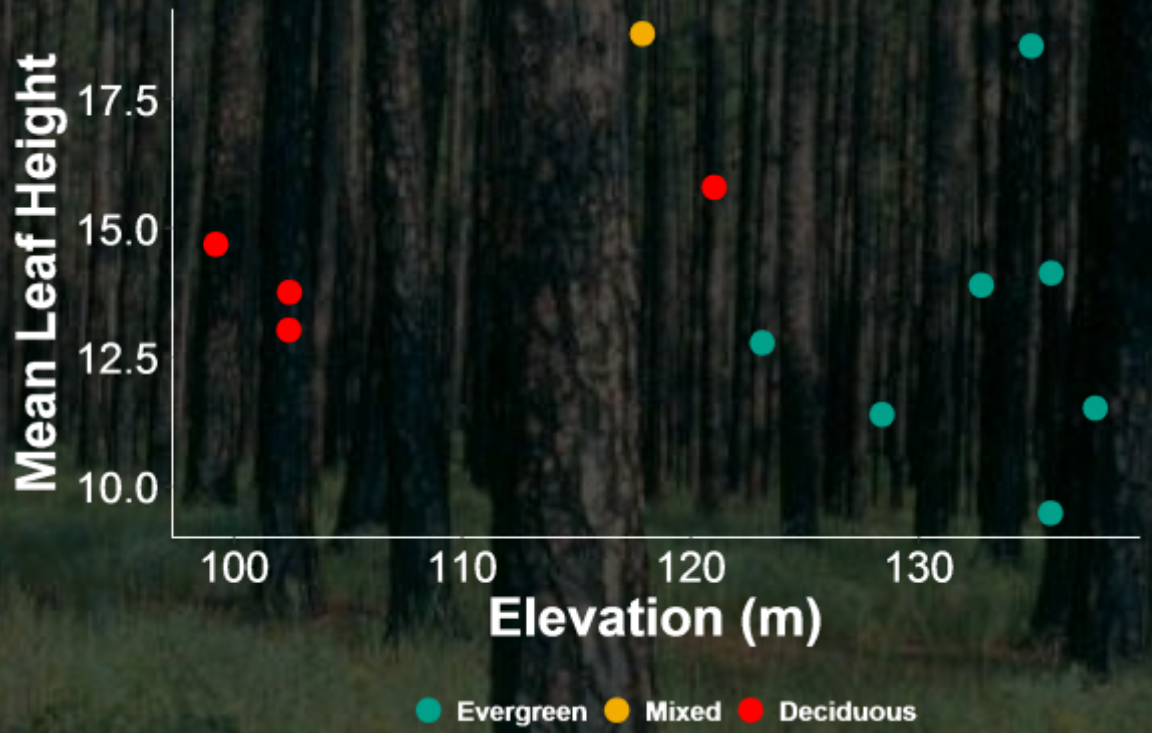


Talladega National Forest

- High variance in vegetation area index (VAI)
- Highest measured mean leaf height of any site
- Mixture of forest communities?
- Are these patterns spatially defined?




VAI
6
5
4
3
100
110
120
130
Elevation (m)
Evergreen
Mixed
Deciduous


Mean Leaf Height
17.5
15.0
12.5
10.0
100
110
120
130
Elevation (m)
Evergreen
Mixed
Deciduous

Can we classify forest systems with structure alone?

Talladega National Forest

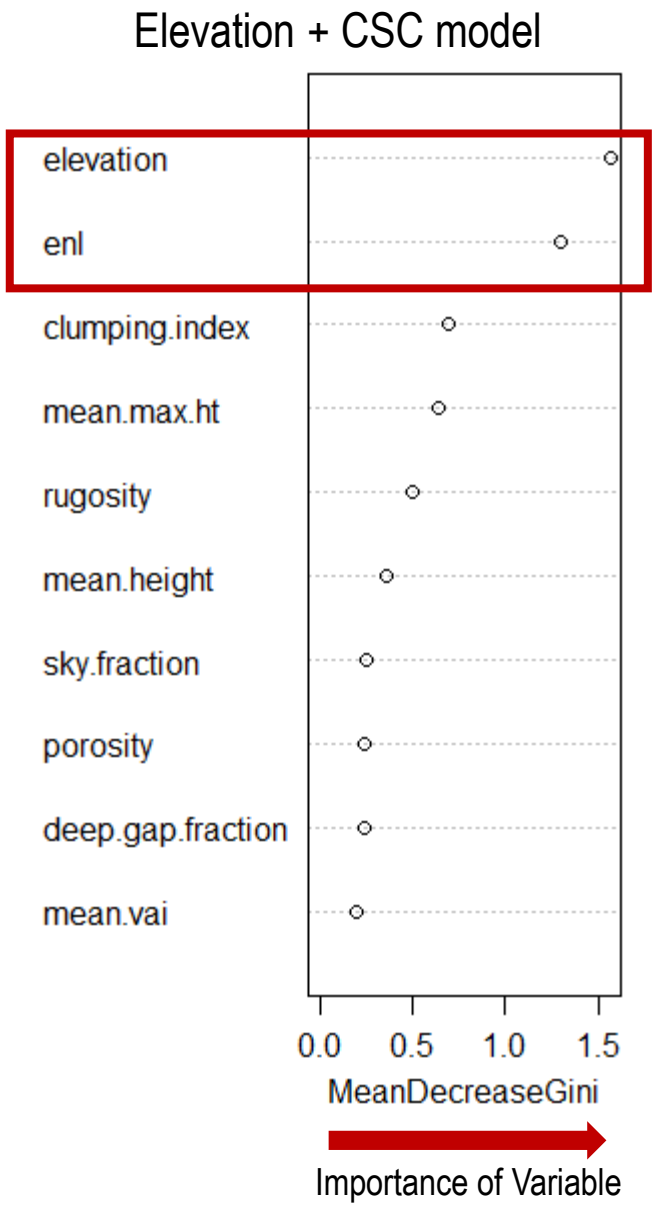
Random Forest Model

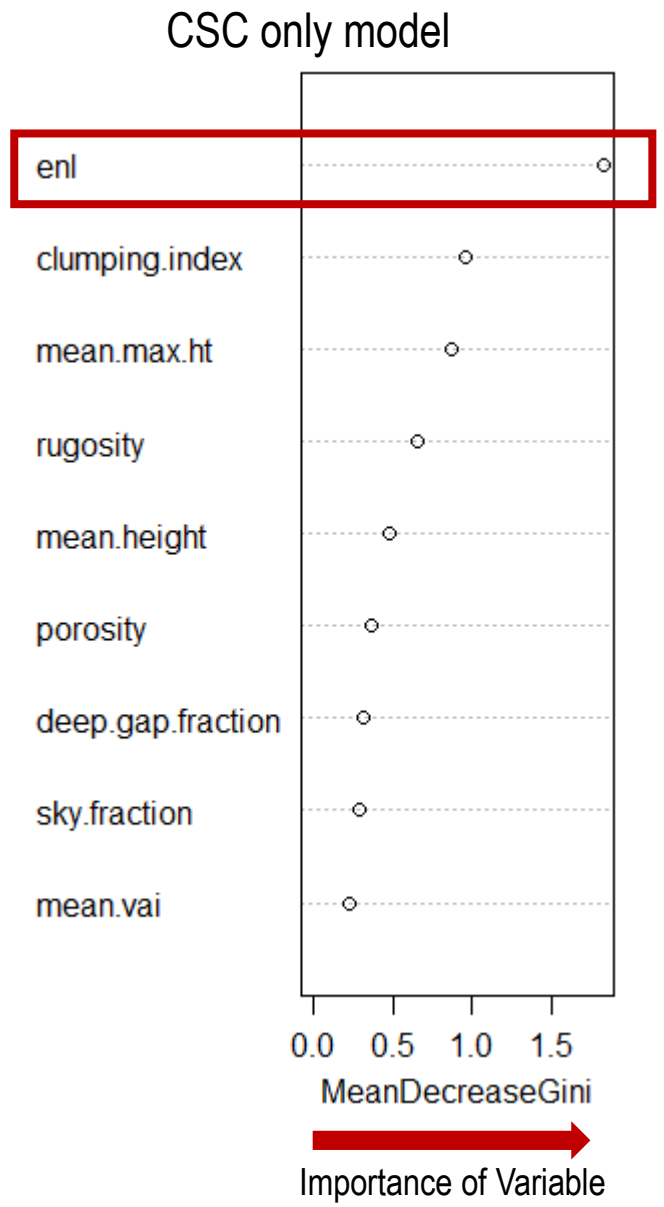
- Canopy structural complexity (CSC) metrics
- NEON spatial and field data
- Two models: 1) with elevation, 2) without elevation
- Can we classify forests using structural data?

Well can we?

- Elevation + CSC - 25% error rate (OOB)
- CSC only - 33.3% error rate (OOB)

What is ENL?

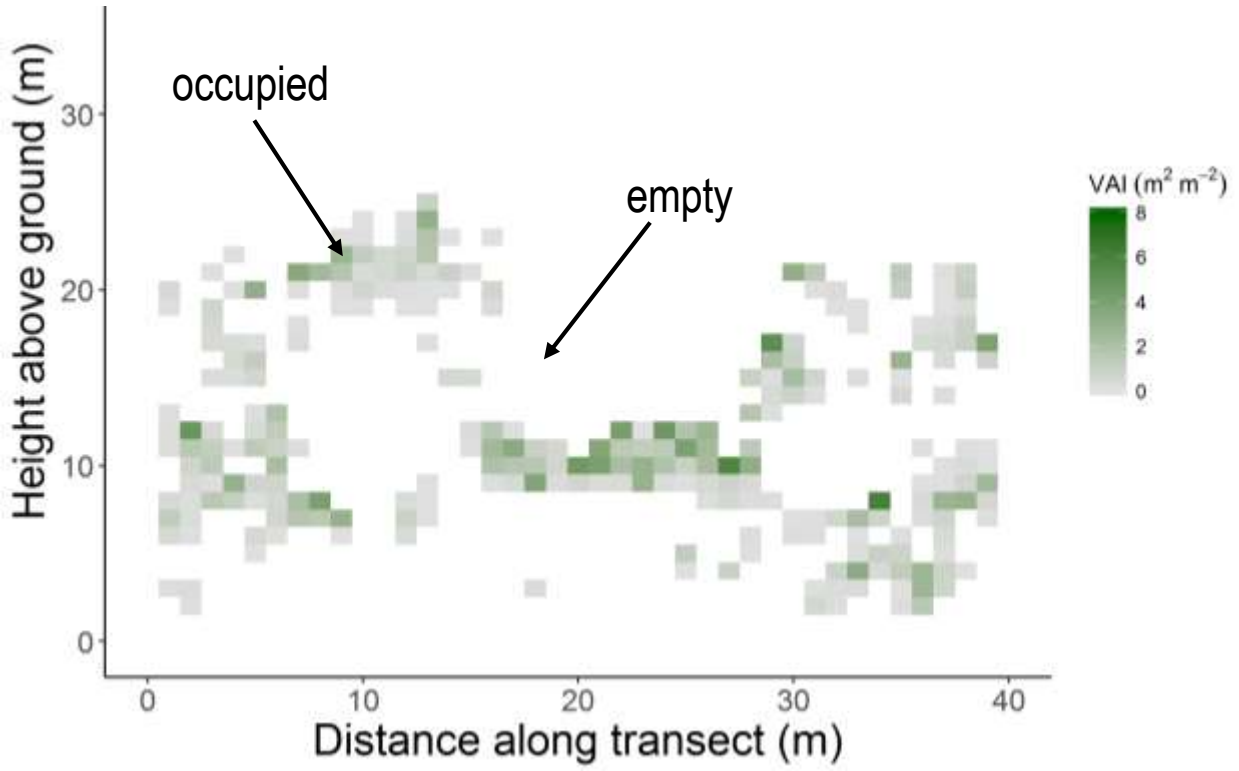




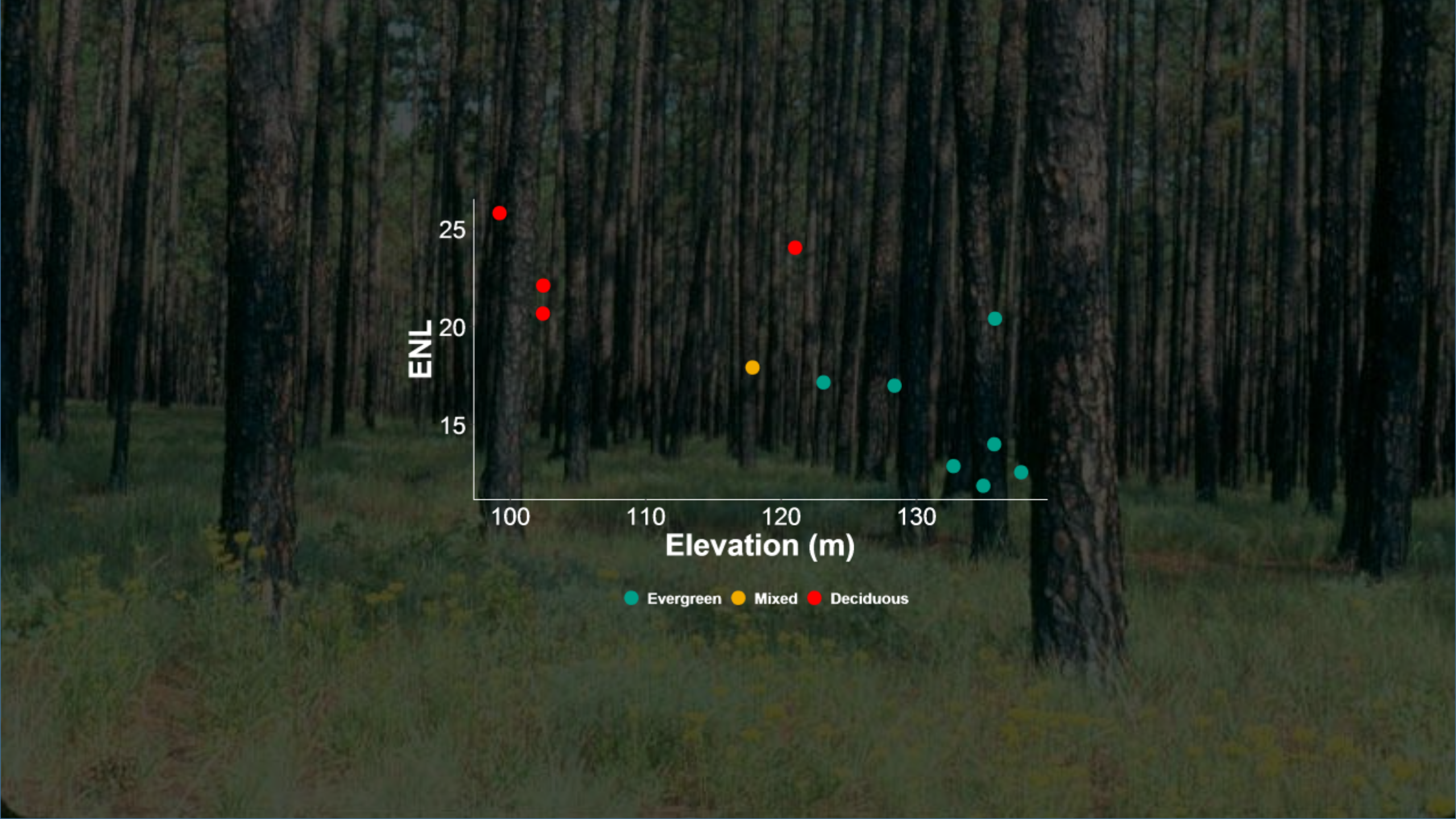
Effective Number of Layers (ENL)

- ENL describes the relationship between occupied and empty spaces in the canopy by layer
- Canopy layering
  From 2D and 3D terrestrial LiDAR

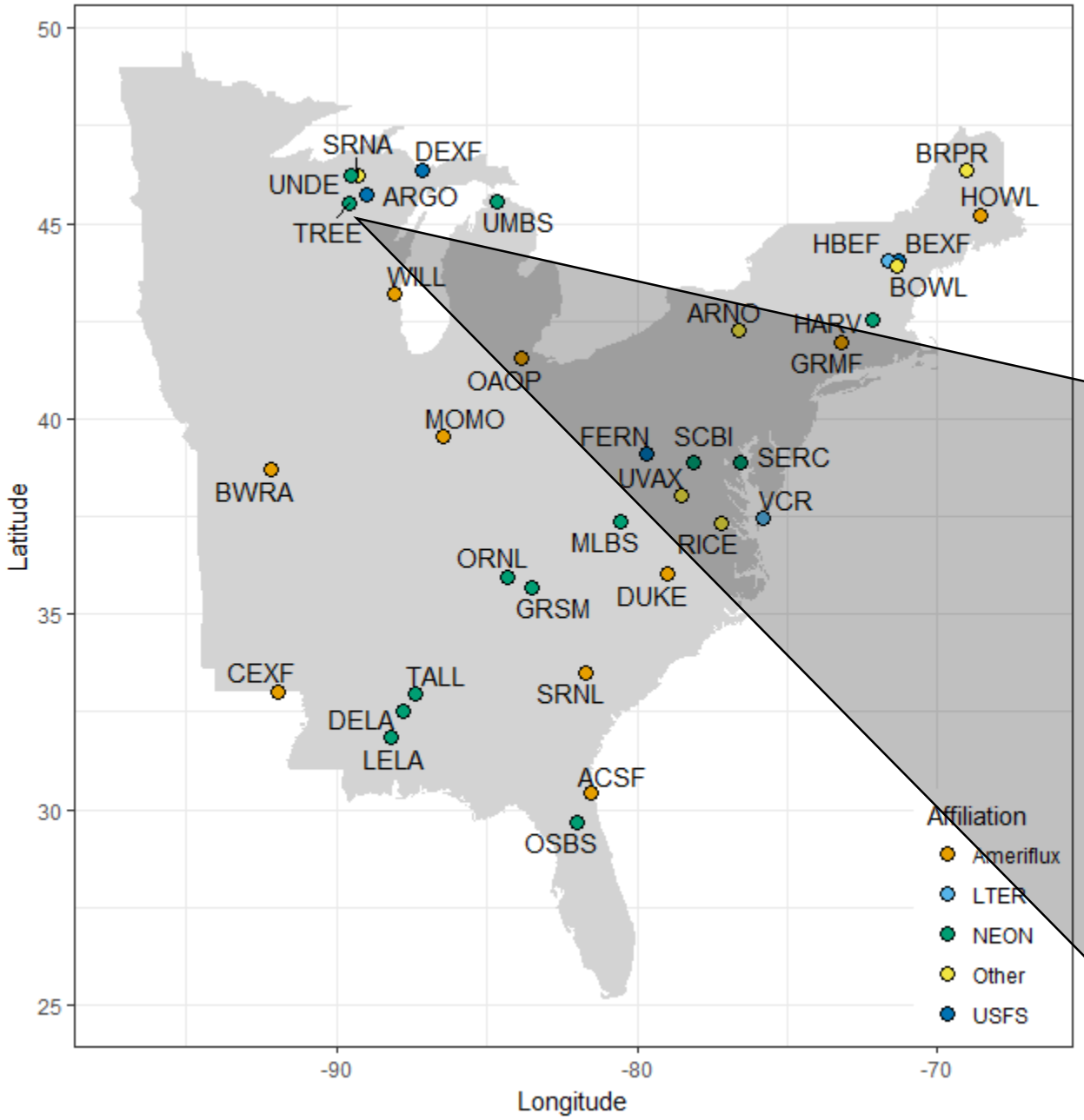
$$ENL = 1 \,/\, \sum_{i=1}^{N_{top}} p_i^2$$



Atkins et al. (In Review); Ehbrecht et al. (2017)


25
20
15
ENL
100
110
120
130
Elevation (m)
Evergreen
Mixed
Deciduous

How can we test this further?



Treehaven

- NEON site (TREE) covers 566 ha
- Virtually no elevation gradient (< 7 m)
- Mosaic of mixed and deciduous
- Harvested and burned from 1800s to 1930s
- Managed by U. of Wisconsin – Stevens Point

Treehaven

Random Forest Model

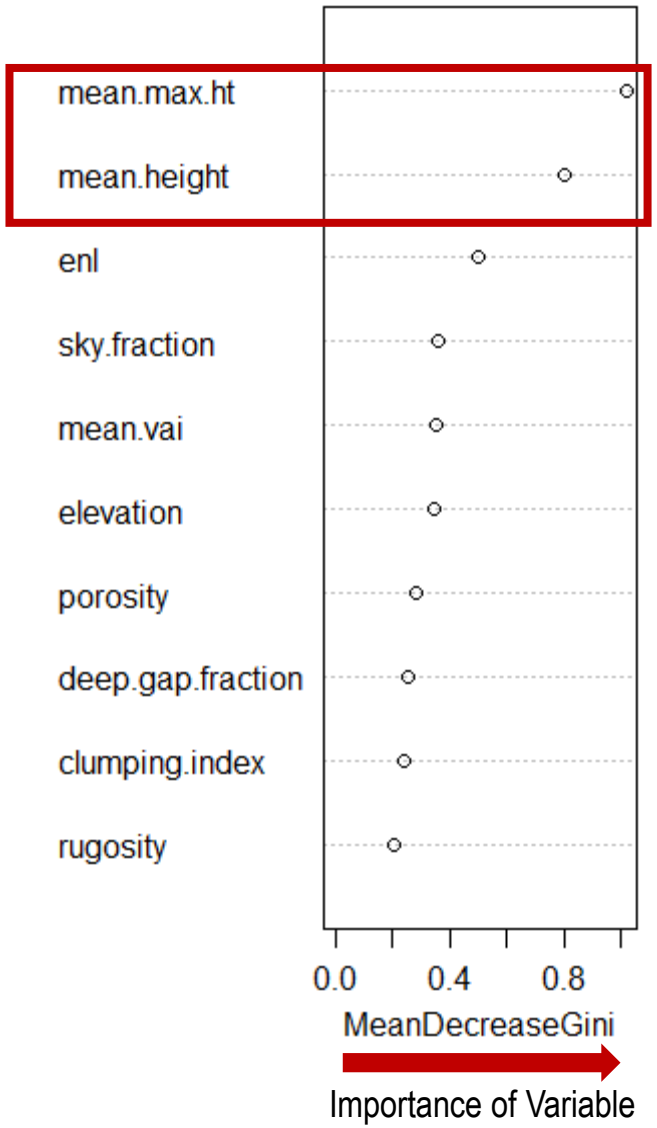
- Two models: 1) with elevation, 2) without elevation
- How does model perform without elevation gradient?

Not well . . .

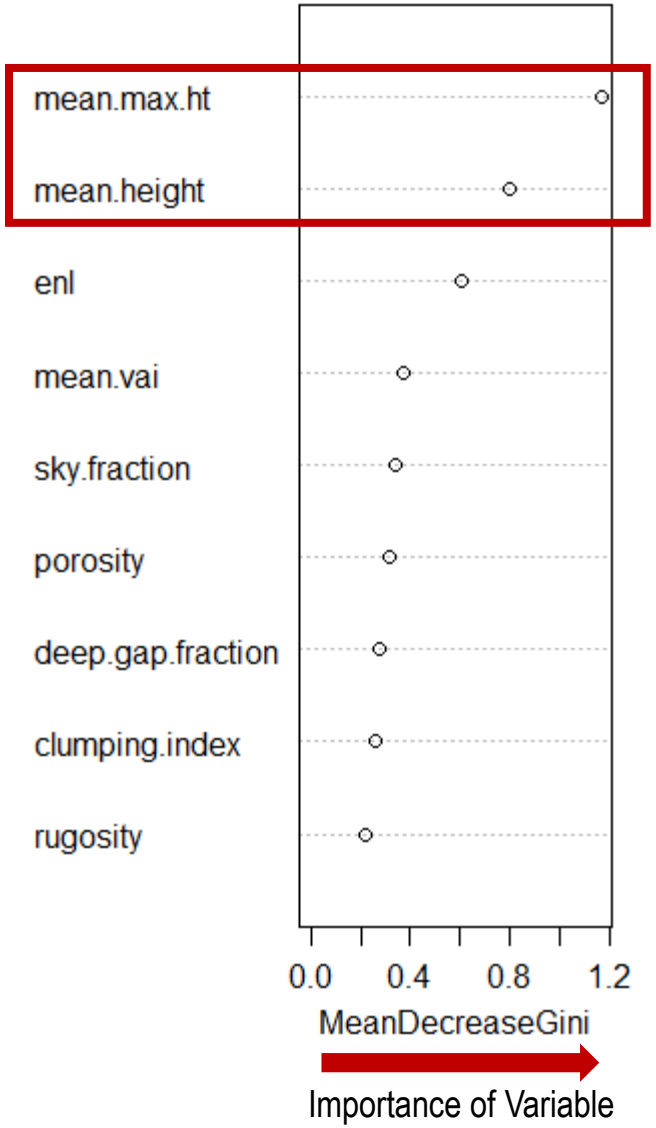
- Elevation + CSC - 50% error rate (OOB)
- CSC only - 50% error rate (OOB)

Why height?

Elevation + CSC model



CSC only model




MOCH
15.0
12.5
10.0
460
462
464
466
Elevation (m)
Mixed
Deciduous

FERNOW!!!

Fernow Experimental Forest

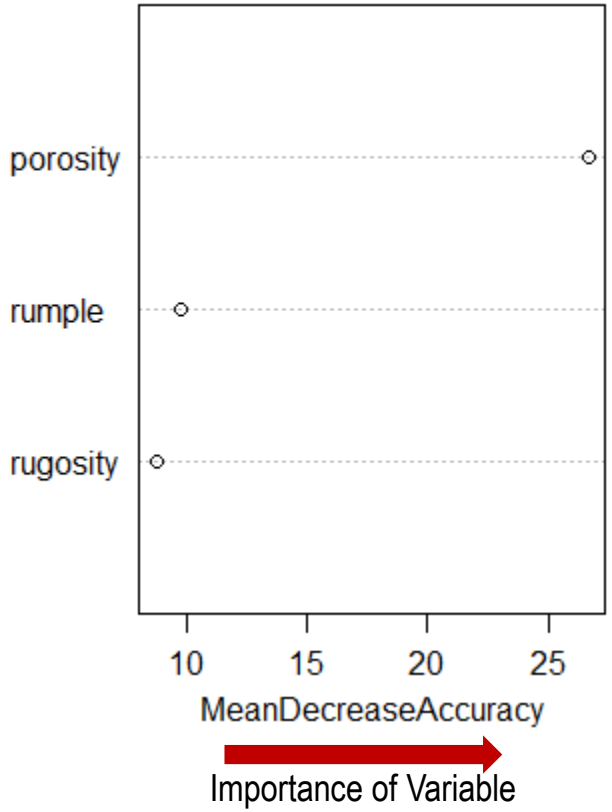
Random Forest Model

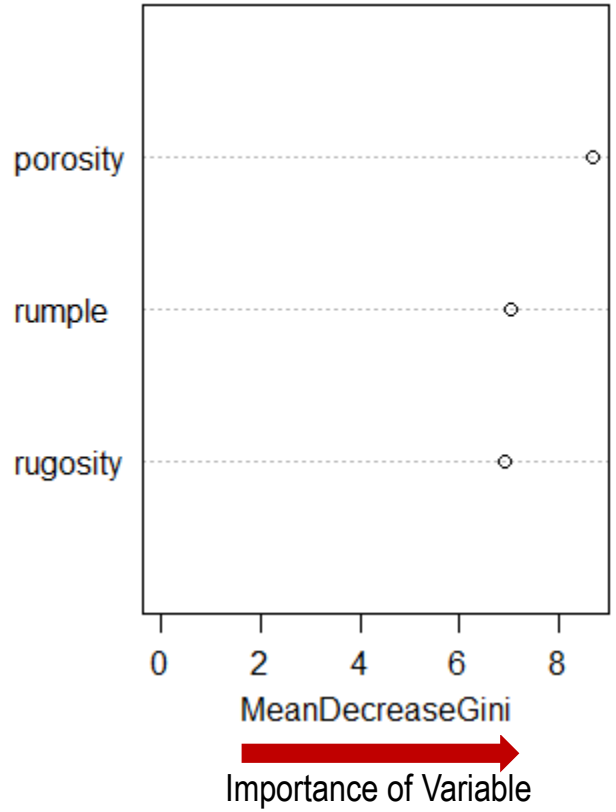
- Parametrized to better fit than a “kitchen sink” model

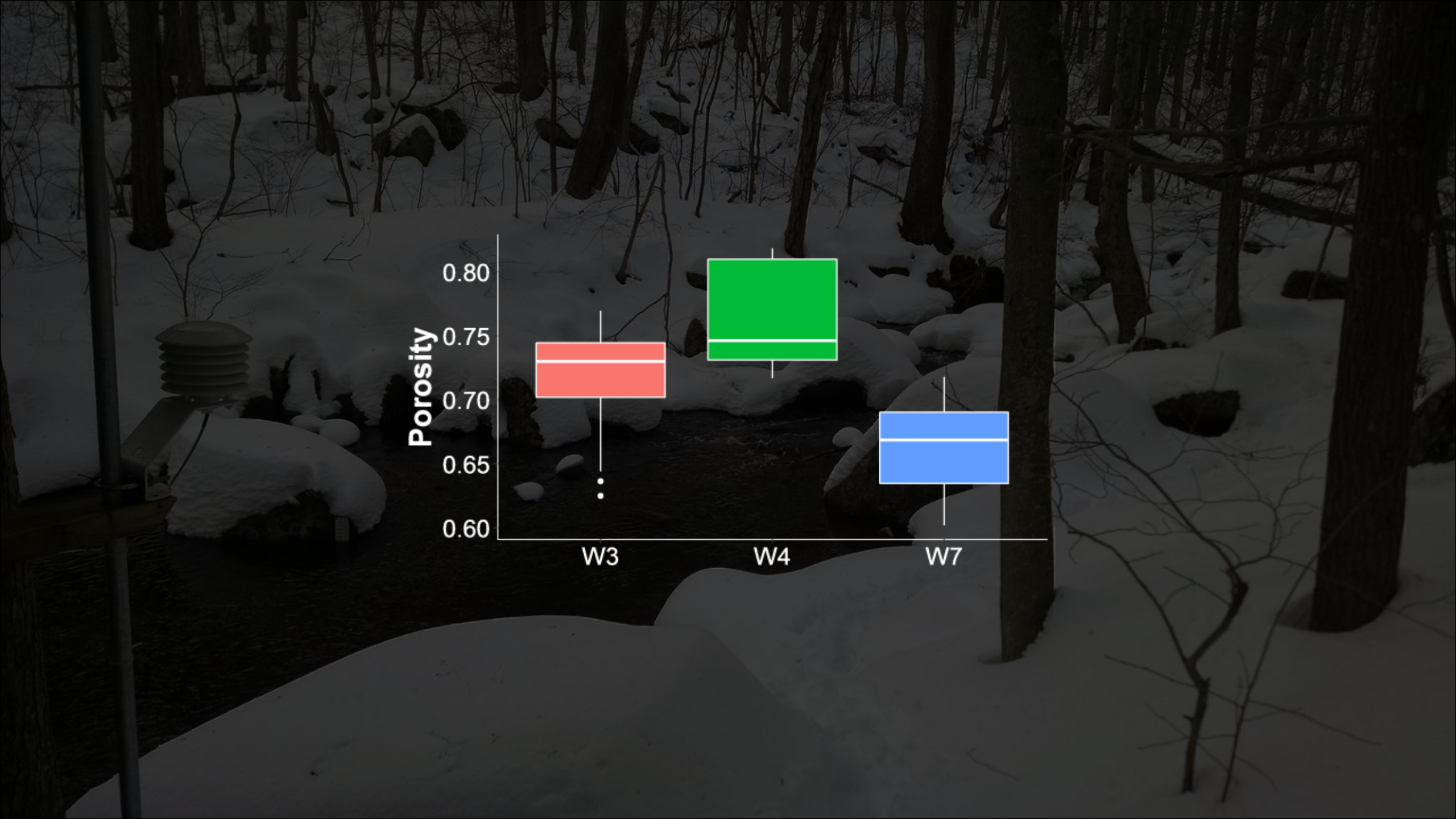
Not bad . . .

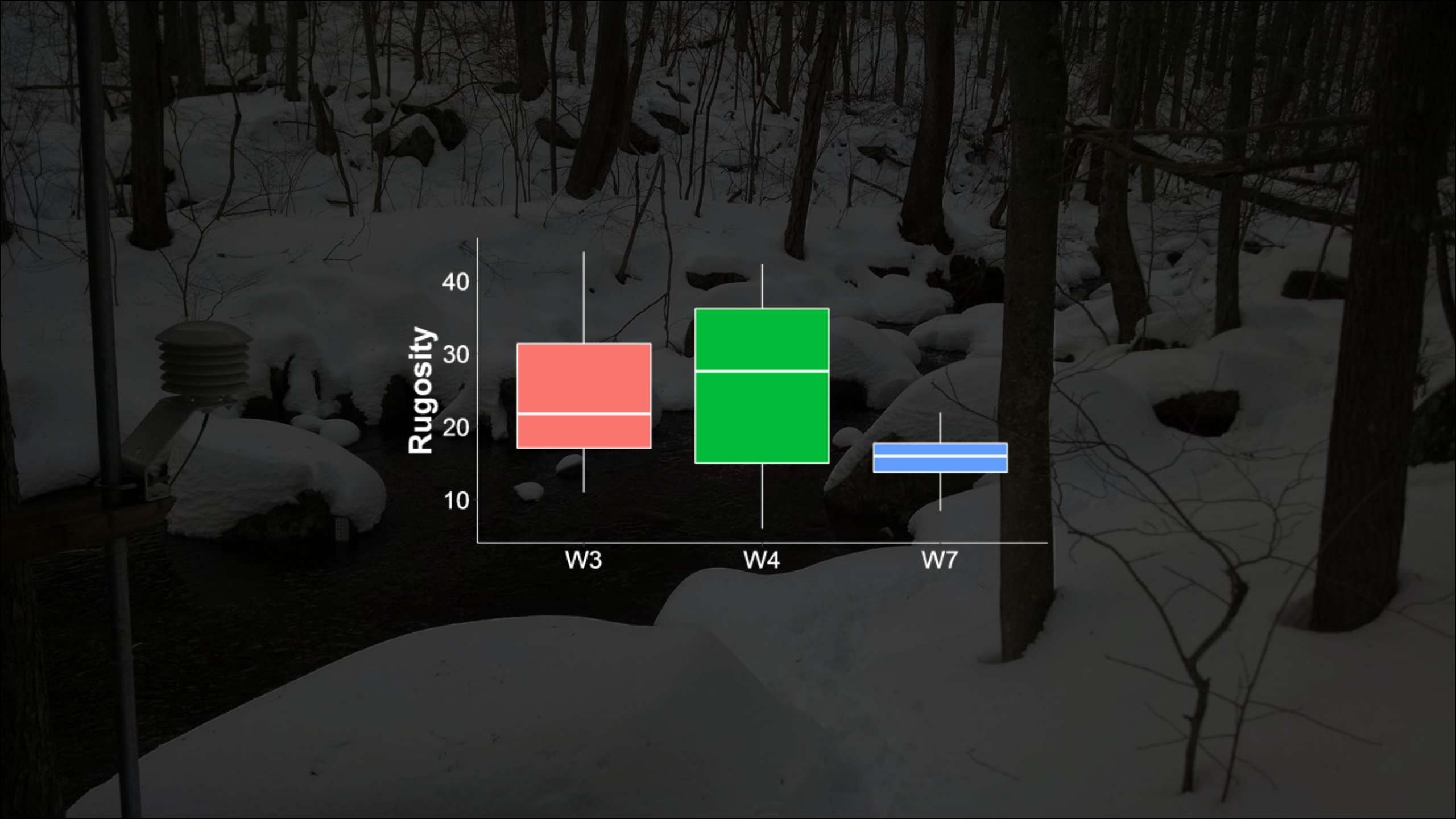
- CSC - 37% error rate (OOB)

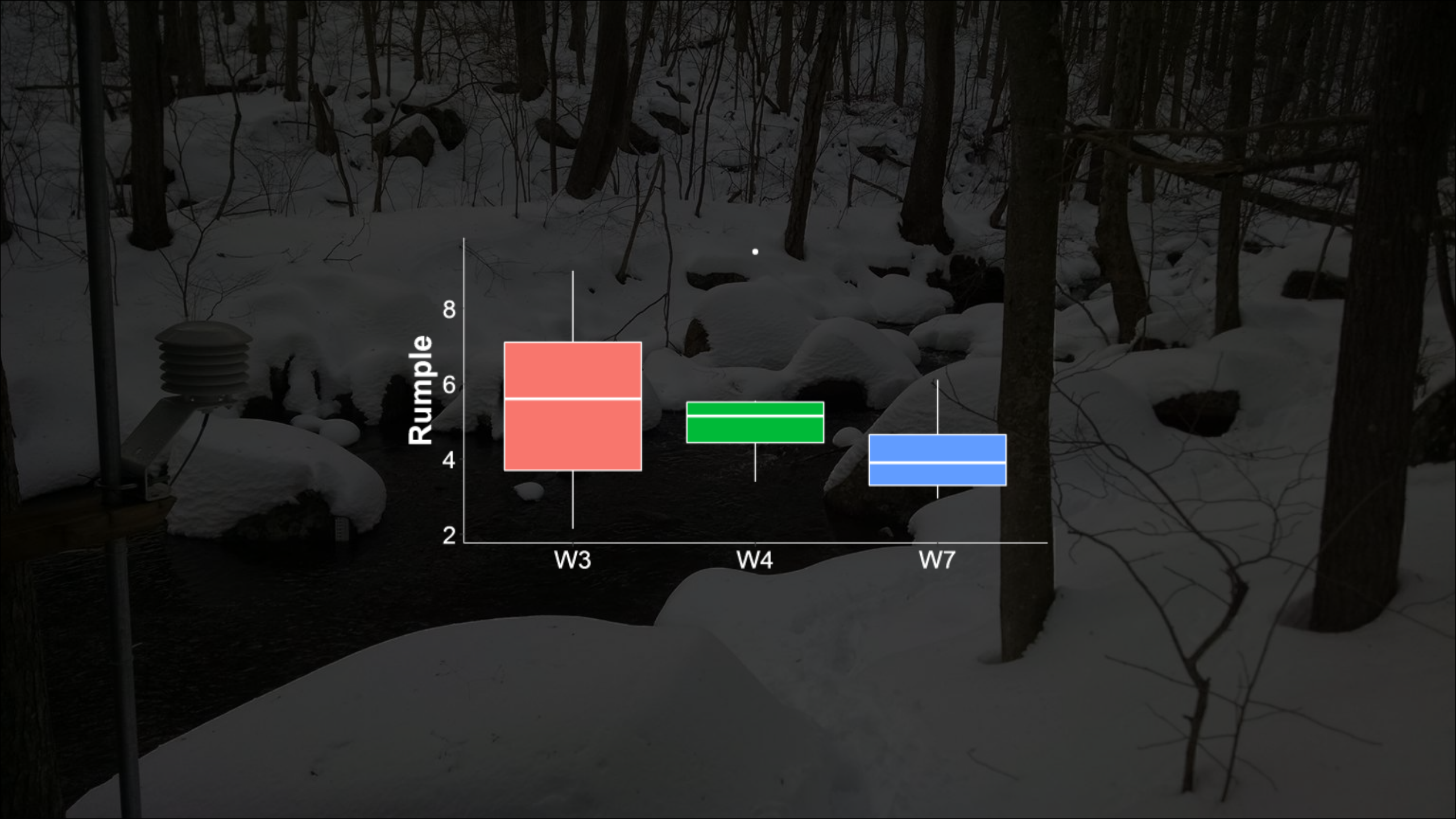
```
Confusion matrix:
    W3 W4 W7 class.error
W3 11  2  4   0.3529412
W4  6  1  0   0.8571429
W7  2  0 11   0.1538462
```



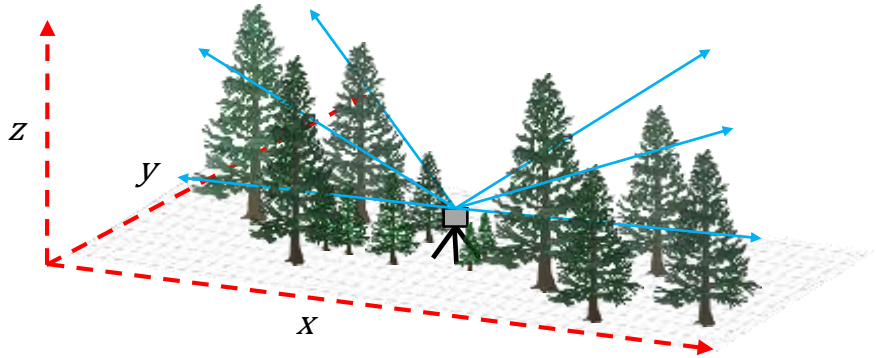


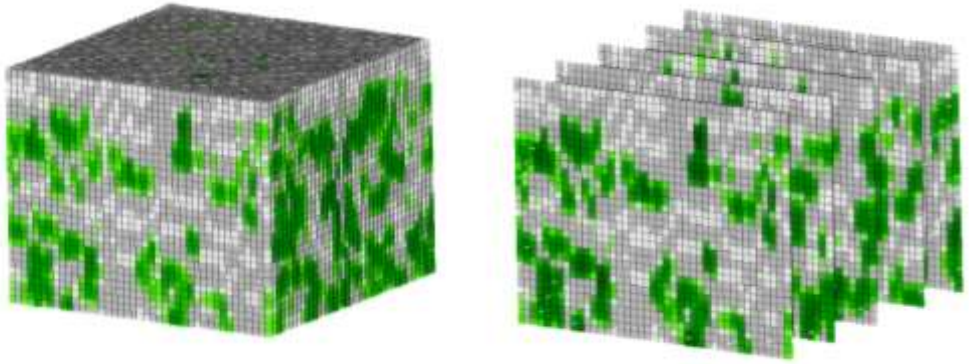

Porosity
0.80
0.75
0.70
0.65
0.60
W3
W4
W7


Rugosity
40
30
20
10
W3
W4
W7


Rumple
8
6
4
2
W3
W4
W7

Next steps: 3-D Scanning LiDAR and more





- 3-D Scanning LiDAR Harmonization

Atkins & Stovall (In Prep)

Questions?

Many thanks to the Gough Lab (Chris, Shea, Lisa, Ellen, Ben, Jeff-Ben, Kayla), Hardiman Lab (Brady, Liz, Gillian, Franklin), Cynthia Scheuermann, Kim Calders, Atticus Stovall, Alan Strahler, NSF RCN, Brenden McNeil, Kyla Dahlin, Jan van Ardt, Jason Tallent, Hank Shugart, Tim Fahey, NEON and Courtney Meier, Naupaka Zimmerman, Gil Bohrer, Tim Morin, all at UMBS, the gracious people at many NEON sites, and many, many more.

Award No. 1550657