The forest from the trees: predicting understory abundance from remote sensing with scaling theory

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University in St Louis

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Department of Agriculture

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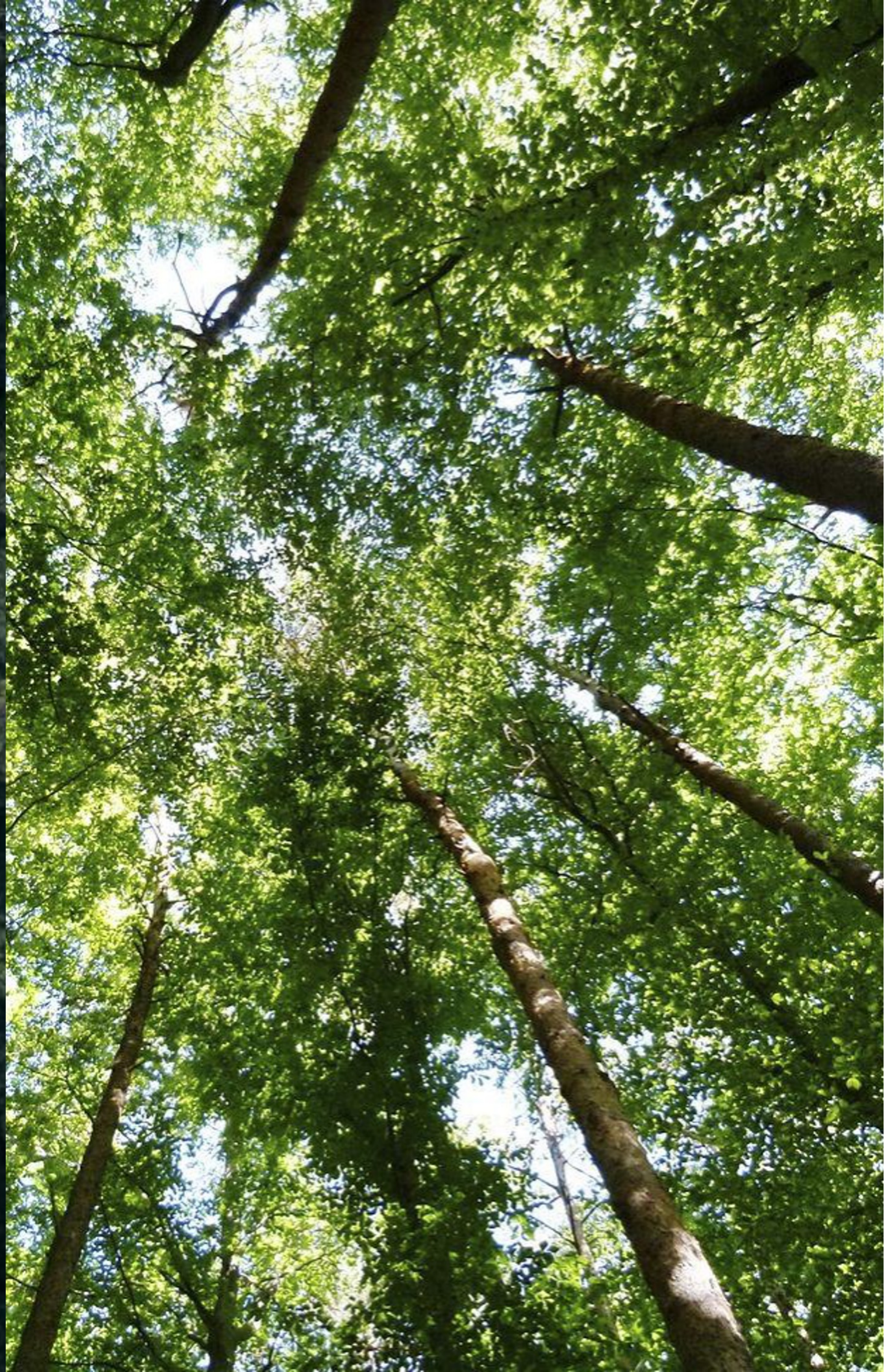
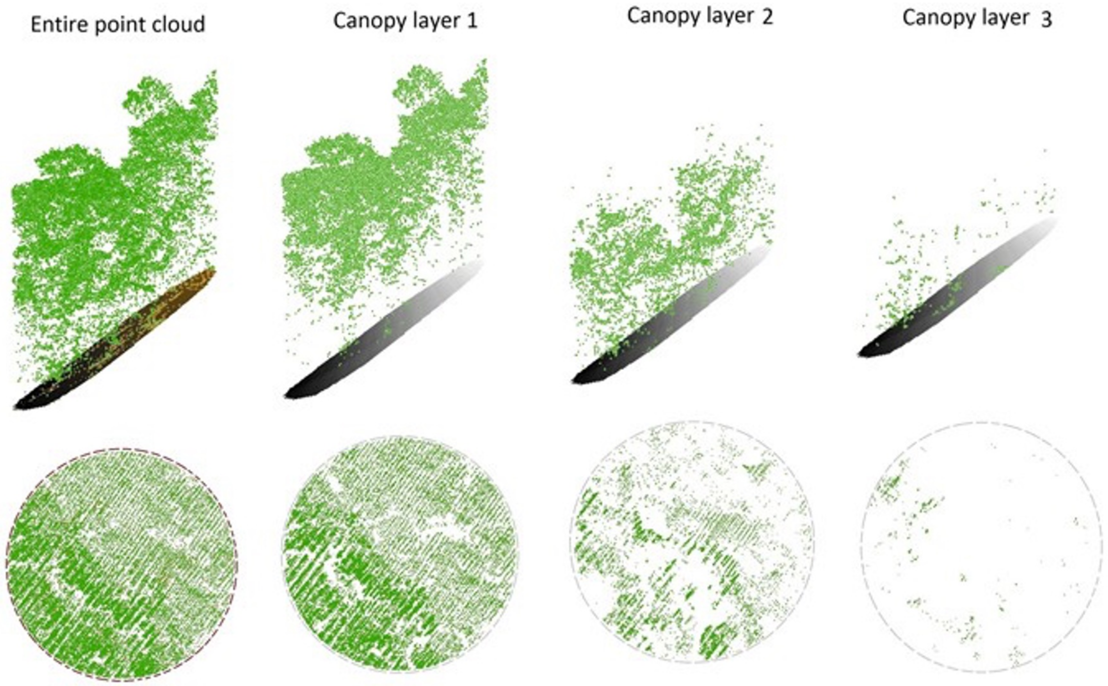
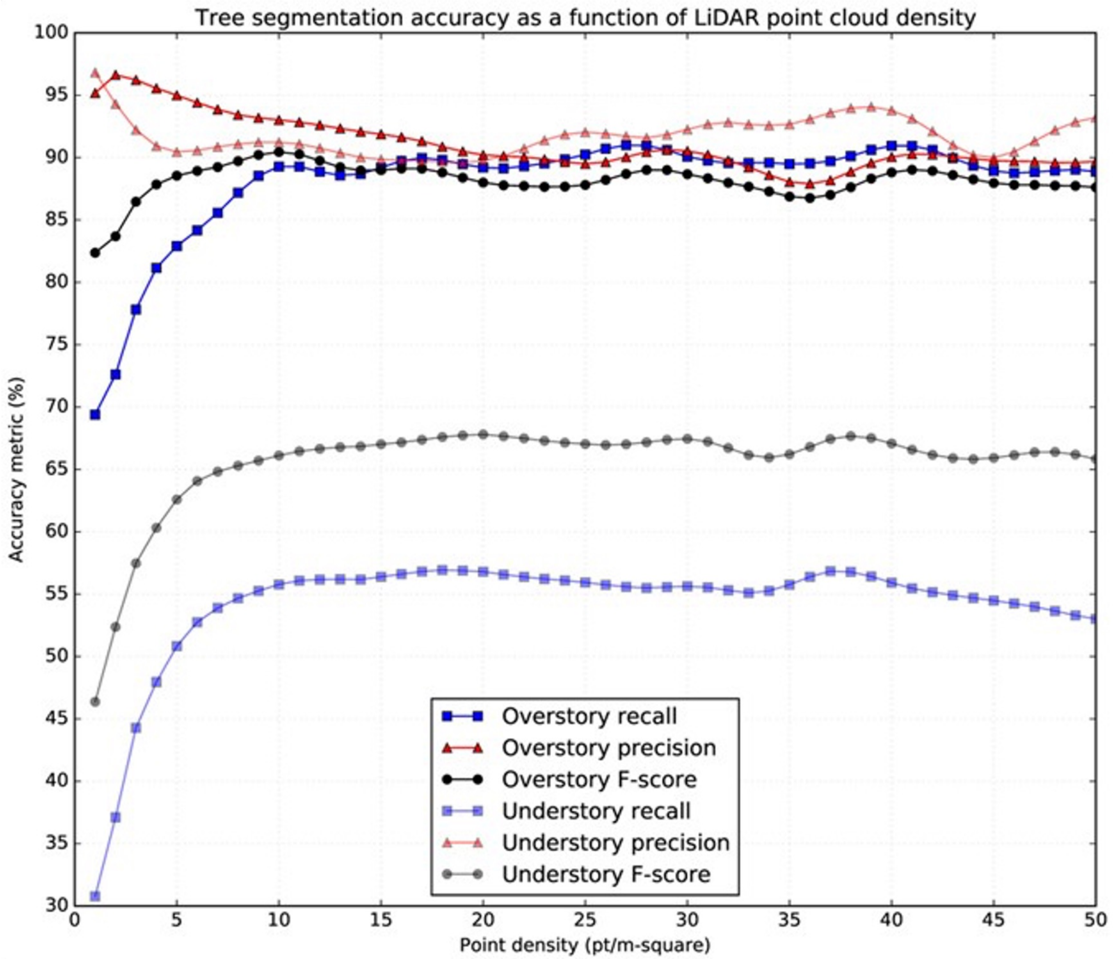
University of Maine



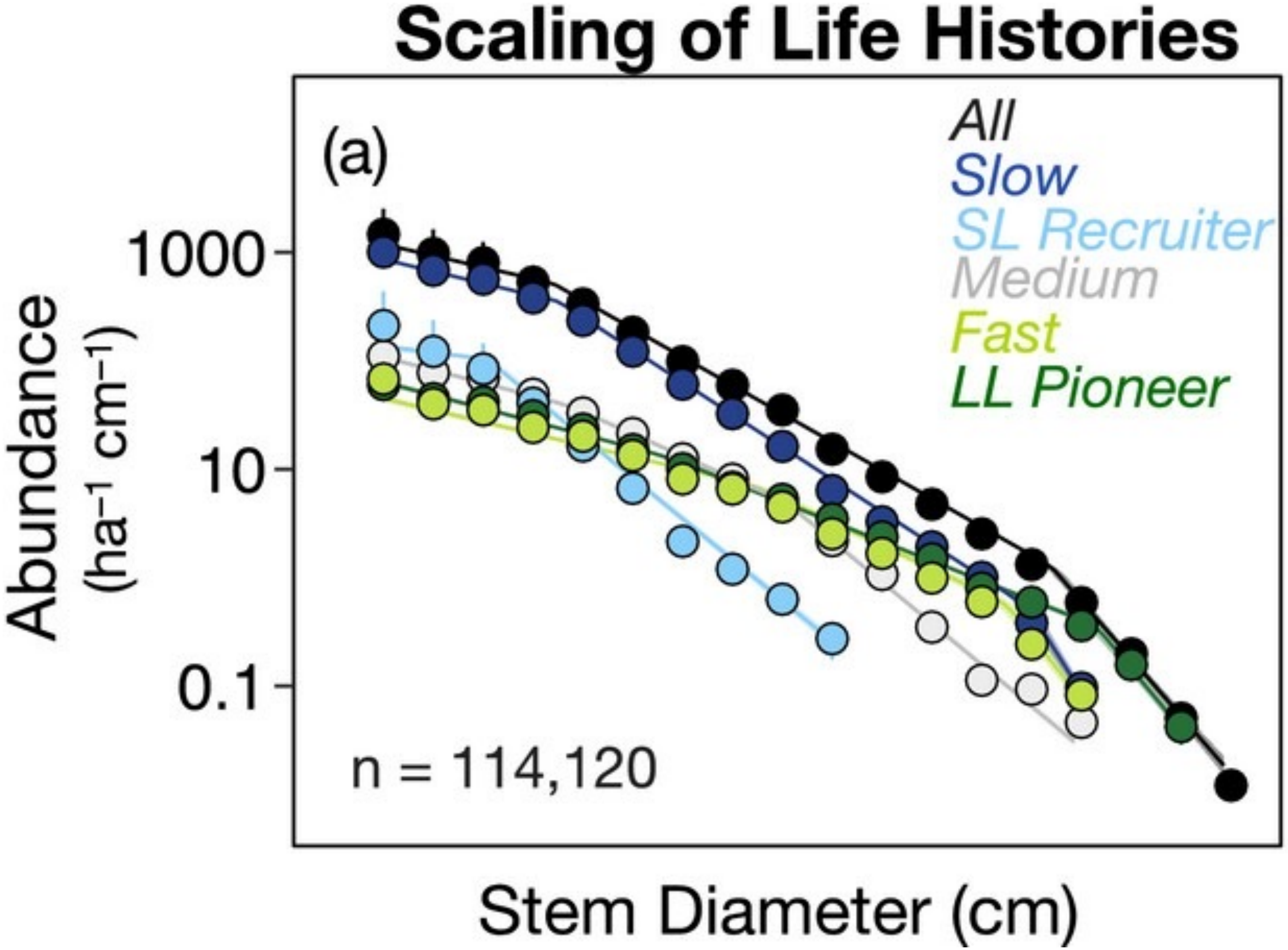
Understory Inaccuracies



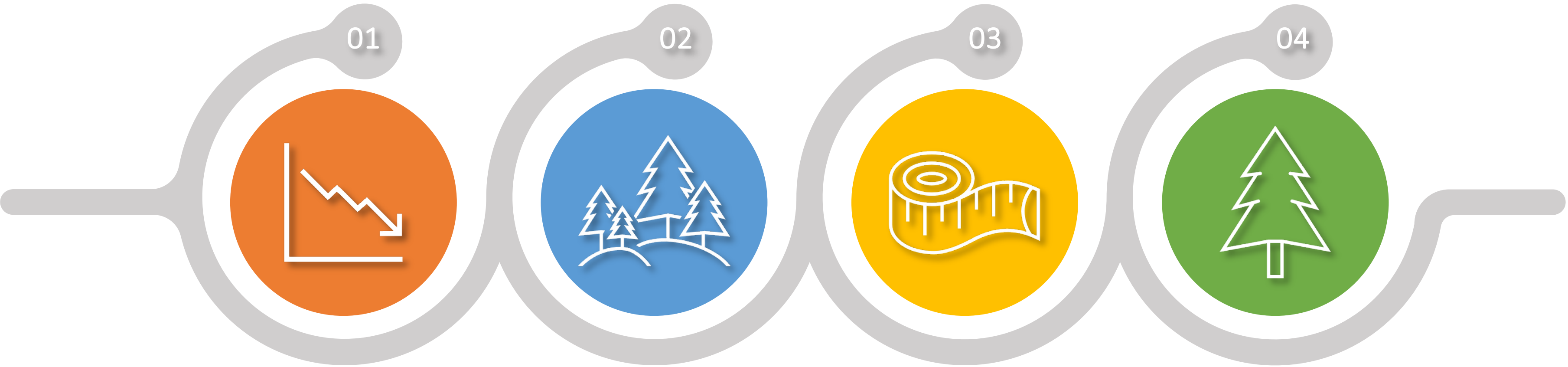


Hamraz et al. (2017) *Scientific Reports*

Grady, John M., et al. (2024). "Life history scaling in a tropical forest."
Journal of Ecology



Workflow



Theory, Scaling Predictions

Determine how scaling relationships should change based on forest environmental characteristics (age, disturbance, type, etc)

Canopy Delineation

Demarcate the crown of each individual canopy tree in a forest from RGB, LiDAR, or hyperspectral images

DBH Estimates of Canopy Trees

Derive the size of each canopy tree from its height, create canopy size-abundance scaling relationship

Predictions of Understory Trees

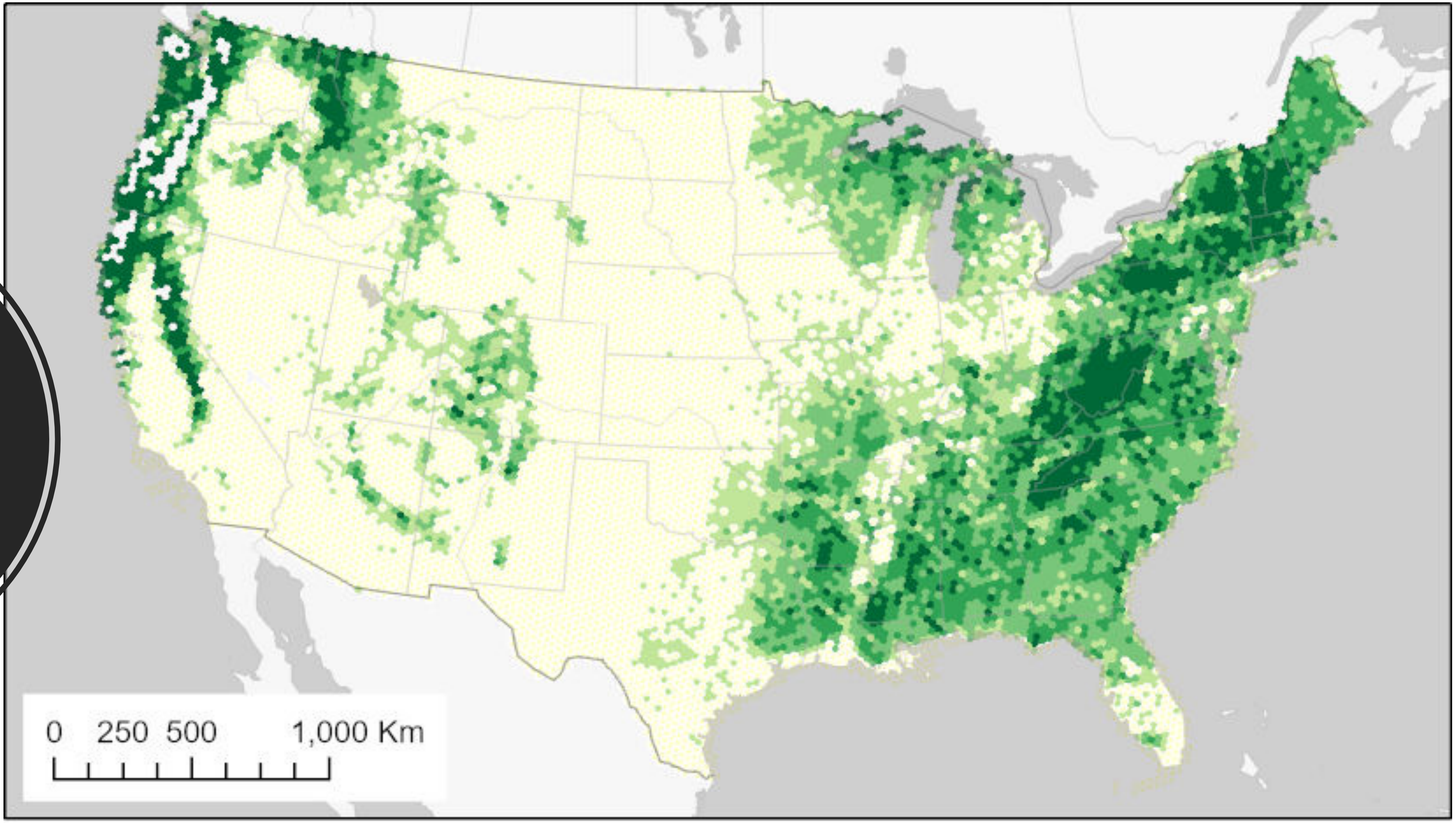
Interpolate the missing component (understory) of the size-abundance scaling relationship based on (1), (2), and (3)

Research Questions

1) Do forests converge to a size-abundance slope of -2 absent disturbance?
2) Does disturbance induce predictable deviations from -2?
3) Do characteristics such as forest age, maximum tree height, and mortality predict size-abundance slopes without accounting for disturbance?

Forest Inventory and Analysis (FIA)

Menlove & Healey (2021) *ORNL DAAC*



Aboveground Live Biomass (Mg ha-1) - CRM

≤15.0 ≤40.0 ≤70.0 ≤100.0 ≤230.0

Methods

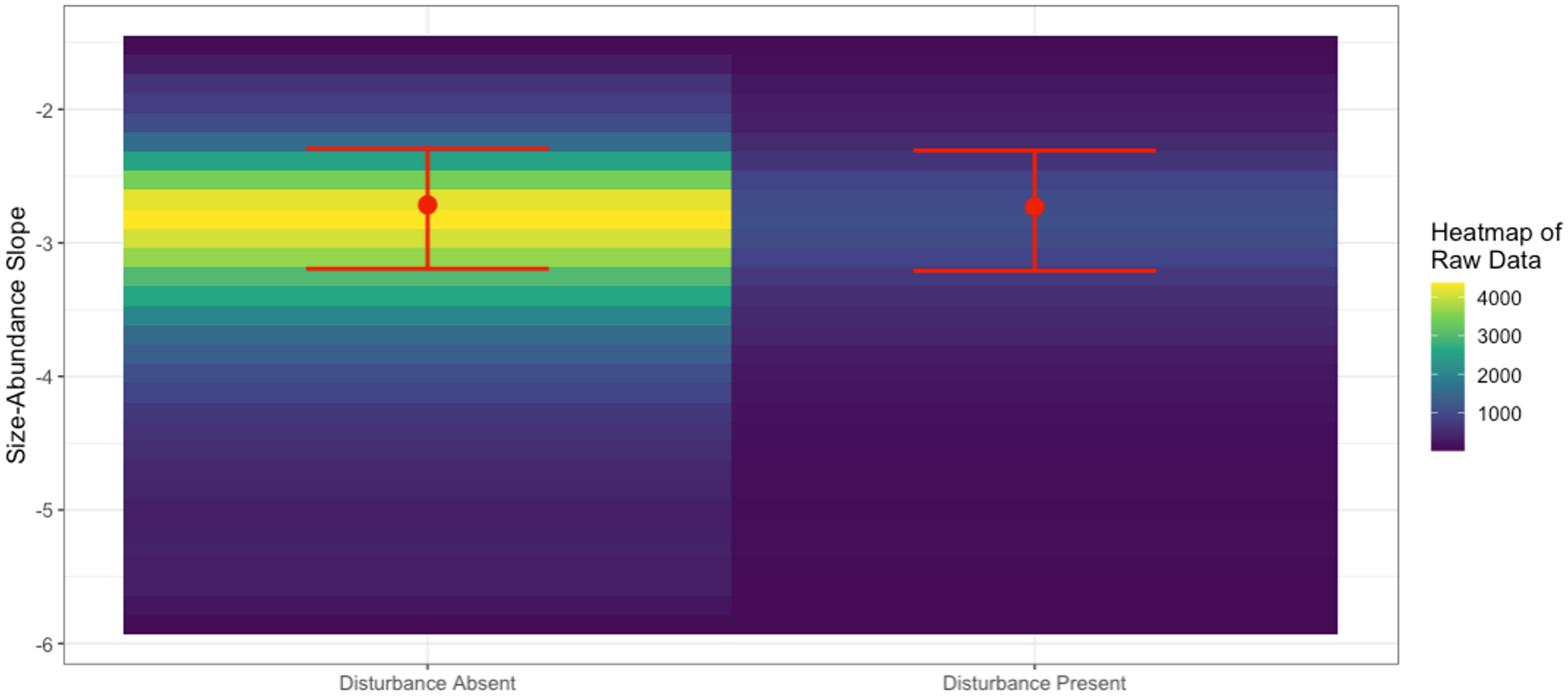
Fit size-abundance distribution to each plot, obtain slope estimate

Model slope as response variable, forest characteristics as predictors using Bayesian statistics

Account for effect of space by including ecoregion as a spatially autocorrelated variable

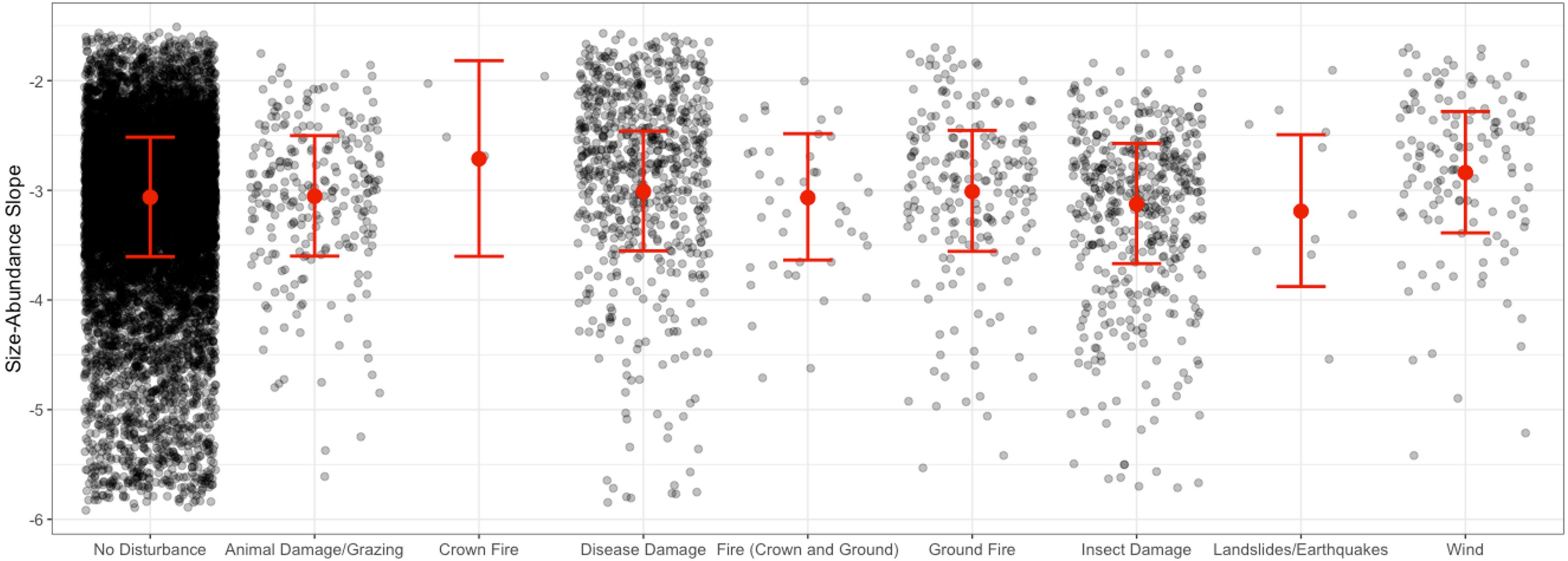
Response variable: Size abundance slope	Predictors: Disturbance presence/absence, maximum forest height, stand age, mortality

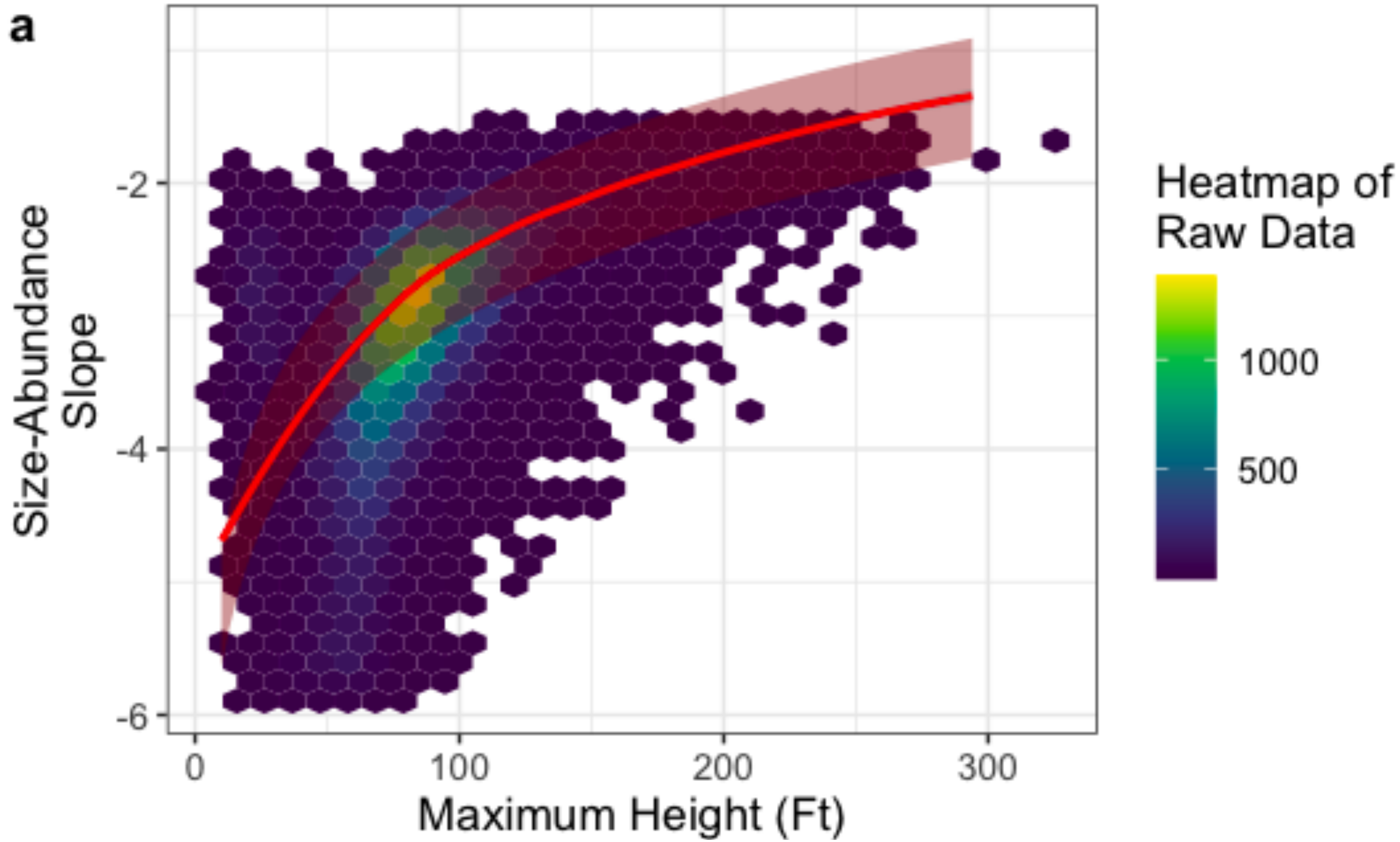
Results

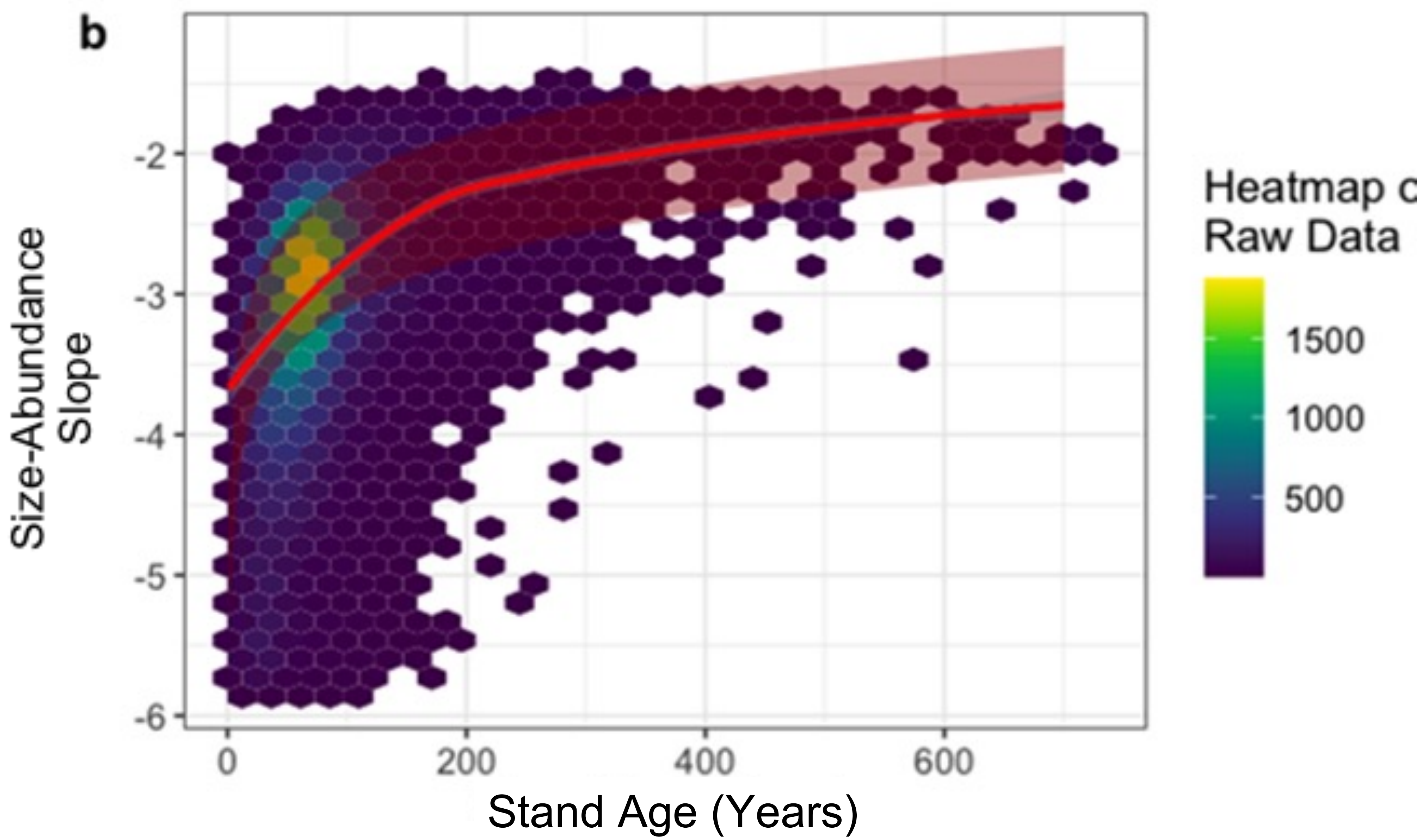

Size-Abundance Slope
-2
-3
-4
-5
-6
Disturbance Absent
Disturbance Present
Heatmap of
Raw Data
4000
3000
2000
1000

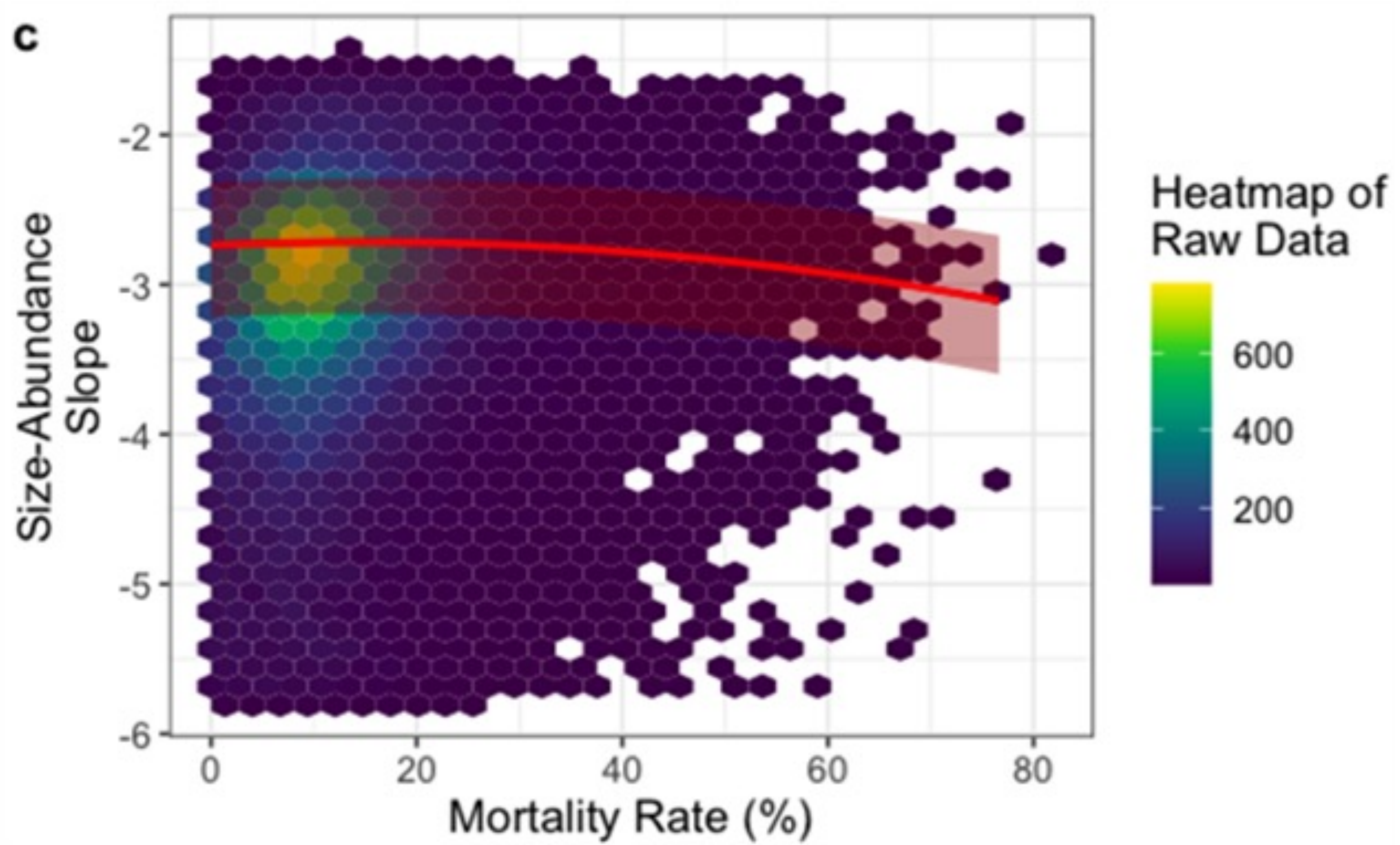
Proportion of Samples Inside the Region of Practical Equivalence (ROPE)

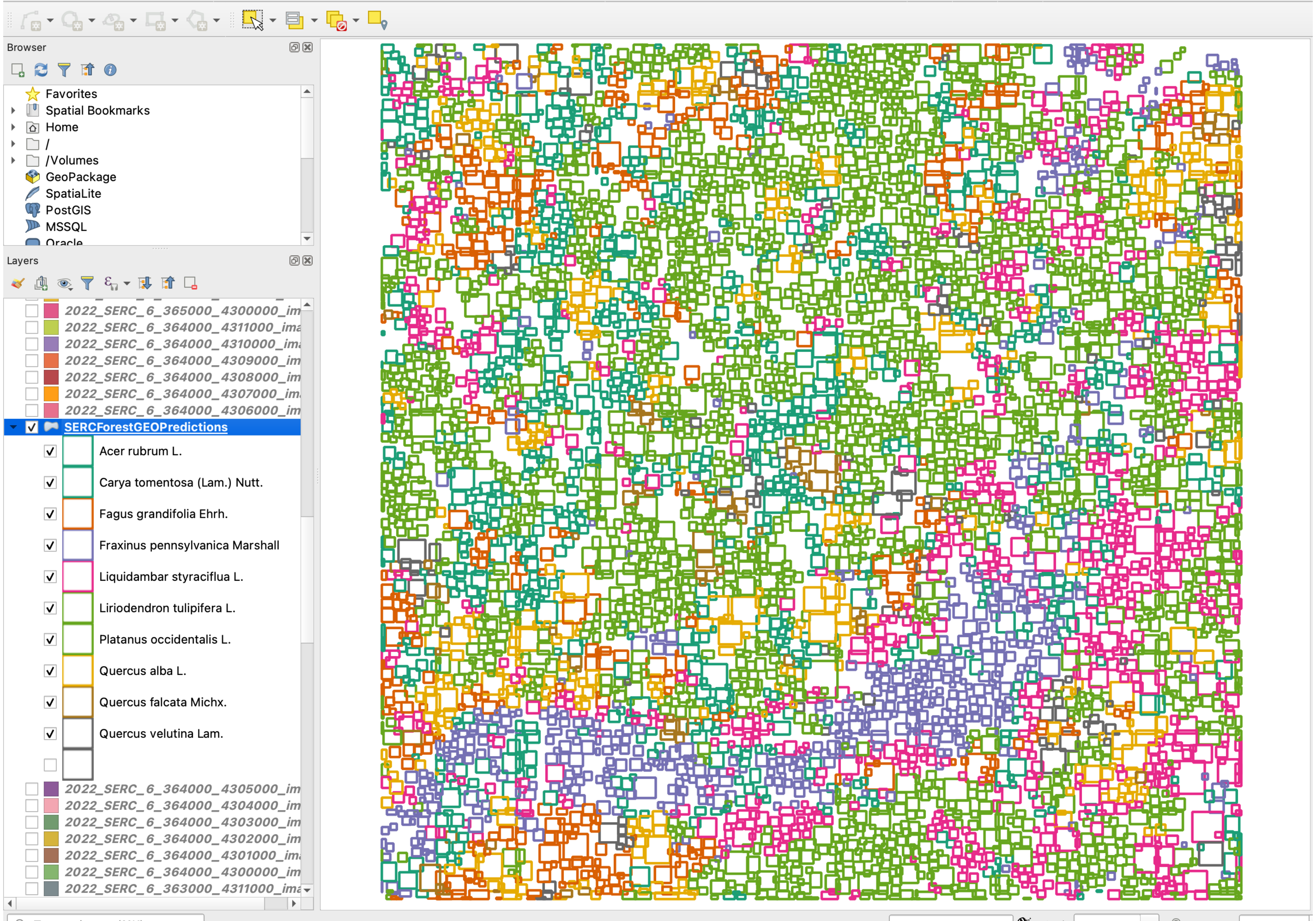
NA	77.43%	11.29%	61.08%	52.01%	74.47%	79.32%	25.03%	0.00%




a
Size-Abundance Slope
-2
-4
-6
0
100
200
300
Maximum Height (Ft)
Heatmap of Raw Data
1000
500


b
Size-Abundance
Slope
-2
-3
-4
-5
-6
0
200
400
600
Stand Age (Years)
Heatmap c
Raw Data
1500
1000
500


c
Size-Abundance Slope
-2
-3
-4
-5
-6
0
20
40
60
80
Mortality Rate (%)
Heatmap of Raw Data
600
400
200



Browser
Favorites
Spatial Bookmarks
Home
/
/Volumes
GeoPackage
SpatiaLite
PostGIS
MSSQL
Oracle
Layers
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2022_SERC_6_364000_4311000_ima
2022_SERC_6_364000_4310000_ima
2022_SERC_6_364000_4309000_im
2022_SERC_6_364000_4308000_im
2022_SERC_6_364000_4307000_ima
2022_SERC_6_364000_4306000_im
SERCForestGEOPredictions
Acer rubrum L.
Carya tomentosa (Lam.) Nutt.
Fagus grandifolia Ehrh.
Fraxinus pennsylvanica Marshall
Liquidambar styraciflua L.
Liriodendron tulipifera L.
Platanus occidentalis L.
Quercus alba L.
Quercus falcata Michx.
Quercus velutina Lam.
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2022_SERC_6_363000_4311000_ima

In revision at PLOS Biology

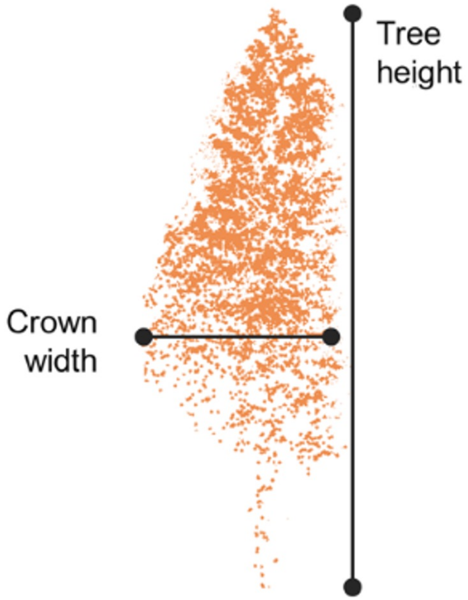
PLOS BIOLOGY

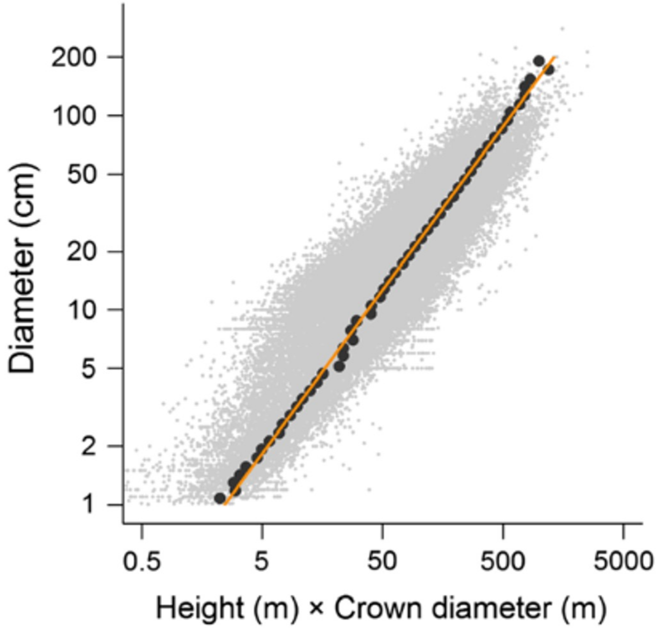
Individual canopy tree species maps for the National Ecological Observatory Network

Ben. G. Weinstein, Sergio Marconi, Alina Zare, Stephanie A. Bohlman, Aditya Singh, Sarah J. Graves, Lukas Magee, Daniel J. Johnson, Sydne Record, Vanessa E. Rubio, Nathan G. Swenson, Philip Townsend, Thomas T. Veblen, Robert A. Andrus, Ethan P. White

Jucker et al. (2017) *Global Change Biology*

$$DBH = e^{[\alpha+\beta*\ln(Height*Crown\ Diameter)]} * e^{\frac{\sigma^2}{2}} + \varepsilon$$





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- Ben Weinstein
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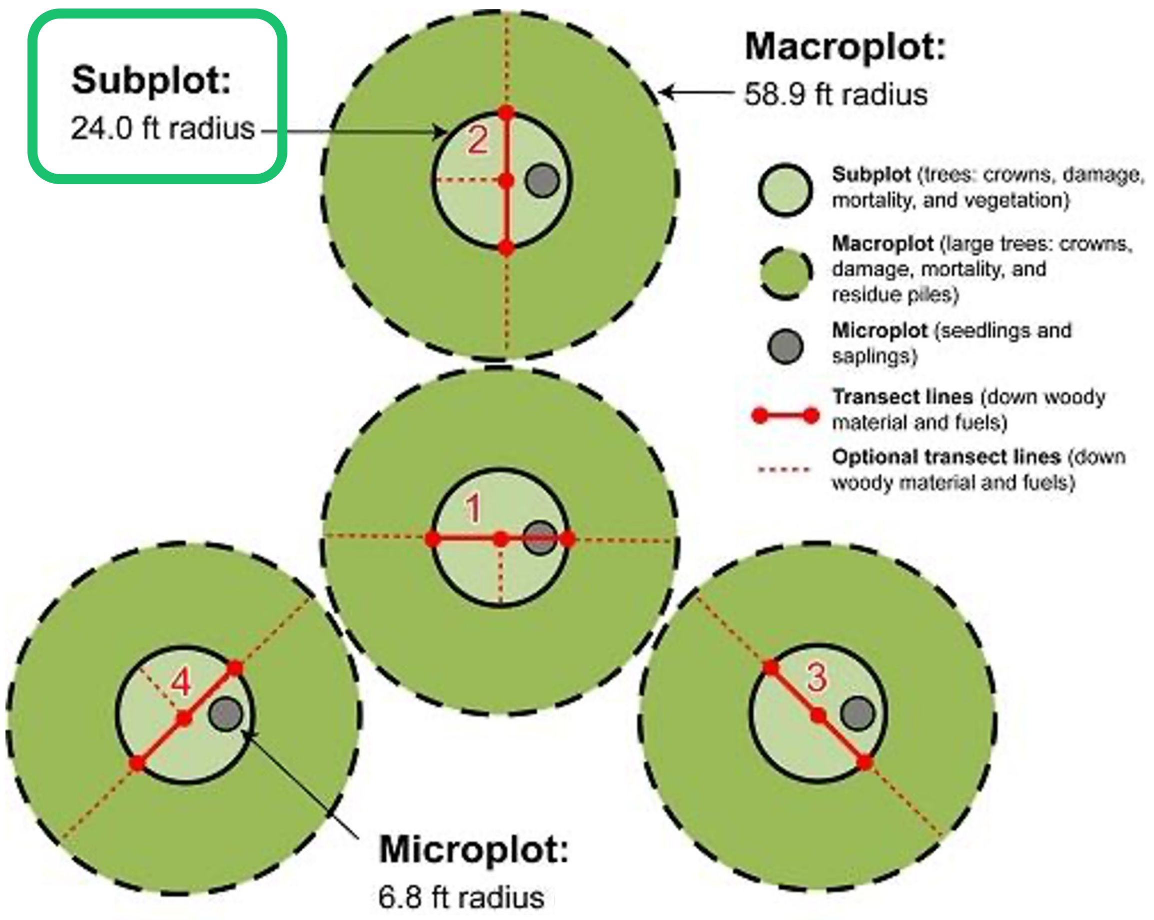
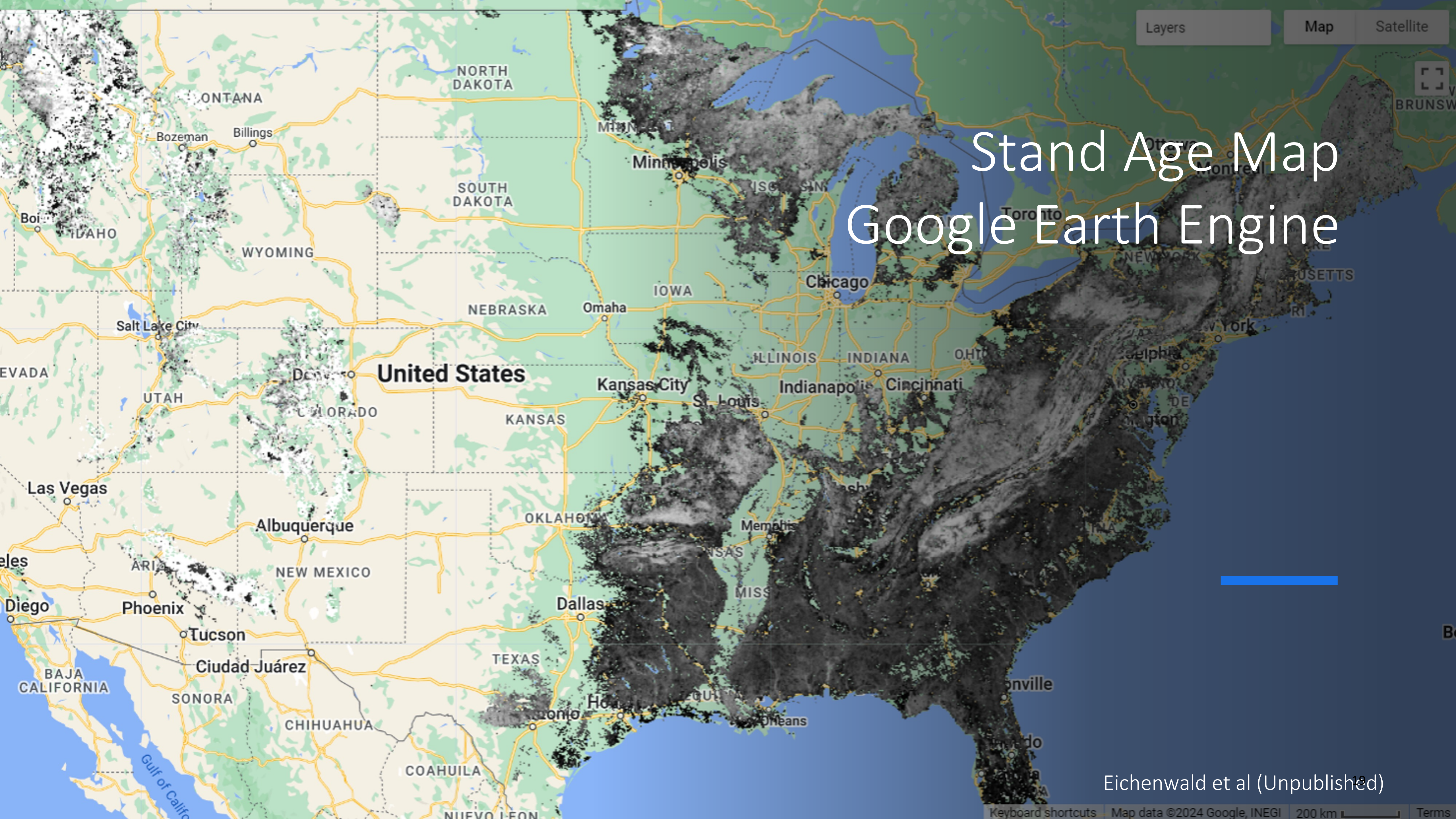
- US Forest Service
- Harvard Forest
- NEON
- Hatch project number ME022425

Plot Design



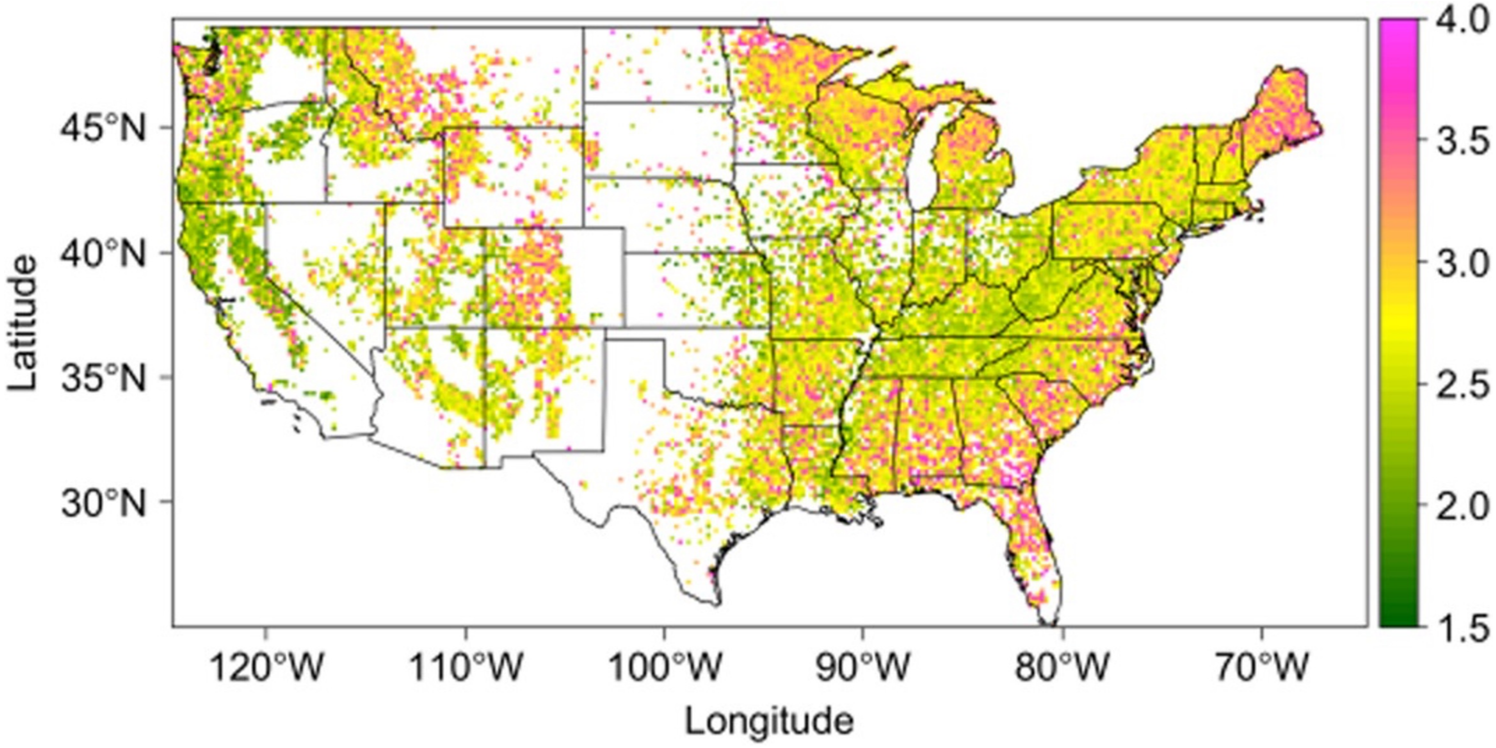
Subplot:
24.0 ft radius
Macroplot:
58.9 ft radius
2
1
4
3
Subplot (trees: crowns, damage, mortality, and vegetation)
Macroplot (large trees: crowns, damage, mortality, and residue piles)
Microplot (seedlings and saplings)
Transect lines (down woody material and fuels)
Optional transect lines (down woody material and fuels)
Microplot:
6.8 ft radius

Stand Age Map
Google Earth Engine



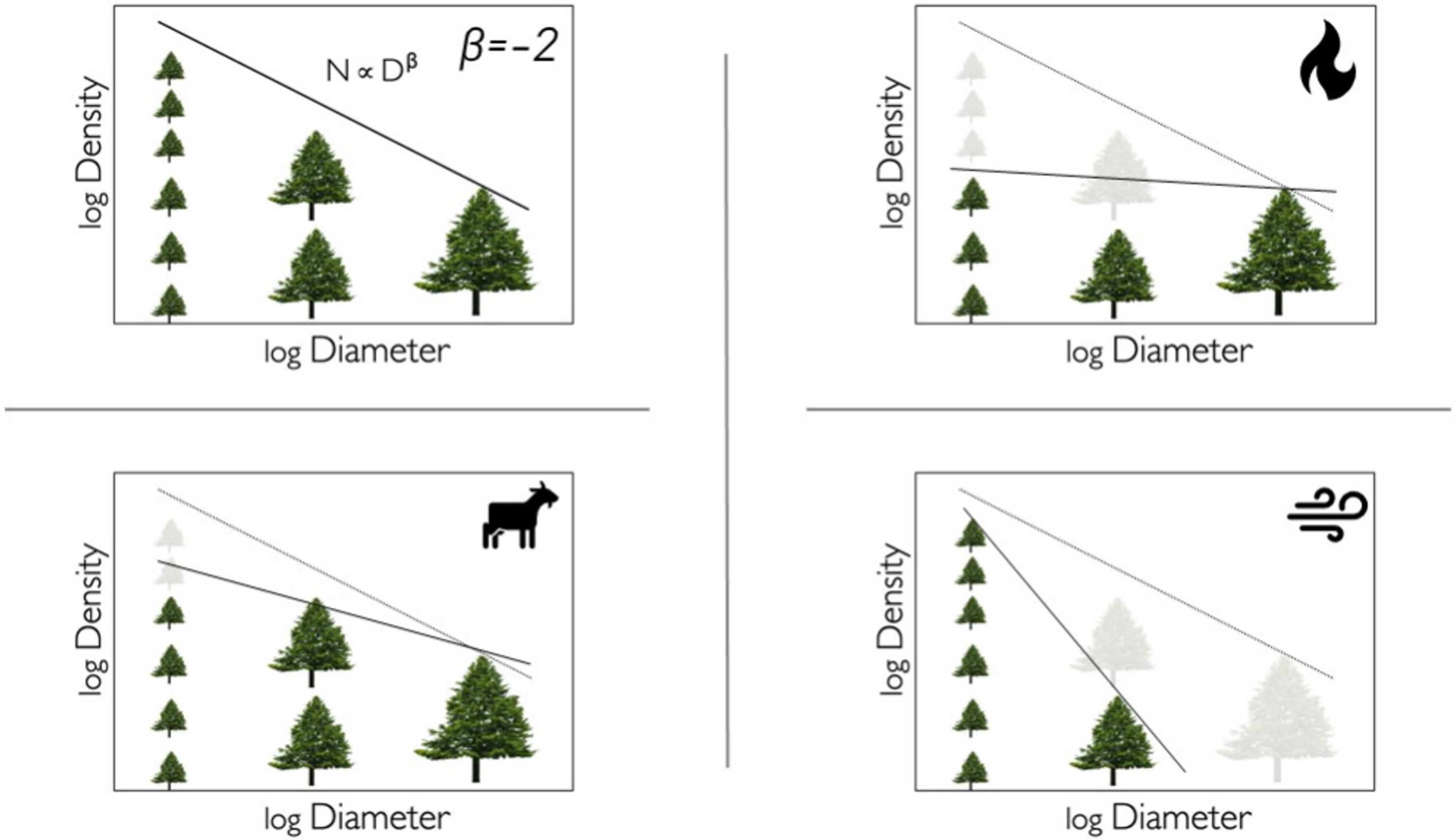
Eichenwald et al (Unpublished)

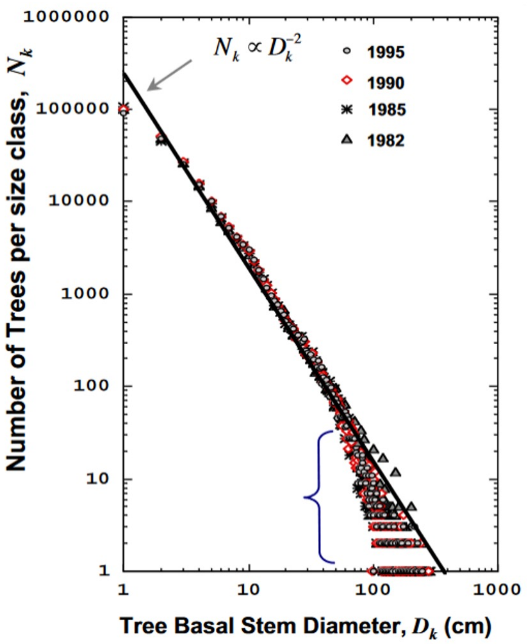
Environmental Variables Alter Scaling Slope



Duncanson et al. (2015) *Global Ecology and Biogeography*

Hypotheses Regarding Disturbances





Enquist et al. (2009) *PNAS*

Journal of Theoretical Biology

journal homepage: www.elsevier.com/locate/yjtbi

Variance in tree growth rates provides a key link for completing the theory of forest size structure formation

Jian Zhou [a,*], Kailiang Yu [b], Guanghui Lin [c], Zhiheng Wang [a,*]

"

Zhou and Lin (2018) showed that this paradox results from the ignorance of growth rate difference...Nevertheless, the −2 [size-abundance relationship] of trees in natural forests is widely demonstrated

"