Imputation of Continuous Tree Suitability over the Continental United States from Sparse Measurements

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OAK RIDGE National Laboratory

Climate Change Science Institute AT OAK RIDGE NATIONAL LABORATORY

ForWarn Satellite-Based Change Recognition and Tracking

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Introduction

- Mapping the range and suitability of tree species are important for the management of forest resources
- Species of economic and ecological importance
- Understand and assess the response of forests to climate change
- Conservation, restoration and diversity
- Observations avaiable are few and sparse
- Upscaling of point measurement is important and challenging problem in Climate and Earth Sciences

Methodology: Associative Clustering

- Climate, topographic and edaphic factors determines the suitability of a tree species in a location
- These factors are surrogates/indicators of growing conditions and productivity
- We delineate the Continental United States in climatic ecoregions using high resolution data sets (k-means clustering)
- Associate depended variables (species level data) to identify the ecoregions suitable for any given species
- Statistical imputation of suitability (Importance Value/Basal Area)

Methodology: Associative Clustering

- All imputations are done in the data space (not geographical space)
- 1.6M cells in CONUS at 4 km^2
- 48.6M cells on the globe
- Analysis carried out for Present and Future time periods (2050, 2100)
- **Statistical data mining approach: Automated, Consistent, Objective**

Data sets used in the study

Models: PCM and Hadley GCMs
Scenarios: Present conditions (WorldClim), A1FI, B1
Resolution: 4 km^2
Variables: 17

1. Precipitation during the hottest quarter
2. Precipitation during the coldest quarter
3. Precipitation during the driest quarter
4. Precipitation during the wettest quarter
5. Ratio of precipitation to potential evapotranspiration
6. Temperature during the coldest quarter
7. Temperature during the hottest quarter
8. Sum of monthly Tavg where Tavg >=5 deg C
9. Integer number of consecutive months where Tavg >= 5 deg C (Length of potential growing season)
10. Available water holding capacity of soil
11. Bulk density of soil
12. Carbon content of soil
13. Nitrogen content of soil
14. Compound topographic index (relative wetness)
15. Solar interception
16. Day/night diurnal temperature difference
17. Elevation

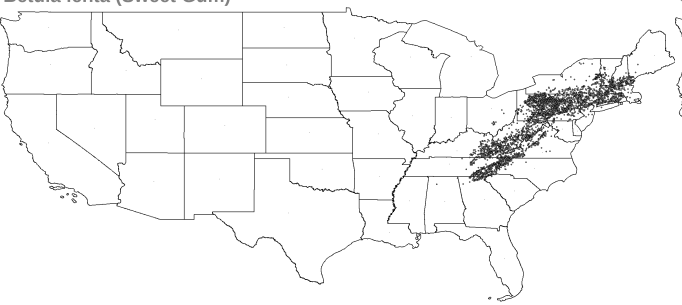
Forest Inventory Analysis Data

Observations from the Forest Inventory Analysis (FIA) plots were employed in the study. 325 species for CONUS.

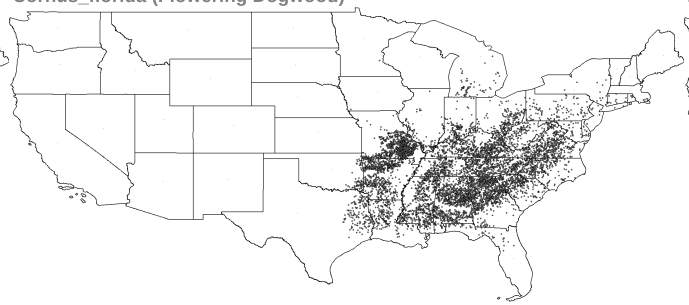
- *Betula lenta*: Sweet Birch (2976)
- *Carya alba*: Mockernut Hickory (8158)
- *Carya glabra*: Pignut Hickory (7405)
- *Cornus florida*: Flowering Dogwood (7473)
- *Juglans nigra*: Black Walnut (3857)
- *Pinus lambertiana*: Sugar Pine (904)
- *Pinus ponderosa*: Ponderosa Pine (6099)
- *Quercus coccinea*: Scarlet Oak (4593)
- *Quercus falcata*: Southern Red Oak (6665)

Forest Inventory Analysis Data

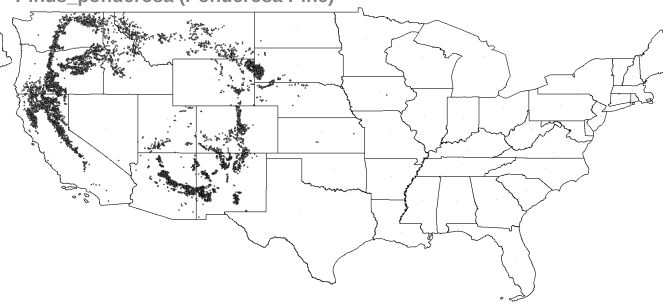
Betula lenta (Sweet Gum)



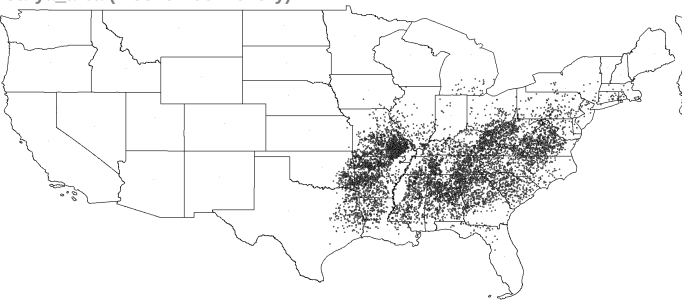
Cornus_florida (Flowering Dogwood)



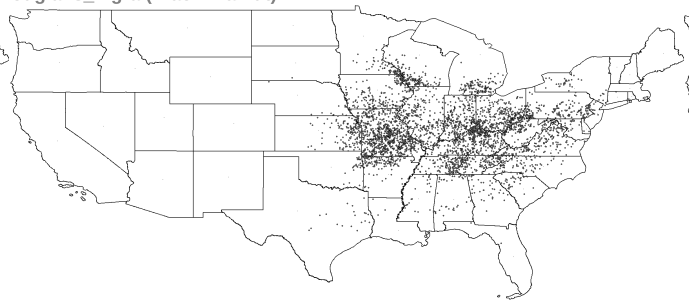
Pinus_ponderosa (Ponderosa Pine)



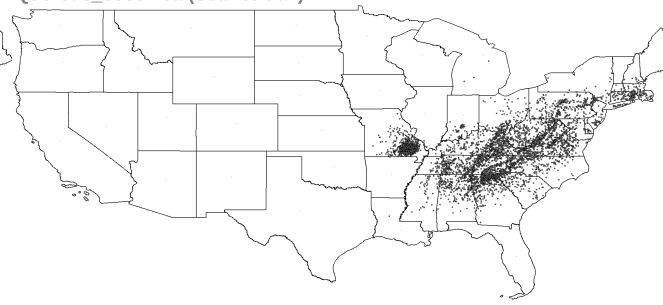
Carya_alba (Mockernut Hickory)



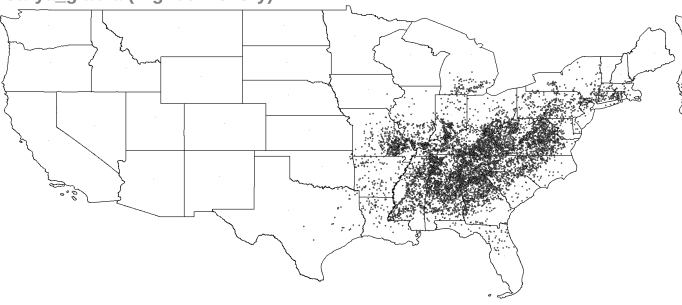
Juglans_nigra (Black Walnut)



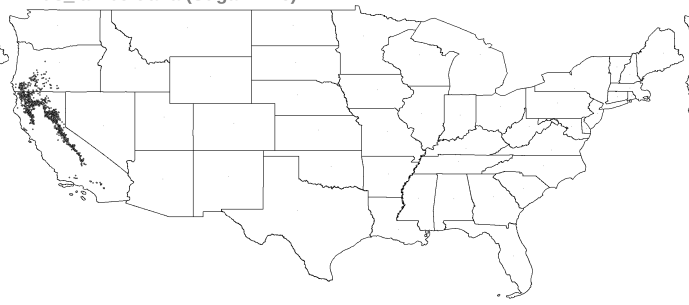
Quercus_coccinea (Scarlet Oak)



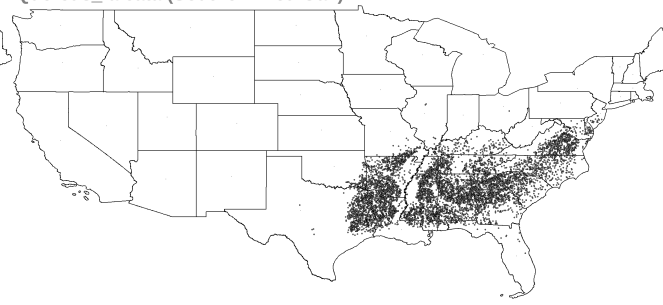
Carya_glabra (Pignut Hickory)



Pinus_lambertiana (Sugar Pine)



Quercus_falcata (Southern Red Oak)



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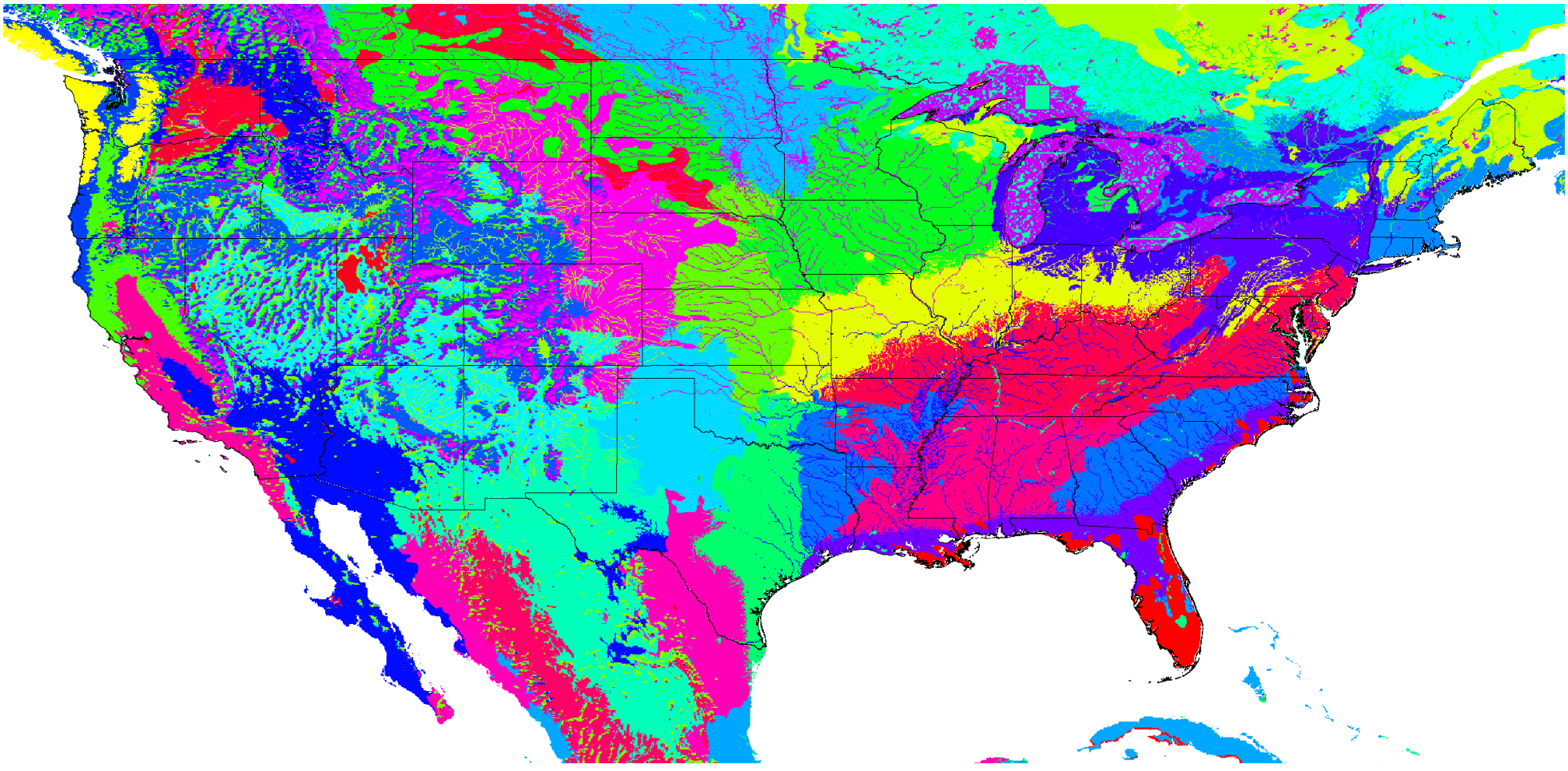
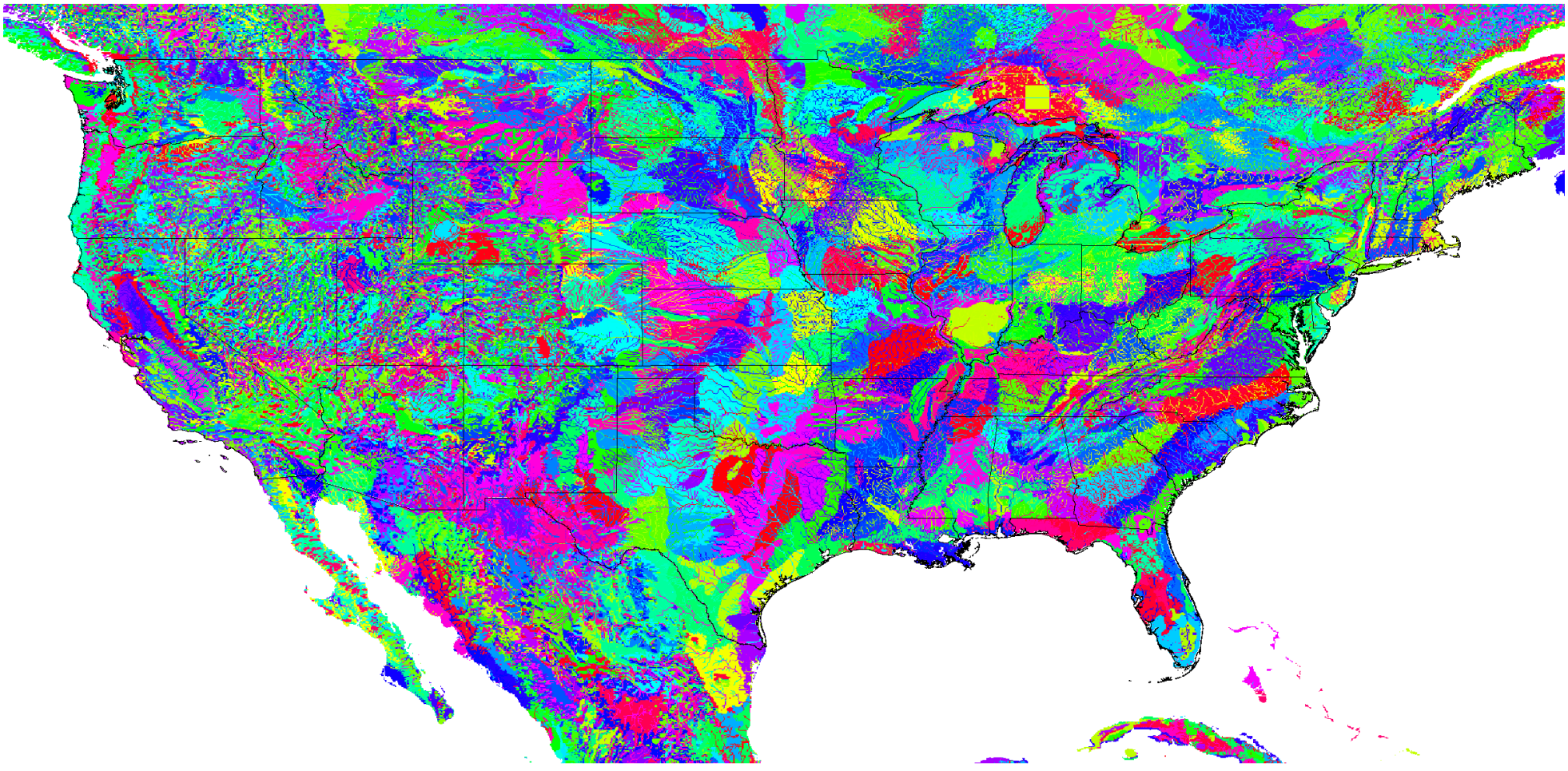
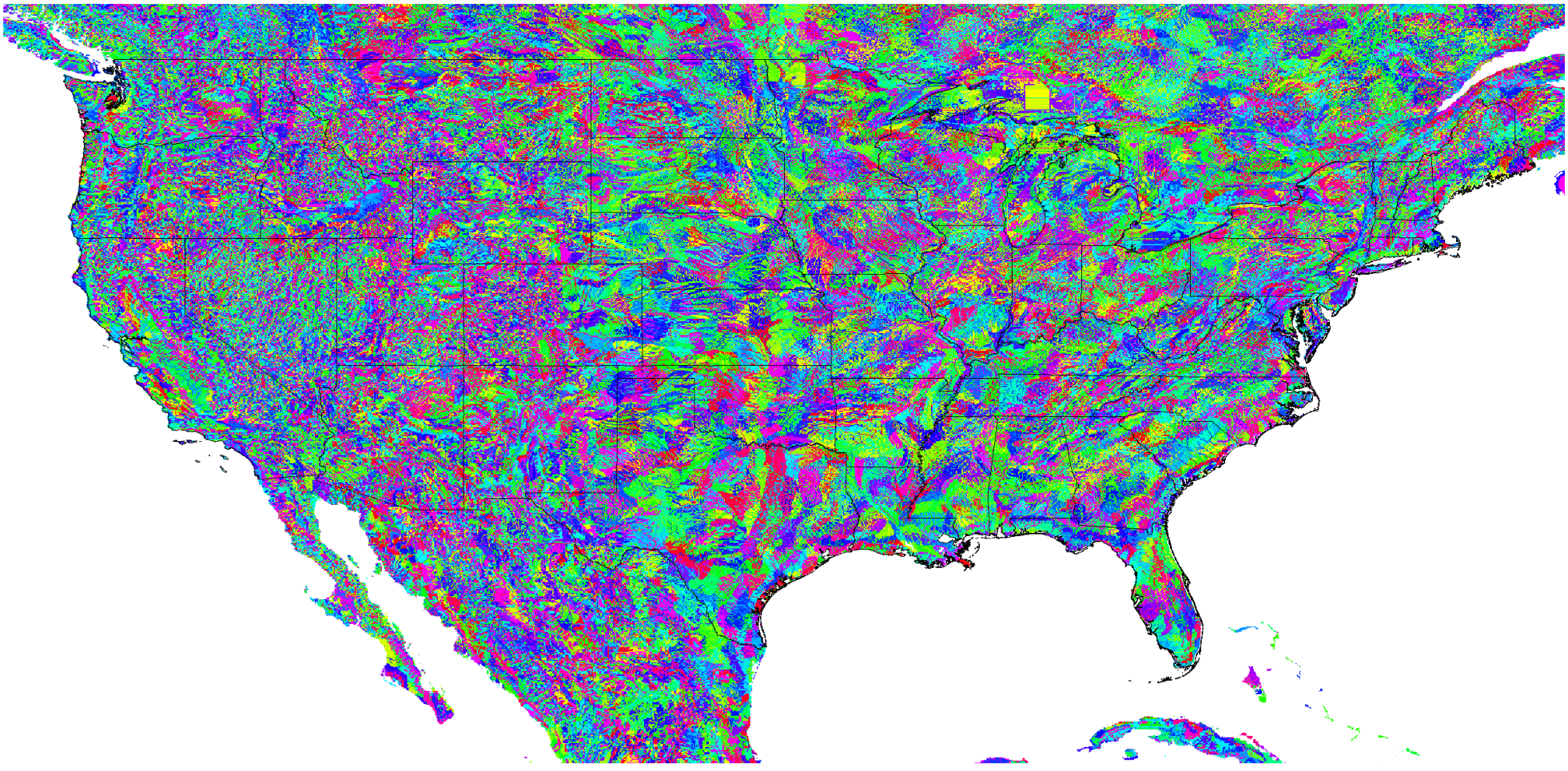
Clustered Ecoregions (K=50)



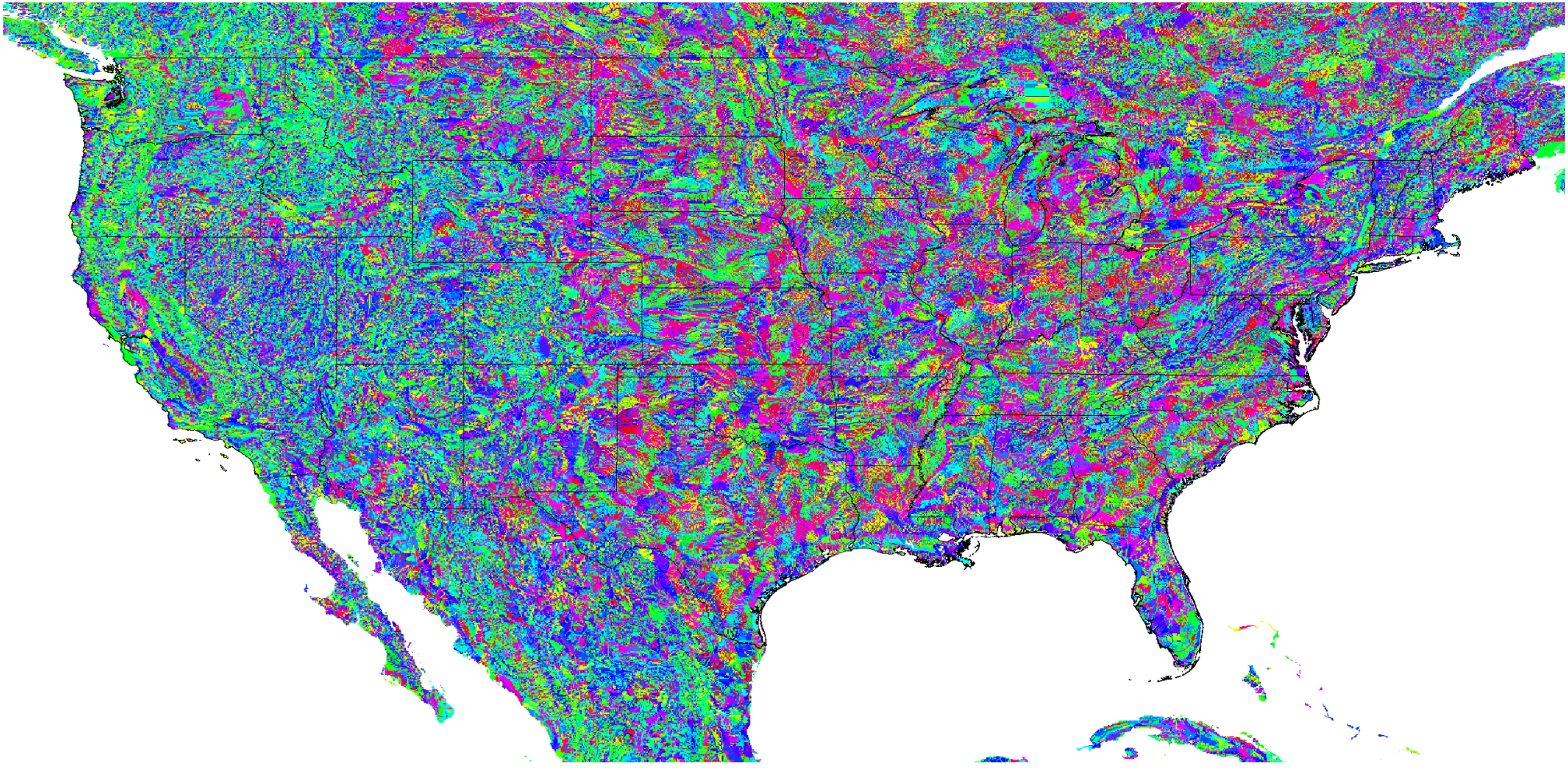
Clustered Ecoregions (K=1000)



Clustered Ecoregions (K=10000)



Clustered Ecoregions (K=20000)



Imputation Schemes

Clustered ecoregions (centroid) based:

- Nearest neighbor
- Mean value
- Maximum value
- Inverse weighted distance mean

Clustered ecoregions (point) based:

- Nearest neighbor
- Inverse weighted mean
- N-nearest neighbor inverse weighted distance mean
- N-nearest neighbor percentiles

Point based:

- N-nearest neighbor inverse weighted distance mean
- N-nearest neighbor percentiles

Imputation Schemes

Clustered ecoregions (centroid) based:

- Nearest neighbor
- Mean value
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Clustered ecoregions (point) based:

- Nearest neighbor
- Inverse weighted mean
- N-nearest neighbor inverse weighted distance mean
- N-nearest neighbor percentiles

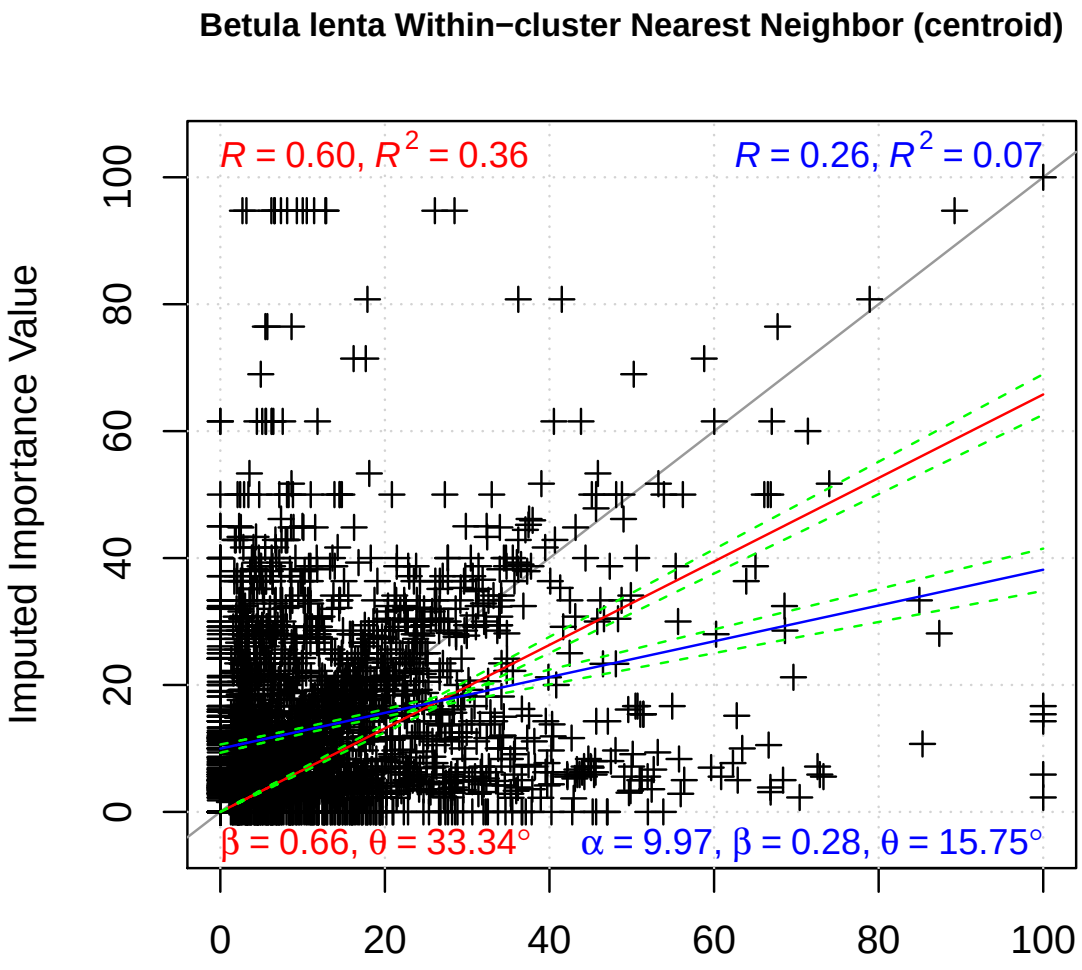
Point based:

- N-nearest neighbor inverse weighted distance mean
- N-nearest neighbor percentiles

Validation for extent using existing range maps and for magnitude using FIA measurements.

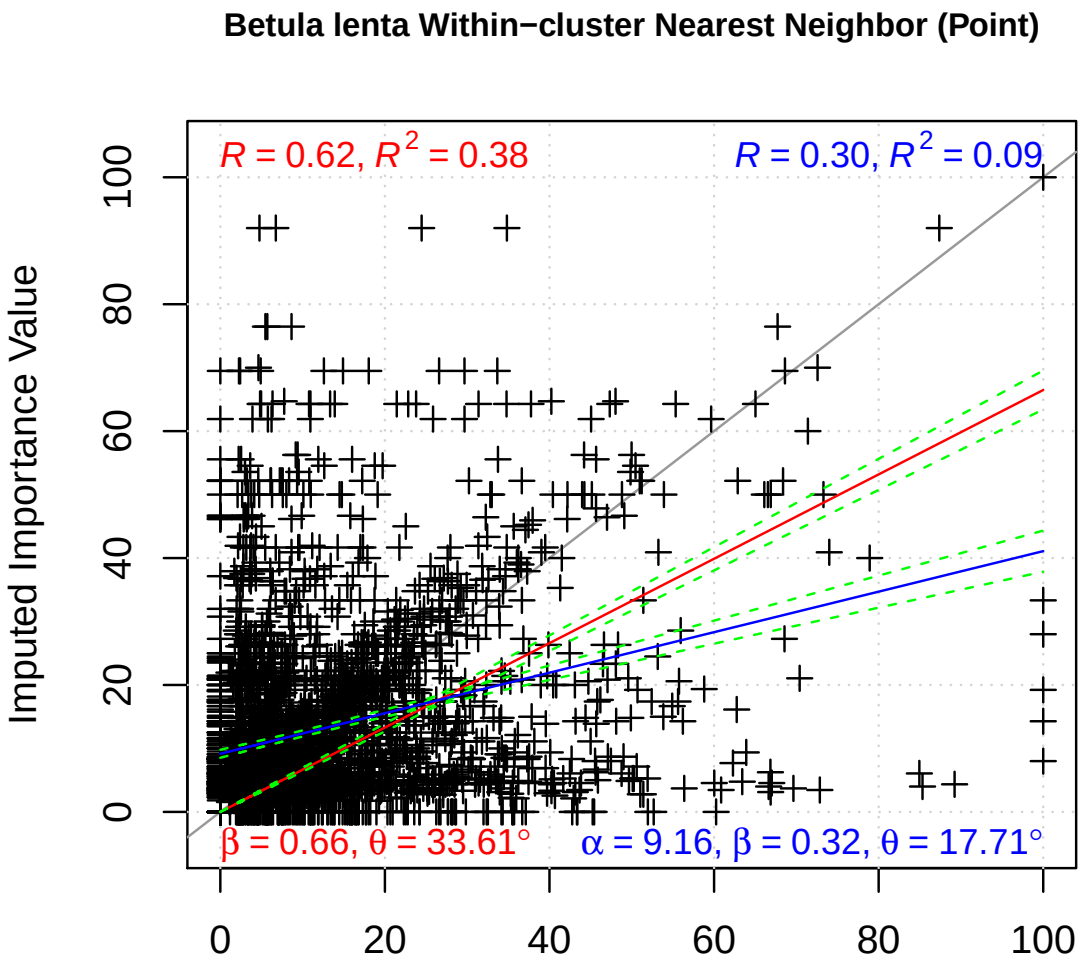
Validation of imputed importance values

Nearest neighbor within the cluster (centroid)



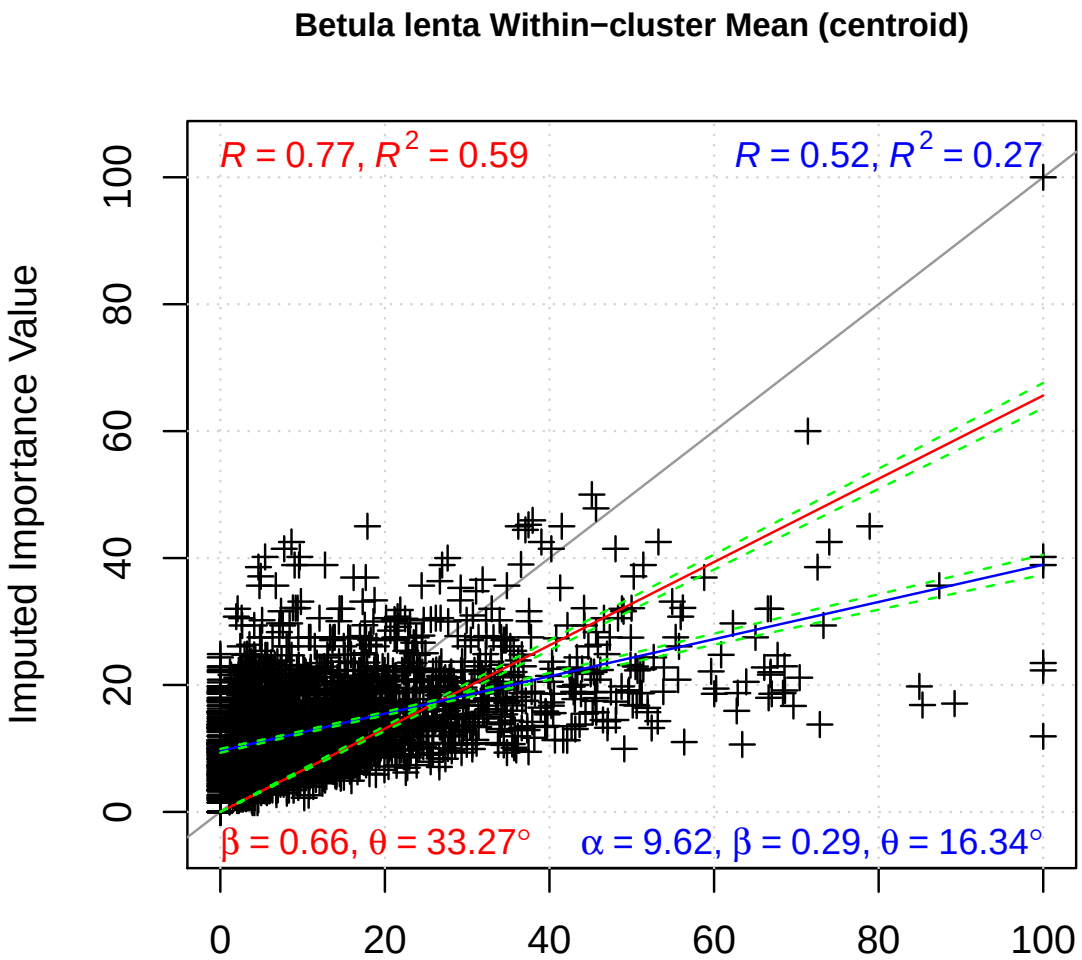
Validation of imputed importance values

Nearest neighbor within the cluster (point)



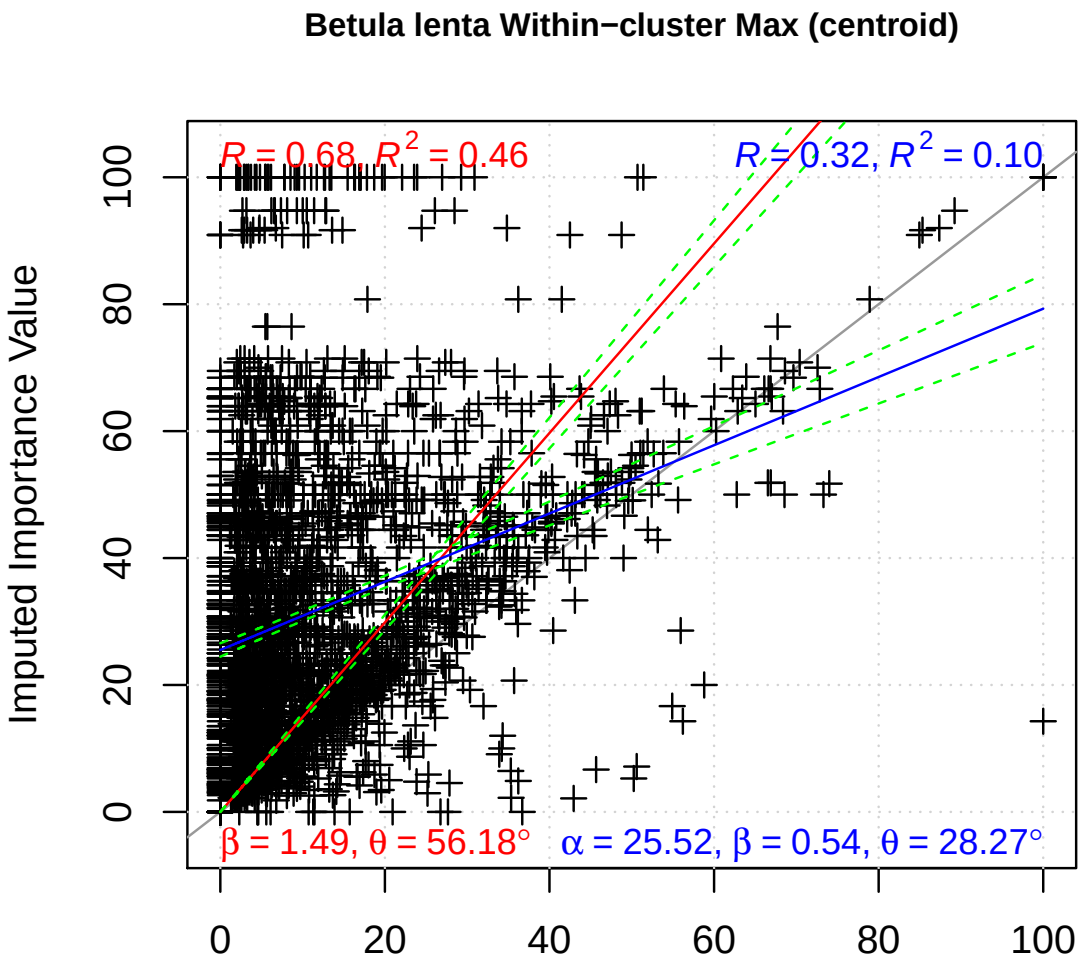
Validation of imputed importance values

Mean of points in the cluster (centroid)



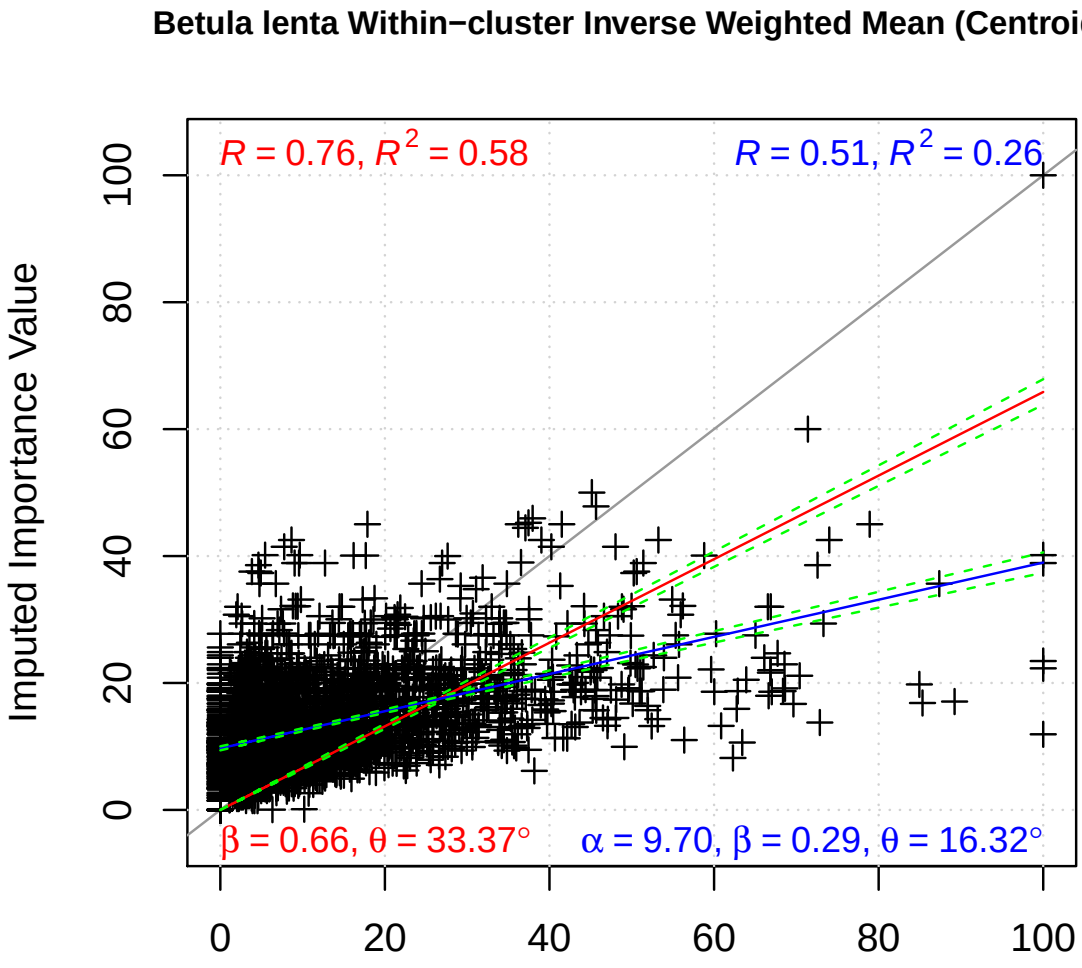
Validation of imputed importance values

Max of points in the cluster (centroid)

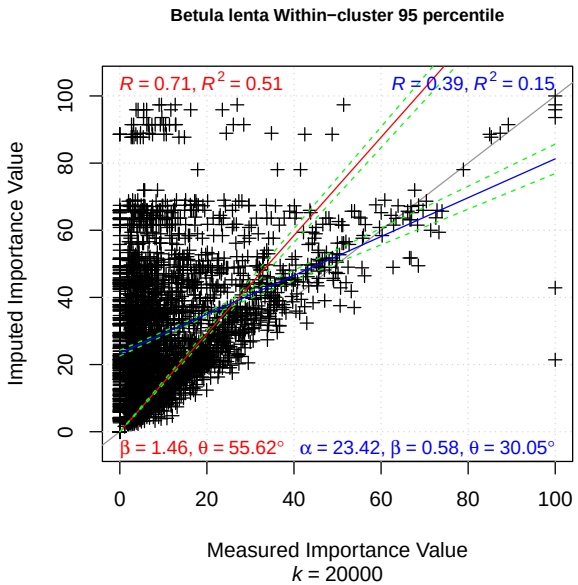


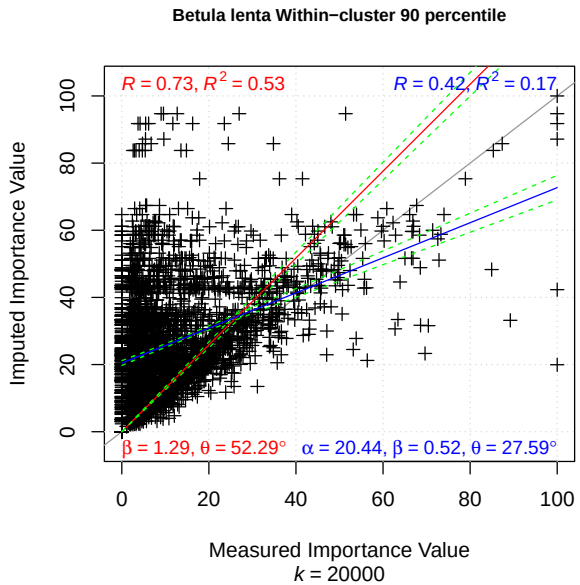
Validation of imputed importance values

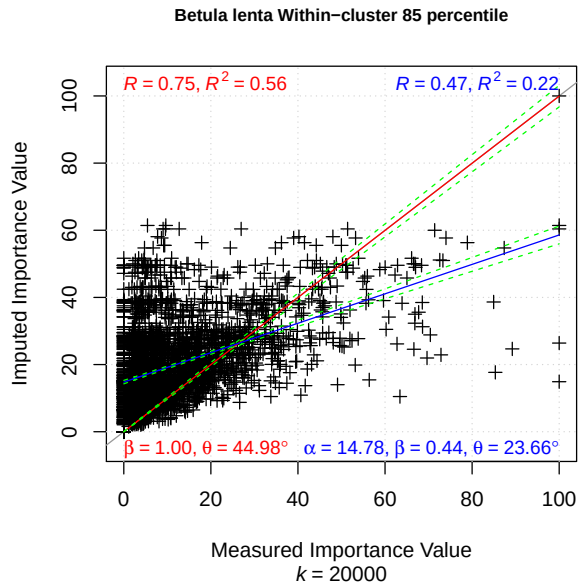
Inverse weighted distance mean of points in the cluster (centroid)

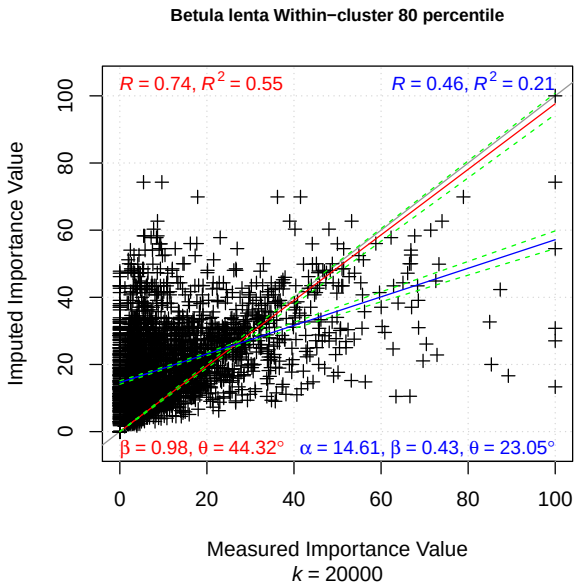


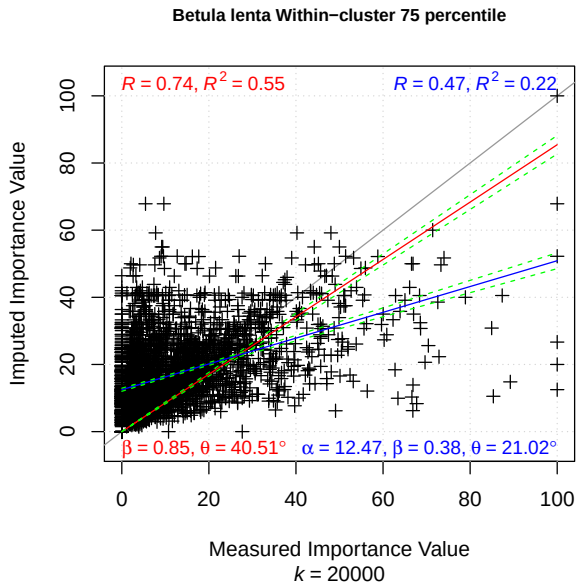
Betula Lenta: Percentiles

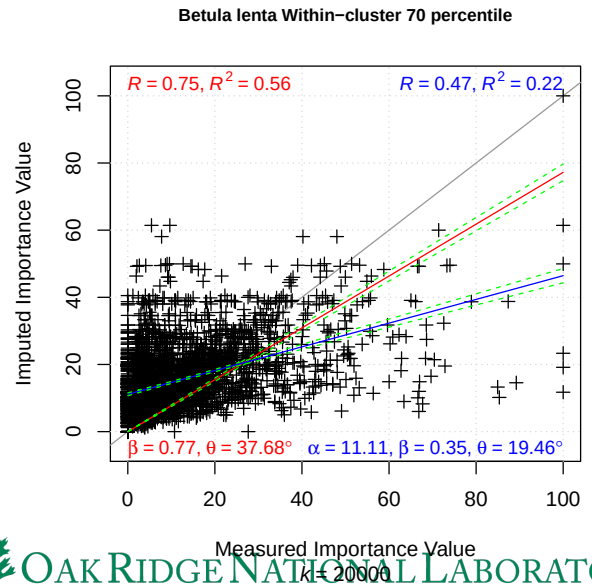




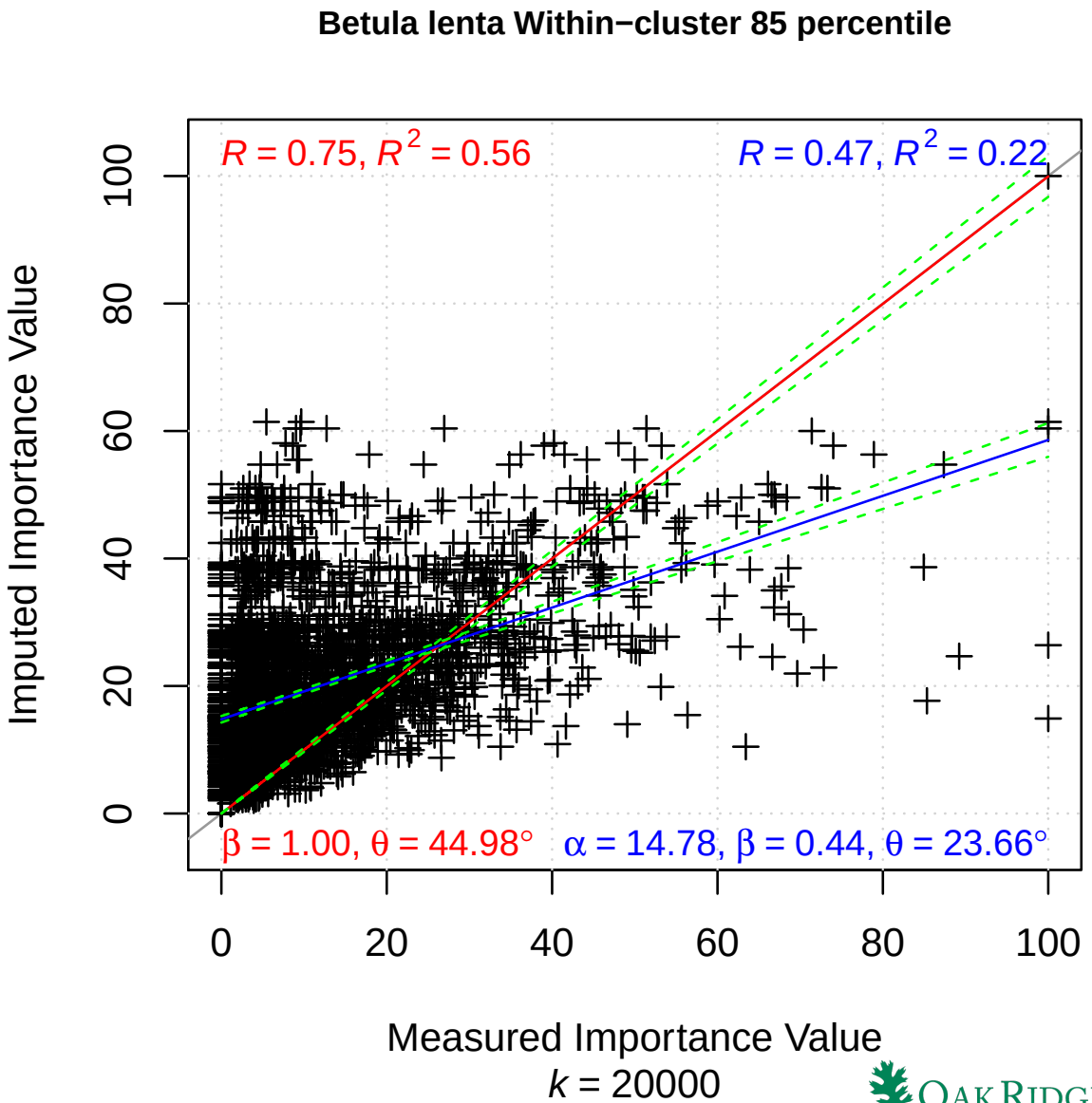




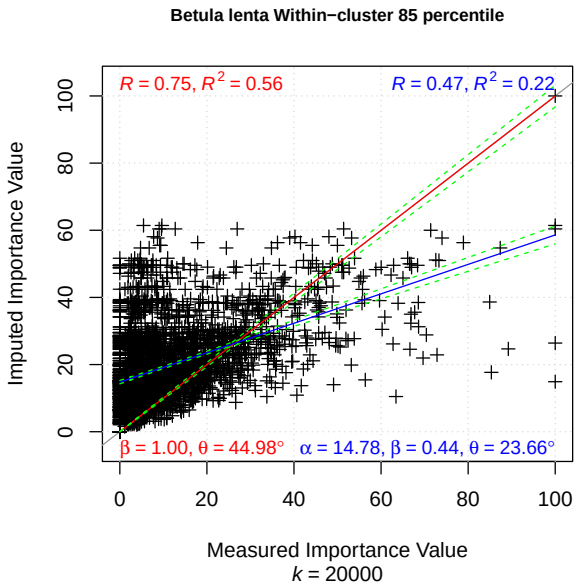


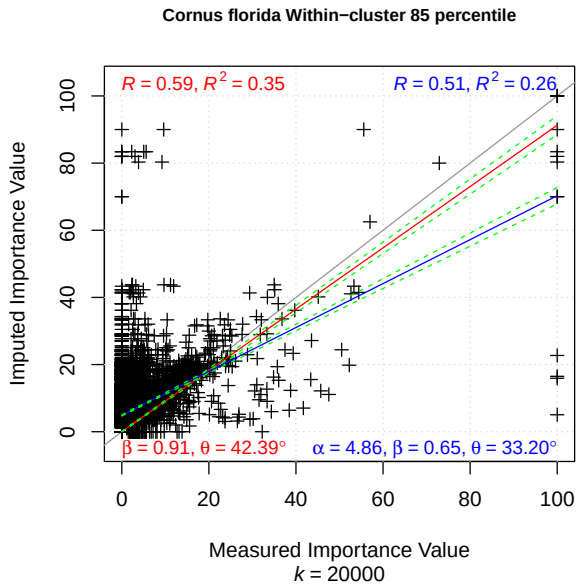


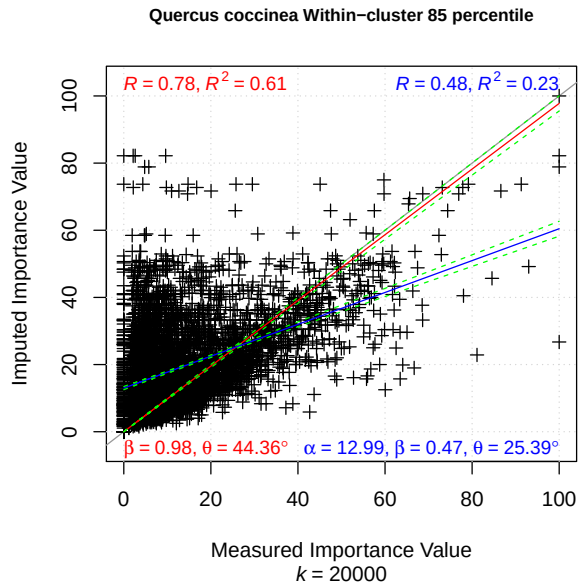
Betula Lenta: 85^{th} Percentile IV

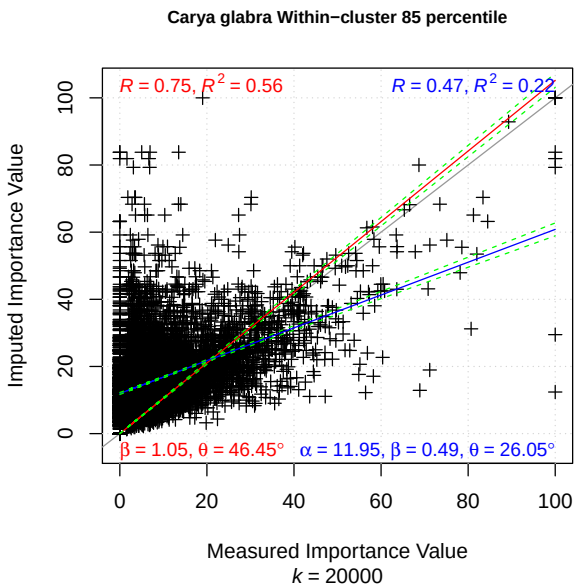


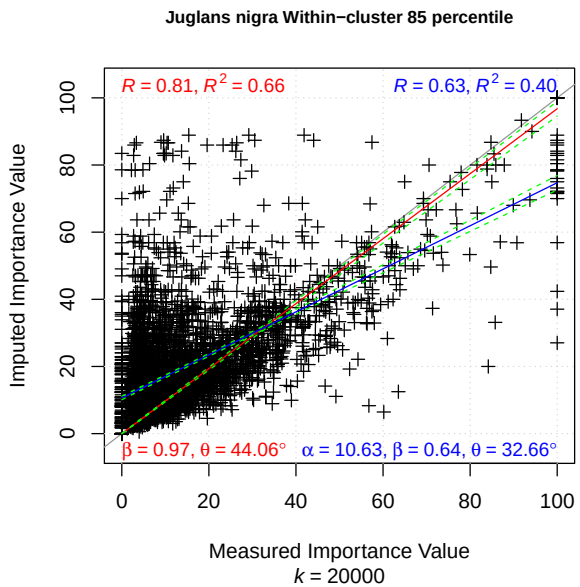
85^{th} Percentile IV for all species

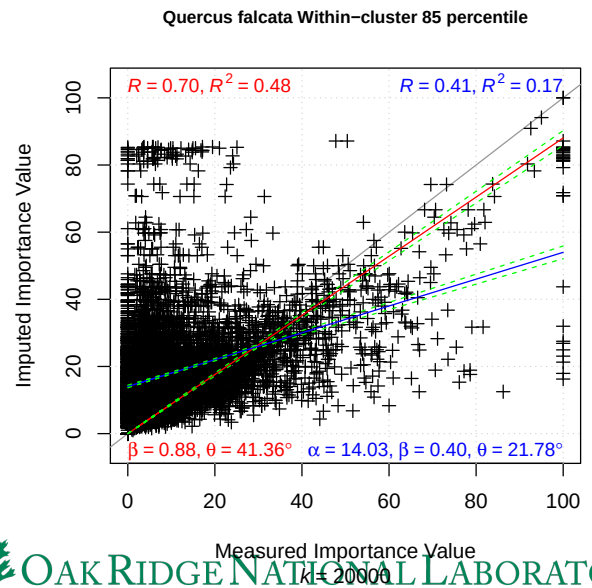




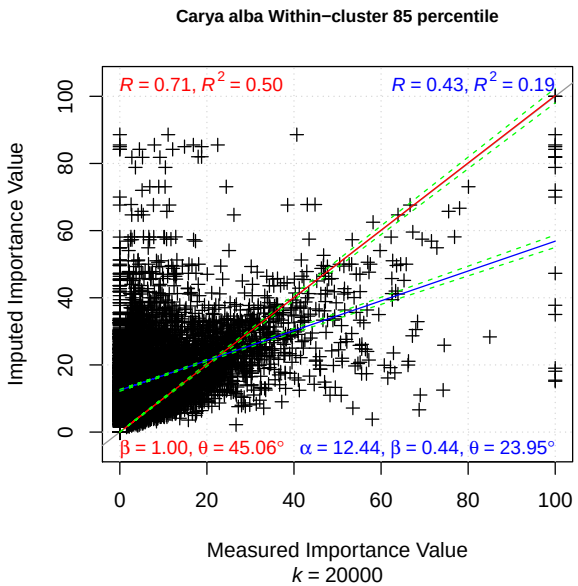


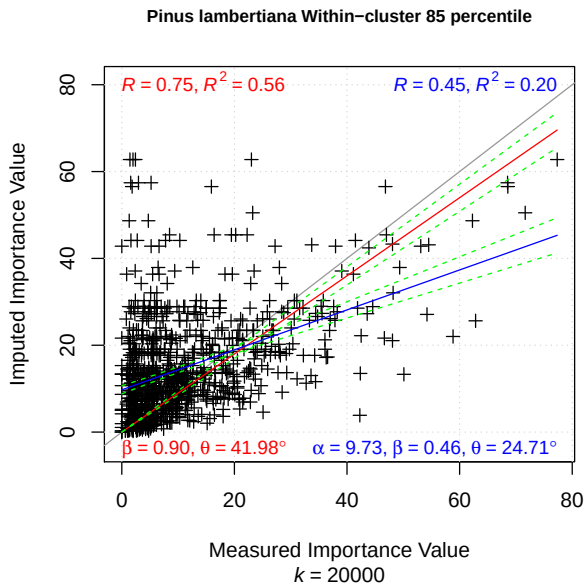


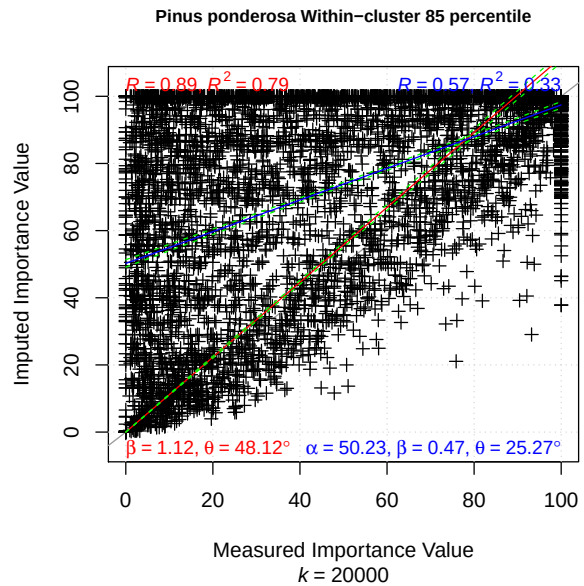




85^{th} Percentile IV for all species

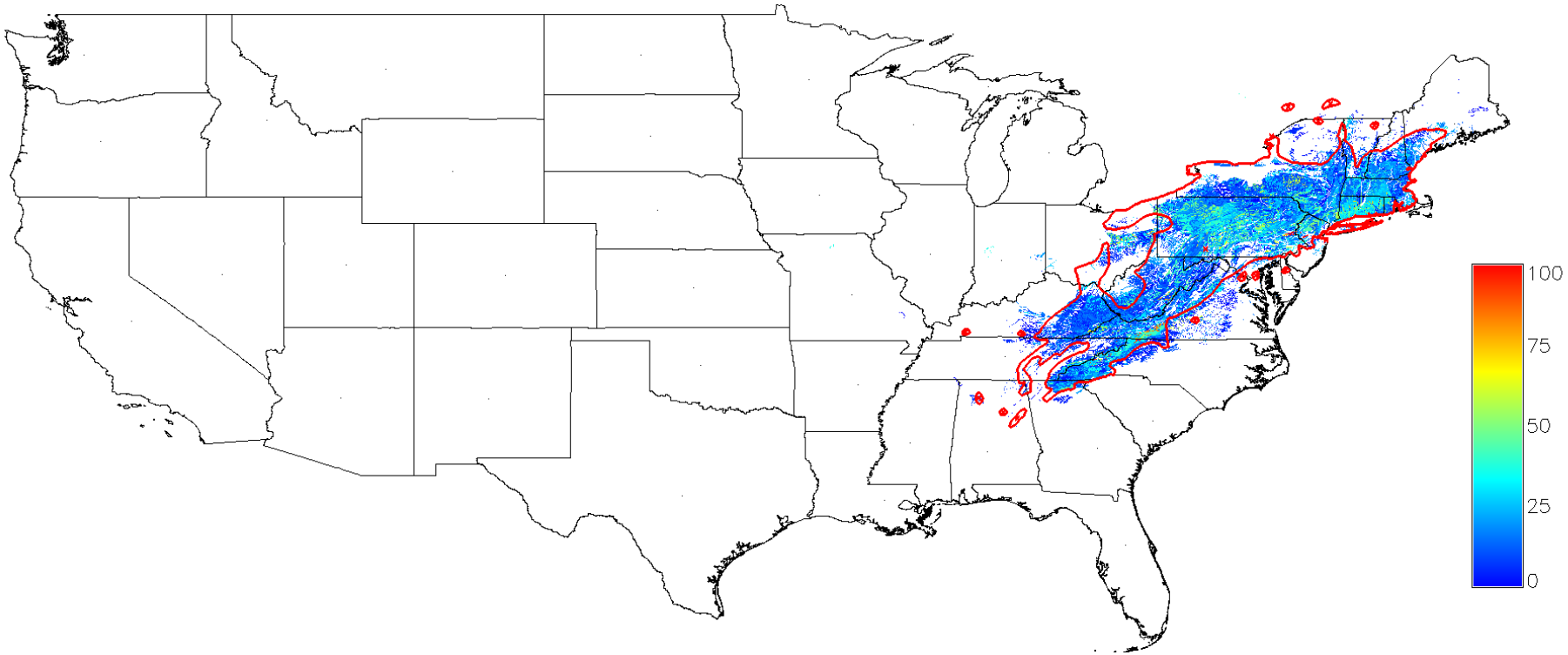






Interpolated Importance Value

Betula lenta [Sweet Birch]

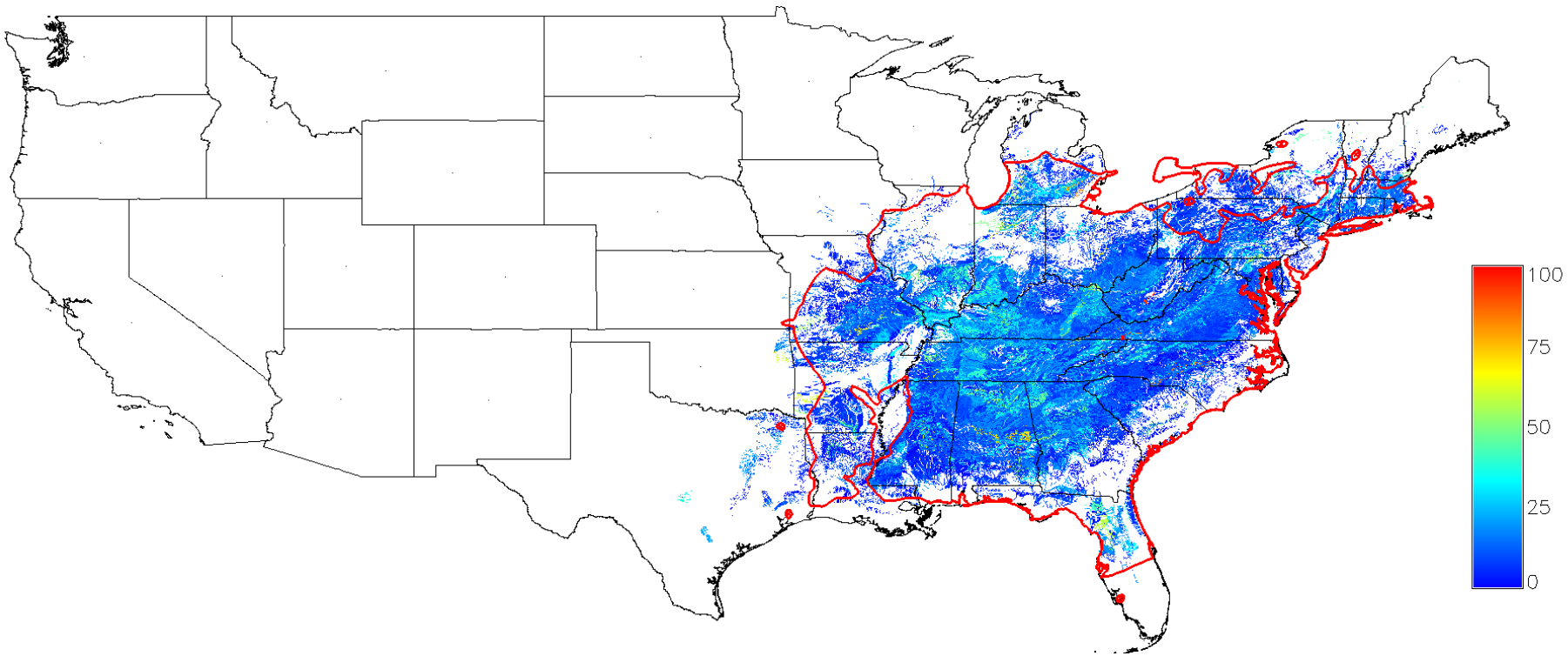


Polygons in red are Little's range map.

Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. http://www.nrs.fs.fed.us/atlas/tree, Northern Research Station, USDA Forest Service, Delaware, Ohio.

Interpolated Importance Value

Carya glabra [Pignut Hickory]



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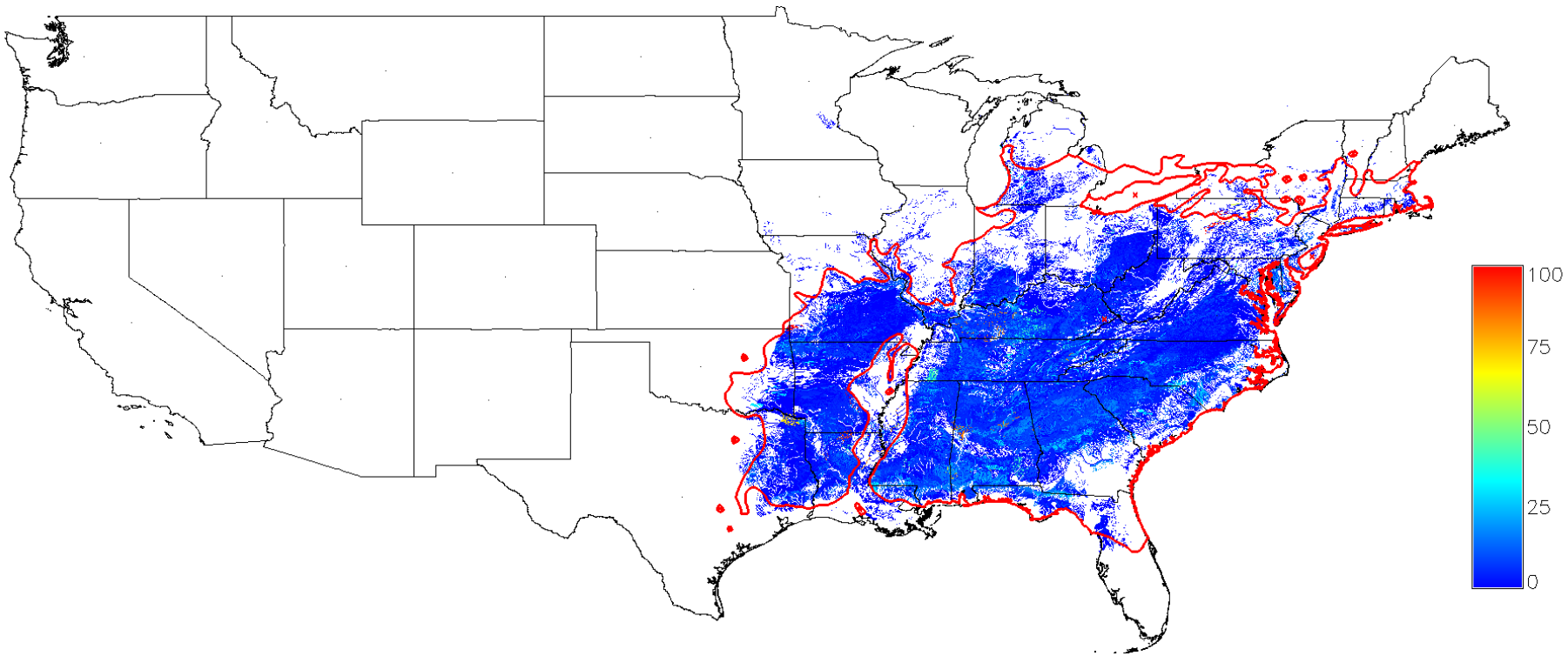
Interpolated Importance Value

Cornus florida [Flowering Dogwood]



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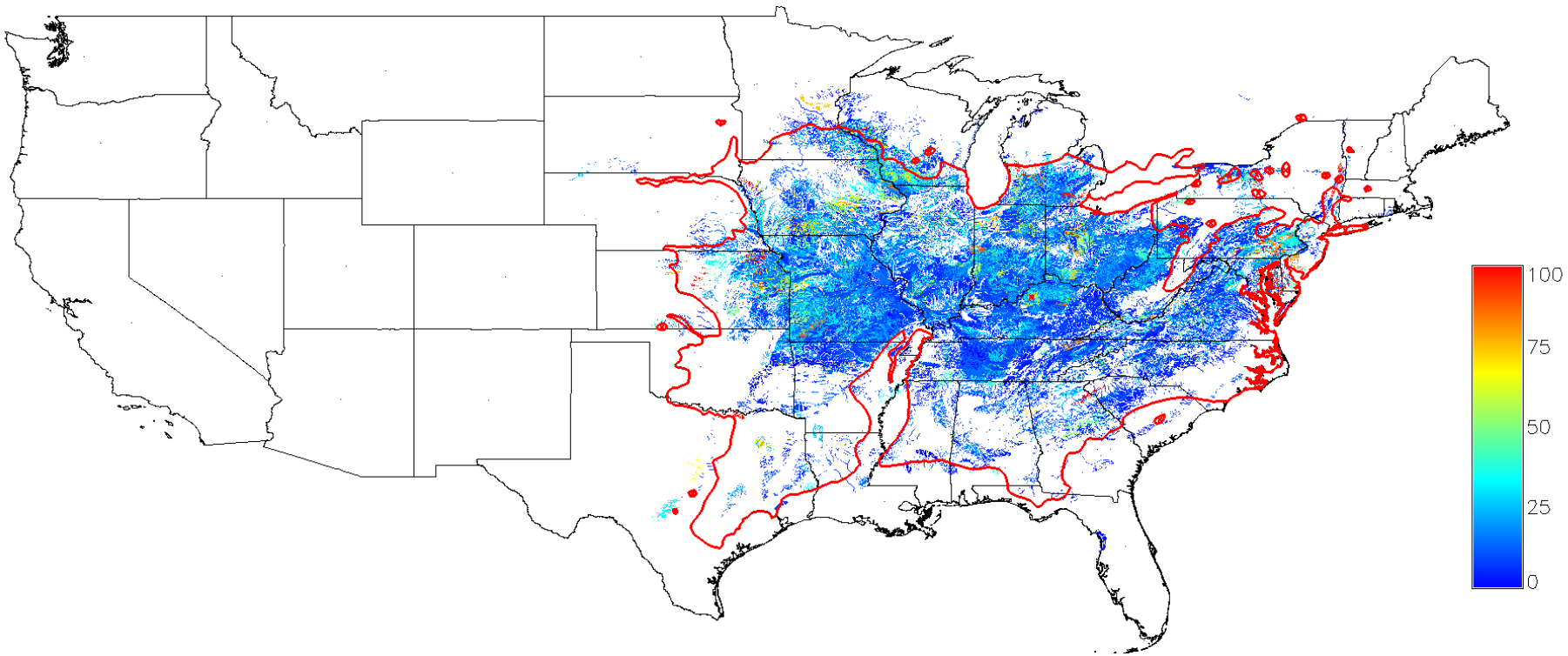
Interpolated Importance Value

Juglans nigra [Black Walnut]



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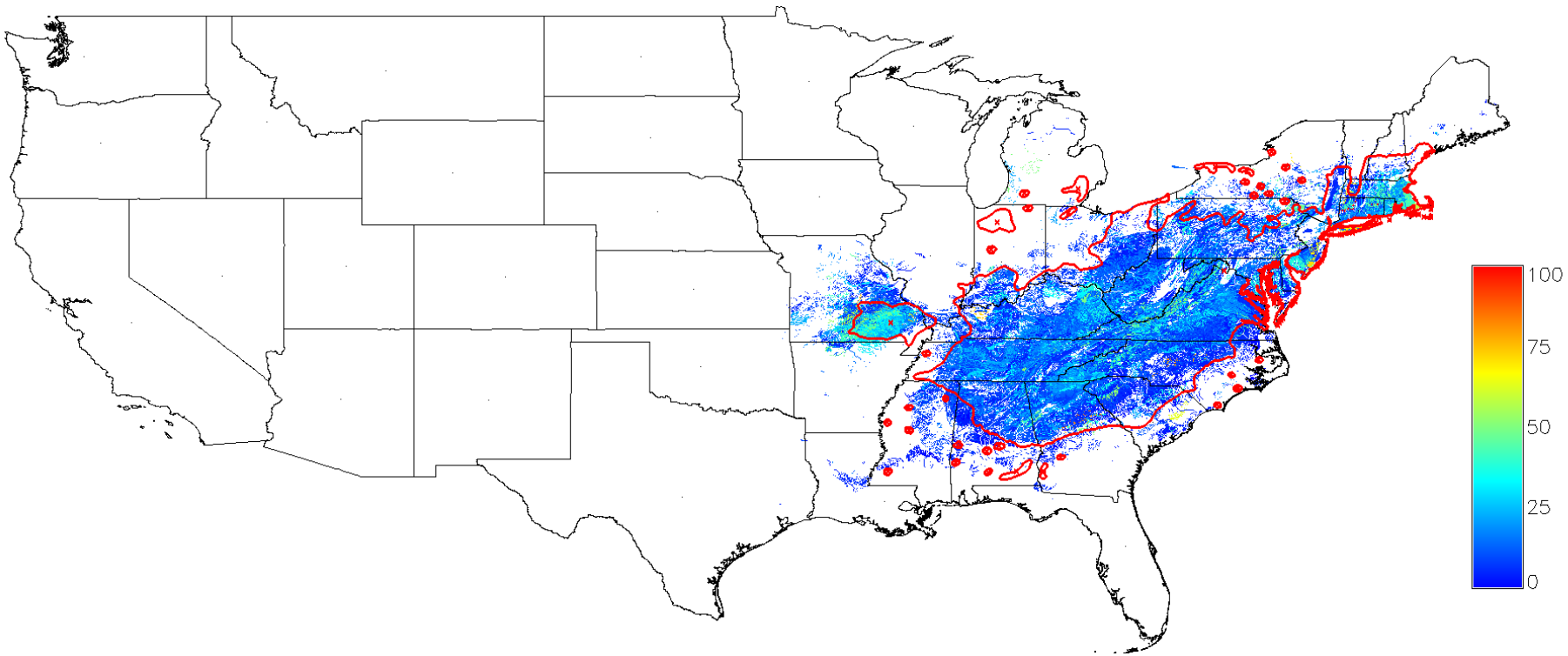
Interpolated Importance Value

Quercus coccinea [Scarlet Oak]



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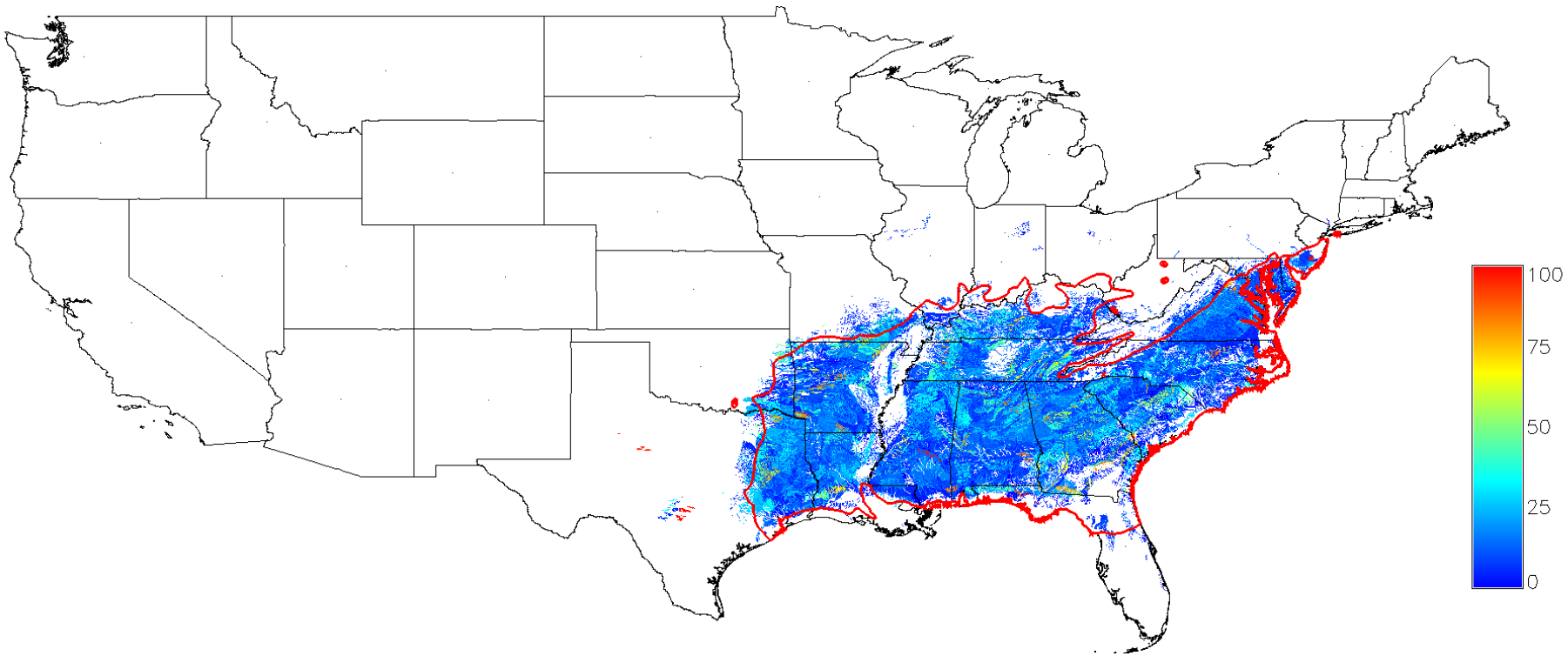
Interpolated Importance Value

Quercus falcata [Southern Red Oak]



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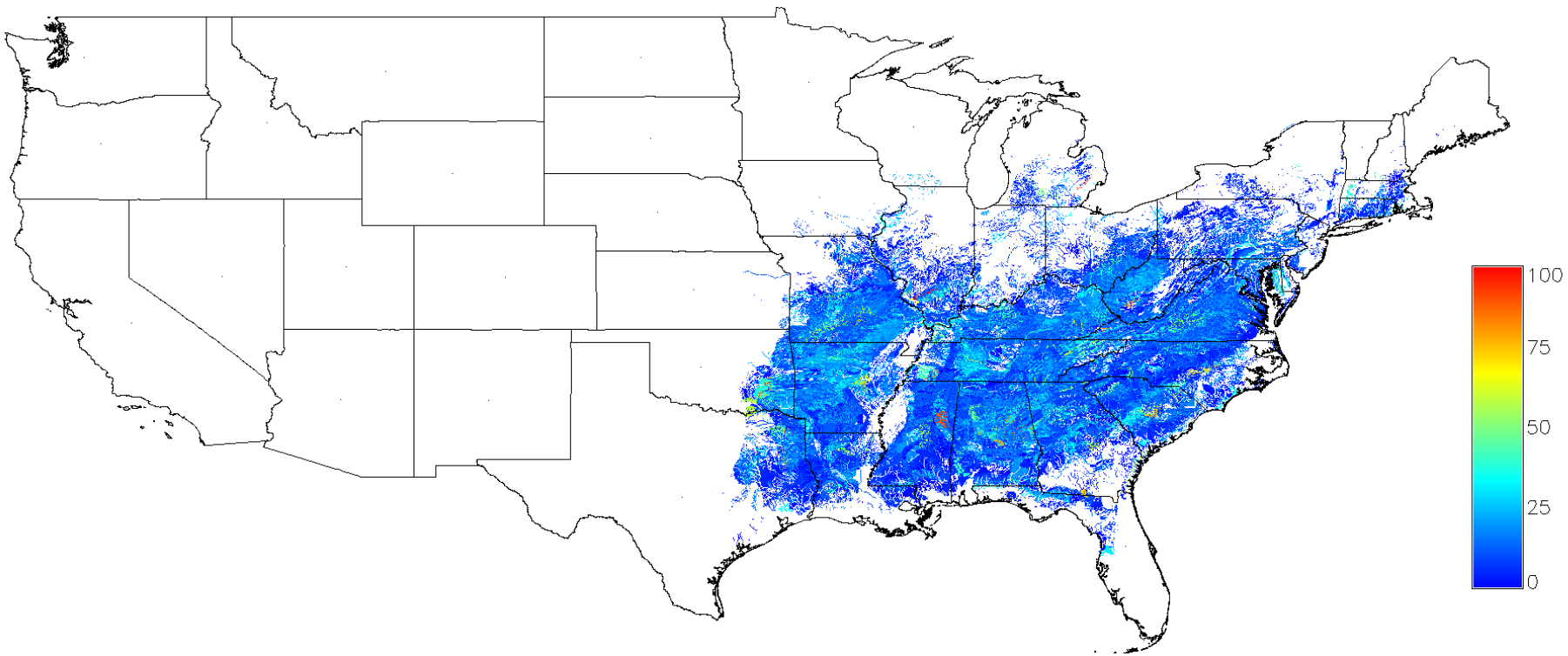
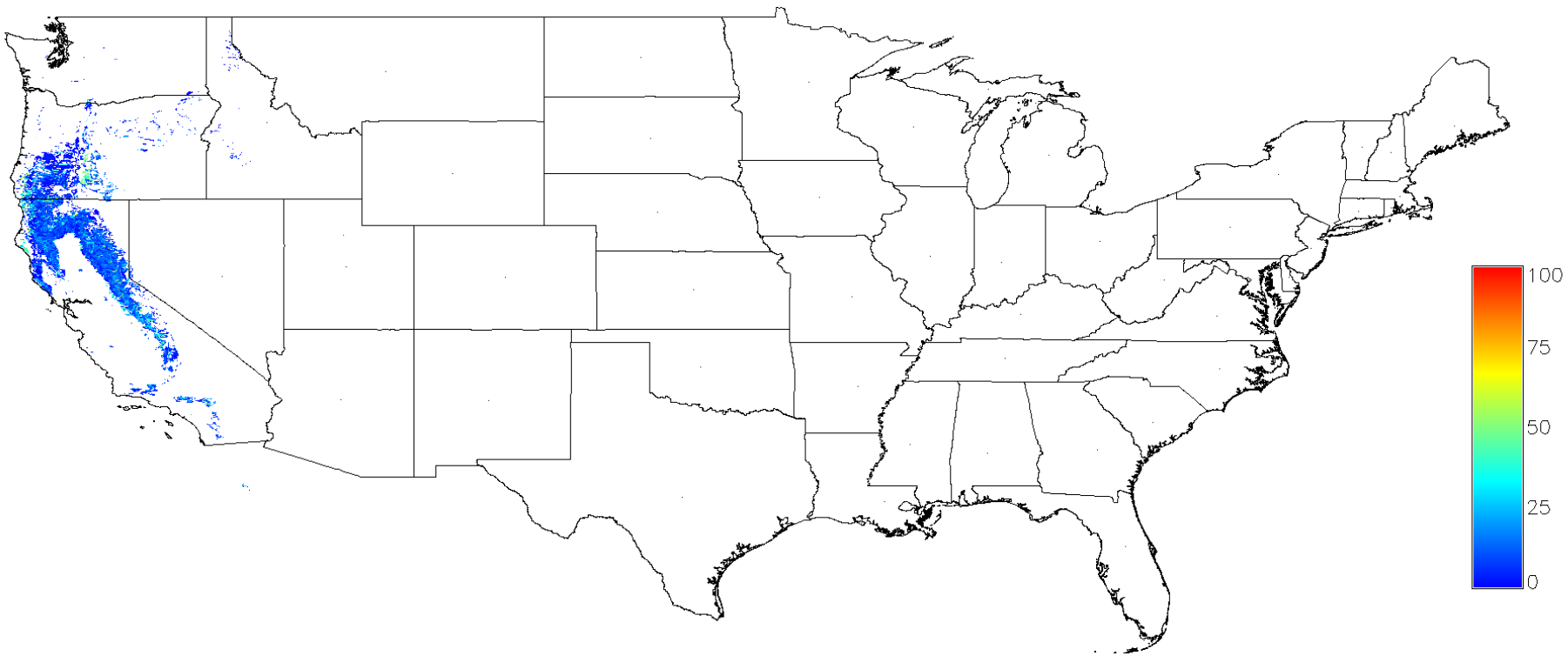
Interpolated Importance Value

Carya alba [Mockernut Hickory]



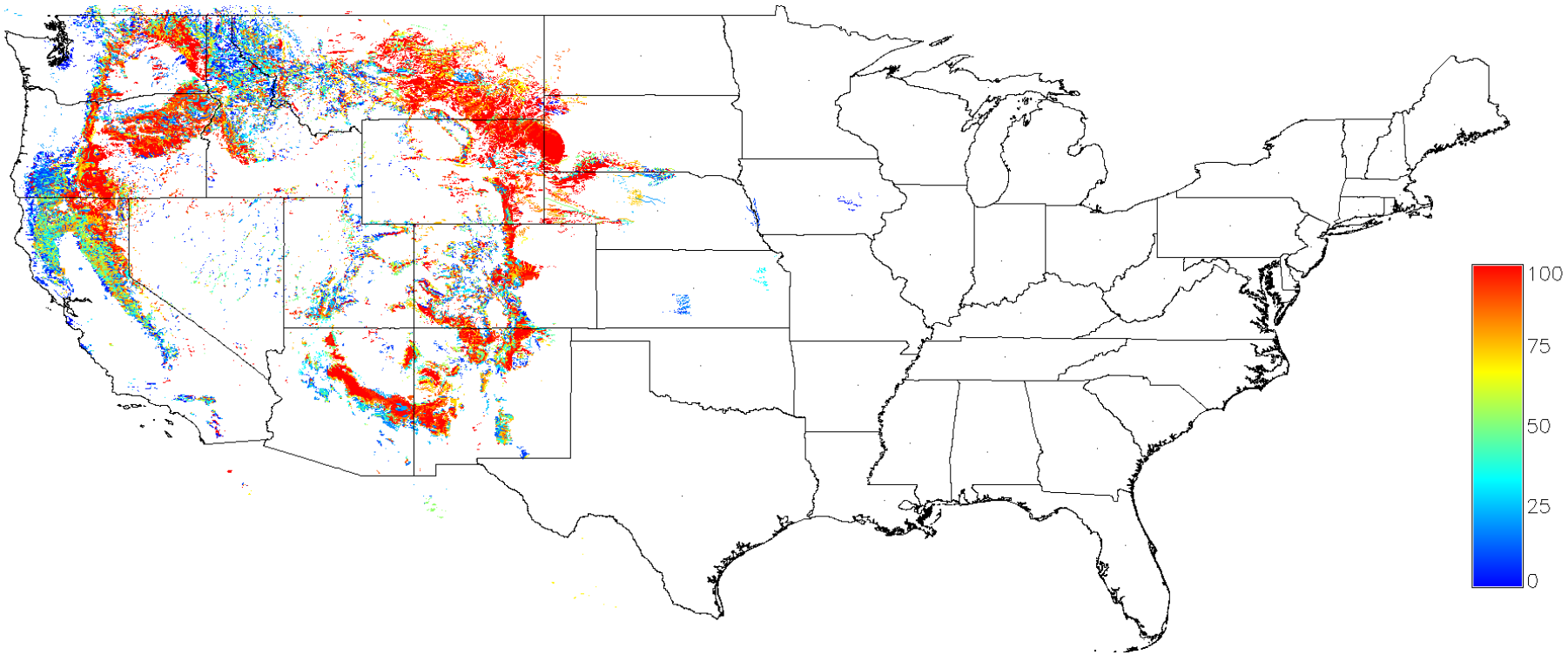
Interpolated Importance Value

Pinus Lambertiana [Sugar Pine]

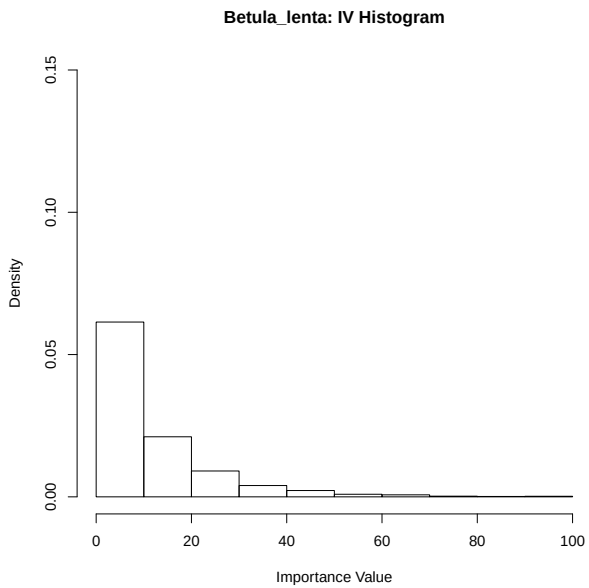


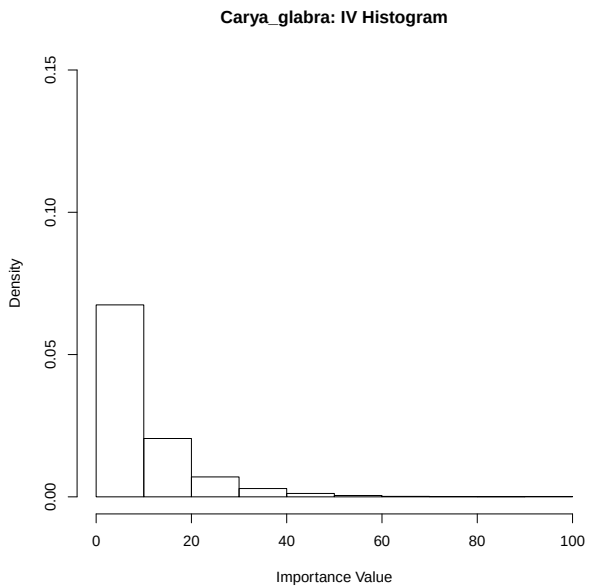
Interpolated Importance Value

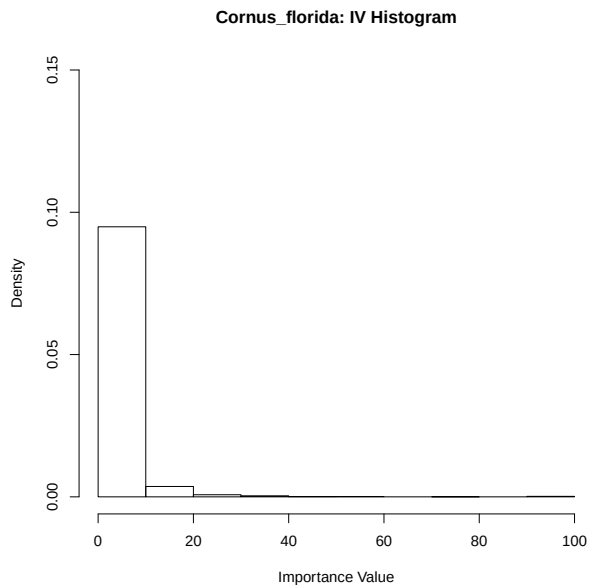
Pinus Ponderosa [Ponderosa Pine]

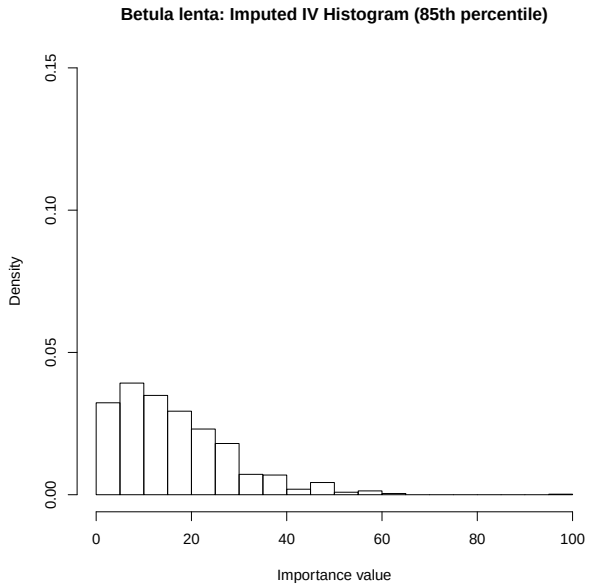


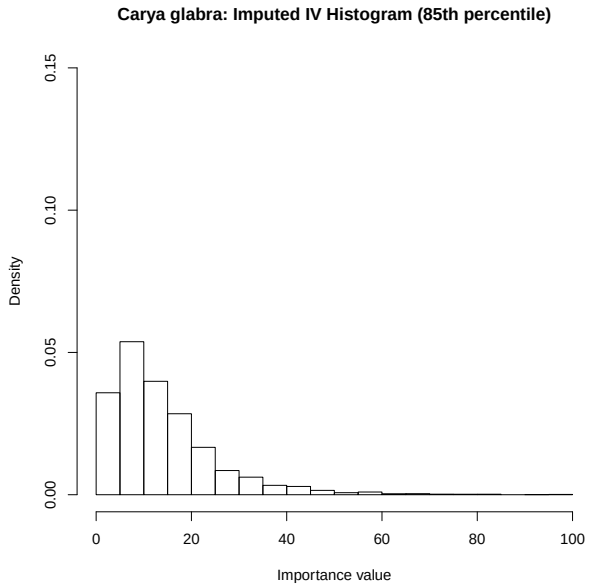
Distribution of measured (FIA)/Imputed IV for all species

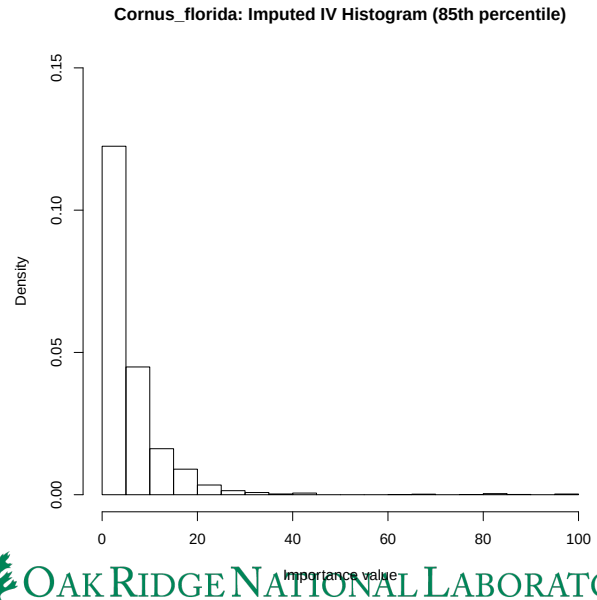




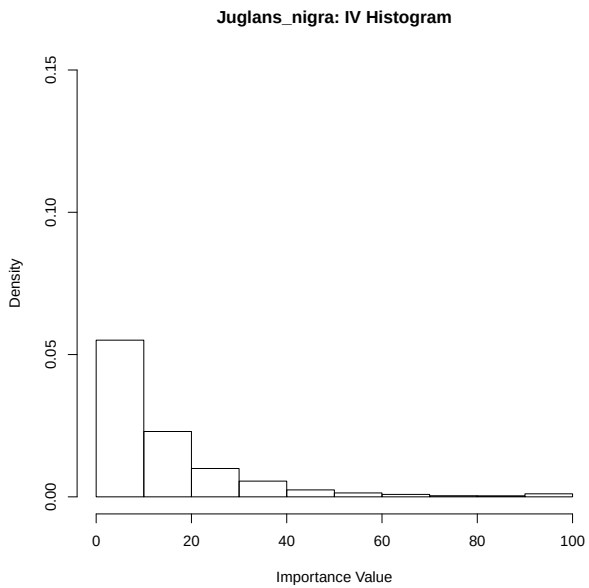


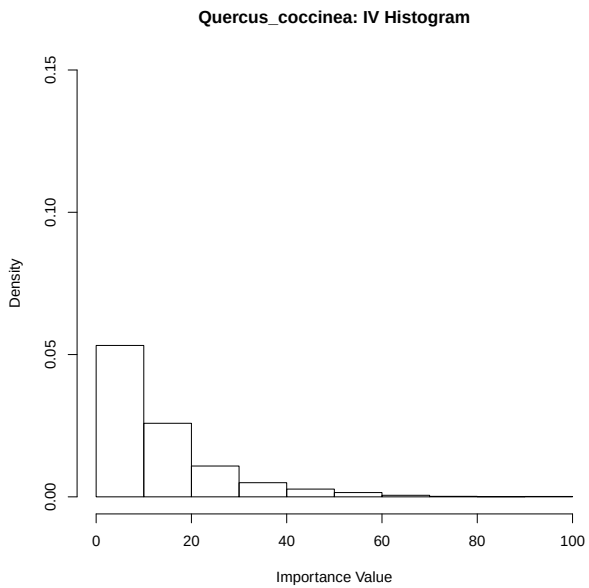


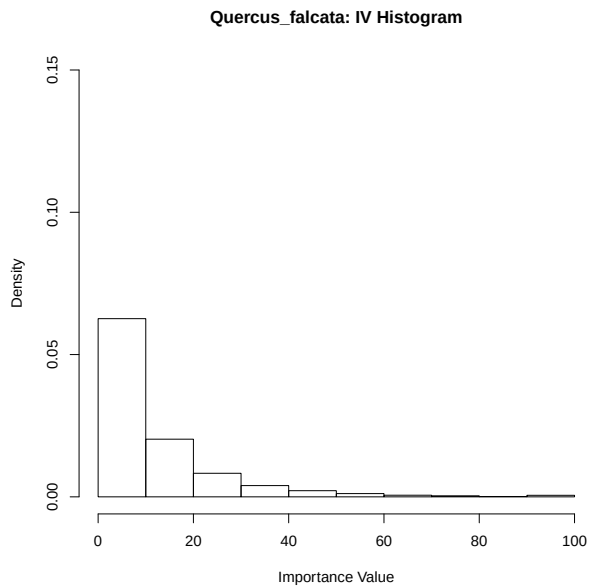


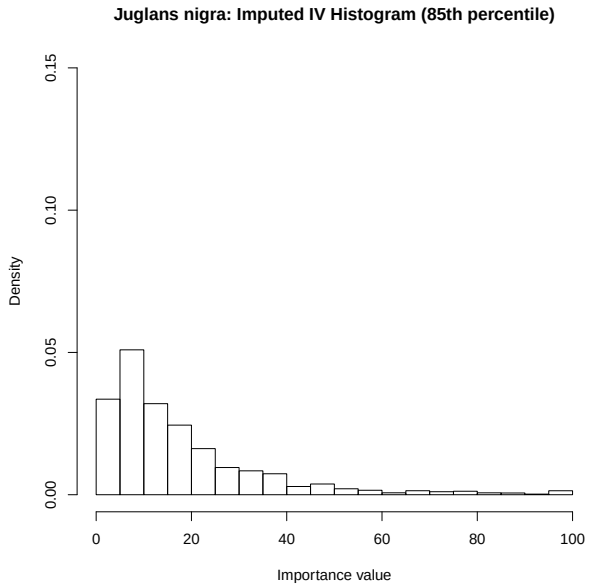


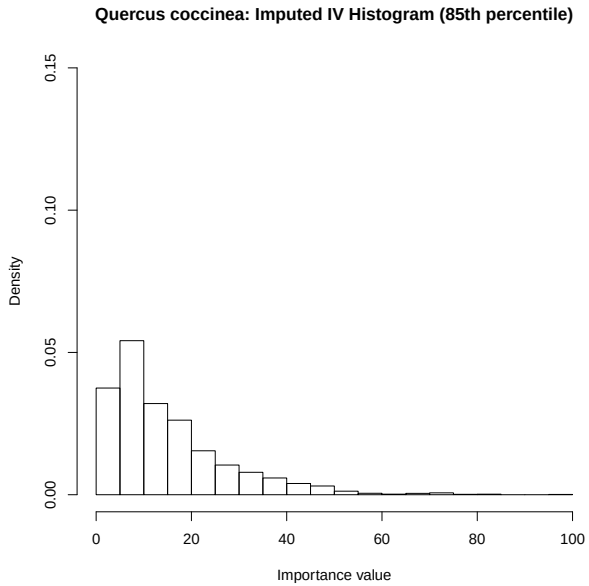
Distribution of measured (FIA)/Imputed IV for all species

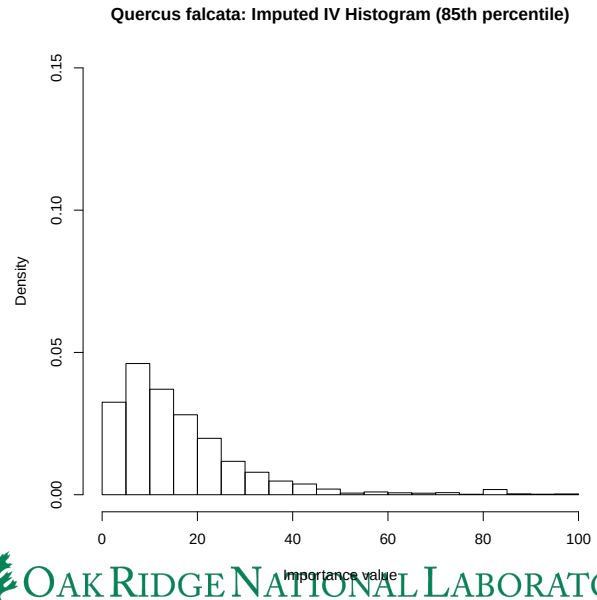




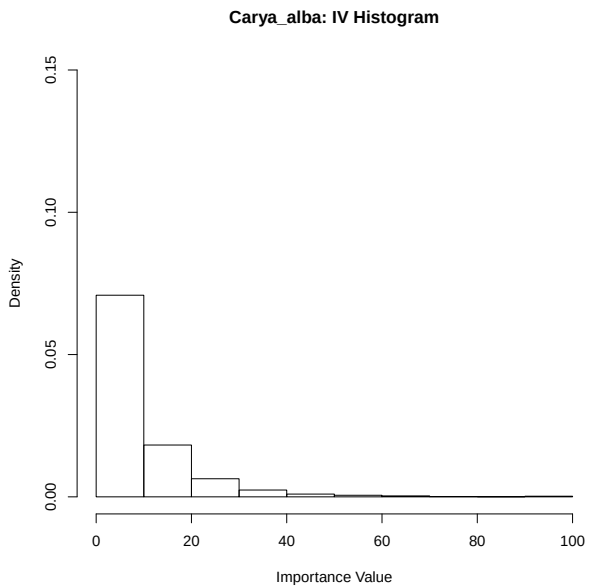


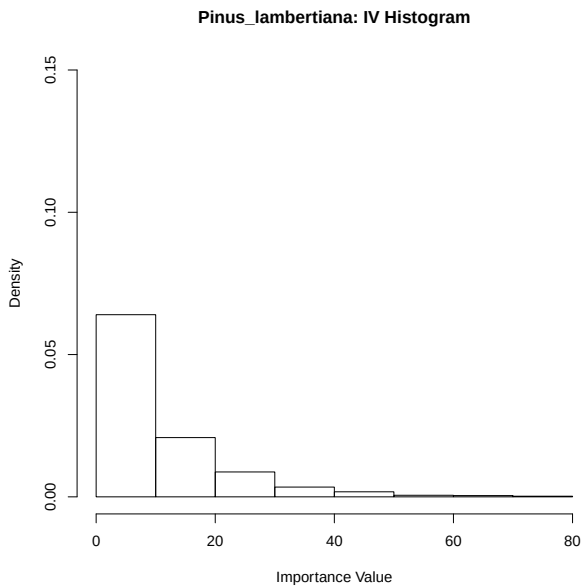


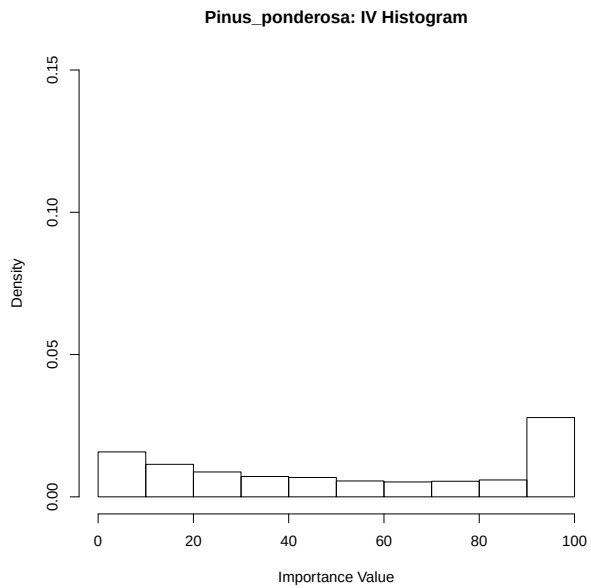


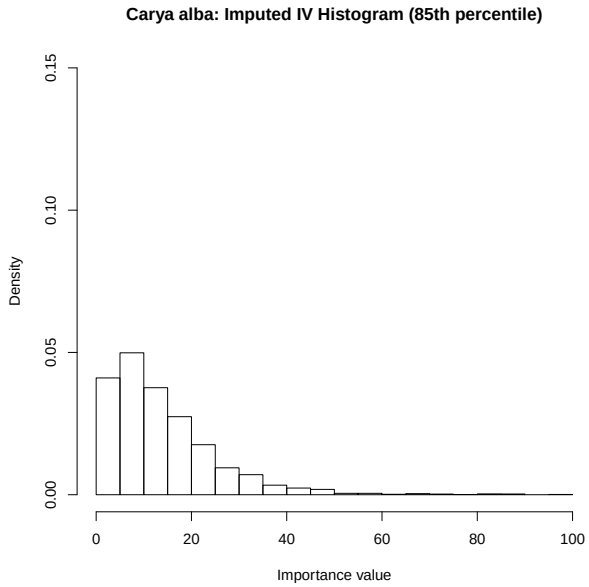


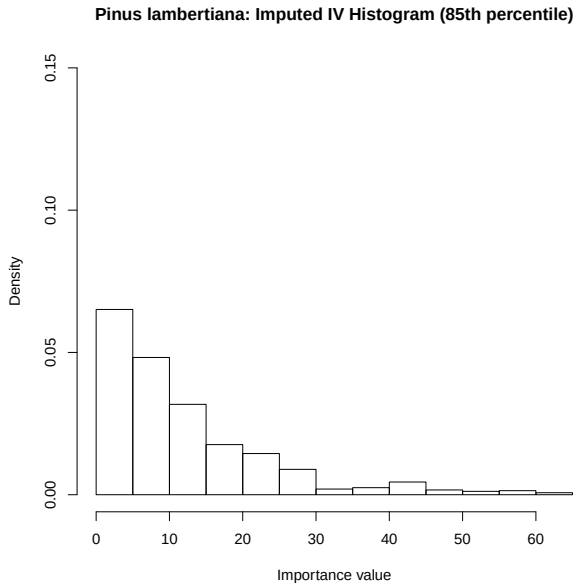
Distribution of Measured (FIA)/Imputed IV for all species

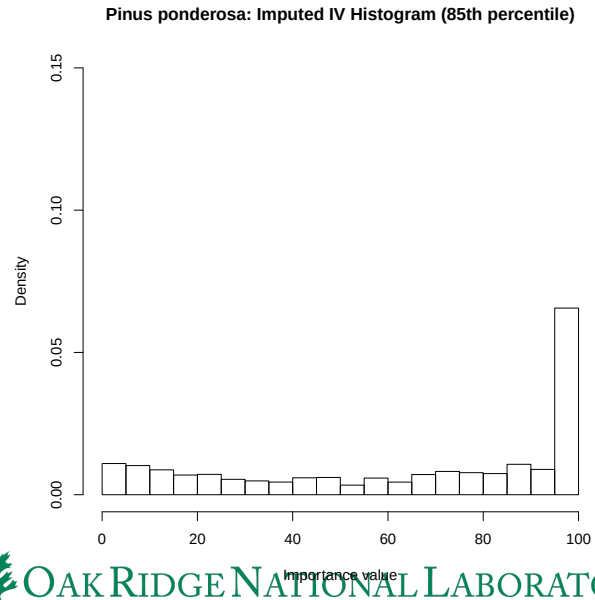












Summary and future directions

Summary:

- Results from associative clustering based imputation approach is promising
- Species distribution maps were developed (good agreement with existing range maps)
- Automated statistical approach using sparse measurement
- Generic upscaling tool for scaling point based measurement to broader landscape

Ongoing/Future directions:

- Approaches for imputation using sparse measurements
- Include more tree species in the analysis
- Analysis of suitability under projected future climate scenarios

Acknowledgments

Thanks for your attention!

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Data Clearinghouse:
https://www.geobabble.org/phenoregions/

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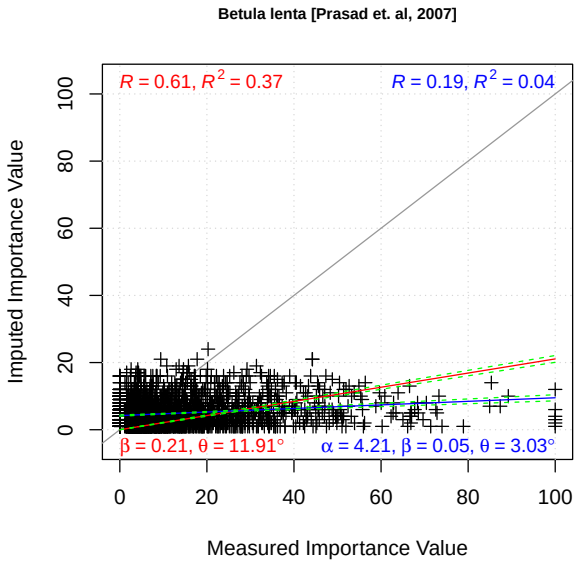
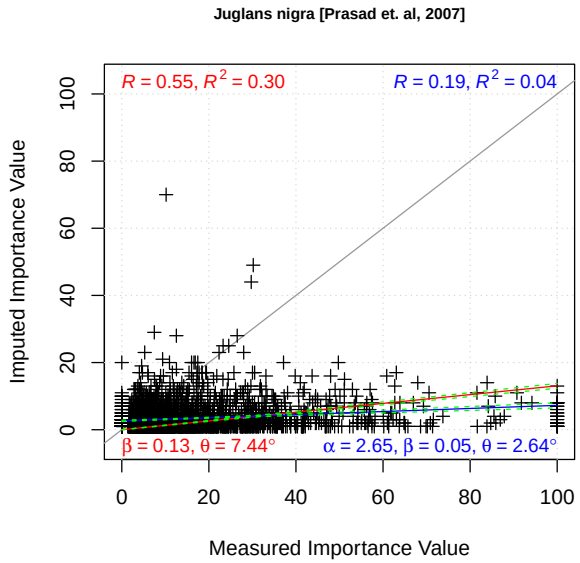
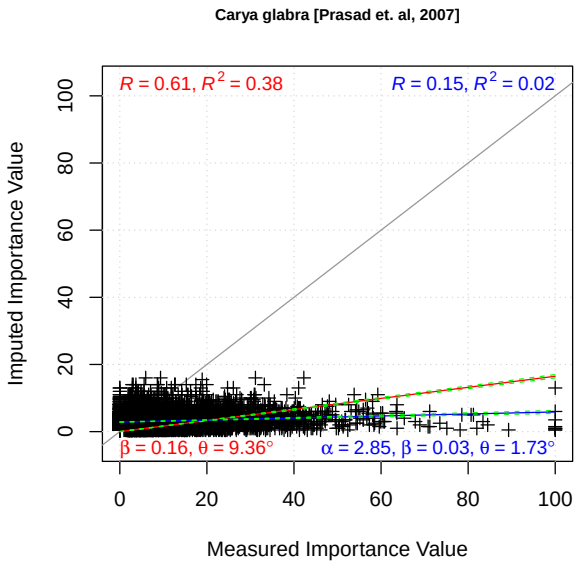
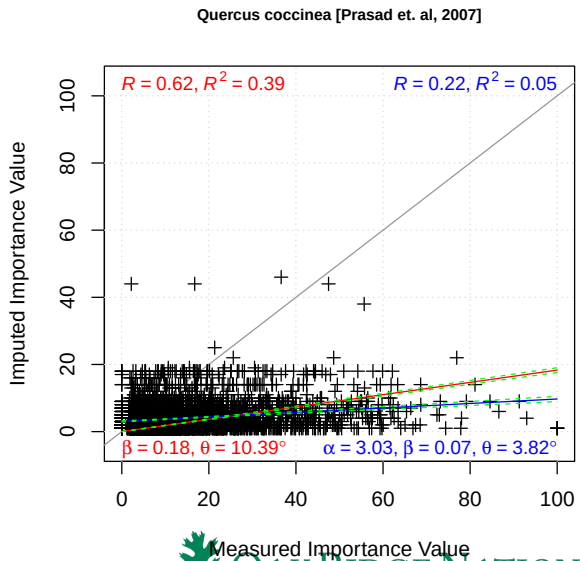
Back up slides

Prasad et al., 2007 vs FIA

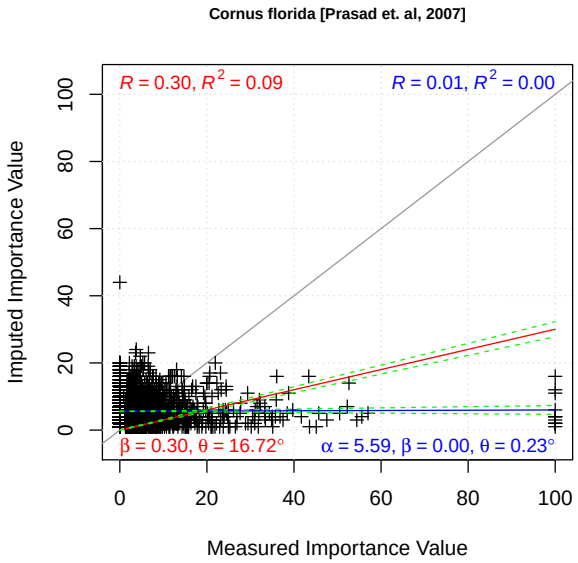


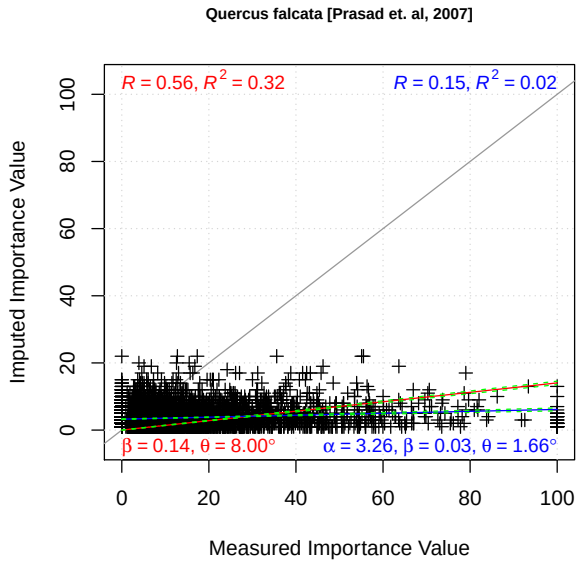






Prasad et al., 2007 vs FIA





Distribution of Prasad et al., 2007's imputed IV for all species