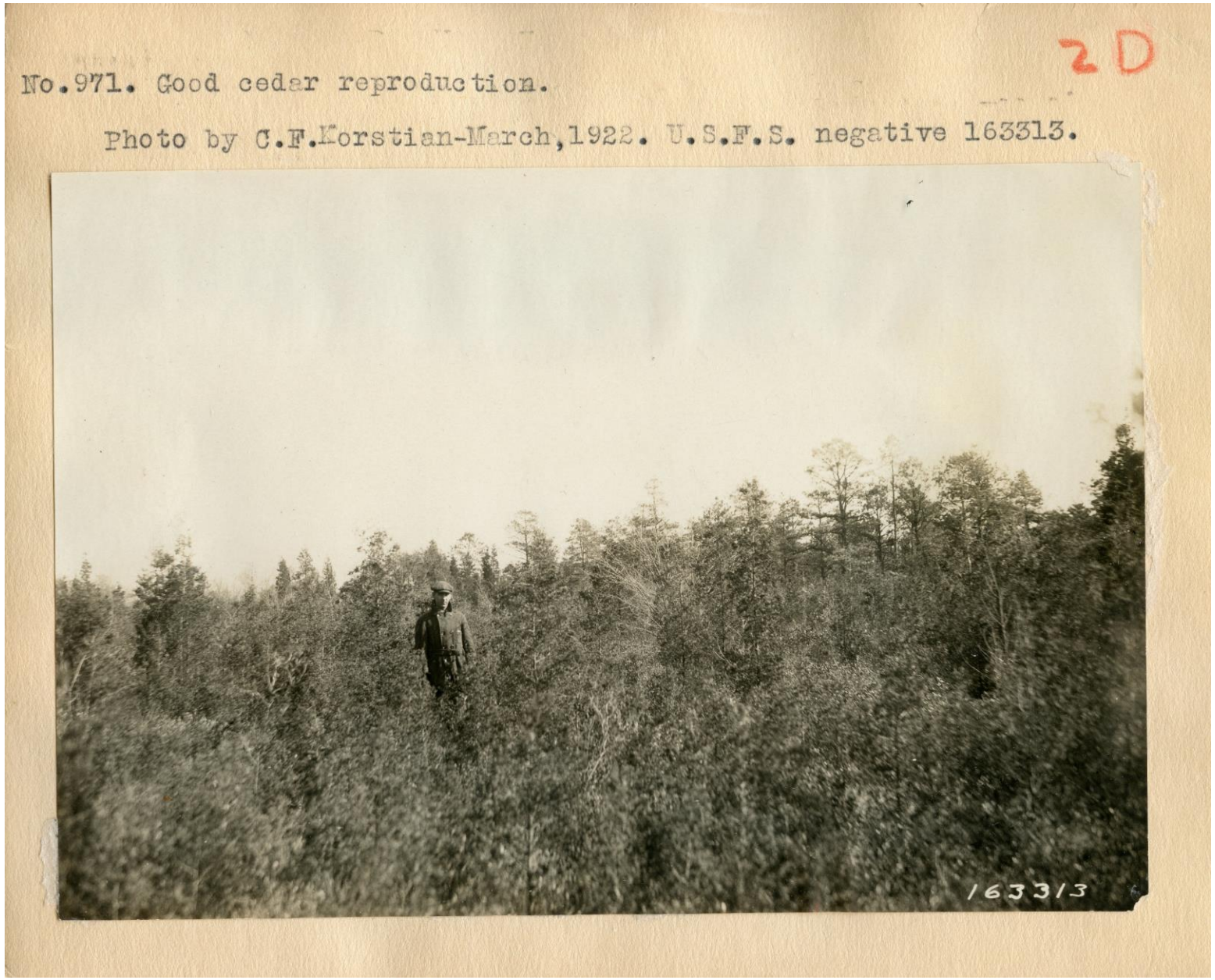
BIGMAP-derived Synthetic Stand Data *to Predict* FVS-ready Regeneration from REGEN3

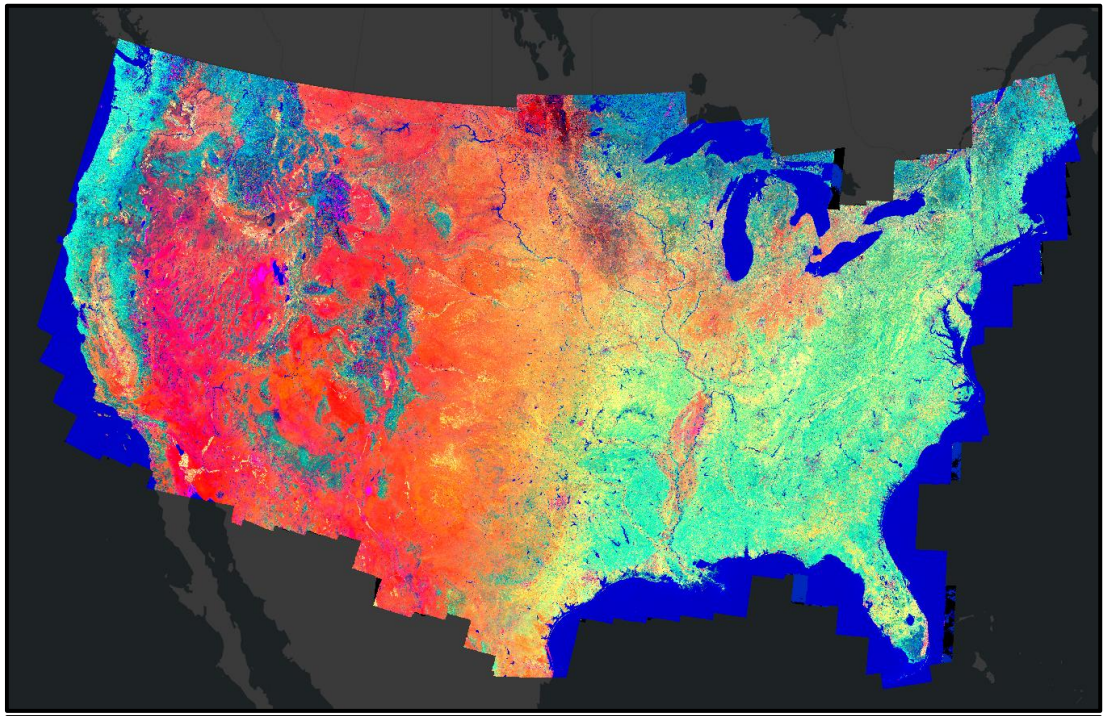
Bernard Isaacson, Barry T. Wilson, Christopher Oswalt, Tara Keyser, Margaret Woodbridge, Callie Schweitzer, James Garner

USDA Forest Service



What's BIGMAP?

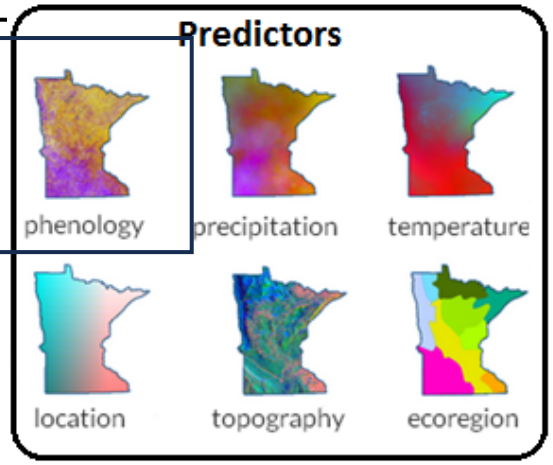
- **Big** Data, **M**apping, and **An**alytics **P**latform
- National scale geospatial modeling environment
- Pipeline from FIA research to development
- Leverages USDA Esri enterprise license in the AWS cloud

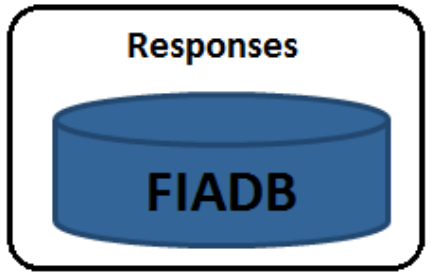


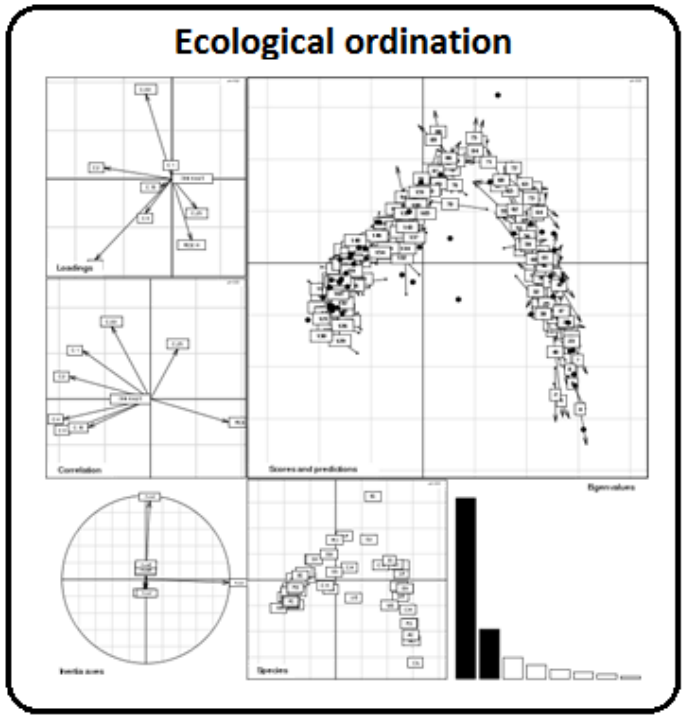
Current BIGMAP Workflows

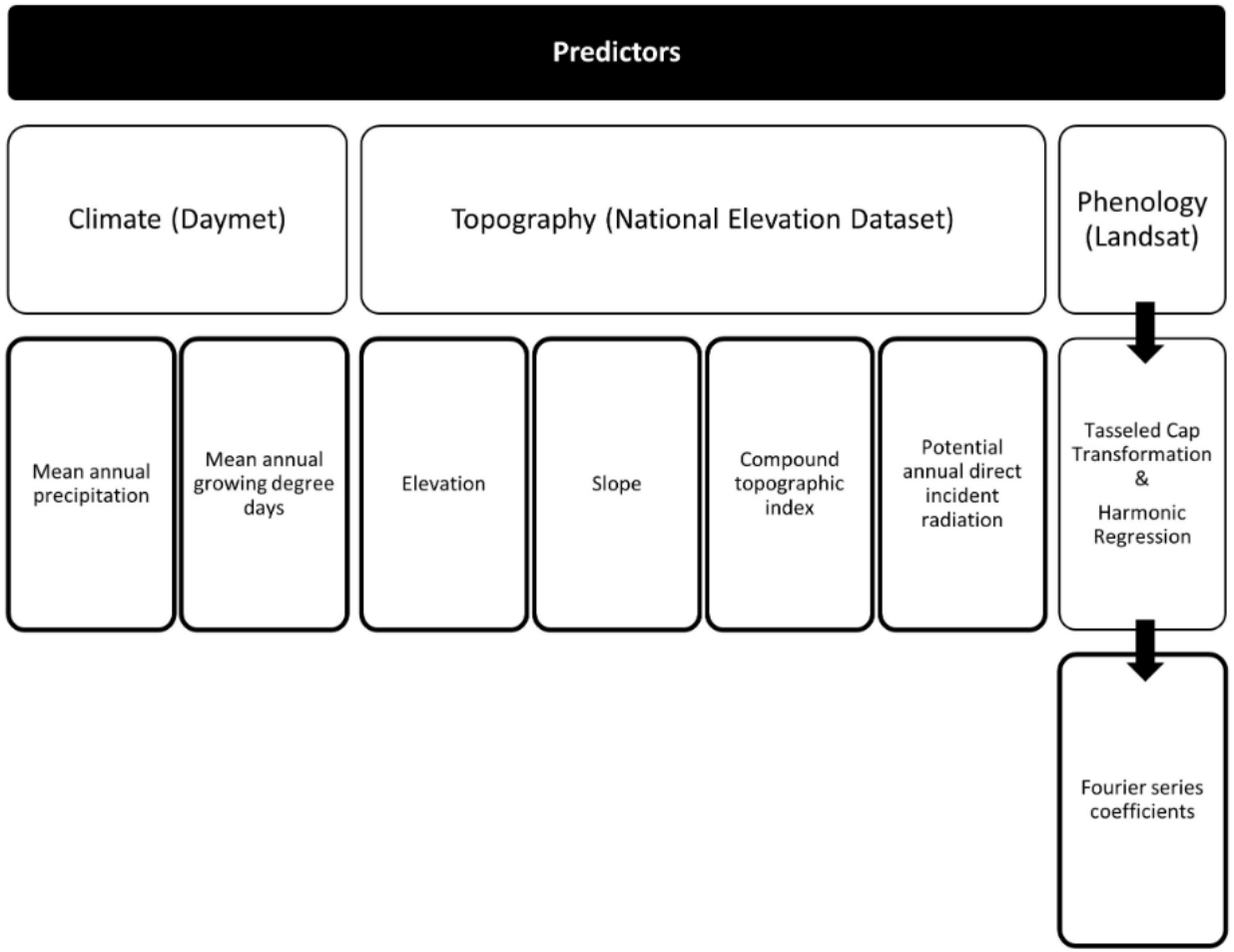
- Time period 2014-2018
- Landsat 8 OLI imagery

- 212,978 FIA central subplots
- CCA models and imputation by ecological province





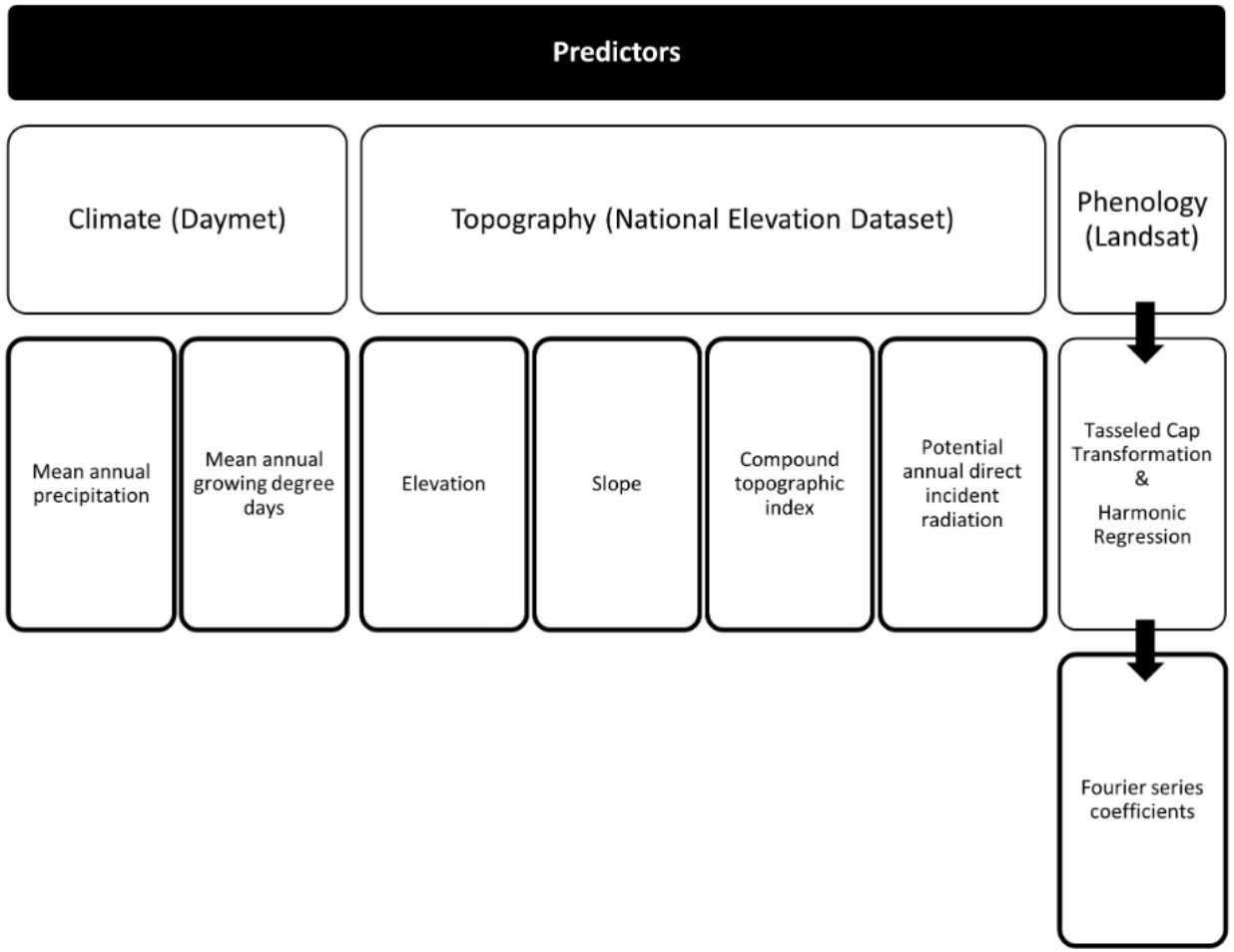


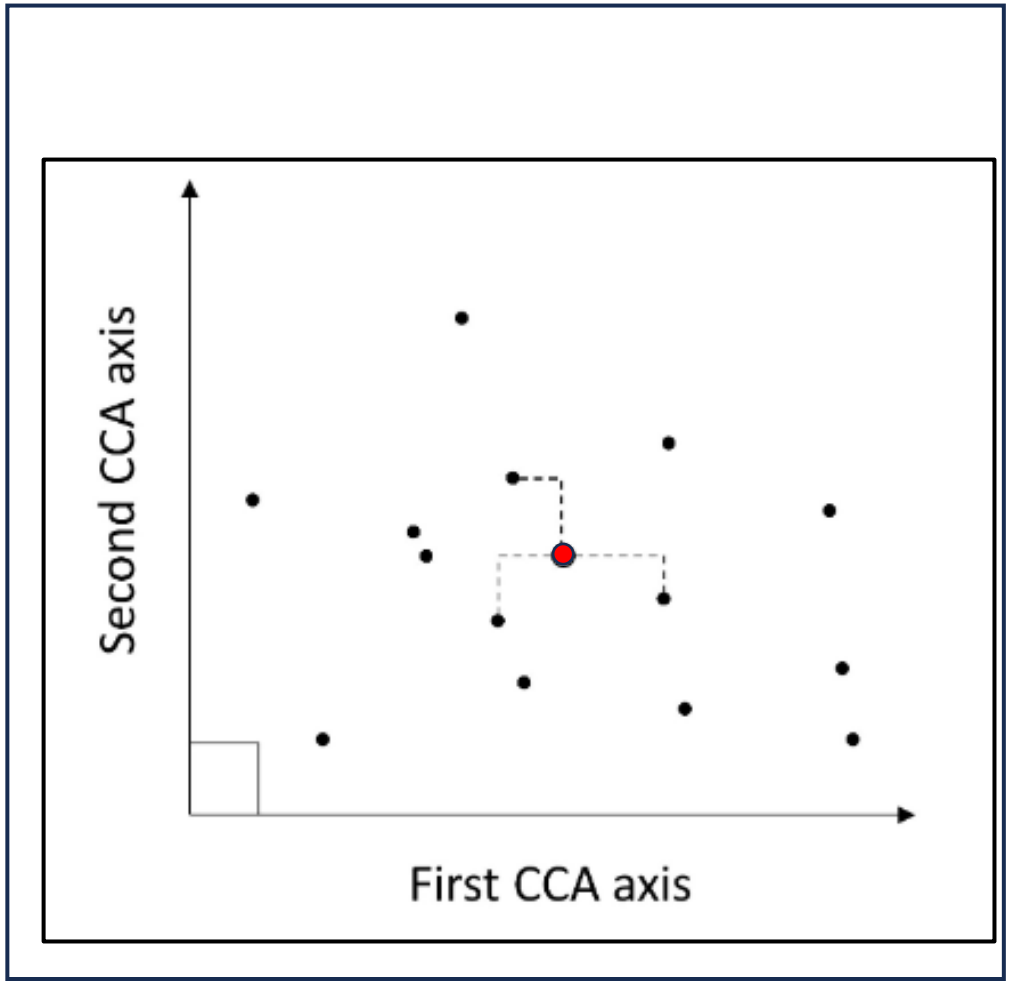


BIGMAP

Bell et al. 2022
Frontiers in Forests and Global Change
https://doi.org/10.3389/ffgc.2022.763422

BIGMAP





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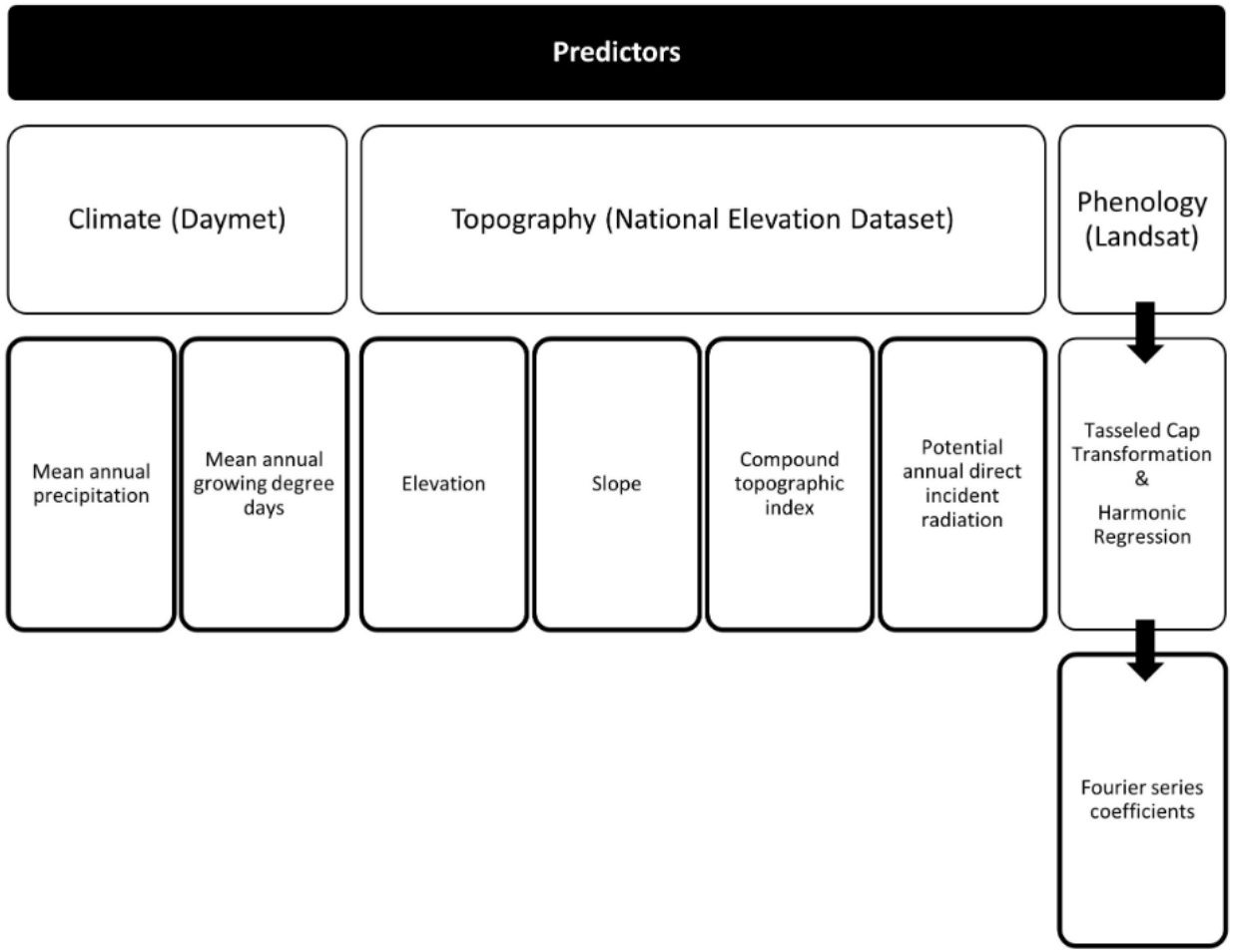
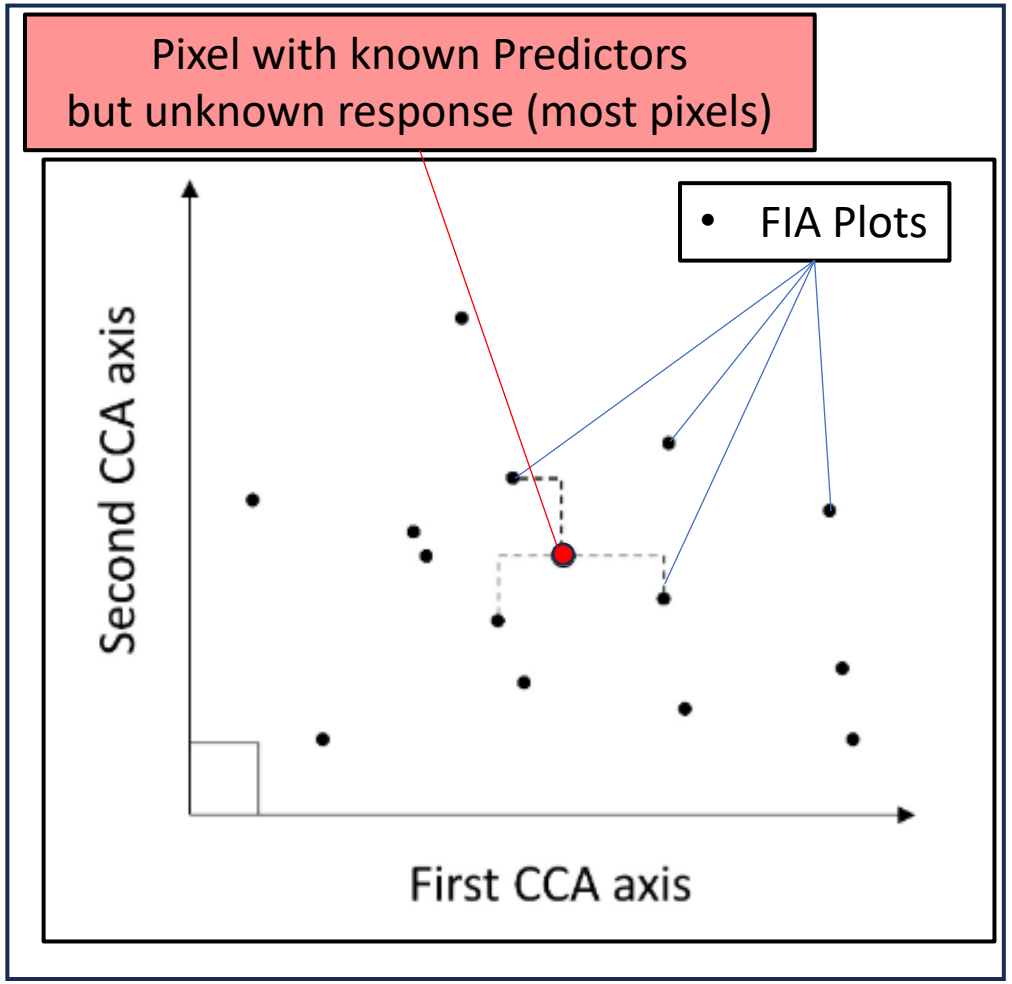
BIGMAP





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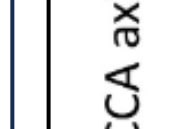
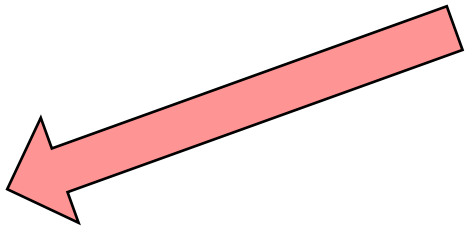
BIGMAP

Predictors

- Climate (Daymet)
  - Mean annual precipitation
  - Mean annual growing degree days
- Topography (National Elevation Dataset)
  - Elevation
  - Slope
  - Compound topographic index
  - Potential annual direct incident radiation
- Phenology (Landsat)
  - Tasseled Cap Transformation & Harmonic Regression
  - Fourier series coefficients





BIGMAP *k* Neighbors

Pixels

	1	2	3	4	5	6	7	8	9
1	137	137	137	137	137	137	137	137	137
2	9269	3738	12563	3738	8362	12289	6356	3770	3481
3	3481	12289	3738	6389	9388	4706	6389	3481	12289
4	3738	3770	1071	12289	12289	3738	9201	3107	12628
5	9249	6389	8362	9249	3481	3481	3736	418	12700
6	12289	1332	12289	8362	3770	8362	12899	9272	1071
7	12899	9388	3634	6167	3107	9388	9388	12555	9269
8	3770	8362	8735	3481	6389	12700	8945	12628	12563
9	4706	8735	4606	183	3738	14102	9269	12453	3770
10	8362	4706	3598	9269	6167	9201	3770	6167	8362
11	6389	9269	288	12899	9269	1071	6167	5136	9388
12	6152	6490	6389	6379	3736	12563	3738	6547	11246
13	9388	12899	6550	6490	9201	375	288	1176	6550
14	183	1071	393	9201	4706	3598	12563	8362	6389
15	3762	1320	8736	6547	12899	12628	6490	6902	8736
16	6167	8736	6490	12700	12738	3770	3481	9201	14390
17	6520	8747	1332	1332	393	6550	8362	12289	9272
18	12453	3107	14583	9388	3786	8736	5778	12186	14102
19	3059	12563	3770	3770	6520	6167	9249	642	5750
20	3107	3634	1058	3634	642	6164	7699	14648	393

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222
251
221
223
Water
332
M221
M223
M231
231
234
255
315
232
kNN Rasters for Ecological Provinces


Stand Scale
synthetic_stands
Command Search (Alt+Q)
Project
Map
Insert
Analysis
View
Edit
Imagery
Share
Help
Group Layer
Map
NFS Data
1:4,806
79.5663453°W 37.9574689°N
Selected Features: 12


synthetic_stands
Command Search (Alt+Q)
Project
Map
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Analysis
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Edit
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Share
Help
Group Layer
Map
NFS Data
Drawing Or
nfs_...
nfs_...
nfs_...
FVS_...
FAC...
Inter...
nf...
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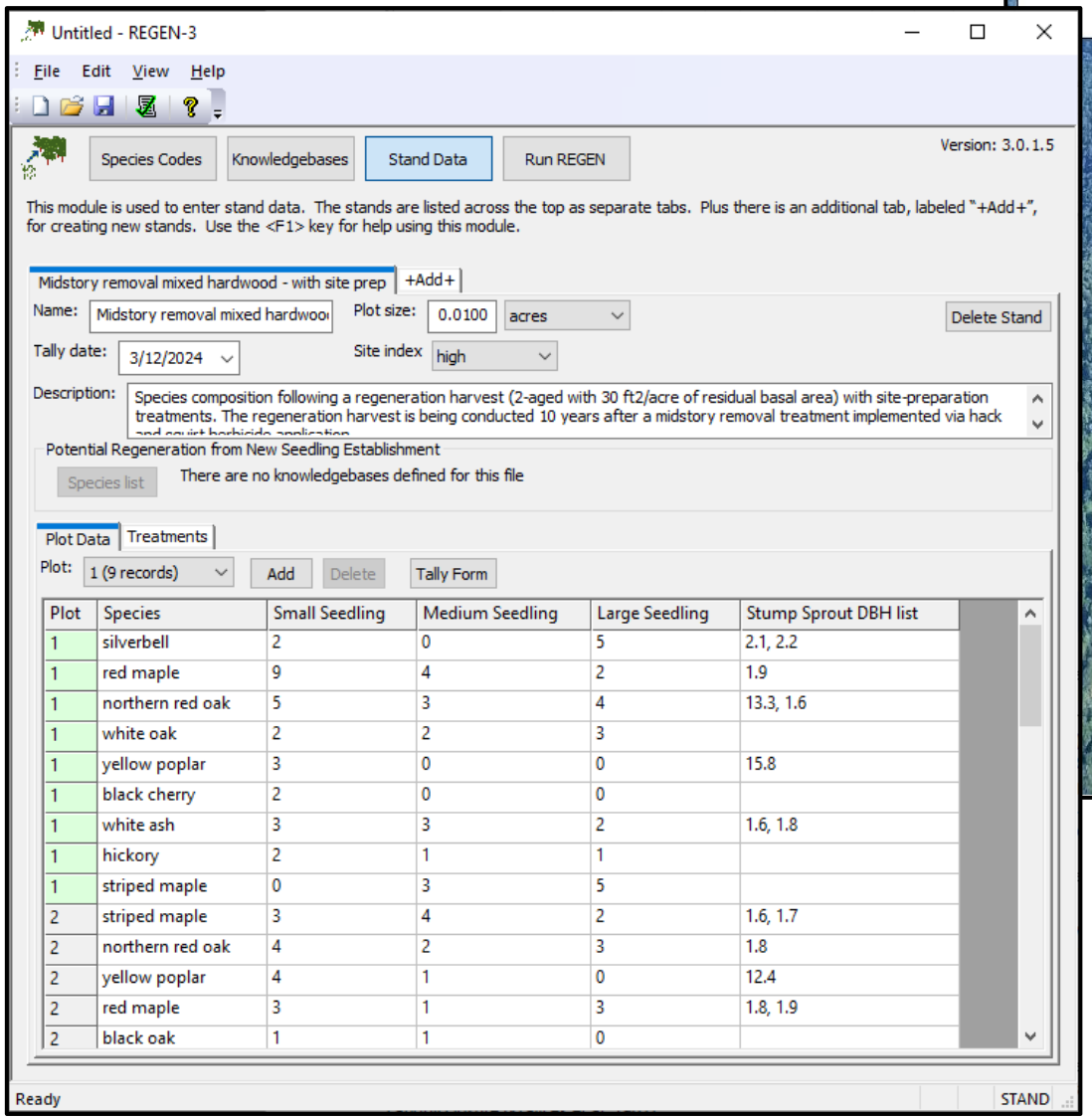
Polys
Ch...
Ch...
Da...
G...
NF...
Actv...
kNN...
H...
H...
Eco...
Hills...
EDW...
N.
Worl...
Standal...
FVS...
1:4,806
79.5687783°W 37.9574346°N
Selected Features: 12
Stand Scale

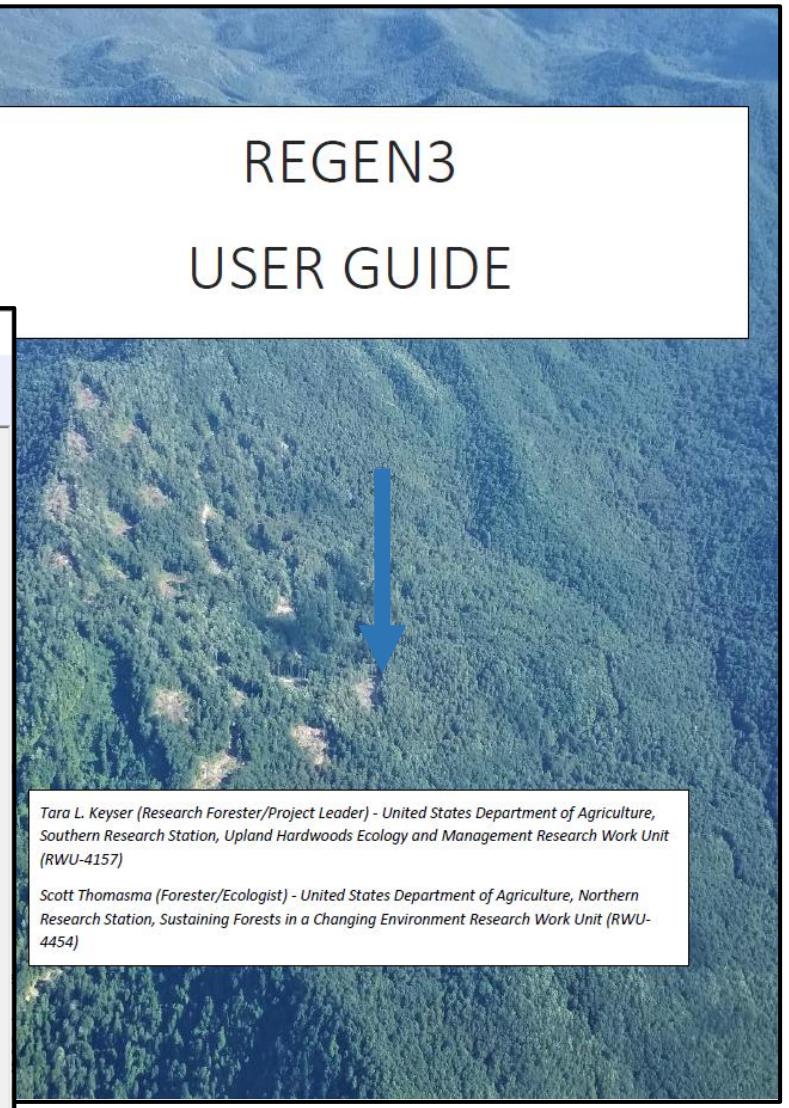
REGEN3 Model

Model to predict compositional outcomes based on the competitive abilities of the different sources of regen

Inputs:

1. Fixed-area regeneration inventory data (1/100th to 1/300th acre plots)
2. ‘Knowledgebase’ for geographic location
3. Site quality





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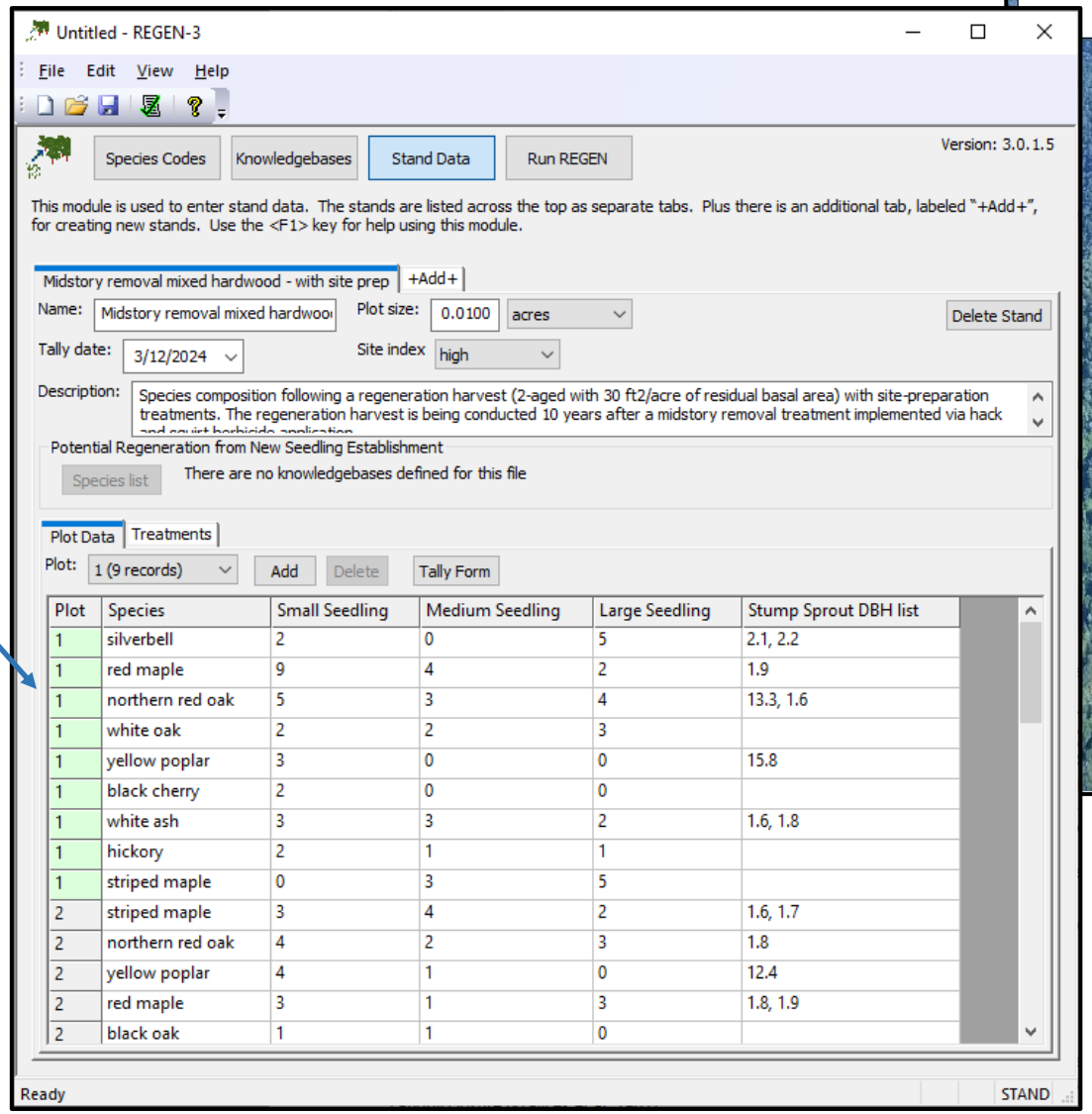
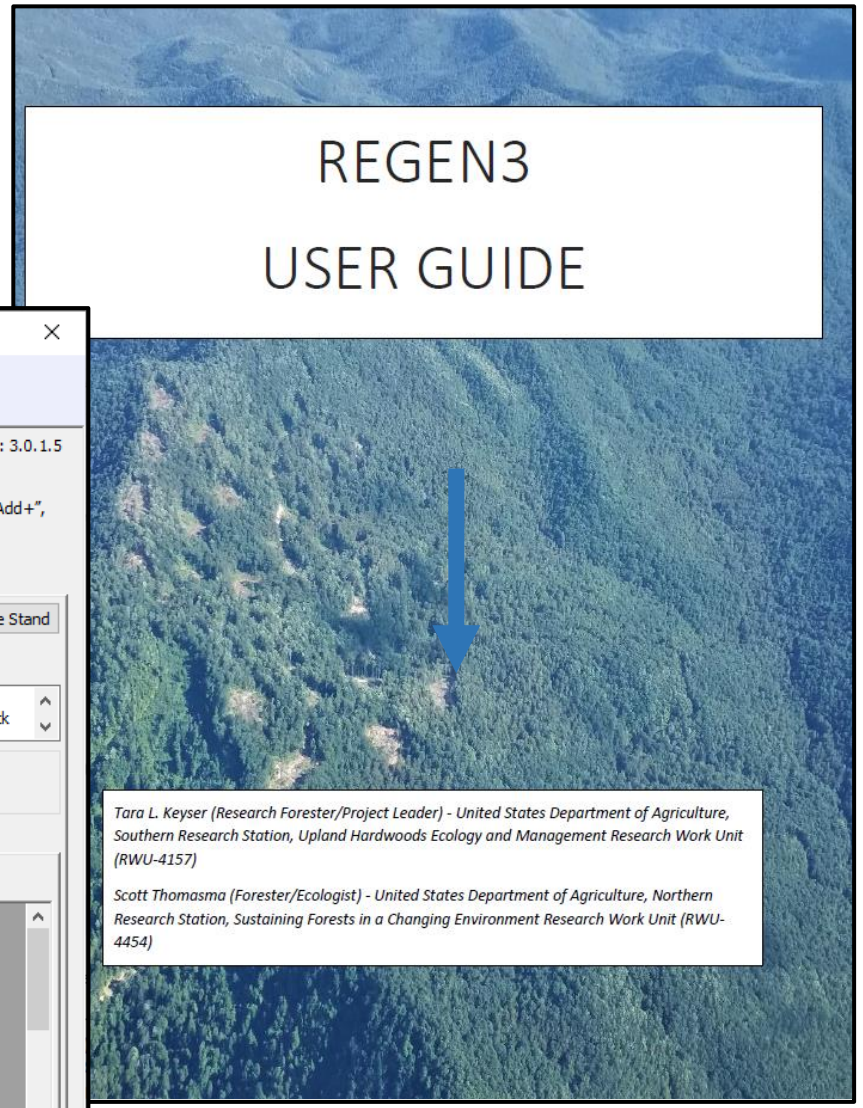


Plot	Species	Small Seedling	Medium Seedling	Large Seedling	Stump Sprout DBH list
1	silverbell	2	0	5	2.1, 2.2
1	red maple	9	4	2	1.9
1	northern red oak	5	3	4	13.3, 1.6
1	white oak	2	2	3	
1	yellow poplar	3	0	0	15.8
1	black cherry	2	0	0	
1	white ash	3	3	2	1.6, 1.8
1	hickory	2	1	1	
1	striped maple	0	3	5	
2	striped maple	3	4	2	1.6, 1.7
2	northern red oak	4	2	3	1.8
2	yellow poplar	4	1	0	12.4
2	red maple	3	1	3	1.8, 1.9
2	black oak	1	1	0	



Plot Data | Treatments

Plot: 1 (9 records) Add Delete Tally Form

Plot	Species	Small Seedling	Medium Seedling	Large Seedling	Stump Sprout DBH list
1	silverbell	2	0	5	2.1, 2.2
1	red maple	9	4	2	1.9
1	northern red oak	5	3	4	13.3, 1.6
1	white oak	2	2	3	
1	yellow poplar	3	0	0	15.8
1	black cherry	2	0	0	
1	white ash	3	3	2	1.6, 1.8
1	hickory	2	1	1	
1	striped maple	0	3	5	
2	striped maple	3	4	2	1.6, 1.7
2	northern red oak	4	2	3	1.8
2	yellow poplar	4	1	0	12.4
2	red maple	3	1	3	1.8, 1.9
2	black oak	1	1	0	

Regeneration Inventory Plots

Model Predictions

Knowledgebase: SApp-sm; FVS variant: Southern Export to FVS

Species	Plot Count	Stem Count	TPA	Percent
red maple	3	10.12	759.27	36.02
black cherry	2	6.00	450.00	21.35
northern red oak	4	5.44	407.73	19.34
yellow poplar	2	1.80	135.00	6.41
white ash	2	1.12	84.20	3.99
hickory	2	1.00	75.00	3.56
eastern white pine	2	1.00	75.00	3.56
cucumber-tree	1	0.67	50.25	2.38
white oak	2	0.50	37.85	1.80
sweet birch	2	0.45	33.40	1.58
black oak	1	0.00	0.00	0.00
basswood	1	0.00	0.00	0.00
serviceberry	1	0.00	0.00	0.00
eastern hemlock	1	0.00	0.00	0.00
hophornbeam	1	0.00	0.00	0.00
sourwood	1	0.00	0.00	0.00
TOTALS	4	28.10	2107.70	100.00

```
Species with SPA below 5.00 will be ignored
END

Compute                 1
_Year = 2019
End
IF                      0
year eq _Year
Then
Estab
Sprout                  0    Parms(All, 0., 0., 0., 999.)
Natural                 1    Parms(RM, 759.266052, 100., 2., . , 0)
Natural                 1    Parms(BC, 450.000000, 100., 2., . , 0)
Natural                 1    Parms(RO, 407.730709, 100., 2., . , 0)
Natural                 1    Parms(YP, 135.000000, 100., 2., . , 0)
Natural                 1    Parms(WA, 84.196882, 100., 2., . , 0)
Natural                 1    Parms(HI, 75.000000, 100., 2., . , 0)
Natural                 1    Parms(WP, 75.000000, 100., 2., . , 0)
Natural                 1    Parms(CT, 50.250000, 100., 2., . , 0)
Natural                 1    Parms(WO, 37.851526, 100., 2., . , 0)
Natural                 1    Parms(SB, 33.401893, 100., 2., . , 0)
End
Endif
```

Exported to FVS as .kcp

REGEN3 Model

‘Knowledgebase’ for location consists of ranks of competitive ability for species/categories

- lower rank is a more competitive stem

Northern Red Oak Large Advance Reproduction (rank 5) << Basswood Stump Sprout (rank 1)

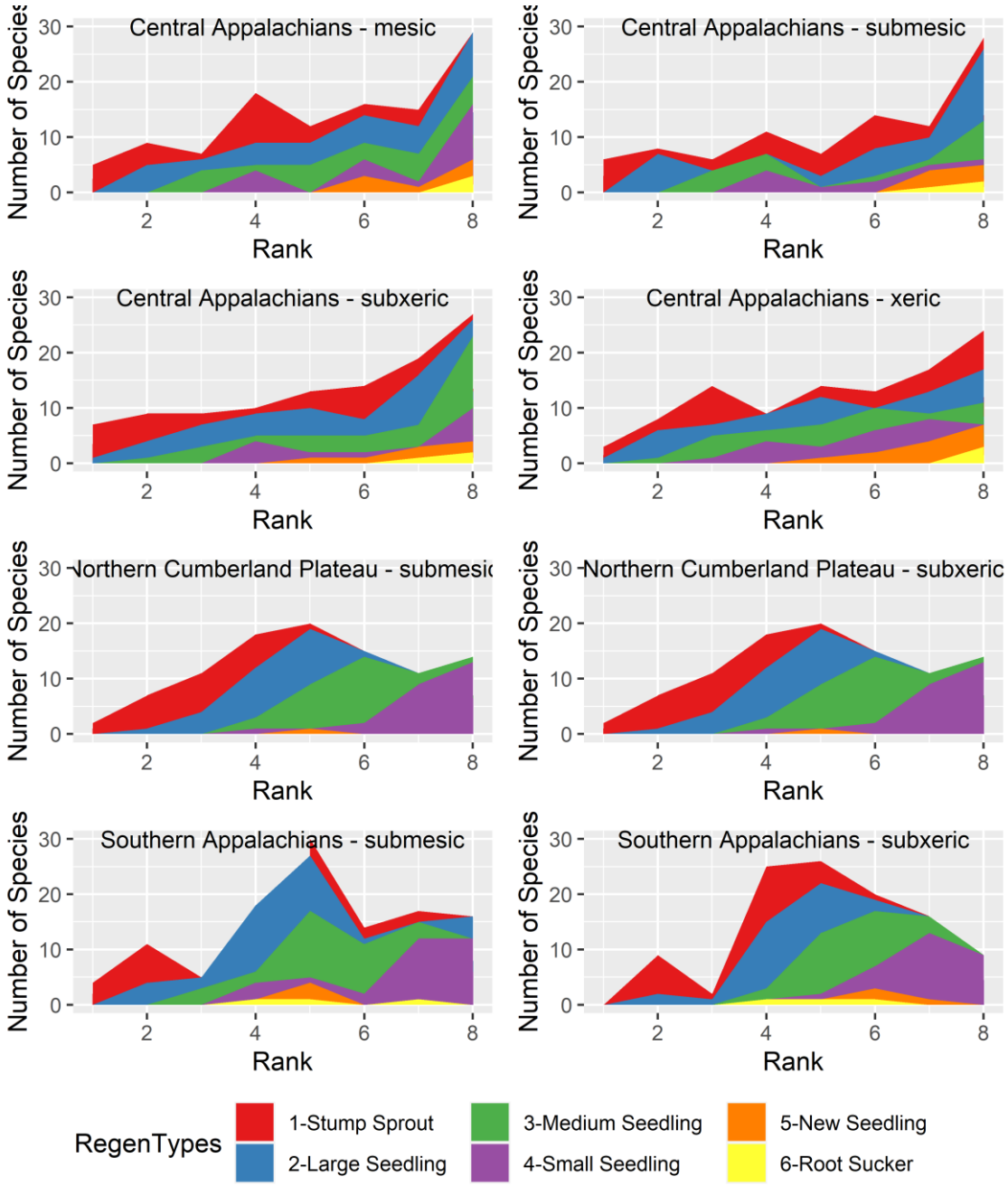
Knowledgebase: Central Appalachian Submesic Site

Regeneration Categories

-if both of these types of regen are present, model predicts basswood will be dominant after 10 years

Species	Small Seedling	Medium Seedling	Large Seedling	Stump Prob.	Stump b0	Stump b1	Stump Rank	New Seed. Prob.	Seed. Count	Seed. Rank	Root Sucker Prob.
American beech	0	0	8	0.50	0.000	0.000	6	0.00			0.30
ash	7	6	5	0.70	0.000	0.000	4	0.00			0.00
basswood	6	4	2	0.80	0.000	0.000	1	0.00			0.00
black cherry	6	4	2	0.70	0.000	0.000	1	0.40	20	8	0.00
black locust	4	3	2	0.70	0.000	0.000	1	0.40	25	8	0.40
black oak	0	8	6	0.00	3.153	-0.205	3	0.00			0.00
blackgum	0	0	8	0.60	0.000	0.000	6	0.00			0.00
buckeye	0	0	0	0.50	0.000	0.000	8	0.00			0.00
chestnut oak	0	0	7	0.00	2.463	-0.088	4	0.00			0.00
cucumber-tree	0	8	7	0.80	0.000	0.000	5	0.00			0.00
eastern white pine	4	3	2	0.00	0.000	0.000	0	0.30	3	8	0.00
flowering dogwood	0	0	0	0.80	0.000	0.000	8	0.00			0.00
hemlock	0	0	8	0.00	0.000	0.000	0	0.00			0.00
hickory	0	0	8	0.60	0.000	0.000	5	0.00			0.00
hophornbeam	0	0	8	0.80	0.000	0.000	7	0.00			0.00
mountain magnolia	0	0	7	0.50	0.000	0.000	6	0.00			0.00
northern red oak	0	8	5	0.00	3.111	-0.108	2	0.00			0.00

Existing Knowledgebase Summary



REGEN3 Model

Lower Rank = Greater Competitive Ability

More Competitive

Stump Sprouts > Large Advance Rep. >4' ht <1.5"dbh > Medium Advance Rep. 2-4' ht > Small Advance Rep. <2' ht > Root Suckers ≈ New Seedlings

From Overstory Data

From Seedling Data

Deliverable Goals

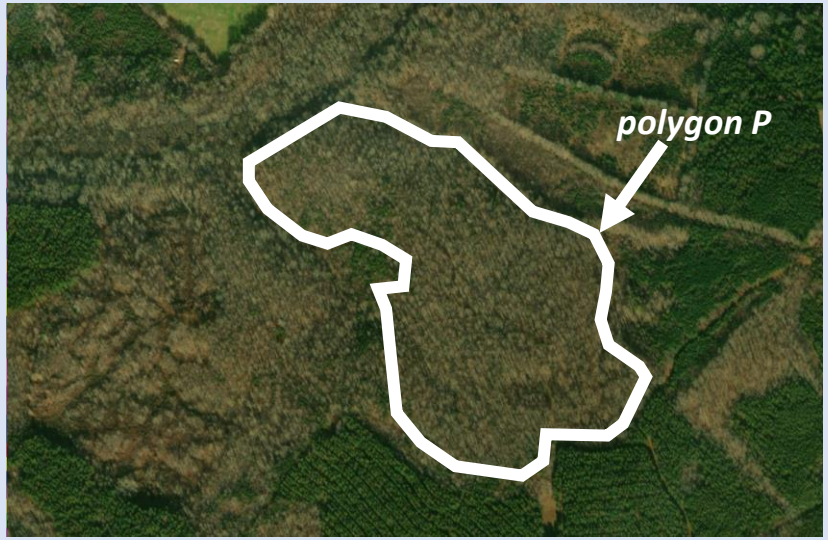
Data Product 1: Synthetic Stand Data for Polygon-wise Analysis

Intended Audience:

NFS Forest Planners

NFS Silviculturalists

"What regeneration can we expect in this stand if we specify a regeneration harvest?"



Output Table

Species	LG Seedlings per Area	MD Seedlings per Area	SM Seedlings per Area	Overstory DBH List in plots

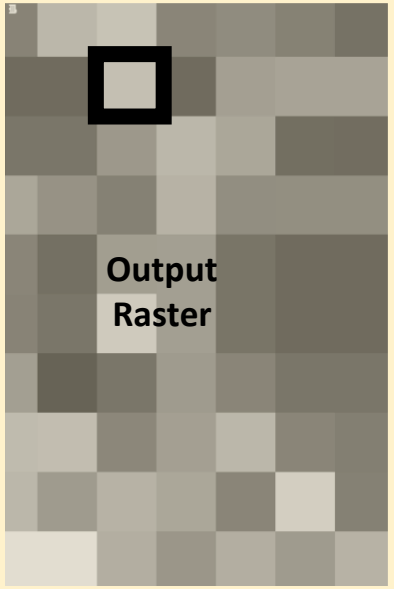
Data Product 2: Synthetic Stand Data for Pixel-Wise View

Intended Audience:

NFS Policy Staff (District Ranger, Supervisor, etc.)

NFS Planners

"What regeneration response can we expect in this landscape if there's widespread major disturbance?"

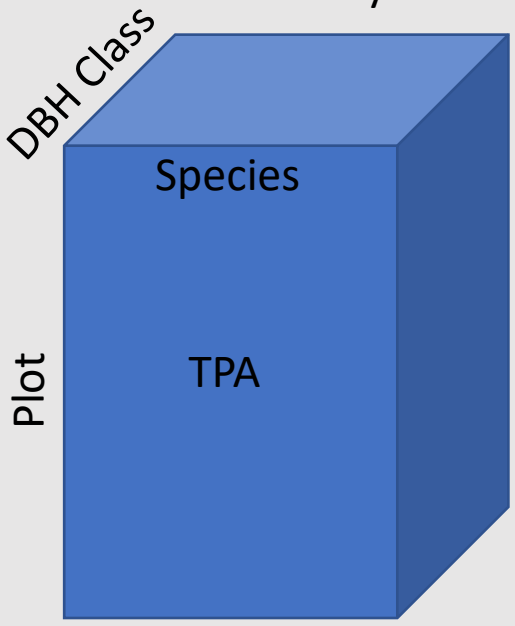


Raster Attributes

Band 1 – Total Stems
Band 2 - % Spp 1
Band 3 - % Spp 2
…
Band n - % Spp n-1

Datasets Needed

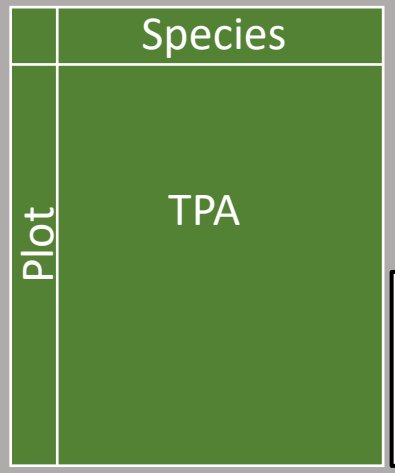
FIADB Datacube:
Overstory



Stump sprouts
Root suckers
New Seedlings

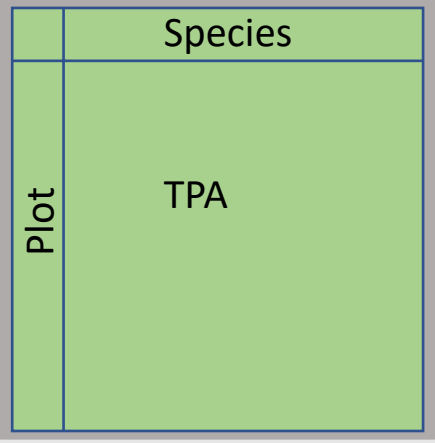
From:
FIAdb &
Workflow 1

FIADB Table:
Large Seedlings

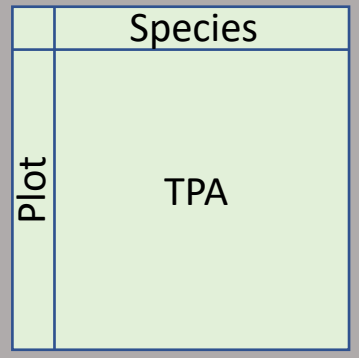


Synthetic Stand Data

FIADB Table:
Medium Seedlings



FIADB Table:
Small Seedlings



R9: FIAdb

R8: FIAdb + Workflow1

From:
Workflow 3

Needed for REGEN3

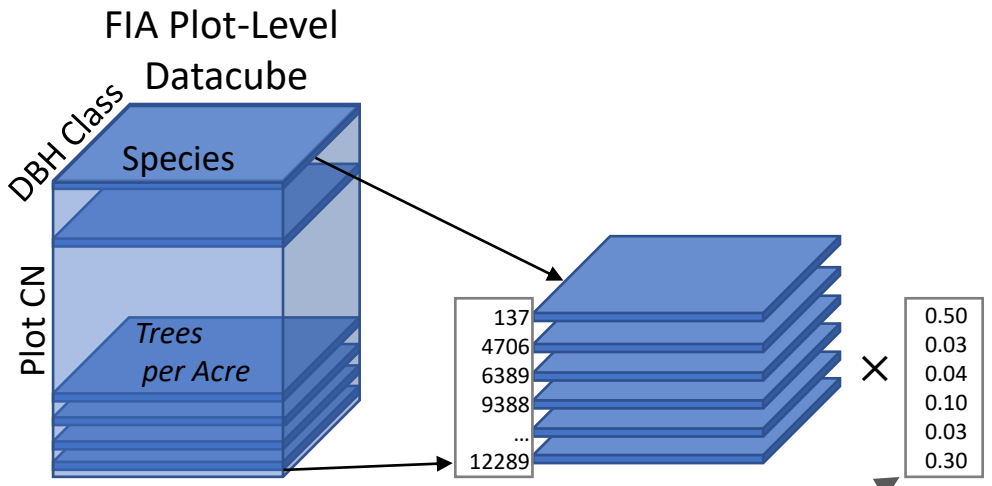
Ecoregion Knowledgebases

From:
TBD

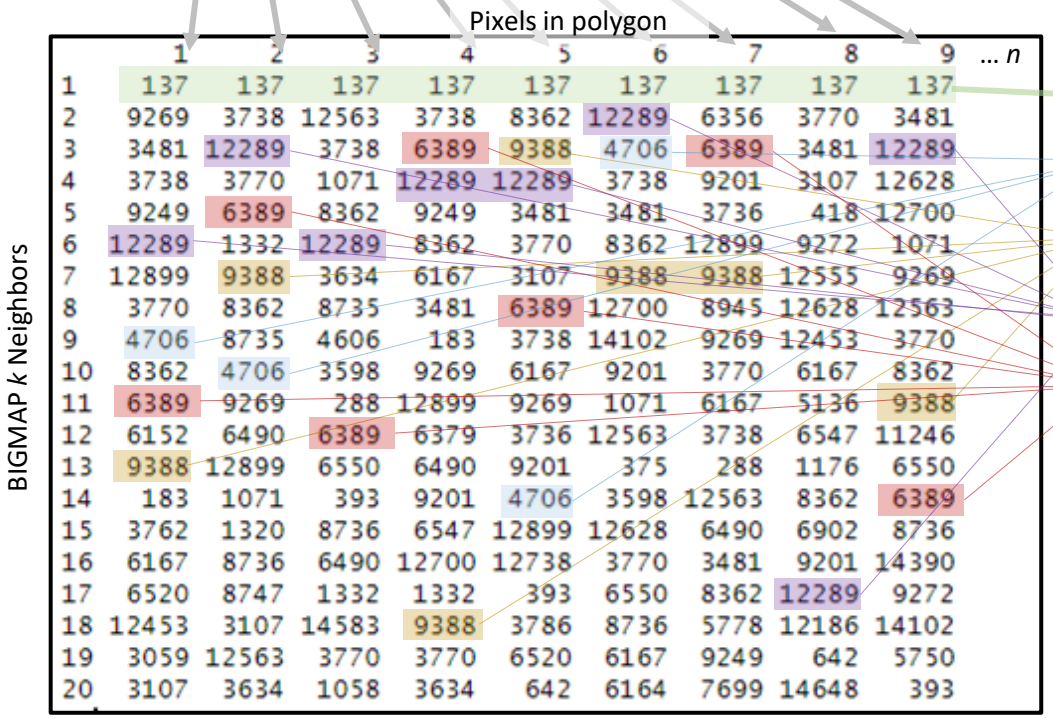
Site Index

(lo/med/hi)

Synthetic Stand Construct



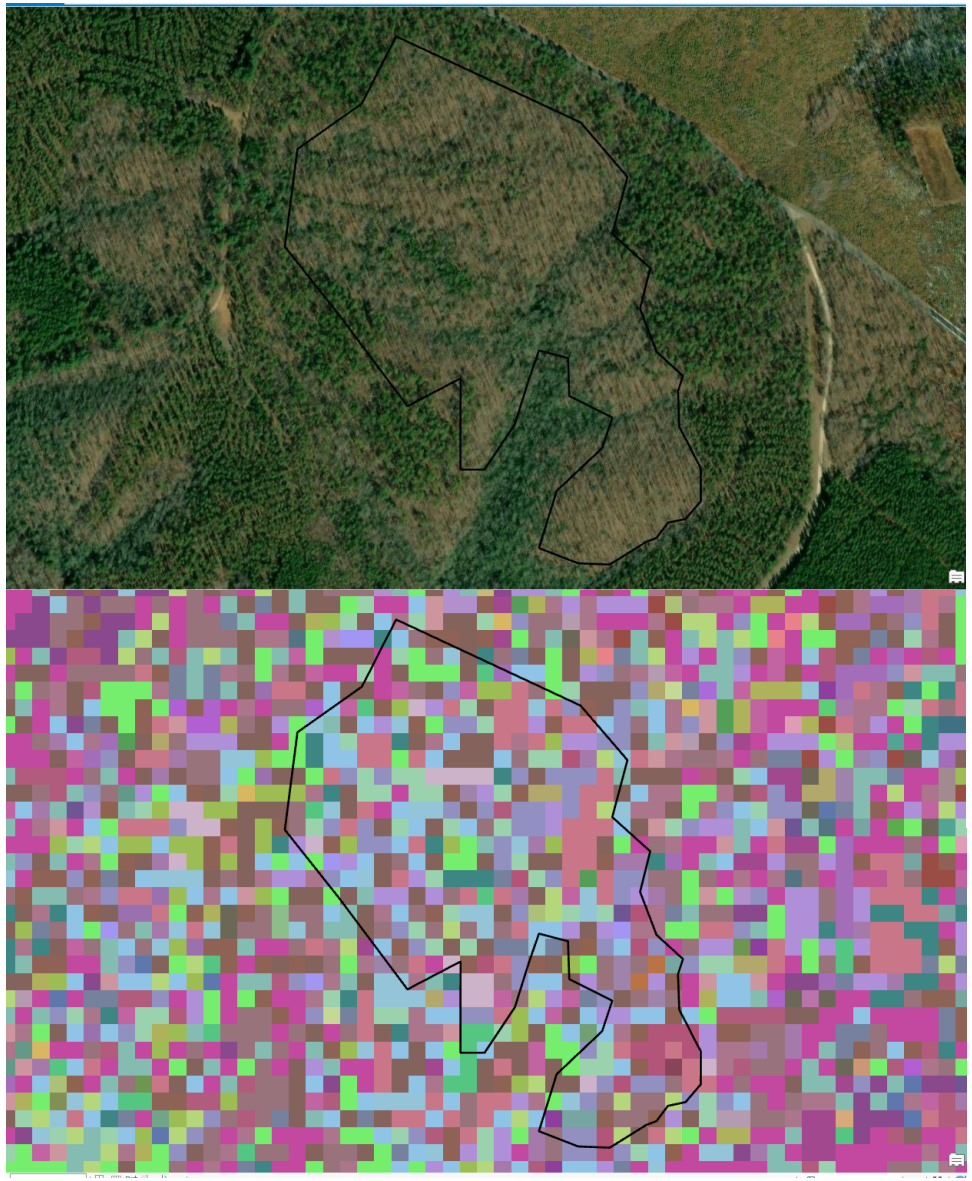
= 'Synthetic Stand Table'

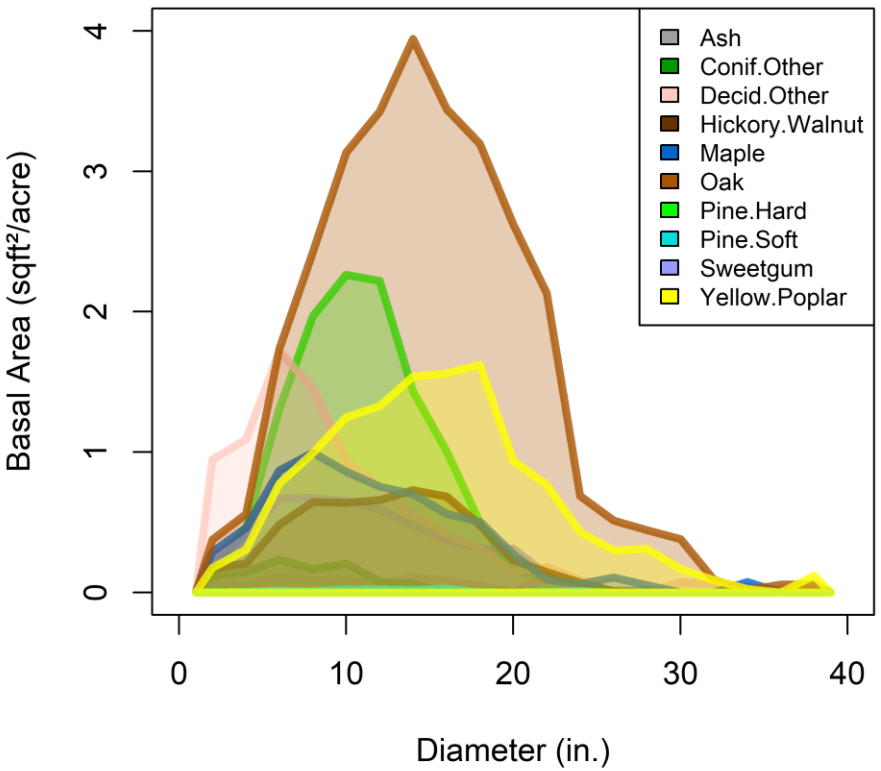


Plot	Freq.
137	300
4706	18
6389	24
9388	60
...	18
12289	180

Spp. Code - Species	1-3"	3-5"	5-7"	7-9"	9-11"	...	>37"
372 – Sweet Birch	130	28	3	2	1		0
693 – Blackgum	1	11	0	0	1		1
833 – N. Red Oak	6	22	2	1	1		0
837 – Black Oak	5	3	3	2	0		1

Upland Piedmont Hardwood



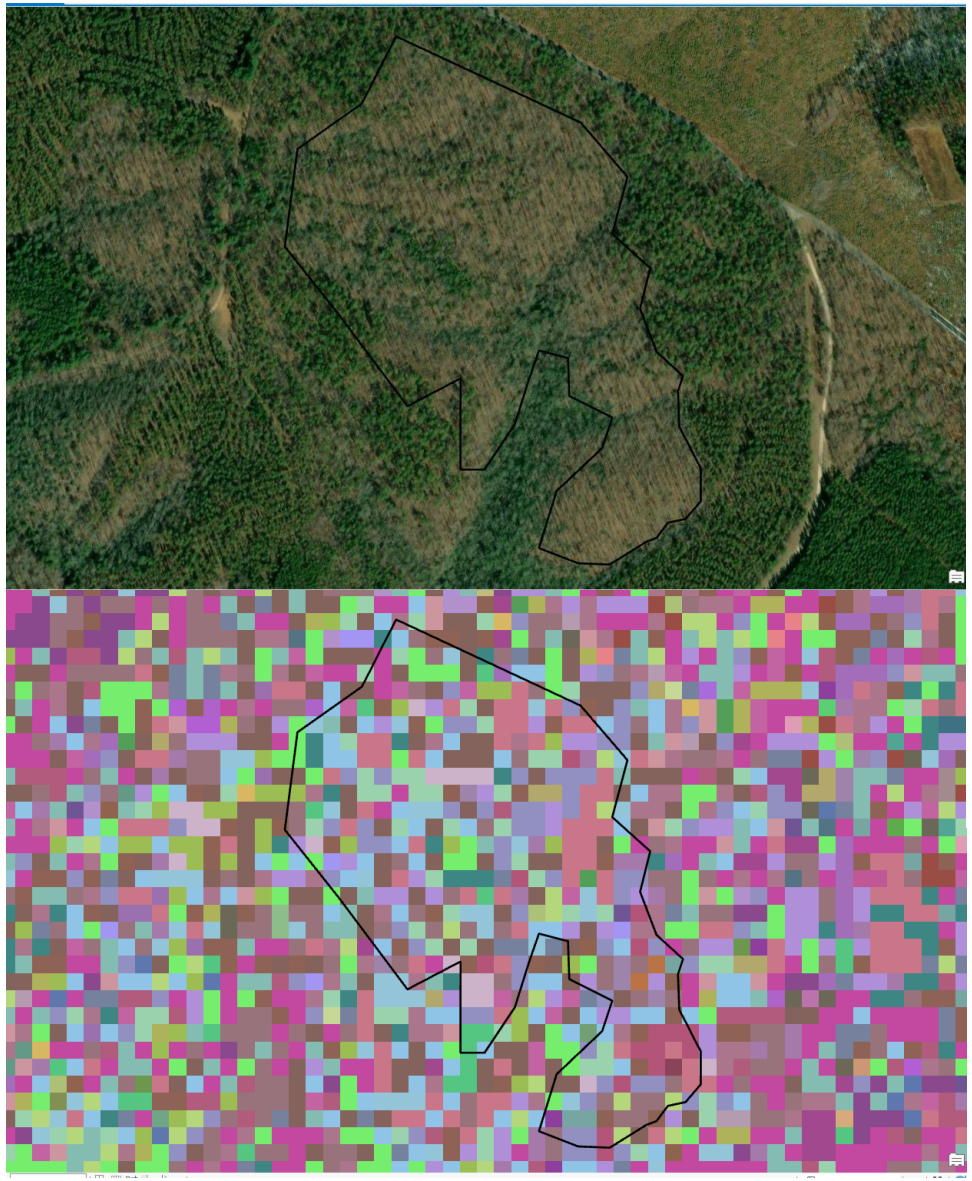


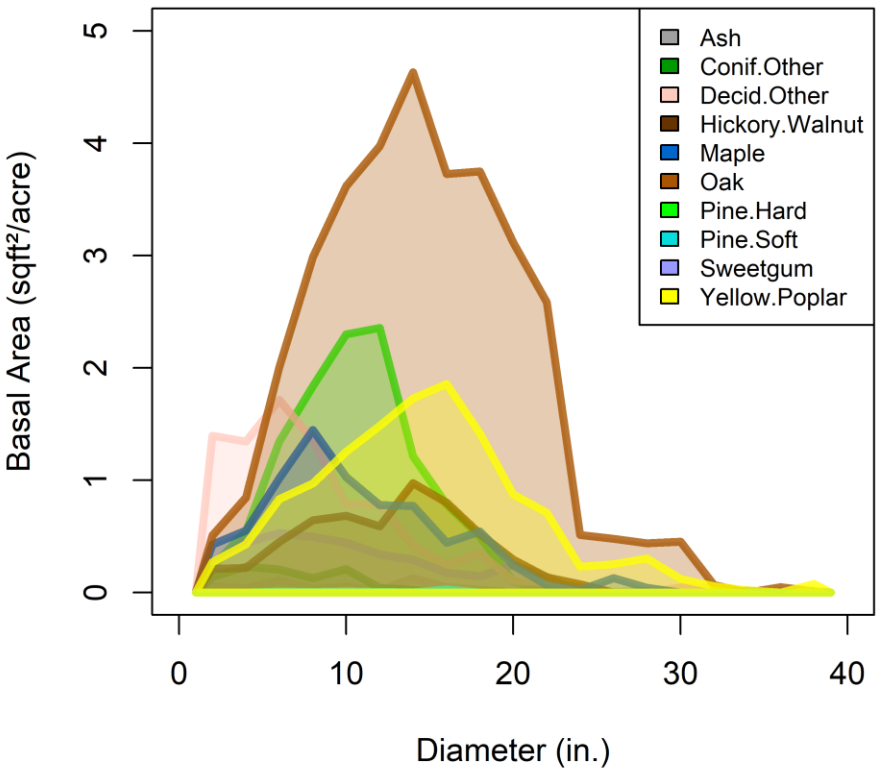
Synthetic Stands

All 171 nearest neighbors

Steps 1 through 2i.-iii.

Upland Piedmont Hardwood



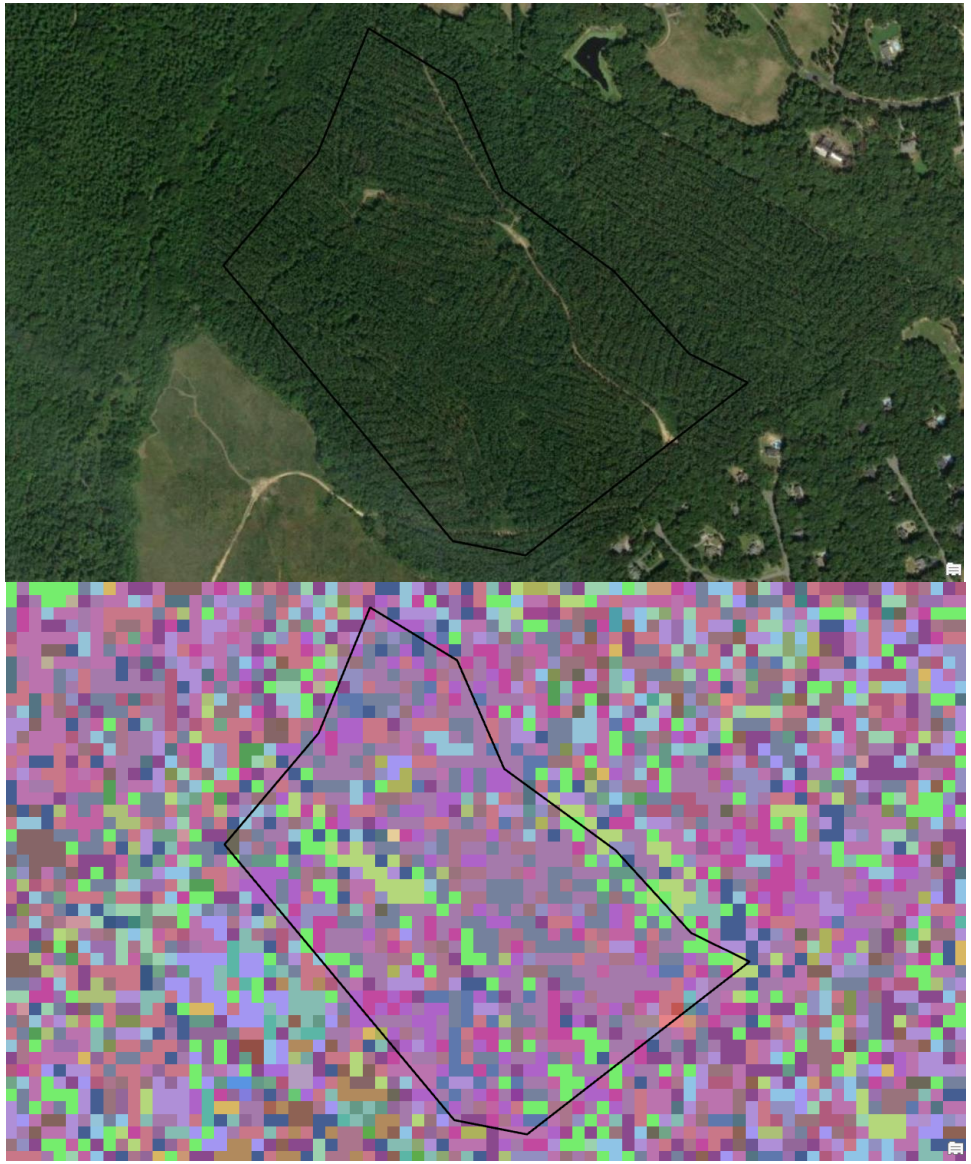


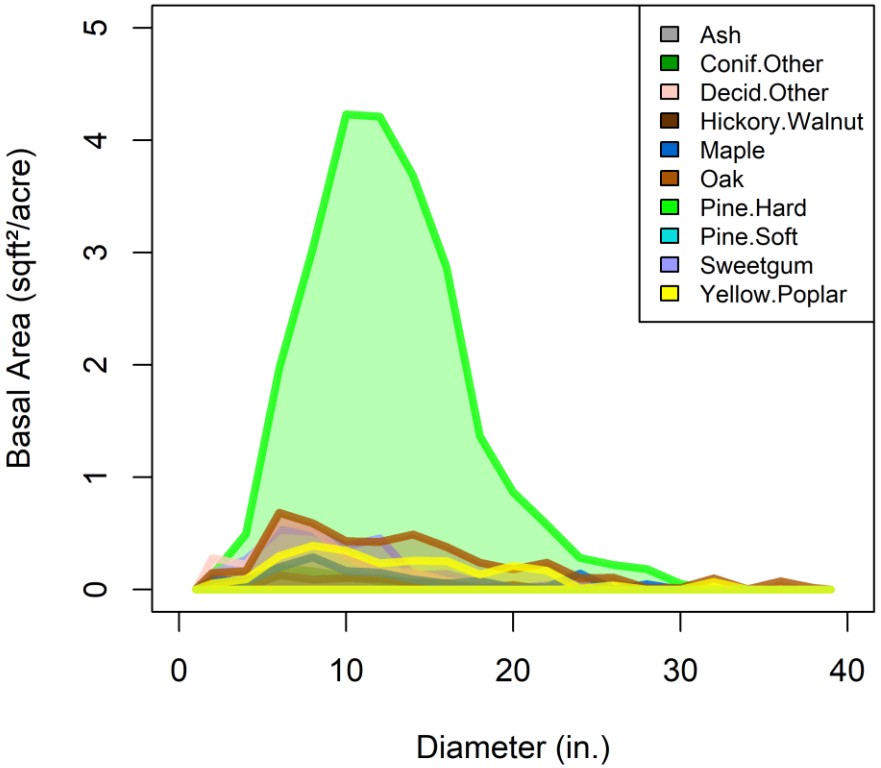
Synthetic Stands

Using k= 1:48

Steps 1 through 2i.-iii.

Pine Plantation



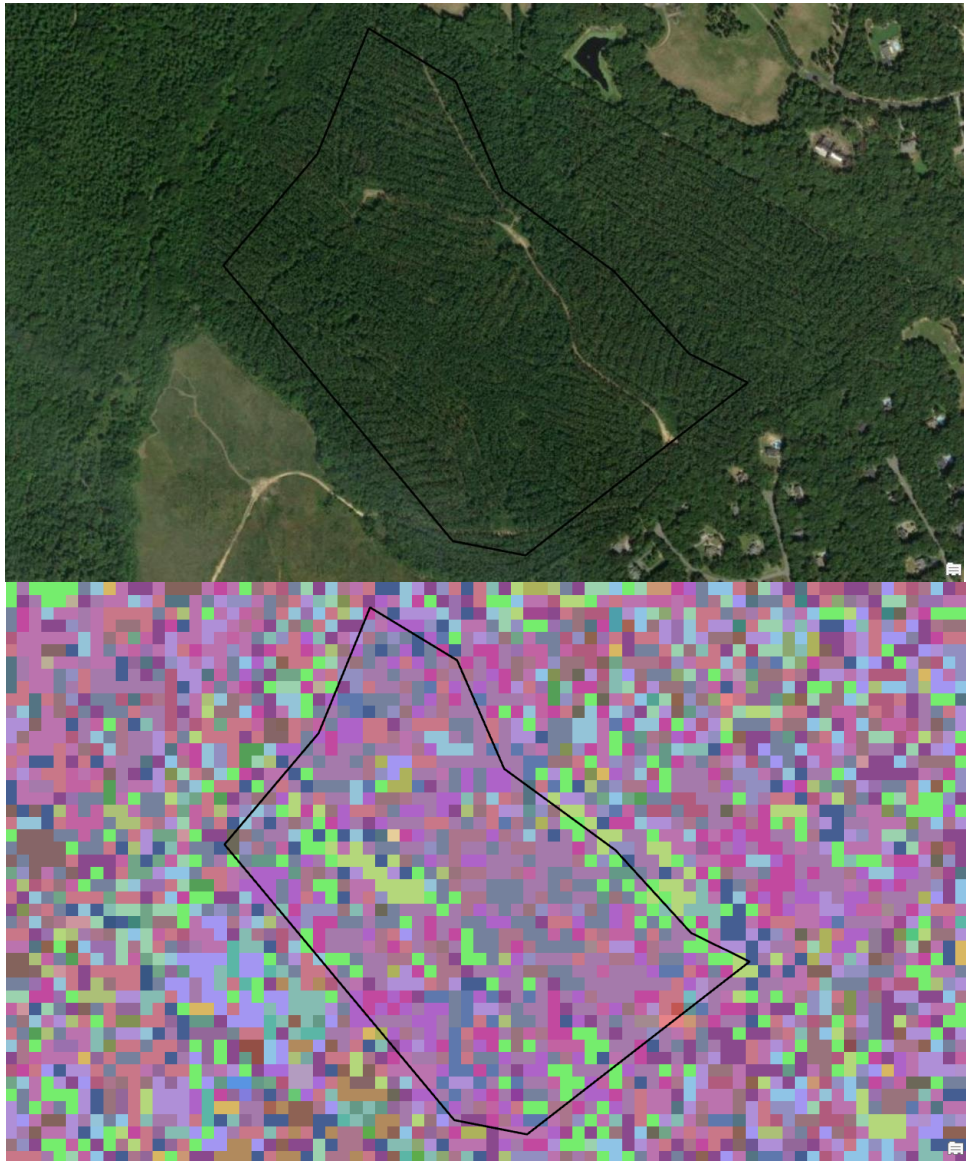


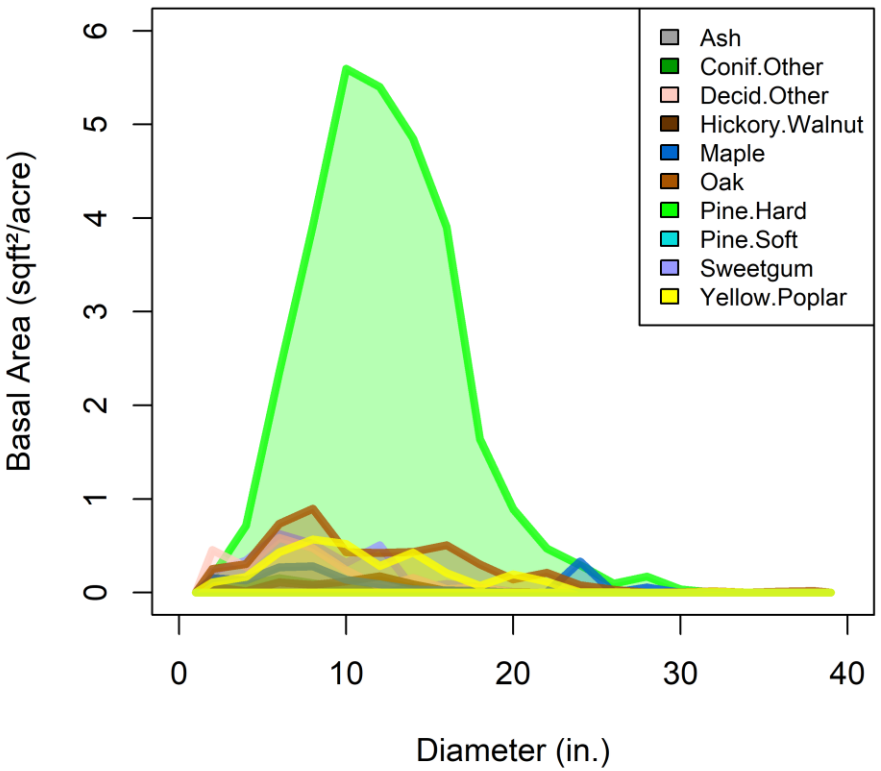
Synthetic Stands

Using k = 1:171

Steps 1 through 2i.-iii.

Pine Plantation



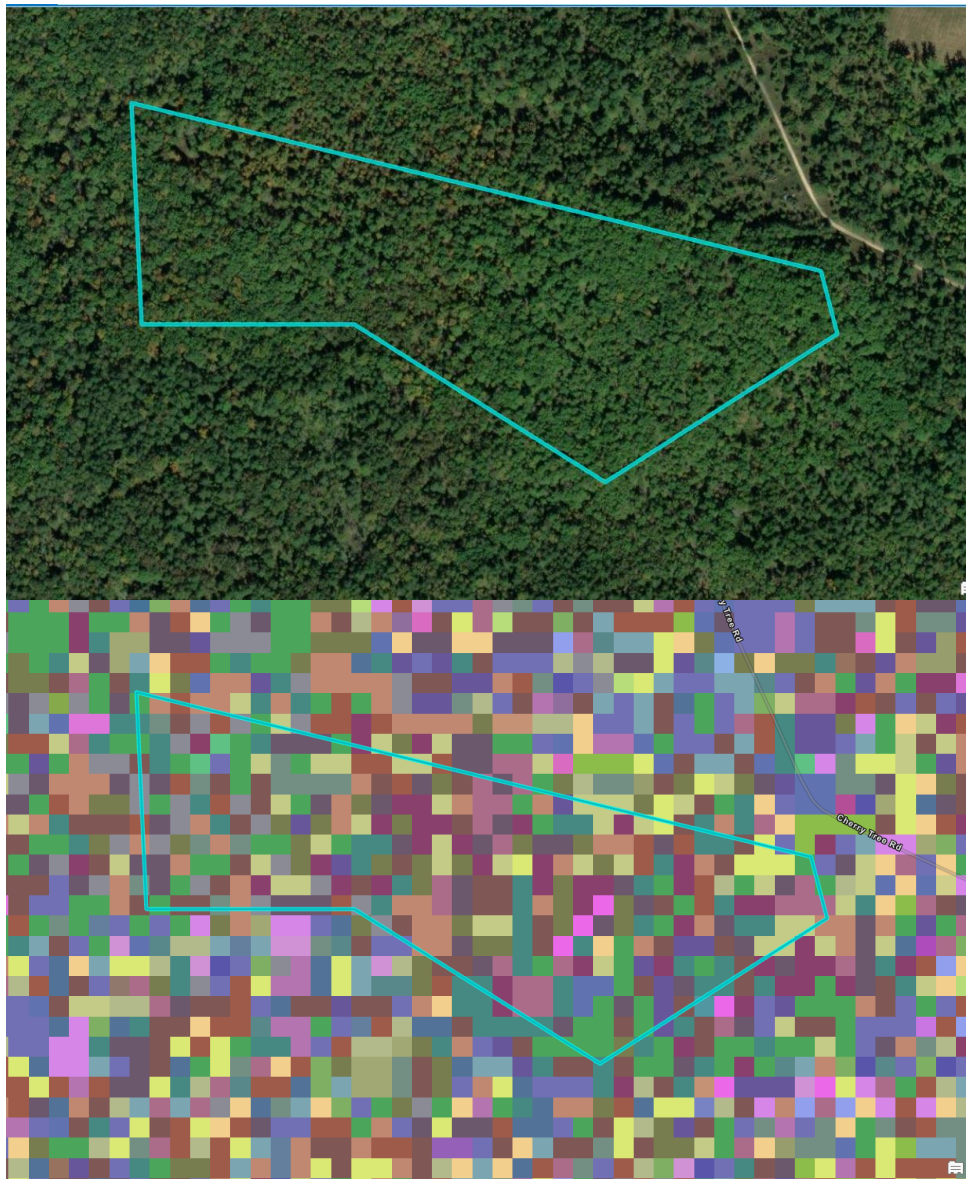


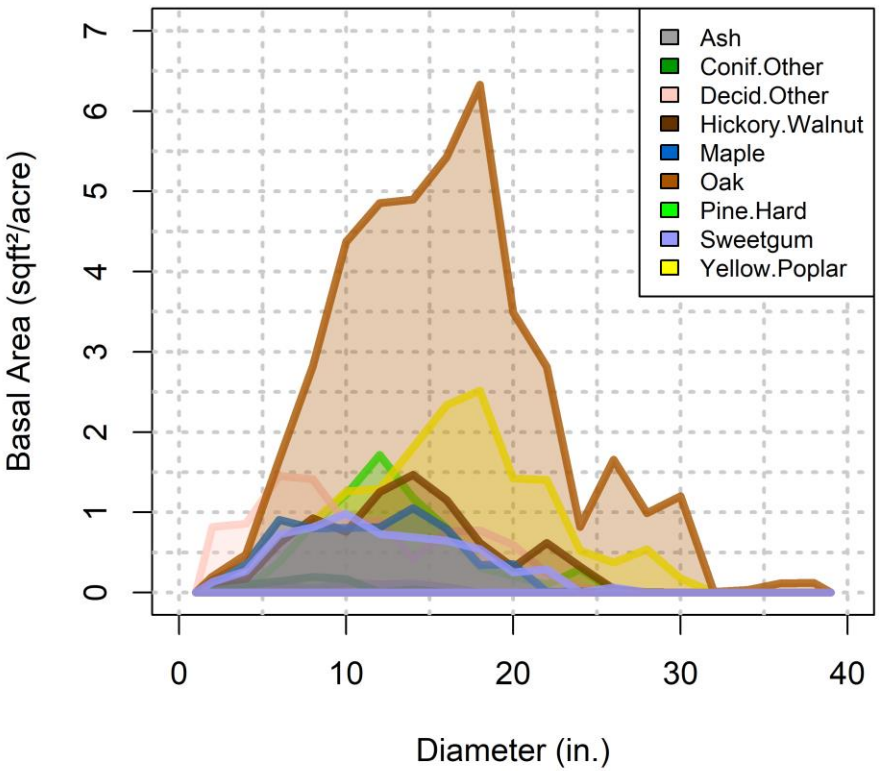
Synthetic Stands

Using k= 1:48

Steps 1 through 2i.-iii.

Fort Barfoot Deciduous



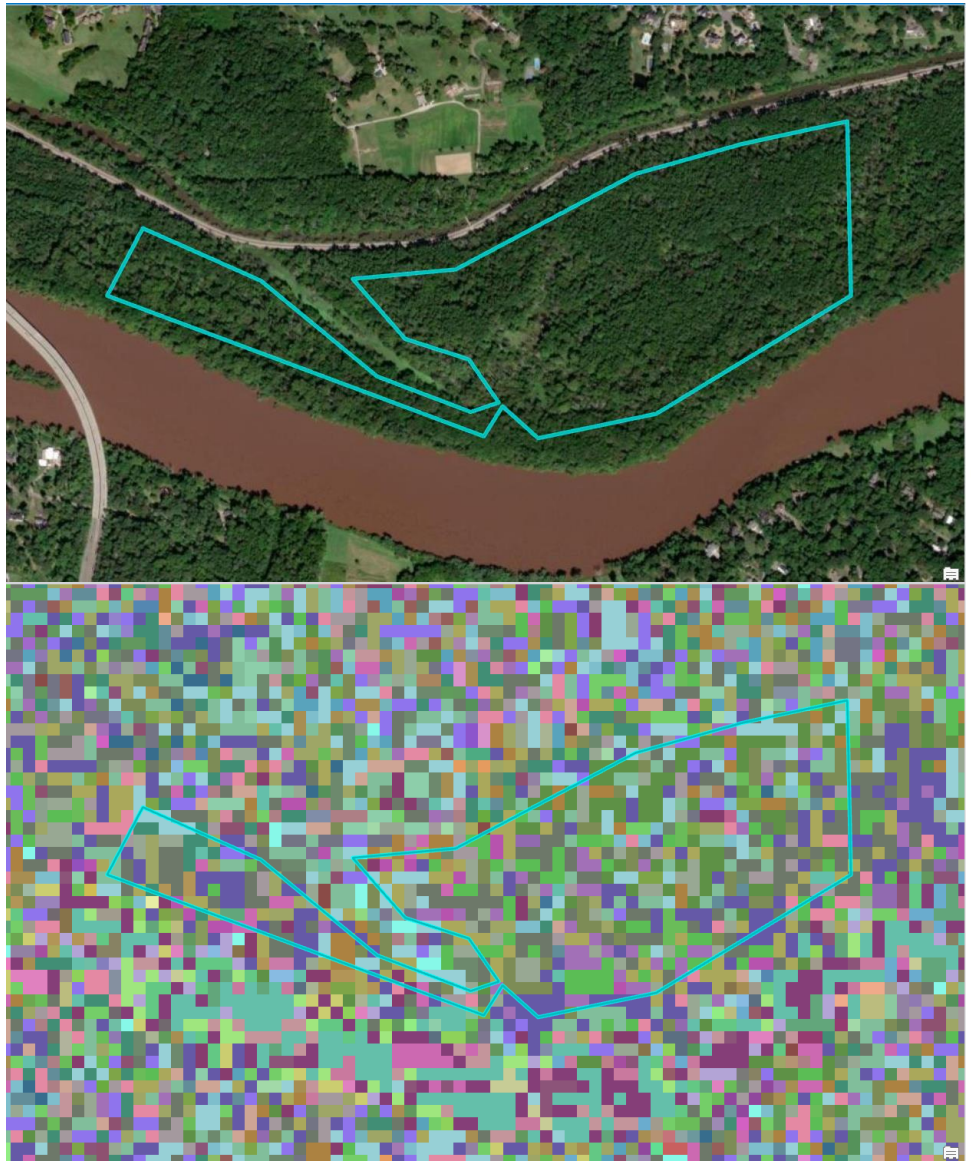


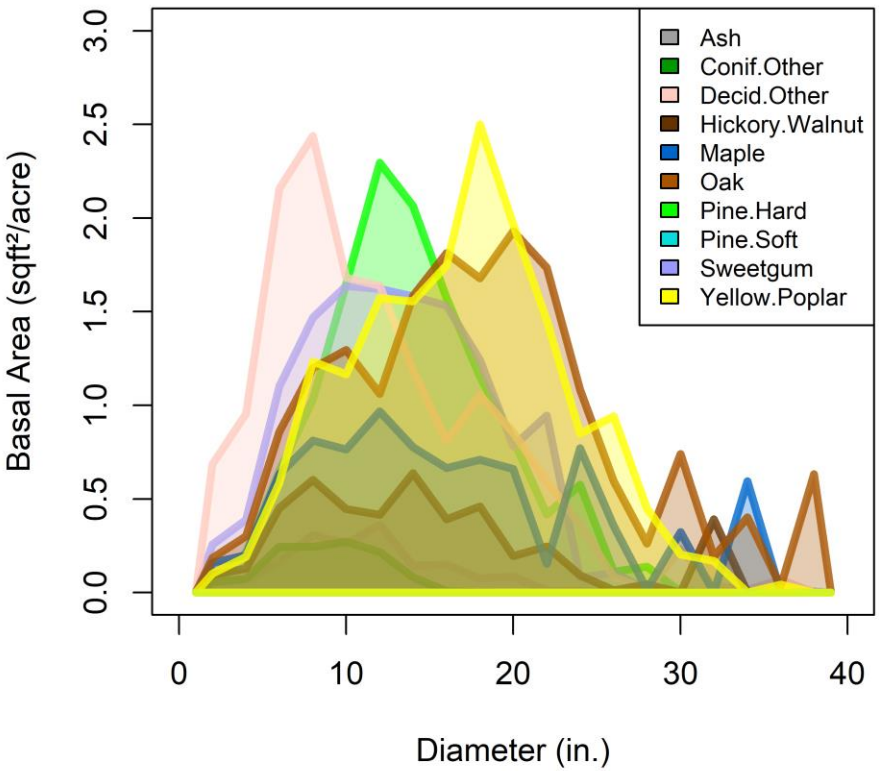
Synthetic Stands

Using k= 1:48

Steps 1 through 2i.-iii.

Bottomland Hardwood



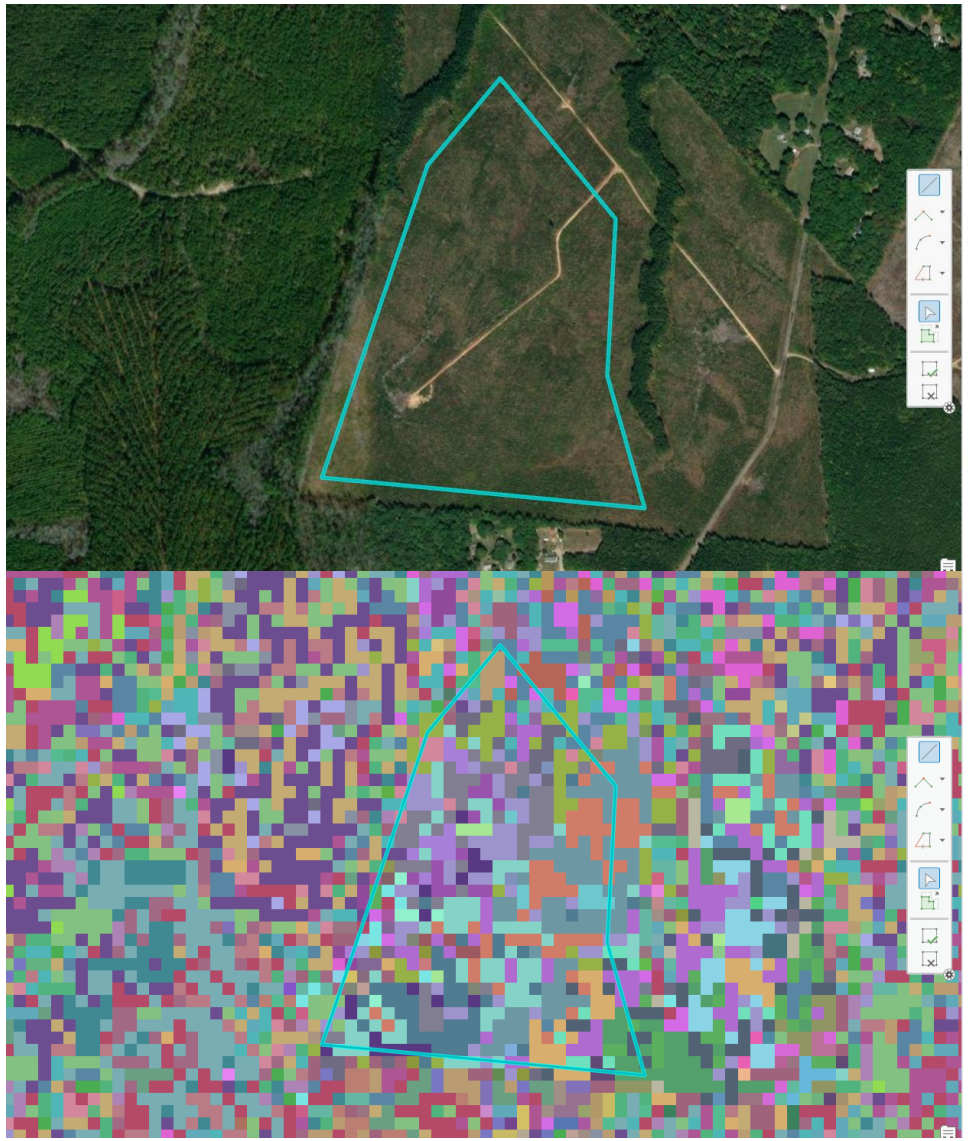


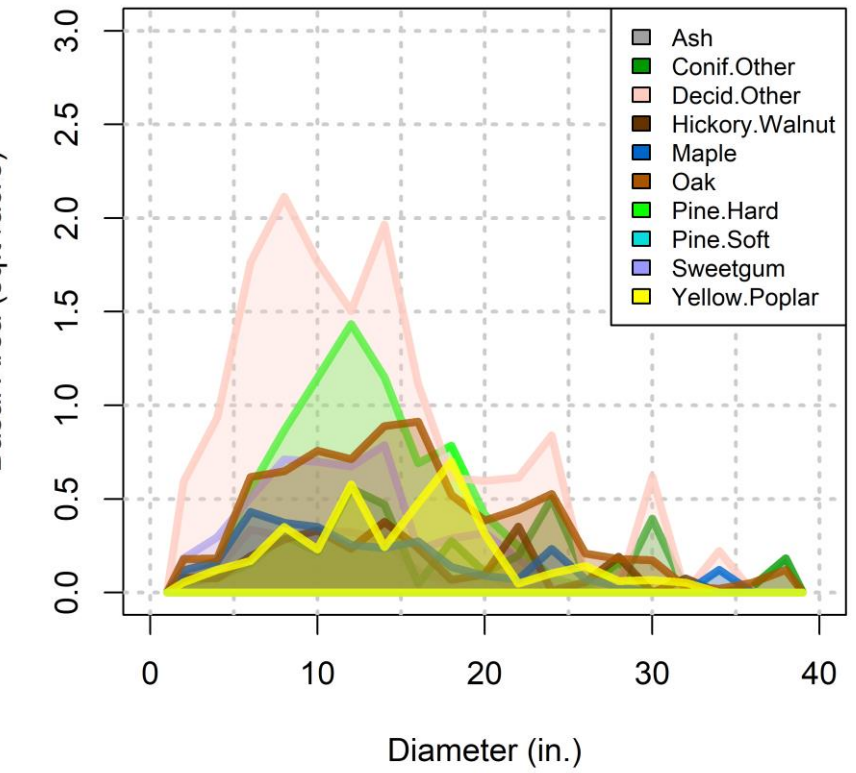
Synthetic Stands

Using k= 1:48

Steps 1 through 2i.-iii.

Recently Cut Pine Plantation



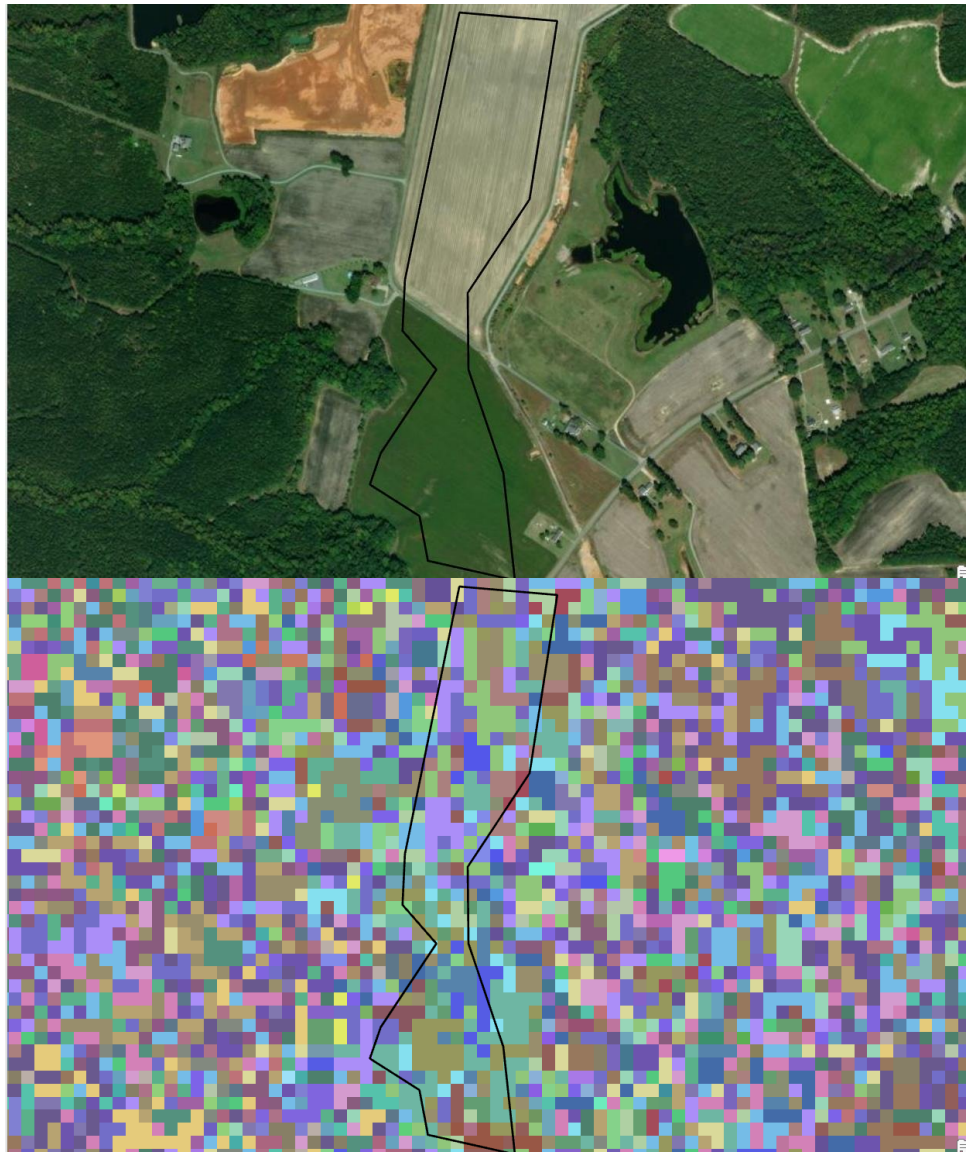


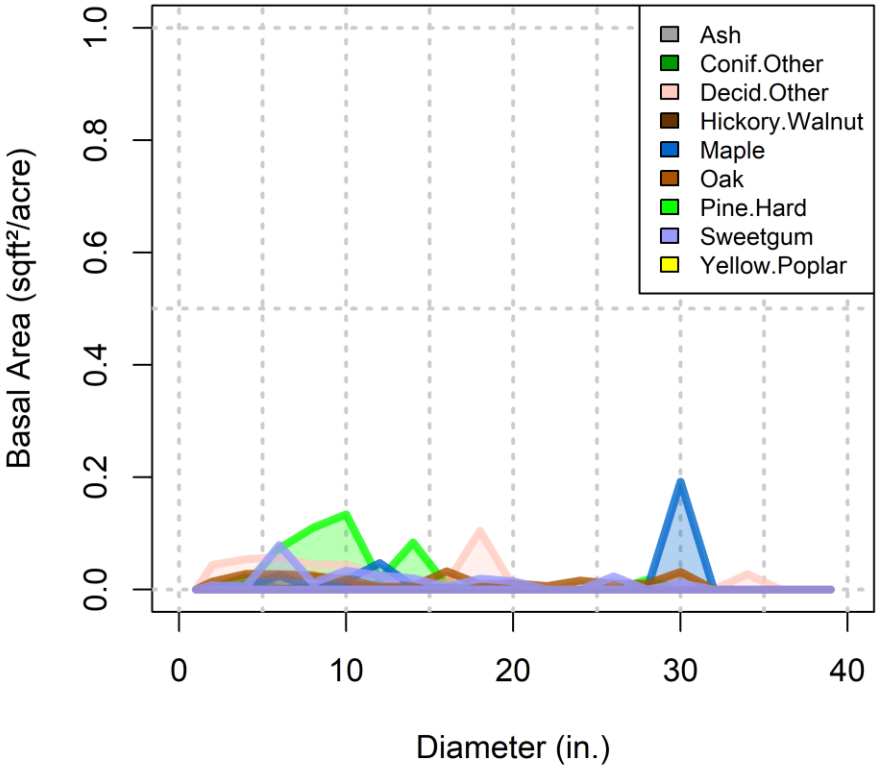
Synthetic Stands

Method struggles with stands disturbed during interval of BIGMAP imagery (2014:2018)

Steps 1 through 2i.-iii.

Agricultural Field





Synthetic Stands

Using k= 1:48
Capable of incorporating Non-Forested plots with some noise expected

Steps 1 through 2i.-iii.

Synthetic Stands

Synthetic Stand Attribute Summary

How many k neighbors used in this stand?

Current Summary Attributes

- TPA
- BA
- QMD
- BA sawtimber
- Shannon Diversity Index
- Simpson Diversity Index
- % Basal Area by Species Group Code

FIADB plotCN

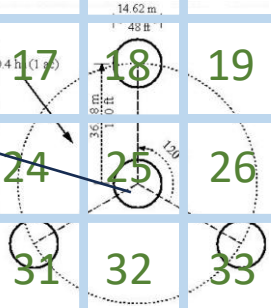
```
, , 1

                      TPA        BA      QMD BAsaw   ShanTPA    ShanBA   SimpTPA   SimpBA Longleaf and slash pines
335444999489998  158.3889  17.47559 4.497694    NA 0.8861618 0.5786193  2.230789 1.495932              0.000000000
335445000489998  164.5333  53.56367 7.725819    NA 1.2684395 0.3514631  2.543357 1.158278              0.000000000
335445717489998  473.0556 109.11314 6.503075    NA 2.0835640 1.1430571  4.451392 1.692521              0.000000000
335445736489998  905.4444  44.57935 3.004500    NA 1.7900778 2.4653919  3.838049 8.970726              0.040216853
335445737489998 1214.1444 155.18110 4.840838    NA 2.1050464 1.1984747  4.847022 1.819876              0.000000000
461363022489998  832.9889 131.42014 5.378333    NA 2.2325807 1.6672136  7.185914 3.095493              0.000000000
461363019489998  417.0000  21.81225 3.096838    NA 1.5512305 1.6178906  3.998715 3.717436              0.000000000
461363020489998  384.4222  72.16767 5.866829    NA 1.4294428 0.6554507  3.047409 1.337962              0.000000000
335444145489998 1186.7556 147.75642 4.777810    NA 2.1001708 1.6171017  5.118445 3.074598              0.192972066
335444146489998  451.4222  61.56116 5.000325    NA 1.5622116 0.9208115  3.545201 1.602318              0.000000000
264157970489998  337.7889  88.10761 6.915448    NA 1.8024556 1.7934908  4.022033 3.556155              0.000000000
264157971489998 1897.0667  93.56928 3.007195    NA 0.6583284 0.7501455  1.332209 1.372160              0.001398960
264157972489998  923.7000 104.12416 4.546180    NA 1.7799517 2.0204749  4.917307 5.965838              0.000000000
264157973489998  279.7778  84.90275 7.459171    NA 2.1928786 1.9061645  6.639411 4.719108              0.000000000
264159709489998 1574.6778  60.55808 2.655379    NA 2.3473106 2.4727026  8.308572 9.343123              0.000000000
264160422489998    0.0000   0.00000 0.000000     0 0.0000000 0.0000000  0.000000 0.000000              0.000000000
264160424489998  407.6222  41.13474 4.301419    NA 1.9816850 1.9828560  5.031300 4.619194              0.000000000
                 Loblolly and shortleaf pines Other yellow pines Eastern white and red pines Jack pine Spruce and ba
335444999489998                   0.79605227          0.000000000                         0         NA
335445000489998                   0.92818805          0.000000000                         0         NA
335445717489998                   0.77246270          0.000000000                         0         NA
```

Point-Scale Validation

7x7 Window

Centered on Subplot 1, the 'focal' pixel

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49

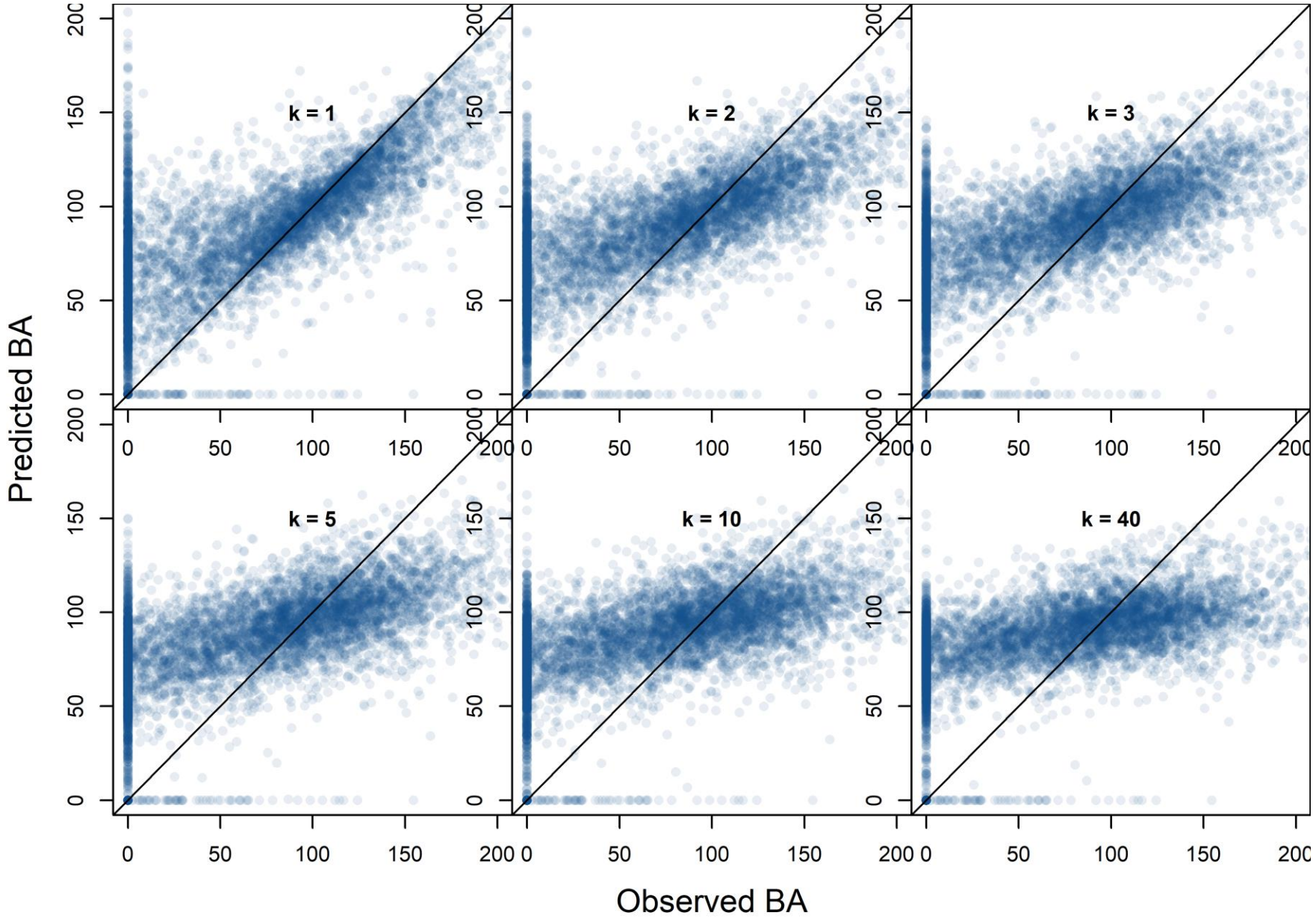


Use a 7x7 window to mimic the pixels that would be in the stand characterized by the FIA plot

- Mask out non-forest
- Mask out 'focal' plot (the actual pixel used in FeatureSpace)
- Mask out occurrences of 'focal' plot anywhere in frequency table

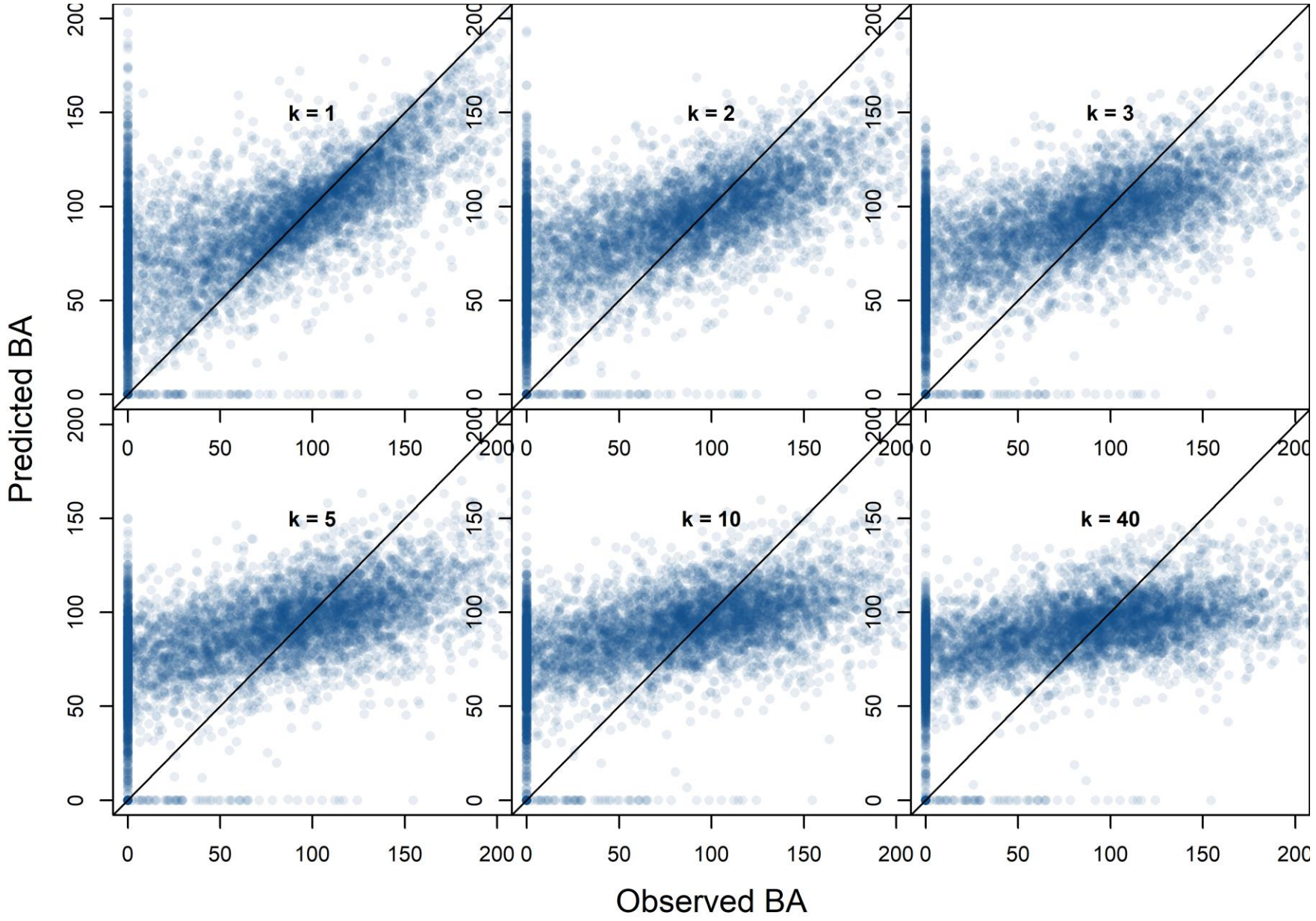
Pixels/plot to scale

Point-Scale Validation



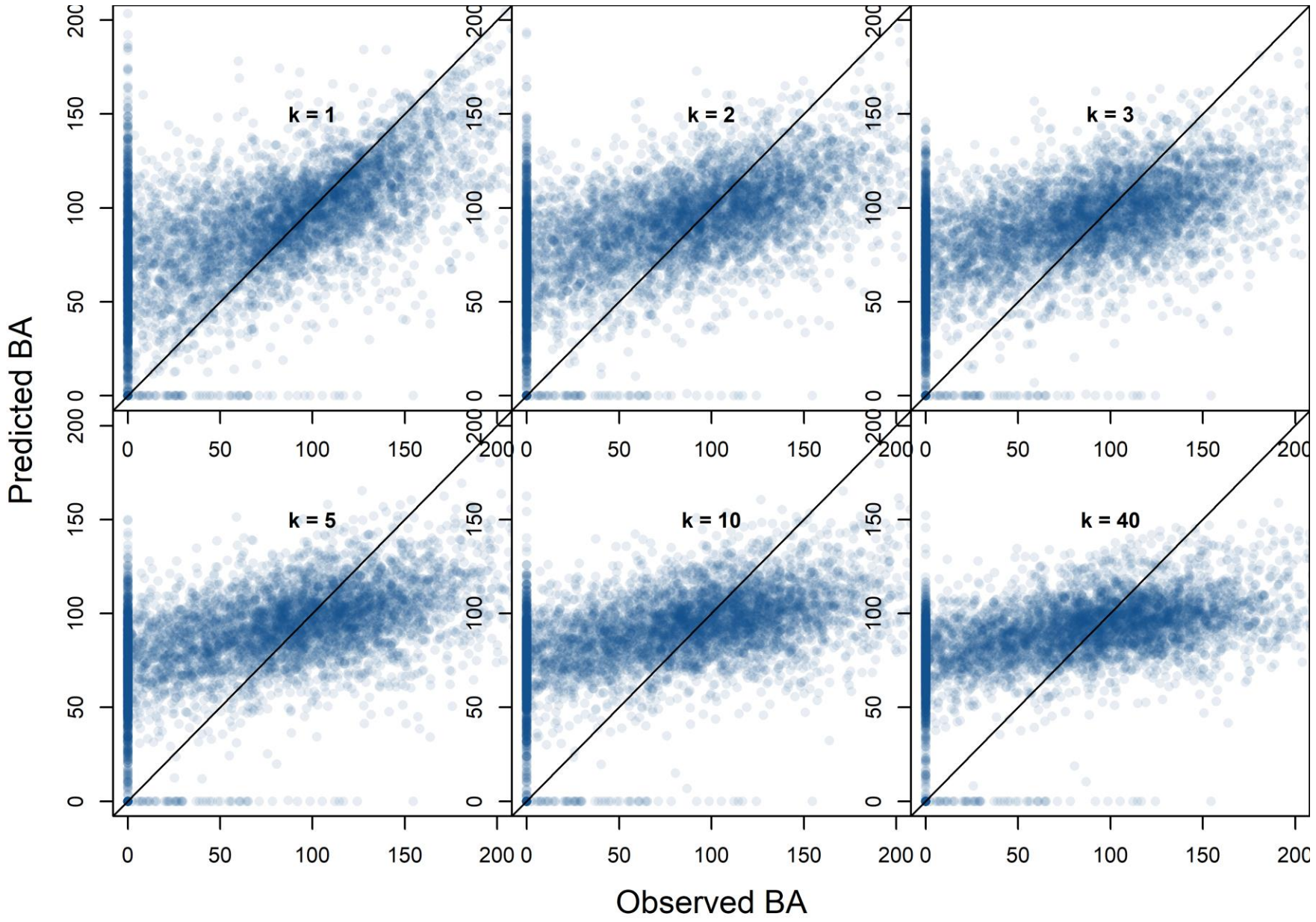
7x7 window
Masked to just forest
Holdout central instance of focal plot

Point-Scale Validation



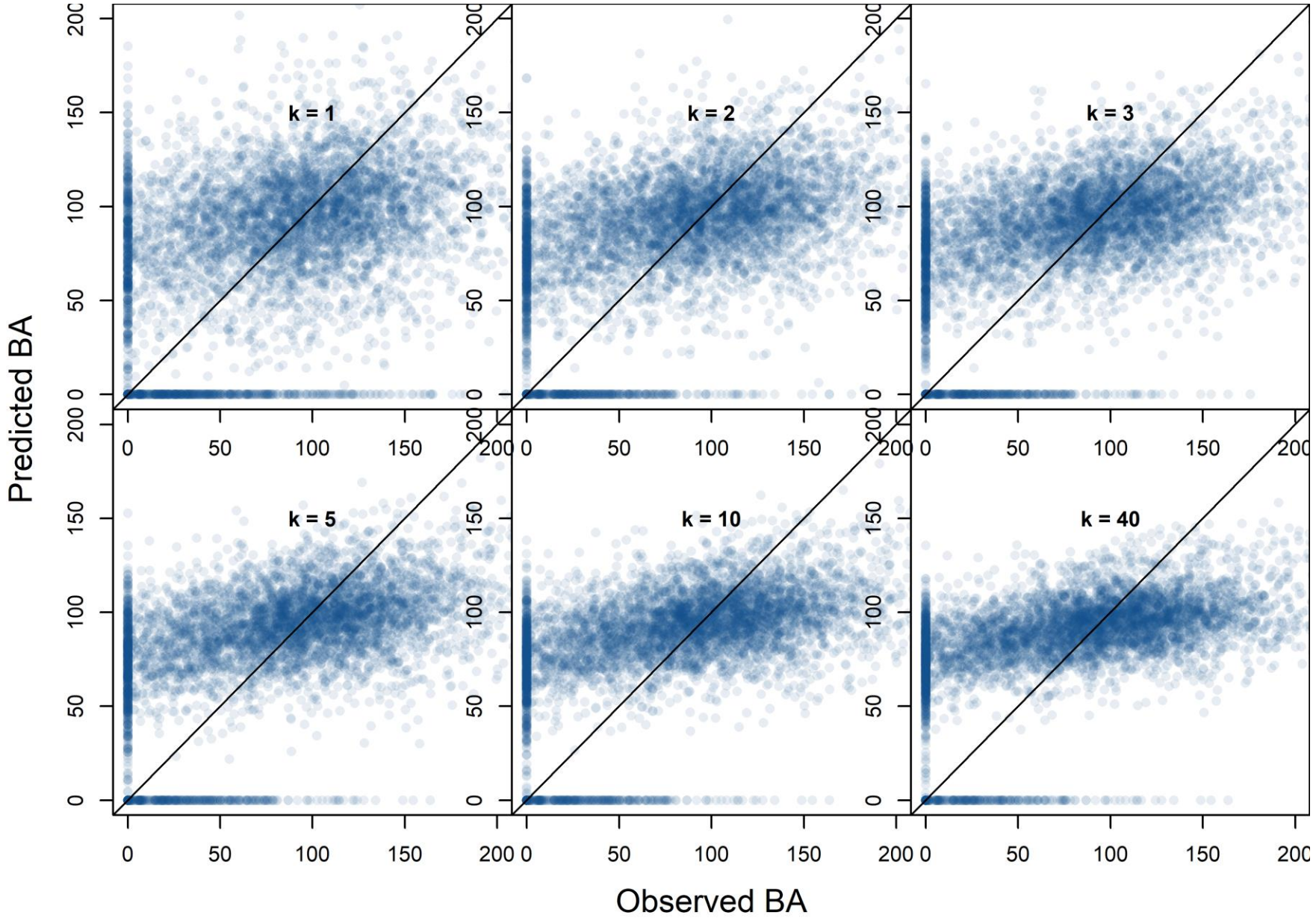
7x7 window
Masked to just forest
Holdout any instance of focal plot in central 3x3 window

Point-Scale Validation



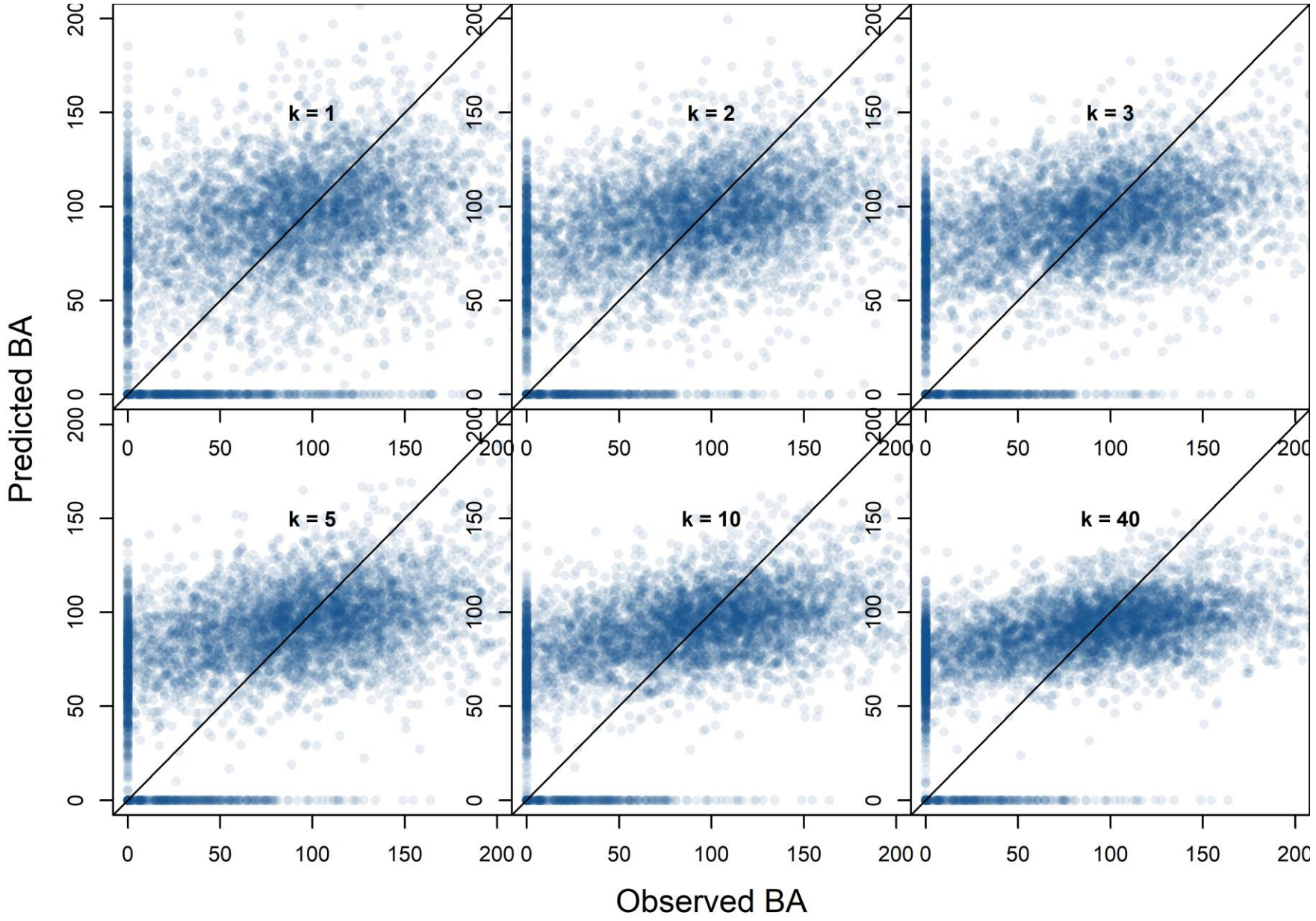
7x7 window
Masked to just forest
Holdout any instance of focal plot in central 5x5 window

Point-Scale Validation



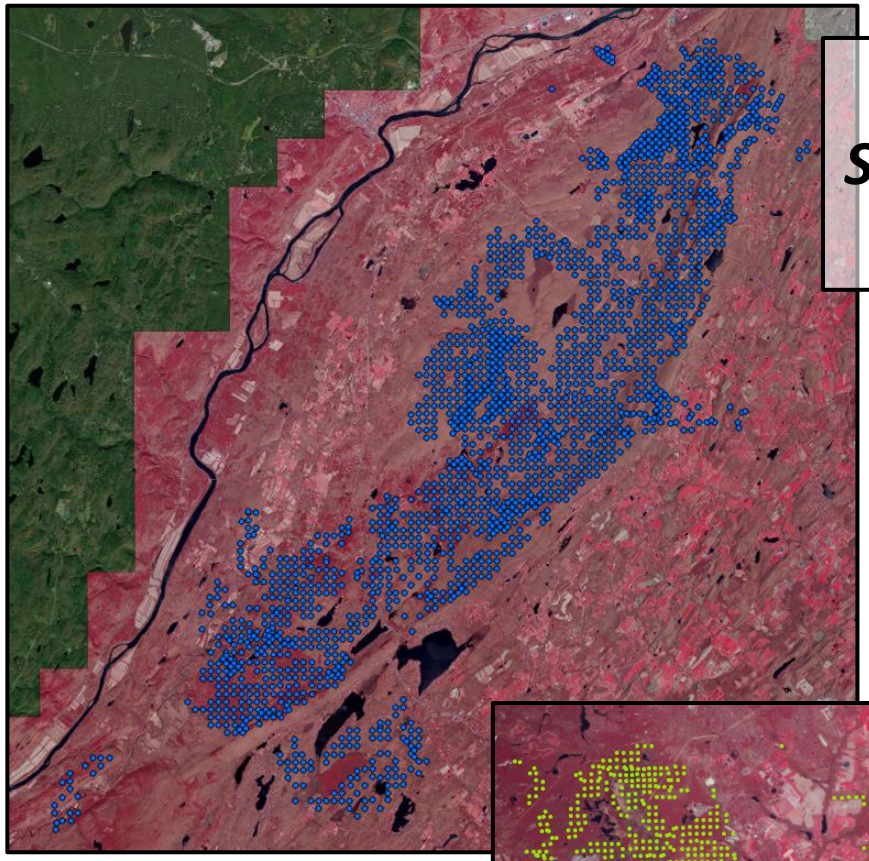
7x7 window
Masked to just forest
Holdout any instance of focal plot in whole window

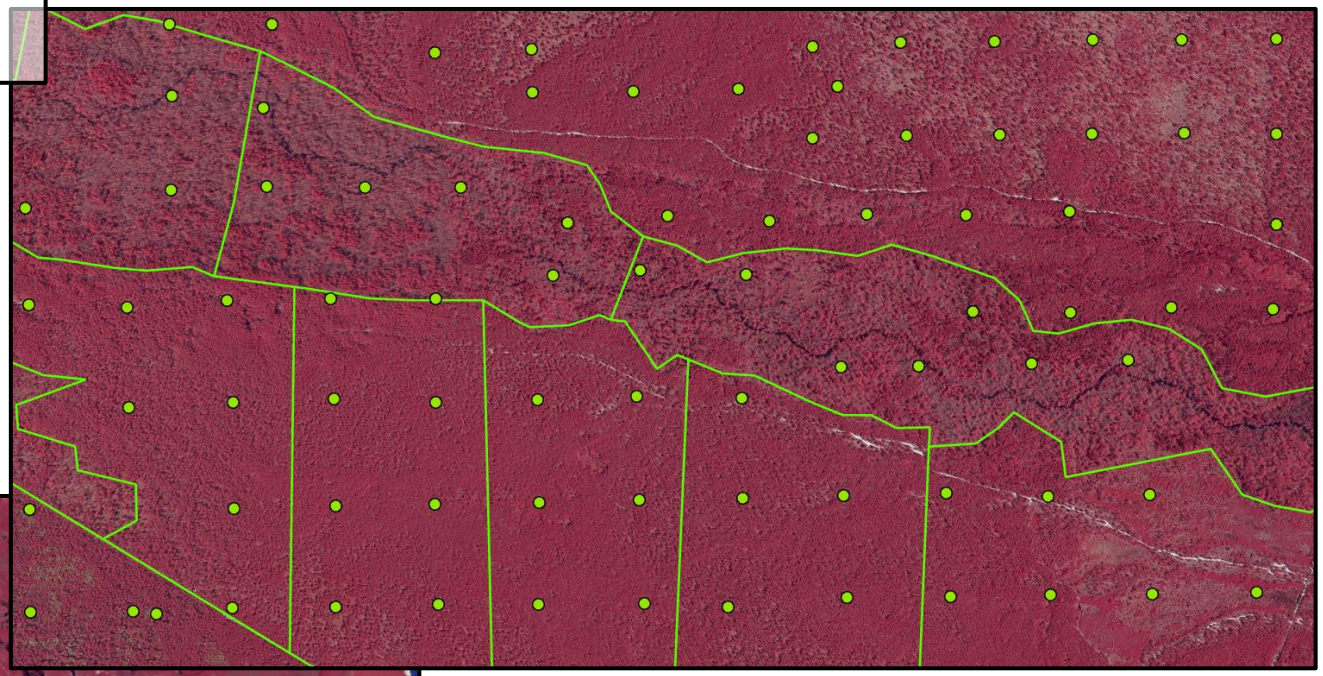
Point-Scale Validation

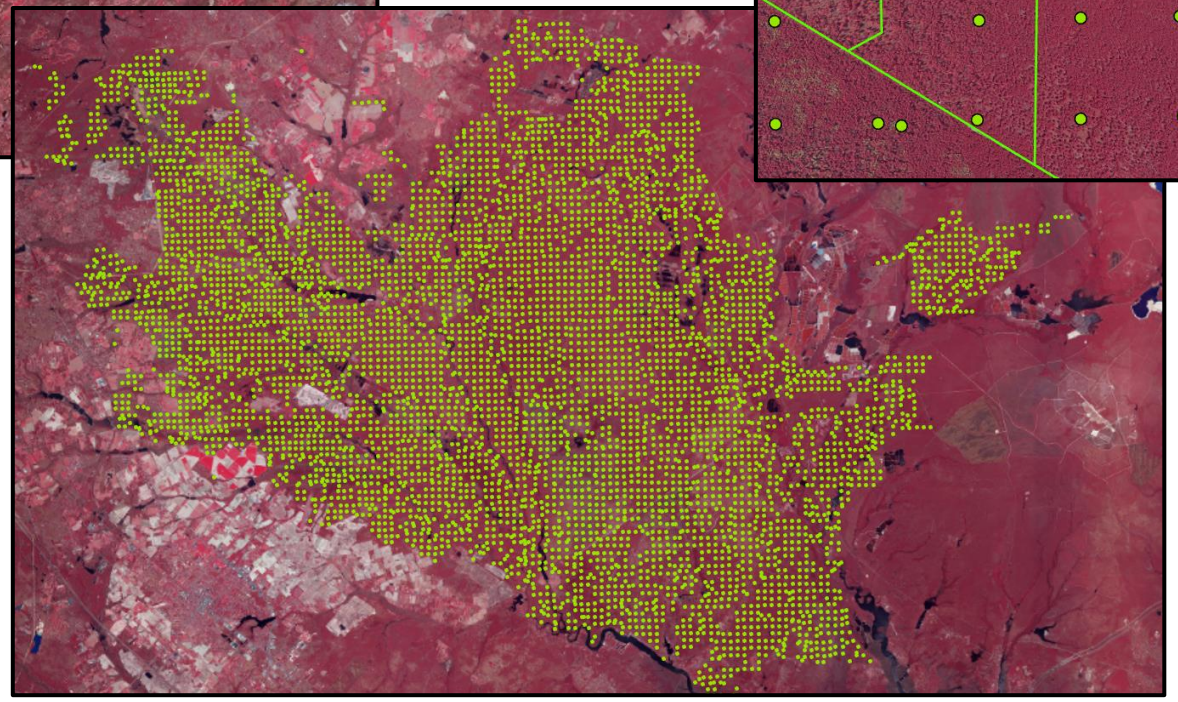


7x7 window
Masked to just forest
Holdout any instance of focal plot in whole window
Neighborliness Weights (1/freq)

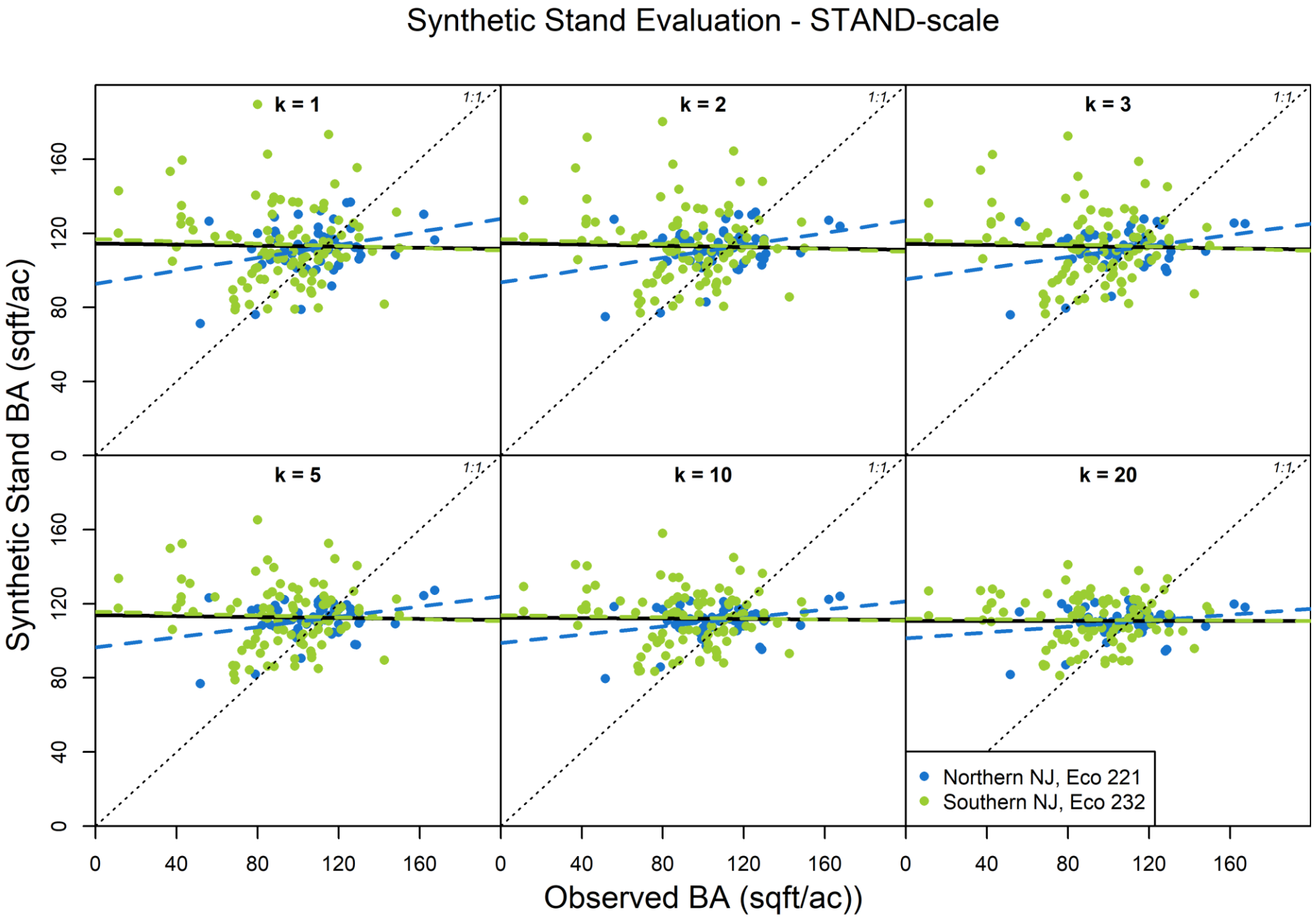
New Jersey State Inventory Stand - Scale





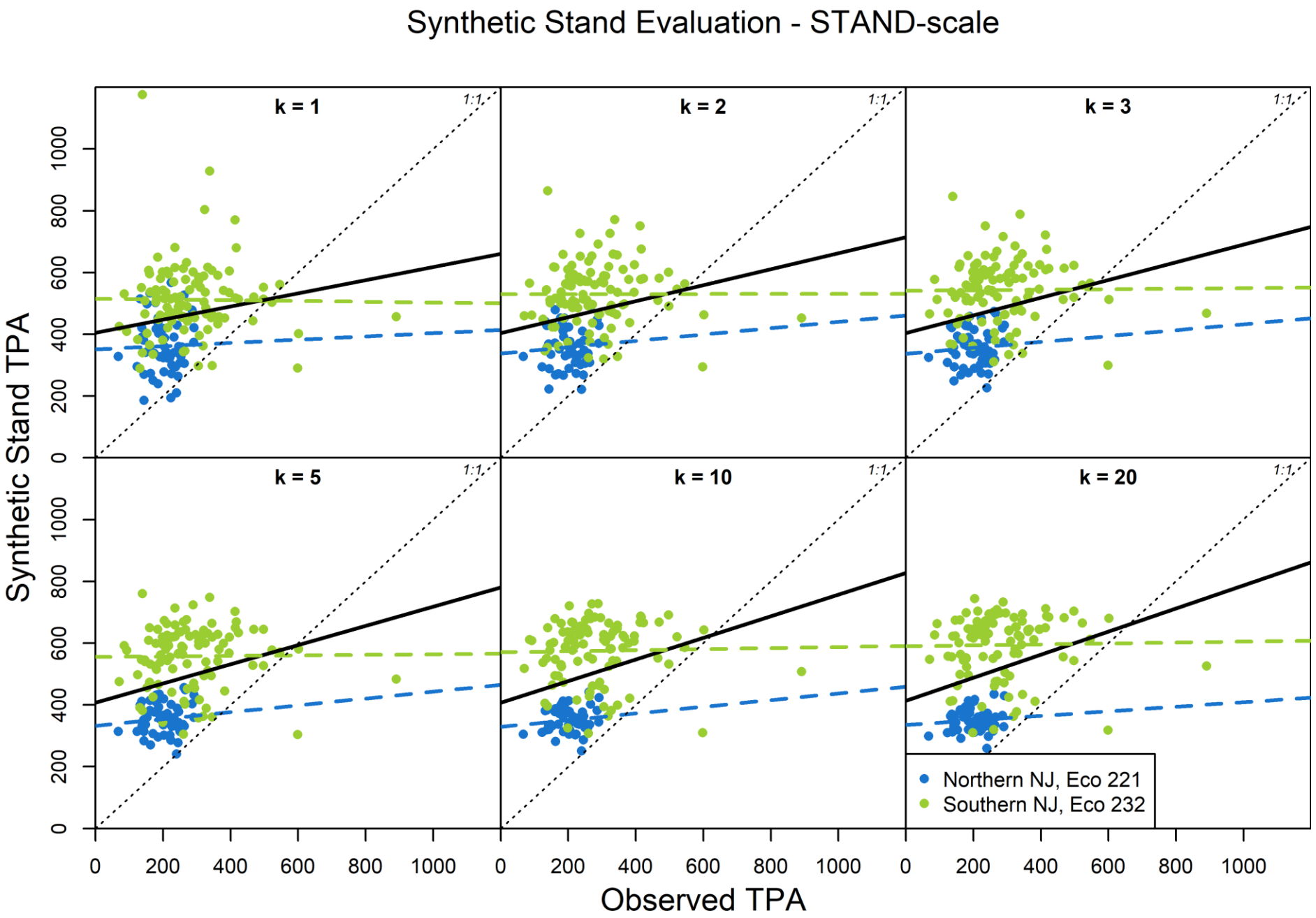


New Jersey State Inventory Stand - Scale



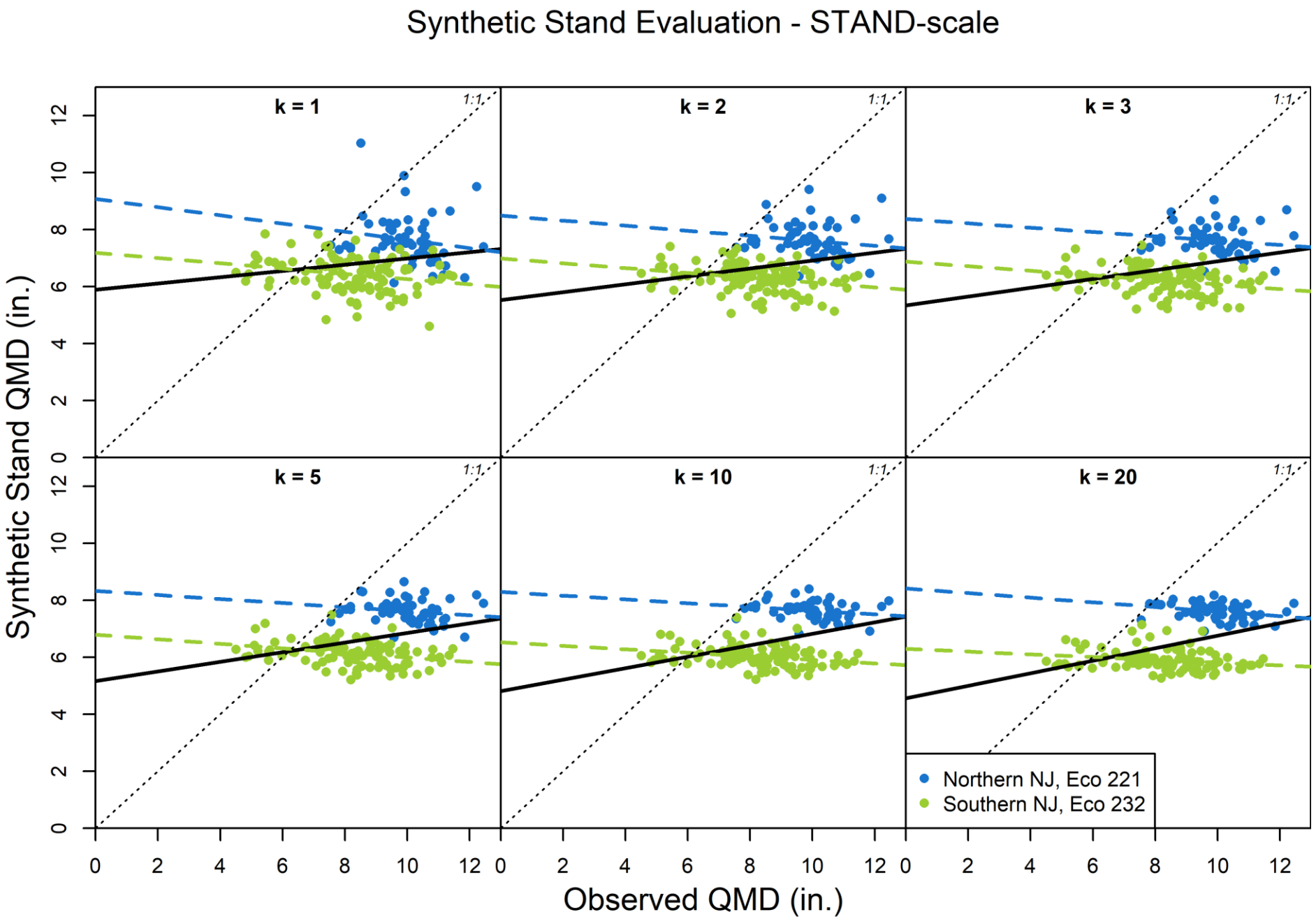
Stand structure needs improvement

New Jersey State Inventory Stand - Scale



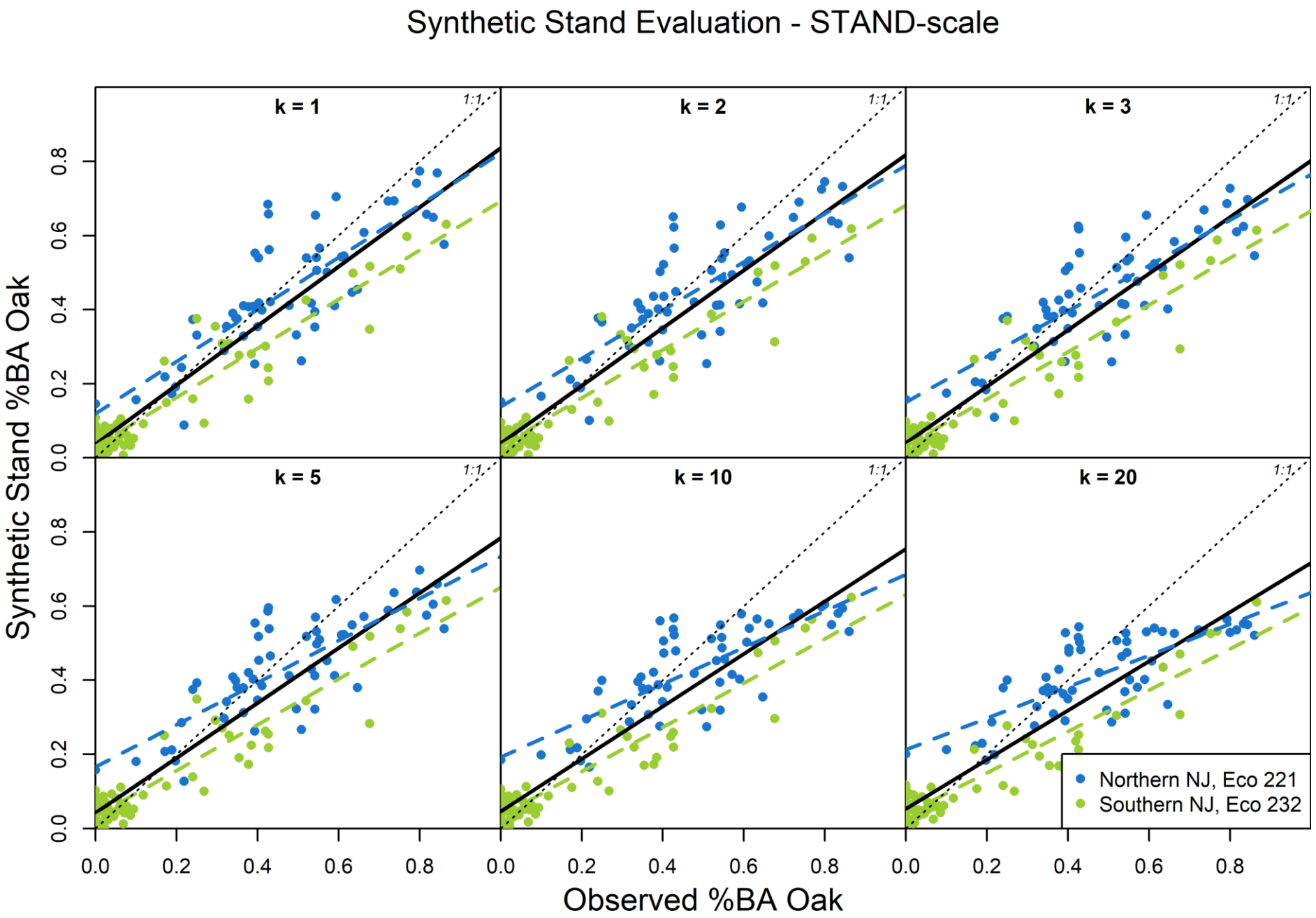
Stand structure needs improvement

New Jersey State Inventory Stand - Scale



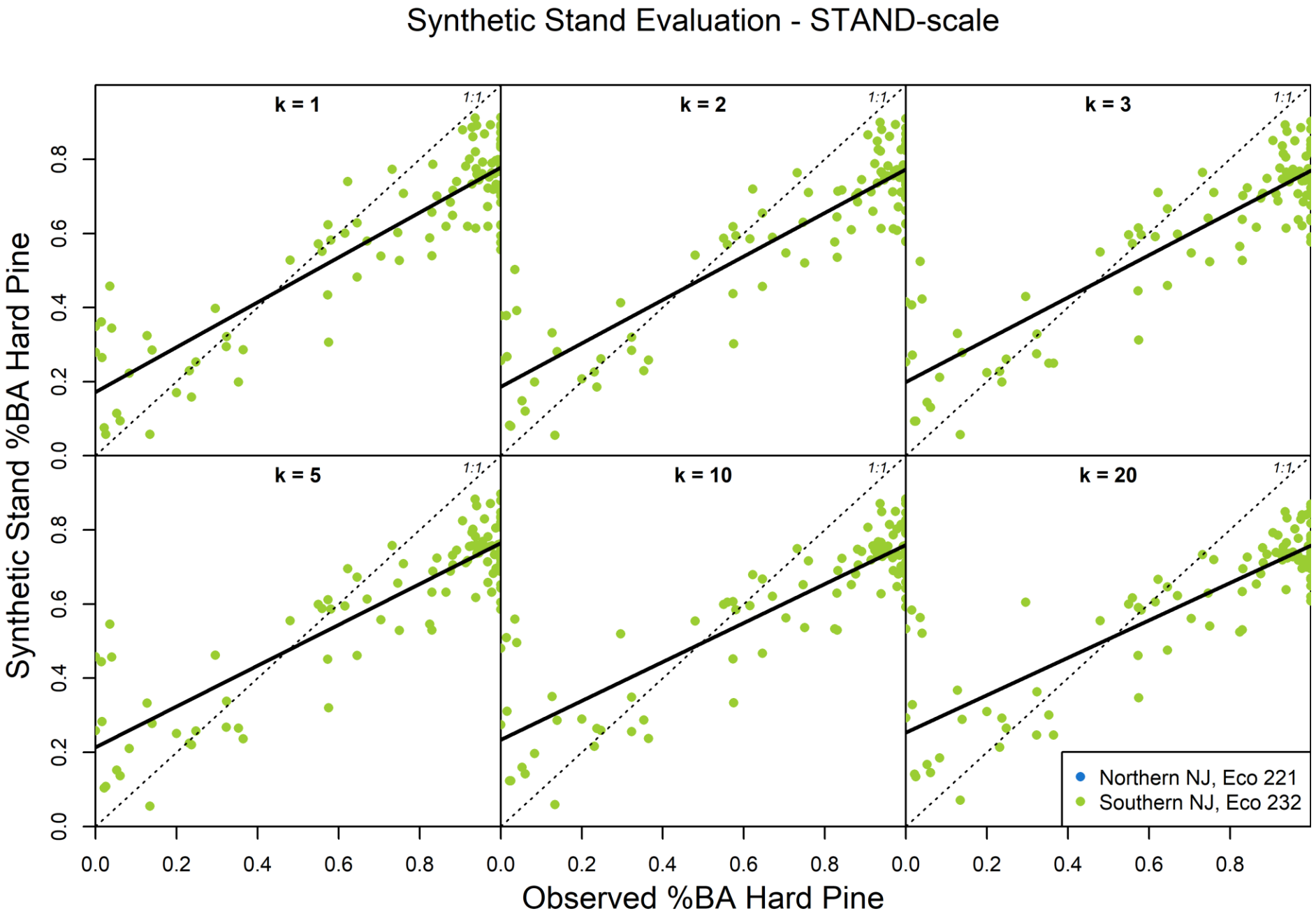
Stand structure needs improvement

New Jersey State Inventory Stand - Scale



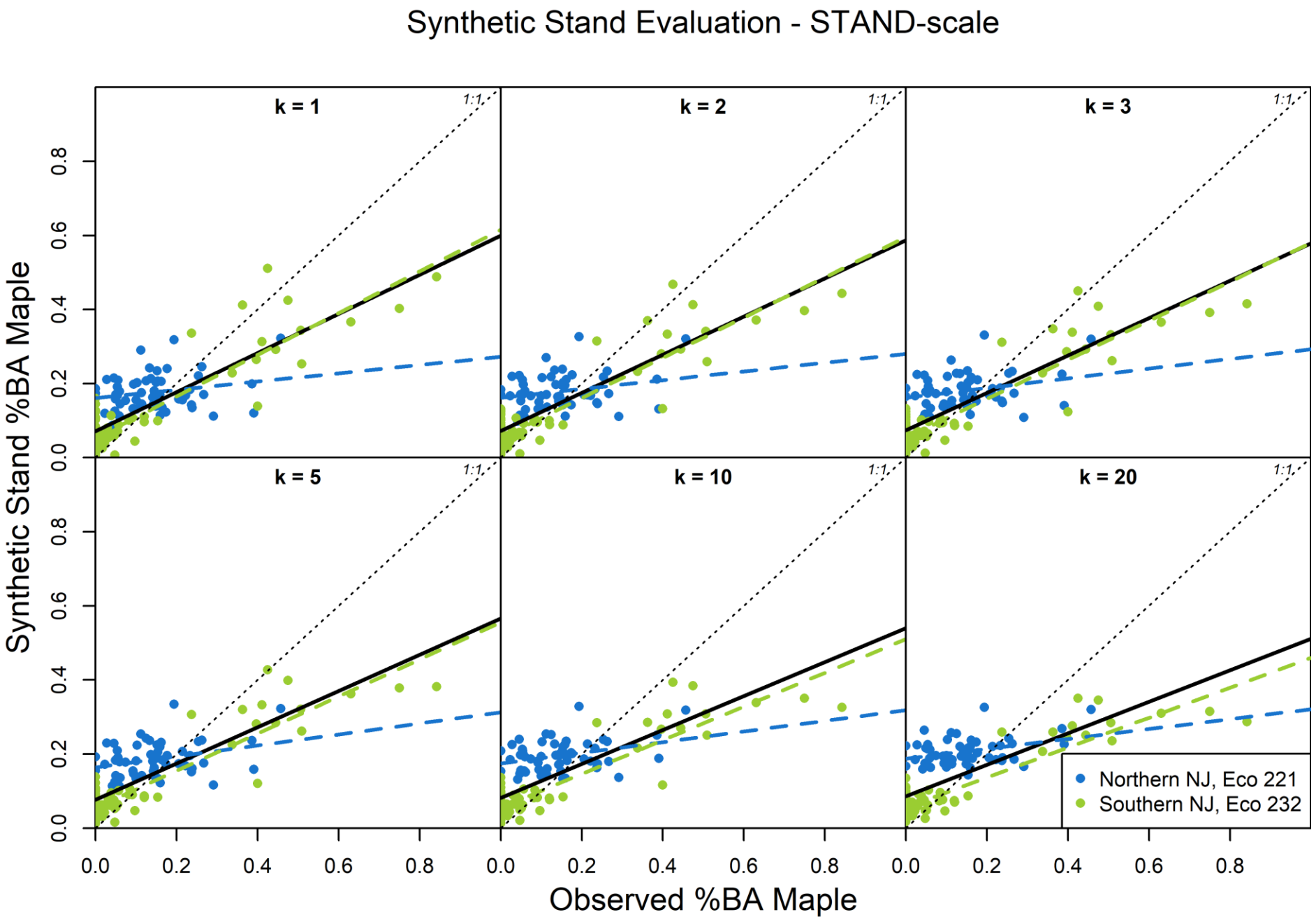
Relative composition at the species group appears usable

New Jersey State Inventory Stand - Scale

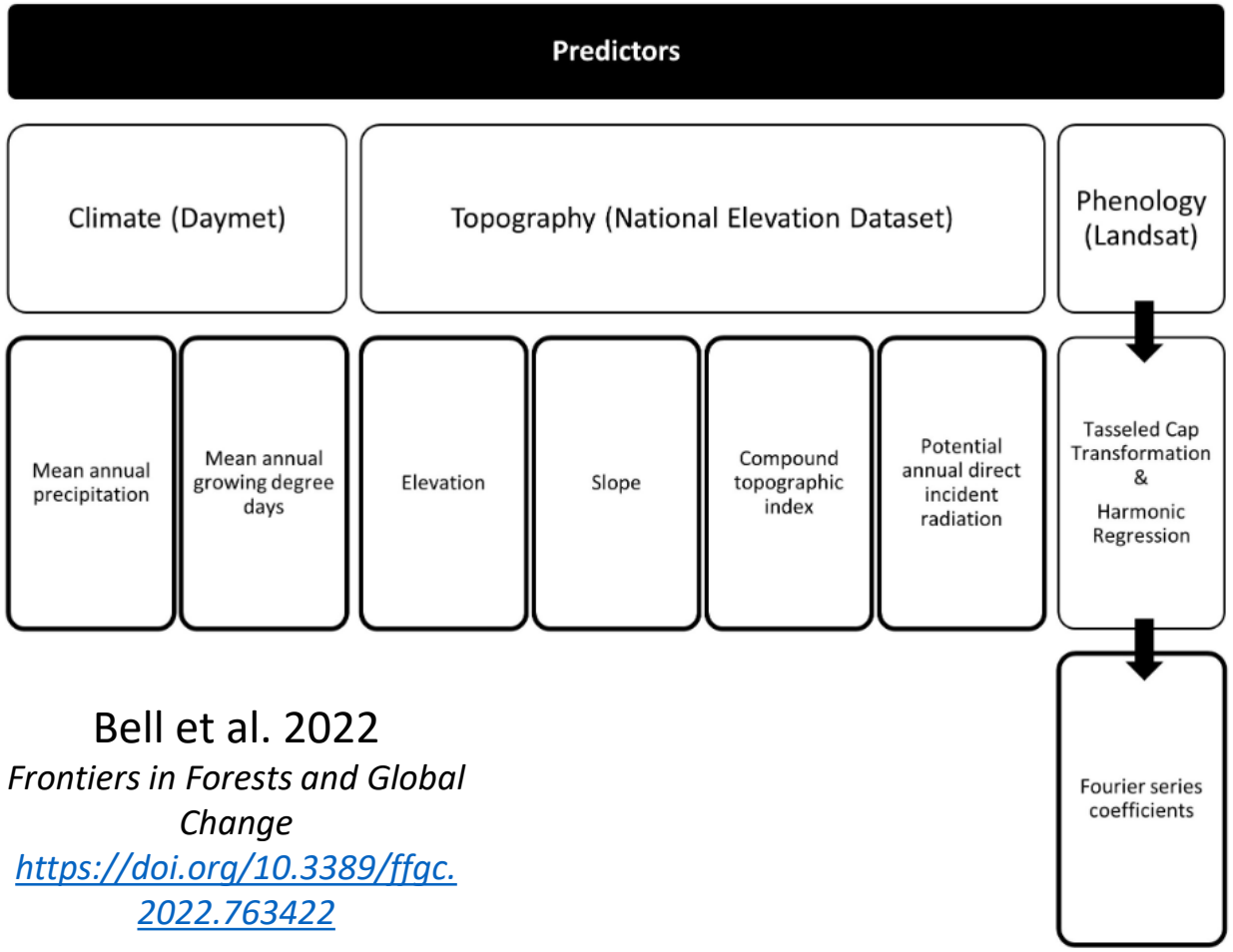


Relative composition at the species group appears usable

New Jersey State Inventory Stand - Scale



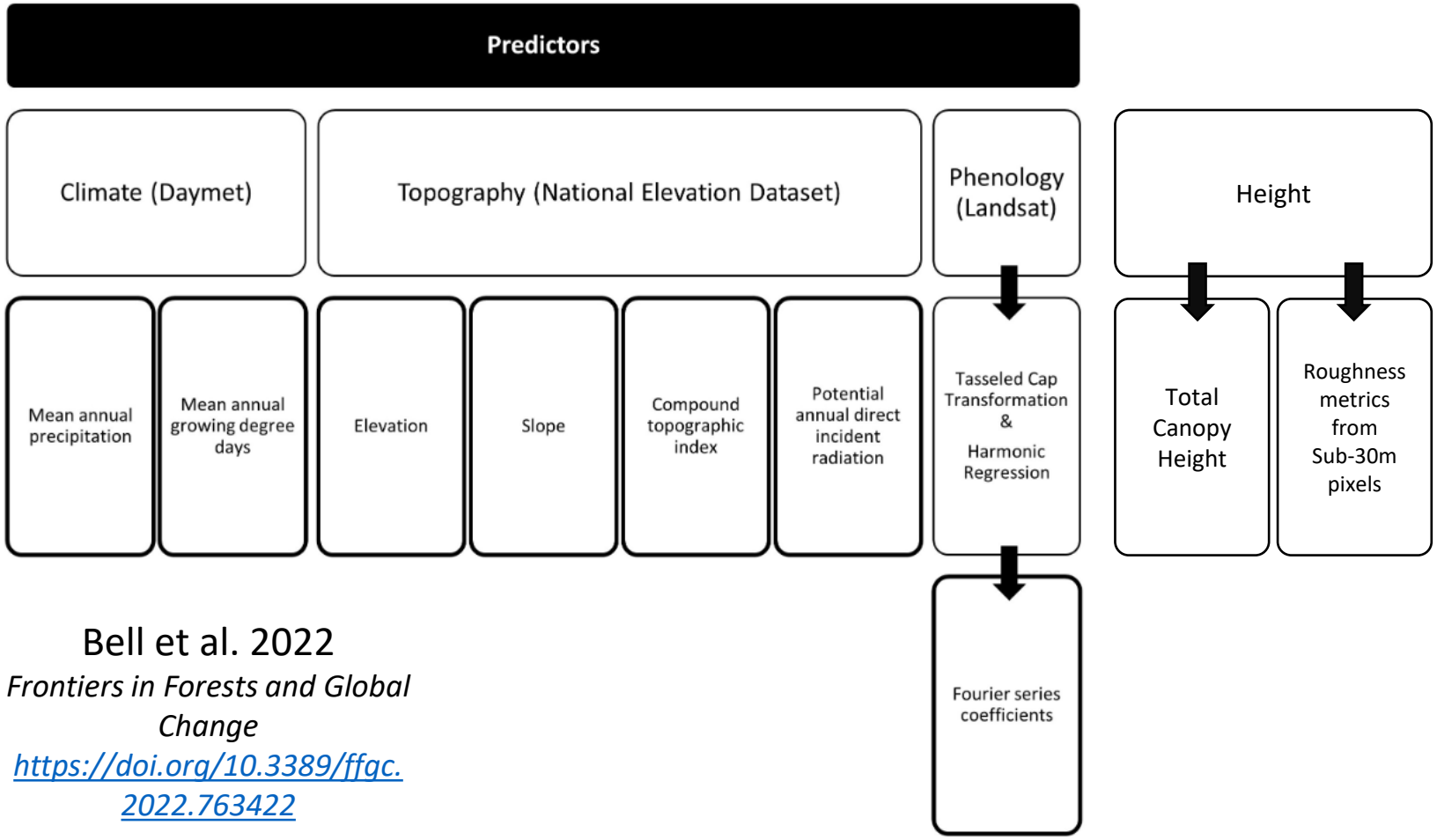
Relative composition at the species group appears usable



Bell et al. 2022
Frontiers in Forests and Global Change
https://doi.org/10.3389/ffgc.2022.763422

Improvement Steps

None of the existing predictors directly characterize stand structure



Bell et al. 2022
Frontiers in Forests and Global Change
https://doi.org/10.3389/ffgc.2022.763422

Improvement Steps

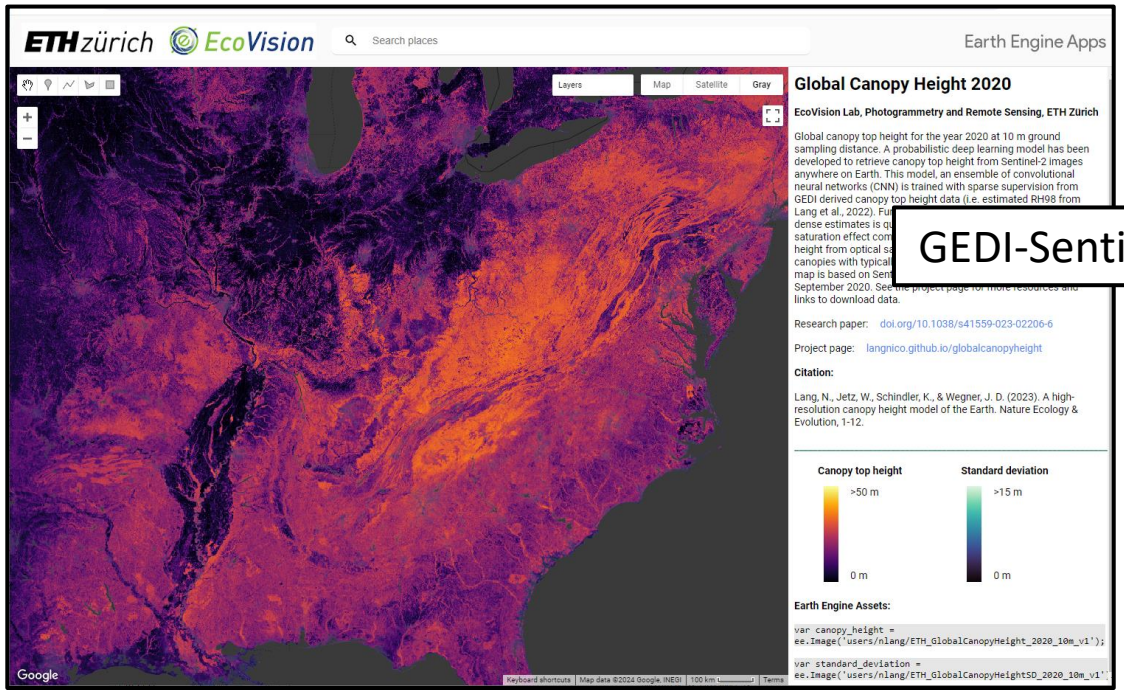
None of the existing predictors directly characterize stand structure

Re-run BIGMAP with structural information (e.g. height+) for selected provinces

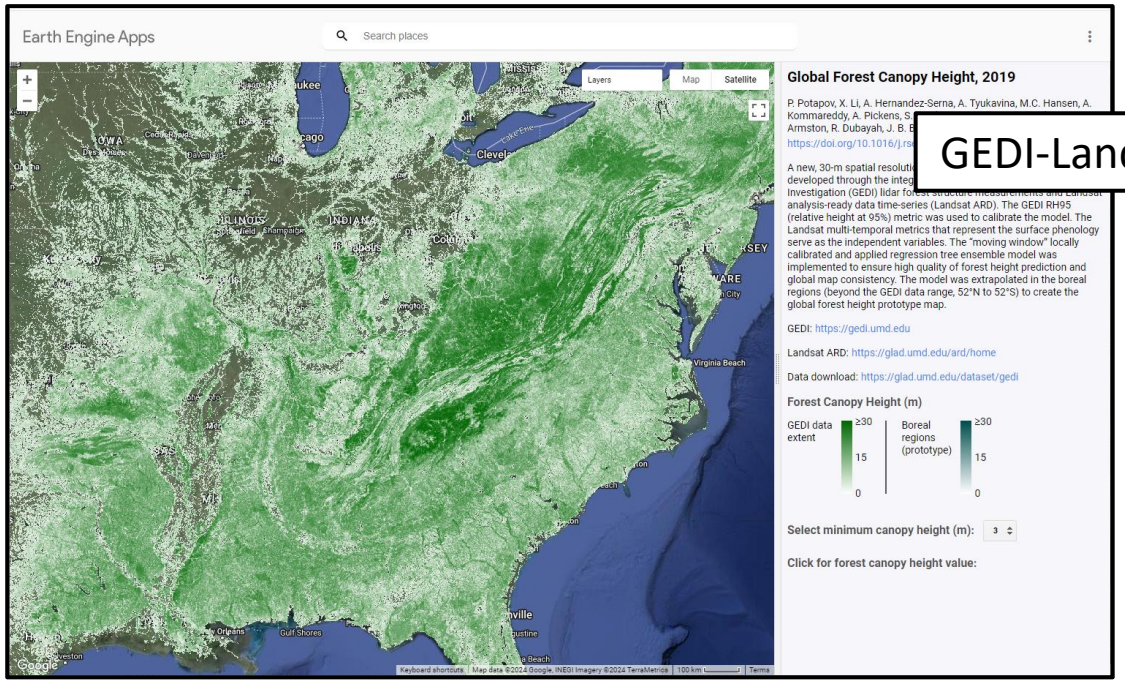
Estimate improvement in aboveground biomass estimates by adding height

Use derivatives of pilot to estimate improvement in synthetic stand attributes

Canopy Height Products
Off-the-Shelf and in Development



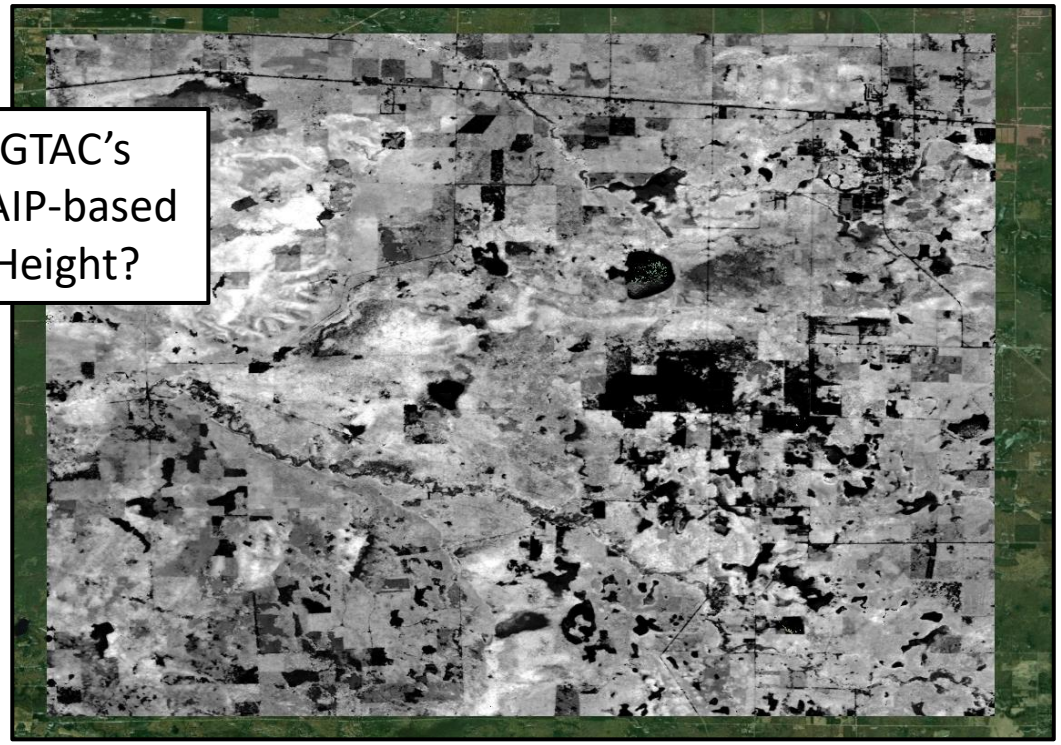
GEDI-Sentinel



GEDI-Landsat

- Height
- Height "+"
  - Sub-30m metrics

GTAC's NAIP-based Height?



Next Steps

- Evaluate Synthetic Stands using USFS National Forest System stand exam data
- Re-run CCA ordination using height products
  - Evaluate effect on live aboveground biomass prediction
  - Evaluate effect on synthetic stand structure
- Expand geographic scope of REGEN3 knowledgebases
  - Hardwood-dominated provinces of regions 8 & 9

Thanks for Listening!

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Margaret Woodbridge

Callie Schweitzer

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