Tree Species Range Shifts Under Climate Change

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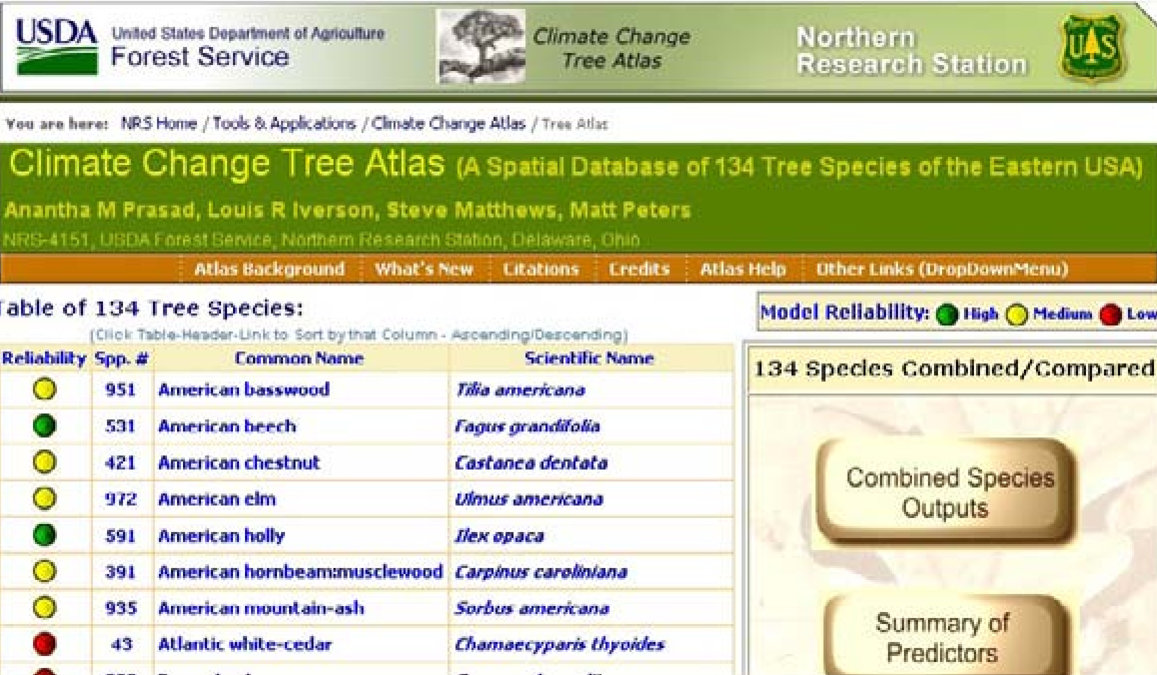
A Taxonomy of Range Models

- Statistical/Empirical Models
  - DISTRIB, GARP, GAM, GLM, Biomapper (ENFA)
- Gap Models
  - FORET, LINKAGES
- Landscape Models
  - LANDSUM, SHIFT
- Biogeochemical Models
  - CENTURY
- Dynamic Global Vegetation Models
  - MC-1, MAPSS, LPJ

Using DISTRIB, a statistical model, and SHIFT, a cell-based model, to assess potential climate change impacts on forests in the Eastern U.S.

Louis Iverson, with Anantha Prasad, Steve Matthews, Matt Peters
US Forest Service
Northern Research Station
Delaware, Ohio



Climate Change Tree Atlas

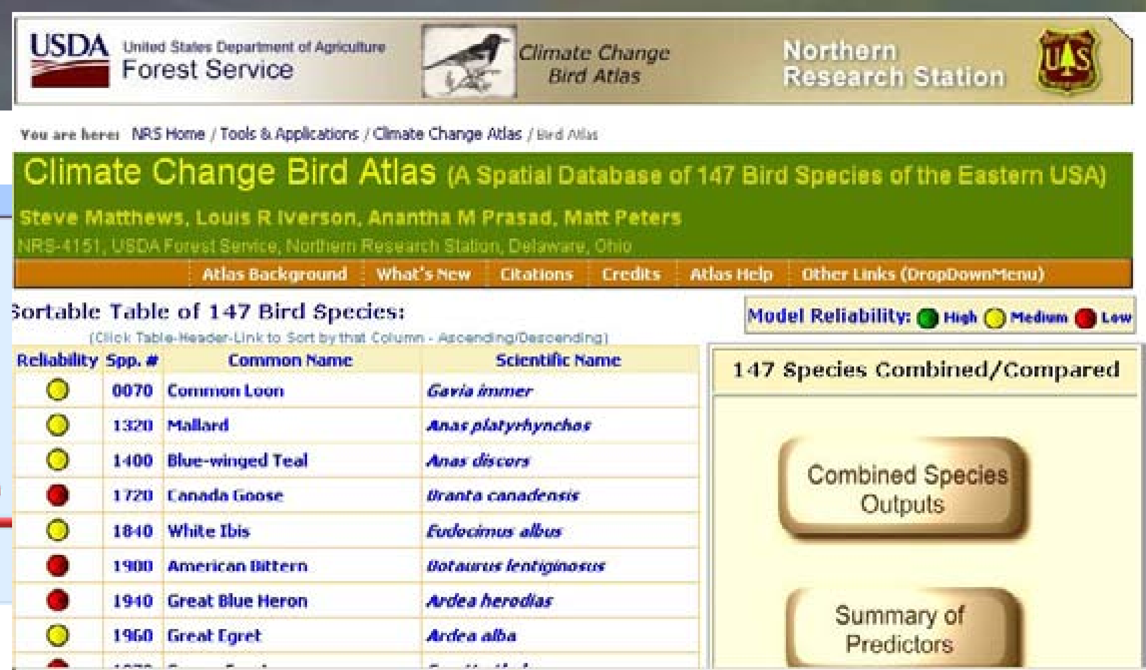
Climate Change Bird Atlas

http://www.nrs.fs.fed.us/atlas

Each unit (▬) represents 1,500 requests for pages or part thereof.

month	reqs	pages
Mar 2007	48	48
Apr 2007	151	151
May 2007	13929	13928
Jun 2007	14428	14428
Jul 2007	15320	15320
Aug 2007	18099	17936
Sep 2007	21089	20997
Oct 2007	28007	27892
Nov 2007	45791	45734
Dec 2007	47529	47432
Jan 2008	25094	25015

Busiest month: Dec 2007 (47,432 requests for pages).

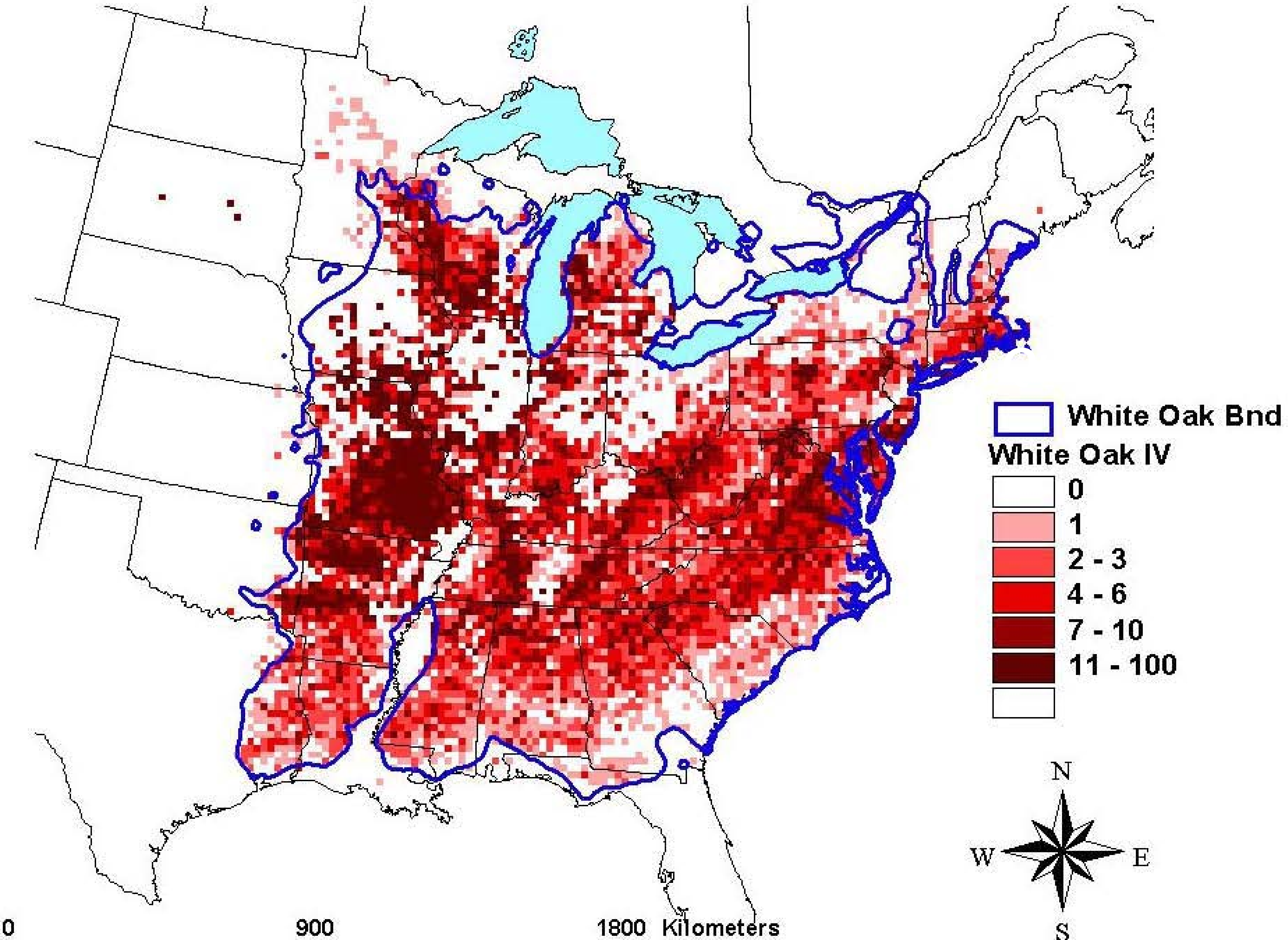


Forest Inventory and Analysis

- **FOREST INVENTORY (US Forest Service)**
  - 37 states east of 100th meridian
  - 134 tree taxa
  - 103,488 plots, ~1 plot per 2400 ha of forest
  - 2,938,518 tree records
- **PROCESS**
  - Extract latest FIA plot data by State
  - Calculate Importance Value based on number of stems & basal area
  - Aggregate points to 20 x 20 km polygons
- **OUTPUT**
  - Importance Value (IV) for 134 tree species, by 20 km cell

Available online: Prasad and Iverson 2003

White Oak Importance Value and Little's Bnd



Environmental Predictor Variables

- Response variable: FIA-derived importance values by 20 km

Climate

AVGT	Mean annual temperature (deg. C)
JANT	Mean January temperature (deg. C)
JULT	Mean July temperature (deg. C)
TMAYSEPT PMAYSEPT	Mean May-September temperature or precipitation
PPT	Annual precipitation (mm)
JANJULDif	Difference temp Jan/Jul

Elevation

ELV_CV	Elevation coefficient of variation
ELV_MAX	Maximum elevation (m)
ELV_MEAN	Average elevation (m)
ELV_MIN	Minimum elevation (m)
ELV_RANGE	Range of elevation (m)

Soil Class

ALFISOL	Alfisol (%)
ARIDISOL	Aridisol (%)
ENTISOL	Entisol (%)
HISTOSOL	Histosol (%)
INCEPTSOL	Inceptisol (%)
MOLLISOL	Mollisol (%)
SPODOSOL	Spodosol (%)
ULTISOL	Ultisol (%)
VERTISOL	Vertisol (%)

Soil Property

BD	Soil bulk density (g/cm3)
CLAY	Percent clay (< 0.002 mm size)
KFFACT	Soil erodibility factor, rock fragments free
NO10	Percent soil passing sieve No. 10 (coarse)
NO200	Percent soil passing sieve No. 200 (fine)
OM	Organic matter content (% by weight)
ORD	Potential soil productivity, (m3 of timber/ha)
PERM	Soil permeability rate (cm/hour)
PH	Soil pH
ROCKDEP	Depth to bedrock (cm)
ROCKFRAG	Percent weight of rock fragments 8-25 cm
SLOPE	Soil slope (percent) of a soil component
TAWC	Total available water capacity (cm, to 152 cm)

Land Use and Fragmentation

AGRICULT	Cropland (%)
FOREST	Forest land (%)
FRAG	Fragmentation Index (Riitters et al. 2002)
NONFOREST	Non-forest land (%)

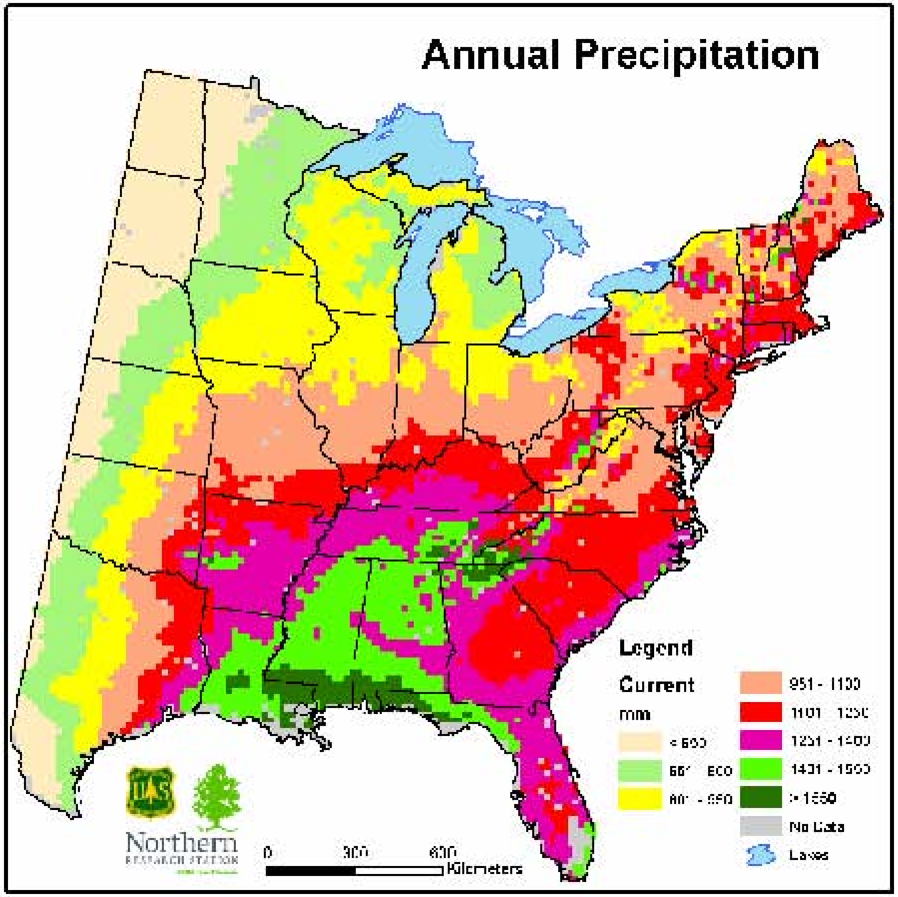
- 3 Climate Models

- Hadley CM3 (Severe)
- PCM (Mild)
- GFDL

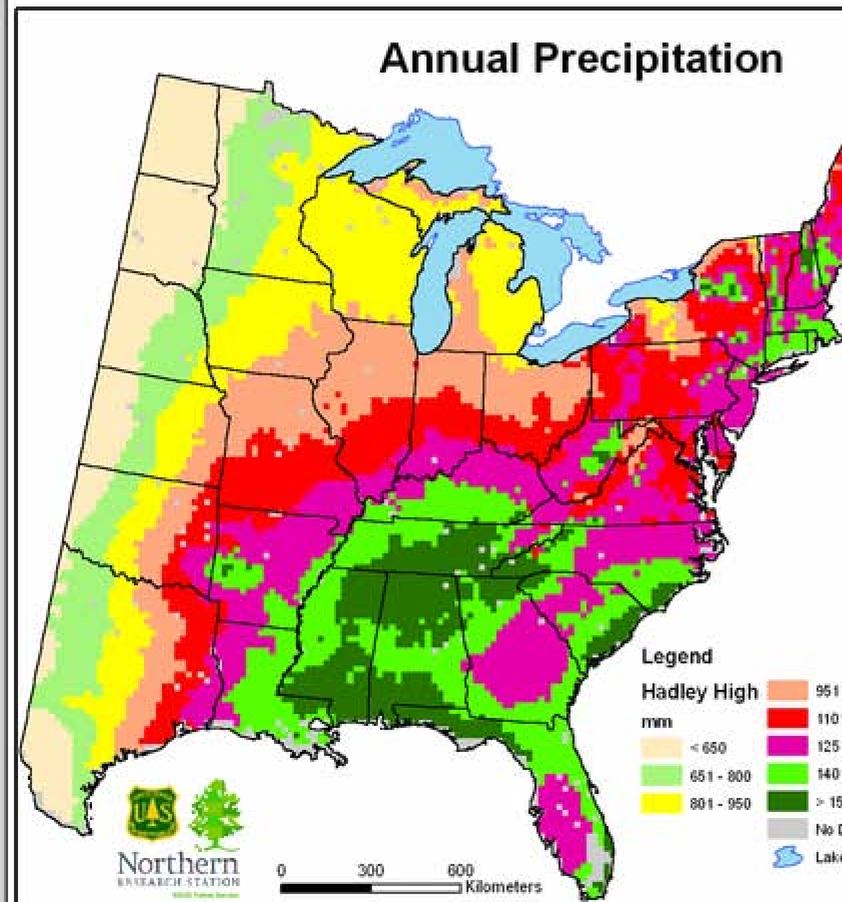
- 2 Scenarios

- A1FI (Low or Best)
- B1 (Hi or Worst)

Current

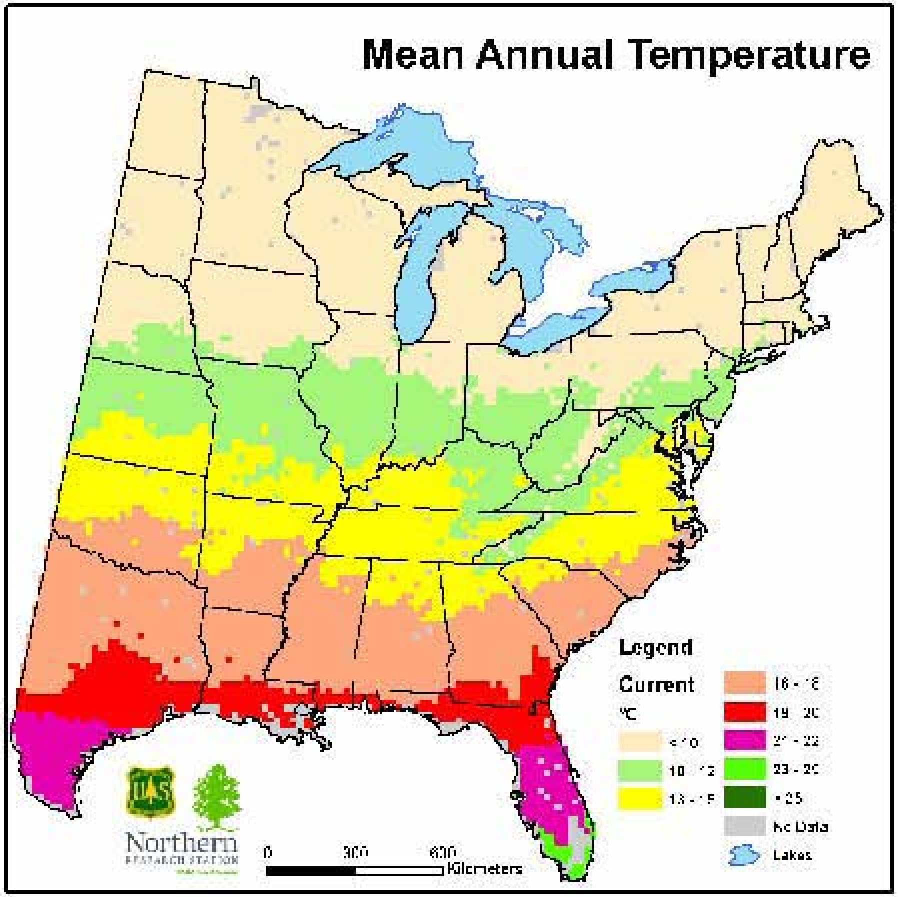


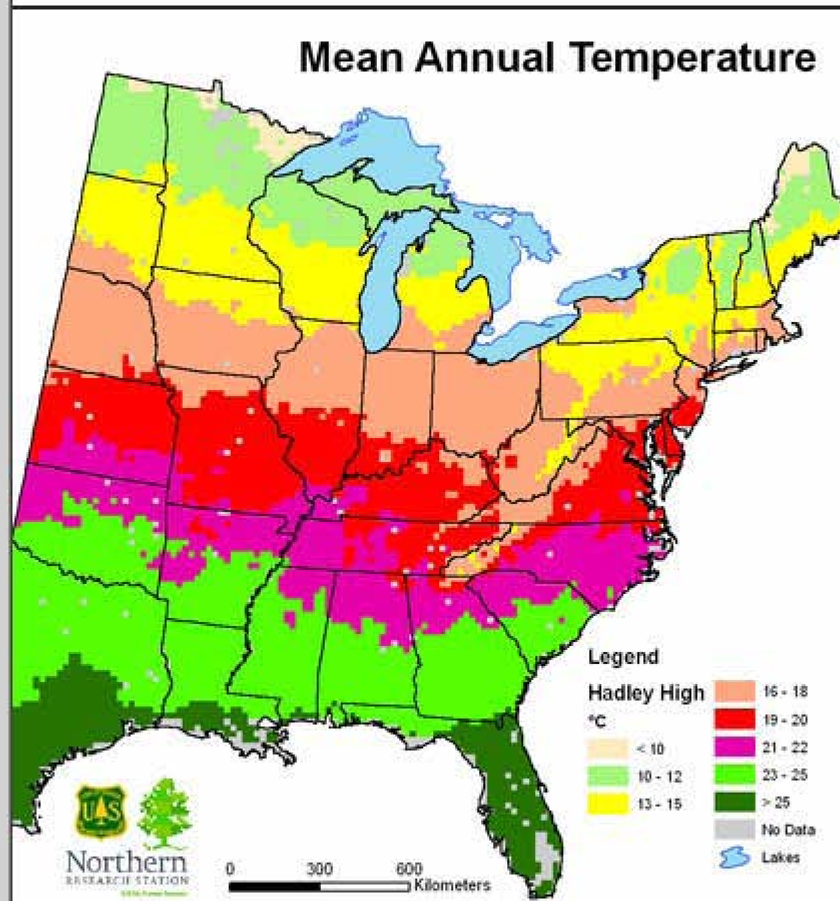
Hadley Hi



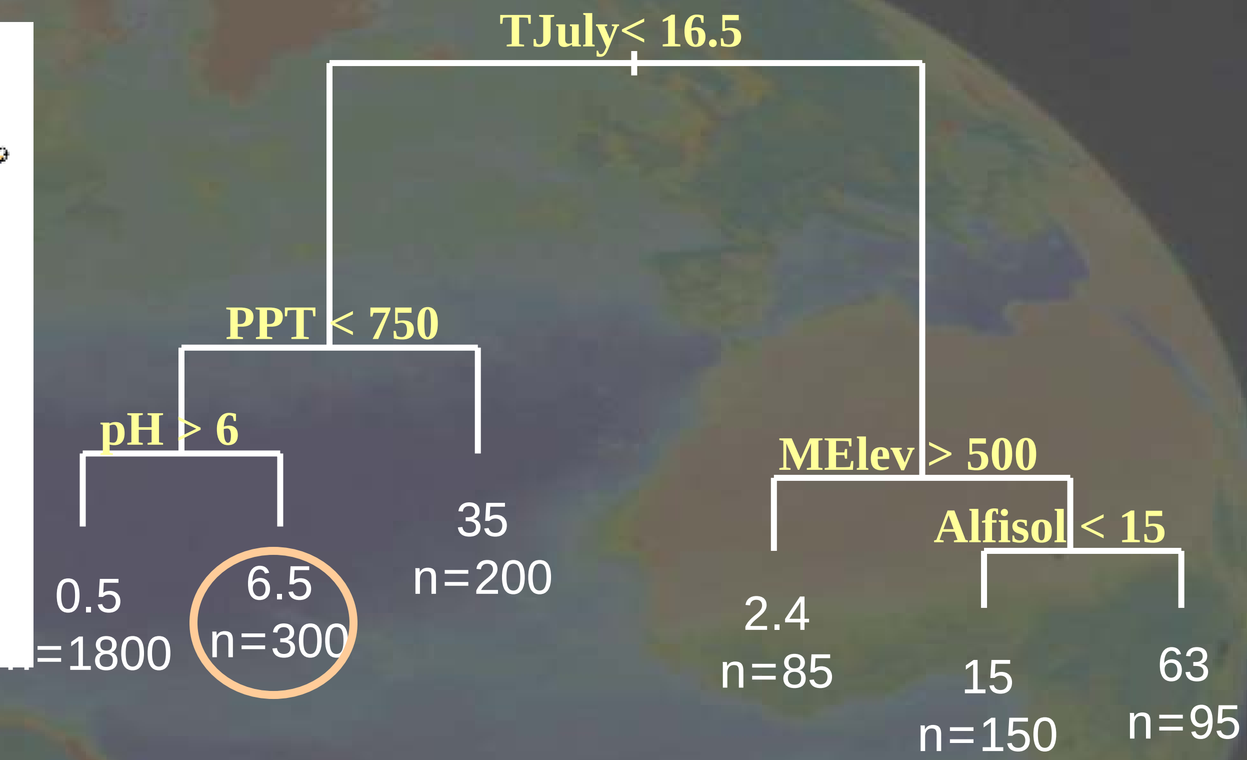
Current

Hadley Hi





Regression Tree Analysis (RTA)



creating branches of a Tree

TJuly < 16.5 &
PPT < 750 &
PH <= 6

•At the bottom is series of ***terminal nodes*** which contains the predicted value of species importance

•These values are then mapped

Mapping Geographic Predictors

Highly suited for distributional mapping where different variables operate at different geographic regions – *can map predictor-rules driving the distribution.*

Iverson and Prasad 1998 Ecological Monographs

Tree-based ensemble

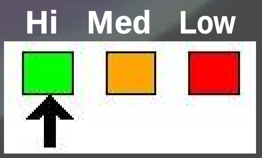
(the “Tri-mod approach”)

- Regression Tree Analysis (RTA or CART)
  - (help understand relationships, map drivers)
- Bagging Trees (BT)

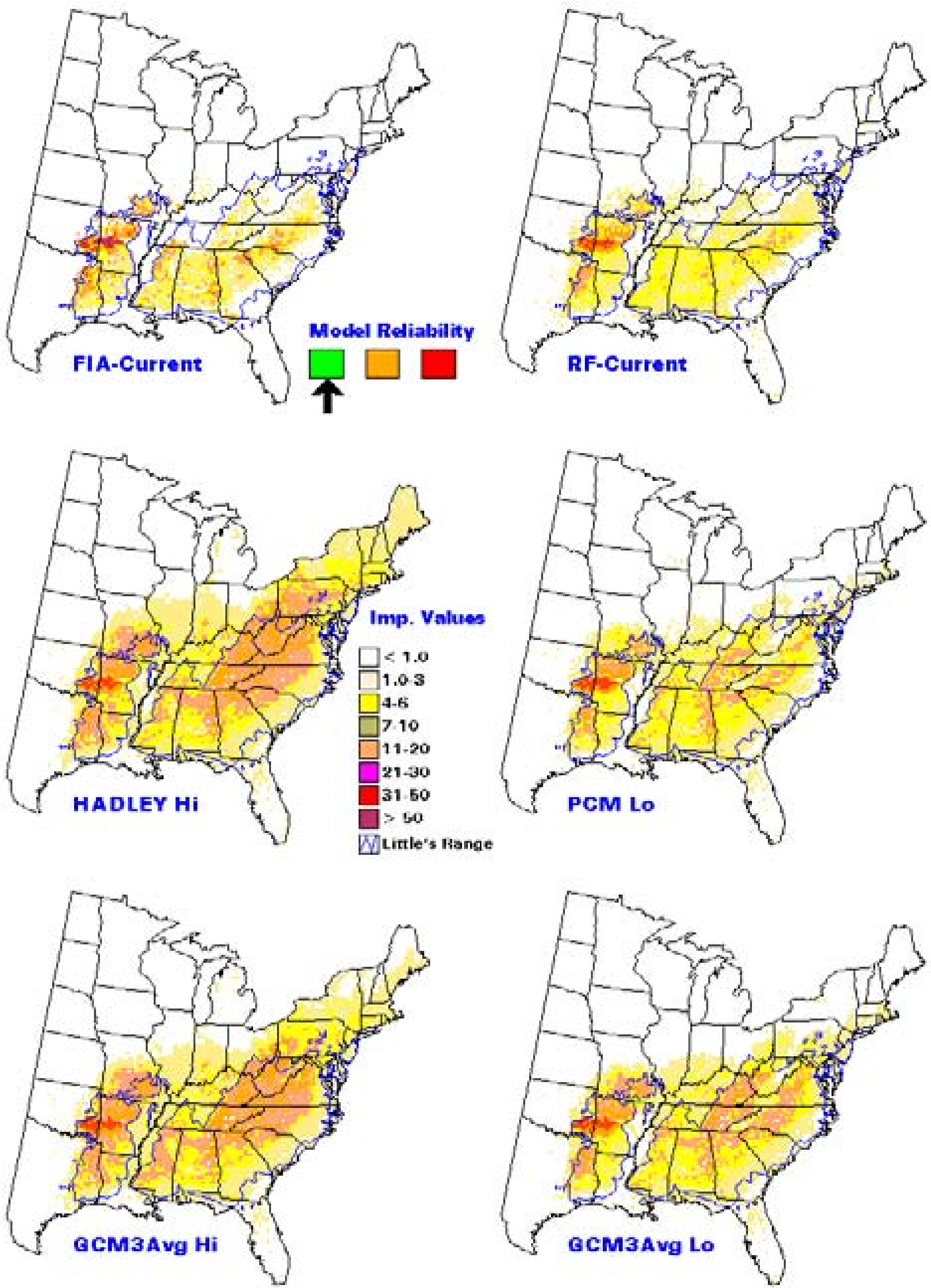
  \- combines 30 trees using bootstrap sampling and averages the results
  - (use 30 trees to assess variability among individual tree models = a measure of model reliability)
- Random Forest (RF)

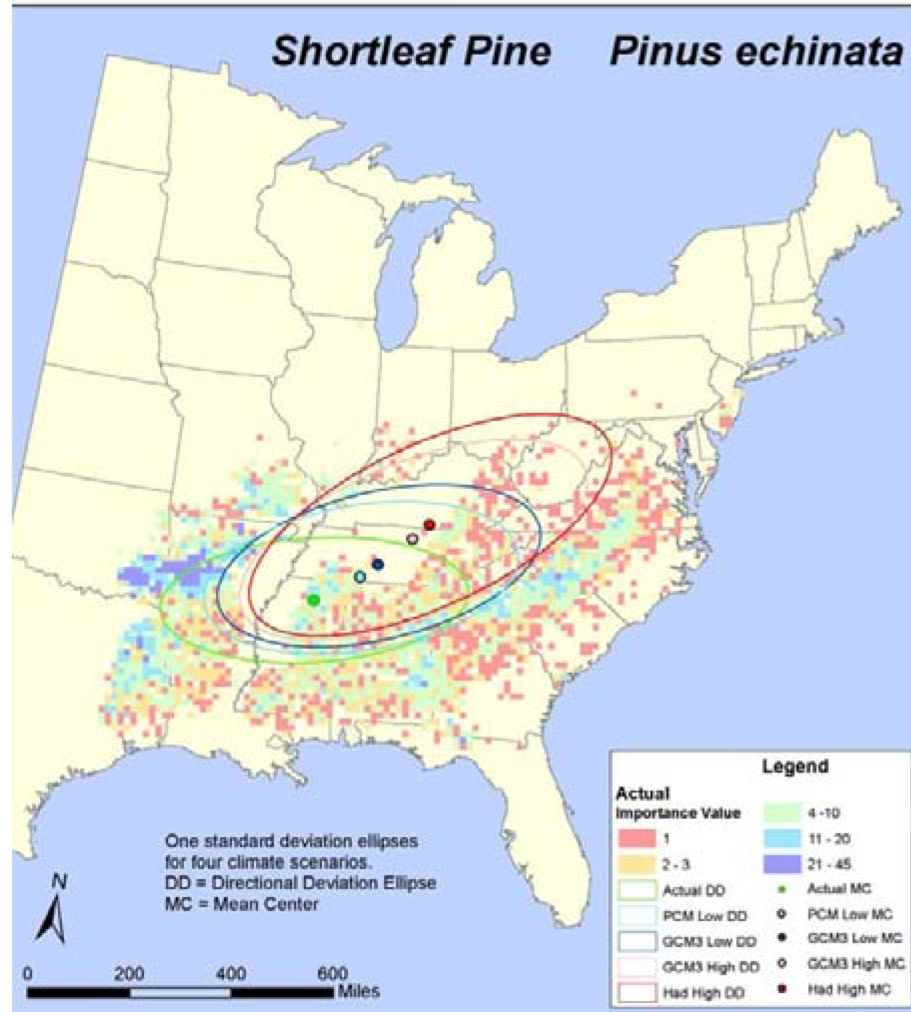
  \- combines 1000 trees like in BT, but each with a randomized subset of predictors
  - (best for prediction without overfitting)

Model Reliability

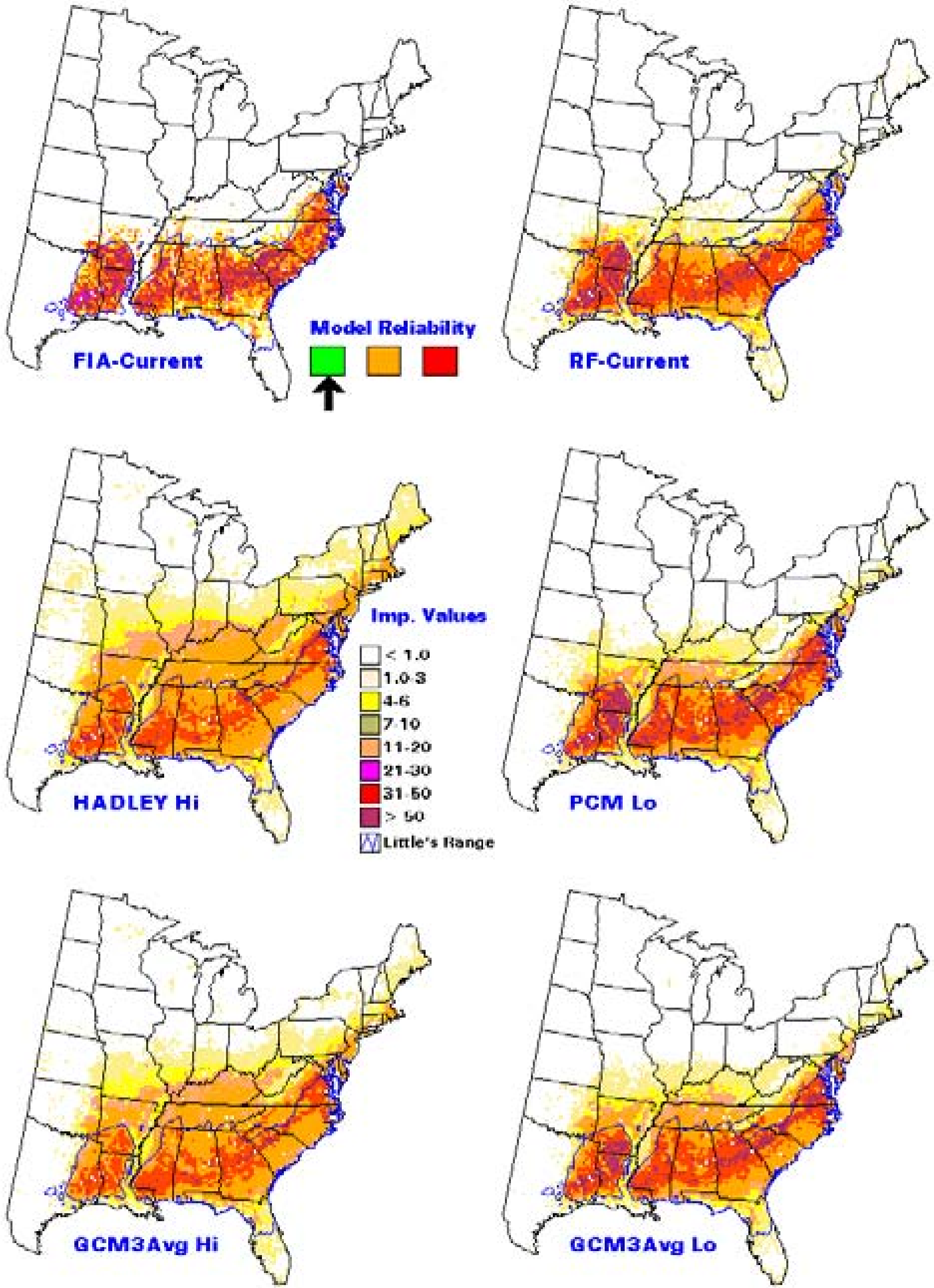


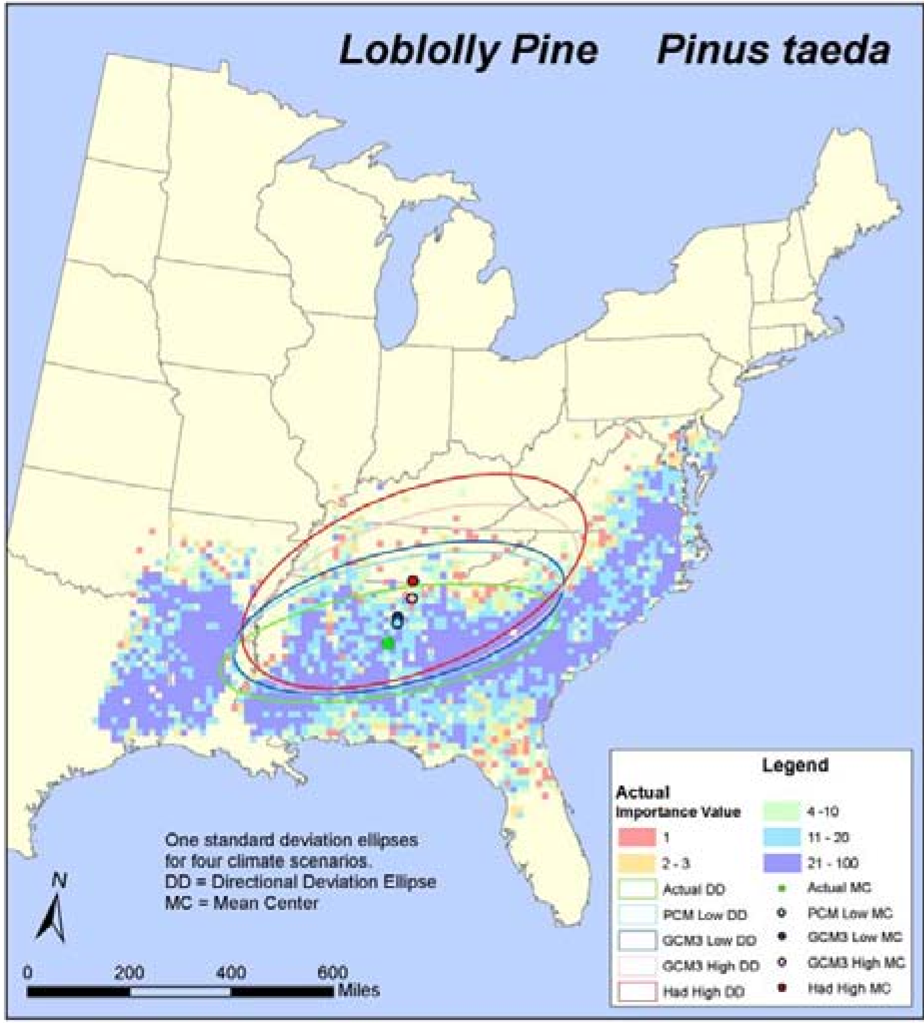
shortleaf pine - Pinus echinata - (110)



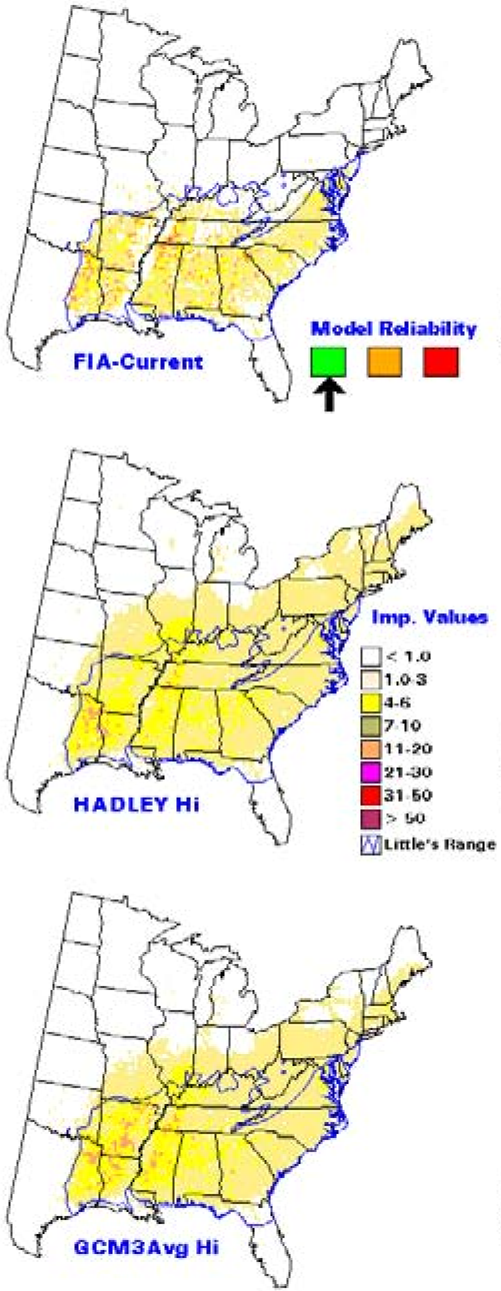


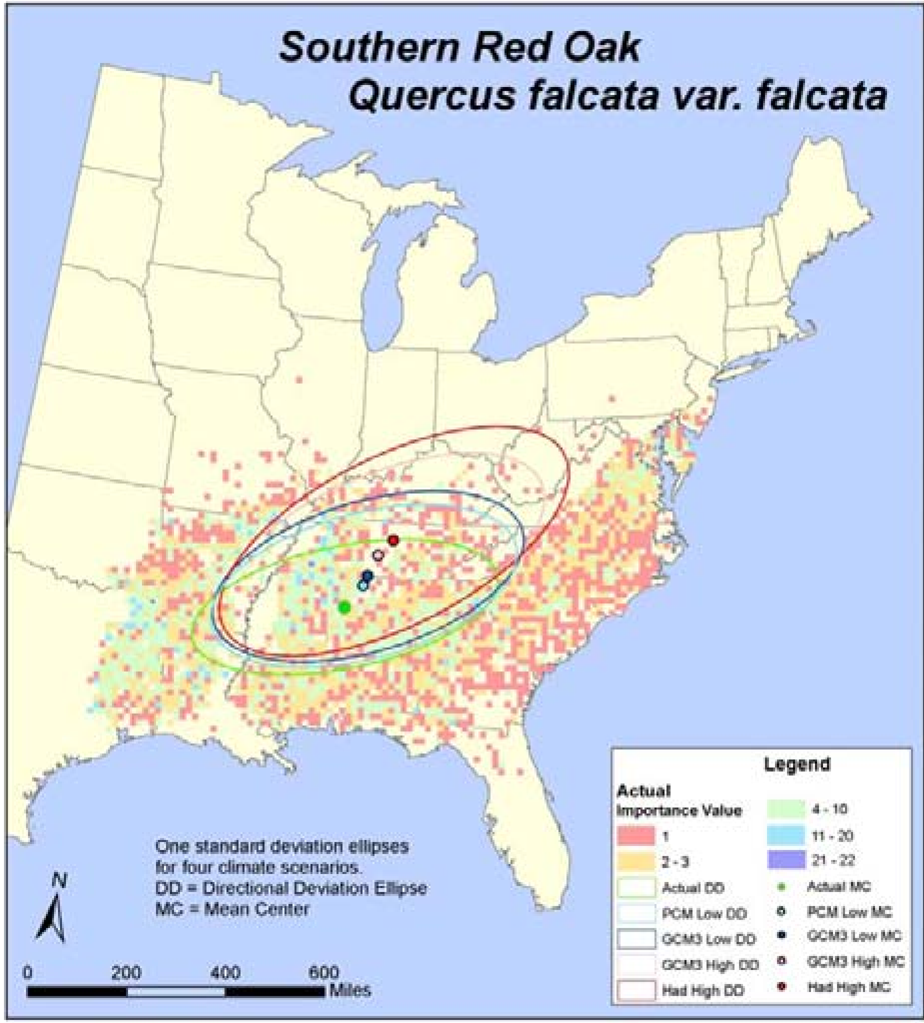
loblolly pine - Pinus taeda - (131)



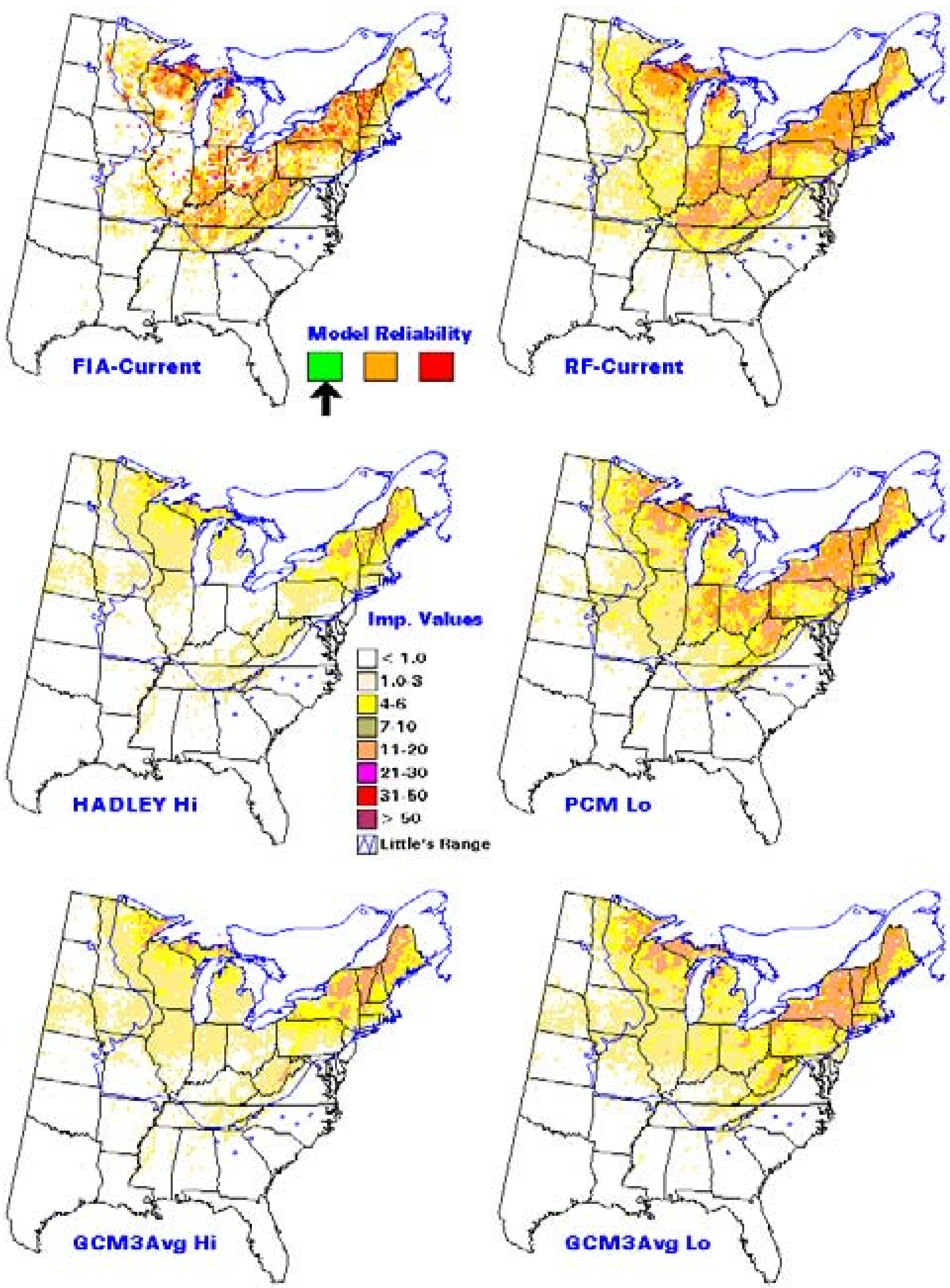


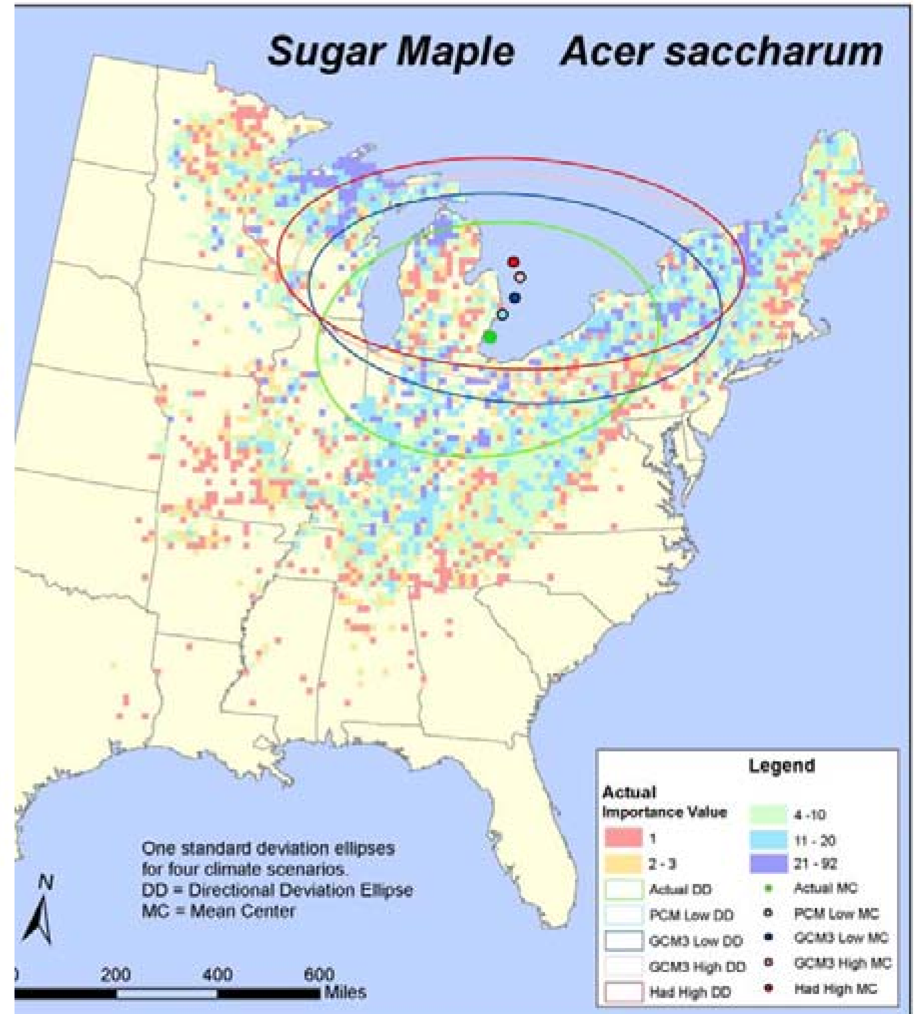
southern redoak - Quercus falcata var.falcata - (812)



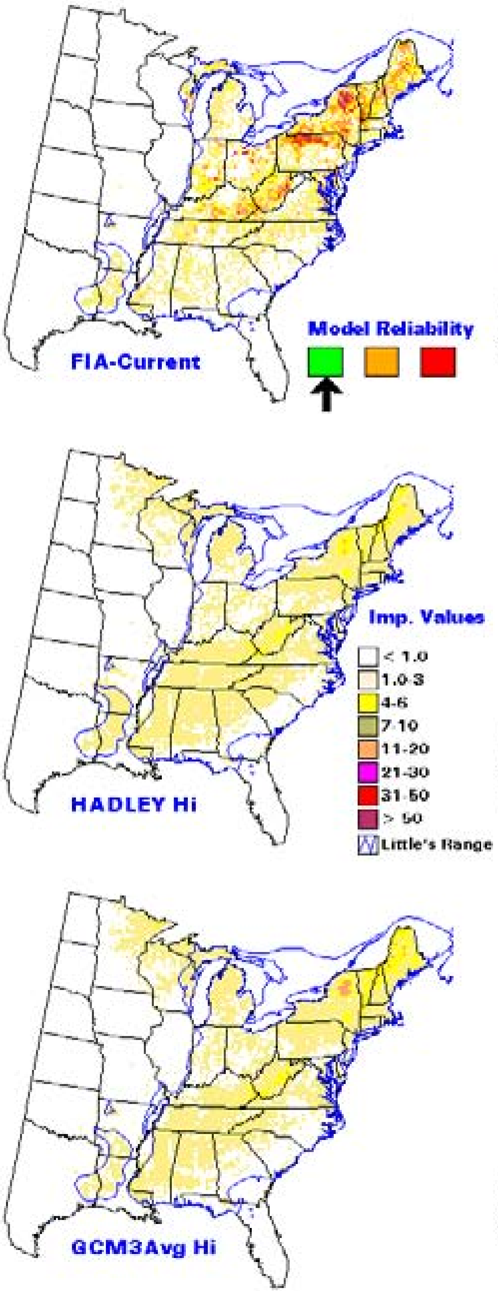


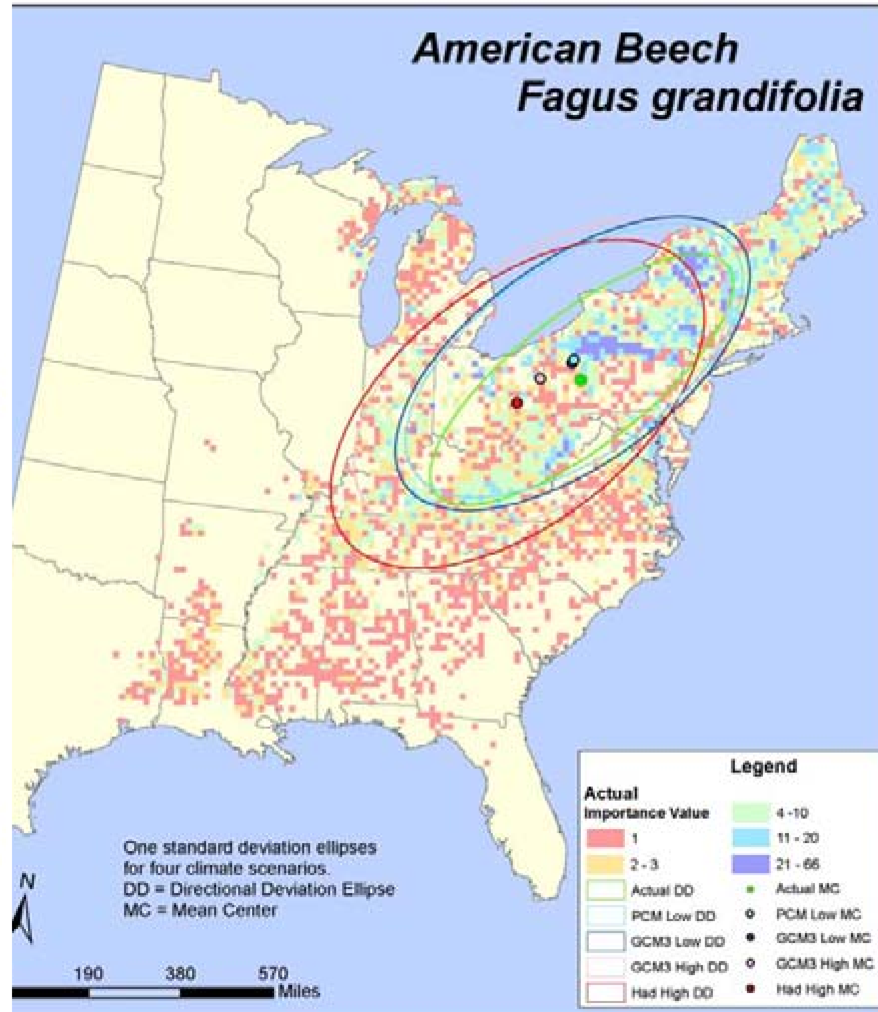
sugar maple - Acer saccharum - (318)



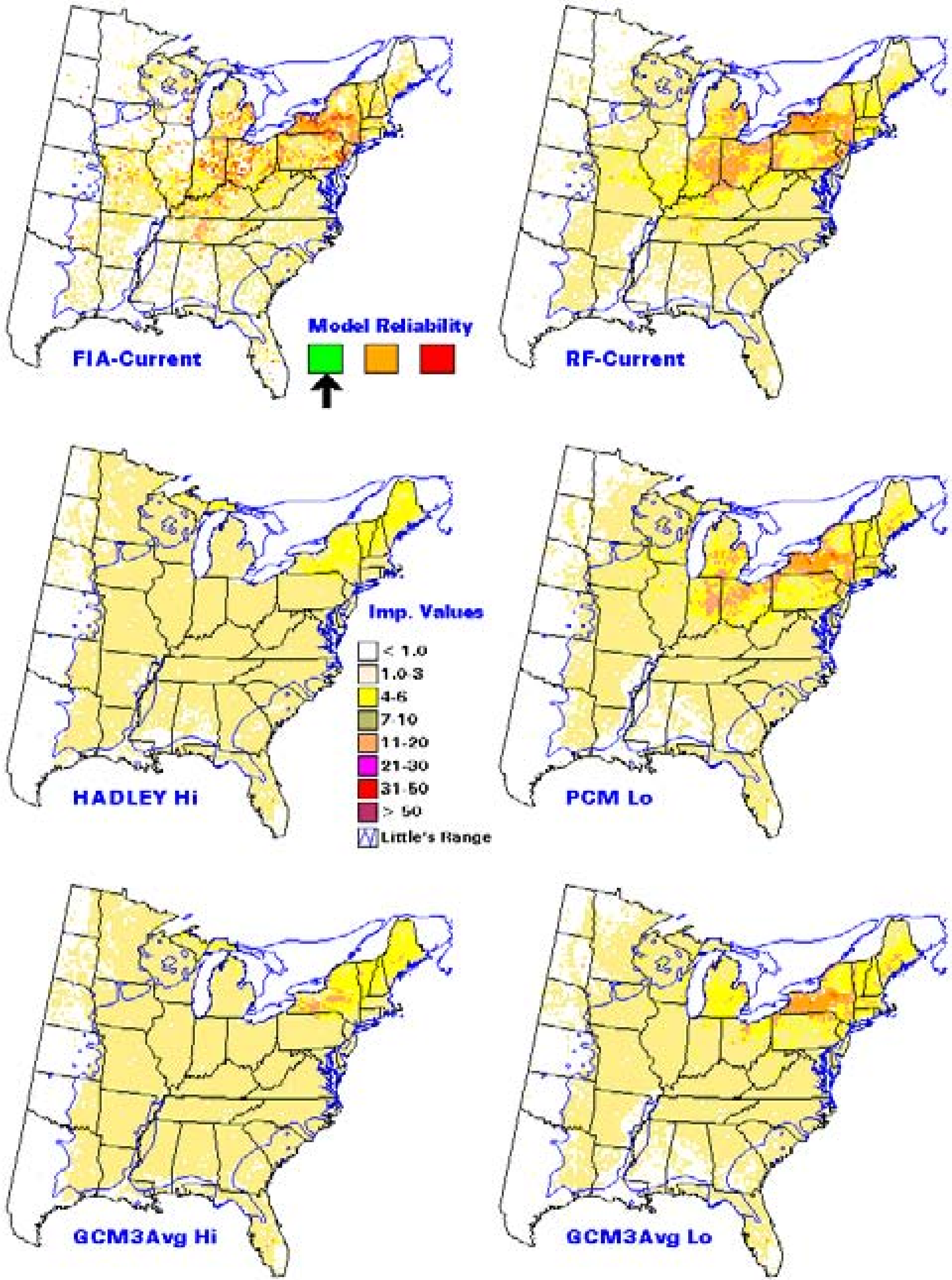


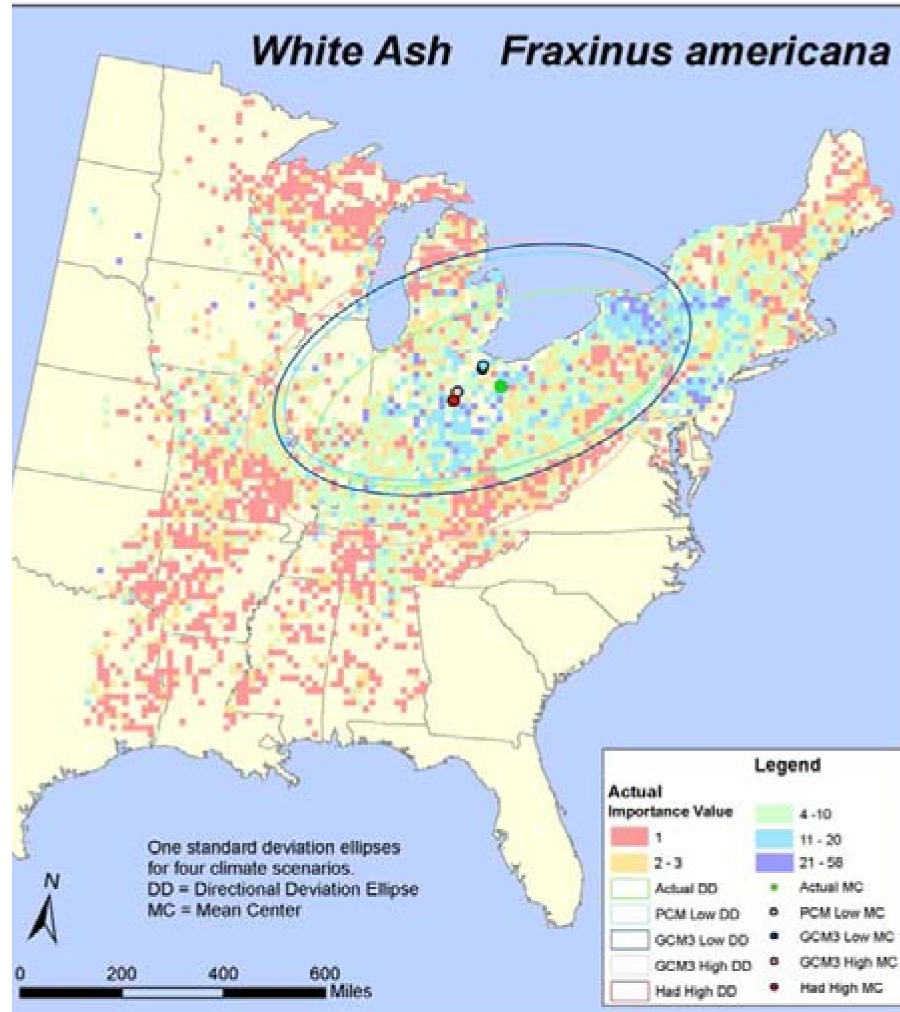
American beech - Fagus grandifolia - (531)



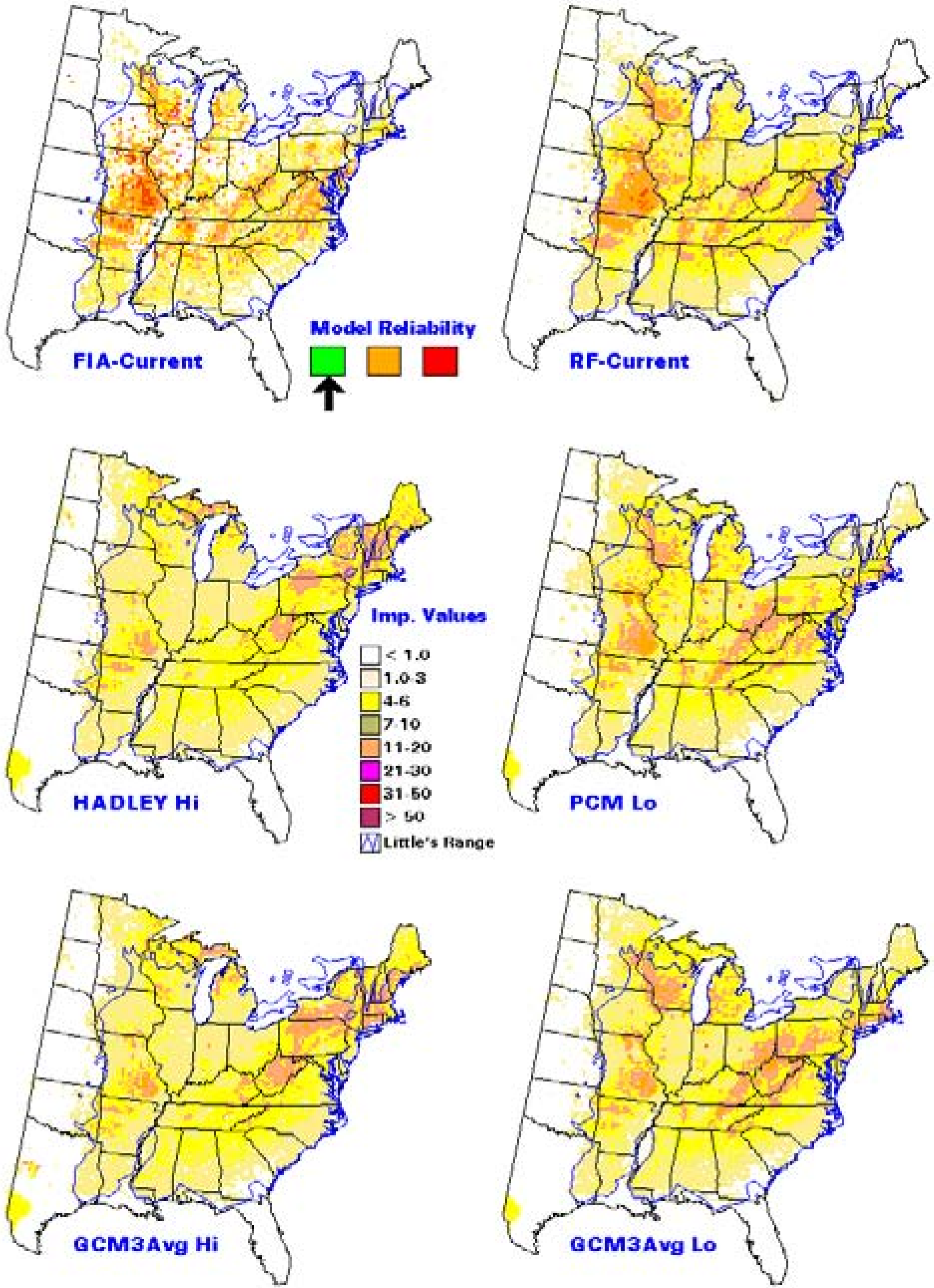


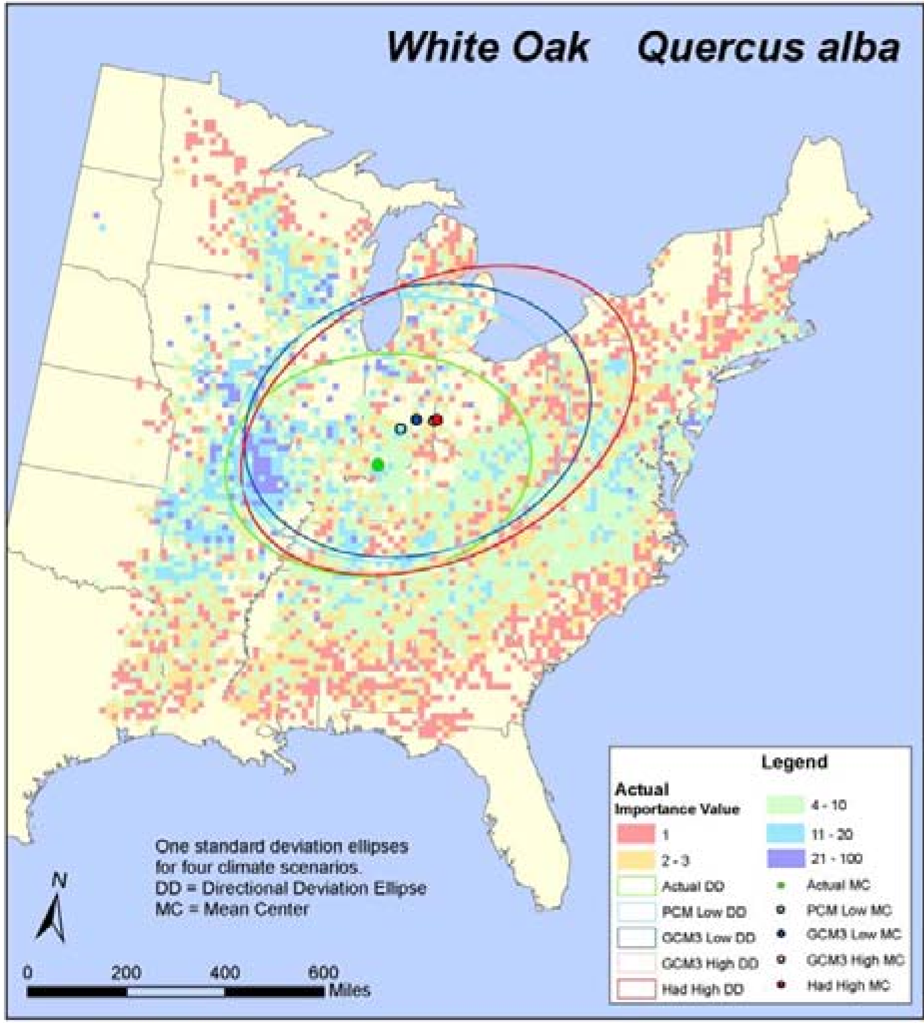
white ash - Fraxinus americana - (541)



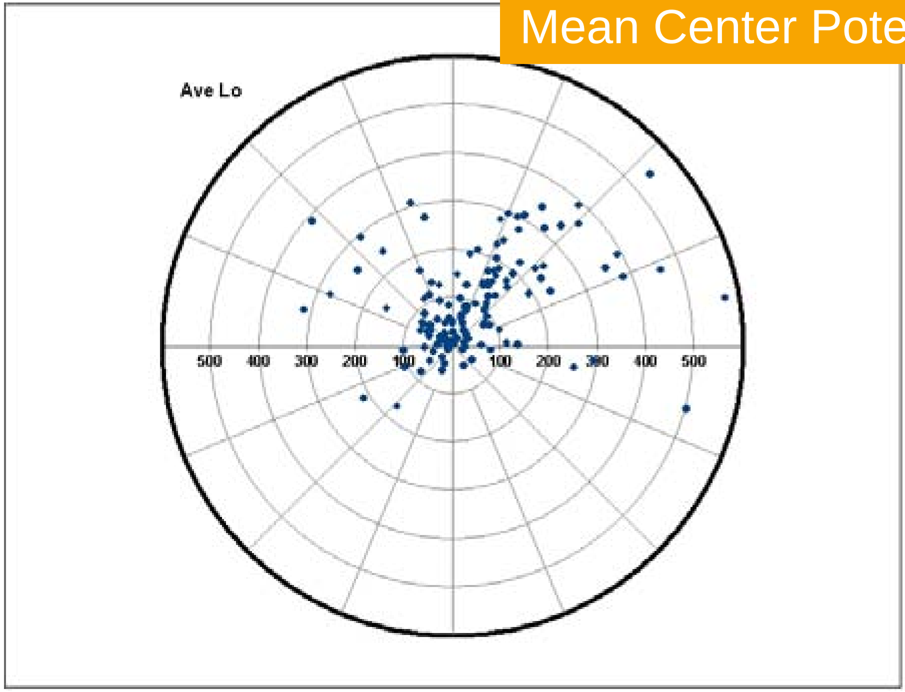


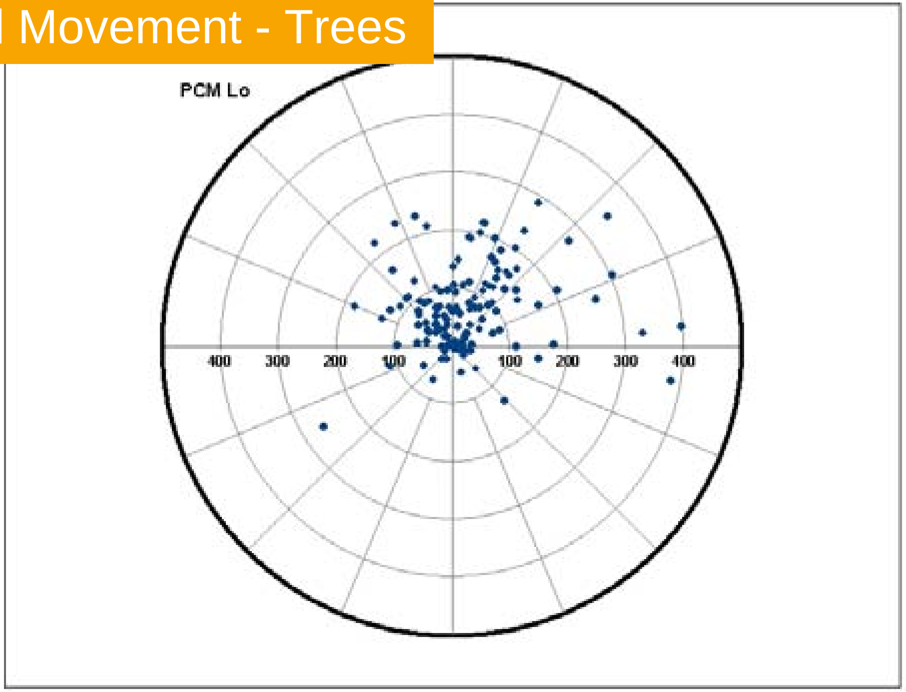
white oak - Quercus alba - (802)

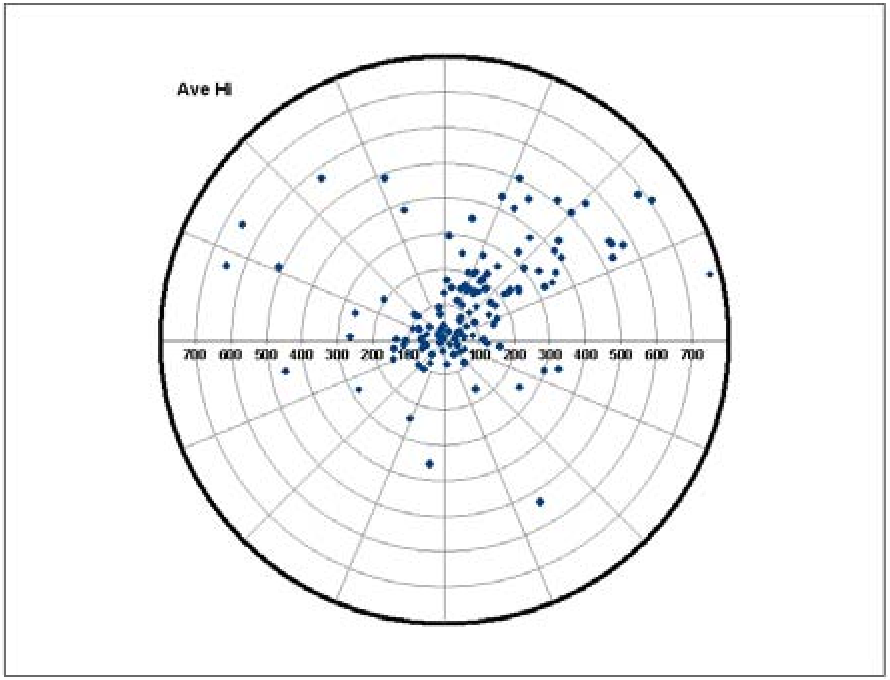


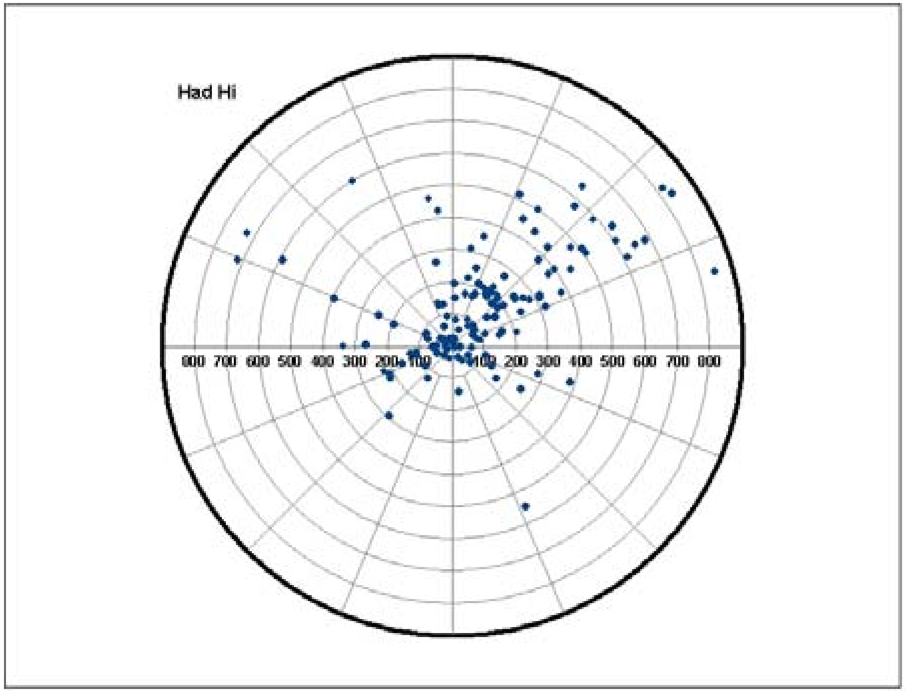


Mean Center Potential Movement - Trees





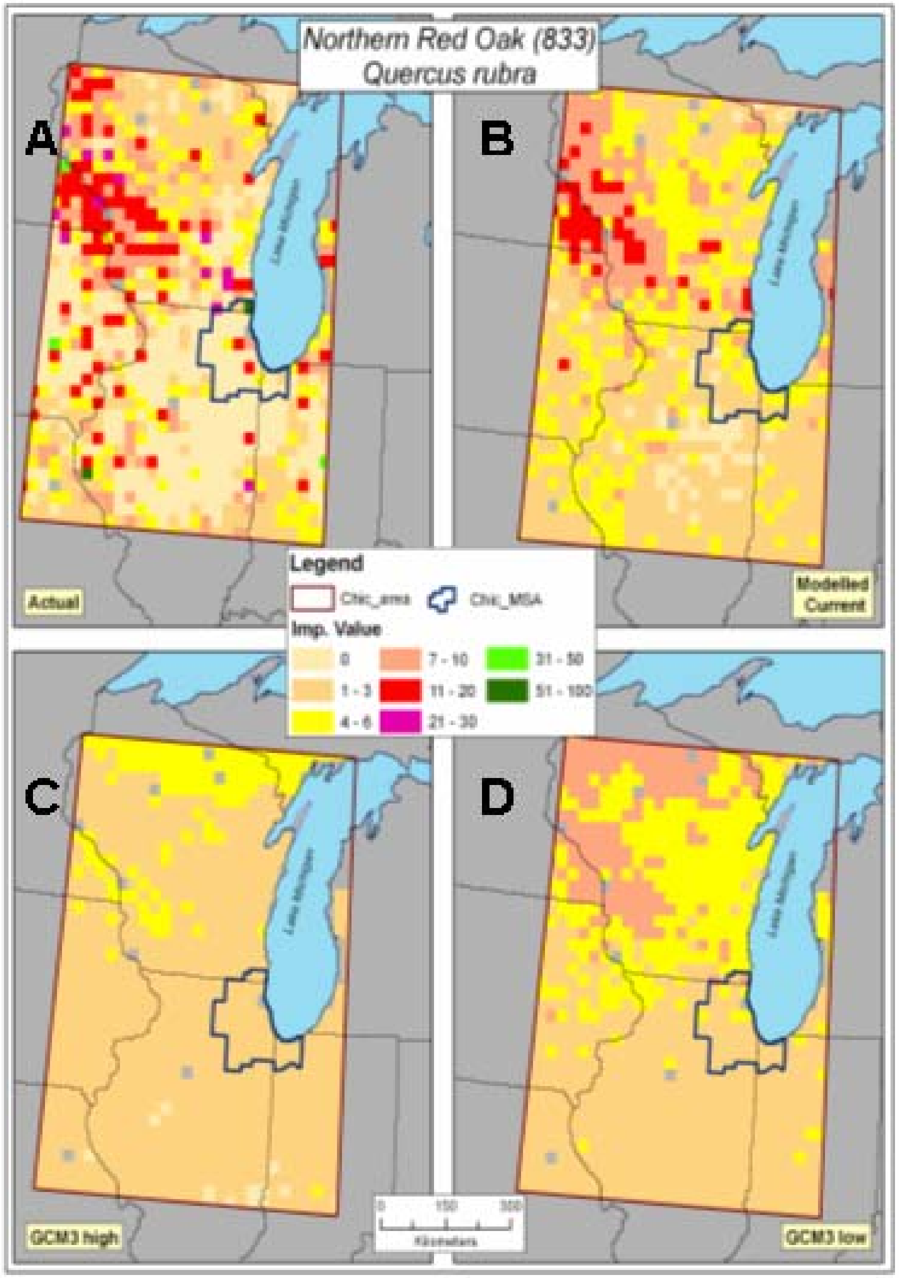


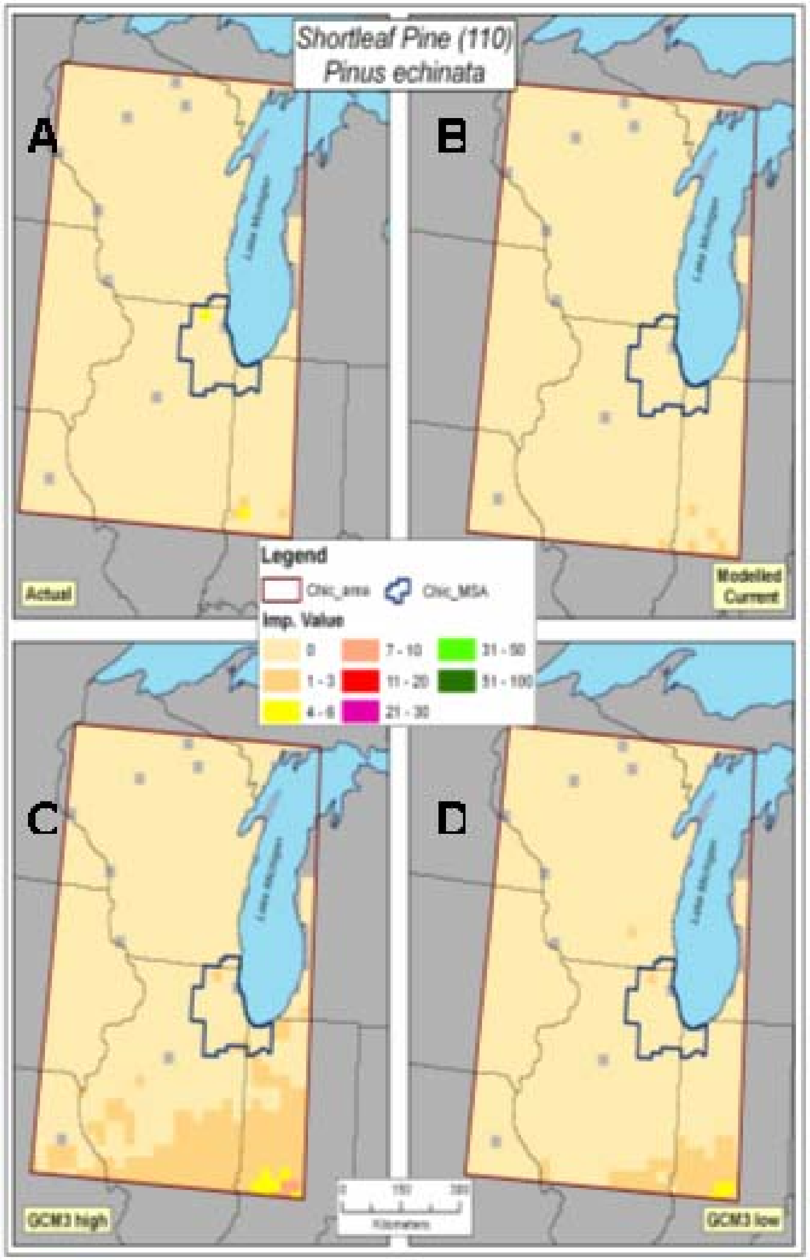


Important!

- With these models, we are predicting potential suitable habitat by year 2100. We are NOT predicting where the species will be at that time, as great lag times are involved in tree species migrations. Trees live a long time and move slowly (~50 km/century in the Holocene).

Suitable Habitat Potential Changes – Ave lo and hi emissions



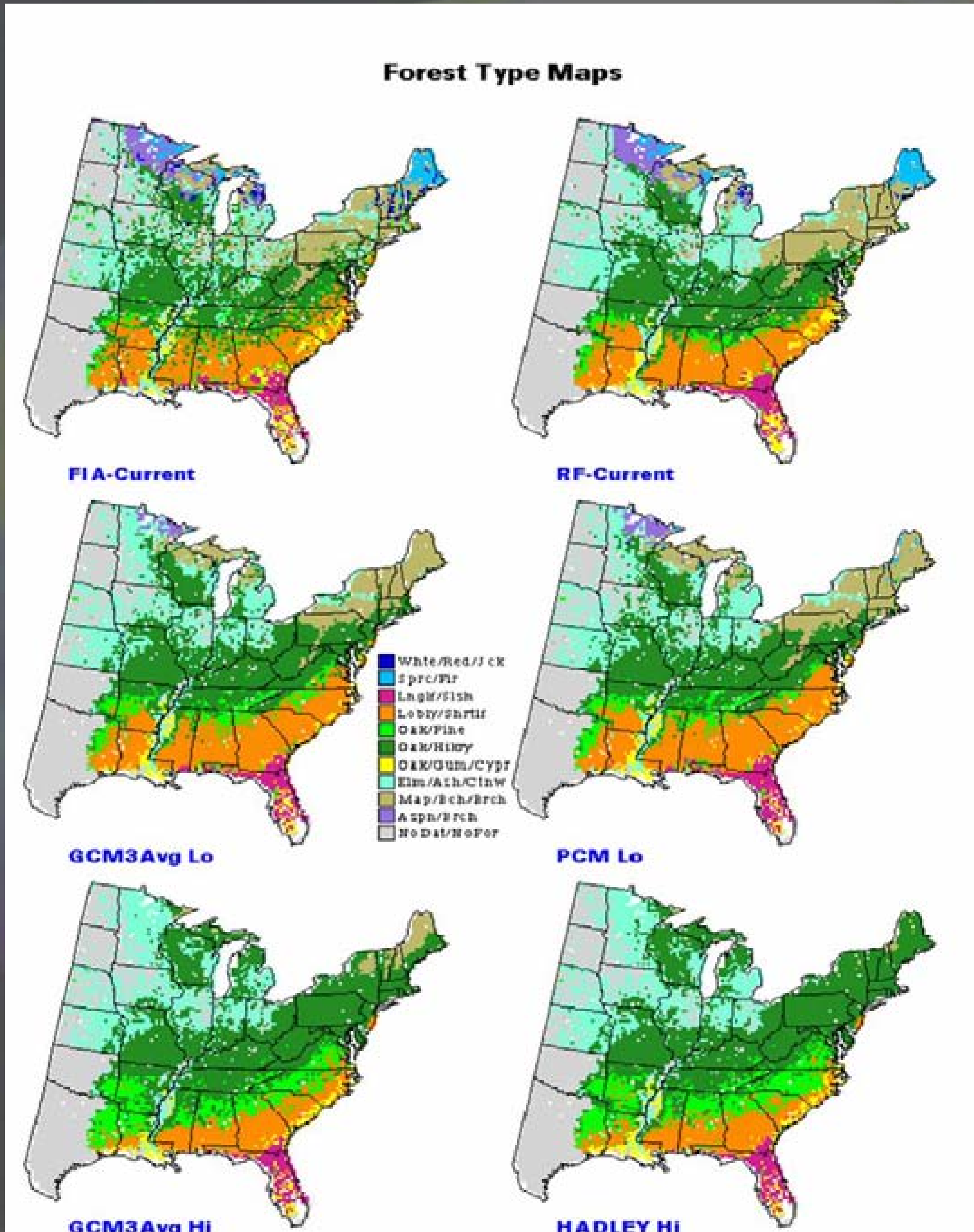


Potential species changes in area-weighted importance value for habitat suitability
(Chicago region)

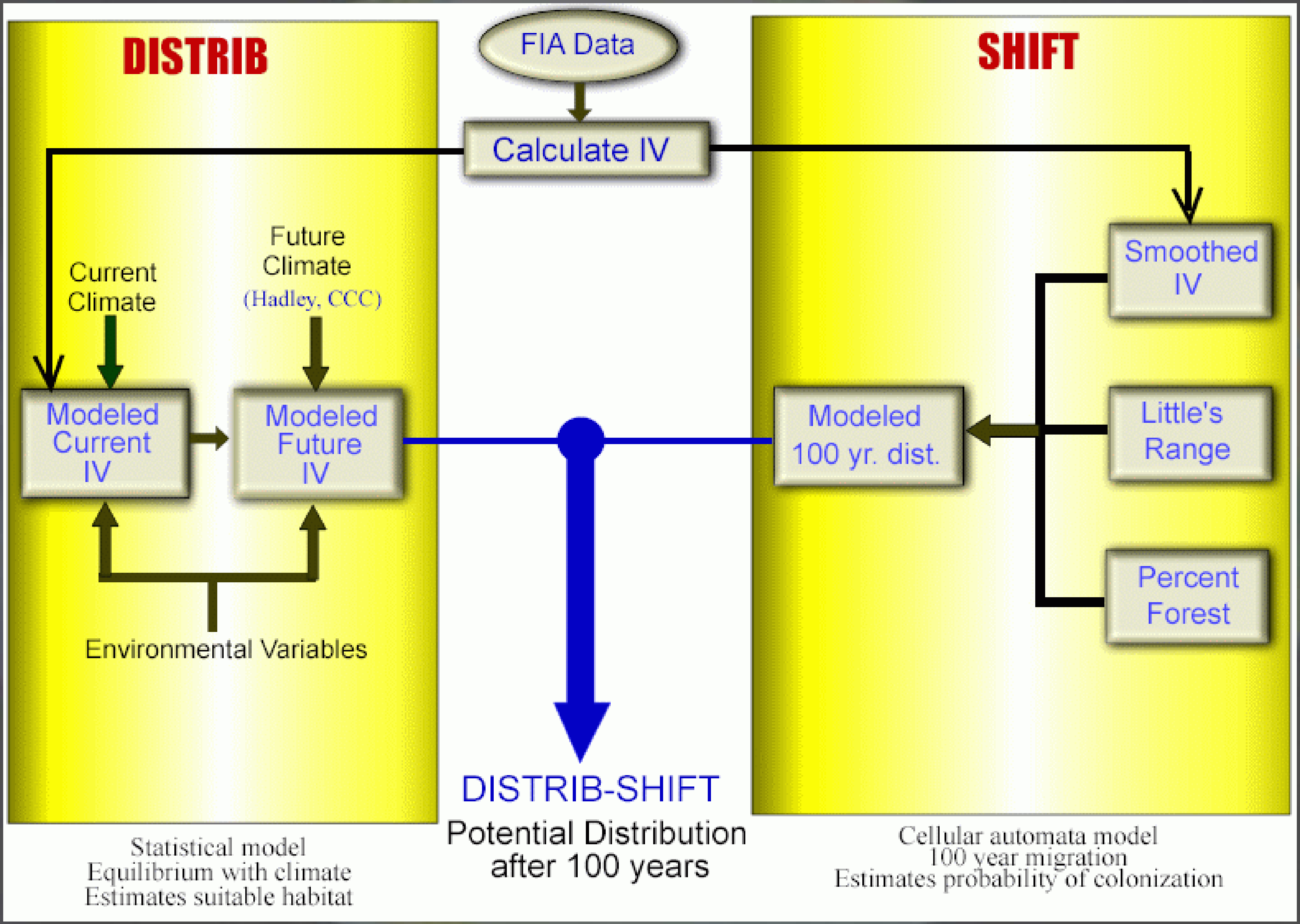
Future: current ratio

Scenario	< 0.5	0.5 - 0.9	0.9 - 1.1	1.1 - 2	> 2	Total
PCM lo	32	17	6	26	33	114
Ave lo	35	22	13	17	33	114
Ave hi	43	17	4	17	33	114
Had hi	44	18	8	15	27	114

A future : current ratio below 1 indicates a loss (red),
while a value above 1 indicates a gain (green).

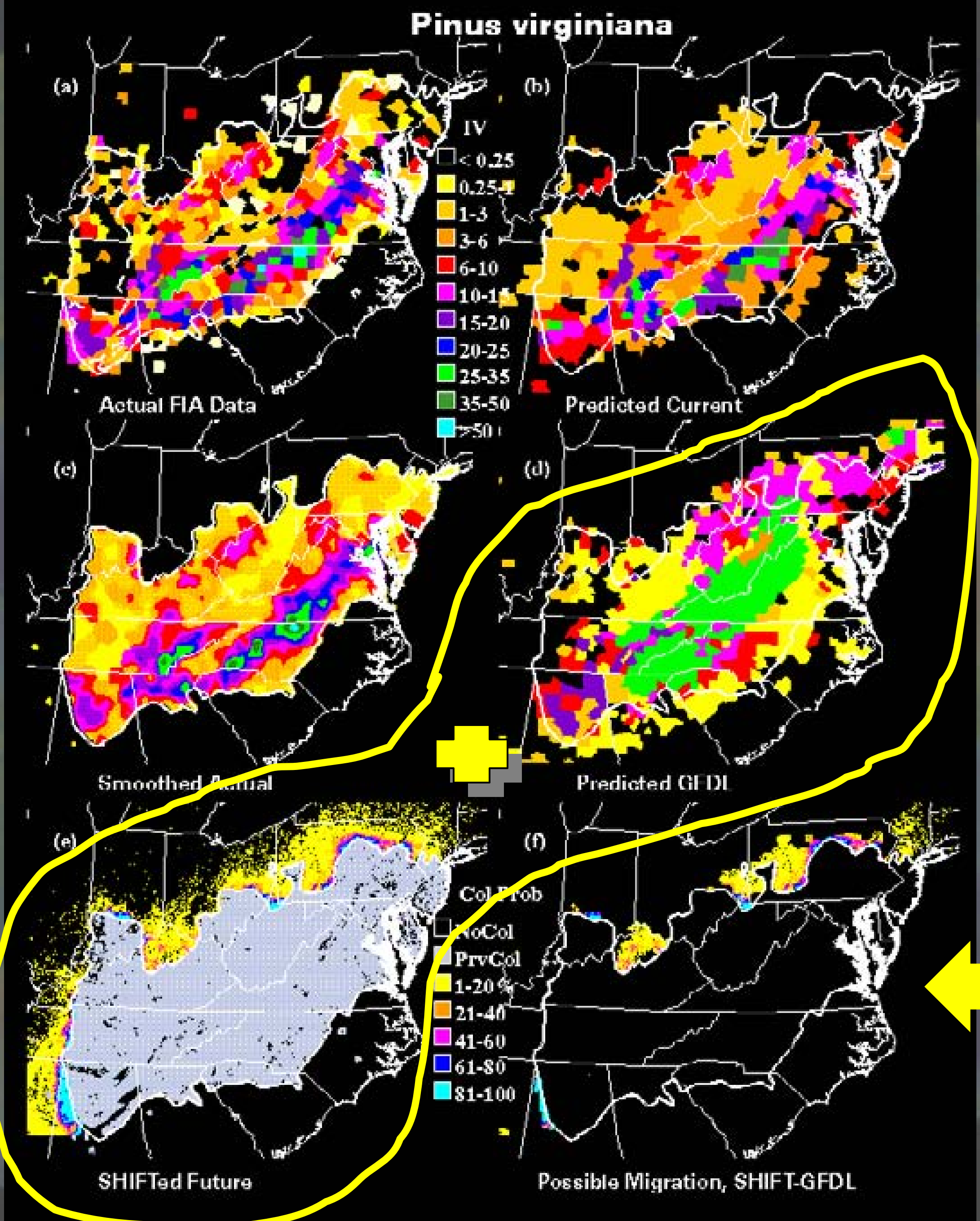


Forest Types from combinations of species.


DISTRIB
FIA Data
Calculate IV
SHIFT
Current Climate
Future Climate
(Hadley, CCC)
Modeled Current IV
Modeled Future IV
Environmental Variables
Smoothed IV
Modeled 100 yr. dist.
Little's Range
Percent Forest
DISTRIB-SHIFT
Potential Distribution after 100 years
Statistical model
Equilibrium with climate
Estimates suitable habitat
Cellular automata model
100 year migration
Estimates probability of colonization

Animation of colonization using presettlement vegetation – *Pinus virginiana* in Ohio

Current



DISTRIB

SHIFT

Constrained by DISTRIB and SHIFT

Potential effects of climate change on the tree species of Hoosier NF, Indiana

Top Habitat Gainers

SppCN	SppSN	HadHiPcmLoAvgDiff
post oak	Quercus stellata	2.225
winged elm	Ulmus alata	1.183
shortleaf pine	Pinus echinata	0.908
black hickory	Carya texana	0.867
blackjack oak	Quercus marilandica	0.708
sweetgum	Liquidambar styraciflua	0.617
southern redoak	Quercus falcata var.falcata	0.567
pin oak	Quercus palustris	0.425
loblolly pine	Pinus taeda	0.425
silver maple	Acer saccharinum	0.425
hackberry	Celtis occidentalis	0.417

Top Habitat Losers

SppCN	SppSN	HadHiPcmLoAvgDiff
sugar maple	Acer saccharum	-2.442
yellow-poplar	Liriodendron tuliperfia	-1.325
white ash	Fraxinus americana	-0.900
American beech	Fagus grandifolia	-0.792
red maple	Acer rubrum	-0.417
black cherry	Prunus serotina	-0.350
sassafras	Sassafras albidum	-0.350
flowering dogwood	Cornus florida	-0.267
eastern whitepine	Pinus strobus	-0.258
chestnut oak	Quercus prinus	-0.242
northern redoak	Quercus rubra	-0.233

Change in average importance value of suitable habitat on the forest averaged across climate and emission scenarios

Conclusion:

- Lots of models
- Lots of predictions
- Lots of disagreement

- We need long-term forest health monitoring to sort them out

For Further Information

- Web site for most data presented today:
  - Little's boundaries
  - FIA data grouped by 20x20 km cell
  - Climate change atlases
  - Species-environment data for 134 trees
  - Pdfs of related papers

www.nrs.fs.fed.us/atlas

- For free hard copy of atlases or reprints:

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Thanks to USDA FS Northern Global Change Program for support