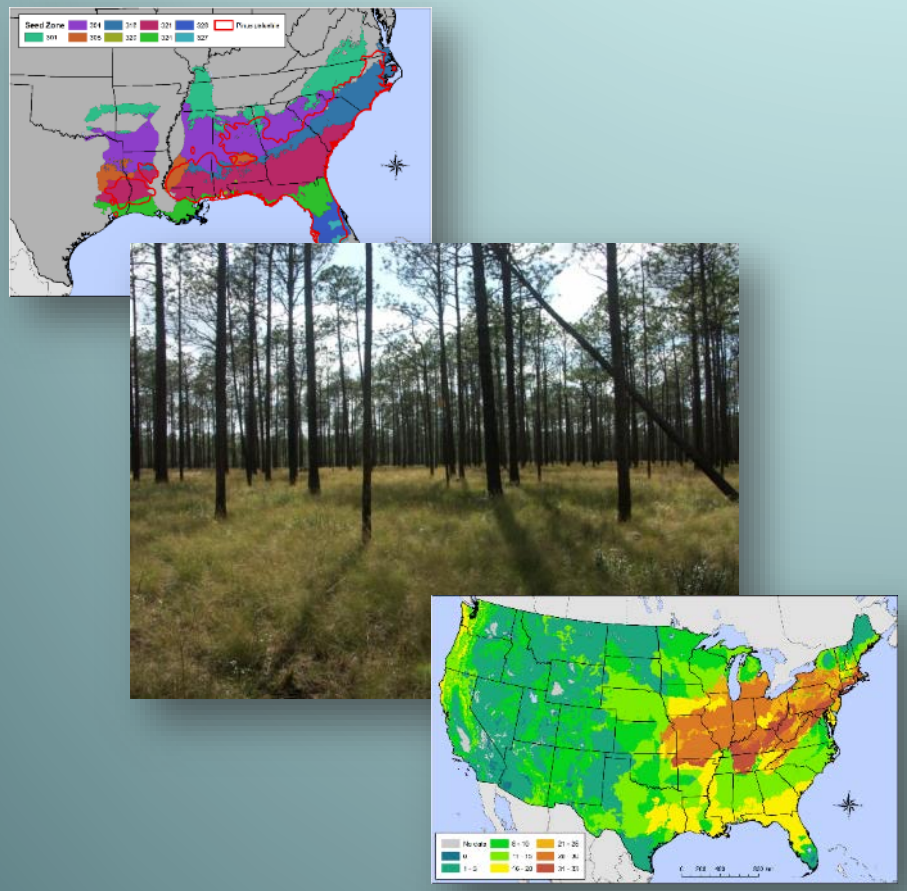
Provisional seed zones: Indispensable tools for conservation assessment



Kevin M. Potter

January 24, 2018

Eastern Seed Zone Forum Webinar

ESZF

NC STATE UNIVERSITY

FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

This webinar in a nutshell

1) Our forest resources face serious threats

2) Seed zones are important conservation tools

3) Generalized provisional seed zones are most useful for conservation purposes

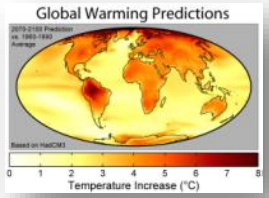
   - Climatic zones: Bower *et al.* (2014)
   - Quantitative ecoregions: Potter and Hargrove (2012)

4) Provisional seed zones are being applied in conservation assessments

   - For assessments of forest sustainability
   - For efforts to prioritize species for conservation, restoration, etc.

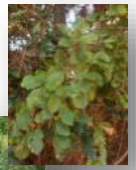
Trees and forests face complex, interacting threats

Insects and disease



Climate change

Invasive plants



Tree health

Wildland fire

Forest Health

Fragmentation and conversion

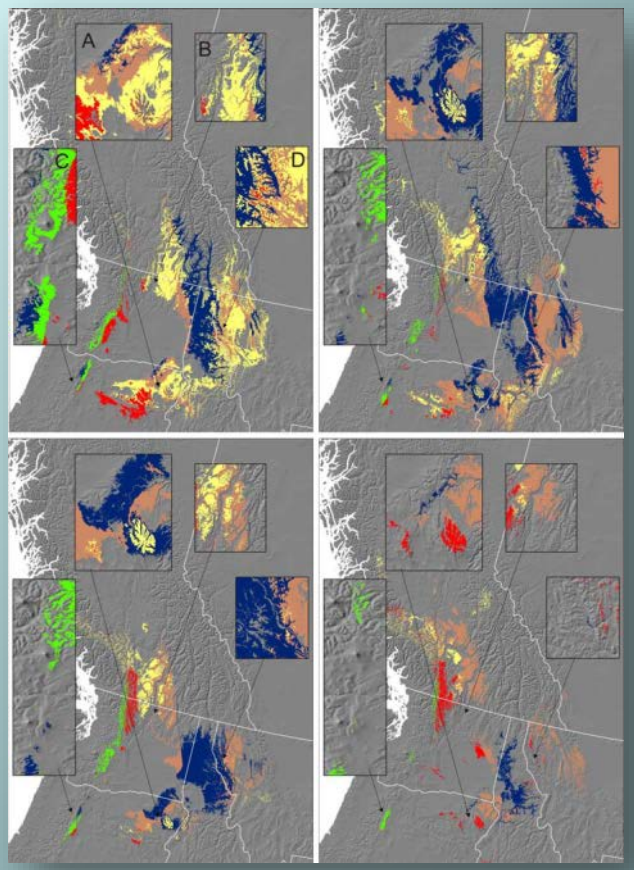
Seed transfer zones and guidelines

- **Seed transfer zone:** A defined area within which plant materials can be transferred with little risk of being poorly adapted to their new location
- **Seed transfer guidelines:** Suggestions about distance plant material can be moved while remaining adapted
- Adaptation implies populations are genetically "fit" with their environmental conditions

British Columbia Ministry of Forests, Lands and Natural Resource Operations (*www.for.gov.bc.ca*)

Seed zones and conservation

- Understanding the degree and extent of genetic variation is important for conservation
  - Need to describe genetic variation before it's possible to protect it
  - Seed zones are one way to delineate genetic units
- Empirical seed zones have been developed for some commercially important tree species
  - Based on adaptive genetic variation data from common garden experiments



Western larch (*Larix occidentalis*) seed zones in 2030 under three GCMs (Rehfeldt and Jacquith 2010)

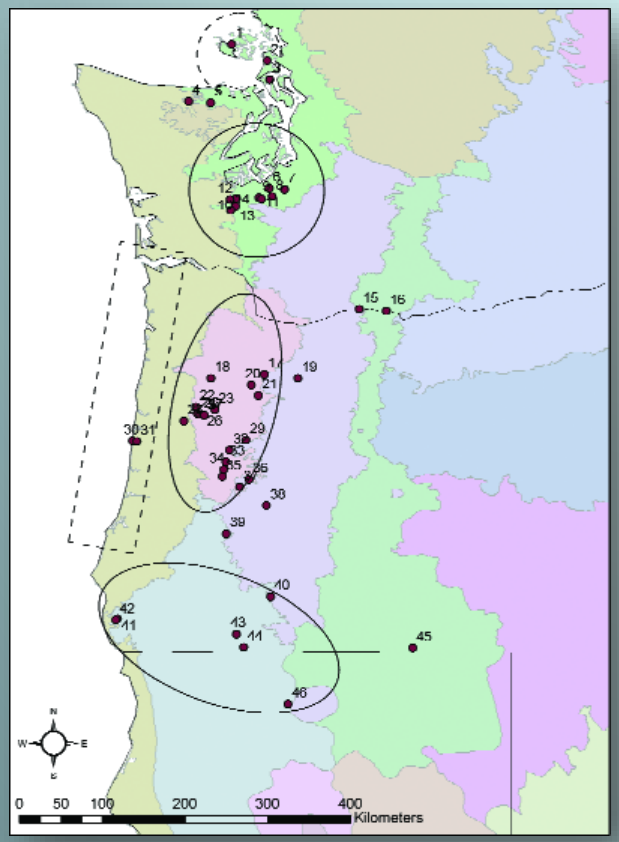
However…

- The continental United States encompasses more than 400 tree species:
  - Little if any information on adaptive genetic variation is available for most
  - Collecting this information is time-consuming and expensive
  - Time is of the essence: Several are at risk from pests and pathogens and/or climate change

What about those species?

- Use provisional seed zones
  - Determined based on environmental information, independent of genetics
  - Assumption: Adaptive variation in species associated with conditions that define the zones
- Can define seed transfer areas quickly and for many species

Generalized provisional seed zones

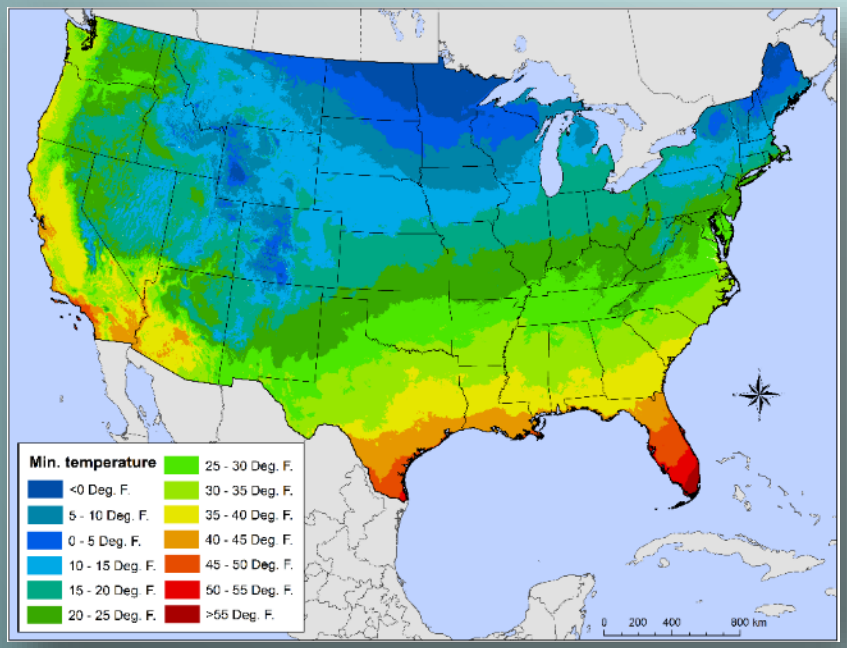


EPA Level III ecoregions used as seed transfer zones for a native grass species (Wilson *et al.* 2008)

- Areas with similar geology, climate, soils, hydrology, vegetation, etc.
  - Climatic zones (e.g., USDA Plant Hardiness Zones)
  - Coarse-resolution ecoregions (EPA Level III ecoregions, USDA Forest Service hierarchy of ecoregions)
  - Finer-resolution quantitative ecoregions

Seed zones based on climatic similarity

- Bower *et al*. (2014), *Ecological Applications*
  - Intersected minimum temperature with aridity



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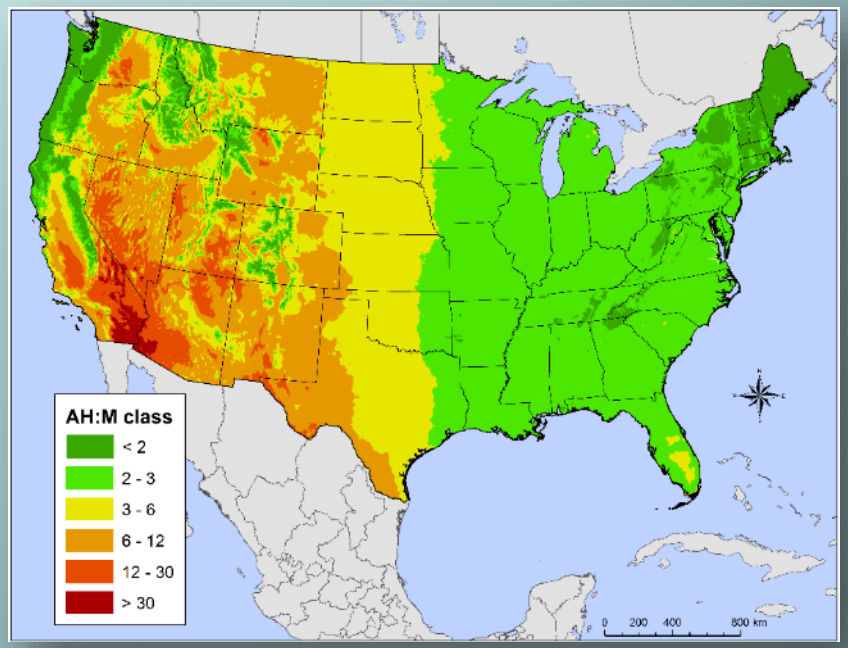
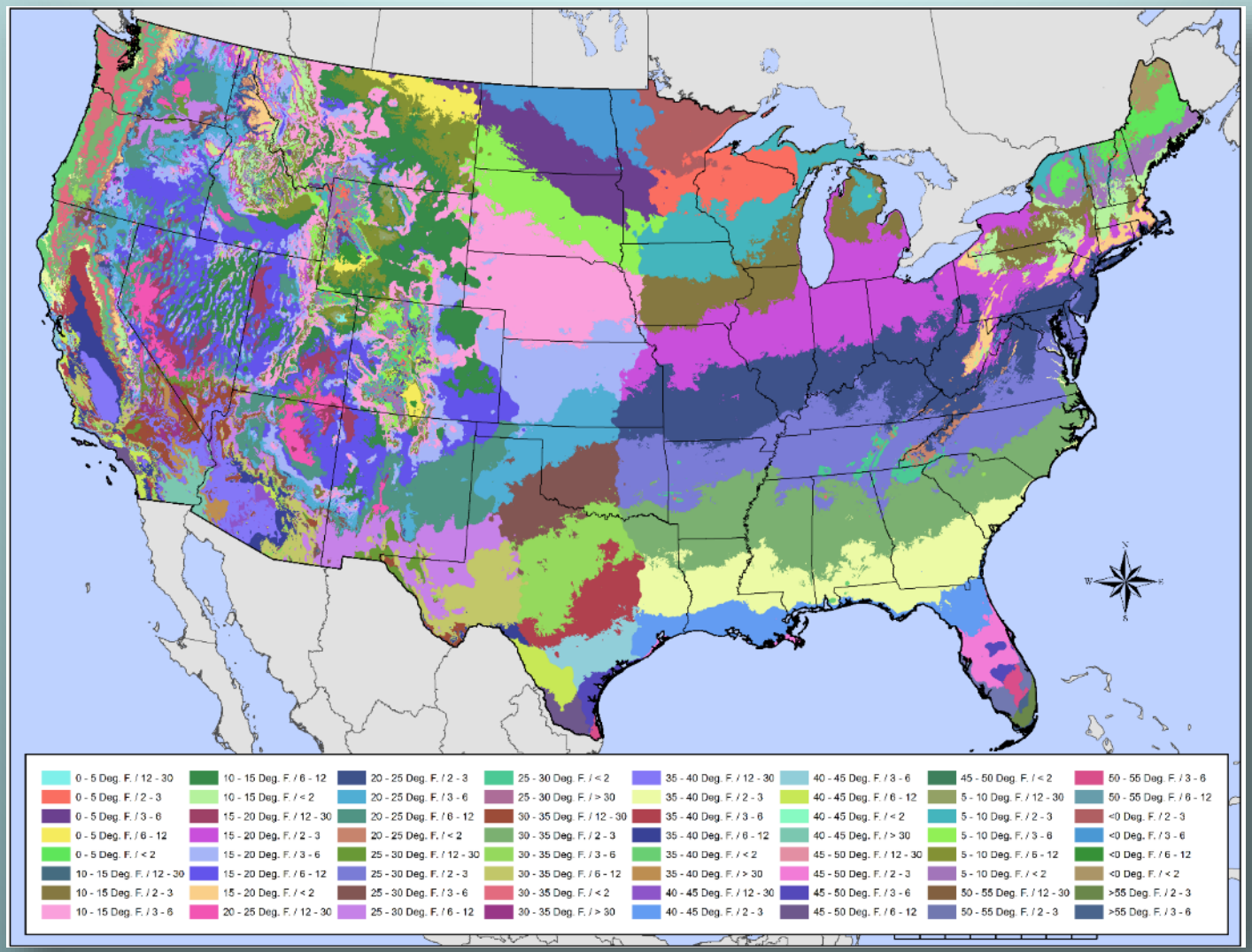
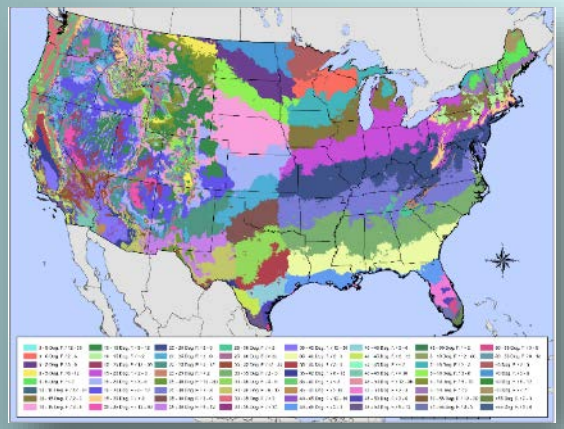


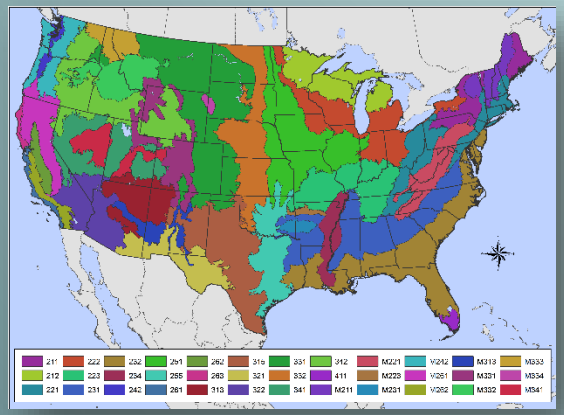
Bower *et al.* (2014): 64 provisional zones



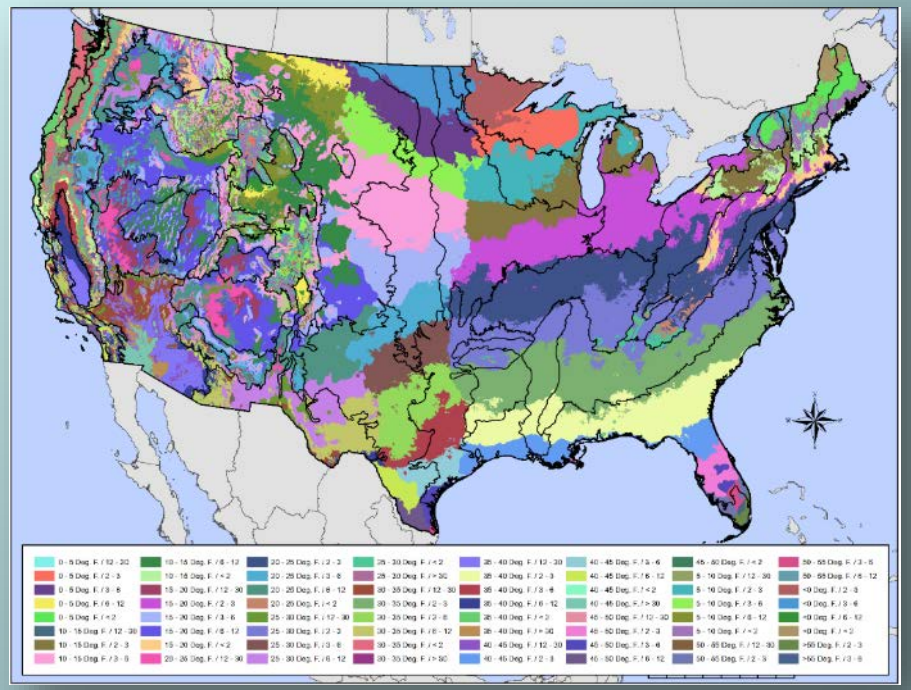
Climatic zones overlaid by ecoregions



Climatic seed zones
(Bower *et al.* 2014)

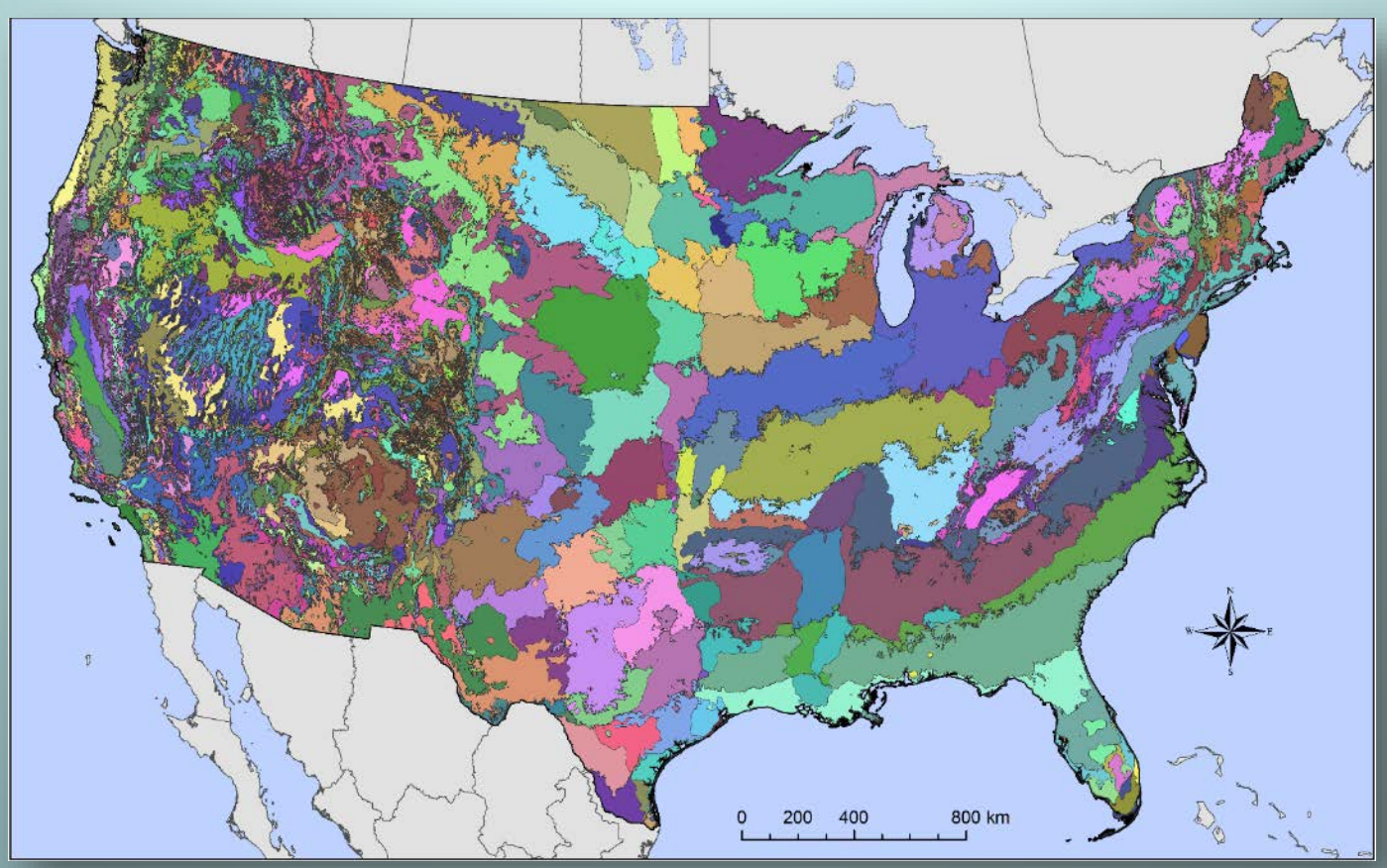


Ecoregion provinces
(Cleland *et al.* 2007)



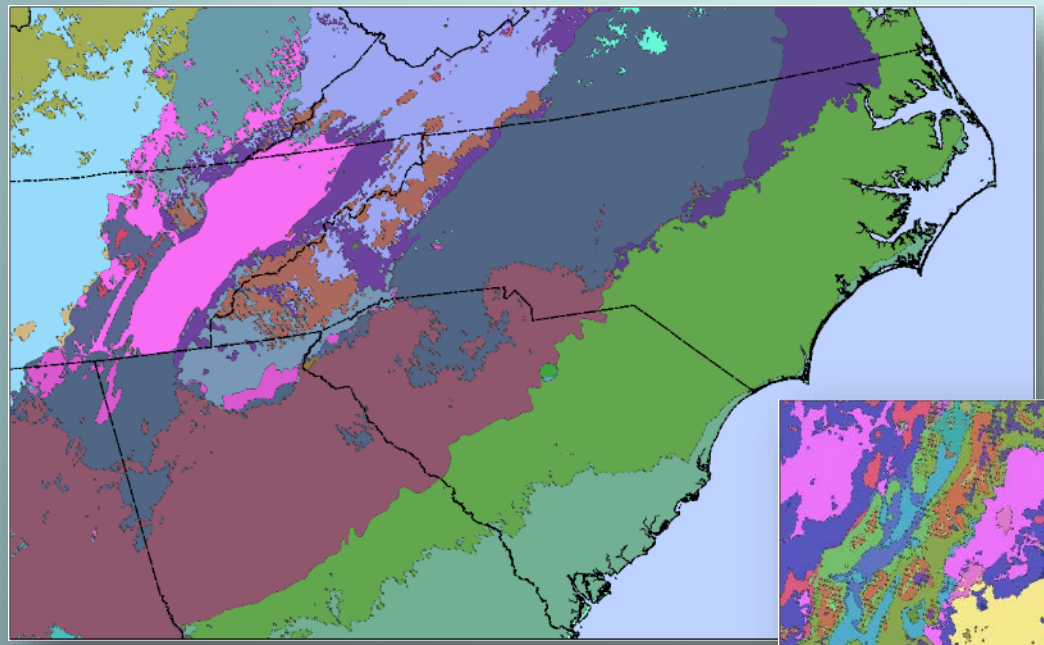
Bower *et al.* (2014): Such seed zones were nearly as good as empirical ones for accounting for adaptive variation in native plants

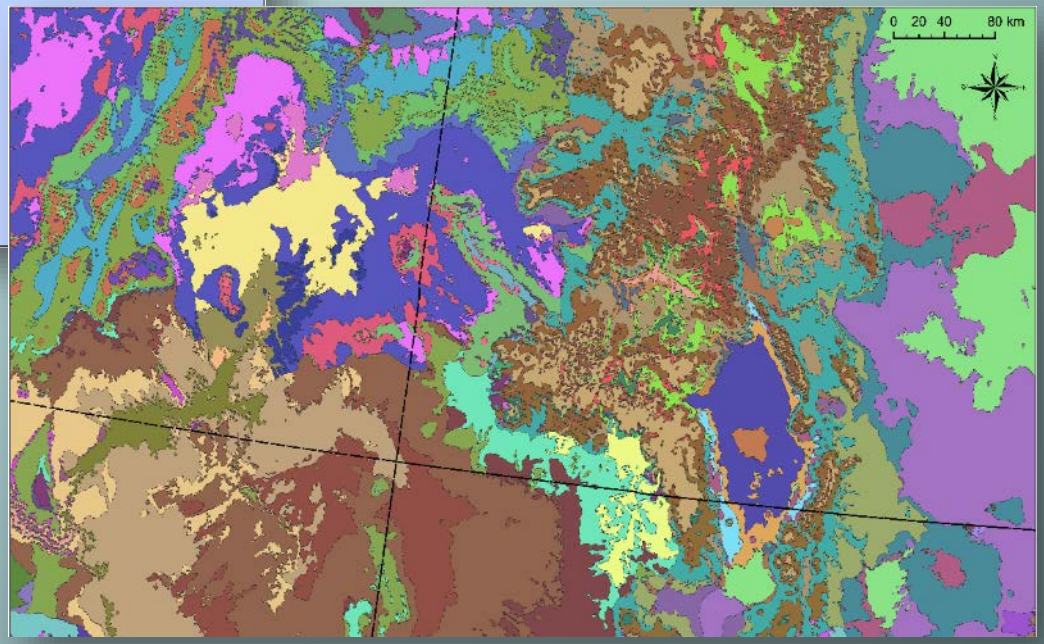
Climatic zones overlaid by ecoregions



- 474 zones containing forest or > 100,000 ha
- Average area: 1,637,809 hectares

Climatic zones: A closer look



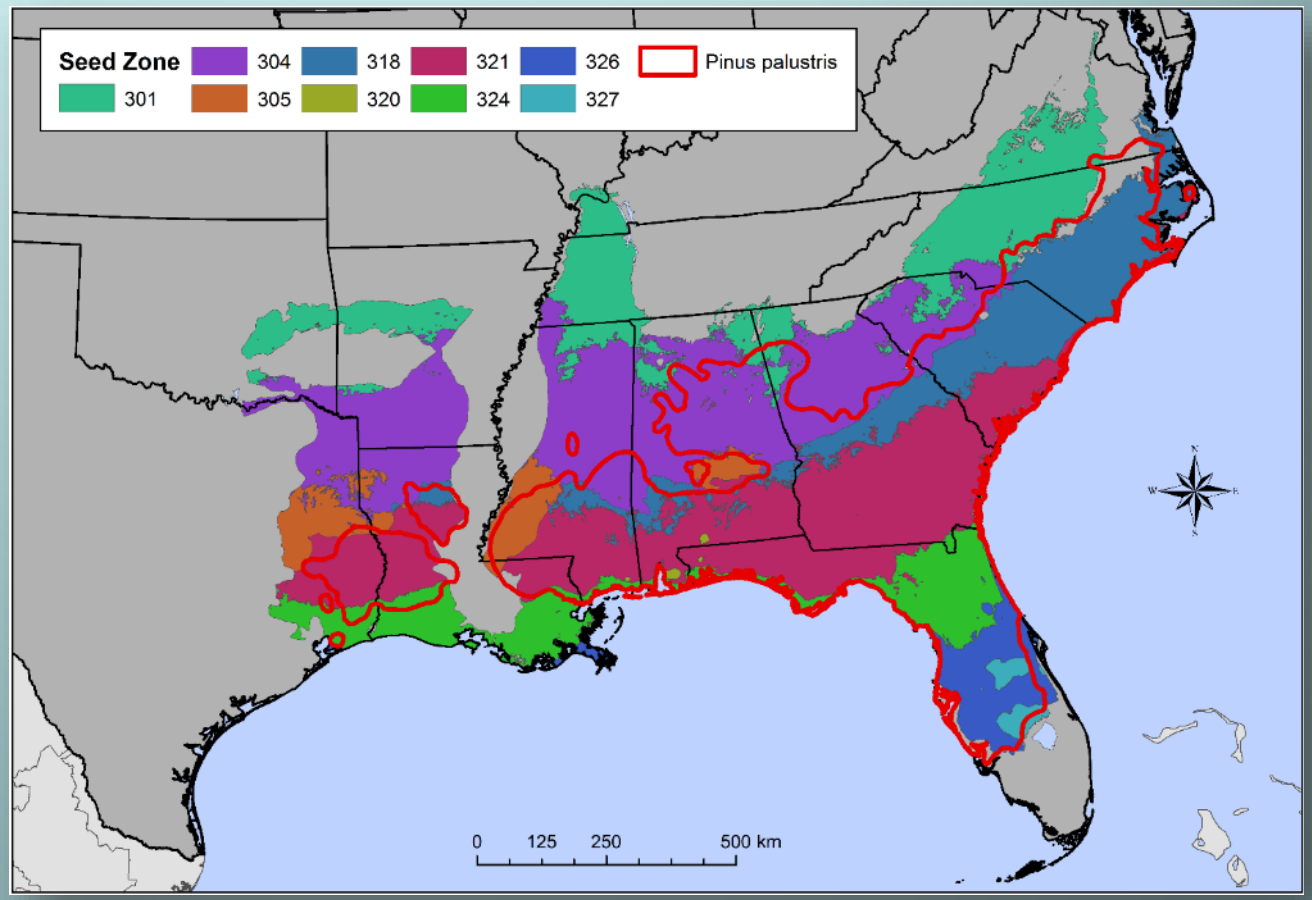


Above: The Carolinas

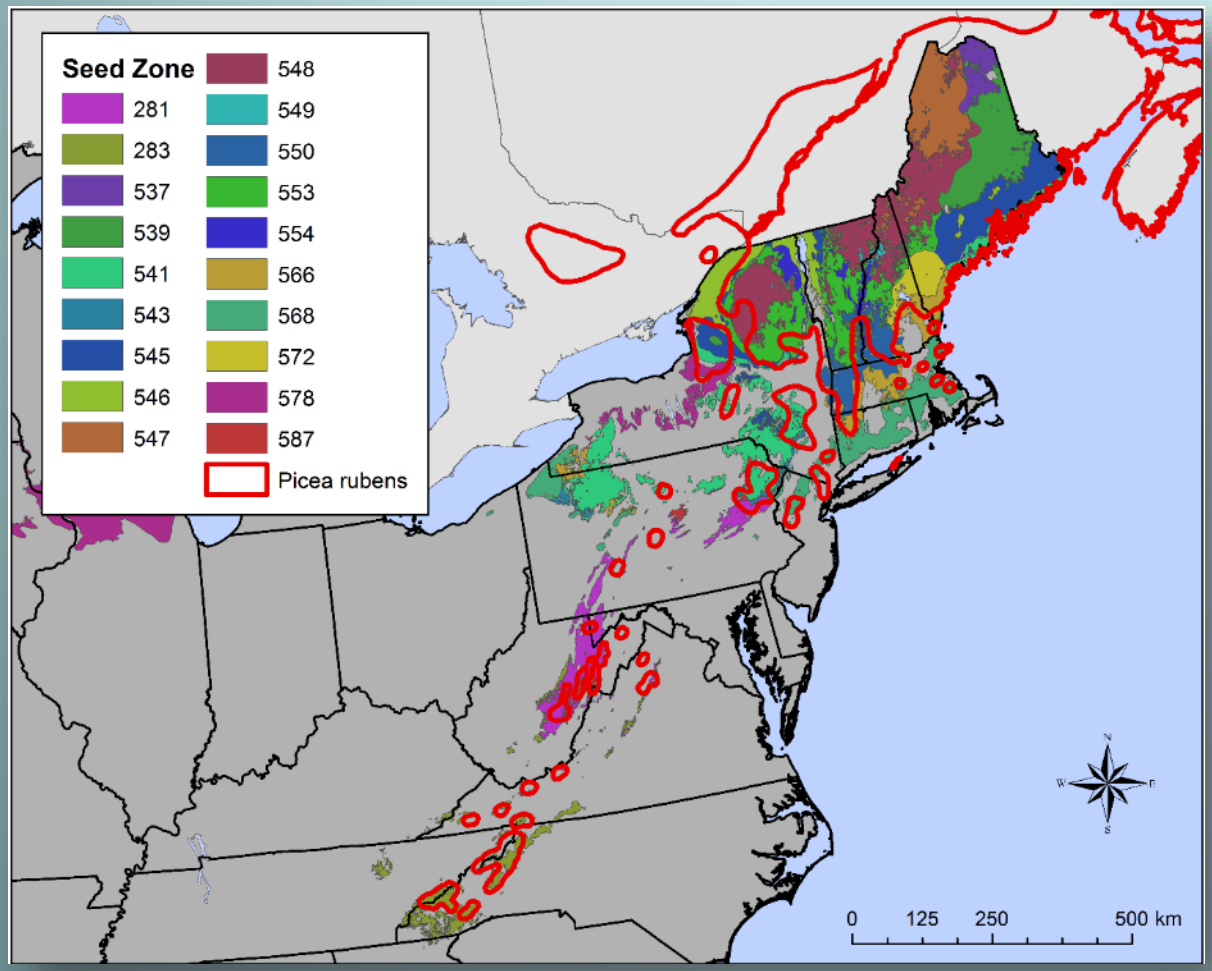
Right: The Four Corners region

Example: Longleaf pine (*Pinus palustris*)

Occurs in 9 provisional seed zones (on >5 Forest Inventory and Analysis plots)



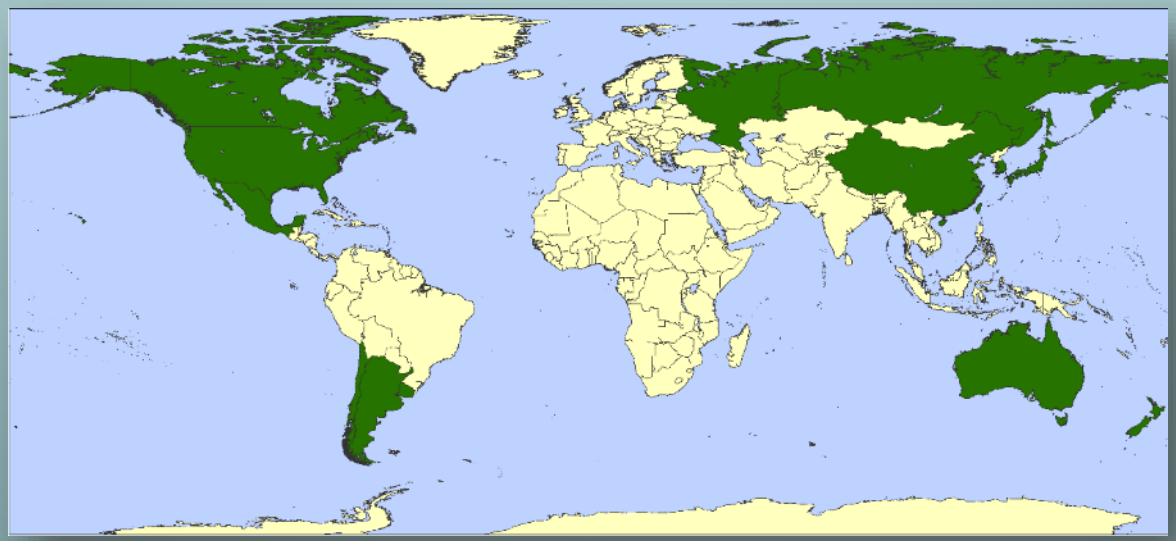
Example: Red spruce (*Picea rubens*)



Occurs in 19 provisional seed zones (on >5 Forest Inventory and Analysis plots)

Application for conservation assessment

- Montréal Process (MP) Criteria & Indicators (C&I)
  - International framework for assessing forest sustainability in 12 countries (7 criteria, 67 indicators)
  - Criterion 1 focuses on biological diversity: within species, between species, and of ecosystems



Montréal Process Criteria and Indicators

- USDA Forest Service's main sustainability assessment framework
  - Regular reports highlight the state of US forests and tracks trends in indicators

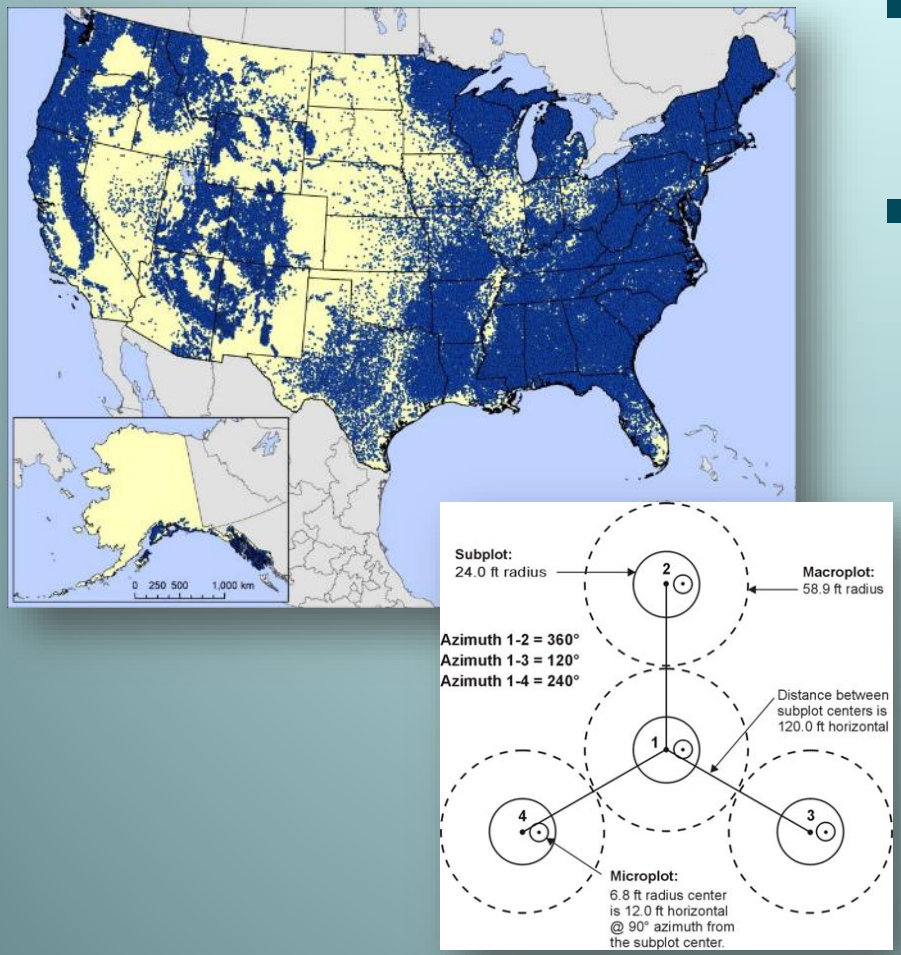
Criterion 1: Conservation of Biological Diversity

Subcriterion		Indicator
Ecosystem Diversity	1.01	Area and percent of forest by type
	1.02	Area and percent of forest in protected areas
	1.03	Fragmentation of forests
Species Diversity	1.04	Number of native forest-associated species
	1.05	Number and status of native forest associated species at risk
	1.06	Status of onsite and offsite efforts focused on conservation of species diversity
Genetic Diversity	1.07	Number and geographic distribution of forest associated species at risk of losing genetic variation and locally adapted genotypes
	1.08	Population levels of selected representative forest-associated species to describe genetic diversity
	1.09	Status of onsite and offsite efforts focused on conservation of genetic diversity

Needed: Genetic diversity indicators

- **<u>Indicator 1.07</u>**: Number and geographic distribution of forest associated species at risk of losing genetic variation and locally adapted genotypes
  - Proposed indicator: tree species regeneration (from inventory data) within provisional seed zones

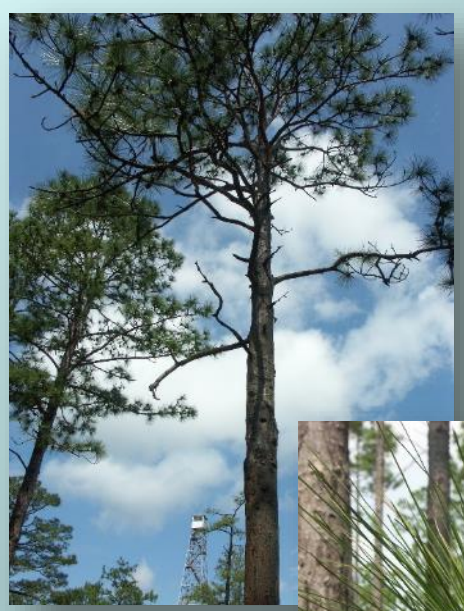
Forest Inventory and Analysis (FIA) plots



- Collected by USDA Forest Service
- ~130,000 plots across the lower 48 states and coastal southeast Alaska
  - 1 plot per 2,428 ha
  - 0.067-ha fixed-area plots
  - Remeasured 5-7 years in East, 10 years in the West

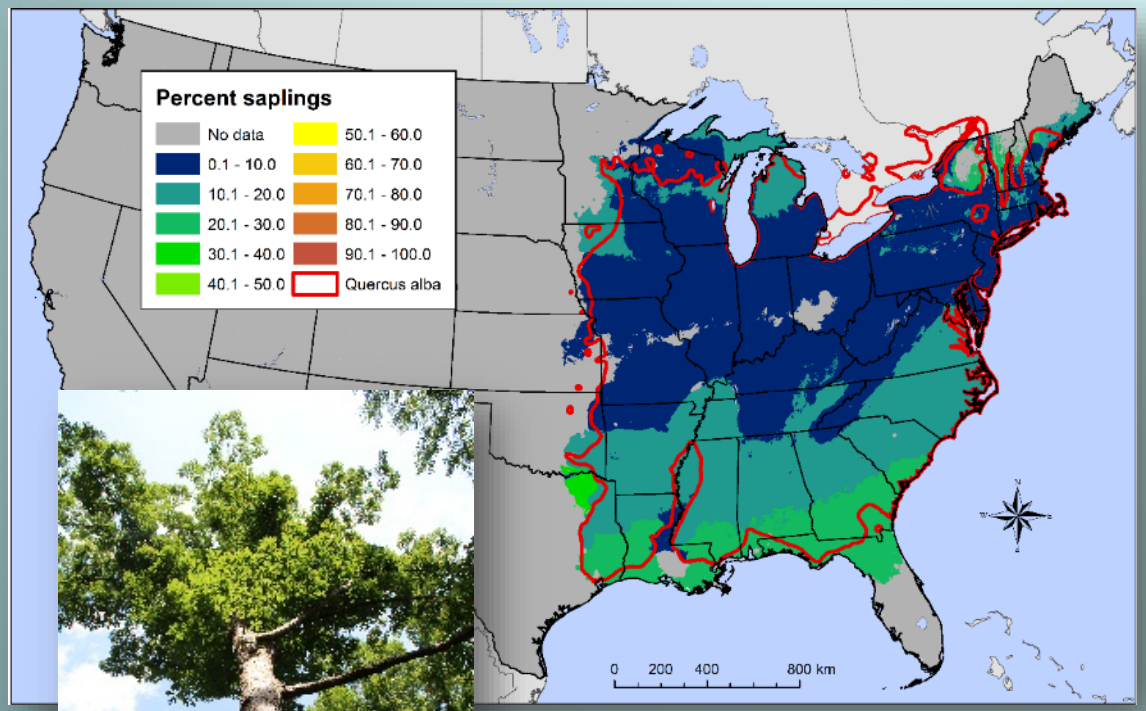
Regeneration indicator

- Percent of inventoried trees across plots that are saplings (1-5 inches dbh) for each species
  - Smaller numbers suggest insufficient recruitment
- "Unsustainable" regen-eration: <10 percent saplings
  - Calculated across a species' range and within seed zones with ≥5 plots
  - Adjustable threshold



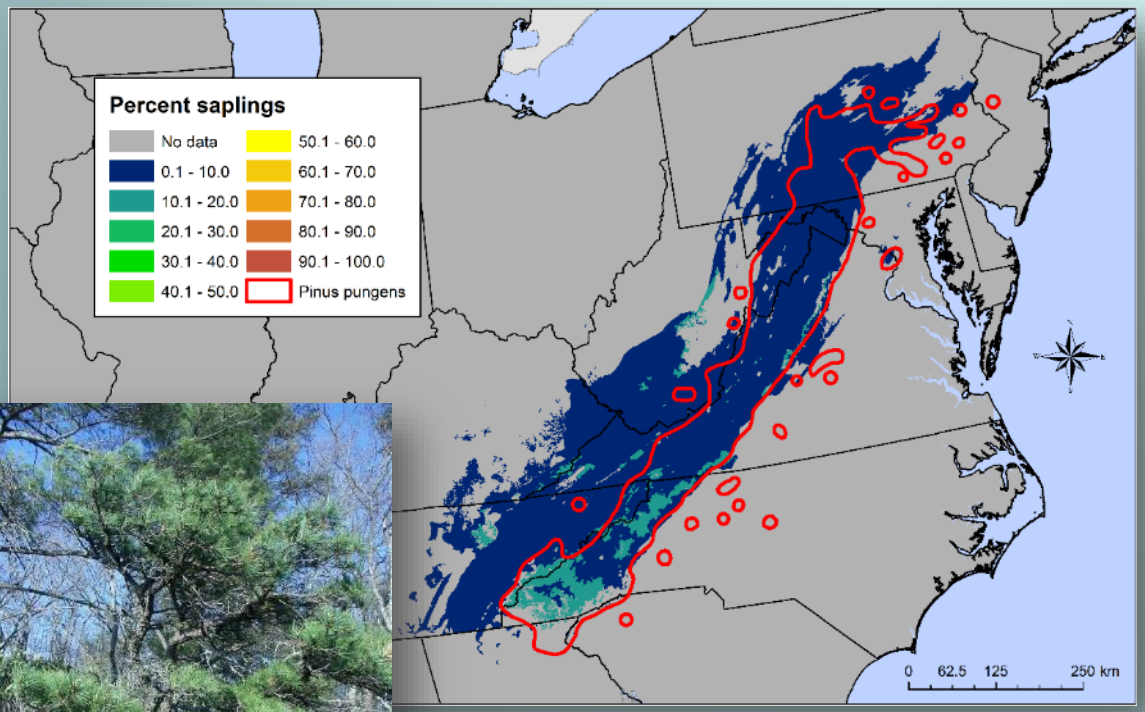
Longleaf pine (*Pinus palustris*)

White oak (*Quercus alba*)



- Saplings: 10.2% of trees across range
- <10% saplings on 39 of 66 seed zones (59%)
  - Mean across zones: 8.0%

Table Mountain pine (*Pinus pungens*)

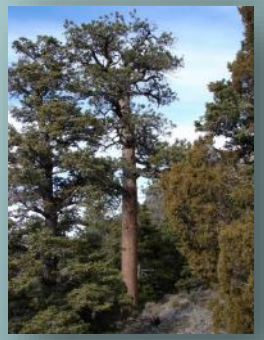
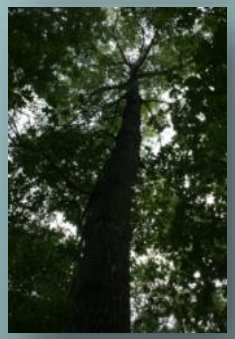


- Saplings: 5.7% of trees across range
- <10% saplings on 4 of 5 seed zones (80%)
  - Mean across zones: 6.2%

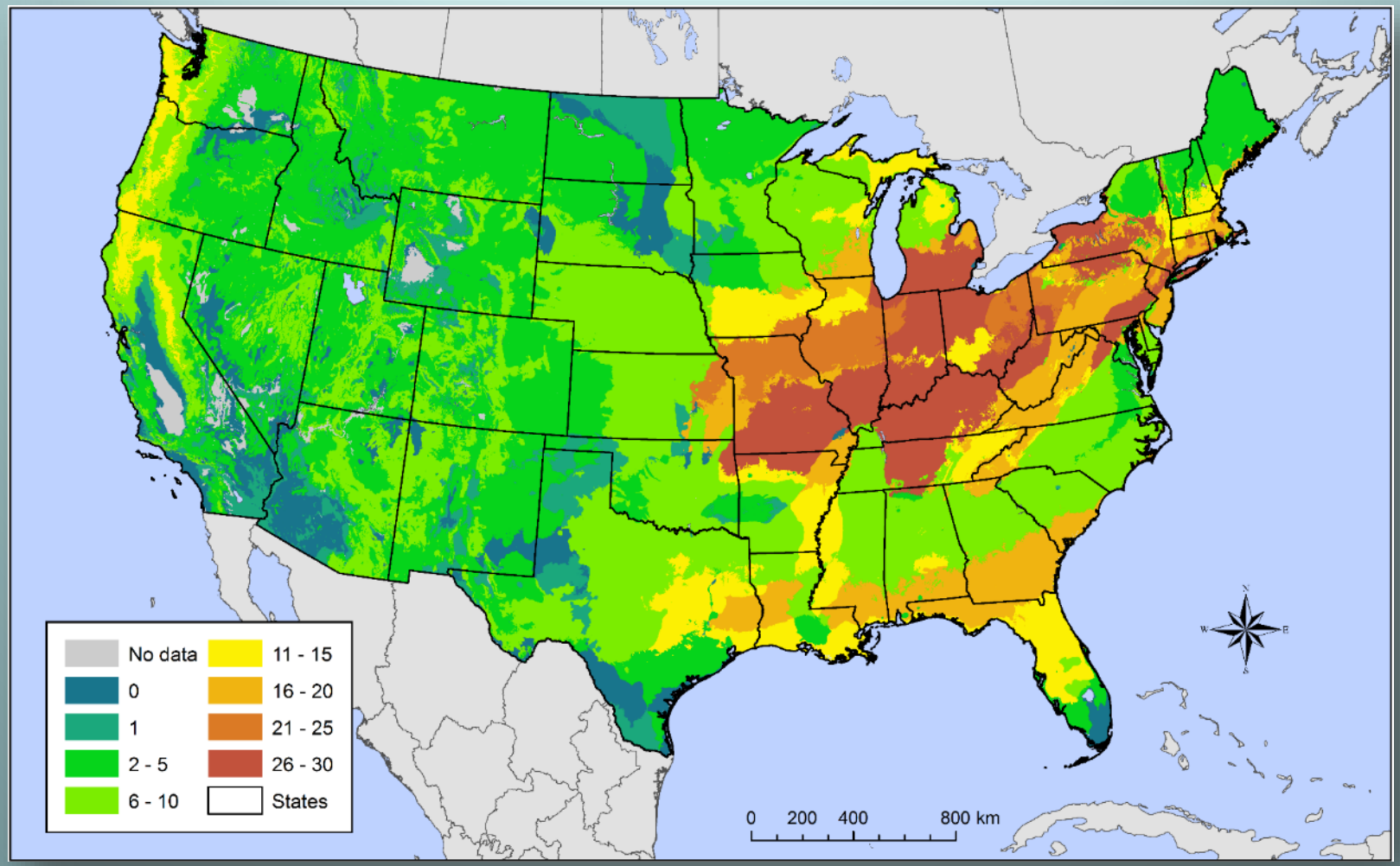
Tree species at risk

- Of 295 tree species, 81 (27.5 percent) have <10 percent saplings across their ranges
  - Average: 25.0 percent
- Examples:
  - Giant redwood, Rocky Mountain bristlecone pine (0 percent)
  - Sugar pine (5.4 percent)
  - Black walnut (6.6 percent)
  - Ponderosa pine (7.2 percent)
  - Red oak (8.7 percent)
  - Sugar maple (8.8 percent)
  - Butternut (9.6 percent)



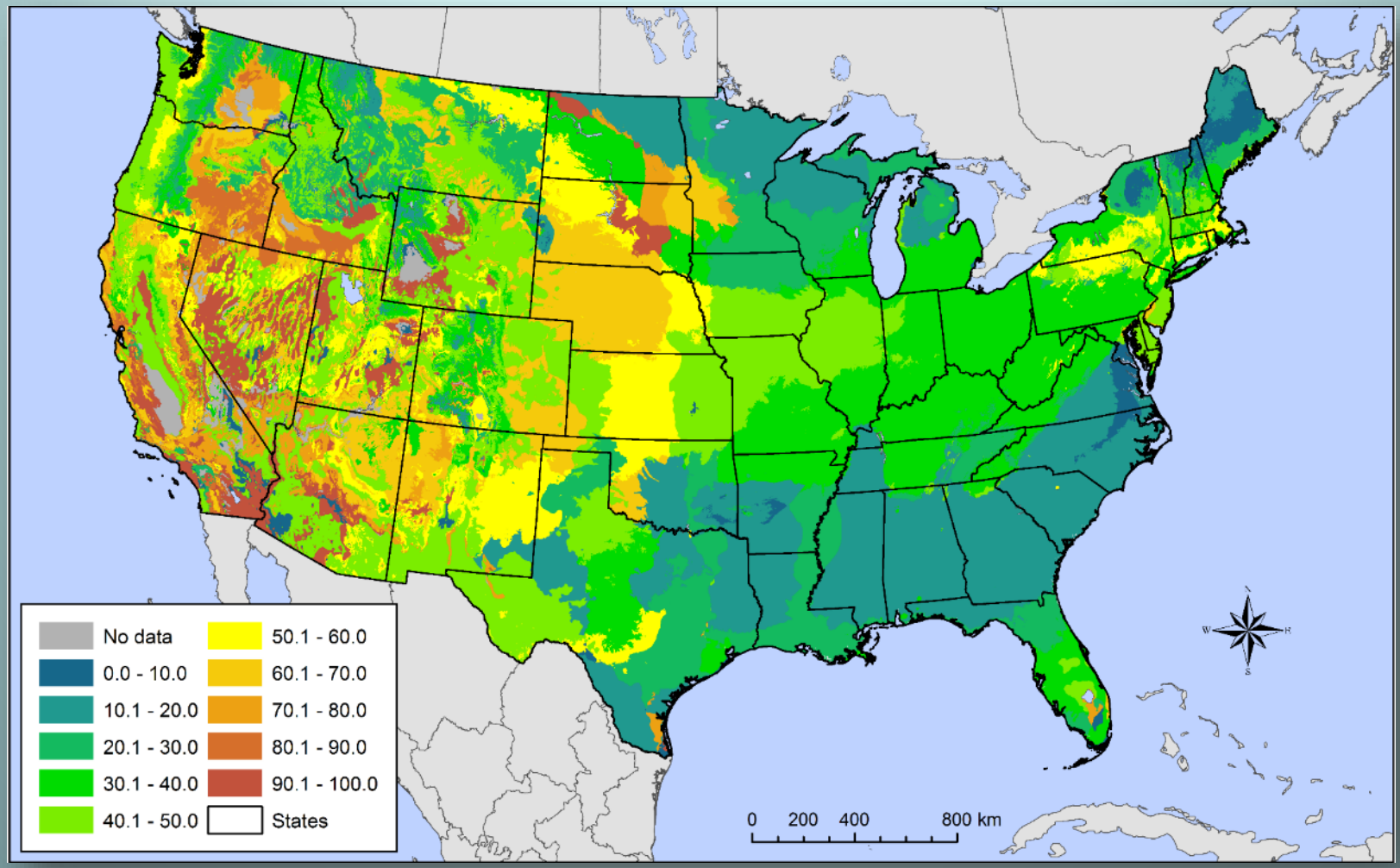





Geographic distribution of tree species at risk



Number of tree species with <10% saplings (of 295), by seed zone

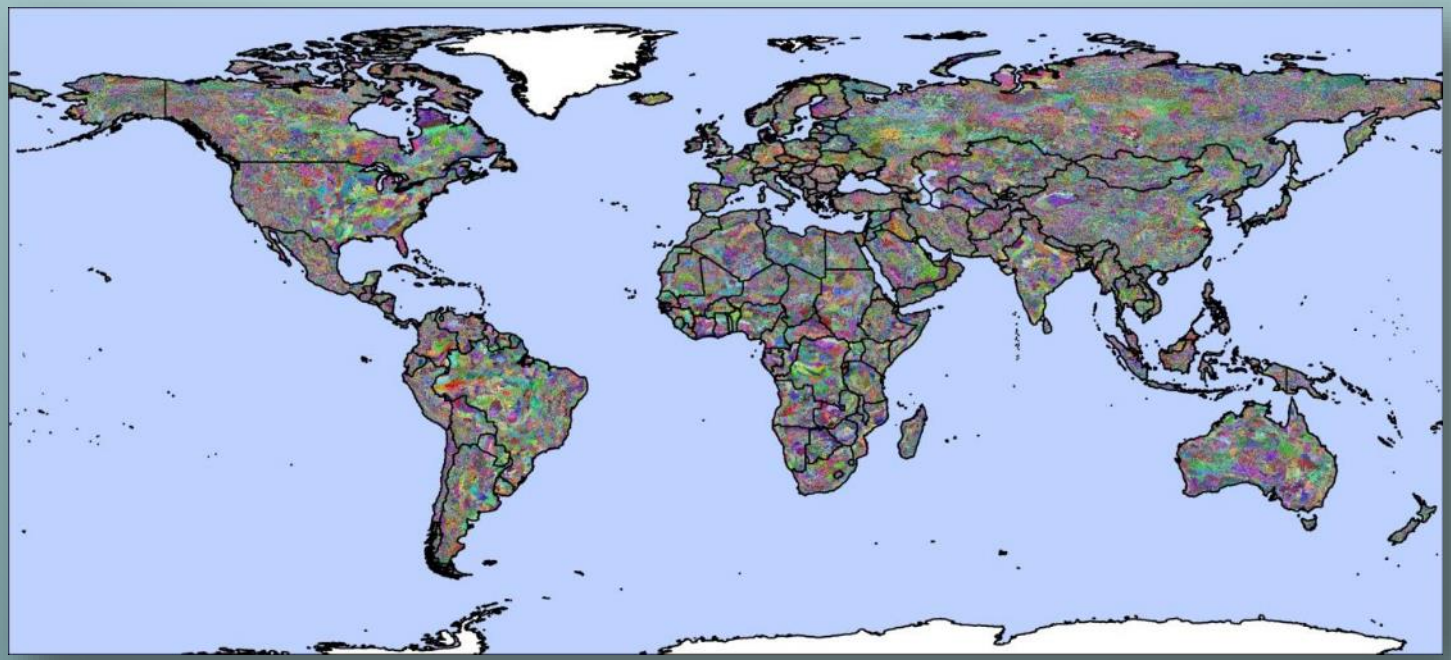
Geographic distribution of tree species at risk



Percent of tree species with <10% saplings (of 295), by seed zone

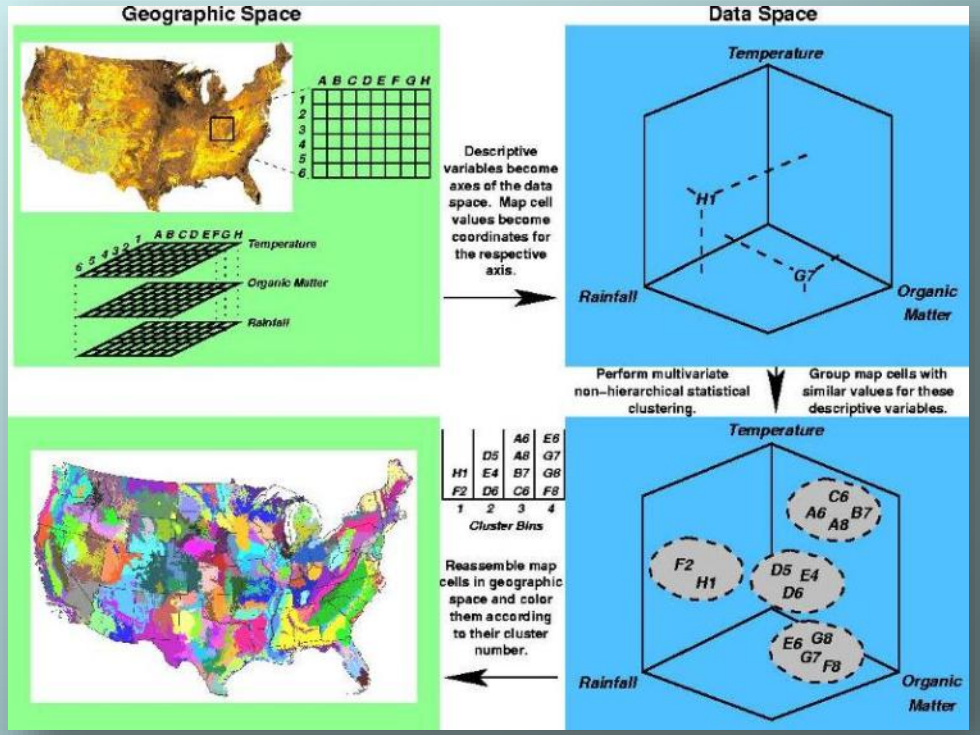
Quantitative ecoregional seed zones

- Potter and Hargrove (2012), *New Forests*
  - Based on quantitative clustering of 16 environmental variables



Multivariate Spatio-Temporal Clustering

- Hargrove and Hoffman (2005)
  - Assigns each 4-km^2 pixel across the globe into one of 30,000 unique "ecoregions" based on 16 spatial environmental variables
  - Two pixels with similar characteristics will be located together in this data space



(Hoffman et al. 2002)

Environmental variables

- **Soils**
  - Plant-available water capacity
  - Bulk density of soil
  - Kjeldahl soil nitrogen
  - Organic matter in soil
- **Temperature**
  - In the coldest quarter
  - In the warmest quarter
  - Diurnal temperature difference
  - Biotemperature
  - Solar insolation
- **Precipitation**
  - In the driest quarter
  - In the wettest quarter
  - In the warmest quarter
  - In the coldest quarter
  - Ratio of precipitation to potential evapotranspiration
- **Topography**
  - Compound topographic index
- **Growing season**
  - Length in integer months

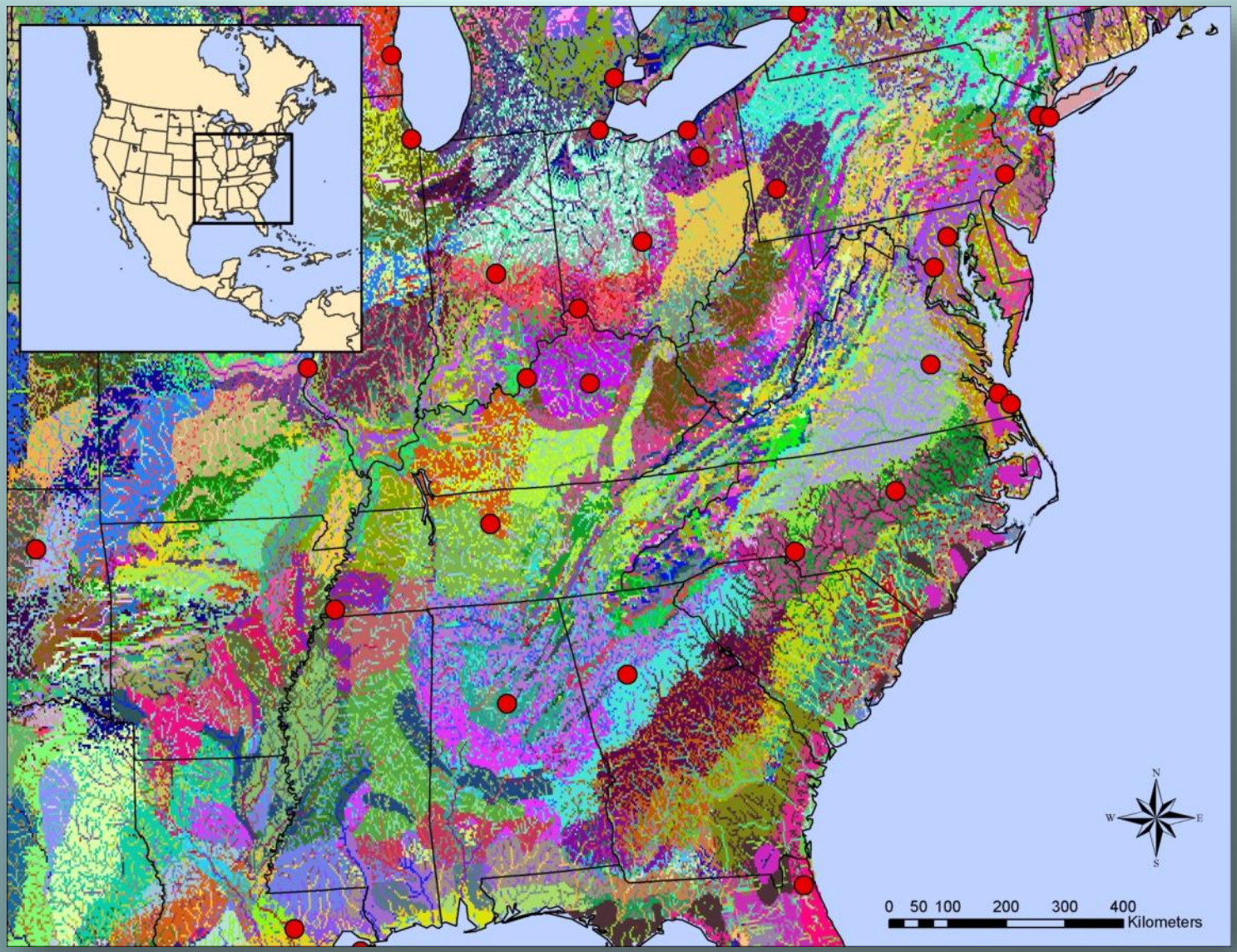
Ecoregions = quantitative seed zones

1) Ecoregions contain roughly equal environmental heterogeneity
   - Possible to use fewer, larger ecoregions (e.g., 10,000) with greater heterogeneity
   - We present more, smaller ecoregions (30,000) with less heterogeneity

2) Possible to measure the environmental distance between pairs of ecoregions
   - Closer in data space = more environmentally similar

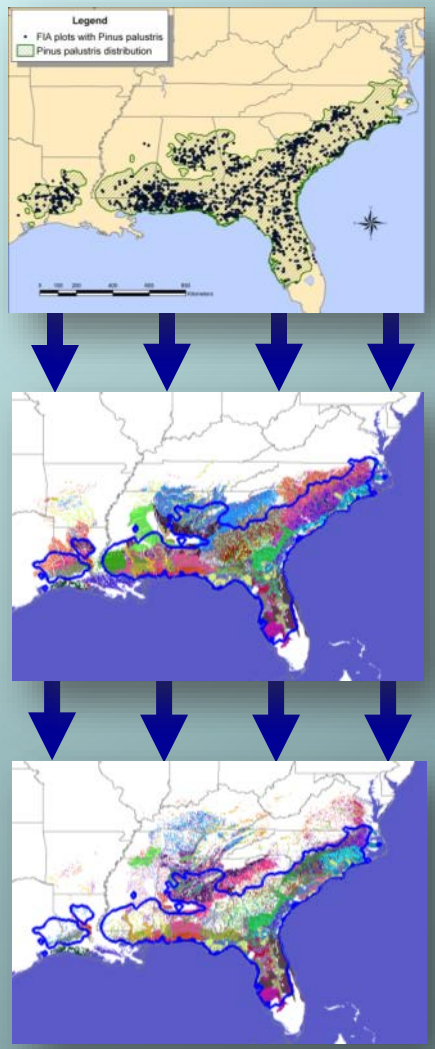
3) Can be projected forward and backward in time based on global circulation models and emissions scenarios

Current ecoregional seed zones, North America

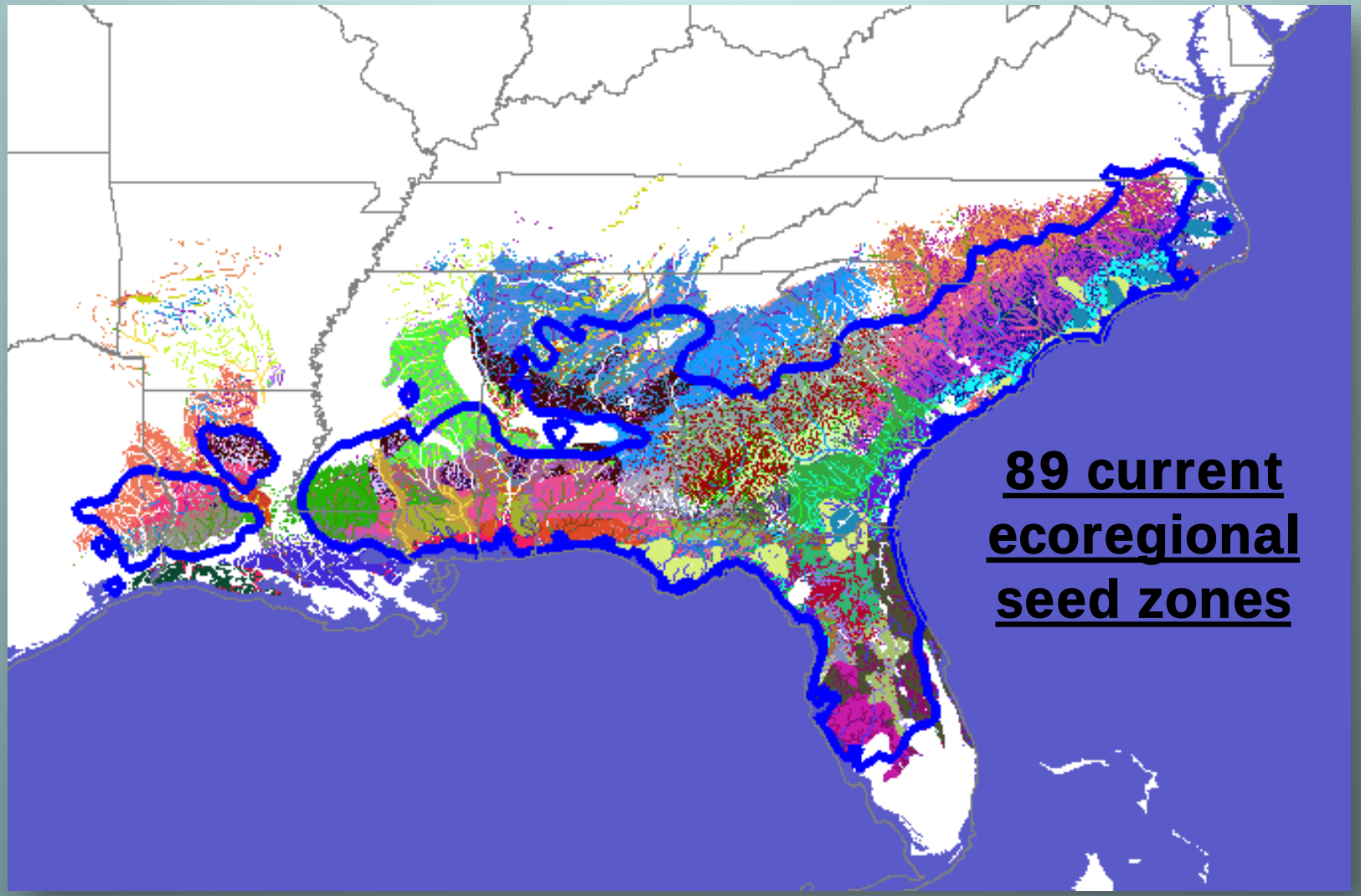


Ecoregional seed zones for species

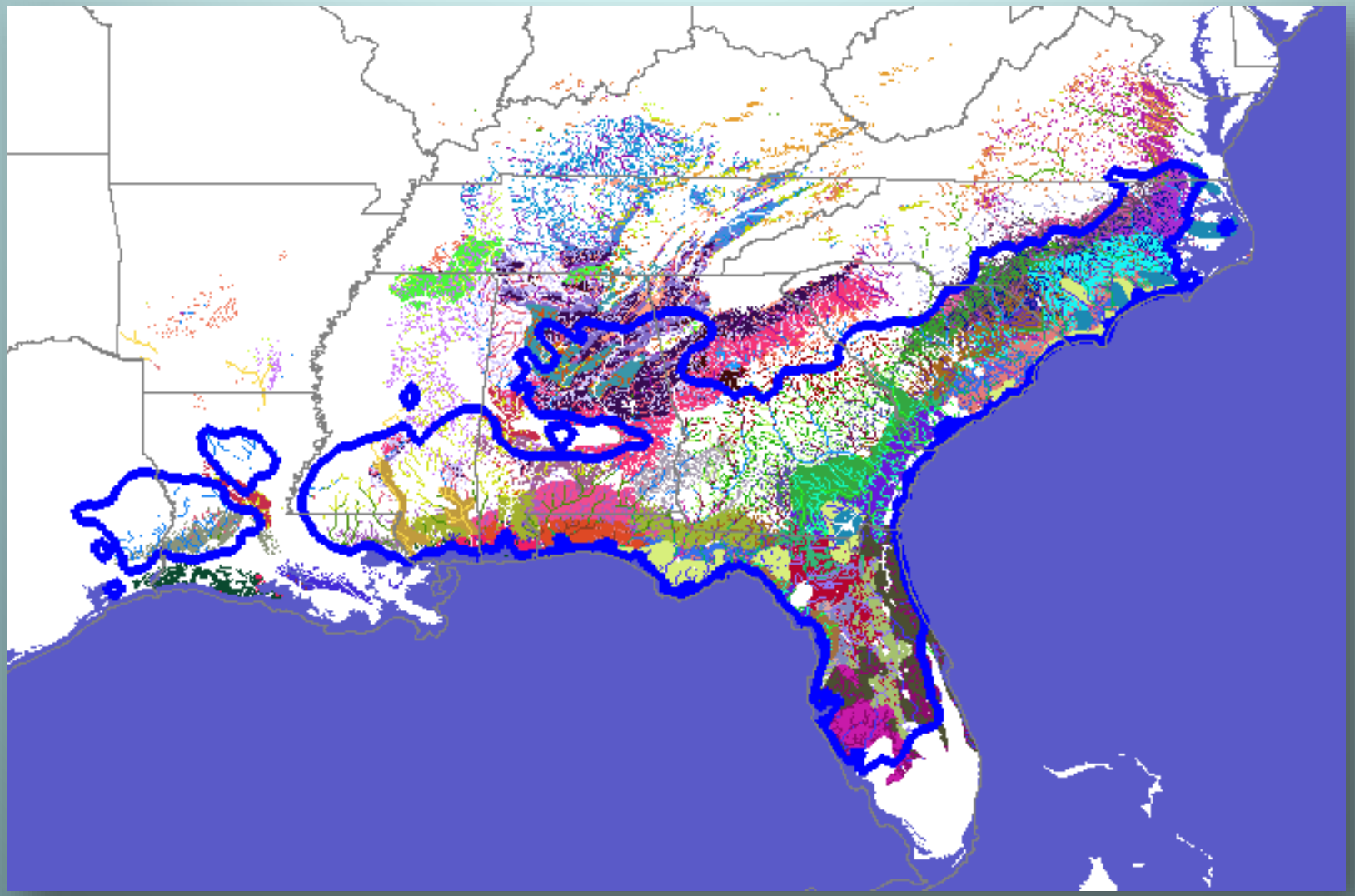
- MSTC predicts current ecoregions suitable for species, then projects future locations of those ecoregions
  - Two global climate models (GCMs): Hadley and PCM; two emissions scenarios high and low emissions
  - Training data: tree occurrences from Forest Inventory and Analysis data



Longleaf pine current seed zones



Longleaf pine 2050 seed zones, Hadley B1



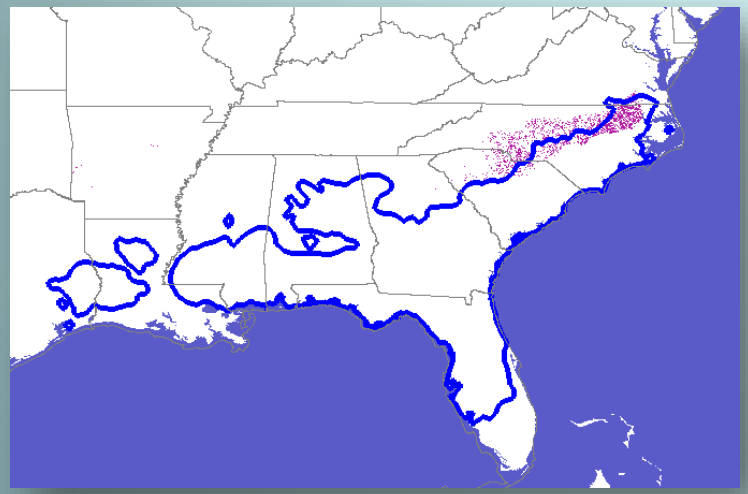
Forward and reverse projections

- **Forward:** *"If I have seeds from a given location, where can I plant them to best ensure the trees will be well-adapted in the future?"*

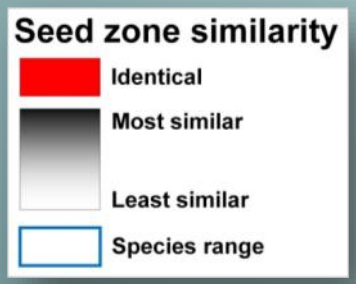
- **Reverse:** *"If I want to plant trees in a given location and best ensure those trees will be well-adapted in the future, where do I go to collect the seeds?"*

Seed zone similarity

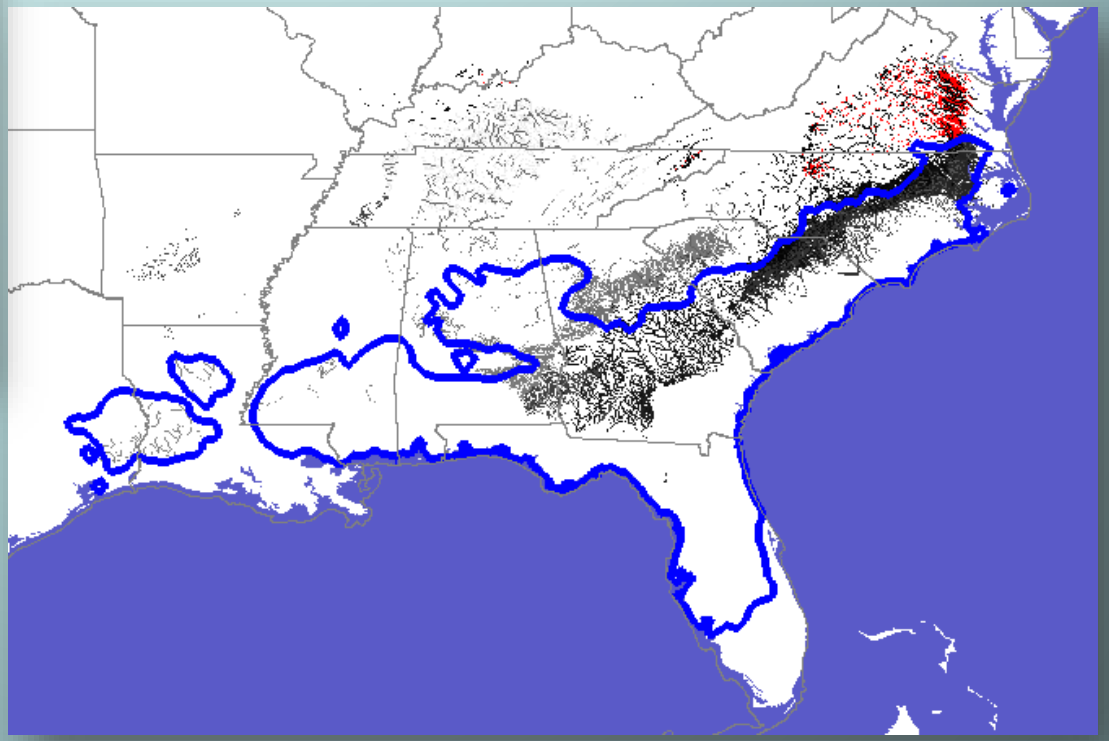
"Seeds from here now, plant where for later?"



Target seed source, current time



Longleaf pine



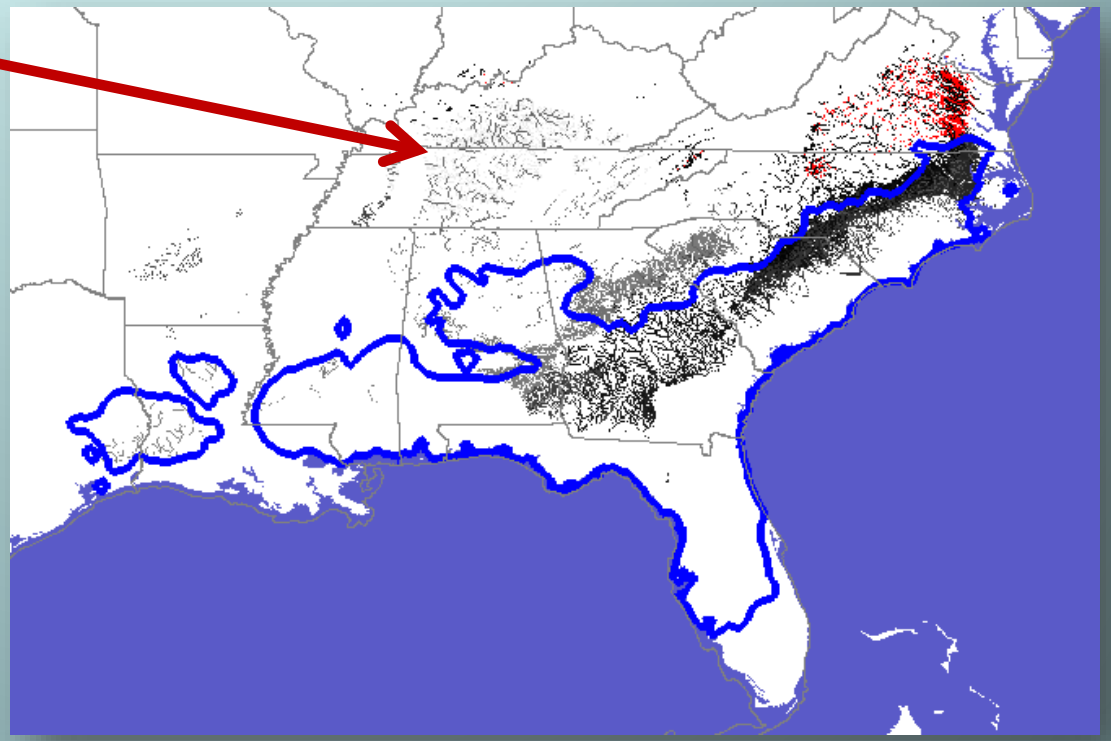
Predicted suitability, Hadley B1, 2050

Seed zone similarity

"Seeds from here now, plant where for later?"

Longleaf pine

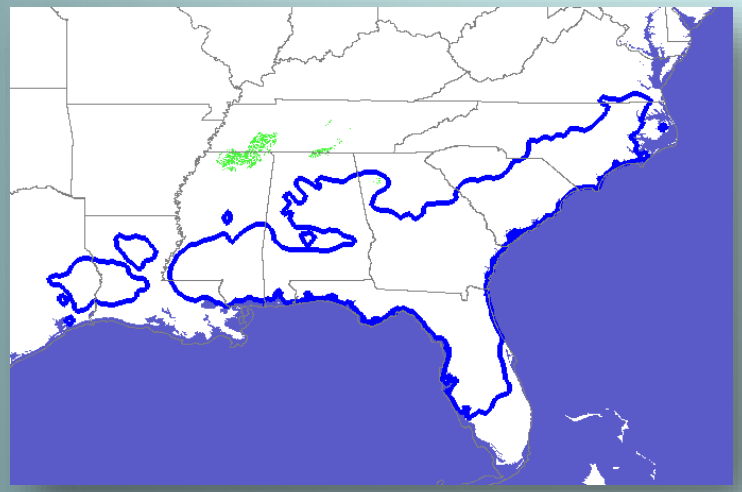
Similarity gradient:
The farther seed transfer occurs along the gradient, the greater the risk of maladaptation to new site.



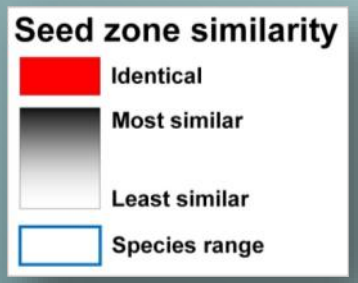
Predicted suitability, Hadley B1, 2050

Seed zone similarity

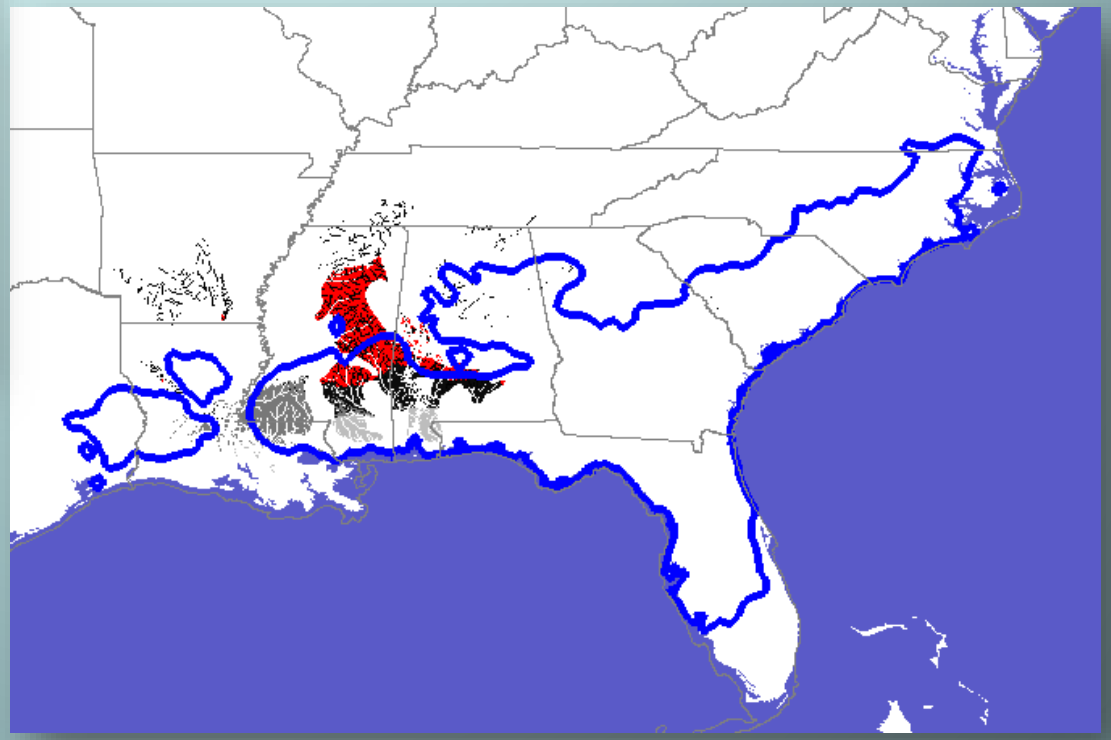
"Trees for here later, seeds from where now?"



Target planting location, Hadley B1 2050

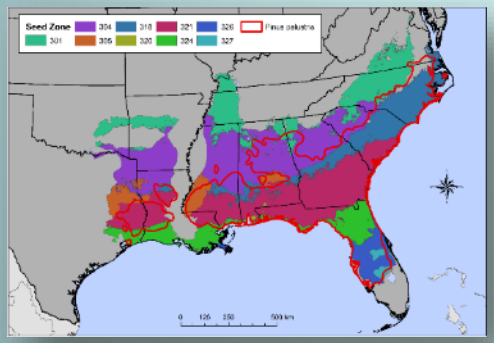


Longleaf pine

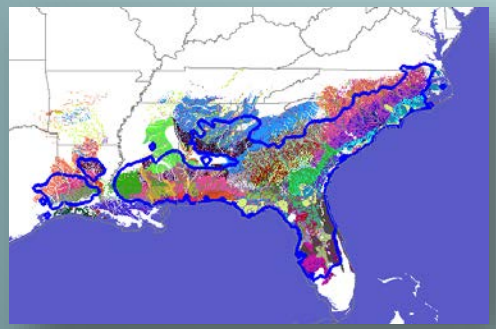


Predicted suitable current seed sources

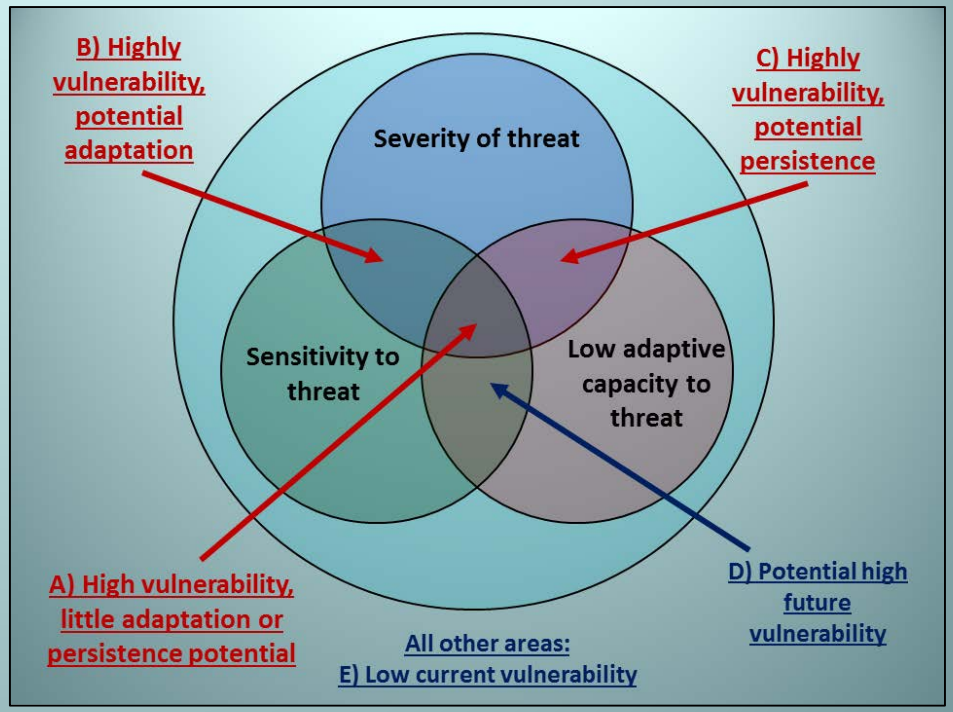
Informing conservation prioritization



Climatic seed zones (Bower *et al.* 2014)



Quantitative seed zones (Potter and Hargrove 2012, 2013)

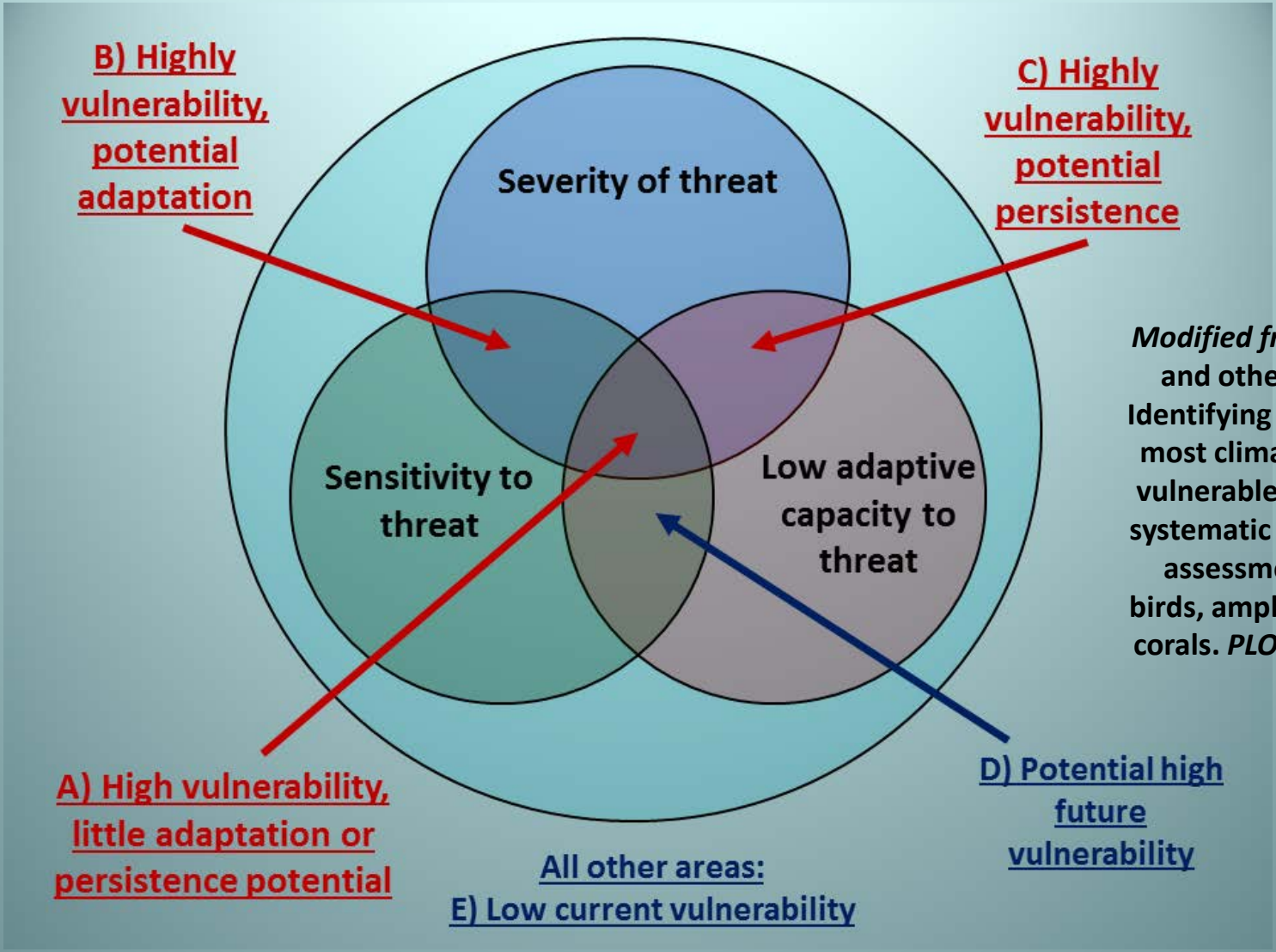


Project CAPTURE (Potter *et al.* 2017)

Project CAPTURE

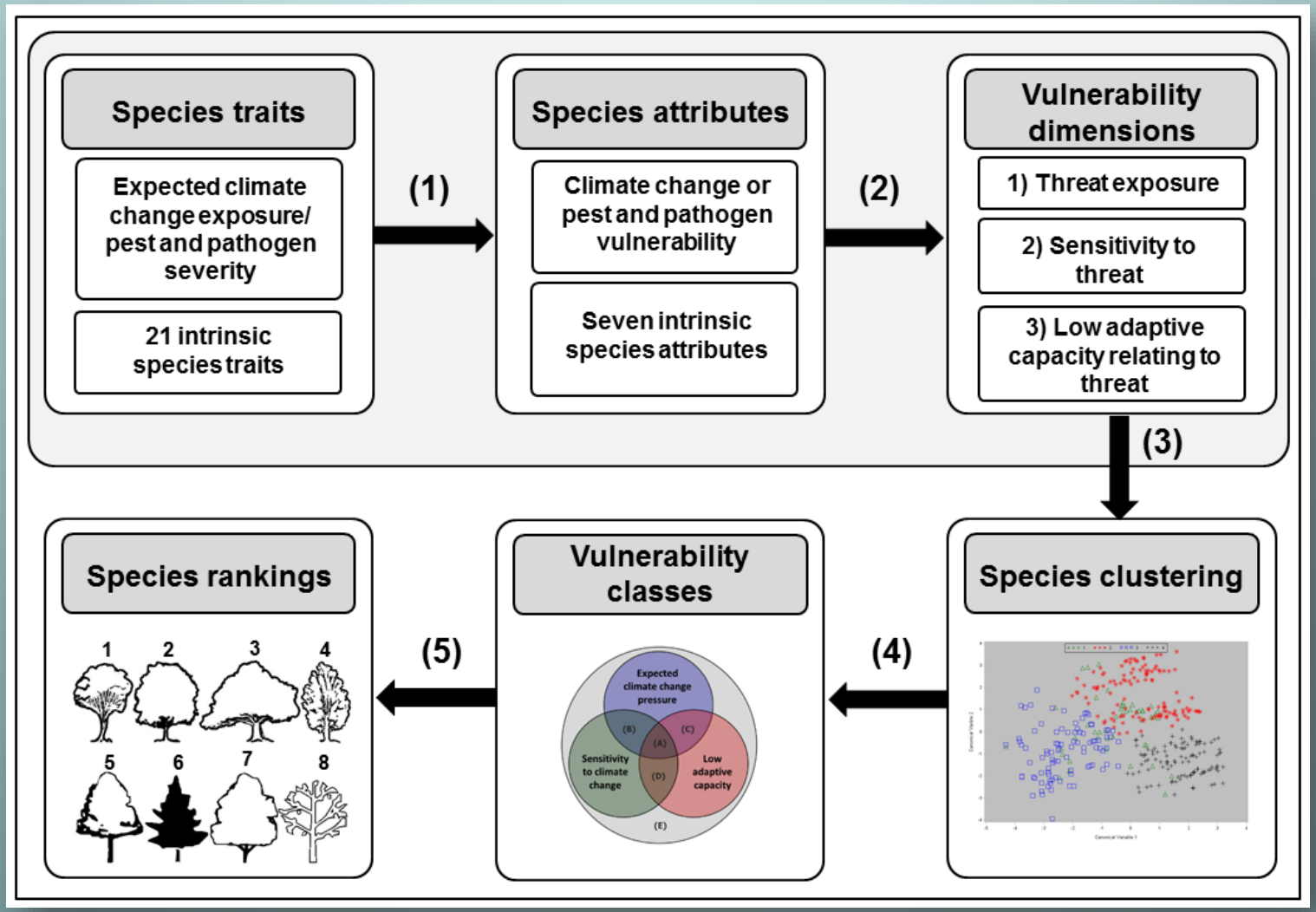
- Conservation Assessment and Prioritization of Forest Trees Under Risk of Extirpation
- National, multi-scale project to identify, categorize and prioritize forest tree species and populations at risk of genetic degradation
  - Funded by USDA Forest Service (all three deputy areas)
- For gene conservation, monitoring, management and restoration; covers ~400 native tree species
- Data-driven process guided by expert opinion

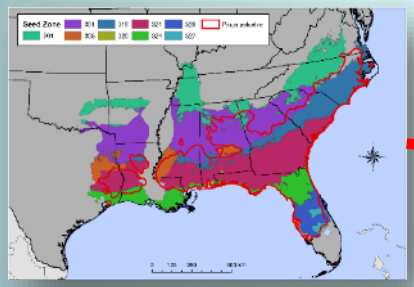
Grouping species into vulnerability classes

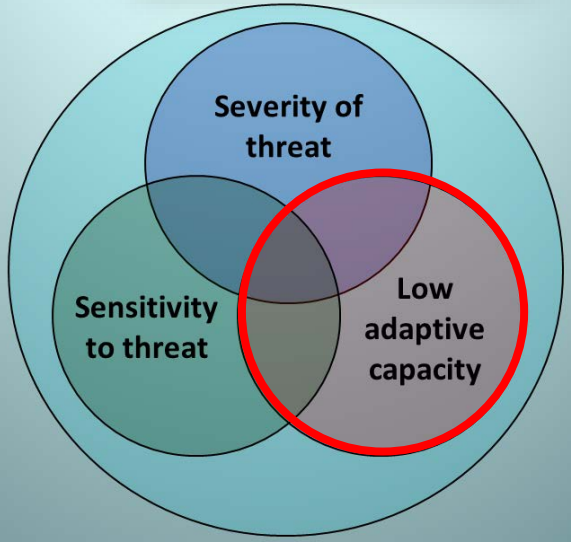


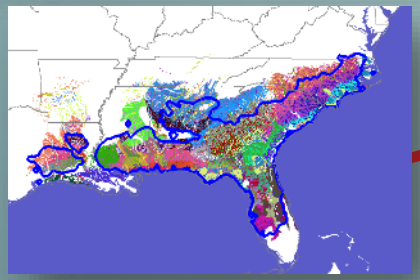
Modified from: Foden and others. 2013. Identifying the world's most climate change vulnerable species: A systematic trait-based assessment of all birds, amphibians and corals. *PLOS One*. 8:6.

The framework process









Regeneration Capacity

- **Large seed crop frequency (↓)** (Brook *et al.* 2008)
- **Long-term seed viability (↓)** (Fenner and Thompson 2005)
- **Reproductive maturity age (↑)** (Stork *et al.* 2009)
- **Sexual + clonal reproduction (↓)** (Steinger *et al.* 1996)
- **Lifespan (↑)** (Jump and Peñuelas 2005)
- **Dioecy (↑)** (Vamosi & Vamosi 2005)

Genetic Variability

- **Number of seed zones (↓)** (Hamrick 2004)
- **Population differentiation (↑)** (Hamrick 2004)
- **Pollination vector (insects = ↑)** (Aitken *et al.* 2008)
- **Number of disjunct populations (↑)** (McLaughlin *et al.* 2002)

Ecological Requirements

- **Successional stage (later = ↑)** (Myking 2002)
- **Site affinities (generalist =↓)** (Myking 2006)
- **Fire dependence (greater =↑)** (Brown and Smith 2000)
- **Niche occupancy (greater =↓)** (Potter and Hargrove 2013)

Species Attributes Associated with Low Adaptive Capacity

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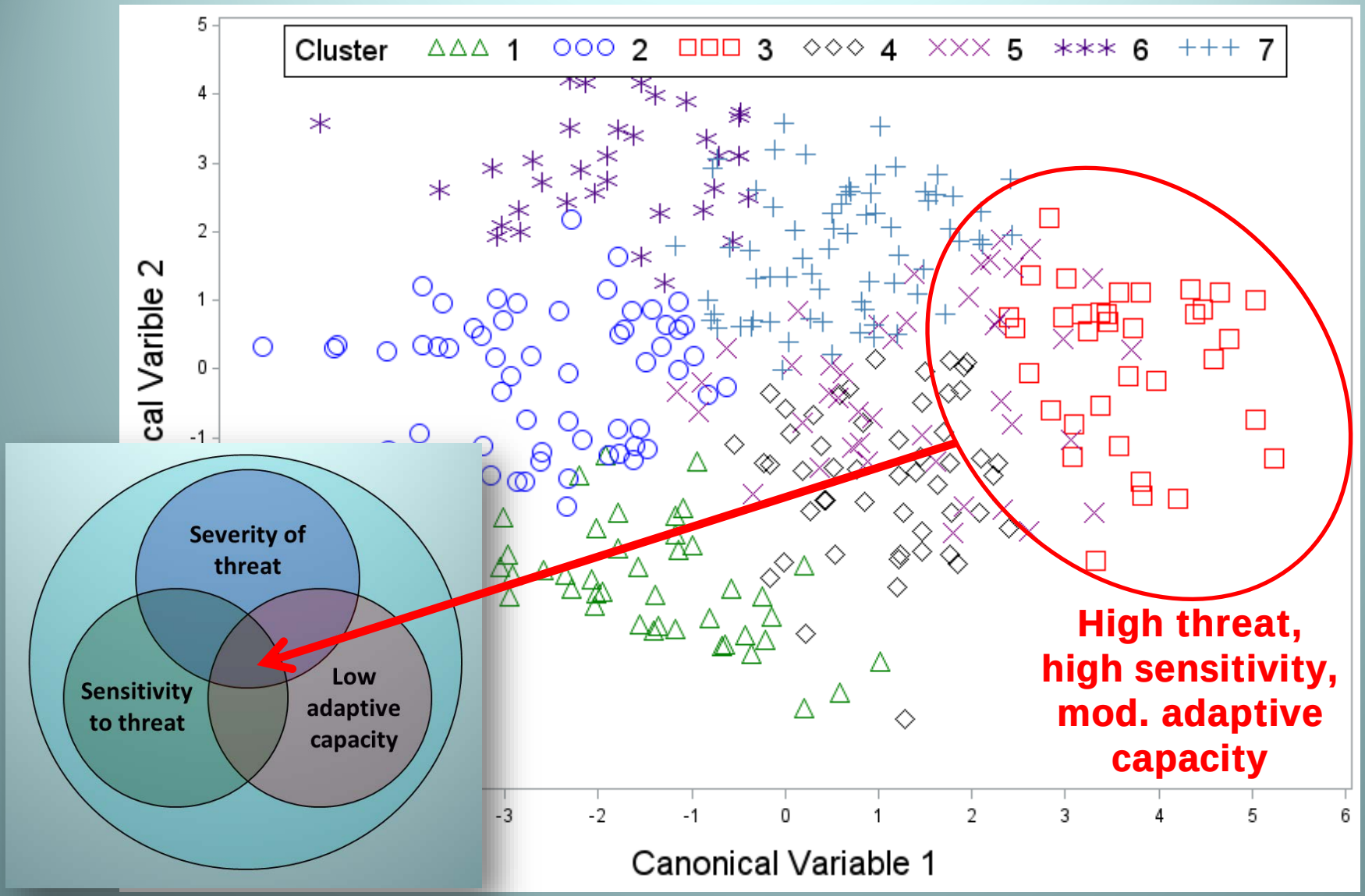
ESZF

Climate change vulnerability classes



Conservation/management triage

1) **<u>High climate change vulnerability:</u>** high threat severity, high sensitivity, moderate adaptive capacity ***(35 species)***

   - *<u>Action:</u>* gene conservation ASAP; plan for climate change threats
   - *<u>Examples:</u>* bristlecone fir, bigleaf magnolia, Ohio buckeye, yellowwood, American chestnut





Caveats

- Provisional seed zones are far from perfect
  - Assume species are always well-adapted to their current environmental conditions
  - Assume adaptive variation is partitioned similarly across species
  - May or may not be at the appropriate spatial resolution
- There's no substitute for detailed, long-term studies of the association between adaptive variation and environmental variation
- Results need to be considered alongside local knowledge from foresters, ecologists, etc., about target species

But…

- Some information – though imperfect – is better than none
- We need information now – not in 20-30 years
  - We have to make conservation decisions relatively rapidly
  - We have >400 tree species to consider, but little funding
- Provisional seed zones offer a convenient tool to assist in conservation assessment and decision-making
  - Having an agreed-upon set of provisional zones nationally (and in the East) could be very helpful

Thanks to…

Funding

(USDA Forest Service)

Forest Health Protection (FHP)

R&D Inventory, Monitoring and Analysis

Forest Health Monitoring (FHM) program

Eastern Forest Environmental Threat Assessment Center (EFETAC)

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Mark Ambrose

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Forrest Hoffman

Thank you for your attention!

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