Ecological Impacts from the Interactions of Climate Change, Land Use Change and Invasive Species: A Joint Research Solicitation - EPA, USDA

Michael A. Bowers
National Program Leader-Ecology
Institute of Bioenergy, Climate, and Environment
National Institute of Food and Agriculture

The purpose of the joint solicitation was to quantitatively investigate how climate change, climate variability, and land use change:

- *influence the establishment, abundance and distribution of invasive species;*
- *interact with invasive species to create feedbacks that increase their success;*
- *interact with invasive species to cause threshold responses in natural and managed systems; or*
- *affect the chemical, biological and mechanical management of invasive species.*

Proposals responding to this solicitation addressed goals 3, 4 and 5 of the USCCSP Strategic Plan (i.e., the Ecosystems chapter as they relate to invasive species):

- *8.1. What are the most important feedbacks between ecological systems and global change (especially climate), and what are their quantitative relationships?*
  8.2. What are the potential consequences of global change for ecological systems?
  8.3. What are the options for sustaining and improving ecological systems and related goods and services, given projected global changes?

EPA SUPPORTED PROJECTS

R833838- Interaction of Climate Change, Landuse and Invasive Species: Tests of Contrasting Management Scenarios for Coastal Communities- Whitlatch & Osman, University of Connecticut, Smithsonian Environmental Research Center

R833835- Understanding the Role of Climate Change and Land Use Modifications in Facilitating Pathogen Invasions and Declines Of Ectotherms, Rohr, Blaustein, & Raffel,

University of South Florida, Oregon State University

R833834- Integrating Future Climate Change and Riparian Land-Use to Forecast the Effects of Stream Warming on Species Invasions and Their Impacts on Native Salmonids. Olden, Beechie, Lawler, & Torgersen, University of Washington, Forest and Rangeland Ecosystem Science Center, Northwest Fisheries Science Center

R833836- Beach Grass Invasions and Coastal Flood Protection: Forecasting the Effects of Climate Change on Coastal Vulnerability. Seabloom, Hacker, & Ruggiero. Oregon State University

R833833- Predicting Relative Risk of Invasion by Saltcedar and Mud Snails in River Networks Under Different Scenarios of Climate Change and Dam Operations in the Western United States. Poff, Auble, Bledsoe, Dean, Friedman, Lytle, Merritt, Purkey, Raff, Shafroth. Colorado State University, Oregon State University, Stockholm Environmental Institute, ,U.S. Bureau of Reclamation,U.S. Forest Service, ,U.S. Geological Survey July 2008 -

R833837- Elevated Temperature and Land Use Flood Frequency Alteration Effects on Rates of Invasive and Native Species Interactions in Freshwater Floodplain Wetlands. Richardson, Flanagan, Qian, & Ho. Duke University, Nicholas School of the Environment and Earth Sciences

NIFA SUPPORTED PROJECTS

- *Project Directors: Silander, J. A.; Civco, D.; Wang, G.; Ibanez, I.; Gelfand, A.; Reid, C.; PERFORMING INSTITUTION: UNIV OF CONNECTICUT; Title: A MULTI-SCALE APPROACH TO THE FORECAST OF POTENTIAL DISTRIBUTIONS OF INVASIVE PLANT SPECIES*

- *Project Director: Gao, W.; Liang, X. ; PERFORMING INSTITUTION: NATURAL RESOURCE ECOLOGY LAB, COLORADO STATE UNIVERSITY; Title: INTEGRATED BIOCLIMATIC-DYNAMIC MODELING OF CLIMATE CHANGE IMPACTS ON AGRICULTURAL AND INVASIVE PLANT DISTRIBUTIONS IN THE UNITED STATES*

- *Project Directors: Sagers, C. L.; Van de Water, P. K. PERFORMING INSTITUTION: BIOLOGICAL SCIENCES , UNIVERSITY OF ARKANSAS ; Title: GLOBAL CHANGE AND THE CRYPTIC INVASION BY TRANSGENES OF NATIVE AND WEEDY SPECIES*

A multi-scale approach to the forecast of potential distributions of invasive plant species

Sarah Treanor Bois

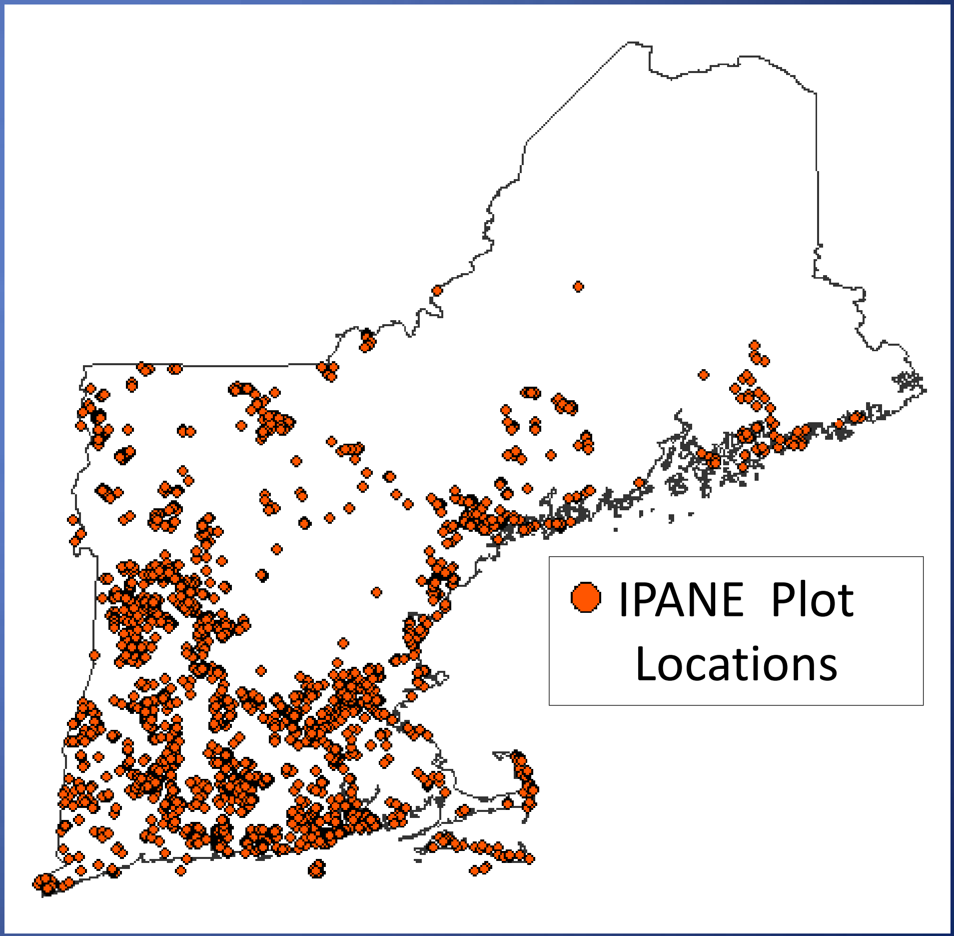
John Silander Jr.

University of Connecticut

Ecological Impacts from the Interactions of Climate Change, Land Use Change and Invasive Species: A Joint Research Solicitation – EPA, USDA

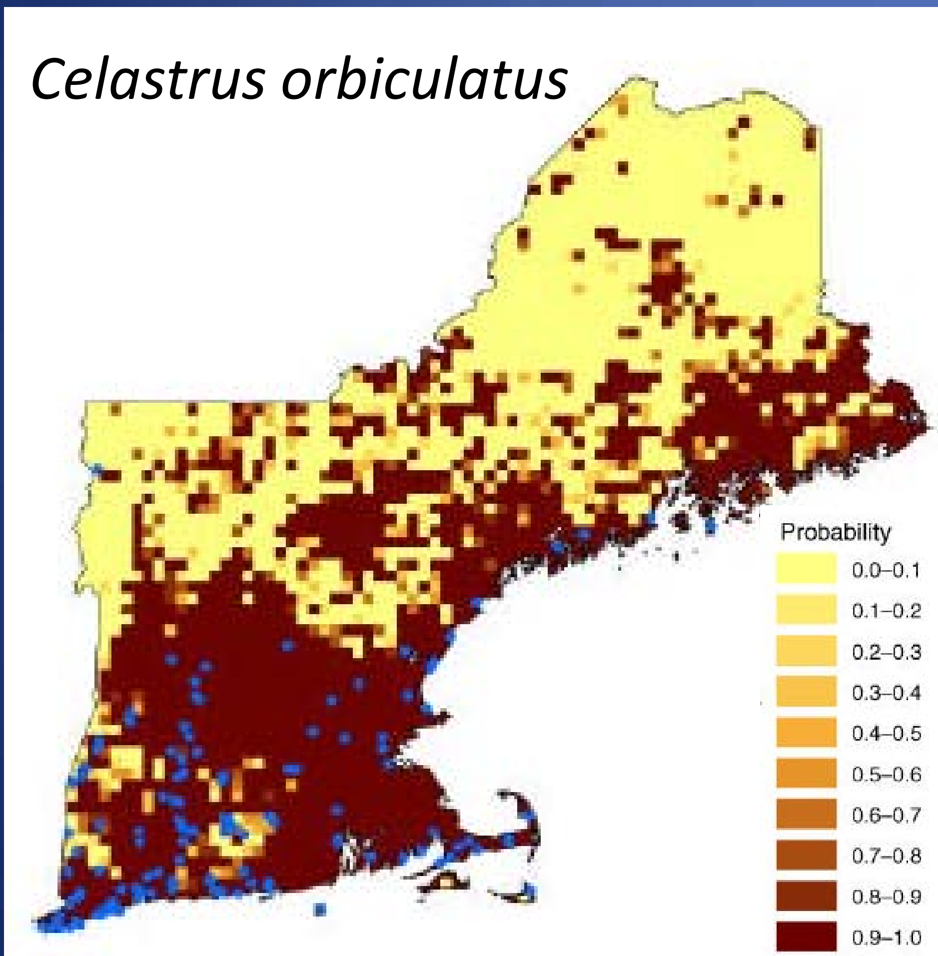
Invasive Plant Atlas of New England (IPANE)

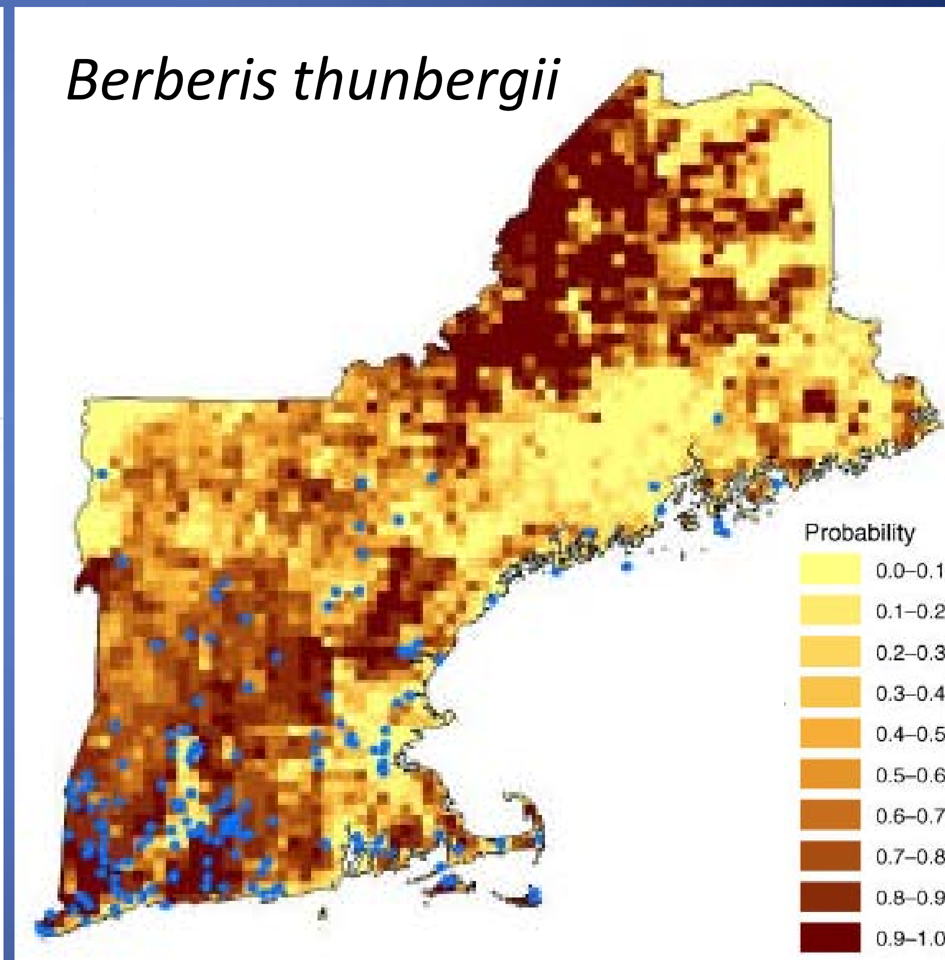
- One third of the vascular plant flora is non-indigenous
- 3–5% of which are considered invasive
- Currently:
  - Over 5,000 IPANE plots
  - Over 12,000 individual species observations



Mehrhoff, L. J. 2000. *Rhodora*

Multi-variate forecasts of potential distribution of invasive plant species





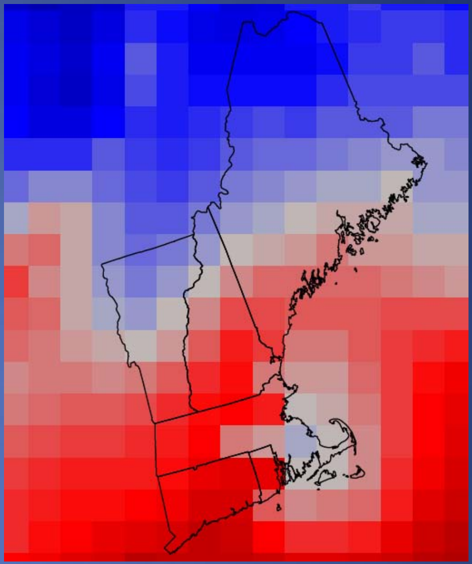
Ibáñez et al. 2009. *Ecological Applications*

A multi-scale approach to the forecast of potential distributions of invasive plant species

- Predict potential spread of invasive plant species
  - Be comprehensive over the next few decades
    - Climate change
    - Land-use change
    - Elevated CO_2
- Combine experimentation and spatio-temporal models
- Verify results of previous predictive models

Multi-scale approach

- Regional level
  - Regional climate models
- Landscape level
  - Modeling regional land use change



Multi-scale approach

- Regional level
  - Regional climate models
- Landscape level
  - Modeling regional land use change
- Local level
  - Species demographic models
  - Habitats and environmental conditions
- Individual level
  - Effects of increased CO_2 levels temperature, and decreased soil moisture

Demographic Models

- Integrate knowledge across multiple vital rates (fecundity, growth, survival, etc.) to understand consequences for populations.
- Identify the critical stages driving population growth rates
- Link vital rates back to abiotic conditions

Large-scale transplant experiment

- Estimate species colonization potential across the region
- Look at areas of potential range expansion
- Calculate demographic parameters for each study species (survival, growth, fecundity)
- Establish thresholds for representative species selected

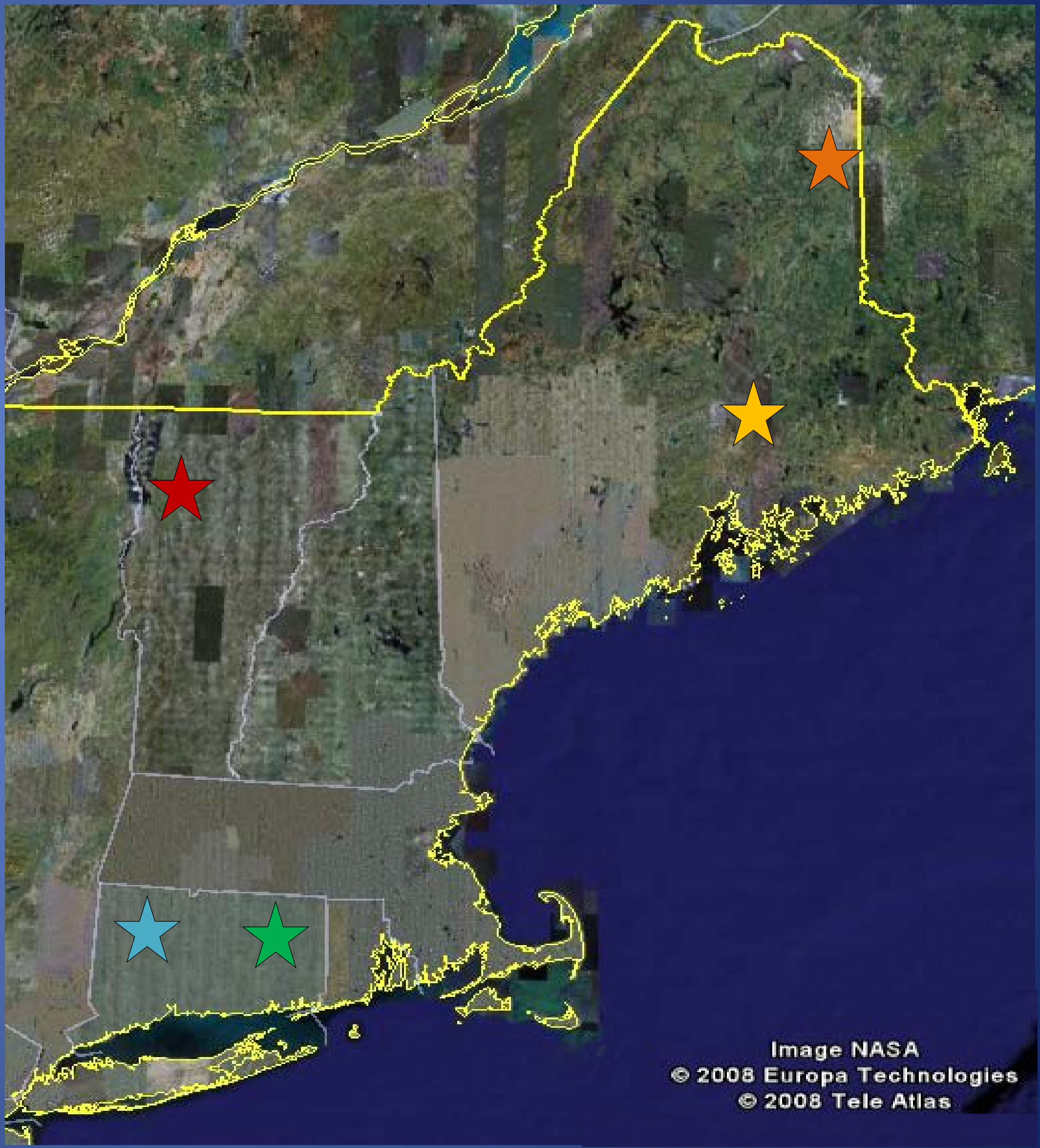
- *Celastrus orbiculatus* (CO)
- *Vitis labrusca* (VL)
- *Berberis thunbergii* (BT)
- *Lindera benzoin* (LB)
- *Alliaria petiolata* (AP)
- *Arabis glabra* (AG)



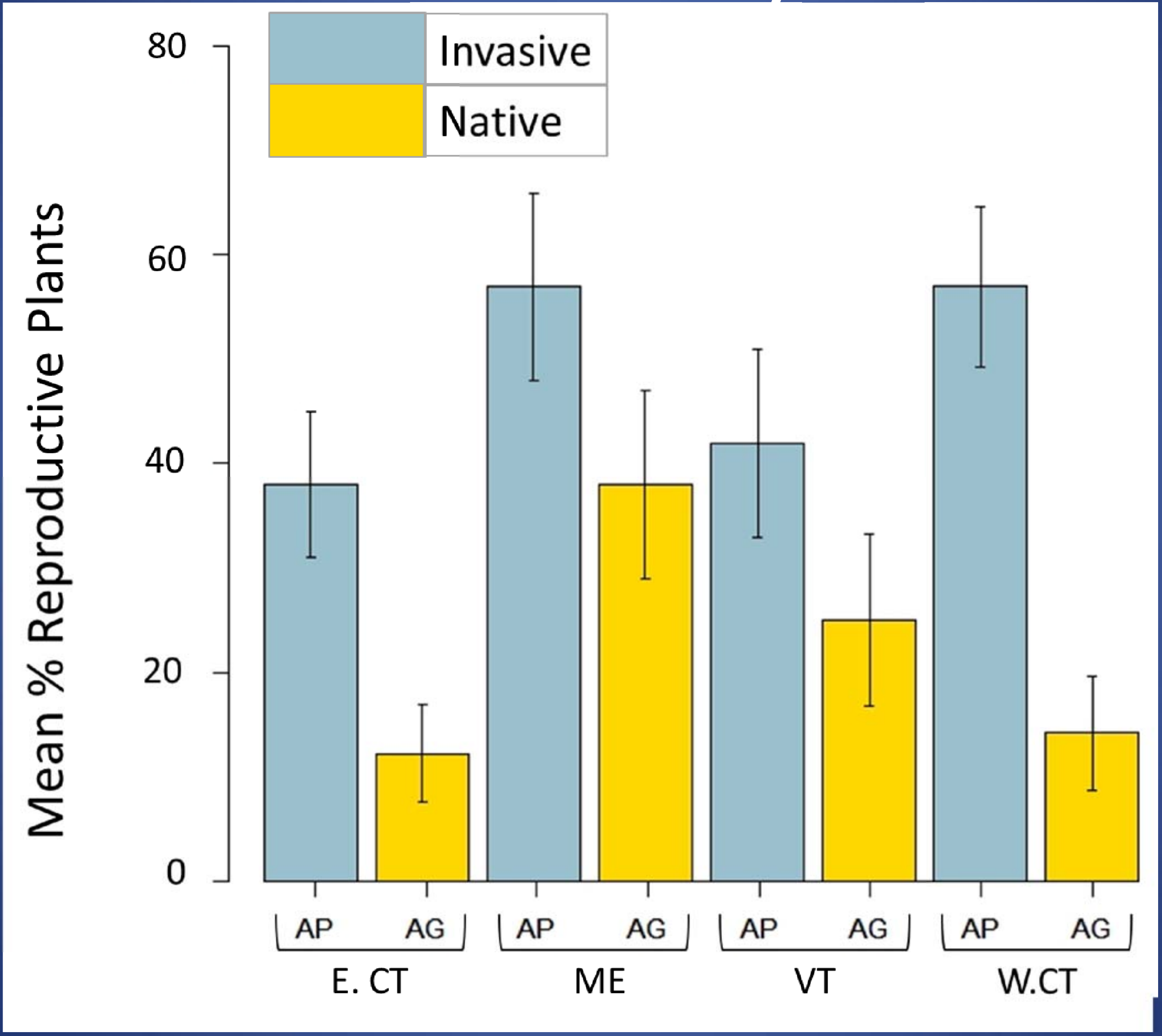


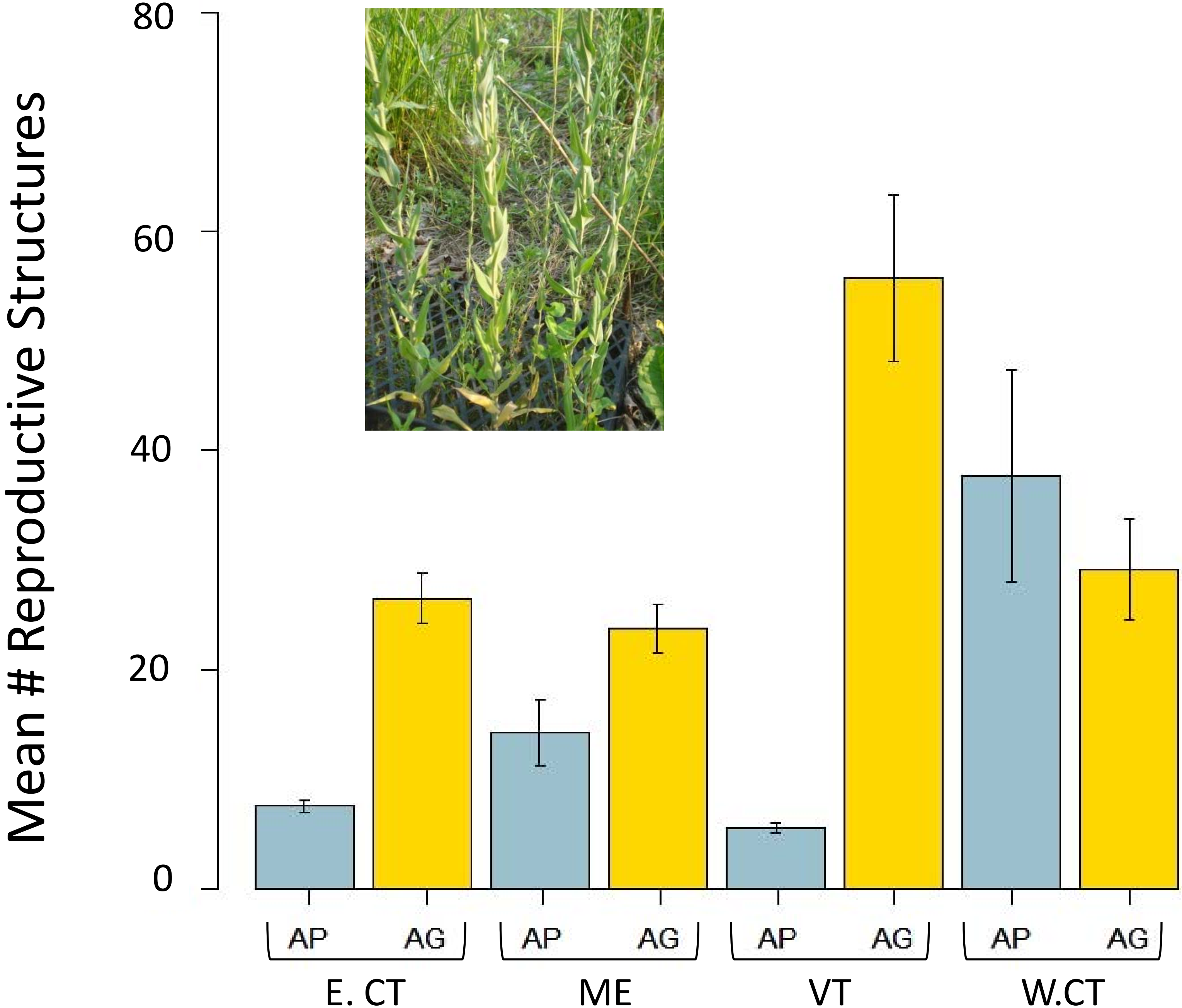

Plot locations

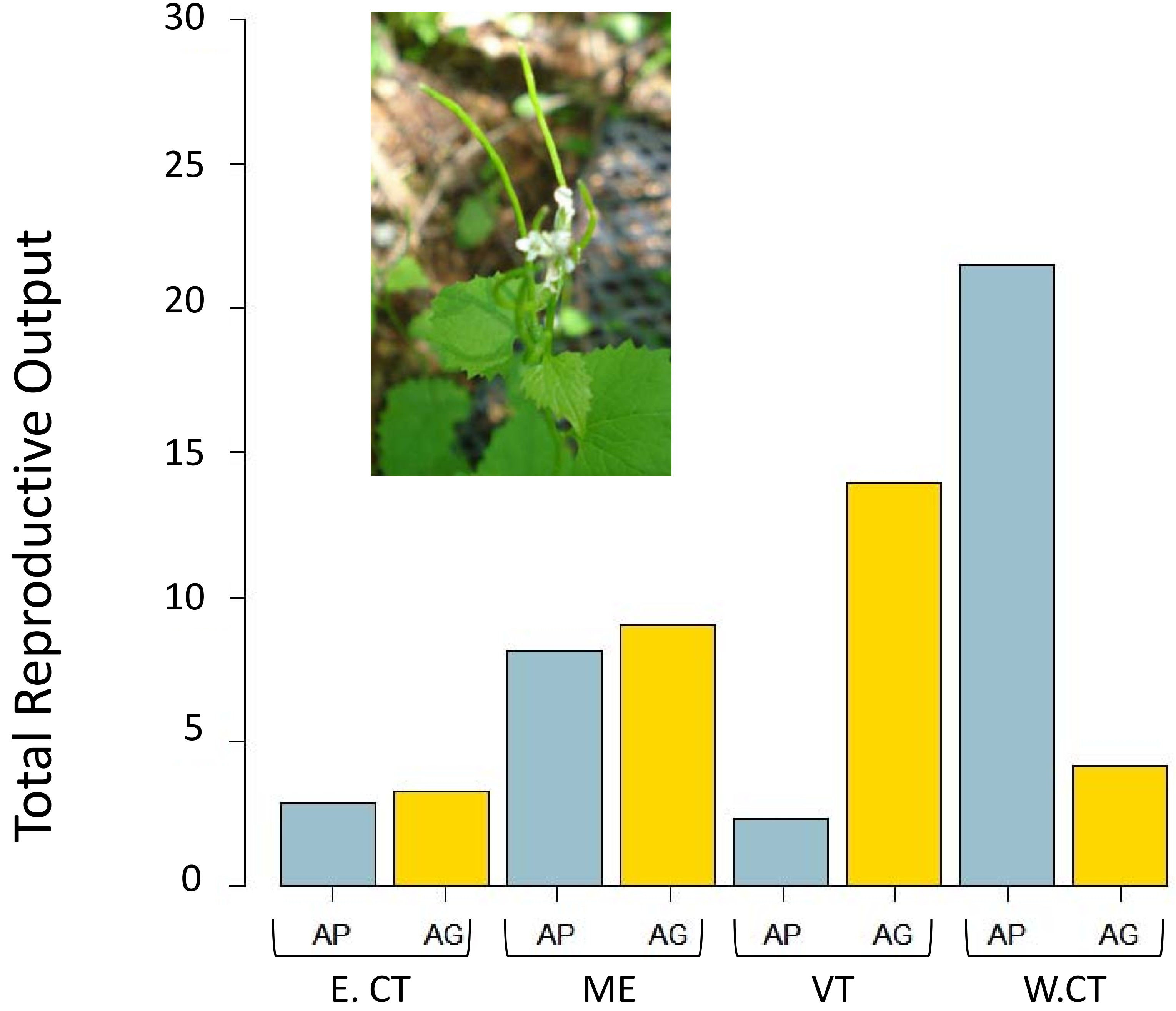
- Eastern Connecticut
  - 7 plots
- Western Connecticut
  - 6 plots
- Burlington, Vermont
  - 4 plots
- Orono, Maine
  - 2 plots
- Presque Isle, Maine
  - 2 plots



Fecundity


Invasive
Native
80
60
40
20
0
Mean % Reproductive Plants
AP
AG
AP
AG
AP
AG
AP
AG
E. CT
ME
VT
W.CT


Mean # Reproductive Structures
0
20
40
60
80
AP
AG
AP
AG
AP
AG
AP
AG
E. CT
ME
VT
W.CT


Total Reproductive Output
30
25
20
15
10
5
0
AP
AG
AP
AG
AP
AG
AP
AG
E. CT
ME
VT
W.CT

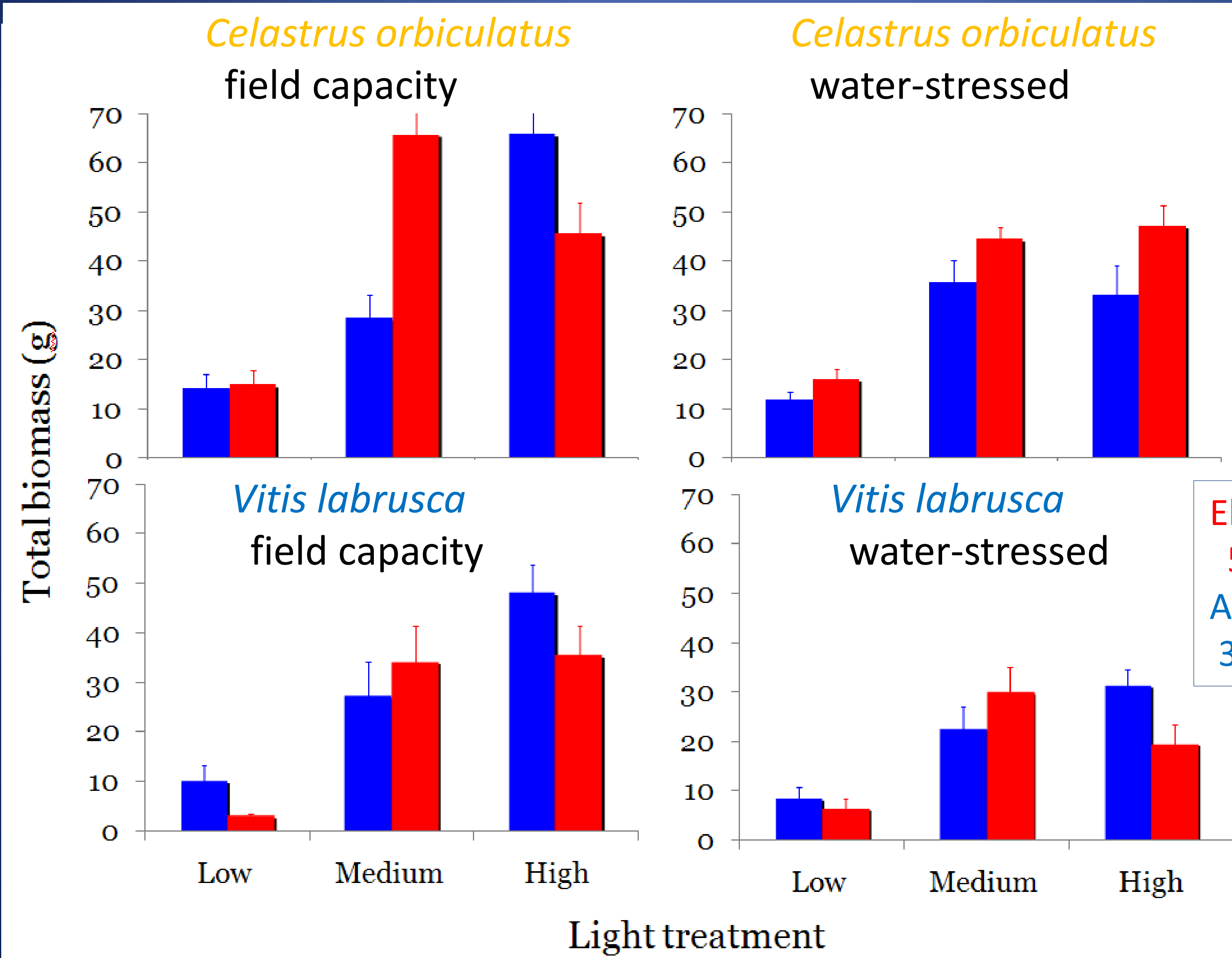
Multi-scale approach

- Regional level
  - Regional climate models
- Landscape level
  - Modeling regional land use change
- Local level
  - Species demographic models
  - Habitats and environmental conditions
- Individual level
  - Effects of increased CO_2 levels temperature, and decreased soil moisture

Environmental growth chambers at Duke University Phytotron

- **CO_2** (μmol CO_2 mol^{-1})
  - Ambient
  - Elevated (+200)
- **Moisture**
  - Field capacity (FC)
  - 25% field capacity (WS)
- **Light levels**
  - 50% full sunlight, simulating open fields (Hi)
  - 20% full sunlight, forest edges (Med)
  - 5% full sunlight, forest understory (Low)

Native *vs* invasive woody vines: Response to elevated CO_2, light and soil moisture



Experimental biogeography (early observations):

- Invasives can establish and thrive beyond their current range, matching predictions.
- Invasives outperform native species analogs: germination, survival, growth and reproduction across sites.
- Invasives show greater biomass under elevated CO_2 than native analogs, and respond better to water stress.

Integrated Bioclimatic-Dynamic Modeling of Climate Change Impacts on Agricultural and Invasive Plant Distributions in the United States

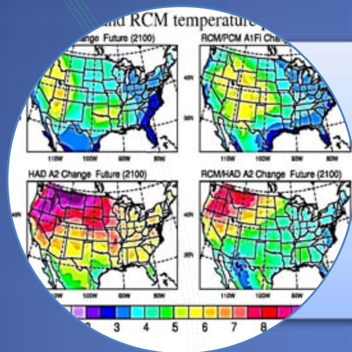
Shuyan Liu, Xin-Zhong Liang, Thomas J. Stohlgren, Wei Gao

July 20, 2011

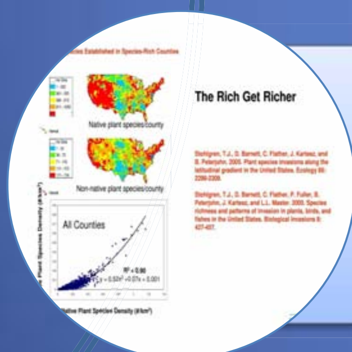
Background

- **Objective:** to better understand how global climate changes affect the U.S. agricultural and invasive plant species distributions
- **Current problems:**
  - **1)** full range of future emission scenarios need to be considered;
  - **2)** niche-based models carry substantial errors in predicting species distribution due to the lack of dynamics and physics ;
  - **3)** generally ignored scale consistence and spatial dependencies
- **Proposed solution:**
  - **1)** low and high climate sensitivity under four (high, medium high, medium low, low) emissions scenarios to represent the likely range and uncertainty of the future climate change projections;
  - **2)** ensemble species distribution models;
  - **3)** high-resolution, physically-consistent, and most-complete set of climate predictors
- **Hypothesis:** Minimizing known errors in predicting the current distribution will likely reduce the overall uncertainty in projecting future range shifts in response to climate changes.

Climate Data



CEP: CCSM3, GFDL CM2.1; CMM5, CWRF



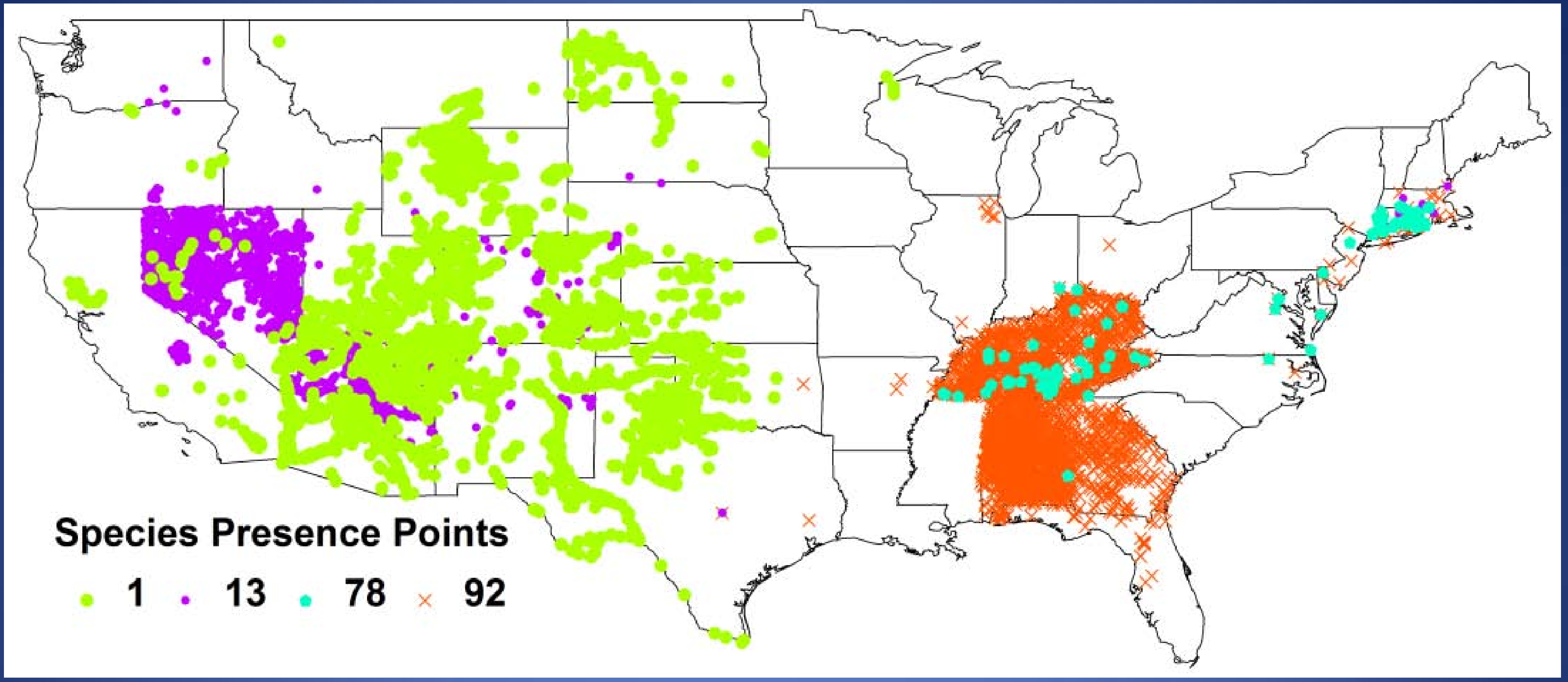
SEM: MaxEnt, GARP, CART, BRT, LR, LSR, BIOCLM, DOMAIN, ENFA, Envelope

- ✓ Crop adaptation
- ✓ Invasive species distribution

CEP—Provide Bioclimatic Layers

Variable	Description	Variable	Description
BIO00	Annual mean temperature	BIO10	Mean temperature of coldest quarter
BIO01	Mean temperature diurnal range	BIO11	Annual precipitation
BIO02	Isothermality	BIO12	Precipitation of wettest month
BIO03	Temperature seasonality	BIO13	Precipitation of driest month
BIO04	Maximum temperature of warmest month	BIO14	Precipitation seasonality
BIO05	Minimum temperature of coldest month	BIO15	Precipitation of wettest quarter
BIO06	Temperature annual range	BIO16	Precipitation of driest quarter
BIO07	Mean temperature of wettest quarter	BIO17	Precipitation of warmest quarter
BIO08	Mean temperature of driest quarter	BIO18	Precipitation of coldest quarter
BIO09	Mean temperature of warmest quarter		

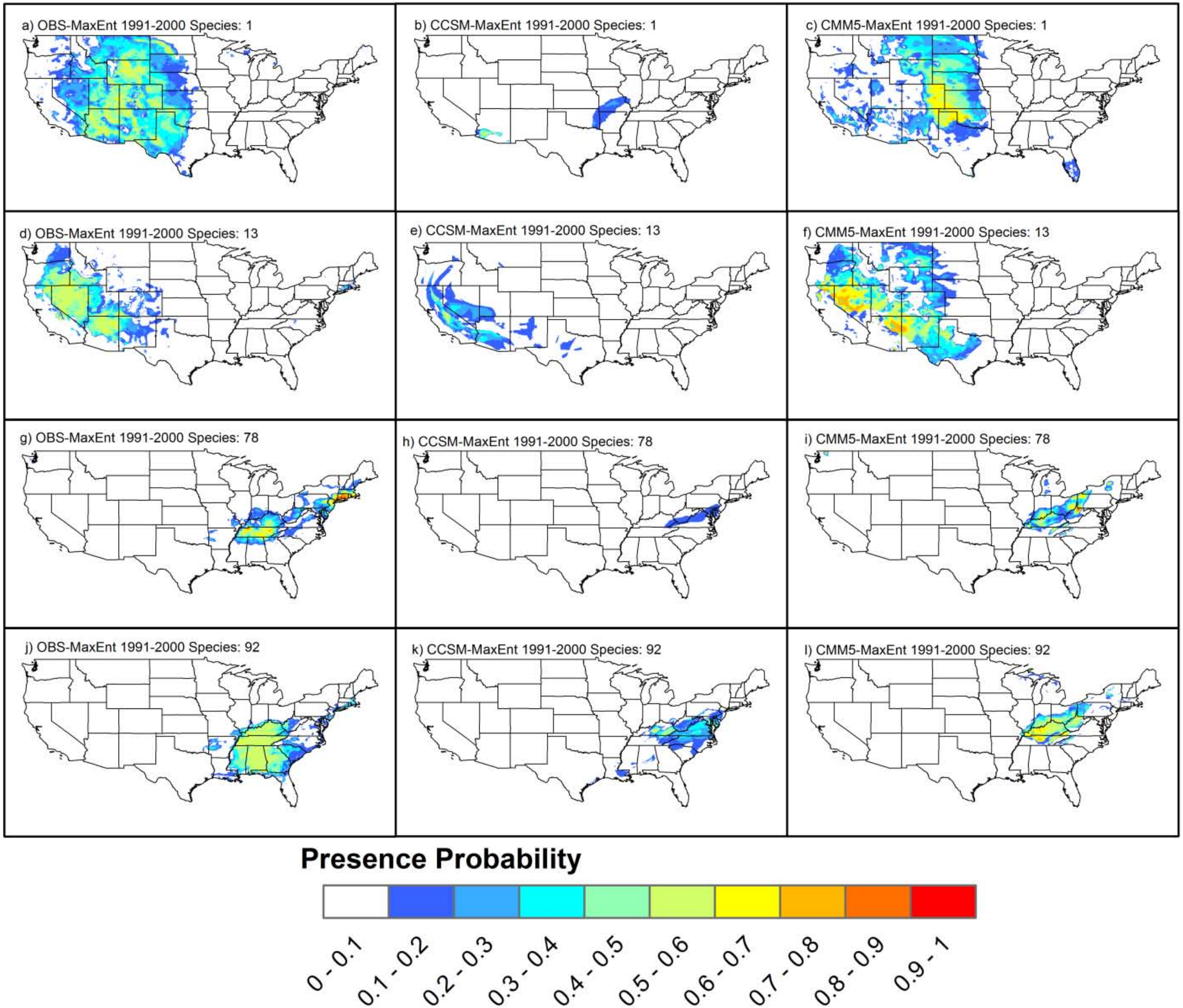
SEM—Build Species Distribution Model

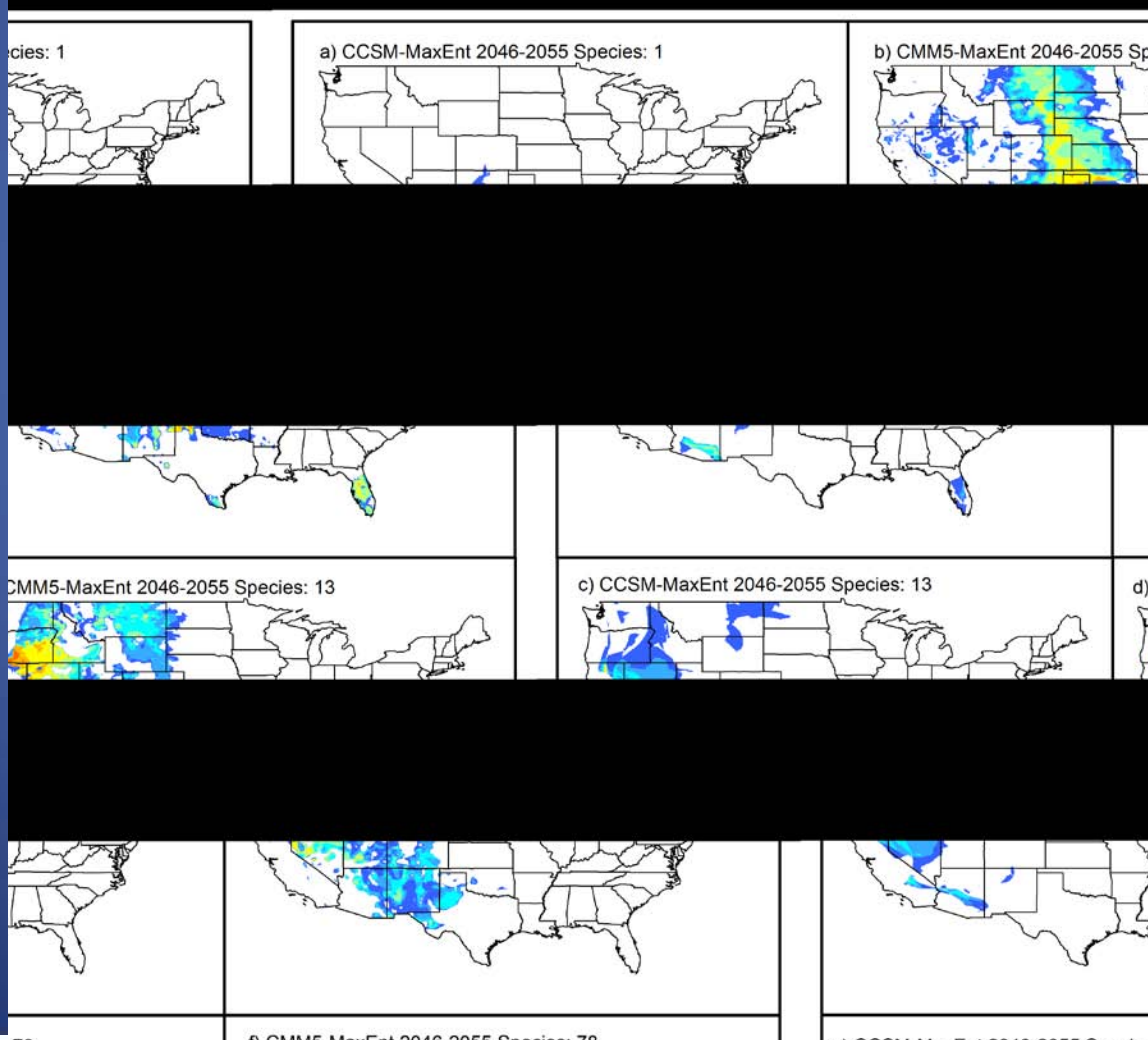


Species ID	Common name	Scientific name	Total points	Training points	Test points	Train AUC	Test AUC	Maximum possible test AUC
1	Tamarisk	Tamarix	7644	5733	1911	0.79	0.78	0.77
13	Cheatgrass	Bromus tectorum	4589	3442	1147	0.85	0.85	0.85
78	Japanese stiltgrass	Microsteqium vimineum	101	76	25	0.98	0.96	0.97
92	Japanese honeysuckle	Lonicera japonica	2400	1800	600	0.90	0.90	0.90

Section II: Results—Skill enhancement by Regional Climate Model

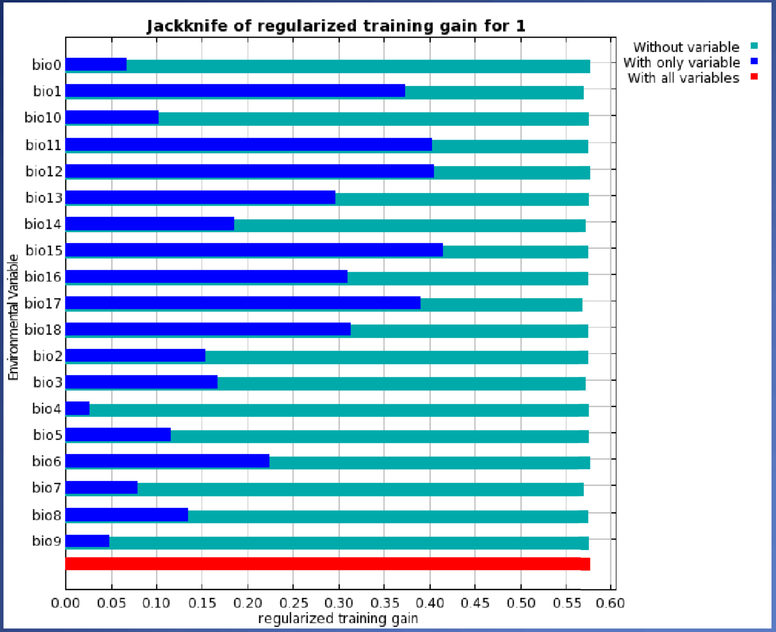
- CMM5-MaxEnt significantly improved the simulation of observed species potential distribution
- Dramatic future species distribution difference exist between predictions from CCSM-MaxEnt and CMM5-MaxEnt
- CMM5-MaxEnt results are more reliable


a) OBS-MaxEnt 1991-2000 Species: 1
b) CCSM-MaxEnt 1991-2000 Species: 1
c) CMM5-MaxEnt 1991-2000 Species: 1
d) OBS-MaxEnt 1991-2000 Species: 13
e) CCSM-MaxEnt 1991-2000 Species: 13
f) CMM5-MaxEnt 1991-2000 Species: 13
g) OBS-MaxEnt 1991-2000 Species: 78
h) CCSM-MaxEnt 1991-2000 Species: 78
i) CMM5-MaxEnt 1991-2000 Species: 78
j) OBS-MaxEnt 1991-2000 Species: 92
k) CCSM-MaxEnt 1991-2000 Species: 92
l) CMM5-MaxEnt 1991-2000 Species: 92
Presence Probability
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1

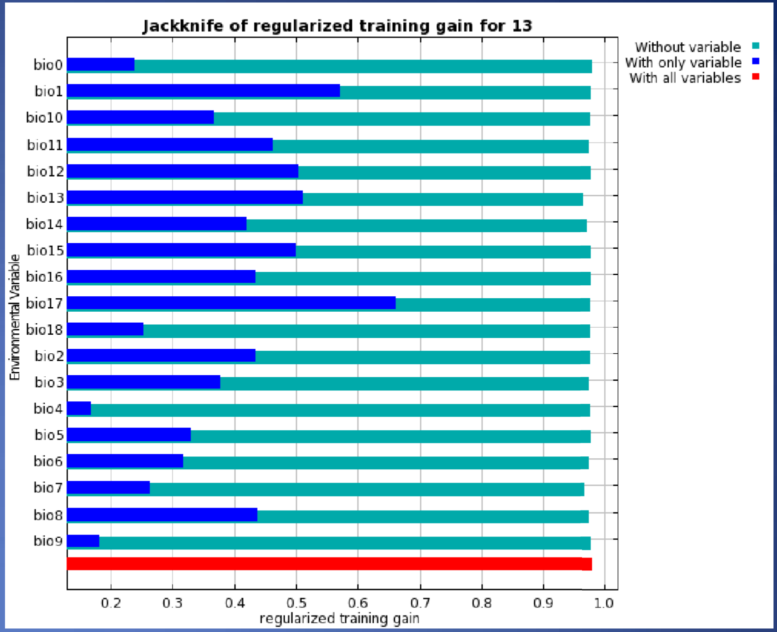

a) CCSM-MaxEnt 2046-2055 Species: 1
CMM5-MaxEnt 2046-2055 Species: 13
c) CCSM-MaxEnt 2046-2055 Species: 13

Section III: Discussions—Reasons for CMM5 skill enhancement

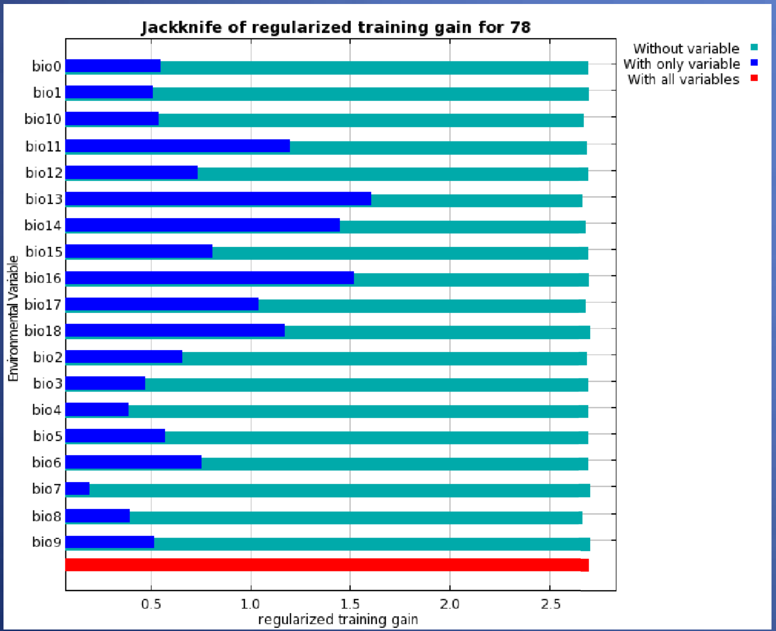
- Based on Jackknife analysis, the bioclimatic layer which contribute most to the constructed model for each species is identified
- The bioclimatic difference between CMM5 downscaled and CCSM simulation are dramatic which propagating to future
- The superior skill of CMM5 in reproducing the observed precipitation and temperature than CCSM explains the skill enhancement of CMM5-MaxEnt in simulating current species potential distribution.
- CMM5 and CCSM produced very different precipitation and temperature trend



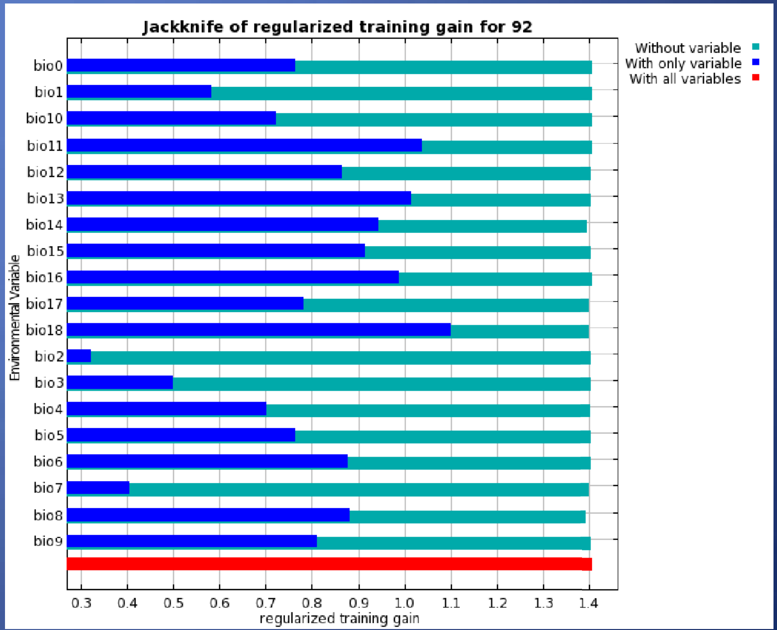
BIO15: Precipitation of wettest quarter



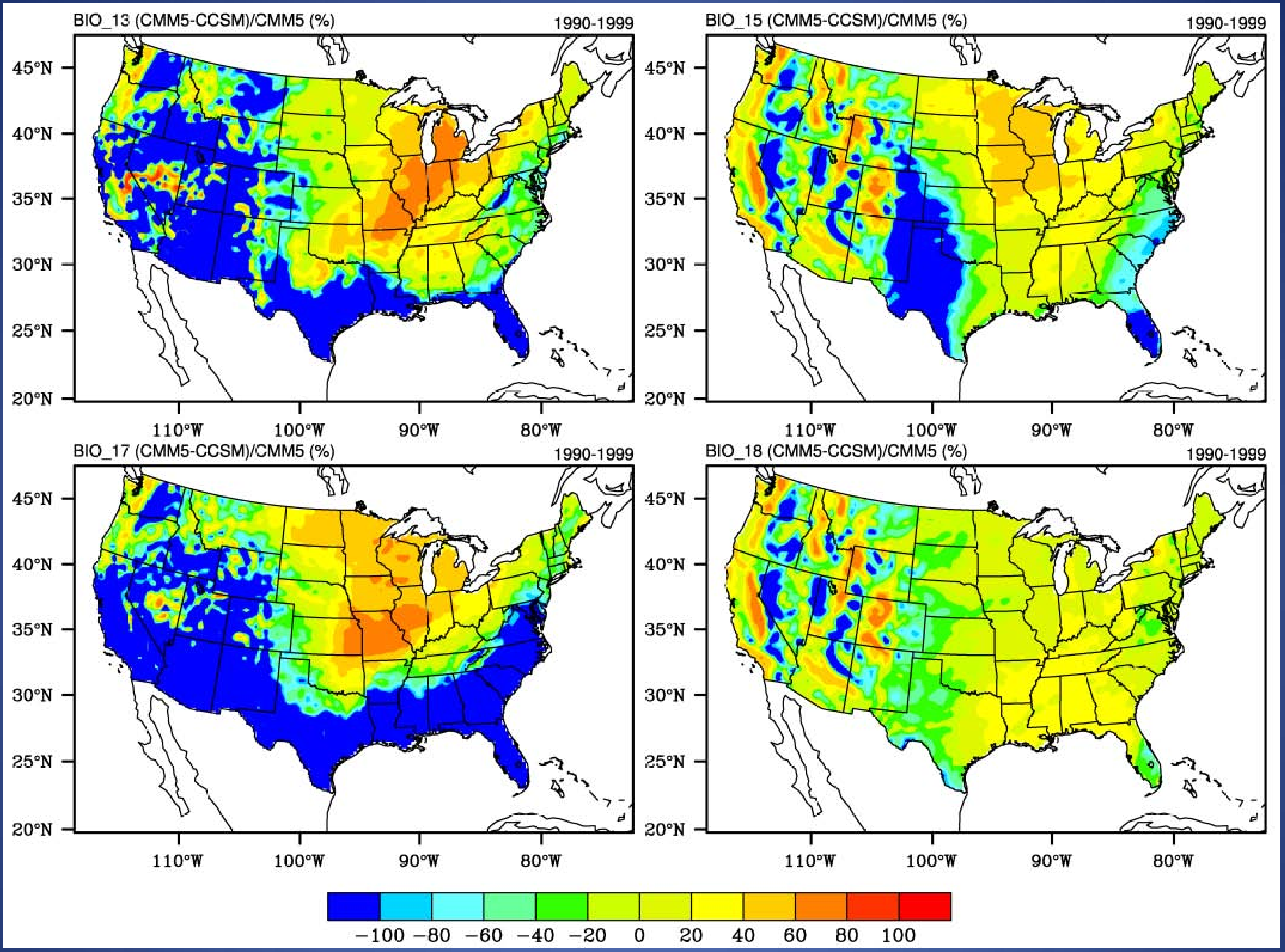
BIO17: Precipitation of warmest quarter



BIO13: Precipitation of driest month



BIO18: Precipitation of coldest quarter

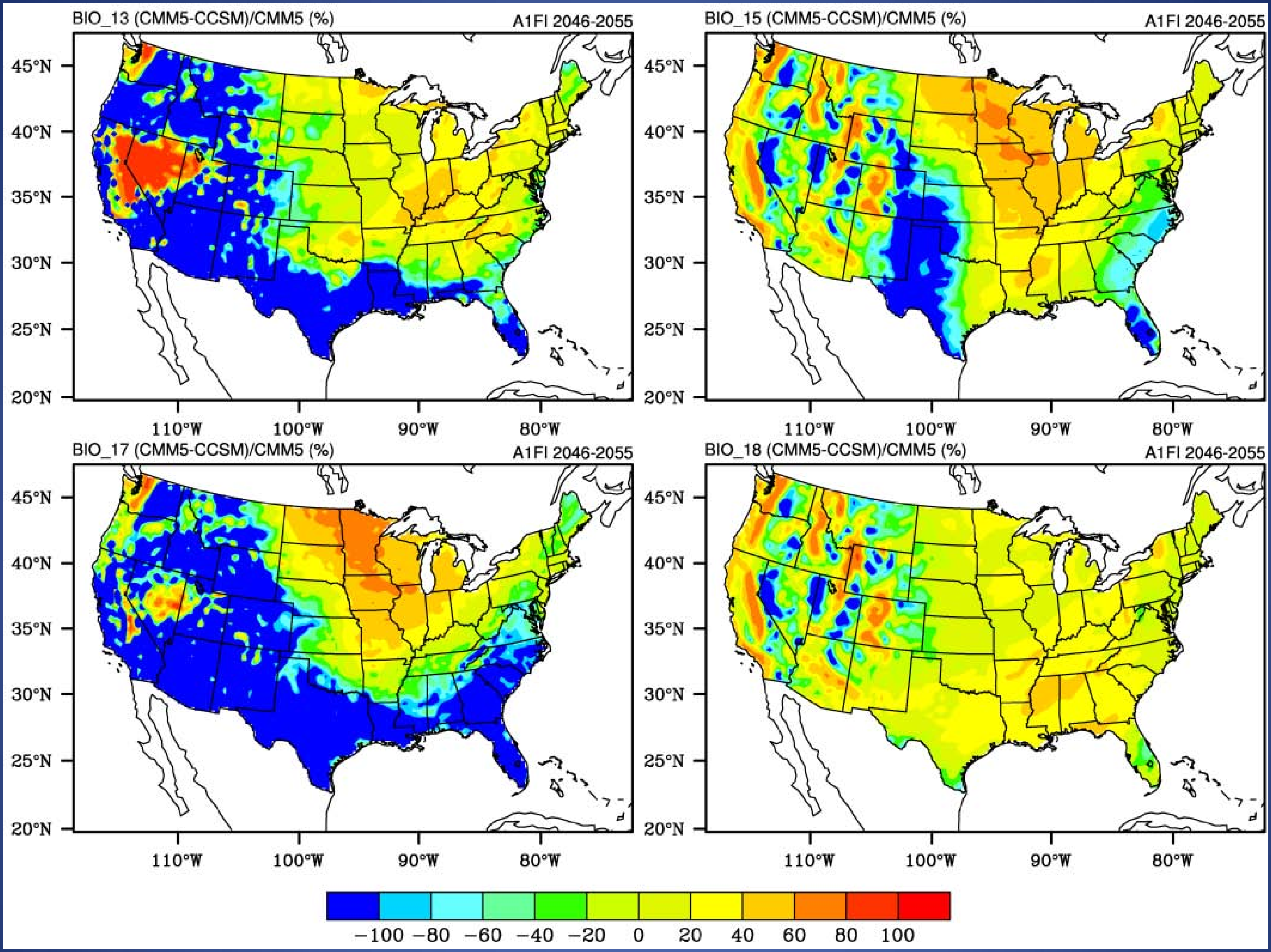


BIO13: Precipitation of driest month

BIO15: Precipitation of wettest quarter

BIO17: Precipitation of warmest quarter

BIO18: Precipitation of coldest quarter



BIO13: Precipitation of driest month

BIO17: Precipitation of warmest quarter

BIO15: Precipitation of wettest quarter

BIO18: Precipitation of coldest quarter

Section IV: Conclusion— RCM Downscaling Improves Invasive Plant Projection

- The prediction skills of MaxEnt models for the 4 case invasive species were greatly improved by regional climate model.
- Invasive species future distributions were dramatically affected by the model driving bioclimatic layers.
- Using regional climate model provided driving bioclimatic layers are recommended given the more reliable invasive species prediction for species’ present potential distribution.

GLOBAL *CHANGE AND THE CRYPTIC INVASION BY TRANSGENES OF NATIVE AND WEEDY SPECIES*

Sagers, C. L. & Van de Water, P. K.
UNIVERSITY OF ARKANSAS & Cal. State University, Fresno

Systematic road surveys and field collections of feral canola populations were made in North Dakota during the summer of 2010 to answer the following:

- 1. To what extent has genetically modified canola escaped from agriculture in North Dakota?
- 2. How large are escaped populations, and how are different transgenic varieties distributed throughout the state?
- 3. Can novel combinations of transgenic traits be found in plants growing outside of cultivation?

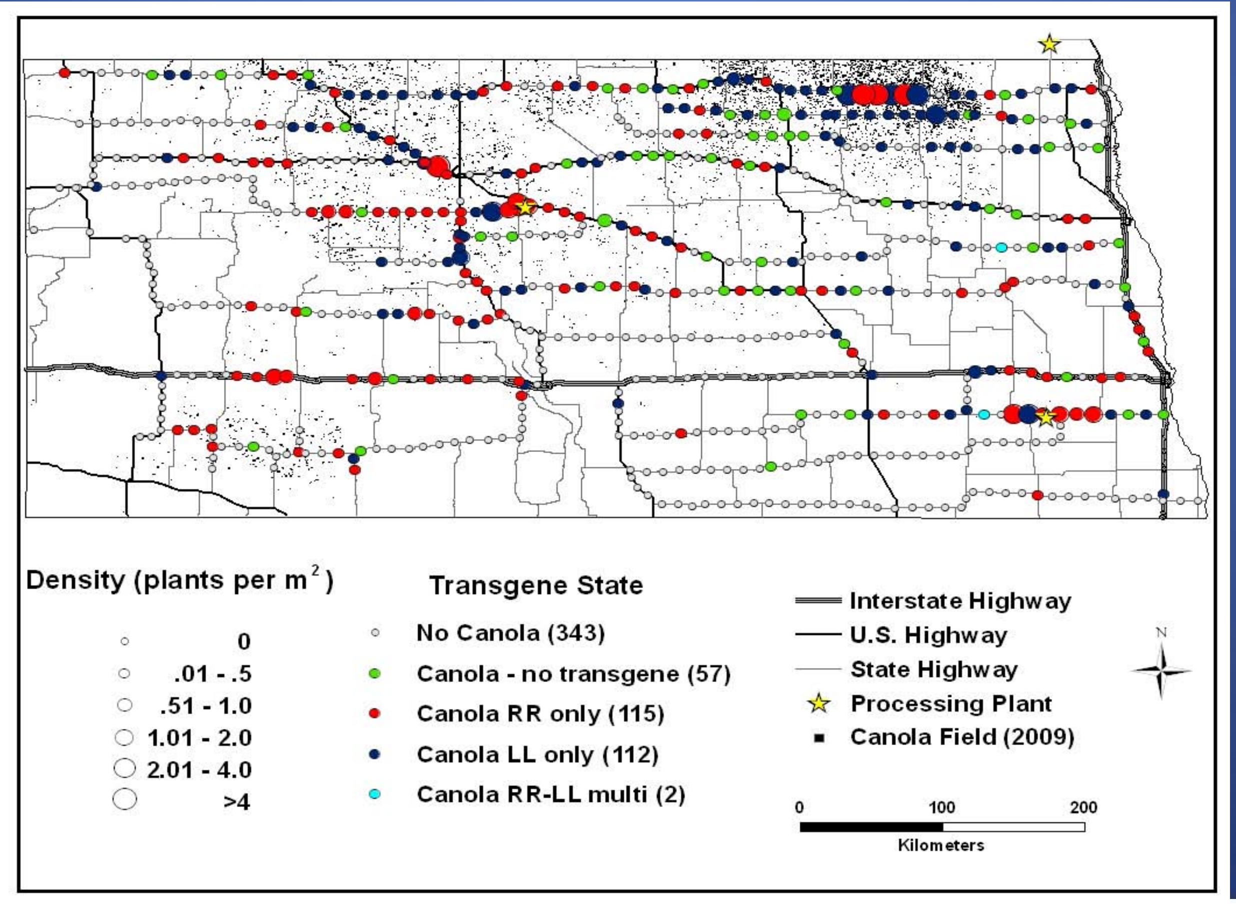
B. napus was collected at nearly half (46%) of the sampling sites with:

80% (231/288) possessing at least one transgene:

41% (119/288) were positive for CP4 EPSPS;

40% (114/288) were positive for PAT;

two plants (0.7%) expressed both resistance phenotypes,



Regional Approaches to Climate Change

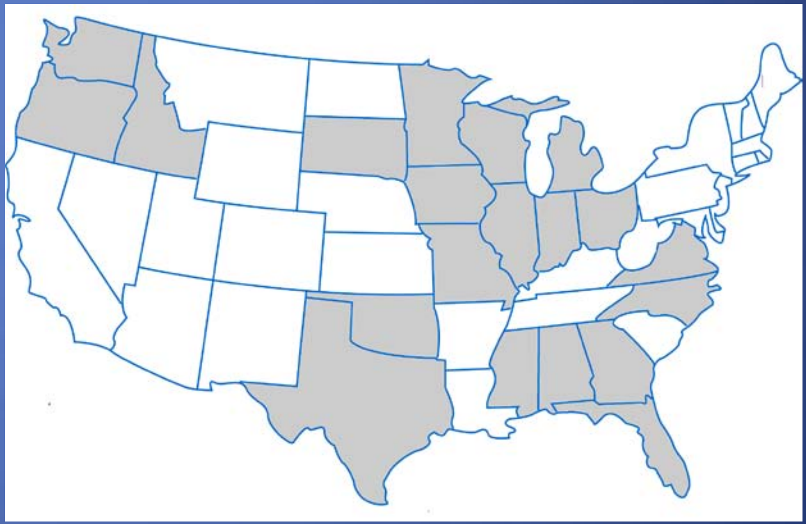
IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

UF UNIVERSITY of FLORIDA

University of Idaho

Numbers in Brief

- 3 Coordinated Agriculture Projects (CAPs)
- 115 total Co-PIs
- 20 states
- 24 Land-grant institutions
- 4 Federal partners



IOWA STATE UNIVERSITY

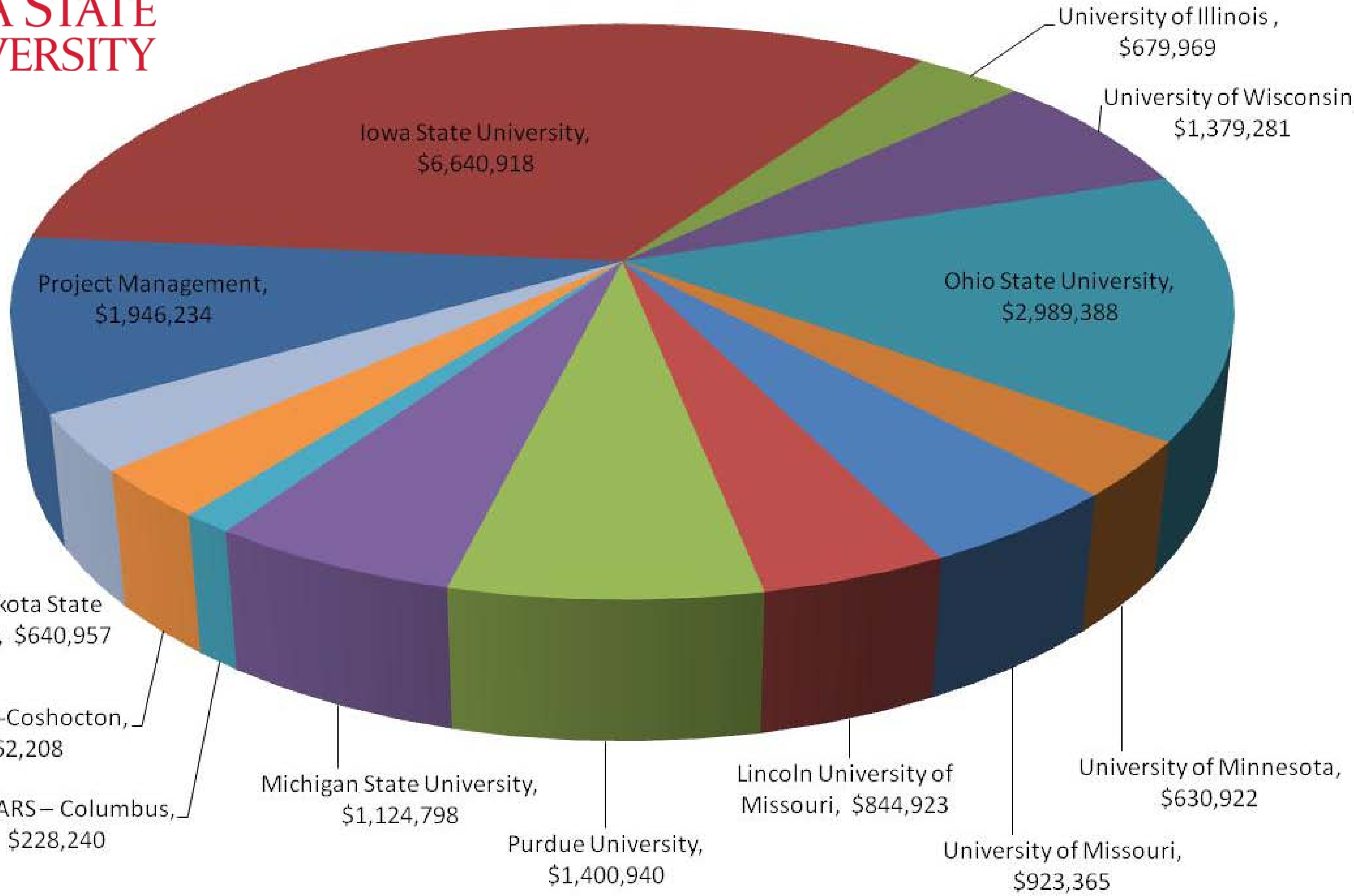
Climate Change, Mitigation, and Adaptation in Corn-Based Cropping Systems

- 43 Co-PIs
- 9 states (Illinois, Iowa, Indiana, Michigan, Minnesota, Missouri, Ohio, South Dakota, Wisconsin)
- 10 Land Grant Universities, including 1890 (Lincoln University)
- 2 USDA Agricultural Research Service (ARS) laboratories

IOWA STATE UNIVERSITY

Climate Change, Mitigation, and Adaptation in Corn-Based Cropping Systems

- Goals
  - Estimate C, N, and water footprints of corn production
  - Evaluate crop management practices on C, N, and water footprints
  - Model variable climate and economic scenarios
  - Perform life cycles analyses (LCAs) to model producer and farmer adoption of new practices
  - Integrate education, extension, outreach, and stakeholder participation across the program



*Subject to annual appropriations

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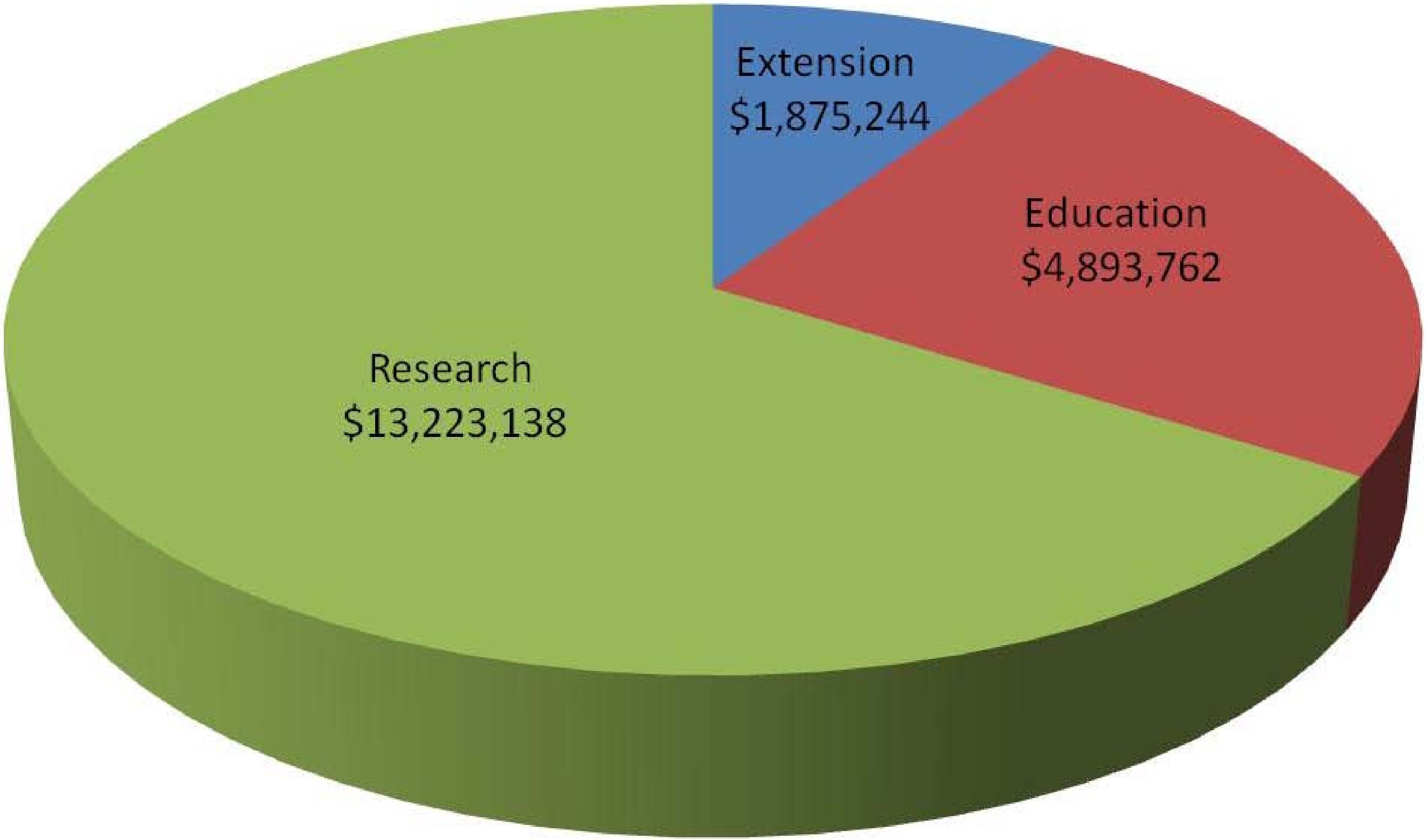


*Subject to annual appropriations

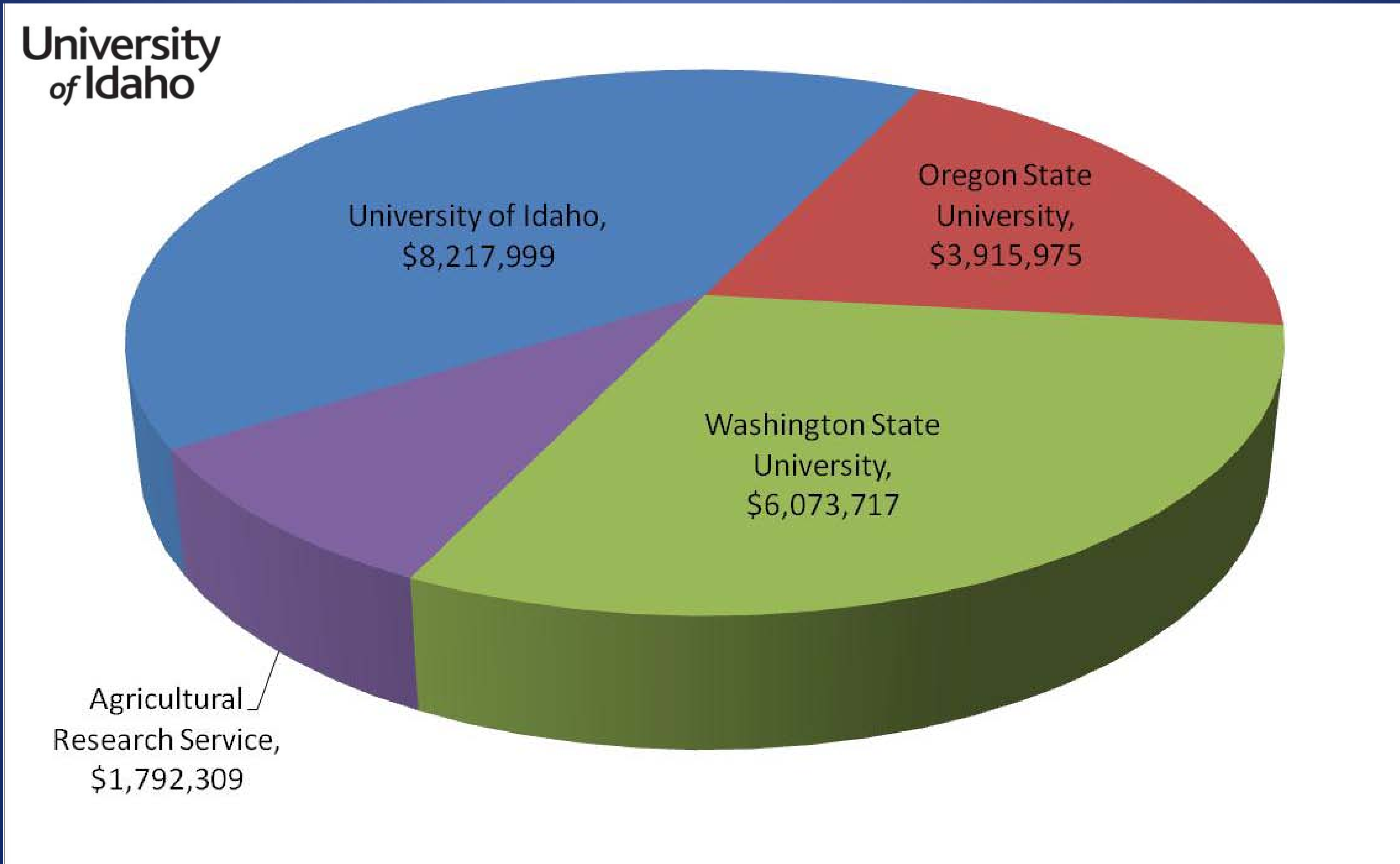
University of Idaho

Pacific Northwest – Regional Approaches to Climate Change (REACCH)

- 22 Co-PIs
- 3 states (Idaho, Oregon, Washington)
- 3 Land Grant Universities
- 1 USDA Agricultural Research Service (ARS) laboratory

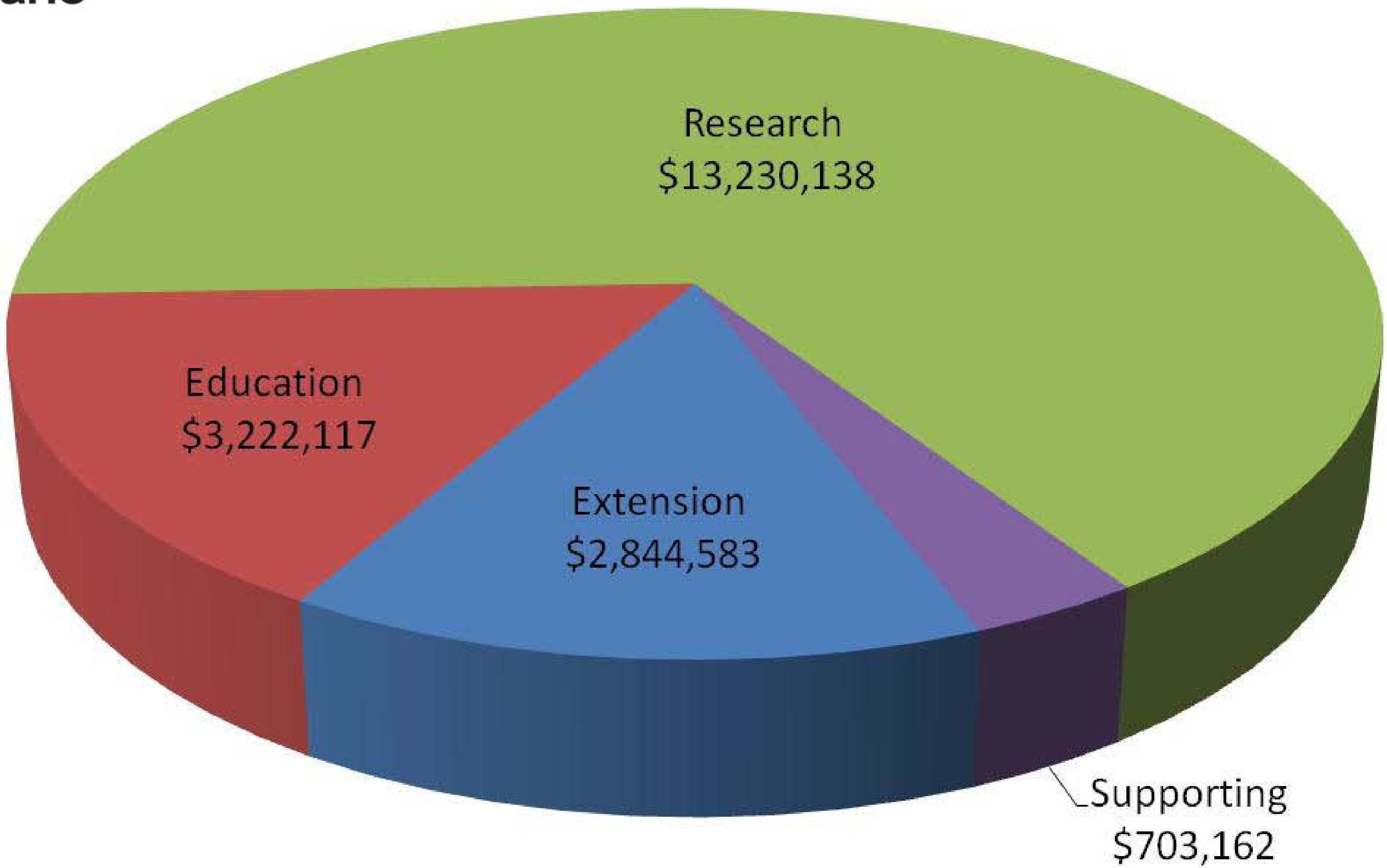
Pacific Northwest – Regional Approaches to Climate Change (REACCH)

- Goals
  - Establish a trans-disciplinary framework to understand the interactions between climate change, agriculture, social, and economic systems in the region
  - Work with K-12 teachers to develop curricula; train graduate and undergraduate students
  - Provide extension to help stakeholders respond to climate change
  - Build sustainable partnerships for continued research, extension, and education concerning climate change and agriculture



*Subject to annual appropriations

University of Idaho



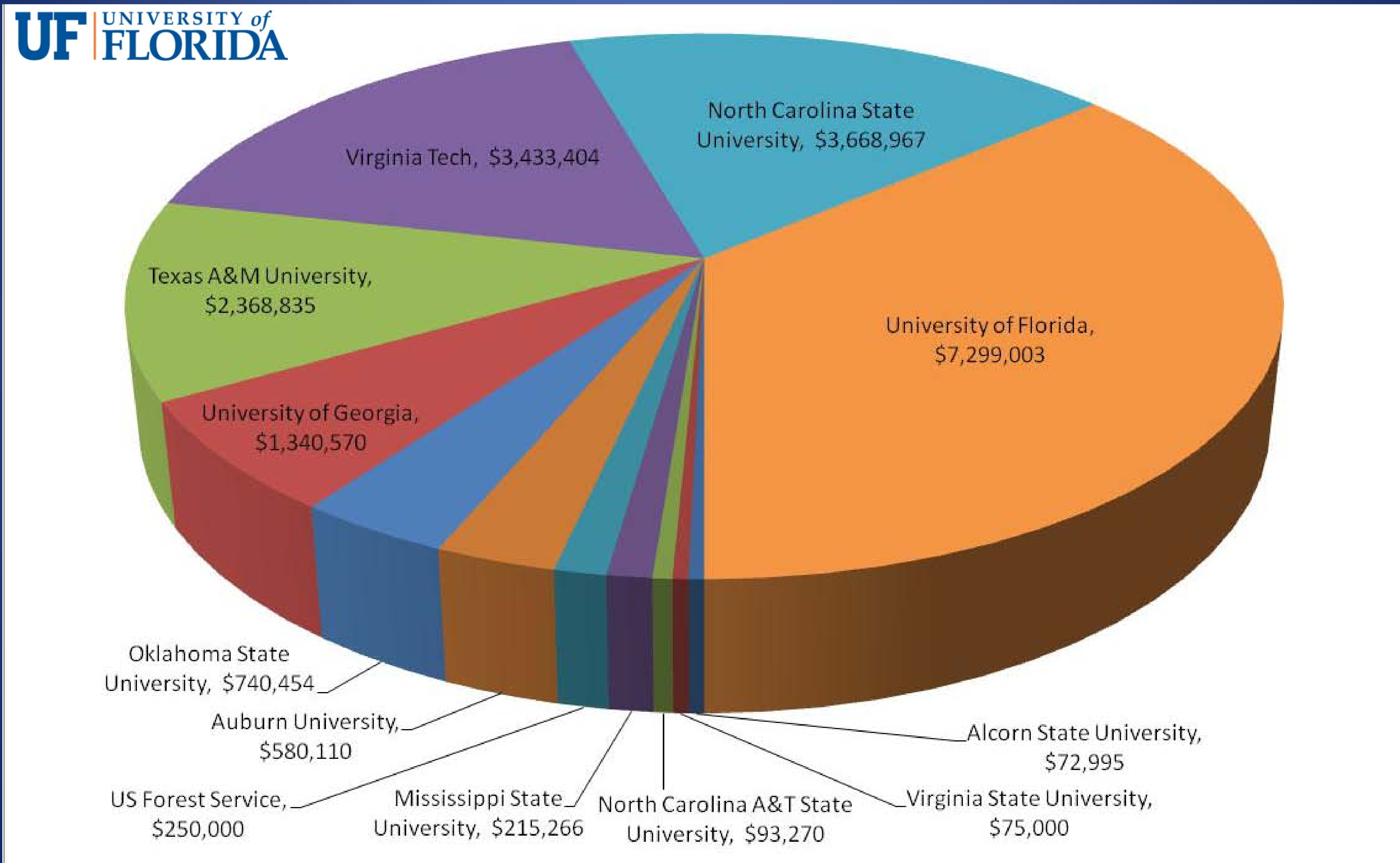
*Subject to annual appropriations

Integrating Research, Education, and Extension for Enhancing Southern Pine Climate Change Mitigation and Adaptation

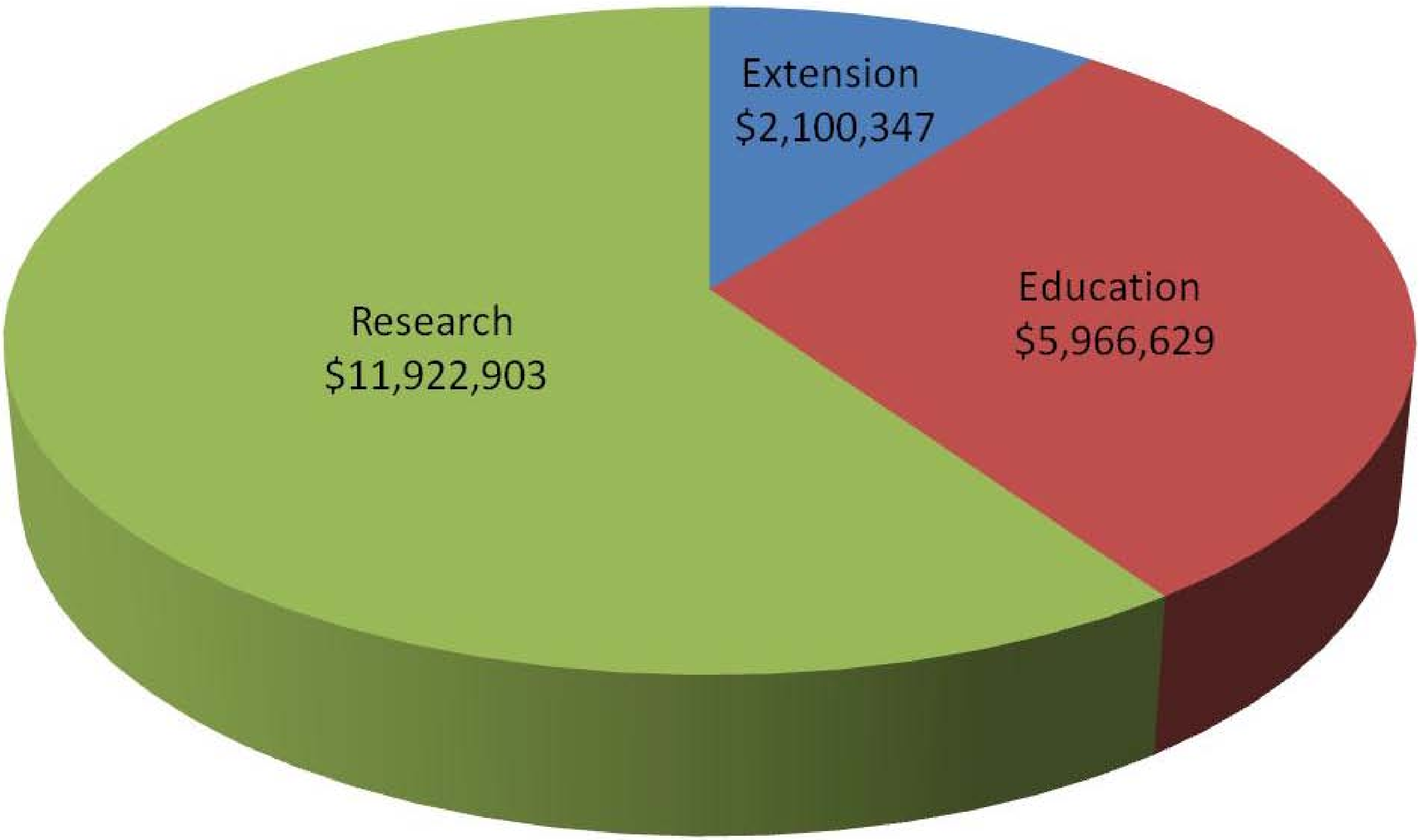
- 50 Co-PIs
- 8 states (Alabama, Florida, Georgia, Mississippi, North Carolina, Oklahoma, Texas, Virginia)
- 11 Land Grant Universities
- 1 US Forest Service Collaboration
- 8 regional industrial research cooperatives

Integrating Research, Education, and Extension for Enhancing Southern Pine Climate Change Mitigation and Adaptation

- Goals
  - Quantify the effects of climate, soils, and management on C sequestration and water regimes
  - Analyze the genetics of pine populations to determine important adaptation and mitigation traits
  - Use life-cycle analyses and models to evaluate forest management systems and climate effects
  - Develop education and extension resources to help stakeholders understand the relevance of southern forests and to manage for increased climate change mitigation and resilience



*Subject to annual appropriations



*Subject to annual appropriations

Funding provided through the USDA National Institute of Food and Agriculture Agriculture and Food Research Initiative (AFRI)

More information is available at http://cris.nifa.usda.gov/ (search by grant number)

- Climate Change, Mitigation, and Adaptation in Corn-Based Cropping Systems
  - Grant number: 2011-68002-30190
- Pacific Northwest – Regional Approaches to Climate Change
  - Grant number: 2011-68002-30191
- Integrating Research, Education, and Extension for Enhancing Southern Pine Climate Change Mitigation and Adaptation
  - Grant number: 2011-68002-30185