Potential Impacts of Climate Change and Population Growth on U.S. Water Supply and Demand in the Next 50 Years

Steve McNulty, Ge Sun, Jennifer Moore Myers, Erika Cohen, and Emrys Treasure
Southern Global Change Program
Eastern Forest Environmental Threats Assessment Center
Southern Research Station
USDA Forest Service, Raleigh NC

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Why is the Forest Service Interested in Water and Climate Change?

- Forests provide the best water quality among all land uses
- Forest lands (30% of land area) provide >50% of water supply in the US
- Climate change, disturbances, population growth, urbanization and land use change could impact water quantity

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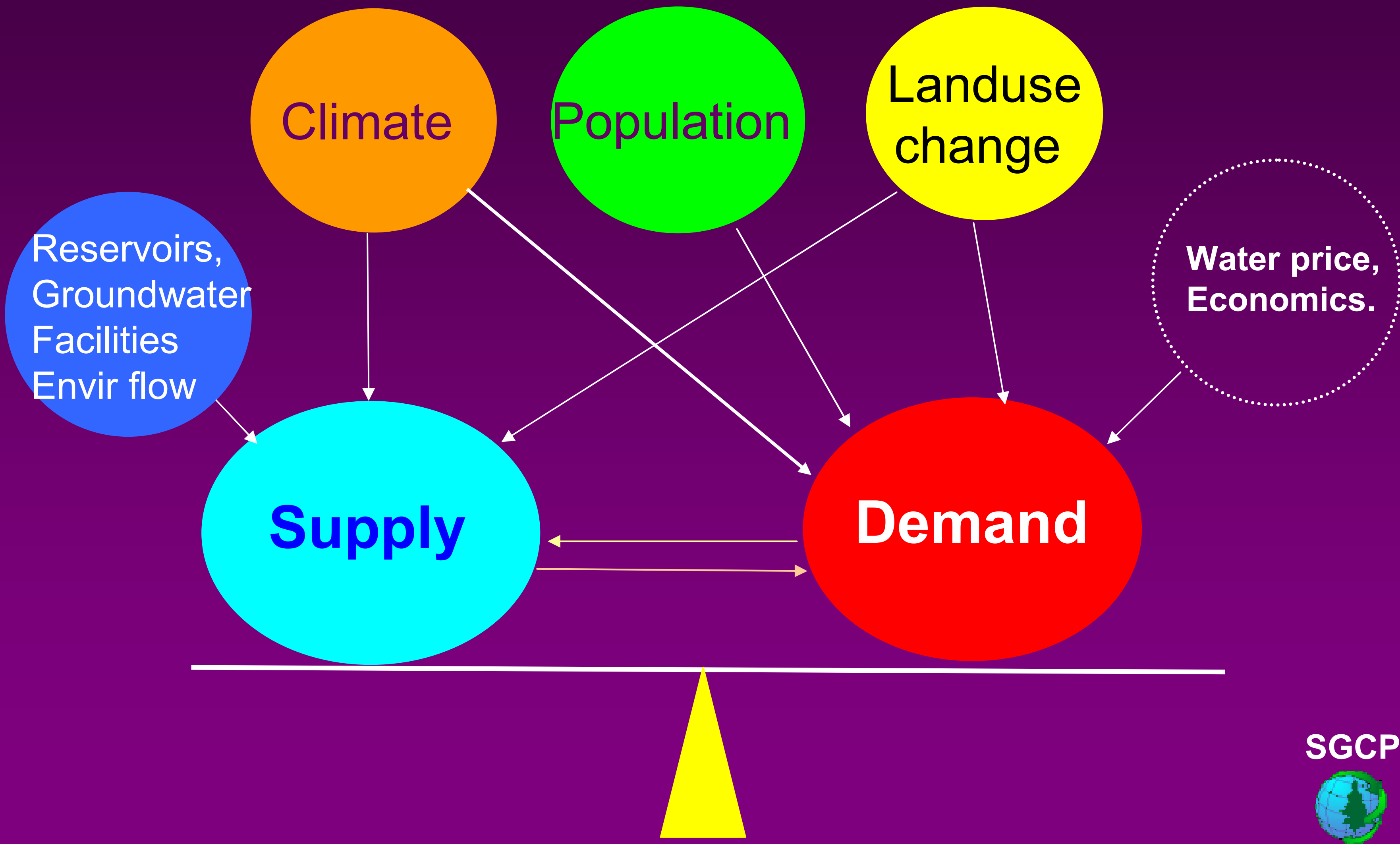
Water Supply and Demand



Water Supply Stress Index (WaSSI):

$$\text{WaSSI} = \frac{\text{Water Demand}}{\text{Water Supply}}$$

(Sun et al. JAWRA, 2008 44(5):1073-1075)

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Definitions

Water Supply at Hydrologic Unit Code (HUC) Scale (Watersheds)

= Precipitation - Evapotranspiration + Groundwater Supply + Returnflow from Water Users - Environmental Flow

Water Demand by Humans at HUC Watershed Scale

= Water Use by Sector (Thermoelectric, Commercial, Domestic, Irrigation, Livestock, Industrial, Mining, Public Supply Use/Loss)

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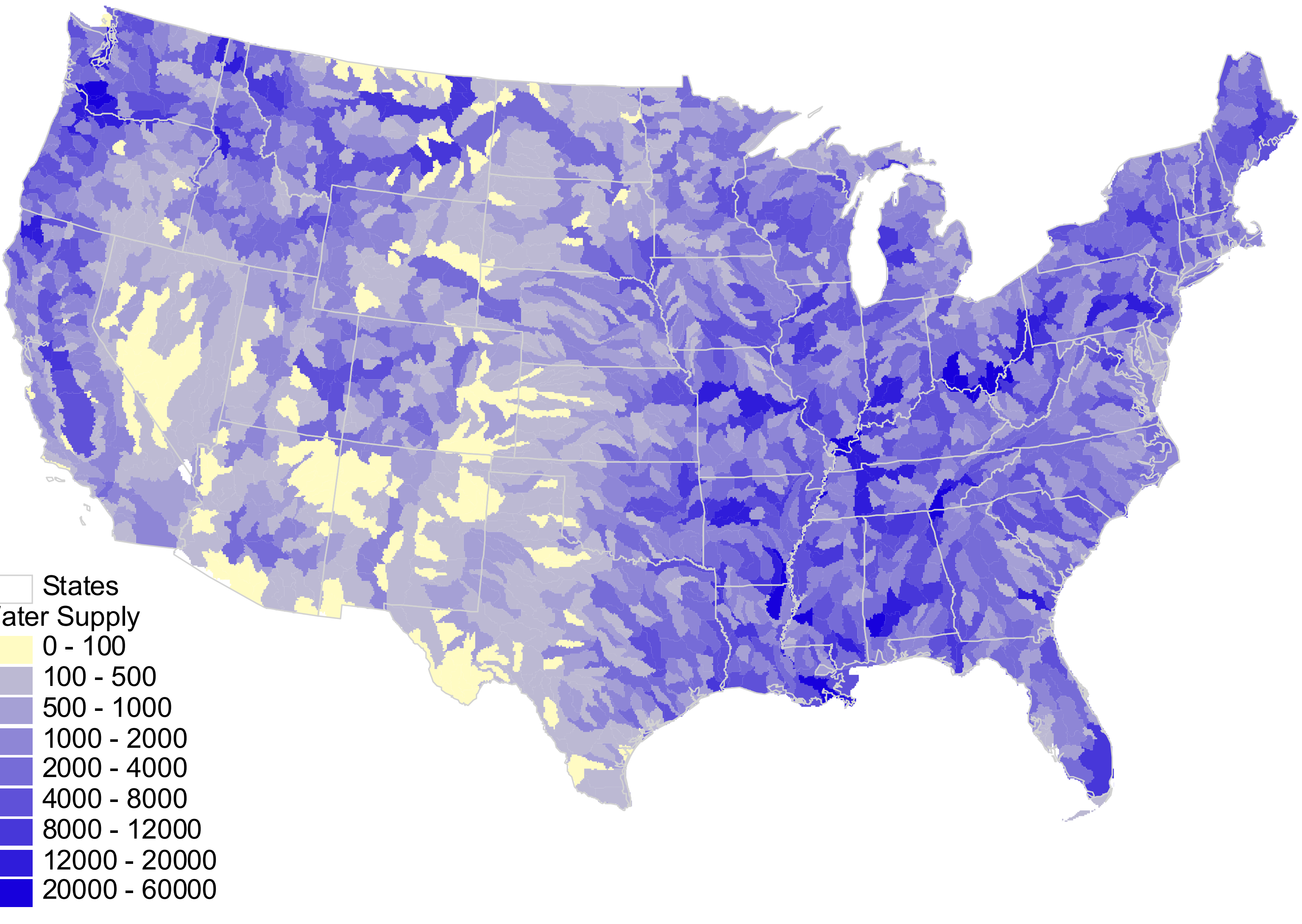
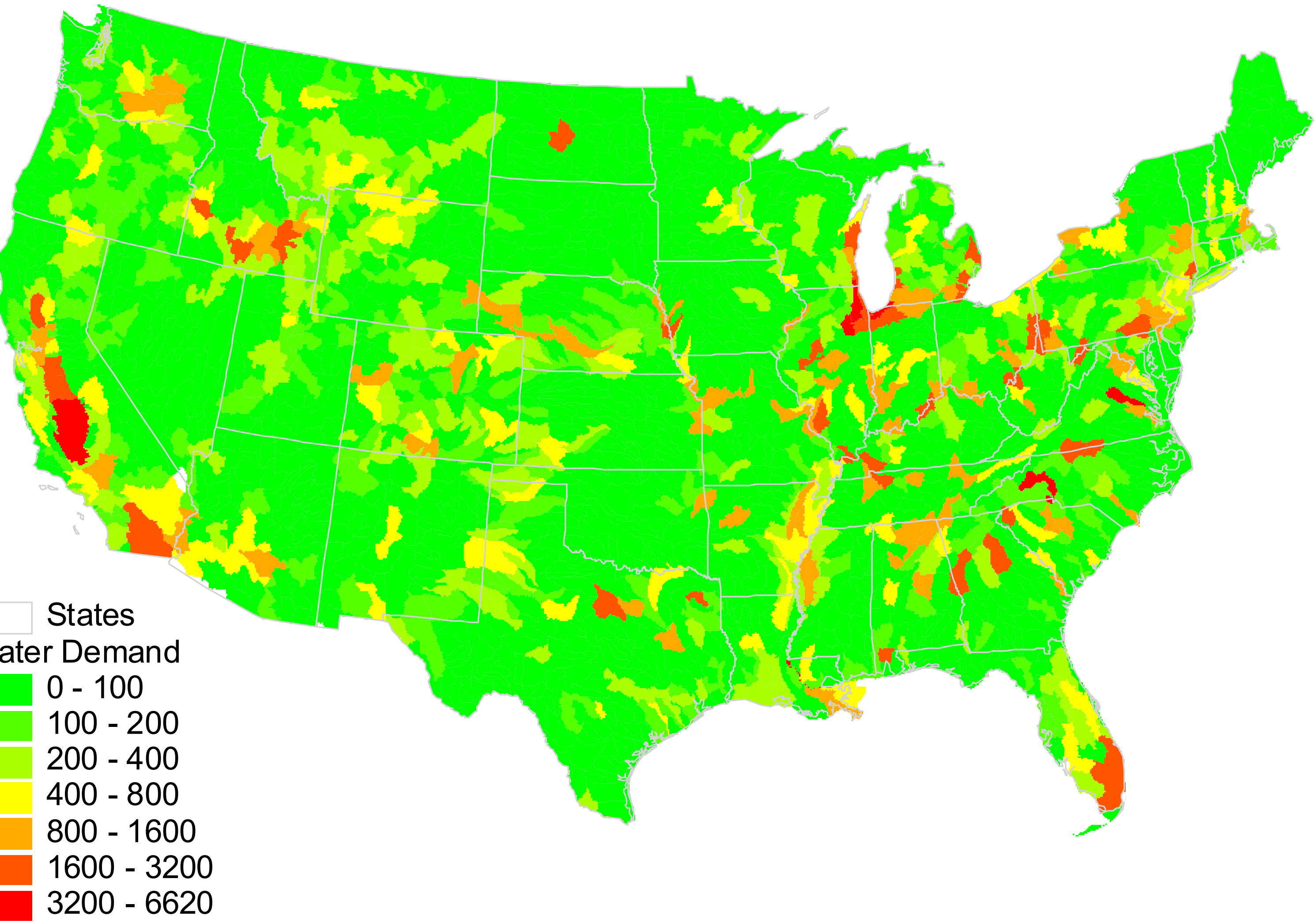
Current Water Supply (MGD)



Current Water Demand (MGD)



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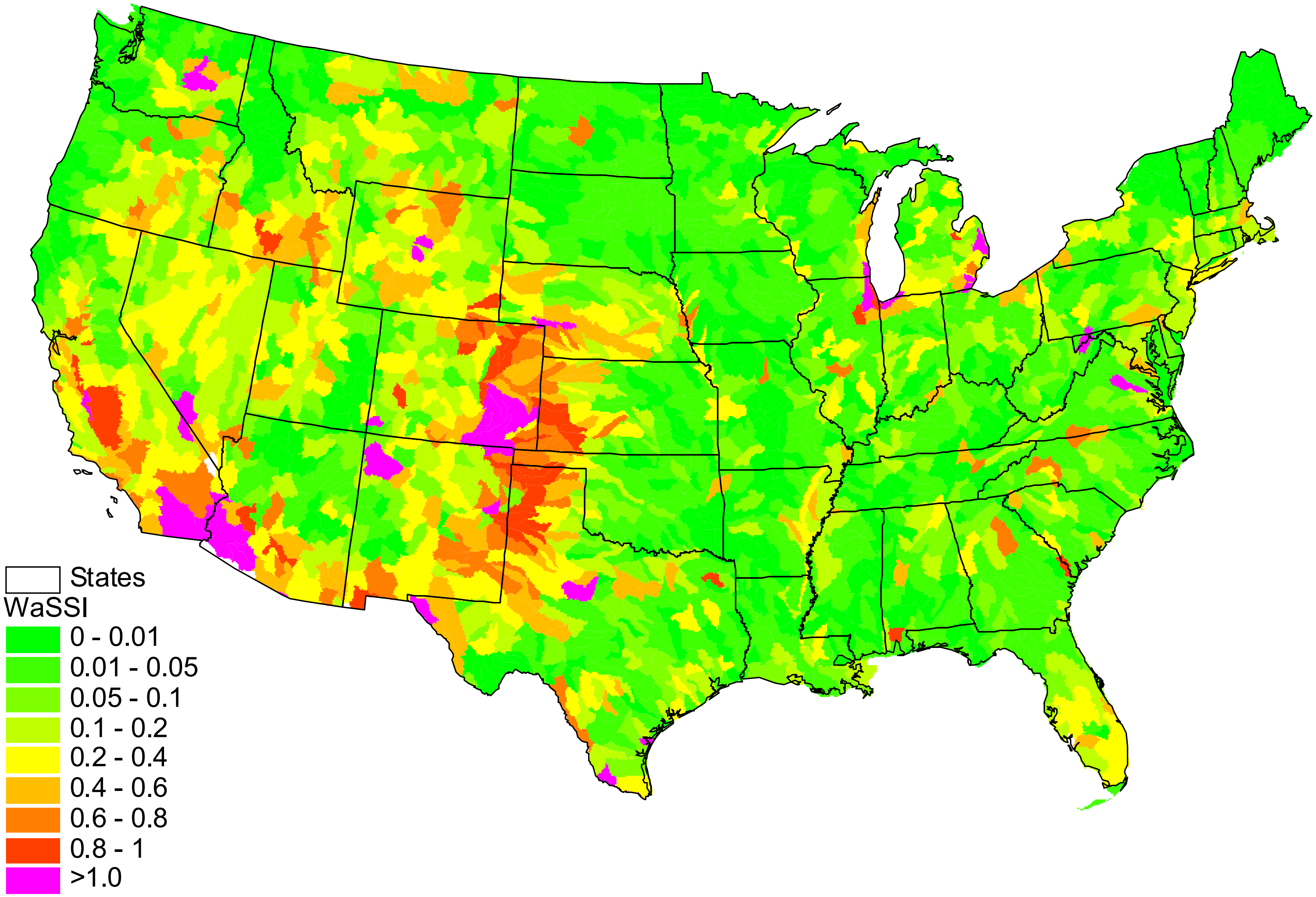
Water Demand / Water Supply (WaSSI) (1974-1993)



Projections

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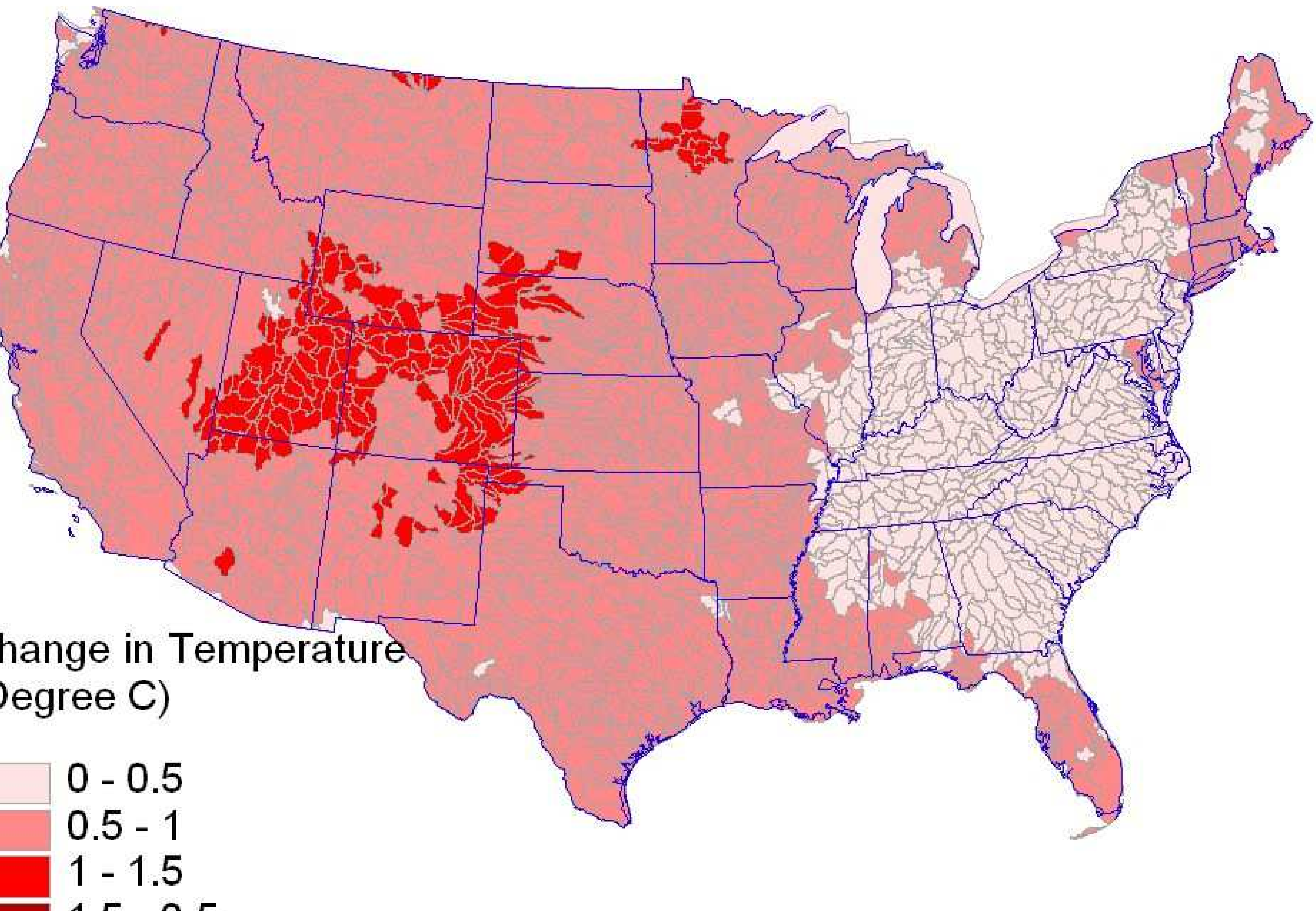
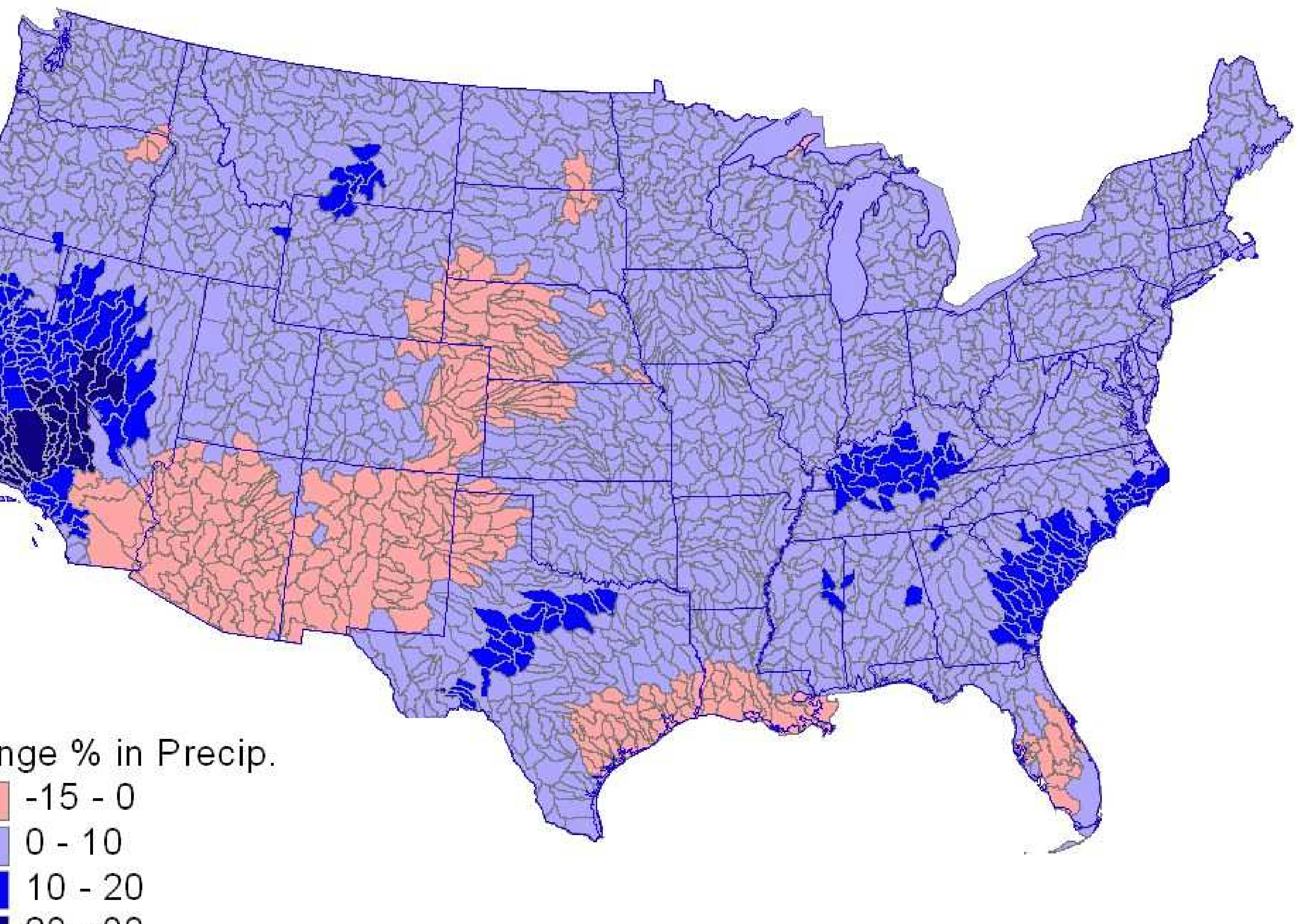
Air Temperature Change (HadCM2Sul) over Next 20 Years



Precipitation Change (HadCM2Sul) over Next 20 Years



Hypothetical Scenarios Examined

- Scenario 1 = Baseline
  - 1992 landcover, historic climate and water use
- Scenario 2 = Historical climate+Pop change (2050)
- Scenario 3 = Historical climate + Deforestation 10%
- Scenario 4 = Historical climate + Irrigation -10%
- Scenario 5 = climate change (HadCMSul2, CGC1)
- Scenario 6 = Climate change + Population growth

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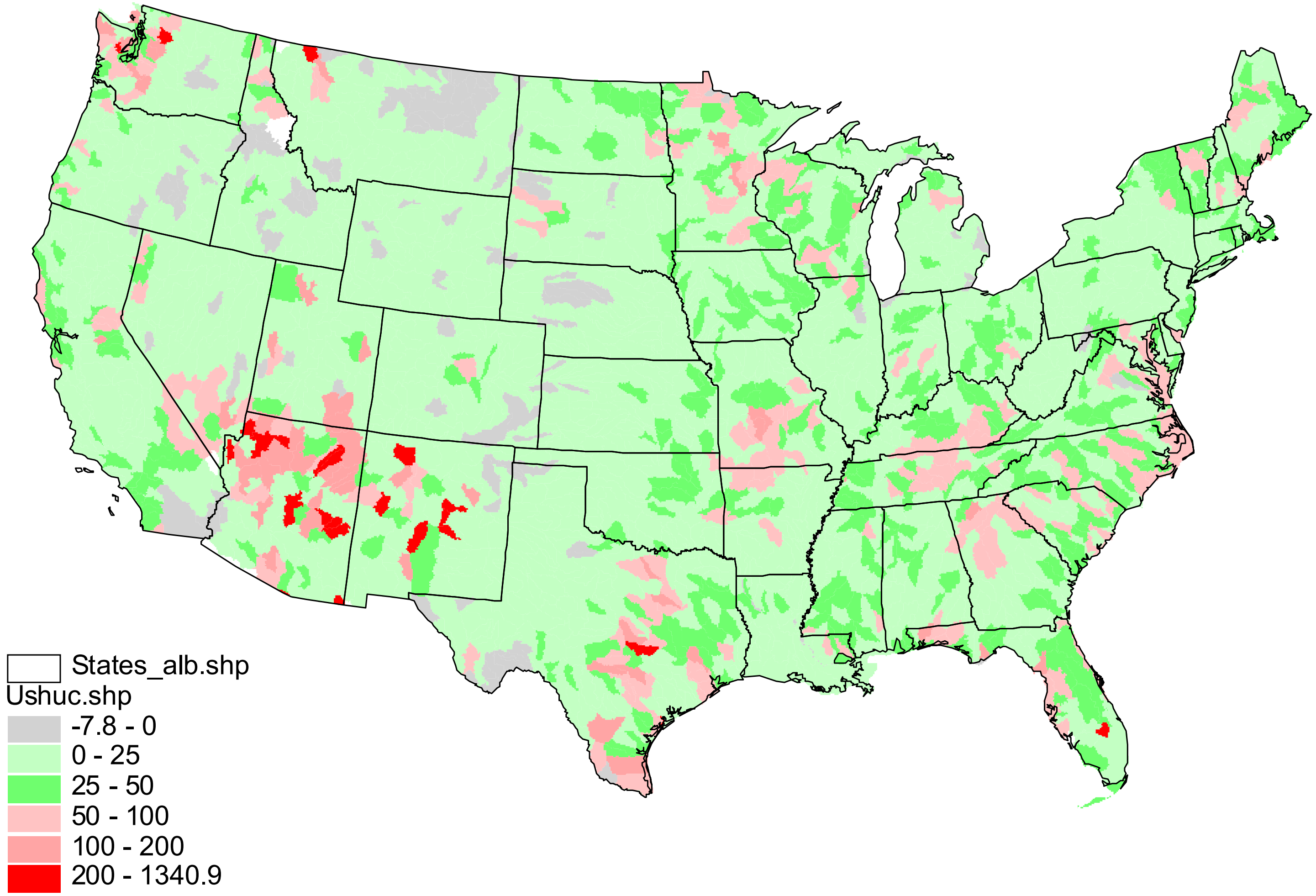
% Changes in Water Demand / Water Supply (WaSSI) due to: Population Growth (2050)



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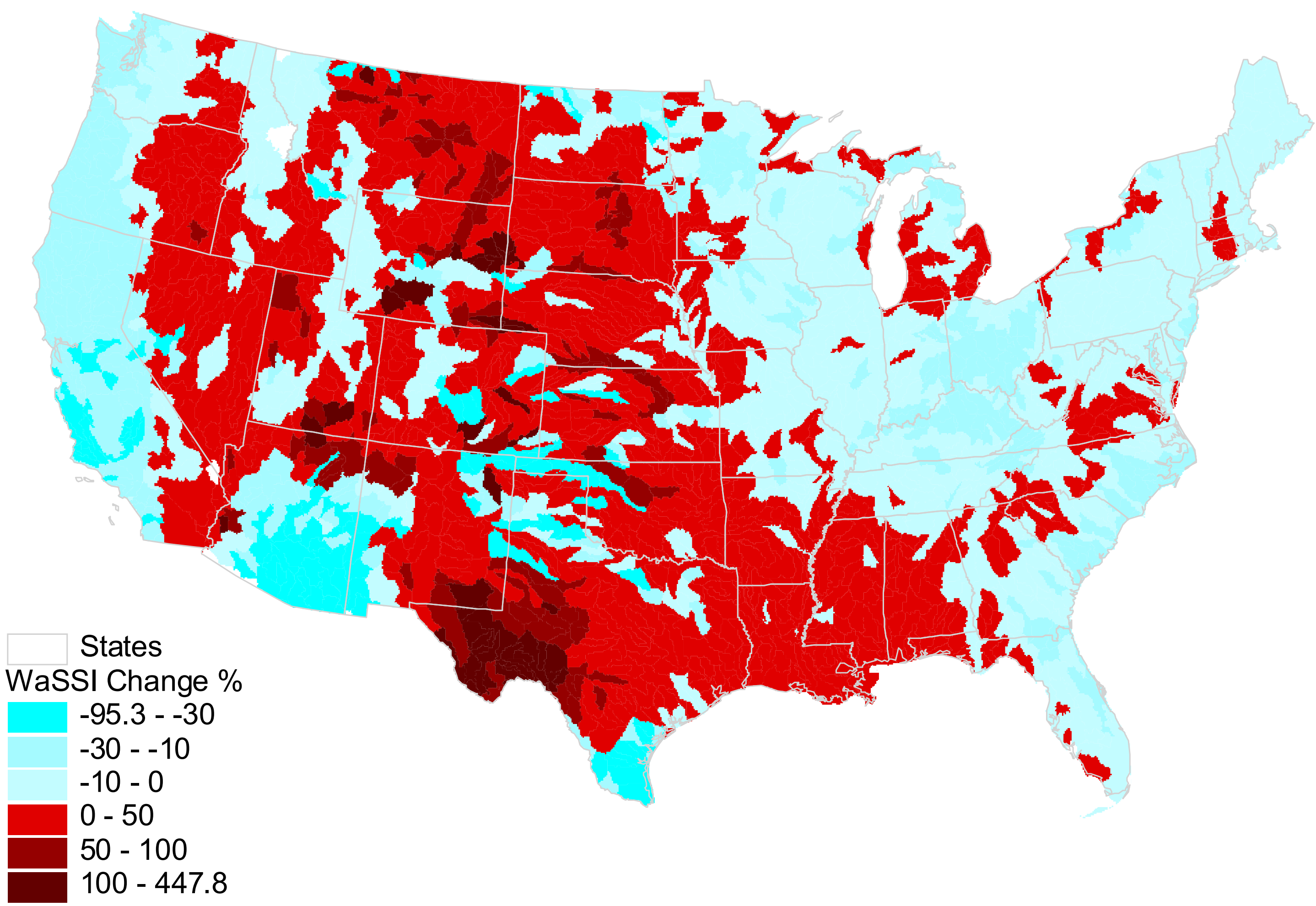
Climate Change (Hadley2)



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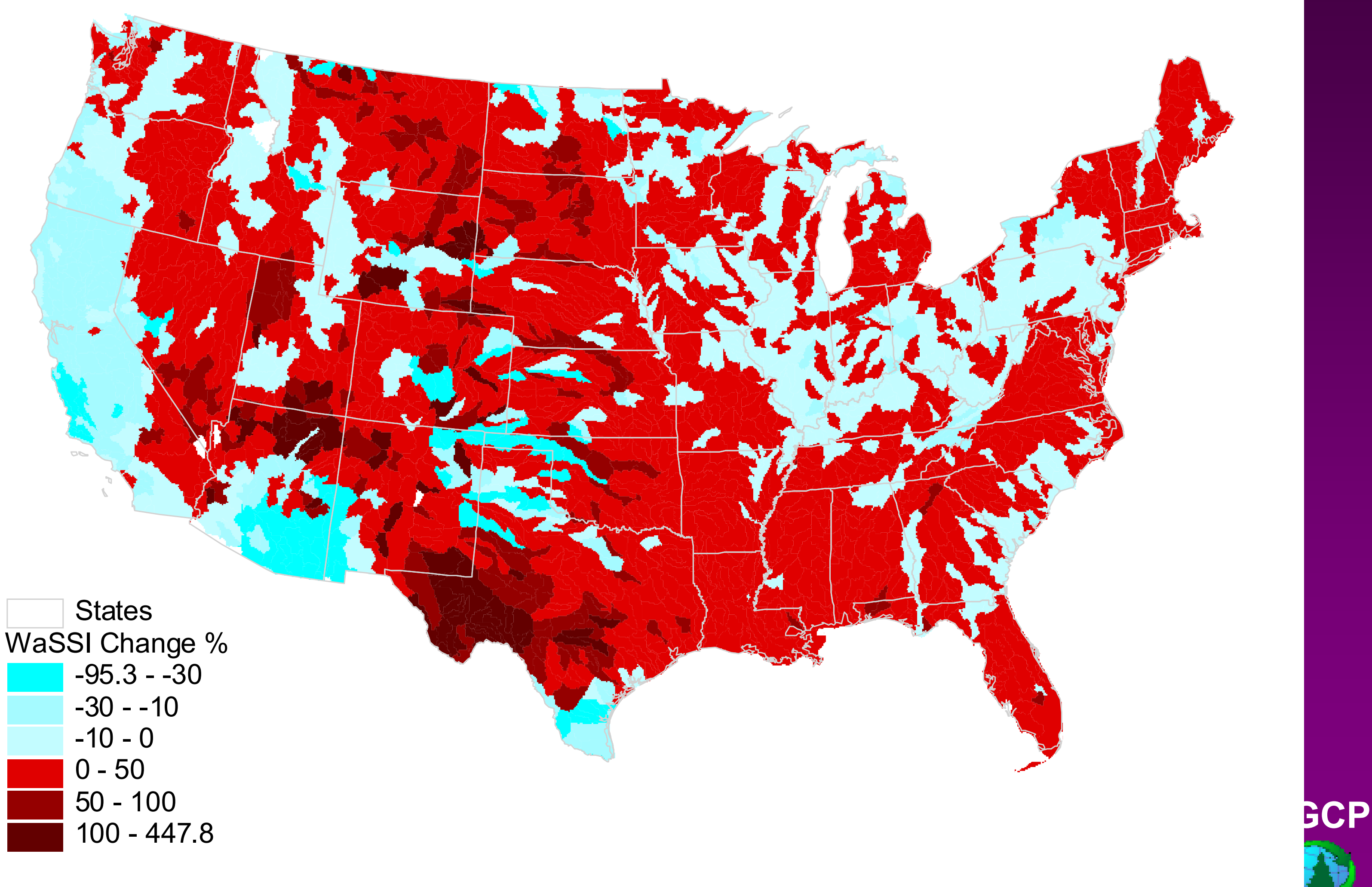
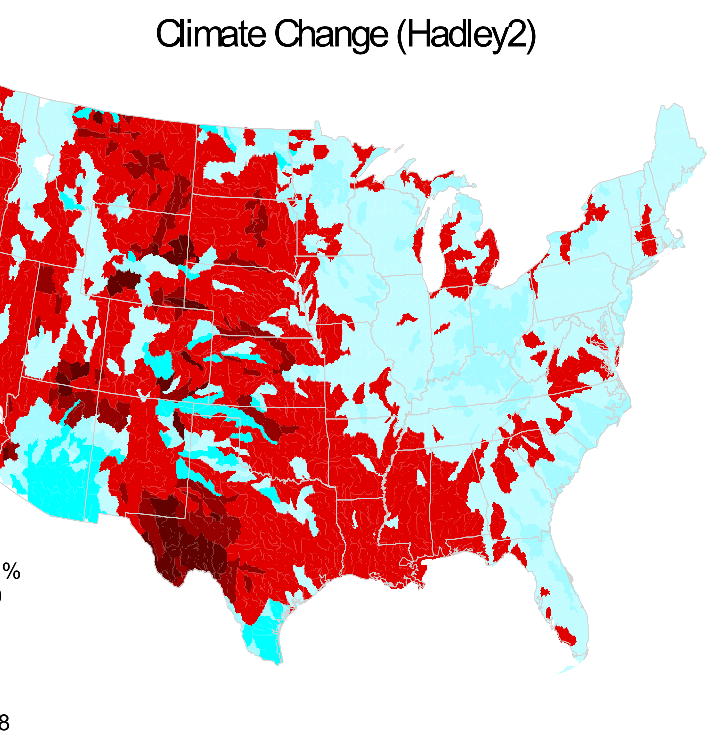
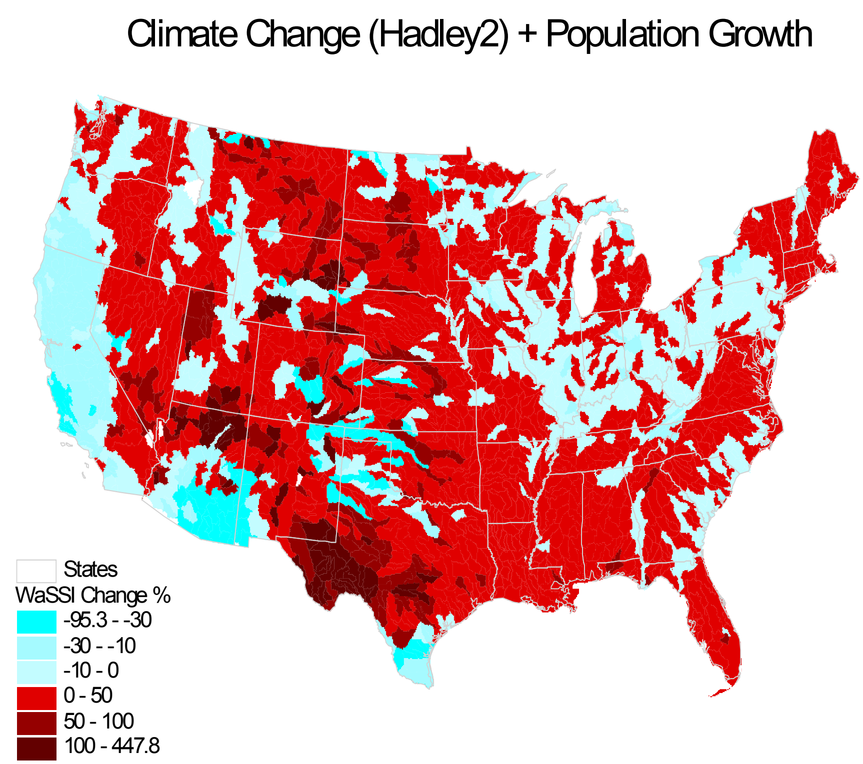
Climate Change (Hadley2) + Population Growth



te change only (1994-2050)



Climate change + Population growth



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National Overall Pictures

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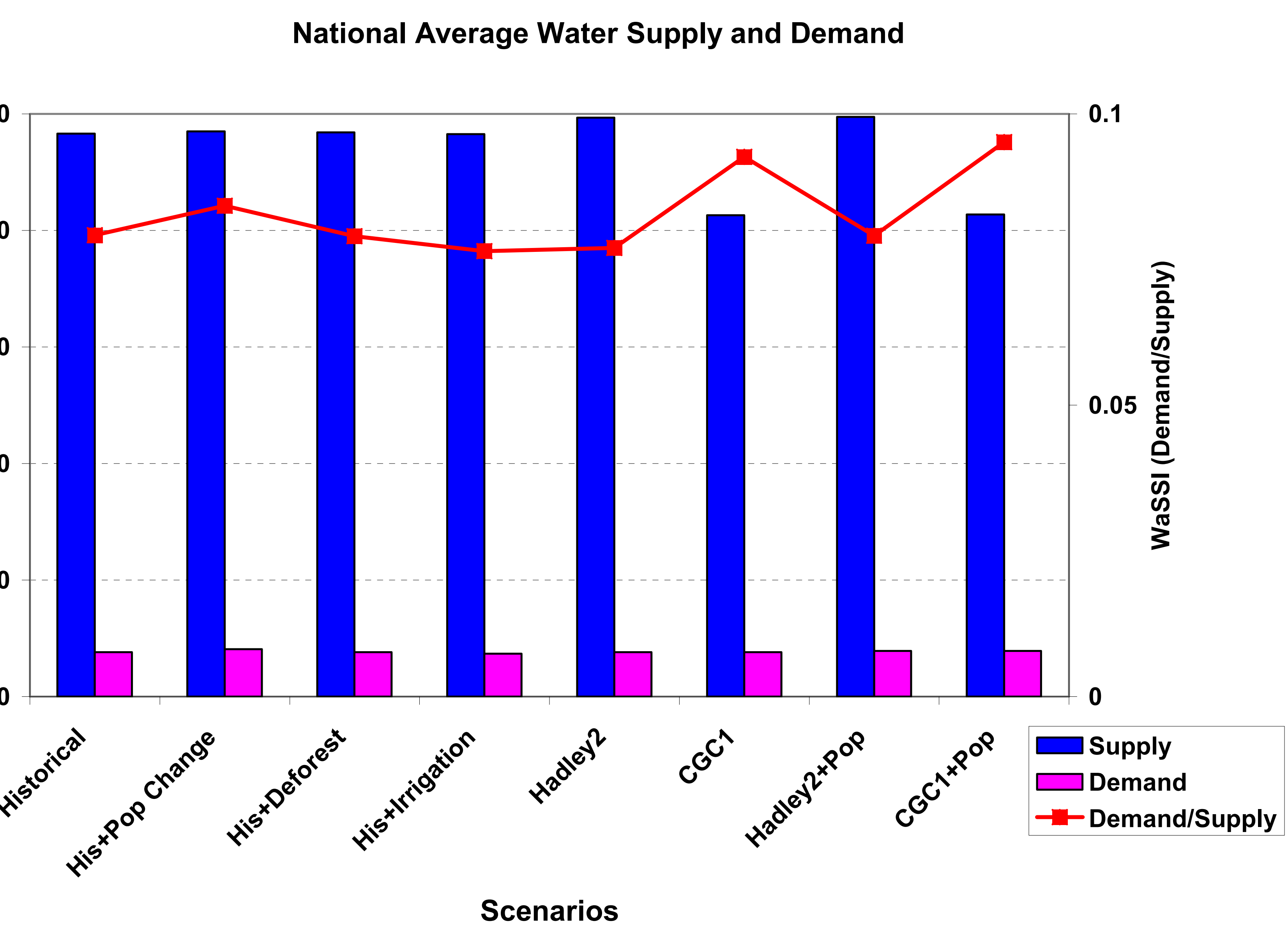
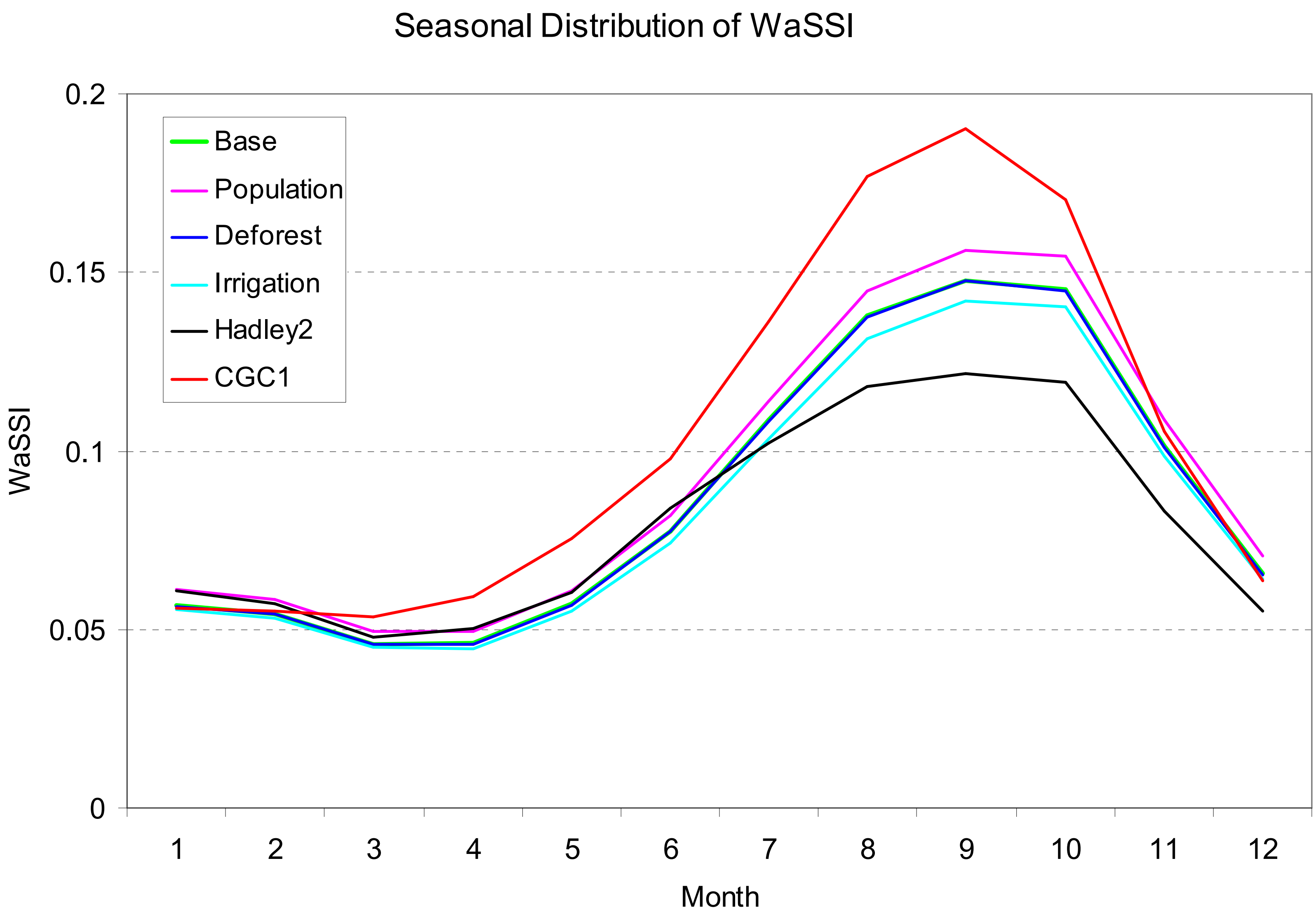


National Average Water Supply and Demand
0.1
0.05
0
WaSSI (Demand/Supply)
Historical
His+Pop Change
His+Deforest
His+Irrigation
Hadley2
CGC1
Hadley2+Pop
CGC1+Pop
Scenarios
Supply
Demand
Demand/Supply



Seasonal Distribution of WaSSI
0.2
0.15
0.1
0.05
0
WaSSI
Base
Population
Deforest
Irrigation
Hadley2
CGC1
1
2
3
4
5
6
7
8
9
10
11
12
Month

Model Expansion

Flow Routing

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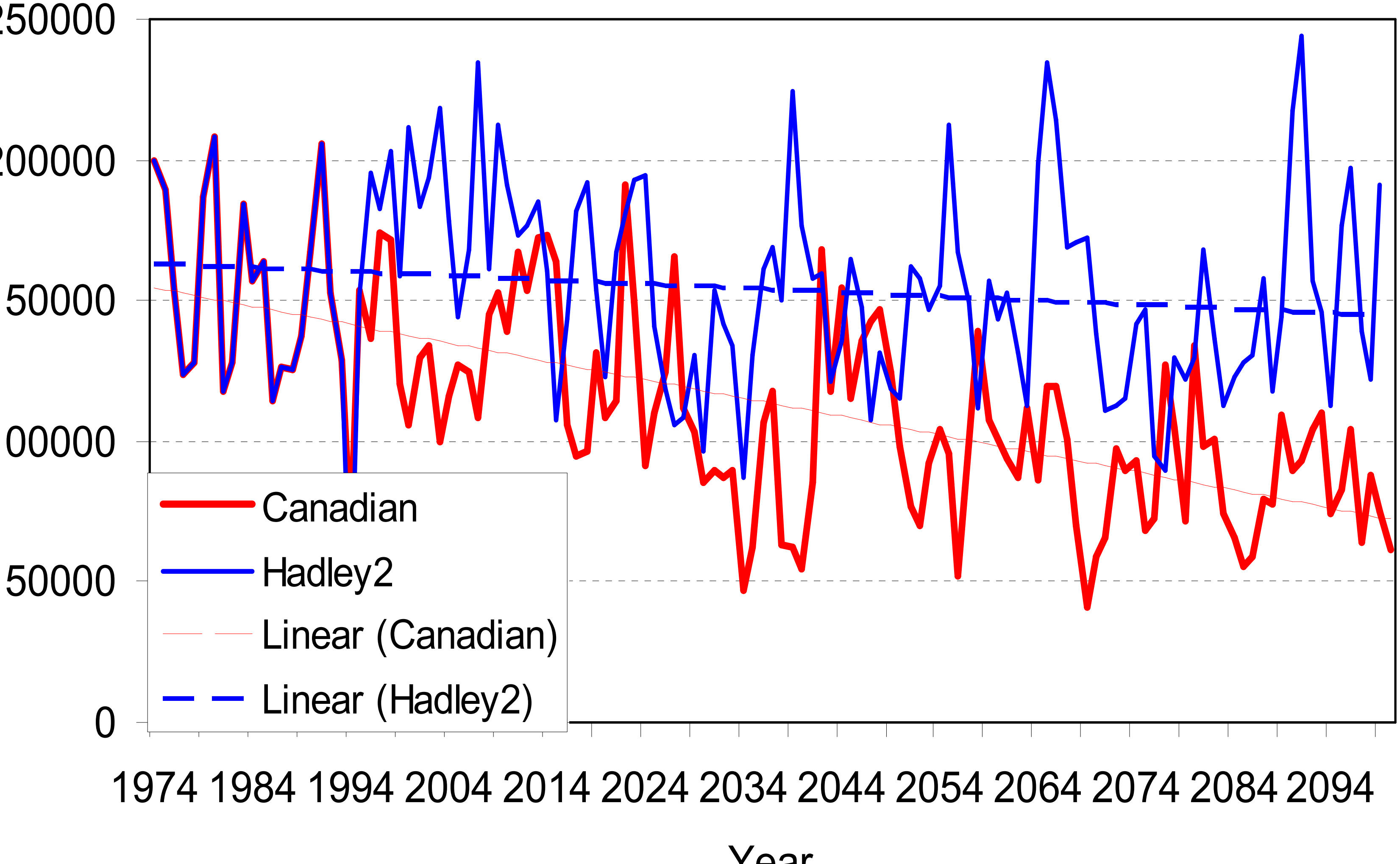
Mississippi River Flow Under Two Climate Change Scenarios



Model Expansion

aSSI-CB (Carbon and Biodiversity)

- Applying other equations to the WaSSI database

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Primary Model Relationship
Model Shared Data Input
Validation Input/ Function

Equation (Sun)

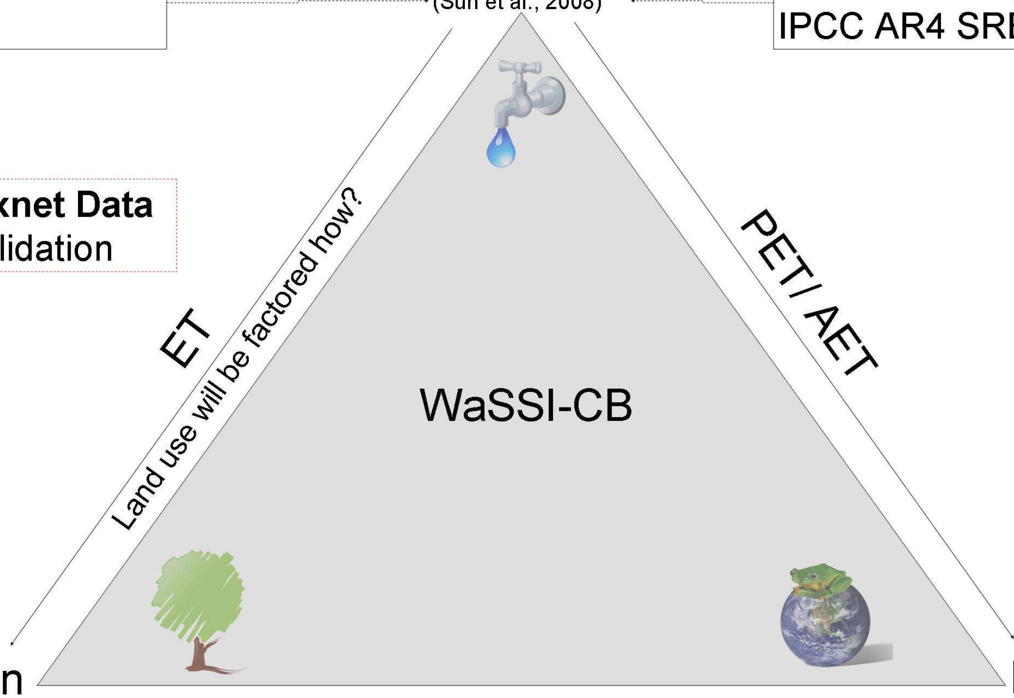
$$\frac{ET}{P} = \frac{1 + w\frac{PET}{P}}{1 + w\frac{PET}{P} + \frac{P}{PET}}$$

Land Use Data
MRLC 2001

Water
(Sun et al., 2008)

Climate Data (Temp. & Precip.)
IPCC AR4 SRES A1B, A2, B1

Ameriflux/ Fluxnet Data
Point Based Validation



Carbon
(Law et al., 2002)

Biodiversity
(Currie, 1991)
(Currie & Paquin, 1987)

Equations (Law)

(1) Evergreen Conifers
GEP (g CO_2 m^{-2} mo^{-1}) = 30.43 + 2.43*ET (kg H_2O m^{-2} mo^{-1}) ; r^2 = 0.58
NEE (g CO_2 m^{-2} y^{-1}) = 285 – 0.44* GEP (g CO_2 m^{-2} y^{-1}) ; r^2 = 0.59

(2) Deciduous Broadleaf
GEP (g CO_2 m^{-2} mo^{-1}) = 3.42*ET (kg H_2O m^{-2} mo^{-1}) – 0.35 ; r^2 = 0.78
NEE (g CO_2 m^{-2} y^{-1}) = 618 – 0.67* GEP (g CO_2 m^{-2} y^{-1}) ; r^2 = 0.63

Equations (Currie)

Group	Domain	Model	r^2
Birds	PET < 525 mm yr^{-1}	1.40 + .00159 PET	
	PET ≥ 525 mm yr^{-1}	2.26 − .0000256 PET	.81
Mammals	All observations	1.12[1.0 − exp(−0.00348 PET)] + .653	.80
Amphibians	PET ≤ 200 mm yr^{-1}	0	
	PET > 200 mm yr^{-1}	3.07[1.0 − exp(−0.00315 PET)]	.84
Reptiles	PET < 400 mm yr^{-1}	0	
	PET ≥ 400 mm yr^{-1}	5.21[1.0 − exp(−0.00249 PET)] − 3.347	.93
Vertebrates	All observations	1.49[1.0 − exp(−0.00186 PET)] + .746	.92

Tree Species Richness = 185.8/[1.0+exp(3.09 - 0.00432 ARET)] ; r^2 = 0.76

Biodiversity Data

Equation (Costanza et al., 2006)

Carbon

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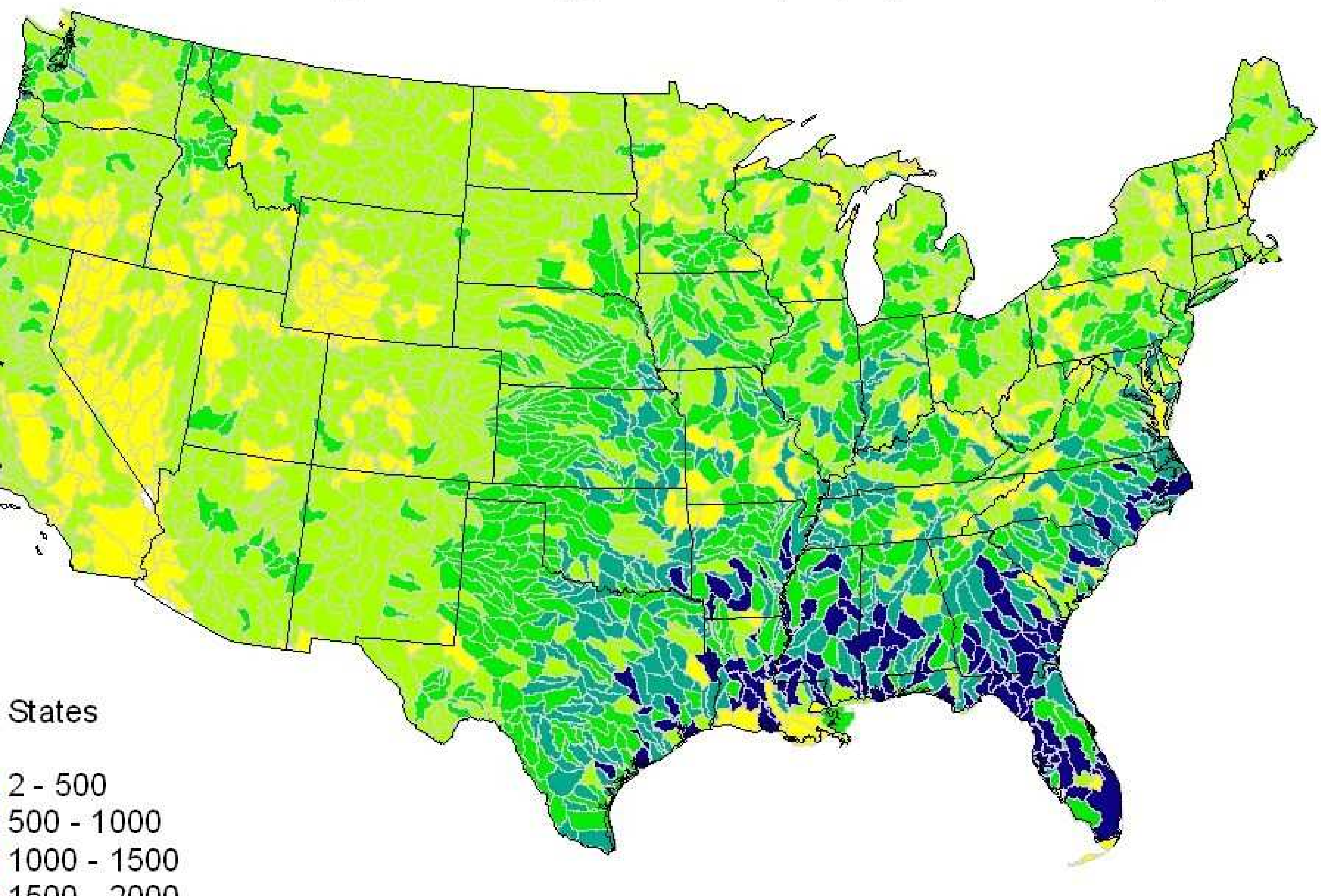
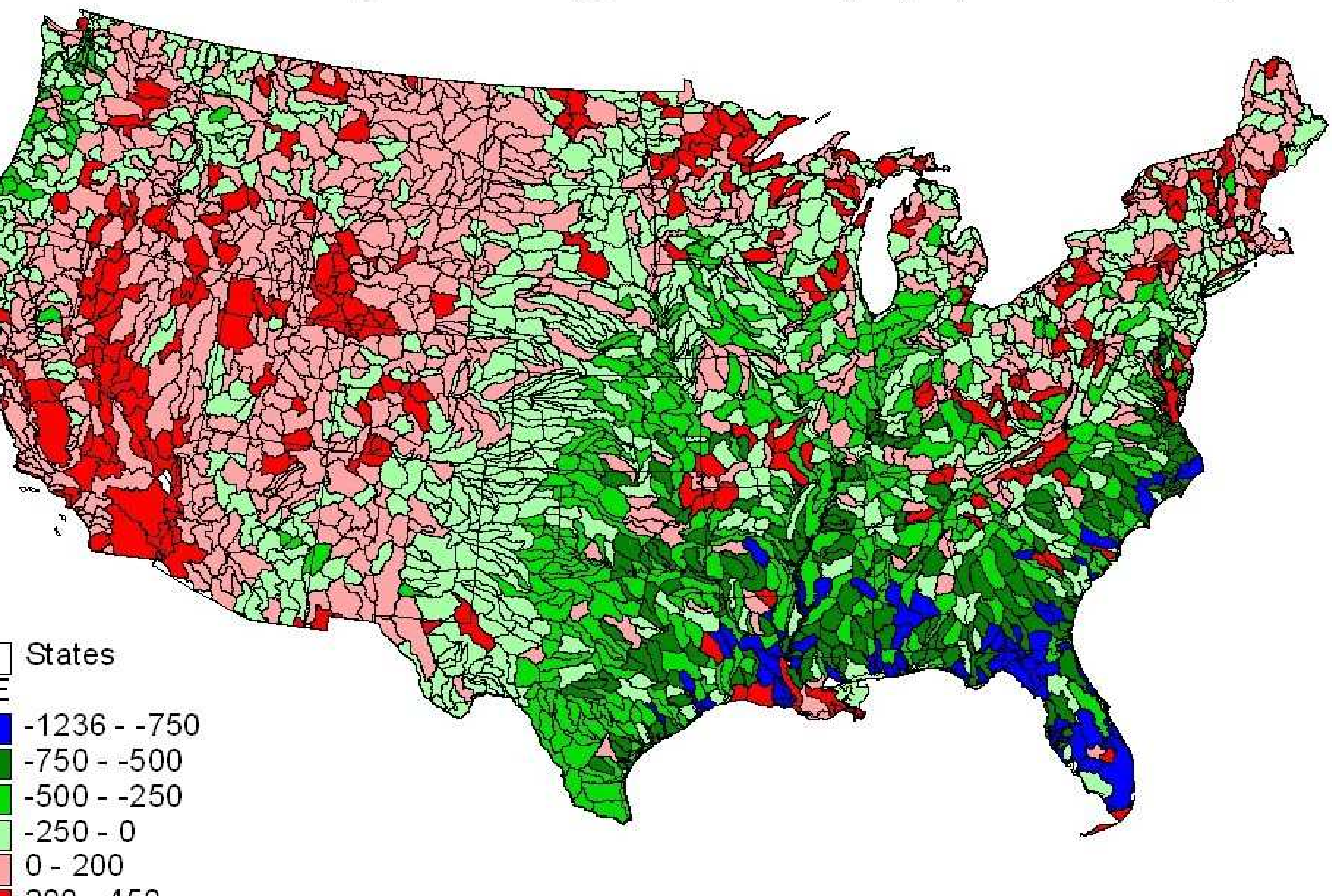
Average GEP (g C /m2/yr.) (1974-1993)



Average NEE (g $CO_2/m^2/yr.$) (1974-1993)



Biodiversity

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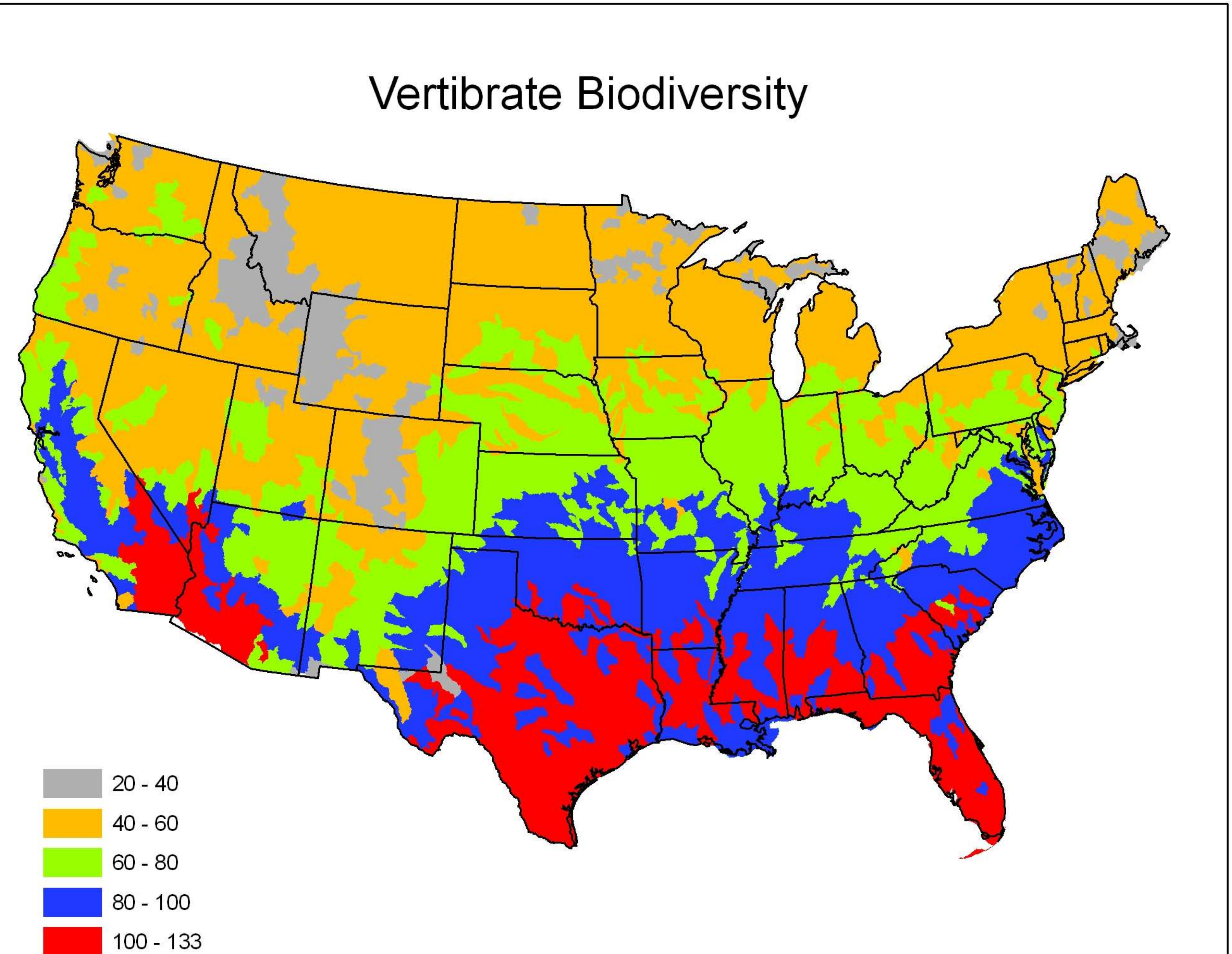
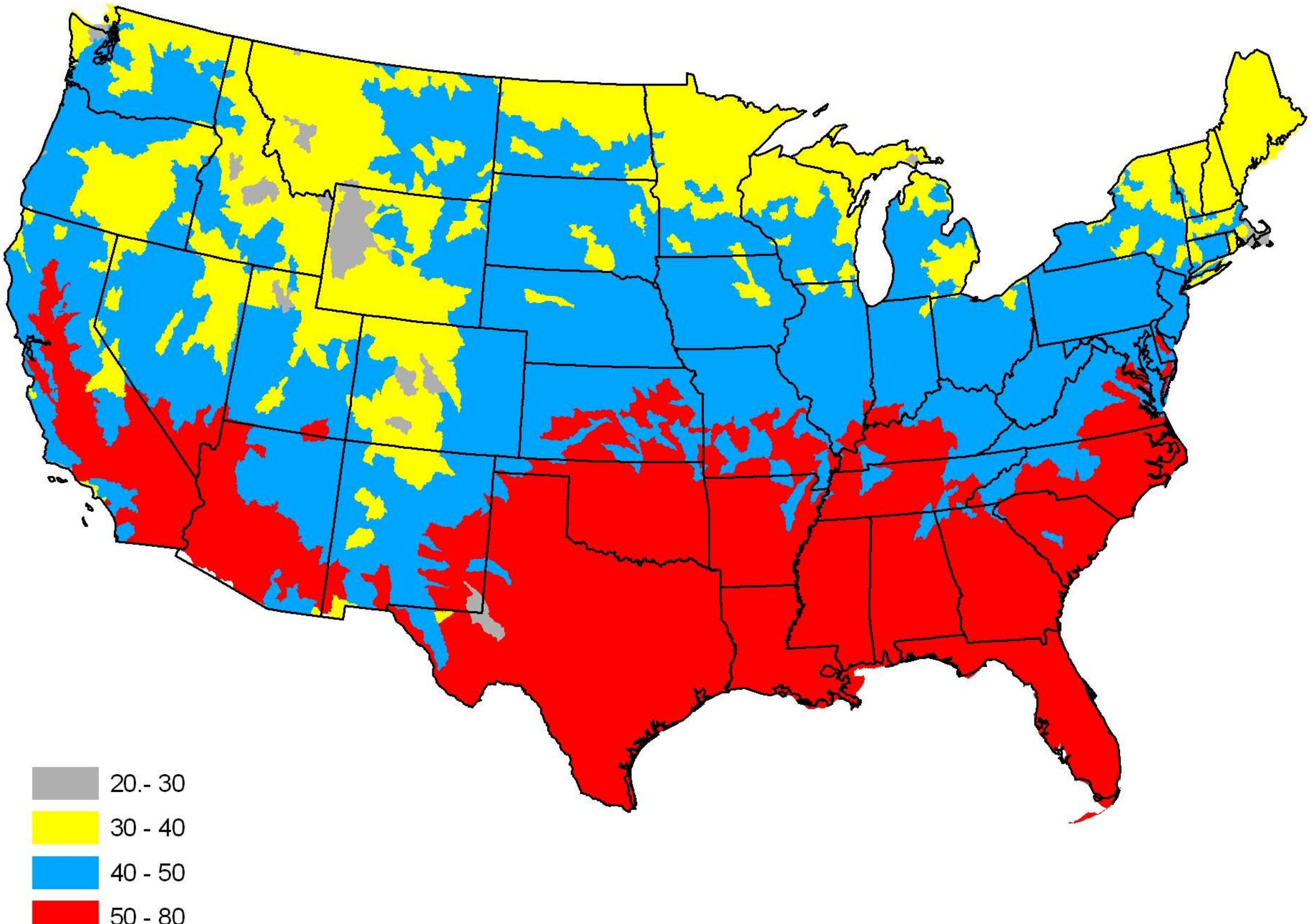
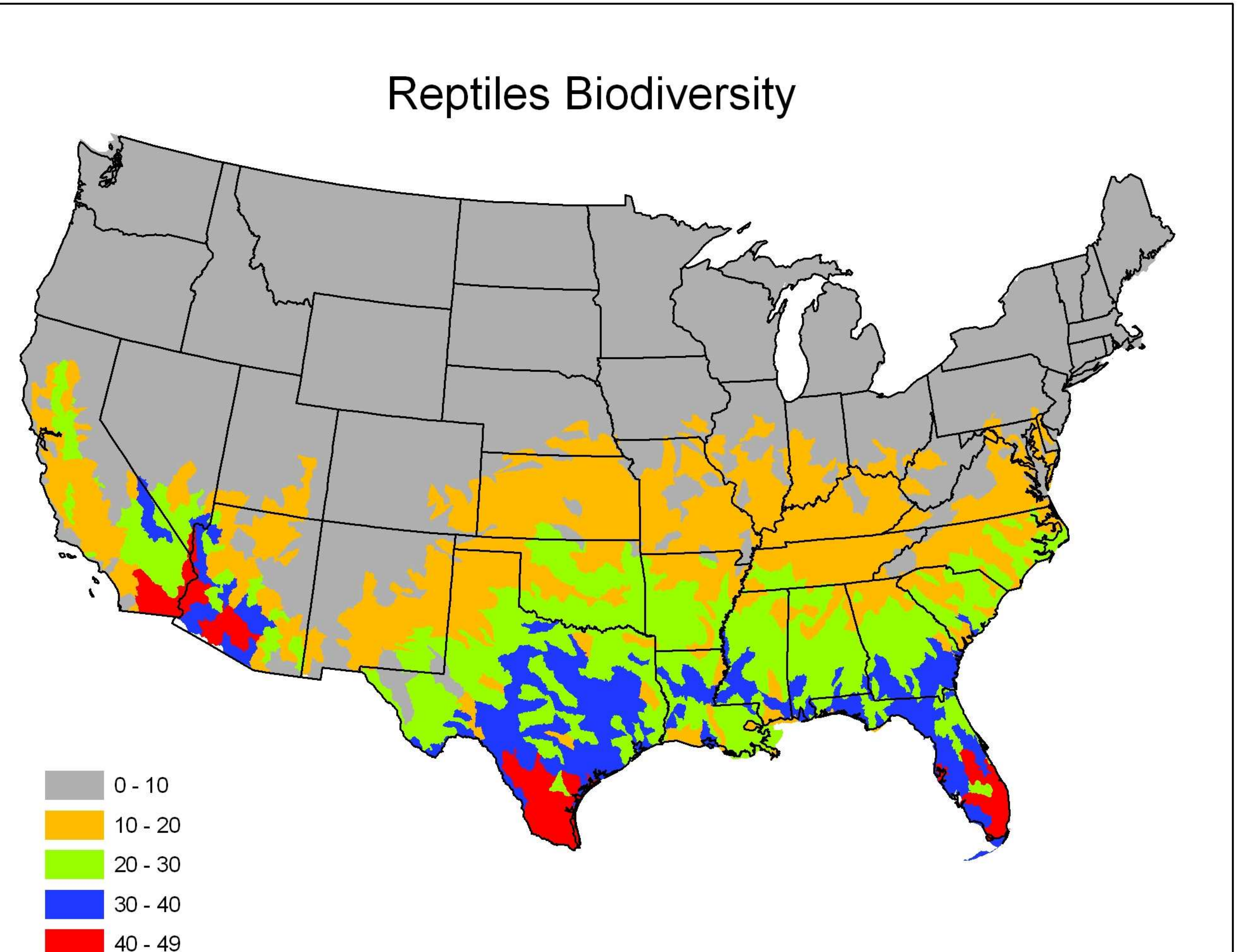
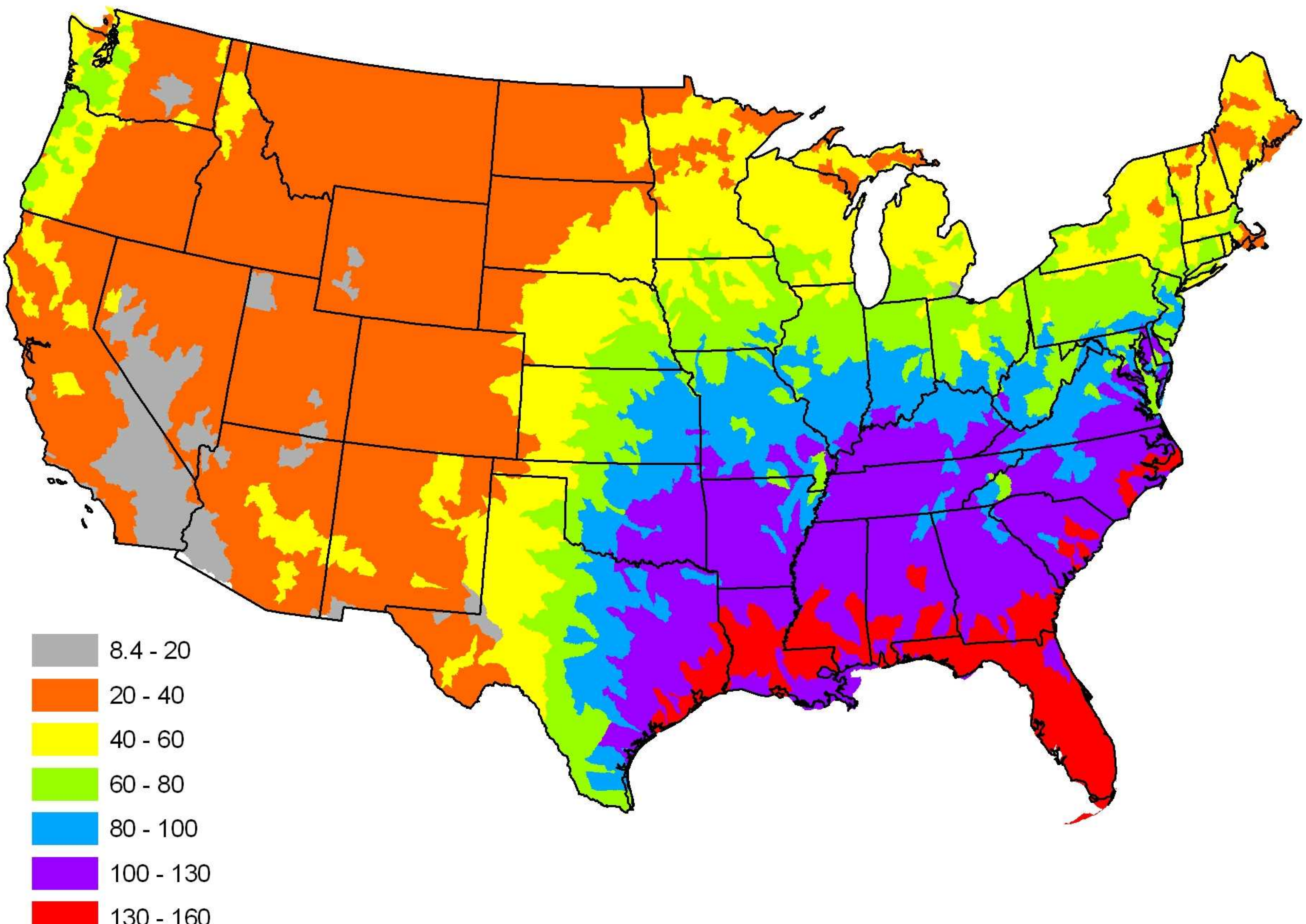

Vertibrate Biodiversity
20 - 40
40 - 60
60 - 80
80 - 100
100 - 133

Mammal Biodiversity




Reptiles Biodiversity
0 - 10
10 - 20
20 - 30
30 - 40
40 - 49

Tree Biodiversity



Summary

Water supply and demand must be addressed together at the basin scale (upstream and downstream; and seasonal scale)

Regardless of climate change, population growth will cause water stress problems in metropolitan areas

Climate variability will likely have a larger impact on episodic water shortages than will climate change over the next several decades

The ability to synergistically examine tradeoffs between water availability, forest carbon sequestration and biodiversity is an important addition to our assessment capabilities

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