Modeling Spatial Population Scenarios

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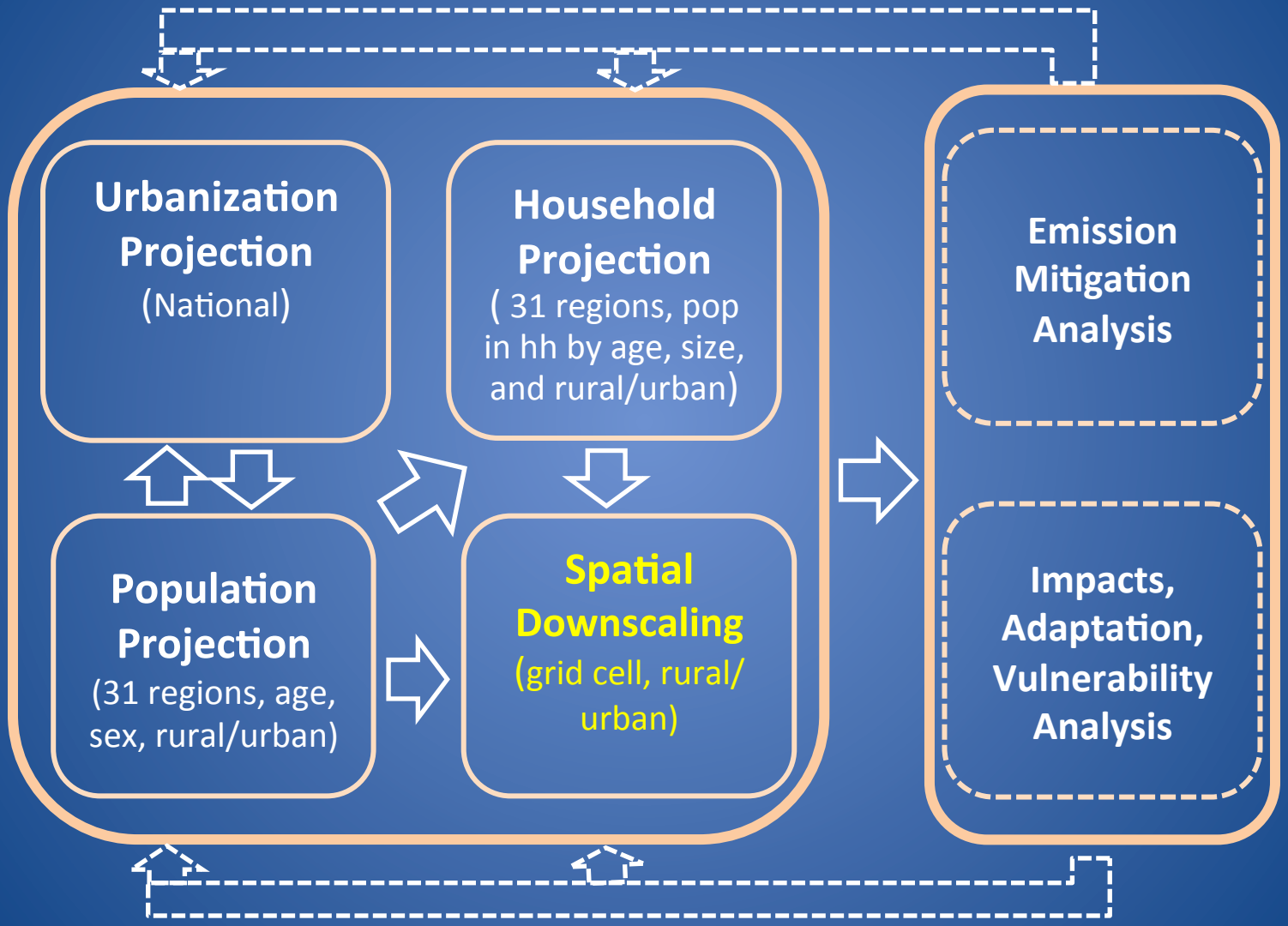
Agenda

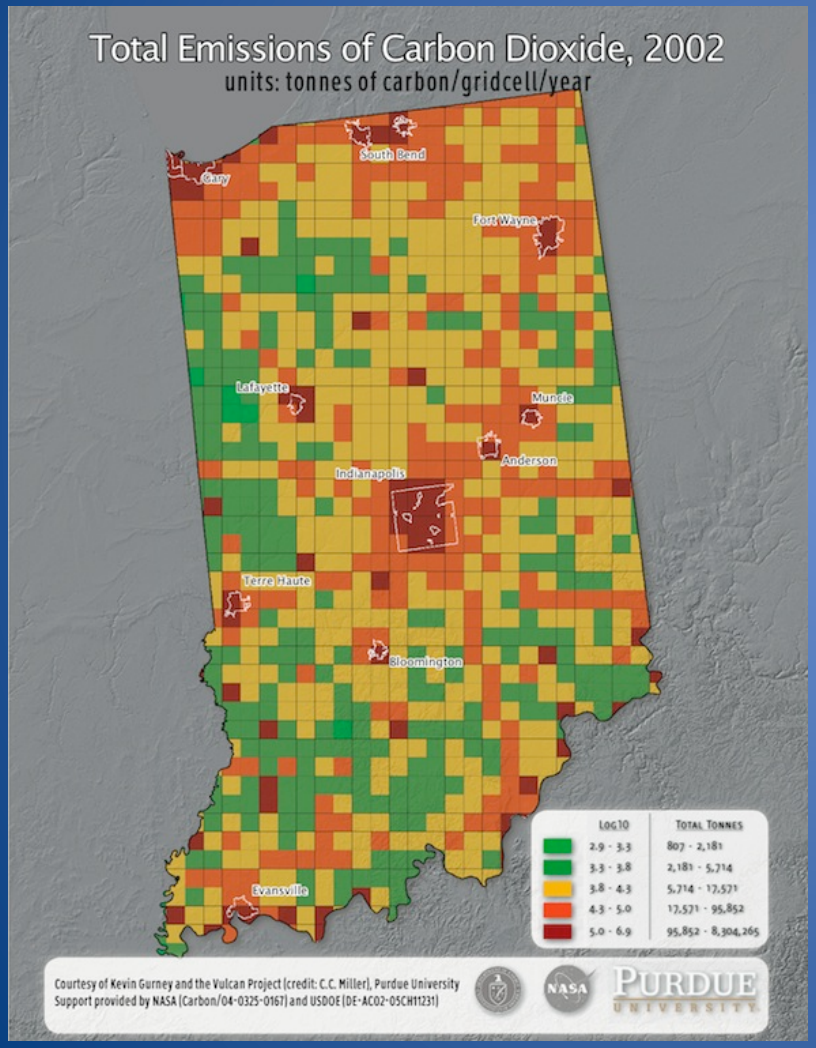
1. Introduction
    a. Importance
    b. Research goals
2. Methodology
    a. Current methods
    b. Gravity models
    c. Our approach
3. U.S. Scenarios
4. Producing Global Scenarios

Community Demographic Model (CDM)

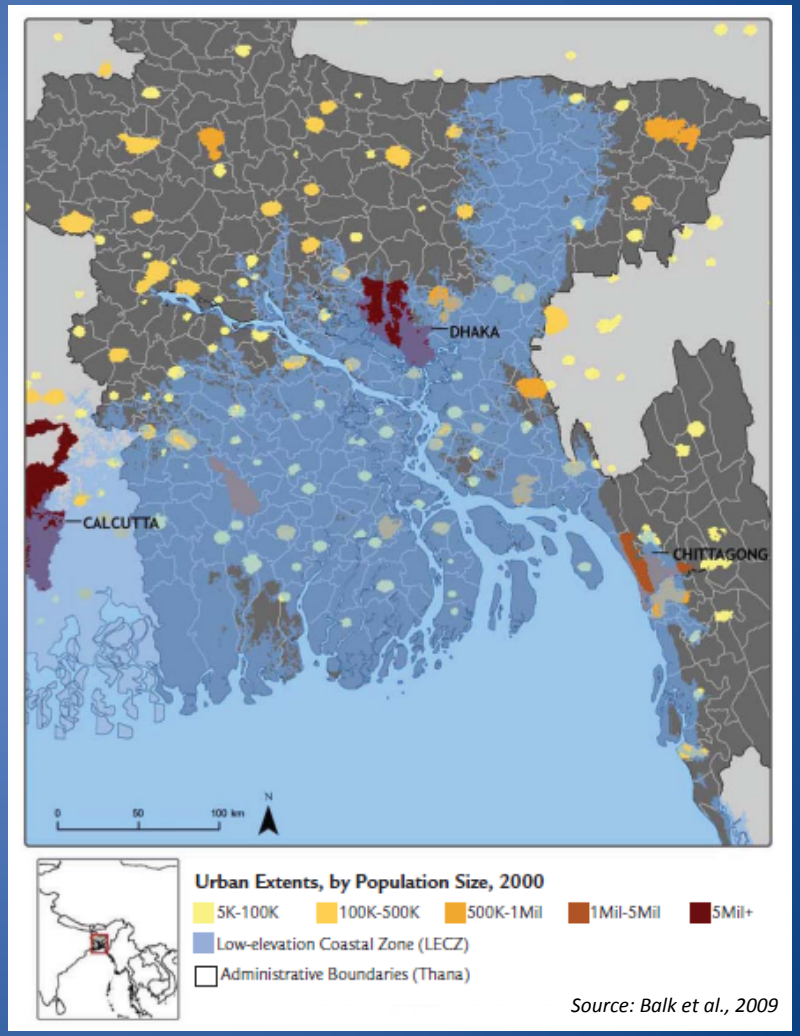


Why are spatial population projections important?

Spatial Emissions



Risk and Vulnerability Assessment



Source: Balk et al., 2009

Project Overview

Research Goal:

To develop an improved methodology for constructing large-scale plausible future spatial population scenarios which may be calibrated to reflect alternative regional patterns of development.

- Large-scale
  - Data constraints
  - Scale of application
- Scenarios
  - Storylines (SRES, SSP)

Process:

1) Assessment of leading existing methodology.
2) Identify problematic features and test modifications.
3) Apply modified methodology to produce 100-year spatial scenarios for the United States (SRES A2 & B2 scenarios)

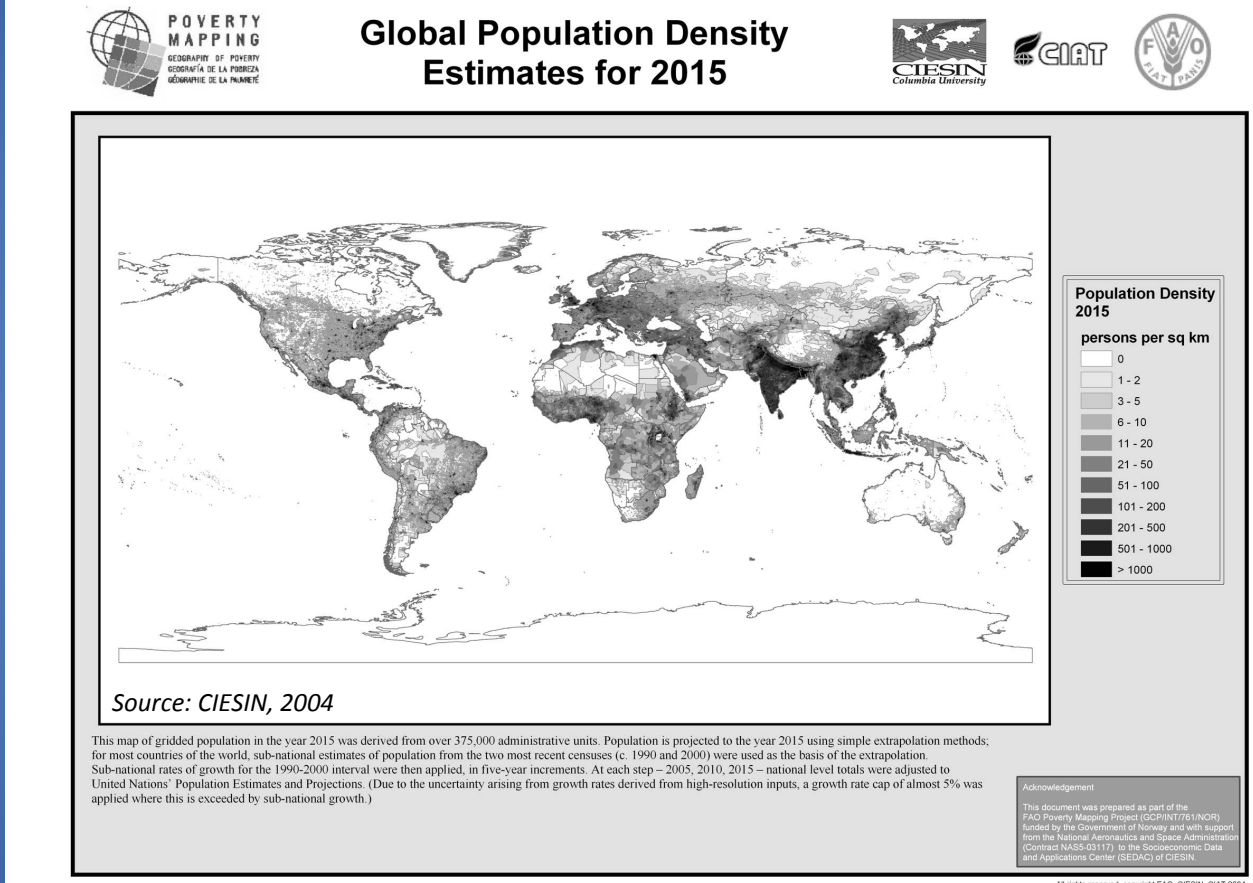
Existing Methods

Proportional scaling
- Gaffin et al., 2004
- Bengtsson et al., 2006
- van Vuuren et al., 2007

Trend extrapolation
- Balk et al., 2005
- Hachadoorian et al., 2011

Projected economic data
- Asadoorian, 2005

Gravity-based
- Grübler et al., 2007



Smart Interpolation
- Use of ancillary data to enhance allocation of population (e.g., EPA, 2010)
- Data and computational issues with global application

Gravity-Based Models

Gravity

$$I_{ij} = \frac{P_i P_j}{D_{ij}^2}$$

- Flows – 2 directions
- Spatial interaction
- Migration and transportation

Potential

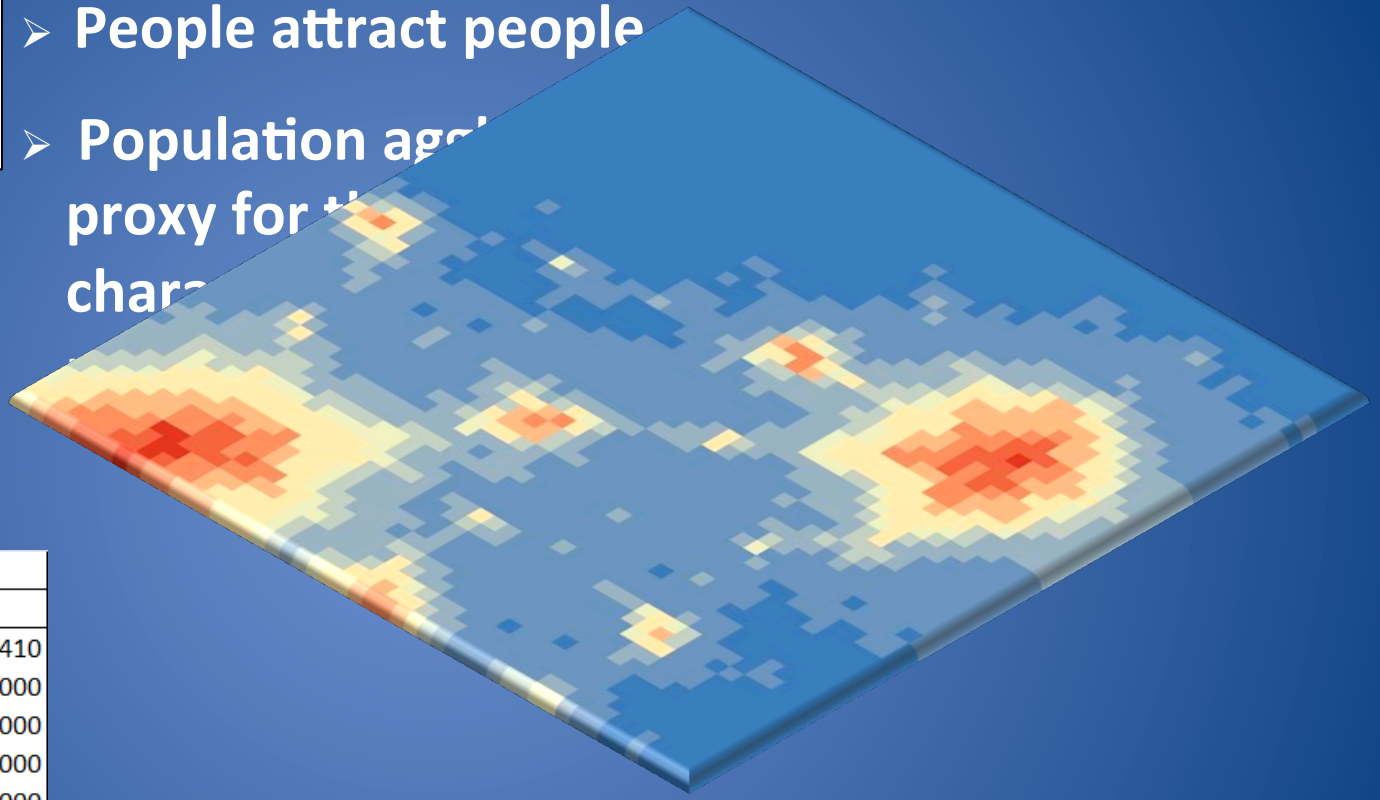
$$v_i = \sum_{j=1}^{n} \frac{P_j}{D_{ij}^2}$$

- Influence – 1 direction
- Spatial allocation
- Accessibility or attractiveness

Potential-Based Spatial Downscaling Model

$$v_i = \sum_{j=1}^{m} \frac{P_j}{D_{ij}^2}$$

- People attract people
- Population agg… proxy for t… chara…



Projected US Population:
IIASA A2 Scenario

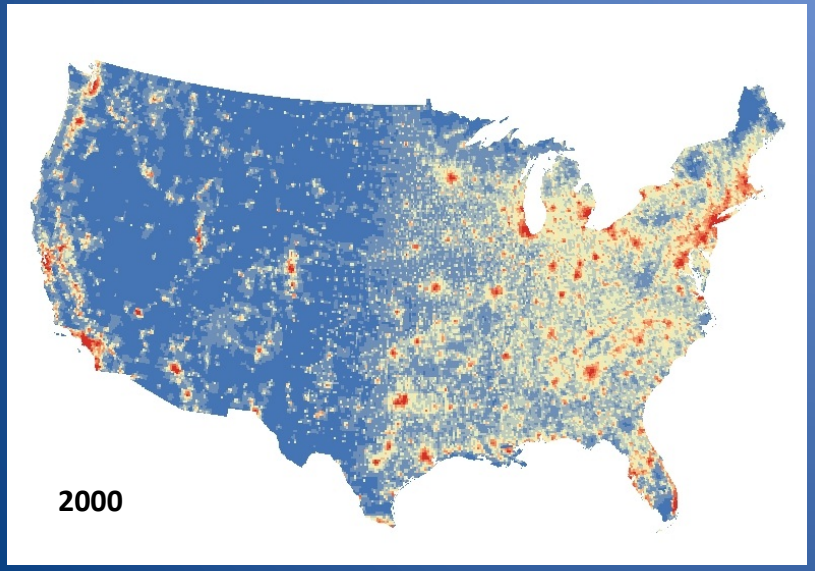
Year	Projected Population	
	Urban	Rural
2000	220,841,027	58,742,410
2010	240,970,000	61,520,000
2020	271,300,000	58,610,000
2030	300,640,000	56,300,000
2040	327,570,000	52,630,000
2050	349,530,000	48,380,000
2060	370,280,000	44,170,000
2070	390,760,000	40,160,000
2080	410,320,000	36,330,000
2090	425,480,000	32,460,000
2100	439,840,000	28,910,000

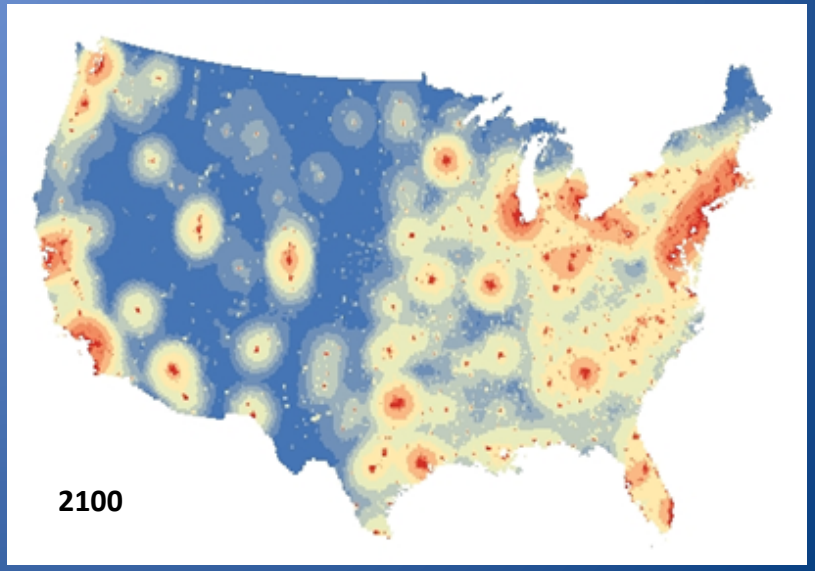
Replicates two commonly observed patterns of spatial development :

- Urban sprawl
- Development of urban corridors

Assessment of the IIASA Methodology

- Not validated against or calibrated to historical data
- Limited range of development trajectories
- Border effects
- Irregular patterns along the urban/rural border
- Population loss is misallocated
- Allocation into areas unsuitable areas for human habitation





IIASA A2 Scenario (Gruebler et al., 2007)

The Modified Potential Model

IIASA potential model:

$$v_i = \sum_{j=1}^{m} \frac{P_j}{D_{ij}^2}$$

NCAR modified potential model:

$$v_i = a_i l_i \sum_{j=1}^{m} P_j^{\alpha} \; e^{-\beta \, d_{ij}}$$

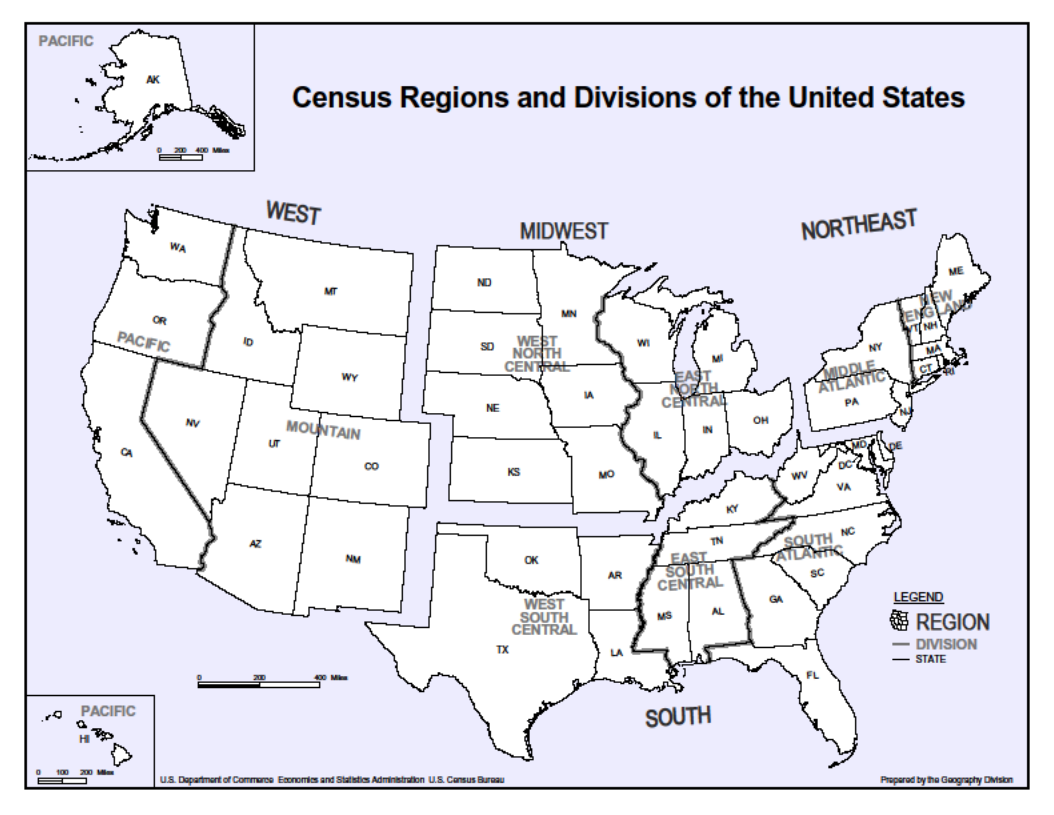
- **Urban and rural populations coexist within grid cells**
- **Allocation occurs as proportional to the inverse of potential during projected periods of population loss**

Calibrating the Parameterized Model

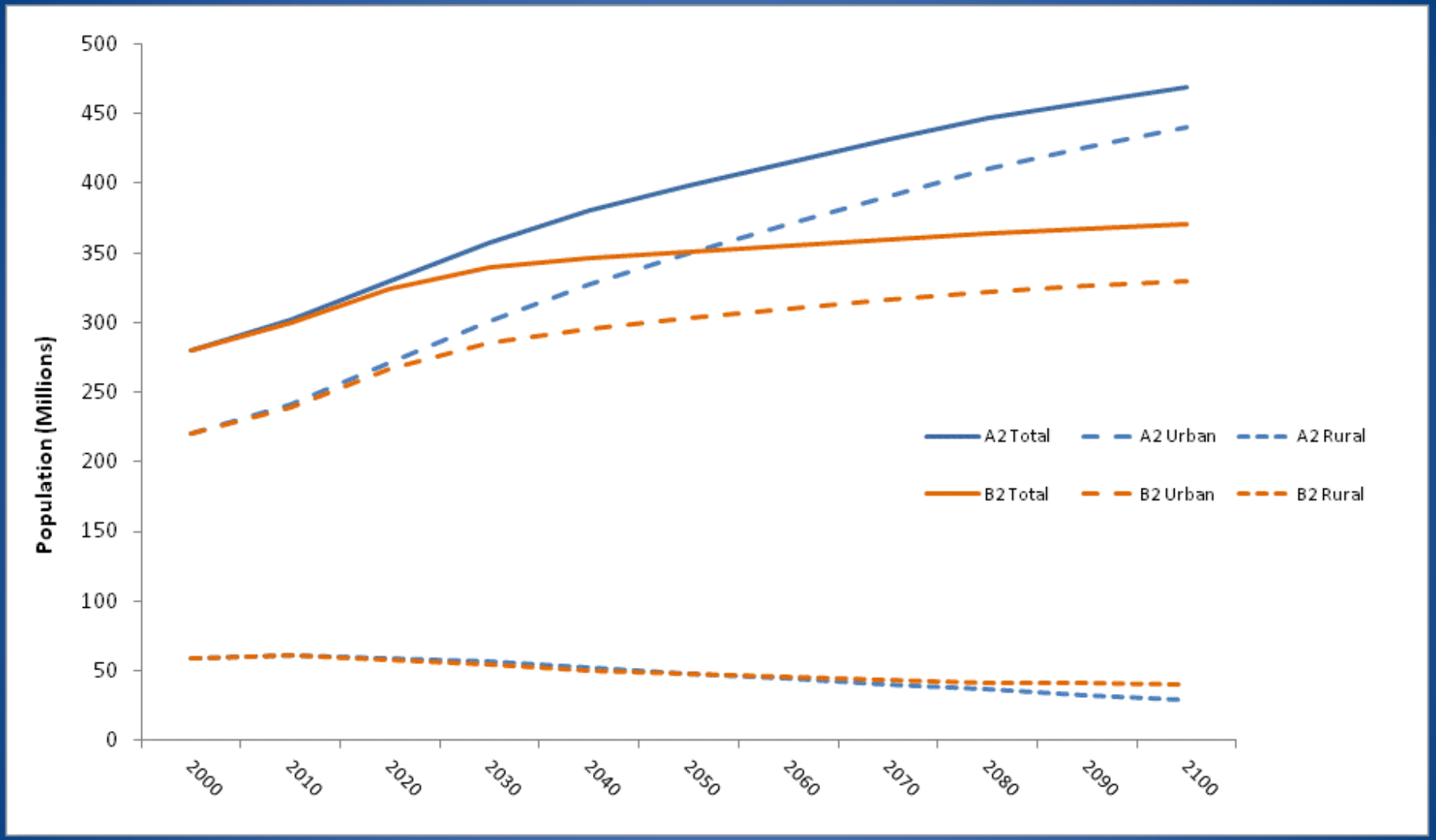
$$\frac{P_{i,2000}^{obs}}{P_{T,2000}^{obs}} = \frac{P_{i,2000}^{\mathrm{mod}}}{P_{T,2000}^{\mathrm{mod}}} + \varepsilon_i(\alpha,\beta)$$

- Unconstrained minimization problem
- Generalized Reduced Gradient (GRG2) algorithm (Lasdon and Warren, 1986)

Historical data test: Continental US 1950-2000

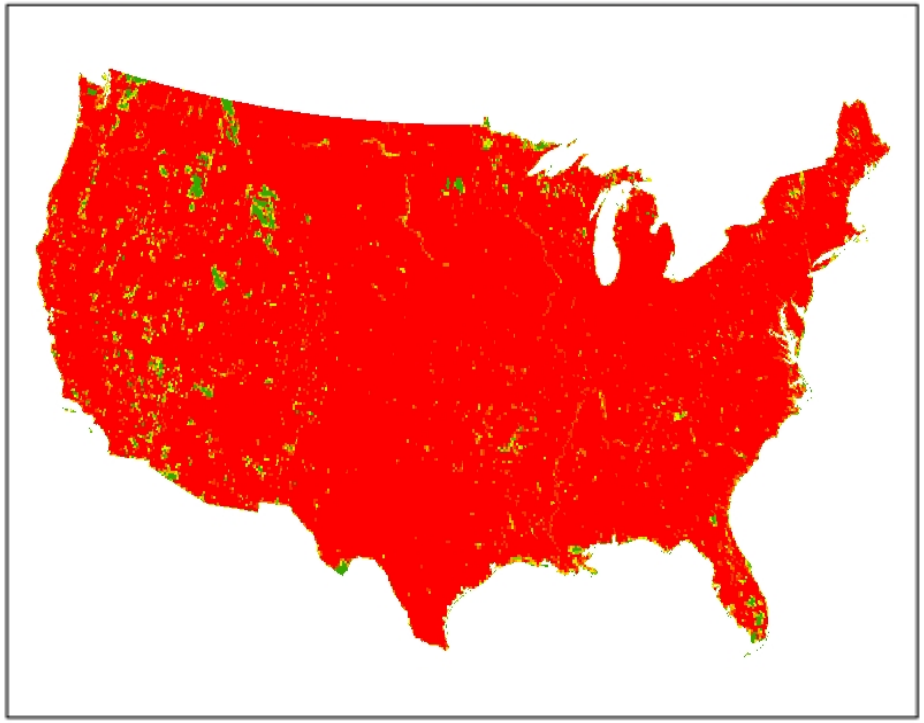


Population and Urbanization: IIASA A2 & B2 Scenarios

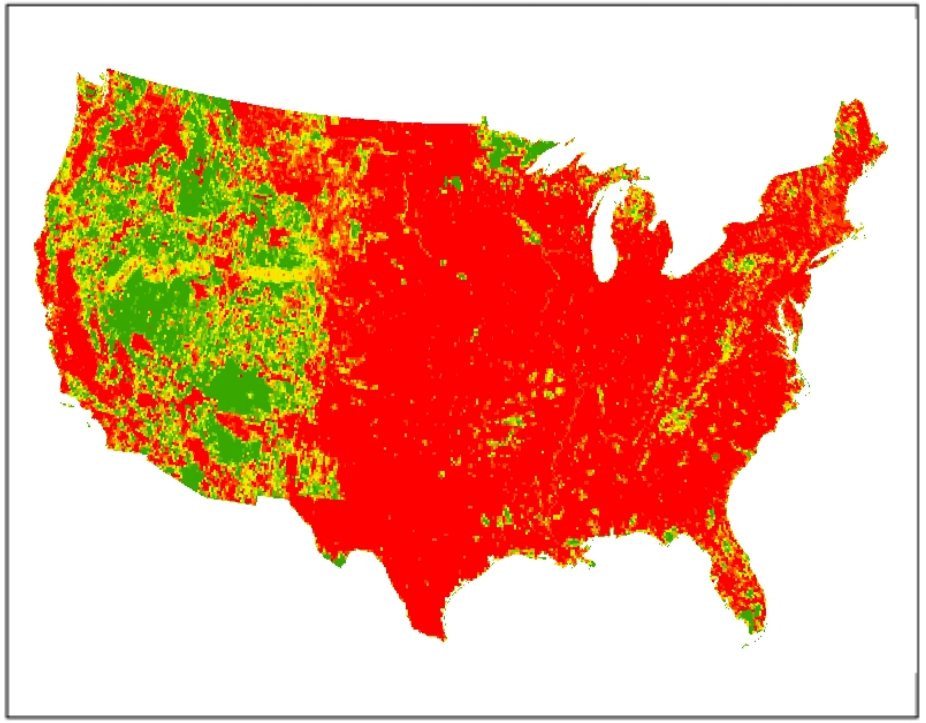


Geospatial Mask: IIASA A2 & B2 Scenarios

Low Protection: A2 Scenario



High Protection: B2 Scenario



Percent of grid cell suitable for habitation

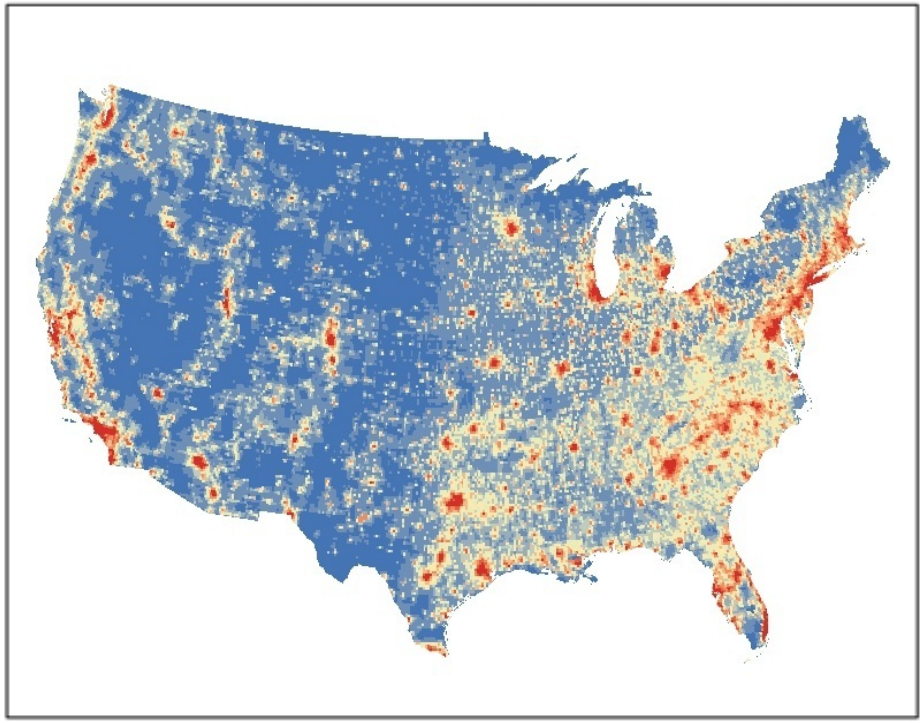
0% 50% 100%

- Slope
- Elevation
- Surface water
- Protected land (USGS GAP status)

Comparison to the IIASA A2 Scenario

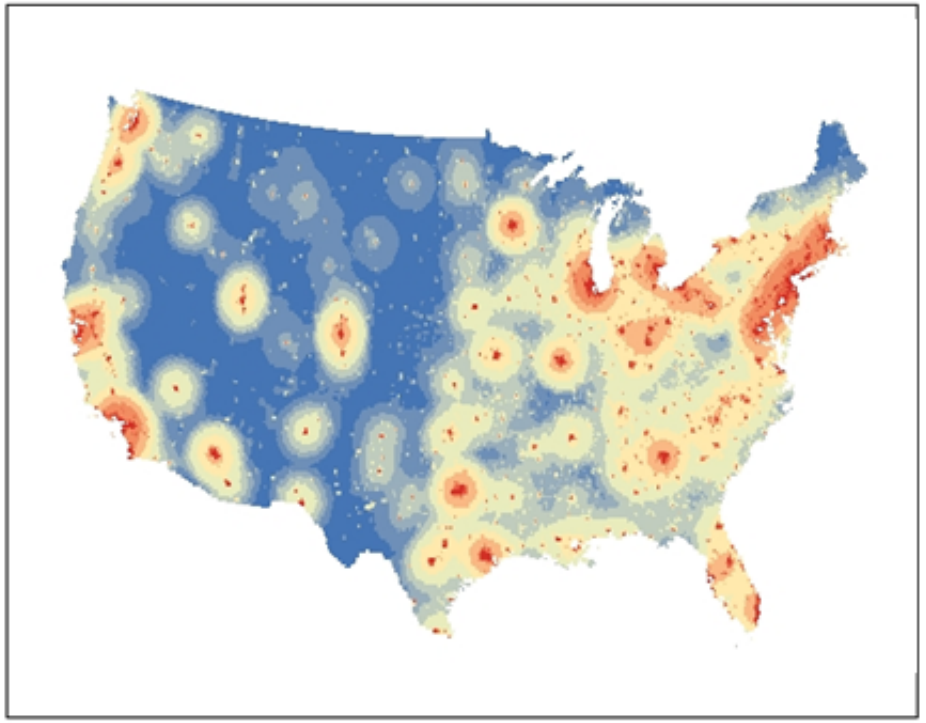
Projected Population Density

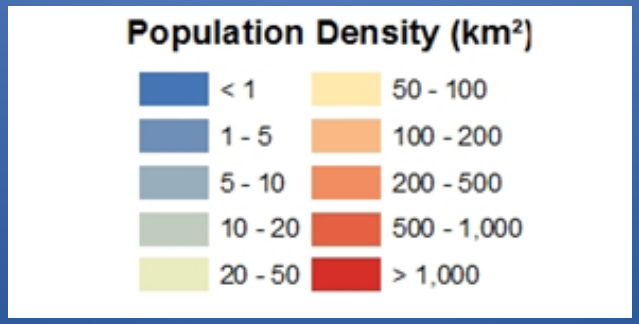
NCAR A2 Scenario, 2100



Projected Population Density

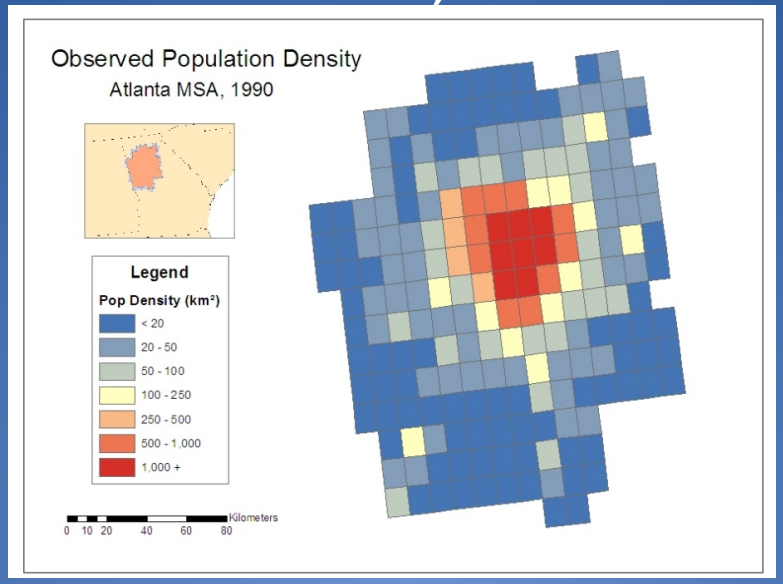
IIASA A2 Scenario, 2100



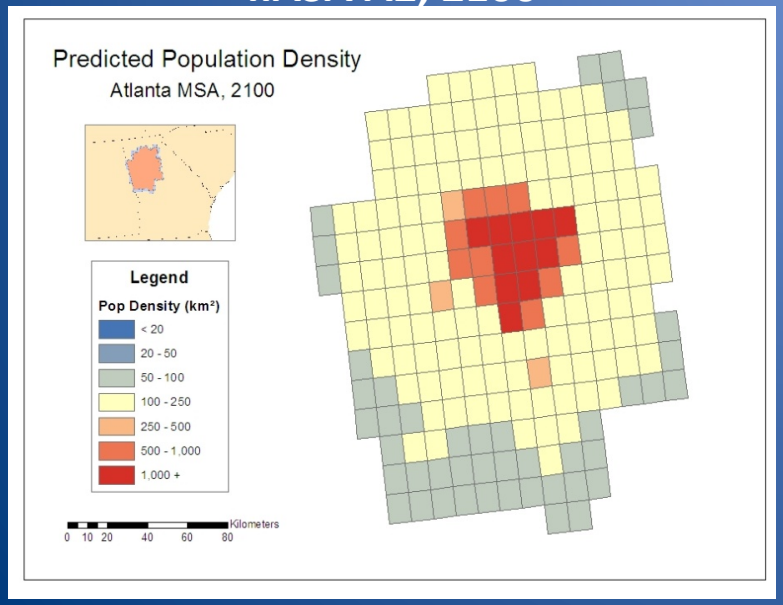


Patterns of Spatial Development: Atlanta MSA

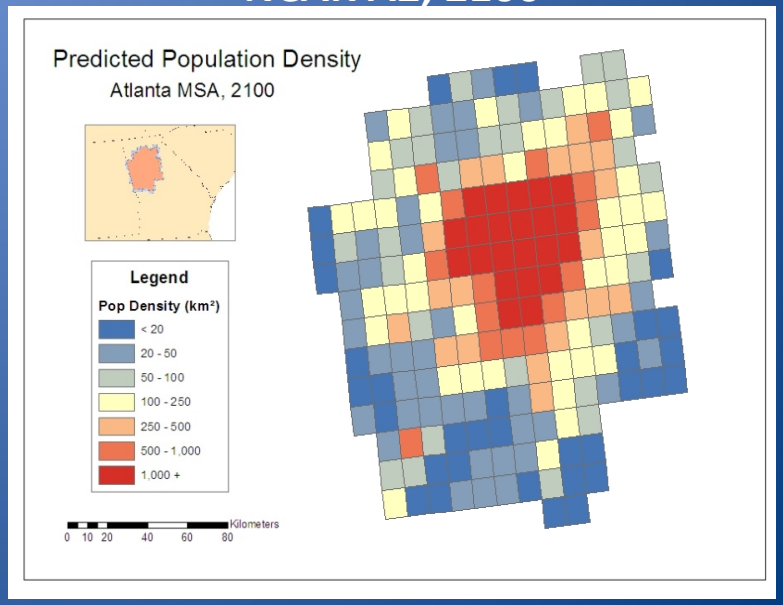
Observed , 1990



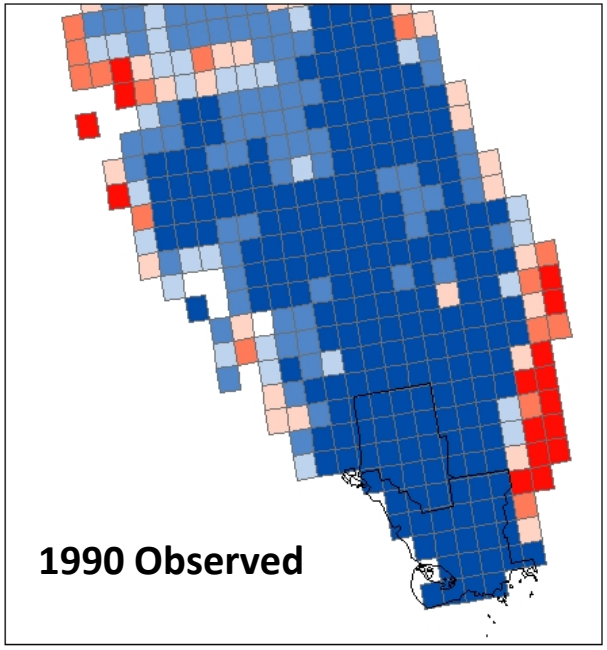
IIASA A2, 2100

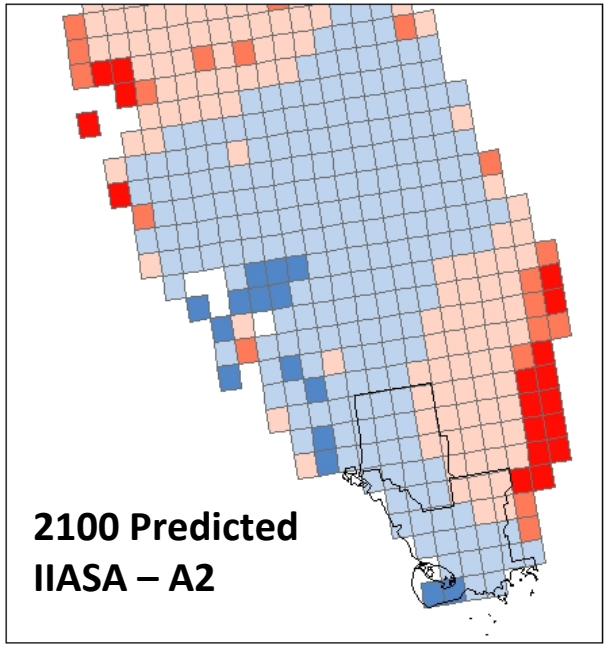


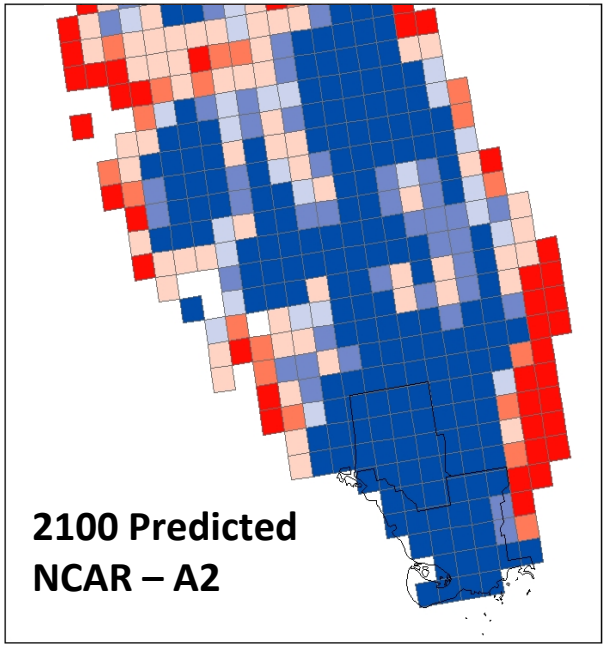
NCAR A2, 2100



Geophysical Spatial Mask: Everglades Example







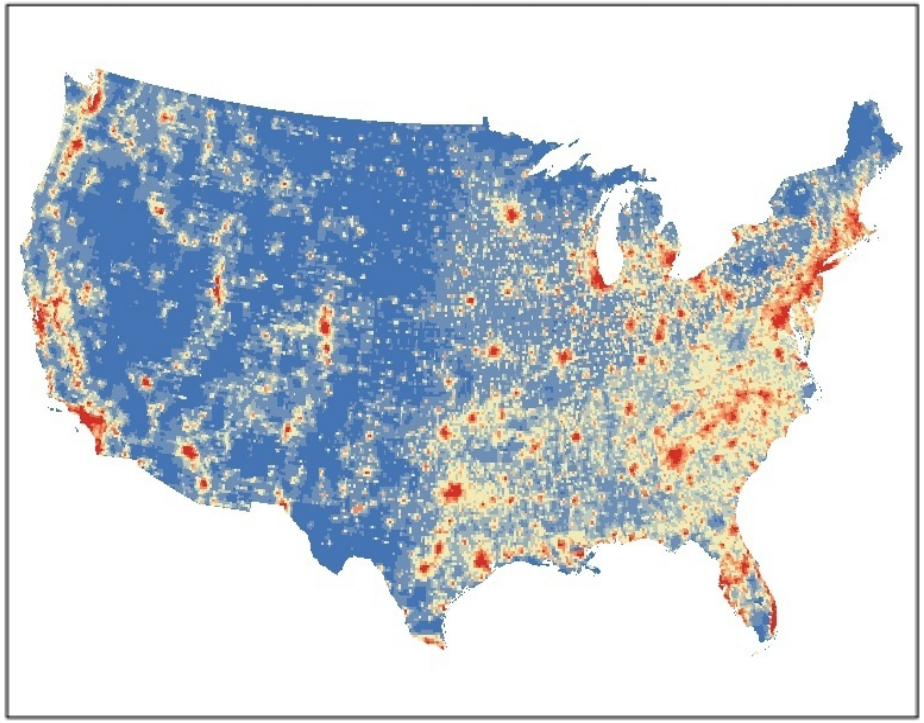
Population Density (km²)

< 10	100 - 500	Everglades
10 - 50	500 - 1,000	
50 - 100	> 1,000	

NCAR Projections: A2 and B2 Scenarios

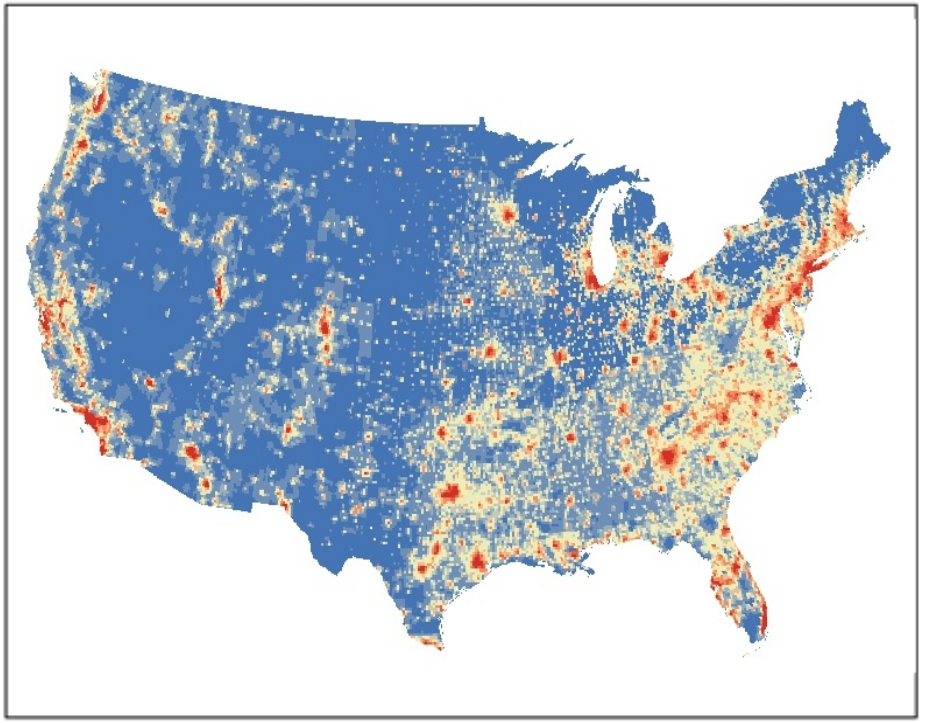
Projected Population Density

NCAR A2 Scenario, 2100



Projected Population Density

NCAR B2 Scenario, 2100



Population Density (km²)

< 1	50 - 100
1 - 5	100 - 200
5 - 10	200 - 500
10 - 20	500 - 1,000
20 - 50	> 1,000

Producing Global Scenarios

- Scenarios consistent with new SSPs
- Regional/national patterns of spatial change
  - Estimates from historical data
  - Expand catalog of parameter estimates
  - “Families” of countries following specific trajectories
- Output/useful metrics
  - Location-based vulnerability to climate impacts
  - Urban structure

Future Work

Methodological

- Higher resolution
- Calibration: additional countries, catalog of parameters
- Reclassifying urban /rural populations
- Modeling urban primacy

Applications

- Global scenarios
- Integrated urbanization

http://www.cgd.ucar.edu/events/seminars/2011/movies/jones.html