Observing and Modeling Land Use Change and its Ecological Implications in the Mid-Atlantic and New England

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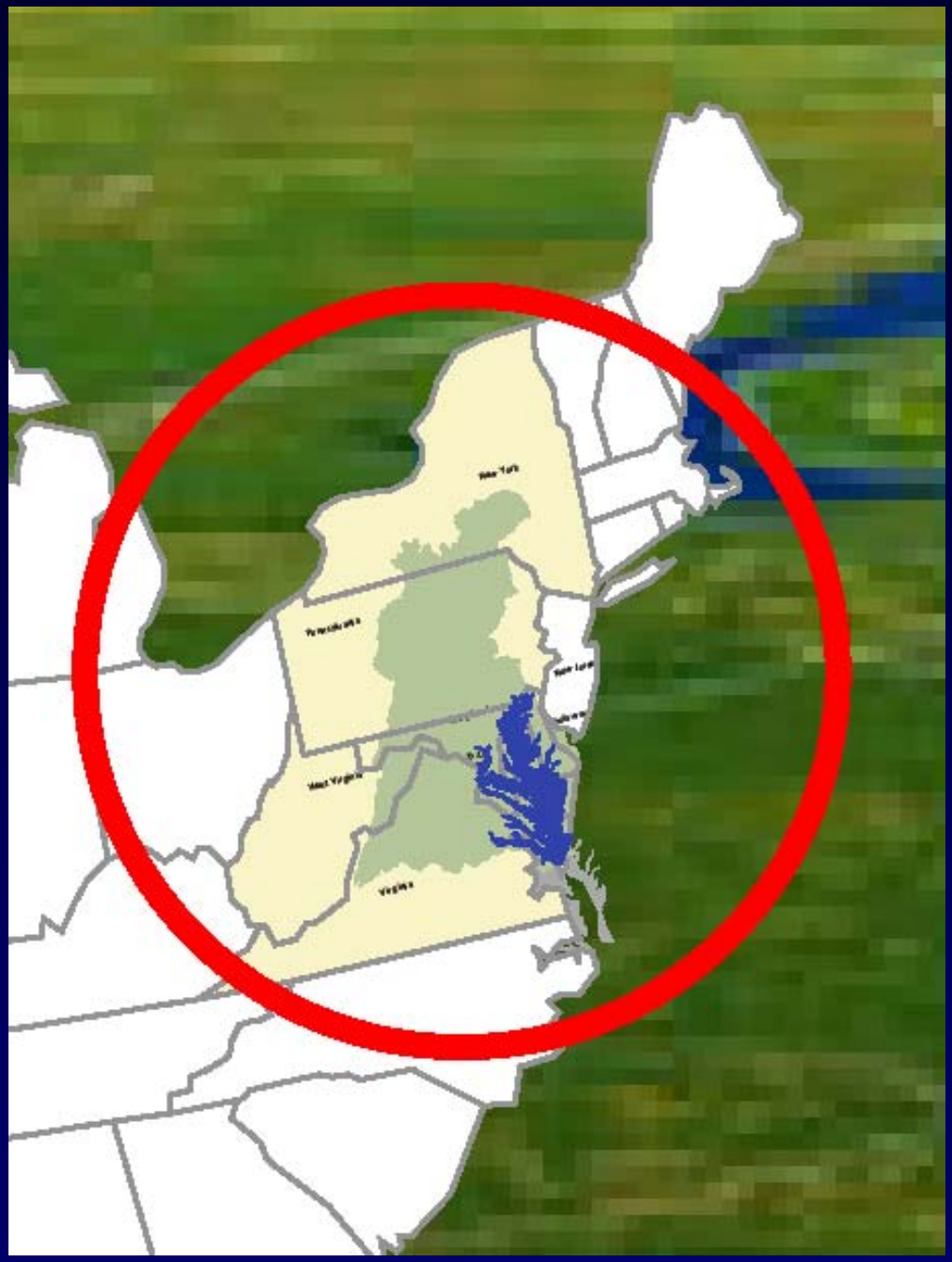
The Woods Hole Research Center

Outline

- Mapping & Monitoring change
  - Mid-Atlantic
  - New England
- Ecosystem Impacts
  - Resource lands
  - Stream biota
- Core roadless areas
  - Habitat connectivity
- Modeling Future change
  - Alternative Scenarios



Mid-Atlantic Region

Chesapeake Bay
Largest Estuary in US @ 7,000 km^2

Average Depth 6m

Watershed
168,000 km^2
(64,000 mi^2)

Population growth is offsetting incremental restoration gains

Officially an
"Impaired Watershed"
under the Clean Water Act

Over 15M inhabitants of the Bay Watershed as of 2005

Greatest need is for
current information on land use change &
projections of where future change will occur.

Monitoring the Urbanization Process

Satellite imagery essential

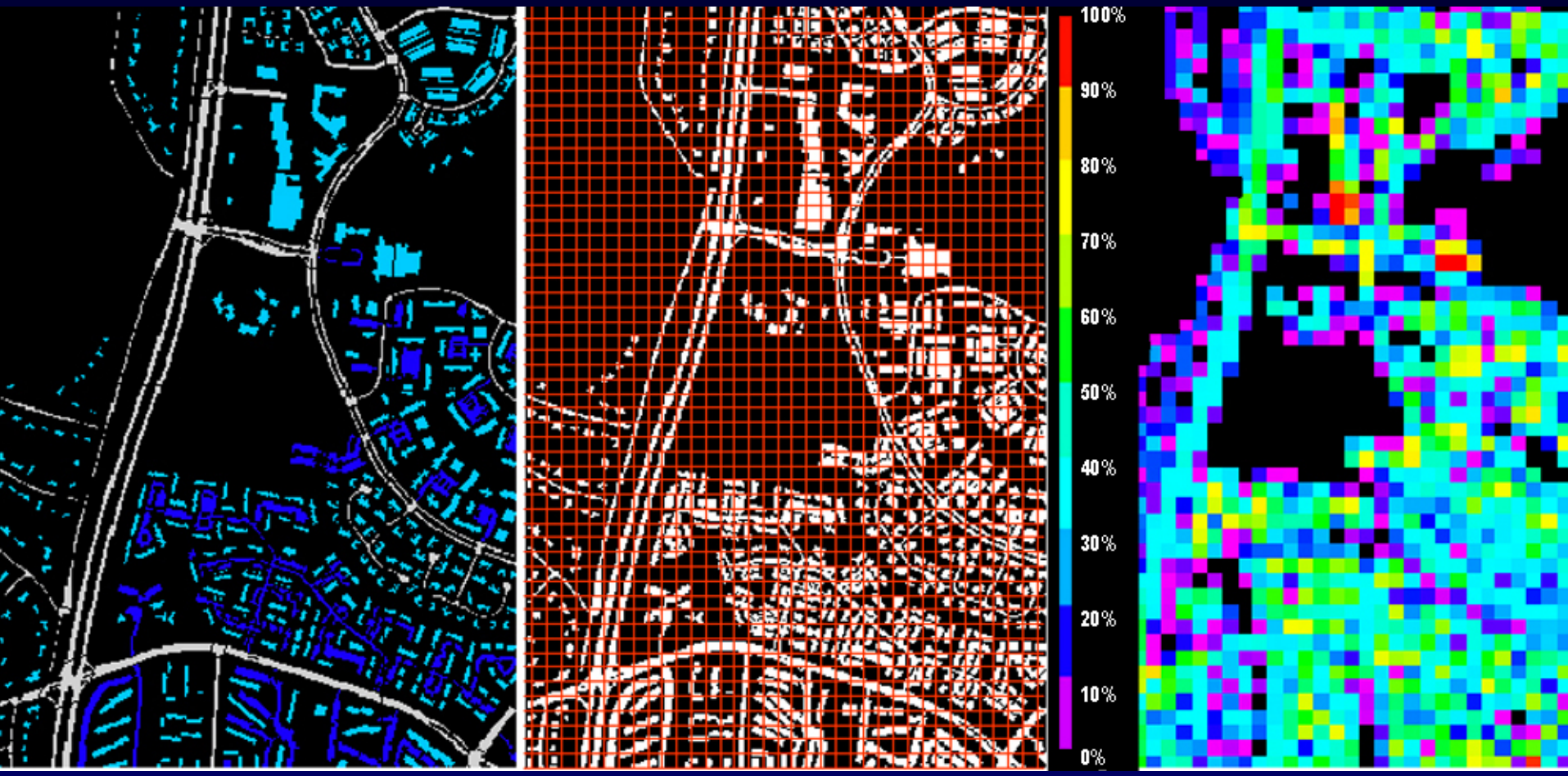
Landsat Image Mosaic

20 scene area
3 seasons / year

Repeat as needed

Mapping the Urban Environment

Impervious Surfaces

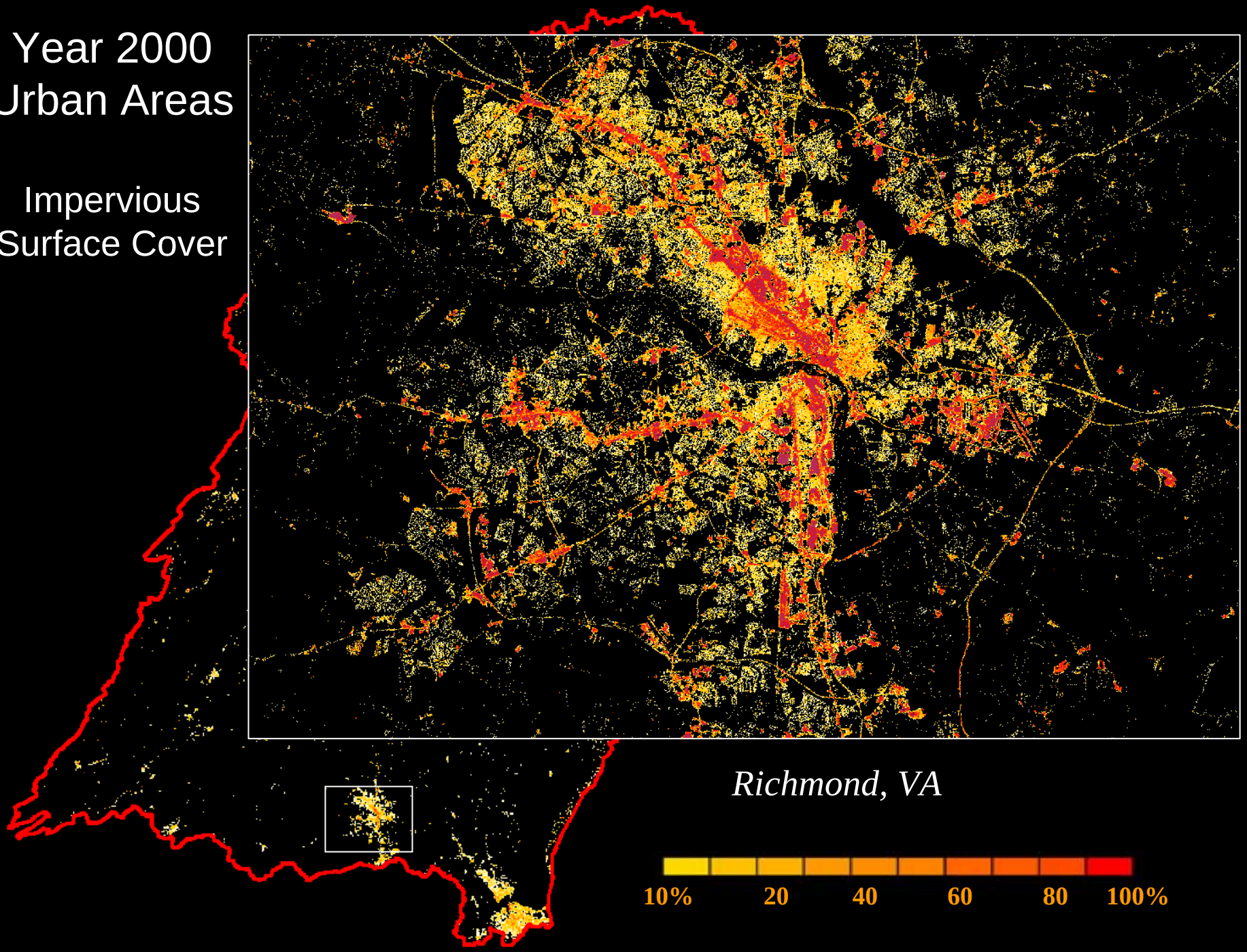


Aerial Photos → 3m to 30m Grid → %Impervious Cover

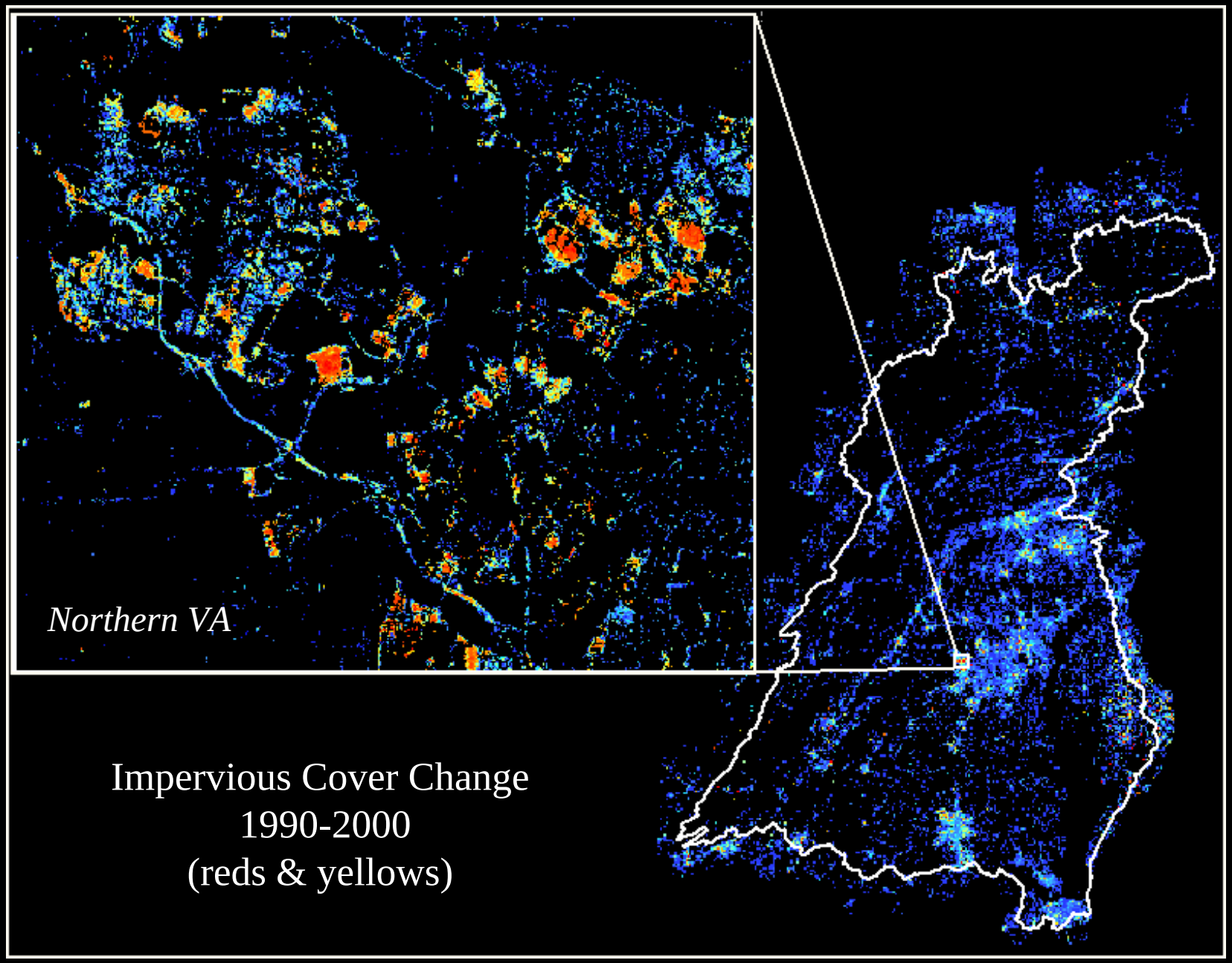
Development of "Training Data" for Satellite Mapping

Year 2000 Urban Areas

Impervious Surface Cover

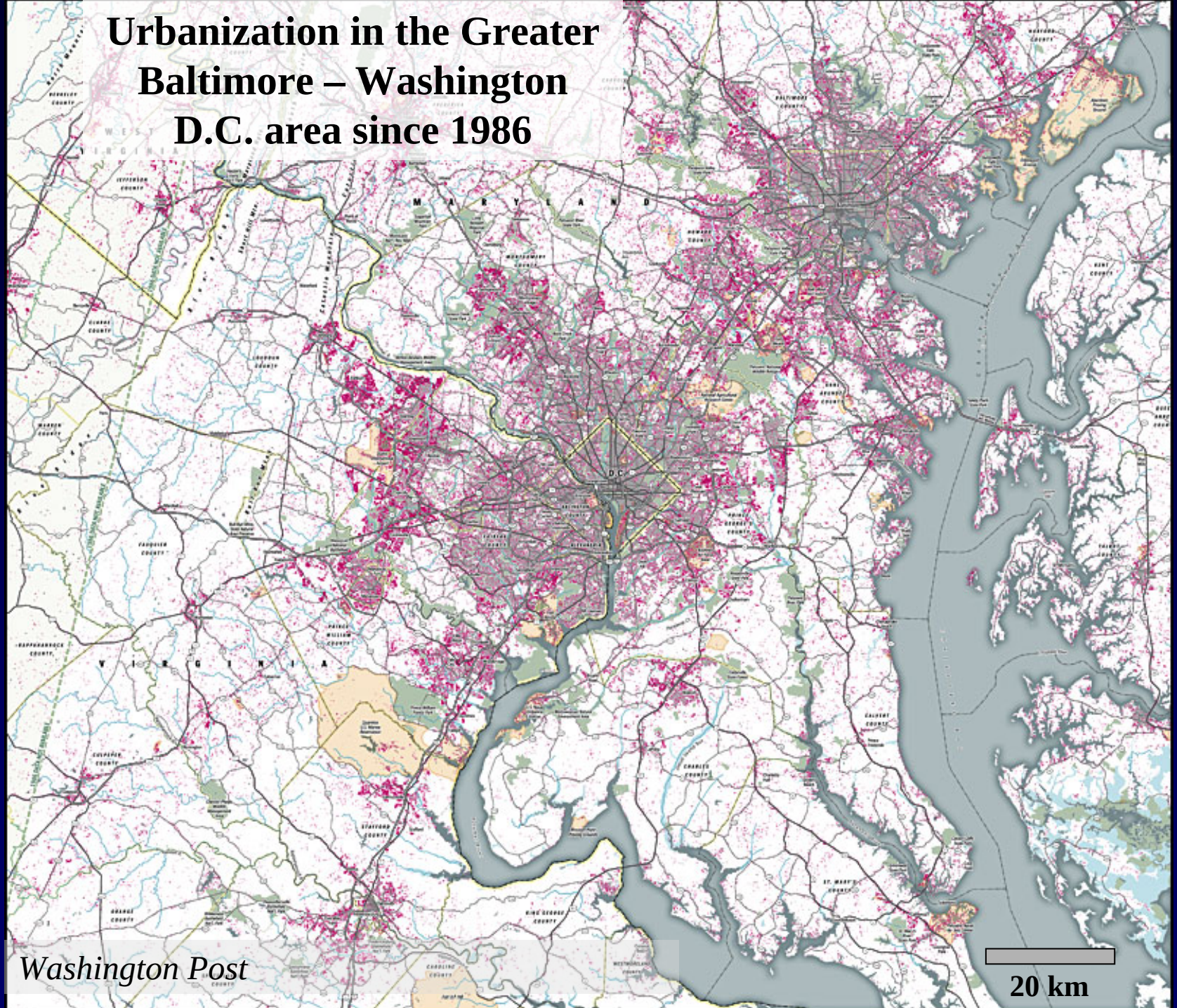


Change in Urban Areas

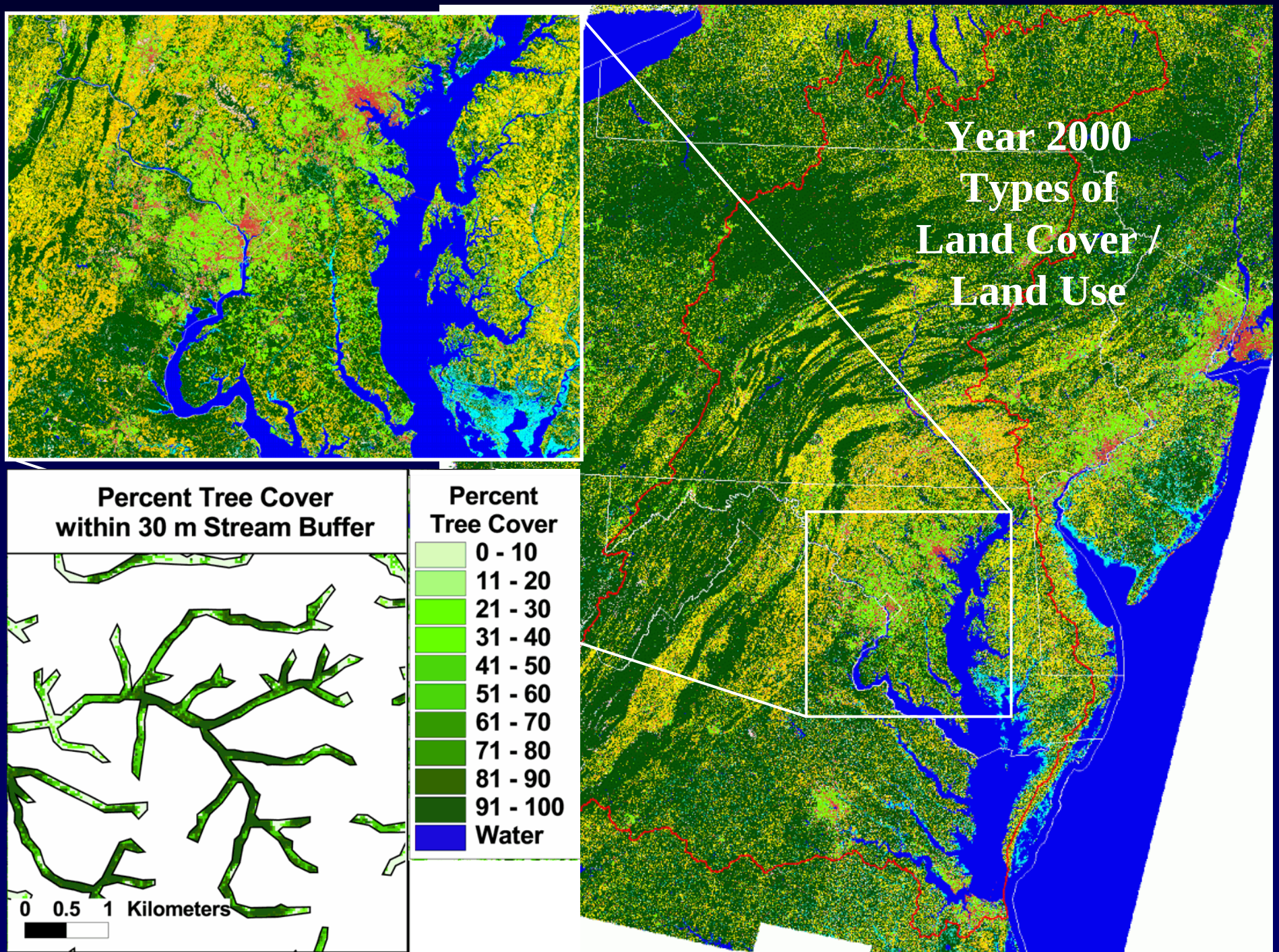


Impervious Cover Change
1990-2000
(reds & yellows)

Urbanization in the Greater Baltimore – Washington D.C. area since 1986



Washington Post

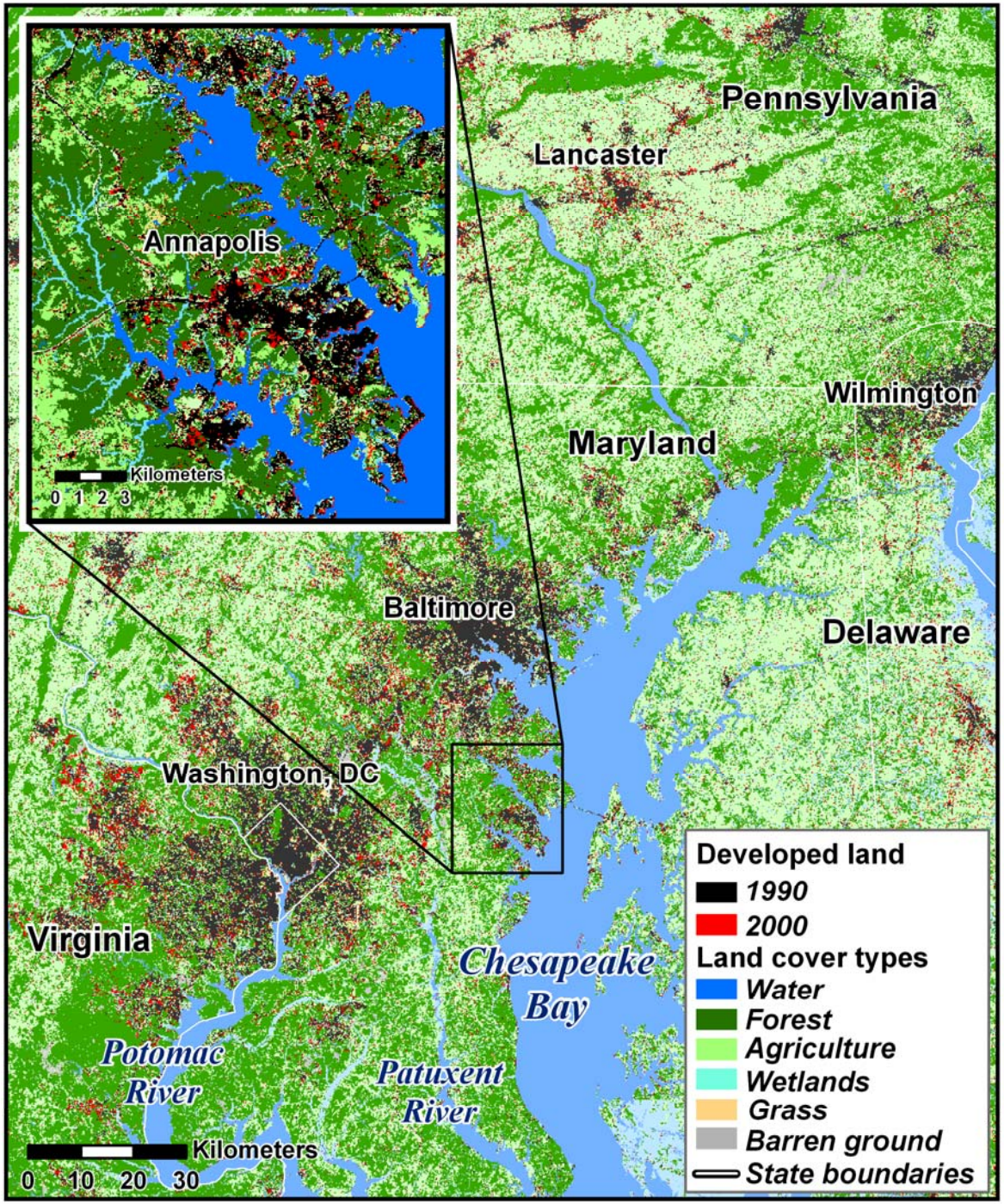

Year 2000
Types of
Land Cover /
Land Use
Percent Tree Cover
within 30 m Stream Buffer
Percent
Tree Cover
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
Water
0 0.5 1 Kilometers

Impacts: Changes in "Resource Lands" since 1990

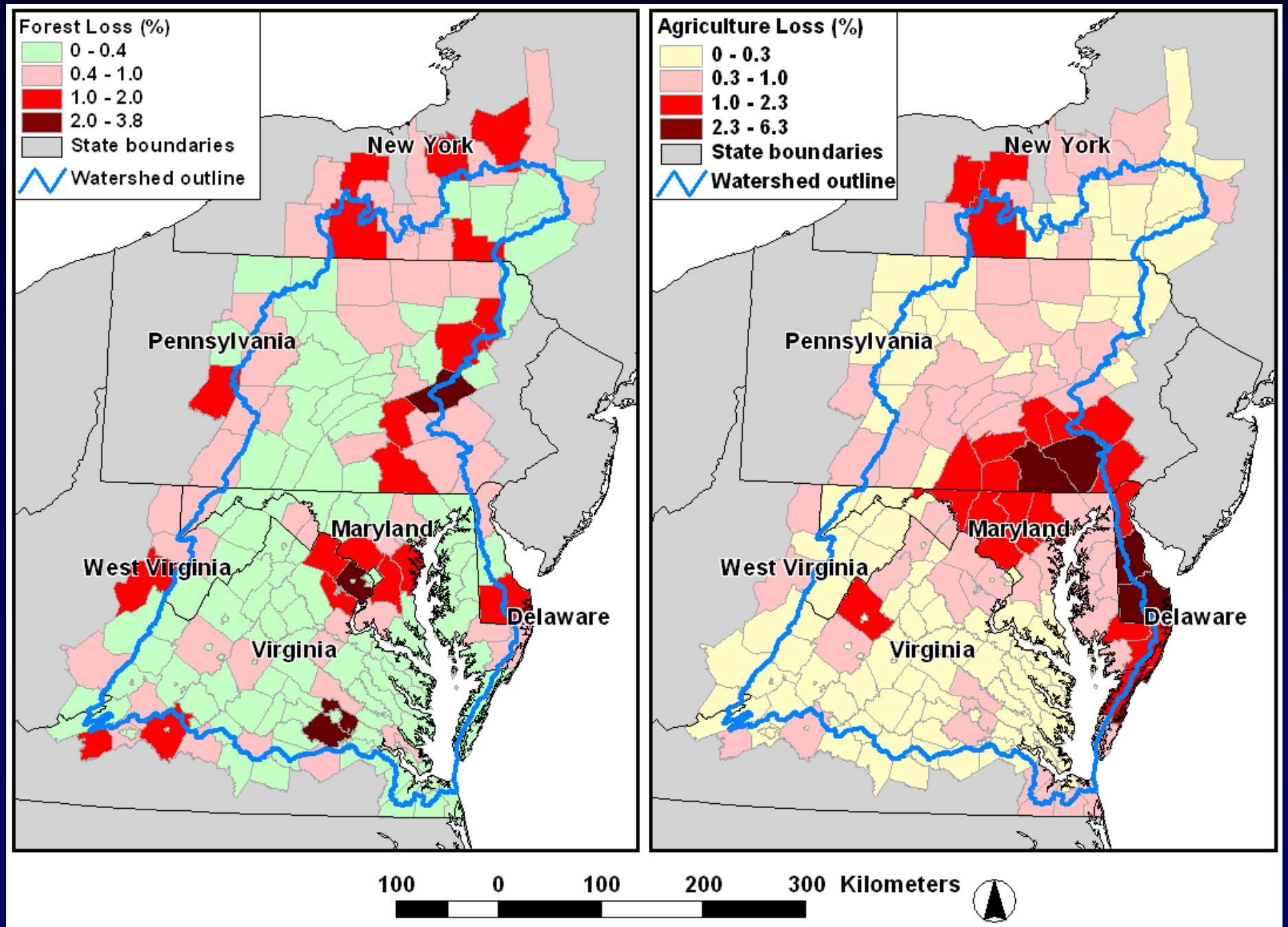
Forests
>334 km^2
(120 mi^2)

Agriculture
>888 km^2
(320 mi^2)

Wetlands
>2 km^2



County Contribution to Total Resource Land Loss



Satellite Maps Show Chesapeake Bay Urban Development

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The extent, density, and configuration of the built environment—such as buildings, roads, parking lots, and other materials constructed for human use—have an impact on a wide range of biogeochemical and hydrological processes. These built areas, which are impervious to water infiltration, modify hydrology through the combined influence of increased peak flows, reduced base flows, flashier stream hydrographs (decreased lag times between storm events and peak discharge), and changes in bank and streambed erosion [*Nikson et al.*, 2003]. Additionally, increasing impervious cover has long been known to amplify point source pollution discharges into streams, including chemical runoff from parking lots and roads [*Schueler*, 1994].

Two maps of the built environment, expressed in terms of impervious surface area, have been derived for areas that encompass the 168,000-square-kilometer Chesapeake Bay watershed (Figure 1), a region that has been highly altered by human land use [*Goetz et al.*, 2004; *Jantz et al.*, 2005]. One map was developed for the region at fine (30-square-meter) spatial resolution, and the other covers the extent of the conterminous United States at one-square-kilometer resolution [*Elvidge et al.*, 2004]. A finer-resolution regional map was used to assess the quality of the national map, demonstrating the utility the latter map for a range of applications related to monitoring land transformation and assessing watershed impacts.

Regional and National Maps of the Built Environment

The regional map was derived for the year 2000 using 60 multitemporal Landsat Enhanced Thematic Mapper Plus (ETM+) images, each rectified for a variety of geometric and radiometric discontinuities [*Goetz et al.*, 2004]. The map contains subpixel information on the proportion of each 30-meter (900-square-meter) pixel that is occupied by impervious cover, ranging from approximately 10 percent for low-density residential development to nearly 100 percent in intensively developed commercial and industrial areas. The extent of impervious cover represented in the map was validated using higher-resolution imagery, with overall accuracy approaching 90 percent [*Jantz et al.*, 2005]. This map is currently being used in the Chesapeake Bay Program restoration effort as one of the key drivers of a community watershed model, and related baseline mapping and monitoring activities (http://www.chesapeakebay.net).

The national map was derived using Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) imagery, which has the unique capability of detecting low levels of visible and near-infrared radiance at night. These data were processed to create a map of the percent of impervious surface cover at one–square-kilometer resolution for the United States [*Elvidge et al.*, 2004] by augmenting the OLS imagery with a vector road database and urban cover classes derived from a circa-1990 National Land Cover Database (NLCD) map at 30-square-meter resolution [*Vogelmann et al.*, 2001]. High-resolution aerial

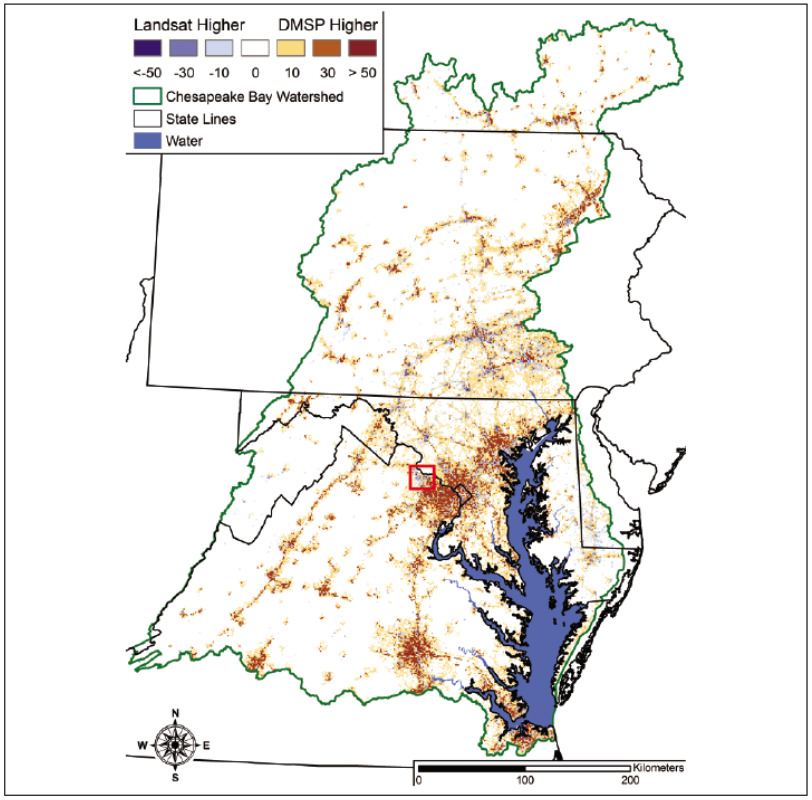
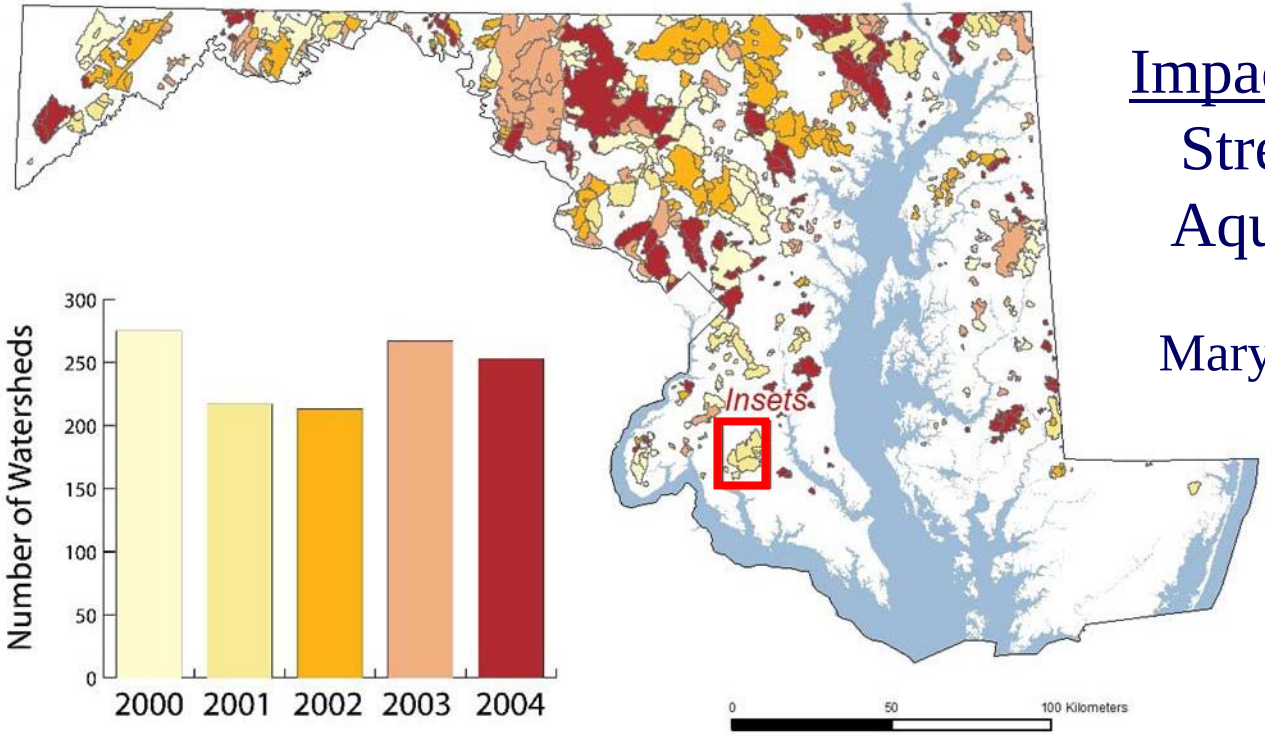


Fig. 1. Differences in impervious surface estimates between the national (DMSP-NLCD) and regional (ETM+) maps across the 168,000-square-kilometer Chesapeake Bay watershed. The regional map was aggregated to match the one-square-kilometer resolution of the national map. The red box encompasses an area shown in more detail in Figure 2.

BY S. J. GOETZ AND P. JANTZ

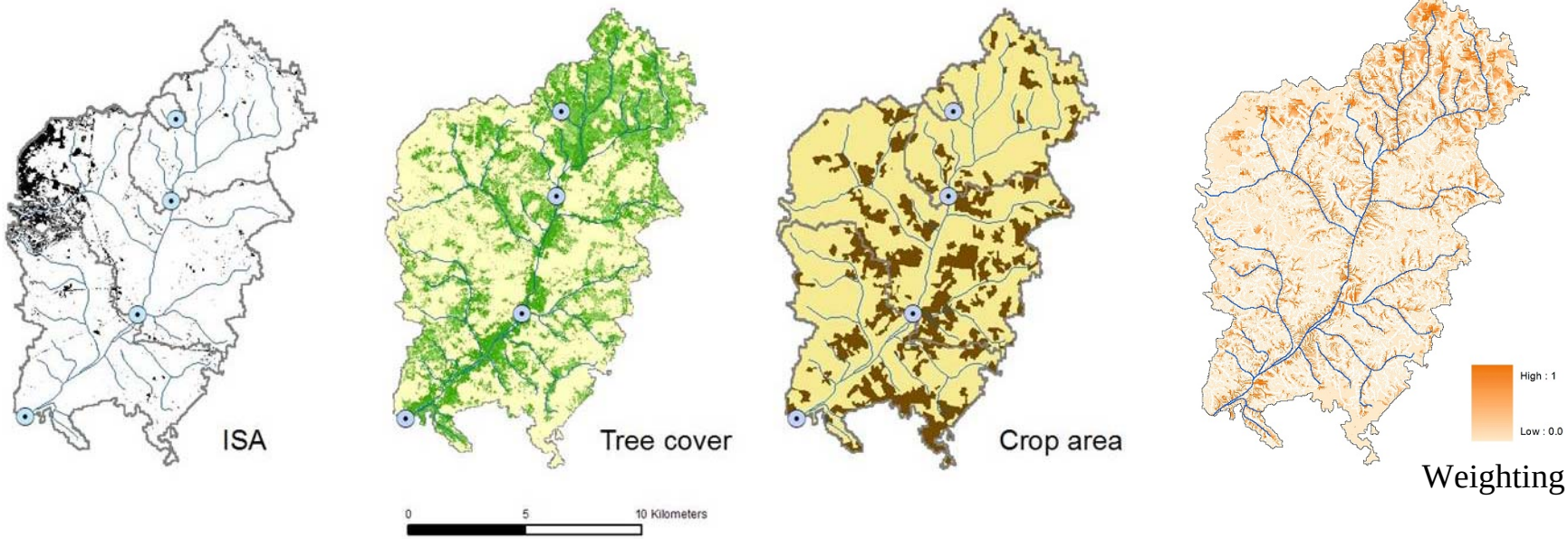
Impacts: Water Quality, Stream Ecosystems, Aquatic Biodiversity



Maryland Biological Stream Survey

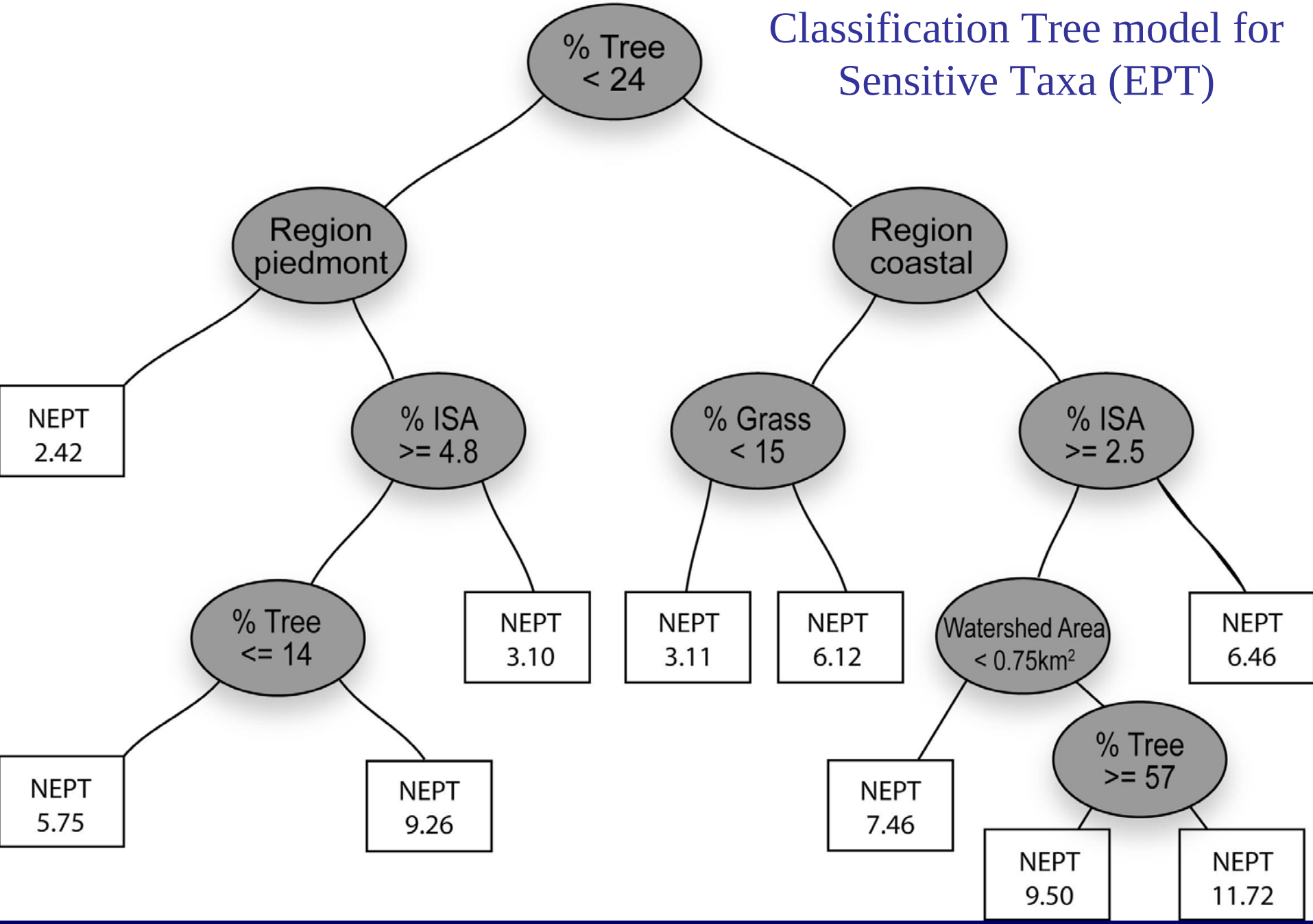
(over 1000 sampling locations)

Land Cover Information

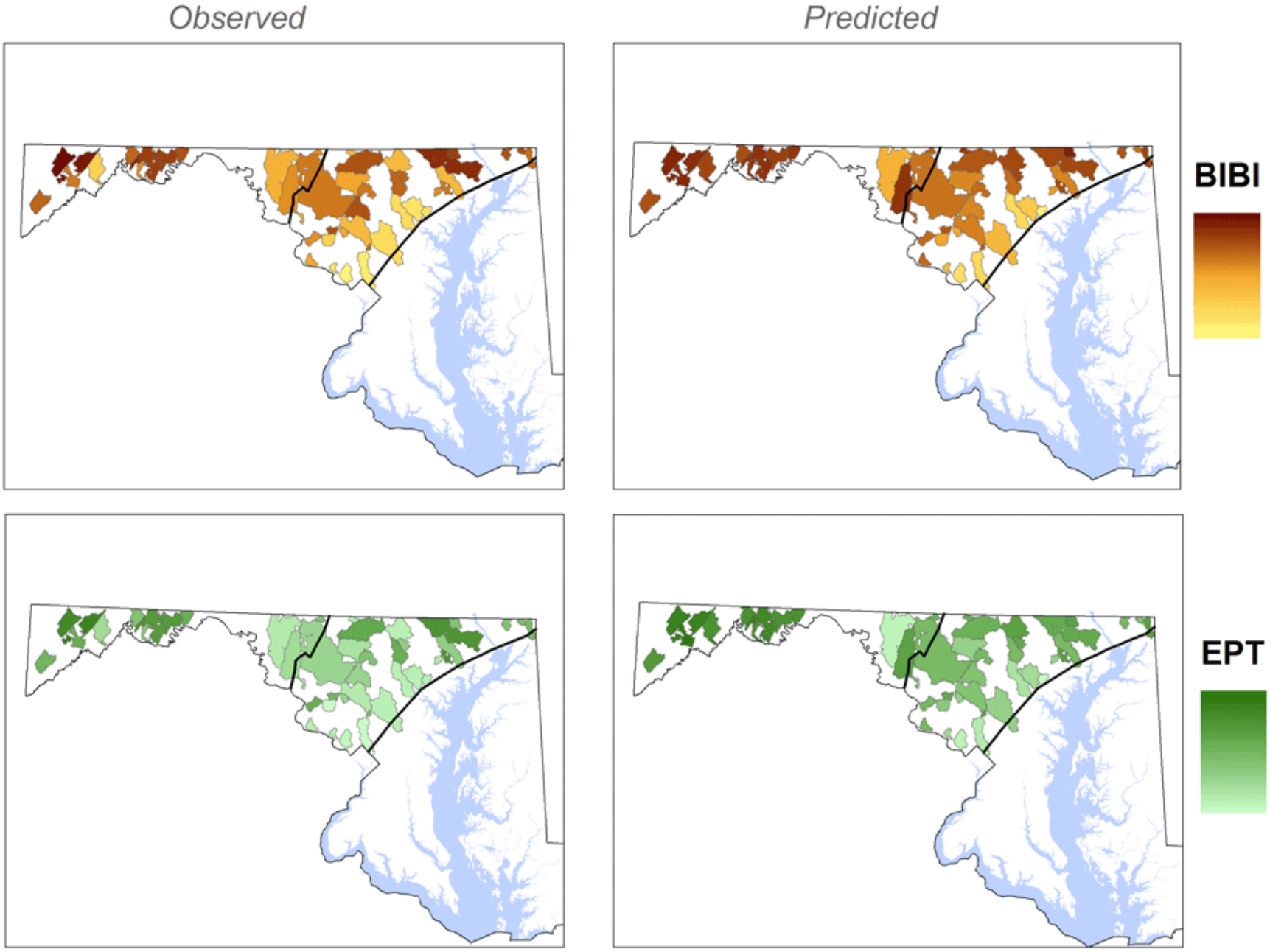


Weighting

Classification Tree model for Sensitive Taxa (EPT)

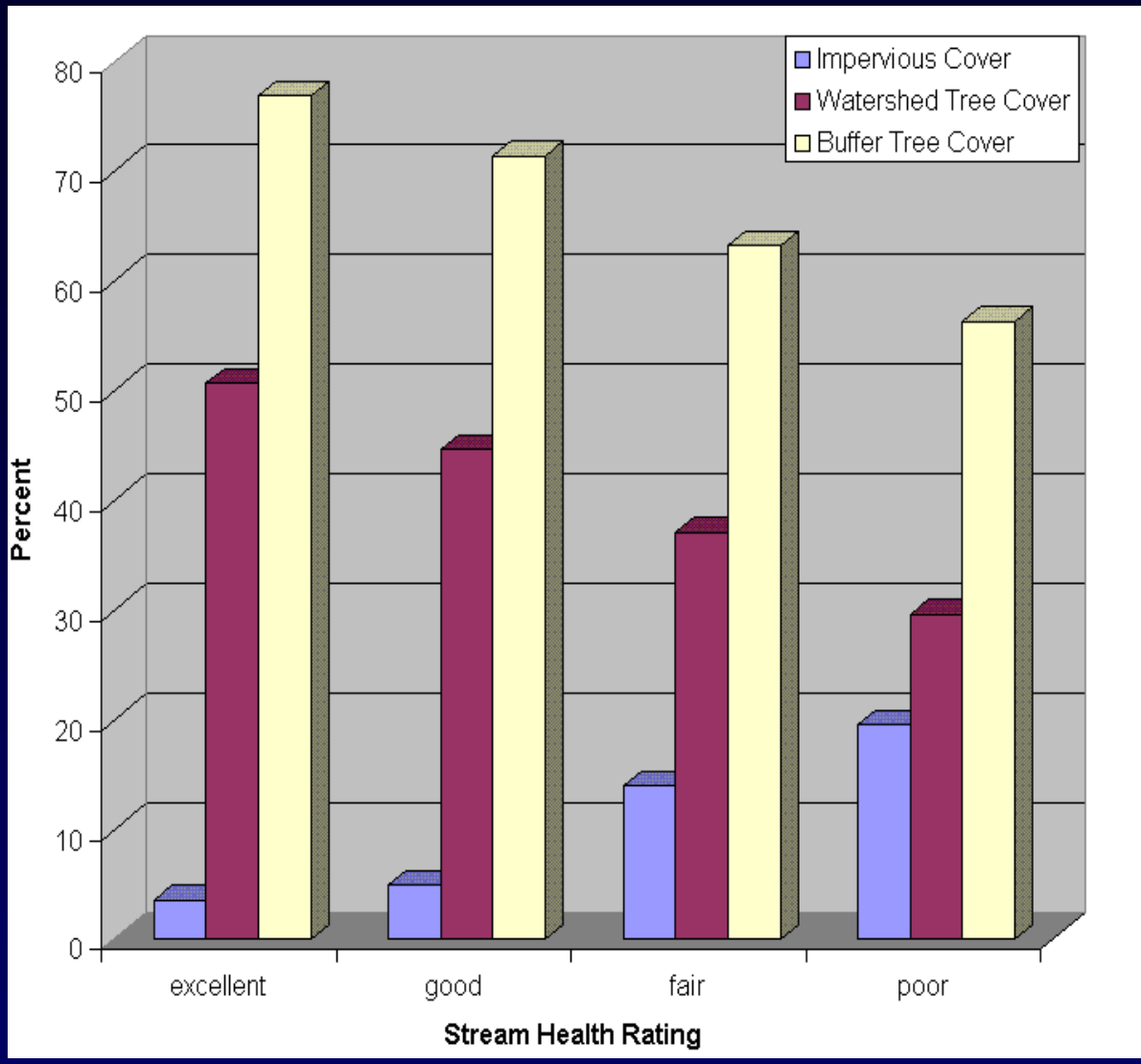


Highland and Piedmont Watersheds



Assessments of Watershed Health Rankings

1) Impervious cover
2) Tree cover within stream buffer zone
3) Landscape configuration



<u>Restoration Targets</u>

Excellent rating: < 6% impervious, >65% tree buffers

Good rating: <10% impervious, >60% tree buffers

Next Steps

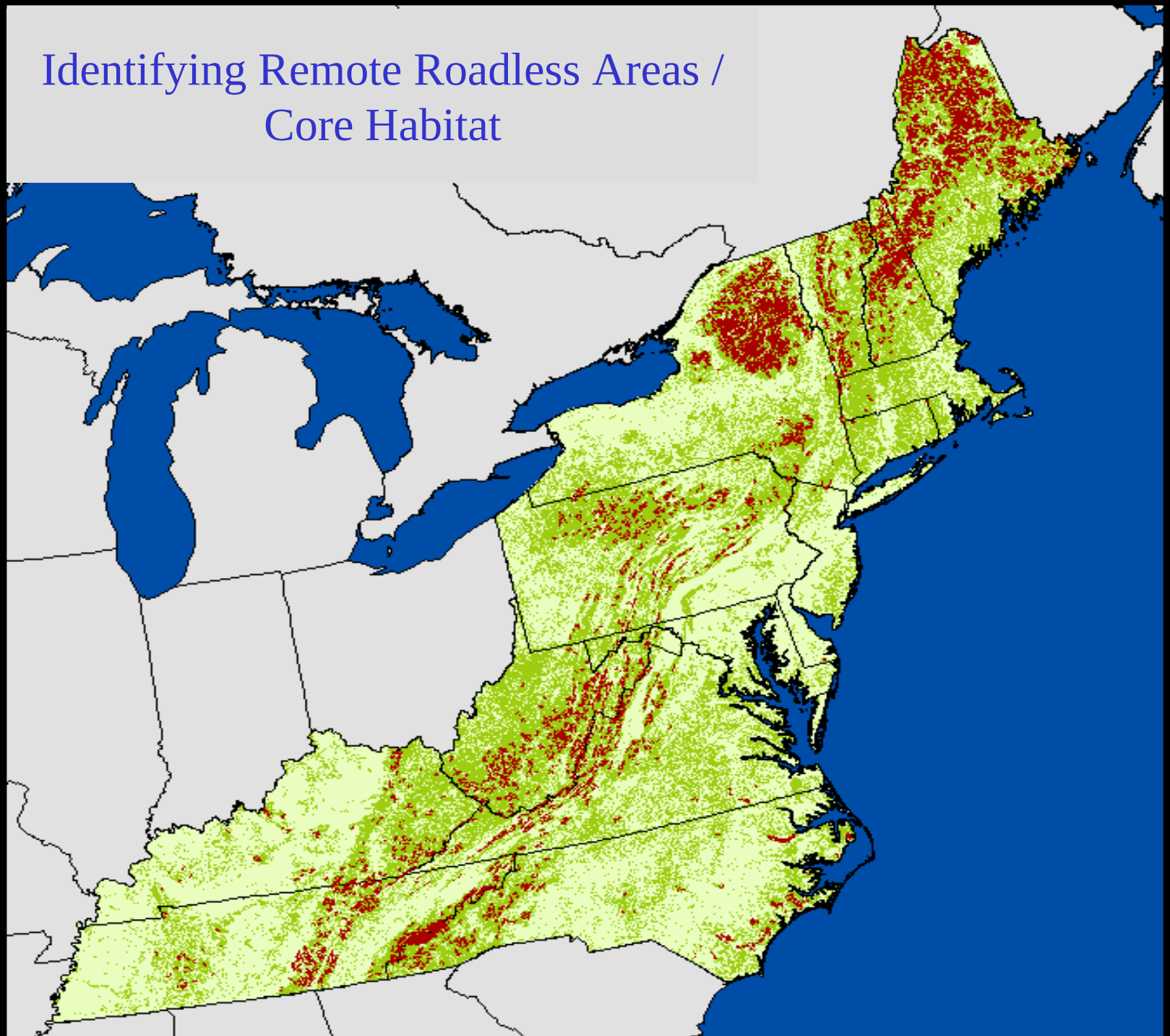
Link Land Use Model with Grid-based Hydrology Model

Focus on Upper Delaware (ERMN)

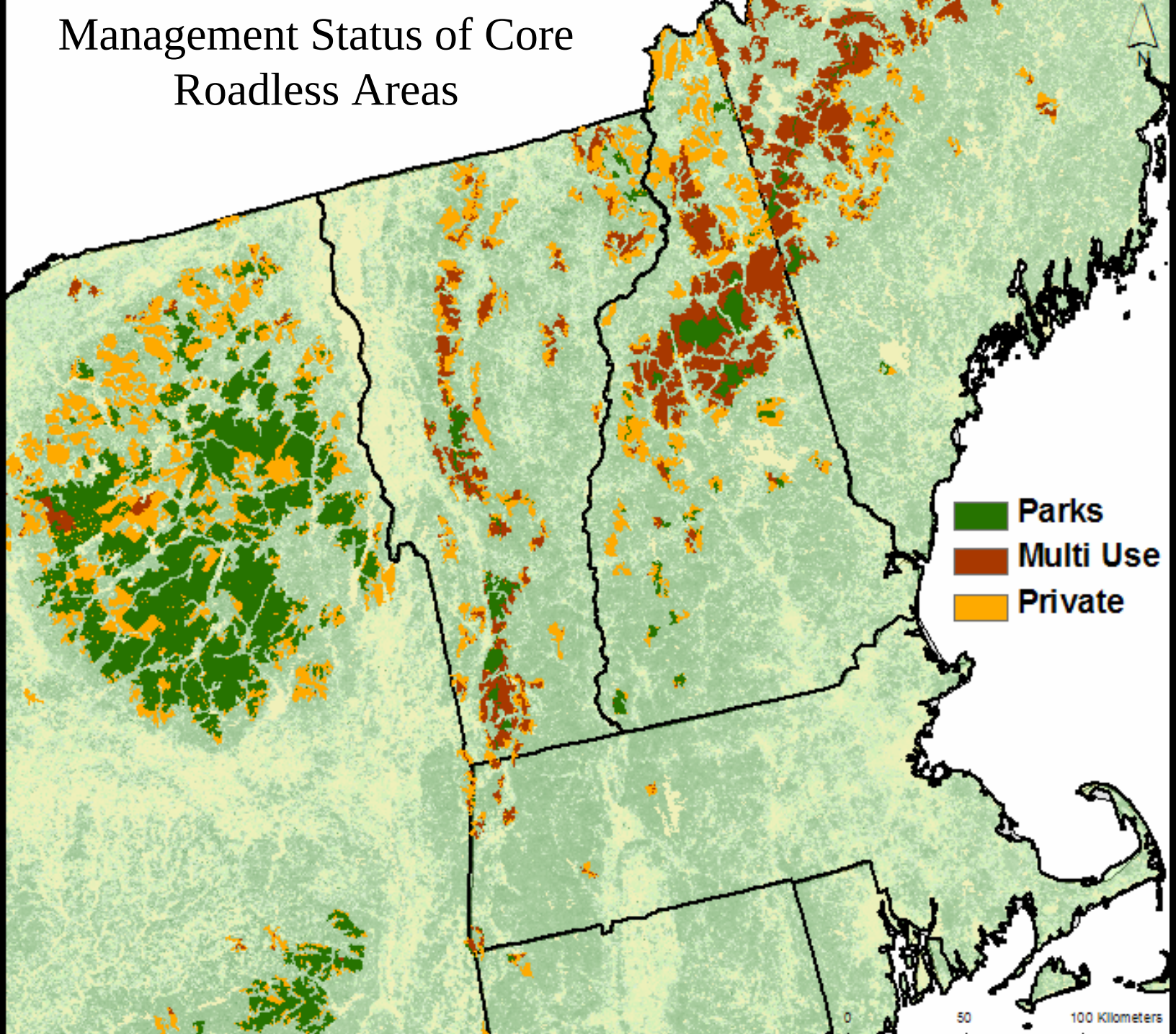
Alternative Development Scenarios

Simulate the Influence of
Low Impact Development techniques
Landscape Configuration
Buffer Zones

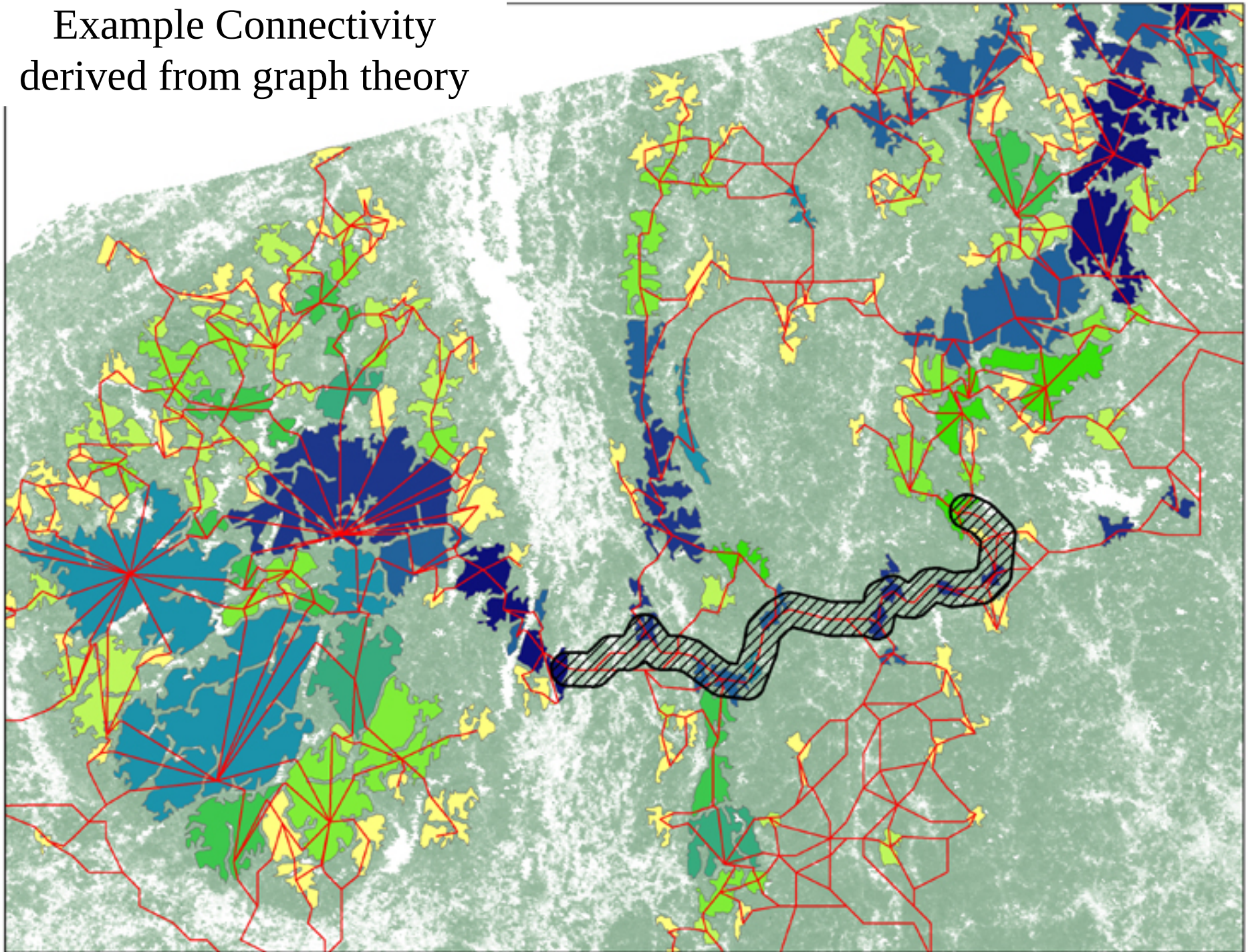
Identifying Remote Roadless Areas / Core Habitat



Management Status of Core Roadless Areas



Example Connectivity derived from graph theory



Partners & Collaborators

Chesapeake Bay Program
A Watershed Partnership

STATE OF MARYLAND DEPARTMENT OF NATURAL RESOURCES

NATIONAL PARK SERVICE

CHESAPEAKE BAY FOUNDATION · SAVE THE BAY ·

NATIONAL CENTER FOR SMART GROWTH RESEARCH & EDUCATION

SERC

Financial Support

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NCER STAR Science to Achieve Results

NASA

Research Assistance

THE WOODS HOLE RESEARCH CENTER

Future Scenarios
Predictive Modeling of the Urbanization Process

Urban Growth Model ("SLEUTH")

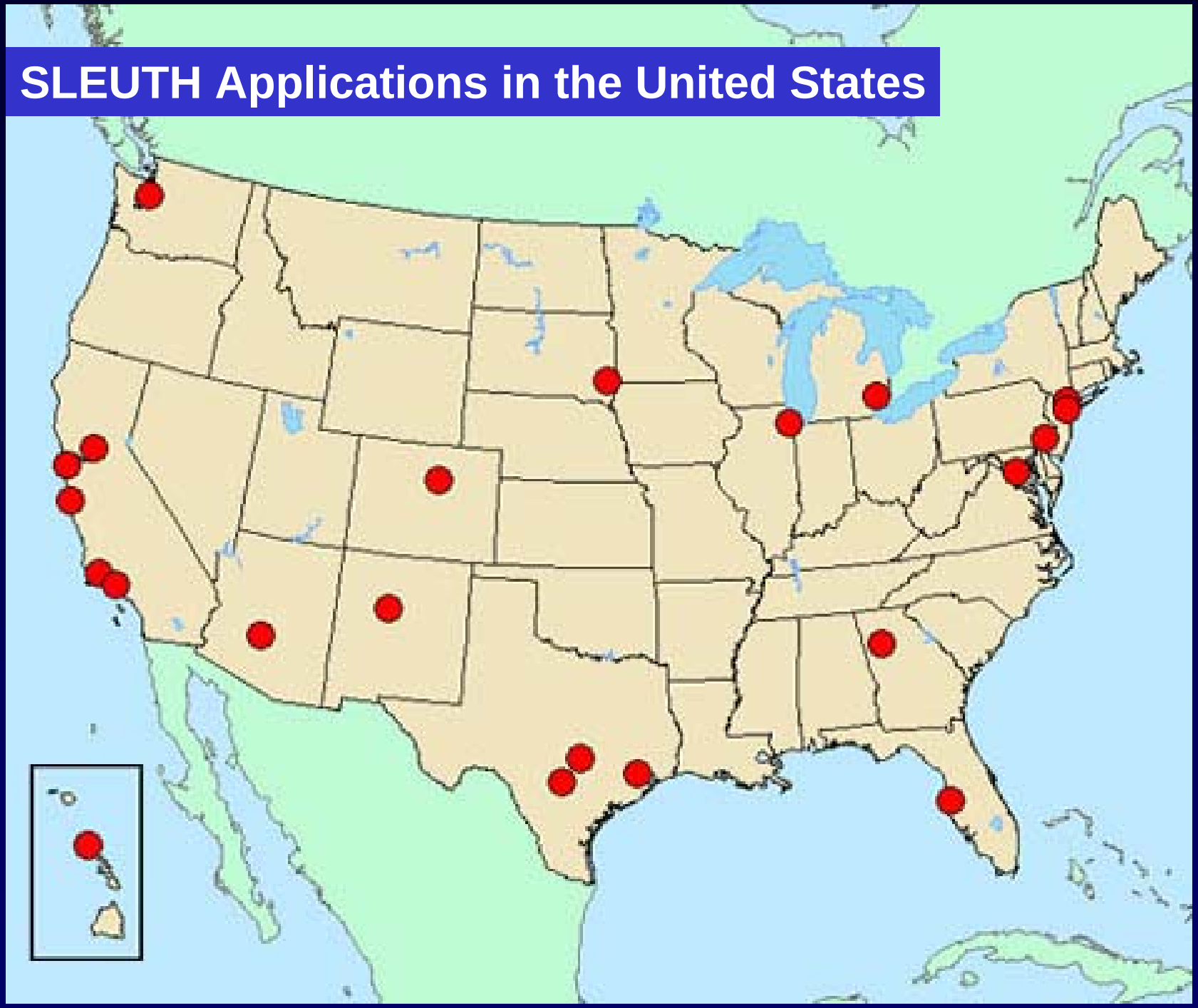
- Simulates urban extent (not intensity)
- Grid (cell) based (like imagery)
- Growth rules (dispersion, edge, roads, *etc*..)

Calibration (rate & pattern matching)

Prediction

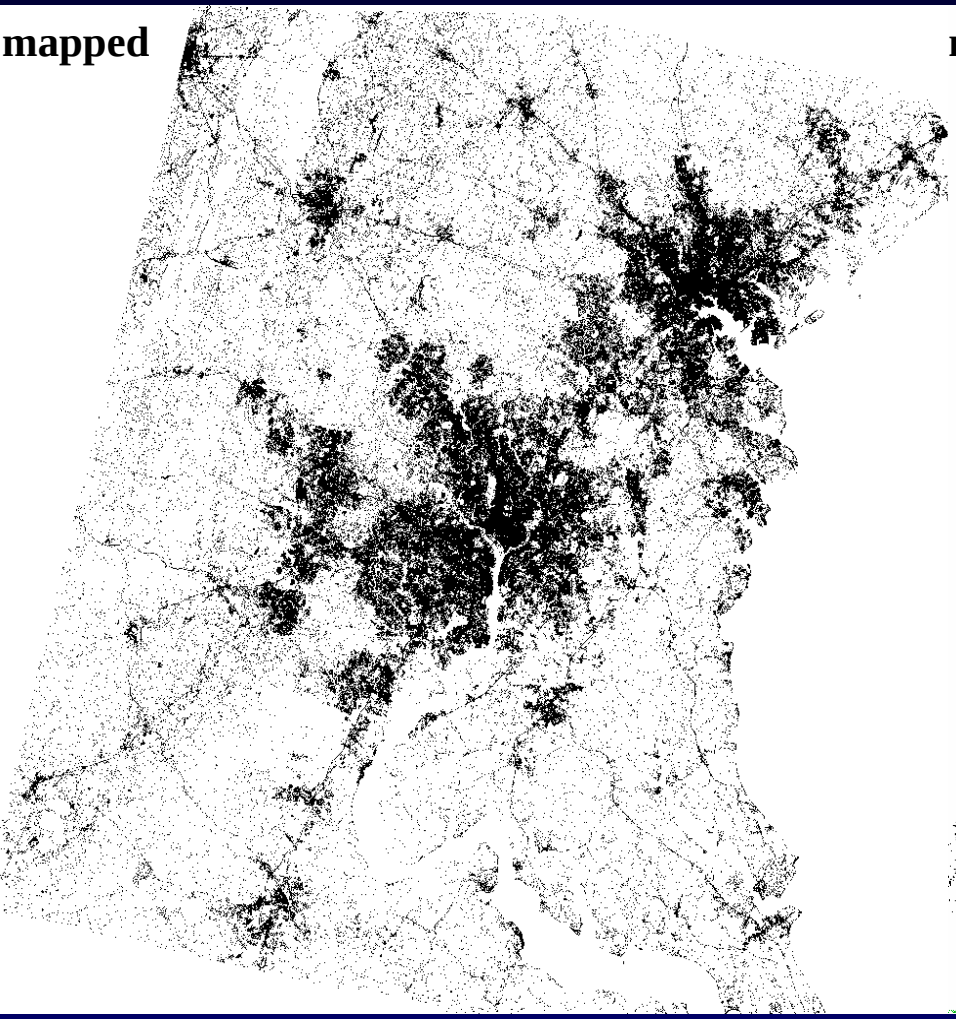
Simulate implications of policy & management decisions

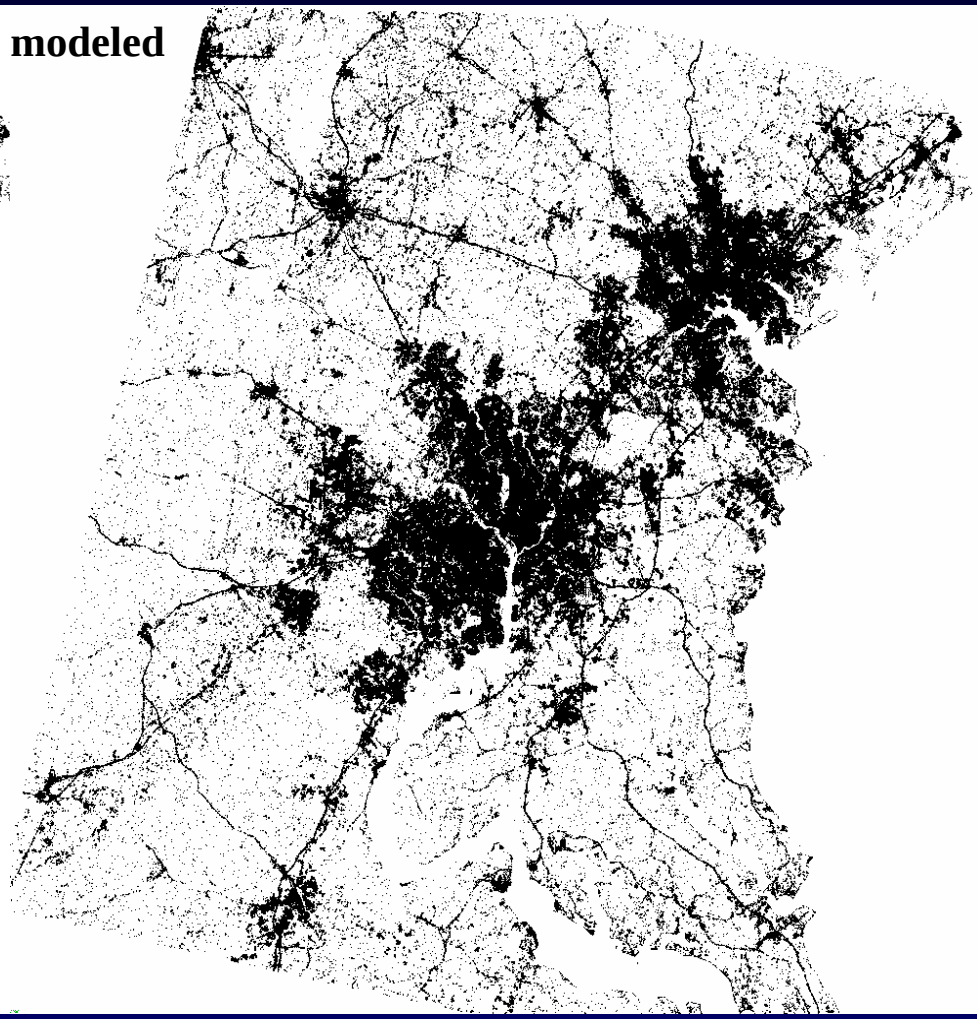
SLEUTH Applications in the United States

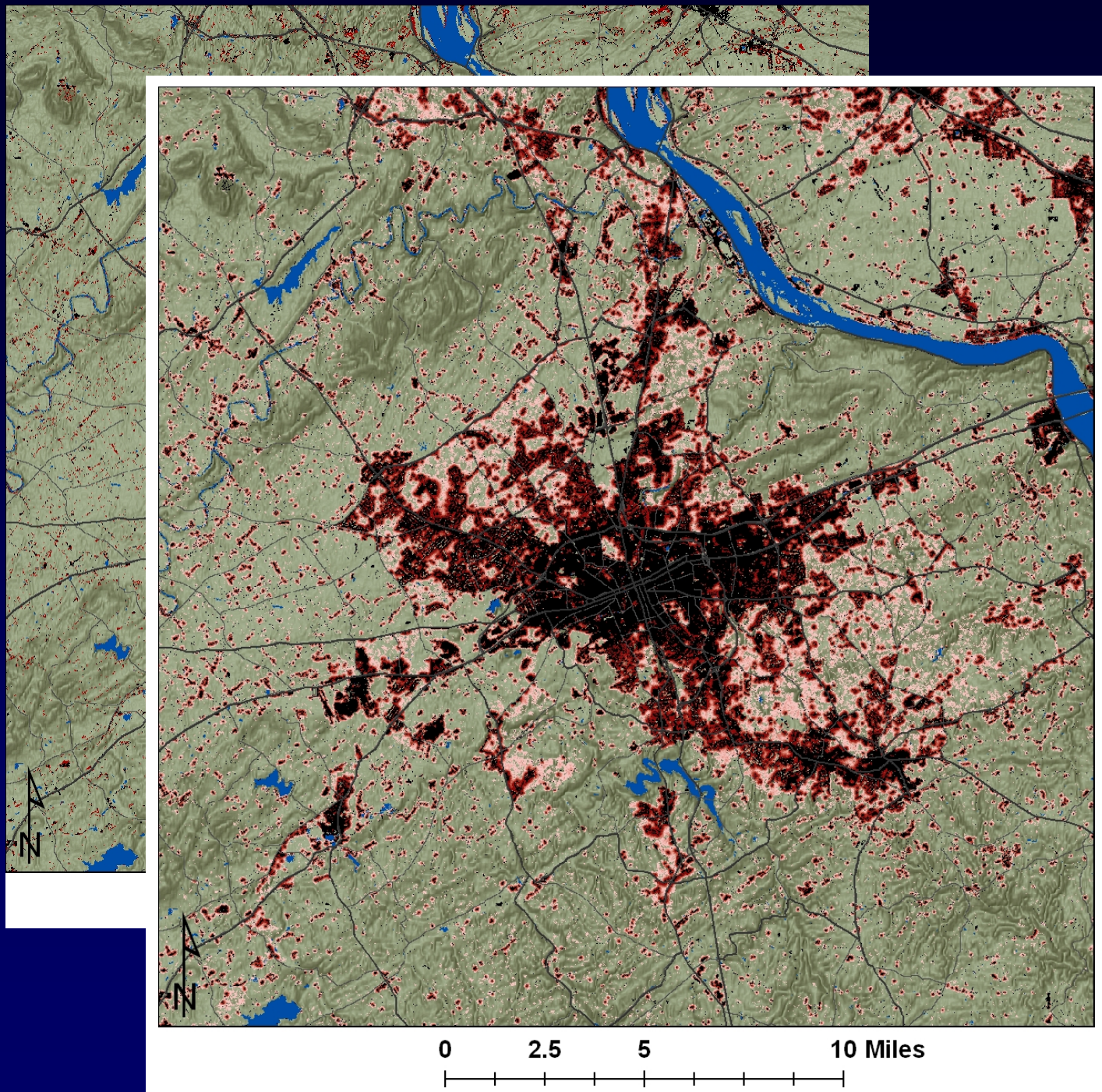


SLEUTH model calibration

The greater Baltimore – Washington DC metropolitan area, circa 2000







Extent of developed land

- 2000

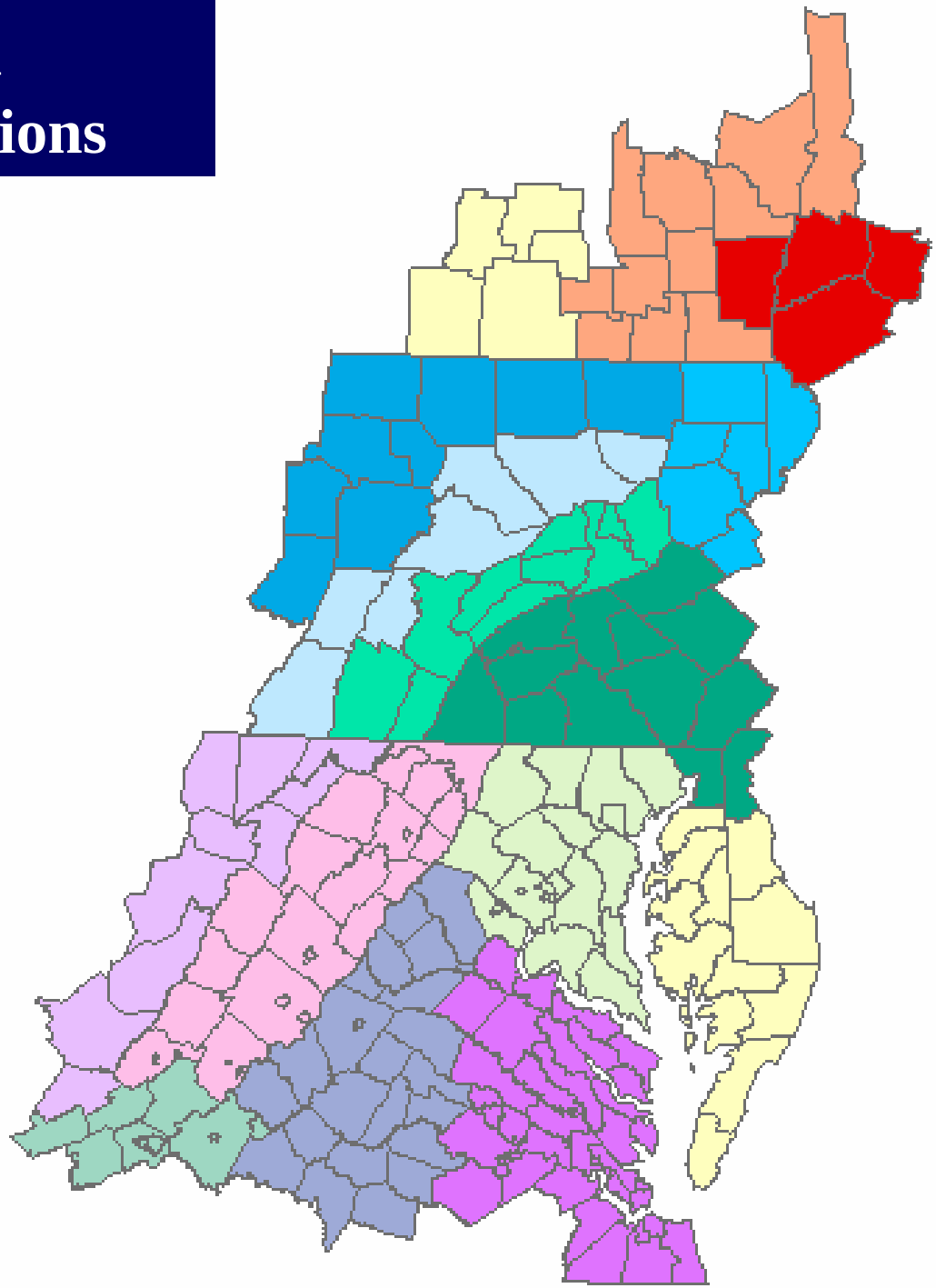
Forecasted development (2030)

Probability

- 0 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100

Regional Model
Calibration & Predictions

Modeling Segments



- 168,000 km^2 @ 30m = ~200 million cells..
- iterative process >>*CPU*