

Spatial Predictive Modeling and Remote Sensing of Land Use Change in the Chesapeake Bay Watershed

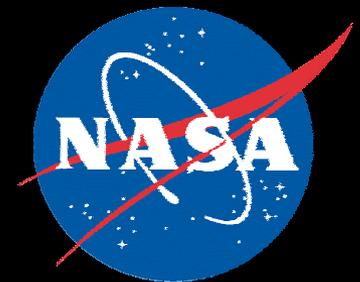
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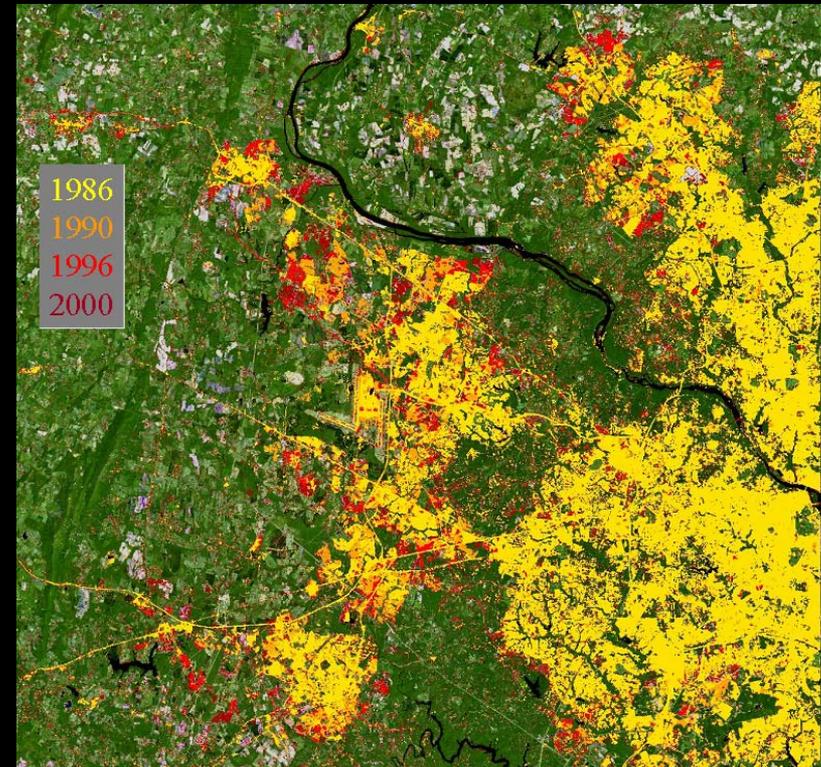
- Questions

- How has urbanization changed the landscape and consumed resource lands?
- What form will urbanization take in the future under different land use scenarios?

- Goals & Approach

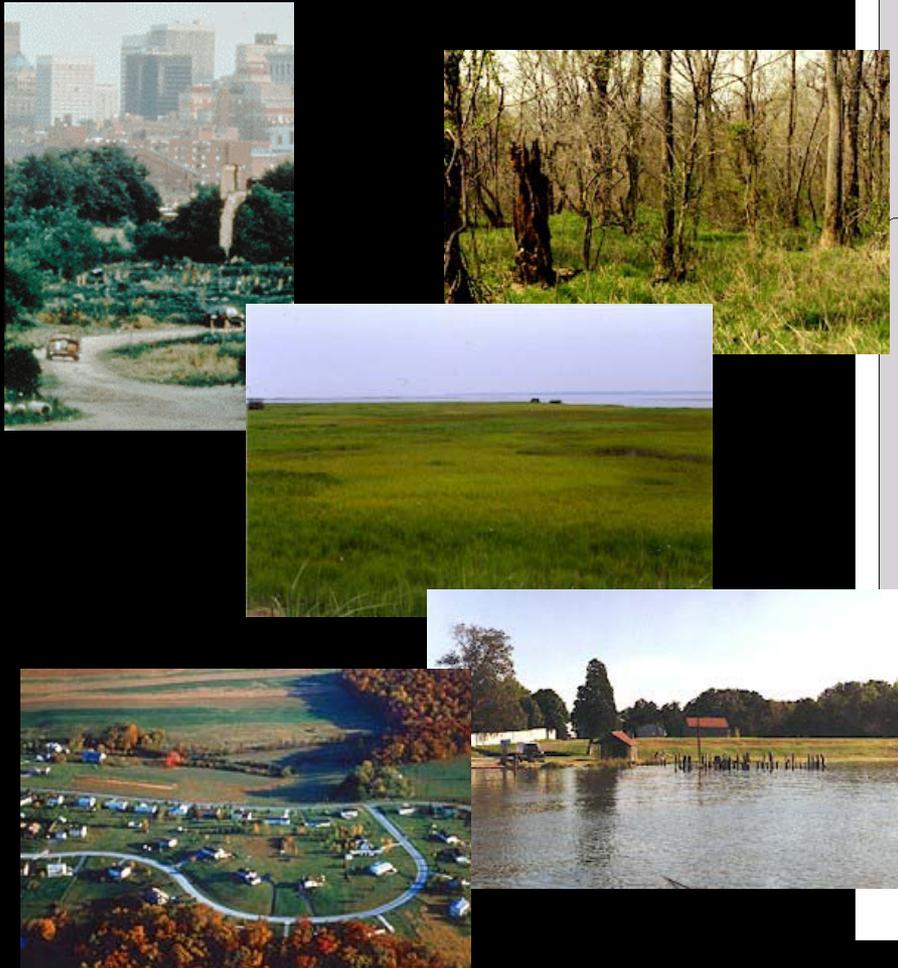
- To map and monitor changes in the urban / exurban environment using multi-scale satellite imagery.
- To develop economic models of land use change over time, focusing on low density development at the urban-rural fringe.
- To exploit data derived from satellite imagery to calibrate cellular automaton models and enrich economic models.
- To compare and contrast economic models with cellular automaton and resource allocation models, and test the performance and sensitivity of the models.

Objectives

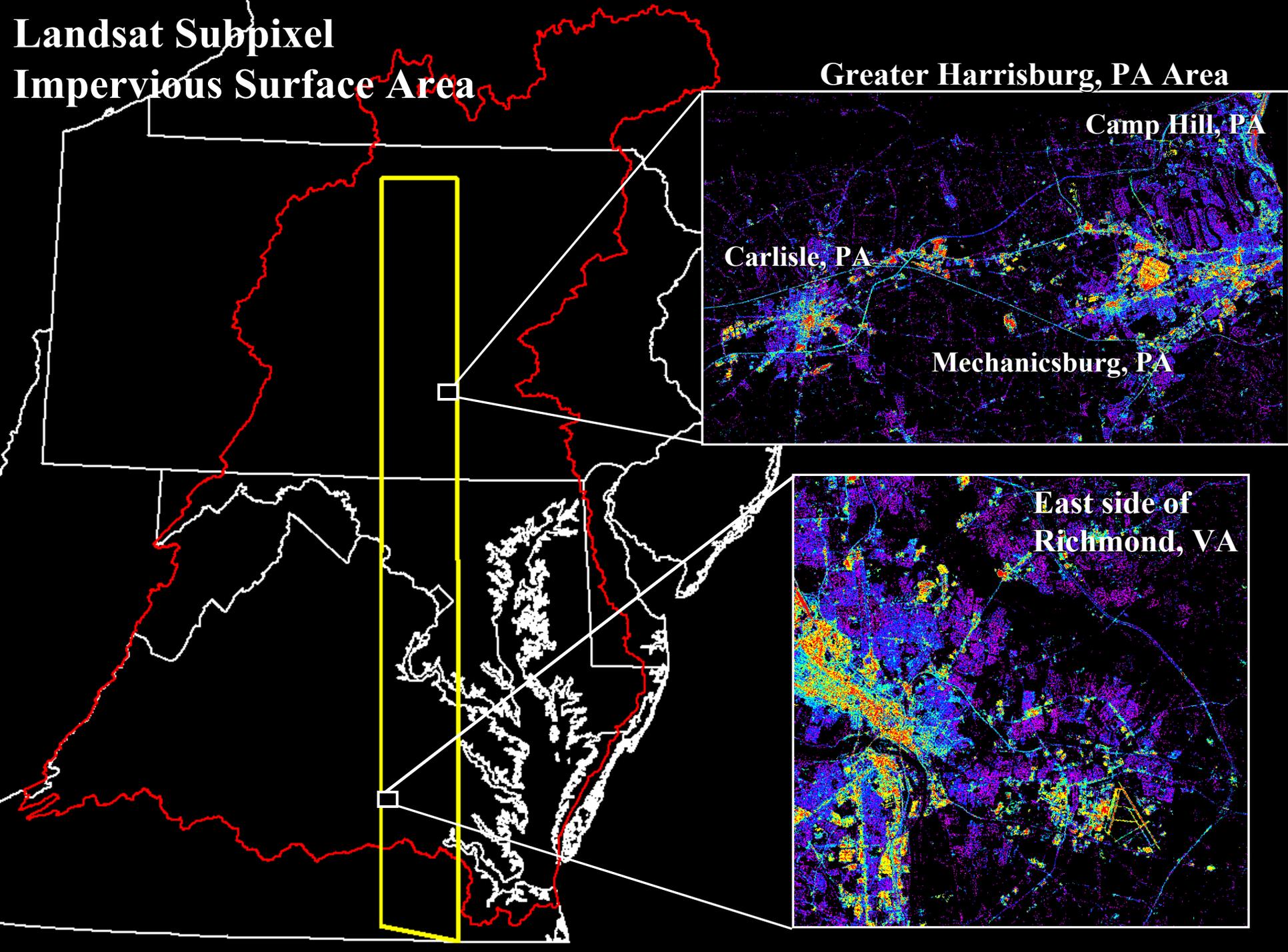


Changes in impervious surface cover (urbanization) northwest of Washington, DC

The Chesapeake Bay Watershed



Landsat Subpixel Impervious Surface Area



Greater Harrisburg, PA Area

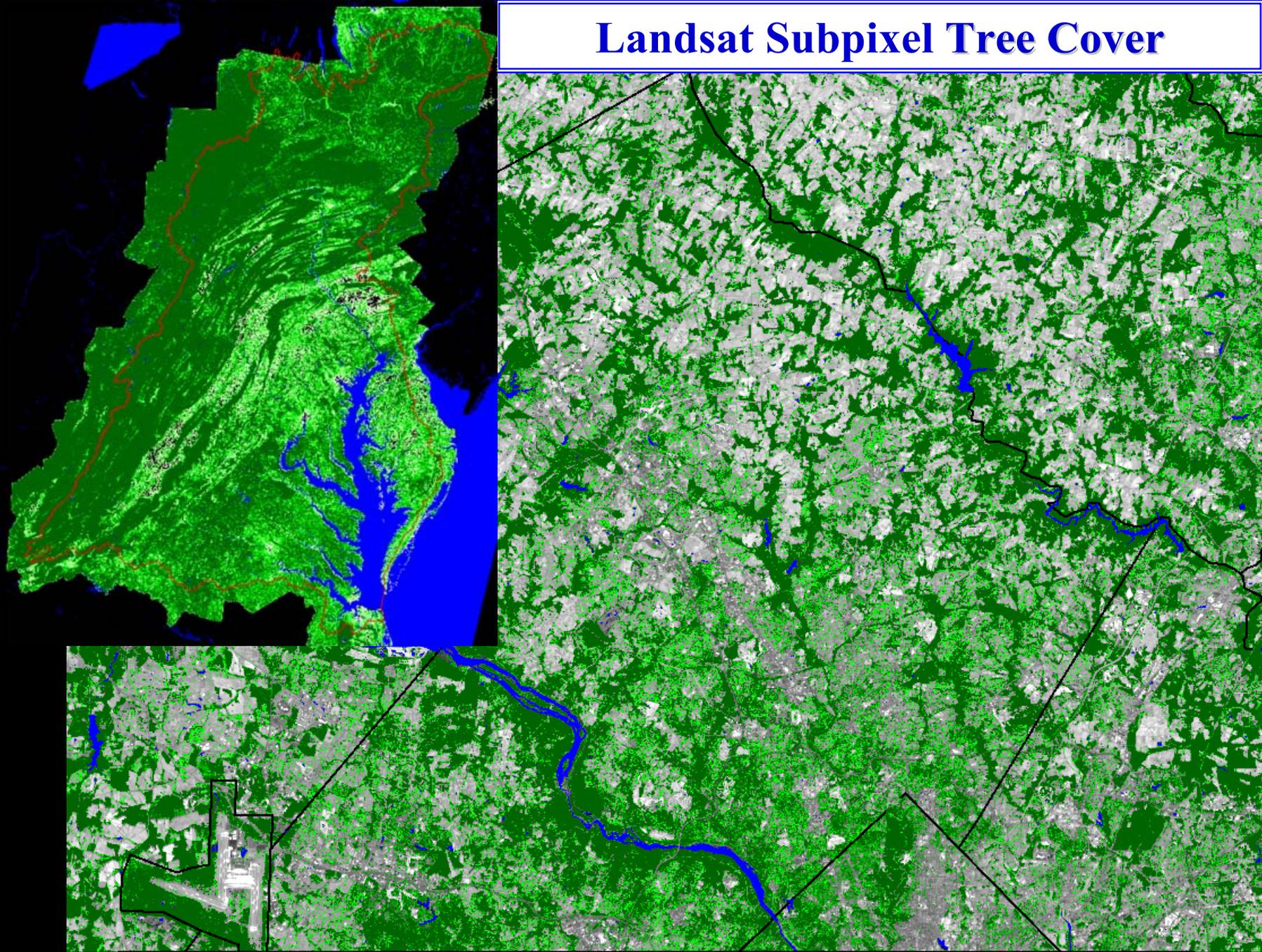
Camp Hill, PA

Carlisle, PA

Mechanicsburg, PA

East side of
Richmond, VA

Landsat Subpixel Tree Cover



% Impervious Within Watershed



STREAM HEALTH APPLICATIONS

Across 246 small watersheds there was a *significant decrease* in stream health with:

- 1) more impervious cover
- 2) fewer trees in riparian buffer
- 3) less tree cover in watershed

PROVIDES SPECIFIC MANAGEMENT GUIDELINES

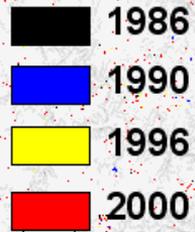
% Tree Cover Within 30m Buffer



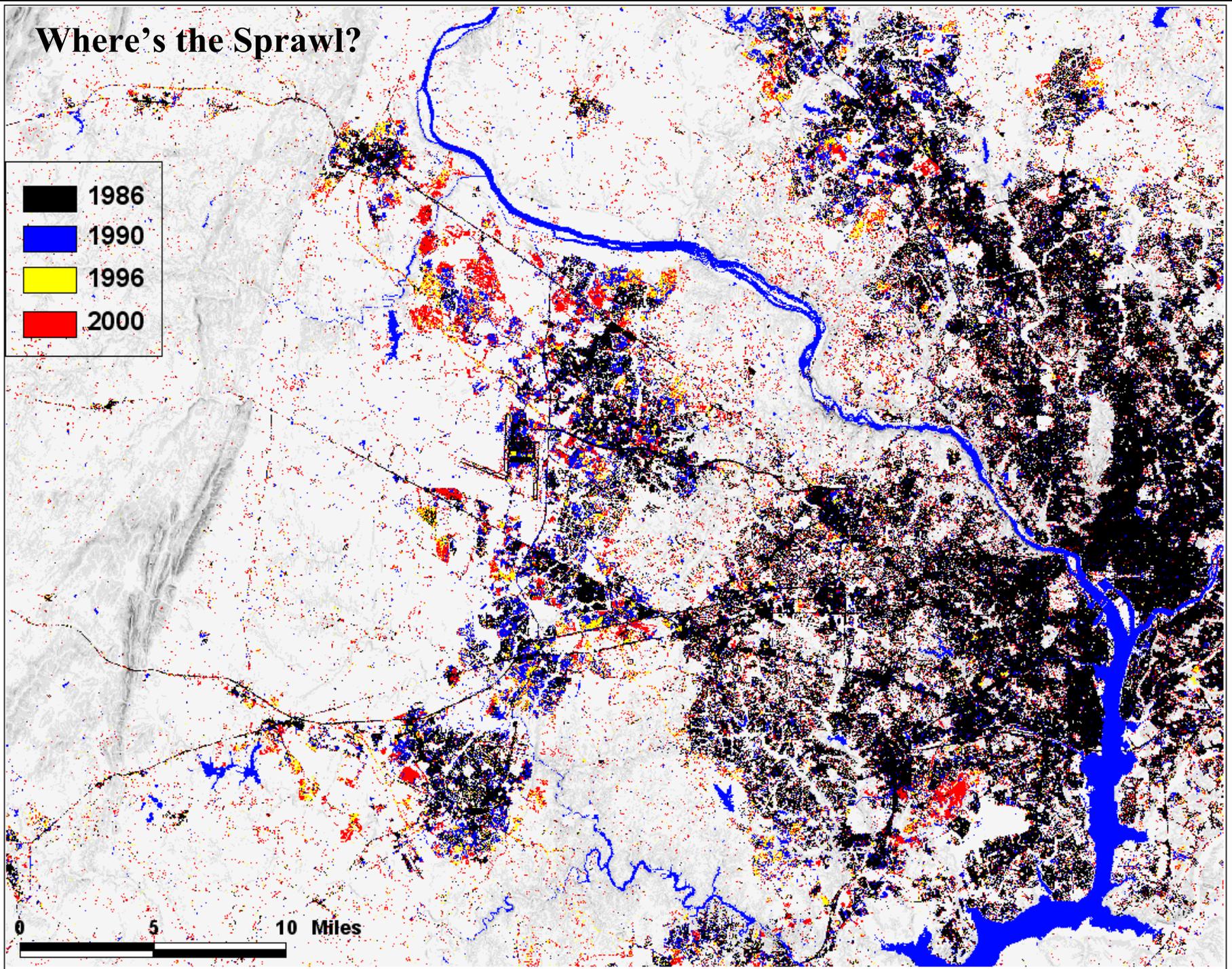
% Tree Cover Within Watershed



Where's the Sprawl?



0 5 10 Miles

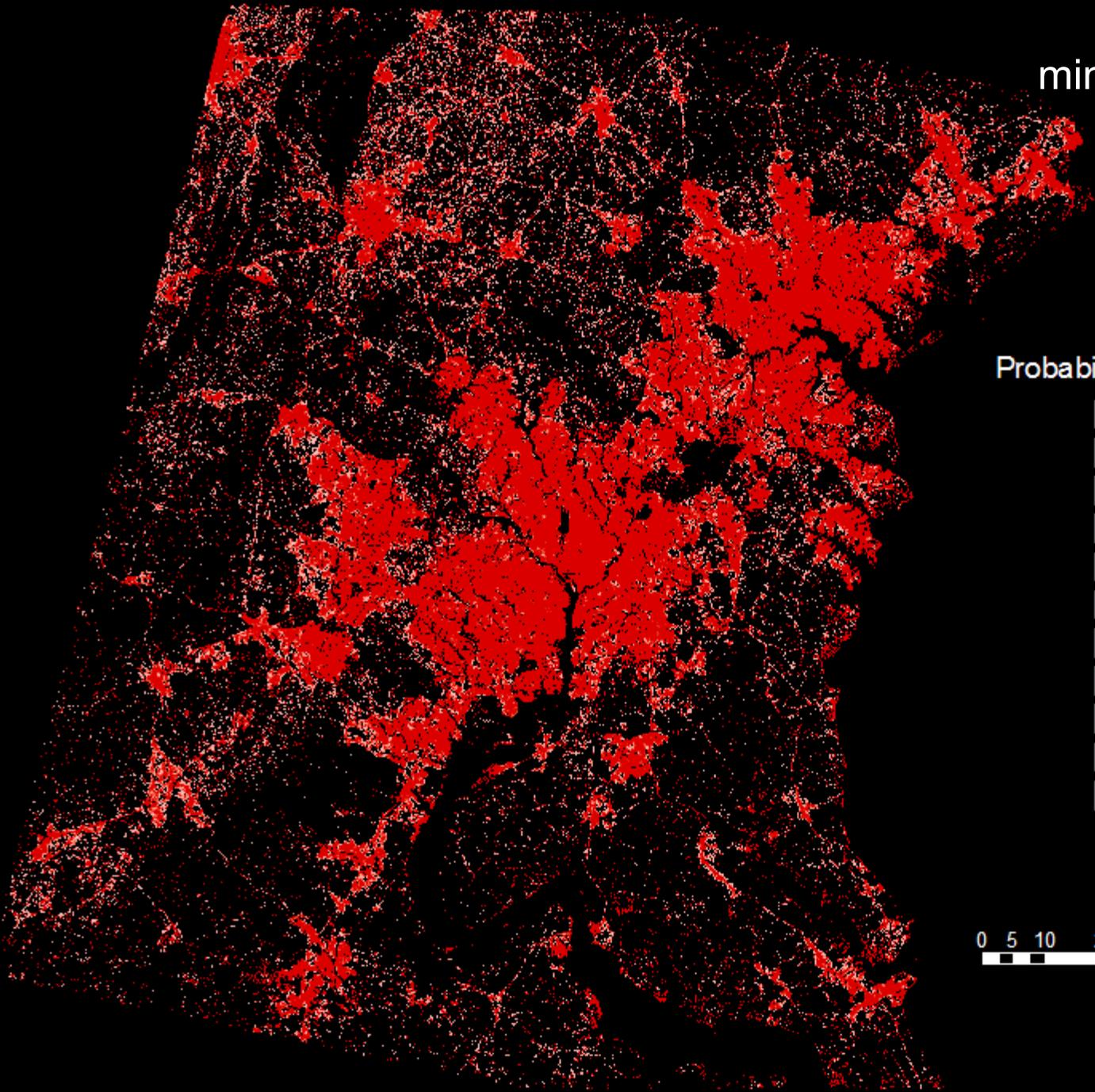
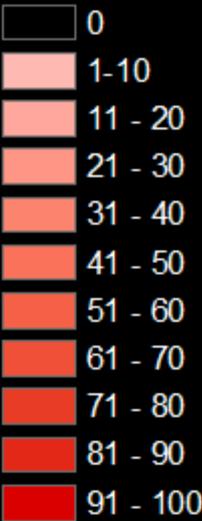


SLEUTH Urban Growth Model

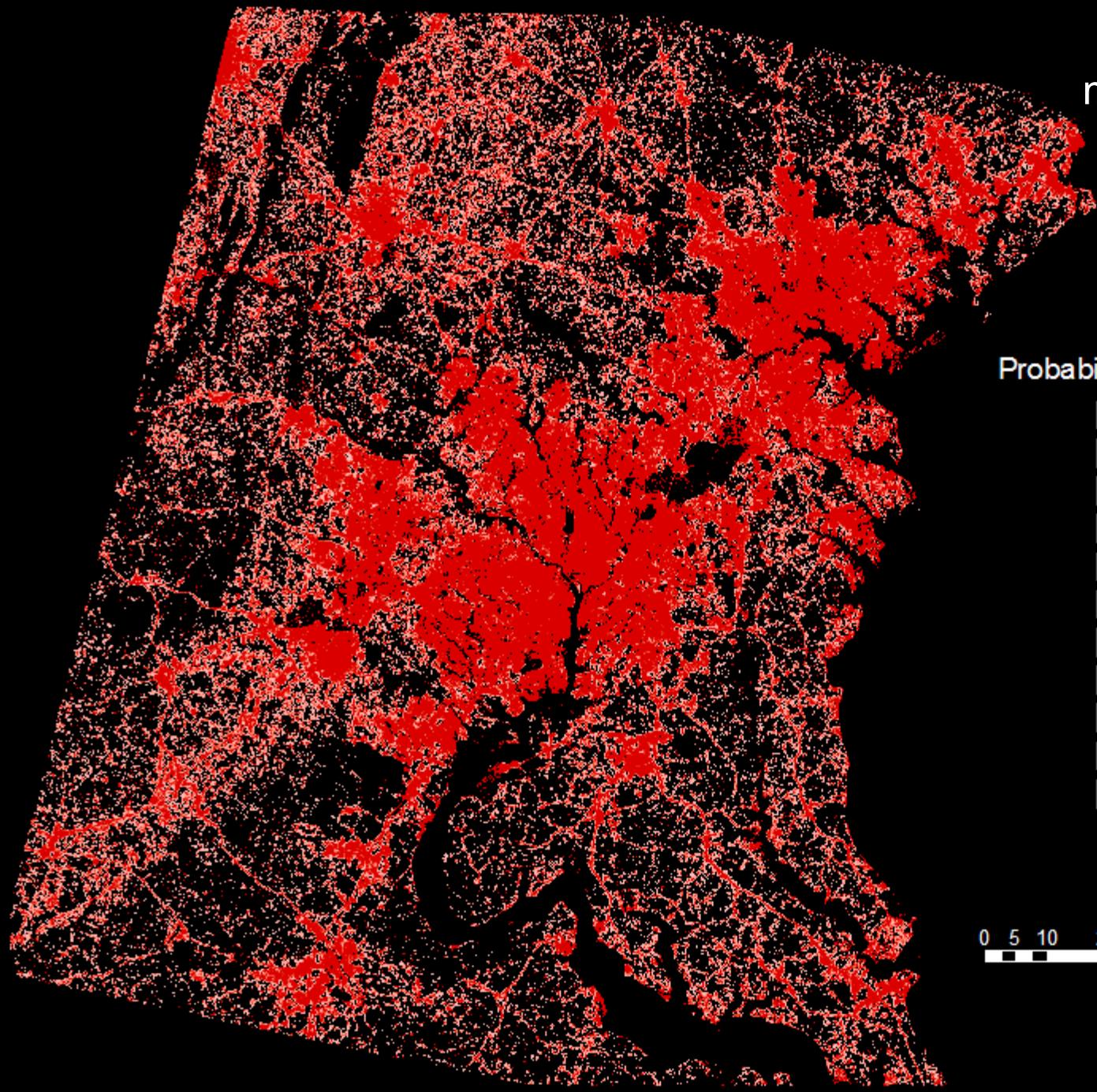
- Cellular automaton model
- Calibrated with ISA time series
- Probabilistic (Monte Carlo simulations)
- Growth rules
 - Spontaneous (*dispersion*)
 - New spreading center (*breed*)
 - Edge (*spread*)
 - Road-influenced (*road gravity*)
- Resistance to development
 - Slope (*slope coefficient*)
 - Excluded layer (*user-defined*)

2030
minimal development
scenario

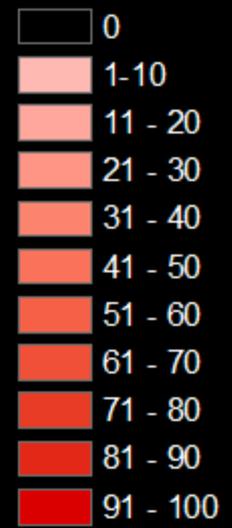
Probability of Development



2030
managed growth
scenario

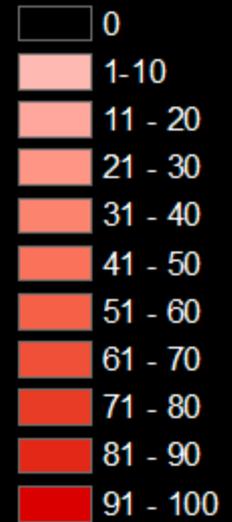


Probability of Development

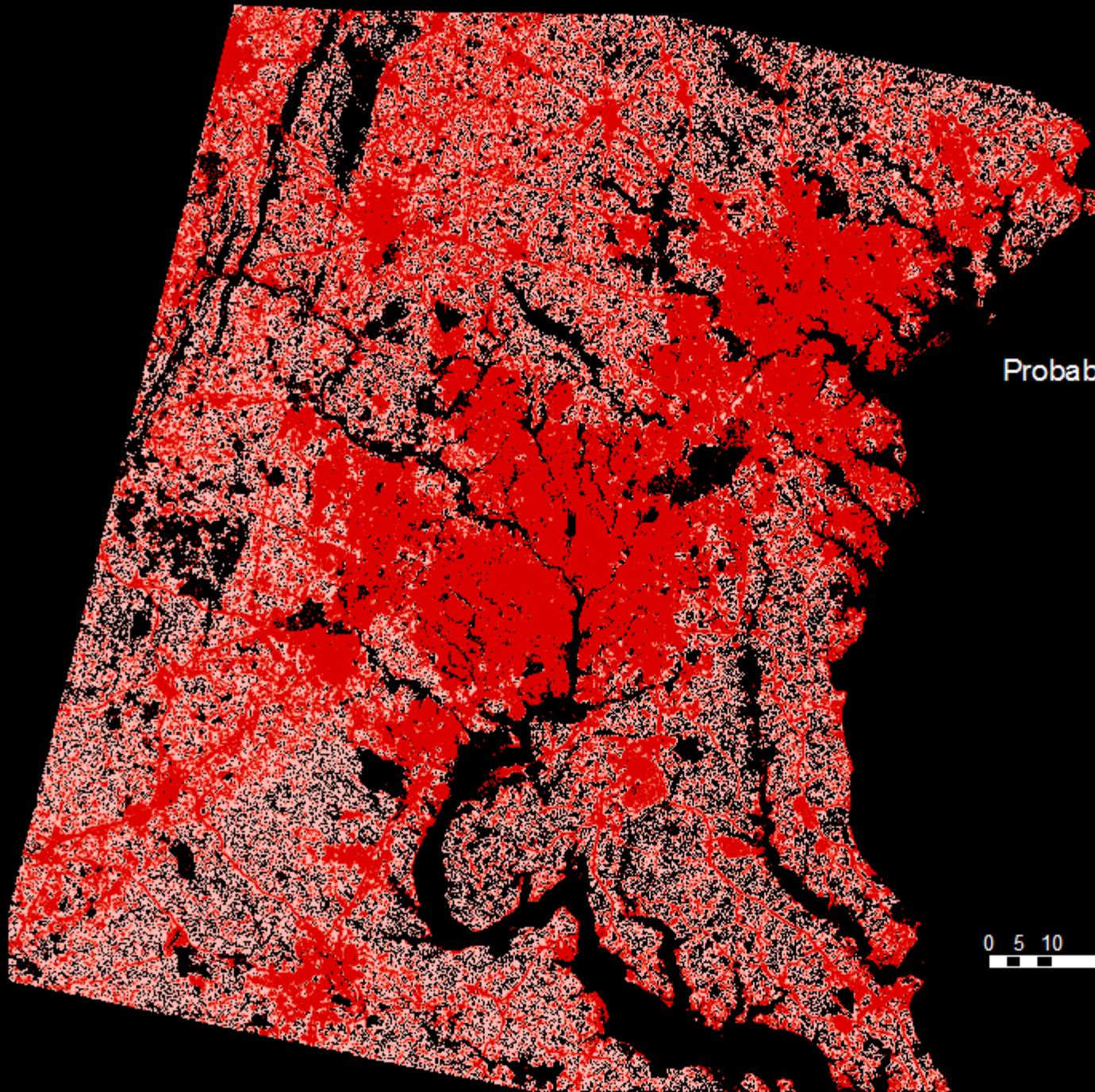


2030
current trends
scenario

Probability of Development



0 5 10 20 30 40 Kilometers



A Different Approach to Modeling Land Use Change

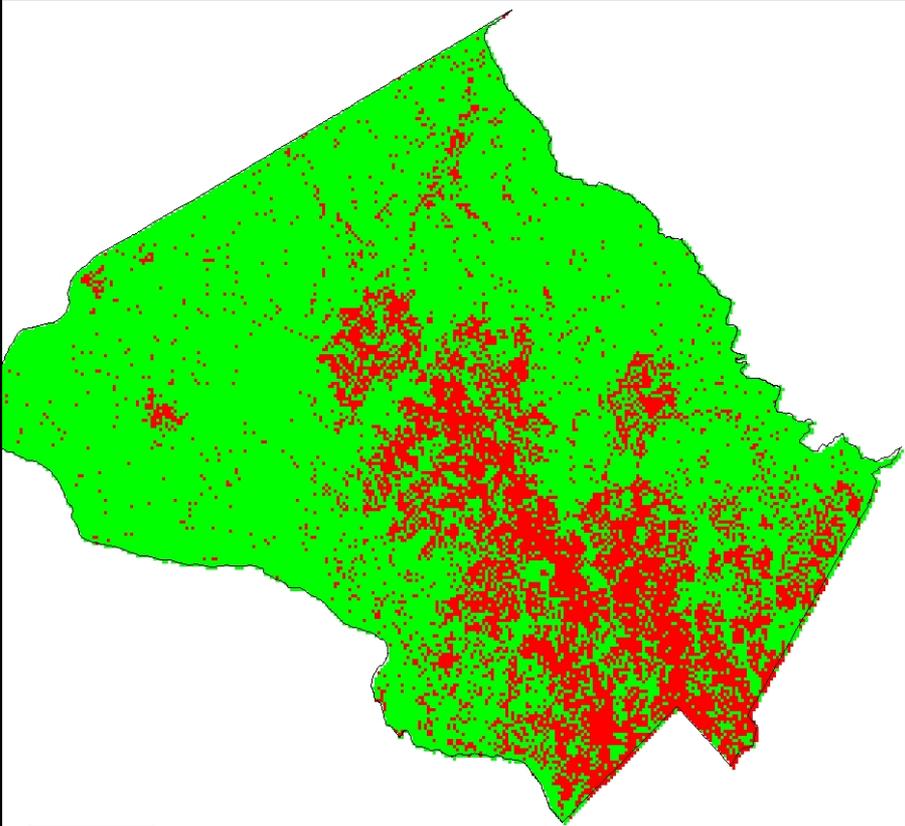
Economic Modeling Process-based Modeling

- Units = parcels
- Transition 'rules' describe economic decisions and market functions
- Calibrated from satellite data, parcel level data, and market data
- Parcel interactions important but difficult to incorporate into simulation mechanics
- Produces probabilistic output

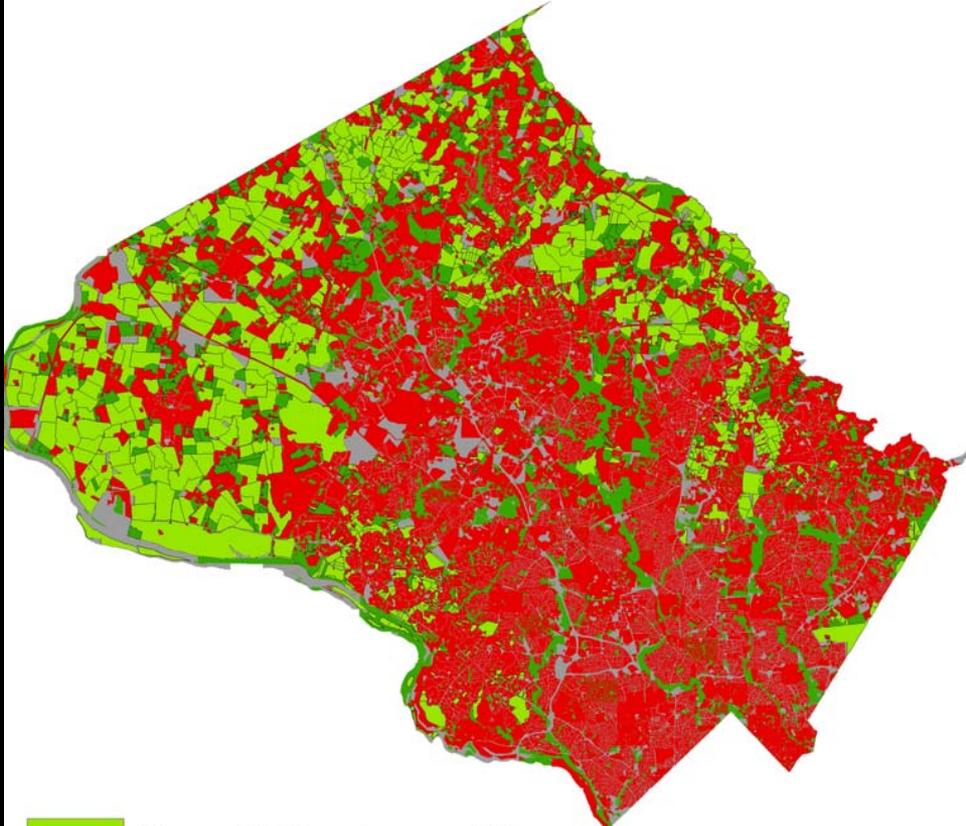
SLEUTH Pattern-based Modeling

- Units = cells
- Transition 'rules' mimic historical pattern
- Calibrated from satellite data only
- Handles cell interactions and generate dynamic simulations with relative ease
- Produces probabilistic output

Pixel vs Parcel View – as of 2000

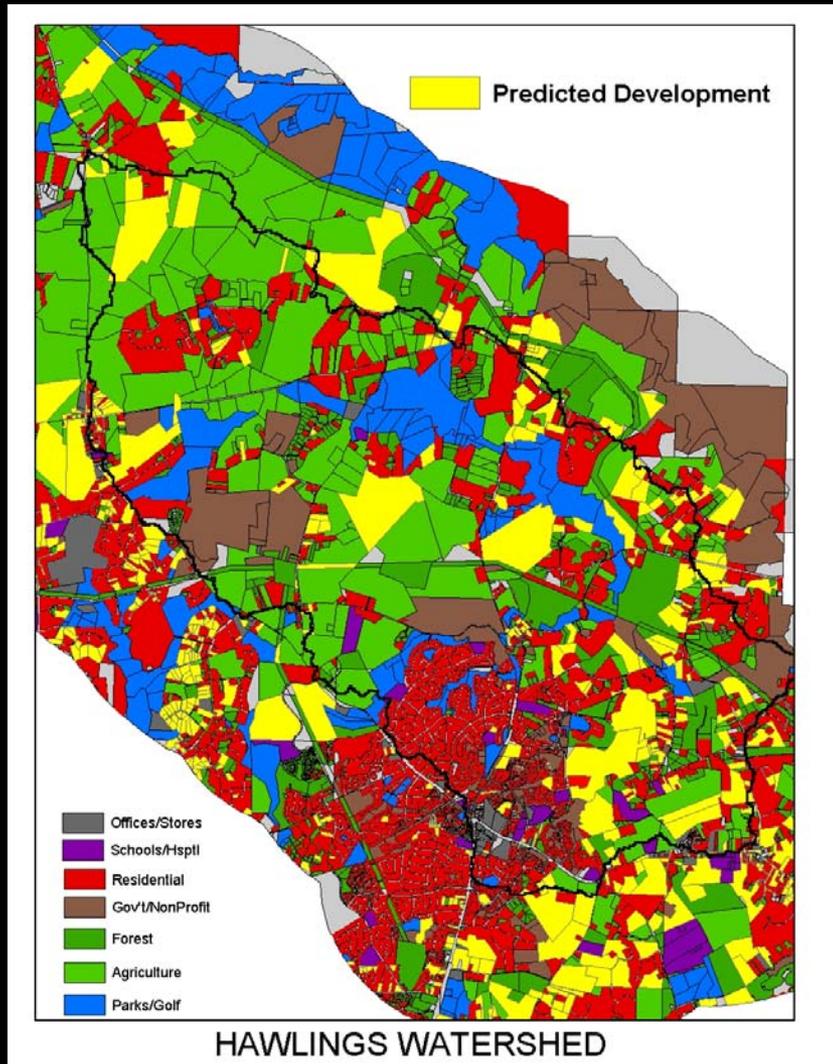


 Undeveloped
 Developed

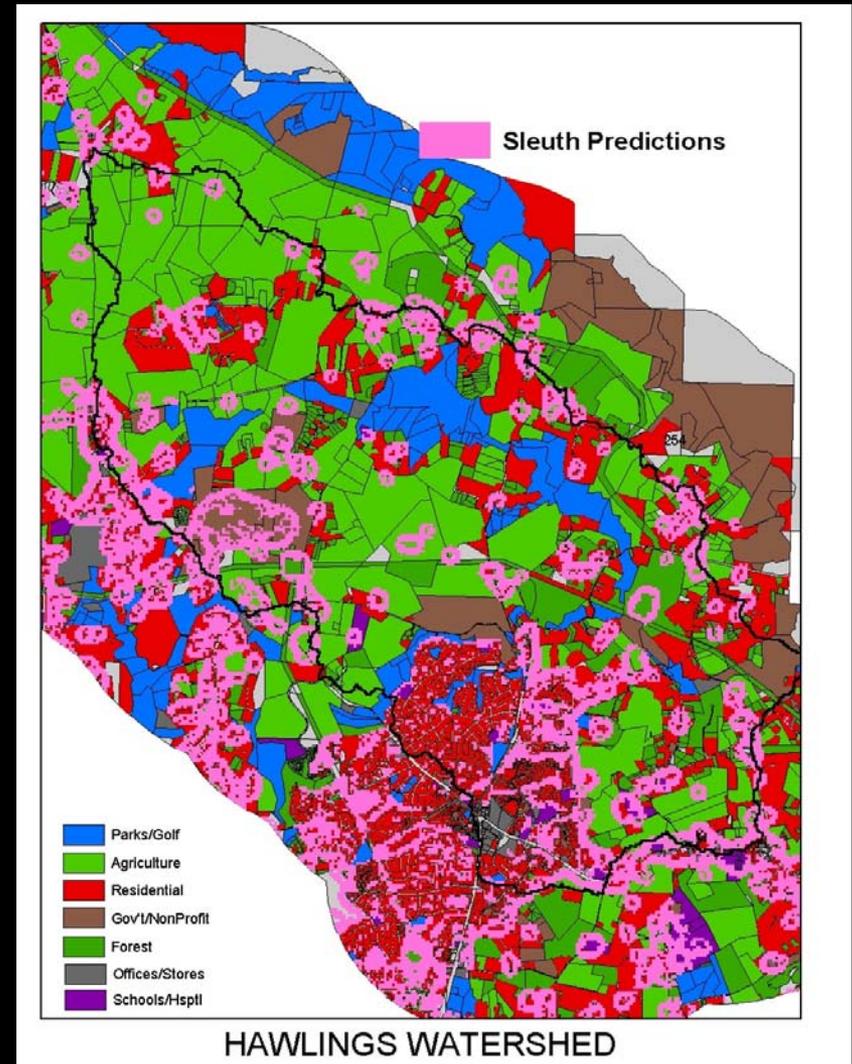


 Res with Development Capacity
 Undeveloped
 Developed

Why the Unit of Observation Matters...



Type of output from economic model



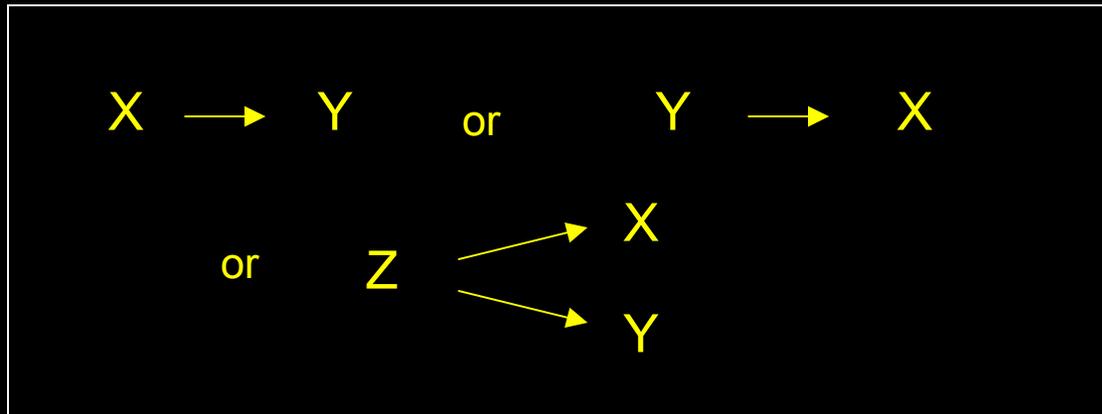
Type of output from Sleuth

Process based modeling is important because:

observationally equivalent patterns can be generated by many different processes.

Correlation is not the same as causation -

snapshots of land cover cannot distinguish whether:



Sorting this out requires careful statistical identification.

Some examples

1. Does development follow roads?

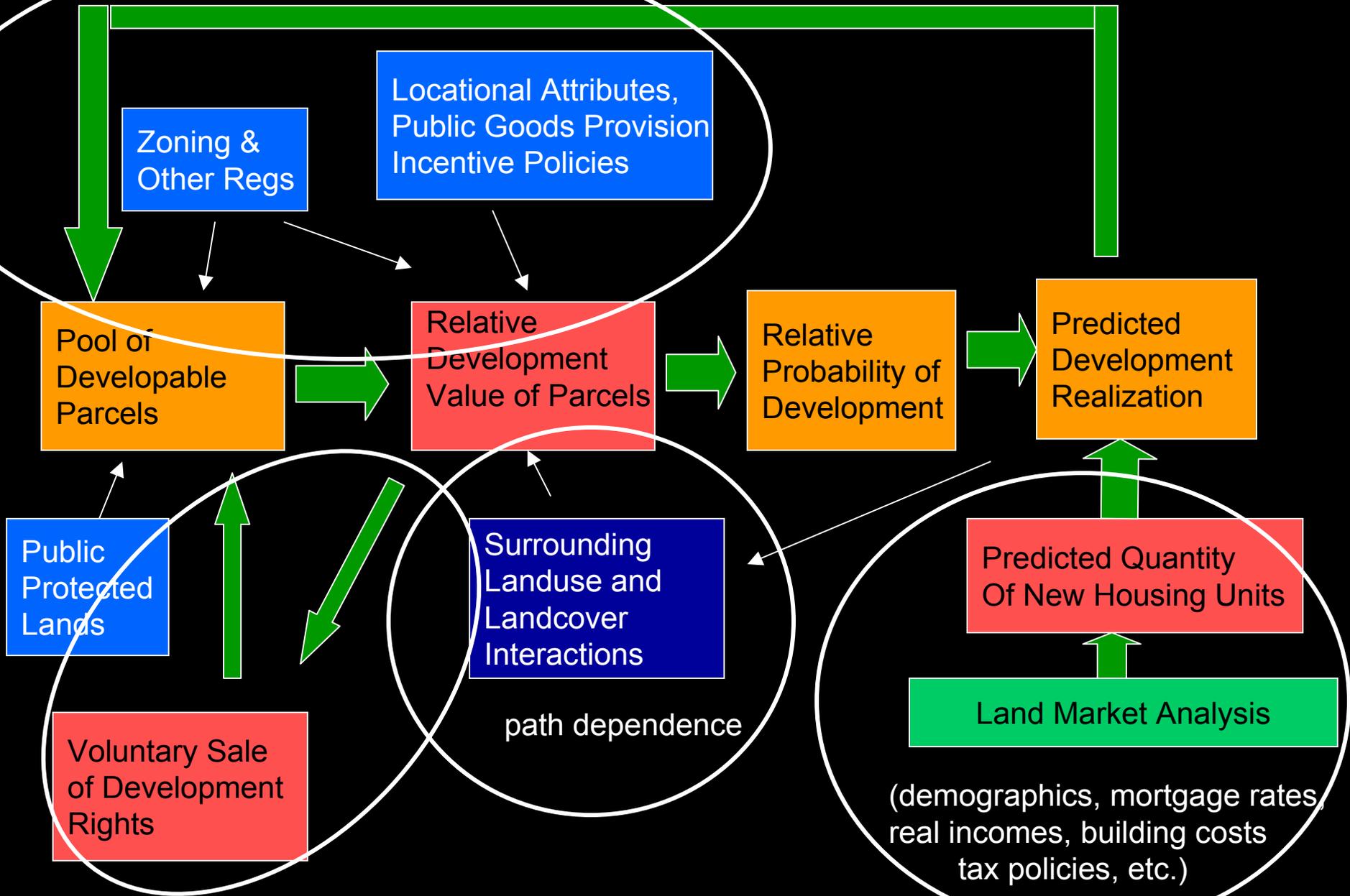
Or are roads built to reduce congestion from previous development?

2. Does development spawn neighboring development?

Or are both spawned by spatially correlated exogenous features?

3. Does open space provide an attracting or repelling effect?

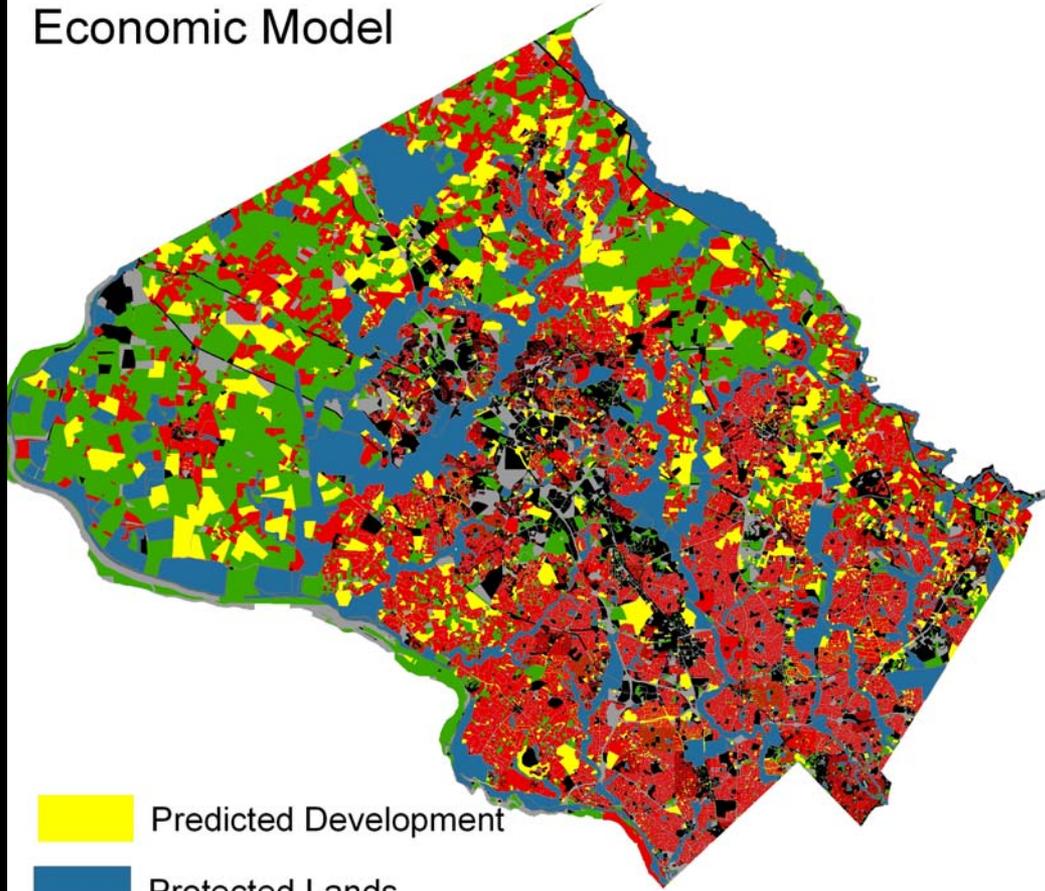
Spatially Explicit (Parcel) Level of Model



Role of Satellite Imagery

- *Impervious surface and tree canopy remote sensing products found to be best measure of surrounding landscape; used in economic model to calibrate landscape interactions.*
- *What we learn from process-based models where parcel level and satellite data are available, we hope to transfer to other settings where only satellite data are available.*

One Realization from the Probabilistic Economic Model



-  Predicted Development
-  Protected Lands
-  Developable
-  Commercial/Institutional
-  Residential

No policy change scenario - 2030

Both **single family and multiple family** housing developments simulated using predicted probabilities from economic parcel level model.

Predicted number of total sf and mf housing units forecasted from market model.

Policy scenarios can be introduced based on what we have learned about responses to specific types of regulations, surrounding land use interactions, etc.

Some Conclusions and Suggested Strategies

- **Leverage remote sensing data with economics data**

Advances in remote sensing of exurban land use change can be used to calibrate, constrain and inform various types of land use change models.

The value of remote sensing data is increased when combined with economic data.

- **Merge strengths of pattern and process based modeling**

Process based models allow us to test hypotheses about causation, e.g.-

- Nature of surrounding land use interactions
- Effectiveness of different forms of existing regulations and incentives

Cellular automata models provide mechanics of dynamic simulations and interactions

Publications

- Bockstael, N. and E. Irwin. Public policy and the changing landscape. *Estuaries* (in press).
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- Irwin, E. and N. Bockstael. Endogenous spatial externalities: empirical evidence and implications for exurban residential land use patterns. *Advances in Spatial Econometrics, Methodology, Tools and Applications*. Edited by L. Anselin, R. Florax and S. Rey (in press).
- Irwin, E. and N. Bockstael, “Land Use Externalities, Growth Management Policies, and Urban Sprawl,” *Regional Science and Urban Economics* (in press).
- Jantz, C. A., S. J. Goetz, and M. A. Shelley. 2004 Using the SLEUTH urban growth model to simulate the land use impacts of policy scenarios in the Baltimore-Washington metropolitan region. *Environment and Planning B* 31(2):211-228.
- Jantz, C. and Goetz, S.J. Scale dependencies in an urban land use change model. *International Journal of Geographic Information Systems* (in press).
- Goetz, S.J., Jantz, C.A., Prince, S.D., Smith, A.J., Varlyguin, D. and Wright, R.. Integrated analysis of ecosystem interactions with land use change: the Chesapeake Bay watershed. In: G.P. Asner, R.S. DeFries and R.A. Houghton (Editors), *Ecosystem Interactions with Land Use Change*. American Geophysical Union, Geophysical Monograph Series. Washington DC, 13 pp. (in press).
- McCauley, S., and S. J. Goetz. Mapping residential density patterns using multi-temporal Landsat imagery and a decision-tree classifier. *International Journal of Remote Sensing* 25(6):1077-1094.
- Nilsson, C., Pizzuto, J.E., Moglen, G.E., Palmer, M.A., Stanley, E.H., Bockstael, N.E. and Thompson, L.C. Ecological Forecasting and the Urbanization of Stream Ecosystems: Challenges for Economists, Hydrologists, Geomorphologists, and Ecologists. *Ecosystems*, 6 (7): 659-674. 2003.
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