Biocomplexity Project Overview

"**Biocomplexity in Linked Bioecological-Human Systems:** Agent-Based Models of Land-Use Decisions and Emergent Land Use Patterns in Forested Regions of the American Midwest and the Brazilian Amazon"

•Awarded under the National Science Foundation "Biocomplexity in the Environment" initiative (NSF Biocomplexity Grant SES0083511)

• Support also provided by the Center for the Study of Institutions, Population and Environmental Change (CIPEC) (NSF Grant NSBR9521918)

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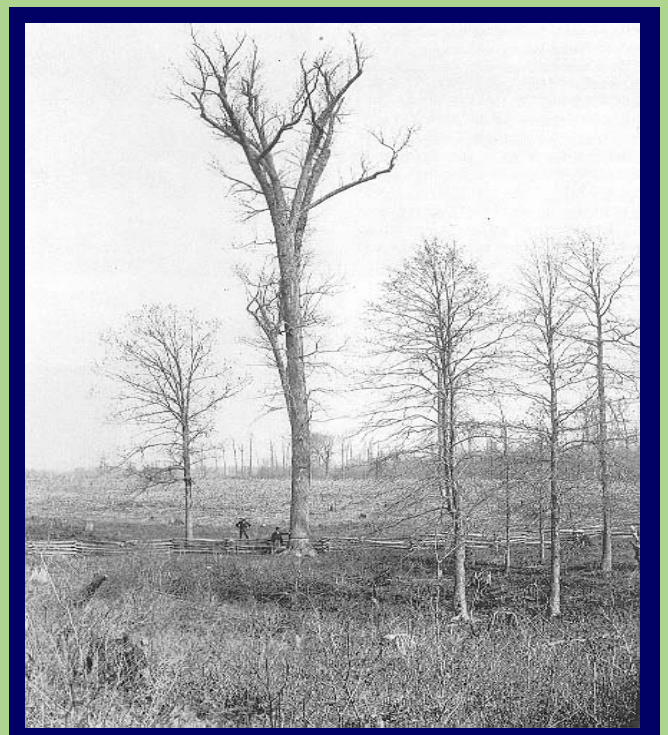
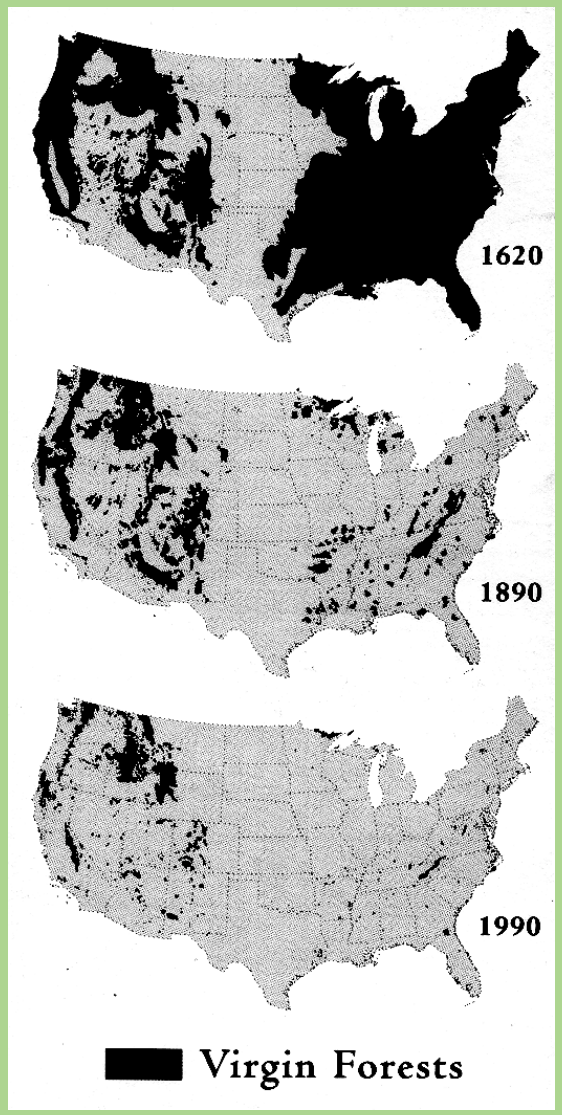
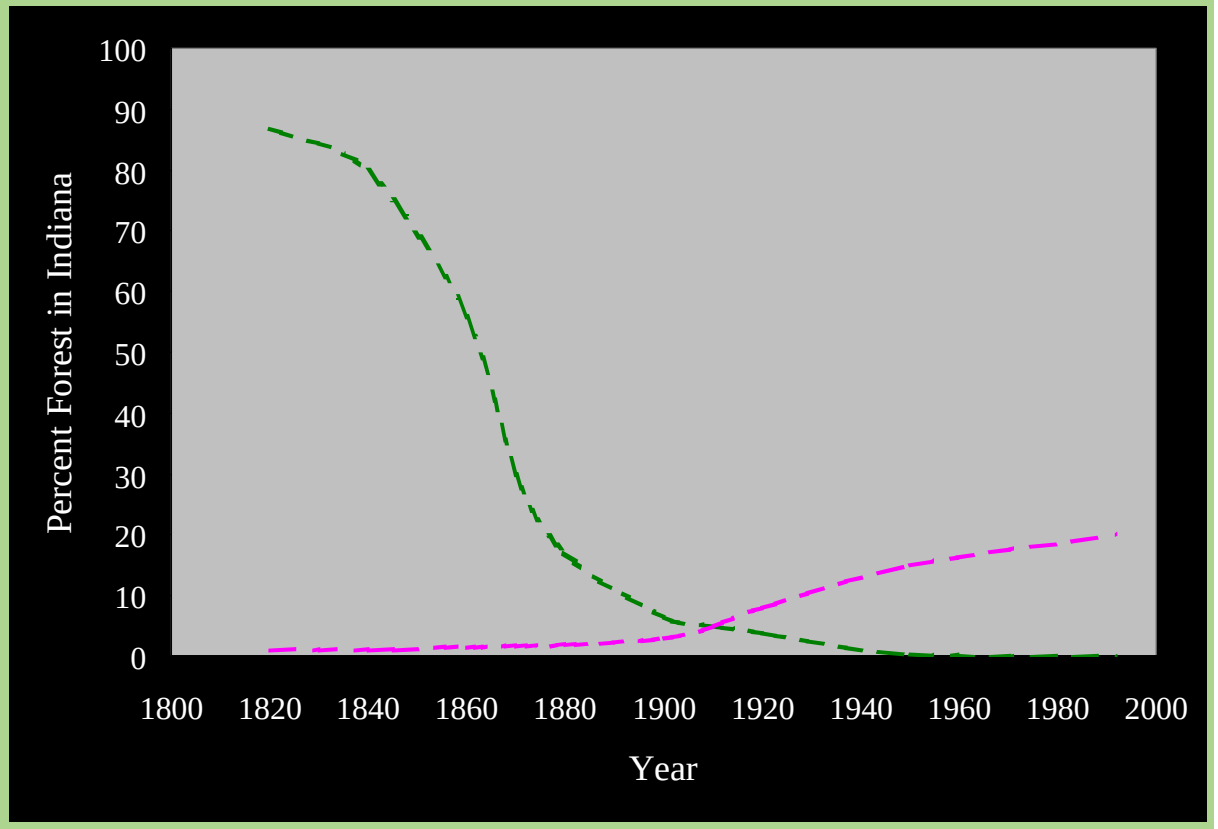


A Little History

- Indiana landscape has undergone dramatic changes
- Where, when, and why?

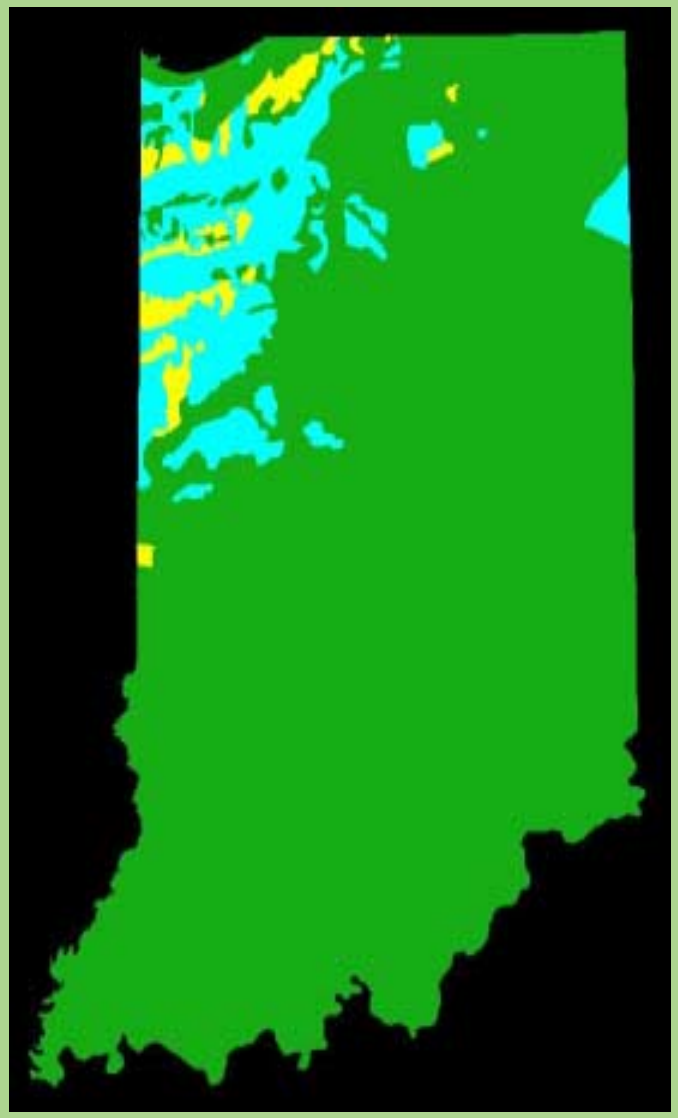
Indiana Deforestation and Afforestation



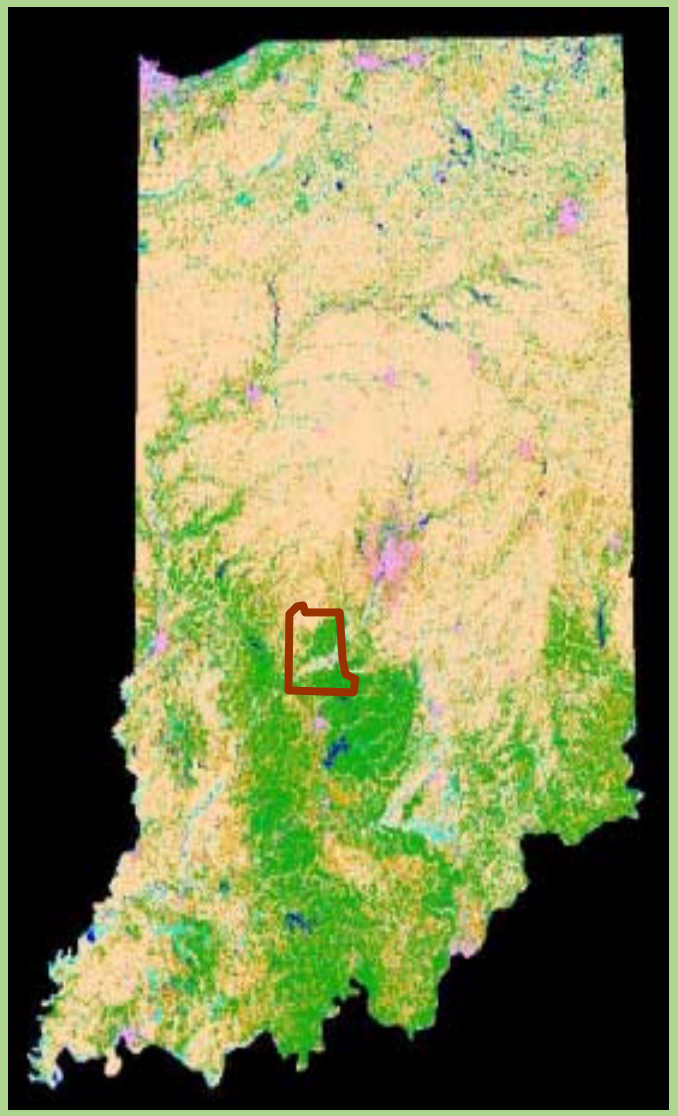


Indiana has experienced massive deforestation in the 1800's followed by gradual regrowth in the 1900's

Landcover Change in Indiana 1820-1992



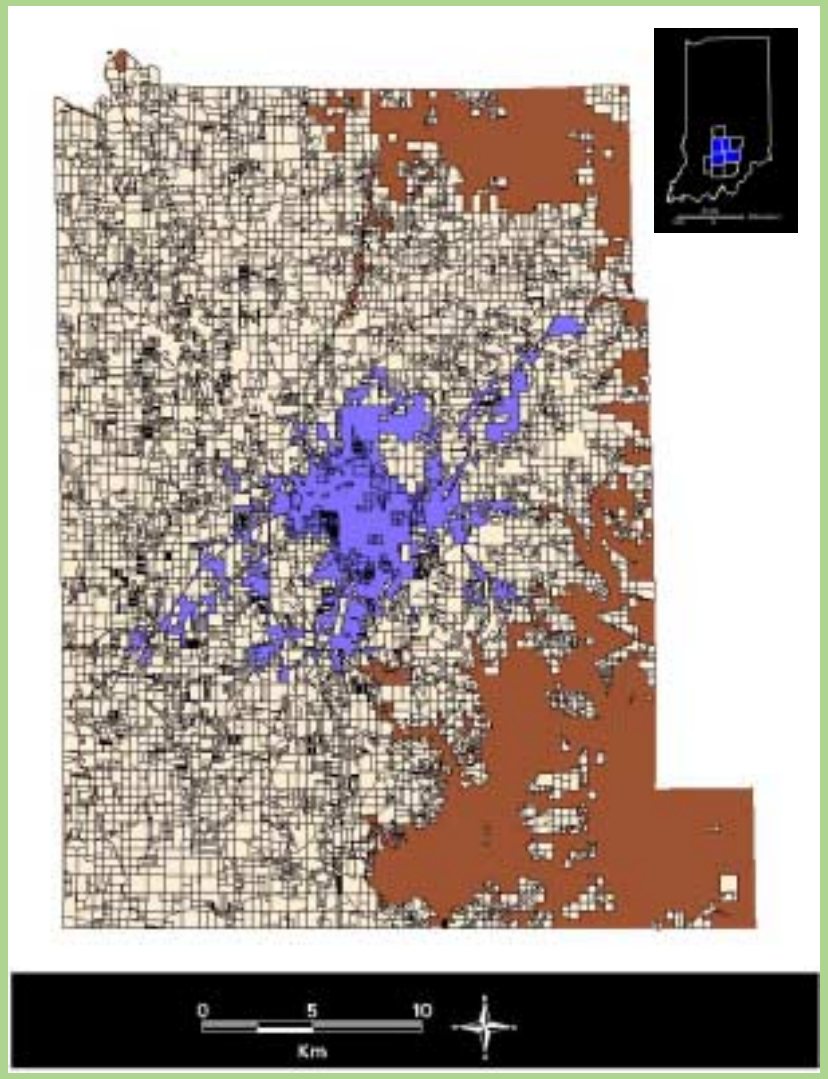
Landcover Circa 1820
(Lindsey)



Landcover 1992
(Indiana GAP Analysis)

Forest
Wetland
Prairie
Water
Row Crop
Pasture/Grassland
Urban

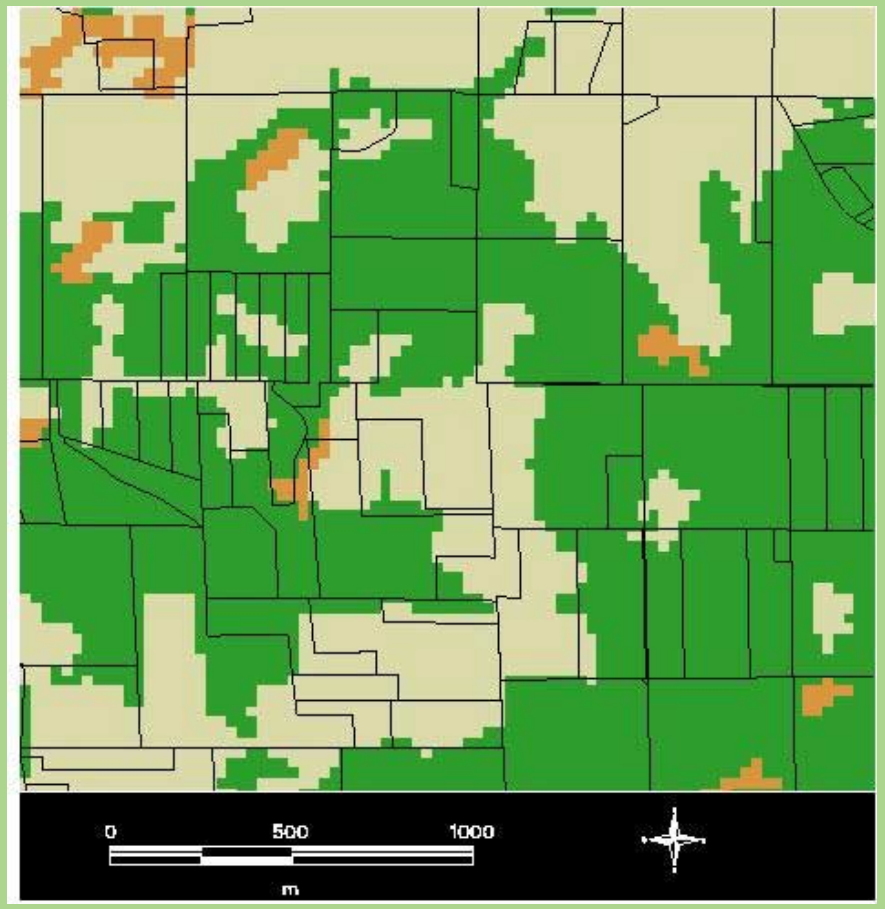
Monroe County, Indiana



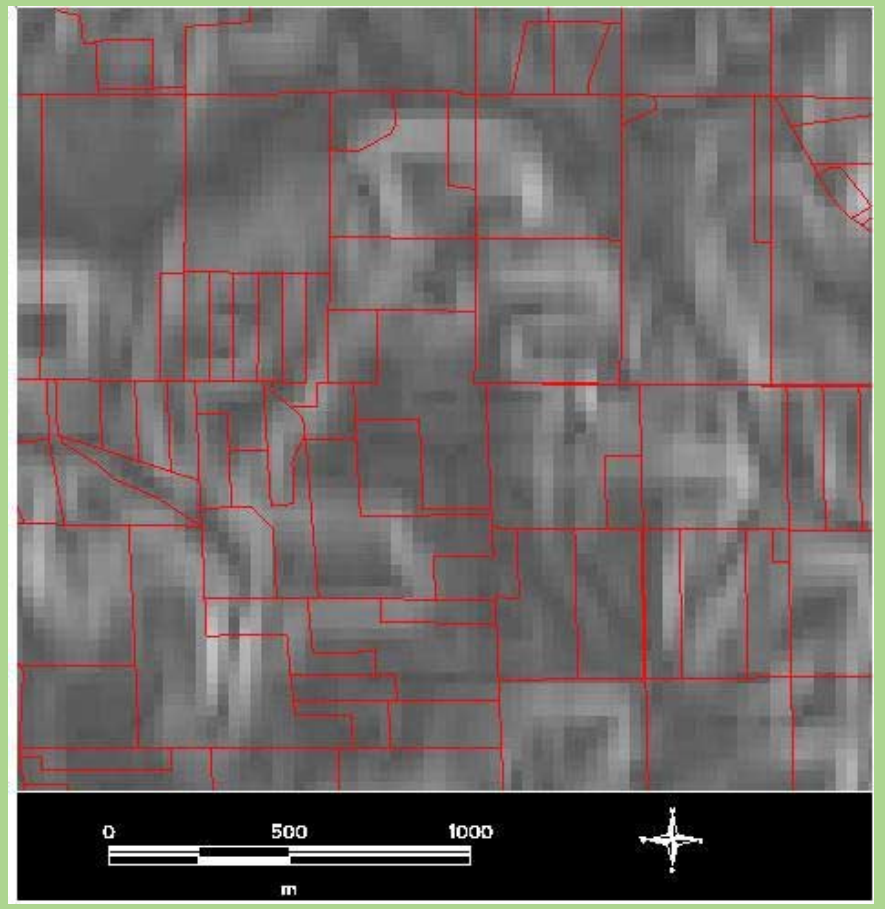
- Mosaic of agriculture, forest and residential/commercial landuses
- Varying topography
- Landcover change in Monroe County
  - Agricultural abandonment
  - Urban expansion
- Rural land is in residential, ag, forest, or combination uses

Parcel Boundaries – link between agents and landscape outcomes

Landcover 1992 (Indiana GAP)



Slope (USGS, 1:24,000)



Key Questions

1. How do individuals make labor allocation, production, consumption, and investment decisions in risky, multi-asset environments?

2 What factors affect individual preferences and actions related to land use?

3 What is the impact of landowner actions on the landscape?

4 How do socioeconomic landscape patterns and ecological landscape patterns interact?

Key Questions (cont.)

5. How does a change in land use in one location influence the probability of a change in land use at a neighboring location?

6. What is the role of scale in the observed changes in land use in southern Indiana?

7. What are some key ways of testing our theoretical models? How do initial assumptions impact model outcomes? Can differing assumptions lead to observationally equivalent outcomes?

Dual Methodological Approach

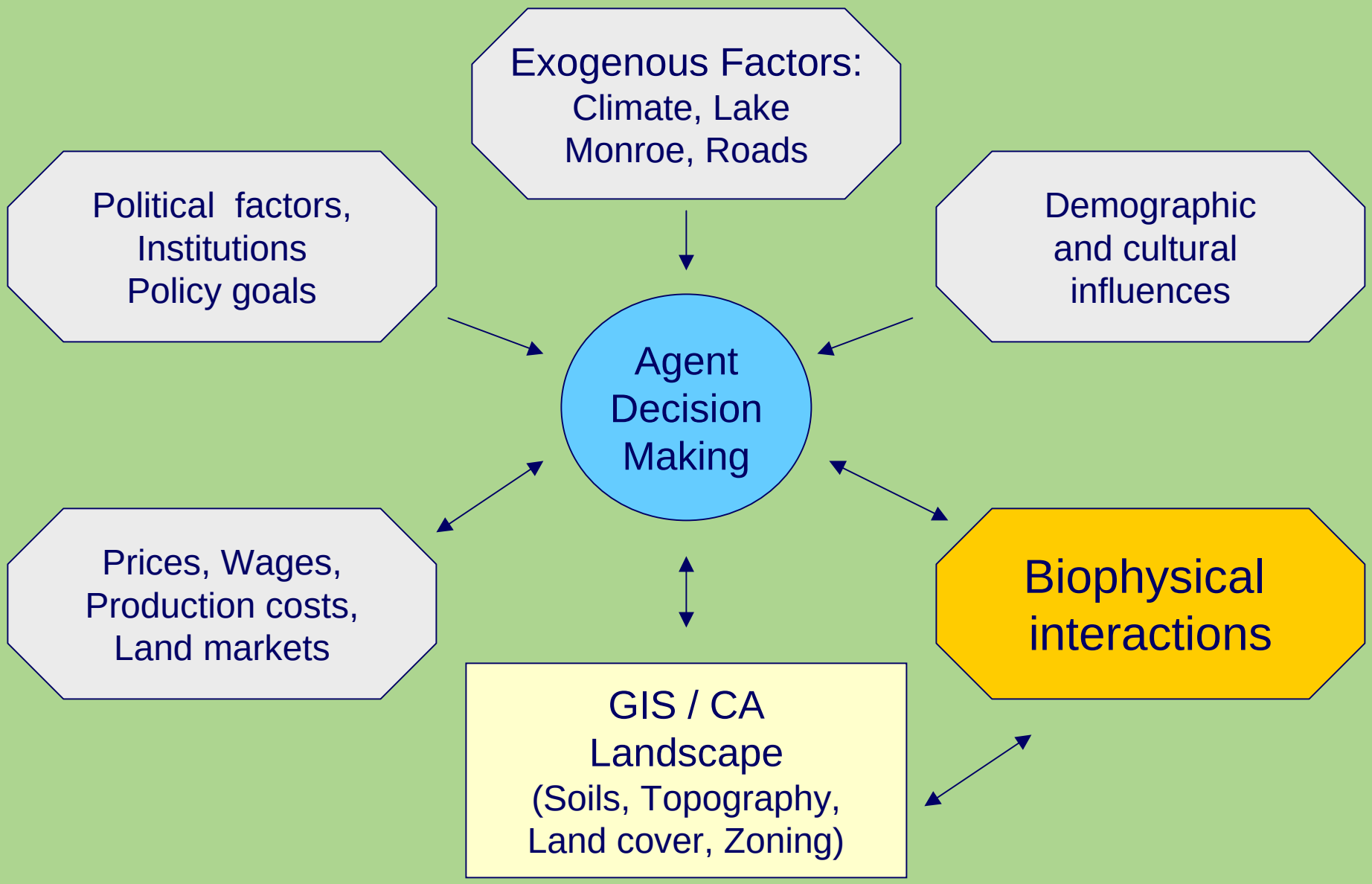
Empirical Agent-Based Modeling
Econometric Analysis

Rich datasets for both Indiana and Brazil are available for both modeling strategies

Comparisons: What are the strengths, weaknesses and unique capabilities of each modeling approach?

Complementarities: Statistical regression analysis will inform ABM model development

Modular Model Structure



Agent Decision Making

Incomplete Factorial Design

- Preference Specification
- Information Processing
- Decision Strategies
- Learning Models

Agent Decision Making

Incomplete Factorial Design

Preference Specification

- Goods
- Functional Form
- Constraints
- Exogenous Factors

Agent Decision Making

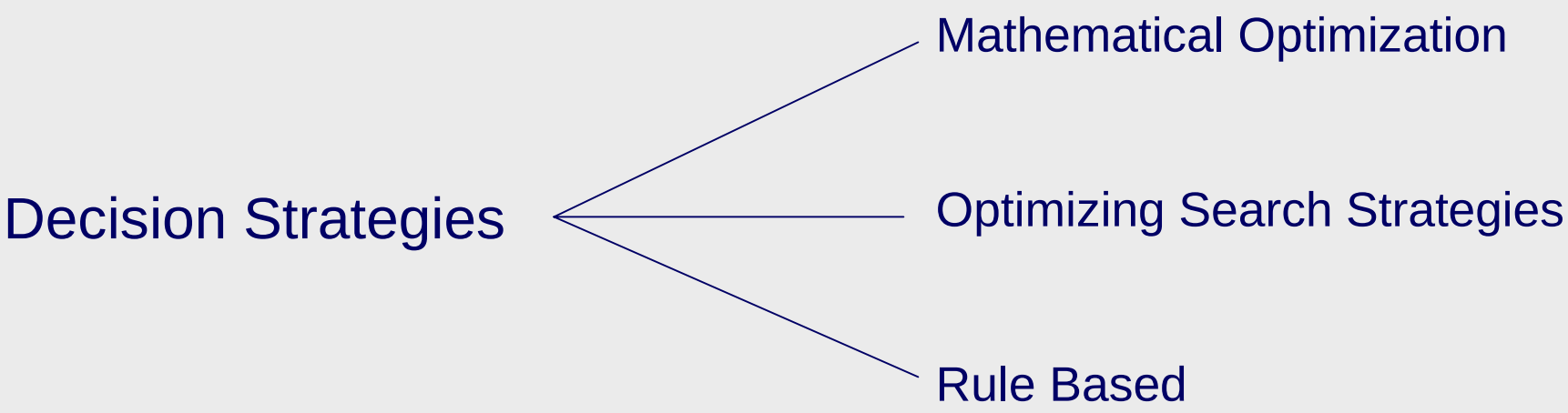
Incomplete Factorial Design

Information Processing

- Time Horizon
  - Myopic ⟷ Infinite
- Information Signal
  - Noisy ⟷ Perfect

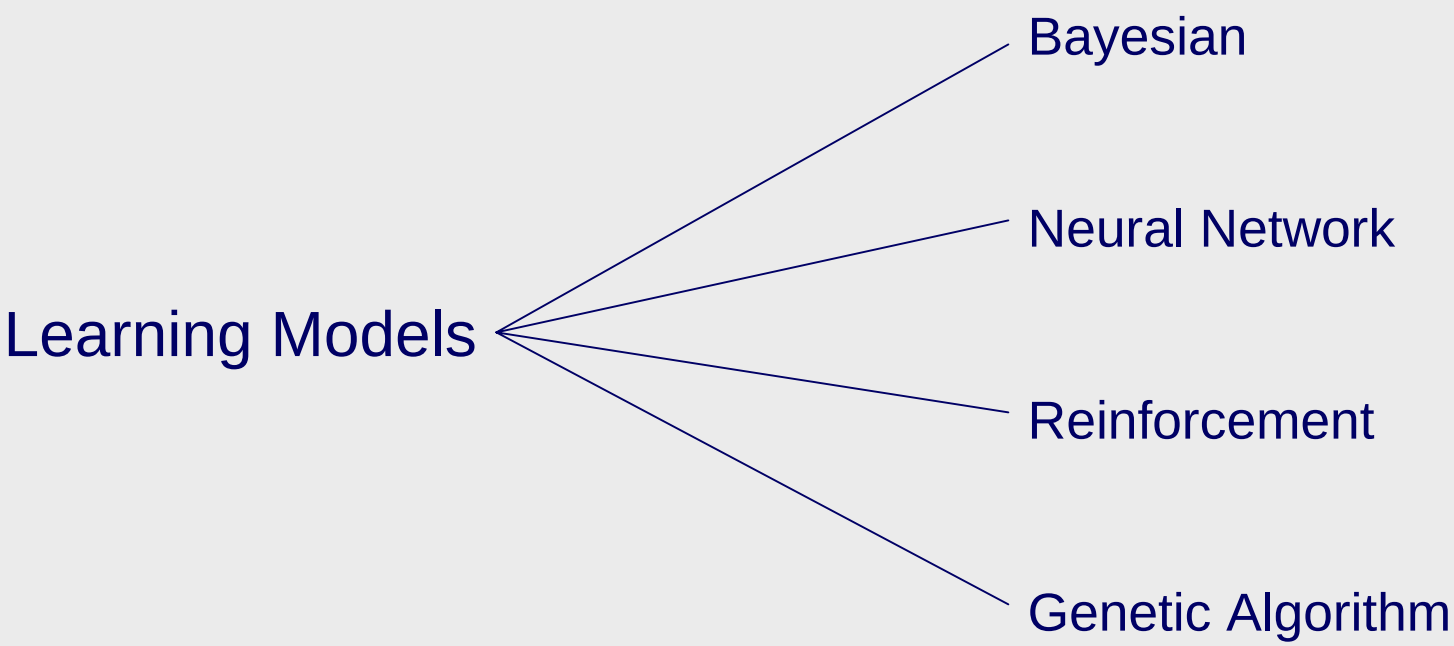
Agent Decision Making

Incomplete Factorial Design



Agent Decision Making

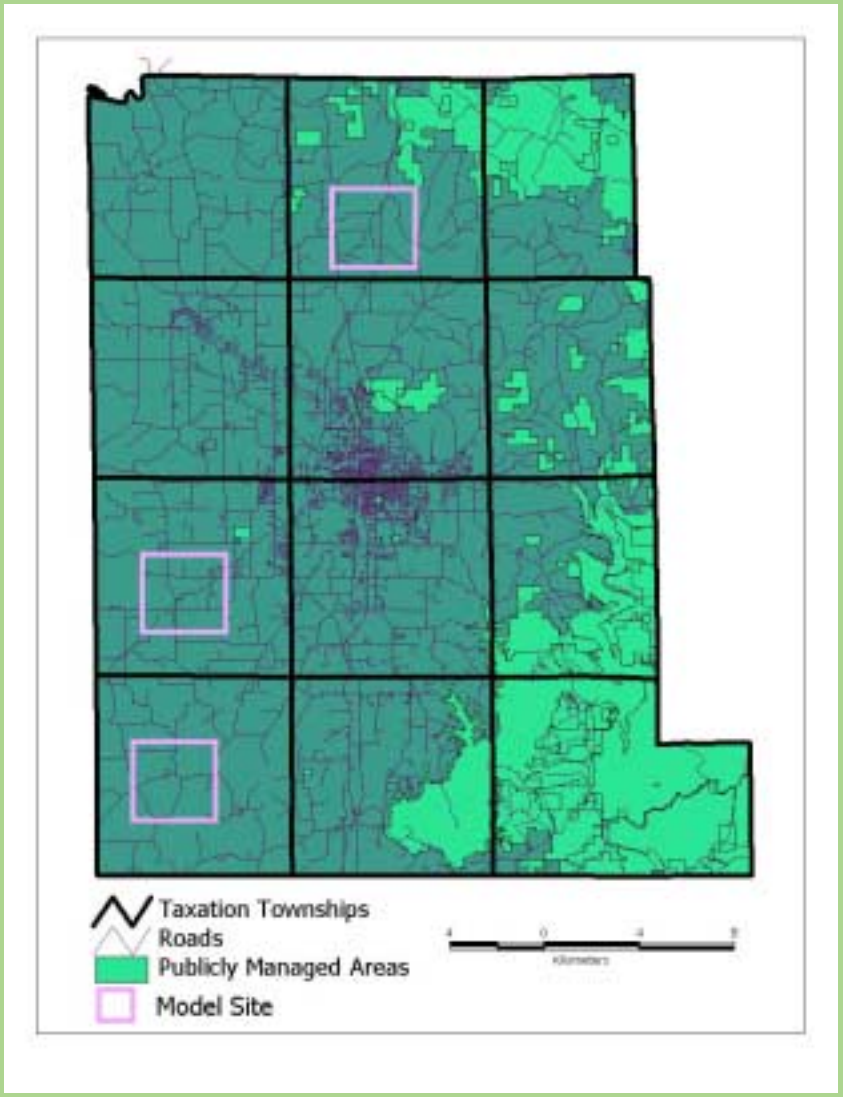
Incomplete Factorial Design



Evaluating Agent Decision Making

- "Comparative static" and "comparative dynamic" analysis
- Academic literature on determinants of land-owner decision making
- Survey of 250 Monroe County land owners
- Additional interviews with local decision makers
- Planned experimental work

Spatial Sampling Strategy: 1939-present
Sample requirements

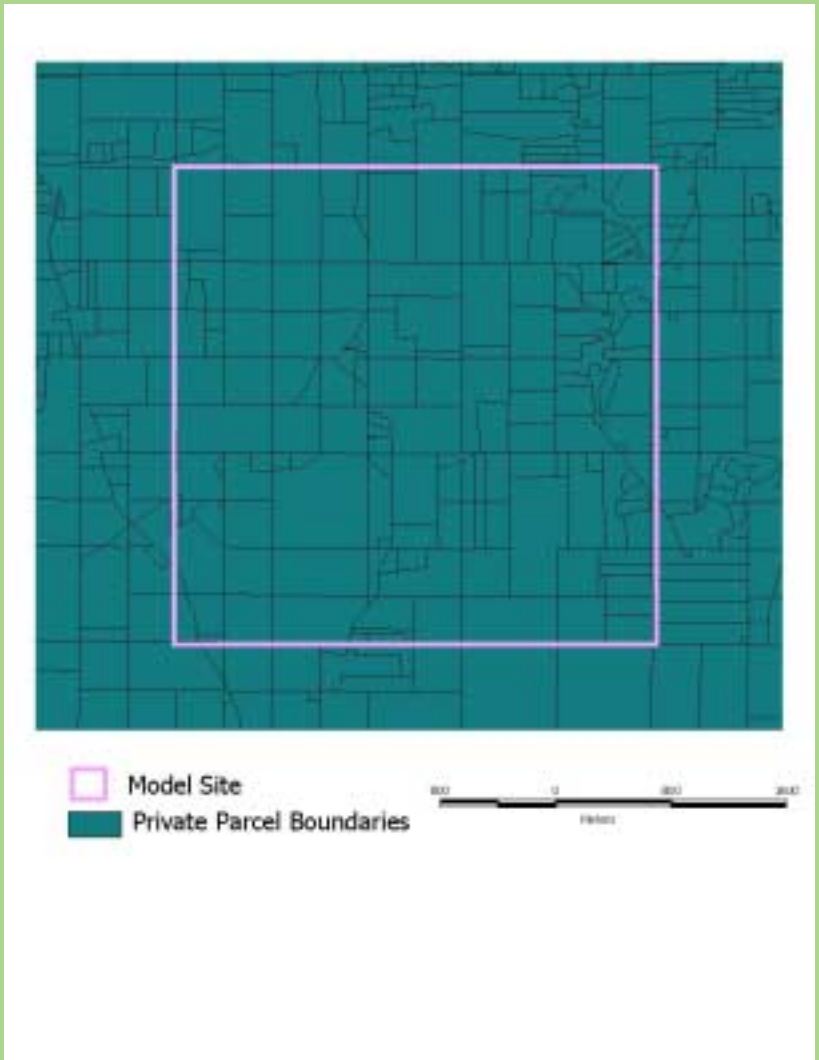


Three modeling zones

- Represent major land use / covers and change processes in Monroe County
- Stratified by topography, accessibility, and degree of development
- Models will be run for each zone independently

Modeling Zone Detail

Sample modeling zone



- Sufficient spatial resolution to characterize parcel level pattern and composition
- Sufficient spatial extent to characterize landscape level metrics
- Need to minimize number of agents and parcels to reduce processing requirements

Validation via Composition and Pattern

- Composition should be a minimum hurdle
- Pattern is important for several reasons:
  - Links between landscape patterns and economic function
  - Pattern can vary independently from composition
- Absolute location should be de-emphasized
  - Spatial processes do not map one-to-one with location
  - Stochasticity can lead to economically insignificant differences in location

Landscape Metrics

- Landscape Composition: economic and ecological function
- Mean Patch Size: impacts of externalities, optimal spatial scale
- Number of patches: impacts of externalities, landscape connectivity, transportation efficiency

Landscape Metrics, cont.

- Area-weighted mean shape index: *Measures deviation of a parcel from a compact, square shape.* Impacts of externalities
- Contrasting edge density: *Ratio of conflicting borders to total class area*. Index measure of externality impacts
- Total contrasting edge: Measures total externality damage or benefits

Landscape Metrics, III

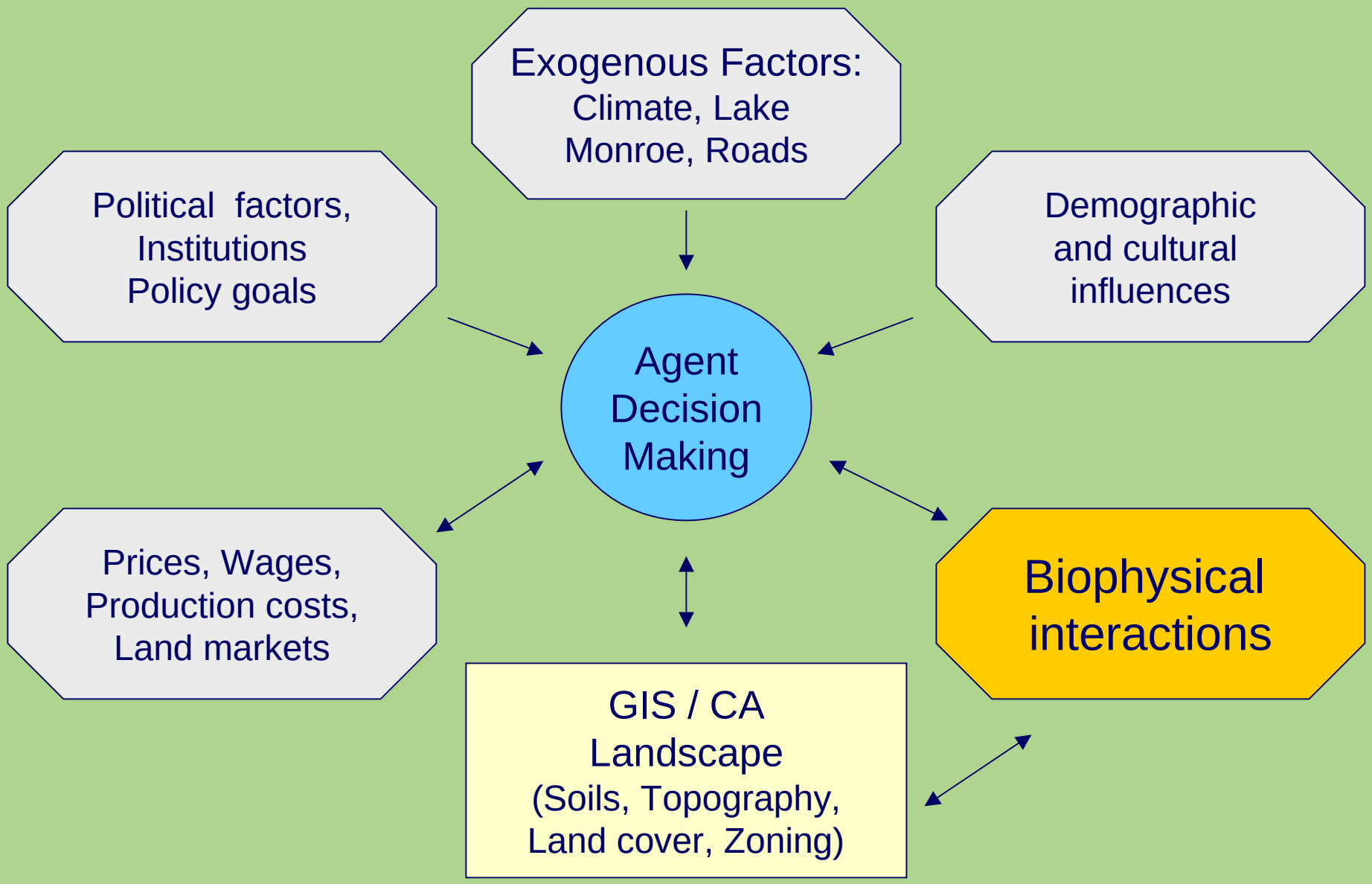
- Mean nearest-neighbor distance: Efficiency of transportation networks, impacts of sprawl
- Average product / Average core area: Measures impacts of externalities. Closely correlated with edge density and fractal dimension

Statistical Analysis
1950 – Present

- Inductive: statistical patterns -
  - Components of land-use change
    - Correlating changes in forest cover with changes in labor and land markets
  - Scale effects
    - Regional and national structural changes and local land use

- Deductive: hypothesis testing -
  - Framework to follow biocomplexity

Modular Model Structure



Econometrics as a complement to ABM

- Data from actual, historical events
- Parsimonious models
  - Changing land rents and opportunity costs of agricultural production
- Statistical hypothesis testing
  - Ranking of relative effects
  - Sign and magnitude of effects
- Links with ABM
  - Calibration of ABM

Econometric Modeling: *Hypothesis*

Land use change is a function of:

Employment

Urbanization

Migration

→

Change from primarily agricultural use to rural residential