MODELING PROCESSES AND PROJECTIONS OF LAND USE CHANGE

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LCLUC Program Priorities

- Forcing Factors
- Responses and Consequences
- Modeling and Implications
- Techniques and Methods
- Transitioning to Operational Domain
- Regional Priorities

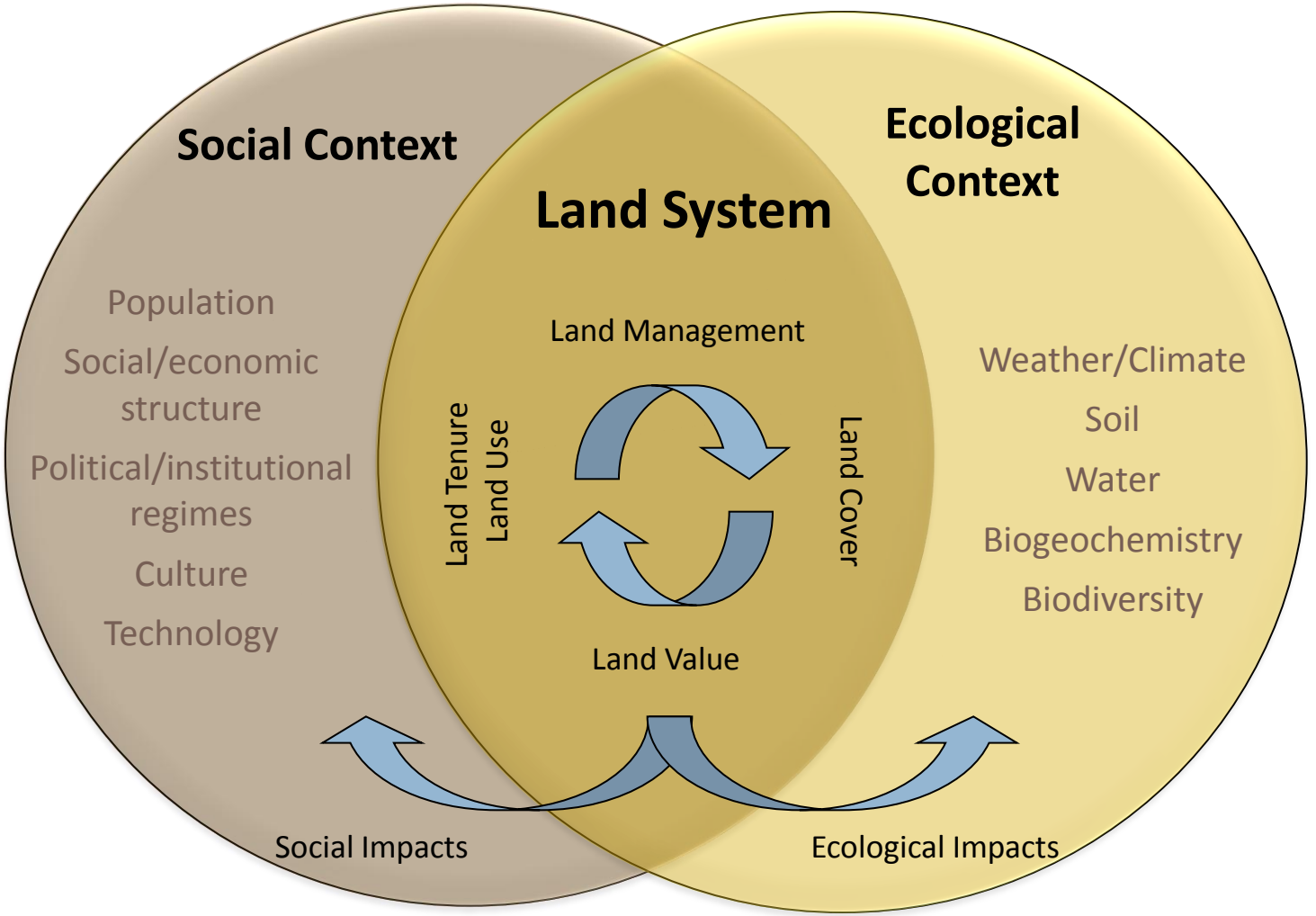
from lcluc.umd.edu

Themes in GLP

- *Theme 1*: Dynamics of Land Systems
- *Theme 2*: Consequences of Land System Change
- *Theme 3*: Integrating Analysis and Modeling for Land Sustainability

From GLP Science Plan, IGBP/IHDP, Ojima, Moran, et al., 2004

Linking Land Use & Earth System Process



Land Change Models

- Encode our knowledge of process
- Help test pattern-process links
  - Can help us examine feedbacks between ecosystem structure/function and human actions
- Provide dynamic landscape information for input to ecosystem process models
- Test alternative futures under various hypotheses, policies, practices, and incentives
- Make projections of future landscape patterns

Scale and Timeframe

			Timeframe for Projection	
Spatial Extent	***Spatial Resolution***	**Short (5yr)**	**Medium (20yr)**	**Long (50yr)**
Local	10 - 100m	**XXX**	XX	X ?
Regional	100m - 1km	**XXX**	**XXX**	XX
National	1-10km	X?	XX	**XXX**
Global	>10km	X ?	XX	**XXX**

Dimensions of Land Change Models

Key

A-Time series statistical models, STELLA models with no human dimension

B- Time-series models with human decision-making explicitly modeled

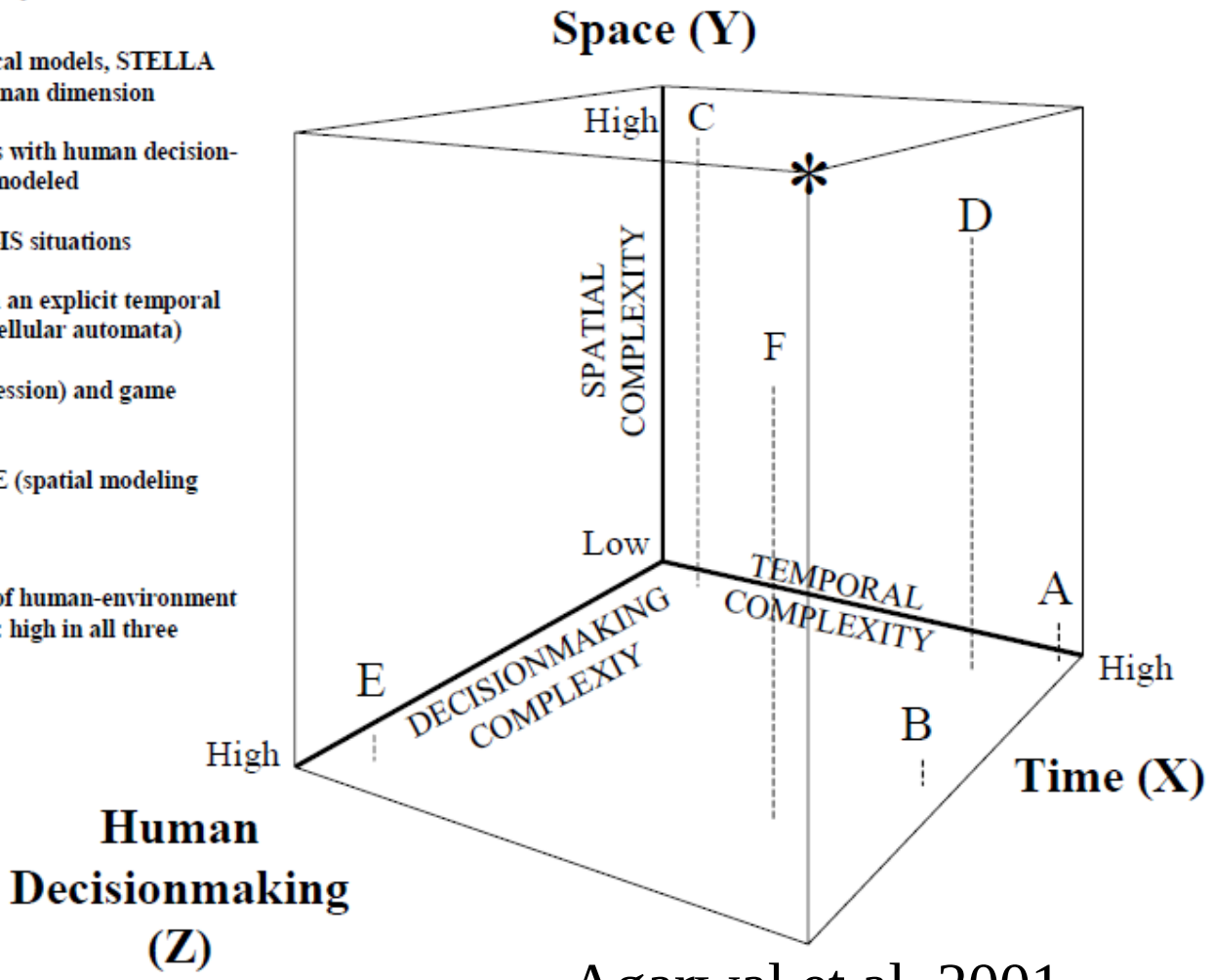
C- Most traditional GIS situations

D- GIS modeling with an explicit temporal component (e.g., cellular automata)

E- Econometric (regression) and game theoretic models

F- SWARM and SME (spatial modeling environment)

* The ultimate goal of human-environment dynamic modeling: high in all three dimensions



Agarwal et al. 2001

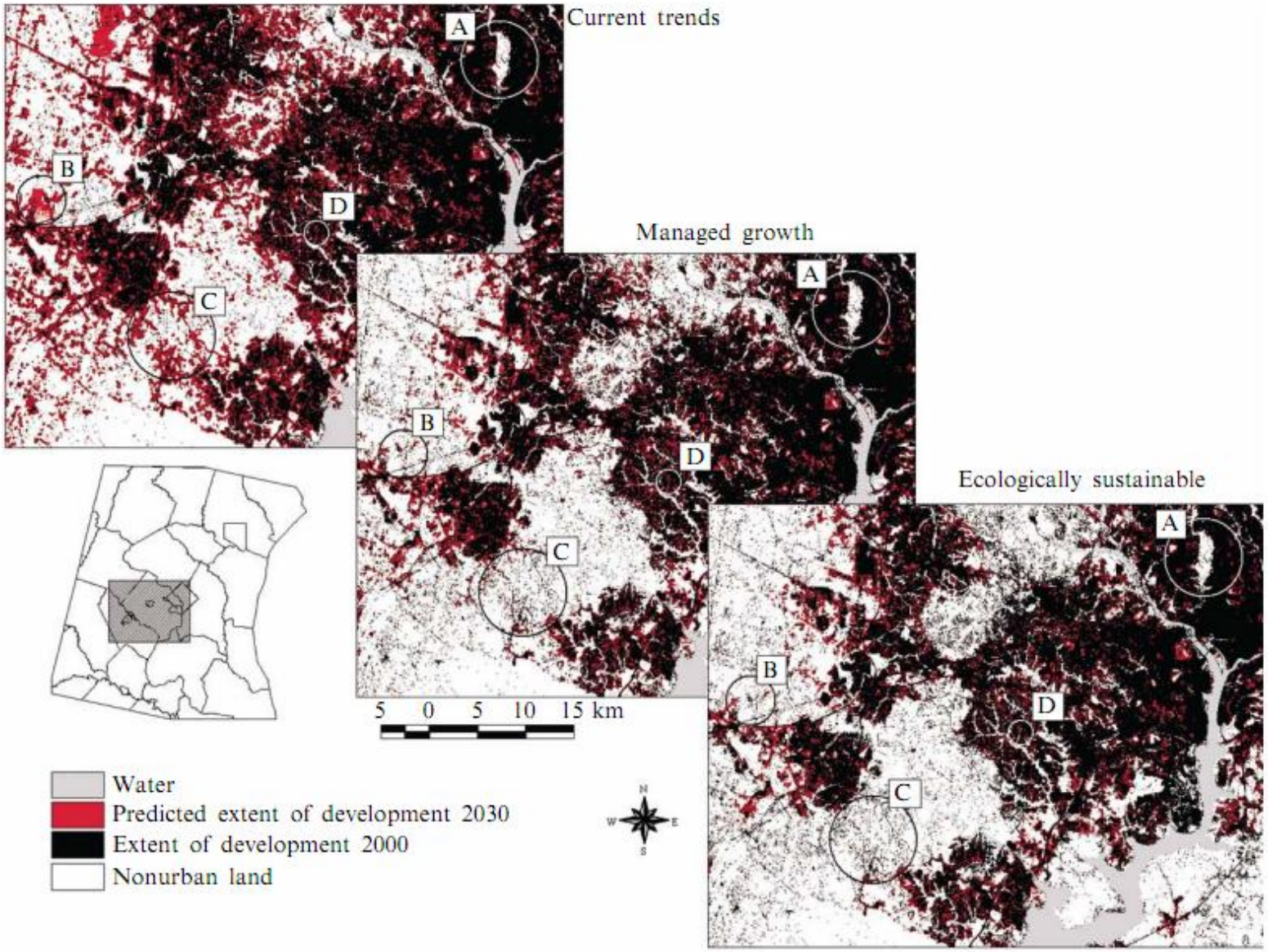
Why represent human decision making?

- We cannot afford to ignore ecosystems and habitats that are occupied by people.
- Human decisions shape landscapes, even when those decisions are to set them aside for preservation.
  - Because human decisions are also shaped by landscapes, there are feedbacks that can produce complex dynamics.
- By representing decisions, a model includes mechanisms that represent the *processes* by which humans actions are motivated and affect the landscape through land use and management.

Non-Behavioral Geographical Models

- Focus is often on reproducing or predicting patterns without explicitly representing the processes by which patterns come to be.
  - Useful for spatial forecasting and spatial scenarios, but do not represent decision processes
- Based on specifications of demand for land uses and spatial patterns of land suitability and availability.
  - Examples: LTM (Pijanowski et al. 2002), geostatistical (Brown et al. 2002)
- Some involve dynamic interaction rules learned based on historical patterns
  - Examples: SLEUTH (Jantz et al. 2010), DINAMICA (Soares-Filho et al. 2006)
- Land-use and LU-change processes are either not represented explicitly, or represented with non-behavioral models (like CA transitions)

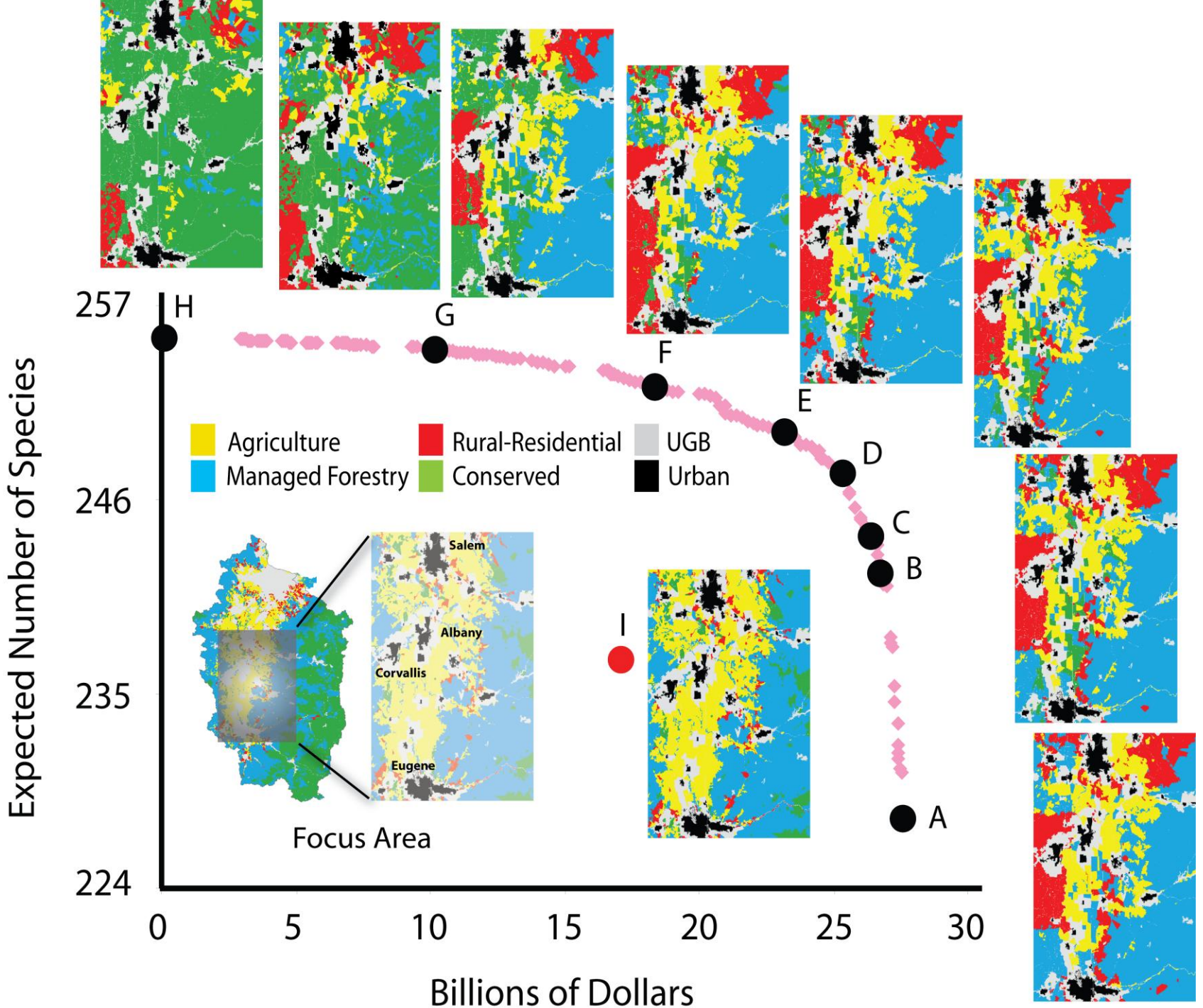
Growth Scenarios in DC Area



Jantz et al. 2003. *Env Plan B*

Econometric Models

- Estimate model parameters from spatial and temporal data, including multiple-levels
- Usually assume profit or utility maximization
- Economic theory informs explanatory variables and structure of relationships
- Econometric approaches lie at the heart of many regional and national policy assessments (e.g., INVEST)
  - Seto and Kaufmann 2003, *Land Economics*.
  - Nelson et al. 2008, *PNAS*; Lubowski et al. 2006, *J Env. Econ and Mgt*.


Expected Number of Species
257
246
235
224
0
5
10
15
20
25
30
Billions of Dollars
H
G
F
E
D
C
B
A
I
Agriculture
Managed Forestry
Rural-Residential
Conserved
UGB
Urban
Salem
Albany
Corvallis
Eugene
Focus Area

Issues in Representing Human Processes

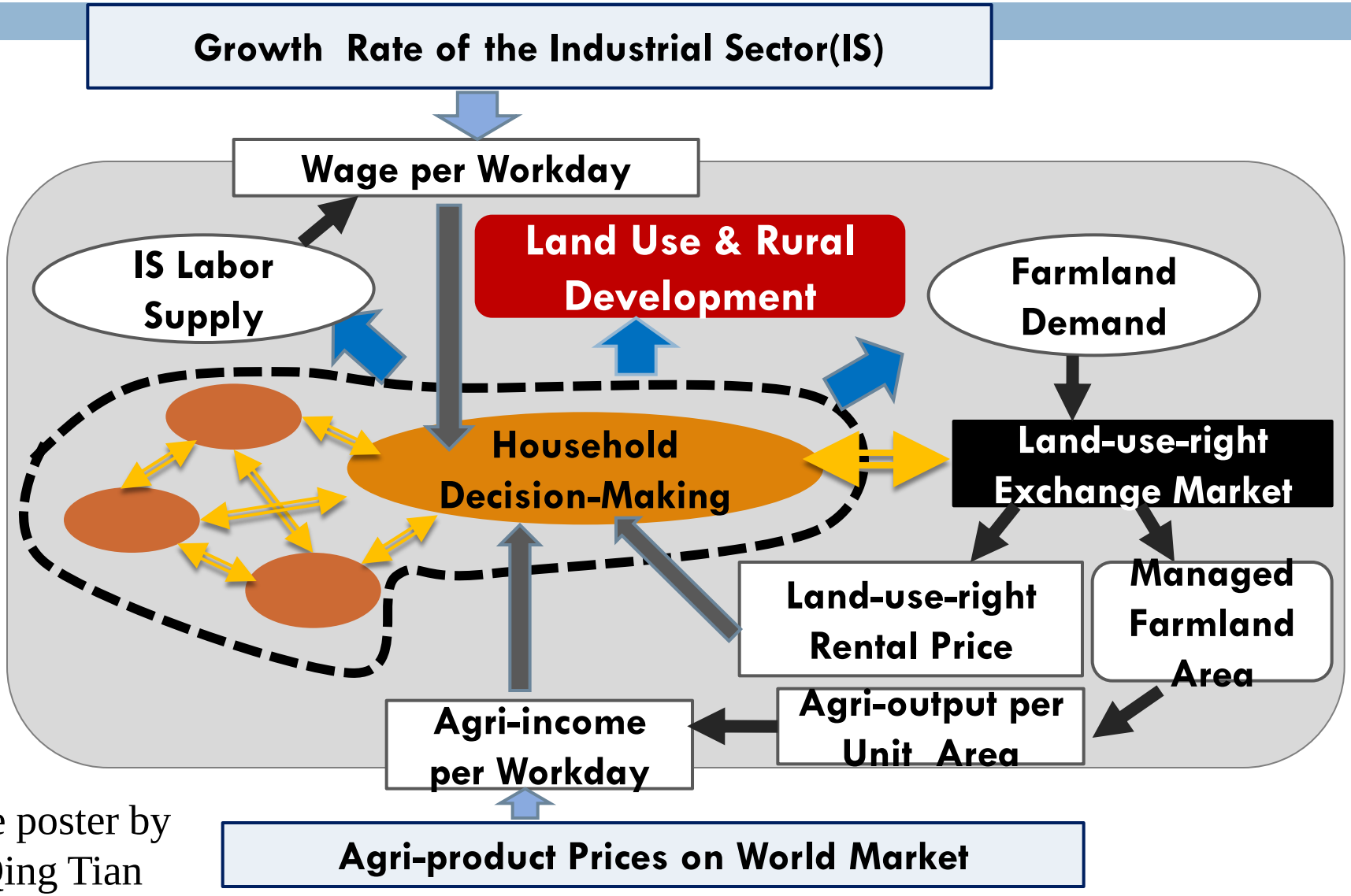
- Various decision-making strategies
  - Rational actors, Bounded rationality, Satisficing
- Heterogeneity – not all people are alike
- Adaptability – people respond to changing contexts
- Interaction – people learn from each other
- Time and space scales – multiple processes acting at multiple scales
- Stochasticity – we don't know everything deterministically

Process Simulation Models

- Focus is on describing the process dynamics of change.
- Predictions can be difficult to interpret in presence of non-linear dynamics;
  - Multiple equillibria, path dependence
- Useful for identifying possible futures, linkages, lever points, cross-scale interactions

- System dynamics
  - Useful for aspatial models, or with few well-mixed regions.
  - Process descriptions in terms of stocks and flows
- Agent-based models
  - Useful where heterogeneous actors interact
  - Process descriptions in terms of agent decisions

Human Well-Being in Poyang Lake Region

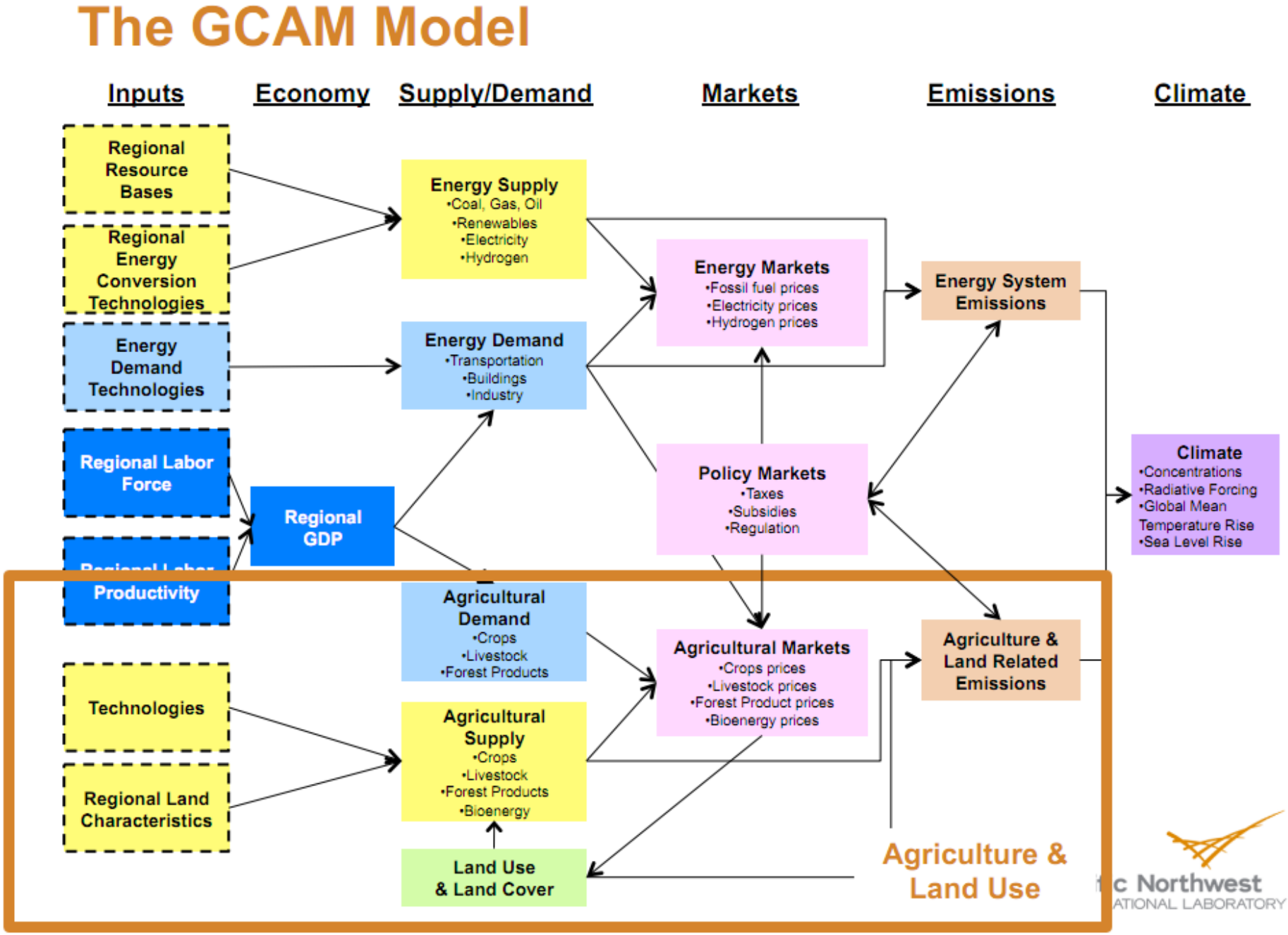


See poster by Qing Tian

Integrated Modeling

- Ultimately, an important benefit of modeling land-use change is the ability to integrate with other Earth system models.
- Integration can happen across multiple systems and at different scales
  - Global scale climate assessment models
    - Two-way links with climate models
  - Region-to-local scale ecosystem/economic integration
    - Two-way links with hydrological, biogeochemical, economic models

Global scale



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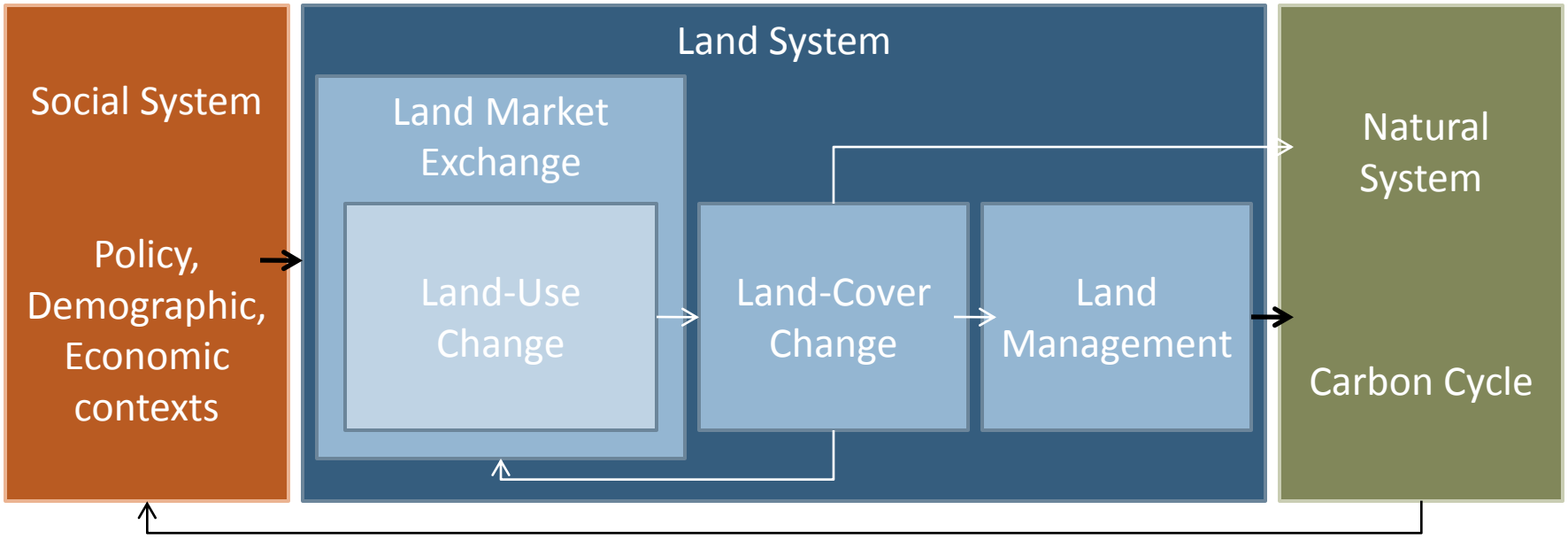
SLUCE II Conceptual Model

Local to regional scale



Scenarios

Agent-Based Model

Biome-BGC

Resolution = 30m

Challenges

- Understand more about land-management choices and their effects.
- Synthesizing lessons learned from modeling projects all over the world and with many different approaches.
- Scale integration of multiple models.
  - ABMs are still largely focused on local/case applications.
  - Ecosystem and climate process models tend to be regional to global and don't deal well with heterogeneity
  - Time scales and variability of integration are challenging
- Developing metrics of and improving "skill" in forecasts that are still process based.
- Complexity in land-change processes.

NRC Modeling Study

- Goals
  - Assess the analytical capabilities and science and/or policy applications of existing modeling approaches.
  - Describe the theoretical and empirical basis and the major technical, research, and data development challenges associated with each modeling approach.
  - Describe opportunities for improved integration of land observation strategies (including ground-based survey, satellite, and remote sensing data) with land-change modeling to improve land-change model outputs to better fulfill scientific and decision making requirements.

A Community Land-Use Model

- Idea within LCLUC community to contribute to global change research through development of a model or models of land use and cover that couple to and interact with general circulation models and ecosystem process models.
- Such models would build on the experience of the community.

Thank You