Comparison of empirical methods for building agent-based models in land use science

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Pedro Ribeiro de Andrade, 2008/02/13


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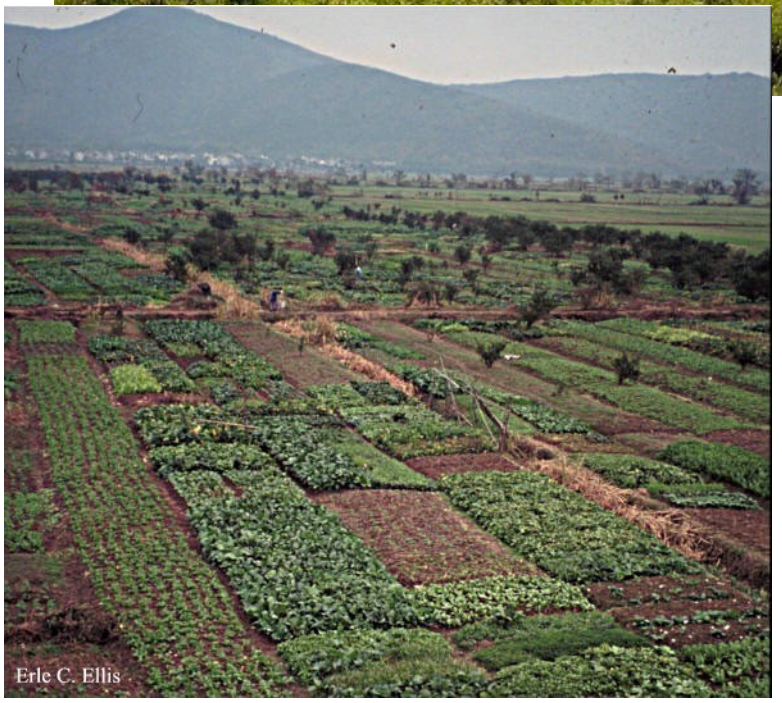
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Simulation

- integrating **multiple disciplinary perspectives**
- training intuition about the **causes of observed patterns** and dynamics
- testing for plausibility of **candidate explanations**
- developing conceptual frameworks for empirical **data collection**
- creating **scenarios** about future system states
- testing possible effects of **alternative policy** or management interventions

Agent-based modeling

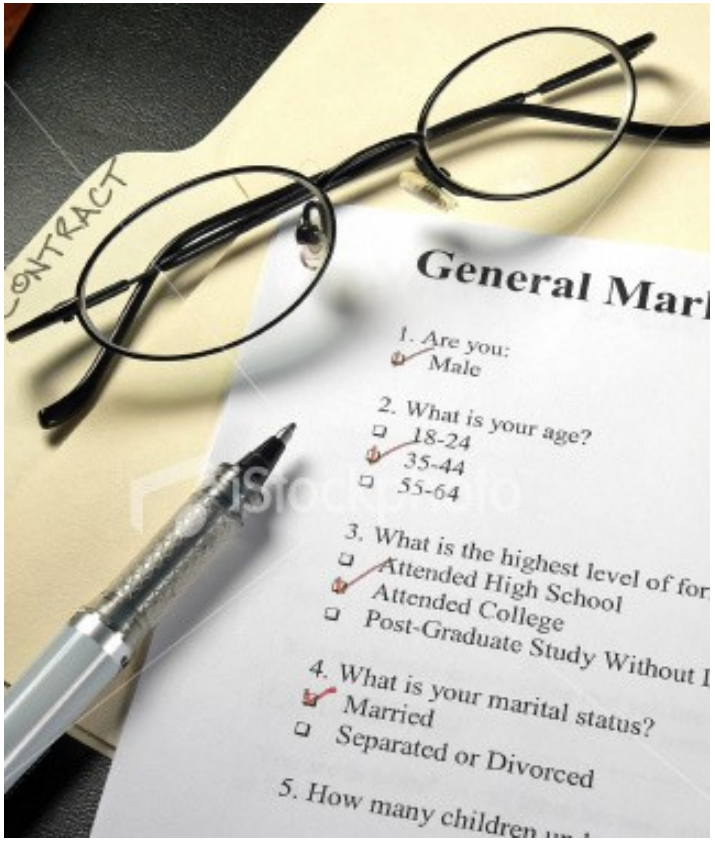
Formalize **simple to complex** representations of the **behavior** and cognitive processes of **actors** who make land and resource use decisions

- Document the **macro**-phenomena
- Inform **micro**-process modeling

Typology for data collection

- Sample surveys
- Participant observation
- Field and laboratory experiments
- Companion modeling
- GIS and remotely sensed spatial data

Sample Surveys



Quantitative methods for collecting data using mostly closed-ended questions.

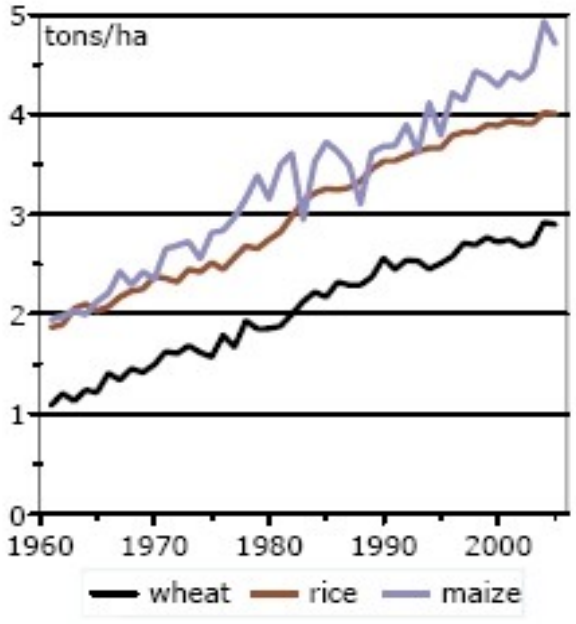
Questions addressed

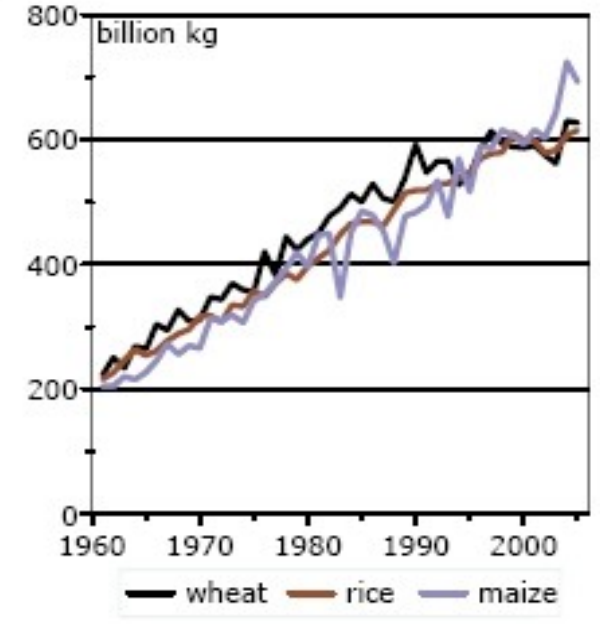
- Provide information on the **distributions** of characteristics, beliefs and preferences within a population of agents;
- **Estimate** behavioral models based on economic theory;
- Provide rough **estimates** of local-level change variables; and identify constraints on decision-making.

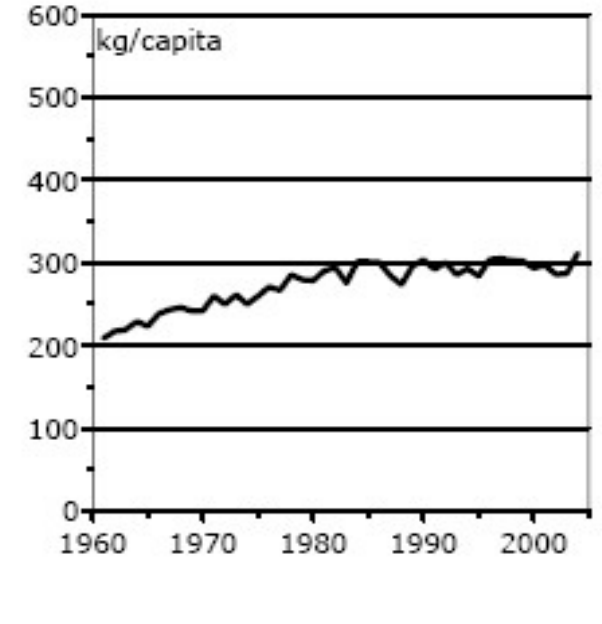
Sample Surveys

Strengths	Weaknesses
• Can be representative of larger population/geographical area	• Generally a snapshot in time, not very suitable to represent temporal variation due to high implementation costs
• Represents heterogeneity in terms of: household composition, resource endowments, and access to services and markets	• Household is usually represented as unitary unit of decision-making, which is unrealistic for some decisions and neglects the intra-household decision-process
• Suitable for application of statistical methods to isolate the effects of behavioral variables	• Statistical methods are based on many structural and technical assumptions and often lack transparency
• If well documented, the data can be shared among researchers; i.e. an 'outsider' can analyze the data	• If designed by an 'outsider' the questions can be biased (Chambers 1997)
• Can be combined with a community survey or group surveys to capture additional aspects	• Data quality depends on design and implementation (Grosh and Glewwe 2000)

Case Study: Simulating soil fertility decline, population growth, and poverty dynamics in Uganda

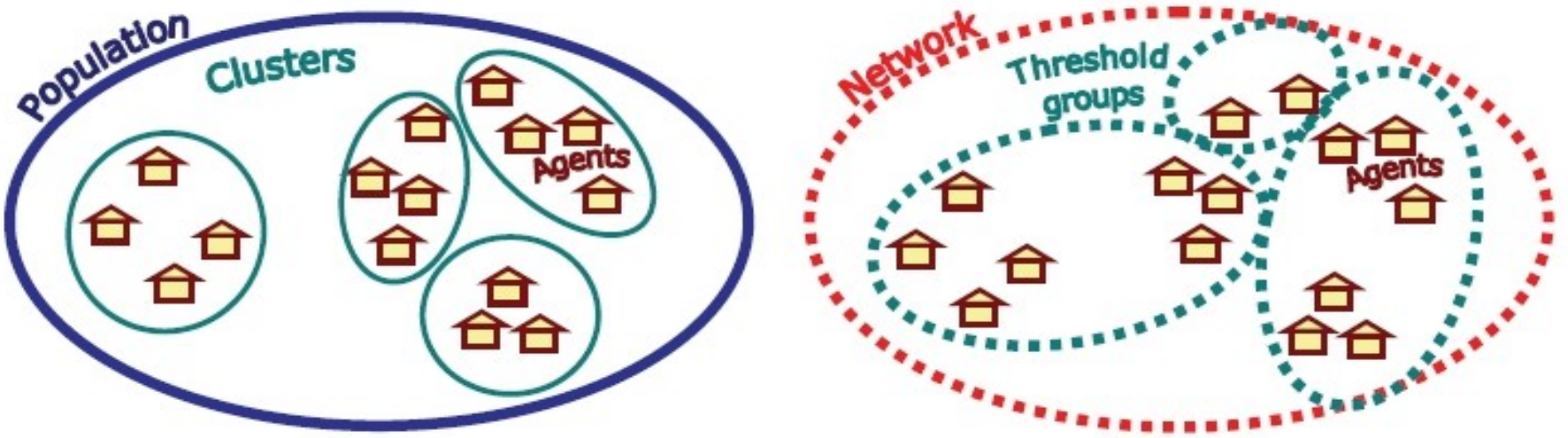






Source: (Schreinemachers, 2006)

Case Study



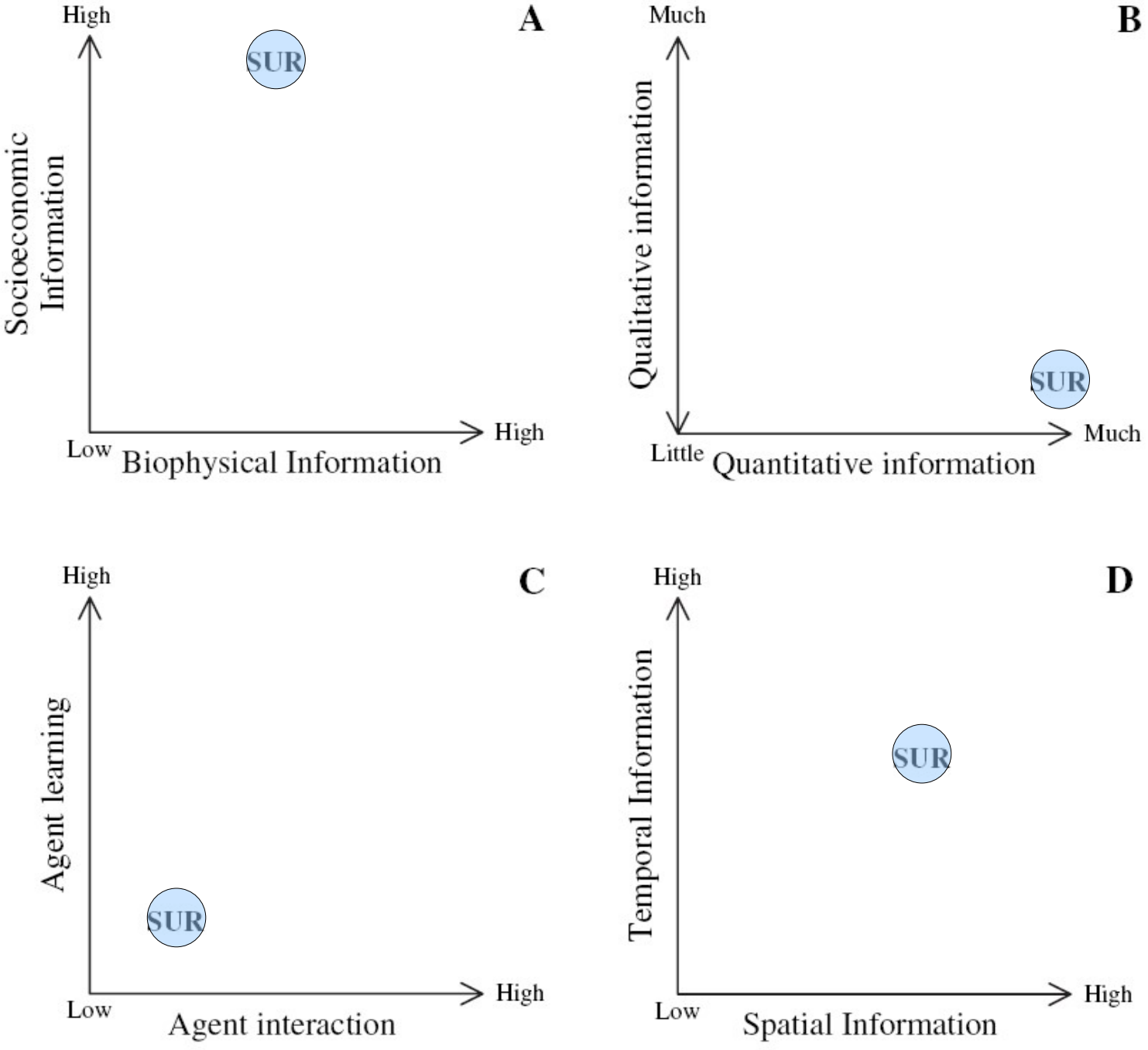
1. land quantity and quality;
2. labor quantity (household size) and quality (sex and age composition);
3. livestock quantity (number of animals) and quality (species and age);
4. quantity of permanent crops (ha of coffee) and quality (age of plantation);
5. membership to threshold groups determining the access to innovations.

communication => spread of innovation

Maximization of expected utility

Source: (Schreinemachers, 2006)

Sample Surveys



Participant Observation

- identify the key agents in a system
- generating plausible explanations for the actions and interactions of agents

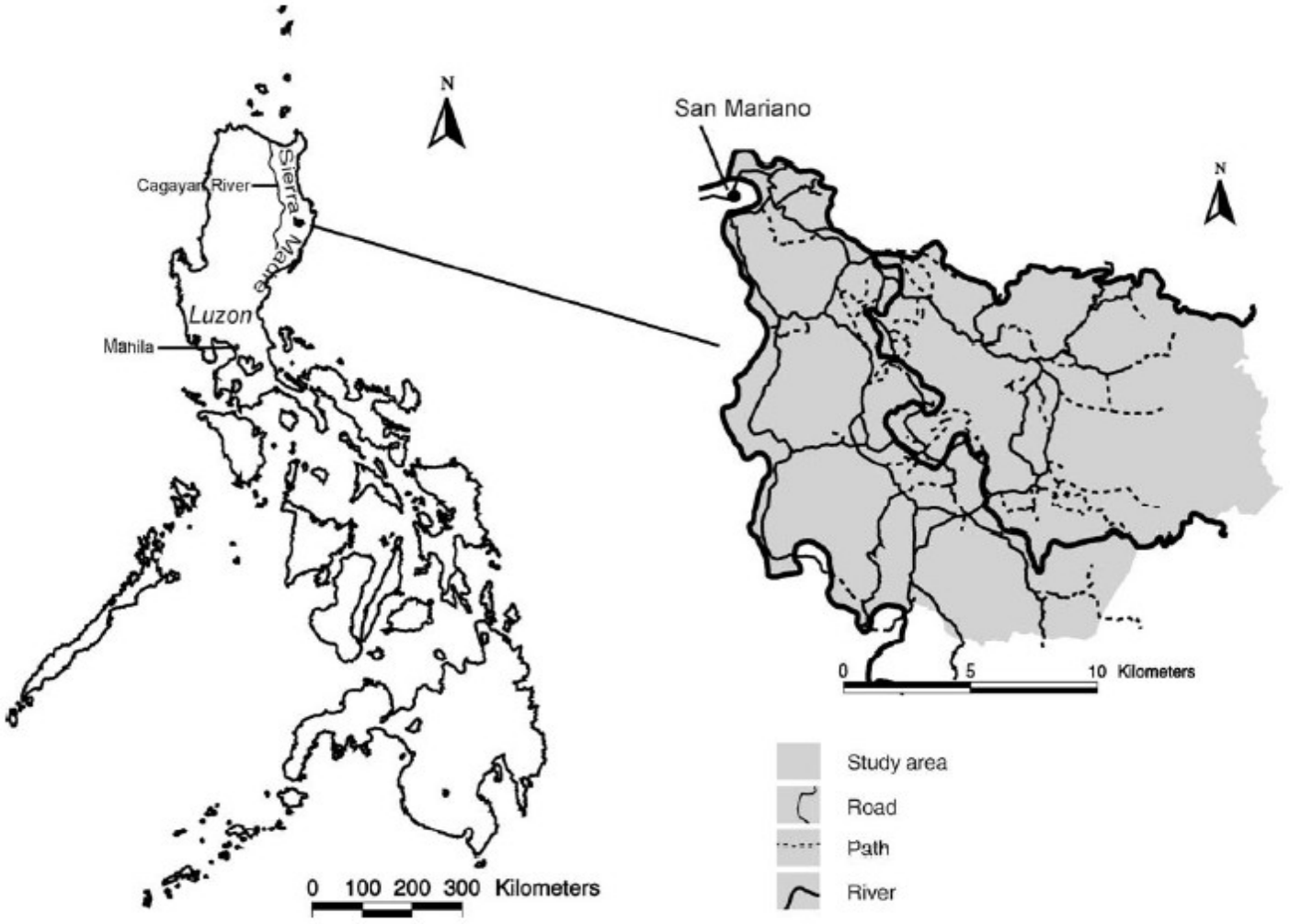
Questions addressed

- the **driving forces** in the system;
- how actors in the target system **conceptualize** their situation;
- the importance of **contextual** (e.g. cultural) and/or temporal dynamics;
- how individuals **influence** the social system, and vice versa;
- the structure and functioning of local social networks, including the way that **collective decision-making** is carried out

Participant Observation

Strengths	Weaknesses
• Captures detailed knowledge of a local situation concerning a range of issues, including land use drivers from any sub-system: cultural, political, economic, social or other.	• The researcher goes into the field without specific hypotheses to test, or questions to answer (not theory-driven).
• Can identify how people conceptualize their situation, how they interrelate socially, and how they modify their beliefs and adapt to change.	• Not as repeatable as other collection techniques. Method does not provide quantitative and representative information. Very limited scope for generalizations
• Draws on the researcher's tacit knowledge of how social systems work, as they have time to develop an intuitive feel for the particular system studied.	• There is a possibility that the researcher will be perceived to take sides in local disputes and fail to understand opposing points of view.
	• The method is less suited to answer questions with a strong spatial component, such as where actors carry out specific actions.

Case Study: the effects of land-use policies and programs on biodiversity conservation in San Mariano, Isabela, the Philippines.



Source: (Huigen, 2004)

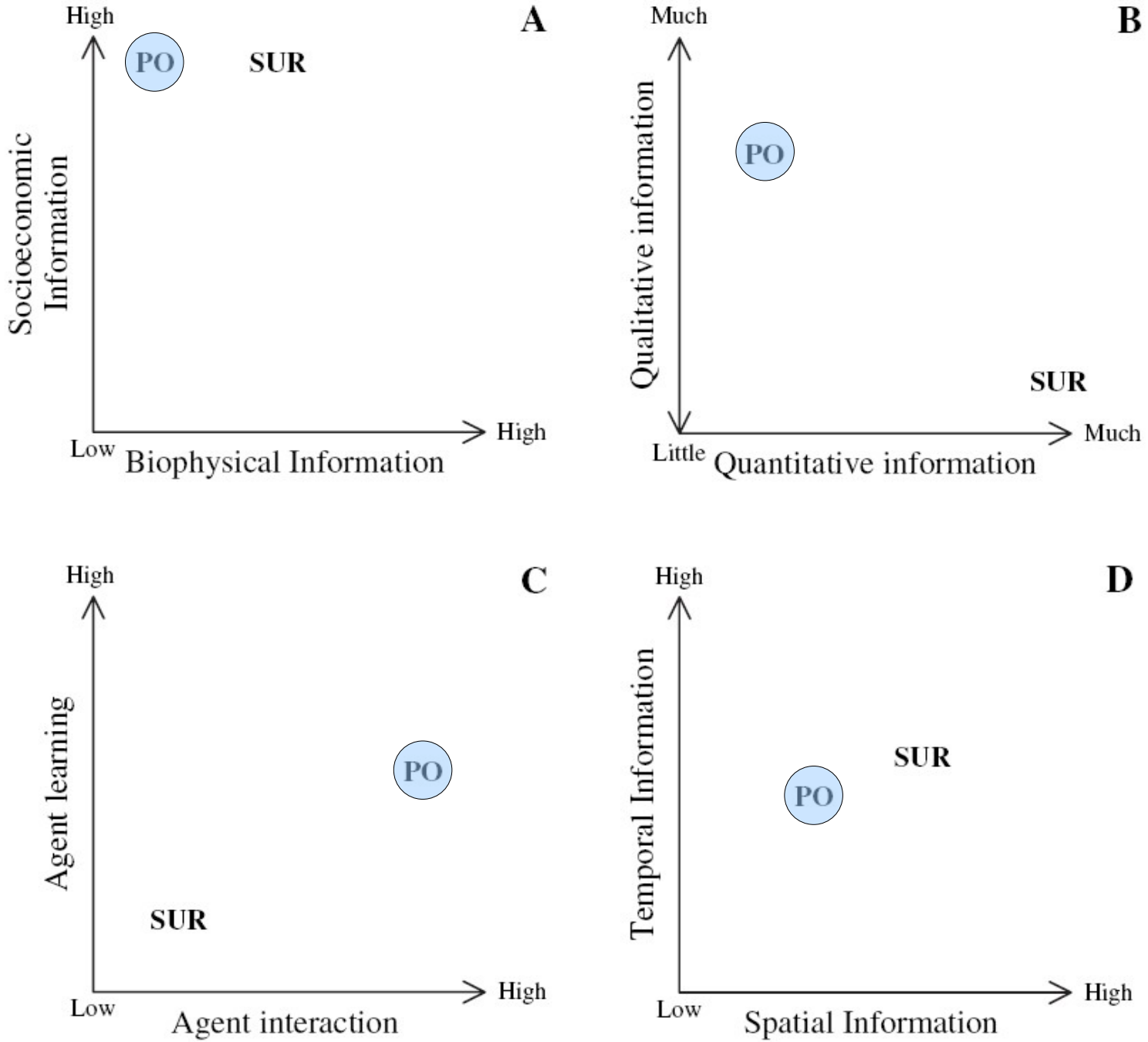
Case Study

Effects of potential land use policies on **illegal logging** along the border of the largest national park in the Philippines.

Researchers **lived for extended periods** with a number of farm households to understand their options and motivations for land use decisions. The researchers created a **snapshot of the farmers' life**, which included ranking different actions.

- Three **categories** of agents (logging companies, crop market actors, and farm households) and variation among the households is defined by **ethnic identity and religion**.
- Each ethnic group has different preferences, rules of decision-making and interaction and strategies for farming.
- Government land use program **scenarios**: development of irrigated areas, introduction of agroforestry and market reforms.

Participant Observation



Field and laboratory experiments

Participants are faced with a **specific problem and certain rules**. Researchers observe the outcomes of the **decision process** and either observe or infer the way the participants go about solving the problem.

Questions addressed

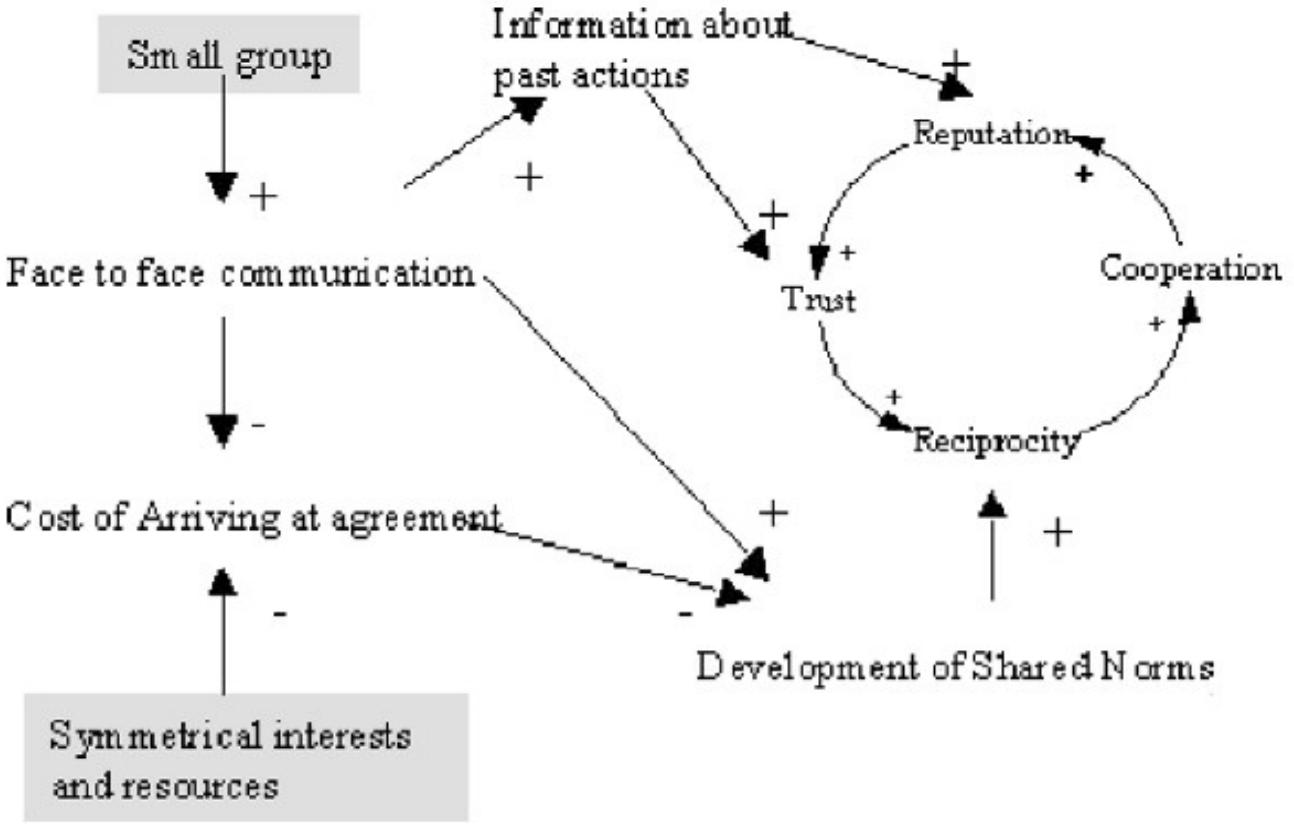
- How are **decisions** about resource use made? Do subjects strategically forecast the behavior of others, or do they rely only on past observations?
- How do specific **rules** of the game affect resource use? For example, using different rules (i.e. treatments) the impact of communication can be quantified
- Which of a number of competing theories can best **explain behavior**?

Field and laboratory experiments

Strengths	Weaknesses
• Can be used to test general models of decision-making and learning processes. • Provides a means to test scientifically the structural or behavioral aspects of decision-making. • Can be used to test the effects of different levels of information, communication, and incentives on behavior.	• Decision-making models being tested are general and used in simplified situations. • Limited number of participants (small sample size). • Omits potentially important contextual elements. • Can be used only for qualitative parameterization of ABM.

Case study: collective action of fishermen and crab hunters on Providence Island, Colombian Caribbean Sea

Case study



Trust: the expectations individuals have about other's behavior

Reciprocity: the norms individuals learn from socialization and life's experiences

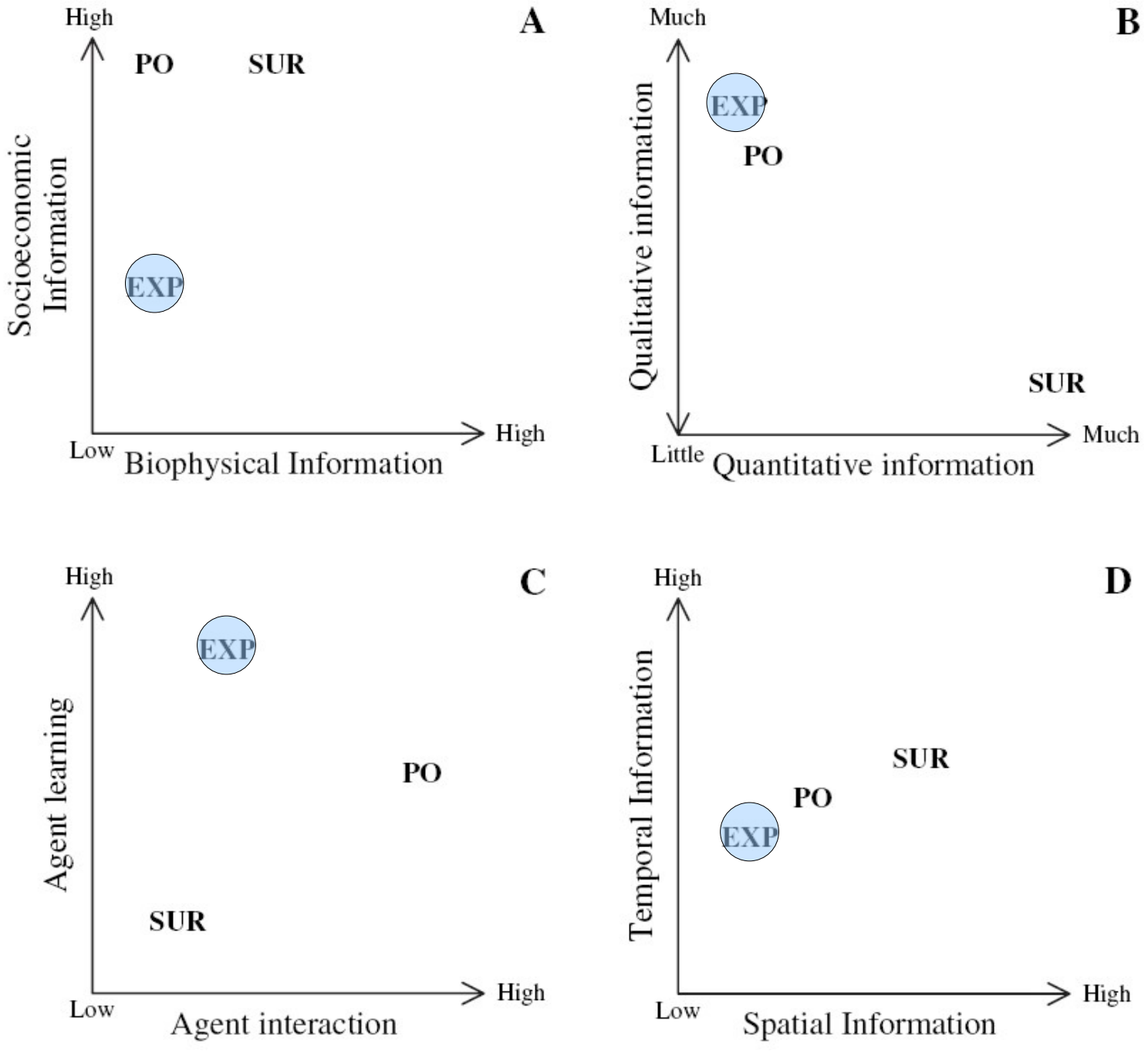
Reputation: the identities individuals create that project their intentions and norms

Source: (Castilloa; Saysel, 2005)

Case study

- **Harvest** from a virtual common resource.
- There is a discrepancy between the **individual and collective interest** measured in monetary incentives.
- The two different treatments in this experiment were **communication and punishment.**
- The experiments with communication converged to the cooperative solution, while punishment performed well initially, but over time produced more defection from cooperative behavior.
- **Simulations** using the model were able to replicate the experimental data for the communication and punishment treatments.

Field and laboratory experiments



Companion modeling

Role-playing games (RPGs) are designed to make use of a **virtual world** and to collect information about the perceptions of stakeholders concerning the situation depicted in the model, including decision-making rules and behavior.

Source: (Gurung *et al*, 2006)

Questions addressed

- Analyze the **interactions** among actors, their institutions, and the natural environment;
- Evaluate the process of **collective decision-making** as observed within the RPG context;
- Improve the stakeholder's knowledge of the **diversity** of perceptions and beliefs held in the community.

Companion modeling

Strengths	Weaknesses
• Role-playing games can be used to confirm known decision functions, both individually and collectively.	• Modeler can play many roles, including being part of the system being modelled.
• Testing of decision-making strategies occurs within the context of the situation being modeled.	• Independent tests of the model and game are difficult to design, given involvement of subjects throughout.
• Facilitates awareness in subjects of the modeling goals and approaches, and allows broader discussion.	• Very costly and time-consuming to devise role-playing situations.
• Provides a structured opportunity to observe agent–agent interactions.	• Limitation in the number of players in any game.
	• Limits to generalizability of the findings.

Case study: access to credit in Northern Thailand

Case study

- Highlands of Northern Thailand
- Study credit access, and subsequent effects of credit access on crop choices and soil erosion

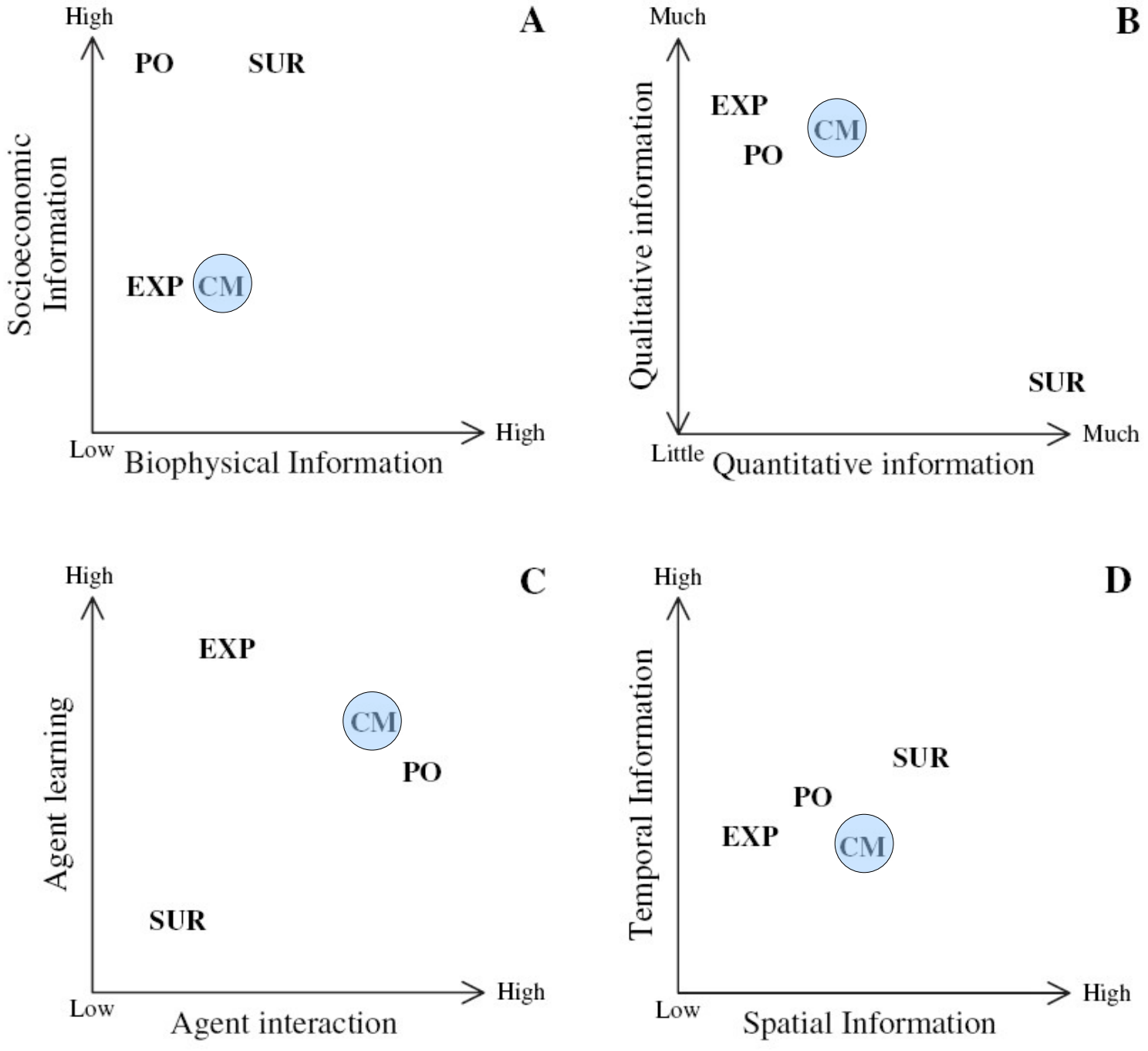
In the model as in the game, the players:

- search for and/or pay back credit each year if needed,
- make decisions regarding off-farm employment,
- allocate crops in their fields,
- harvest products and sell them in the market,
- pay family expenses.

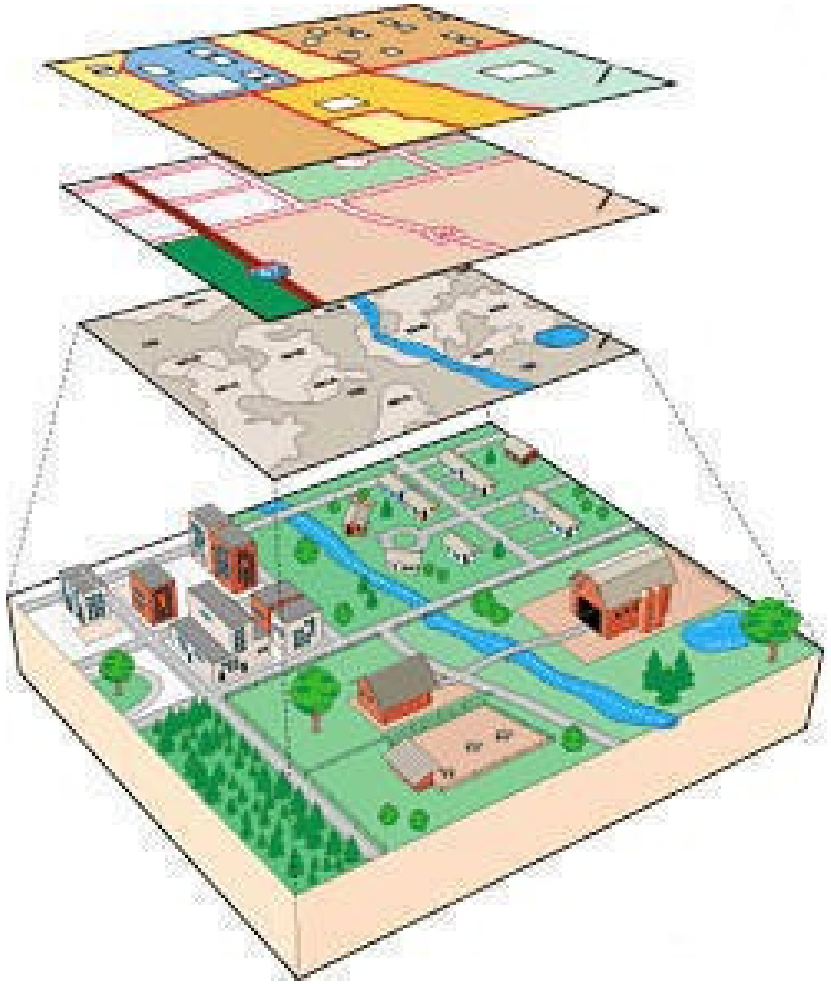
Case study

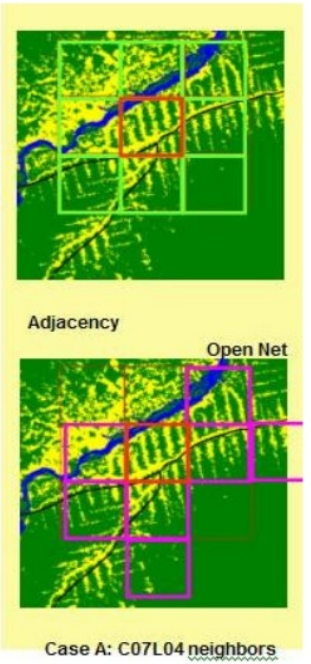
- The RPG sessions allowed us to validate and to better understand farmers' **behavior** as it revealed tacit knowledge about the credit system.
- Post-RPG interviews clarified this behavior and assessed villagers' perceptions of how closely the game **corresponded** to the way they perceived reality.
- The collective discussions provided information about people's **preoccupations** and were used to adjust the model accordingly.

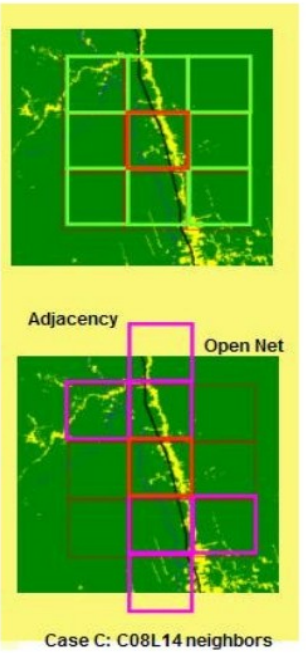
Companion modeling



GIS and remotely sensed spatial data







Spatially explicit data for deriving input variables that reflect the drivers of land use.

Source: (Aguiar, 2003)

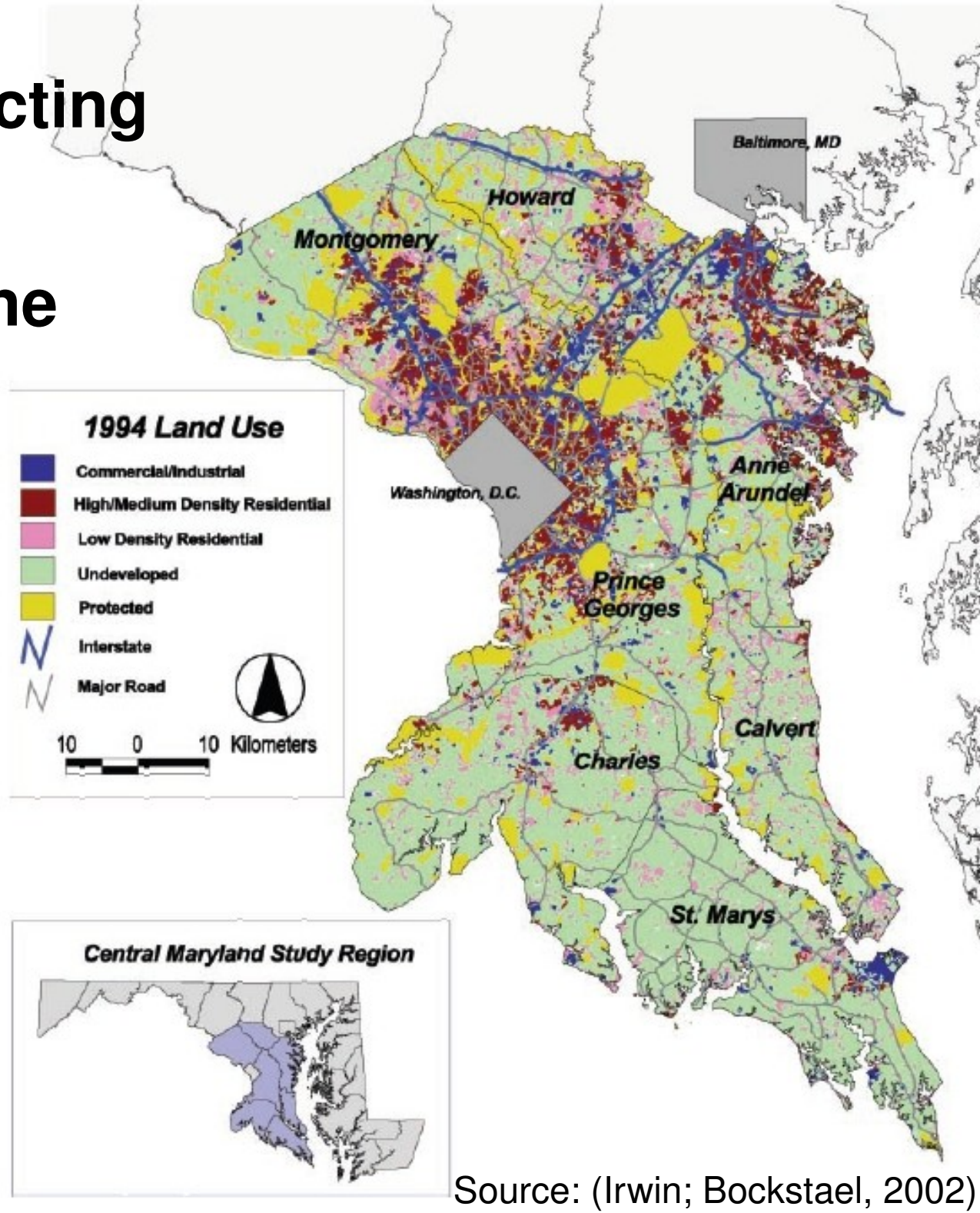
Questions addressed

- What is the relative influence of **biophysical factors**, such as soil fertility, on the probability that an agent will convert from one land use to another?
- How do **biophysical factors** interact to affect particular decisions?
- How do **neighborhood** characteristics affect decision-making?
- How do **spatial relationships** vary over time and space?

GIS and remotely sensed spatial data

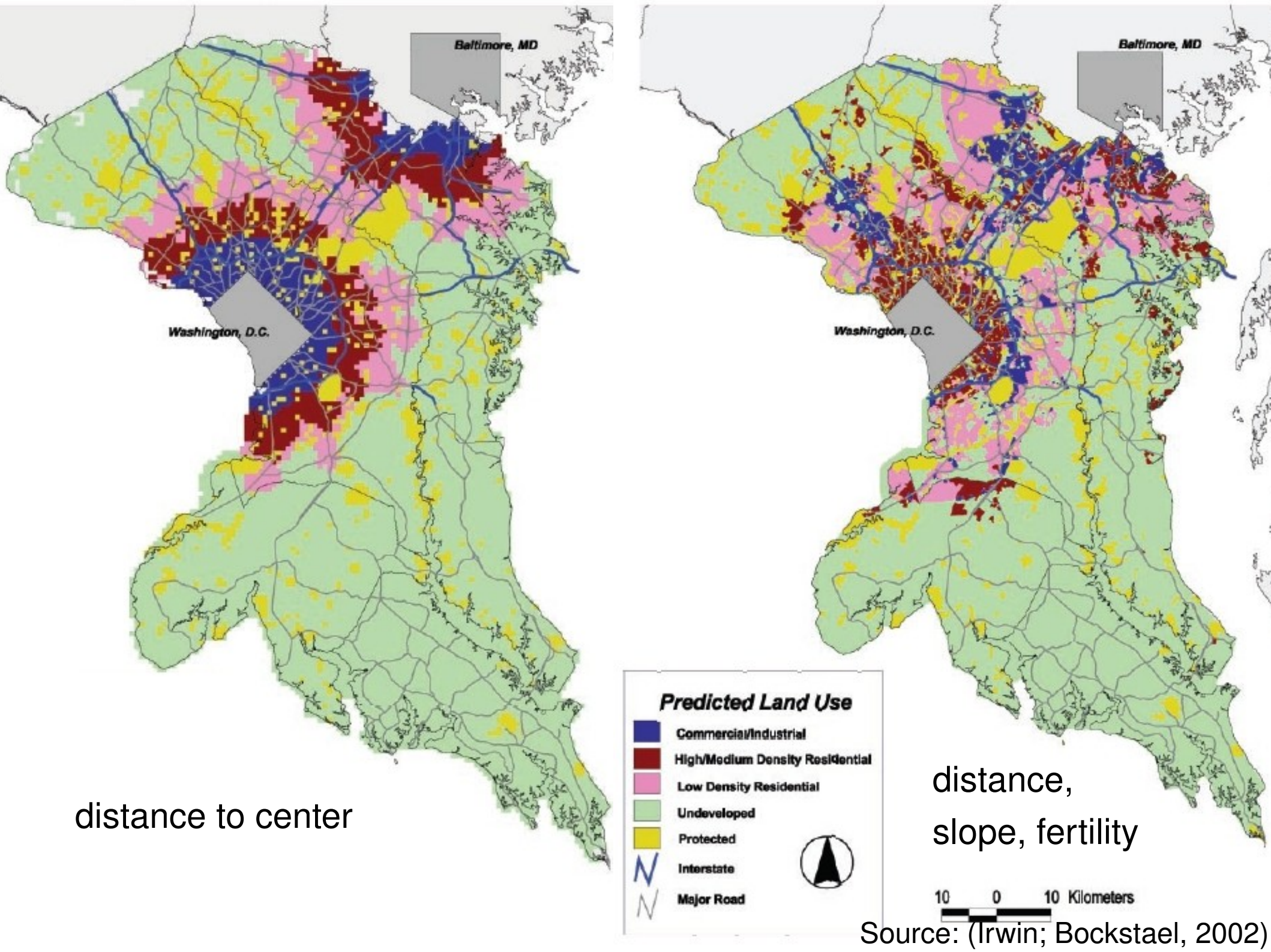
Strengths	Weaknesses
• Can be useful in some historical contexts, for generating data about past agent behavior.	• Cannot directly identify agent/household characteristics.
• Inexpensive as long as data are available through public sources.	• Inferences are subject to mis-estimation due to complex interactions and confounding factors in the observed system.
• Can identify suitability and spatial driving factors.	• Requires assumed underlying decision model, which cannot be tested. Analysis cannot refute anything in the conceptual model.
• Good for parameterizing drivers already identified.	• Data-intensive.
• Can cover a large area.	• Model must be simple/have few parameters.
	• Interpreting results can be difficult because of non-stationarity, feedbacks, time lags, heterogeneity in the system.

Case study: interacting agents, spatial externalities and the evolution of residential land use patterns



Irwin and Bockstael (2002)

Source: (Irwin; Bockstael, 2002)

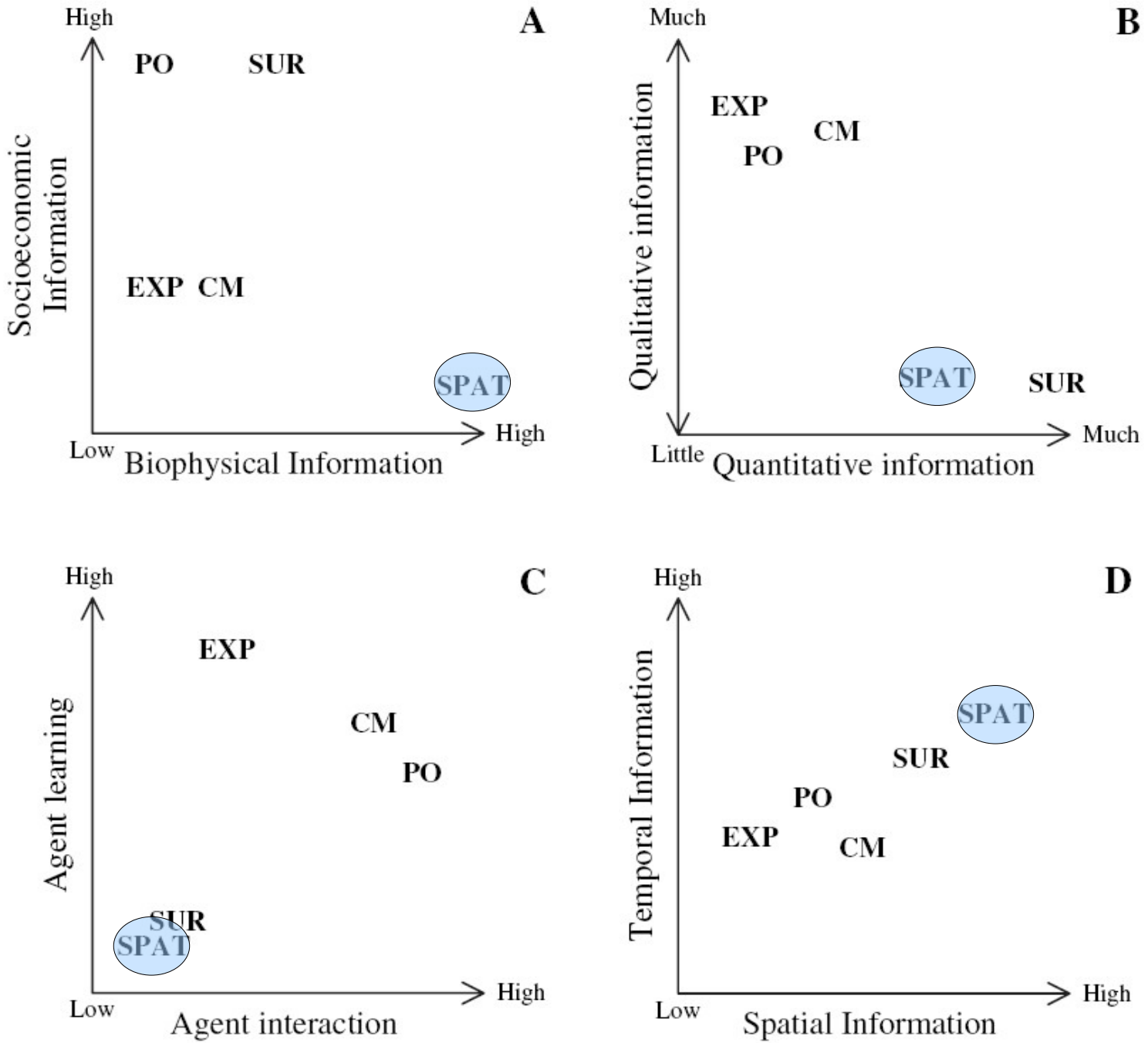


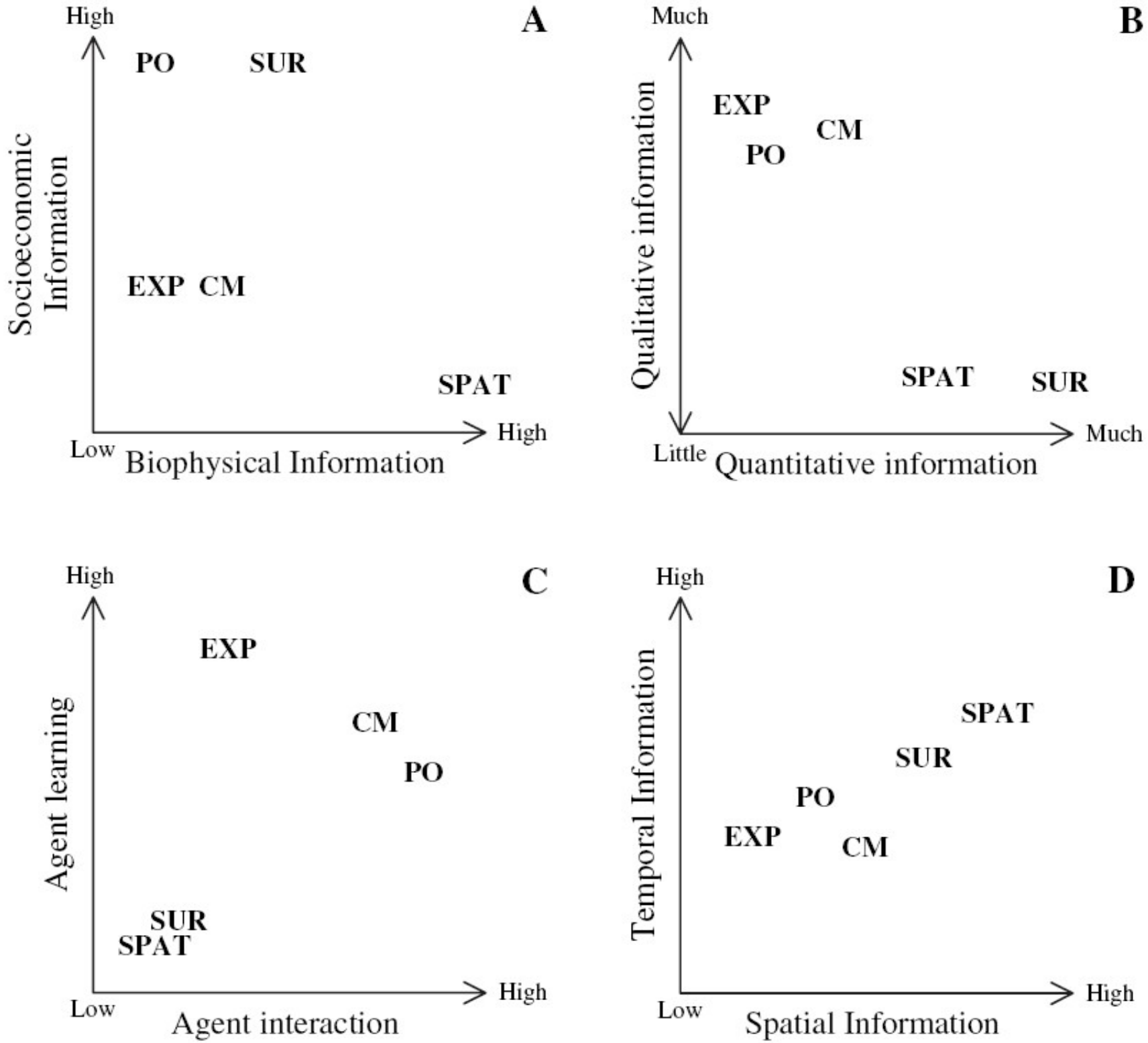
distance to center

distance,
slope, fertility

Source: (Irwin; Bockstael, 2002)

GIS and remotely sensed spatial data

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Socioeconomic Information
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C
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Agent learning
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Temporal Information
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Spatial Information

Conclusions

- ABM is a process that involves an iterative cycle of observation, modeling, prediction and testing.
- The best way to empirically inform an ABM is to use some combination of approaches.
- Multi-disciplinary teams when developing ABMs of land-use systems