Spatially Explicit Computer-based Experiments as a Tool for Exploring Heterogeneous Decision-Making Dynamics in Agent-Based Models of Landcover Change

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Many agent-based models of landuse/landcover change are constructed at a local level of analysis to explore the heterogeneity of decision-making and the factors that contribute to this heterogeneity. These factors include both agent characteristics as well as landscape or portfolio characteristics. At this scale of analysis, model validation is a particular challenge because of the data demands related to this local level of analysis. In this research we present a research design for informing an agent-based model of parcel-level landuse/landcover change developed for south-central Indiana. This design includes: household level survey data, spatial experiments to explore key decision-making dynamics, and a rich time series of economic based data (commodity prices, wage labor rates) and a series of GIS based data layers of land ownership, landcover and land suitability.

Analysis of historical landcover data for a study area in south-central Indiana (1939-present) suggests the importance of a household level approach. Two parcels with similar biophysical and geographic characteristics may exhibit entirely different landcover change trajectories over time. There are many possible explanations for these diverse landcover trajectories including (but not limited to):

1) Demographic structure/composition (age, # of individuals in household)
2) Household financial position (wealth, debt, income)
3) Labor/Employment
4) Past experience, knowledge
5) Access to information
6) Decision-making dynamics – risk, learning

A central challenge to landcover change modeling is how to incorporate these heterogeneous landcover change trajectories. In the absence of household level data to incorporate socioeconomic factors at the household level the modeler must develop methods to incorporate heterogeneous landuse decision-making to produce the various landscape outcomes. One method to accomplish this is to simply use a stochastic term to vary the model behavior. However, this approach does not provide any insight into the decision-making process or build upon any kind of theoretical basis. A more compelling rationale for incorporating heterogeneous decision-makers in agent-based models is needed.

Experimental economics has provided a rich set of results associated with individual and group decision-making. This literature has contributed to the theoretical foundation underlying issues such as decision-making under uncertainty, risk, altruism and other topics central to landuse decision-making. We have developed a series of spatially explicit experiments which we use to examine the potential spatial outcomes in different decision-making contexts. The experiments present subjects with an abstract landscape

about which they make spatially explicit decisions. Different spatial patterns emerge from different subjects landscapes at each time point. Spatial analysis of the pattern and composition of these landscapes identifies how the spatial configuration or allocation of heterogeneous decision-makers produces particular landscape level outcomes (where a landscape is the aggregation of several parcels controlled by multiple decision-makers).

A variety of observations from these spatial experiments provide a theoretical basis for incorporating heterogeneous decision-makers into agent-based models of landcover change. We have observed a mimicking behavior where subjects who are aware of the spatial decisions of other subjects copy or mimic those decisions at subsequent time points. We also observe that some subjects tend to be very risk averse while others are much more likely to attempt different strategies through the experimental session. In addition, some subjects are more likely to rapidly change their landscapes while others have more "inertia" where they are less likely to modify their spatial landscapes. These decision-making dynamics produce interesting spatial outcomes that can be analyzed at the parcel and landscape level.

The data from these spatial experiments provides a theoretical basis for incorporating these dynamics into an agent-based model of landcover change that includes heterogeneous decision-makers. The distribution of agent-types in model runs is modified and the model fit to observed landcover data. We compare model results using a homogenous utility maximizing agent to model results where we modify the distribution of agent-types. Data are presented to identify how many (and which) agents fit each agent-type according to the following typology: utility maximizing, risk averse, high inertia, mimicking. We use the same typology to characterize individual subjects from the spatially explicit experiments and compare the results from out agent-based simulations to the experimental results.

The purpose of this design is to provide a foundation for exploring why different landowners make different decisions given the same basic environmental condition. These agent heterogeneities in turn produce diverse landscape management trajectories. The combination of spatially explicit resource experiments, household survey data and agent-based modeling provides an integrated research design that allows ABM's to be more tightly tied to traditional empirical analysis.