Exploring Colonist Household Structure and Land Use Change in the Amazon Rainforest

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This research effort represents a collaboration between people at the University of Waterloo and the Center for the Study of Institutions, Population, and Environmental Change at Indiana University. To date, work has focused on the development of a pilot simulation system called LUCITA (Land Use Change In The Amazon) designed to explore the factors influencing land use decisions made by individual households in the Altamira region of the Brazilian amazon.

While it has been assumed that deforestation rates in the Amazon are directly tied to population changes, resulting from high rates of in-migration and subsequent high natural increase, these general observations do not explain the spatial variation that can occur in colonized regions, such as that near Altamira. Neighboring farms in the Altamira region can have very different patterns of land use. This observation has raised research questions related to the relative importance of family and market factors in shaping land use decisions. One approach to this problem has been to study the individual cohorts who arrived on the Altamira frontier at different times, along with age and period effects. Utilizing this approach, an analysis of data collected in Altamira has led to the development of a model which proposes that land use changes in the region should be understood as a product of the age and gender characteristics of farm households. This conceptual model maps out a trajectory for families, which relates the type of agricultural practices pursued to the available capital resources and labor pool within each household. Five temporal stages of household composition are proposed by the conceptual model, with each stage of development characterized by increasing levels of capital and available family and male labour. This conceptual trajectory inspired the development of LUCITA.

LUCITA is a spatially referenced simulation, comprised of 2 sub-models that interact with one another through a raster landscape. These 2 sub-models are designed to capture the actions and interactions of the ecological and human systems characteristic of the study region. LUCITA can be configured to run simulations on one individual household, or on a landscape comprised of 236 properties. The raster landscape is an abstraction of the intensive study area described during field studies by Fearnside (1986). The landscape is representative of the Agrovila (village) Grande Esperança area, located in the municipality of Prainha in the state of Pará, approximately 50 km west of Altamira. Each cell in the raster grid is representative of an area of 1 hectare. Each cell in the grid references an object data structure, which is used to store soil properties including pH, phosphorus, aluminum, nitrogen, and carbon.

During the simulation, the soil object of each grid cell is linked to the environment object so that the soil properties of that cell, as well as crop yields, can be calculated based on the events that have occurred on that cell during the previous round of the simulation run. The environment object sub-model of LUCITA calculates these changes with the use a set of multiple regression equations developed for the KPROG2 model by Phillip Fearnside. Within LUCITA, a household agent may clear three types of land covers; virgin forest, secondary forest, and weed covered areas. The environment object also simulates the processes of secondary succession on the raster landscape.

In LUCITA, frontier colonists are modeled as a collection of intelligent agents, where each agent represents the actions of one household. The model of the environment contained by each household agent includes information on which cells constitute that agent's property, and the land cover on each of those cells. The architecture of an agent also specifies the agent's model of itself. This model includes a set of parameters describing the demographic composition of the household, the monthly available family and male labour, available capital, and a rule base where alternate land use strategies are contained. Eight possible land use strategies can be considered by the agent including; the production of rice, beans, manioc, maize, black pepper, and cacao, pasture development, and cattle grazing. A classifier system is used for agent decision making in each round of the simulation. The agent utilizes this classifier system to determine which land uses to implement on a given cell, given the resources of the agent and the previous experiences, expressed as crop yields, with that particular land use.

In each round of a simulation, the household agents execute a series of actions governing how the individual cells within their 100 hectare property will be managed. These actions include: maintaining existing pasturelands or perennial crops, clearing and burning land, and planting and harvesting crops. The agent determines which crops to plant by using the classifier system to compare its own capital and family labour resources with the labor and capital requirements for each of the available land use strategies. The agent has a predefined set of clearing preferences for determining which currently unused cells are to be converted to crops. For the simulations described here, the agents clearing preferences are set to place the highest priority on cells with advanced secondary succession, followed by cells with progressively younger secondary succession, then bare land, and finally virgin forest.

The pilot version of the simulation, while limited in scope, has allowed researchers at Waterloo evaluate an architecture for the development of additional simulations. Future goals are focussed on exploring alternate decision making architectures for the household agents and the effects of outside factors such as credit rates and commodity prices on household behaviour.