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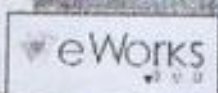
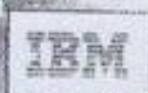
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Agent Modeling of the Caparo Forest Reserve

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Environmental Science, Simulators, AI in simulation, AI-supported simulation, Object Oriented.

ABSTRACT

This article presents a preliminary model of the biocomplexity of a Venezuelan forest reserve. The computational model describes the interactions between human systems and their environment, following the guidelines of a multi-agent simulation theory. Land use changes are simulated using Cellular Automata. This project is supported by a multi-agent simulation platform called GALATEA, and the Cellular Automata library of SpaSim.

1- INTRODUCTION

This study is a subproject of Biocomplexity: Integrating Models of Natural and Human Dynamics in Forest Landscapes Across Scales and Cultures (<http://www.geog.uni.edu/biocomplexity>). It aims to model and simulate land use processes and changes in vegetation cover as a consequence of human actions.

The National Science Foundation (NSF) defines Biocomplexity as the resultant phenomenon of dynamic interactions among biological, physical, and social components at different environmental systems of the earth (North Texas University, 2003). The purpose of these studies is to achieve an understanding of those interactions and to be able to analyze and possibly forecast their effects.

As a first approximation, we have devised a set of toy models to cater for 1) the human dynamics, using a set of conceptual tools and data structures provided by GALATEA (Uzcátegui, 2002) and 2) the environmental dynamics, by integrating a cellular automaton from the SpaSim (Moreno, 2001, 2002) library into the actual simulator of the reserve. The data structures of Galatea provide for the representation of the agents' goals, beliefs and observations, and, also, for a very elementary reasoning engine to deduce actions for each agent, according to its circumstances.

We started by developing an elementary model ("toy model #1") that simulates some of the interactions that

occur at Caparo Forest Reserve. As we improve our platform capacity we will include new features to our toy models aiming to achieve real system complexity.

2.- CASE STUDY

Various processes have attempted against the sustainability of one of the oldest forest reserves of Venezuela, "the Caparo Forest Reserve (CFR)". As other reserves, this was created to guarantee the maintenance of the logging industry in the zone, and, at the same time, to preserve one of the best forests of Venezuela. Regrettably, these good purposes were never achieved, and in a few decades the reserve went from a forest, that practically had not suffered human intervention, to a highly deforested zone, occupied by many settlers (Tonella et al., 1998).

CFR was created in 1961 and it's located at Southeast of Barinas State, in the Venezuelan western plains region. It had 176,434 hectares, divided in three units to facilitate its management. Our study takes place at Unit 1, which had 53,358 hectares, and includes a special area called the Experimental Unit, that was assigned to Los Andes University, to develop research and educational activities.

Many factors have contributed to forest disappearing at RFC, such as unsuitable forest management of some lumber concessionaires (Government had assigned Forest Reserve Units to some Logging Companies in concession form), contradictions between different governmental organisms, poverty and the demand of lands for agricultural activities, and the existence of political interests in favor of settlements, among others factors. All of them have fomented the establishment of settlers, and consequently, the advance of the farming activities in wooded zones without any control.

Currently, just 7,000 hectares of forest at RFC have survived, which are located at the Experimental Unit and are not exempted of future deforestations due to agrarian settlement process such as the ones previously described.

According to Rojas (Rojas, 1993), the agrarian settlement process of forest reserves at the Venezuelan western plains has developed through the following stages:

- **Primary Cycle:** The first settlers take possession of a certain area at the reserve and practice subsistence (i.e. slash and burn) agriculture. This surface can be an uncultivated land (previously deforested and unoccupied) or can be forest land deforested by the settler. Before five years, the soils are exhausted, and the harvests are no longer enough to sustain the settler and his family. Some settlers try by expanding their farms at the expense of new deforestation. However, sooner or later, they will end facing the same situation. The alternative is to seed pasture (which gives value to the land) and later, to sell its improvements to landlords or other settlers, luckier than them, whom soon will be using the initial settlers as their workers.
- **Land Market:** Land improvements are sold and they are registered. Then settlers can buy off new land to other more recent settlers, or just return to initiate a new primary cycle of invasions. If there is some money left, they would generally prefer to invest in cattle because it is much more profitable and it does not have as many disadvantages as agriculture. But definitively, the settler returns to invade because he has the hope to receive money again if things do not go well for him (Tenella et al., 1998). At this stage, the pasture retailers and landlords acquire the improvements of primary settlers. Extensive cattle ranch dominates the land use. After years, the property of the parcels is transferred to the settlers, by application of the Agrarian Reform. Then they are sold at ridiculous prices, to the landlords, politicians and cattle dealers who urged and supported the original settlements (Centeno, 1997).
- **Cattle Ranch Consolidation:** Cattle ranching is the main activity. Landlords use previous deforestation done by the settlers, buy their improvements, and acquire greater extensions for cattle raising, (this activity is developed as a capitalist company by landlords). This process, characterized by the concentration of the property, forces the initial group to move towards primary cycle settlements or to wage-earning work (Sánchez, 1989).

3.- THE MODEL

During this first stage of the project we developed a simplified model that considers several instances of settler agents and a lumber "concessionary" agent, whose behaviors will be described next.

3.1.-Settler Agent Characteristics

The settlers are people of limited economical resources that arrive at the reserve aiming to improve their economical status and to obtain the property of the land that they occupy. Initially they are dedicated to subsistence

agriculture and they just try to maximize the benefits from their occupation in the area, without considering soil exhaustion due to inexistent or poor management practices, and without taking into account the ecological damage that might be caused. After five years, the land loses its fertility, and the settler must move to another place or expand his farm by deforesting some adjacent land.

The behavior of the settler agent is defined by all the actions that it executes within the reserve from the initial moment of occupation or invasion to the moment of his abandonment of the reserve. The following items describe his behavior:

- 1.- When a settler arrives at the reserve, he observes the environment around him.
- 2.- He looks for a unoccupied place without vigilance to settle down.
- 3.- Once he has settled down at the forest reserve, he proceeds to deforest, to clear the land of weeds or to harvest some crop for his subsistence, depending on land use. In the clearing process trees are destroyed and the settler could obtain some monetary income from the sale of any existing wood of commercial value.
- 4.- Settler sells wood of commercial value. In this first model, this will be the only way to receive a monetary income, because the commercial transactions between settlers due to land improvements are not considered.

Table Number 1 shows detailed settler agent characteristic.

3.2.-Rules for Settler Agent

To detail settler agents rules we use Actlog Language, which is a language to write generalized, condition → action, activation rules. The semantics of the language is based on the assumption that implications (conditional goals) can be used to state integrity constraints for an agent. These integrity constraints describe conditions under which the agent's goals must be reduced to plans that can be executed. For instance, a rule such as if A then B, will indicate to the agent that whenever it can prove that A is the case, it then should pursue goal B. B is normally the description of a task that must be reduced to a set of low-level, primitive actions that the agent can execute. See (Dávila, 2003) for more details.

For settler agent we have several rules:

- **ZONE VIGILANCE:** A vigilance zone map will be considered, including neighborhoods to the National Guard control places, the organism in charge of the vigilance of the reserve, and the effect of the forest plantations monitoring (plantations of less than two years) by the logging concessionaires. The following code line in Actlog language establishes the rule that will govern the behavior of settlers in case of existing vigilance at the zone.

Table 1: Settler-Agent Characteristics

Percepts	Internal State	Environment	Possible Decisions	Actions	Goals
To observe the environment (zone vigilance, land use, land occupation)	-Economic Status. -Land Ownership	-Level of zone vigilance. -Land fertility. -Land use (uncultivated and unoccupied, plantations, forest with or without commercial valuable species, agriculture, farming or cattle activities). -Land occupation.	-To harvest crops for own subsistence -Moving -Deforesting -Invading unoccupied lands. -Expand farms. -Illegal selling of wood.	-To harvest crops for own subsistence. -Farming activities. -Moving -Deforesting -Invading unoccupied lands. -Expand farms. -Illegal selling of wood.	-To improve economical status. -To become a landlord. -To get legally ownership of the land in the reserve.

if vigilancia then pensar en otro sitio .

- **SETTLER INITIAL ESTABLISHMENT:** If there is not vigilance at the zone and zone is unoccupied, the colonist can settle down in the chosen area. Vegetation is destroyed, high commercial valuable woods are sold and farms or harvests are established. The next Actilog language code line indicates establishment rules for the settlers in the reserve.

```

if vigilancia then pensar en otro sitio,
if not(tierra ocupada), not(vigilancia),
uso de la tierra igual baldia then establecerse1,
if not(tierra ocupada), not(vigilancia),
uso de la tierra igual bosque sin madera then
establecerse2,
if not(tierra ocupada), not(vigilancia),
uso de la tierra igual plantacion then establecerse2,
if not(tierra ocupada), not(vigilancia),
uso de la tierra igual bosque con madera then
establecerse3,
to establecerse1 do invadir,
to establecerse2 do invadir, talar,
to establecerse3 do invadir, talar, venta de madera.
    
```

- **FARMS EXPANSION:** There is only one possibility for farm expansion of fundos, which is carried out at neighboring unoccupied land, because commercial transactions between settlers are not considered. The next Actilog language code line indicates the only way to farm expansion:

```

if pensando en sitio vecino, not(tierra ocupada),
not(vigilancia) then expandir fundo,
    
```

13. Concessionary Agent Characteristic

The lumber concessionaires are represented by private companies that have the function to carry out the forest exploitation and management plans in the reserve areas

under the supervision of the Ministry of Environment. These companies must develop the necessary infrastructure for the logging industry in the zone and protect their assigned area at the forest reserve (Sanchez, 1989).

At this stage, the lumber concessionary agent implemented, makes a very simplistic and hypothetical forest management within the reserve: the lumber concessionaire exploits the forest and proceeds to plant commercial valuable species regardless of the native species or the initial physical and ecological conditions in the area; furthermore, the concessionaire is in charge of forest plantations vigilance during the first two years. If concessionaire finds a colonist on its assigned zone, he will ignore the settler and continues the work at another place that is not occupied by settlers.

Table Number 2 shows detailed concessionary agent characteristic:

3.4. Rules for Concessionary Agent

It is assumed that there is just one concessionary agent operating at our forest reserve area. Its behavior is determined by following rules:

- If the concessionaire finds a forest area that is not occupied by settlers, will proceed to explore it and plant the place with high commercial valuable species.
- If the concessionaire finds a place uncultivated and unoccupied proceeds to establish a forest plantation on it.
- It is important to notice that concessionaire will watch this plantation during the first two years, according to what was established by the Government at the Concession contract.

Next Actilog language code line shows concessionaire behavior: