ODD Protocol Model description

1. Purpose

This is an agent-based Land Use and Cover Change (LUCC) model. This model aims to simulate the growth of permanent crops in the buffer area (avocado) of the Monarch Butterfly Biosphere Reserve. It also seeks to generate scenarios that mitigate this change in the buffer zone through the implementation of payment schemes for environmental services.

2. Entities, state variables, and scale

2.1. Agents

Each agent represents a type of landowner, located in the buffer zone of a biosphere reserve. Each type of landowner has a certain area, following the following assumptions: 1) the international price of avocado continues to rise, so that the areas with optimum suitability will be transformed into permanent crops inexorably; 2) the landowning agents have the capacity to transform the use and coverage of the land at the same rate; 3) only small landowners can receive payments for environmental services, the types of payments for environmental services are not compatible with each other[1]; 4) payments for environmental services are supposed to represent higher revenues than avocado production in sub-optimal areas.

Attribute	**Brief description**
Property types	Defines the type of land owners
Available area	Area of each property
Land use content	Types of roofs and land uses contained in each of the properties
Payments for environmental services	May or may not receive payments for environmental services

2.2. Spatial Units

A landscape represented in cells of 50 by 50 meters is used. Each cell represents 0.25 hectares. Each cell represents biophysical and land property attributes.

[1]Two types of payments for environmental services are contemplated: 1) Payment for conservation of primary forest; 2) Payment for agroforestry environmental services (traditional management practices are employed).

Attribute	Brief description
Slope	Slope expressed as a percentage calculated from a digital elevation model. The digital elevation model was obtained from the website of the National Institute of Statistics and Geography (INEGI).
Land use	The land use has seven categories, 1) Permanent agriculture (avocado), 2) Temporary agriculture, 3) Primary forest, 4) Secondary forest, 5) Pasture, 6) Water, 7) Urban area.
Precipitation	Average annual rainfall (mm).
Temperature	Average annual temperature (mm).
MMRB zones	Represents the two zones of the. biosphere reserve area nucleus and area buffer .
Land tenure	Represents agents by type of property. 1) Ejidos (smallholders), 2) private property.

2.3. Spatial and Temporal Scales

The landscape is represented by 50 x 50 m cells, with a total of 184992 cells valid for a total area of 462.48 km^2 . Each step of this model represents one year, the total modeling period is 30 years.

3. Process Overview and Scheduling

This model employs logical conditionals to simulate agent decision making.
Three scenarios were coded.

3.1. Trend scenario

There is an increase in the use of land for' permanent crops', only over the area suitable for avocado cultivation. Once the optimum area is exhausted the continued growth over the sub-optimal areas.

3.2. Payment for environmental services - Primary forest

For privately owned areas use scenario 1; for ejido areas, permanent crop growth is not allowed on primary forest.

3.3. Payment for agroforestry environmental services,

This scenario behaves in the same way as the two previous ones in the optimal areas for the avocado and for the private areas, as far as the ejidos are concerned they will change the temporary crops for an agroforestry system (representing this as secondary forest), no changes are allowed on the existing primary forest.

4. Design concepts

4.1. Basic Principles

The hypothesis behind this model is that in the medium term payments for environmental services only to small landowners will not be sufficient to maintain forest cover over the core area of the reserve.

In a next step this model should incorporate realistic elements, for example a supply and demand sub-model that includes global prices and product demands, as well as change probabilities based on previous land cover and land use data.

4.2. Emergence

This model is designed to explore patterns of change in the landscape under the influence of product price and payment for environmental services. Changes in the landscape are emerging in the sense that they are the product of local land-use decisions and the international values of a product.

4.3. Adaptation

They are not considered rules that allow them to make decisions or change their behavior in function of the changes they produce in the landscape.

This model reproduces "observed" or hypothetical patterns.

4.4. Objectives

The agents may have 3 objectives depending on the availability of cells or the payment or non-payment of environmental services in section 2.1 decision rules are described.

4.5. Learning

The agents in this model cannot change their characteristics or assume features of adaptation based on experience acquired in a previous step, in other words, they do not learn.

4.6. Prediction

The objective of the agents is to maximize their profits by having a finite number of cells with a determined land use. Permanent crops have priority over other land uses unless the agents receive another incentive.

4.7. Sensing

The agents know the optimal areas for cultivation in which to maximize their income, they also know the number of cells that can be changed at each step.

4.8. Interaction

The interactions between agents in this model are not considered, they only interact with the landscape through changes in land cover and use.

4.9. Stochasticity

The model uses the sowing of patches ("plots") of permanent crops, shading the coverages that can be transformed in each iteration.

4.10. Collectives

The agents themselves are an aggregate number of owners.

4.11. Observation

Observations include the graphical visualization of land use patterns in terms of area at each step of the model.

5. Initialization

The landscape begins with 50 x 50 m cells with a total of 184992 valid cells, the land uses that can be transformed are primary forest, secondary forest, rainfed crops, and pastures. Additionally, the optimal area of productivity of the avocado is estimated, considering the average annual rainfall and the average annual temperature.

6. Input data

The exchange rates included in this model are still "riddles" on the part of the author, as far as the optimal harvest zones are concerned this was provided by means of expert criteria. In the near future it will be necessary to obtain these data in a more realistic way and to adjust them with the international demand of the avocado, that is to say to model using an approach of telecoupling systems.