Analyzing gendered patterns of tree cover transition through agent-based modelling

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Agent-based models (ABMs) are widely used to explore and understand social phenomena such as migration, group formation, and interaction with the environment. ABM can be applied and used for policy analysis and planning, participatory modeling, explaining spatial patterns of land use or settlement, testing social science concepts, and explaining land use functions. The ABM method enables researchers to analyse complex systems arising from local interaction of system entities. In Indonesia, we applied ABM to explore gender-segregated decision-making to understand tree cover transition in a temporal and spatially explicit way (Figure 1).[1]

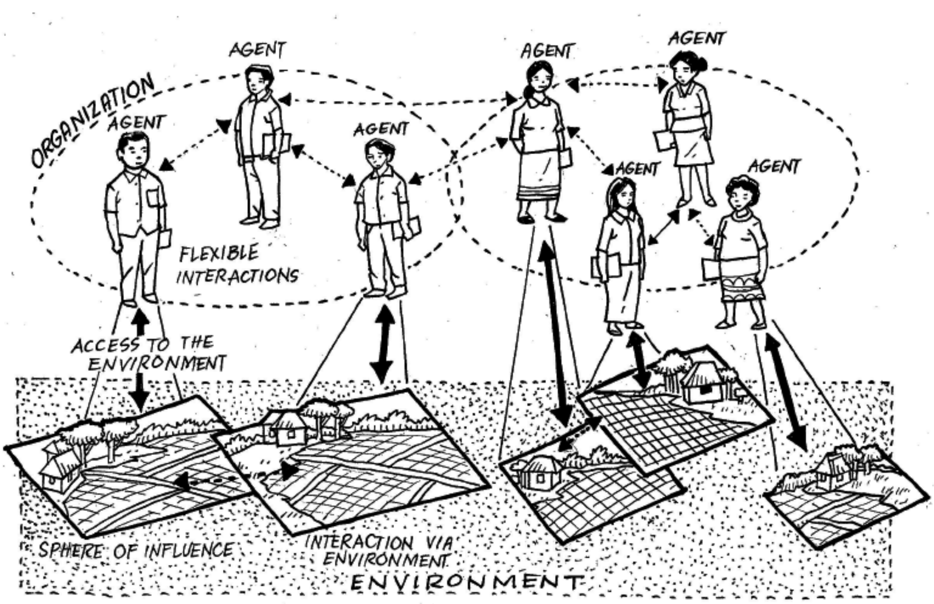

Figure 1: Gender-segregated interactions can drive changes in the way land is used.

[1] Empirical land use ABM requires a considerable amount of data for household agents and environmental processes (see Smajgl et al. 2011 for specific parameters).

The rubber agroforests in Jambi province in Indonesia provide livelihoods to the local community as well as ecosystem services such as carbon sequestration, biodiversity and landscape beauty. However, due to low rubber production from agroforests, farmers are now considering converting their agroforests to highly profitable monoculture crops like rubber and oil palm. Through ABM, we examined the relative values of appreciation of tree cover and associated ecosystem services according to the ecological knowledge of men and women in the area.

Study team

- A modeler with knowledge of object-oriented language is required.
- Facilitator
- Documenter

Materials

Computer loaded with:

- NetLogo 5.1 software (free download at http://ccl.northwestern.edu/netlogo/)[2]
- Gender-disaggregated household data (i.e. time series and cross-sectional information)[3]
- Data on crop production, forest inventories, and vegetation assessment
- Major commodity prices
- Maps: administrative maps, soil map, digital elevation map, land use maps (preferably time series)

Steps

The steps in ABM follows the modeling cycle presented in Figure 2.

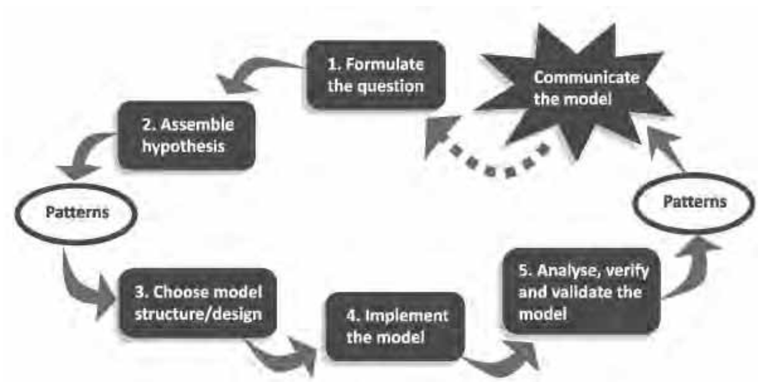

Figure 2: Modeling cycle (adapted from Railsback and Grimm 2010)

[2] Other ABM environmental platforms are also available (see Gilbert 2008 for criteria for selecting appropriate platforms).

[3] To make the model spatially explicit, take GPS readings of households and farming plots.

1. **Formulate the question.** Start with a very clear research question. For example, 'How do differences in men and women's choices and decisions over land use affect the dynamics of tree cover transition?'

2. **Assemble hypotheses to define ABM processes and structure.** This step explores key questions: What factors have a strong influence on the phenomena or interest? Are these factors independent or interacting? Are they affected by other important factors? An extensive literature review on tree cover transition or land use change, including sectoral causes of the change, is therefore required to determine patterns of behaviour. The use of land use role playing games (RPGs) can generate behavioural patterns (see Gender, land use and role-play games paper) that can be compared with the results of the ABM.

3. **Decide on the model design and details.** A standard documentation protocol (i.e. overview, design and details) is already available to convey the entire modeling process (Grimm et al. 2010). The basics that should be prepared are the following:

- **Agents:** Identify the agent types and other objects along with their attributes.
- **Environment:** Define the environment the agents will locate and interact with.
- **Agent methods:** Specify the methods by which agent attributes are updated in response to either agent-to-agent interactions or agent interactions with the environment.
- **Agent interactions:** Add the methods that control which agents interact, when and how they interact during the simulation.

4. **Implementation of model.** This is the most technical part of the modeling cycle. Mathematics and computer programs (NetLogo is recommended) are used to translate verbal model descriptions into animated objects. In the context of tree cover transitions, a computer program called Land Use Dynamic Simulator (LUDAS) has been applied in Vietnam (VN-LUDAS; Le et al. 2008) and Indonesia (LB-LUDAS; Villamor 2012). Statistical analysis (e.g. logistical regression) is commonly used to develop land-use choices, while other researchers use a decision tree.

5. **Analyse, test and revise the model.** This stage, which involves analysing and interpreting the model output is the most time-consuming. First, verify the results and then validate by comparing the patterns of behaviour generated by ABM with the results of RPG. Once some patterns coincide or support your hypothesis or the results of RPG, begin documenting the results, including the details of the modeling processes. When new issues or disagreements arise, reiteration (including necessary model adjustments) is required to ensure that the modeling exercise is scientifically acceptable or valid.

6. **Communicate the model.** Results from the simulation can be useful in

explaining and understanding the possible effects of introduced interventions or future scenarios.

Example of results from ABM application in Sumatra, Indonesia

Using the characteristics and decision-making behaviour of male-dominated households in three villages in Jambi province, the model simulated the payments for ecosystem services (PES) scenario through the eco-certification scheme of rubber agroforestry in the area.

Although only 30-40% of households successfully adopted PES, the adoption led to the decision to maintain rubber agroforests for a period of 20 years, which increased species richness while reducing carbon emissions.

Moreover, the simulation showed an increase in farmers' income of 60% from rubber agroforests. This is because the labour required to maintain rubber agroforests is less compared to that of other land uses (e.g. rubber and oil palm plantations). As such, farmers are able to use their free time in collecting non-timber forest products, which they sell for income.

Advantages

- The tool incorporates decision-making processes of human agents and ecological processes in the system; and
- It can capture socio-ecological interactions at the local level resulting to emergent property at the macro level.

Limitations

Limitations include issues of validation of agents' behaviour (Heckbert et al. 2010), weak representation of human decision-making, and missing confounding variables (Villamor et al. 2012). To address these limitations, validation using RPG is recommended (see previous paper). Also, note that empirical ABM is a data-hungry model.

Key considerations

Data

- Sufficient background information of the area is needed, especially about temporal land use change, actors and sectoral causes/drivers of land transitions. In the ABM application in Indonesia, data on rubber agroforest plots of different ages, crop yield, and carbon densities of each land-use type were collected to generate sub-models for crop production, carbon emissions, and natural succession processes.

- An intensive gender-disaggregated household survey should be conducted preferably with 20-30% sample of the household population.
- An up-to-date land use map is preferred. The choice of resolution (i.e. 10 m^2, 30 m^2 or 1 hectare) depends on the research question and interactions being modeled. In the case of Indonesia, a 30 m^2 resolution was used.
- A framework is available for determining the parameters of agent behaviour (Smajgl et al. 2011).

Programming

- The researcher must have a clear conceptual framework of the relationship or interactions in order to design the model. The conceptual framework enables the modeler to envision the possible simulation procedure. A modeler with basic knowledge of the NetLogo programming is an advantage.
- Work closely with the modeler at every stage of the modeling cycle.

Scenario testing

- Composition of households (i.e. women-only, male-only, mixed gender) decision-making agents should be parameterized and tested.

Do’s and don’ts

- Do use existing models relevant to your research question.
- Do keep the model as simple as possible for easy implementation and analysis.
- Don’t cram too much information into the first model version; instead, use a step-wise approach by adding new information on every simulation.

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Recommended readings

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