

An Agent-based Approach to Simulating Spatial Patterns of Shifting Cultivation in Vietnam

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1. Introduction

Shifting cultivation is a type of agricultural system where land is cleared by slashing and burning and plots are rotated for food crop production (Angelsen, 1995; Do, 1994; Gilruth *et al.*, 1995). In upland Vietnam, shifting cultivation is a popular and traditional method of agricultural production where more than 4.8 million households are engaged in shifting cultivation (Do, 1994). However, Vietnam's national government and resource managers currently view shifting cultivation as both highly destructive to the forest and the cause of serious soil erosion (Vien *et al.*, 2006). Planners, therefore, need a decision making tool to manage shifting cultivation and protect the forest, that provides visual monitoring of future impacts of policy and other external interventions. A method that has shown promise for achieving these goals is agent-based modelling (ABM) (Bonabeau, 2002). This approach allows one to effectively describe this type of agricultural practice at household level, in terms of livelihood, as well as at the landscape scale, in terms of land-cover change and natural resource management. This paper presents an agent-based model of an upland village in Vietnam where shifting cultivation is the main type of livelihood. The model framework is presented along with some initial results.

2. Previous Work

Although shifting cultivation has been a topic of research for a some time (Bui, 1990; Do, 1994; Dvorak, 1992; Le, 1993; Le *et al.*, 1990), the application of GIS and agent-based modelling to this type of cultivation system is relatively recent. For example, Gilruth *et al.* (1995) have developed a dynamic model of shifting cultivation in Guinea, Brown (2005) has built a spatiotemporal model of shifting cultivation and forest cover dynamics in Cameroon, and Becu *et al.* (2003) have developed an agent-based simulation of a small catchment for water management in Thailand. Two previous studies have been carried out in Vietnam: agent-based modelling of shifting cultivation field patterns (Jepsen *et al.*, 2006) and modelling of agrarian transition and lowland-upland interactions (Castella *et al.*, 2005). However, limitations have been identified with these studies. For example, the model by Jepsen *et al.* (2006) is simplistic in its assumptions about the decision making context such as ignoring all economic factors, e.g. price or household potential capital that could be unreasonable to other regions. There is also no relationship between yield, which is derived from the cell age, and labour cost, which is based on the number of adjacent cultivated cells. The research in this study improves upon on both of these aspects.

3. Agent-based Model of Shifting Cultivation

The agent based model developed in this research is based on the concepts of the FEARLUS (Framework for Evaluation and Assessment of Regional Land-use Scenarios) and FLORES (Forest Land Oriented Resource Envisioning System) agent-based models (Castle *et al.*, 2006; Cioffi-Revilla and Gotts, 2003; Haggith *et al.*, 2003). However, the main difference is that the basic behaviours of the agents, which includes social decision-making (e.g. marriage, giving birth, and household partitioning) and land-use decision-making (e.g. land tenure transference, land selection for cultivation etc.) have been formulated in a much more explicit manner. This formulation is also more compatible with Vietnam's conditions than those of other existing models. For instance, FEARLUS operates at a household level and is therefore limited in its ability to simulate and monitor the dynamics of individuals within a household. Whilst FLORES is very well developed for simulating individual behaviours at a micro level such as different types of land tenure transference and labour distribution, it does not mention details of how personal perceptions and land accessibility are collectively formulated in the land-use decision making of communal lands (Haggith *et al.*, 2003).

The model of shifting cultivation proposed here is divided into a land module and a human module. The land module simulates the dynamics of the land characteristics such as land-cover and land-use, soil, fallow length, cultivation length, land ownership, etc. The human module deals with the social dynamics at both individual and household level such as marriage, birth, death, migration and livelihood seeking strategy, etc. These modules have been coded in Netlogo (Wilensky, 1999) and are integrated in one model to simulate the interaction between humans and the land within a shifting cultivation system. Human effects on the landscape through land-use activities (i.e. shifting cultivation) and the response of the land to human actions are based on land-cover change and economic return (i.e. yield). The main processes that are simulated are illustrated as in Figure 1.

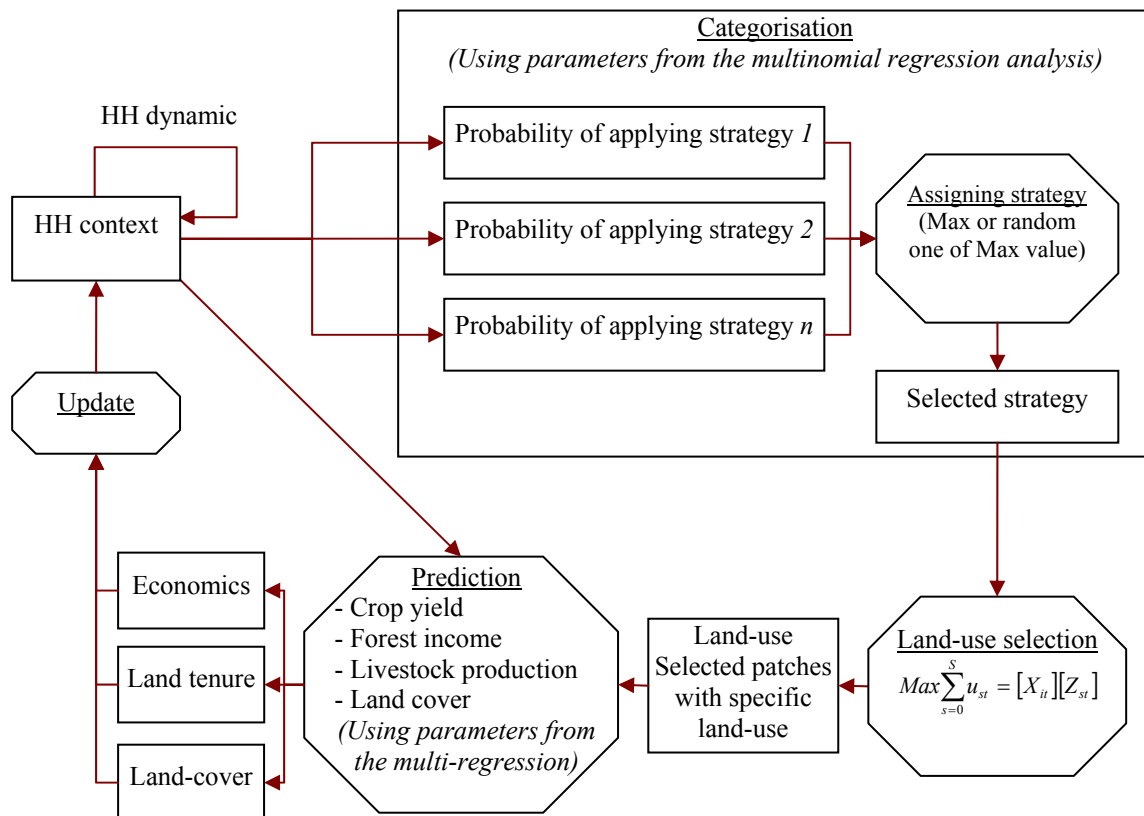


Figure 1. General process of simulation in the shifting cultivation model

The model was developed based on the assumption that the livelihood strategy of the shifting cultivator depends on their household context which includes accessibility and their personal perception of the available resources. The relationships between the household context factors and the land-use strategies were developed using statistical regression on data collected from a village in upland Vietnam. These statistical relationships have been embedded into the model to assign a land-use strategy to each household to determine the selection of fields for shifting cultivation. The selection function is adopted from Brown (2005) as follows:

$$\text{Max} \sum_{s=0}^S u_{st} = [X_{it}] [Z_{st}]$$

where u_{st} is a deterministic component of the utility function inferred by household i at patch s and time t , Z_{st} is the land specific factors and X_{it} is the land preference factors of the household, which can be predicted from a set of household specific characteristics (or context factors). A patch with the maximum value of u_{st} within the accessible land S will be subsequently selected for cultivation at time t .

The resulting land-use at each patch is then predicted by using estimated parameters from statistical analysis and assumptions from the field work data. The yield prediction function is in the form of $Y_{ist} = [H_{it}] [Z_{st}]$ where Y_{st} is predicted yield for household i with specific characteristics H_{it} (e.g. education level, land per capita etc.) at patch s with properties Z_{st} . Similarly, land-cover is predicted as $C_{st} = [C_{st-1}] [Z_{st-1}] [\lambda_t]$ where C is the land-cover type and λ is the human intervention factors that indicate possible human interactions with the field during the fallow period.

This ABM requires information on the status of shifting cultivation at the initial stage ($t = 0$) and possible behaviours of shifting cultivators at the study site. This information has been obtained through satellite image interpretation, field observation and an initial set of interviews carried out in the summer of 2007. Time series satellite images with ground truth data were used to produce land-cover and to predict the fallow length of land patches. All the spatial information has been captured in a GIS database, and then further populated with other key land properties that are important in the farmers' decision making processes regarding shifting cultivation. The household survey data collected in the field were used to formalise the decision making and other collective rules governing swidden field selection at household level while plot interview data was used for estimating the yield prediction model.

4. Model Prototype

Figure 2 shows an example of the integrated land and human modules as a Netlogo implementation. The figure shows an example of running the model for the village of Binh Son-1 with assumptions such as: the degree of forest protection is high so farmers will not cut down forest for shifting cultivation and farmers are not yet allocated land but can move to new areas for cultivation. The model takes both individuals and households into account when modelling the human side. Figure 2 shows an example of the location of active areas of shifting cultivation (in orange) after running the model with these assumptions.

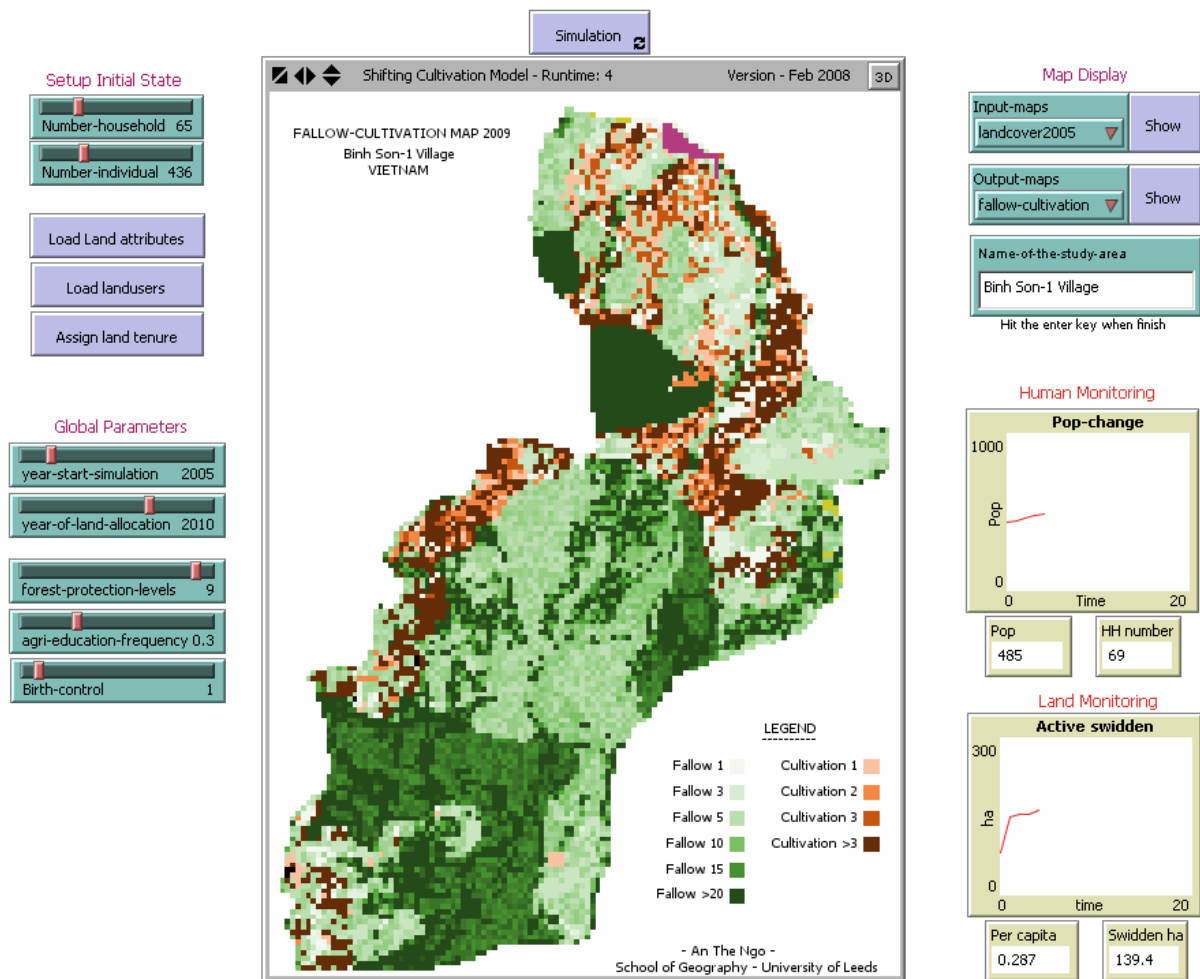


Figure 2. An agent-based model of shifting cultivation implemented in Netlogo

5. Conclusions

This paper has provided a brief overview of the agent-based model of shifting cultivation in Vietnam. Once the model is fully verified and calibrated, it will be used to consider testing different scenarios such as the effects of: (i) different levels of forest protection (ii) agricultural extension training and credit (iii) population controls and (iv) land allocation to farmers following new land laws.

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Biography

An The Ngo is a second year PhD student in the School of Geography, University of Leeds. Back in Vietnam, Mr. Ngo is a lecturer in GIS application for natural resources management at Hanoi Agricultural University.

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