Governing Forest Plantation to Reduce Poverty and Improve Forest Landscape: A Multiagent Simulation Approach

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Abstract: Good forest governance lets all relevant stakeholders participate in the decision-making processes. Illegal logging and forest degradation are currently increasing, and logging bans are ineffective in reducing forest degradation. At the same time interest in forest plantations and concern about poverty problems of people adjacent to forests continue to increase rapidly. Governments have identified the development of small forest plantations as an opportunity to provide wood supplies to forest industries and to reduce poverty. However, the development of small plantations is very slow due to an imbalance of power and suspicion between communities and large companies. Current regulations do not offer many links amongst various stakeholders. The paper proposes a framework to link up social, economic and biophysical dynamics using multiagent simulation to explore scenarios of collaboration for plantations. Multiagent simulation is a branch of artificial intelligence that offers a promising approach to deal with multi-stakeholder management systems, such as the case involving common pool of resources. It provides a framework, which allows analysis of stakeholders' (or agents') decisions in interaction. Each stakeholder has explicit communication capacities, behaviors and rational from which emerge specific actions. The purpose of this modeling is to create a common dynamic representation to facilitate negotiations to grow trees. Collaborations involving multi-stakeholders, especially local communities and wood based industries, appeared to offer the most promising pathway to accelerate plantation development toward local communities' poverty alleviation and forest landscape improvement.

Keywords: *Governance, forest plantation, local communities, collaboration, multiagent simulation, multiple stakeholders*

1. INTRODUCTION

Principle 22 of the Rio Declaration on Environment and Development (1992) highlights the importance of local people and their participation in sustainable development. In forest plantations, this applies to local communities living in or near forest plantations. In Sabah forest plantation stakeholders believe that many opportunities are met for smallholder forest plantation development. A lot of logged over land is available for plantation. The Sabah natives have the possibility to get security over land and the rural people have the will to invest in forest plantations (to secure their ownership of land, to rehabilitate the landscape, to rehabilitate wildlife resources for hunting, and to invest for themselves and the coming generations). Nevertheless, they do not want to invest as long as the wood prices are low. This situation is a major impediment for development of small plantations.

The challenge is to create the conditions for the co-development of plantation forests and down stream industries using plantation wood. On the one hand, investors will consider investments into down-stream industries for plantation wood if mature plantations are available; they might also differ such investments as long as faster returns from natural forest logging exist. On the other hand, smallholders will not invest in plantations as long as they do not have the guarantee of better prices. Currently SAFODA (Sabah Forestry Development Authority) have to export, at low price, fast growing wood produced on its own plantations as the existing paper mill in Sabah (Sabah Forest Industries) is too far away from SAFODA plantations.

Sabah State has already invested a lot in smallholders' plantations and SAFODA Estates. However, this development is in crisis as SAFODA is facing problems in self-financing its development in the current context of low wood prices. It looks like more coordination is needed between the Sabah policy of plantation and smallholder development and wood processing development.

The goal of the model is to observe the impact of wood processing development on land use and incomes of different stakeholders at regional level.

The local government perceives the development of forest plantations in this part of Sabah as a means to improve the landscape. Today most of the land, which has been logged over and is unused, is highly fire prone (a lot of areas are covered with *Imperata cylindrica*, and large stocks of remaining dead wood). The development of smallholders plantations backed by different small-scale wood processing industries (sawmills) could produce a variety of plantation systems. These plantations will reduce the areas' fire proneness and would involve the local population in fire control. This research explores such scenarios of co-development of smallholder plantations and wood processing industries.

2. MULTIAGENT SYSTEMS

Policy makers should be able to assess the very long term impacts of their decisions, such as the establishment of plantations or wood processing industries. Some major impacts might happen beyond the normal periods of monitoring. Simulation is one way to address this question, and may be the only viable alternative if the system is large or complex. "Simulation" means making a simplified representation of a real-world situation, and animating it so that stakeholders might envision what might be the future situation. Multiagent simulation (MAS) is a promising way to examine natural resource and environmental management issues (Bousquet et al. 1999). The hallmark of MAS is the recognition of "agents", which are entities with defined goals, actions, and domain knowledge. Some degree of agent autonomy is central to the notion of multiagent modelling (Weiss 1999). These interactions can be cooperative or selfish, with agents sharing a common goal or pursuing their own interests (Sycara 2000). Agents are entities within an environment, which they can sense, modify and move on. Their ability to sense means that they need not act as isolated entities, but can communicate and collaborate with other entities.

Simulating the stakeholders' activities and interactions requires a tool that is able to represent the individual's knowledge, belief, and behavior. MAS has its roots in the emerging field of artificial intelligence. Hence, most of the early theoretical development of MAS evolved from computer-related work (Weiss, 1999). Recognizing the close analogy between distributed artificial intelligence and individual-based modeling, a number of authors saw the potential for adopting MAS in natural resource management, particularly in areas where the management of the resources is shared among a number of stakeholders.

The research used CORMAS (Common Pool Resources and Multi-Agent System), a multi-agent simulation platform specifically designed for renewable resource management systems. It provides a framework for developing simulation models of the interactions between individuals and groups that jointly exploit common resources. CORMAS facilitates the construction of a model by offering predefined elements, which the user can customize to a wide range of specific applications (CIRAD 2001).

3. SITE DESCRIPTION

Malaysia is situated right in the heart of South East Asia and is divided into two geographical sections: Peninsular Malaysia and the East Malaysian provinces of Sabah and Sarawak in North Borneo. Figure 1 shows the map of Sabah.

Figure 1. Sabah location map

SAFODA was created by the Sabah Legislative Assembly in 1976. Its mission is to develop highly productive forest plantations for long-term supply of wood resources and the improvement the socio-economic status of the state and country on a sustainable basis (SAFODA n.d.).

Currently SAFODA manages about 100,000 Ha of land in Sabah located mostly in Bengkoka, Marudu and Keningau districts. The forest area amounts to 31,000 Ha. The planted species are *Acacia mangium* (28,000 Ha) and rattan (2,100 Ha). SAFODA and Sabah Forest Industries (SFI) promoted small landowners, adjacent to their forest plantation areas, to grow trees. Currently these smallholder plantations amount to 3,000 Ha and 1,900 Ha respectively, supervised by SAFODA and SFI.

4. THE SIMULATION

4.1. Methods

Stakeholders were identified according to the following criteria: proximity to the forest, legal or traditional rights over the forest, dependency on the forest and knowledge of forest management. Stakeholder characteristics were recognized through field visits and discussion. Researchers facilitated the discussion to establish stakeholder identities, their rational, and their behavior and actions. These characteristics formed the basis for the MAS model subsequently developed. We obtained other data from SAFODA and related literature.

There are four key phases in the development of a model (Grant et al. 1997) i.e. (a) *Forming a conceptual model* is to state the model's objectives, bound the system of interest, categorize its components, identify relationships, and to describe the expected patterns of the model's behavior; (b) *Quantifying the model* is to identify the functional forms of model's equations, estimate the parameters, and to represent it in CORMAS; (c) *Evaluating the model* is to re-assess the logic underpinning the model, and compare model predictions with expectations; (d) *Using the model* is to develop scenarios.

4.2. Results

Currently we have not incorporated the real spatial data into the model. Thus, the model is more a general model rather than a site-specific model. Even though, this model was constructed based on our study in Sabah we found this general model could apply, for instance, to plantations in Indonesia.

Identifying Stakeholders
The stakeholders identified, based on the criteria mentioned previously, are SAFODA, smallholders, buyers (for pulp and sawmill), sawmills, a pulp mill and the government. Table 1 describes the goals and strategies of those stakeholders.

Constructing the Model
The conceptual model is illustrated in Figure 2. SAFODA and the smallholders grow Acacia in their plantations. Then they negotiate with a buyer to sell their timber. The buyer sends the wood he bought to mills. The government observes the impacts of stakeholder interactions on the incomes of smallholders, pulp availability and landscape. The current study represented forest

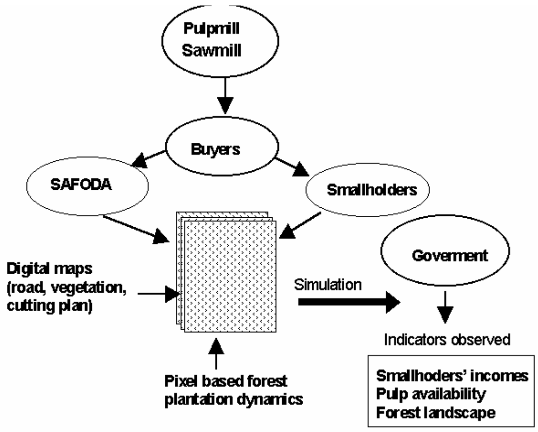

Figure 2. An overview of the model

Table 1 : The selected stakeholders, their goals and strategies

Stakeholder	Goal	Strategy
SAFODA	Improve its returns	By reducing its costs and increasing its revenue.
Smallholders	To improve their well being	They have lands and can expand the plantations. If the wood price is high enough, they expand their plantations for pulp or timber. If their wood pulp plantations are not commercially viable, they can convert it to timber wood plantation or other uses.
Buyers	To improve their profits	They take care of logging and transportation costs. They need a global margin of 20 %.
Sawmill *)	To improve their profits	It can be set up any where on the map; it generates a demand for wood at sawn-log price. The buyer takes into account the sawmill location to calculate the sawn-log price.
Harbor/pulp mill *)	To improve their profits	Wood for pulp is carried to the harbor for export.
Government	Forest sustainability	More smallholders, more wood resources and forested landscape

*) This is virtual. It does not exist currently

landscape as pixels, including explicit location of roads, vegetation and forest management plots. Each pixel represents an area of 25 ha.

Figure 3 shows as an example a virtual map of forest landscape where SAFODA, smallholders and the pulp mill are located. Small triangles represent smallholders. They can move during the simulation if they are not satisfied with the plot production where they are at the beginning of the simulation. Large plots marked 1 are SAFODA forest management plots. The different gray values relate to the plot wood stock, while black illustrates that the plot is ready to be cut. The black area at the map bottom represent the sea (5) and the harbor (7) from which wood is exported. In the top right of the large area marked (5) is the pristine forest. The white areas represent land devoted to agriculture, access for forest development is forbidden. The Y shaped lines are roads, with different grey colors relating to road qualities and subsequently to different transportation costs. A growth volume model represents plantation dynamics.

Table 2 shows the dynamic of pulpwood growth volume, which is used in the simulation; it is issued from different sources. At 10 years mean annual increment growth it is 14 cubic meters/ha.

Figure 4 illustrates the interactions between agents as a sequence diagram of unified modeling language.

Table 2. Wood growth for Pulpwood plantations

Year	1	2	3	4	5	6	7	8	9	10
Volume (Cubic meters /ha)	0	5	15	25	35	50	70	100	120	140
Annual volume increment		5	10	10	10	15	20	30	20	20

SAFODA has only pulp plantation, but smallholders might have small plots for pulp wood or also plots for sawn timber. When SAFODA has a plot ready to be cut, it sends a message to pulp buyers. If they are interested, negotiation between buyers and SAFODA follows. At the same time pulp and sawn timber buyers are looking for wood from smallholders.

If the smallholders have plots ready to be cut, they will send a message to buyers and then negotiation follows. Negotiation happens also between buyers and mills about wood prices. The negotiation results between SAFODA and buyers will affect SAFODA's strategy to re-plant during following years. If SAFODA implements benefit cost analysis for each plot then it will have two

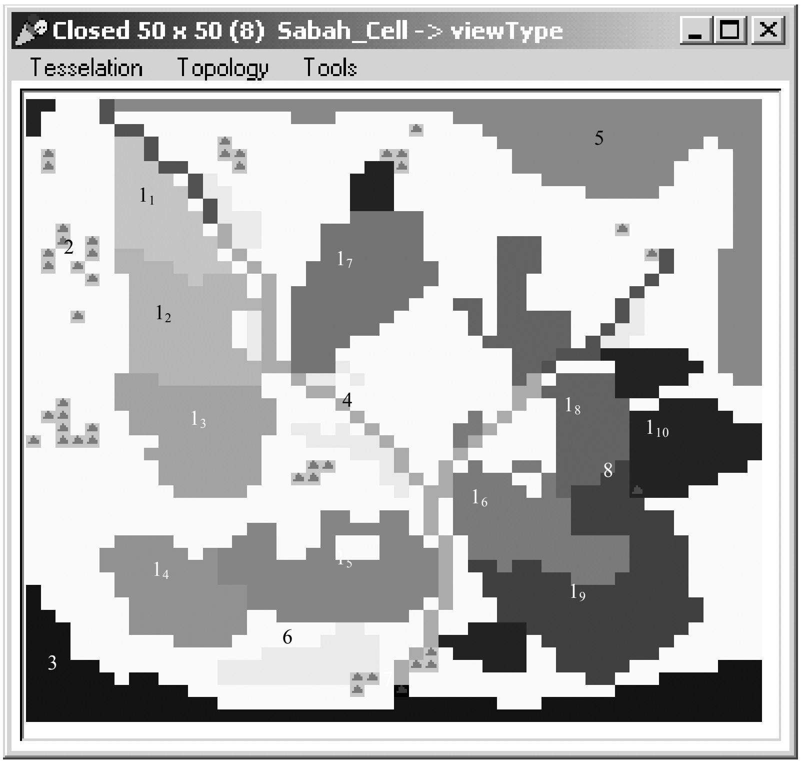

Figure 3. Representation of forest landscape.

1_n : SAFODA forest management plots (age 1 to 10);

2 : smallholder plots;

3: sea;

4 : road network;

5: pristine forest;

6: agricultural land;

7: harbor and

8: SAFODA field office.

Small triangles represent smallholders located in their forest plots at the beginning

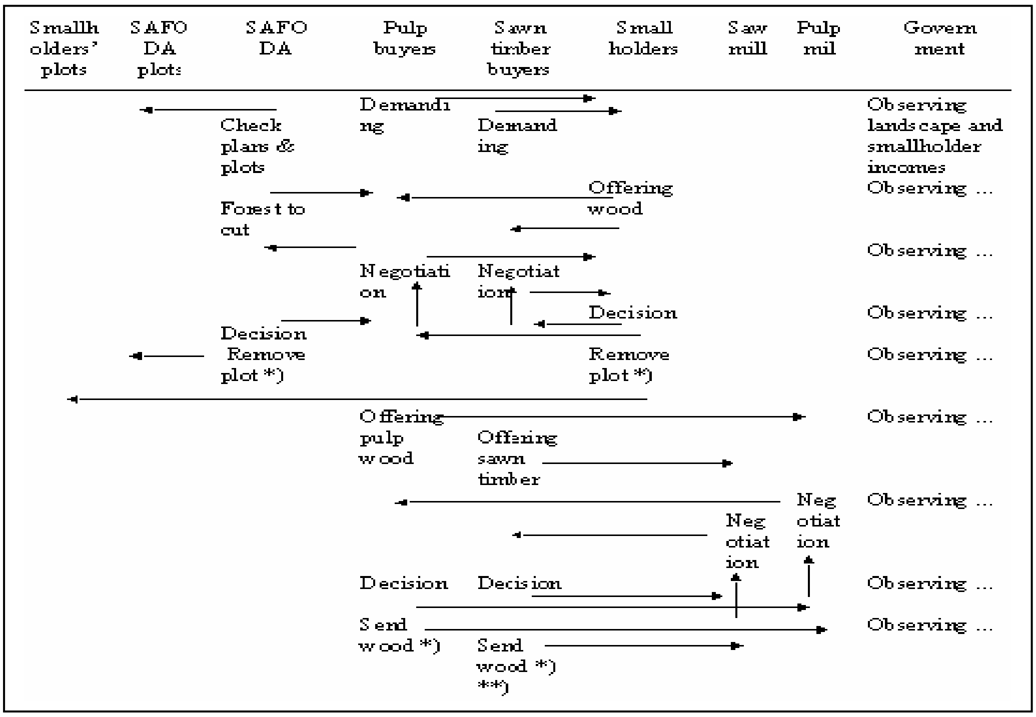

Figure 4. Sequence diagram of agent interactions. Note symbol *) If agreement is achieved; **) If there is a sawmill

options i.e. to grow or not to grow trees. If it uses a plant-cut-replant approach then it will grow tress regardless of income generated from the plantation. The smallholders take also into account outcomes of past decisions to decide about future activities. If they get good income from it then they will expand the plantation to new unproductive land.

The buyers propose prices to the tree growers based on the prices they can sell the wood for, to mills or at harbor for export. However, if there is no sawmill then it creates a problem of marketing and reduces the prices. The different distances, between plots, to the road network and to the mills will create different production costs. The rate of wood transport cost from plots to roads is higher than from road to mill. A spatially explicit algorithm to compute transportation cost was developed.

Evaluating the Model

The study was planed to involve development, tests and model use. Tests rely on the comparison of observed and simulated outcomes as well as careful consideration of the logic and behavior of the model. The dynamic responses implicit in many natural resource management questions add to the challenges of interpretation and testing (Barreteau at al. 2001).

The present model was evaluated using two criteria: the logic of the model and its outcomes and the similarity between predictions and expectations. The model passed these criteria. The assessment that the model was reasonable was based on systematic checking of all the relationships within the model, from the simplest sub-model (forest plantation growth), to the more complex sub-models (e.g., the agents' communications). Finally, the overall model performance was assessed. This assessment led to the conclusion that the model complied with the patterns we expected before.

The model has been found to be useful, particularly for developing scenarios and observing the likely impacts of each scenario on forest landscape and on the well being of smallholders. The model also acts as a general model by which a site-specific model can be derived through calibration and adaptation.

Envisioning scenarios of Forest Plantations

Under the current scheme, after 10 years, the smallholders move to the sites close to the road network to maximize their benefits in relation to transportation costs (Figure 5). If existing plantations are not sustainable, they just leave them. This will decrease the available wood for pulp, degrade the forest landscape and decrease their incomes.

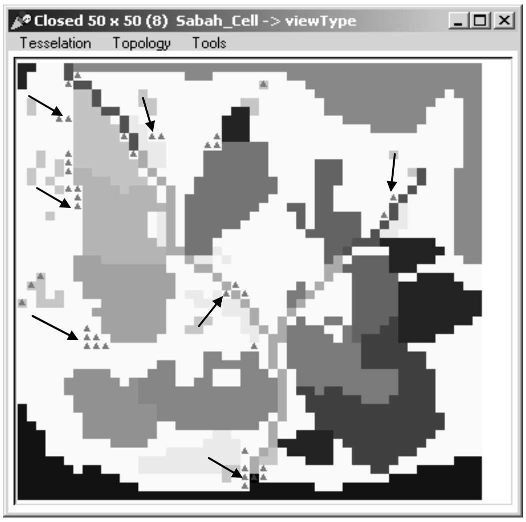

Figure 5. Smallholders leave their plantations. They leave their plots as indicated by arrows, and look for new accessible plots closer from main road

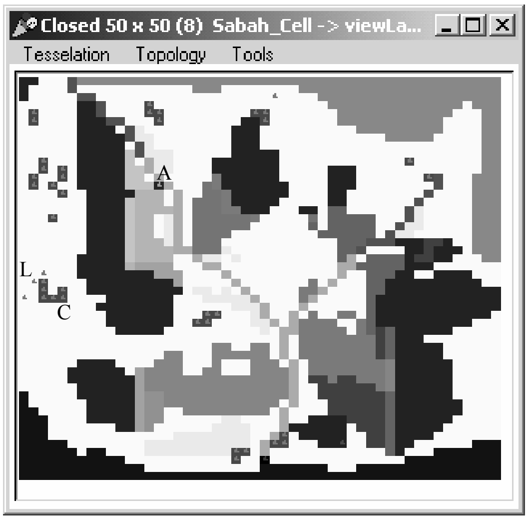

Figure 6. Impact of a sawmill establishment scenario. A is a sawmill, L example areas where the smallholders left, C example areas converted into sawn timber plots

Figure 6 is a scenario of sawmill establishment. The smallholders convert most their wood pulp plots into sawn timber plantations. These sawn timber plots are commercially sustainable and give more income to the smallholders. The smallholders leave several plots which are far away from the road network. The forest landscape is larger compared to a scenario where the sawmill does not exist.

5. CONCLUSIONS

The research concludes that MAS can be used to envision scenarios of forest plantation development over the long term and involving multi-stakeholders. Setting up a sawmill adapted for processing small logs from plantations would be a huge incentive for smallholders to develop plantations, including areas far from roads. The sawmills would increase the wood value. The outcome besides landscape management is also better incomes for smallholders. Without a sawmill, smallholders move to sites close to the road sides and leave their remote plots. Thus, wood supply to industries, smallholder incomes and forest areas are all reduced.

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