40. MODELLING THE DYNAMICS OF AGROFORESTRY ADOPTION IN THE UPLANDS OF SOUTHERN PHILIPPINES USING COMPANION MODELLING APPROACH

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A model was developed following an iterative process based on repetitive back-and-forth steps between the model and field activities. A Multi Agent System (MAS) was integrated with a Role-Playing Game (RPG) to understand the dynamics of agroforestry adoption in Claveria, Misamis Oriental. The model simulated and observed different scenarios: cumulative income of agroforestry adopters and non-adopters, impact of market information on farm income, and neighbour effects on the spread of agroforestry adoption. Results of the computer simulations were verified using farmer games and focus group discussions. Agroforestry and non-agroforestry farmers were invited to participate in the role-playing game in order to understand more precisely and validate the model. During the conduct of the role-playing game, the individual behaviour of agents under a number of scenarios and the properties of the system emerging from their interactions were examined and discussed among the players. The model scenarios and role-playing game can serve as a decision support for policymakers, farmers and other stakeholders towards sustainable management of resources. It is envisioned to produce information useful for understanding the decision-making strategies of farmers with regard to agroforestry adoption that can be essential to the success of efforts to address the sustainability of upland areas in the Philippines and elsewhere in south-east Asia.

INTRODUCTION

The companion modelling (ComMod) methodology uses role games to acquire knowledge, build a Multi Agent System (MAS) model and validate it, and use it as a support in the decision-making process dealing with collective resource management (Bousquet and Trébuil 2005). A MAS model is made up of a set of computer processes that represent several agents existing at the same time, sharing common resources, communicating and interacting with each other, and are making collective decisions about their resources (Ferber 1995, Bousquet and Trébuil 2005). The collective creation of a common artificial world serves for simulating various scenarios, to understand the coordination the various processes and increase scientific knowledge about the ecological and social processes at stake.

In the ComMod approach, the stakeholders participate actively in the construction and improvement of the model through an iterative process between the model and real environment. The various points of views are integrated in the development of the model which serves as a platform for simulating scenarios, dialogue, shared learning and the collective decision-making process. The ultimate aim of the ComMod approach is to strengthen the adaptive management capacity of local communities (Bousquet and Trébuil 2005).

The ComMod approach involves the use of MAs models and role-playing games. The three main stages involved in the development of the MAs model are: (1) field investigations and literature search to generate explicit hypotheses for modelling; (2) construction of the MAS model; and (3) simulations using the MAs model to challenge the former understanding and identify new researchable questions arising from the simulation process.

Stakeholders are invited to participate in the role-playing game in order to understand more precisely and validate the model. During the conduct of the role-playing game, the individual behaviour of agents under different scenarios and the properties of the system emerging from their interactions will be examined and discussed among the players. Role-playing games will also help stakeholders to follow the results of the simulations of the MAS model. In the iterative ComMod cycle, the model and the game co-evolve, complementing their improvement. The RPG facilitates the sharing and modification of the conceptual model with the stakeholders, whereas the MAS model allows fast simulations of various scenarios proposed by the stakeholders.

Agroforestry is an ecologically sound approach that has been promoted as a sustainable alternative in managing upland landscapes. It involves the integration of annual and perennial food crops, as well as livestock that generates social, economic and environmental benefits. A model to understand the adoption of agroforestry technologies in Claveria was developed using a companion modelling approach. The SAFODS-MAS model has been used to simulate and predict land-use change in Claveria as a result of agroforestry system adoption by the various farmer types. It aims at supporting discussion and coordination among stakeholders at the study site to manage better their resources by simulating the decision-making strategies of upland farmers in adopting crops and trees.

RESEARCH METHOD

SAFODS-MAS Model Development

The SAFODS-MAS model was developed using a stepwise approach. A series of Participatory Rural Appraisal (PRA) activities, case studies and household interviews and literature review were conducted to gather information on the study area. Particular consideration was given to the farmers' and stakeholders' perceptions, motivations and actions.

The PRA activities including reconnaissance survey, transect line, mind mapping and a focus group discussion were conducted to obtain an initial biophysical characterization of the study site and a socio-economic profile of the farmers in the area.

Explicit assumptions were made about the elements and structure of the agroforestry adoption in Claveria. These assumptions were used and implemented in CORMAS (Common-pool Resources and Multi-Agent Systems), an object-oriented programming environment created in VisualWorks using the Smalltalk programming language. This language is designed for developing simulation models of coordination modes between individuals and groups that jointly use common resources (CIRAD, 2001).

The farmer's farm, designated as a plot represented the spatial entity of the model. Attributes including area, slope and elevation are included in the biophysical characteristics of the plot. The passive objects in the model are crops including maize and tomatoes, timber trees including *Gmelina arborea*, fruit-bearing perennials including bananas, and the market. The crops are characterized by their yield and the elevation of the land where it is suitable to plant them while trees are attributed with their age or the readiness to harvest. The market is attributed with the lists of possible prices of crops and trees. The communicating agents including the farmers perform the greatest number of activities, including adopting particular agroforestry system (AFS), maintaining the AFS, harvesting the trees and crops and selling them, while timber traders and crop traders have the cash to purchase tree products and crops, the set of prices and the knowledge of the market.

Farmers' associations were introduced thus: a farmer knows a set of farmers in the neighbour network; farms close to each other formed a network within which farmers can observe the activity and methods of other farm members; farmers' decisions to cut and sell trees depend on both selling price and the actions of neighbouring farmers, as they may imitate what their neighbours are practicing.

Decision-making Processes and Activities in the Model

Farmers were classified into agroforestry adopters and non-adopters. Non-adopters need to perform three activities: (1) making a choice of crops; (2) harvesting and sale of crops; and (3) observing their neighbour agroforestry adopter. After each harvest farmers updated their cash. Because of the farmer's neighbour network, they can observe and compare their income with those of the agroforestry adopters. The chance of shifting from non-agroforestry adopter to agroforestry adopter is depends on the level of income received. The extent of farmers' knowledge of the crop, timber and fruit market affects their decision to sell his tree products.

Adopters perform four activities: (1) crop choice; (2) agroforestry adoption; (3) collection of seeds for barangay nursery; and (4) harvesting and sale of crops and trees. They have to assess the availability and sufficiency of planting materials before they finally decide the area of their farm that will be planted to a particular crop or tree. If an adopter farmer is a member of the barangay nursery cooperative, they are required to give the nursery excess tree seedlings from their collection of planting materials. These planting materials are pooled together by the barangay nursery operators, and are distributed equally between members.

Farmer adopters then assess the availability of space to adopt block planting, because this system requires at least 1.5 ha of farm area. If the farm area is limited, farmers need to see if they can adopt border planting or the parkland system instead of block planting. Hedgerow planting is limited to areas with slope greater than 18 degrees. Initially, farmers have to buy the planting materials for timber and bananas. Later on, these initial trees and banana plants will be sources of planting materials for the farm and the barangay nursery.

In marketing the crops and trees, farmers have the option to sell them to the market or to the set of traders with which they are acquainted. Farmers will sell their harvested ground crops (maize and tomatoes) to the crop trader with the highest buying price. They allocate a portion of their maize harvest (30%) and banana harvest (20%) for home consumption. The rest of the maize harvest is sold to the crop trader with the highest buying price and bananas are sold in the local market.

In selling the timber, the farmers may decide to imitate other farmers within their network of farmers who are selling timber trees, reflecting the social network effect (as described by Janssen and Jager 2001). The observation of the effects of the farmer network and the timber trader network on the selling price will determine the decision whether to harvest the trees. If price is acceptable to farmers, they will sell the timber. However, in cases where selling price at farmer network and traders are both not acceptable, farmers' knowledge of the market price is an advantage.

The SAFODS Role-playing Game (SAFODS-RPG)

The SAFODS-RPG is designed as a representation of the real decision-process undertaken by farmers in Claveria in adopting agroforestry. The game was conceptualized to validate the simulation results of the SAFODS-MAS model. Actual players, cards and diagrams represented each entity of the MAS model. Rules and explicit and concrete assumptions were used. These are lists of actions or activities and possible results or outcomes of the actions.

Structure and elements of the SAFODS-RPG

There are four important components of the RPG: the rules and assumptions of the game, the players, game board and tokens. In the SAFODS RPG, farmers are the key players. They were chosen based on the slope and elevation characteristics of their plots and the farming system they adopt. They are allowed to plant any crop and tree on their plots as well as the farming system adopted. The farmers were given the following choices:

1. crop choice between tomatoes and corn;
2. fruit bearing perennial choice among bananas, rambutan and lanzones;
3. timber tree choice among *Gmelina arborea, Acacia mangium* and *Eucalyptus deglupta;*
4. farming system choice between annual cropping and agroforestry system.

In order to show to farmers a representation of the actual environment of Claveria, a 3D boardgame was constructed based on a topographic map of Claveria (Figure 1). It represented Lower Claveria (300–600 masl), Middle Claveria (600–800 masl) and Upper Claveria (> 800 masl). Plots are located in each region, and are characterized by slope. Three slope classes are considered and they are represented by varying hues of green colour: flat or level (light green), slightly steep (green colour) and very steep (dark green). Rivers running through the landscape are demarcated by white colour.

Figure 1. The SAFODS-RPG board game representing the landscape of Claveria

Tokens (pieces of coloured 'Post-it' paper) are used to represent social and passive objects on the playing board. Farmer plots are represented by pieces of specially prepared 'Post-it' paper (Figure 2). Information about the annual crops, timber and fruit trees, age of trees and the AFS practiced are written on these tokens and are placed on the game board. Income cards on the other hand are used to indicate the money gained or lost by each farmer from the adoption of a particular farming system (Figure 3).

Figure 2. 'Post-It' papers representing the plots with their attributes

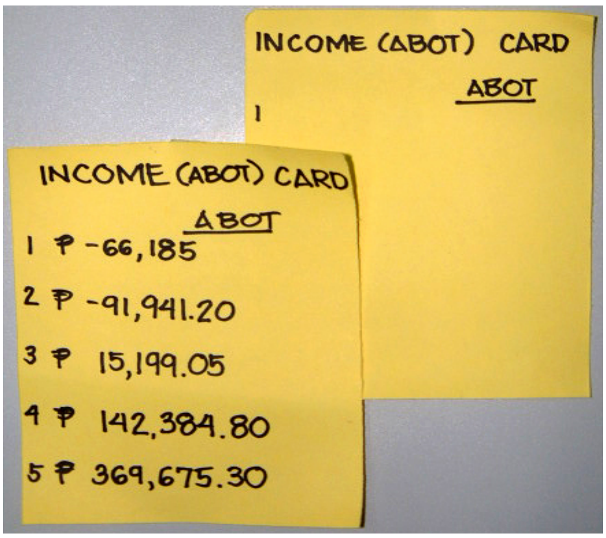

Figure 3. Income cards indicating the amount of money gained or lost by farmers

Phases of the game

The game is designed for 5 to 10 players taking part in each gaming session. Before the start of the game, participating farmers are assigned plots on the playing environment which is a 3-dimensional board model that represents the typical local landscape. The farmers then examine the location and properties (slope and elevation) of the plots assigned to them from which their decisions on farming strategies will depend. This will be their assigned role. The assigned roles of the participating farmers will depend on the slope and elevation of their plot.

The game begins with farmers (players) deciding on the crops and trees to plant on their plots, the proportion of the area to be planted with the selected crop and trees, and their field layout. The players hand over the tokens to the game organizer who will record the data (crop/tree, area and arrangement) in a prepared spreadsheet. At each time step, all crop and tree yields depend on the weather, which is randomly defined by the game organizer after all the crops and trees are planted. Toward the end of each simulated 'crop year', the game organizer informs the players of the weather and climate during the simulated 'crop year' and the prices of the commodities. Based on the climate, location of the plot (elevation and slope), proportion of area planted to each crop or tree, age of the tree, type of tree (timber or fruit tree), and agroforestry system practiced (arrangement of trees and crops), the game organizer will compute (using a separate computer software package) and inform the farmers of their harvest for the simulated 'crop year'.

Based on their computed crop and tree harvests (timber or fruit) and the announced commodity prices, the farmer will allocate portions of their harvests for household consumption and for marketing. The players will hand over to the game organizer the data on the allocation of harvests for marketing. The game organizer will then compute the money gained or lost based on the farming system adopted, whether annual cropping or agroforestry practices. The results are then relayed back to each player using an income card. The income gives the farmers insights on whether to continue adopting their farming system or shift to other more productive system. The farmers as players can interact with other players and exchange information on their income and farming strategies from the past 'crop year'. This will constitute one round of the game. Each game round represents three years or six cropping cycles or six time steps of the SAFODS MAS model.

During the game, researchers take notes on the decision process undertaken by farmers in the adoption of agroforestry. A complete game consists of 5 rounds, equivalent to 15 years of farming. After the completion of the game, focus group discussion is conducted with the farmer players to elicit the reasons and motivations of farmers in adopting or not adopting agroforestry and in changing their farming strategies.

OBSERVATIONS FROM GAMING EXPERIMENTS

SAFODS-MAS Simulation

Simulation results showed the effects of the interactions among farmers in the diffusion of agroforestry systems in the area. The indices of income from crops and tree products over time allowed comparisons of economic benefits gained in the adoption of agroforestry systems and annual cropping. The simulations also allowed the evaluation of the consequences of farmers' marketing knowledge. It displayed the effects of establishing a common nursery for the barangay and the influence of farmers' neighbours on their decisions.

Cumulative income of agroforestry adopters and non-adopters

The cumulative income of adopters and non-adopters from a particular farming scenario is presented in Figure 4. At time steps, early in the game, the cumulative income of agroforestry adopters is lower than the cumulative income of non-adopters. This can be attributed to the initial costs of establishing trees. However, at time step 45 (after 23 years), agroforestry adopters derive higher income than non-adopters. Although farmers received positive income from trees after 100 time steps, the increase in income from adopting agroforestry is relatively small compared with the income contributed by the production of high value annual crops including tomatoes. The long gestation period from planting to marketing tree products is an important factor.

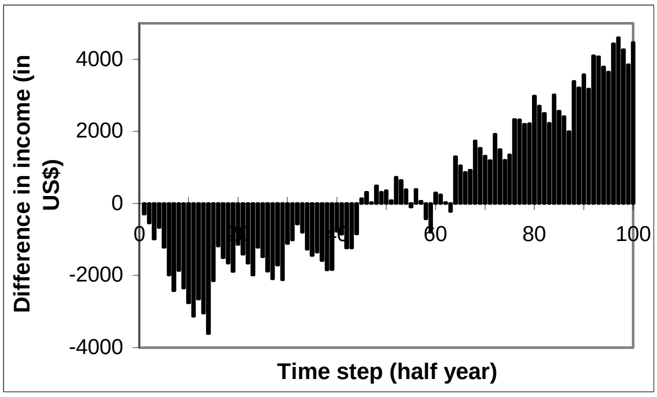

Figure 4. Seasonal farm income of agroforestry adoptors relative non-adopters

Neighbour effects

To determine the extent of neighbour's influence in agroforestry adoption, two scenarios were simulated using the model. In both scenarios, each plot will have four neighbouring plots. The farmer may have adjacent plots, in which case he will not include himself in the observation.

In the first scenario, about 30% of the population (7 out of 20 farmers) are annual cropping farmers or are not adopting an agroforestry system while the other 70% are agroforestry farmers. In the second scenario, 95% are annual cropping farmers and only 5% of the population (one out of 20 farmers) is an agroforestry adopter, as illustrated in Figure 5.

Simulation results of the first scenario reveal that at time step 4 or at the second year, about 15% of the non-adopters adopted a particular agroforestry system. On the other hand, simulation results of the second scenario indicate a gradual or slower rate of agroforestry adoption up to the 30th time-step. In both scenarios plateaux for the number of adopters are reached. In the first scenario, a plateau was reached at time step 14 while in the second scenario a plateau was reached at time step 30.

Results showed that farmer neighbours have great influence on the spread of agroforestry in Claveria. The more farmers adopting an agroforestry system in the neighbour network the greater is its influence to motivate the non-agroforestry farmers to practice an agroforestry system. Farmers shifted because of the increased income from harvesting and selling bananas and adoption of agroforestry was observed even at the 14th time step or the seventh year when gmelina trees are ready for harvest (Figure 5).

Plateau was attained at an earlier stage in scenario 1 because shifting from non-adopter to adopter ceased at an earlier time. The remaining non-adopter farmers are those with three to five parcels who are able to plant tomatoes. They have a much higher income than those farmers adopting agroforestry. In the second scenario, the plateau is reached at a later time because of the spatial distribution of adopter farmers in the landscape. The likelihood of an agroforestry adopter occurrence in the neighbour network is lower, thus it will take several time steps for a non-adopter to shift to agroforestry. The spread of agroforestry is slow across the landscape in the second scenario.

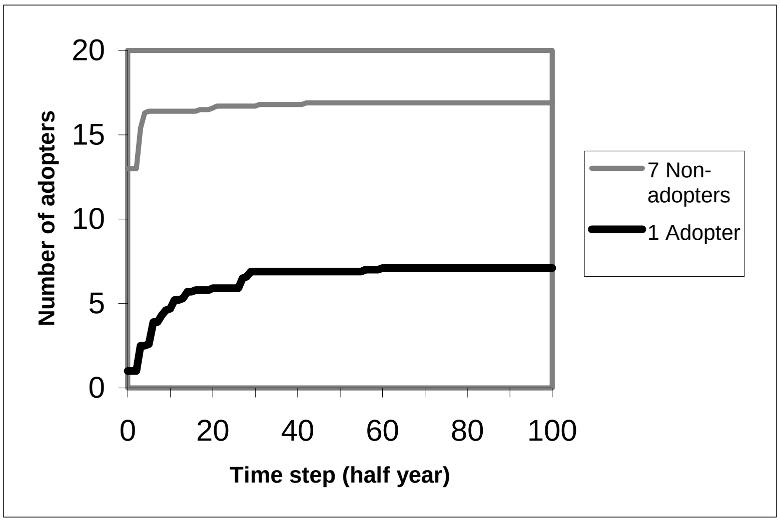

Figure 5. Effects of neighbours on the adoption of agroforestry

Market Information

Market state is one of the major factors contributing to sustainable agroforestry. Farmer adoption of agroforestry technologies is strongly affected by the availability of markets for crop and tree products. In this scenario, market information is implemented by allowing farmers to compare the prices between the market and the traders, which is not done in the base model. In the base model, a farmer who knows traders would automatically sell their produce to the trader offering the highest price without going to the market, which may have a higher price than the trader. If farmers have limited access to information on market prices, they cannot optimize the opportunity to sell at the highest price offered in the market. Figure 6 shows the increase in income by allowing the farmers to compare the prices between the traders and the market and being able to sell at the highest price.

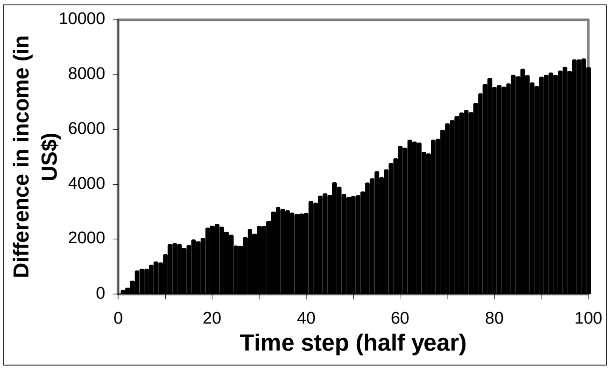

Figure 6. Cumulative difference of income of farmers with market information relative to farmers with limited market information

ROLE-PLAYING GAME RESULTS

Corn is preferably planted in flat areas and the purpose of planting corn is mainly for household food. In steep areas, corn may also be planted provided the soil is not stony and contouring is practiced to prevent severe soil erosion. The inputs required to raise corn are lower compared with tomatoes, a high value crop. Some farmers say that even if the income from planting corn is negative, they will still opt to plant their farm to corn instead of leaving the land idle during the cropping season.

Farmers do not plant native corn varieties with low fertilizer requirements due to the problem of cross-pollination. A combination of yellow and white kernels in one corn cob – obtained with improved varieties – is not marketable in the area. Also, this corn cannot be stored for a prolonged period of time because it is highly prone to attack by insects.

Tomatoes grow well in high elevation areas (>800 masl) where the temperature is lower. Planting tomatoes would require high inputs including fertilizer and pesticides. However, if they have a good harvest with a high market price, farmers can 'hit the jackpot' with returns from corn. The problem with a high-volume harvest crop of tomato is that overall market supply becomes high, and consequently the tomato price becomes low.

Planting pineapples along the hedgerows of native vegetation strips is an effective strategy for control of soil erosion. When mother plants are allowed to grow continuously, they can produce 4–5 suckers after one year. Bananas bear fruits after 12 months and a mother banana plant can produce 4–5 suckers after six months. If there is no infestation, usually, there is no mortality of the suckers. The only management requirement is that farmers have to maintain the area weed-free. The mother plant has to be cut off after fruiting. Different varieties of banana have different longevity. *Bululan* and *saba* varieties produce continuous and permanent crops while *lakatan* variety lasts for only three generations.

Trees are preferably planted along farm boundaries and for soil erosion control. Particularly in flat areas, trees are planted along the boundaries while the farm is planted to corn. This way, competition for nutrients coming from the fertilizer is minimized. Timber trees are planted mainly for construction materials to be used on the farm. Farmers are willing to wait for 20 years before they harvest *Gmelina arborea*. Many farmers have observed that gmelina is not suitable as a hedgerow species. Prunings from timber trees are also a source of fuelwood. Falcata is the preferred timber tree for income. Another consideration is the quality of the land; if the area is stony, farmers opt to plant timber trees.

A major concern of subsistence farmers is the long wait before fruit trees start to bear fruits. However, when fruit trees begin to bear fruits, the income generated from selling fruit is helpful to augment family income. The preferred fruit trees are durian and lanzones because of their high market price. A high fruit tree diversity such as a combination of coconuts and bananas with fruit trees (star apple, jackfruit, marang and lanzones) is ideal, providing diverse sources of family income and food. The main constraint to growing fruit trees, however, is land tenure. If the farmer does not own the land, he has to ask permission from the owner of the land, and if the owner decides not to plant trees, farmers cannot plant trees. Security of fruits from theft is another concern, thus there must be someone to guard the fruits. Road accessibility is another concern when marketing fruits. Competition for light and space is a factor to consider in planting different species of trees in the farm. Lanzones have a narrow canopy even up to maturity and the root system is relatively small, thus corn can be planted under lanzones trees. Lanzones provides high income to farmers. Planting fruit trees as hedgerows along the contours will also provide soil erosion control.

One farmer practices a combination of multiple agroforestry systems. She has hedgerows of rambutan and corn and tomatoes, block planting of mahogany, and border planting of gmelina.

Strategies of farmers in transition to agroroforestry

Trees are planted 10 m apart so as to be able to plant corn in between the trees. In this way, there is no need to apply fertilizers to the trees because they can avail of the nutrients from fertilizers applied to corn. Under circumstances when the canopy of the trees grows so full that it is not feasible to grow corn in between the trees, farmers plant shade loving plants instead, and example being wild taro (*Colocasia esculentum*).

CONCLUSIONS

Multi-agent systems and role-playing games are tools that can tackle complex and dynamic systems, including agroforestry systems. The role-playing game is an effective tool in eliciting farmer knowledge in the management of their natural resources, and the players learn from the game while they are having fun playing it. Scenario simulations can serve as a tool to facilitate interactions between stakeholders and scientists and in the future as decision-support for policy-makers, farmers and other stakeholders towards sustainable management of resources. It is envisioned to produce information useful for the design and dissemination of agroforestry technologies to other sites.

Results of the RPG indicated that farmers are motivated by biophysical and socio-economic conditions in adopting annual cropping and agroforestry systems. In relatively flat areas, planting of annual crops including corn and tomatoes give higher priority than planting trees. Because farmers have less land to spare, they primarily allocate the planting of staple food including corn to plot areas where they can grow best.

The adoption of agroforestry systems is greatly influenced by the biophysical conditions of the farms. Border planting is a widely adopted agroforestry system because this system occupies a relatively small space. On slightly steep areas, a hedgerow system is adopted to minimize soil erosion. On very steep areas block planting of timber is preferred because this system will entail minimal management. Fruit bearing perennials are preferred primarily for income. Fruit tree species that provide relatively high returns for farmers are lanzones, durian and bananas. Falcata is the preferred timber tree for income.

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