Developing a multi-agent systems model of agroforestry adoption on smallholder farms in the Philippine uplands

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The SAFODS-MAS (Smallholder Agroforestry Options for Degraded Soils–Multi-Agent Systems) model was developed following an iterative process based on repetitive back-and-forth steps between the model and field activities. Gradual changes in the model were introduced as new ideas from fieldwork were collected. Ideas, information, and knowledge about the study area were gathered and accumulated using a combination of participatory rural approaches (PRA), household surveys, and case studies. The model was developed to understand the adoption of agroforestry technologies by smallholder farmers in the sloping uplands in Claveria, southern Philippines.

Two versions of the model are presented here. The initial version of the SAFODS-MAS model is composed of the Crop-Tree Choice module and Timber Harvesting and Marketing module. The main features of this version are that (1) farmers' choice of crop to plant is greatly influenced by elevation and financial capital, (2) planting of trees is largely dictated by land tenure, and (3) harvesting and marketing of mature timber trees are influenced by timber price. Modifications in the second version of the model included farmer typologies (agroforestry adopter and nonadopter), fruit traders, choice of agroforestry system as affected by available capital and slope, and the social network effect.

The second version of the model was used to simulate and observe the different scenarios: cumulative income of agroforestry adopters and nonadopters, impact of market information on farm income, neighbor effects on the spread of agroforestry adoption, and impacts of the establishment of a tree seedling nursery on tree planting and income from trees.

The model scenario simulations can serve as a decision support for policymakers, farmers, and other stakeholders toward sustainable management of resources. It is envisioned to produce information useful for the design and dissemination of agroforestry technologies to other sites.

The sloping uplands are geographically the most extensive ecosystem in Southeast Asia, constituting from 60% to more than 90% of the total land area of the respective countries. These areas are likewise the most threatened ecosystem in the region because of increasing populations of subsistence farm families cultivating the infertile soils, land degradation, soil erosion, and deforestation (Garrity 1993). A large and rapidly expanding portion of the upland landscape is being converted to permanent annual cropping. These cultivation systems are usually found in the relatively accessible sloping areas, close to lowlands and roads.

Many factors limit the stability, productivity, and sustainability of upland farms, including inappropriate land use considering land topography, soil fertility, vulnerability to soil erosion, lack of planting materials, climatic variation and lack of irrigation systems, biological stresses, insecure land tenure, and social and economic uncertainty. New technologies will be essential in sustaining the stability and productivity of upland farms.

Agroforestry is a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms, diversifies and sustains smallholder production for increased social, economic, and environmental benefits (Leakey 1996). Trees and crops in agroforestry systems interact in relation to total nutrient and water cycles as well as light capture. Several positive interactions take place. Nutrient and water recycling occurs. Tree roots act as a "safety net" for nutrients that have leached down the soil profile below the crop roots and as a "nutrient pump" for weathered minerals in deep soil layers. Old tree root channels improve water infiltration and can reduce soil erosion. Nitrogen is supplied by tree roots due to root decay or by nitrogen fixation. Mycorrhizal associations enhance phosphorus availability, litter production, and maintenance of soil organic matter. Mulching conserves soil moisture and enhances soil microbial activity. Shading and microclimate improvements render temperature and humidity favorable for understorey species, and maintain carbon stock and belowground biodiversity. Negative interactions that may be involved between trees and crops are aboveground competition for light, belowground competition for water and nutrients, pests and diseases, and the allelopathic effect (Rudebjer et al 2001).

In the past three decades, a stream of government programs and externally funded projects were introduced and implemented in Claveria, southern Philippines. Among these were Sustainable Agriculture, SALT (Sloping Agricultural Land Technology), community-based forest management (CBFM), reforestation, agroforestry systems, and Landcare. However, most of these projects had low rates of adoption and success and were not sustained after project termination. The adoption of agroforestry systems was found to be concentrated at specific locus points and lacked widespread adoption in the municipality.

A model to understand the adoption of agroforestry technologies in Claveria was developed using a combination of participatory approaches, household surveys, and agent-based modeling. Understanding the decision-making strategies of farmers with regard to agroforestry adoption is essential to the success of efforts to address the sustainability of upland areas in the Philippines and Southeast Asia. In developing the model, we follow the "companion modeling approach," in which we start with a preliminary model with initial ideas about the system that is eventually revised and rebuilt. The model evolves as a result of the addition of new information from actual observations and experiences in the field. This process leads to the construction of a new model and, as this cycle is repeated, a family of models representing the successive interactions between the researcher and the field is developed (Barreteau et al 2003). The SAFODS-MAS (Smallholder Agroforestry Options for Degraded Soils–Multi-Agent Systems) model is a work in progress resulting in a genuine knowledge-based system that allows interactions between researchers and stakeholders (Berkes and Folke 1998, as cited in Barreteau et al 2003).

Land-use change involves interactions between ecological and socioeconomic systems (Polhill et al 2002). The FEARLUS (Framework for the Evaluation and Assessment of Regional Land-Use Scenarios) project applied agent-based modeling techniques to explore possible land-use outcomes under different scenarios such as the introduction of new legislation, globalization of markets for farm produce, or climate change (Polhill et al 2003). In our study, the SAFODS-MAS model will be used to simulate and predict land-use change in Claveria as a result of agroforestry system adoption by the different farmer types.

The SAFODS-MAS model aims at supporting discussion and coordination among stakeholders at the study site to better manage their resources by simulating the decision-making strategies of upland farmers in adopting crops and trees.

The study site

Claveria is a municipality of Misamis Oriental, Mindanao, about 40 km southeast of Cagayan de Oro City. Claveria is the biggest municipality in the province of Misamis Oriental, with a total land area of about 82,500 hectares, which is 30.5% of the province. In 1999, the population was estimated at 46,745 and it is scattered sparsely at 61 people per km^2, with an annual growth rate of 4.62% (CCLUP 2000).

The municipality is on a volcanic plateau ascending abruptly from the west from about 350 m to about 1,200 m in the east. Its topography is generally rugged, characterized by gently rolling hills and mountains with cliffs and escarpments. It sits on six major watersheds. The area is divided into two topographic regimes: Upper Claveria with an elevation of 650–915 m and Lower Claveria with an elevation of 390–650 m. Upper Claveria is located in the north and northeast areas of the town while Lower Claveria lies in the west and northwest section of the municipality.

Soils from Claveria are derived from pyroclastic materials and classified as acidic-upland (fine-mixed, isohyperthermic, Ultic Haplorthox) with a depth of more than 1 m (Garrity and Agustin 1995). The soils are usually characterized by high organic matter content, low pH (4.2–5.2), and low CEC and anion activity (Hafner 1996, CCLUP 2000).

According to the Philippine climatic system, the area belongs to Type 2 climate, with pronounced dry and wet seasons. The wet season is from June to December (>200 mm rainfall mo^{-1}) and the dry season (<100 mm rainfall mo^{-1}) from January to May (CCLUP 2000). The average annual rainfall in the area is 2,000 mm (Garrity and Agustin 1995). However, rainfall patterns throughout the municipality vary with elevation, with the upper areas of Claveria having relatively more rainfall than the lower areas (CCLUP 2000). The rainfall pattern is one factor that determines cropping patterns and land use across Claveria's landscape.

The municipality of Claveria has a total estimated open cultivated/agricultural land area of 26,055 ha. The dominant crop in Claveria is maize, with 51% of the arable land devoted to maize production. In Upper Claveria, 1,837 ha are planted to tomato. Cassava is a widely grown root crop in Lower Claveria (CCLUP 2000). Selected permanent crops are orchards, coffee, cacao, coconut, banana, and others. Banana occupies a larger area (641.5 ha). It is followed by coffee (497 ha) and coconut (172 ha). The presence of promising high-value permanent crops such as durian, rambutan, mango, lanzones, and mangosteen is thriving in the area.

Soil erosion occurs frequently in sloping areas cultivated to annual crops (Beniest and Franzel 1999). Increased pressure from rapid population growth has resulted in the clearing of remaining forests and grasslands, causing watershed degradation. Several NGO-assisted projects advocating agroforestry technologies to minimize soil erosion, restore soil fertility, and improve crop production have been introduced to farmers at the site (Mercado et al 1999). Although positive results of agroforestation have been observed at several experimental and demonstration sites, farmer adoption of the technology has been poor. This low adoption is associated with the constraints of high labor requirements for establishing and managing agroforestry systems, the longer time for a return to investment, above- and belowground competition of crops and trees causing poor crop yield, and a lack of marketing knowledge of farmers for timber and other tree products (SAFODS 2003).

Methodology

The SAFODS-MAS model was developed using a stepwise approach. A series of participatory rural appraisal (PRA) activities, case studies, and household interviews were conducted to gather information and accumulate knowledge on the study area. Particular consideration was given to the farmers' and stakeholders' perceptions, motivations, and actions. Two versions of the model were developed representing the evolution of knowledge resulting from the interactions between the researchers and the actual conditions in the field (Barreteau et al 2003).

Participatory rural appraisal (PRA)

PRA is a growing family of approaches and methods to enable local people to express, enhance, share, and analyze their knowledge of life and conditions, to plan and to act (Chambers 1994). A four-day PRA with key informants from different *barangays* (smallest political unit) in Claveria was conducted to obtain an initial biophysical characterization of the study site and a socioeconomic profile of the farmers in the area.

A reconnaisance survey and transect line were conducted on the first day to have an overview of the area's landscape, biophysical conditions, and existing agroforestry and cropping systems. These activities were done to assess the strengths, potentials, constraints, and opportunities for agroforestry adoption. One-on-one interviews were conducted with selected key informants, including farmers, barangay officials, elders, and extensionists in the area. Key informants (KI) were selected on the basis of their perceived level of knowledge and experience on the different topics that were tackled. General topics discussed in the KI interviews were agroforestry systems, soil erosion, soil fertility management, marketing, and farm production.

On the third day, farmers were grouped into two: Upper Claveria and Lower Claveria farmers, based on the general elevation of their local community (barangay). The mind-mapping activity was done separately for the two groups of farmers. Farmers' ideas and knowledge on soil degradation, strategies to examine soil degradation and rationale, local ecological knowledge on trees, tree-crop preferences, perceived improvement needs in the marketing of farm products, and the relevance of different institutions in the locality were probed. The two groups of farmers were also asked to recall significant events pertaining to land-use change and the introduction of trees in the area for the time-line activity.

These activities were carried out to come up with a stratification scheme or typology of farmers based on resource endowment, ratio of land to family labor, farmers' motivations to plant trees, and farmers' local ecological knowledge on soil conservation and tree-crop interactions.

Results of the PRA showed that farmers practiced four types of agroforestry system based on spatial arrangement of trees, hedgerow planting, parkland or scattered planting, block planting, and border planting. This facilitated the stratified random sampling in selecting the respondents for the subsequent activity, the household survey.

Household survey

The study area covers 17 barangays in the municipality with a total of 6,918 households, of which about 89% of the households are engaged in farming. Interviews of 300 households were conducted to collect primary data on farmers' demography, farm biophysical resources, household socioeconomic data, motivations for planting trees, and ecological knowledge.

Verification of information

Verification of the information gathered from the household survey was carried out through case studies, traders' interviews, and consultations with farmers and government agencies.

Model development

The SAFODS-MAS model was implemented using the CORMAS (common-pool resources and multi-agent systems) software. Two versions of the model have been developed as data and knowledge on the field accumulate through the conduct of the different research activities.

The initial version of the model was conceptualized from the results of the conduct of the PRA activities. These activities lead to exposure of the researchers to the field and interaction with farmers in the area. Farmers' adoption of crops and trees is mainly affected by elevation and land tenure.

The model was further developed into its second version as more information was gathered from the subsequent household survey and case studies. Changes made in the second version of the model included the addition of farmer typologies, crop and timber traders, and choice of agroforestry system to adopt depending on available capital and slope. The landowner entity was deleted in the second version of the model based on the household survey results that the majority of the farmers hold land tenurial instruments. Thus, the farmers themselves are the ones making the decisions on tree planting on the farms.

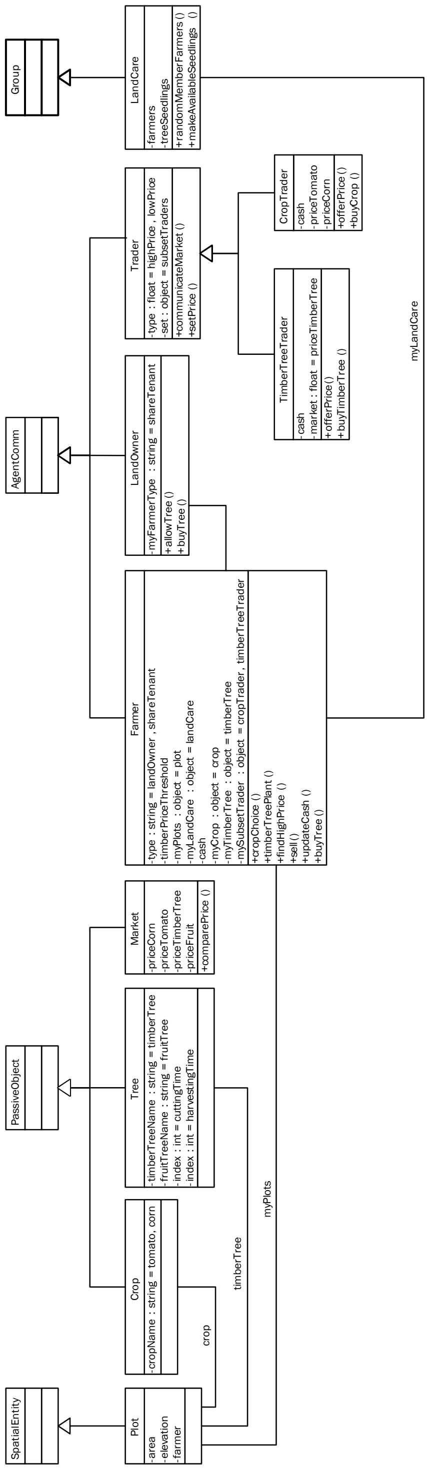

Fig. 1. Class diagram of the initial version of the SAFODS-MAS model.

General structure of the models

Diagrams constructed in unified modeling language (UML) (Le Page and Bommel, this volume) show the model structure, which was illustrated by a class diagram (Figs. 1 and 3) and flow or activity diagrams (Figs. 2, 4, and 5). The class diagram describes the model's structure, associations, and links. It displays the features of the different model entities: the passive objects and the communicating agents. Each box features the set of attributes or characteristics of each entity and the various methods characterizing the main behaviors of each entity. Passive objects such as the market, crops (tomato and maize), and timber tree (gmelina) are the entities that the agents can perceive, create, remove, and modify (Ferber 1999). The evolution of these objects is basically based on the methods or actions of the social agents. On the other hand, social agents such as the farmers and traders are entities that can communicate and can form an association. The flow or activity diagram represents the model's set of actions and their sequences and describes the behavior of the agents and their interactions.

Initial version of the SAFODS-MAS model. The initial version of the model is made up of two modules: the Tree-Crop Choice module and the Timber Harvesting and Marketing module. In the Tree-Crop Choice module (Fig. 2A), farmer agents can choose the type of tree or crop they want to plant on their farms. Most farmers plant maize in the area because it is their staple food. Farmers in high-elevation areas have the opportunity to plant tomato, a high-value crop because of the lower temperature in high-elevation areas. The main constraint to Upper Claveria farmers in planting tomato is the availability of cash for the inputs used in planting, as this crop requires high inputs for fertilizer, insecticides, and labor. Farmers may decide to integrate trees on their farms if they have space available for the trees. If they are tenant farmers, they have to ask permission first from the landowner to plant trees on the farm.

Farmers were classified into two groups: the landowners and the share tenants. They were categorized according to tenure and capacity to plant trees on their farm.

- Landowners—have permanent land tenure, directly influence the decision of the share tenant to adopt trees on the farm, have a relatively greater financial and natural capital, and can be a member of Landcare.
- Share tenants—have no land tenure security since they do not own the land, have lower financial and natural capital, and can be a member of Landcare.

Another social agent is the timber trader (Fig. 1). The timber trader is capable of manipulating prices and is the sole buyer of trees. Landcare is a program composed of extensionists and farmer-led organizations in each barangay in Claveria, with a primary objective of raising a tree seedling nursery to make it available to its members for planting on their respective farms. Landcare has a large impact on the adoption of agroforestry by farmers as this program provides seedling materials for trees (Fig. 2A).

In the initial version of the model, the inclusion of trees in the plots depends on the farmers' resources in terms of natural capital (land area), financial capital, and social capital (access to institutional support).

In the Marketing module, farmers decide on when and to whom to market their products. The price of timber is the major determining factor for the farmer to harvest the mature timber trees (Fig. 2B).

SAFODS-MAS Model version 2. As more information and knowledge about the farmers and the field accumulated arising from our interactions with the farmers and extensionists through the household survey and case studies, the SAFODS-MAS model was further developed, leading to the creation of its second version.

The factors that affect a farmer's decision to adopt a certain type of agroforestry system are multidimensional. The decision-making process of the farmer on whether to adopt agroforestry is influenced by the complex interplay of physical, biological, demographic, institutional, and socioeconomic factors (Garcia 2000, Lapar and Pandey 2000).

In this model, we consider the following factors affecting agroforestry adoption: (1) the availability of planting materials, from one's own farm and the barangay nursery; (2) the effects of the farmers' network or linkages on the adoption of agroforestry; (3) the farmers' market information; and (4) total area of the farm, as farmers with larger farms are more likely to adopt new technologies than farmers with smaller farms (more land to spare) (Fig. 3).

In this version, farmers must perform four groups of methods. They are allowed to finish the set of methods in the group before moving on to the next set of methods (Fig. 4). The set of methods are (1) collection and giving of seeds to the barangay nursery, (2) agroforestry system adoption and/or crop planting, (3) harvesting and selling, and (4) checking of adopter neighbors by the nonadopters. Also, the extent

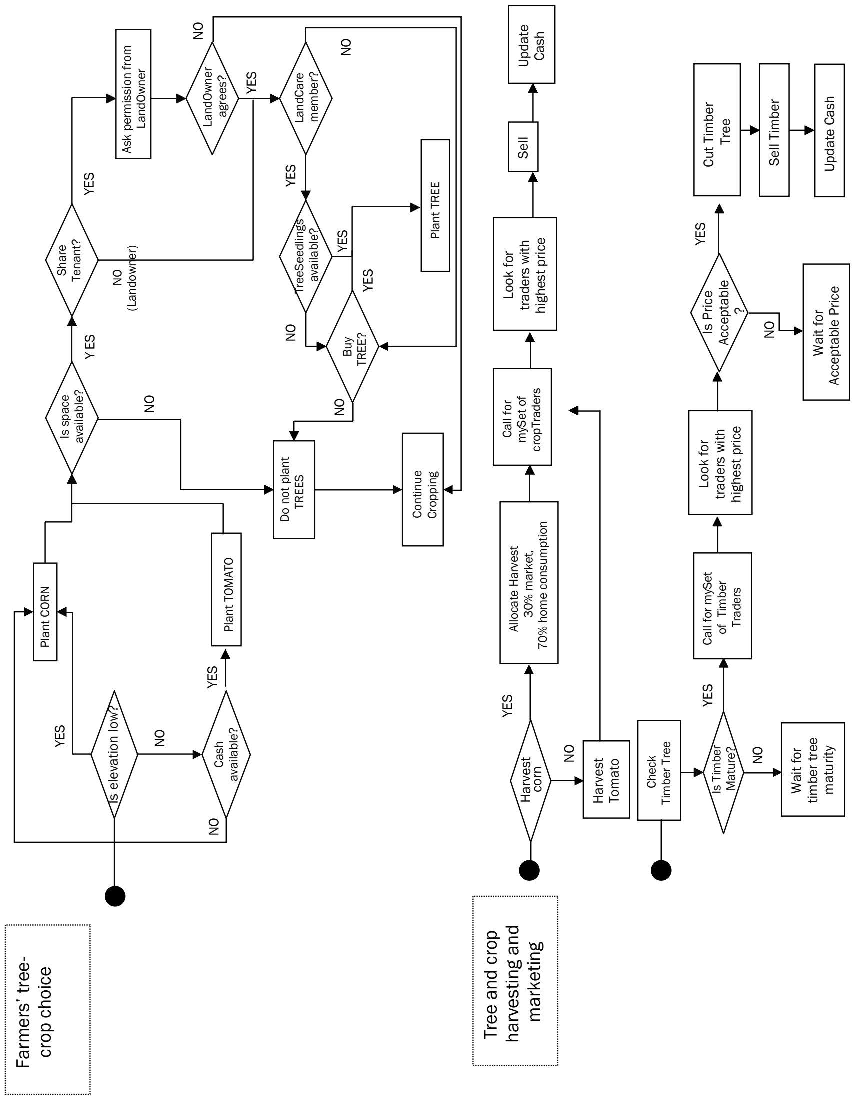

Fig. 2. Activity diagram of the initial version of the SAFODS-MAS model.

of farmers' knowledge on the crop, timber, and fruit market affects their decision to sell their tree products (Fig. 5).

Adoption of the agroforestry system in the second version of the model was influenced by the farmers' motivation and availability of resources. Additional attributes were featured in the revised version. Slope was added to the plot's attributes and banana fruit was added to the crop's attributes (Fig. 3). The farmers' neighbor network was also introduced. Farms close to each other composed a network. They can observe the activity and methods of each farmer member. The model featured farmer typologies based on their motivation to adopt the agroforestry system on their farm and their financial capital: block planting, parkland system, border planting, and hedgerow farmers (Fig. 3). About 70% of the farmers in the model adopt a particular agroforestry system.

- *Block planting*. Farmers implement this system if they have three or more plots. Farmers can have only one plot that is using a block system. Initially, they must also have the financial resources to afford the high-cost inputs needed in practicing this system. Crops may be planted on the same plot for the first three years or six time steps and/or after the tree-stumps (left after harvest of timber) have decayed. Most of these farmers are motivated by an increase in income and they have the greatest financial capital.
- *Hedgerow system*. Farmers adopting this system are usually motivated by soil and water conservation. This is implemented when plots have slope greater than 18 degrees. The decision to adopt is made before cropping. Initially, farmers must at least have the funds to plant maize. Effective area devoted for crops is 70% of the plot, and trees can occupy at least 30% of the area. Initially, about 33% of the total number of trees planted are fruit-bearing perennial (banana), whereas 67% are timber trees (gmelina).

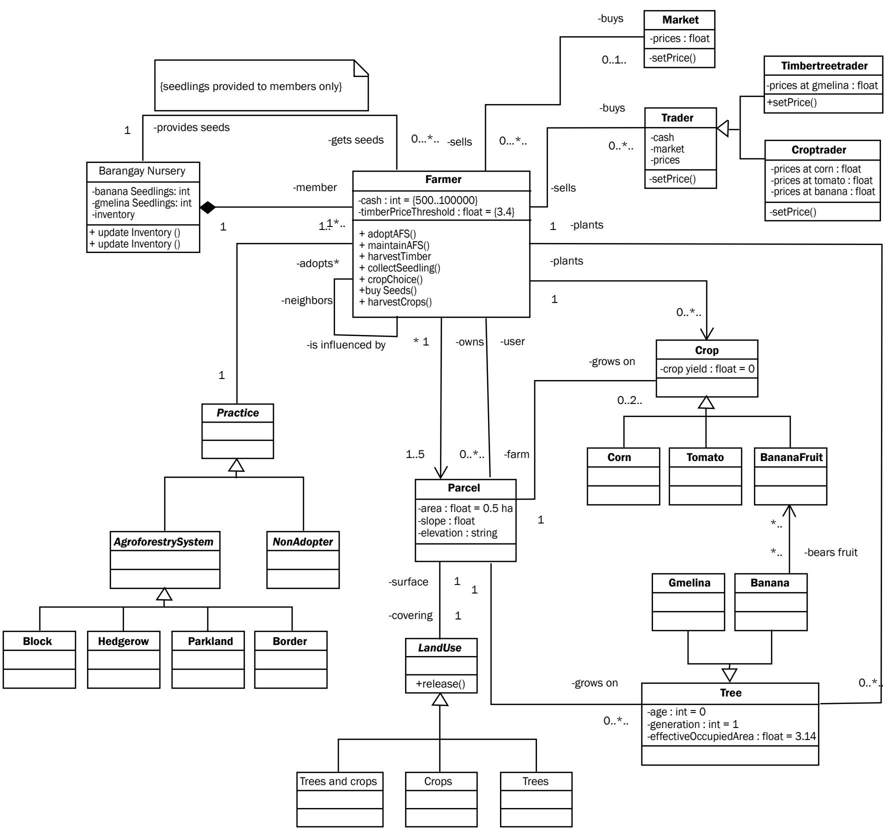

Fig. 3. Class diagram of the second version of the SAFODS-MAS model.

- *Border planting*. This system is adopted when farmers can cover the effective area for cropping. The decision to adopt is made after cropping. Trees are usually planted on the buffer areas to mark the farm boundaries.
- *Parkland system or scattered planting of trees*. This system is adopted if the farmers cannot meet the requirements of starting a block, hedgerow, or border system. The decision to adopt is made after cropping. Initial trees planted are banana, whereas gmelina is incorporated depending on the remaining area after crops and banana have been planted.

Thirty percent of the farmers are nonadopters of agroforestry. They plant tomato and maize only on their plots. Each cropping season, farmers will plant a crop whether they have enough money or not to secure the need for food of the household.

Other communicating agents included in the second version are the timber and crop traders. Association among farmers was introduced; thus, a farmer knows a set of farmers in his network. Farmers' decisions to cut and sell trees depend on both the selling price and actions of neighboring farmers, as they may tend to imitate what the neighbors are practicing.

Decision-making processes and activities in the model

Farmers were classified into agroforestry adopters and nonadopters (Fig. 4). Nonadopters need to perform three methods: (1) the choice of crops, (2) harvesting and selling of crops, and (3) checking or observing their neighbor agroforestry adopter. After each harvest, farmers updated their cash. Because of the farmers' neighbor network, they can observe and compare their income with that of the agroforestry adopters. The chance of shifting from nonagroforestry adopter to agroforestry adopter is highly associated with the level of income received.

Adopters, on the other hand, performed four methods: (1) crop choice, (2) agroforestry adoption, (3) collecting and giving of seeds to the barangay nursery, and (4) harvesting and selling of crops and trees. Adopters have to assess the availability and sufficiency of planting materials. If the adopter farmer is a member of the barangay nursery, he has to give it excess tree seedlings from his collection of planting materials. These planting materials are pooled together by the barangay nursery, and are distributed equally to members.

Farmer adopters then assess the availability of space to adopt block planting, as this system requires at least 1.5 ha of farm area. If the farm area is limited, farmers need to determine whether they can adopt border planting or the parkland system instead. Hedgerow planting is limited to areas with a slope of more than 18 degrees (Fig. 4). Initially, farmers have to buy the planting materials for timber and banana. 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 they are acquainted with. Farmers will sell their harvested crops (maize and tomato) to the crop traders 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 will be sold to the crop trader with the highest buying price. Banana is sold in the local market (Fig. 4).

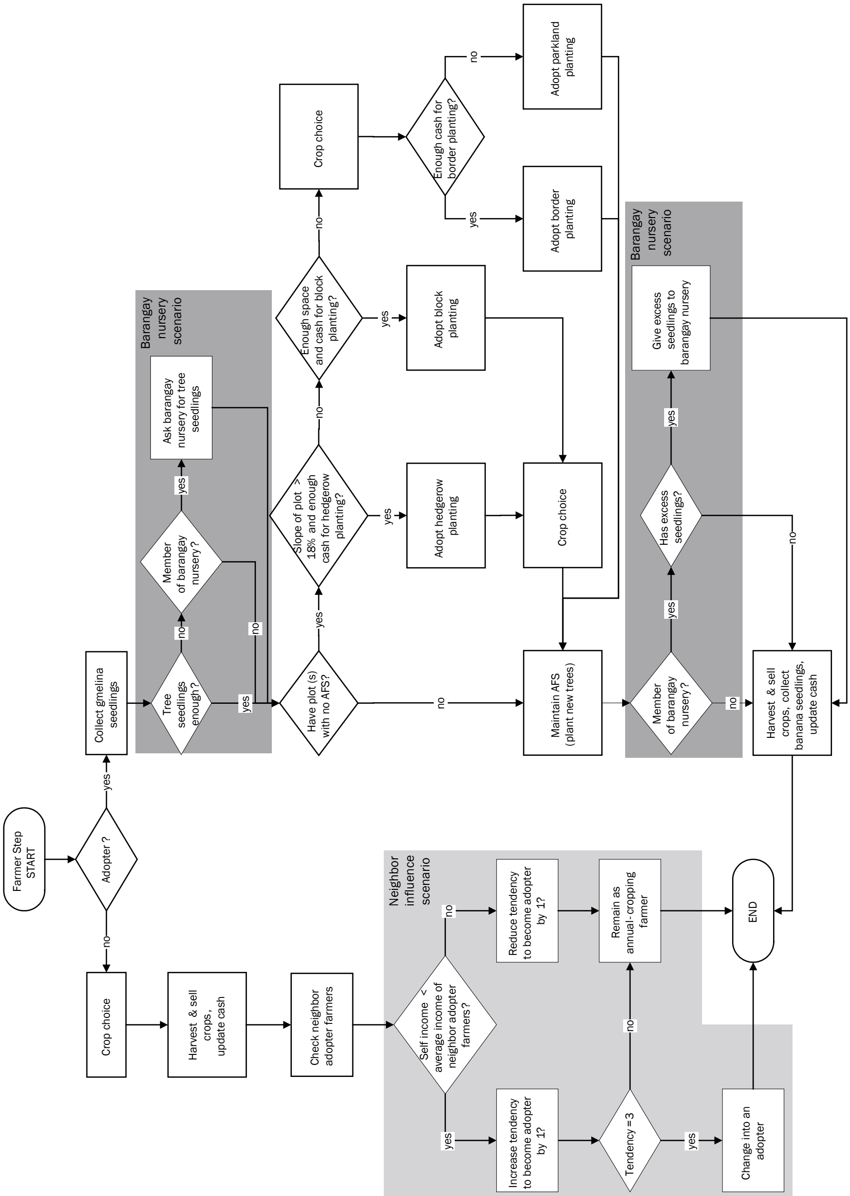

Fig. 4. Activity diagram of farmers' adoption of agroforestry and the neighbors' influence, second version of the SAFODS-MAS model.

In selling timber, the farmers may decide to imitate other farmers within their network of farmers who are selling timber trees (Fig. 5), reflecting the social network effect (Janssen and Jager 2001). The observations from the farmers' network and the timber traders' network on the selling price will determine the decision to harvest the trees. If the price is acceptable to farmers, they will sell the timber. However, in cases where the selling price in the farmers' network and traders' network both is not acceptable, farmers' knowledge of the market price is an advantage.

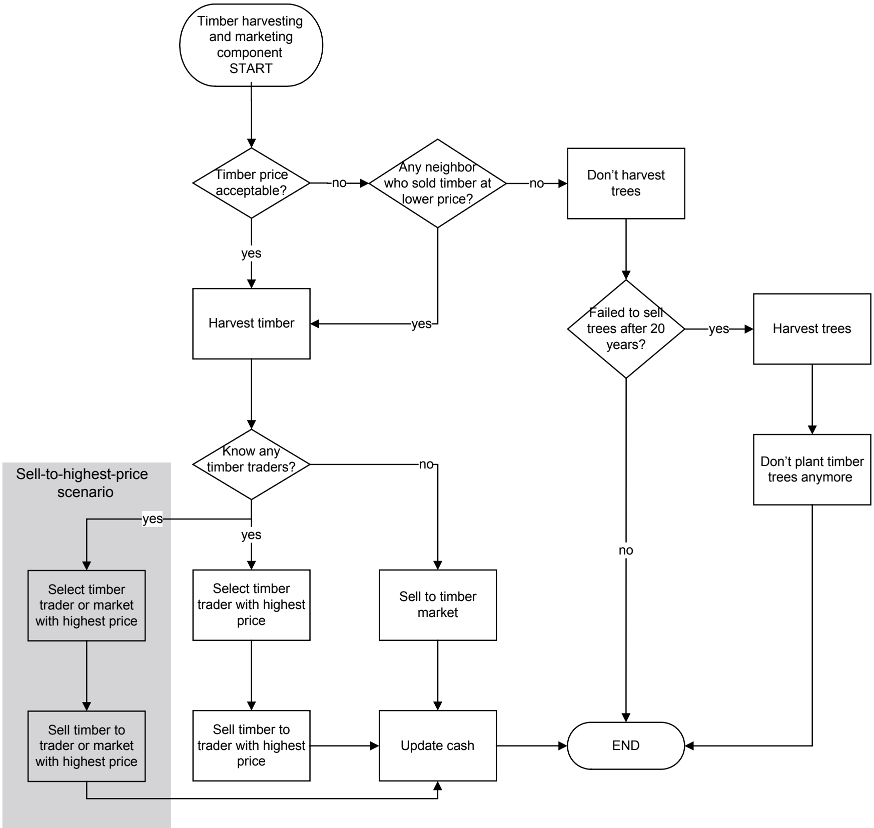

Fig. 5. Activity diagram of marketing timber, second version of the SAFODS-MAS model.

Visualization and initialization of the model

To represent the spatial entity of the model, a 10 × 10 grid space amounting to 100 spatial units (equally sized polygons) representing farm plots was created in the CORMAS platform. The plots were randomly allocated to 20 farmers. The number of plots varied according to the size of the farm. A farmer can own 1–5 farm plots with each plot equal to 0.5 ha.

These plots may contain a single crop type and may be planted with trees. Each crop and tree are represented as a single object and can both occur at the same instance. Each time step of the model is equal to one cropping cycle or 6 months. Crops and trees have a different maturity period. Two cycles of annual crops are grown within one year and they are to be harvested at the end of each crop cycle. Trees are grown for 7 years, and are to be cut after 14 crop cycles.

At the initialization stage of running the model, the space is divided diagonally into three portions to represent the three elevation classes of the landscape: lower, middle, and upper.

Scenario simulations

The second version of the model was used to simulate different scenarios to observe the cumulative income from agroforestry, neighbor influences on agroforestry adoption, the effect of marketing information on income, and the impact of tree seedling nursery establishment on tree planting and income from trees.

At the end of the simulation, the model displayed the spatial distribution of crops and trees in the landscape as well as the distribution of the different agroforestry systems (Fig. 6). The figure showed the variation of agroforestry systems as well as the crops and trees planted in each plot. All the results presented are an average of 10 simulations, with each simulation run for 100 time-steps.

Results of the model simulations 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. They also served as an important indicator to illustrate the socioeconomic status of farmers. Important results of the simulations also allowed the evaluation of the consequences of farmers' knowledge on marketing their crops and tree products. This displayed the effects of establishing a common nursery for the barangay and the influence of farmers' neighbors.

Cumulative income of agroforestry adopters and nonadopters

The cumulative income of adopters and nonadopters is presented in Figure 7. In the initial time-steps, the cumulative income of agroforestry adopters is lower than the cumulative income of nonadopters. This can be accounted for by the initial costs of establishing trees. However, at time-step 45 or 23 years, agroforestry adopters started to gain higher income than nonadopters. 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-

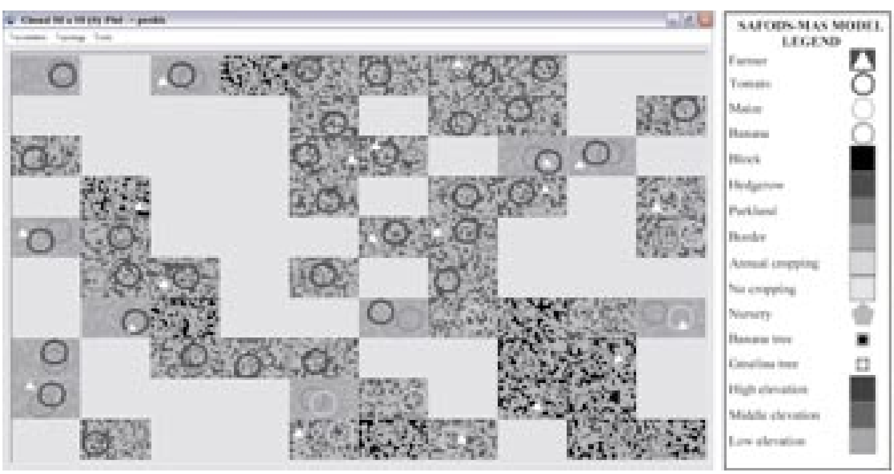

Fig. 6. Distribution of agroforestry systems in Claveria, Misamis Oriental.

value annual crops such as tomato (Fig. 8). The long gestation period from planting to marketing tree products is an important factor that constrains farmers from planting trees on their farms.

Neighbor effects

To determine the extent of neighbors' influence in agroforestry adoption, two scenarios were simulated using the model. In these scenarios, each plot has four neighboring plots following a cardinal direction. Farmers may have adjacent plots, in which case they will not include themselves in their neighbors' plots. Farmers observe unique occurrences of farmers; thus, a certain neighbor farmer is considered only once.

In the first scenario, 35% of the population (7 out of 20 farmers) is annual-cropping farmers or those who are not adopting a certain agroforestry system, while the

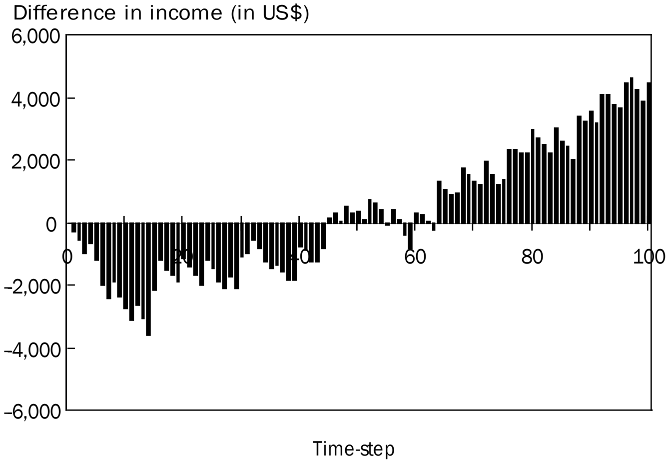

Fig. 7. Seasonal farm income of agroforestry adopters relative to nonadopters.

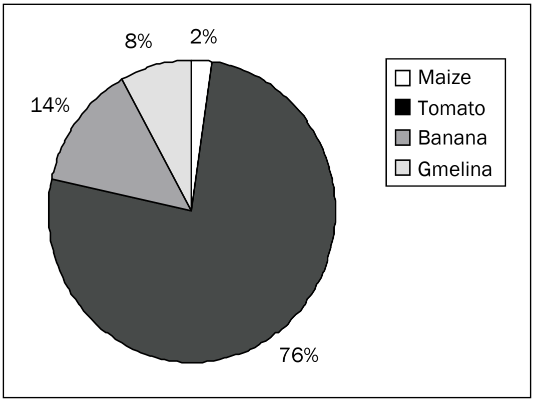

Fig. 8. Contribution of each commodity to the farmers' total gross income after 100 time-steps.

other 70% are agroforestry farmers. In the second scenario, 95% are annual-cropping farmers and only 5% of the population (1 out of 20 farmers) is an agroforestry adopter (Fig. 9).

Simulation results of the first scenario showed that, at time-step 4 or at the second year, about 15% of the nonadopters adopted a certain agroforestry system. On the other hand, simulation results of the second scenario showed a gradual or slower rate of agroforestry adoption up to the 30th time-step compared with the first scenario. In both scenarios, a plateau was reached. In the first scenario, a plateau was reached at time-step 14, whereas, in the second scenario, a plateau was reached at time-step 30 (Fig. 9).

Results showed that farmer neighbors have a great influence on the spread of agroforestry in Claveria. The more farmers adopting an agroforestry system in the neighbor network, the greater is its influence to motivate the nonagroforestry farmers to practice a certain agroforestry system. Farmers shifted because of the increased income from harvesting and selling banana fruits. Adoption of agroforestry by non-adopters was observed even at the 14th time-step or the seventh year when gmelina trees are already mature and ready for harvest (Fig. 9).

A plateau was attained at an earlier stage in scenario 1 because shifting from nonadopter to adopter ceased at an earlier time. The remaining nonadopter farmers are those with 3 to 5 parcels who are able to plant tomato. They have gained 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 environment. The likelihood of agroforestry adopter occurrence in the neighbor network is less; thus, it will take several time-steps for a nonadopter to shift to agroforestry. The spread of agroforestry is slow across the environment in the second scenario.

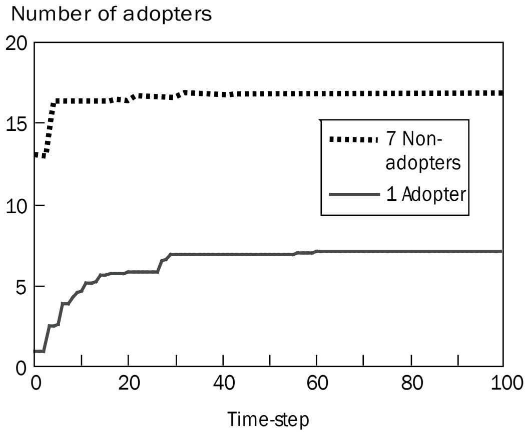

Fig. 9. Effects of neighbors on the adoption of agroforestry systems.

Market information

The market is one of the major factors that contribute to sustainable agroforestry. Farmer adoption of agroforestry technologies is highly affected by the availability of a market for crop and tree products. In this scenario, market information is implemented by allowing farmers to compare prices between the market and traders, which is not done in the base model. In the base model, farmers who know traders would automatically sell their produce to the trader with 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 10 shows the increase in income by allowing farmers to compare prices between traders and the market and being able to sell at the highest price.

Establishment of a tree seedling nursery

The establishment of a barangay tree seedling nursery increased the availability of planting materials for gmelina tree and banana. Nursery establishment has two major effects: (1) income from banana increased dramatically (Fig. 11) and (2) less gmelina is planted because farmers prefer planting banana. Farmers are motivated to propagate banana because it is a relatively short-term perennial with a shorter gestation period than gmelina. Banana starts to bear fruit after about 18 months and the income from selling banana contributes greatly to farmers' household income (Fig. 12).

Future activities

Another tool that will be employed to further understand the decision-making process of farmers in adopting agroforestry systems and to verify the decision-making process model is role-playing games (RPG). RPG will be conducted with farmers and extensionists in the area. An actual model of the Claveria landscape will be constructed and different plots will be assigned to participating farmers. Each plot will

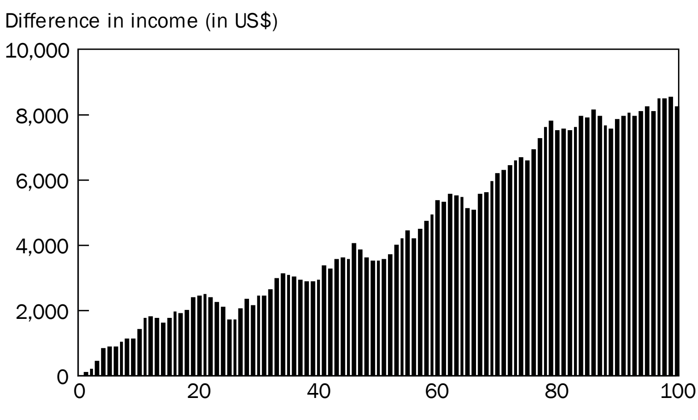

Fig. 10. Cumulative difference in income of farmers with market information relative to farmers with limited market information.

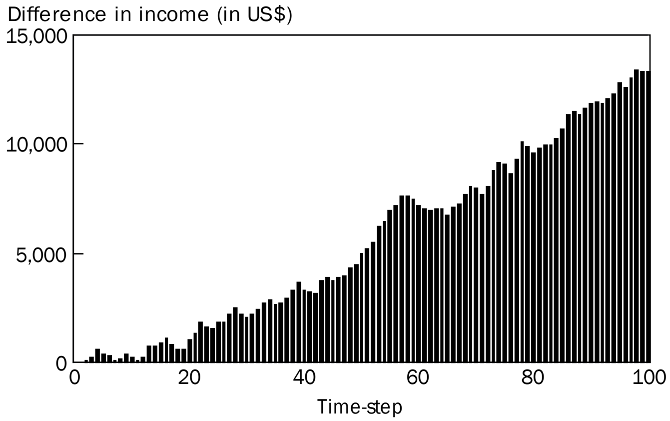

Fig. 11. Cumulative difference in income of farmers with access to seedlings from barangay nursery relative to farmers without access to seedlings.

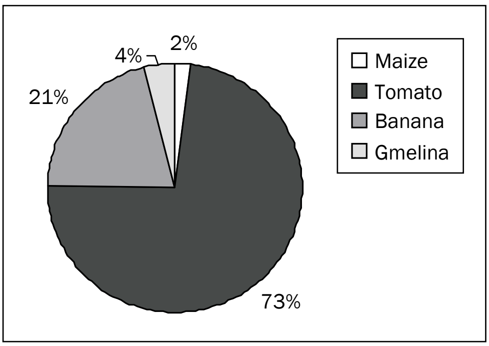

Fig. 12. Influence of the establishment of barangay nursery on the contribution of each commodity to farmers' gross income.

have a characteristic elevation and slope. Farmers will be assigned different farmer typologies with their characteristic plots and farm size. During the role game, different scenarios will be presented to the farmers and these will let the farmers decide on adopting agroforestry or nonagroforestry systems on their plots; harvesting their crops, timber, and fruits; marketing their products; or selecting timber or fruit trees for the next cycle. The frequency of agroforestry adoption and the available cash of the farmer agents will be noted during the RPG.

Conclusions

The SAFODS-MAS model is a work in progress, being revised and improved through repetitive confrontations with real situations in the field. The iterative process with the model is useful in probing deeper into the decision-making process of farmers in adopting an agroforestry system.

The model scenario simulations can serve as a tool to facilitate interactions between stakeholders and scientists and in the future as a decision support for policymakers, farmers, and other stakeholders toward sustainable management of resources. It is envisioned to produce information useful for the design of agroforestry technologies and their dissemination to other sites.

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Notes

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