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Knowledge Integration for Participatory Land Management:

The Use of Multi-Agent Simulations and a Companionable Modelling Approach

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ABSTRACT

The authors consider that in complex agrarian situations, decisions on land management changes should be based on a common understanding of the interactions between ecological/bio-physical and socio/economic dynamics that are at work. As agricultural and environmental issues are more and more inter-linked, the increasing multiplicity of stakeholders, with differing and often conflicting land use representations and strategies, underlines the need for innovative methods and tools to support their coordination, mediation and negotiation processes aiming at an improved, more decentralized and integrated natural resources management (INRM).

During the past ten years, very significant advances in the simulation of societies in interaction with their environment have been achieved. More and more powerful and user-friendly computer modelling tools facilitate the understanding and simulation of such complex interactions. The main objective of this research is to study the use of MAS models, associated with role games, for knowledge integration in collective learning processes focusing on key local INRM issues. How can simulations be involved in such a processes, i.e., how can they help actors to govern the land? We are seeking to develop a companionable modelling use of multi-agent systems. For the past two years, the authors have used this methodology to address specific key INRM issues in northern Thailand and northern Vietnam. An example from Senegal is also presented and discussed.

1. INTRODUCTION

1.1. The problem

During the rapid process of market integration of small resource-poor highland farms, the changing risk of land degradation is a major issue in diversifying farming systems on sloping land of mountain mainland Southeast Asia. In this fragile and heterogeneous environment, an increasing number of individual as well as collective agents and institutions manage soil, water and ground cover in an interdependent way, but according to their own interests and objectives. Past research and extension efforts were often limited to the biophysical aspects of soil and water conservation and have generally yielded very limited impact in farmers' fields.

We consider that in such complex agrarian situations, decisions regarding changes in land use and land management should be based on a common understanding of the interactions between bio-physical and socioeconomic dynamics which are at work. Depending on the kind of key processes being addressed, knowledge integration should also be improved in the management of information obtained at different complementary and relevant (spatial and temporal) levels of organization. As agricultural and environmental issues are more and more inter-linked, the increasing multiplicity of stakeholders, with differing and often conflicting land use representations and management strategies, underlines the need for innovative methods and tools to support their coordination, mediation and negotiation processes aiming at an improved and more decentralized kind of integrated natural resources management (INRM).

1.2 Objectives, approach and methodology

During the past ten years, very significant advances in the simulation of societies in interaction with their environment have been achieved. This leads to a change of point of view on the use of models (Table 1). More and more powerful and user-friendly computer modelling tools facilitate the understanding and simulation of such complex interactions. Particularly, Multi-Agent Systems (MAS) and cellular automata technologies can now be used to create virtual societies acting on a given environment and to study the effects of the different interactive behaviours of various agents on the status of the resources. Potentially, MAS offer an interesting and powerful way to tackle the complexity of such above-mentioned interactions. Particularly when we are dealing with INRM situations and issues characterized by multiple stakeholders acting on a multiple use and distributed kind of natural resource. Over the past seven years, a group of development-oriented researchers at Cirad has been working with colleagues in several developing countries, including Thailand and Vietnam in SE Asia in close collaboration with IRRI, to use MAS for supporting stakeholders' projects and decision-making processes on important INRM problems (Kam, Castella et al. submitted).

Natural sciences paradigm	**Social sciences paradigm**
Epistemology	
Positivism (reality exists independently of the observer) Hard platforms (De Wit, Rabbinge, Van Keulen, etc.)	Constructivism (reality is constructed by the observer) Soft platforms (Checkland, Röling)
Tools and simulation models	
Explorative models Explorative models Evolution from crop models to prototyping for vanguard farms	Heuristic models Evolution from farmer's decision making supports to virtual laboratories for socio-economic experiments

Main characteristics	
Generic models	Negotiation models (location specific)
Long life span	Evolving, obsolete as soon as presented To stakeholders for validation
Linear knowledge transfer from Scientists to extensionnist farmers	Iterative, integrative process
	Facilitation of community learning
Scientific driven innovation	Stakeholders' interactions
Scientific rigor	Relevance for development

Table 1: Natural and social sciences paradigms for sustainable INRM (Castella, Husson et al. 1999)

When its construction is closely combined with intensive field work and the use of existing indigenous and scientific knowledge to feed the computerised representation of the system under study in an iterative way, the MAS model simulates interactions between socio-economic changes and the dynamics of renewable natural resources (figure 1). The collective creation of such an artificial, but shared, representation of a given agroecosystem allows the simulation of various scenarios of its evolution with stakeholders, as well as the search for the conditions and domain of co-viability between its ecological and social transformations.

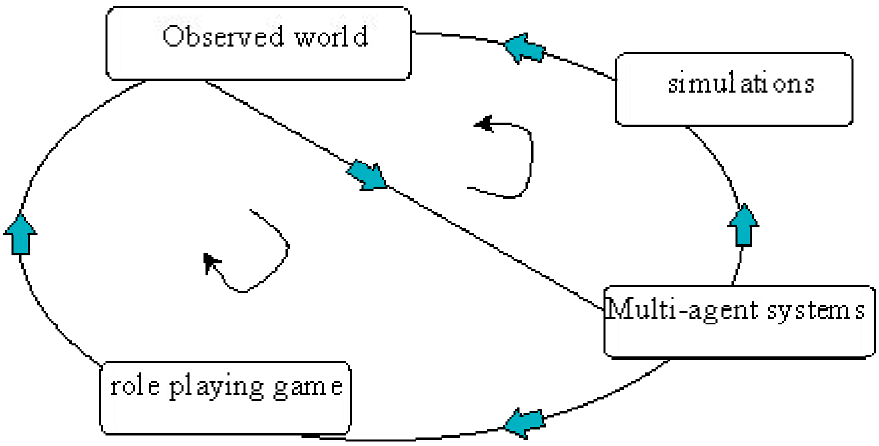

Figure 1: The loop between field work and modelling

Particularly because of its extensive flexibility when compared to previous systems approaches and methods applied to agricultural and rural development, MAS for INRM could lead to significant improvements in:

- knowledge integration across hierarchical levels of organization and scientific disciplines,
- the construction of more or less sophisticated, depending on the needs, generic models to mitigate the site specificity of systems approaches in agricultural development, and

- the production of innovative tools for researchers to work with diverse stakeholders.

Several programming software packages are available for building MAS. Over the past years, the Cirad team has developed a new one called "Cormas" (Common-pool Resources and Multi-Agent Systems, http://cormas.cirad.fr), which is a simulation platform specifically designed for building models that can be applied to renewable resource management. Figure 2 is displaying the main interface of the *Cormas* modelling platform. Relying on the "Smalltalk" object-oriented programming language, it is organised into three units:

- the first one defines the system's entities, or agents, and their interactions. These interactions can be expressed either through direct communication (exchanges of messages), or, in a more indirect way, by sharing the resources offered by a common spatial environment. In this case, the model dynamics are distributed among elementary spatial entities in interaction, (cells of a spatial grid or GIS maps corresponding for example to fields, farms, watersheds, etc.). The cells provide the spatial support for both the natural resources and the agents actions on them. Each kind of agent is characterised by specific attributes and sets of behavioural rules,
- the second unit controls the general model dynamics, and all the events occurring during one of the model's time-step, and this in a systematic bottom-up way,
- the third unit is used to specify the agents' different viewpoints. This key feature means that the capacity and the way to observe the system dynamics can be built into the model itself.

The main objective of our current research is to study the use of such MAS models, associated with role games, for knowledge integration in collective learning processes focusing on key local INRM issues. How can simulations be involved in such a processes, i.e., how can they help actors to govern the land? To this end, we are seeking to develop a companionable modelling use of MAS. This is an approach which is currently being implemented but which has only been partly tested so far. Though it is doubtless original in its use of MAS, some of fundamental ideas upon which our approach is based have already been tested by several researchers, particularly Ostrom (1990 and 1994) and Burton (Burton 1994). Regarding the relationship between the patrimonial approach and actors managing in an experimental situation through role playing, much work has also been done by Mermet (Mermet 1993) and Piveteau (Piveteau 1994). Our theoretical and methodological frameworks are similar to the ones adopted by these authors, but we propose to include the modelling approach with MAS within such frameworks.

In the following section, we present a review of the use of models with stakeholders. Analyses of three complementary and illustrative experiences which are being developed using MAS models in participative approaches follow. They also address the issue of MAS models - role games coupling. Finally, the preliminary lessons learned from these pioneer experiences are presented and some perspectives for further application and development of this kind of participative approach and methodology in South-East-Asia are proposed.

2. MODELS AND STAKEHOLDERS : A REVIEW

There are several starting points to explore an abundant literature on such a subject. The general theme used to make a selection in this literature was participatory development and the use of models and role-games for collective decision-making in natural resource management (NRM). Except for a few papers presented in the next paragraph, most of the references we found do not fit entirely with this theme. Thus, we expanded our search to "games, models and coordination" on one hand and to "models and participatory approaches in NRM" on the other hand.

2.1. Models, role-games and NRM

There are few experiences of joint use of models and role-games for ecosystem management. Meadows and Meadows (Meadows and Meadows) have developed a famous role game named "Fishbanks". The participants play the role of fish companies who share a common resource (two fishbanks). A simulation model simulates the dynamics of the resource at sea and the effects of the players "catches". The objective of *FishBanks* game is to illustrate and to teach the "Tragedy of the commons" principle: free access to the resources leads to biological depletion and consequently to economic over-exploitation. Another game associated with models is Burton's one (Burton 1994). It aims at simulating the management of an irrigated system. These role-games and simulation models have been used for educational and training purposes only.

2.2. Games, models and co-ordination

Modelling interactions among players is the objective of the game theory. Many models have already been developed, particularly in the field of resource sharing. Frequently cited reference papers such as (Hardin 1968; Ostrom 1990; Stevenson 1991; Ostrom, Gardner et al. 1994) are based on a game-theory approach. We do not address that kind of literature here because even if stakeholders' strategies are modelled, they are not themselves involved in the process of building these models. Some experiences in the field of experimental economics are more relevant for this review. A school of economists involved in institutional and policy research is working on linking game theory, institutional analysis and laboratory experiments (Ostrom, Gardner et al. 1994). Players are involved in controlled experiments. The objective is to observe if human beings behave according to the predictions of various economic theories. Several of these types of experimental economics studies are dealing with NRM (Mason and Philipps 1997; Sell and Son 1997; Gintis 2000).

Agent-based modelling has been linked with experimental economics. Duffy (Duffy 2001) uses an artificial agent-based computational approach to understand and to design laboratory environments. Similarly, (Deadman, Schlager et al. 2000) describe the development of a series of intelligent agent simulations based on data obtained from previously documented common pool resources experiments. These simulations are used to examine the combined effects of different institutional configurations and individual behavioural characteristics. Results are compared to those obtained with human players.

In these experiments there is an existing linkage between human players involved in experiments of social interactions and agent-based models. The models may be useful devices for both understanding and designing experiments with human players. But the objective of such experiences is to test very theoretical rules provided by economic theories, and not to simulate a real-life situation. Furthermore there is no participation of the players in the design of neither the model nor the experiments.

2.3. Models and participatory approaches

The study of the relationships between simulation models and collective decision making in natural resource management encompasses a large part of the literature about adaptive management (Holling 1978; Walters and Hilborn 1978). Our particular interest led us to select papers addressing the issue of stakeholders' participation in one (or more) of the modelling steps, from conceptualisation to scenario simulation. Ecosystem simulation models proposed (Costanza and Ruth 1998), as well as two references on Integrated Assessment models, and some Australian experiences are briefly summarised below.

- Costanza and Ruth advocate the use of a three-step modelling process, each step involving stakeholders. They use STELLA, a graphical programming package, to design simple non-linear dynamic systems. The first step is to develop a kind of very general, low-resolution scoping and consensus-building model. It includes rough representations of the various stakeholder groups affected by the problem. The second stage, more research-oriented models are more detailed and realistic attempts to replicate the dynamics of the actual system. It is critical to maintain the stakeholders involvement and interactions with them during this stage of the model development. The third stage of the construction of management models is focusing on producing scenarios and management options based on the earlier scoping and research models. These authors tested this methodology in the case of the management of Louisiana coastal wetlands, South African Fynbos ecosystems and Patuxent River Watershed. The main lesson drawn from these experiences is that the participation of various concerned stakeholders should be maintained through the successive steps of the modelling activities. The second lesson deals with the duration of such exercises : these are long companionable processes lasting several years

- In another article, Nick Abel (Abel 1999) presents the main principles of his approach on rangelands seen as complex adaptive systems. To understand these systems one needs to elicit the mental models of stakeholders managing/exploiting (**???**) them. To achieve a better management, a mutual exploration of these mental models in a collective learning process is necessary. In the case of New South Wales rangelands, this team built and used models assessing the social, economic and ecological sustainability of land use scenarios, by working closely with stakeholders and influential people. Stakeholders lead the questioning of the models and at the same time improve their understanding of key processes with which they may not be familiar, such as climatic changes or regional economic growth. This project refers to previous projects held by Cockes and Ive (1996).

- These other authors have developed a spatial information-based mediation support system, for resolving resource use disputes, called SIRO-MED. While SIRO-MED is not a simulation model, it constitutes an interesting experience illustrating a shift in the use of decision support systems. The authors state that there is a public demand for procedural legitimacy. This concept encompasses either directed or mediated negotiations between stakeholders, rather than seeking submissions. The model is used as a mediator assisting stakeholders to reach an agreement. After an initial agreement on the components of the problem, necessary data are collected. Then stakeholders generate plans. The last step is the mutual adjustment of plans. SIRO-MED offers a range of tools to facilitate this last process.

- (Van Asselt, Mellors et al. 2001) have identified two examples of participatory modelling in the field of Integrated Assessment. The model RAINS (Regional air pollution information and simulation model) started as an IIASA project (IIASA 1999), and was later used as a world wide standard model. Scientific experts and policy makers participated in the model design. QUEST (Quite Useful Ecosystem Scenario Tool) is a computer game (Rothman, J. et al. 2001). The approach focuses on learning through the construction of scenarios rather than by looking at the results provided by a given scenario. Both these models were not participatory when their design started.

Few has been done in participatory modelling but lessons can be learned from participatory GIS research in NRM. This is a more advanced field of research. Today manuals are available for extension agents in rural areas (CBFMO 1998). Participatory GIS has demonstrated the ability of many illiterate people to use tools based on sophisticated technology. Important papers found in the literature on this subject are as follows:

- Fox (Fox 1998) presents the principles of community mapping. Several answers to his paper follow his article. The use of spatial technology for community mapping and counter mapping is very useful but some weaknesses exist. Among others, the making of maps destroy the fluid and flexible nature of boundaries; they can potentially increase the surveillance among stakeholders and privacy violations, and they could raise the problem of the ownership of information, etc. These constructive critiques have to be reminded when constructing and using simulation models with stakeholders.
- (Abbot, Chambers et al. 1998) propose a review of participatory GIS. The same kind of constructive critiques are drawn. GIS, like many technological innovations, present the potential to either marginalise or empowers people and communities simultaneously. A lot of attention should be paid to the issues of confidentiality and privacy of information.

One interesting experience, among others, is the research carried out by(Gonzalez 2000) on watershed management in the Ifugaos of the Cordillera in the Philippines. The author presents GIS as tools for interactive learning, to facilitate what Giddens calls double hermeneutic in science, that is learning from one another. Furthermore, these experiences of using GIS in a participatory way are interesting because one can find experiences for scaling-up the results obtained at the community level.

Our approach use both MAS models and role games, to create a common representation between researchers and stakeholders. The linkages between these two tools are diverse.

3. CASE STUDIES ON MAS FOR PARTICIPATORY INRM

For the past two years, we have started to use the *Cormas* simulation platform to address specific INRM issues in upper northern Thailand and the uplands or northern Vietnam. We also present here an on-going experiment on land-use in Senegal because it provides a more advanced case study and another way of coupling MAS and role games.

3.1. Agricultural diversification and erosion risk in upper northern Thailand

In cooperation with the Multiple Cropping Center of the Faculty of Agriculture at Chiang Mai University (MCC-CMU), KU-Leuven University in Belgium, the Department of Soils and Fertilizers at Maejo University in Chiang Mai (Soil Fertility Conservation project) and the Department of Public Welfare (DPW), a multi-agent modeling experience is being conducted to explore ways for better collective watershed management in the diversifying highlands of Chiang Rai province. Based on several complementary in-depths surveys carried out during two years of intensive filed work in two Akhas villages, a MAS model is being built to integrate knowledge across disciplines (soil science, agronomy, socio-economy, geography) and several spatial levels of organization (homogeneous units on slopes, farmers' fields, different types of farms and the village watershed). It is also used to better understand the interactions between soil erosion risk on sloping land and market integration leading to rapid agricultural diversification and farmers' socio-economic differentiation.

Past efforts focusing on the introduction of soil and water conservation techniques had generally very limited impact in farmers' fields, including at our two research sites. In such complex situations, land management must rely on an understanding of the dynamics and interactions between land resource and social dynamics, as well as the relationships between several levels of organization. The multiplicity of stakeholders, with different land use strategies, underlines the need for coordination, mediation and negotiation tools for improved, more integrated NRM. Closely articulated with field work, a companionable modeling and simulation approach relying on a multi-agent system (MAS) and role-games could help tackling the complexity of such interactions.

The ultimate objective of this on-going case study is to build a MAS model and an associated role-game (based on a simplification of the model) to facilitate the dialogue among local stakeholders and to explore scenarios of land use changes under upland-highland agricultural situations undergoing similar dynamics in this ecoregion. An original characteristic of this example is the fact that here the MAS model is linked with a GIS to manage different spatial entities.

An on-farm diagnostic survey in many farmers'fields analysed the influence of the main cropping systems on the risk of soil erosion under various slope and climatic conditions at the field level. Based on informal and semi-structured interviews of tens of villagers, a typology of the rapidly diversifying household-based farming systems was built to understand farmers' differentiated management strategies. Whereas, a GIS-based analysis of land use changes was carried out at the village watershed level over the 1990-98 period. Building on these complementary data sets, a MAS model is built to facilitate knowledge integration, to go beyond the site specificity of this empirical multi-scale study, and to better understand and model the interactions between agro-ecological and socio-economic dynamics,

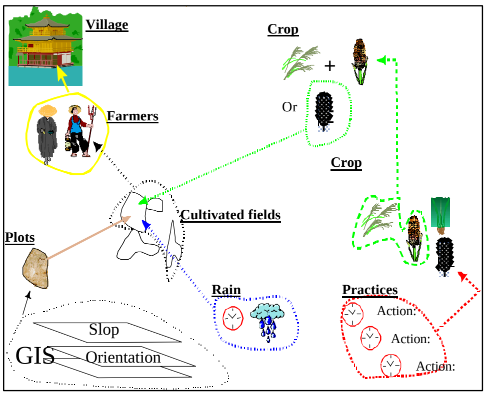

Figure 2: Structure of the model

The general structure of this model is shown in figure 2. The spatial environment and the representation of land resources is provided by the transfer of GIS data files of the watershed into the MAS environment. Actual maps and key layers of information, such as spatial constraints like slope angles and lengths, are used. Two interconnected spatial entities are considered in the model: homogeneous zones (displaying homogeneous slopes) and farmers' fields. Their attributes are: area, owner, slope characteristics (orientation, angle, length), crop being grown. The different classes of agents included in the model are presently:

1. three main types of farming systems found in the area, each of them representing a different historical profile and degree of integration in the market economy. Their attributes represent their respective amount of (land) resources (quantity and quality) and strategies regarding crop combinations. Concerning their dynamics, young farmers inherit from their parents and the farm type can change at the creation of new farms depending on the amount of resources they yield. Results of cash cropping activities in a given year influence the crop allocation to the fields in the next year, as well as the level of off-farm activities in case of losses.
2. the village : its main role in the model is to regulate the beginning and the end of the crop year, farmers' actions in their fields, and the pooling at the watershed level of the results daily assessments of erosion risk in each field, after each rain shower, over the whole rainy season.
3. passive situated agents like crops in farmers' fields. Their attributes are cropping calendars (early-late sowing dates, duration of the crop cycle), duration of their respective periods of susceptibility to erosion, sequences of cultivation practices, minimum and maximum size of fields for each kind of crop.

The control of the simulation can be set up according to a daily or yearly time scale. Actual long chronological series of daily rainfall data for the Mae Chan district are used by the MAS model to assess soil erosion risk for each sloping homogeneous unit, depending on slope characteristics, farmers' practices (resulting in a given type of soil coverage), and climatic conditions.

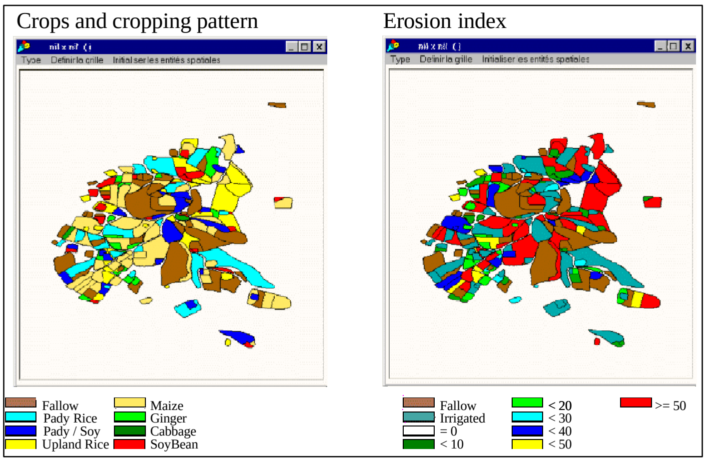

Figure 3 : Evolution of crops and erosion index

Each simulation provides two complementary results which can be visualized on maps of the watershed or on simple graphs:

- the evolution of an erosion risk index from year to year (see figure 3**)**
- the evolution of the distribution of the farms among the three main types identified, plus the number of farmers who had to switch to wage-earning activities to recover their monetary losses.

The model is still being developed. Improvements are still needed, especially to improve the management of spatial entities by allowing farmers to change the size of their fields between years according to the type of crop they want to grow. We also need to refine the quality of the representations of communicating agents' strategies, especially regarding farm labor management. The validation of this model will be conducted with local stakeholders following its simplification and conversion into a role-game to be played with them. Depending on the results of this second phase of the process, we might consider using this tool to facilitate the coordination among stakeholders making various use of similar watersheds according to differing strategies.

3.2. Land use in the uplands of Northern Vietnam

The “Regional” component[1] of SAM (Mountain Agrarian System) program is working in the mountainous area of Bac Kan Province, northern Vietnam. It aims at understanding agricultural dynamics and their consequences on land use systems in order to promote more sustainable natural resource management from the village to the regional level. In this framework, several methodologies have been combined using and/or developing different tools from traditional fieldwork using on-farm surveys to remote sensing data interpretation through computer modeling and role-plays. These various tools, methodologies, and the way they are used, pursue different objectives, especially in the relationship between researchers and their objects of investigation, as well as between researchers and stakeholders (Castella, Boissau et al. 2001).

A first multi-agent model named SAMBA has been developed for testing hypotheses about the differentiation of households at the end of the cooperative period in Xuat Hoa commune, Bac Kan province (Castella, Boissau et al. 2001). The way this model has been developed could be qualified of "armchair modeling"[2] as its construction is built upon data collected in the field but is conducted without interaction with stakeholders. This kind of model serves as a tool for representing, testing, sharing and discussing hypotheses among researchers from different disciplines and thus having different representations of the world.

The problems of validation of this kind of models Axelrod (Axelrod 1997) led us to adopt a new methodology in the process of building it and sharing it with stakeholders. Following previously described experiment in Senegal, we adopted role-plays similar to gaming-simulations (Greenblat and Duke 1981).This methodology, which is still under development, follows four steps that take place over a one-week period:

Step 1: collection of preliminary information and selection of participants (1 day)

From one to three villages in a commune of Bac Kan province are selected based on their original characteristics and the topic pursued[3]. Village headmen are interviewed to collect some basic information and identify participants representing the diversity of the village.

Step 2: role-playing (1 day)

The “SAMBA” role-play is conducted around a game board composed of 1600 wooden cubes, each one comporting 6 colors representing different land uses. The aim was to use an environment as close as possible to the one in the SAMBA multi-agent computer model, developed under CORMAS simulation platform (Figure 4A). Around 10 players and a few observers (e.g. village headmen, forest warden) usually participate in the role-play. The players draw household cards describing the composition of their virtual household and thus their food needs and available labor force. They also get an initial endowment in lowland rice fields and buffaloes. Then, the players have to propose and manage activities in order to feed their family and develop their own strategy. Actions of the players are situated on the board

[1] SAM-Regional is a joint research program of the Vietnam Agricultural Science Institute (VASI, Vietnam), Institut de Recherche pour le Développement (IRD, France), and the International Rice Research Institute (IRRI, Philippines).

[2] As reference to the "armchair economics" denounced by Herbert Simon (1986)

[3] So far, topics have been: the allocation of labor force between paddy fields and upland crops; livestock management systems; the saturation of uplands and the emergence of forestland as a scarce resource.

game and registered by facilitators. During the one-day sessions we already organized, players could simulate around 6 years (i.e. 6 play rounds). The meetings ended with a debriefing session during which the sequence of the game was analysed by both participants and facilitators.

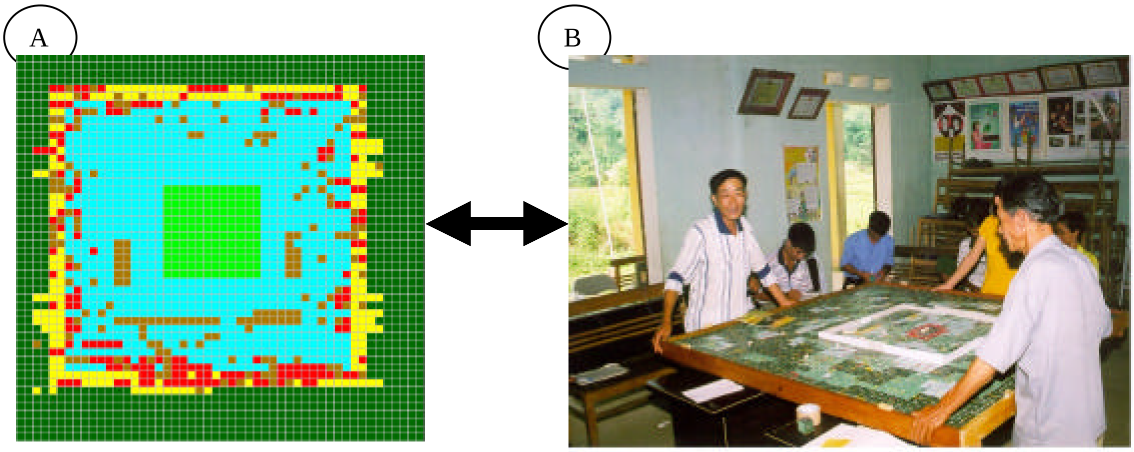

Figure 4: Similarity between the SAMBA computer model(A) and SAMBA role-play (B) environments

Step 3: individual interviews and model construction (3 days)

During the third step, two activities are carried out in parallel. On the one hand, a multi-agent model aiming at representing the sequence of the role-play is developed. On the other hand, individual interviews are conducted with participants to the role-play session (step 2). These individual interviews build upon the actions of the players during the role-play. Through a comparison with the real situation, the surveyors investigate the individual behaviors of the players and the various strategies developed during the role-play.

Step 4: participatory computer simulation (1 day).

A new meeting with participants in the role-play is organized and the model constructed during the third step is presented. The similarities of the environments in the role-play and in the model help participants in getting comfortable with the computer. A first simulation similar to the role-play session is easily described by the participants. Inconsistencies and/or alternatives to this first model can thus be discussed for possible simulations.

The methodology described here serves several interrelated objectives.

First, the role-play proved to be a very efficient way to gather information on selected topics. More traditional interviews usually face problems of confidence between the researchers and the stakeholders, the interviewees being sometimes reluctant to give information asked in a formal way. On the contrary, the gaming aspect of the role-play helps creating a more natural and friendly environment, which in turn facilitates communication. Information can then be collected at two levels: (1) when the player is acting on the board, details can be asked about his actions, and (2) through direct observation of conversations and interactions between participants in a more ethnographic way. Information gathered during the role-play is completed by subsequent individual interviews and discussions around the computer model. Such information is used to explore the evolution of land use systems.

Second, when conducting the role-play, an initial situation is assigned to the players but no rules, especially social rules, are predefined. These rules have to be set by the players themselves in the course of the play, whenever they feel the need for it. Thus, if such rules are enacted, one can say that they are emerging from the convergence of individual actions in a particular environment. Emergence is also a basic principle of multi-agent modeling where macro phenomena are seen as emerging from micro actions following a bottom-up approach. The combination of role-plays and multi-agent modeling thus appears to be a powerful tool for studying the emergence of collective rules that can be identified in the role-play and more precisely explored by the computer model.

Last but not least, through the information gathered and the discussions with participants, problems faced by the local peoples in their production systems can be identified. Role-plays and multi-agent systems can then be used as communication platforms for the introduction of technical innovations. Needs for accompanying organizational changes are explored through the construction of scenarios to ensure successful diffusion of the proposed innovations.

3.3. Land use in Senegal

The experiment was organised by P. d'Aquino, a geographer at Cirad working on the decentralisation process in Senegal. More precisely, the goal was to develop simulation tools to help the Rural Councils to explore new land-use rules. For example, it was intended to explore what parts of space would be reserved for specific activities; what the rules of access might be; which users might be encouraged and which might be controlled, etc... The Rural Councils were seen as the client group. The Rural Councils were sets of elected farmers in charge of managing resources of the Rural Community (from 20 to 300 villages). The goal was to find solutions that allowed the multiple uses of a common space.

Workshops were organized in three villages. The theme of each of these workshops was the relations between agriculture and livestock. About 25 farmers and herders of the villages participated in each workshop, with each workshop taking three days. The following was the general structure of the workshops.

- Day one: Identification of the needs of the different actors (soil quality, water salinity, distance to water, distance between plots, etc...).
- Day one: Design a map representing the village area and the indicators defined in the previous step. A GIS was available for this purpose.
- Day two: Role-play game to represent the dynamics of the system. Month-by-month each player decided which activity he was engaged in and where (he moves a post-it on the map)
- Day two: Definition of the relevant problems encountered during the role-play game and envisioning the different scenarios that might appear in the future.
- Day three: Between the second and third day the model was implemented. The third day was simulation on the computer and discussions on the various scenarios.

As an example, the case of Ngnith village is described. Ngnith is situated on the west side of Lake de Guiers. The main problem, as defined by local people, was a conflict between herders and farmers. The farmers cultivated crops along the riverside and the cattle had to cross the fields in order to have access to the river for drinking. Damage and conflicts often occur.

The first day the needs of each group were identified. Each player was alternatively farmer and herder, depending on the season. For the cattle, the distance to water was recorded, as was soil quality. The farmers cultivated two crops a year. For the crop cultivated at the beginning of the wet season the soil indicator was the unique constraint. The second crop was for market garden produce when the plots had to be near permanent water. The agents simply looked for places that satisfied their constraints. Consequently, problems emerged for the cattle, which had no access to water.

Once the role games were completed the rules and spatial relationships that were presented in these role-play games were used to develop and parameterise the simulation model. This model was presented to the participants, and validated by them on the third day. The model was then used to explore different scenarios that could be used to resolve the conflict situations that had emerged.

Despite most of them never having seen a computer monitor, the workshop participants could easily follow the computer simulations and understood the representations and outputs. Once a simulation reproduced the known situation, the aim was to simulate various scenarios. Discussion began on the water issue. Two alternative scenarios were tested. In the first, a number of water points were sunk in the west and in the second, channels were defined from the lake that would extend the reach of the lake into the grazing areas.

The first scenario resulted in over-exploitation of pasture around the water points. Then discussion about the channels occurred. Without access rules these channels were not useful. The farmers located their crops all along the channel and herders found there was no access to the water. Proposals were then suggested to prohibit agriculture on the last kilometre of channel to allow cattle to have access to the water. These proposals were simulated and resulted in a broadly acceptable solution to the conflict problem, which has since become the focus of a set of implementation meetings involving the stakeholders and the Rural Council.

4. MAS MODELS, ROLE GAMES AND PARTICIPATIVE APPROACHES: SOME PRELIMINARY LESSONS

The decision-making process for NRM can be viewed as a collective learning process. This learning process involving representations and emotions which has been conceptualised by Maturana and Varela (Varela, Thompson et al. 1993; Maturana 1996), and which authors like Roling advocate (Roling 1996), seems to be more relevant than the classical rational scheme. More than an accurate model of reality, the purpose is to reach an agreement: models are used as a mediator towards this agreement.

We think that MAS and role games are relevant tools to accompany this decision-making process, because the emphasis is on behaviour and interactions rather than the more aggregated variables used in system dynamics approaches.

Several conclusions can be drawn:

- confirmation of the results obtained by participatory GIS: people are capable of following simulations on screen and interpreting and discussing them.
- the role game-simulation model sequence seems to be appropriate. Through the game, participants gain an idea of what the model is. They are then capable of following simulations. Better still, they are able to understand the relation between the model and reality. Having been through it, they know that the model is a considerable simplification. As a result, they can measure the importance of the results. As the aim is not to predict but to encourage and enrich discussion, simulations and role games serve to identify and formalize problems for discussion.

- KISS, “keep it simple and stupid”, is one of the principles of complex simulations: the interactions between simple processes are a result of complex dynamics. As a rule, the argument is that this principle is valid on paper, but is not operational. In this particular phase, the collective identification of problems, it appears that simplicity is required. For instance, when developing SHADOC, huge efforts were required to make the model simple enough to play. The same was also true for the Sylvopast model. On the other hand, in the case of SelfCORMAS, a collective discussion process was triggered based on a simple model (designed by the participants themselves), which increased in complexity as the discussions became deeper.
- role games make it possible both to acquire knowledge, which is then introduced into models, and to validate the models themselves.
- Need for an interdisciplinary team: field work by NRM specialists from various disciplines, modeler to transfer field data into formal MAS and computer programmer to develop the simulation tool. MAS constitutes also a tool to facilitate interdisciplinary dialogue on a given issue.
- It is not a predictive tool! But a “companionable modeling” activity to support discussion, coordination, negotiation among multiple stakeholders, based on different scenarios, to help them governing the land.
- Close articulation between field work and modeling activities: the simulation asks questions to the field which answers are new data for feeding modeling.

5. CONCLUSIONS : PERSPECTIVES ON THE USE OF MAS FOR INRM IN SE ASIA

These experiments enabled us to explore an interesting way of using MAS, in support of negotiations between stakeholders. A new horizon has now opened up and other applications are under way or are planned. Now that this feasibility has been demonstrated and that the elements of a method are in place, it is important to study the contributions and effects of such tools over longer periods. How do the models evolve with a decision-making process? Do they disappear? Do they change status? It is now necessary to establish ways of monitoring such research-action dynamics, either in relation to their final purpose or, more generally, in relation to their impact on the local community (impact on stakeholders in the decision, ethics of intervention, etc).

To conclude, unlike the control approach, the supportive approach on which all these experiments and CORMAS are based can be seen as a “bottom-up” rather than a “top-down” modelling method. How can models be used in support of collective decision-making processes without sidelining the responsibilities attributed to the decision-makers? This is the big issue in such operations.

Because they allow to consider agents of very different nature with their own perceptions, modes of communication and control, MAS have a considerable potential in INRM research for the modeling and simulation of complex processes between stakeholders, as well as between social and ecological dynamics.

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