

Preparing a framework for participatory modelling of farmers seed systems in Mali : varieties selection and exchange

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Abstract

The current research is undertaken in the high-risk environment of poor farmers in Mali (West Africa) where agricultural biodiversity is crucial and people are always aiming to be more efficient in their use of the natural resource base. It introduces participatory modelling as a way to strengthen human and social capital in ways that support the management of the natural capital, including plant genetic resources.

During a first stage of the research project, data was gathered and processed in a suitable spatial framework. This paper gives an insight into the methodology we use during the second stage of the project, which introduces Agent-Based Models (ABM).

We present a first prototype that formalize existing assumptions and data within a dynamic framework. The development of this prototype has resulted in the identification of different decision contexts around farmers’ sorghum seed management. It has led us to the next stage of our research that is to gain more knowledge about these decision contexts by the mean of fieldwork and role-playing game sessions. These information will be used to produce a second ABM resulting from a common understanding of farmers’ seed management.

Introduction - Context

In recent decades, agricultural scientists have responded to the threat of genetic erosion by developing a worldwide network of gene bank for conserving the genetic resources *ex-situ*. But this strategy reaches some limits, especially concerning the conservation of the dynamic processes of crop evolution and farmers’ knowledge of crop selection; and it cannot ensure the continued access and use of these resources by farmers.

In situ conservation has this potential to conserve the processes of adaptation of crops to their environments, and conserve diversity at all levels - the ecosystem, the species and the genetic diversity within species, and maintain or increase farmers’ control over, and access to, their genetic resources (Wood and Lenne, 1997)

In the Sahel, farmers rely essentially on informal seed systems built around production of their own seed, kept in an evolving diversified gene pool through networks of exchange and selection. This seed system is embedded in existing social structures and developed in the context of local institutions ranging from families to markets. Local systems of classification of seed traits reflect socio-culturally differentiated attitudes of farmers to seek for, and recognize, diversity and its functional attributes. The wealth of seed diversity and its associated knowledge is regulated by a set of specific rights, responsibilities and division of labour, often related to gender and age that is crucial to understanding crop use and management (Berkes and Folke, 1998).

Farmer participation is regarded as a key factor in the success of any *in situ* conservation program and local seed system enhancement. Farmers and farmers’ organizations form the core group of stakeholders and beneficiaries. This research is part of a project that focuses specifically on the conservation functions of seed systems with an emphasis on farmer’s own management processes and their long-term implications for the genetic resources of useful plants.

The requirement of co-viability of the ecological and social systems results in wondering about the practices and innovations of the local users and their consequences in terms of dynamics of the biodiversity and social and economic dynamics. Is there any traditional seed system on which to rest to ensure the *in*

situ conservation of cereals and to improve the diffusion of new varieties?

In this context, we use participatory modelling techniques in order to determine farmers' own strategy for *in situ* conservation of biodiversity and eventually enhance their concern and knowledge about the aggregated effects of their own strategies and find some ways toward collective management arrangements.

We are still in an early stage of the project, and what we present here is the first Agent-Based Model (ABM) we have built from expert knowledge and the dynamic process surrounding it.

After this research context, this paper replaces the ABM within a broader companion modelling process and explains the purpose of this model. Then it presents this prototype that has been developed as a frame for participative modelling activities, focusing on the farmers' individual choices on varieties selection and exchange. Finally, it gives an insight into how a Role-Playing Game (RPG) has been built in order to fill information gaps revealed by the prototype, and how this RPG sent back inputs to get to a second ABM based on participatory work.

Which purpose for the modelling?

We use Agent-Based Modelling (ABM) as a tool for computing and sharing information about farmers' sorghum seed systems. In this early stage of the project, the main purpose of our model is to gather and formalize existing assumptions and data about the system. In this context, the model as well as the conceptual modelling process itself constitute an artefact that can be discussed among the scientists coming from various disciplines that are involved in the project. It facilitates scientific exchanges and knowledge processing and allows to identify information gaps (Heemskerk, Wilson et al., 2003).

However, our model is embedded in a long-term companion modelling process that consists in repeating cycles from real world to scientific knowledge through 3 stages that are: information gathering (bibliography, fieldwork, RPG), knowledge formalization by conceptual modelling (RPG can be considered as kind of models), and confrontation to field through simulations or game sessions that loop on the 1st stage (Bousquet and Barreteau, 1999).

The sketch on Figure 1 presents the way we have implemented this companion modelling process.

On the stage 0, many on-farm experiments have been conducted during 2001 to 2004 in 12 villages of Mali. They depended on direct field observations, participatory appraisals and interviews with farmers during the field work. They resulted in an amount of data that puts in evidence the biophysical and socio-economic factors that determine the diversity of the farming systems towards sorghum. These data have been structured and spatialised into a GIS (Bazile and Soumare, 2004).

During the stage 1, an ABM prototype has been produced from the expert knowledge resulting from the spatialised data processing work. It results from a characterization of the spatial distribution of crops in response to ecological traits within a village territory and implements crop rotation decisions in an archetypal artificial landscape used to initialize the simulations (Bazile, Le Page et al., 2005). Dynamics in this ABM are driven by farmers' decisions on sorghum varieties selection and exchange. As a result of this conceptualisation work, we have identified several decision contexts about sorghum varieties selection and exchange. As little information was known about the strategies used within these decision context, we used statistical data to implement random decisions. These decision contexts can then be identified as modules that are to be informed with further fieldwork.

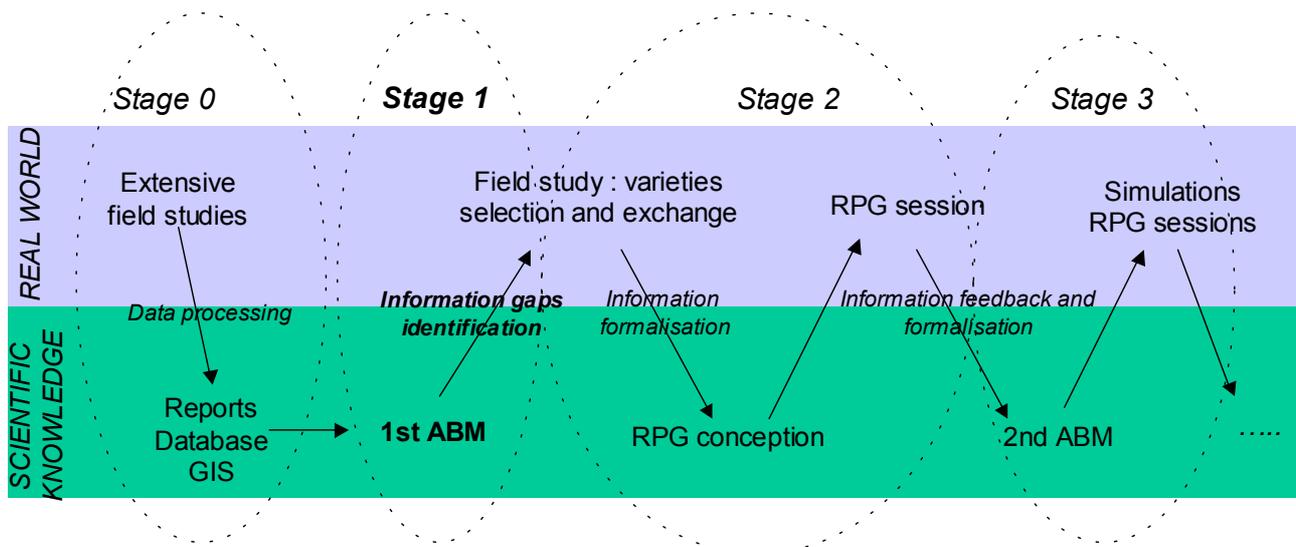


Figure 1. The companion modelling process

The stage 2 occurred during the summer of 2005 : more fieldwork has been conducted in order to gain more information about farmers strategies. This fieldwork has resulted in the conceptualisation of a RPG. One RPG session have be achieved with 6 farmers and resulted in the validation of some assumptions and the elicitation of new information on the system.

During the next stages, new ABMs will be developed that incorporate farmers knowledge and interests elicited through gaming sessions.

In this paper, we focus on the ABM expert prototype produced during the Stage 1. We also present how the decision context modules identified in this ABM motivated further fieldwork, and what are the feedbacks of the subsequent RPG on the ABM. The RPG itself will be presented more thoroughly in another paper.

The ABM expert prototype : focusing on varieties exchange and selection

In the development of this first ABM, we have been careful to identify and separate several modules that corresponds to various assumption sets on the system or

separate decision contexts. We have chosen to integrate all these sub-models in a single model for system exploration and research purpose, but we will be able to present each of these sub-models as an isolated sub-model to the field actors, possibly with the help of role-playing games.

The static model

The first stage of the modelling was to define an village territory presenting archetypal ecological traits (soil types and elevation) of the study area, and to set up a spatial distribution of fields and farms (fields size and number, crops repartition) statistically coherent with these ecological traits. These settings can be used to create archetypal artificial landscapes. When initialising a simulation it is possible either to generate a new landscape, either to load an existing one. This work is presented in detail in (Bazile, Le Page et al., 2005).

Some details of the structure of the model is presented on an UML call diagram on Figure 2:

- Farmers may belong to FamilyGroups (in a proportion of 60%). These family groups define information networks where seeds exchanges are facilitated.

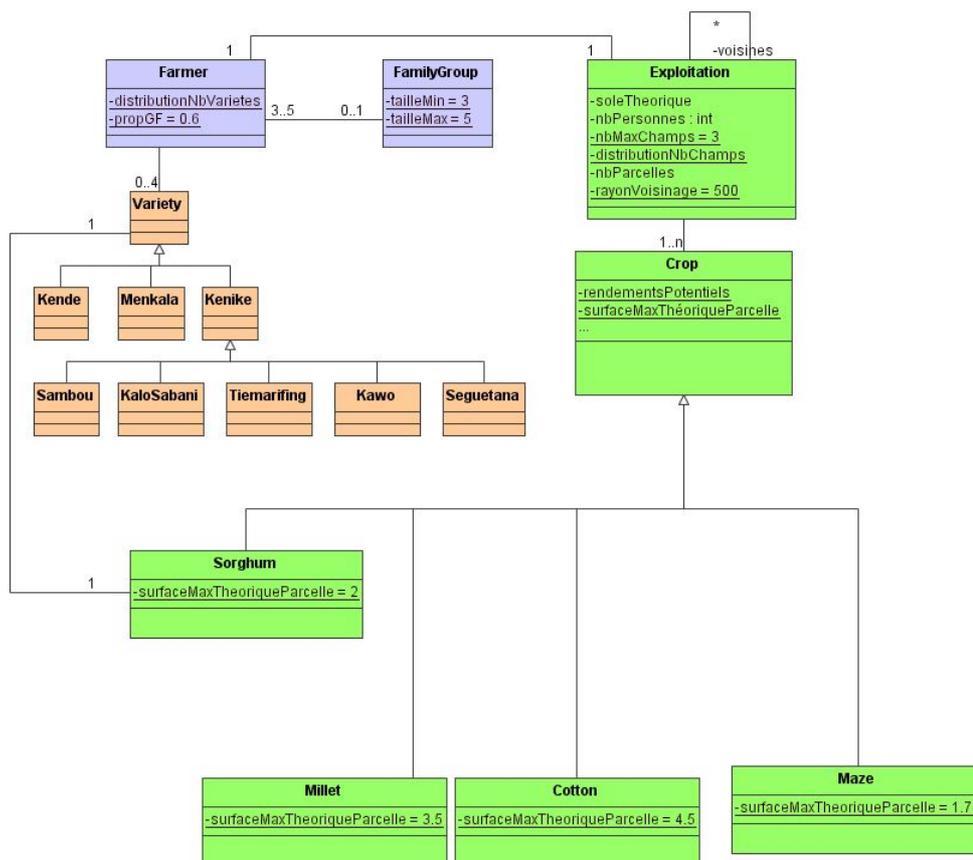


Figure 2. UML class diagram of the structure of the part of the model dealing with seed selection

- Farmers own a maximum number of 4 different varieties of sorghum. The initial number of varieties and the initial varieties a farmer owns are attributed randomly, according to statistical data.
 - Farmers manage an Exploitation. This exploitation is composed of several crops (number, size and type – millet, cotton, maize and sorghum - attributed statistically). The exploitation is spatially situated and gives access to a neighbourhood.
- Spatial entities that define ecological traits are not present on the diagram.

The dynamic model

The second step of the modelling was then to implement some dynamics on sorghum varieties management. The time step of this model is one year and the dynamics are based on the following assumptions :

- (H1) Sorghum varieties choice is independent from crop rotation. Our only concern being sorghum varieties choice, we do not implement dynamic crop rotations
- (H2) In the process of choosing a variety, 3 independent decision contexts can be identified : (a)

deciding whether to change variety or not (b) selecting a new variety (c) finding a provider for this variety.

- (H3) When they choose a new variety, farmers replace one of their old variety.
- (H4) Varieties are exchanged freely and with no counterpart within the village. Exchanges may occur among neighbours or/and within a family group. We do not include yet any agro-climatic model and no assumptions are made on varieties traits or on the way a farmer may evaluate the fitness of a variety.

The resulting actions a farmer performs during a time step are described on the UML activity diagram on Figure 3. Each of the grey activity boxes corresponds to an identified decision context:

- varieties selection module : the farmer decides whether to try a new variety or not.
- he identifies the varieties he has access to (through his neighbourhood and/or his family group) and choose a variety to try and a variety to replace.
- he choose a supplier for this new variety
- if the farmer is currently trying a variety, he has to decide whether he keeps this variety or not.

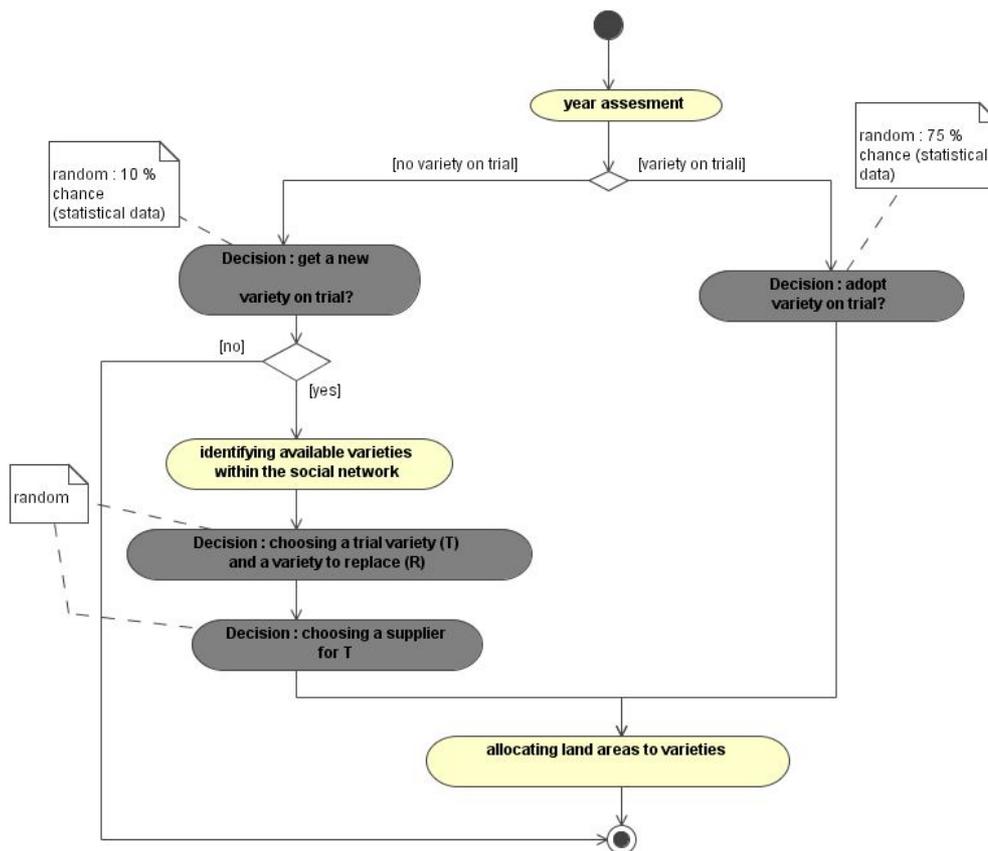


Figure 3 UML activity diagram describing the activities a farmer performs at each time step

As we had little information about the strategies used within these decision contexts, the decisions are implemented with random choices corresponding to statistical results. (some statistical fieldwork results may be used).

Finally a specific module within farmers' activity describes new varieties test organization with 3 available strategies : (S1) the new variety may replace completely the old variety (with the risk of loosing both varieties if the trial fails) (S2) the new variety may be tried on a very small surface and replace totally the old variety if the trial is successful after one year (S3) the new variety is tried on increasing surfaces and may only replace totally the old variety if trials are successful during 3 years. This module is described in the UML activity diagram on Figure 4.

Simulation scenarios and results

We have designed simulation scenarios in order to check that the prototype retrieves the field statistical data properly. Within this prototype, 2 parameters are available for building scenarios :

- the social network a farmer uses to search for new varieties : neighbours, family or resource persons;
- the strategy used for testing a new variety.

We manage to recover the field statistical data gathered and processed during the first stage of the research

project from simulations of our prototype. The modelling platform we use makes it easy to build probes that deliver simulated data in a form that is identical to the field statistical data.

The first results concerning simulations of different social networks scenarios confirm that based on more information, which circulates between farmers, the farmer's social network increases its panel of choices for varieties replacement. So it changes the way varieties distribution inside the territory evolves.

These experiments are actually no more than a verification of the coherence of the prototype which is for now entirely tautological.

Going to the next stage of the research

In order to get further and get some interesting insights from the simulations, it is necessary to acquire more information about farmers strategies on varieties selection and exchange. This is actually the main output of this prototype that helped us to reveal and underline more precise issues to be investigated. It has resulted into more fieldwork and into the a role-playing game session that we will use to get to a new ABM.

Milestones to a new ABM

As a result of the development of the ABM prototype, a new fieldwork session was launched during the spring

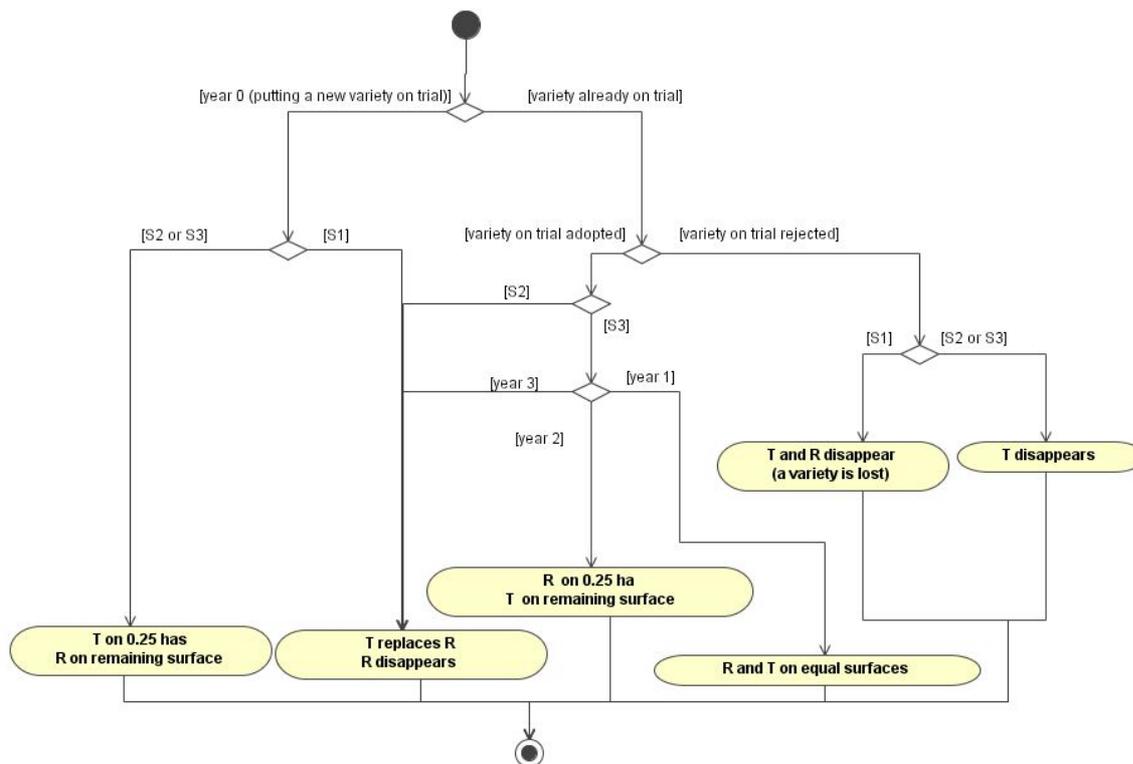


Figure 4 UML activity diagram focusing of the allocation of land areas activity according to the 3 scenarios of strategies

of 2005 in order to enquire specifically about farmers strategies concerning sorghum varieties selection. In order to validate the information acquired during this fieldwork, a role-playing game named “Ci Sunkantini” (“varietals diversity” in Bambara) has been constructed. The game environment is a simplified version of the ABM environment (soil types, farms typology, family groups and neighbourhoods). Farmers have to ensure their family alimentation during one year. The crops rotation possibilities are simplified as farmers may only sow maize or sorghum, which represent the major part of farmers alimentation. A climatic scenario is introduced and a simple agro-climatic model using abacus is used to return yields to the farmers.

Each year, the farmers are announced some climatic conditions (consisting of the date of the rainy season beginning) and they have to decide how much maize and sorghum they cultivate and which sorghum varieties they sow. During the inter-season, they are allowed to exchange varieties with other farmers.

The game was played once with 6 farmers during 3 time steps. We could draw the following conclusions:

- Our representation of their territories and of the parameters they need to make their decisions are accepted by the farmers.
- The agro-climatic model is also accepted to the farmers and can be directly included in a next ABM.
- It is OK to only include maize and sorghum to represent alimentary security constraints, but cotton has to be included in the crop rotation because farmer may change proportions of maize and sorghum depending they cultivate cotton or not, and depending whether cotton was cultivated on a specific field the year before.
- Different strategies could be identified in the decision of changing varieties or not : some farmers have a secure strategy and cultivate varieties that ensure a medium but stable yield (either combining complementary varieties, either cultivating a very rustic one); some farmers have a technical strategy and they change varieties according to the climatic conditions, seeking the variety that ensures the best yield within these conditions. Some farmers can also try new varieties in an innovation strategy.
- Different strategies could be identified concerning the choice of new varieties : some farmers have an observation strategy and acquire varieties that gave a good yield in neighbours or friends field that share the same soil characteristics as theirs; some farmers have an ideotypic strategy and they seek for varieties that meet their ideal requirements.
- The main criteria that influence farmers choice on a variety are its optimal yield, its adaptation to a particular soil type, and its adaptation to particular climatic year.
- Seeds diversity management is an individual strategy and is never thought collectively. The high

diversity observed in the villages is the result of the heterogeneity of these individual strategies.

- The farmers showed great concern about the issue of choosing the sowing dates that are appropriate to a variety in given climatic conditions.

We can now come back on the hypothesis we put into the ABM :

- (H1) independence of Sorghum varieties choice and crop rotation : this hypothesis is partly refuted as we have to include cotton rotation in surfaces attribution.
- (H2) 3 independent decision context in varieties choice: this hypothesis is only partly validated as some opportunist farmers may choose to acquire a variety that they saw giving good results in another farm.
- (H3) a new variety replaces an old variety: this hypothesis can also be validated as farmers always kept the same number of varieties during the gaming session.
- (H4) varieties exchanges: we could observe free exchanges but there was not enough farmers to raise any conclusion about who is exchanging with who.

Finally, we can conclude on the requirements our next ABM will have to meet:

- An agro-climatic module will be included in order to produce yields and give inputs to agents decisions. This module is ready and has just to be adapted from the abacus used during the game.
- A dynamic crop rotation module has to be included and millet can be excluded from the model.
- Criteria concerning yield, soil type and climatic adaptation have to be attributed to the sorghum varieties.
- The strategies identified during the game can be introduced in the decision contexts of the prototype.
- A module concerning sowing dates choices has to be added.

Discussion and prospects

In the context of a project dealing with sorghum varieties diversity conservation, we have initiated a companion modelling process concerning farmers’ management of this diversity. The development of a first ABM for expert knowledge helped us identifying knowledge gaps and gave us a framework for further modelling. A RPG has been built in order to fill these knowledge gaps and the gaming session has been successful in sharing information about farmers practices and strategies (farmers learnt about each other, and we learnt from the farmers). As a result of this gaming session we can validate or refute the hypotheses we put in our ABM and state about new modules that can be included in a next ABM.

This joint use of RPG and models can be described as mutual support in design and analysis. At this stage of the process, it falls in the more precise category of eliciting knowledge and formalizing assumptions constituting the model when the underlying conceptual model is not fully formalized and misses some behavioural patterns (Barreteau, 2003).

However the game is very time consuming and the 3 steps we played with only 6 farmers do not allow us to conclude on seed exchanges networks or on individual strategies influence on global village varieties diversity for instance. In this context, our next ABM will be used to test the new hypotheses, but also to observe their effects on more time steps and with more actors. As it will include some elements that have been validated with the farmers, it may be used to explore the system behaviour with the farmers and be introduced as a concrete element of discussion during the debriefings that follow gaming sessions.

In a more distant schedule, we plan to consider more scales of the seed management system by introducing farmers organization and regional or national actors, as done by (Vejpas, Bousquet et al. 2005).

The companion modelling approach we are leading in this project has now been used and recognized in many common-pool resource management projects (Bousquet and Le Page, 2004; Janssen, 2002). It is the first time though it is applied to seed system issues and it promises to become an efficient tool in acquiring, computing and sharing information about farmers' varietal diversity management, from which little is known, and exploring hypothesis about its consequences on genetic diversity erosion or maintenance in rural communities.

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