

Perspectives of modelling the farmer' seed system for *in situ* conservation of sorghum varieties in Mali

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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 at being more efficient in their use of the natural resource base. Hence, maximising the contribution of agricultural biodiversity to sustainable livelihoods involves strengthening human and social capital in ways that support the management of the natural capital, including plant genetic resources: interdisciplinary study has proven to be an invaluable tool. This research deals with the structure of society, the way the farmers act, where and how decisions are made to manage genetic resources. According to a scaling-up methodology and a systemic approach, data was gathered and processed in a suitable spatial framework. Then dynamic inputs such as farmers' strategies and social network interactions are modeled using multi-agent systems. The first finding from multi-agent simulation is to provide a common understanding of farmers' seed management. The participatory modelling process allows an increase in knowledge and procedural skills by learning from experience with farmers.

Key words: Farming system, Sorghum, Biodiversity, Multi-agent models, Participatory research.

1 Introduction

In recent decades, agricultural scientists have responded to the threat of genetic erosion by developing a worldwide network of gene bank for the genetic resources conservation *ex-situ*. While this has been the main strategy against the loss of genetic diversity in major crops, facilities are unlikely to accommodate the full range of useful diversity in economically useful plant species. In addition, these facilities do not conserve the dynamic processes of crop evolution and farmers' knowledge of crop selection, management and maintenance inherent to the development of local cultivars; nor can they 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 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).

In this context, participatory modelling approaches can be used to provide an insight on the complexity arising from the cumulative effect of farmers' seeds selection strategies and exchange networks over crops genetic diversity at the village scale. Multi-Agent Systems (MAS) are well adapted to support the modelling of heterogeneous social strategies within a spatial framework and simulate the interactions between the social and natural dynamics of a system. Participatory modelling means following an incremental scheme where experiments with the farmers are used as often as possible to refute or feed the model with the farmers' knowledge. At the end of the process, the resulting Agent-Based Model (ABM) should provide a common understanding of the system that can be used as a basis to work with the farmers on enhancing local varieties *in-situ* conservation mechanisms. After the research context, this paper explains the conceptualization of the farmer's seed system and the methodology used to develop an ABM of this system. We also present the major findings during the preliminary phase of the research project that open a way to participatory modeling with farmers to determine their own strategy for *in situ* conservation of biodiversity.

2 Material and methods: Farmers' management of seeds

The data presented in this paper are based on many on-farm experiments from 2001 to 2004 in 9 villages of Mali (fig. 1). They depend on direct field observations, participatory appraisals and interviews with farmers during the field work. We put in evidence biophysics and socio-economic factors and their interactions which determine the diversity of the farming systems.

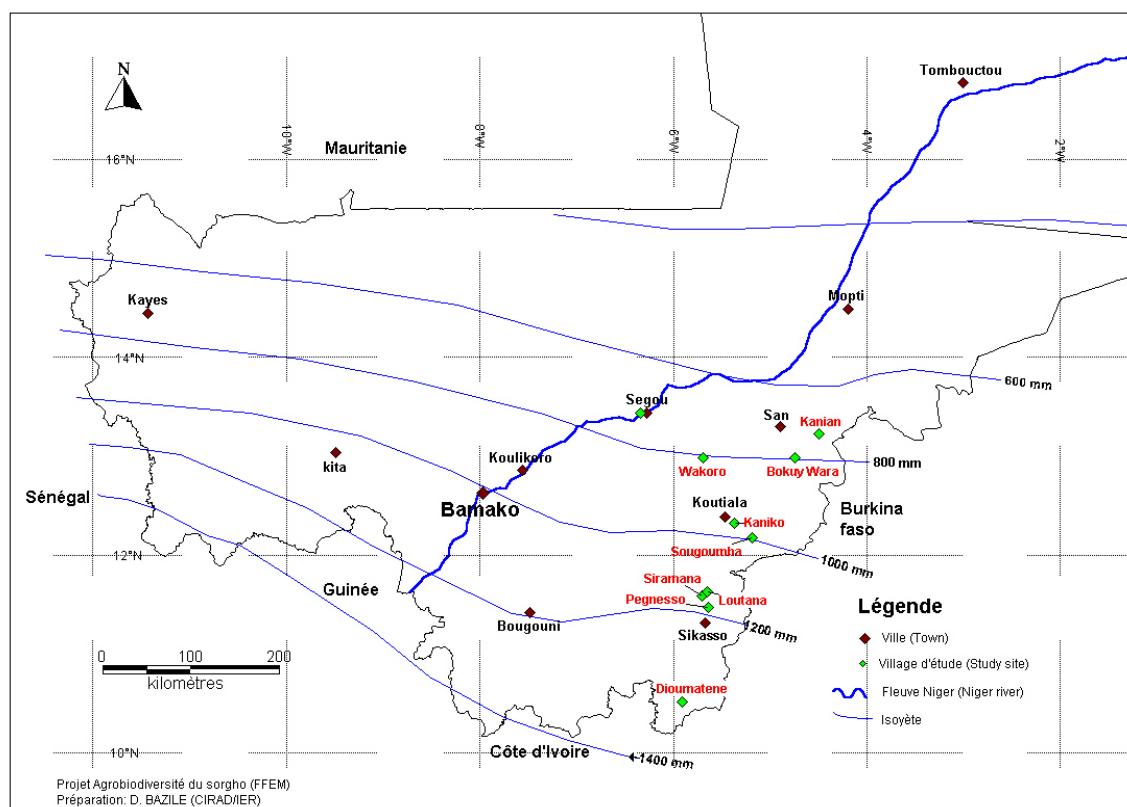


Fig.1. Studied sites on a climatic transect in the agricultural area of Mali.

2.1- Dynamics of the Sorghum in the various agro-ecological zones

In the south of Mali, the percentage of farms cultivating maize as well as cultivated area has been increasing dramatically for the passed 5 to 10 years (fig. 2). This penetration of maize has a detrimental effect on the culture of sorghum, which is being reduced or marginalized on the poorest lands. The disappearance of sorghum presents a stake on the ecological plan (loss of biodiversity) as well as on the food security plan sorghum is a rustic cereal which adapts itself better to difficult ecological conditions (weak water reserves or acidity of soils). The genetic erosion of sorghum is strongly correlated with the penetration of maize in the farms so indications of biodiversity loss for sorghum are sharply weaker in the North (25%) than in the South (60%) of Mali (fig. 3). The use of the genetic diversity of the sorghum

landraces is then perceived as a factor of rustic character of the agroecosystem. Climate is the major risk that presses on the production and consequently on the stability of supply. The use of local varieties is above all a strategy to ensure food self sufficiency but its effects are multiple: minimization of exploitation costs, optimization of water resources and protection against soils degradation.

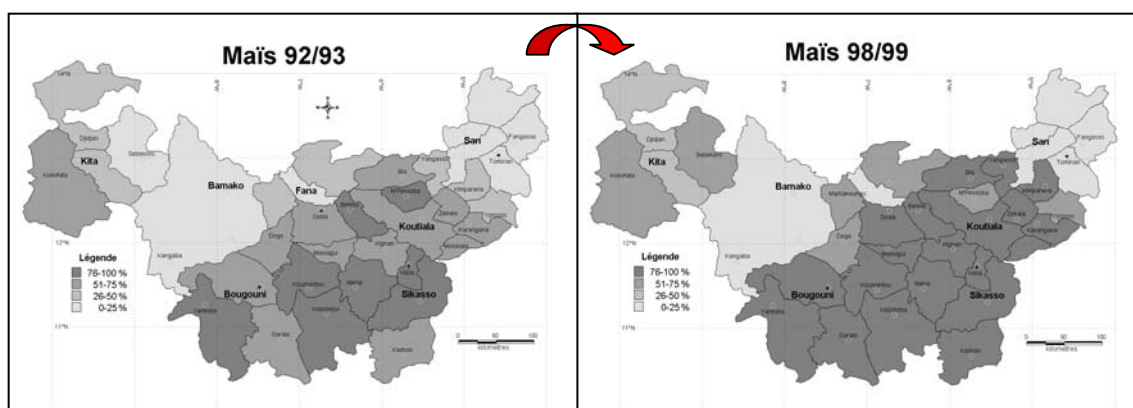


Fig.2. Evolution of the percentage of farms which cultivate maize in south of Mali.

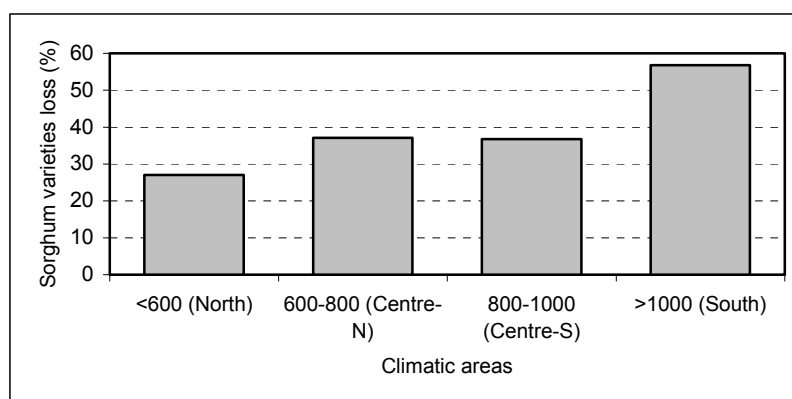


Fig.3. Sorghum varieties loss during the last 20 years in Mali (adapted from Kouressy, 2002)

When land use is important, farming system must be more intensive to contribute to food security. Importance of cotton and maize in the agricultural system provides an economical opportunity to farmers but masks the intrinsic risk of each speculation. On the way of saturation of agricultural land cover, farmers occupy marginal soils with important constraints for agriculture. If maize and cotton provide maximal yields in better conditions, sorghum and millet, with a panel of folk varieties, are more adapted through wide environments and provide more stability in yields. Economical benefits in low input system could be maximised than in intensive system. A long-term approach with a globally spatial use of the ecosystem shows the dispersion/stability of crop yields. There is a sorghum opportunity, with Malian landraces, to improve agricultural system along with conservation of biodiversity (Bazile and Soumare, 2003).

22- Farmers' decision-making on varieties

The genetic diversity of the local sorghum's varieties is then perceived as a factor of adaptation to the agro-ecosystem. The photoperiodism kept in sorghum's landraces supports the synchronicity between the length of the cultural cycle and the limits of the rainy season (beginning and end). The farmers' strategy of using these local varieties is above all an anti-unpredictable strategy to ensure the food self-sufficiency of its family but the effects of which are multiple. The two principal effects are an adaptation to the labour calendar and an optimization of the pluviometric resources during all the rainy season (Vaksmann *et al.*, 1996).

Table 1: Cultivating the diversity of sorghum' varieties at the farm scale

	No variety	1 variety	2 varieties	3 varieties	> 4 varieties	TOTAL
Farms	51	473	107	7	2	640
% farms	7,97%	73,91%	16,72%	1,09%	0,31%	100,00%

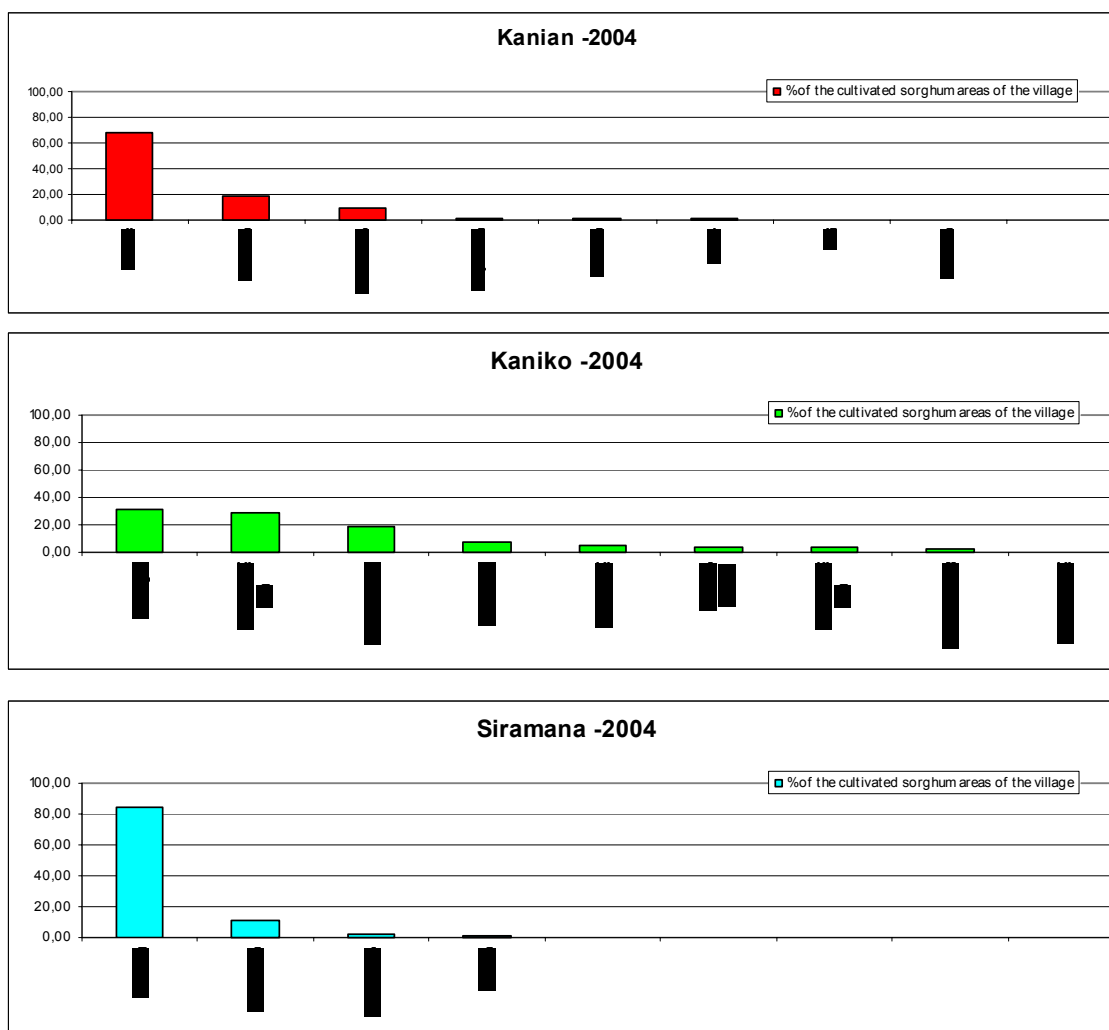


Fig.4. Abundance of the sorghum varieties in three villages of Mali

Crops genetic diversity is playing an important role in livelihood strategies of the rural poor people in marginal areas as follows: diversity of uses (varietals diversity relates to different culinary practices and other uses), optimisation of production factors (farmers select different varieties to match different soil water regimes), risk management (variation in rainfall) (Altieri, 1999; Vom Brocke, K. et al., 2003). Even if we find between 8 to 12 sorghum landraces in a Malian village (fig. 4), the abundance of the three major varieties is often very consequent and they are cultivated on more than 70% of the sorghum's area of the village. The variety richness is an absolute data that doesn't explain genetic diversity in the practise as we can see it through a relative data as abundance. Varietals diversity provides complementarities for agroecosystem management and each peasant cultivates one or two varieties in his farm (tab.1). So the biodiversity is not managed at the farm scale (very low level of varietals diversity) but at the community level (addition of all the individual farmers strategies) through exchanges among groups of peasants which provide seeds for everyone else who needs it in the village.

23- The farming social network

Each farmer has its own strategy but is limited in his choices of varieties so he must ask the community to provide him new landraces for specific micro-environments or uses. High quality supply seeds availability is determined by the connection of the farm to various geographical or social networks. The management of the biodiversity at the village scale through complex and intersected networks of exchanges supports the conservation, the renewal and the diffusion of varieties adapted to the needs of the local populations. Social networks play a key role in determining access to seeds and information. Relationships of trust and affection within the extended family, neighbourhood or beyond are fundamental to the exchange process, while norms, laws, rules, procedures, traditions, customs and

practices influence the choice of individuals. All of which affect the movement of genes within households, villages, between villages, and over larger geographic areas (Subedi, A. et al., 2004). Through participatory social studies, investigations on the role of social and geographical factors and crop management practices on crop diversity will be conducted. Family is the first way to accede to a diversity pool through social network. Then in each village and for each variety, there is always one resource person. A resource person is a farmer who is socially recognized as the best farmer for this variety and who can always provide seeds for this variety. These resource persons are the principal nodes of exchanges at the village scale. Maps at different scales (farm, village, district, region) generated by GIS will be used in participatory exercises to gather information on flows across the landscape and identify these nodal farmers (Fig. 5).

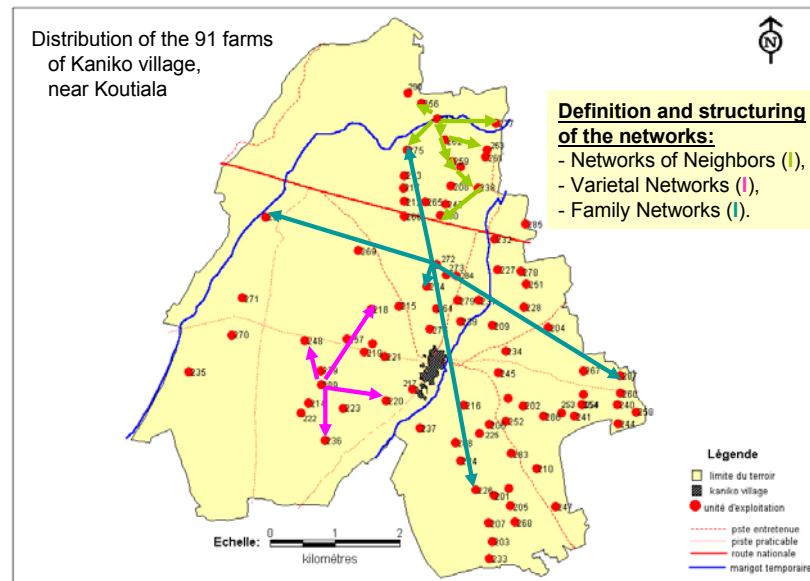


Fig.5. Using GIS Tools to show farmers' links through spatial organization

3 The Agent-Based Model (ABM): Complex system dealing with quality seed supply

Farmers' seed management as it has just been described and its impact on sorghum varieties diversity within a village or a wider area constitutes a complex system. Designing models of a complex system is a way to properly formalize its mechanisms and share this understanding through standardized representations of the models. Then running these models into time through simulation provides insights on the dynamics of the system and material to discuss about management scenarios. Among the various available modelling methodologies, Multi-Agent Systems (MAS) provide a framework that is particularly well adapted to represent common resources management issues and share these representations with the local actors in participatory workshops.

31- The choice of a modeling through MAS

Simulating common resources management raises the issue of modelling the interactions between social dynamics (decisions or practices of actors or groups of actors, exchanges or communications between these actors or groups of actors) and physical dynamics (natural dynamics of the resources). There are several empirical ways of modelling these interactions. Here, the research focus encompasses the relationships between people and resources as much as the relationships between people who affect resources. Multi-Agents Systems (MAS) consist of autonomous data-processing entities, the agents, which evolve in an environment. This environment is made of the objects and resources accessible to the agents and can be settled over a spatial grid. The agents perceive their environment and the other agents and may build up more or less advanced self-representations of them. Using more or less evolved capacities of reasoning, they act then by modifying the environment or by communicating with the other agents. MAS can be used for simulation purposes and provide Agent-Based Models (ABM) of a system.

MAS are well suited to address common resources management issues because they make it possible to model (1) spatially settled natural resources dynamics through environment objects evolution rules (2) heterogeneous management strategies through agents' decision rules (3) information or resources exchange networks through agents' acquaintances who they can exchange messages with. Then during simulations, the dynamics of the system evolves through the interactions between agents and environment objects. These interactions might be direct (between agents that exchange information, or between agents and resources) or indirect (between agents that share common resources). For these reasons, the ABM of a system is a good tool to formalize hypothesis about actors' strategies or networks of exchange and study the impact of different modes of coordination over a resource. (Bousquet and Le Page, 2004). One of the classic uses of simulation is prediction. However, this is not the option we have chosen. ABM building process aims at including stakeholders' perceptions of the present situation and to use simulations as discussion supports about the evolution of the system.

32- The development of the model

The farmers' seed systems take part in more than 90% in the supply seeds in West Africa. They are central for the conservation of biological diversity. The objective of the modelling process is to formalize these mechanisms to better understand their consequences. In a second stage, when the model gives a representation of the system that is well accepted by the stakeholders, it can be exploited in order to improve the mechanisms of *in situ conservation* of the local varieties. During the first stage of the process, the model is developed through an iterative process of confrontations with the stakeholders in participatory workshops so that they can refute or give new inputs in the mechanisms included in the model (Fig. 6).

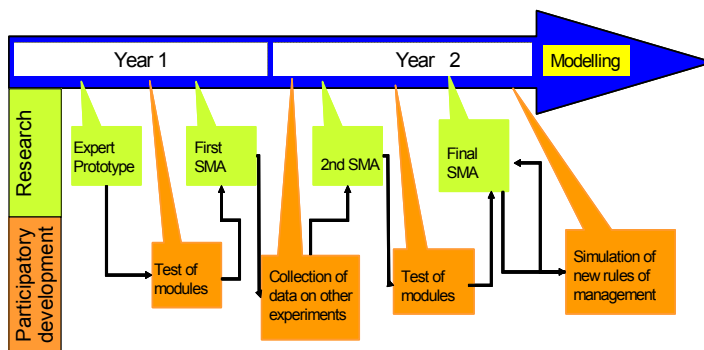


Fig.6 Different steps of the development of the model

During the development of the prototype, we are careful to identify the different decision contexts involved in seed management system, and to separate properly these different contexts within different modules, in order to be able to present an acceptable level of complexity to the farmers.

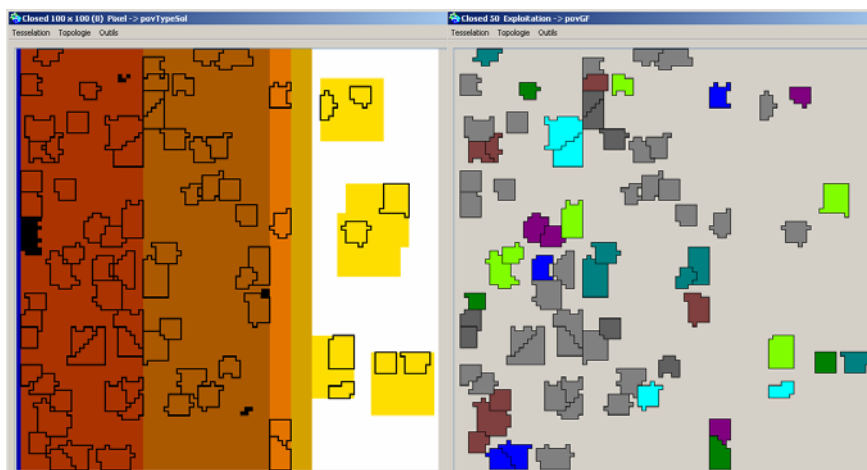


Fig.7. Simulation of the farms on the distribution of soils (left) and among family groups (right) in a virtual village of Mali

Table 2: Parameters of the model

Variables at different scales	Data inputs	Rules of dynamics
Territory	Cultivated or no	Priority of cleared patches according to types of soils
Farm	Typology of farms Fields number Average percentage of culture	Cultural succession function of soils Rules extension
Farmer	Family groups (GF) Nodal people (NP) Resources	Varieties knowledge Communication with GF and NP
Culture Varieties	Distribution of the cultivated areas through culture and varieties Variety richness and characteristics	Yield optimisation; Dynamics of introduction and diffusion

As for now, the different decision contexts correspond to:

- The crop rotation decisions in an archetypal artificial landscape. This module results from a characterization of the spatial distribution of crops in response to ecological traits within a village territory. It is used to initialize the simulations (Fig 7, Tab.2);
- The varieties selection and exchanges. The decisions concerning varieties selection and exchange are localized within the activities a farmer performs at each time step. These activities are described with very few assumptions, and most of the decisions taken by the farmers are actually random choices (some statistical fieldwork results may be used);
- The organization of the seed system at a regional scale. This module will imply the study and modelling of networks, as intended by (Veipas, Bousquet et al. 2005).

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. Coupling between the different modules will come if necessary from interactions with the farmers.

At this stage of the research, each module of the prototype is extracted from the scientific model called "Expert prototype". This expert prototype has been built from the various data issued from previous fieldworks and from expert's knowledge. The next step is to simplify this expert prototype to treat the questions with the involved groups (peasants, NGO working on the biodiversity, Services of Agriculture and National Seed System, Researchers) through confrontation of the representations that allows enrichment of the modules. Participative workshops increase the co-construction of a shared representation of the traditional seed system. During these meetings, we use the models like tools of mediation which support the development of innovation. The attempted output is the co-construction of mechanisms to maintain the genetic diversity *in situ* of the African western cereals. Some new rules or attitudes favourable will be defined at the adequate level with the different actors in presence.

4- Discussion on participatory modeling of new rules and conclusion

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 in order to ensure the *in situ* conservation of cereals and to improve the diffusion of news varieties?

The participatory research is adapted to make innovation and to propose new mechanisms of biodiversity management. With MAS, it is possible to simulate in real time the effects of these rules. The emergence of new rules adapted to the current context of agriculture will be valorised and used through the model to simulate new scenarios. In this way, we can test the robustness of the model and its capacity to be generalised to other contexts.

Even if the general methodology rests on an activity centred on Mali, the model must take into early account other experiments showing the diversity of the situations in West Africa. The concern of developing a generic ABM of farmers seed management and informal seed systems through the analysis of other seed systems results from a will to work with aspects of these systems on a large scale with an aim at increasing the general information or adaptability of the model. This early concern will make it possible to build the model according to an integral iterative process of several situations.

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. Efforts will be made throughout the project to involve them effectively at all levels of the project. The close involvement of farmers in the above research is expected to contribute directly to strengthening farmers' capacity to evaluate traditional and modern varieties and understand the effect of seed management practices on diversity. This project will focus 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.

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