A participatory modeling method for multi-points of view description of a system from scientist's perceptions: application in seed systems modeling in Mali and Chile

Mahamadou Belem[1,2], François Bousquet[1], Jean-Pierre Müller[1], Didier Bazile[1,2], Harouna Coulibaly[4]

[1] Agricultural Research Centre for International Development (CIRAD), UR GREEN, TA C-47/F, 34398 Montpellier codex 5, France
[2.] Fondation 2ie, Rue de la science, 01 BP 594 Ouagadougou 01 Burkina Faso
[3] Institut d'Economie Rurale BP: 262 Bamako, Mali
[4.] Instituto de Geografia / PUC Valparaiso, Avenida Brasil 2241, Valparaiso, Chile
mahamadou.belem@2ie-edu.org
{ françois.bousquet, didier.bazile, jean-pierre.muller}@cirad.fr
hscoulibaly@yahoo.f

Abstract: This paper presents a participatory modeling for multi-points of view description of a system from scientists' knowledge. The method is applied in the development of a generic model for agro-biodiversity dynamics in developing countries with a focus on crop genetics diversities evolution through the stakeholders' management at different scales. The model description is based on the knowledge of scientists from different disciplines and has been validated using role playing game with stakeholders in order to verify its relevance and coherencies. The model has been used to analyze the evolution of crops varietal diversity under two interventions scenarios: agricultural intervention and seeds intervention. The results show that agricultural interventions increase crop varietal diversity at global level more than the direct seeds interventions.

Key words: multi-points of view, role playing game, multi-agents systems, seed system, agro-biodiversity

1 Introduction

The scientists working in the field of complex systems such as natural resources management, ecosystem management, biodiversity conservation, etc. need to integrate knowledge from different disciplines for a better understanding of the studied systems. These different disciplines have not necessarily the same perceptions on the target system, but their perceptions could be complementary and must be integrated coherently for a better understanding of the problem to be solved or the question to be answered. We are ourselves implied in a pluridisciplinary project – the

IMAS project, acronym of Impact of the Access Methods of to the Seeds on the diversity of genetic resources in agriculture - which is interested in understanding the agro-biodiversity dynamics in developing countries with a focus on crops genetic diversity evolution through the stakeholders' management at different scales (plot, farm, village, region and country). IMAS implies scientists from different disciplines: agronomy in order to understand the crops varietal diversity management by the farmers, sociology to understand the impact of social dynamics such as social networks on seed access, economy to understand the economical regulations impacts on the seed system, genetics to describe the genetic distance among varieties of the same species, etc. The scientists involved in such a project need not only to share their knowledge but also to build a common understanding of the studied system.

Modeling is particularly relevant for knowledge sharing and building common understanding. Today, it is more and more recognized that models are an effective support for multi-disciplinary research [1]. In addition to be a mean to understand complex systems [2], modeling allows knowledge acquisition and sharing among different persons and the emergence of a common understanding of both the studied system and the problem to be solved [3]. By recognizing simulation as an intermediate between theory and experience, Varenne [4, 5] underlines the place of models in scientific research.

Varenne's suggestion shows that the modeling process implies at least three persons: the thematician or "knowledge carrier", the modeler or "knowledge broker" formalizing the scientists' knowledge into a conceptual model, and the software developer transforming the conceptual model into a simulation model. If more than one thematician is involved in the modeling process and if they come from different disciplines, the modeler faces a double complexity: the complexity of the system itself and the complexity due to the heterogeneity and multiplicity of scientists' points of view. The problem is how to identify and describe these points of view? How to articulate their points of view in order to build a relevant model? How to ensure that all scientists involved in the modeling process have a common understanding of the model?

Participatory modeling [1, 6, 7, 8] is one possibility to achieve these aims. "It consists in coupling the scientists' knowledge production process with the stakeholders' decision process by building a shared understanding of the relevant system and its issues using modeling" [9]. Participatory modeling is currently used for understanding the stakeholders' perceptions of their systems, to encourage communication among them for a better management of the resources, and to extract and/or validate information for scientists [10, 11, 12, 13]. Today, few studies are interested in the application of participatory modeling in knowledge acquisition and sharing among the scientists.

In this paper, we are concerned in participatory modeling, engaging scientists for the development of a generic model for seed system analysis. Our aim is to use model as a support for multi-disciplinary research as well as for discussing with the stakeholders and decision makers for a best management of agro-biodiversity.

Our methodology is based on (1) the identification and description of scientist's points of view, (2) the construction of a generic conceptual model integrating the scientists' points of view, (3) the implementation of a simulation model and (4) the validation of the simulation model with the scientists and the stakeholders using role playing game. This paper is more focused on the description of our methodology than the description of the model itself. However, a few description of the model is provided. The model has been developed with multi-agent systems (MAS) [14]. using the Mimosa platform {Müller, 2010 #131}. The model allows to simulate the impact of various strategies of crop management and seed exchange on crop diversity dynamics. The model has been validated using role playing games with stakeholders and used to simulate the impacts of seed and agricultural interventions measures on crops varietal diversity evolution. In this article, the simulations concern only the Mali case study.

This paper is organized as follows: the next section describes the material and method used in our study. After, the conceptual model is presented. Finally, some primary results are presented.

2 Material and method

2.1 Material

As noticed previously, our approach is based on the scientists' knowledge production process using participatory modeling. The scientists' perceptions exist at different levels. They concern the target system viewed as a whole (global level), the entities involved in the system (stakeholders, objects and environment) and their interactions which can be explicitly described with MAS. Many modeling experiences show the effectiveness of MAS to support interdisciplinary research [10, 11, 12]. MAS allow the integration of multiple points of view from different stakeholders - including scientists from different disciplines - in order to provide a common understanding of the problem to be solved and the system at hand.

In order to express explicitly the various perceptions, a set of concepts of the OREA meta-model [15] is used. An *organization* (O) describes a point of view on a system at the global level. The concept of *role* (R) is used to identify and describe the organization point of view on the entities involved in the system. The *entities* (E) describe the actors involved in the system and the resources they use. The *aspects* (A) describe how the entities are internally organized.

2.2 Methodology

Our methodology is based on collective modeling for knowledge acquisition from scientists, collective validation with scientists and using role playing game with stakeholders. The objective is to bring together scientists' from different disciplines in order to discuss on different aspects of the system and to identify and describe their representations of the system. At each step of the modeling process, the discrepancies among the representations are identified and solved collectively. Additionally, questions or hypothesis can emerge during the modeling session allowing scientists to conduct new observations. The modeler plays the role of "knowledge broker". He/she builds step by step the conceptual model by integrating the scientists' points of view. In addition, he/she identifies with scientists incoherencies and manages the discussions during the modeling sessions. The methodology is defined as follow:

Step 1: System delimitation and Identification

The objective of this step is to allow different persons involved in the modeling process, to have a common understanding of the problem to be solved and a common representation of the system at the global level. It is achieved collectively. Depending on their discipline, the scientists express explicitly the main aspects of the system in order to delimitate the scope of the study. These various aspects concern the actors, the resources, the dynamics of the resources and actors organized by global functions, and the communication system through with the actors interact and exchange resources. The identified functions decompose a system into sub-systems (the organizations) in order to reduce the scope of the study and to facilitate the description of the system. The communication system describes the different networks (for example, the markets, the social networks: i.e. other organizations) through which the actors interact and exchange resources. The relationships between functions and communication are defined by the actors that participate to the global functions through their roles and interact among them through the communication system.

This step results on the construction of an "overview diagram" (Fig. 1) which provides the description of the main functions, their relationships, the actors and the communication system.

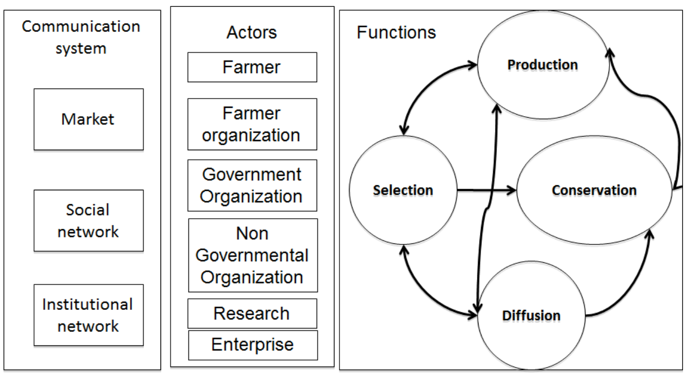

Fig. 1. The overview diagram of the seed system

Step 2: Actors description

As the previous step, the step 2 is conducted collectively. At this step, the descriptions are elucidated actor by actor. The objective is to identify and describe the scientists' points of view on each actor. However, it may exist various points of view on each actor. We assume that a point of view is dependent on a function and defines the role of an actor. During the modeling session, each scientist defines and explains to others scientists its points of view on the actors in the scope of each function. In addition, the scientists identify the interactions in which each actor is involved in the communication system, the resources it exchanges and the actors with which it interacts.

This step results on the construction of “actor diagram” which provides an overview description of the actors (Fig. 2).

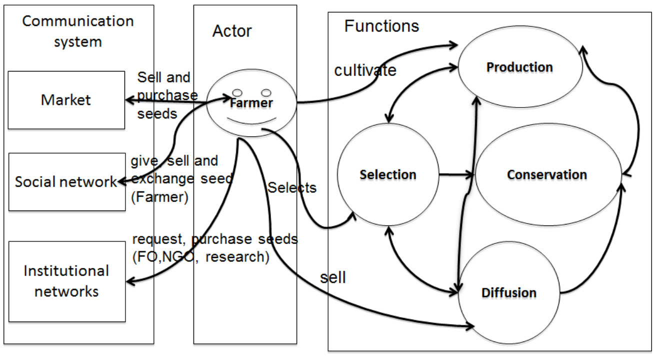

Fig. 2. Description of Farmer through an actor diagram

Step 4: Description of the conceptual model

After the third step, the modeler has a best representation of the different aspects of system (processes, actors, resources, interactions and channels of interaction), scenarios and indicators. Then, he/she formalizes the previous description by a conceptual model using UML (Fig. 3). This step is carried on as follows:

1. The transformation of the functions and communication system into organizations. An organization is represented as a UML package diagram with the “Organization” stereotype.
2. The description of the organization structure: the structure of organization is specified through the roles of the actors realizing it. A role is represented as a class in the object oriented sense with the “Role” stereotype.
3. The description of the actors and resources: it consists in the description of the actors and resources characteristics, also represented as UML classes with the appropriate stereotypes.
4. The description of the dynamics: it consists in the description of the interactions between actors, as well as their decision rules. The UML sequence, activity or statechart diagrams are used.

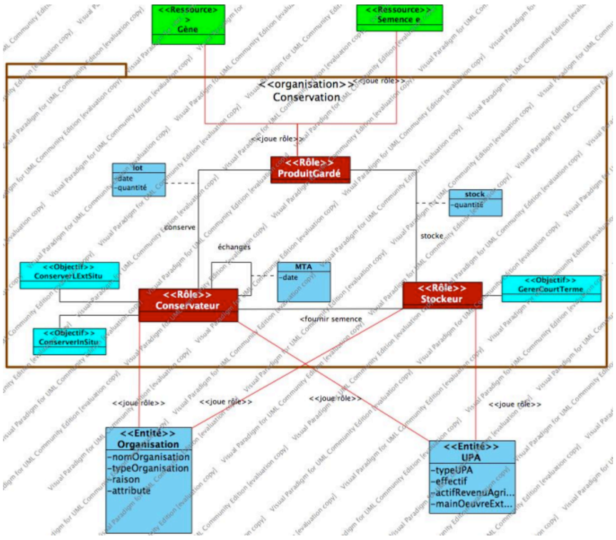

Fig. 3. UML multi-points of view description of "conservation" function

Step 4: Definition of the scenarios and identification of indicators

The scenarios are also defined collectively with the scientists. The objective is to describe the different trajectories the scientists would like to analyze and the indicators that are necessary to analyze the scenarios. For example, a scenario could concern the impacts of climate change on the crop genetics diversity evolution.

Step 5: Implementation of the model

It aims to the concretization of the conceptual through the implementation of a simulation model.

Step 6: Validation of the model

The model is validated with the scientists and the stakeholders using role playing game. During the role playing game, the stakeholders are invited to play the same roles as the agents of the model. This allows to identify the differences between the agent behaviors in the model and the actual stakeholders behaviors and, consequently, to improve the model. The validation with the stakeholders is important in the case of action-research because the model could be used with or by the stakeholders themselves later on.

3 Model description

3.1 Conceptual model

The methodology has been applied to the development of a generic model for seed systems analysis at village level through several modeling sessions in Mali, France and Chile. These modeling sessions brought together scientists working in different fields. Although the corresponding diagrams have been shown to illustrate our methodology, we present the result in more details in this section.

The resulting conceptual model is based on four main functions, six actors and three communication systems (Fig. 1). The first function is the “agricultural production” which concerns grains and seeds production. The second function concerns the “conservation” including in-situ and ex-situ conservation. It provides the resources for grains and seeds production. The ex-situ conservation hold by researchers and enterprises allows to conserve genetics resources used to reproduce seeds, to characterize varieties and to create new crop varieties. The third function identified is “seed selection” through which research creates and improves crop varieties. The fourth function is the “diffusion” function describing the seeds exchange among different actors.

Six main actors have been identified: Farmer, Non-Governmental Organization (NGO), Research, Enterprise, Government Organization (GO) and Farmer Organization (FO). Farmer (Fig. 2) is the main actor of the model. A farmer belongs to a set of social groups which determine its seed access capacity. A farmer is characterized by its farm size, the cropping system, the social networks he belongs to, whether it practices agricultural intensification, and criterions for seeds selection and seeds sources selection. It uses a range of crop varieties in order to meet its different uses and to cope with the environmental variability (climate, soil, etc.).

A farmer produces crops in order to meet its needs (food and money). It selects seeds and participates to seed diffusion through seed exchange with other farmers in the shared social and professional networks and organizations. It sells a part of the production and purchases grains and seeds from market.

Research plays an important role in the seed system. It supports agricultural production such as seed production by providing improved varieties and other facilities. In addition, it conserves genetic materials, creates and improves crop varieties. It interacts through institutional networks with other actors (FO, NGO, GO, Farmer) for seed and material exchanges. FO, NGO, GO supports agricultural production by different interventions.

The model takes into account a range of crop species. Each species is characterized by a set of varieties. A variety is characterized by production cost, yield, color, transformability, conservation, adaptability to climate, sale and purchase price, and gastronomic interest.

After the identification of scientists’ points of view, the previous descriptions have been formalized into UML diagrams in order to build the conceptual model. For example, **Erreur ! Source du renvoi introuvable.** provides a UML description of multi-points of view description of some actors within the function “conservation”.

3.2 Dynamics

The crop production is the main process driving the other processes in the model (seeds selection and breeding, seeds seeking, seeds change, innovation, etc.). The objective of the farmer is to satisfy food and cash needs while taking into account different constraints (resources availability, climate).

Then, depending on its experiences, the beginning of the raining season, and the adaptability of each crop variety to the season, the farmer decides or not to use some crop varieties or to introduce a new variety. Different strategies describe how farmers change crop varieties: the "innovator" is willing to test and experiment new varieties, the "imitator" introduces varieties already produced by other farmers and the "conservator" not willing to change varieties.

Thereafter, the farmer defines the cropping plan, i.e. the area to cultivate for each crop, and defines the needs in seeds. If the available seeds are not sufficient, it seeks seeds in the social network or from others organization (Farmer Organization for example) (Fig. 4). The farmer cultivates and manages production until the end of the season.

At the end of the season, the production is harvested and stored. In order to satisfy his food and cash needs, the farmer defines for each crop the quantity to consume and to sale. A part of the cash from sale is used to satisfy the farmer's cash need and the remainder is invested for equipment. As at the beginning of the season, farmer evaluates each variety at the end of season and updates its knowledge.

The farmer can receive seeds and other facilities (fertilizers, financial, equipment) from FO, NGO, GO, Research that objectives are to support agricultural production and to introduce new varieties.

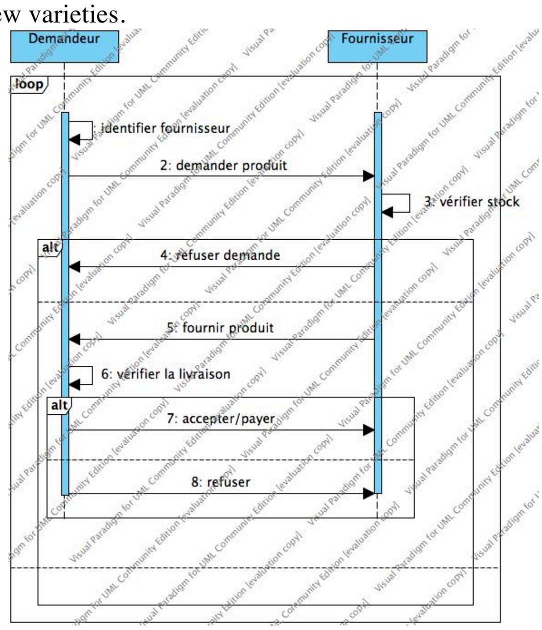

Fig. 4. UML description of seed exchange between a seeker and a provider

3.3 Scenarios

Various scenarios have been identified in order to analyze the impacts of different interventions and climate on crop genetics diversities evolution and the adoption of improved varieties:

1. Scenario 0: baseline scenario

This scenario does not take into account any intervention. The objective is to identify the constraints to the new varieties adoption and diffusion.

2. Scenario 1: Agricultural interventions

The scenario 1 aims at improving the farmers' production and food security through two kinds of interventions. The first kind increases the farmers' intensification level while the second aims at improving market access. They are proposed to the farmers without any constraints. The farmers can choose any varieties according to their criterions and objectives.

3. Scenario 2: Seeds vulgarization

Unlike the scenario 1, the scenario 2 associates interventions to varieties adoption. In this scenario, the interventions are associated only to three varieties. The objective is to analyze the impacts of these interventions on the adoption of these seeds.

4. Scenario 5: Impact of diversification of preferences on varietal diversity

It aims to analyze how the diversification of preferences impact the varietal diversity.

3.4 Implementation

The model is implemented with MAS using the Mimosa platform. The model is generic. It allows to represent a range of territories and villages under various scenarios thanks to the modularity of the model structure and the flexibility of the parameters set. The parameters are defined through a PostgreSQL database.

3.5. Input and output data

The input provides the description of the farmer types, cropping system, social networks, sources of seeds, the number of farmers related to each type, etc. In addition, it provides the description of climate, institutions, and the types of crop simulated in the model.

The model provides a range of outputs. The output concerns the farmer dynamics. For each farmer, the model provides yearly data about its cash, seed exchange (seed supplied and/or received) and the crops production. For each cultivated crop, the model computes the cultivated area, the grain production. The outputs allow to analyze the evolution of crop diversity, seed exchange, food production and farmers income under various scenarios.

20 farmers divided in three types have been simulated (**Erreur ! Source du renvoi introuvable.**). They cultivate 2 or 3 varieties of sorghum (**Erreur ! Source du renvoi introuvable.**) and they differ by their seed preferences and cropping system.

Table 1. Description of the farming typology

Type	Farm size	Intensification	Cropping system	Crop varieties	Preferences
T1	5	0.6	Maize, sorghum, sorghum	Kalosabani, kendeblema	yield consumption Transformation
T2	10	1	Maize, sorghum, sorghum	Kalosabani, kendeblema, kendeblema	yield price
T3	5	0.6	Maize, sorghum, sorghum	Kalosabani, seguetana	yield selling price transformation

Table 2. Description of crop varieties

Variety	Yield	Producti on cost	Price	gastrono mic interest	transformation
Kalosabani	1	0.5	5	3	1
kendeblema	3	0.5	5	1	3
seguetana	2	0.5	6	2	2
sorgho4	5	1	10	3	3
sorgho5	4	0.8	10	3	3

3.6. Simulation and Results

The simulations allowed to analyze the impacts of different interventions and climate on crops varietal dynamics at a village scale and the adoption of two crop varieties (sorghum 4 and sorghum5). We observed that agricultural interventions allow adoption and diffusion of improved varieties more than the seed interventions. Agricultural interventions increase the farmers' production, decrease their vulnerability and therefore increase their willingness to cultivate new varieties. The seed interventions increase the farmers' willingness to adopt only a limited number of varieties i.e. the supported varieties. Additionally, we observed that diversity in crop preferences enhance crop varietal diversities.

Conclusion

The study showed the effectiveness of participatory modeling to support multi-disciplinary research. It is relevant in the way it allows scientists to share their representations, to build a common understanding of the system and to solve incoherencies. Additionally, it allows scientists involved in a project to organize their activities in order to achieve the central problem of the project.

In IMAS project, some questions have emerged during the modeling sessions that scientists found interesting for the project purpose. However, participatory modeling requires a real implication of scientists; this is not always easy. In addition, some scientists are not necessarily willing to share their knowledge with other scientists in the same field impacting the quality of the model. Another difficulty is related to the scientist place in the target system. Scientist can be an active actor within the target system. His description could include both his point of view as a scientist and his point of view as a stakeholder. This could lead to confusion requiring the modeler to take into account the scientist double position in the modeling process.

In the future, the model would be improved and used to discuss the impacts of different interventions and agro-biodiversity dynamics with stakeholders, scientists and decision makers.

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