STUDY OF THE INTERACTIONS BETWEEN STAKEHOLDERS BY A MULTI-AGENTS SYSTEM: APPLICATION TO THE GOVERNANCE OF NATURAL RESOURCES IN MIARINARIVO DISTRICT (MADAGASCAR)

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ABSTRACT
This article proposes to study the interactions between the stakeholders through the study of management transfers in favor of the Common Pool Resources (CPR). The SIEGMAS model (Stakeholders Interactions in Environmental Governance by a Multi-Agent System) shows the interest of using a multi-agent simulation to build new alternatives to existing approaches in the context of decision support to implement Common Pool Resources governance policies. Agent Based Simulation (ABS) that were used in community complex systems offer an innovative approach to this field of economic and environmental study where non transfer modelling transfers of management has yet been made for all the island territories in the Indian Ocean. This article argues that carries extend the application of this method to the study of interactions between stakeholders in relationship to transfers of management in the others parts of Madagascar and others islands in the Indian Ocean.

Keywords: Interaction in Common Pool Resources, ABS

1. INTRODUCTION

The model SIEGMAS (Stakeholders Interactions in Environmental Governance by a Multi-Agent System) uses an ABS approach in order to establish a model for interactions of stakeholders in the management's transfers in Miarinarivo district of the Itasy region (in Madagascar). In the context of this project, the economic and classic steps being limited enough for the conceptualization of the individuals' behaviors and the process of common pool resources, the ABS approach allows some improvements in the study of these phenomenon and the creation of a sales tool for the decision. This establishment of a model must check if the management's transfers are efficacious via the application of penalties. It should allow us to study the actors' strategies as well as their behaviors.

2. MAJOR HEADINGS

2.1. Context of the Common Pool Resources (GCRN)

The Common Pool Resources points out the efficient application from the strategies of sustainable developments to common goods thanks to the decentralization of powers to the regional authorities. This approach is applied in various countries like the developing countries which, facing the inexorable destruction of the organic diversity, seeks an efficacious and local management, (Wade 1987) by adopting an environmental regulation in favor of the management of resources (Alden Willy 2004). The management's transfers allow the governments to decentralize the management of natural resources to the defined actors in this process. In 1990, Elinor Ostrom establishes a theory of common natural run in common by the stakeholders for more performance. In addition, for Ostrom (Ostrom, 2010), the local governance comes under the interrelations between a beam of discipline; it comes as a political, social, legal and economic problem. Ostrom establishes a list of eight principles of governance to achieve an optimal management of common property:

- To regulate access to resources;
- To make the costs and benefits commensurate with this approach;
- To make decisions jointly with the whole of the stakeholders;
- To coordinate and monitor the governance;
- To apply penalties for transgressions;
- To establish methods of dispute resolutions;
- To promote this management by state organs;
- To act as the supra-regional infrastructure.

With regard to shared resources and those in open access, (Ostrom, 1994) considers that sanctions and monitoring highlight good practices.

2.2. State of art

The structuring of environmental models constitutes a starting point unavoidable for the development of our establishment of a model (Müller and Aubert 2012) and (Bousquet and al. 2001).

Several cross-disciplinary and economic methods are conceivable for the study of natural resources and interactions. However, they hardly model the interactions between the stakeholders. The methods of the market's efficiencies and general economy focus on the relative analysis to the market's value and the theories of the growth and the models of Calculable general balance.

- The environmental methods used, focus on the analysis, mono or several criteria, the restorative or compensatory measures and the Eco-certification as well as the Eco-potentiality.
- The methods relative to the ecological economy come under some indicators of biodiversity, the calculation of the ecological loan and some indicators relative to the national accounting. Moreover, the incorporation of biodiversity in the methods of economic calculations remains controversial and limited (Nunes, Van den Bergh and Nijkamp, 2001). The economic analysis *ex ante* and *ex post* of biodiversity focus on either rationality of the preservation (analysis, cost-profit and the social well-being earned for each invested euro) or the effectiveness from the strategy of retained preservation.
- The cross-disciplinary methods focus on law economy and the ABS. We use ABS to optimize economics theories such as individual and collectives preferences (Arrow, 1951) to improve their performances.

The MAS have been choosed because they provide directly some pioneer tools for the problem.

3. THE ESTABLISHMENT OF A MODEL

We use an architecture, which allows us to describe the phases of our simulation (Ralambondrainy 2009). To create an ABS model for behavior and interactions between stakeholders, we use the method explained by (Gangat, 2013) that can be resumed in **Erreur ! Source du renvoi introuvable.**.

3.1. The conceptual establishment of a model

SIEGMAS models the interactions of the stakeholders in the context of the management's transfers in Miarinarivo District, the capital of the Itasy region (in Madagascar) thanks to the ABS approach. Itasy constitutes the smallest of the 22 regions from Madagascar in term of surface area with 6570 km2.

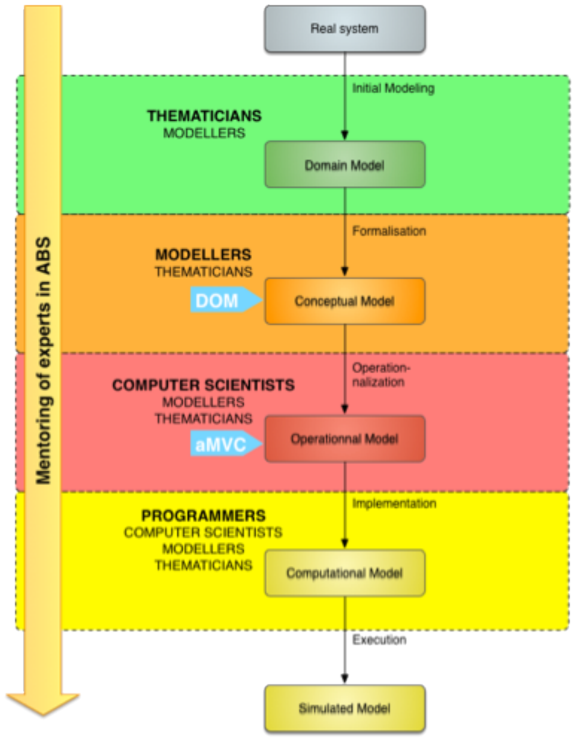

Figure 1 - Core Curriculum to the methodologies conception ABS

The Common Pool Resources emerged from the ninth Century in Malagasy environmental law and became intensified with the translation of French law under the French colonial era (1864-1960). The decade 1990 marks a real turning point in law of Malagasy environment with the apparition of the laws in favor of the safeguarding of common goods. Thus, the Charter of Environment in 1990, Law N° 90-033, the Gélose law (Secured Local Management) and the Contracted Management of Forests mark the emergence of a real consensus for Environment in Madagascar by the establishment of the management's transfers.

The Gélose Contract, Law N° 96-025 of 30 September 1996, for the local management of natural renewable of resources establishes a general framework for the preservation of the territory resources and its ecosystem. The Gélose Contract is composed of a contract of a management transfer, which contains a bill of specifications, the Dina controlling the basis community also called the COBA and a simplified land inventory known under the name of a collect Relative Security Land. The whole of stakeholders (Wade 1987) participates in the creation of the contract about the management's transfer signed by the COBA, the town and the local government representatives.

The Contracted Management of Forests, CMF, established by the decree N° 2001/122 of 14th February

2001, simplifies the procedure of the Gélose Contract but its duration is the same as one Gélose Contract: three years for the initial contract which can be renewed after a control for 10 years. We can count two parts for this contract: the forestry administration and the COBA. The community, as the secondary actor raises awareness and informs the COBA.

Since the coming into force of the management transfer contracts in 1999, more than 2000 contracts have been signed in Madagascar. These transfers have been converged by a strengthening of awareness and the application of sanctions. The good application of the transfers depends on the interactions between the actors and the controls.

This model has been conceptualized in order to study the deviances of the farmers against the forester and natural resources protected by the management's transfers or another text of law. The farmers know some sanctions granted in case of transgression by the government. The farmer (deviant or not) aims to make his land the more profitable as possible given that the spending he must use for his activity his personal needs, the costs generated by his cultivation (the costs of maintenance and investments) and the discounted profits. Thus, a farmer can choose to spread legally his cultivation via the purchase of new plots or the use allowed / controlled of natural resources. In fact, the management's transfers grant the farmer through the basis community some right of cultivation of some natural resources. However, the farmer can be a deviant by farming illegally some plots of natural and forester resources.

3.2. The working establishment of a model

The realization of the Ontology allows us to point out the concepts (Grüber, 1993) relative to the entities of the Common Pool Resources and the current links between the concepts. The use of ontologies in order to model the multi-agents simulations facilitate the conceptualization of the officers' characteristics within the platform of retained (Ralambondrainy, 2009).

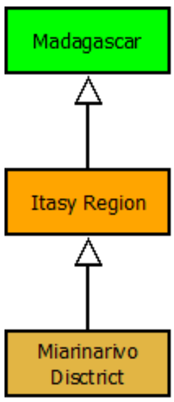

Figure 2 - Ontology of the reviewed territory

The arrows represent the relations of subsomption, « is a/an», on the **Erreur ! Source du renvoi introuvable.** to **Erreur ! Source du renvoi introuvable.**.

Four stakeholders compose the model (**Erreur ! Source du renvoi introuvable.**):

- The citizens, working via the natural resources, are the farmers and the other citizens.
- The Malagasy government which the ministries, the decentralized instances (Decentralized regional authorities and Services, Regional management of Environment and the Forests), the basis communities.
- The firms
- The sponsors and the stranger governments.

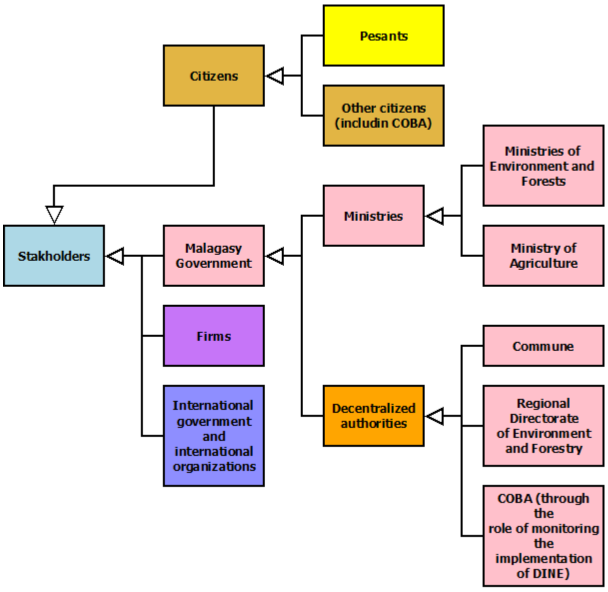

Figure 3 - Ontology of the stakeholders

However, only the first two actors interest our model: the farmer and the Malagasy government. We chose to study the actors two by two in the different establishments of a model.

This study is focused in the forester and Common Pool Resources as well as the resources produced on the farms (Figure 4).

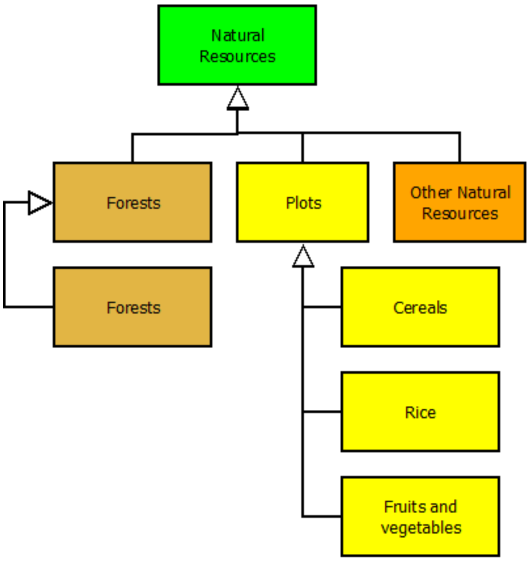

Figure 4 - Ontology of natural resources

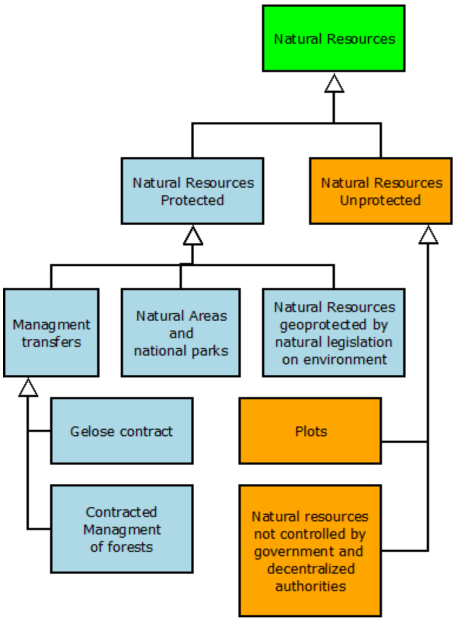

Figure 5 - Ontology of protected and not protected natural resources

4. IMPLEMENTATION

The model SIEGMAS has been implemented under the MABS platform called NetLogo (Wilensky, 1999).

4.1. Overview

The whole of elements of the model represents the different entities and variables clarified in the table.

4.1.1. Temporal and space scales

An iteration corresponds to a month in the model SIEGMAS. In this simulation, a patch represents an agricultural plot, or a plot of forest or natural resources.

Our environment of simulation is composed of 1936 plots, that is to say 44x44 patches. The surface area of Miarinarivo is 2818 km^2. The district is composed for the best part of natural resources and farms. The average surface of a plot hold by a farmer in the district rises to 1.4 hectares, which corresponds to about 1990 plots per a farmer in the model.

Table 1 : Our model and its implementation

	Establishment of a model	Implementation
Agents	**PEASANT** Some farmers work on some exploitations: to cultivate and exploit the resources that are available (those which belong to him).	**Peasants peasant** - nbPeasants (peasants)
	DEVIANT Some of the farmers are some deviants. They can exploit the neighbouring plots not belonging to other farmers, a forest or a plot that they consider farmable. It is possible to fix a percentage of deviants.	**Deviants deviant** - deviantsPercentage (deviants)
	EXPLOITATION The farmers have several agricultural practices : - bio : bio - conventional : con - On burnt land : snb A number that determines the order of creation identifies the owners. Different colours also identify the owners and their farming. We consider that the farming belong to the farmers.	**Exploitations exploitation** Each type of agriculture represents a certain percentage. Other variables: - Colour (the colour of the peasant to be identified visually) - owner

Environment	**PLOTS** By default, the plots are all some natural resources. We consider that it exists a percentage of the deterioration level of these natural resources.	- deteriorationLevel
	OTHERS PLOTS We consider that the areas that are not farming plots are either natural resources or forests that do not belong to any farmers. The environment (composed of cells) has a dynamic size, because his dimension could be changed through the values of width and height configurable via the interface. We chose 18 pixels for the size of a patch in order to be able to appear on screen. It is a matter of an arbitrary choice for the visual comfort.	 Plots - IsOwned brownn : Ressources Naturelles autres que forêts.
	FOREST The forester surface area is defined by a percentage of parameter. The forests are some protected areas by the contracts of the Contracted Management of Forests and the environmental legislation. The other natural resources (others than the farming plots) are supervised by the same plans of protection.	 Forest - isForest - ForestPercentage -Pcolor (a variant of green for the forest)
	AGRICULTURAL PLOTS A farming plot is a cell that belong to the farmer.	Pcolor : three colors  brown Very deep agriculture at dominance on burn land Orange: The bio agriculture Purple: The conventional agriculture

However, we count about 1936 plots according to its size 44x44. A farmer can have several plots, from one to five.

4.1.2. Organization of the model

The land is created according to a certain number of obligations given by the interface (Figure 6) like the size of the land, in number of patches, and the percentage of land, formulated in number of patches, and the percentage of land covered by the forest. We also distribute a determined number of farmers (from the interface) randomly on the in a way that they are not superimposed. Then, their farming are created around them in a radius going until 8 patches for now all by avoiding to use a patch already exploited or forbidden like the forest. For the farming of natural resources, the farmers exploit or try to exploit as much as possible resources neighboring their farming than the resources separated geographically.

4.1.3. The sanctions

The farmers can respect or transgress the legislation towards the protection of natural resources.

The controls or the rupture can identify the transgressions. The authorities grant some individual sanctions to the deviants. Thus, no collective sanction affects the respectful farmers of the legislation. Besides, the state laws for Environment, the laws and traditional rules like the Dina permit the excise of sanction based on the habits et traditions as well as the respect of nature.

4.2. Payment mandate of the process

4.2.1. Concept of elaboration

In our establishment of a model, the level of detail depends on the link between the number of patch and the actual size. Knowing that the smallest indivisible unity under the NetLogo is the patch, this latter will correspond to one type of land. A patch can point out either plot of forest, or a plot of farming and natural resources. Besides, a farmer adopts a unique mode of agriculture per a plot: organic, conventional or on burnt land. It does not exist any segregation about the plots.

The farmers have some information relative to the localization of the agar areas, under the GCF, some other resources under the environmental legislation and some farms of environment from the simulation. The farmers also know the farming, which belong to them. The government is not directly represented by an agent. It acts through the checks and the sanctions applied on the patches and the farmers.

In this simulation, we consider, basing upon the theory of games (Von Neuman and Morgenstern, 1944) that environment can be random and interdependent. In our simulation, the officers will exploit the neighboring plots or the forest illegally in order to maximize their profits. Thus, on one part, it is a matter of a random environment because the chance and the behavior of an officer in order to maximize his profits. Also an environment of interdependence because the collective behaviors and the individual behavior of an officer, i.e. his rationality, influence the maximization of these profits (Cavagnac 2006).

In the game where each of some n officers of the game chooses the behaviors maximizing his profit in the whole of the possible behaviors. In our establishment of a model, the games can be static or dynamic and the complete or incomplete information. In a static game, an officer acts (an action is a strategy) without knowing the behavior of another officer whereas they act simultaneously in a dynamic game. The strategies can be dominant or dominated. A whole of strategy is a balance of Nash (1950). When we maximize his expectations of profits basing upon his beliefs, the whole of strategies that he deploys is a «

Bayesian » balance (Kreps and Wilson 1982). The plays can be also be repetitive or mixed (Kuhn and Tucker 1950).

4.2.2. Adaptation

The farmers set yourself in order to increase their productivity and to perpetuate the trust that the state authorities grant them (or to avoid the sanctions for everything by having a nearby context in favor of their activity. (Wade, 1987; Grüber, 1993; Bontems and Rotillon, 2007; Brandouy, Mathieu and Venryzhenko, 2012).

farming on a patch. The rules and sanctions of the State are applied during the month through the check of some patches). The sanctions are applied by collecting money to the farmer when we calculate his income available at the end of the month via the variable « outgoing » which points out the maximal money spent by a farmer in order to « live » in an iteration (random).

The deterioration is made at random for the patches non exploited, « update-rawPatches ». Moreover, a random and natural deterioration «update-exploited Patches » applied for each farm according to the

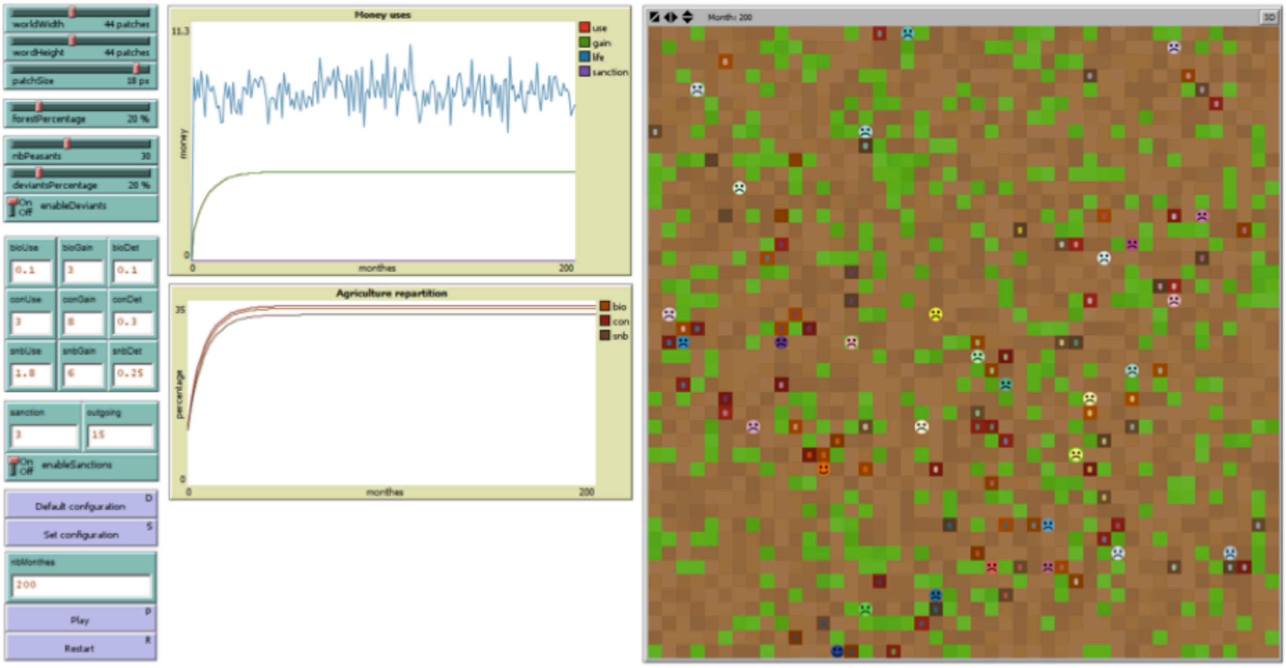

Figure 6 - Intitial conditions of simulation

4.2.3. Perception and interaction

The arbitrary data can be distinguished in this simulation.

Being a matter of different types of agriculture, the variable « Use » corresponds to the investments that the farmers make according to the type of agriculture adopted. Iteration allows getting the cost for 100 % of agriculture. A farmer makes no investments if he chooses the organic agriculture in iteration. However, if he either adopts conventional agriculture or burnt land, these investments are equivalent in an iteration.

Concerning the profits relative to the variable « Gain », they fluctuate in accordance with the type of agriculture chose by the farmer. For this simulation, the income that 100% of three types of agriculture bring will be given in some fields intended to this effect on the graphic interface. Likewise, the variable « Det » determines the variable « Det » shapeless of the deterioration level from the grounds of farming plots revealed in percentage in an iteration.

Being a matter of sanctions, at each iteration, we puncture some money in the form of fee to the farmer at each iteration for 100 % of damage created by an illegal

percentage and the type of agriculture. We also obtain, according to the percentage and the type of agriculture, the money spent for the farming as well as the money earned by the farmer. The sum, which a farmer has, is updated each month according to the results of their farming. This available sum of money can lead to a change of the types of agriculture being able to be random and dependent on the money from the money remaining to the farmer.

The deviant, « update-deviants », remarks the neighboring plots to his ones. Then, he will or not exploits a land that does not belong to him. If during a made control, the « government », acting through a check, notices that a non-exploited land normally can be in the major of case illegally exploited, it punishes the deviant responsible for the transgression by a fee to pay every month in accordance with the degradation of the patch run by the illegal farming.

4.3. Results

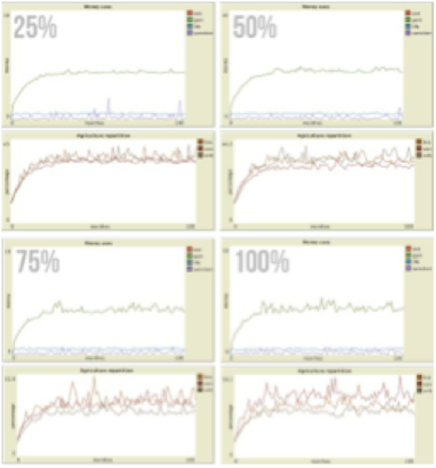

Figure 7 - Curves of evolution at 25 %, 50 %, 75 % and 100 % of deviants from the distribution of the use of money by the farmer and the distribution of the agriculture

4.3.1. Manipulation of a model

Firstly, the initial conditions of simulations are fixed (Figure 6). The simulation contains thirty farmers and takes place on a hundred iterations, that is to say hundred months. Then, the farmers can be some deviants. The following step consists in choosing some proportions of conventional and bio farming and on burnt land as well as some rate of deterioration for these three modes of agriculture. Thereafter, it must fix some values for the variable « Use », corresponding to the investments that the farmers make according to the types of agriculture. For these simulations, the values « gains », « use », « Det » and the percentage of deviants vary thanks to the changes of the slider « deviants' Percentage ». It is a matter of favoring the impact of the deviants on Environment.

For the protections, when a land of natural resources hold by the State and which does not belong to the farmers arrives at more than 75 % of « deterioration Level », the land must be considered as strongly damaged and set under high protection by the government. Thus, during the lapse of time when the land is considered as protected by a management's transfer or a plan of emergency. The land will be able to see only its deterioration level reduce up to come back to 25% all by preserving at this stage, the maintaining of status of increased protection. The deterioration level random is from 0 to 0.2 at each iteration.

For the simulations, with 25 % of deviants on the territory, Oscillations are enough stables (Figure 7)

Thus, the area is poorly degraded. For 50% of the oscillations, we note light peaks of oscillation in Figure 7 are observed. To 75% and 100% of the deviant oscillations increases. This reflects a strong or very strong natural resource degradation Miarinarivo.

For the sanctions, the deviants want to exploit randomly the lands being around his farming, even those, which they have been created illegally. At each iteration, the government comes under a random number of lands exploited illegally and seeks the one who created the farming. The government calculates a sum (value of the sanction x level of damages brought by the farming x ratio) like a fee to pay by the farmer before destroying his farming. If at the time of the sanction the land is protected, a ratio is added to the fee. This ratio equal to x2 for a protected land and still at x1.5 for a forest). This ratio also equal to x1 for a protected ordinary land, to x2 for a not protected forest, to x3 for a protected forest (x1.5 + x2).

4.3.2. Results of simulations

After launching several times the simulation with different values of configurations, it appears by observing the variation of the rate of deviants that if the government controls the management's transfers correctly, the sanctions are well applied (Figure 7). The presence of the deviants engenders more deterioration of the lands (Figure 8). Some deviants avoid the sanctions and run some non-taxable income. However, the application of the sanction to the deviants rebalances the system so that the deviants could not get any profits in the illegal practice of agriculture or the exploitation of natural resources. Thus, the individual behaviors will affect the collective behaviors if a farmer knows the gestures of his neighboring. The farmer grants his trust to his neighbor when it is not a matter of a deviant. However, if he knows the acts of deviance of his neighbor, he will be more suspicious against him and he will denounce him.

Figure 8- Representation of a situation of deviance

By fixing the rate of deviants at 50 %, we notice that the use of money which the farmer is going to decrease then increase strongly whereas the individual profits of the farmer and the lifespan of the farming will have tendency to remain stable. This intensive farming is going to decrease the lifespan of the farming. The type of agriculture fluctuate and the conventional agriculture and on burnt land dominate. The sanctions are also less applied (Figure 10).

Figure 9 - Representation of a situation of deviance with a deviants ratios of 50%

By fixing the rate of deviants at 75 %, which would correspond to a situation of strong degradation from environment, we can notice that the individual profits, the lifespan of some farming remain stable notwithstanding, the money that he spends increases very much (Figure 10 and 11). It is a matter of situation when the controls are rare even missing.

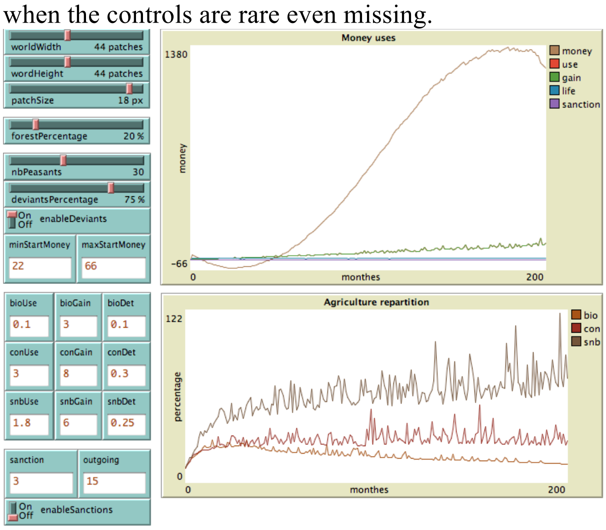

Figure 10 - Simulation of 75 % of deviants

4.3.3. Supply of this simulation in economy

The use of the MAS for the creation of a sales tool for the decision in economic sciences and of environment in order to study the interactions opens the disciplinary field of the MAS to the study of the management's transfers and environment in a developing country which is also an island territory. Thus, it is easier to study the process of communication and cognition of the individuals are difficultly educable by the current economic methods.

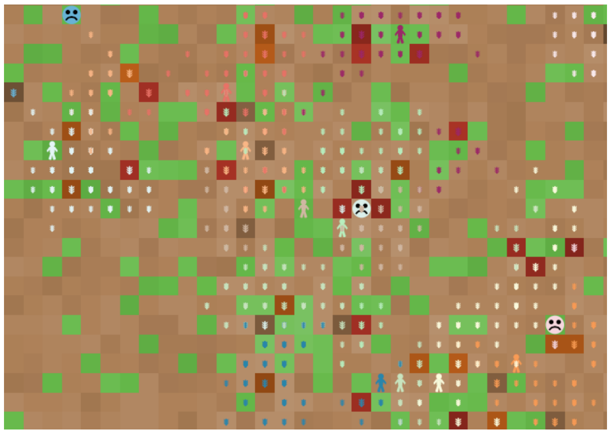

Figure 11 Representation of a situation of deviance with 75% of deviants

5. CONCLUSION

The realization of a sales tool for the multi-disciplinary decision in order to study the interactions of the actors in the Common Pool Resources in Miarinarivo district brings a pertinent response to the study of the interactions, being difficultly a model by the economic methods. This simulation allowed to identify the interactions between the actors of the governance taking part in the management's transfers and to propose some targeted measures in agreement being able to reduce the merging anomalies. Thus, this model reveals that the knowledge of the sanctions by the farmers does not prevent them to infringe the legislative measures of protection of natural resources below the management's transfers or located in some few protected areas.

Further to this simulation, firstly, the realization of a simulation with the incorporation of the identified agents will permit the acquisition of a global simulation for other regions from Madagascar and the island territories of Indian Ocean (Reunion Island, Mauritius, Seychelles, Mayotte and the Comoros). In fact, it is a matter of aspect which has not been treated in the isles of Indian Ocean and that it would be flourishing to spread in order to check the transposability of the model. We are working on a tool of extraction about knowledge from the geographic maps of reference in order to reach a largest pertinence in our simulations in order to show the transposability of the model.

Thus, we can mutualize the positive synergies and to make the forecasting in order to be proactive in the environmental management in the decades to come.

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