Accompanying governing processes in land use management with linking role playing games, GIS and MAS: The SelfCormas experiment in the Senegal river valley.

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Abstract

For several years Multi-Agent Systems have been used in the field of natural and renewable resource management. As agricultural and environmental issues are more and more inter-linked, the increasing multiplicity of stakeholders, with differing and often conflicting land use representations and strategies, underlines the need for innovative methods and tools to support their coordination, mediation and negotiation processes aiming at an improved, more decentralized and integrated natural resources management (INRM). How can these new tools be involved in such a process, i.e., how can they help actors to govern the land ? We are seeking to develop a accompanying approach using of multi-agent systems. CORMAS is a multi-agent simulation platform specially designed for this sort of support and we have conducted participatory modeling experiments through the joint use of MAS models and other modeling tools (specially GIS and role playing games).

Several experiments have been conduct in Europe, Africa and South Eastern Asia, specially about scheme irrigated management, natural resources and land use management. The main objective of these researches is to study the use of these tools for knowledge integration in collective learning processes focusing on INRM issues. As regards of LUCC management, our longer experiment is called "SelfCormas", which has been under way since 1997 in the Senegal River valley. In support of a local decentralization policy, the aim is to test tools (maps, GIS, simulations, role-play,...) that will help local principals to improve their empowerment on planning decisions about sustainable land use management. The main objective was to test direct modeling design of tools (GIS, MAS) by stakeholders right from the initial stages, with as little prior design work by the modeler as possible. This "self-design" experiment was organized in the form of participatory workshops including role playing games, which lead on discussions, appraisals, and even decisions about planning land use management, already applied two years after the first workshops.

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I. Theoretical grounds.

The main objective of this research is to study the use of MAS models and cartographic tools, associated with role-playing games, for knowledge integration in local governing processes focusing on land use management issues. Our works are based on three principles, withdrawn from Ostrom (1990 et 1994), Burton (1991) Mermet (1991 et 1993) and Funtowicz (1999):

1. LUCC is a complex issue and complexity presents an irreducible uncertainty that implies a multiplicity of legitimate perspectives.

2. Scientific knowledge is not able to solve this uncertainty and it is only one of the several legitimate perspectives should be taken in account.

3. Due to this complexity, decision-making process is incremental, iterative and continuous. That means decision's acts are always imperfect but they simply have been seen to be progressively less imperfect. In others words, the stake for principals is not to solve uncertainty but to handle it.

All this has already been explained, but this increasing multiplicity of stakeholders, with differing and often conflicting land use representations and strategies, underlines the need for innovative methods and tools to support their coordination and negotiation processes aiming at an improved, more decentralized land use management. Then how can some new methodological supports fit this analyze, i.e., how can they *help actors to govern themselves* instead of propose unsuitable technical solutions ? We are seeking to develop an *Accompanying Approach* whose aims are not to produce definitive decisions and results but to improve collective decision-making processes, on sociological aspects (negotiation, empowerment,...) as much as technical aspects (data, technical quality,...). That is an incremental, iterative and continuous *Accompanying*, facing to an incremental, iterative and continuous decision-making process. That means we have to put all supports that can be mobilized at stakeholders' (and others principals) disposal, in order that they can themselves handle their issues. Anything related to problem solving, evaluation or prediction is thus beyond the scope of our approach. On the contrary, according to our theoretical grounds, *Accompanying Approach* implies these following assertions:

- The stake of decentralized land-use management is first of all political: we need a shared, effective, and sustainable socio-political process for tackling a territory

- Tools must serve stakeholders and their representatives. That is, tools able to:
    - take into account their own perceptions
    - put external knowledge at their disposal
    - be directly controllable by them

- Scientific information is thus summoned up progressively by these principals, with their own framework representations.

Basis on this grounds, several experiments have been conduct since 1995, in some different situations (irrigated schemes, land use management, negotiations between stakeholders and environmental departments,...)[1] and with the support of CORMAS[2] (Common-pool Resources and Multi-Agent Systems). It is a MAS platform designed for renewable resource management with the aim to simplify task of simulating, especially as regards as stakeholders and principals (Bousquet *el al.* 1998). As regards of LUCC management, our longer experiment is called "SelfCormas", which has been under way since 1997 in the Senegal River valley.

II. Helping stakeholders to conceive theirs LUCC models: the SelfCormas experiment.

We are on land use management issues, with multipurpose uses and local principals who try to handle the puzzle of a sustainable development. Our aim is to help these principals to progress towards a better self-management, especially by strongly involving stakeholders. In this experiment, the first land use scale considered is around 2 500 km² and 40 000 people., This experiment has resumed in a practical way our hypothesis about tools (see above): take into their own perceptions; put external knowledge at their disposal; be directly handled by them. According to that, we have tested a methodology for a shared collective design of planning supports, from GIS to MAS.

The first step was a *GIS self-design*. A participatory approach has conducted, where stakeholders identify themselves spatial information they consider important for the specific matter of their collective decision in process. It is not a mental map process. People identify topics not with a spatial support but only with debating between them (for instance: swamping length for each different area in a delta river, livestock lanes in agricultural areas,..). After that, all information they have on these topics is **precisely** gathered in a participatory way. On the opposite page, once could see an example of chart designed and filled by stakeholders. Then, participants judge the lacks in this information, as regards their own perception of the quality necessary. So, if they could complete by field investigations, they do it themselves and technical assistance only mend it for GIS. In fact, a crude GIS is thus building by participants, crude for his organization but not for his data resolution. As noticed above, we choose *to put external knowledge straight at stakeholders' disposal*, by providing up directly complex information. We think complex matters need not simplified information to reach operational

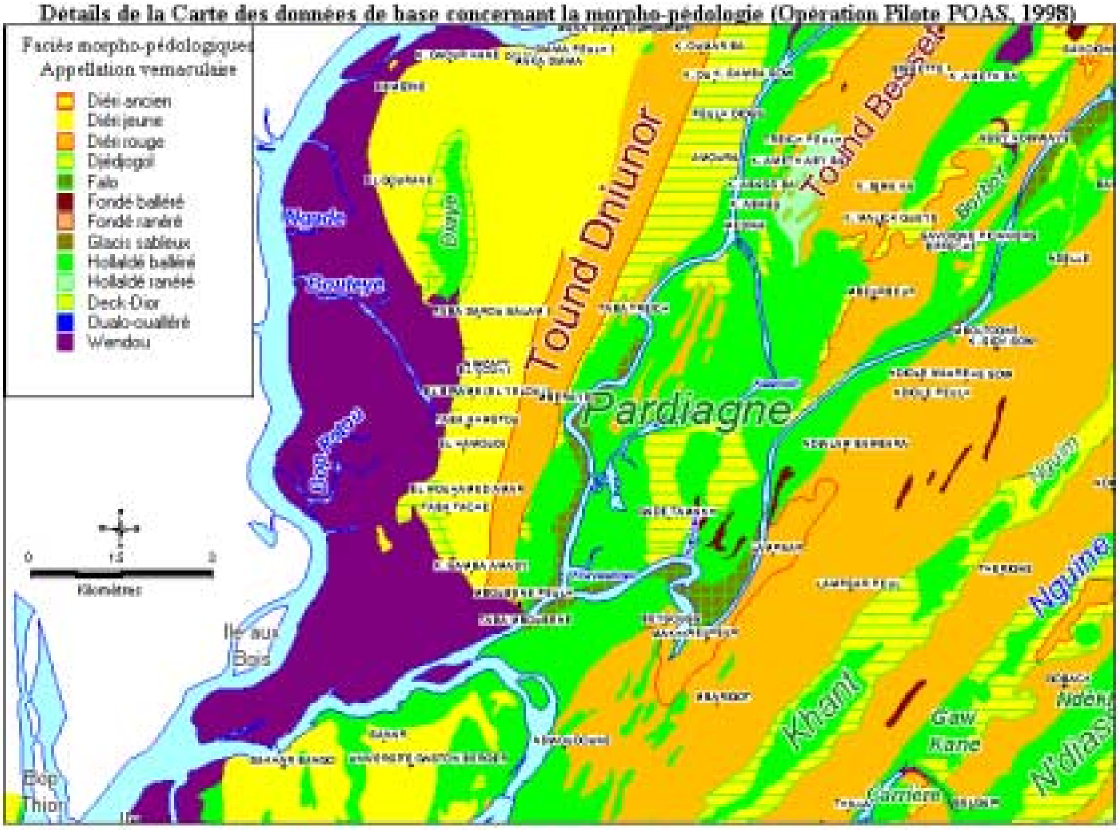
[1] See http://cormas.cirad.fr. The goals of these different experiences are (i) to simulate the variability of irrigation schemes in Senegal, where a role game presents the model to the various stakeholders (see refer.); (ii) to help with mediation in biodiversity management processes in Madagascar, where a role playing games is supported by a SMA model (see refer.); (iii) to predict the impact of sylvo-pastoral development within forest fire prevention plans, where a model of negotiations between foresters and livestock farmers was simplified into a role game with a view to communicate with different sorts of people(see refer.); to simulate scenarios of reactions to the spontaneous establishment of conifers in natural ecosystems, where a model led to a role game and serves to simulate the dynamics of the resource (see refer.); to test hypotheses about the differentiation of households in Vietnam, where a role game is proposed to validate the simulation model and gather information from the stakeholders(see refer.).

[2] The main goal of CORMAS is not to make accurate predictions about the behavior of complex systems, but rather to provide a framework to help people develop new ways of thinking. CORMAS is based on the software VisualWorks which, in turn, is a programming environment based on Smalltalk. Cincom, the American company that markets VisualWorks, distributes the software freely (for educational and research purposes). CORMAS is also available to the scientific community (http://cormas.cirad.fr).

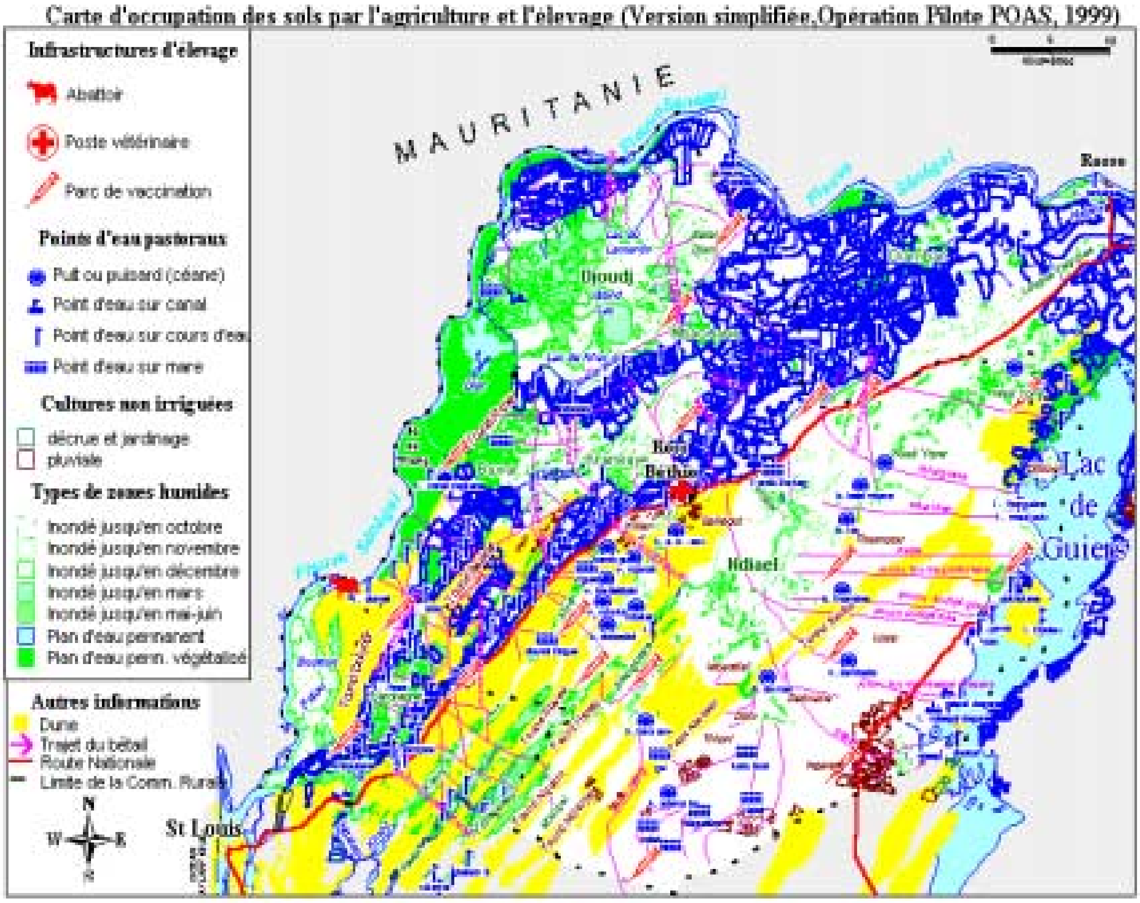
decisions and actions. So, putting knowledge at stakeholders' disposal should not mean oversimplifying it, as many participatory approaches do. Here, we choose to help stakeholders to handle rapidly complex information about their LUCC, that means to handle a real GIS. On opposite page, once could see examples of maps filled and used by participants with support of our method. These maps are corrected then validated by them, during a short (always less than a month) learning-by-doing shared process for map analyzing.

Figure 2 : some examples of self design maps

Détails de la Carte des données de base concernant la morpho-pédologie (Opération Pilote POAS, 1998)



Carte d'occupation des sols par l'agriculture et l'élevage (Version simplifiée,Opération Pilote POAS, 1999)



Analysis of diachronic stakes by participants
for a multi-purpose use of renewable resources

User	Sort of needs	Annual cycle of "needs" according to participants											
		10	11	12	01	02	03	04	05	06	07	08	09
Breeder	Pasture												
	Water												
Agricultr.	Crop												
	Water												
Fisher	Fish	?	?	?	?	?	?	?	?	?	?	?	?
	Water	?	?	?	?	?	?	?	?	?	?	?	?
NationalParc	Veget.												
	Water												
Hunter	Bird												
	Water												

Legend

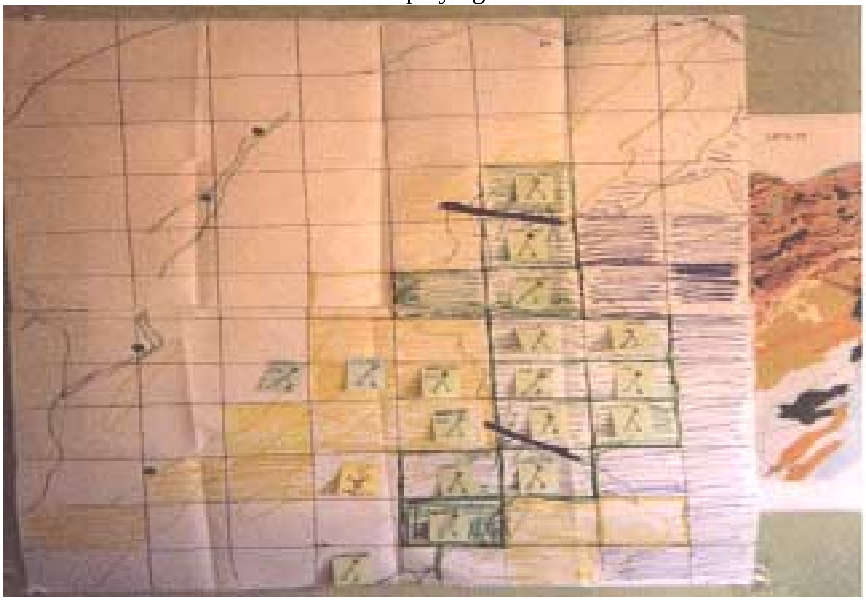
- : swamping until November
- : swamping until February
- : swamping until May
- : crops
- : water

Then, people begin to debate from their maps and look for new elements to improve their situation. For instance, maps bellow are a collective decision about breeding and farming activities location. However, these collective progress lead people to deeper dialogs towards a more accurate planning and at that point, they ask for more convenient forms of accompanying, including dynamics. So, we propose to provide them supports for a simulating process. It is the second step of the approach. In the previous chart, you could notice during participatory analysis people select not only spatial and time information about uses, but also types of stakeholders they thought it's important to take into account (fisher, farmer, breeder...). For each stakeholder, they have identified needs about resources (see chart), including for example distance matter. We could then organize a role playing game to help participants to simulate the situation they previously designed : a *role playing game self-design*, e. g. a role playing game only designed by their own analyzing process: GIS maps are the set of the game, the different types of stakeholders selected by participants are the players of the game and all elements they put out of their previous debates (see chart above) are its crude rules. Obviously, while maps are rather accurate, rules of the game are very simplified. But participants test their own perception of their practical situation, with their own simplification choices. They consider this perhaps oversimplified analyze is valid, because it's their own simplification choices...And we agree with them. According to E. Ostrom (1991), self-government of commons is a learning, incremental and self-transforming process, improved step by step by trial and error methods. That's we choose to accompany, providing technical information only when they ask for it and within their own framework representations. In our all experiments (Barreteau *et al.* 2001, Boissau et Castella 2001), these sorts of role playing games are then used to simulate scenarios imagined by stakeholders, and triggered a group discussion of possible interactions between users and resources. However, role-playing games are not a realistic and accurate way to carry on such an accompanying process. Exhausted by long game sessions, people ask rapidly for a more convenient support. Computer modeling is then interesting.

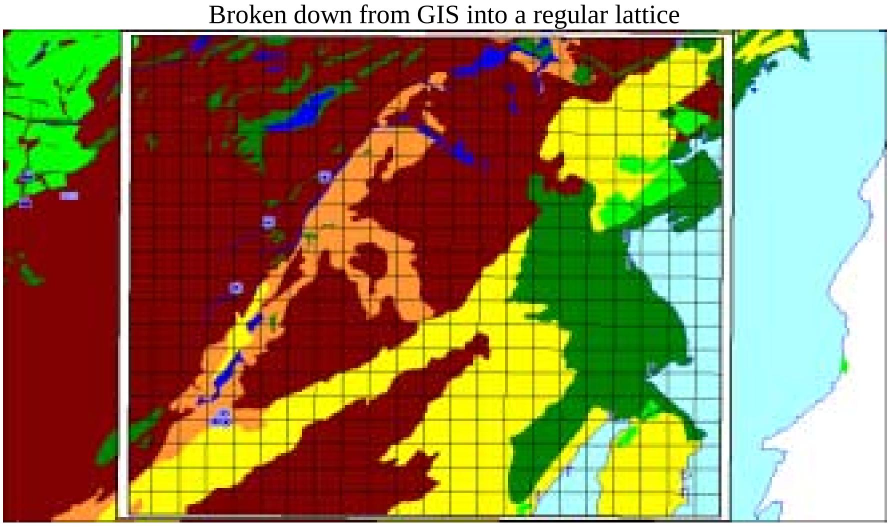
The first step of the approach is in a method accompanying players towards a MAS platform that takes up the previous role-playing game model : a *MAS self-design*. Same set game, same crude rules are transferred from the game to the MAS; same GIS maps designed by participants are integrated by CORMAS (see pictures on the opposite page). Indeed, thanks our MAS flexible platform, CORMAS, we keep much more possibilities to go further than with the heavy game sessions.

Figure 3

Role playing set



Broken down from GIS into a regular lattice



Spatial lattice in CORMAS

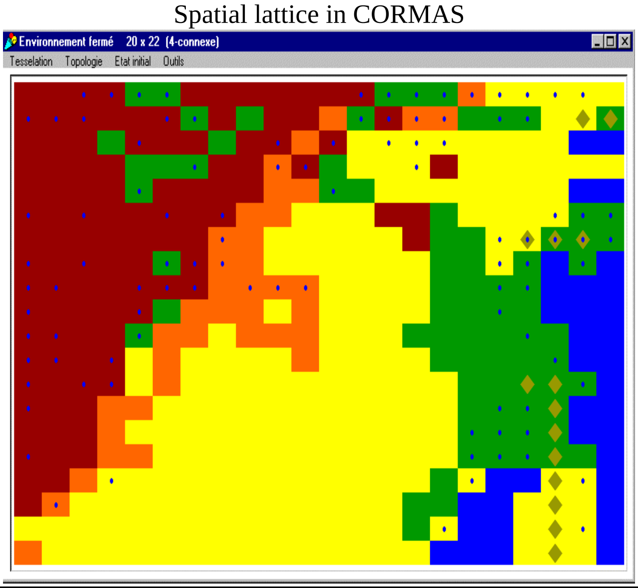
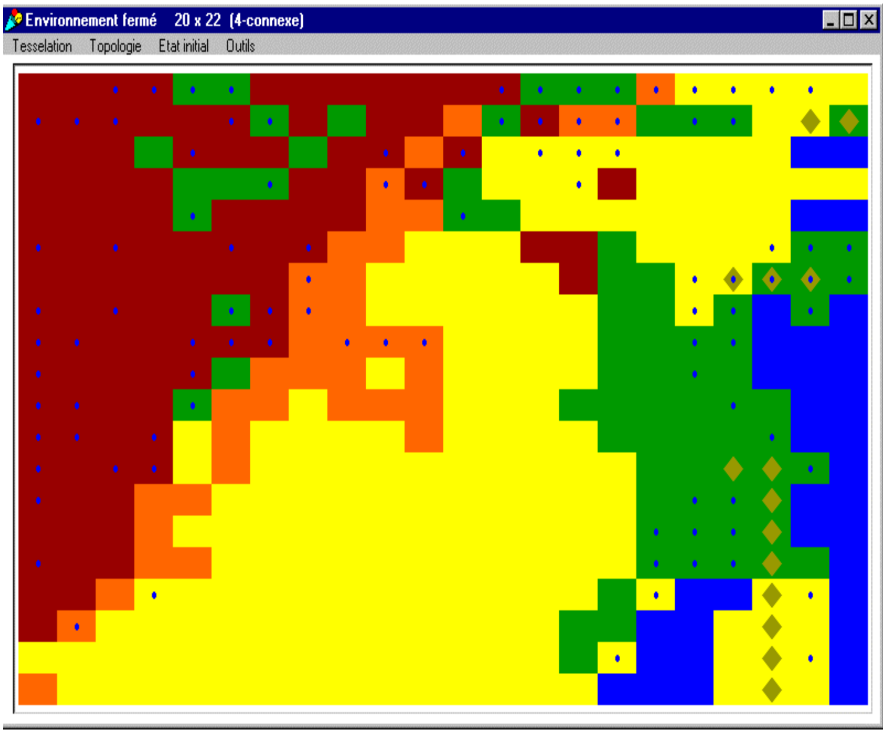


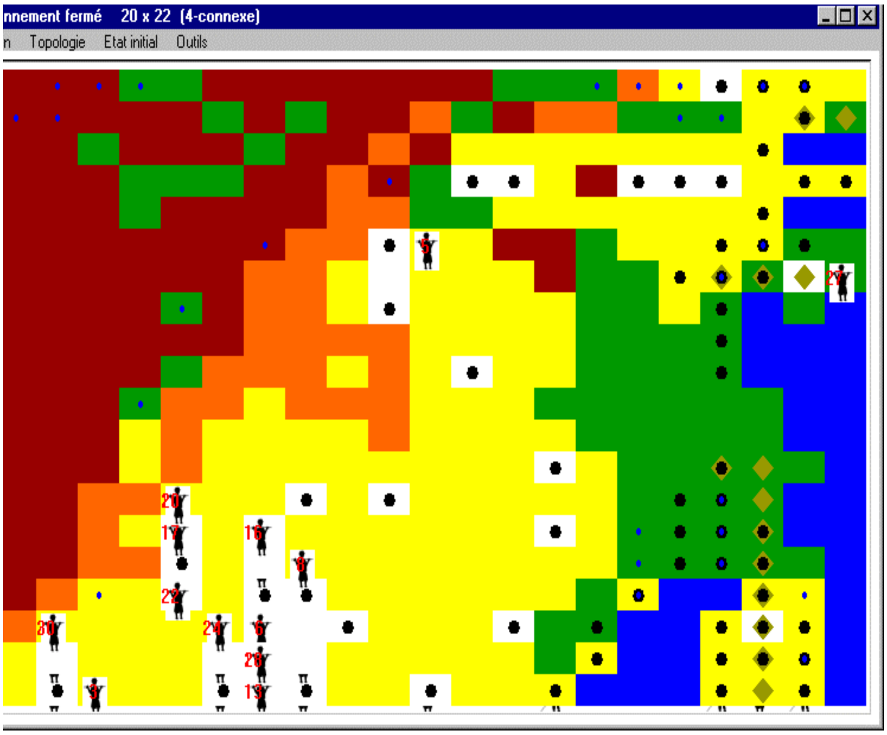
Figure n°4
Example of a simulation (Gnith area)

t = 0



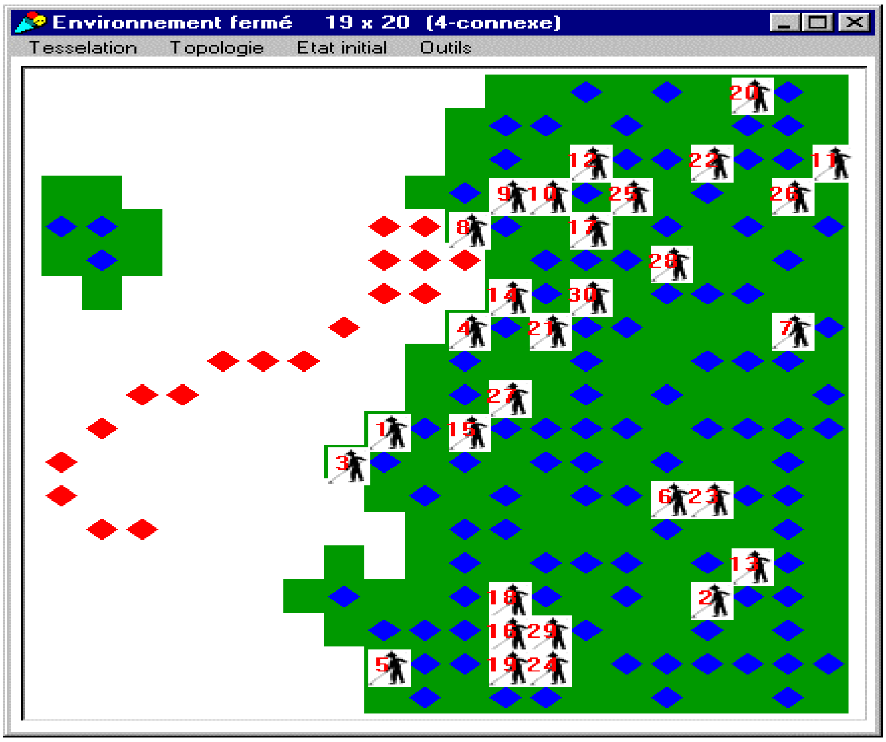
Blue polygons are a lake, brown diamonds are livestock lanes, blue points are watering place; others colors different soil features.

End of a simulation

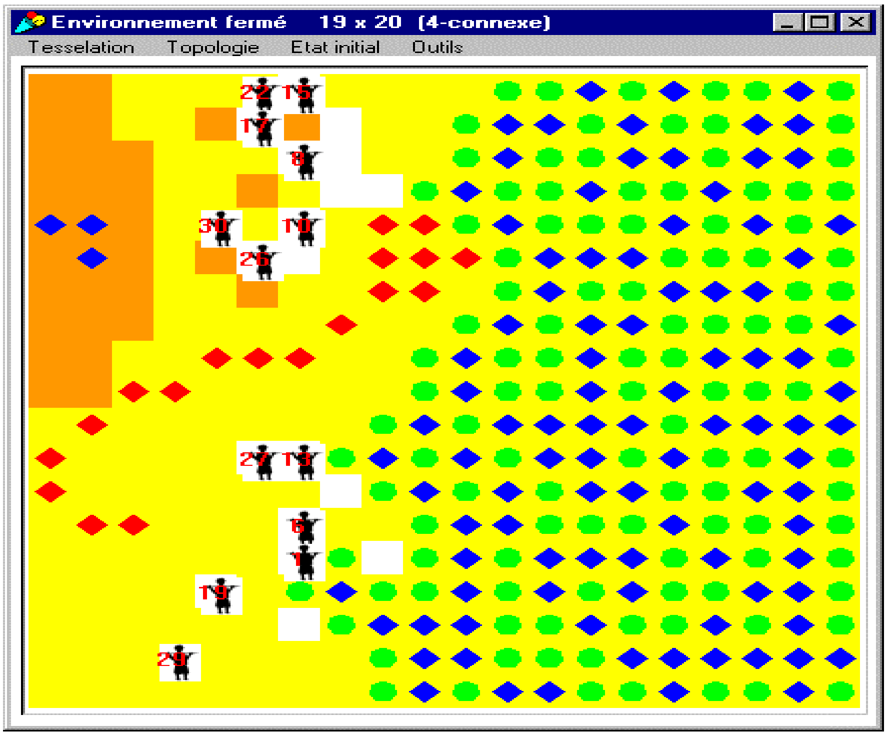


Black points are crops, white ones are plots where forage is disappeared. Because dry season, some watering place are disappeared too. A south-west transhumance of breeders is perceptible, like in the reality.

Figure n°5
Example of two points of view in a same simulation (Mboundoum area)



Farmer perception



Breeder perception

Figure n°6

Figure n°7

II. CORMAS, a flexible platform for accompanying incremental self-governing.

CORMAS is commonly used for economics and modeling grounds theorizing, specially about renewable resources managing but also on individual/society relationships (Antona *et al.* 1998, Bousquet *et al.* 1999, Rouchier *et al.* 1998, Rouchier *et al* 2001a, Rouchier *et al.* 2001b). However, the transfer from the role playing game to the MAS model was also strongly helped by the characteristics of CORMAS. The construction of a spatial support in CORMAS goes throw the elementary spatial entity (ESE), which will represent the smallest homogeneous portion of the space in the model. These ESE have specific attributes and methods (for topology for instance) but can also integrate others attributes (for example, on biophysical and tenure features) of the plot of space they represent. On that subject, there is any constraint in CORMAS for integrating new attributes in ESE, as regards of a specific use or perception (for instance, customary banning in using an area). CORMAS can represent these ESE on a regular lattice, created automatically, or with irregular polygons generated or loaded (for instance from GIS software). CORMAS also allows to explicitly incorporate higher spatial levels by defining “compound spatial entities” (CSE). A CSE is a collection of spatial entities from a lower level sharing one (of several) same property. The CSE may have specific dynamics and in the meanwhile, each constitutive spatial entity can keep its own dynamics. CSE are also useful to define specific perceptions related to different ways of using natural resources. In other words, it's at the same time a perception level (which could being used as spatial indicator for instance) and an action level.

CORMAS provides an another way for organizing ESE, strongly used in our experiment : the “points of view” (PoV). Outside CSE, which could be seen as the modeler's point of view on space, CORMAS also allows to distinguish spatial points of view *of* MAS social agents. Each social entity can thus have its own spatial perception, formed by a specific appraisal of ESE attributes' values (for instance, biophysical parameters, tenure status, land use rules,...). It is this peculiar perception that involves then agent's behavior towards the space. In fact, in SelfCormas the MAS model (for us, the role playing game is a model itself) is organized in "activities" (breeding, hunting, farming,...). Each activity gathers a group of features and a point of view, all withdrawn from participants (e. g. from GIS and role playing game self-design). The logic of these PoV is simply added in the model by a SmallTalk script into the activities implemented methods. This encoding gives the "activity's perception" about each ESE, according to their attributes' values (biophysical parameters, tenure status, land use rules,...). Given there is any constraint for adding new attribute in ESE, this process is very flexible and could integrate any sort of spatial representation, which is obviously useful in our self-design context. Moreover, new forms of land improvement could be created only by new combining of values of ESE attributes (f. i. a forage intensifying action by increasing the value of the "forage quality" attribute and changing the value of "appropriation form" attribute). Last but not the least, CORMAS social entities can switch from one to another activity during the same simulation. Every social MAS entity can thus have a real collection of points of view, as regards all the different activities is able to practice. Moreover, by switching runtime from an agent point of view to another, CORMAS allows to correct and valid during a simulation the first representations of stakeholders directly with them. Apart from that, this sort of flexibility is not only for managing the space. Attributes' values of ESE can also change according to time. This concerns ecological dynamics (f. i. progressive weakening of resources during the dry season) as much as social rules (f. i. use allowed during only a period).

The third spatial flexibility aspect of CORMAS is about the possibility to locate passive objects on spatial entities. Depending on the spatial resolution of the grid, an ESE may represent a relatively large portion of space and then it is useful to define tight elements like paths or watering place as entities located *on* the ESE. At last, CORMAS allows the shifting of all spatial features, including information initially loaded from the GIS (attributes of the ESE), but also the creation or the destruction of passive objects (paths, watering place) with an easy click on the located point in the spatial lattice. Being able to incorporate the suggestions of the stakeholders when running a scenario is very interesting for paving the way to an adaptive and social learning process.

Concerning the links between GIS and MAS, two possibilities are offered by CORMAS (Le Page *et al.* 2001). The first one is a static integration of GIS data (raster or vector)[3] into MAS model, to define initial environment, to restitute a final environment or even to transfer a state of environment during simulations. The second possibility is a dynamic coupling with Arcview (Lieurain 1999), where CORMAS sends requests to the GIS for the execution of more complicated spatial analyses (distance from water for instance) during simulations. GIS data thus could be linked with ESE or with CSE, that is an interesting approach for multi-scale handling. That is a fact that dealing with multiple scales is often a key question in renewable resources management and it is important to have the possibility to manipulate and to incorporate into the same model spatial entities defined at different hierarchical levels.

III. Outcomes and perspectives.

For us, the potential strengths of MAS in LUCC models is to focus on the heterogeneous aspect of decision making process, not only in encoding but also in the model design with concerned people. Once could tackle different processes and even different perceptions of processes....It seems to us essential for a wiser complexity design. In a similar direction, another advantage is that MAS allow deep coupling between spatial phenomenon and social networks, in other words social and spatial dynamics. And in our peculiar works' subject a strong plus is about their easier capacity to be incrementally and progressively designed. That is particularly fitted with participatory approaches which want to tackle complex information about LUCC. Actually, all the CORMAS flexibility leads to an real incremental, progressive and iterative support for accompanying the complex land use self-management. ***Thus, in our experiments the support have grown richer progressively on the same beat of the collective making decision process***, thanks its use in different situations and scales as much as its continuous progress in a given site. This concerns, for example, categories of activities, which are progressively deepening by platform users. Indeed, the flexibility of CORMAS allows then to add easily a new activity or to specialize different ones from a previous activity implemented. SelfCormas has gathered thus progressively several generic activities[4] that will represent basic ones of all the different workshops (breeding, farming,...) so that some specific sub-models[5] are designed in every new use of the platform, taken elements from generic activities while particularizing them. It's always our incremental and bottom-up accompanying of progressively complex self-governments.

In conclusion, it's a self-incremental modeling process, supplied by an accurate information system (GIS). It should make it possible to forecast various prospective actions, and therefore needs to be flexible. Thanks to the self-design, participants become capable to have more

[3] MIF and MID format.
[4] Classed in the "model activities" sub-repertory.
[5] Classed in the sub-repertories of every experiment.

insights in the results of the simulations. They are also better to take into account distance between model and reality, because it's their own simplification. This operation provided us with confirmation of the feasibility of using computers in such socio-cultural situations. Thus, developing a role game in conjunction with stakeholders seems to be an interesting way of enabling stakeholders to play an active part in design a multi-agent model. The role game serves in this case as a sort of dialogue interface between computer modeling, the “machine”, and stakeholders. The stakeholders who developed and played the game were fully capable of interpreting the results of the model. As they were themselves the initial designers of the simulations carried out, they were also entirely aware of the distance between the model and reality, and of the way in which simulation results should be used. Moreover, simulation made it possible to go much further than the role game. For one thing, it would have been physically impossible without computer simulation to “play” the different scenarios selected by the stakeholders and to observe their multiple impacts over sufficiently long time lapses. Furthermore, a sufficiently flexible modeling platform offers many more possibilities of modifying the rules on request than cumbersome game sessions. Simulation thus multiplies the effectiveness of the role game and can take the decision-making process much further, be it by taking into account of the long-term future or through the feasibility of the decisions made. Lastly, in line with the option of supportive modeling, in this case, it is not up to the model to provide solutions to problems, but to encourage discussion of the different alternatives, to improve the effectiveness of a collective decision-making process and even to change the behavior of local stakeholders with respect to their technical partners. In our approach, recourse to technical expertise is the stage that follows, and not that which precedes, the collective choice of scenarios that can “reasonably” be envisaged by the community. From this initial discussion, which supportive modeling made both endogenous and technically valuable, it was the representatives of local populations who themselves identified the priority types of support they required within their decision-making process and who contacted the services capable of satisfying their needs directly. Decision-making processes are about that too.

The incremental side is also strongly linked to the choice of a collective learning-by-doing process (see Ostrom 1991), advancing practically step by step towards a better self-government, by trial and error methods. Role playing games are already a quite common tool for these training purposes, for example in the management of irrigated systems (Burton 1989), natural resources systems management (Hatchuel 1993) or for negotiation (Heathcote 1998). For their part, MAS provide a tool for playing with possibilities and exploring their consequences on local communities and their ecosystems. They give the opportunity to test the sensitivity of the consequences of a given set of collective rules with respect to a set of assumptions on individual behaviors. At last, self-design methods allow principals handling all this tools, for a more empowered local process in land use management. In our experiments, many practical actions in regional planning have been withdrawn from the uses of these supports. It is used to support dialog on possible evolutions rather than to reproduce any real phenomenon, in a complex situation where the representation of the reality is in any case too ambitious. Hot debates could emerge and prove interests of these tools for the improving collective processes.Thus, this approach combining role-playing games and MAS is used to support dialog on possible evolutions rather than to reproduce any real phenomenon, in a complex situation where the representation of the reality is in any case too ambitious. It has used in the same period at several land use scales, from a few hundred square kilometers to 2500 km².

Concerning the linking between models and data in this kind of approach, we would like to stress the weight of social interactions, between individuals and between them and society, which can not be withdrawn from simple data surveys. We need some more sociologic ones if LUCC works are interested by interactions between society and space: life history surveys, open interviews, investigations for social representations of phenomenon,...For us, LUCC modeling is *not* only a spatial modeling. We have the same approach of validation. We distinguish three sorts of validation process :

- confrontation to the present reality,
- reconstruction by the model of a real past dynamic,
- model acceptance by concerned people.

In this case, landscape and behavior comparisons could be valuated through these three ways, though it could be more difficult to take into account past behaviors. The first element towards a cautious behavior is so in the use of the three (see above) validation methods together. The second is to test and experiment our models in the mean while at different scale levels. The third is to practice an real action-research that involves concerned principals, at these different scale levels, in the model design, not necessarily by self design (we have others methods, where role playing games could be an interesting support). As regards a complex puzzle like LUCC management, difficulty is most of these assessment devices look at results of modeling, not at its design. We could have same results than in a given reality without a suitable model design. That is why we think it's interesting not to underestimate model acceptance by concerned people, and specially acceptance of the way of reality is represented in the model, not only results produce by the model. Thus, about this validation of the model design and not the model results, we think it is something to be gone more deeply, with the help of social sciences (not only economists), as regards the subject we deal, e.g. social interactions in complex levels. LUCC management is strongly linked with politic makers. We have to integrate their own logics and incentives (about power, ethic, group dynamics,...), not only individual economic strategies of stakeholders.

Our researches now goes on towards two directions. At first, technologic improvements for a better self-use of these information systems, especially by links between role-playing games, GIS, MAS and Internet. Secondly, we conduct theoretical, modeling and practical investigations for a *self-interconnecting* between different scales of collective decision processes. We are combining all these tools to represent knowledge on processes at various levels of complexity, towards a bottom-up approach for understanding but also accompanying land use management dynamics. For us, the multi-scale puzzles are one of the most important issues with respect to spatial and temporal scale.

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