The multi-level participatory modelling of land use policies in African drylands: a method to embed adaptability skills of drylands societies in a policy framework.

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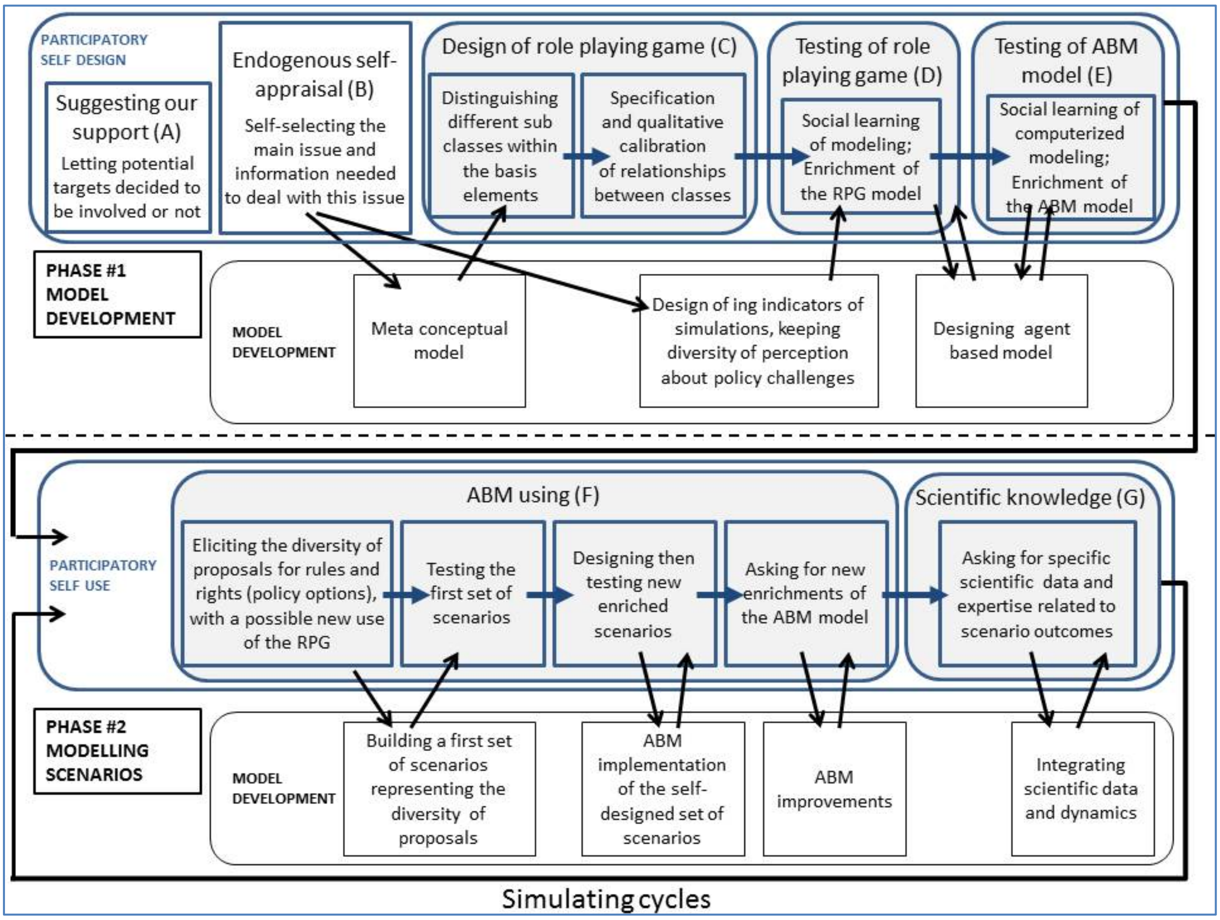
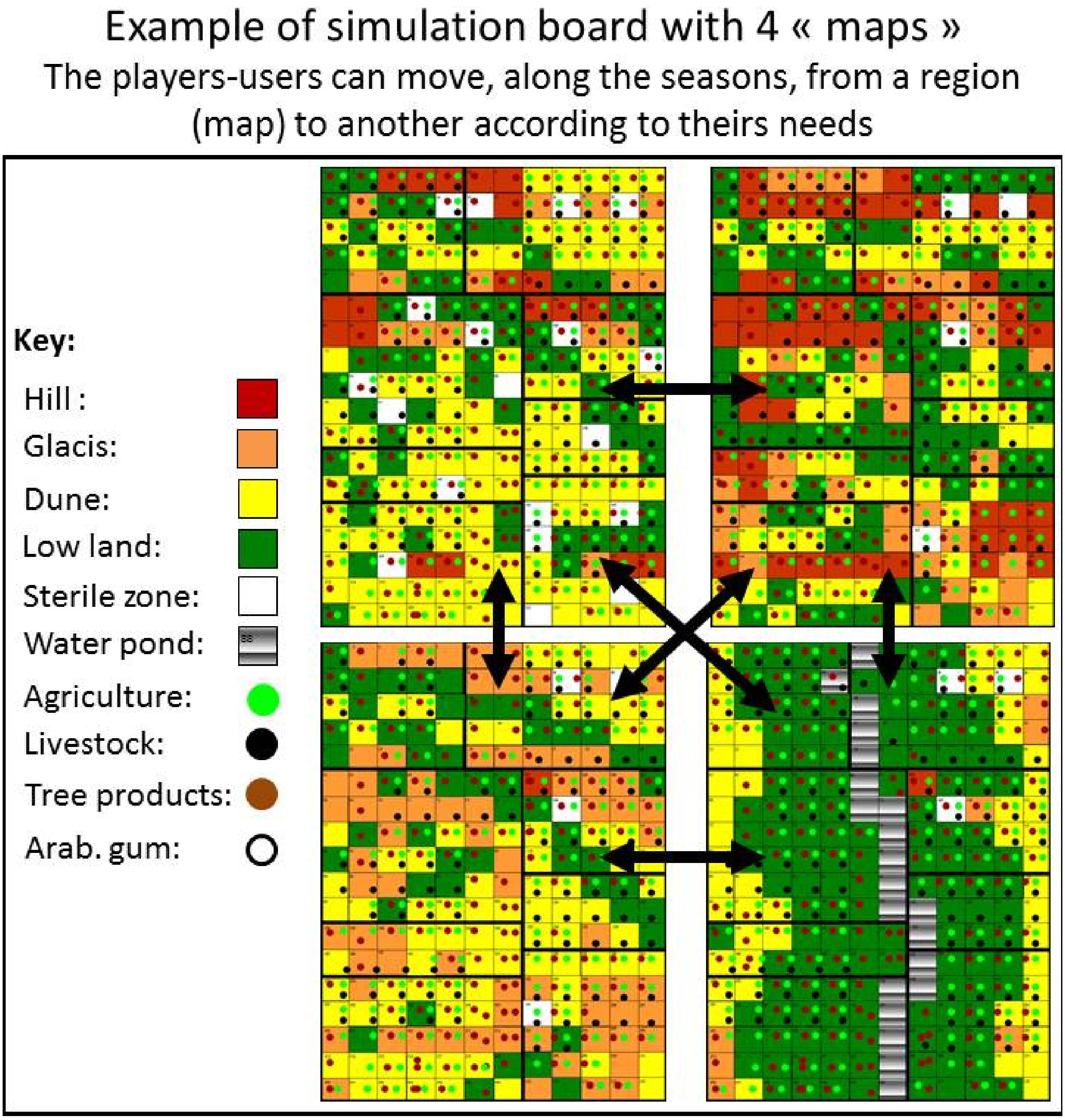
A participatory modelling approach using agent based modelling, called "self-design", has been experimented in Senegal with the aim of letting farmers design their own model of the local natural resources management issues. The success of the experiment and its outputs led to a new participatory modelling based on the central principle of letting stakeholders design and use their own conceptual model of environmental management. In a scientific perspective, the relevance of this endogenous model is currently enriching the debate about the value of local worldviews for environmental modelling. In a policy perspective, the participatory use of the modelling approach led to an inclusionary multi -level policy approach. The modelling approach is used into an inclusionary method which involves and interlinks stakeholders at local to national levels. Participants create a qualitative model that nevertheless reflects the complexity of drylands environmental uncertainty. Then, participants, gathered into a multi-level participatory modelling approach, use the model to shape unusual uncertainty management principles for policy design.

Figure 1: The self-design modeling process



The method focuses on how to enable stakeholders to incorporate their own perception of environmental uncertainty and the way to deal with it in a policy simulation. This approach uses role playing games and agent based modelling to ensure a range of different points of view are preserved in the shared modelling of resources management, with outcomes in terms of mutual learning and management innovations (Barreteau et al., 2003b; Etienne, 2011). From the outputs of this step, the structural components of a meta-conceptual model are built progressively (d'Aquino and Bah 2012a). The outputs of this workshop are used to prepare a more operational role-playing game and a computerized version of the game using an agent-based model (ABM), which has exactly the same features as the game (d'Aquino et al., 2002). Following the self-design method, the multi-scale representation of the issue is the second methodological thrust which helps participants to elicit their background worldview on how to manage uncertainty. A multi-scale representation of the Sahelian environment is supplied within the 'game' with the aim of encouraging participants to reflect on management rules which are not only appropriate for the participants very local location but also for other places and at other scales: in other words a policy scope. For this reason, the game map provides a multi-scale representation of the drylands (Figure 2), as a simulation support which enables participants to handle both the logic of uses and environmental management options at different scales (especially mobility). Players can design regional maps and add them to the game (see Figure 2) if they wish, in an 'open-scale' way to assess their environmental policy options. Therefore, the multi scale scope is twofold. On one hand the whole Sahelian logic of multi-scale, or even open-scale, can then be expressed and on another hand stakeholders are able to deal with region-wide changes of implied by a policy decision.

Figure 2: Structure of model maps (resulting from the co-design process with stakeholders)



Given participants can adapt the content of the maps to their context and scales, this multi-scale representation is able to model different ranging of scales, depending on the decision levels choosen by participants: the basic spatial unit may represent a farm parcel, several parcels the land base of a farm, while the geographical level two (in bold lines) will be community territory, a « map » a regional area, and several « maps » a national territory. But in others simulations, the basic unit may be considered right as a community territoryt (and the players will thus play communauties), the evel 2 will represent a region, a « map » the country, and several maps a multi national region. Other usable interpretation, a « map » is a seul village territory, the sub level (level 2) the lineages land bases, while a group of maps will be a small inter communities area.

INTRODUCTION: "SURFING ON UNCERTAINTY", AN INDIGENOUS WAY OF THINKING

Contrary to common misconceptions, rural people in southern countries have efficiently dealt with ecological and socio-economic scarcity for several centuries. Embedded in deeply uncertain contexts, local communities progressively developed particular ways of thinking about how to organize access to nature in a way that "surfs on uncertainty" rather than contending with it. This is particularly true in risk-prone environments like drylands. Sahelian societies are a prime example of such "surfing", as for centuries. Drylands farmers may use different practices in the same field, for example, spreading manure on only one part, and hoeing another, i.e. increasing their range of practices to be sure to have included the practice that is best adapted to the uncertain climate that year. In the same way, in response to the spatial uncertainty of rainfall and to avoid uncontrolled access, herders shaped collective rules for open access to land based on subtle social agreements that may vary from family to family and from village to village. These rules enable many different uses for each piece of land, as they allocate specific rights of access for each possible use of each natural resource, such as cultivating annual crops, planting an orchard, creating a pasture, hunting, gathering wild fruits, collecting firewood or fodder, or harvesting wood for crafts. In addition, rights of access may change with the season and with the duration and the economic value of the activity, an annual or perennial crop, fruit trees, or gum trees, among others. Rather than being interpreted as land ownership, these complex access rights should be seen as a "bundle of rights" that control the appropriation, exploitation and use of natural resources in a given space. On the whole, traditional practices and livelihood strategies are based on diversity, whether of seeds, livestock breeds, technical practices, or land uses, and on the resulting flexibility, with the aim of improving their adaptability.

Drylands societies' rules and practices may be less suited to contemporary demographics and climate changes, but their way of thinking about adaptability may still be useful in the search for new forms of adaptability. However, designing new policies using this adaptability only makes sense if new policy paradigms are created in which flexibility is a key value. This could be achieved by more efficiently embedding the specific worldviews of drylands societies in the current policy framework paradigm. The participatory modelling approach presented here takes up this challenge.

Participatory modelling experiments have expanded considerably in the last decade, especially for the management of socio-ecological systems. The purpose is to reach mutual understanding between the modellers and stakeholders on their knowledge and points of view (Gaddis et al., 2010; Purnomo et al., 2009; Voivnov and Bousquet, 2010). Many methodological options have been explored, the diversity of which can be classified in different ways (e.g. Lynam et al., 2007; Mendoza and Prabhu, 2006; Parker et al., 2002; Renger et al., 2008; Rouwette et al., 2002). Participatory modelling approaches may have a variety of goals, which can range from involving stakeholders in the choice of goals and modelling agenda, methods that incorporate empirical knowledge in the modeller's knowledge structure (e.g. Argent and Grayson, 2003; Martinez-Santos et al., 2008), others that let the stakeholders explore and test the modeller's knowledge (Barreteau et al. 2003a), and yet others that let stakeholders try to model their own worldviews (d'Aquino et al., 2003 and 2013; Simon and Etienne, 2010). The scientific value of including local subjective knowledge is often questioned. First, because some stakeholders' intuitive assertions may appear to be unsound and to threaten the quality of the model; Secondly, because managing stakeholders' conflicting views in the model may be difficult and thus call into question the efficiency of the whole process. Finally, many modellers simply wonder what is the point of this unusual methodological option. Here, we test and then discuss the value of incorporating stakeholders' worldviews in modelling, based on the outcomes of ten years of experience in participatory modelling in Africa. We describe a modelling method designed to highlight stakeholders' worldviews, then discuss the value of the modelling outputs produced by the stakeholders.

METHOD: THE "SELF LAND POLICY" MODELING PROCESS: A SPECIALLY DESIGNED METHOD TO LET INDIGENOUS THINKING FRAMEWORKS EMERGE

"Self-design" modelling

It has been increasingly recognised that modelling and participatory approaches can be mutually reinforcing when applied to complex environmental issues (e.g. Reed et al., 2008; Voinov and Bousquet, 2010; Dougill et al., 2010). A wide range of participatory modelling approaches exists, from those which incorporate empirical knowledge in a scholar's prior knowledge structure to those which let the stakeholders test the scholar's knowledge, and yet others which focus on eliciting local knowledge (Stringler et al. 2006; Reed et al., 2008). The method described here belongs to the last category. It focuses on how to enable stakeholders to incorporate their own perception of environmental uncertainty and how to deal with it in a simulation. This approach uses role playing games and agent based modelling to ensure a range of different points of view are preserved in the shared modelling of resources management, with outcomes in terms of mutual learning and management innovations (Barreteau et al., 2003b; Etienne, 2011).

Since 1999, we have been working on a particular kind of participatory modelling we call "self-design". "Self-design" means letting participants design their own conceptual framework of issues and goals with no inputs from facilitators, modellers, or scholars' perceptions (d'Aquino et al., 2003; d'Aquino and Bah, 2013). The process has two main phases which specifically focus on letting participants decide on all the crucial elements (Figure 1):

A first "suggesting" meeting. This first meeting is held in many different locations to reach out a wide panel of potential local partners. During the meeting, the participatory simulating approach is presented in detail including a detailed explanation of its objective, i.e. to support people in designing their own land policy views, and of the method, i.e. the self-design of a role playing game and a computerized model. Participants are then asked to contact the team if they are interested in implementing this approach on their own.

Next, a "self-eliciting" workshop. An endogenous self-appraisal (B) is held with the local partners who re-contacted the team. During this workshop, the participants themselves identify the aims of the process, i.e.: (i) the policy stakes they wish to target; (ii) the stakeholders they think they will need to take into account in their self-policy design, (iii) the information they think they will need to tackle the policy issues on their own and (iv) the constraints they think could be critical for these issues. Participants are made aware of the level of description they will be asked to provide: i.e., detailed enough to capture their local needs but sufficiently summarized to enable analysis at the national scale.

A second participatory workshop (C) is then held during which participants "self-design" their own conceptual model. For this purpose, the outputs of the previous "self-eliciting" workshop are structured by the research team into a first simple role-playing game, as a way to let the participants design a conceptual model of their issues.

The settings of this first game are basic but nevertheless very subtle. The challenge is to summarise the major stakeholders' needs and constraints and the main policy stakes they identified in the previous workshop in a qualitative support. First a spatial grid is provided to highlight the simplest environmental typology that can be used without concealing the structural components of the issue. Coloured pawns are provided to represent the different potential uses of each type of landscapes; the different colours represent the range of possible activities. Tokens are provided as a way of qualitatively assessing indicators of the major policy stakes. The tokens are removed from the landscape as the players consume the natural resources of the landscape parcels and keep them as a cash stock. The tokens thus enable both the qualitative assessment of the natural resources available on each landscape parcel and the capacity for self-sufficiency of the different stakeholders. Lastly, 'events' cards represent crucial factors and trends (for example climate events, demographic pressure, arrival of agribusiness…) in the game.

The background structure of the role playing game must not embody the modeller's perception of how to improve the environmental situation. The goal is not to have participants progress towards the modeller's knowledge system but to let them design their own conceptual model based their own worldview (Figure 1). This is why the structure of the game is intentionally kept simple. The board game combines different maps in order to highlight the possibility of the seasonal movements, pastoralism for example. The geographic structure of each map is open to modification by the players: four maps are provided for the first exploratory game, and the participants are asked to modify the maps on their own, i.e. the typology of landscapes and the layout of the parcels. The time component of the game is a year, which comprises three seasons (rainy, dry cold, and dry hot seasons). In each season, the players choose the activities they want to carry out, place their activity pawns on the appropriate landscape parcel, and remove the appropriate amount of resource tokens from the parcel, if the climate in the year concerned combined with the type and state of the landscape parcel they have chosen allows agricultural production. The game rules concerning the different activities must be simple but nevertheless incorporate elements that would be affected by land policy, i.e. a participatory calibration about how many resources tokens players can remove, depending on the activity they implement, the landscape they used, and the annual rainfall on the parcel concerned. This means the rules that apply to the farmers' production activities and environmental impacts are very qualitative, with the sole aim of allowing qualitative comparisons between different land uses scenarios. The rules that apply to land access are also kept very simple, to leave the frame sufficiently open to the players' conception of collective rules. This means that players can place a pawn representing a particular activity anywhere they choose among the several board maps provided, but cannot place two pawns representing agricultural activities on the same parcel at the same time, because contrary to pastoralism and gathering activities, this is physically impossible to have two fields on the same place. So no collective rules are pre-established, because that would mean imposing the designer's conception of the relevant collective rules. For example, the risk of crop injury cause by livestock is incorporated as follows: when a pawn representing a livestock activity is placed close to pawn representing an agricultural activity, the risk of damage occurring (quantified by throwing a dice) is incurred by the agricultural activity and the pastoralist is not affected as long as the players themselves set up a collective rule about sanctions in the case of damage.

In this way, participants have the opportunity to thoroughly check -and if necessary improve- the initial structural elements of the game (see stages D and E), for example by enriching the spatial legend or extending the list of potential uses or assessment indicators.

A participatory simulation (F). At this point, thanks to the previous learning-by-designing process, participants are able to handle the participatory simulation support satisfactorily. Consequently, in the third workshop, participants use the final simulation support to think among themselves about how to improve land policies and test new environmental management options: collective rules, new forms of land rights, new infrastructures, new practices, etc. The outputs of the previous self-design workshop are used to provide a more complete support for this simulation, i.e. a more complex role-playing game but also a computerized version of the game, using an agent-based model (ABM) which has exactly the same features as the board game (d'Aquino et al., 2003). As the computerized model (Figure 2) is based on the game they themselves designed, the participants can use it on their own. They are thus able to continue testing some of the scenarios they started testing in the game but this time on the computer. When playing the board game, the participants play the role of local users who consume natural resources and who also draw up the rules of access which apply to the players-users. In the computerized version of the game, computerized agents act as users who have the same incentives as the players in the role playing game, and the participants no longer play but only define the collective rules which apply to the agents. These two forms of the same conceptual model are complementary. The board game helps stakeholders to tailor their own representation of the issue and its challenges, while the computerized version allows them to test more detailed and operational scenarios. While social complexity is clearly more efficiently comprehended by playing the game (because players can try out new behaviours and practices), biophysical and long-term dynamics are more efficiently comprehended using the computer. In other words, the role playing game supports the self-design of the participants' conceptual model of environmental uncertainty, and the computerized version supports a more accurate but simulated use of this conceptual model.

The two supports, i.e. the game board and the computer simulation (Figure 3 and 4) are intentionally left sufficiently open so they can be enriched and contextualized in a continuous and iterative "companion" process (Etienne 2011). Participants can incorporate new rules and items including risk events (climate, bush fires, prices of goods, etc.), new forms of land use (intensive farming, hunting, tourism, etc.), social behaviours (users' or managers' strategies, forms of negotiation for access to land, etc.), or collective rules and organisation (decentralization, common pool resources, etc.).

Figure 3: The conceptual model emerging from the stakeholders' self-design of the game

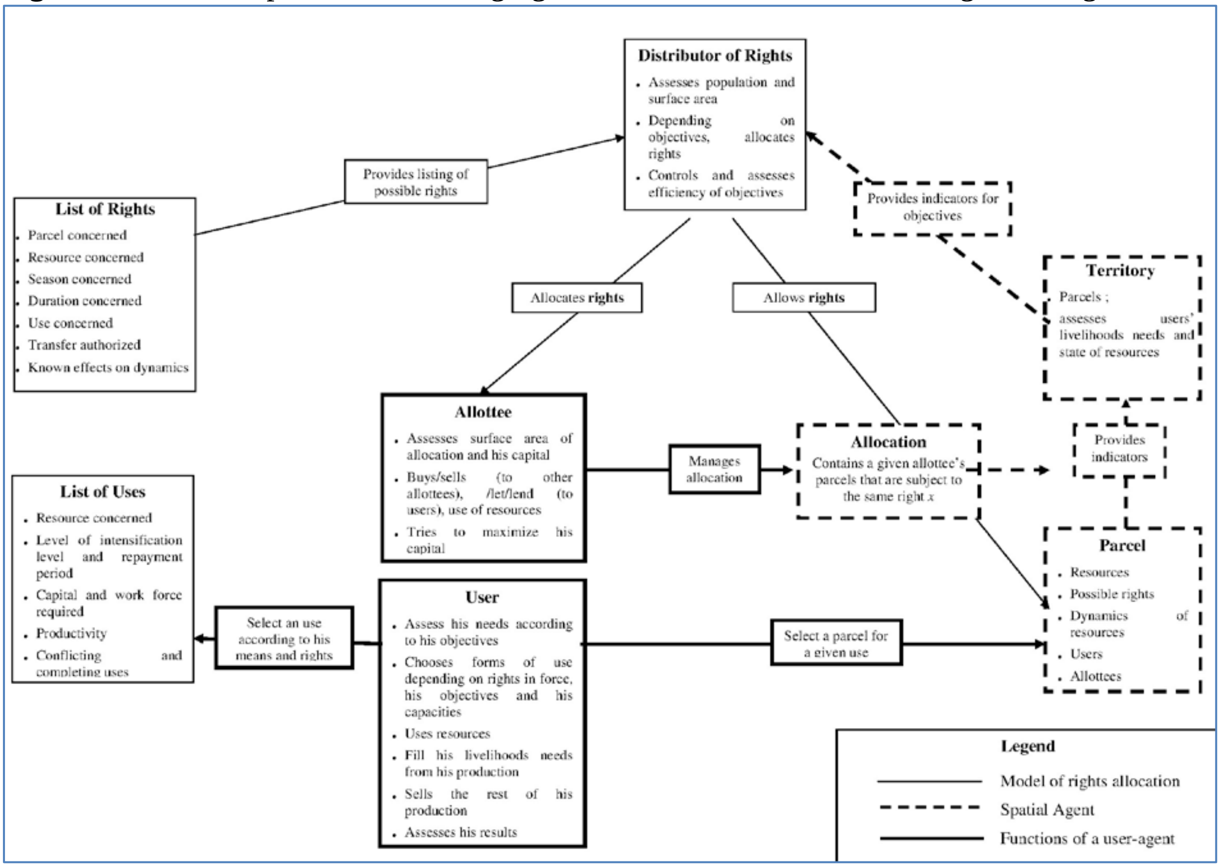
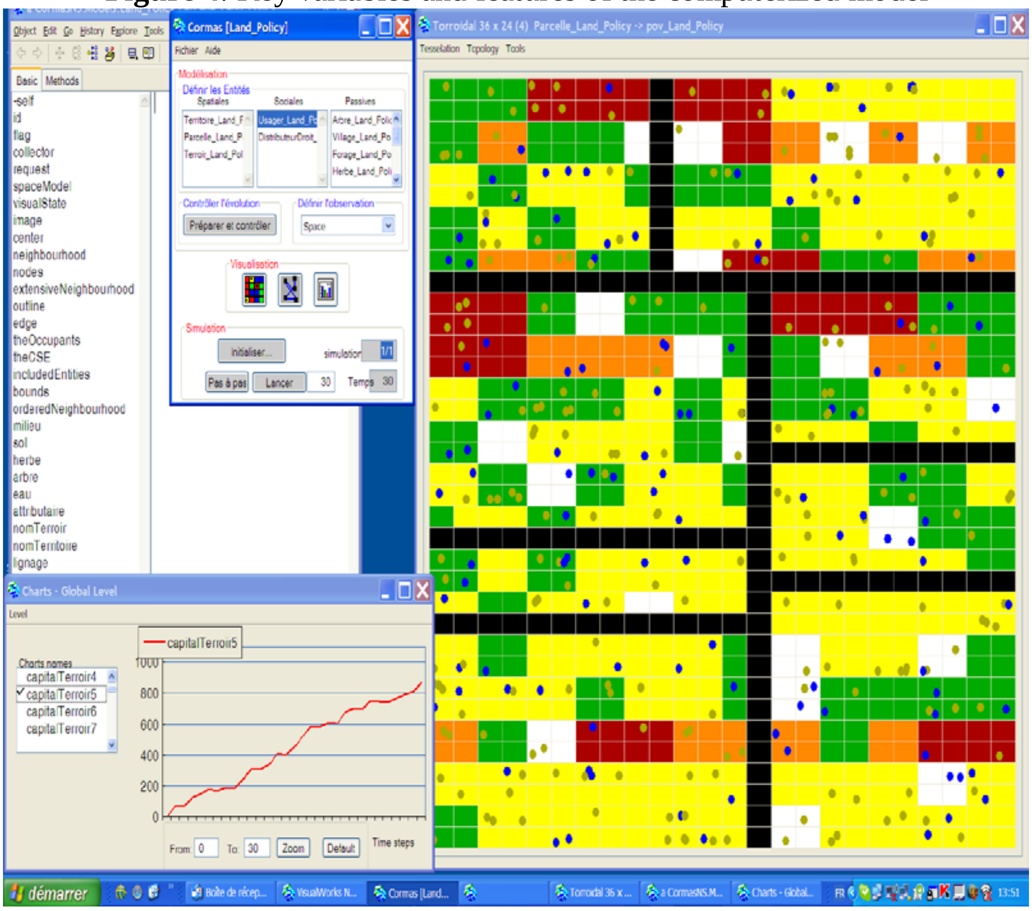


Figure 4: Key variables and features of the computerized model



The use of the participatory simulation support enables participants to design the simulation scenarios themselves (see stage F) by combining (i) a ***climate scenario***, i.e. a sequence of « high », « moderate », and « low » annual rainfall years in the model; (ii) a ***socio-economic scenario***, including user densities for each social scale, the user's workforce and starting capital. (iii) a ***regulatory scenario***, i.e. the different rights and rules concerning access to land and to the natural resources in each spatial cell, which are defined by combining two cell attributes: « right of use », which defines the uses allowed in the cell in each season, and a « right of access to land », which defines who has right of access to the cell. Participants are then left to iteratively explore and modify not only the scenarios but also the model while they are actually using it, and in this way, to increase the complexity of their representation of the issue.

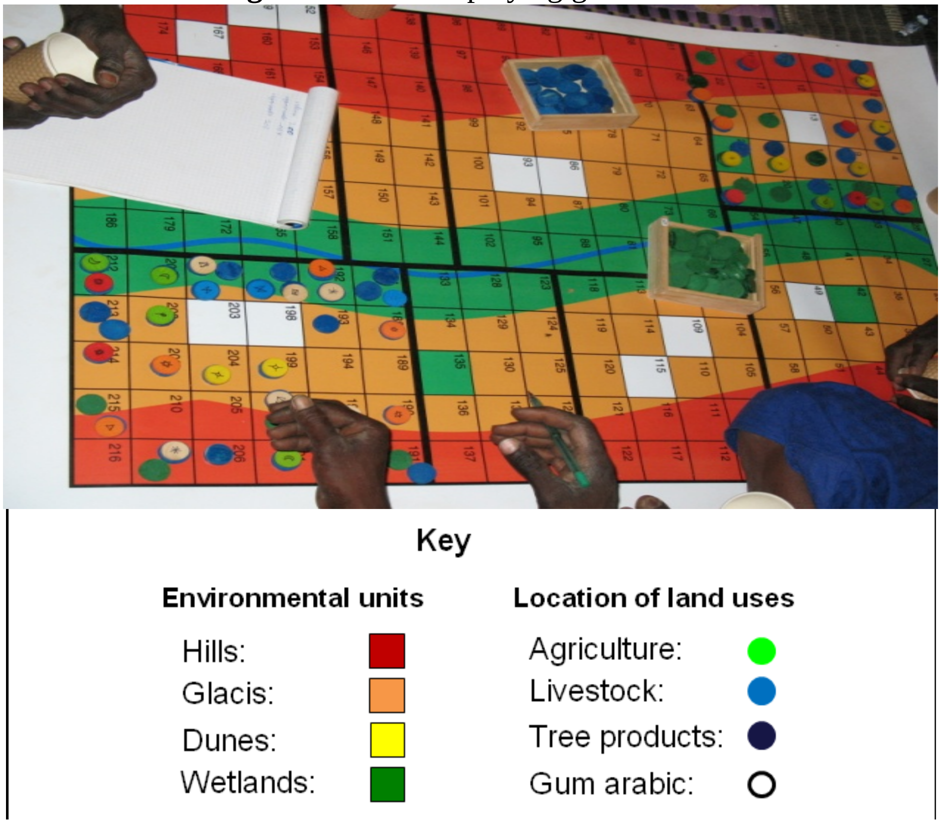
Then, introducing scientific knowledge (G). The modelling settings are at this point sufficiently "self-framed" to allow *external* scientific knowledge and points of view to be incorporated without masking "local uniqueness". Given that facilitators also have their own unconscious perceptions which affect the way they conduct a participatory appraisal, one of the aims of the self-design process is to mitigate this influence.

1.1. A multi-scale focus

The game board map provides a multi-scale representation of the drylands (Figure 2), as a simulation support which enables participants to handle both the logic of uses and environmental management options at different scales (especially mobility, as players are able to move from one board map to another to place the pawns representing their different activities on any of the maps). This multi-scale representation of the Sahelian environment also aims to encourage participants to reflect on management rules which are not only appropriate for their own particular location but also for other places and at other scales: in other words a policy scope. This multi-scale feature supplements the set of indicators we provide to encourage the participants to take everybody else's needs and interests into account, in other words the "common interest", while engaging the participants in a multi-level assessment of their own scenarios (see for example Figure 5). The aim of the multi-scale focus is twofold: on one hand to enable the whole multi-scale Sahelian logic to be expressed and on the other hand to encourage the players to deal with possible region-wide changes implied by their policy scenarios.

We have also implemented a "multi- level inclusionary strategy" (d'Aquino and Bah 2014). The objective is to be very explicit with the stakeholders about an inclusionary challenge: letting the participants depict uncertainty issues from their own point of view before incorporating the policy makers' points of view, so that they are then able to design and test some policy options together, in order to comply with both their own uncertainty management principles and current policy needs. Then, in order to balance power relationships between local and national stakeholders, each step of the self-design process (see above) is first organized at the local level and afterwards at the national level. As a result, a same single "self-simulating" process brings together two target groups, local and national stakeholders, but the process involves two separate but parallel "modeling arenas". The design and use of the model is nevertheless shared thanks to structural links between the workshops and the tools: all the components incorporated in a simulation session, for example a tool which has been enriched, or a new simulation scenario, are also incorporated in the equivalent parallel session. This means creating a sort of single exchange arena but with two different interfaces, one for the local workshops and one for the national workshops. This shared design has proved to be capable of mixing appropriate policy goals both from the national and local points of view (d'aquino and Bah 2014).

Figure 5: The role playing game board



To recap, the self-design approach includes several "self-handling" steps, from the initial "self-commitment" to launch the process to the final step of "self-policy design". This process results in a simple qualitative representation but which is nevertheless fine enough to accurately capture the complexity of drylands uncertainty, as shown by the results.

FIRST RESULTS: AN APPROPRIATE METHOD FOR SELF ELICITING A LOCAL SOCIETY'S POINT OF VIEW

Key variables and features of the final computer model (figure 3)

Different features must be distinguished. Firstly, some 'basic' features are fixed by participants during the self-design phase (landscapes, farmers' needs and strategies, rainfall impact on natural resources). These features are considered fixed but can be modified by participants if needed be.

Secondly, some variables are used and combined to design 'environment' modelling scenarios: demographic densities (different from one landscape to another), average level of annual rainfall (which is afterwards differently applied according to northern –drier- and southern –wetter- region maps), and the possibility to change some parts of landscape units.

Thirdly, land uses rules can be modified for each cell, with this simulating grid:

- One can specify the resources of the cell which are allowed to be used (soil, water, grass, or tree), the kind of use which is allowed (agriculture, pastoralism, gathering), and the seasons concerned. Every combination of these three elements is possible.

- One can also specify which social categories of users are allowed to use this cell: only locals, only people from a specific lineage (synthetizing a customary land tenure), or for a nuclear family.

The wanted combining of these two variables is implemented and conserved as a ‘land rules option map’ and can be mobilized for simulations.

Consequently, a simulation scenario gathers a specific combination of environmental features and a specific combination of land rules access and tenure.

Then, a simulation is monitored by the follow-up of few variables, along the simulation and for the different landscapes (see one of these graphs at the bottom left of the figure 4):

- The evolution of the quantity of the four natural resources;
- The production of each use;
- The economic success of every user.

Stakeholders’ ownership of the method

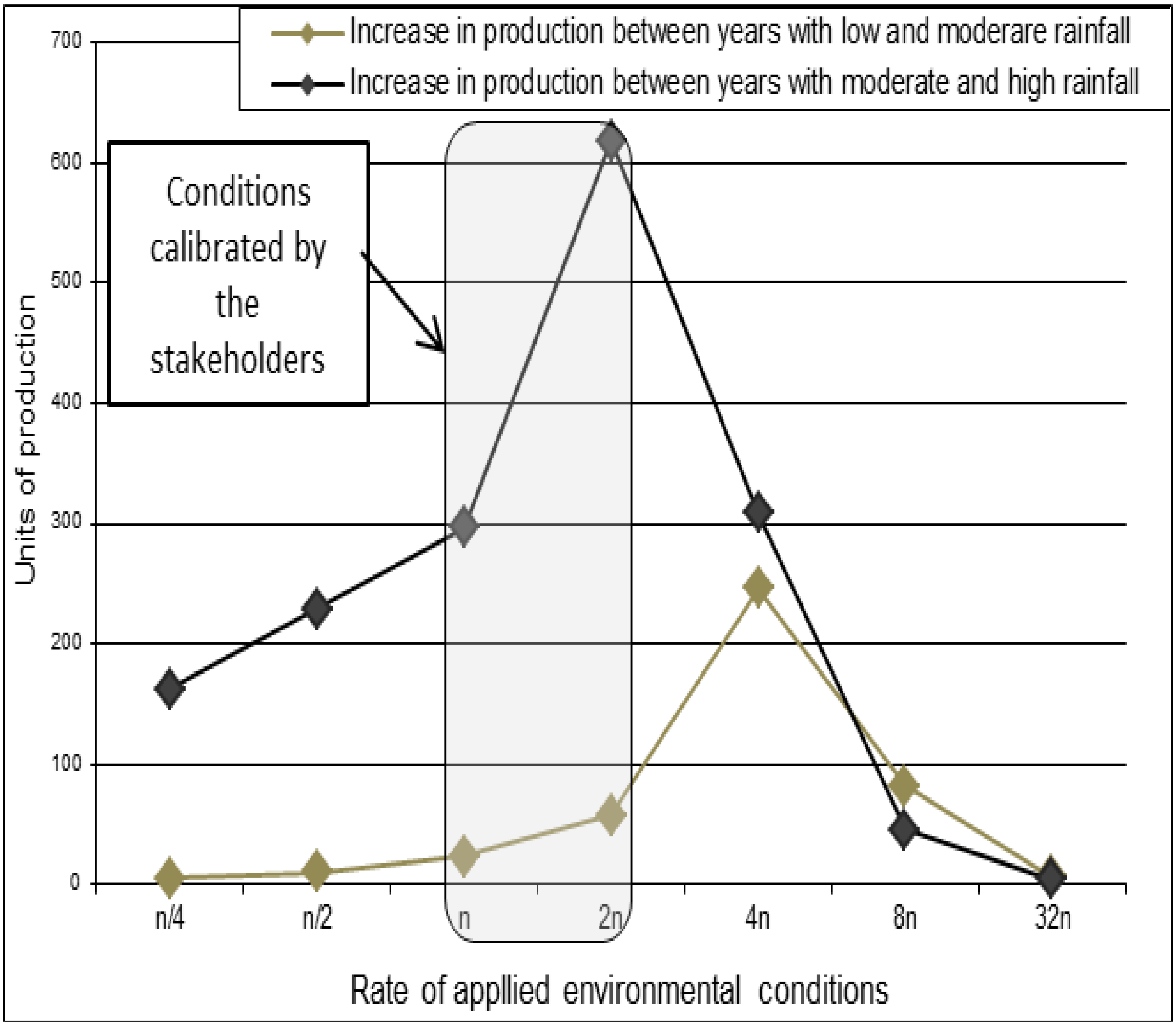
Participants revealed their incentives and demonstrated their ability to incorporate an eclectic list of relevant policy challenges (see Figure 1) in order to ensure everyone’s point of view was included. Both local stakeholders and policy makers (quite surprising on the part of the latter) showed great interest in incorporating the other stakeholders’ indicators. Indeed, they were interested in designing innovative policies by mixing local and policy frameworks.

Last but not least, their use of self-modeling led to some unusual principles of uncertainty management.

The Emergence of Specific Uncertainty Features from the Self-Design Process

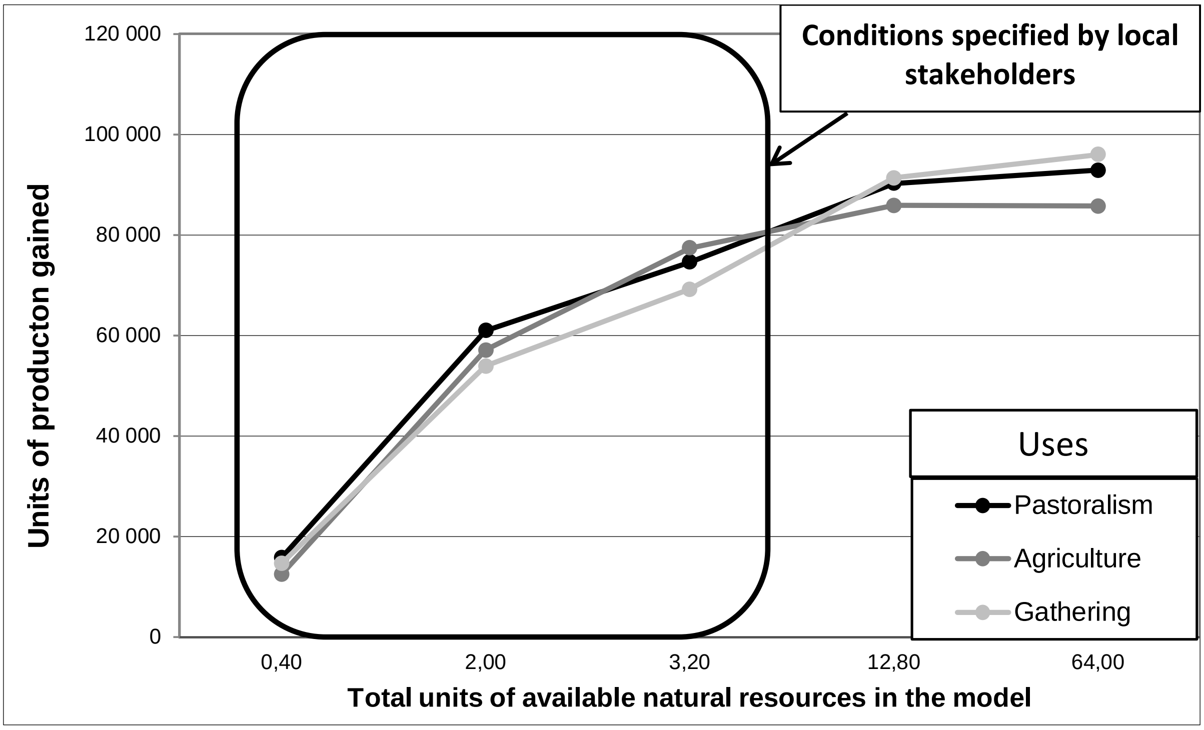
The first fundamental element participants introduced in the game settings was a qualitative calibration of the relationships between the amount of rainfall in one year and production. They were asked to qualify the difference in productivity between years with “high”, “moderate” and “low” rainfall. As the computerized version of the game enables variations in the different qualitative calibrations of the game, the effects of selecting the stakeholders’ ratio can be simulated. Yet, while running the model, the only way to reveal the difference in productivity between high”, “moderate” and “low” rainfall years (defined by the stakeholders) was not to simply reduce the direct impact of rainfall on the production of resources but also to increase the scarcity of resources (Figure 6). Moreover, figure 6 shows that the conditions described by the stakeholders resulted in a simulation support in which a slight difference in resources availability caused a considerable difference in productivity. Thus, behind its apparent qualitative simplicity, the model simulation support provides an interesting representation of Sahelian uncertainty conditions based on a fine balance between the scarcity of resources and rainfall (see Bourgoin et al. 2014). Because of the way the stakeholders calibrated this fragility, the most advantageous use can vary even in the case of limited environmental variability (Figure 7).

Figure 6: Impact of variation in rainfall on different types of production according to the scarcity of natural resources in the computerized version of the game



The graph shows the results of a series of computer simulations in which natural resources in the landscape vary (see x axis: rate of available resources). The y axis shows the rate of production depending on the yearly rainfall: a higher curve means a greater effect of rainier years on productivity. Consequently, the peak of the greatest impact of rainier years is in the middle of the graph when resources are least scarce (following better environmental conditions when a rainy year is less useful, and before resources become so scarce that even rainy year cannot have really beneficial impact). Actually, the qualitative model calibrated by local stakeholders in the game sessions matches the period when the impact of rainfall on productivity is highest, and the rainiest years provide the greatest benefit: participants instinctively shape a model which summarizes the specific conditions of land uses in the Sahel, and thus produce a user-friendly model that can be used to help design policies to fit these particular conditions.

Figure 7: Productivity of the three major uses according to the level of resources scarcity



The x and y axes are the same as in the previous graph (x axis: the varying parameters of natural resources in the computer model; y axis: users' production according to the availability of resources). The box highlights the same area as in the previous graph: the qualitative conditions of available resources designed by stakeholders during the self-designed game. While the previous graph focuses on the greater impact of climate in the stakeholders' model, this graph highlights another feature that also only comes to light in the environmental conditions designed by the stakeholders (i.e. in the box): the shift between agriculture and livestock as the most productive use; in other words, with the environmental conditions self-depicted by stakeholders, a slight difference in annual climate causes a shift in the most productive use between agriculture and livestock.This variability results in highly variable spatial productivity, which is the product of many different sources of diversity and uncertainty (d'Aquino and Bah 2012c): climatic uncertainty, the range of different landscapes, the varying location of key resources, the variety of resource uses, and, depending on the season, the users' mobility, and finally, changes in user density. Thus, the self-designed simulation support describes a situation in which a particular land use may have certain advantages depending on the prevailing environmental conditions, and a particular landscape may be advantageous for a particular use, but only with a combination of particular environmental conditions, such as rainfall in the year concerned, user density, or the location of certain key resources. Certain ecological units may be a key resource for a particular type of production but only if used in a particular season. The overall long term productivity balance relies on certain key resources, like the use of wetlands for agriculture in wetter years, wetlands being unevenly distributed in space, but also the use of wetlands for gathering natural products in drier years, dry years being unevenly distributed in time.

Qualitative and easy to use, but nevertheless appropriate for complex management of uncertainty

Despite its simple qualitative structure, the first outputs showed that the model manages to conserve the fundamental subtle features of complex Sahelian uncertainty. First, the specific combination of environmental conditions (semi-aridity and climatic uncertainty, scarcity of natural resources, specific spatial high variability, etc.) crafted by participants, led to a modelling situation in which natural resources are so rare that in the worst cases, the intensive use of natural resources may be economically less efficient than extensive use. This claim has been made by Sahelian researchers for many years but was not often accepted by decision makers until they themselves designed the game. In fact, decision makers and stakeholders designed a model in which they did not 'come up with' these dynamics, but in which the dynamics 'emerged' as logical outputs of their world view: an emergent feature that matched scientific reality.

Last, the most interesting feature that emerged from the modelling outputs is the fact that overall yield is correlated with a very rare and localized condition: the agriculture use of lowland parcels in years with the highest rainfall. A particular aspect that land tenure rights and management need to take into account by incorporating a multi-annual perspective: how can the use of these vital resources during these particular years be preserved for all the users and not only for some owners? This is the kind of issue our modelling support can help decision makers and stakeholders resolve together.

Indeed, a more detailed run of the computerized version of the game demonstrated that the self-designed model is a true model of non-equilibrium ecological dynamics, shaped by a complex combination of specific features characteristic of drylands uncertainty:

- There is no general economic advantage of any particular use. Model outputs underlined the fact that the most profitable use differs not only depending on annual rainfall, resource scarcity, and the density of users, but also on the spatial structure of the ecological landscape, confirming the value of multi-purpose use in this kind of uncertain environment.
- No specific type of landscape has an overriding economic advantage. The spatial combination of variability and uncertainty results in complex variability of landscape potentialities that depend on the type of use and exploitation rate, as well as on resource scarcity and annual rainfall. This means the potentially best parcels of land and landscapes change from one year to the next depending on subtle environmental conditions and uses.
- The environmental potentialities are unforeseeable because the above features are combined in such complex and varying ways.
- Last but not least, the future sustainability of the whole agrarian system depends on specific access to some restricted space-time resource niches. A very remarkable Sahelian environmental uncertainty feature was revealed by this self-designed model: long term yield depends entirely on a few resource niches that are spatially and temporally rare, such as specific wetlands that can be used for agricultural purposes in the wet season in years with high rainfall and for livestock in years with moderate rainfall, or sandy land for grazing livestock in the dry season in years with low rainfall. This specific environmental

context has long been reported by drylands researchers where key high value resources are found alongside low value extensive resources (Scoones 1994, Mehta et al. 1999, Dougill et al 2010). Thus the stakeholders' intuitive modelling proved its relevance, even based on such fine features. Moreover, it now provides a simulation support that summarizes this environmental specificity in a user-friendly frame and hence makes it more appropriate for inclusion in policy frameworks…and resilience modelling.

The Emergence of First Indigenous Principles for Collective Rules from the Self-Simulation Process

As the modeling platform is shaped by the stakeholders themselves, it is easy for them to use and is consequently a powerful support to help stakeholders to reflect among themselves on the best environmental policies to enhance drylands sustainability. At the same time, it tests drylands peoples' ability to design innovative principles of environmental management, drawing on the historical ability of their society to surf on uncertainty. Thus, after self-designing a multi-scale "model" of environmental uncertainty, stakeholders use the model they have crafted to test (in the form of a game) scenarios of environmental policies they would like to implement to improve their current situation.

The outputs of these first experiments are rules the participants tailored and tested. Participants naturally introduced unconventional environmental management principles: first, they intentionally kept multi-use and multi-user access to land because of the spatial uncertainty and variability of their environment. They then agreed on a "priority principle" for collective regulation: each area had a priority use or user but with a "soft" restriction, meaning all users can access the area but are responsible and answerable for not disturbing the priority use or user. As one participant remarked, this means "freeing up the zoning'.

Another highly innovative proposal shaped by the participants that emerged was distinguishing a soft flexible "common law", similar to the "priority zoning" mentioned above, to be applied in standard areas and years, and on the other hand, common ownership with strict collective rules for rare and vital space-time resource niches. Participants listed the following vital space-time niches:

- exceptional rainfall in drought years,
- certain local wetlands in years with high rainfall,
- other types of wetlands in drought years,
- particular regional spots of pasture biodiversity that play an essential role in pastoral productivity,
- bush resources for gathering in the dry season.

These critical space-time resources belong to a common pool and are controlled by strict allocation rules in such a way that everybody profits from partial access. The distinction between the two regulation systems applies at all management scales, from local districts to natural regions and beyond, to the international Sahel. The details of these regulations and their overlapping regimes are not yet finalized and require further investigations in a new set of simulation workshops, but they already describe general natural resources management which distinguishes between two regulation systems: the first applies in normal situations, i.e.

reasonable environmental conditions, when rules of access can be softened and controlled using the original “priority principle”, and the second to be applied in a critical situation that can occur at a seasonal, annual or regional scale.

This unusual indigenous proposal leads us to a peculiar multi-level perspective. While some of these micro spots of resources may be too small to be integrated efficiently at regional or even at local management scales, by combining particular rules for micro specificities within a generally flexible regulation, these Sahelian stakeholders propose an interesting multi-level form of natural resources management, and they appear to have the necessary experience to put it into practice.

Obviously these initial results (the emerging policy principles), require deeper collective adjustments to become operational. Scholars’ expertise and policy makers’ points of view will also need to be incorporated (see perspectives below). Yet the indigenous principles of environmental management drawn up by the stakeholders are already sufficiently innovative to fuel the current Senegalese debate about land tenure reforms.

DISCUSSION

The kind of role playing game we used has been successfully tested all over the world in the last decade (see commod.org). When participatory approaches succeed, the main question that arises is whether they are reproducible, as success is always embedded in the local features of a society. Of course, like any other participatory approach, the success of the self-design process depends on the facilitator’s awareness of the social background, and this usually takes a few months to acquire. However, mobilizing the participants can only succeed if the issue proposed for discussion is a ‘real’ issue for them (Kok et al. 2007): what we are describing here is not an awareness approach but a support for a collective discussion about the participants’ own issues. Indeed, the only true obstacles to this kind of approach are first, that the participants must already have the same aims and feel the need to be involved. In the case of policy design, in some societies, very local users may be not interested in being involved in policy design, even though the policy will have an impact on their livelihoods. The second obstacle is the difficulty for facilitators to avoid incorporating their own points of view when framing the process, either intentionally, for example, with an environmental aim, or subconsciously.

The self-design approach presented above takes up this methodological challenge by supporting people in designing their own conceptual settings, and then using these endogenous settings to define their own regulation options. We believe that a major requirement of this methodological approach is limiting the influence of external scientific point of view on the stakeholders’ eliciting process. The first milestone is then making sure that very limited external scientific data and knowledge are incorporated during the diagnostic process, so that the participants’ framework is not ‘spoiled’ by exogenous points of view. In the self-design approach, adding scientific knowledge and data is only appropriate when the local framework and model are sufficiently solid to withstand the influence of prevailing scientific opinion. The second milestone is still trickier: limiting the influence of the facilitator, like that of the scientist, on the stakeholders’ eliciting process. In fact, whatever the approach, simply by establishing a dialogue, the facilitator already influences the participants’ reactions. This is a fact that scientists simply must understand. Consequently, the only scientific way to tackle this influence is to acknowledge it, and then carefully and rigorously limit and control it. We need to rigorously check the very limited questions we toss out in front of participants.

However, some tricky epistemology issues arise from this kind of maieutic process (d'Aquino and Bah 2012a): faced with such a deep iterative analysis, researchers find it very difficult to adhere to a sufficiently rigorous process. For this reason, from our ten years' experience with this kind iterative modeling, we have extracted some sound principles to ensure a rigorous procedure (Etienne 2011), applying a monitoring framework that makes every researcher's choice of social setting explicit and expressible in a refutable form: why and how should each form of knowledge be used and at what stage, why and how should the different stakeholders' points of view and goals be incorporated in the development of the appraisal process, and so on. Even though -as stated above- this self-modeling process enables the expression of indigenous frameworks, we still need to know how to incorporate scientific knowledge at a later stage, in our particular case, knowledge of the dynamics of natural resources depletion under increasing pressure. Indeed, in our experience, the stakeholders themselves often want scientific knowledge when they reach a stage in their self-appraisal process where this type of knowledge serves a purpose; for instance, when in their simulations, increasing the production of fodder becomes indispensable for sustainability (Corniaux et al. 2003). However, in some cases, local people may not acknowledge the authenticity of certain environmental facts (Dray et al. 2007). In such cases, the first part of the solution may be helping people first to assimilate a multi-scale view of their problem (see our multi-scale settings), as this will reveal aspects that are not visible at their usual scale of perception. Another part of the solution may be that scholars reorganize their approach in a more comprehensive framework (d'Aquino and Bah 2012a), by starting with a true co-definition of the priority issue that really takes local priorities and points of view into account, not only the scholars' economic and ecological viewpoints (see post-normal attitude: Funtowicz and Ravetz 1994).

Back to the Policy Challenge

The last hurdle in this kind of policy design is embedding local proposals in the policy making process. Indeed, it is difficult to change policy makers' ways of thinking about regulations, i.e. privatization and closure of landscapes, zoning land for separate uses, enforcing static carrying capacities, corporate management linked to territorially delimited pastures, formalized nested regulatory structures, all measures that restrict flexibility and adaptability. Despite the successes of the first self-designing process experimented at the local level in 2000, which subsequently publicized a new form of local land use management and zoning to other Sahelian countries (d'Aquino and Papazian 2012b), the basic structure of the policy, such as the legal access rights, has still not changed. Thus, the success of the self-designed approach in developing local management tools has highlighted the need to change the environmental management paradigm at a more general level. This is why a bottom up self-design, like the one described here, is called for. Indeed, if policy makers are involved in the local stakeholders' design, like in the process we have described here, the chances of succeeding in embedding indigenous skills about uncertainty in the policy debate will be greater.

CONCLUSIONS AND PERSPECTIVES

The multi-level self-design process tested in the Sahel succeeded in eliciting the background principles of adaptability. The results, which confirm the relevance of the method and of the simulation support produced, mean that this simulation support can be used to enable stakeholders to design their own operational ideas of policies and then to analyze the outputs of the policies using scientific adaptability frameworks.

Another option is the use of this kind of 'paradigm exchange' between indigenous knowledge and scientific knowledge. If indigenous thinking about adaptability can improve our management of adaptability, it should be included in the resilience thinking framework. Pursuing this goal may lead to the use of the self-designed process not only to elicit indigenous points of view, but also to facilitate constructive exchanges with other bodies of knowledge on environmental management. Indeed, the self-design process translates a part of indigenous knowledge into a qualitative language, and could do the same with other forms of knowledge with the aim of achieving better mutual understanding and exchange. On one hand, theories of environmental management can be formalized in the form of a rules scenario which can then be used in the self-designed game, and subsequently easily debated with the players. On the other hand, empirical scenarios formalized by indigenous players can be assessed in an economic and juridical framework, and can fuel scientific debate about adaptability and resilience. Thus, the next step in our work in Senegal is to analyze to what extent these empirical principles of adaptability management can be transformed into practical rules and institutions for resilience and co-adaptative management policies.

In conclusion, more work remains to be done than the work accomplished up to now. Nonetheless, the very first results reported in this paper confirm the value of this approach: first, some innovative participatory methods enable stakeholders to use their indigenous way of thinking to design a "modern" model of environmental management; second their model may provide new insights into how to design flexible rules to manage uncertainty. In point of fact, the entire methodological framework described in this paper is an attempt to find a better way for future hybridization of scientific knowledge and indigenous capacity for adaptability, by taking the first steps towards creating an amenable arena for a more comprehensible exchange between different sources of knowledge, towards the co-building of new "post-normal" knowledge.

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