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**PARTICIPATORY SIMULATION FOR COORDINATION AWARENESS
CONCERNING SMALL WATER INFRASTRUCTURE AND DROUGHT
ADAPTATION PLANNING IN SEMI-ARID MOZAMBIQUE**

C., Legrand^{a*}; R., Ducrot^b; A., Van Paassen^c; C., Monteiro^d; M. Rousseau

Abstract

In semi-arid area where water is scarce and natural resources constraints often limit rural livelihoods opportunities, Small Water Infrastructures (SWI) are essential to the local development. However the expansion of SWI raises new challenges as many small dispersed point of water extraction are difficult to adequately control and regulate. This brings the attention to the planning of SWI development planning along with the classical and non resolved issue of their long term sustainability. This paper argues that a participatory modelling and simulation approaches helps local actors to better understand the interactions between resources and actors strategies which in time could contribute to an integrative planning processes. It draws on a companion modelling approach using the Wat-A-Gale tool kit. The results of this pilot project show that the participants could acknowledge the local complexity associated with their livelihood strategies. In addition, some participants who had been included in the overall process and could more easily extrapolate were able to reflect on local integrative planning.

Keywords: water infrastructure, integrative planning, adaptation, companion modeling

^aMaster Student at Wageningen University, Netherlands chloe.legrand@wur.nl

^bResearch associate to the international center of economy and water governance in Africa, of the faculty of agronomy and forestry engineering of Eduardo Mondlane University (IWEGA / FAEFUEM) and Centre International de Recherche Agronomique pour le Développement (CIRAD, France) -Research Unit on Water Management, Actors & Uses – UMR GEAU)

^cKnowledge, Technology and Innovation Studies, Wageningen University, P.O. Box 8130, 6700 EW Wageningen (Holland)

^dMaster Student at Eduardo Mondlane University

1. Introduction

In rural area extended water access is associated with the development of appropriate technologies and community based management process. Appropriate technologies, also referred as Small Water Infrastructures (SWI) are now the cornerstones of all development policies dealing with water in most development countries. These policies often strongly related to poverty alleviation mechanisms.

For rural water supply program and interventions have shifted from a project based approach centered on the building of infrastructure to service delivery approaches encompassing the full cycle from planning, design, implementation, maintenance and operation and if necessary rehabilitation or upgrading. This approach underlines also the role of intermediate administrative level between community and government in these program development and implementation. The use of small water lifting technologies for agricultural or breeding activities is increasing in Sub Sahara Africa and is shifting from public and community managed schemes support by government and donors to privately owned and managed system. But the expansion of SWI raises new challenges as many small dispersed point of water extraction are difficult to adequately control and regulate while they can contribute to resources depletion, pollution, salinization and conflicts with other users. This raises the attention to the planning of SWI development planning along with the classical and non resolved issue of their long term sustainability.

This is particular crucial in semi-arid area where water is scarce and natural resources constraints often limit rural livelihoods opportunities. This paper argues that a participatory modelling and simulation approaches helps local actors to better understand the interactions between resources and actors strategies which in time could contribute to better and more inclusive planning processes. It draws on a companion modelling approach that has been developed to support *“negotiation and learning processes among stakeholders; the design of new management rules and routines; and the creation of environmental organizations, such as catchment committees”* using the Wat-A-Gale tool kit (Ducrot, Van Paassen et al., 2014^b).

2. Context of the study

The district of Mabalane is situated in the upper-Limpopo agro-climatic region, where extreme climatic events such as droughts and floods can occur. Moreover, as the flow of the Limpopo branch in this zone isn't regulated by an upstream dam as the Massingir dam does for the Elephant River and the Macarretane dam does in the Lower Limpopo region, the flow is irregular and interrupted during the dry season. The salinity and depth of the underground water limit its use to mitigate droughts.

These phenomena generate heterogenous and overall little access to water over the year, and as rainfed agriculture can only provide food for 6 months of the year from January/February to September/October, food insecurity is widespread in the district (FEW NET, 2011).

The hydrogeology challenge prevailing small water infrastructures for water consumption such as boreholes. In 2010, half of the 67 boreholes of the district were dysfunctional (Ducrot, 2012). Besides, the population relies mostly on agro-pastoralism activities for its livelihood. Indeed, the hydrological and climate characteristic of the region constrains agriculture but embed a rich forest ecosystem with pastures potential for cattle grazing.

The Forest ecosystem called Mopane forest because of the dominant Mopane species saw its area decrease significantly these last years to provide the Provincial and Capital City with charcoal. The commercialization of charcoal to city entrepreneurs brings a significant additional income to the household, particularly during the lean season when agriculture isn't securing household food necessities. The other livelihood strategy that relies on irrigated agriculture is still marginal with 6 small water systems (Ducrot, 2012)

Provision of small-water infrastructures have been identified by the government as one of the drivers for the District development. It is being done through national programs such as PRONASAR or through local development funds such as the OIL. These infrastructures consist in boreholes to provide water for household consumption and small irrigation systems to improve the food security and income generation. The PRONASAR program emphasizes on the importance of supporting an inclusive, bottom-up planning involving the local participative planning institutions and on the information and participation quality all along the process.

In her papers, Ducrot (2012, 2013) shows PRONASAR's limits to reach its direct (water supply coverage in an equal and sustainable manner and capacity building in WASH sector) and its indirect (strengthening local institutions) objectives. She also describes how these objectives were interdependent: the centralization of the decision-making (including planning) at the provincial level under cultural hierarchic culture and the overlooking of the local actors relationships had led to an unequal distribution of water points, high salinity of many of them at the origin of the program mitigated results.

The local actors with their respective knowledge on the system are often disjoined in SWI planning, which result in their mismatch to local specificities and needs. Integrative planning approaches seek to reduce the gap between the strategic planning elaborated by the provincial administration and the complex reality as encountered by the citizens (Waard, 2005 in Ligtenberg, 2006). But it can only work if all actors are aware of this complexity and can handle it using legal planning space such as consultative councils. Their interactions in such spaces could put in light the perspectives and local knowledge concerning key local issues.

Connecting this environmental and social complexity to the small-water infrastructures planning is the objective of our case study. This paper will investigate if the use of a companion modelling (comMod) role play game (RPG) can bring more understanding to local actors of local complexity and coordinated action, and if, in a greater extent, it can contribute to their reflection about integrative planning.

3. Theoretical Framework

In this study of the sustainable planning of small water infrastructures we consider the local context of Mabalane as a complex socio-ecological complex system. The social-ecological system and its subsystems are complex in the sense that their global level properties aren't observable at the level of their constitutive elements and their unpredictable global dynamics can't be observed or analyzed from their elementary interactions (Weisbush, 1991, C.G. Langton 1992 in ComMod. 2009). It is called the emergent properties of the complex system. Our assumption is that the large development of SWI as new elements of the socio-ecological system of Mabalane will likely change the system global dynamic and should, therefore, be considered carefully. In fact, the development of SWI will affect the global dynamics of the system such as food security or deforestation, which can't be explained by the study of the cause and effect relationships these infrastructures have with its close system's elements such as water resource or the communities.

The ecological and social systems are sub-systems of a global system where they mutually interact (Gallopín, 2006). It presupposes that the environment and the society are intimately related and evolve under a co-evolution, co-adaptation process (Afromaison, 2014). This concept draws attention toward the impact of path-way dependencies the implementation and maintenance of small water infrastructures as technologies have on the socio-ecological system of Mabalane (Foxon et al., 2008). In fact, the process of the small water infrastructures development by evolving social actors and changing their practices will transform the socio-ecological system and consequently determine the infrastructures natural and social outcomes.

In her study, Ducrot (2013) reveals how SWI implementation and management in Mabalane can locally have impacts on others interdependent natural resources than water. For example, to pay the cost of the boreholes maintenance or the fuel of motor-pump, the farmers engage in cash-production activities such as charcoal exploration. In the evaluation of PRONASAR (Ducrot 2014^a), she acknowledges also the importance of a good process quality for efficient implementation and sustainable management of SWI. She observed that the unequal distribution of water points was equally justified if not more by actor's relationships and their strategies, than the unforeseen hydrogeological context. She adds that the capability of the community to maintain the boreholes depended on the coordination between various communities' actors including the leaders, and villagers rather than the water committee alone.

The interaction of a diversity of private and public actors distributed at different jurisdictional levels in PRONASAR implementation evokes a multi-level governance model (Görg, 2007). Thus, the quality of the SWI development depends on the attention paid to the implications of this model of governance. The confrontation of the multi-actors perspective could allow the local knowledge and perspective to be considered in the decisions making and increase the allocation performance of sparse resource (Ducrot, 2014).

The integration of both interdependent natural resources and multi-level, public and private actors in the decision-making could be done in SWIs integrative planning (Hassenforder and Noury 2012, 2014). The planning is fundamental step in the management of SWI. It is the place where decisions are taken and actions are set among the different actors. The integration of the different actors and resources as an integrative planning requires and exchanges of their perceptions and a negotiation over the allocation of resources and the action to take. This has been thought and applied by a consortium of researcher in the approach for sustainable natural resource management called companion modelling or ComMOD. According to this approach participatory process which includes models could support a capitalization of the knowledge and information about the socio-ecological systems by the various actors over a determined issue. This capitalization would support their discussion and elaboration of a common perception of the complex system (both in natural and social aspects) which would allow them to elaborate common strategies (ComMod, 2005; Étienne, M., 2011).

4. Methodology

a. Participatory planning process

The research project focused on the design and simulation of a prototype of RPG (role play game). The production of this prototype aimed at setting up a more intensive participatory planning process at intermediate level for natural resource management. This participatory process will be based on the further development and use of this RPG tool with others social

learning tools (e.g. others games) in order to diversify the ways of thinking and confront intermediate and local levels participant's point of views in an active way. Through this longer time and careful development, the RPG model could be replicated and autonomously managed by the cross-level stakeholders. This would allow them to understand cross-scale complex issues and the communities to give their voice and discuss options proposed by the intermediate actors such as provincial and local technicians. This process is inspired from the use of RPG simulation for participatory planning in Ugandan and Ethiopian case studies within Afromaison project. RPG simulation coupled with others participatory tools had permit cross level actors such as communities' members or natural resources managers to understand their respective activities impact on the local complexity and supported the inclusion of the cross-scale actors in the planning process (Afromaison, 2014). These case studies and the overall methodology of the project are exposed in detail on <http://www.afromaison.net/>.

In Mabalane, decentralized institutions in charge of the local planning called Consultative Councils (CC) are distributed on three jurisdictional levels from the locality, the post to the district and gather a variability of public and private actors from these levels. Besides they are legally accountable for the local planning including infrastructures planning. Therefore, they could draw on and confront the interests and perspectives of the multi-level actors. Although for some authors, the consultative councils have been politically instrumentalized by the political elite narrowing society representativeness in the decision-making (Pereira, 2011, Farré, 2010); there are functional and "the closer form to democratic involvement in District management" (Ducrot, 2013; Tvedten, Paulo and Rosário, 2010). Thus, these institutions were selected to embed the RPG simulations.

In the evaluation of PRONASAR, Ducrot (2013) acknowledged the determinant role district technicians played in the nuanced outcomes of PRONASAR. She noticed that district technicians missed to communicate and consider local governance. During the implementation of the boreholes, they focused on the completion of the number of boreholes drilling as a chance to tackle water crisis in the District. Meanwhile they overlooked the local specificities and expectations, eroding the communities trust in them, which could challenge future coordination. A change in SWI development would require in the first place the district technician's awareness rising on integration issues. Therefore, they were involved all along the participatory process. Technicians were selected to participate in the co-construction (co-design, test and monitoring of the RPG sessions) of the RPG according to their differentiated knowledge on the district development and their likeliness to be interested in new methods.

The consultative council's members were integrated in the simulation process. This was done to support the representation of the local dynamics and make these local champions aware of their local complexity and its implication for SWIs planning.

b. Wat-a-Game

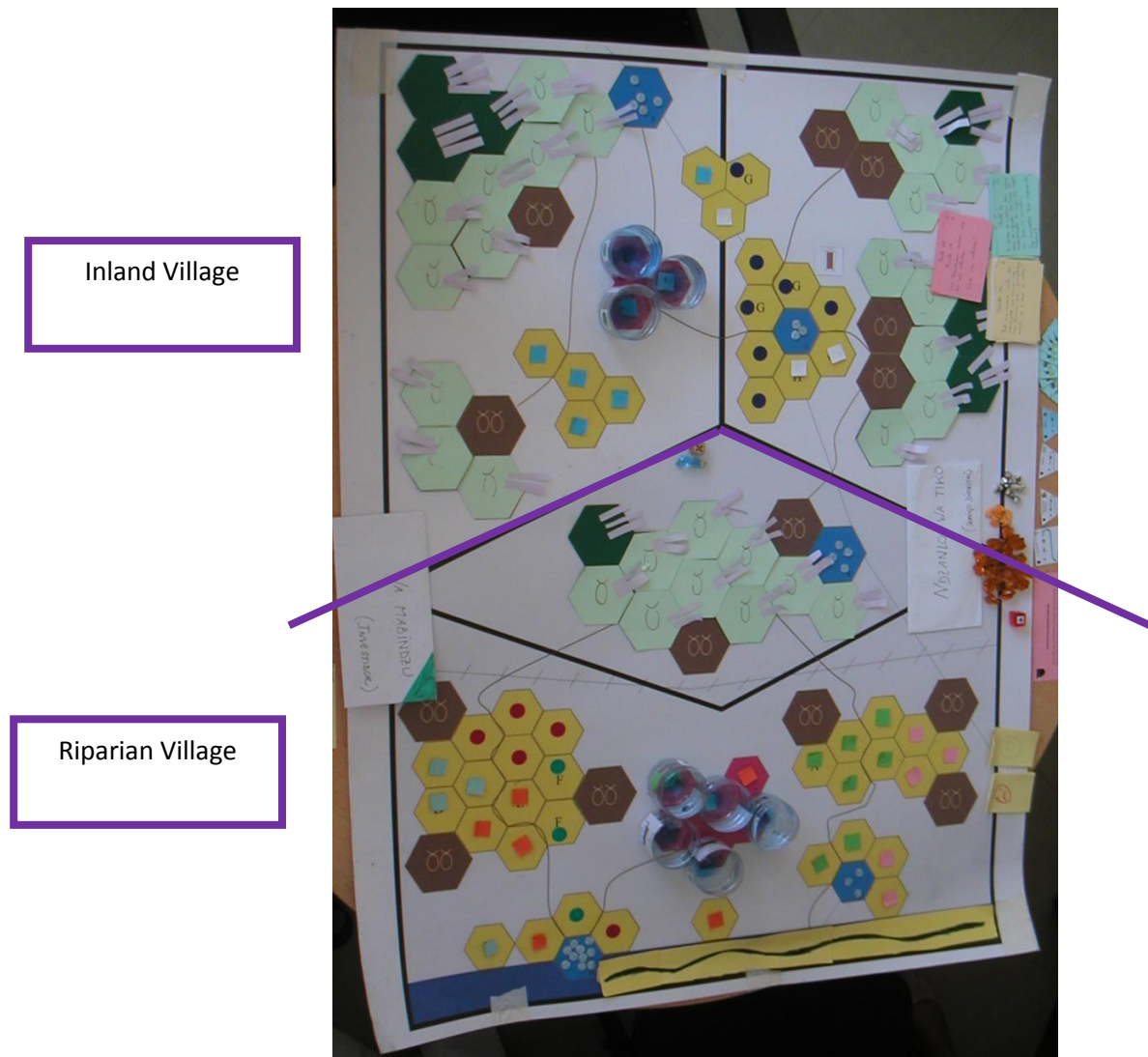
The participatory tool used to confront the diversity of actors perspective and knowledge on the system was a RPG based on Wat-a-game Toolkit.

“Wat-a-game is an open toolkit developed by ISTEA and CIRAD which enables participants to design and run simulations for water management, policy design and education. Wat-a-Game is an open toolkit developed by IRSTEa and CIRAD which enables participants to design and run simulations for water management, policy design and education. The basic version of the game aims to show how water moves within a landscape, how it is used, polluted, transformed and shared by actors. Using WAG, participants can simulate various actions or strategies and assess the resulting impact on their household economy, their wellbeing, labor, and the surrounding ecosystem.[...]The design of specific games using the WAG platform encapsulates a participatory situation analysis for the chosen ecological unit” (Afromaison 2014)

Following a comMod approach, the WAG paradigm insisted on the quality of the design and building of the RPG. By its adaptability to a large range of stakeholders and cases including various land and water management issues and scales; it made it an interesting tool to bridge knowledge and perspective from district and community actors. It capitalizes district technician’s knowledge and information of the district ecology and society in the design of the RPG and confronts indirectly their perspective to the CC member’s ones in the RPG simulations. Besides, the representation of the local social and ecological complexity in the RPG simulation using easy rules facilitate the emergence of an integrated knowledge of the system complexity by both type of actors and would lead perhaps to insights on SWIs planning.

The slow implementation and simulation process of the RPG unsuitable to test several scenarios in order to make the players aware of the long term natural resource impact. Instead, we focus on making explicit the interactions in play in the player’s socio-ecological systems and their implications for small water infrastructures planning.

c. *The RPG called “Mabulu kuyacana” (Let's talk development)*



The role play game had a time scale of a year (one run) and required 7 to 11 players. It represented local social and natural dynamics in a spatial interface considering the two distinct ecological zones of the District of Mabalane. Two villages' dynamics were represented. The “inland” village from the plateau areas was characterized by a temporal access to water source via small reservoirs; great forest areas and little density of households. The “riparian” village along the river had a continuous access to water through riverbed pools, was more densely populated and forest areas were lesser than pasture and fields.

During the simulation, preselected advisory councils members were invited to enact one role (farmer (FR), district services (DSR) or foreign investor (IR)) and use or regulate the natural resources (forest, rain water, from small reservoirs or alluvial resources, pasture and cattle) to achieve food security and/or generation of income. Each role play was done using simple rules and call out of the player's rationality.

The District services role (SDR) regroup all the services of the district. SDR mobilized one of the three technicians and money at his disposal to deliver public infrastructures with different outcomes and resource constraints such as school, hospital or SWIs to the villages and emits charcoal licenses. The SWIs are boreholes and reservoirs build with food-for-work schemes or with a digger (Ducrot, 2012). This mechanism was represented in the game by the allocation of labor force for the construction of the small reservoir in exchange of food units. These SWIs are called local SWIs since they are supposed to be financed by the SDR annual plan funding. They are opposed to external SWIs financed by donors or the province. the SDR would receive subsequently to a radio enouncement. External SWIs are motor-pump, reservoir or a borehole and distributed along with food or money.

The investor role (IR) represents Mozambican and to a lesser extends foreign investors. He had a car and two labor forces as well as enough money to engage into whatever activities he wishes notably cattle raising, irrigation and/or intensive charcoal making. The third role in the RPG was the farmer role (FR). It represented a village household. FR was located in a house and could perform the main livelihood activities of the District such as forest exploration, pluvial and irrigated agriculture, cattle rising and hunting in his private and community areas. Food security was the main objective of the farmer which depended on the number of family's members which is also his labor force. The five to seven players endorsed FR while there were only one for the SDR and IR.

d. Design and simulation of the RPG

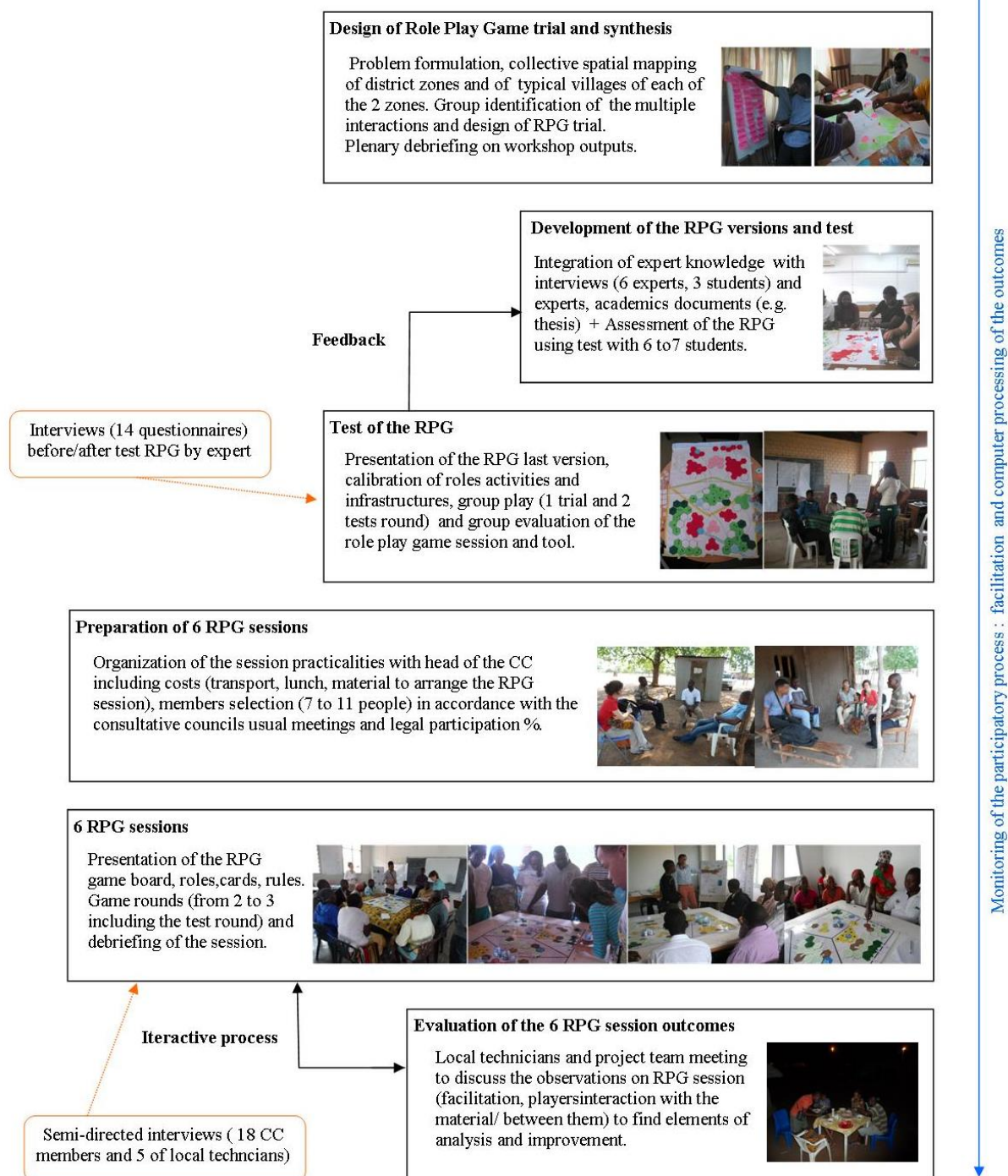
The International Center for Water Economics and Governance in Africa center (IWEGA) of FAEF/UEM in the Limpopo Basin development of the Challenge Water and Food Program team composed of the researcher Raphaëlle Ducrot and two master students Carla Monteiro and Chloé Legrand constituted the project team. They facilitated the design and simulation of the RPG as an interactive process. The IWEGA team co-designed, tested and simulated the RPG with a selected group of local informants who were in their majority Mabalane district technicians, the “technicians”.

The co-design phase started with a workshop in beginning of September 2013. During two days of workshop, the technicians identified the major socio-and ecological dynamics of the system using the Wat-a-Game methodology toolkit (Afromaison, 2014). Based on these elements; two master students researched, translated into simple rules the social and ecological dynamics to create a RPG and tested the playability of the model with students. In the end of October 2014, the technicians calibrated and tested the model in Mabalane. The OMEGA refined the model according to their new insights and feedbacks.

Consultative Councils members
Locality chefe, Posto chefe, leaders of the locality, leaders of the neighborhood, women, young people

Local Technicians
District services technicians and planning expert

The Project team
*IWEGA team
 2 translators*



Finally, with the approval of the District head representatives, a team composed of the OMEGA researchers, two translators and three technicians organized 6 RPG simulations between the 25/11/2014 and 09/12/2014. Four sessions were organized at a post level, 1 in the village of Mabomo (Mo); two in the town of Mabalane (Mb1, Mb2), 1 in the town of Combomune Posto (CbP). Two sessions were organized at a local level, respectively in Tsocate (Ts) and Combomune Rio (CbR). In each of the CC, seven to eleven of the CC members were selected according to the legal CC composition (40% of leaders, 30 % of

women and 20 % of young people) (Ducrot, 2012). The number of sessions was limited by the time of the project and the distances to cover. Thus, CCs at a Post level were privileged over locality level since by their constitutions they include already Local Consultative councils (LCC) members. RPG sessions were scheduled considering their time preparation and evaluation in the following order: Mo, Ts, Mb1, Mb2, CbR, CbP. The three technicians were in charge of the monitoring of the role play game sessions on a rotating basis apart for one of them.

e. A typical session

A RPG session was orchestrated as follows: the project team did a 30 min presentation of the game materials and rules before players would be invited for a test their understanding in a trial run. After handling the game, players were invited to perform two to three real game runs. Each run including the trial one would last in average 45 min. The trial run is a run that doesn't count. The RPG session ended with a 45 min debriefing. This phase allowed players to reflect on global dynamics and major events that had occurred during the game. Each RPG run had a predetermined sequencing. The project team acting as facilitators was first assigning players game roles and asks the FR of the inland and riparian villages to elect among them their respective leaders. After this preparation, players would enter in interaction or not to make their individual choices for the year to come according to their role objective, activities and resources. At the end of this phase, facilitators would give the outcomes of the player's activities as money of food gained or build the SWI planned. This phase is called the individual and collective run review. Finally, a virtual consultative council session (CCV) was autonomously set up by the players for 15 min. Just before the CCV ends, the facilitators would enounce weather forecast for the coming year and communicate as if they were the local radio, the arrival of provincial or donor's projects for local development. The weather forecasts were uncertain, varying between two of the four possible scenarios: humid, medium, dry and very dry. The nature of the development projects SWI or public goods was random but systematically done at the end of the each game run with the exception of the trial run.

f. Interviews and analyze

The data which has been used for this study was based on 14 open questionnaires made to evaluate the technicians learning before and after the test session as well as sessions resume merging the monitoring sheets of the technicians and the evaluation discussions. In addition 17 individual semi-directed interviews (3 from CbP; 3 from CbR; 1 Mb1; 3 Mb2; 3 Mo; 3 Ts and 6 technicians) had been analyzed to evaluate the final learning of technicians and Consultative Councils members. Time and coordination issue with local leaders had limited the number of interviews in Cb1.

5. Results: CC members awareness

a. The dynamic of decision-making

In every game session, the development of SWI during the period allocated for individual choices was undertaken by the District services role (SDR) without previously consulting the communities or their leaders. There were two exceptions to this behavior in Ts (Tsocate) and CbR (Combomune Rio) sessions, in which the government had financed SWI on the players' demand. He had respectively constructed a borehole to answer to the private need of a riparian farmer adjacent to his property or to co-finance a motor-pump with the investor in the inland village. The later co-financing was justified by the utility the water pump could have

for the community and the previous relations the investor had with the community members. Thus, the majority of the decisions concerning SWI implementation were taken with no consultation of the population either directly or via their leaders.

The other decision-making moment was the virtual Consultative Council (CC). An active participation of the players during the virtual Consultative councils (VCC) was observed in only 3 out of 6 game sessions. Among these three sessions, two levels of participation have been identified. Local SWIs, decided by the SDR, only generated consultation. Players made claims, expressed their needs in terms of SWI but did not take part in the planning of the latter. On the opposite, the radio announcement of external SWIs initiated a concertation about the allocation of such infrastructures.

As there were no external investments made during the Mabomo session, only local, SDR-led SWIs were discussed. Players made claims, which were taken into account by the SDR for the next round, with the allocation of a reservoir. Participation remained at a consultation level.

Whereas local SWIs have been subject to the same level of participation in the two sessions of Mabalane, discussions went further concerning the spatial allocation of external SWIs. In Mb1 (first session in Mabalane), “the advisory board, the players decided to allocate tillage equipment in the village close to the river, knowing that the coming year would be dry, the area suited more agricultural production than the other one. Meanwhile, the borehole or reservoir would be allocated in the inland village: the most sensitive area to water scarcity” (Mb1 session resume). In Mb2 motor-pumps allocation was similarly discussed during the virtual CC meeting. On the contrary to Mb1 session, in Mb2 session, the discussion had been monopolized by two players, local leaders in the real context, who had participated in Mb1 session.

No discussion upon SWI allocations occurred in the CC virtual meetings of the 3 others role play game (RPG) sessions. There were few discussions in the CCV apart from SWI allocation. In CbP and Ts sessions, players discussed about the over-exploration of the forest. In the case of CbP, inland villagers decided after the discussion to create a village reserve. In the others CCV, players wouldn’t discuss a lot. Their interaction was limited to the review of the FR’s activities outcomes and general advices by the SDR and leaders on their coming activities such as food production.

The virtual CC meetings offered dialogue spaces where occasionally the allocation of SWIs was discussed by the players. The dominant pattern of decision making sustained mainly individual strategies.

b. Individual and collective strategies

i. Individual strategies

1. Attached to public SWI

SDRs’ local strategies consisted in building SWI without taking into account local needs.

In Ts session, the SDR launched in a game run the construction of a reservoir with a “food-for-work” program following a virtual consultative council (CC); He also made available a water-pump for each village. After a first mobilization of the riparian villagers to construct the reservoir; they had rapidly neglected the construction to favor their individual strategies of irrigated agriculture. This shift was traduced in the game by a reallocation of the farmers labor force from the construction site to their private fields. As an answer of this demobilization, the

SDR allocated the food randomly to the villagers. In this case, the SDR's strategy was constrained by the individual strategies of the riparian FR.

In the second turn of Ts RPG, the SD had also allocated a borehole close to the railway and distant from any of the village.

2. Attached to private SWI

In every RPG sessions, individual players bought and managed individually motopumps for the irrigation of their fields. The management of private and subsidized motor-pump was the main challenge identified by the players. At least, in two third of the sessions, players had experienced a shortage of water and had needed to fall back on others livelihood strategies such as working for their neighbor (also called *ganho* in real life). Two players who experienced this issue thought of two different solutions for a hypothetical next round. One planned to reallocate his pump from inland temporary reservoir to the river where access to water is secured (box 1) The other wanted to continue in the next round to operate his motor-pump at the expense of selling animals if water fall short.planned tosell animals to sustain his family in case of water scarcity.

I: If there was another game run, what they would have done?

R: I would make sure not to have his household members be employed anymore

I: how would you do it?

R: I would go in the area where you have water and pasture and I would ask the people if I can put the motor-pump there (NM Mb1).

1

The virtual village chosen leaders also prioritized their individual strategies. Thus, in four out of the six sessions, leaders weren't engaged in the implementation of SWI. Either was the village/leaders left out by SDR and or the players dived into their individual farmer's role and "forgot" their leader's responsibilities.

The importance of individual strategies over others collective functions led in some occasions to the privatization of public resources. In the case of the CbR session, the distribution of the subsidized 5 food units and the money to both leaders from the inland and the riparian villages were differently handled. The inland leader kept the five units for him; and did not decide of a collective strategy for the allocation of the money. In fact the money stayed a while on the panel before being used by the villagers including the leader to upgrade their private homes. In the final interviews, SDR's perception of the leader's attitude nuanced his apparent individualistic behavior. He stated that the leader had kept the food in order to prevent potential food insecurity of the villagers.

R: he only remembers that one individual (speaking of the investor) asked money to the government to buy a pump for his own use.

I: The government accepted to lend some money to the investor?

R: the government helped the action because it was an action that would also help the community and that it was an "trusted/reliable" person(?) because in the population had gone to lend him money to buy goats, cows, money they could see it was a good person. (R1, CbR)

¹¹ R for respondent and I for interviewer

In some occasions, individual decisions supported collective strategies in the form of one-to-one interactions.

ii. Collective strategies

1. One-to one interactions

According to the participants, players were mainly involved in occasional one-to-one relations. Players were mostly engaged in negotiations among farmers. The interviewees mentioned likewise (3 times each) two types of negotiations. They are commercial exchanges of production infrastructures such as tillage equipment for money or labour and mutual help relationships. The mutual help varied from the exchange of labor force to work in the neighbor parcels in exchange of food an exchange form locally called “kukathekela” to the exchange of tillage services or “kurimela” against labour

“Throughout the game, she felt need to plough her fields. She resolved to go to her neighborhood and offered him to work in his field in exchange of his plough”(FR, Mo)

An interesting example of mobilization of “kukathekela” is when a farmer from the riparian village constructed a canal to bring water to its distant fields, giving some food to two workers from a poor farmer located in the inland village in exchange of their work.

The players also negotiated individually with a villager from the other village to access to its natural resources. Village leaders if prevailed, others players such as farmers and investors controlled natural resource access which differs from the real context. There were also on a lesser extent, relationships between investors and farmers; and government and farmers. Negotiations between farmer and the investor were based on strictly commercial exchange or relations: the investor for example would finances farmer’s productive assets such as small water infrastructures in exchange of labor force or money. The RPG incentivized IR in comparison to the reality to hire local labor force since he had only three employees and his activities were labor intensive. Even though the labour forces negotiations between FR and between FR and IR were limited showing the local reluctance to work in others players estate:

R: They couldn’t do any activities so they were forced to work for other people

C: If there was another game run, what they would have done?

R: I would make sure not to have his household members be employed anymore” (farmer facing the lost of his crops, Mb1)

In the majority of the cases, it appears that the IR was accessing to forest or water ressources without preliminary negotiations with the communities leaders. IR would rather enter in coordination SDR after FR in order to acquire licences for forest exploration and enter in coordination with SDR punctually (cf Box).

R: he only remembers that one individual (speaking of the investor) asked money to the government to buy a pump for his own use.

I: The government accepted to lend some money to the investor?

R: the government helped the action because it was an action that would also help the community and that it was an “trusted/reliable” person(?) because in the population had gone to lend him money to buy goats, cows, money they could see it was a good person. (FR, CbR)

2. Associations and partnerships

Players more rarely gathered in farmers associations or committed to occasional partnerships. For example, four interviewees referred to the creation of association of farmers during sessions, three of them aiming at collectively manage a motor-pump. The association members shared both costs and revenues from the irrigated scheme at the reception of the motor-pump

In one case, the association resulted from a leader decision which led the villagers to engage in a collective scheme

In the RPG of CbR, three farmers from the riparian village performed most of their activities within their association. The leader of this village had taken the initiative of its creation after receiving from the SDR 2 motor-pumps at the end of the first round. He created the association with two others sharing the access to the same river pool with him while the two others from the same village who had access to another pool managed individually their farming activities, one taking in charge the operating cost of the motor-pump. The leader of the association had later also received from the SD 5 units of food for the village and decided to aggregate it to his association harvest. He also decided to invest external financing transferred by the SDR in the construction of a canal to irrigate further fields and increase the capacity of the small river pool where the motor-pump was irrigating from. The two women of the association individually engaged in a specific mutual help relationship based on informal exchanges called “Matsoni”. Their interactions went beyond the share of operational cost of the motor-pump and harvest with the other association member (the leader here). Both women had put in common their resources and shared livelihood strategies. The women cultivated irrigated crops in the associations and put in common their cattle resources to graze. Besides, they had performed also individual strategies. One had for example focused on constructing a house in brick.

The two other associations described by the interviewees in Ts and Mb1, which hadn't been noticed by the facilitation team, were private affairs between two (or more farmers).

. They considered it as an OIIL loan. The interviewees considered it as an important strategy to secure their food security and access to water.. In this session, players had adopted collective livelihood strategies.

The collective strategies supported in some case monetary exchange to foster and maintain access to the water resource. In Mb1, after the consultation of the CCV the riparian leader proposed to establish a regular fee to maintain the borehole as in reality. In the CbR session, one villager from the riparian zone lacks one water unit for household consumption. To secure it, he first borrowed money to his association to pay, the Investor Role IR, the cost of

translocation to the inland village where a borehole had good water. He then entered in negotiation with the three inland villagers to access to their borehole. Even though the individual strategies were dominant, the RPG sessions had offered the place for significant collective strategies in the form of farmers associations to manage motor-pumps and partnerships and the formulation of innovative rules for SWI management (e.g taxes).

c. Debriefing and learning

They were very little reclamations during the virtual consultative council's sessions about SWI allocation. Nevertheless, a debate emerged around these issues in two debriefings. In one case a reservoir and a borehole had been allocated in the inland village while none had been distributed to the riparian village. The debate was soon dominated by reclamations over SWIs allocation.

“Three players (two FR and the IR) told the allocation was wrong. The SDR agreed saying that it wasn't the norm. Their argumentation let think the leader from the dispossessed village was weak and didn't communicate the needs of his population to the government. A FR was also in favor of allocating the small reservoir in the riparian village since the boreholes situated in this area have salted water” (summary, CbR).

After the session, the players from both Ts and CbR concord to identify the leaders as main actor to improve the SWI implementation. According to three of them, *“the state before starting a public work has first to talk to leaders”* (or CCL). *“The leaders are the one to give directives on where and how the job should be done”* (FR CbP). This dominant perspective was nuanced by another FR perspective in CbP. According to him, the SDR misunderstood the RPG rules and materiality which led him to a controversial allocation.

The interviewees said their main learning from the game was to test and formulate new strategies as farmers. There are some nuances among the players regarding this learning. Some of them learned to plan, by anticipating and allocating a set of resources needed to perform some of their farming activities while others focused on innovative farming infrastructures such as motor-pumps, plough and chainsaw (ref table 1).

Learning	Test and formulate FR strategies				others
	Plan individual strategies	Test farming infrastructures	Interact with other players	The game experimentation	
CC members (nb)	6	3	3	3	2

table 1: Distribution of the learning of CC members

They would sell in the game session cattle or borrow money to buy these infrastructures.

I: Did you learn something new in the game?

R: I learned how to borrow a motor-pump, to use it until the end of the game or to return the money; and if I didn't have enough money to operate it, I learned to sell a goat, or an ox to make the payment. (SG, Mo)

While testing, players observed the dependence of the SWI to water dynamic and spatial heterogeneity. For example, they mentioned how important is a constant volume of water for the motopump or the dependence of the boreholes functioning to the groundwater quantity

and quality. One of the interviewee mentioned the relationships between infrastructure development and natural resources preservation a motor-pump could decrease the pressure on forest exploration by permitting agricultural activity all year round through irrigation

R: [...]the charcoal production finishes the forest but it only happens when you cut the tree very low close to the level of the person, but if the tree is cut at an average height, height of the bike over her, (the tree)has a possibility to sprout. We may need to incentivize agricultural activity to preserve it.

I: Do you think it is possible to encourage agriculture to preserve forest here?

R: The solution according to him is to lend some money to the government in order to have a motor pump to pull water from the river up to the farm (SG Mo)

Three players stated that the game had made them think about the importance of negotiation and resources exchange to sustain FR individual strategies. Finally three others insisted on their experimental learning using scenarios and individual balance to evaluate, test and ameliorate these strategies. This concept is described more exhaustively in (Ducrot, Van Paassen et al., 2014^b).

Only four players out of the 17 interviewees played the role of the investor or the SD. None of these four players mentioned any learning while playing these roles. Other players rarely mentioned any learning made by the SD or investor, except when talking about a specific case of infrastructure mismanagement that would have been rectified on the next round: “I believe that the borehole that was placed on railway line, if we had had another run, wouldn’t have been placed there, even the government activities would be different. We understood something new every time the game was repeating itself” (pro Ts).

One Ts session player who is the secretary of LCC in Tsocate transposed his learning from the RPG to Tsocate reality. According to him, the RPG session made him aware of the reduce participation of Tsocate LCC in the real planning of small water infrastructures: “*We were discussing issues in the virtual CC but we weren’t searching for solutions. This is also what we miss in our consultative councils*” (talking about LCC of Tsocate) (pro Ts). He identified two means to overcome this gap. The first element was the increase of the CCL awareness and capacity to propose small water infrastructures and the second was the strengthening the existing mechanisms from which the locality communicates with upper administrative levels or “*forward questions to the rightful*”. The two mechanisms, he referred to were the consultative councils or the open governance meeting (visit of the administrators or higher level politicians to village and district).

6. Results: technicians awareness

a. Learning from the participatory process for the CC members

They recognized the difficulty for players to understand the game at first. And that some of them would more easily recognize the tools of the game and rules of the representation of their reality than others. The board did not allow for an easy perception of the virtual world. But they acknowledged that after the first round, the players would project themselves in their role and situation and bring their reality into the game.

According to the technicians who monitored the RPG’s sessions scenarios allow the players to test the environment and social response to their livelihood strategies and/or management of the natural resource. Through feedback loop of their activities, the farmers could “bet” on

productive infrastructure such as motor-pump.. The three technicians go further along in the interpretation of the game learning, clearly saying that through this process and because the faithful and wide representation of the reality, they believe the players could apply this learning in their day to day routine. This learning akin to experimental learning. They thus assessed the tool as able to support the self-capacitating of the inhabitants to formulate better livelihood strategies or their accountability toward a sustainable resource management in the context of Mabalane. Finally four out of the six technicians underlined the importance of interactions and exchange among players. Two interviewees insisted that the game had revealed the importance of mutual help relationship between players as livelihood strategies. The two others rather observed monetary exchanges such as trade of resources or infrastructures (e.g. plough) and job creation between players.

b. Learning from the Participatory process for themselves

During the participatory process, the technicians learning didn't follow the same evolution. Therefore, a typology was made to differentiate them (table 2).

Type	A	B	C	D
Number of technicians	2	2	2	1

table 2: technicians learning typology

Two players A had a very distinct point of view since the beginning and maintain it all along: they had observed the need of local knowledge integration for a better natural resource management since the design workshop. After this exercise, both integrated others actors perspective in the planning of their professional activities.

“After the workshop in September I met with colleagues from the department to tell them of the importance of planning the daily, weekly and Monthly work and coordinate with other departments. I have promoted a lecture of 1hour/day for all workers in the park on the following themes: biodiversity, natural resources, climatic change, communication and mission, vision and objectives of the Park and its benefit to the communities living in it”. (Technician A)

Two other technicians (B) came to the same conclusions as the A participants, but only after the game test session. Both type of technicians (A and B) associated the planning in the game to a planning in their reality that should include colleagues or the local communities.

“Planning in the game was ok. The SDR did ok. In the game as in reality the players were waiting for the public service campaign to finish. During the game session, players were waiting for the construction of the hospital. They were complaining only in the next round of the game if it (the infrastructures) hadn't been constructed. There should be person such as a fiscal agent tax who could control the process of implementation, to see if it is done as planned”. (Technician B)

One technician (D) observed FR livelihood strategies which made him think of the need to increase inter-district services coordination. Unlike B technicians, the D type professional transposed RPG interactions to the District reality at the end of the process, when he was being interviewed.

D: [...] Government is accountable for transport delivery to bring extension services to the community. When we (the technicians of the agriculture district service) stay here with the seed too long, they become out of date. It is the same when we receive vaccines and can't dislocate in time to the communities, the vaccine becomes out of date. These aspects should improve [...]

C: how can be improved these difficulties?

D: We need to collaborate, an intra-institutional collaboration. I do not have transportation here but I have seeds, I'll talk to the government. I have to give the seed to the people, there in the bush but I lack of transportation. If the government gives me the transport, I can carry the seed and give them to the population. There should always be coordination between the government, communities and others institutions.

C: How did you come to have this idea during the test?

D: I found very important in the game that there was the investor at the game table since I could borrow him some money when I was in difficulty, there was also the government from which I could ask the value of 7 million to invest in agriculture. So for me, it's was like a family, a group of people who I could work with. (Technician D)

The two others (C) kept on considering from the beginning to the end of the participatory process, the RPG as a tool for the players learning alone.

The RPG monitoring supported the development of new insights by the technicians of the type A and B. For example, one type B technician observed correspondence between the lack of implication of local communities in the development of infrastructures (SWIs and non-SWIs) and in the real context. Therefore, he proposed the creation of a new actor -a fiscal agent -who would have the responsibility to monitor infrastructures development on behalf of the Local Consultative council. Another technician (type A) confirmed through the simulation, his belief that CC members were able to choose, and prioritize non-SWIs infrastructures in a rational and informed way. He proposed a bottom up participatory process in which each council starting from the CCL to the CCD would select three types of non-SWIs infrastructures. But both of the technicians weren't considering SWIs because they are not perceived as planned at the District level.

The D technician stated that inter-organizational coordination to provide public services such as seeds and vaccines was lacking in the real context. This was made obvious by the possibility that the simulation offer for players to coordinate.

The C technician who monitored the RPG sessions considered he hadn't learned much as participant to the co-construction of the model and the monitoring of its simulations. He considered that the RPG had only aimed to teach CC members. He added that the lack of representativeness of his own activities (the SDR activities) had constrains his personal learning.

I: Do you think you can put in the practice of your profession any learning?

R: lets me think of it, I don't in how I can relate the exercise we did with my practice. The water sector wasn't represented much in the game; the game didn't involve much the community. Who was in charge of allocating the boreholes in the village was the SD. He did without the full consent of the villagers, without knowing if the village wanted a borehole or not. [...]. The fact that there wasn't a direct relations between the communities and the water infrastructures didn't allow me learn things in the water sector.

(Technician C)

7. An individual stance on local complexity

FR, IR and SDR undertook a variability of individual activities using different sets of resources. The players got aware of the resources' distribution among players and sometimes entered in one-to-one relations with others to exchange their natural resources, non-natural resources or infrastructures to foster their individual goals. In these exchanges the players kept a narrow perception of the system's complexity in the sense that they acknowledge only direct interactions between the systems socio-ecological elements. For example, many got aware of the dependence motor-pumps had with the uncertain water dynamics and hydrogeology of their village. Similarly they noticed the income generation these new infrastructure could provide. Though, few observed the indirect impact motor-pump had on other natural resources dynamics such as forest management. The same narrowing down characterized their relationships. They engaged in one-to-one interactions as a punctual exchange of resource with another player. Besides they rarely considered other roles in their interactions.

This perception is confirmed by player's post-session interviews. On one hand, it seems that by not integrating the others roles in their individual strategies they also didn't considered these roles as opportunities to learn the SD and investor activities. Indifferently from their role the majority of the interviewees said they had learned to test and formulate FR strategies from the simulations. On the other hand, many of them stated that they hadn't acknowledged activities from other players in their village and the opposite village up to the debriefing phase at the end of the RPG. CCV, which had been set to emphasize exchange of perspectives on the game play at the end of each round, had been overlooked. In the CCV, some players expressed some of their livelihood difficulties, others gave advices but the CCV wasn't the place of intensive discussions. The exchange of player's perspectives and information about the system for SWI allocation or Natural Resources Management (NRM) had happened in only three CCVs.

To conclude, in a test stand alone session system complexity was perceived in terms of plurality and uncertainty of natural dynamics by the farmers. The farmers used this learning to undertake individual adaptive planning. They focused on elementary interactions in the system rather than on global ecological and social dynamics. This focus didn't prevent them to engage in resource exchange or coordinate their planning with others players. But these interactions were mainly one-to-one and occasional to support their respective livelihood strategies. Thus, in this pilot session when they discovered the tool, they didn't take advantage of the emergence properties of the socio-ecological system when implementing and managing SWI. This point was confirmed by the technician's analysis of player's learning from the game. Nevertheless, the research as an introduction to complex thinking, their understanding of the plurality in the system and the elementary interactions is promising result for their participation to further RPG sessions within the up-coming participatory planning project.

8. A partial understanding of the multi-governance complexity

The players observed the importance of the SD and leaders coordination in the adaption of new SWI to the local context. They identified the community leaders as key actors to communicate on the village needs and specificities and missed his integration by the SDR in the planning of SWI. The implication of the village leaders in the management of motor-pump was also important despite their exceptional occurrence. From the CbR session, the riparian leader had supported an active collective management of a motor-pump by creating a farmers association in the first place and allocating public aids to secure the reliability of water

delivery and the food security of its members. In others irrigation associations where the motorpump was privately owned, the leaders were not involved, as in reality. What is observed in these associations is that the individual management dominated the collective management of the motor-pump after the first round so that it seemed to the facilitators that there weren't any. The central place leaders in Mabalane have in assuring collective action to sustain SWI had already been noticed in PRONASAR evaluation (Ducrot, 2014^a)

Discussions and reflection upon the allocation of SWIs by the players rarely took place in the RPG. The CCV were the place where FR made their demand known and the SDR and IR took decision. The little use of CCV to confront perspectives on the best SWI pictures what happens in the reality (Ducrot, 2012). The CCV in comparison to the CC in the reality gathered cross-scale and actors such as IR, SDR and FR at a same table for discussing with some collective radio enouncements. Nevertheless the relative short time of discussion (0 to 15 min) and the novelty of the exercise may have limited potential negotiations among them. This dominant perspective was nuanced by one of the member of Ts presidency who thought to enhance discussions and decision-making on SWIs in the Ts LCC by raising CCL member's awareness and strengthen integration of their perspectives in the planning process

His awareness of CC potentialities to acknowledge local specificities and include local actors in the infrastructure planning was shared by the two third of the technicians.

The technicians (technicians A and B) got insights to integrate local actors' perceptions in order to improve the allocation of district infrastructures. One considered strengthening the decision-making within the CC while the other opted for the provision of a technician who would specially work on behalf of the CCL. The other technicians did consider the importance of the coordination between the leaders and the SD, saying that SD hadn't properly considered local needs in the RPG issues. Nevertheless they blame the game materiality rather than transpose these issues to their professional context. It is difficult to assess of their difference in the learning process comes their difficulty to extrapolate from the RPG interactions any relevance for the district planning or others constrains. According to Ajzen (1991); the normative perception of planning hold by the technicians and their feeling of self capacity contribute to their overall perception on planning.

9. Discussion and conclusion

a. Evaluation of the participatory process

The level of understanding of the technicians didn't depend on their level of participation. The three technicians who had been invited to monitor the RPG sessions had already formed their opinion on integrative planning after the RPG sessions. Monitoring the RPG sessions has only confirmed their learning and allows them to elaborate insights using practical references from the RPG. However, the participatory process influenced their understanding of the system. Indeed, two technicians established their perspective, learning after the phase of co-design (type A) and others had change their perception on learning after the test phase of the participatory process (type B) or remembering the game test (technician D). It seems that the phases of co-design and testing have been more important for the technicians learning that the simulation phases. .

To conclude, the participatory process brought new meaningful insights to the technicians. Two third consider the need to integrate local actors and the district services in a more participatory planning.

b. Evaluation of the RPG simulation

The design of the RPG has influenced the session's outcomes. I refer here to the unfamiliar materiality of the game for the players and the accumulations of functions for some roles such as the village leader. Players focused on the game materiality and their role's objectives and activities rather than interacting with each other and looking at other players' activities. On the other hand, players were able to bring their reality to the RPG play. They interpreted with the help of the facilitator team their game activities and felt some ownership for their actions. They introduced local norms such as water taxes, asked for new infrastructures in the game like small irrigation systems and reproduced real collective interactions including mutual help relationships and farmers associations. The realism of the game was nuanced by a little emphasis on money exchange and trade. The comments of the players reveal the economical orientation of the game that can be due to the simplification. The players state that in the game they were selling cattle to pay food and invest in infrastructure as plows and motor-pumps. The players considered it as a new strategy since in the real Mabalane context, selling cattle is less usual. This result shows the limits of the game and its ability to represent some cultural and social factors that also determine the choice of activities in real life.

Finally three others insisted on their experimental learning using scenarios and individual balance to evaluate, test and ameliorate these strategies

Besides, the technicians and players agreed on identifying experimental learning using scenarios and individual balance to evaluate, test and ameliorate individual strategies as important aspects of the RPG tool. They value this experimentation for players to learn how to adapt their individual livelihood strategies to a dynamic context. Nevertheless, the low number of RPG rounds failed to make the players draw on the emergence properties of the socio-ecological system. The limited number of rounds made difficult for the players, as a first introduction, to understand global dynamics such as deforestation or food security and how SWI implementation and management is related to them.

In return, the objective of the research was to introduce a new participatory tool with key local actors and made them reflect on local complexity and its implication for SWI planning. It wasn't expected from this participatory process any changes of behavior among the participants. The results are quite appealing for the continuation of the participatory planning process. In fact, players had got aware of a plurality of resources and actors involved at a local level and could identify their interactions. Moreover, this pilot co-construction and simulation process permitted players who could easily extrapolate from the RPG representation and the great majority of the technicians to reflect on the interest of integrative planning. In the continuation of the participatory planning process, the players and technicians will be involved in a second round of simulations aiming at brainstorming on local issues related to SWI and natural resource management. This phase will precede the construction of strategies to tackle the issue; their plan and finally their test of these strategies using participatory and learning tool such as the RPG.

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