PARTICIPATORY SIMULATION TO RAISE AWARENESS ABOUT INTEGRATIVE PLANNING FOR SMALL WATER INFRASTRUCTURES AND DROUGHT CONTROL IN SEMI-ARID MOZAMBIQUE

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Preface and Acknowledgement

From August until December 2013 I worked for the International Center for Water Economics and Governance in Africa (IWEGA) at the FAEF (Faculty of Agriculture and Forest Engineering) at Eduardo Mondlane University (UEM) in Mozambique. As part of the field work for my MSc thesis at the Knowledge Technology & Innovation Group of Wageningen University, I carried out research collecting information from a process trial inspired by the Companion modeling approach to start a participatory planning project for sustainable natural resource management in a semi-arid district of Mozambique. The role playing game to co-design, play and analyze was my interest: together with another master's student from the FAEF-UEM and a researcher, we created a trial participatory process and a role playing game in the semi-arid district of Mabalane. The researcher is from IWEGA and a French research unit specializing in water resources (UMR-Geau) from the International Research Center on Agricultural and Development issues (CIRAD). This research was funded by the Challenge Water and Food Program (CWFP) of IWEGA.

I learned a lot developing a ComMod approach in Mozambique and interacted well with our team and the professionals from UEM. Thus I would like to thank all the people who helped me conduct this research. First place, I would like to thank my two supervisors Annemarie Van Paassen and Raphaëlle Ducrot for their constant guidance and support during this research process. I also thank Raphaëlle Ducrot for her research proposition, the opportunities she gave me to elaborate academic materials coming out of this report and presenting for me our research results, despite unfortunate events, in the 15th Waternet symposium organized in Lilongwe, Malawi, from October 29th through 31st in 2014. Second place, I would like to thank Carla Monteiro for her support and insights during the design and implementation of the role playing game. Our cohabitation was cheerful, and it helped me to grasp Mozambican history and culture. In addition, I would like to thank all the technicians who helped us organize the participatory process in Mabalane: Pitrosse Manuel Valoi from the department of the administrative secretary, and Edgar Samuel Machacha and Rafael Macuácua from district services. I would also like to thank the two students from FAEF-UEM who worked as translators during the role playing game sessions and who shared with us their impressions of the participatory process: Emanuel Malai and Lacião Titosse Bango and to a larger extent thank all the participants of the workshops, the district head office and the FAEF staff without whom we wouldn't have been able to organize and conduct this research. Finally, I would like to thank my family and particularly my cousin Mathilde for their feedback and support during the analysis and writing of this thesis.

In this report, I will present and explain the trial participatory process we put in place and try to analyze its outcomes to highlight the first results it generated among its participants. I will also give some recommendations on the role playing game and the participatory process for the continuation of the project and to improve awareness raising on integrative planning for future similar research. Knowing that some of the participants are interested in moving forward, I hope these results will help out to design and implement a more fitting companion modelling approach,.

Abstract

In semi-arid areas where water is scarce and constraints on natural resources often limit rural livelihood opportunities, Small Water Infrastructures (SWI) are essential to local development. However, different studies evaluating the program and PRONASAR SWIs Mabalane, Mozambique, have shown that the hierarchical culture that prevails in their implementation and management does not take into account the diversity and complexity of interactions between actors' strategies and natural resources and that it leads to an inequitable distribution of infrastructure. In addition, the sustainable and equitable management of natural resources is not considered an important element in the management of these structures, which jeopardizes the long-term livelihood strategies of beneficiaries and the ecological balance of the region. Thus, the planning of SWI development requires scientific attention, as does the classical and unresolved issue of SWI's long-term sustainability. This paper argues that a participatory modeling and simulation approach helps local actors to better understand the interaction between resources and actor strategies, an understanding that, in time, could contribute to an integrative planning process. It draws on a companion modeling approach using the "Wat-A-Game" tool kit. The results of our pilot study show that the participants were able to acknowledge the local complexity associated with their livelihood strategies. In addition, some participants who were 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

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1. Introduction

Soon after colonization, many African countries adopted a centralized form of development in which the state was considered the provider of all development services. The end of the Cold War's opposition to the leading USSR and US bastions in Africa also ended the omnipotence of centralized governments in Africa. Local administrations, which were weakened by the long-standing centralization policies, emerged and could not provide local development. Therefore, in favor of the African government economies' liberalization, development in rural areas was provided by non-profit organizations and donor-funded international NGOs working directly with the communities (Bank of Mozambique, 2008).

At the same time, donors promoted national reforms toward decentralization as a model of good governance. By providing local government with increased authority and autonomy, donors fostered better consideration of local specificities and needs. Thus, since the beginning of the 21st century, local governments have gained a number of responsibilities and resources, such as responsibility for planning and local development budgeting. This was concretized by the creation of public services aligned with each ministry at a local level, as well as decentralized planning programs (Bank of Mozambique, 2008).

The access to water via small water infrastructures in South-Saharan countries has been central to all development policies, particularly in semi-arid areas. It has been shaped by the development paradigm. Similarly to other development policies, NGOs first worked directly with local communities before working with national governments, in partnership with donors, through decentralized planning institutions(AMCOW & WSP, 2010). Due to restricted access to material and technical or financial resources, community management was limited in the maintenance of small water infrastructures (SWI) (Moriarty, Butterworth, & Franceys, 2013). Moreover, community-level focus on definite water related projects overshadowed both community coordination at the district level and interdependent natural resources for SWI management.

In the last decade, with the strengthening of local-level decentralized planning, donors have aimed to enhance the role of civil servants, along with the communities, in providing water access (AMCOW & WSP, 2010; Bank of Mozambique, 2008). With this approach, communities would manage the SWI but be held accountable with regulations enforced by the local district-level government, which would also provide them with financial and technical support(Dill, 2009; Lockwood & Smits, 2011; Moriarty et al., 2013). This ensured the spatial homogeneity and sustainability of SWI management. Along with this new approach to water services, the donors invested in state development budgets or programs rather than external organizations such as NGOs.

In Mozambique, where this research was conducted, the donors form an aid partnership program creating a common fund for development and harmonizing their activities in order to avoid, as stated in the "Paris Declaration on aid effectiveness", the fragmentation of financing in definite sectors and the ensuing bureaucracy (OECD, 2005). In the water sector, the first

initiative of this kind was under a program called PRONASAR. But this program did not bring the expected results. In one of her papers, Ducrot demonstrates PRONASAR's inability to reach both its direct objectives (water supply coverage in an equitable and sustainable manner and capacity building in the WASH sector) and its indirect objectives (strengthening local institutions) in Mabalane (Ducrot & Bourblanc, 2014).

Mabalane is a semi-arid district located in the upper-Limpopo river basin of Mozambique. It is characterized by a strong interdependence in terms of natural resources. Due to water scarcity, Mabalane's inhabitants depend on many other natural resources for their livelihood. Because agriculture cannot be their only source of income, Mabalane's inhabitants must rely on an assortment of other natural resources such as wood, cattle, fruit collection, or fish. The lack of access to water critically limits their dependence on natural resources that have a long renewal time. Therefore, funding for SWI had been identified by the Mozambican government as one of the driving forces behind the district's development.

In Mabalane, PRONASAR reached its objective of providing access to boreholes but this did not offer more water access for poor people than many NGO projects. According to Ducrot, this was due to the centralization of the decision-making process (including planning) at the provincial level under a hierarchical culture and a consequent overlooking of the local actors' relationships in this challenging environment(Ducrot & Bourblanc, 2014).

The analysis of PRONASAR's program in Mabalane has underlined the fact that the reform and defunding of decentralization worldwide toward an ideal of good governance did not consider local complexities. It overlooked ecological complexities as well as the inherited hierarchical and top-down culture of this district that, ultimately, weakened efforts to improve water access. Some authors (AMCOW & WSP, 2010)still argue for the reinforcement of decentralization by strengthening the civil servant and civil society separately as "one set of people getting another set of people to behave better" for "good governance"(Booth, 2012). Other researchers advocate the need to go beyond the current development paradigm, which they consider unachievable, and to gradually develop local governance within the context's specificities (Booth, 2011; Dill, 2009; Grindle, 2004; Levy, 2011). For them, present-day solutions to local issues of water access could be achieved with collective measures taken by local actors, while taking their respective interests, the local culture, and the interdependency of natural resources into consideration(Booth, 2012).

These challenges can be met by integrative planning that considers natural resources as a whole as well as the interests of different stakeholders in the current decentralized institutions. These local institutions, also called consultative councils, act as meeting places for development planning by local multi-level planning actors. They are functional, legitimatized at a local level, and gather the local elite and district technicians whose interests govern local public service. They are also key actors for change toward more integrative planning. According to Booth "the public good will be better served when it becomes of interest to the political leadership to impose limits on socially destructive behavior, and worse when any such limitations (e.g. 'zero tolerance of corruption') are promoted independently of elite interest calculations (e.g. as donor conditionality)"(Booth, 2011). Furthermore, even though

the planning is oriented toward personal interests, the local elite have taken civil society interests into account when considering vital issues. Ducrot states that "villagers could accept compromise concerning public good or as essential issues like water access. An arena gathering politicians, technicians and civil society represented by local elites can be the place where these different notions of equities discussed so that compromise and acceptable solutions to allocate sparse resources can be found"(Ducrot, 2013).Capitalizing on local knowledge to show the consequences of prejudicial behavior on the livelihood of the poor in a complex environment may change the elite's view of planning.

To guide the stakeholders toward a more integrated form of planning, we use a participatory model and simulation inspired by the companion modeling approach (ComMod). ComMod is an approach developed in the field of renewable resource management. It assumes that a broad range of multi-level stakeholders, such as farmers, technicians and politicians, perform different tasks but all manage the natural resources. Therefore, sustainable natural resource management depends on consensus and collective action. In order to support the identification of collective actions and assure the commitment of all actors, ComMod researchers have developed methods and participatory modeling tools (ComMod, 2013). These methods and tools facilitate the integration of different stakeholders' system knowledge and the exchange of underlying norms and values. ComMod's objectives are: understanding collective action and facilitating its implementation using planning methods. Researchers identified the first step in this participatory process as the need to make different stakeholders aware of the complexity of local socio-ecological dynamics, creating a diagnosis of the situation. For this purpose, a group of researchers developed a methodology called Wat-a-Game that works with local actors to construct a paper model representing the social and ecological dynamic of their reality.

Using this methodology, this action research aims at helping actors in charge of the local planning; such as district technicians and consultative council members; understand the local interactions between resources and actor's strategies. By raising awareness of complexity, the research fosters the district technicians' understanding of the need to integrate different people's knowledge to develop a rich picture of complex socio-ecological dynamics, thereby allowing the formulation of a locally applicable service system for sustainable development.

My personal action research component will help determine whether technicians and consultative council members really understand local complexities, and whether this understanding led them to reflect on the integrative planning process. Since these groups did not have the same involvement in the process, different reflection levels were expected from each group. The district technicians were expected to easily form an opinion on the planning process for improving the sustainability and equitability of water services.

2. Context of the study

2.1 Geographical context

The district of Mabalane is located in the agro-climatic region of the upper-Limpopo River (Mozambique)(Ducrot, 2011). This region, situated between Chokwe in Mozambique and the Zimbabwe border, is a semi-arid place characterized by a temperature shift from 19°C in the dry season to 28°C in the rainy season and an annual precipitation under 600mm. The flow of the Limpopo branch in this zone is not regulated by an upstream dam. Consequently, the flow is irregular and interrupted during the dry season. The population's access to water is uneven and threatened by extreme climatic events. The risk of flood and drought is high. For example, a drought occurs 7 years out of every 10 and can be extreme in half of the cases. During the 2 or 3 years considered 'good', flood often takes place (Ducrot, 2011). These droughts and floods contribute heavily to food insecurity in the district.

Mabalane has an estimated total land area of 9,100 km². It has a plateau relief that increases its sensitivity to droughts. The salinity and depth of underground water limit its use for mitigating droughts. However, the relative altitude of the district and the average river flow contribute to the resilience of Mabalane in floods. Medium floods such as the 2013 one can have a positive impact on agricultural production, since these soak the river banks, securing water provision for the entire crop season.

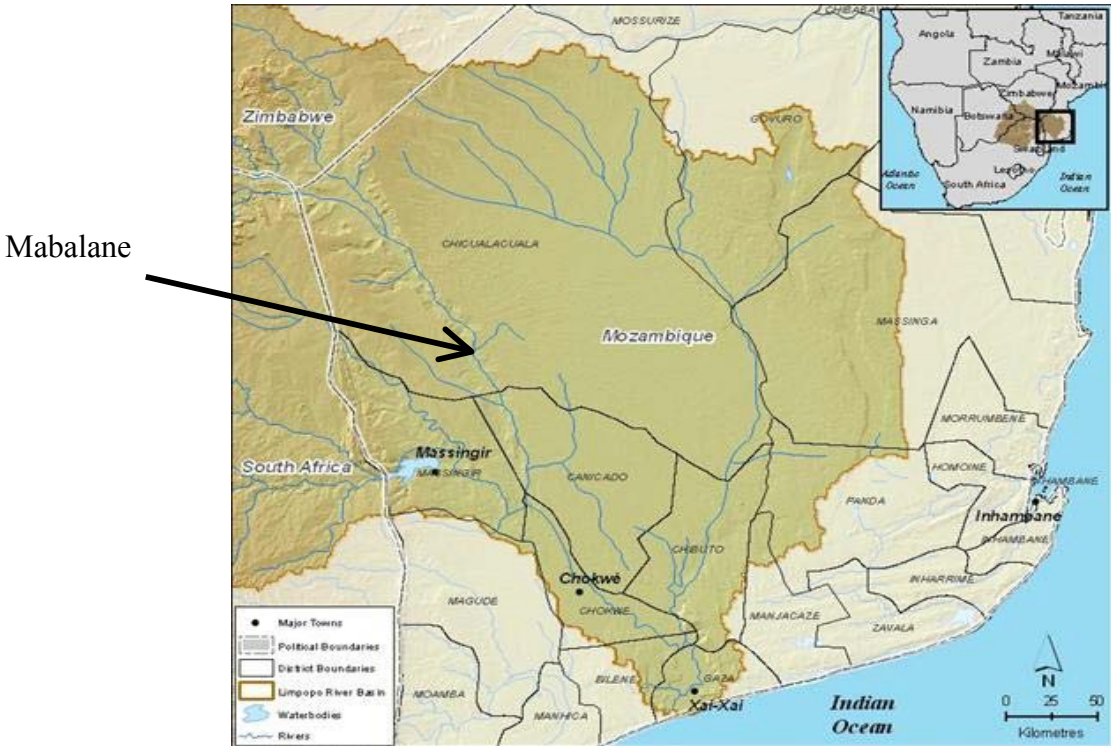

Figure 1: Limpopo River Basin

The lack of water from its climate and the hydrogeomorphology of the district first constrain its development. Rain-fed agriculture provides food for only 6 months of the year, from

January/February to September/October. Thus, the population relies mostly on agro-pastoral activities for its livelihood. The hydrology and climate of the region constrain agriculture but encourage a rich forest ecosystem with potential for cattle grazing. In fact, the forest provides shadow and rich grass under the trees and small clearings for the cattle. Thus, Mabalane counts 32 000 heads of cattle and small ruminants which are mostly located inland. The inhabitants use their cattle as investments. They are sold for different purposes, such as buying corn or other staple food during drought periods, organizing community events (wedding, funerals) or paying the cost of hospitalization. The forest ecosystem, called Mopane forest because of the dominant Mopane species, saw its area decrease significantly during the last few years in order to provide the provincial and capital cities with charcoal. The commercialization of charcoal to city entrepreneurs brings significant additional income to Mabalane households, particularly during the lean season when agriculture isn't able to secure food. Despite these activities, during a normal year, the people still suffer from a food shortage for 3 to 5 months (FEW NET, 2011).

The commercialization of charcoal and other agro-products is made possible through a functioning railway, inherited from colonialism, and 100 km of a non-tarred road over 125 km that connects the district to the closest city, Chokwe. The distance from the economic centers of the Province and the poor quality of the roads isolate the Mabalane district. This is particularly true during the rainy season, when the non-tarred road becomes impassable. Consequently, the Mabalane market economy and employment are low. To respond to this economic and physical isolation, the inhabitants of Mabalane have developed a set of activities to sustain their livelihood. The combination and relative importance of these activities depend on the location of the household in the territory (see Box1), the availability of external income (mostly from migration to South Africa), the relative wealth of a family and the connection to the traditional owner of the land in the village. The wealth of a family is often related to the availability of labor in the household (FEW NET, 2011).

Box 1: Mabalane ecosystem zones

Ducrot(Ducrot, 2013) distinguishes in her reports four distinct areas in the district. She bases this distinction on geomorphology, institutional organization and network transport.

The first area consists of two main cities, respectively Mabalane Sede and Combomune Estação. They built their economic and regional importance from the central position they have in the transport of goods and people through the railway during the colonial period and later through the main road that runs alongside it.

The second area is the riverine area on the right bank of the Limpopo River. This area is located between the railway / main road and the Limpopo River. It has arable land close to the river, which allows agriculture in the rainy season, some grassland and forest, and vestiges of the Mopane woodland ecosystem in the upper lands. Households here depend mostly on unreliable rain-fed agriculture and, to a lesser extent, on cattle breeding in the grasslands.

The third area is on the left bank of the Limpopo River. This area is similar in soil and vegetation to the one on the right bank, with the difference that the woodland ecosystem did not suffer from extensive exploitation. This area is distinguishable since it has been included in the buffer zone of the Limpopo National Park (LNP). Thus, this institutional delimitation restricts woodland exploitation and consequently the diversity of livelihood activities available for the inhabitants. The gathering of forest products in the forest is limited to household consumption while charcoal making and hunting are prohibited. Besides this limited access to natural resources and threats from wildlife, the inhabitants are isolated from the economic and political centers of the district by the Limpopo and park's rivers. The inhabitants are, however, supposed to receive 20 % of the Park revenue to compensate and be used to found community's projects.

The fourth area is on a plateau in the upper regions, 10 to 50 km from the Limpopo River. The soil is sandy and surface water is available in the form of temporary reservoirs and rivers. These edaphic and hydraulic specificities make it hard to raise agriculture in reliable conditions. Inhabitants engage in high-risk rain-fed agriculture and base their livelihood on charcoal production in the Mopane woodland's ecosystem and exploring its biodiversity (fauna and flora).

The geomorphic factors, institutional organizations and network transport differentiate access to and use of the natural resources by the inhabitants in the second, third and fourth zones.

A new road is expected in 2014 to replace the non-tarred road and connect Mabalane with its neighboring cities (Chokwe, Combomune Estação), increasing product exchange and making a passageway for international exchange with Zimbabwe (it being the shorter way from Maputo to the Zimbabwe border). This new road would also facilitate the provision of public services. In fact, the population of Mabalane, 32,000 inhabitants, is mostly poor. Their

poverty is defined by food security and nutrition indicators but also by access to public goods such as education and healthcare indicators. HIV is high in Mabalane, with a rate of 28%.

The provision of Small-Water Infrastructures (SWI) has been identified by the government as one of the keys to the district's development. This is being done through national programs such as PRONASAR or through local development funds such as the OIIL. There are boreholes to provide water for household consumption and small irrigation systems to improve food security and income generation. The Mabalane population relies on traditional water sources such as small reservoirs and charcos as well as boreholes for their domestic use (charcos are natural depression that fills up during the rainy season)(Ducrot, 2012).These are normally used by the cattle but when water from other sources becomes scarce, some inland communities temporarily use them. This can happen, for example, when a borehole breaks down or small reservoirs dry out during a long drought. 30 boreholes have been recently implemented by the national project PRONASAR.

Ducrot(Ducrot & Bourblanc, 2014)shows PRONASAR's limitations in reaching both its direct (water supply coverage in an equitable and sustainable manner and capacity building in the WASH sector) and its indirect (strengthening local institutions) objectives. In Mabalane, the PRONASAR objective of giving access to 30 boreholes was reached but did not lead to a more equitable and sustainable access to water. The marginalized villages had also been the least equipped; some boreholes needed three people to be operated, others were saline, and all were susceptible to frequent breakdowns. During the planning stage of this project, PRONASAR was willing to strengthen local and decentralized planning institutions. However, as soon as difficulties emerged regarding infrastructure implementation, these multi-level institutions were not solicited again by the district government, although they could have helped find alternative solutions. According to Ducrot(Ducrot & Bourblanc, 2014), this was due to the centralization of the decision-making process (including planning) at the provincial level under a hierarchical culture and a consequent overlooking of the local actors' relationships.

Mabalane district counts in total 82 motor-pumps. They irrigate three types of farms: medium commercial ones; private smallholder ones; and collective ones. Only the two last receive subsidies from the government to support the district's food security. While the size of the commercial systems is more than 20ha, the average size of smallholders' irrigation systems varies from 10 to 20ha (FEW NET, 2011).

The small water irrigation systems have been increasingly favored by drought relief projects and the OIIL funds. Smallholders in the east bank of the Limpopo River benefit from OIIL funds, receiving loans to build their irrigation systems. Their production is for both commercialization and consumption. In the west bank, under the Park of the Limpopo (PNL) administration, the villagers are gathered in collective irrigation systems. The PNL committee promoted forming groups of 15 to 30 farmers to collectively manage an irrigated area of 5 to 10 ha. The selection of the motor-pump for smallholders and collective irrigation schemes was motivated by the lack of labor force in the district. Migration and HIV prevalence limit the labor force.

Although the funding for these projects is done through the local decentralized planning institutions, they are mainly intended for individuals, and their monitoring and management are left entirely to the expense of beneficiaries. Several factors constrain the sustainability of the collective system, such as land access and the high functioning costs of the motor-pump in terms of money and labor. In every collective scheme, farmers have their own plot and share a collective area. The sale of the collective production from this area should cover the fuel costs of the water-pump for the next season. Unfortunately fuel costs exceed the profits from collective production and require an additional monetary contribution from the farmers. Most of the farmers can not afford to pay or can not pay on a regular basis. Consequently, the more wealthy farmers or the ones with social and/or political capital end up controlling the small irrigation system. Besides this, land access can be competitive. The land in the district with the potential for irrigation systems is located in the Limpopo river bed. These locations secure access to the water all year. From July to October, when the river becomes a series of disconnected pools, the lands connected to these pools are the only ones with access to enough water for the scheme. The problem is that they are also the most fertile. In some of the cases, the landowner blocks the development of the scheme or secures its relocation to settle his own irrigation scheme.

To resume, the development of small irrigation schemes results in the strengthening of local elite that gradually privatize the irrigation systems. Indeed, in addition being in a strong position to propose projects, and thus receive funds to implement irrigation systems, they also jeopardize collective systems. They take advantage of poor farmers, abandon the collective schemes due to the high SWI management costs, or demand to recover lands they lent to the association. We are thus faced with a concentration of resources, both economic and social by the local elite. In addition, developing private irrigation in this area, where no labor market exists, has very little chance to contribute to new jobs and wages as a positive alternative for local development(Ducrot, 2014).

In describing the geographic context, we picture the natural dynamics of Mabalane. After having detailed their spatial and temporal distribution we describe the broad social dynamics related to them. It appears that Mabalane district development relies much on natural resource's exploitation. The district's livelihood falls back on a multiplicity of natural resource uses while the district economic development counts on intensive natural resource exploitation, such as making charcoal. In Mabalane context, we particularly focused on the use of SWI to access water for consumption or production and how the equitability and sustainability of this access depended on the relationship between different actors such as communities, district civil servants and external actors. In this second part, we will detail Mabalane formal (rules, regulation, legislation) or informal (norms, behaviors, conventions) institutions controlling and regulating natural resource uses among competing local actors. This description will focus particularly on how actors put into practices these rules or in other words, how they organize themselves to manage natural resources from the district level down to the community level.

2.2 Territorial governance

Because of their central place in district life, natural resource management intervenes in most public spheres of the district. Therefore natural resources are regulated through public services by formal government administrations and local leaders. The level of fragmentation of natural resource management increases with the size of the territory and the multiplicity of natural resources use it encloses. For example, community's leaders control the use of a large range of local natural resources. In the contrary, the district natural resource management is specialized and fragmented. It takes the form of several public services (Figure 2).

Administrative level	Person in charge	Related services	Interface with civil society
District	Administrator	Various services among which: *SDPI (*Serviço Distrital de Planeamento e Infraestrutura* or District Service for Planning and Infrastructure): in charge of works and development of infrastructure (road, water infrastructure), planning and environment *SDAE (*Serviço Distrital de Agricultura e Actividades Economicas* or District Service for Agriculture and Economic Activities) : development of agriculture (including irrigation, fishing, cattle breeding), wildlife, charcoal production and economic activities Secretariat of District : planning; organization of Consultative Councils	The Consultative Council (*Conselho consultative do distrito*) gathers some village leaders and member of civil society chosen by the district government
Administrative post (3) ("*posto administrativo*")	Post chief "*chefe de posto*"	Local decentralization services with aggregated services and local civil servant	The Administrative Post Consultative Council (*Conselho de Posto*) gathers some leaders and members of civil society of the administrative Post
Locality ("*localidade*")	Locality chief "Chefe de localidade"		In each locality a council of leaders gathers 1st scale leaders and 2nd scale leader

Figure 2: The different administrative levels in Mabalane (Ducrot, 2012)

The district government was first formed in the 70's, just after the independence of Mozambique, under local government reforms process undertaken by the government of Mozambique to replace the Portuguese Colonial administrative structure (Cuereneia, A,:2001 and Massuanganhe, I.J., 2005 cited in (Bank of Mozambique, 2008)). Still today, the first and second scale leaderships are directly inherited from this reform. The local planning and decisions were centralized by institutions called "district assemblies". But despite this decentralization initiative, the government was heavily centralized at the national level with

no great investment in strengthening the new institutions at the provincial and district levels(Bank of Mozambique, 2008).

At the end of the cold war, in 1987, a second reformed local government. This government meant to reinforce its role by promoting greater participation of the civil society within the district assemblies and local government accountability. At the end of the civil war, the process of consolidation of local authorities continued with a second decentralization reform. In 1997, this reform created autonomous municipal governments whose first elections were held in 1998(AMCOW & WSP, 2010; Bank of Mozambique, 2008). The decentralized and integrated local governance approach encouraged by the international community, ultimately lead to the creation of new local participatory planning structures. New multi-sector development teams were institutionalized at district level to "organize the information that [came] from the communities" and to elaborate the district plans. They are called district services. Each district service corresponds to a particular ministry. The district services related to natural resources at district levels are respectively the district service for the planning and development of infrastructures (SDPI) and the district service in charge of economic activities (SDAE). The SDPI monitor the construction of infrastructures including, small water infrastructures. The SDAE gives technical advice for agricultural production, including irrigated agriculture as well as delivering charcoal licenses to provincial small investors and taxing charcoal making. In Mabalane, there is an ongoing transfer of the surveying task from the SDAE to the SDPI. This implies new activities for SDPI technicians such as identifying community versus private forests and greater coordination with their colleagues from the SDAE (Box 2).

Box 2: Description of Mabalane services by the SDAE technician who participate in the overall process

I: Are the district services in Mabalane coordinated?

R: The coordination among services fluctuates. Some are good, others more difficult. Sometimes some technicians from different services do the same activity independently when they could do it together. For example, in forest management, both SDAE and SPDI services are concerned. The SDAE take care of the forest production of wood and fruit. It looks at technical parameters of the production to see if some can be reforested. The SDPI is in charge of the [surveying]. It indentifies the owner of the forest; monitors the number of forests per leader, etc…
I: Where does the problem of coordination between these two services come from?
R: The SDPI is new. Before the service was created, the SDAE was accountable for the cadastre. The SDPI did not realize yet this was one of their tasks.

[1]

[1] R for respondent and I for interviewer

Next to the district services there are participatory planning institutions located at different levels – district, post, and community- called the consultative councils. Both are supervised by the permanent secretary of the district(Bank of Mozambique, 2008).

The twenty year change has modified a lot the governance structures of Mozambique. Nevertheless, the hierarchic and top-down culture inherited from the colonization and the post-colonization central government was maintained. This culture challenges the ongoing intensive decentralization reform by compromising its sustainable and equitable results. Decentralized development programs and funds do not fit the local specificities such as resources and needs. This is particularly observable in the management of consultative councils in Mabalane and how delivered funds differ from local development initiatives.

2.2.1 Consultative councils

Consultative councils are local institutions legally in charge of the local planning and allocation of the budget for public policies(Pereira, 2011). They were created in 1990 by the Mozambican government, to facilitate coordination between foreign and national actors in the planning of development, and to assure their alignment with local needs. They are implemented at different administrative levels- district, post and local- and managed by the district (see Figure 3). According to the law called "Lei dos Orgões Locais do Estado" (LOLE) approved in 2003, the district administrator should manage and finance the consultative councils. In practice, it is the district secretary who has this function. LOLE also insists on the participation of 40% leaders, at least 30 % women and 20% youth, in the consultative councils. According to LOLE, the power of selecting consultative council members is left to the local authorities. The trend is, administrative head office select legitimate recruits (Pereira, 2011). By including a large range of local actors from the administration and civil society, the consultative councils are meant to assure the deliberation of local plans and development programs. This process would allow programs and projects to align with the local population's needs and the specific context.

By law, the consultative councils should take part in the elaboration of the District Strategic Plan (PEDDs), elaborated every 5 years, as well as the Economic and Social Plan and the District Budget (PESOD), elaborated every year. These plans detail infrastructure planning, including small-water infrastructures and investments for the next year (PESOD) and for the next five years (PEDDs) (Ducrot, 2013). Along with the elaboration of local plans, consultative councils allocate District development funds called Orçamento de Investimento de Iniciativa Local (OIIL) or Fundo de Desenvolvimento Distrital (FDD).These were created in 2006 to support access to credit for local people with project proposals in food production and small income-generating activities. The consultative councils offer an opportunity for coordination of these different levels of local development. Consultative council members can select OIIL projects according to the infrastructure and service support defined in the district plans or, contrarily, fulfills the plans in order to answer local or individual projects. In the context of Mabalane, where resources and public services are scarce, the need for synergy among local development projects is significant.

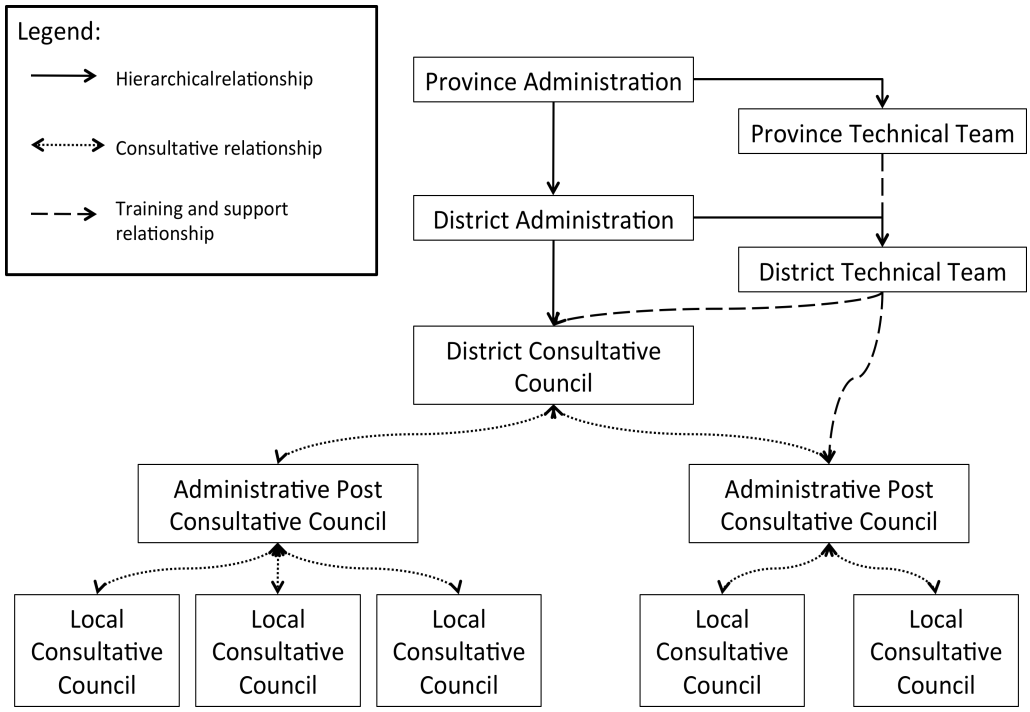

Figure 3: Organizational structure of the district decentralized planning process

The performance of formal consultative process described in the figure 3 differs from the legal outline. The consultative councils are today overlooked when adapting district development programs and/or projects to the local context and coordinating them with local individuals' initiatives. In the multi-level consultative councils, the district consultative council discusses and evaluates the district plans (PESOD and PEDDs) the district technical team has elaborated. It gives a space for autonomous members of civil society to question the district civil servants about ongoing development programs and projects (Ducrot, 2013). This deliberation offers an opportunity for civil society scrutiny, but is limited by some factors including the consultative council's members' representativeness (women, youth, etc…). In fact, the legal prerogative of the different level authorities to invite the personalities who would advocate rural interests and provide diversity has resulted in a homogenous group selected for their political affiliation or their family membership (Pereira, 2011). Ducrot(Ducrot, 2013) acknowledges the relation of local élite with the local leaders in Mabalane and encourages further study to identify the family connections of the council members.

The civil society members are selected with the same leader prerogative at the post and locality administrative levels. Yet, at the local level, all government representatives such as 1st and 2nd scale leaders are gathered. This arrangement offers an opportunity for upper administrations to disseminate government information and policies to the local leaders (Ducrot, 2013). The post and local consultative councils evaluate the feasibility of collective or individual projects (OIIL) and the owner's ability to pay back the funds. The projects are, later on, evaluated by the district consultative council and financed if they deserve to be (Box

3;Forquilha & Orre, 2011). To evaluate the OIIL project the district consultative councils from post and district levels seek advice from the district technical team. The capacity of the funds to provide a response to the food insecurity of the under powered population of the district has been questioned (Ducrot, 2013). In fact, OIIL projects are mainly owned by local élite. The reasons are, firstly, that the local élite are often affiliated to the local leadership and therefore more susceptible to selecting OIIL projects from their consultative council's membership. Secondly, poor people are less confident to propose projects than the local elite who can rely on their political and social network to elaborate and support their demand. Thirdly, the poor never access OIIL funds due to the funds' inherent properties. The OIIL funds are development loans. Therefore, they target income generating projects that make ruling people richer rather than food security schemes poor people ask for (Ducrot, 2013). Next to these legal assignments, the consultative councils arbitrate occasionally the allocation of external development projects. Post consultative councils are in charge of identifying the localities to benefit external aids according to their ecological specificities and their previous access to other development projects. They seek advice from the district technicians who work at the level of the post. These activities as well as the use of local consultative councils to manage local governance of natural resources and emergency aid should be further researched. In fact, the Tsocate local consultative council board stated that local consultative councils were gathered in an exceptional meeting to facilitate the distribution of flood relief aid and improve local leaders' coordination. Other participants from the plateau ecosystem zones added that their consultative councils were in charge of mobilizing the population to adopt collective livelihood strategies, such as collective crop parcels and creating charcoal reserves, or intervening in negotiating with external entrepreneurs for access to the community forest. These specificities identify the local consultative councils as if it was only composed of leaders.

Box 3: OIIL allocation in 2010, Mabalane

In 2010, Mabalane district allocated 6.7 million in meticais (158,000 Euros) to 12,185 projects. Half of these supported activities that created jobs and small incomes such as commerce, agro-processing, small industries, and transportation. The other half was dedicated to agriculture and cattle breeding. The projects in agriculture usually concerned providing a small water system which includes a power pump, tubes, the first year of diesel fuel and the cost of fencing the plots (Ducrot, 2012). To apply for these loans, the local people wrote a project proposal that was later evaluated by the local councils during one of their two annual meetings before being sent to the Post and, if elected, to the District. After approval, the District contacted the project owner, making him sign a contract stipulating his rights and payment duties before delivering a check (Ducrot, 2013).

Aside from this formal, decentralized process for local development planning, another consultative process exists: open governance. In this process, party officials from provincial (governor) or national levels (ministries) visit localities in order to monitor the

implementation of national policies through local programs and get to know local needs (Ducrot, 2013).

In Mabalane, the consultative councils are managed in a top-down mode with centralized coordination of local development programs. Looking at the theoretical advantage of this centralization, it might commit the service staff to their tasks. This is not the rule, however, Dill (Dill, 2009) observes that in some cases the hierarchy in public administration disciplines the civil servants to have a concrete impact on the ground, rather than capturing upcoming aid from donors' projects and programs' rents. It could also support coordination between locally-funded projects and district plans. By distancing ourselves from reality, we could imagine that OIIL projects could be selected by the district officials according to their feasibility and the government policies and plans. This theory is far from the reality of Mabalane. In fact, OIIL funds are presented and perceived by all local actors as an individual financial support rather than an instrument of local development by public administrations. The study of small irrigation systems shows this feature. OIIL funds favor individual interest rather than district political strategies. Besides, the limited participation of post and local consultative councils in the elaboration of plans questions coordination effectiveness between the district plan (PESOD & PEDDs) and other development projects (e.g. drought relief funds, donors' projects). In other words, centralization questions the district plans adaptation to local need, initiatives, and ecological specificities. For example, the PRONASAR program evaluation describes how local initiatives, such as financing boreholes through OIIL funds as a local initiative for water access, were overlooked by the district institutions.

In addition, the current representation of civil society in the consultative councils hinders the exchange of perspectives and discussions at the local level, as well as the democratization of OIIL.

2.2.2 1st and 2nd scale Leaders

The leaders play a key role formulating cross–level natural resource regulations when they are not participating to consultative councils. They are the ones to translate formal institutions, such as upper level policies and norms, to the local ecological and social context, even fitting community informal rules. This translation is influenced by the relationship the leaders have with other multi-level actors.

A plurality of leaders co-exist at the local level(Ducrot, 2011). These are hierarchically organized and given different functions. The co-existence of several types of leadership can easily lead to conflicts that are exacerbated by issues surrounding the capture of external resources (project and interventions). In some cases, this may lead to problems of SWI management. Traditional leaders inherited their leadership and are in charge of the traditional and religious routine, including the allocation of land. The first- and second-scale leaders are official representatives at the local level. They are elected and in charge of official and administrative tasks, such as tax collecting and infrastructure development. The first-scale leader is in charge of several villages while second-scale leaders represent a village. All three

leaders and particularly the first- and second-scale leaders, since they are included in consultative councils, are at the interface between the government and the villagers.

This position makes them strategic intermediaries for the allocation of development programs, since they can identify the best allocation for a specific development project (infrastructures included), and mobilize the population for its implementation and management (Ducrot, 2012, 2013). From this position they can also capitalize on information on local needs, local initiatives (through the selection of the OIIL) and ecological specificities. The few visits of government officials from post and district levels (2 times a year) confirm the role of local leaders as information gatekeepers. Beside, their roles in the allocation of development programs, local leaders as community representatives negotiate with the district administration and other actors around access to community natural resources. For example, even though the district administration regulates through exploitation permits the access to community forests for small provincial entrepreneurs, local leaders negotiate with the latter compensation for the villagers. In particular cases, when the SWI aren't managed by the community, the leaders interact with government administrators or the outside groups such as NGOs to negotiate water tariffs and services for their people. Ducrot noticed that issues at the village level weren't always discussed in the local consultative councils and that local leaders maintain a privileged relationship with the district local élite, ensuring that their herds are taken care of or that their SSI is selected to be financed by local funds for development. These examples question the leader's position to defend community interests over those of the local elite (Ducrot, 2012).

2.2.3 Community

At the community level, villagers enter in relationships and regulate their access to natural resources according to particular informal institutions, such as mutual help relationships, arrangement for SWI maintenance or compensation for cattle damages.

A mutual help relationship is, according to the authors, an institutional arrangement focusing on the sharing of food, goods or animals and/or organizing savings or credits (Osbahr, Twyman, Neil Adger, & Thomas, 2008).It supports access to resources for poorer people to sustain their livelihood and so to increase their resilience to extreme climate events such as droughts (Brouwer & Nhassengo, 2006). Mutual-help relationships are privileged among the same families. Thus it is not rare that access to resources, such as riparian plots in drought periods, between villagers of the same village or between villages, is mediated by family boundaries. The poor villagers are often the ones with no or very little family, such as widows.

In Mabalane, the mutual help relationships involve predominantly poor villagers. They labor on a regular basis in other people's fields for money (Kurimela/Kukathekela) or food (ganho-ganho). The larger population mostly engages in exchanging of a workday for tillage equipment, as the only way by which "under-equipped households get their fields ploughed". Otherwise, villagers weed occasionally in exchange for a traditional beer" (Ducrot, 2013).

In rare occasions, some local arrangements also enable the poor to access water resources through SWI. For example, the management of SWI requires villagers to make a financial contribution in the form of a fee (coupled to the volume taken or not).These mechanisms allow poor villagers to pay the financial cost in labor. Magaia and Manjate (2010) (in (Ducrot, 2011)) acknowledge an occasional form of labor-based compensation for the poorest to pay for the management and maintenance cost of boreholes by providing labor in the form of community service, such as cleaning the borehole spot. The creation of organizations to use and manage SWI has proved to support the access of poor people to SWI benefits. For example, as long as the irrigation association is maintained, the poor farmers can benefit from the partial sharing of costs, including renting the land, labour needs (with Matsoni) and payment of the motor-pump fuel to cultivate crops for commercialization or food security (Ducrot, 2013). But these organizations are often constrained by the control of funds by a small elite and the local hierarchic and top-down culture. In addition to these associations, partnerships between a few farmers exist to manage and maintain motor-pumps. One of the farmers owns the motor-pump and rents land and the use of his motor-pump to other farmers (Ducrot, 2014).

The poorest people are usually the ones who are the most impacted by the limitation of mutual help relationships. They depend most on the social network but also have more difficulty returning the help through labor or goods. In this case, we mean widows and women with HIV from the poorest strata of rural society (Ducrot, 2011). To conclude, in Mabalane, mutual help relationships are few and fragile (Eriksen & Silva, 2009).

Table 1: Mutual help relationships: definition from Brouwer & Nhassengo (2006)

Local name	Description
Kurimela	Keep livestock in somebody else's homestead and reciprocate with the same service
Kurimelisa	Move temporarily to another area to work for food
Matsimo	Individual labor exchange – work on somebody's land in exchange for ploughing
Matsoni	Informal exchange between women: labor and other things to guarantee that a plot is planted

Cattle herds can greatly damage the fields close to the river when they are brought from inland or riparian villages to drink from the river. The regulation of water access to the cattle has been set by several actions and arrangements. The riparian farmer fences in his plot but if cows are encountered in his field he is allowed to collect the cattle that are wandering in his plot and fine the breeder for the farmer's production loss. Nevertheless, since this arrangement isn't formal it is possible that the cattle owner bypasses this norm using his political relationships with village leadership or district administration (Ducrot, 2012).

Finally in rare occasions villagers also interact directly with outsiders. This is the case when access to natural resources hasn't been previously negotiated with leaders. For example, in an inland village, it was reported that a small charcoal investor was forced by some villagers to fetch water from the river instead from the community inland reservoir.

3 Theoretical Framework

3.1. Social and ecological systems interactions

In this study of the sustainable planning of small water infrastructures, the local context of Mabalane district is considered a complex socio-ecological system. Ecological and social systems are sub-systems of a global system within which they mutually interact (Gallopín, 2006). The socio-ecological system typically provides society with essential services such as food, drinking water, or energy (Berkes & Folke, 1998).

There are various frameworks that analyze socio-ecological systems. They adopt different perspectives that are influenced by their objectives, disciplinary background, temporal and spatial scales, and other factors. Some focus on elucidating the impacts of human behavior on ecological systems, others focus on analyzing complex issues derived from the dynamic interactions between social and ecological systems, and still others foster the design and application of solutions that reduce societal impact on the ecological environment. Finally, there are frameworks that study the impacts of ecological change on people, particularly in situations where by society is not in the position to influence the natural environment. This typology is exhaustively explained by Binder, Hinkel, Bots, & Pahl-Wostl(2013). For my action research, I am interested in demonstrating to key local planning actors that natural resource management and local development issues are complex. Their complexity is derived from the interaction between local stakeholders and their natural environment. Therefore, in my research, I equally describe the social and ecological dynamics, and their interactions. To raise local actors' awareness I asked them describe the ecological system as they perceive it, and combined this knowledge to form a representation of the natural dynamics. Finally, to raise awareness, I opted for a diagnosis of the local situation rather than searching for actions. In Binder et al.'s typology (2013), this refers to the integrative frameworks of socio-ecological system analysis. More precisely, I am attempting to describe the ecological system dynamics in detail. This level of precision is similar to the socio-ecological systems' framework developed by political scientists such as Ostrom (Ostrom, 2009). To further investigate this integrative framework, I will first define Mabalane's socio-ecological system and then explain how its embedded interactions lead to complex issues.

In Mabalane, the social system is composed of the district multi-level actors (communities, their leaders, district civil servants, investors) while the ecological system is formed by a variability of natural resources (forest, underground and surface water, land, crops, cattle, wild animals and charcoal). The elements of each sub-system interact in a dynamic way. The social actors interact to access natural resources on multiple organizational levels as I have described in chapter 2. For example, in Mabalane, farmers' access to water for living depends

very much on the interactions between other local and non-local actors. In her evaluation of small irrigation systems development, Ducrot(Ducrot & Bourblanc, 2014), acknowledges the importance of interactions between district technicians, the district's political élite, leaders, and communities to shape water access. In addition, social interactions in their environment often explain the spatial and temporal distribution of natural resources within Mabalane local system. To come back to the example of small irrigation systems, the multi-level actor's interactions have molded SWI allocation and maintenance according to their interest and knowledge of the system. This has resulted in a specific water and land temporal and spatial distribution. Water is extracted from the riverbed pool to irrigate all year adjacent arable lands. Since the social and ecological systems mutually interact, natural dynamics also have an influence on social dynamics. For example, the climatic variation will determine the available water volume in the river pool and therefore the viability of the small irrigation systems. This would create social tension in the distribution of water between and within the schemes, speeding up the schemes progressive abandonment. In this sense, SWI are at the front edge of the social and ecological system. Their development shapes human-nature interactions.

3.2.Complex systems

The interactions of the social and ecological dynamics are not easily definable. The socio-ecological system of Mabalane and its subsystems are complex in that their global-level properties, such as the district's vulnerability to drought, are not observable at the level of their constitutive elements, which include SWI type solidity and community awareness of the means to prepare for and overcome drought stresses (Bankroff, 2007 in(Ducrot, 2012). Similarly, their unpredictable global dynamics, such as migration and water depletion, can not be observed or analyzed by elementary interactions such as a community's borehole management (Bossomaier & Green, 2000; Langton, 1991; Weisbuch & Ryckebusch, 1991).

The transformation of elementary interactions into unforeseen broad dynamics can also be described as the emergent properties of a complex system. Our first assumption is that the development of SWI as a new element of Mabalane socio-ecological system will likely change the system's social and ecological dynamics in a complex way and should, therefore, be carefully considered. The development of SWI will affect the broad dynamics of systems, such as food security and deforestation, in ways that can be only explained by studying the cause-and-effect relationships that these infrastructures have with other system elements such as water resources and human communities. In her study, Ducrot(2013) reveals how SWI implementation and management in Mabalane can locally impact interdependent natural resources other than water. For example, to pay for the cost of borehole maintenance or motor-pump fuel, farmers engage in cash-production activities such as charcoal exploitation. Thus, access to water shapes the interactions farmers have with other natural resources. In other words, water access depends on the management of other natural resources from the district.

3.3.Wicked problems and integrative planning

Actors working for the local development identify the emergent properties of this complex system, such as challenge of deforestation, the development of SWI, or public policy, as second order impact or complex problems. These problems are socially constructed in the sense that their definitions are shaped by the values, education, culture, and interests of the different actors they affect (Ker Rault, 2008). Thus, these complex issues are eminently social and political rather than technical. This challenges solution designs in the planning process. Contrary to technical issues, they have *no optimal solution and the partial solutions invariably cause new, often unforeseen, problems* for local actors (Rittel & Webber, 1973). In social planning literature, they are called ill-structured, unstructured, or wicked problems(Conklin, 2005; Hoppe & Dunn, 2011; Ker Rault, 2008).

Unlike conventional planning issues, the nature of wicked problems requires non-linear problem solving methods. In the planning of SWI management and maintenance, this would require public servants to shift their perspective from effective coordination between actors in a "technical" performance of SWI toward an understanding of the context from a multi-disciplinary stance (Lach, Rayner, & Ingram, 2005). In others words, due to their inherent knowledge uncertainty, and the plurality norms and values of the stakeholders they affect, wicked problems require an integrative form of planning. For this purpose, authors (Hisschemöller & Hoppe, 1995) recommend the involvement of a group of actors "*as heterogeneous as the problem ... requires"*. Through active participation these multi-level public or private actors can fill the knowledge gap concerning natural resources and social interdependency and, thereby, find more consensual solutions (E. Hassenforder & Noury, 2012, 2014). Author (Ker Rault, 2008) recommends the development of tools and exercises that comprise a participatory approach. Stakeholders can use this approach to deliberate and discuss complex problems. To conclude, a planning process that integrates multi-level actors' perceptions of natural resource management offers a constructive path toward a more sustainable and equitable form of SWI development in Mabalane. We chose a participatory approach in order to raise awareness about the potential of this type of planning.

3.4.ComMod Wat-a-Game

In order to raise awareness on integrative planning, we decided to use a framework that invites local actors to exchange their knowledge on the local complexity. In fact, an approach in the diagnosis of socio-ecological system, called Companion modeling (ComMod) gathers different actors in a participatory process aiming at the co-construction of a model of their reality. The model works as an intermediary object. Its co-construction allows actors to exchange their point of view on social and ecological dynamics and interactions. The participatory process facilitates a dialogue among participants necessary for a reciprocal sharing of their reference framework of the system dynamics, including their underlying norms and values (Daré et al., 2014).

Following the Companion Modeling (ComMod) approach, we built up a participatory process. At the origin, a consortium of French researchers developed ComMod in order to facilitate an understanding of the complexity of human-nature interactions for natural resource management. In this approach, a small group of local actors, together with the researchers, design and test a model of their reality which emphasizes natural resources and human interaction dynamics. The representation of their reality is then materialized on paper model as a role playing game coupled (or not) with a computer simulation model. Through these models the same or other local actors can further explore their local complexity, play out ongoing practices and see their far-reaching effects or even test new individual or collective strategies for natural resource management(ComMod, 2005; Étienne, 2011).In fact, the model offers a place for the participants to evaluate and test their actions according to various scenarios (ComMod, 2005). By providing a dynamic representation of social interactions as well as including the uncertainty of human decisions, ComMod details a step further the social system compared to other integrative frameworks for socio-ecological system analysis. It defines a number of variables using natural language to describe socio-ecological systems frameworks. Its novelty is to model their evolution in time and space allowing in addition to the diagnosis of the system, a test of broad collective strategies.

3.5.Learning process

I assessed the participants learning outcomes of the ComMod participatory process using two different theories. The first is Ajzen's planned behavior theory (Ajzen, 1991; L. E. Davis, Ajzen, Saunders, & Williams, 2002), which is widely applied in social psychology in order to predict behaviors. I also refer to the concepts of single and second loop learning from the Argyris and Schön's organization theory(Argyris & Schön, 1978; Argyris, 1976). Azjen's theory is a referent theory for predicting and changing behavior in organizations. Like Argyris and Schön's theory, the theory of planned behavior has been influenced by the evolution of psychological learning theories. They both bridge previous discoveries in the learning process, including the influence of environmental, cognitive, and social factors. Furthermore, they were built on the exploration of learning mechanisms. Both learning theories bring to light interacting variables that impact the research participants' existing knowledge. For this study, the learning process perspectives were selected in congruence with the companion modeling approach and the influence of social context on planning.

Azjen's (Ajzen, 1991) theory shares concepts with a social learning perspective. Like in the latter, a person's behavior is strongly dependent on his or her social context. Furthermore, both theories are considered important behavior change theories for enforcing governance (CommGAP, 2009). Bandura's social cognitive theory (A Bandura, 1986; Albert Bandura, 1991) is based on the assumption that people can learn by observing others' behavior. While processing information, a person applies cognitive learning mechanisms, which are used to replicate the observed behavior. Bandura identifies three interacting factors (personal, environmental, and behavioral) that influence behavioral change or replication. In addition to social learning, Prochaska et al.'s theory, a transtheoretical model (Prochaska & Velicer, 1997)focuses on the development steps of behavioral change, from the pre-contemplation,

contemplation, and preparation to the action and maintenance of a new behavior. The Ajzen theory of planned behavior specifically acknowledges the different individual drivers or motivations of an intended behavior, for example a change of beliefs along with a change of values and norms in a given context. To this end, Azjen has created an intermediary concept known as intention to perform a behavior, which differs from attitude toward a behavior (Zanna & Rempel, 1988). Moreover, in Azjen theory the change of beliefs about a certain behavior can be based on observation of other behavior, previous experience, or access to new information.

Argyris and Schön's theory of single and double loop learning was derived from the constructivist perceptive on learning. According to this perspective, learning is an active process by which learners construct new ideas based on previously acquired knowledge. Viewing a participant as an active learner is a prerequisite of the participatory approach. The particularity of the simple and double loop learning theory is that it emphasizes action as the process of gaining new learning material. It shares this perspective with other constructivist theories such as situated cognition(Lave, 1991)and experiential learning (Kolb, 1984). Contrary to other theories, the single and double loop learning theory uses action to identify and correct errors related to two different types of existing knowledge – operational strategies and their normative foundations. Therefore, as with the planned behavior theory, Argyris and Schön's learning theory analyzes participants' norms and values, in addition to their cognitive beliefs. This aligns their theory with a humanist perspective on learning(Maslow, 1965). Furthermore, it considers experience as a fine learning process that corresponds with the modeling process used for this action research.

Figure 4 is a conceptual representation of the theory of planned behavior.

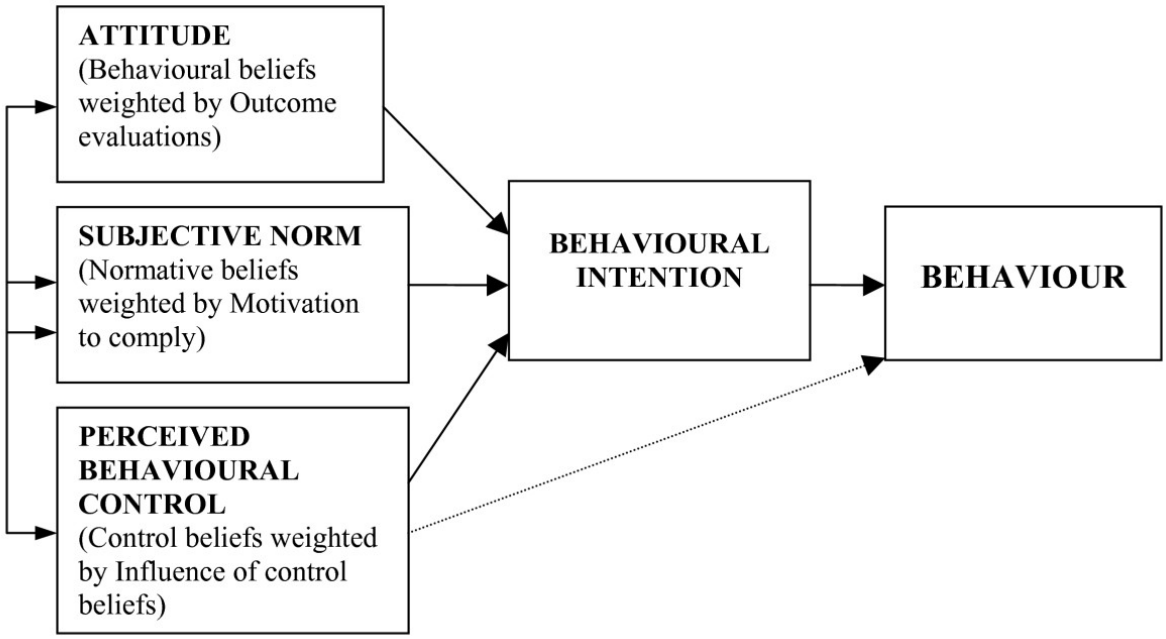

Figure 4: Theory of planned Behaviour (Ajzen, 1991)

The theory of planned behavior states that a person's attitude toward behavior (the belief about likely consequences of the behavior), subjective norms (internalized norms toward a certain behavior)) and perceived behavioral control (perceived ease or difficulty in performing the behavior) influence behavior mediated by the behavioral intention. The subjective norms are often influence by the perceived social norm to perform or not a certain behavior. For the sake of this research I combine this conceptual framework with the concepts of organizational learning theory. Figure 5 is a conceptual representation of the concepts of 1st and 2nd order learning.

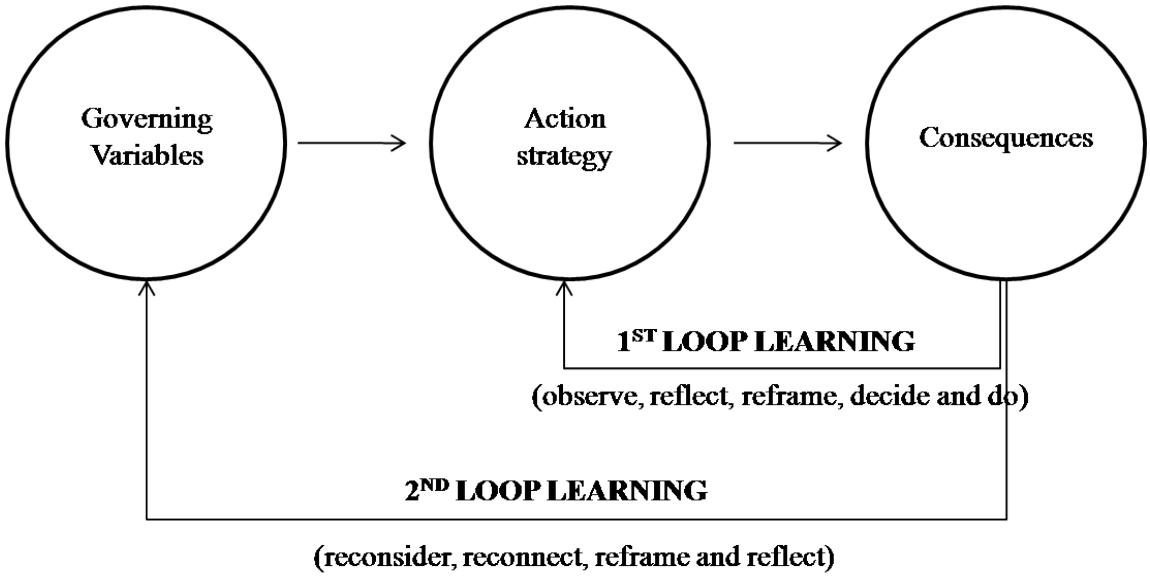

Figure 5: Double-loop's learning from (Argyris & Schön, 1978; Argyris, 1976)

According to Argyris and Schön, human actions are governed by a set of variables that are values and norms collectively designed. In usual actions, humans do not question these variables. Instead, they refine their actions from the consequence they observe within the acceptable limit of their "shared truth[s]". This is called first loop learning or 1st order learning. The second loop learning aims at a more fundamental change since human underlying norms and values are questioned from the result of actions. Figure 6 is a conceptual representation of the theoretical framework of this research in which I integrate part of both theories.

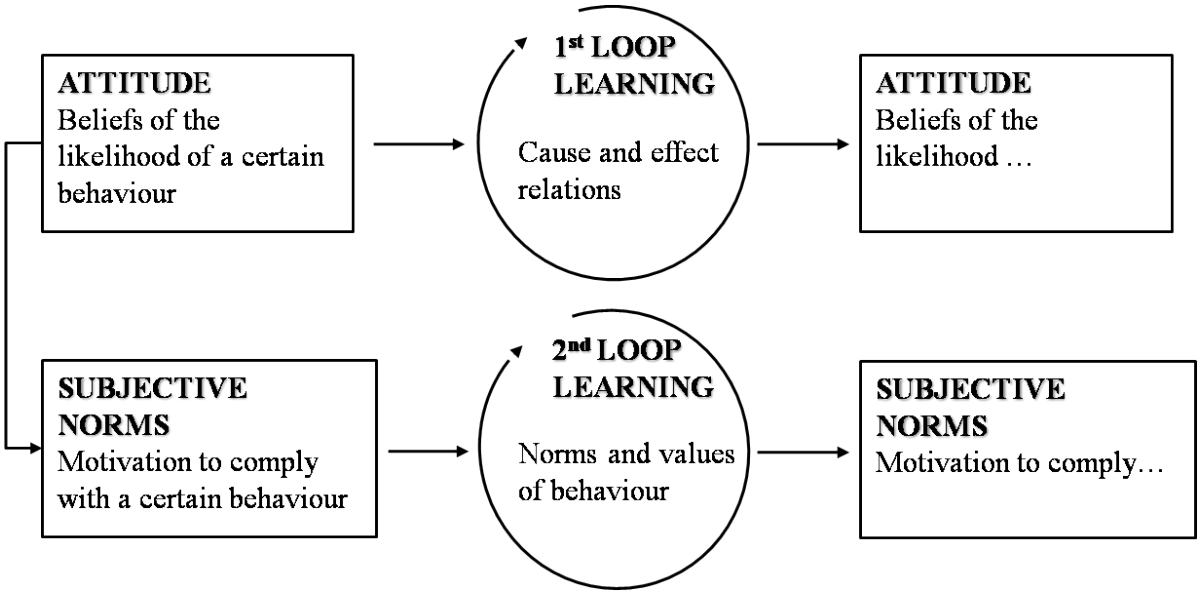

Figure 6: My theoretical framework

Attitude according to Azjen is the belief someone has on the likely consequences of a certain behavior. The likely consequence of a determined behavior or expected outcomes of a behavior in complex environments take the form of a set of cause and effect relationships. In this sense, the evaluation of cause and effect relationship results from our actions and also from the observation of others' actions the is called experiential learning (Kolb, 1984) or first loop learning(Argyris & Schön, 1996). This can change our beliefs toward a certain behavior. The participatory process offers a particular place to learn the cause and effect relationships involved in the socio-and ecological context of Mabalane. The socio-ecological dynamics are made explicit through the description and possibility to test the outcomes of our own or others' behaviors. In the design phase the participants are invited to discuss and describe cause and effect relationships or socio-ecological interactions. In the test and implementation phase the Role Playing Game allows them to enact and see the effects of their or other participants' actions upon socio-ecological dynamics.

According to the theory of planned behavior of Ajzen, in addition to attitude, there are subjective norms and perceived behavioral control that influence behavior. This research mainly focuses on the reflection about planning but not yet its performance. Therefore the perceived ease or difficulty the technicians have to change their behavior isn't central to this study. I will rather focus on their motivation to comply with a more integrative planning norm. According to Ajzen theory, attitude, subjective norms and perceived behavioral control, influence each other. A change of attitude may reinforce or lessen the motivation to comply with an assumed behavioral norm. In the participatory process, each of the different phases, design, test and implementation repeats the opportunity for their respective participants to learn from the cause and effect relationships of the socio-ecological systems. Since learning from these cause and effect relationships change participants' beliefs, the incremental learning of these relationships through the participatory process may strengthen their new beliefs on planning and subsequently influence their subjective norms associated with planning. In the view of this learning process, the local technicians we involve in at least the design and test

phases will most likely question the validity of the underlying norms and values of their behavior on socio-ecological system. This ultimate learning is called according to Argus, the second order learning. The other group of participants from the multi-level consultative councils only participates up to the implementation phase. Since they were confronted with the local complexity just once via the role playing game, we expect very few to change their norms about planning. Thus, we want to study how they act upon the observed socio-ecological dynamics of the system and analyze if and what they learn from the research experience.

4. Problem statement

Mabalane district has been the subject of many implementations of SWI, but they often did not reach the intended results. The reason for this is that the district Mabalane is a complex socio-ecological system that is difficult to grasp through the current approach to infrastructure management. Thus, there is a margin of improvement in sustainable and equitable access to water that starts with the consideration of the dependency of water resources on other natural resources and their interactions with multi-level actors' strategies.

5. Research question

GRQ: Can a companion modeling (ComMod) role-playing game (RPG) help local actors to better understand the socio-ecological dynamics of Mabalane system, and contribute to their change of beliefs and subjective norms on planning?

This general research question is operationalized in three sub research questions:

RQ1: What did CC members learn about socio-ecological system dynamics in Mabalane, and specifically the outcome of their planning behaviour, through the ComMod process?

RQ2: What did technician members learn and perceive about CC members learning about socio-ecological system dynamics in Mabalane, and specifically the outcome of theirs and CC members' planning behaviour, through the ComMod process?

RQ3: To what extent did the local technician's change of beliefs about socio-ecological system dynamics in Mabalane in general, and the outcome of their planning specifically, lead to new subjective norms on planning?

6. Methodology

6.1.Participatory planning process

These questions were operationalized according to the different actors' levels of participation within the participatory process. Before justifying this selection of actors and their respective level of participation within the process, we provide below a review of the overall research context within which this research is embedded.

This participatory process is inspired by RPG simulation for participatory planning in Ugandan and Ethiopian case studies within the Afromaison project. Afromaison is a European research project held from 2011 to 2014, involving African and European teams who cooperate to design and test new methods and tools for integrated natural resource management at the intermediary level of decision-making (Kabaseke C, Abrami G, Ferrand N, Gumpinger E, Baha K, 2013).RPG simulation, coupled with other participatory tools, permitted the selection of collective actions and their definition in time and space using Just-a-Grid and COOPLAN participatory tools. Just-a-Grid is a tool that forces actors to prioritize specific issues or actions according to time and space levels. The COOPLAN participatory tool is a table that helps actors to collectively define and select actions to solve the issues. Later on, the strategies and actions were tested using Role Playing Game scenarios. Thus, these participatory methods supported the inclusion of cross-scale actors, such as community members or natural resource managers, in the planning process, and a test of their strategies on the local complexity (Emeline Hassenforder et al., 2014).These case studies and the overall methodology of the project are given in detail on http://www.afromaison.net/.

Raphaëlle Ducrot, researcher at the International Center for Water Economics and Governance in Africa (IWEGA) of the FAEF (Faculty of Agriculture and Forest Engineering) at Eduardo Mondlane University, participated in the Afromaison project and was willing to develop an action research project about participatory planning in Mozambique and, particularly, Mabalane district. She had already studied the district's SWI management relationship with poverty alleviation in the Challenge Water and Food program. In this context, she acquired an understanding of the local complexities and observed the potential for consultative councils to encourage an increased exchange of knowledge and information among the different actors. With her knowledge of the district, her previous relationship with the local administration, her engagement with the participatory planning process, and her knowledge of planning tools and methodology, including Wat-a-Game and COOPLAN, she decided to start an action research project. She initially planned to co-create a role-playing game prototype with the district's local technicians and a leader she knew from previous studies. She included them in the process both because of their roles in planning and natural resource management and because they were young and dynamic. She believed they were more likely to question the current planning system and to commit themselves to the overall research project. They were also higher-level administrative workers, which could facilitate change in the planning process in the hierarchical and top-down culture of the areas**.** After introducing the participatory process, she planned a second round of simulations to brainstorm

local issues related to natural resource management. This phase preceded developing strategies to tackle the issue, implementing Just-a Grid and COOPLAN and, finally, the test applying the finalized RPG version.

This vast research project combines my MSc research with Mozambican FAEF student Carla Monteiro's MSc research. Raphaëlle Ducrot, Carla Monteiro and I co-constructed and implemented the RPG prototype within the Challenge Water and Food Program of IWEGA. This research project focused on the design and simulation of the RPG (role playing game) prototype. is prototype aimed at raising awareness of social and ecological dynamics for key local actors, such as local technicians and the community, in addition to raising farmers' awareness of more integrative planning as a step toward the water service delivery approach. We operationalized the understanding of this local complexity in a particular type of cross-level institution: the consultative council. The reason we chose this type of institution is its role in aligning the district's technicians and community representatives with the question of local development and SWI allocation. The councils offer the opportunity to confront the community and district's knowledge of natural resources and development as a prerequisite to allocating SWI funds in a more sustainable and equitable manner.

6.2. Wat-a-Game

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

> "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." (Emeline Hassenforder et al., 2014)
>
> "It is a custom Mock-up of a watershed where policy makers, technicians and the public can understand and discuss economic, social and environmental impacts of action choices; and where new rules and policies can be explored and tested." (Abrami & Ferrand, 2011)

Following a ComMod approach, the WAG paradigm insisted on the quality of the design and building of the RPG rather than on the product itself. Its adaptability to a large range of stakeholders and cases, including various land and water management issues and scales, made it an interesting tool for bridging knowledge and perspectives from district and community actors. The companion modeling process used in this research requires a small group of key informants to co-design the RPG. The participatory process is based on the exchange of knowledge and information between participants in various exercises about the contexts of ecology and society. To guarantee participant dialogue, their number was limited approximately ten. Their perspective was later indirectly confronted with that of a larger range of stakeholders via RPG simulations. This is called the implementation phase. Technicians were selected to participate in the co-construction, which consisted of co-

designing, testing and monitoring the RPG sessions. Both consultative council members and technicians were involved in playing the RPG at different phases of the participatory process: the technicians in the test phase and the consultative councils in the implementation phase.

Additionally, the level of precision simplifies the phase of model development by experts while illustrating the main issues, bringing about debate among the players. For example, representing local social and ecological complexity in the RPG simulation using easy rules facilitates the emergence of an integrated knowledge of the system's complexity by both types of actors and would lead perhaps to reflection on more inclusive SWI planning. The slow implementation and simulation process of the RPG makes it unsuitable to test several scenarios in order to make the players aware of the long-term impact on natural resources. Instead, we focus on making explicit the interactions in play within the players' socio-ecological systems and their implications for small water infrastructure planning.

6.3.Design of the RPG

The Challenge Water and Food Program team 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 the majority, Mabalane district technicians, known below as the 'technicians'.

Technicians were selected to participate in the co-design and testing of the RPG according to their differentiated knowledge of the district's development. The design phase included three technicians from different district services – one in planning and infrastructures services, one in economic activities services and one in administration planning. Additionally, there was one leader from the Tsocate locality chiefdom, a PNL technician, a local NGO technician and two academics – a technical professor and a PhD student from the province and capital city, respectively. This diversity of local and external technicians fostered a plurality of viewpoints on local dynamics. In the test phase the NGO technicians and both academics were replaced by two of the district's technicians, one from economic services and one from PRONASAR. After the plurality of perspectives on district dynamics was attained, the second phase was implemented in order to include the district's technicians.

The selection of the technicians was coupled with theoretical and practical considerations. The technicians' literacy, ability to share and exchange knowledge on district-level dynamics, and Portuguese language skills facilitated their interaction with the design supports, including diagrams. The co-design phase began with a workshop in early September 2013. During the workshop days the technicians identified the major social and ecological dynamics of the system using the Wat-a-Game methodology toolkit (Emeline Hassenforder et al., 2014). In this process they first listed the actors and resources of the system, then selected the major factors and described actors and resources' interactions in a functional diagram. For example, a human/resource interaction could be: actor A controls/uses/produces Resource B.A human/human interaction could be: actor A taxes/provides infrastructure for actor B.

Similarly, participants identified three different district zones according to their geographical and governance specificities: the Riverine and plateau areas, located in the right bank of the Limpopo River, and the PNL buffer zone, which is located in the left bank. The process, demonstrated that people in the riverine and plateau areas relied on different natural resources but were administrated by similar institutions. On the contrary, in the PNL buffer zone, livelihood largely depended on other natural resources, such as wild animals, and was governed by the PNL administration. In a third exercise, participants were invited to systematically represent the most important actor and resource interactions for a hypothetical village in both riverine and plateau ecosystem zones. The facilitation teams focused particularly on these two villages because of interest in working with cross-level and local institutions in these areas. In fact, the interactions between villagers of the two ecosystem zones was one strategy for accessing natural resources, particularly water during drought period. Thus, social and ecological dynamics were congruent between the two ecosystem zones while the PNL buffer zone was an independent system.

To conclude, during the design process, the district's technicians learned about local, social, and ecological interactions on the sub-district level from their pairs and the community leader, allowing them to reflect on the impact of these dynamics on the system. This would potentially cause them to rethink the current district services fragmentation on natural management. Based on these elements, Carla and I researched and translated the social and ecological dynamics used to create an RPG into simple rules and tested the playability of the model with FAEF-UEM bachelors and masters students. At the end of October 2014, the technicians calibrated and tested the model in Mabalane. During the test, technicians played two rounds of the RPG. The IWEGA team refined the model in accordance with their insight and feedback.

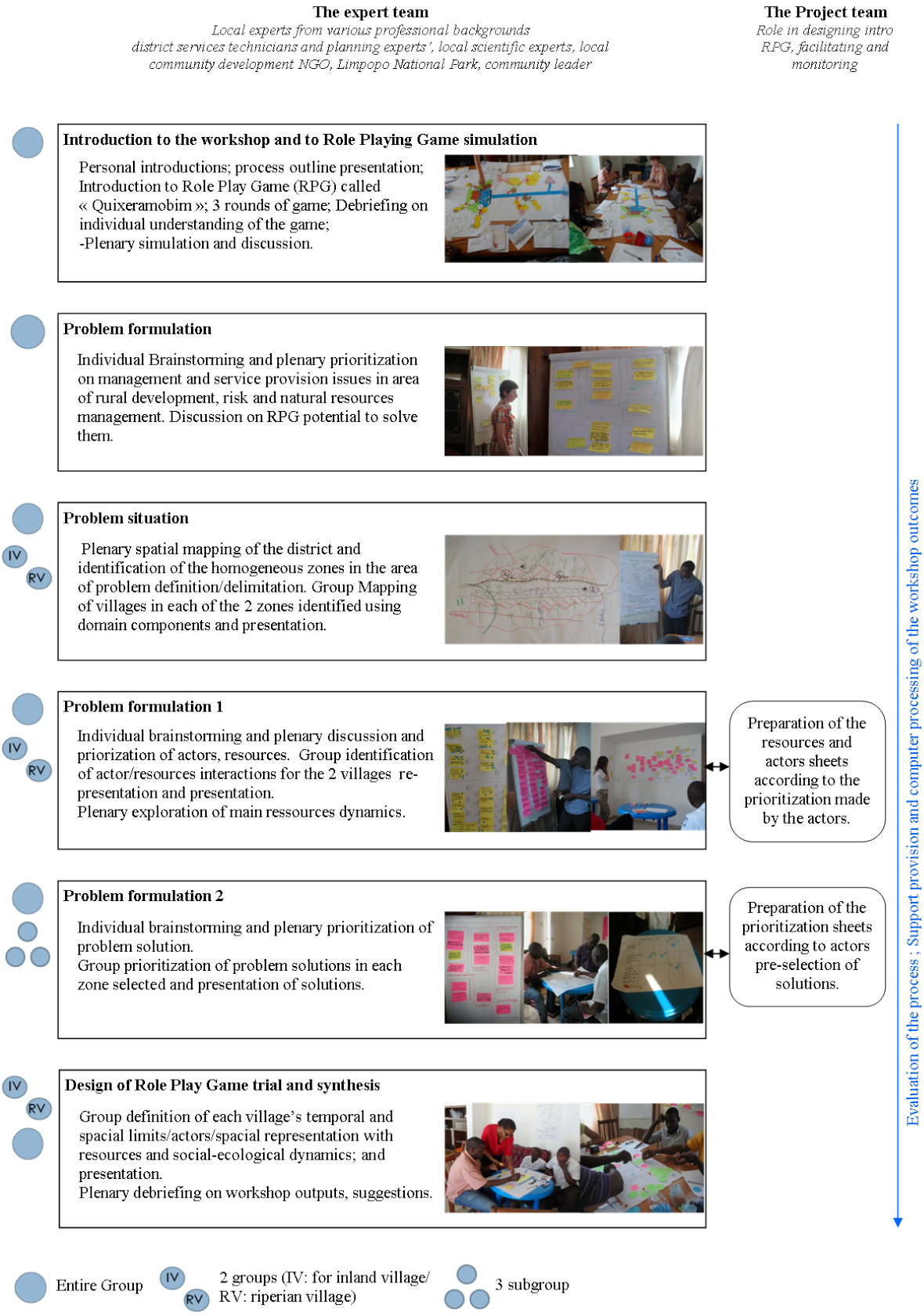

Figure 7: Co-design

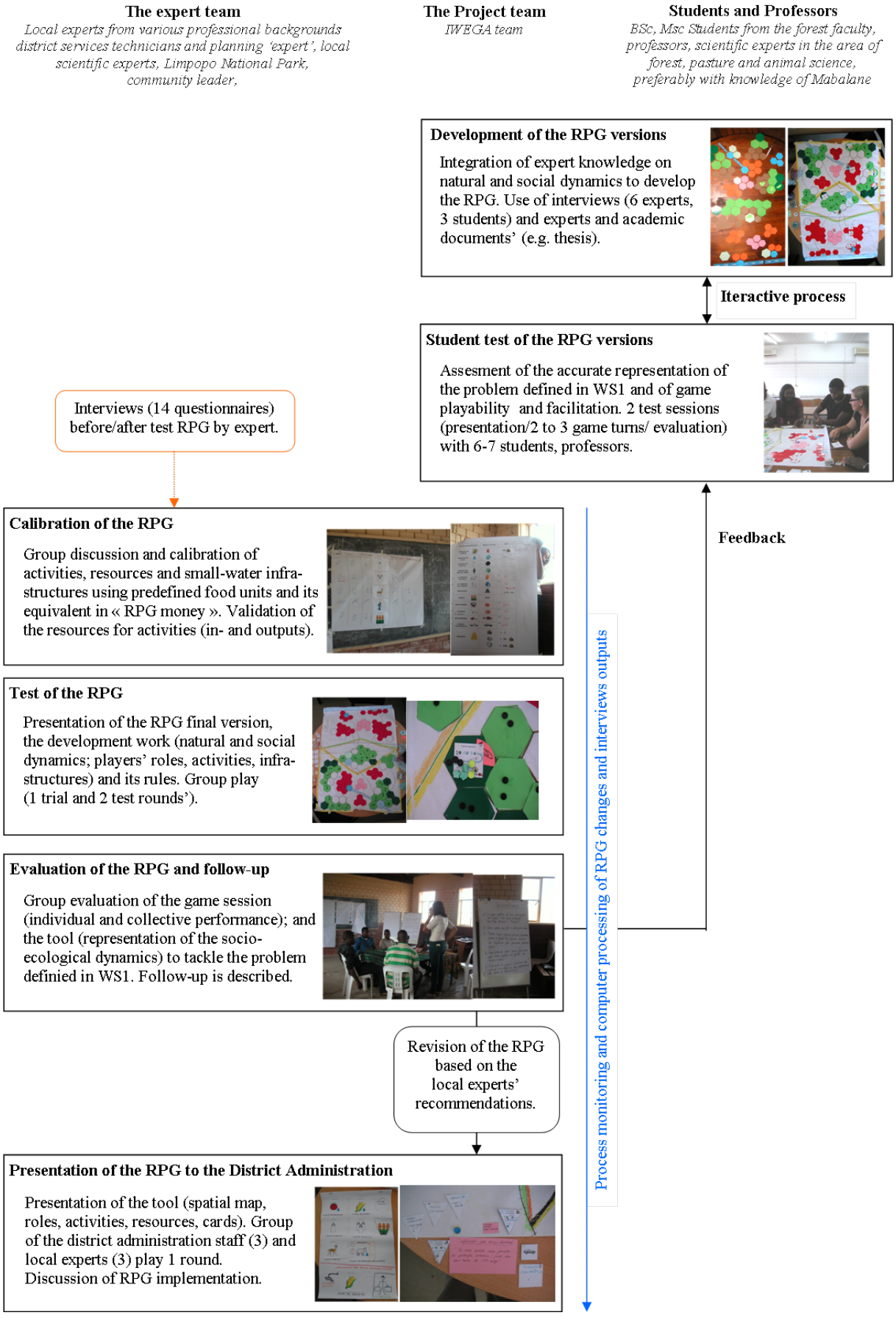

Figure 8: Calibration and Test

6.4. The RPG called “Mabulukuyacana” (Let's talk development)

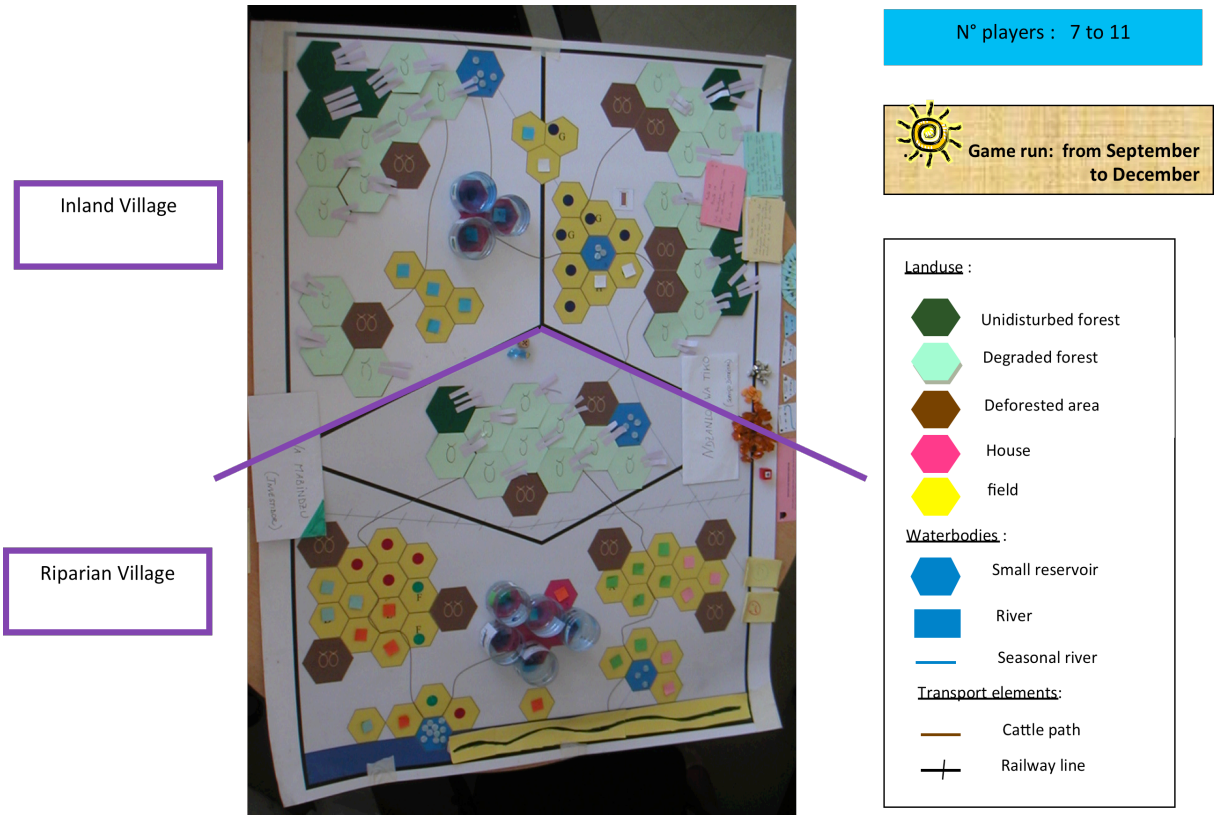

Figure 9: Role playing game board and legend

The RPG constructed in the design and test phases modeled the social and natural dynamics of two villages, one from the riverine and the other one from the plateau areas of the district. The RPG combined social and ecological dynamics and represented their interactions. Natural resource cycles, such as the water cycle, were represented and combined with social dynamics, including negotiations between multi-level actors through role-playing. The specificities of the game board and multi-level roles set up to represent this complexity are shown above.

The role-playing game had a time scale of one 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 in Mabalane district. Two villages’ dynamics were represented. The “inland” village from the plateau areas was characterized by temporal access to water via small reservoirs, large areas of forest and small density of households. The “riparian” village along the river had continuous access to water through riverbed pools, was more densely populated and forest areas were fewer than pastures and fields.

During the simulation, preselected advisory council members were invited to enact a 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 playing was done using simple rules and asks players to be rational.

The District Services Role (SDR) regrouped all the services of the district. SDR mobilized one of the three technicians and money at his disposal, with different outcomes and resource constraints, to deliver public infrastructures, such as a school, hospital, pest control tank or SWIs to the villages and gave out charcoal licenses. The SWIs are boreholes and reservoirs built manually 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 for food units. These SWIs are called local SWIs since they are supposed to be financed by the SDR annual plan funding. The annual plan funding is equivalent in Mabalane's reality to the PESOD. Local SWIs are opposed to external SWIs financed by donors or the province. The SDR would receive external SWIs through a radio announcement. External SWIs, including motor-pumps, reservoirs, and a borehole were distributed along with food or money by the facilitators. In contrast to local SWIs, external SWIs were distributed at a key moment during the session, a moment thought to enhance discussion and interaction among players (section 6.5).

The investor role (IR) represents Mozambican and, to a lesser extent, foreign investors. He had a car and two labor forces as well as enough money to engage in whatever activities he wished, 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. The FR was located in a house and could perform the district's main livelihood activities, such as forest exploitation, pluvial and irrigated agriculture, raising cattle, and hunting in private and community areas. The FR's main objective for his livelihood activities was to gain sufficient food for his family members, who also made up his labor force. Five to seven players took on the FR role while there was only one player each for the SDR and IR.

To conclude, from their interactions with others players and with the game board, technicians in the test phase and consultative councils in the implementation phase could recognize how the interaction of social and ecological dynamics led to impacts they also observed in real life. In particular, this dynamic representation aimed to demonstrate how the construction, use, and management of SWI, such as boreholes and motor-pumps impact socio-ecological systems. For example, players could observe the impacts of their individual SWI management on social indicators, such as the food security (minimum water and food requirements) of the villages' households and natural resources indicators, such as the availability of forests and water.

The role-playing game also enhanced interactions between players by fostering a playful environment, keeping a certain distance from the player's reality, and using incentives, such as external SWI or simulated planning places (section 6.5). Through these interactions, players may discover and reflect on the potential of collective actions when monitoring predefined socio-ecological indicators.

6.5.A typical session

An RPG session was orchestrated in the following manner: the project team gave a 30-minute presentation about the game materials and rules. The presentation was not meant, however, to orientate the players' learning experience and interactions in the play by explicating normative objectives for each role. The participants were expected to develop individual strategies according to their knowledge of the roles' real interactions and practices. Furthermore, the role-play was meant to encourage the participants to exchange perspectives and knowledge about the interests, actions and interactions of the roles in real life. To facilitate such an exchange, the presentation focused on the RPG rules and the activity sets for each role. The farmer role was an exception because his livelihood objective was believed to be largely shared by the players as common knowledge. The presentation preceded the random assignment of roles among participants and the invitation to test their understanding in a trial run.

During this trial it was possible for facilitators to observe how players coped with their role and the game rules. Facilitators would assign investor roles (IR) and District Services or government Role (SDR) to the players that seemed better equipped to handle the RPG. The project team decided not to assign pre-determined roles to each consultative council's members because the team believed these members could acknowledge the interests and actions of each role. The participatory process showed that investor roles (IR) and government roles (SDR) were more difficult to play. Therefore the process was adapted and these roles were assigned to players that seemed to have easily grasped the game rules. There was a second exception to the random distribution of roles among consultative council members in the RPG sessions. In fact, when consultative council members came from both inland and riparian ecosystem zones, they were assigned to opposite villages in the game, when possible. Therefore, a consultative council member from the plateau ecosystem zone in real life would be assigned a farmer in the riparian RPG village if he did not show a particular desire for playing the roles of either IR or SDR.

After the game, players were invited to perform two to three real game runs. Each run including a trial session would last 45 minutes on average. The trial runs did not count. The RPG session ended with a 45-minute debriefing. This phase allowed players to reflect on district-level dynamics and major impacts of the game. Each RPG run had a predetermined sequence. The project team, acting as facilitators, first assigned each player's game roles and asked the farmer roles (FR) of the inland and riparian villages to elect, among themselves, their respective leaders. After this preparation, players would enter (or not) into interaction to make individual choices for the coming year according to their role objective, activities, and resources. At the end of the individual choice phase of the game, facilitators would reward the outcomes of the players' activities with money or food, and with new SWI. This phase is called the individual and collective run review. It supports players' reflexivity on the impact of each player's actions on their personal play objective. The farmer role (FR) objectives are clearly defined as household food security. This phase also allows players to use ecological indicators to observe the impact of their and other's actions on the state of natural resources.

Finally, a Simulated Consultative Council session (CCS) was autonomously set up by the players for 15 minutes. Facilitators would introduce them in a simulation of a "real" consultative council session. Immediately preceding the end of the CCS, the facilitators announced, as if they were the local radio, the weather forecast for the coming year and the arrival of provincial or donor-funded projects for local development. The weather forecasts were uncertain, varying between two of four possible scenarios: humid, medium, dry, and very dry. The nature of the development projects, either SWI or public goods, was random but systematically announced at the end of the each game run, with the exception of the trial runs. The simulated consultative council session associated with weather forecasts and external SWI's was meant to create a privileged opportunity for interactions and discussions among the participants. Simulated consultative councils were strategically located at the end of the game round balance and ended after announcements of the impending availability of water, SWI, or other public goods. The game round balance is a time after players have received the outcomes of their individual activities. It shows the evolution, using social and ecological indicators, of individual and collective natural resources. Simulated consultative councils highlighted information about challenges and future opportunities that players would need to collectively discuss at SWI planning. The players were not given any objectives during the consultative council meeting simulation because the research aimed to make players reflect on planning in relation to their understanding of the complexity that was facilitated by their knowledge exchange on reality dynamics. Instead, this window was left open for the players' interpretations of integrative planning.

6.6.Implementation of the RPG

Finally, with the approval of the head district representatives, a team composed of the IWEGA researchers, two translators and three technicians organized six RPG simulations between November 25, 2013 and December 9, 2013.Four sessions were organized at a post level – one in the village of Mabomo (Mo), two in the town of Mabalane (Mb1, Mb2), and one in the town of Combomune Posto (CbP). Two sessions were organized at a local level, in Tsocate (Ts) and Combomune Rio (CbR). In each of the CCs, seven to eleven of the CC members were selected according to the legal CC composition (40% leaders, 30% women and 20% young people) (Ducrot, 2012).The number of sessions was limited by the time of the project and the distances that needed to be covered. Thus, CCs at the post level were prioritized over the local level because they, through their constitutions, already included Local Consultative Council (LCC) members. RPG sessions were scheduled with their time preparation and evaluation in the following order: Mo, Ts, Mb1, Mb2, CbR, CbP. Two of the three technicians were in charge of monitoring the role-playing game sessions on a rotating basis. Monitoring RPG sessions was important for allowing the technicians to discern informal relationships at a local level, such as mutual-help relationships and negotiations for access to resources. Furthermore, technicians could observe how the formal norms, policies, and implementation of the subsidiary SWI program they defined in the design phase would be implemented on a community level by the key intermediaries –the community leaders in the RPG sessions.

Implementing consultative council members was intended to provide a place for the technicians to visualize and concretize their knowledge of local social and ecological dynamics. It was meant to offer a wider perspective on district-level complexity, perspective they would not acquire in real-life situations. Additionally, by assigning different roles, such as farmer, investor, and district services worker, they could reflect on their knowledge of real local stakeholder interests, as well as their interactions with natural resource management. In particular, the simulated consultative council space, allowed them to re-endorse their consultative council roles and discuss local planning with knowledge of their role, other's roles, and by means of exchanging perceptions on dynamics with the other players. Therefore, without influencing their discussion with objectives and rules, they were provided with a place to reflect on their consultative council member role. This allowed them to co-learn about complexity, to integrate the local actors' interests and knowledge, and to test how this integration could support more sustainable and equitable water access delivery. We hoped they would, particularly, see the value of poor local farmers' interests.

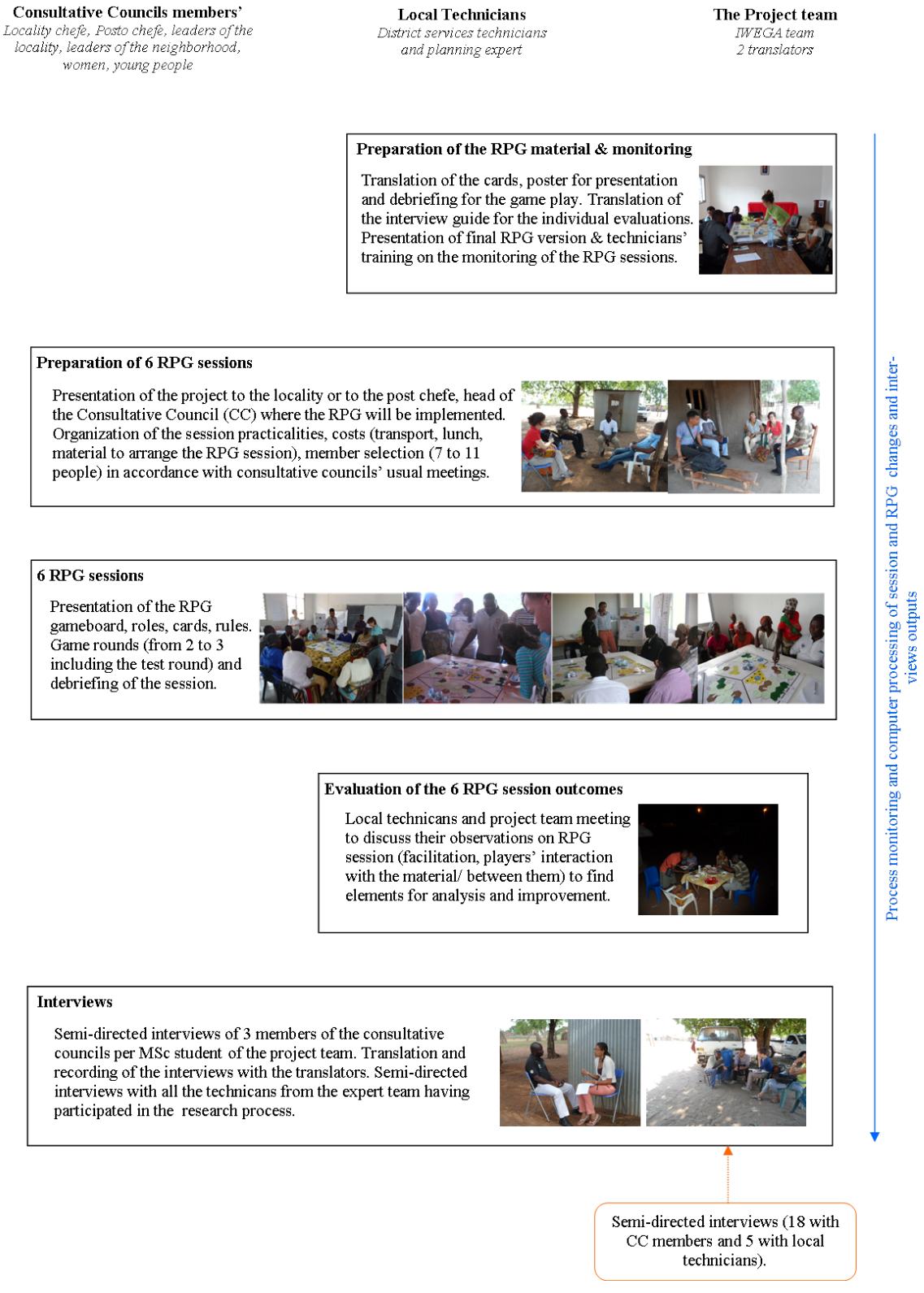

Figure 10: Implementation and evaluation

6.7. Interviews and analysis

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. 7 open questionnaires were

distributed to the technicians before the test and 7 after to assess their change of beliefs on local complexity and norms about natural resource planning derived from the design and test phases. A month after the co-design workshop, an auxiliary questionnaire about behavior change was added to the evaluation of technicians' new beliefs and norms. The table bellow synthesizes how beliefs on planning and subjective norms were operationalized in these open questionnaires.

Table 2: Technicians' beliefs and behavior change assessment for design and test phase

	Learning assessment loop	Belief & Behavior type	Operationalization of integrative planning concept
Questionnaire 1: evaluation of the co-design phase	Part 1: Before	Beliefs on complexity	What are the challenges in NR Planning for the following organizational level*? *(technical service/community/district/national)?
	Part 2: learning associated to design workshop	Beliefs on complexity	Did the co-design workshop made you think differently about: natural resources? Your partners? Others actors?
		Subjective Norms on planning	Did the test session make you think differently about your role in planning?
		Behavior	Did you change behavior/enter in relations with others after the co-design workshop?
	Part 3: After	Beliefs on complexity	What could be done for NR planning for the following organizational level*?
Questionnaire 2: Evaluation of the test phase	Part 1: After	Beliefs on complexity	What did you find interesting in the test session?
	Part 2:learning associated to test session	Beliefs on complexity	Did the test session make you think differently about: natural resources? Your partners? Others actors?
		Subjective Norms on planning	Did the test session make you think differently about your role in planning?
		Subjective Norms on planning	Did the test session make you think you could change your relation with others? Adopt a new behavior? Influence your organization's actions/decisions?

In order to guide the technicians' reflections on complexity and integrative planning, the questionnaires were structured in the form of a loop. This loop assessed technicians' beliefs about local social and ecological dynamics and interactions within the context at the time of the questionnaire, and then asked each one to further elaborate on any changes in beliefs and norms typical to the co-construction phase, before finally reassessing his beliefs on complexity. The change of beliefs about complexity from the co-construction phase was detailed using complexity-related concepts, such as natural resources (operationalized with the terms: water, land, forest, cattle), and multi-level actors and their interactions. The change of beliefs about complexity in a real context was assessed by means of the technician's definition of current multi-level issues in NRM planning or management, and what he expected their multi-level solutions to be. This was meant to show technicians that multi-level issues are related to one another because they are derived from multi-level socio-ecological interactions. The change of norms concerning planning was assessed via the perceptions technicians had about planning their current and future professional activities.

The merging of the completed RPG monitoring sheets and the evaluation discussions served as the data base, along with 23 individual, semi-directed interviews (table 3) that evaluated the final learning of technicians and consultative council members. Time and coordination issues with local leaders limited the number of interviews in Cb1.

Table 3: Distribution of semi-directed interviews

Consultative councils members in chronological order						technicians
Combomune Posto	Combomune Rio	Mabalane 1	Mabalane 2	Mabomo	Tsocate	
3	3	1	3	3	4	6

The semi-directed interviews differed between technicians and consultative council members. We evaluated the technicians' change of beliefs and norms concerning complexity by assessing the RPG monitoring and the technicians' reflections on it in their final evaluation, which measured the technicians' awareness of the overall participatory process (table 4).We assessed CC members' understanding of complexity from the RPG playing (table 5).

Table 4: Technicians' beliefs and norms change assessment for the implementation phase and overall participatory process

		Learning assessment loop	Belief & Behavior type	Operationalization of integrative planning concept
Interviews with technicians:	Evaluation of the Implementation phase	Part1: Before	Beliefs on complexity	What do you think is important in order to improve NR planning?
		Part 2: learning associated to the RPG	Beliefs on complexity	What did you learn from the RPG session monitoring?
			Beliefs on complexity	Did you observe particular interactions, relations, arrangements during the RPG sessions? Were they realistic? If not, what are the limitations in reality for such arrangements in planning?
			Subjective Norms	Did the monitoring of RPG session make you think differently about today's NR planning?
		Part 3: After	Subjective Norms	Do you think you could put in practice some of these solutions?

Table 5: Technicians' beliefs change assessment for the implementation phase

		Learning assessment	Belief & Behavior type	Operationalization of integrative planning concept
Interviews with CC members:	Evaluation of the Implementation phase	Learning associated to the RPG	Beliefs on complexity	What did you learn from the RPG playing?
			Beliefs on complexity	Did you observe particular interactions, relations, arrangements during the RPG sessions? Were they realistic? If not, what are the limitations in reality for such arrangements in planning?

7. Results

In order to understand the learning outcomes of both consultative councils and technicians from the participatory process of the research, I first describe the planning behaviour consultative councils members adopted during the game play. Later on, I describe the learning they acquired from this experience. To assess technicians learning, I am interested in their representation of Mabalane while designing the role playing game and comparing it with the learning they got from monitoring the playing sessions.

7.1.Consultative councils members' playing strategies

7.1.1. 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 Tsocate (Ts) and Combomune Rio sessions (CbR), in which the government financed SWI at the players' demand. They respectively constructed a borehole to answer to the private need of a riparian farmer adjacent to his property and co-financed a motor-pump with an 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 had with 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 during the Simulated Consultative Council meeting (CCS). Active participation of the players during the Simulated Consultative Councils was observed in only 3 out 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. By contrast, the radio announcement of external SWIs initiated a consultation about the allocation of such infrastructures.

As there were no external investments made during the Mabomo session (Mo), 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 consulting level.

Whereas local SWIs were 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 consultative councils and the players decided to allocate tillage equipment in the village close to the river, knowing that the coming year would be dry and that the area was more suited to agricultural production than the other one. Meanwhile, the borehole or reservoir would be allocated in the inland village: the area most sensitive to water scarcity" (Mb1 session resume). In Mb2, motor-pump allocation was similarly discussed during the simulated CC meeting. In contrast with the Mb1 session, in the Mb2

session the discussion was monopolized by two players, local leaders in the real context, who participated in Mb1 session.

No discussion of SWI allocations occurred in the simulated CC meetings of the 3 other role Playing Game (RPG) sessions. There were few discussions in the CCS apart from those around SWI allocation. In the CbP and Ts sessions, players discussed the over-exploitation of the forest. In the case of CbP, inland villagers decided after the discussion to create a village forest reserve. In the other CCS, players would not discuss a lot. Their interaction was limited to a review of the FR's activities' outcomes and general recommendations by the SDR and leaders on their coming activities, such as food production.

The simulated CC meetings offered dialogue spaces where the allocation of SWIs was occasionally discussed by the players. The little use of CCS to confront perspectives on the SWI allocation and management considering the local complexity, is similar to what is observed in Mabalane(Ducrot, 2012).

7.1.2. Individual and collective strategies

The dominant pattern of decision making sustained mainly individual strategies. We particularly were interested in SWI-related individual strategies. Therefore, the main roles and SWI type (e.g. private or public) involved in each role were distinguished. To a lesser extent, players were also involved in bilateral interactions. Few participated in collective actions, such as associations or partnerships, which will be elaborated upon (table 6).

Table 6: Hierarchy of mentioned and observed players' strategies in all RPG sessions

Ordering	Strategy type	Ordering	Strategy sub-type related to water access	Roles
1	Individual	1	Attached to public SWI	District Services (SDR)
		2	Attached to private SWI	Farmer (FR)
		3	Attached to development subsidies	Leaders
2	Collective	1	Bilateral interactions	All (Investor (IR); FR; Leaders; SDR)
		2	Association and partnerships	FR/Leaders

7.1.2.1. Individual strategies

Table 7: Individual strategies and level distribution

Roles	Type of individual SWI strategy	Organizational level
SDR	Construct boreholes with annual district budget	District to village
FR	Buy and manage its motor-pump	Village
Leader	Privatized subsidiaries delivered by SDR	Cross-level interaction

- **Attached to public SWI**

SDRs' local strategies consisted of building SWIs but he did not take into account local needs.

In Ts session, the SDR launched during the individual choice phase of the RPG round, the construction of a reservoir with a "food-for-work" program. He also made available a water-pump for each village. He had received both subsidized (also called external) infrastructures from the national government at the end of the simulated consultative council session. After a first mobilization of the riparian villagers to construct the reservoir; they had rapidly neglected the construction to favor their individual farmer's strategies of irrigated agriculture. This shift was seen 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 SDR also allocated a borehole close to the railway and distant from any of the village.

- **Attached to private SWI**

In every RPG sessions, individual players bought and managed individually motor-pumps for the irrigation of their fields. The management of private and subsidized motor-pumps was the main challenge identified by the players. At least, in two thirds of the sessions, players experienced a shortage of water and needed to fall back on other livelihood strategies, such as working for their neighbor (also called ganho-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 an inland temporary reservoir to the river where access to water is secured. The other wanted to continue in the next round to operate his motor-pump at the expense of selling animals if water fell short.

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

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

I: how would you do this?

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

[2]

- **Attached to development subsidies**

The simulated 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 the village/leaders were 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 cases to the privatization of public resources as illustrated by the way subsidies (in the form of 5 food units and money) were handled in CbR session, or Mo sessions (Box 4).

Box 4: examples of individualistic strategies of leaders

The inland leader kept the five units for himself; and did not decide on 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. The riparian leader in the contrary used the money for a farmers' association. (Analysis from CbR individual interviews)

The inland leader distributes the subsidies to the farmer he knew from his village and the investor role. (Analysis from Mo individual interviews)

The individual form of planning livelihood activities or managing SWI matches with the top-down and hierarchic culture of Mabalane society that Ducrot describes(Ducrot, 2014). Below, we will show how in some occasions, individual decisions supported collective strategies in the form of bilateral interactions.

*7.1.2.2. **Collective strategies***

- **Bilateral interactions**

According to the participants, players were mainly involved in occasional bilateral relations. Players' bilateral relations were mostly negotiations among farmers (table 8).

[2]R for respondent and I for interviewer

Table 8: Bilateral interactions mentioned by CC members

Interviewees (number)	Roles	Relation Type	Organizational level
3	FR-FR	Commercial exchange of production equipment	Village
3	FR-FR	Mutual help relationship	Village >Inter-Village
2	FR-Leader	Access negotiation to opposite village natural resources	Inter-village
2	FR-IR	Commercial exchange and lending money	District
1	FR-SDR	Private FR negotiates with SDR allocating SWI	Cross-level
1	IR-SDR	Lending money	District

The interviewees mentioned likewise (3 times each) two types of negotiations. They are exchanges involving equipment against money or labour and mutual help relationships. The mutual help varied from the exchange of labor force to work in the neighbors' parcels of land in exchange for food, an exchange locally called "kukathekela" to the exchange of tillage services or "kurimela" in exchange of labour.

> "Throughout the game, she felt the need to plough her fields. She resolved to go to her neighbor and offered to work in his field in exchange for 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.

Some players also engaged in individual negotiations with a villager from the other village to acquire access to its natural resources. Farmers would preferably ask the leaders of the opposite village for permission to access natural resources. Nevertheless, it was not systematic. Other players, such as farmers and investors were also providing access to natural resources (Box 5).

Box 5: examples of inter-village relationships

In Mo and CbP, farmers asked authorization from the inland village leader to hunt in their forest. The leader in CbP of the session would consult with his population before giving his consent (Analysis from CbP, Mo individual interviews).

I: During the session, I saw Farmer role from the other village hunting in the forest areas of your village. How did it happen?

R: They talked to our leader. He showed them the areas where they could hunt.

I: Why did he let them hunt in the community forest? Did he know them?

R: No. He let them hunt because it was his area. He told [the villagers], others wanted to come to hunt and we accepted this. (FR, CbP)

There were also to a lesser extent, relationships between investors and farmers; government and farmers, and yet very little investors (IR) and government (SDR). Negotiations between farmer and the investor were based on strictly commercial exchange or relationship: the investor for example would finance farmer's productive assets, such as small water infrastructures in exchange for labor force or money. The RPG gave incentive t investors, unlike real situation, to hire local labor force since he had only three employees and his activities were labor intensive. However, the labour forces negotiations between farmers (FR) and between farmers (FR) and investors (IR) were limited, showing the local reluctance to work in other player's estate:

R: They could not do any activities so they were forced to work for other people

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

R: I would make sure not to have my household members be employed anymore." (Farmer facing the loss of his crops, Mb1)

In the majority of the cases, it appears that the IR was accessing forest or water resources without preliminary negotiations with the communities' leaders.Aside from interactions concerning game rules (licenses delivery by SDR to FR), FRs in a few occasions would negotiate boreholes with the SDR sitting next to them.

R: One player asked me to construct a borehole in my village and I authorized its construction.

I: Who was the person willing to construct it?

R: The person in charge of [the SDR's] activity. He had no land to construct the borehole and asked if he could construct it on mine. (FR, CbP)

Finally IR would prefer to coordinate with FR. If not, the IR would coordinate SDR in order to acquire licences for forest exploration.

> R: He only remembers that one individual (speaking of the investor) asked for money from 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 he was a "trusted/reliable" man because the population had gone to lend him money to buy goats […] and cows. They could see he was a good person.
> (FR, CbR)

- **Associations and partnerships**

Players more rarely gathered in farmers associations or committed to occasional partnerships. For example, four interviewees referred to the creation of an association of farmers during sessions, three of them aiming at collectively managing a motor-pump. The association members shared both costs and revenues from the irrigated scheme when the motor-pump arrived (table 9).

Table 9: Associations described by CC members

Mentions	Type of association	Sessions	Roles	Organizational level
3	Association of FR in irrigation schemes	1 (CbR)	Village leader gathered some neighboring villagers and lead the association.	Village
		2 (Mb1,Ts)	Neighboring FR gather to manage a private or subsidized motor-pump.	Village
1	Association of FR for hunting	1 (Mo)	Farmers from riparian village capitalized their resource to pay their hunting license without which they could not have hunted in the inland village.	Village

In one case, the association resulted from a leader's 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 took the initiative of creating the association after receiving from the SDR 2 motor-pumps at the end of the first round. He created the association with two others, sharing access to the same river pool with him while

two others from the same village, who had access to another pool, managed individually their farming activities. One took charge of the operating cost of the motor-pump. The leader of the association later also received from the SD 5 units of food for the village and decided to add these to his association's harvest. He also decided to invest external financing transferred by the SDR in constructing a canal to irrigate further fields and increase the capacity of the small river pool from which the motor-pump was irrigating. The two women of the association individually engaged in a specific mutual help relationship based on informal exchanges called "Matsoni". Their interactions went beyond sharing operational cost of the motor-pump and the 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 association and managed in common their cattle. In addition to, they also performed individual strategies. One, for example, focused on constructing a brick house.

I: I remember that you played a lot with your neighbor. Is it true?

R: Yes we were together

I: What did you do together?

R: We lent each other money when one did not have any. Sometimes we farmed together. (FR, CbR)

The two other associations described by the interviewees in Ts and Mb1, which had not been noticed by the facilitation team, were private affairs between two (or more) farmers. After the first round, the individual management of the motor-pump dominated collective management, with one farmer paying for the maintenance costs.

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

I: Were there other forms of help during the game?

R: There was a phase where I was renting water when the farmer association, I was part of, had been given a motor-pump […]

I: Do you think you lacked help?

R: We were helping each other a lot because every time I was going to farm I could have access to water. Every time the motor-pump was there to irrigate my fields. It was a unified solidarity: everybody helped each other. (RM, Mb2)

The collective strategies supported, in some cases, monetary exchange to foster and maintain access to the water resource. In Mb1, after consulting the CCS, the riparian leader proposed establishing a regular fee to maintain the borehole. The importance leaders in Mabalane have

in assuring collective action to sustain SWI was described in PRONASAR's evaluation (Ducrot & Bourblanc, 2014).

In the CbR session, one villager from the riparian zone lacked one water unit for household consumption. To secure it, he first borrowed money from his association to pay the Investor Role (IR), the cost of translocating to the inland village where a borehole had good water. He then negotiated with three inland villagers to access their borehole. Even though the individual strategies were dominant, the RPG sessions offered a 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).

7.1.3. Members of the consultative councils members change beliefs

There were very few discussions during the simulated 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 were allocated to the inland village while none was distributed to the riparian village. The debate was soon dominated by complains about SWIs allocation.

> "Three players (two FR and the IR) said the allocation was wrong. The SDR agreed saying that it was not the norm. Their arguments let others think the leader from the dispossessed village was weak and did not communicate the needs of his population to the government. A FR was also in favor of allocating the small reservoir to 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 agreed to identify the leaders as main actors to improve the SWI implementations. According to three of them, "*the state before starting a public work has first to talk to leaders"* (or CCL). *"The leaders are the ones 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 game materials 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 (Box 6). There are some differences among the players regarding the first declared learning. Some of them, most importantly learned to plan, by anticipating and allocating a set of resources needed to perform some of their farming activities (Box 7) while other focused on innovative farming infrastructures, such as motor-pumps, ploughs and chainsaws (Table 10, Box 8).

Table 10: Distribution of the learning of CC members from individual interviews

Learning	Test and formulate FR strategies				
	Plan& test individual strategies	Test farming infrastructures	Collaborate with other players	Plan &Test activities using scenarios	Others
CC members (number/17 respondents)	6	3	3	3	2

Box 6: Test and Formulate Strategies

Excerpt from a Combomune Rio and district CC member:

I: And if we play this game in the village, trying to show how people live […] Do you think the game could be used to find solutions?

R: Yes

I: Why?

R: Because the game opens our mind in the sense that we learn from looking at the consequences (constraints or new opportunities) of our actions. (FR, CbP)

Or stated by a CC member from Tsocate consultative council presidency:

"In this exercise, what raised my attention was learning how to invest, how to work in a certain zone, because in the end we often make investments in the wrong, inadequate zones. This is the case, for example, when someone wants to farm in non-arable lands, or cultivate irrigated crops in areas where there is no water. We learned in the RPG to pay great attention to how to do the works: where and how."(IR, Ts)

Box 7: Plan farmer's individual strategies

I: Did you like the game?

R: I liked it. It was illustrating what you need to do in order to sustain your family. Because, you shouldn't do just one activity, but many in order to secure food at home. (FR, Ts)

They would sell in the game session cattle or borrow money to buy SWI infrastructures or production equipments (e.g. chainsaw).

Box 8: Test farming 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 did not have enough money to operate it, I learned to sell a goat, or an ox to make the payment. (FR, Mo)

While testing (Box 8), players observed the dependence of the SWI on water dynamics and spatial heterogeneity. For example, they mentioned how important a constant volume of water is for the motor-pump or the dependence of the boreholes' functioning on the groundwater quantity and quality. One of the interviewees mentioned the relationship between infrastructure development and natural resource 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 there, the tree has a possibility to sprout. We may need to incentivize agricultural activity to preserve [the forest].

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

R: I think the solution is to borrow some money from [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 (Box 9).

Box 9: Collaborate with others players

I: Did you learn something from the game?

R: I learnt many things. First I learned to associate with another farmer to produce in association. Then I learned that when there is hunger at home, I can sell cattle or goats in order to solve the problem. I learned also that if I have some money, I can rent a car and go to the river and get some water… these kinds of things […]

I: What do you think the game can bring?

R: The game can be used to show that when you are associated with some people, you can easily get a motor-pump, whereas if you are alone, you could die before buying one…You can also borrow a plough from people who have one. (FR, CP)

Finally three others valued the changing climatic scenarios to evaluate, test and ameliorate these strategies (Box 10).

Box 10: Plan activities with scenarios

R: [...] I came to understand that after all we were discussing about the zone where we live and that the living conditions are the same in reality and that activities are similar to our daily ones. The game was to show us what we were doing every day. To show us how we do things, if we do them well or not.

I: How can the game help?

R: With the game, people could have more capacity to act. They could require financing for agriculture or other projects. But the people here do not have any vision. They do not believe they can improve their situation. For example, if there is water close to the river, they could use the area to make recession crops and gain from [these crops]. This would need to plant a certain crop there. Not for irrigated corn, corn is too cheap. People here know about these things but they do not know how to do them, put them in practice. They lack vision.

I: Did the game bring knowledge for this?

R: The game was repeating situations. We planned 3 times our activities. Every time we were making the balance, discussing issues at the level of the consultative councils (CCS), some things were improving in the next round. (FR, Ts)

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, would not 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 reduced participation of Tsocate LCC in the real planning of small water infrastructures: "*We were discussing issues in the simulated CC but we weren't searching for solutions. This is also what we miss in our consultative councils "(talking about LCC of Tsocate) (IR, Ts).* He identified two means to overcome this gap. The first element was the increase in the CCL's awareness and capacity to propose small water infrastructures and the second was the strengthening the existing mechanisms through which the locality communicates with upper administrative levels. The two mechanisms he referred to were the consultative councils and the open governance meeting (visit of the administrators or higher level politicians to village and district).

To conclude, the following observations can be made about how the CC members played during the RPG sessions and what they learned. The CC members mainly made decisions by themselves in order to build up their individual strategies. They rarely took advantage of collective spaces to discuss the allocation of external aids, such as subsidies or external SWI. Instead, they focused on their individual strategies when they needed natural or non-natural resources to implement their strategies in bilateral interactions. Therefore, collective strategies, though diverse and more highly represented than in reality, were undermined. This individual perspective on natural resource planning was confirmed by players' compliance with the actions taken by others, such as SDR, and whose overall understanding of individual farmer's livelihood strategies.

7.2.Technicians change beliefs and norms

7.2.1. Learning from the interactions during co-design of the RPG

In the workshop design, after describing the interactions between local actors and resources, technicians were invited to sketch a dynamic representation of these interactions using pebbles and other game materials. For this exercise, the group of technicians was divided in two. One group described the natural and social dynamics of the inland village while the other group focused on the riparian village. In addition to defining natural dynamics for each village, technicians defined individual strategies of key local actors, such as villagers, and tax agent and charcoal investors. The individual strategies are similar to the those of the final RPG draft, namely that the farmers' livelihood activities encompassed farming, cattle breeding and charcoal production; the tax agent or SDR livelihood activities were the delivery of exploration licenses and control of forest exploitation; and the investor's livelihood activities were charcoal production. Technicians from both groups defined collective strategies, including bilateral and association relationships. For example in the inland village, the farmers could commercialize their charcoal for local investors near their village.

R: The local investor comes from his camping site to explore the surrounding forest areas while the households of the nearby village also come to the same forest areas to explore charcoal for living. Villagers use the road built by the investor to carry their charcoal load from the forest to a commercialization place. The villagers can also sell their production directly to the investor.

I: So [in the RPG] there will be a rule allowing such arrangement in charcoal production and commercialization?

R: Yes
(Technician A2, design phase)

Similarly, in the riparian village, the tax agent or district services would come to chase the elephants away when they threatened the farmers' crops.

"When a group of elephants comes to a crop parcel its damage is equivalent to one unit of food produced by the farmer role for a year. But when it happens, a player in the role of a fiscal comes with his bicycle and a weapon to chase the elephants."
(Technician A1, design phase)

According to the technicians, the riparian villages would organize themselves around the management of SWI.

"In relation to the dynamic of water, we represented the village consumption of two hundred people using a borehole, here [showing it]. Thus, every three months, this borehole needs to be revised. It can still work but must be carefully managed."
(Technician A2)

In the inland village, farmers would need to manage the boreholes, which were prone to frequent breakdowns while in the riparian village the farmers would manage the motor-pump as an association.

"There is the possibility for farmers to gather in an association to manage a motor-pump. They will preferentially use the motor-pump after the end of the rainy period, when they finished collecting rain-fed crops such as corn, or in case of drought."
(Technician A1, design workshop)

Finally, some of the production infrastructures for allocating new resources were viewed in connection with several natural resources. In the riparian village, the availability of the motor-pump was meant to increase opportunities for new livelihood strategies in farming during the dry period while, in the inland village, the use of a tank would support the development of cattle grazing and decrease the pressure on less-renewable resources, such as the inland forest.

I: Why is there [showing the representation of the inland village dynamics] a pest control tank?

R: The communities have, for main livelihood strategies, charcoal exploration. If farmers' cattle do not suffer from pests, instead of exploring the forest, villagers will develop their cattle as a reliable source of income. (Technician A2, design phase)

It should be noted that technician A1 and A2 dominated the presentation and in answering questions about the game draft. In the group representing the inland vilage, the type C technician started to present the sketch but focused mostly on the description of pebbles and the panel. The A2 technician replaced him to present the natural and social dynamics.In the group representing the riparian village, the A1 technician presented the group work and answered the majority of the questions.

7.2.2. Learning about planning from the Participatory process

During the participatory process, the technicians' learning did not follow the same evolution. Therefore, a typology was made to differentiate them (table 11). The technicians type A got an inclusive perspective on planning before the test phase, the technicians B came to the same conclusions as the A participants, but only after the game test session, while technicians C did not adopt this perspective at all.

Table 11: Technicians learning typology

Type	A	B	C
Number of technicians	3	1	3

Before, discussing this learning, we introduce the playing strategies technicians elaborated in the design phase of the role playing game.

7.2.2.1. Evaluation of the design & test Technicians type A

- **Evaluation of the design phase**

The design workshop impact on technicians learning was evaluated before the test of the RPG started. Two technicians and the community leader, the group 'technicians A', got a distinct perspective on planning from the evaluation of the design workshop. The technician is a coordinator from the PNL (National Park of the Limpopo, see Part 2, above) also Technician A1, and the community leader (Technician A2) both formed a new attitude toward natural resource management in this phase. They perceived how people and resources were interacting and could threaten ecosystem as well as the local population's livelihoods.

> "I started to value and see the importance of natural resource conservation once I saw the relationships between [the natural resources]."(Technician A2)

Thus, both valued the relationships between different actors to avoid unsustainable practices and find compromise between each actor's interests.

> "In fact, from this reflection, I questioned myself and discussed with colleagues about the negative factors that can put our lives and the health of our natural environment at risk."(Technician A2)

> "The different actors (communities, government, donors, and entrepreneurs) have their own specific interests. What is important is to put in practice the game with these actors in order to make more consensual decisions about natural resource management." (Technician A1)

Similarly, the design workshop made them reflect on their profession. The PNL technician (Technician A1) started to plan actions with other technical services and provide training on natural resource management as a result of his observations.

> "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 A1)

The community leader (Technician A2) did not yet engage in particular actions. Nevertheless, his understanding of the sources of different impacts made him think of the need to collectively plan the use of natural resources.

> "I came to understand that there is no risk we can not completely avoid or prevent. Thus, we need to involve everyone in the conservation and preservation of the [natural] resources and that we need to evaluate the work to be done and prioritize actions."(Technician A2)

It is worth noting that their understanding from the design phase and their motivation to engage in new professional practices did not appear very consistently in their general reflection on natural resource planning. In fact, they stated that actors from different levels (communities, district government, technical services, and other actors, such as NGOs, investors) should be considered in their respective plans and activities for natural resource management but do not describe their coordination. According to Technician A1, for example, technicians should become more informed about natural resource management,

make the communities aware of their potential impact on natural resources while the district government should elaborate clear policies for natural resource management and provide means by which to tax irregular activities. Additionally, he includes the need for other actors, such as NGOs or entrepreneurs to consider their impact on natural resources as part of their projects.

> "Communities, district services, government, NGOs, entrepreneurs, need to work for development without damaging the natural resources, in order to guarantee their availability and restoration."(Technician A1)

The other technician, A3, is a technician from the planning service of the district and comes from one of Mabalane communities. He remembered to have prioritized and discussed the important actors and resources that were related to natural resources.

> I: What do you remember from the design workshop?
>
> R: I remember listing actors and resources and discussing them. We were asking: what is hunting about? We were thinking that cattle breeding were very important to preserve natural resources as well as irrigated agriculture. Thus we prioritized them. We also found out it was important to represent the district government, district technical services and funds such as the OIIL funds. (Technician A3)

He considered his main learning from the design workshop was to consider local communities in the planning of natural resource management. His general assessment of the issues involved in natural resource planning and his recommendation focused on this inclusion. According to him, technicians should consider the local context before constructing infrastructures and include local communities through their community leaders and, more importantly, the consultative councils when planning natural resource management. Therefore, local government should facilitate and give financial means for this inclusion.

> "The exploitation of natural resources should always come after a study of its viability." (Techncian A3)

After the design workshop, this technician put this learning into practice in his professional sphere. He consulted communities through their leaders before planning. In addition, he wished also to increase the time spent planning together with technicians from different district services.

> "Basically, I have changed my behavior by consulting communities before making decisions […] Every time a particular action is to be planned or performed, it needs to be articulated with other district services and involve communities." (Technician A3)

- **Evaluation of the test phase**

The test phase, during which technicians were invited to calibrate and play the RPG, reinforced the three technicians' perspectives on planning. All maintained the need for more inclusive planning. During the test, they learned from the dynamic representation of natural resources and people interactions.

> "So far, [the game] made us remember to take care and preserve natural resources."(Technician A2)

For Technicians A2 and A3, this representation confirmed their awareness of natural resource scarcity and local heterogeneity.

> "From [the test], I was satisfied with my own resources to seek resources owned by other non-villagers (e.g. investors)." (Technician A2)

Technician 1 stated that he learned that "natural resources need to be managed considering their dynamics". The test also made them reinforce their belief that more actors should be involved in natural resources planning. This understanding correlated with their willingness to engage in more inclusive process themselves. Technician 2 planned to listen and enter into closer interactions with the leaders and population of his locality. Also, the game made him realize how resources were distributed among the local actors. Thus, he was willing to engage in new relationships.

Technician A3 learned from the test that other actors were depleting natural resources. Therefore, he likewise expressed the need for the inclusion of local communities through the consultative councils and the involvement of local entrepreneurs.

> "Still, there is a need to coordinate with investors in order to concretize some significant actions." (Technician A3)

Finally, Technician A1 concretized his idea of collaborative planning for natural resource management and identified the PNL technicians as the right guards for natural resources in the PNL buffer ecosystem zone. According to him, the technicians would keep communities informed and ensure them that NGO or investor interests aren't compromising natural resources.

> "The different actors should act in collaboration with a technical group to guarantee their individual interests along with the preservation of natural resources toward sustainable management." (Technician A1)

In addition, Technicians A1 and A2 underlined the potential of the game to facilitate decision-making around natural resources.

"[The test] helps me to make decisions and analyze them."(Technician A2)

Technician A1 became motivated to design, along with the communities, a role-play game in the National Park buffer zone. In addition, he considered the possibility of using the model to plan his technical service actions.

"We are talking about a participatory tool, in which actors are involved, and therefore can more easily change their way of thinking about natural resource planning […] I need to show this model to my colleagues for them to understand that natural resources should be used in a sustainable manner. This tool could be used for the planning of activities in the park margin zone." (Technician A1)

7.2.2.2. Evaluation of the design & test Technicians type B

- **Evaluation of the design phase**

The technician (type B) is a district service technician from the SDAE. He came to the same conclusions as the A participants, but only after the game test session. During the design phase, the technician did not change his perspective on planning. He noticed as an issue for natural resource management: the need for robust infrastructures, studies on the viability of infrastructure construction, and an increase in the communication and coordination between technicians' services at the district level. He did not explicitly state much of his learning from the design phase.

He said that he would communicate to his colleagues about natural resource management. He also underlined the need for an increased coordination between actors. Nevertheless this normative statement did not apply to him. He stated he was already involved in multidisciplinary technical teams.

"[The design workshop made me think of my professional activity] since every time there is [something] to do, I insist on the participation of technicians from different services." (Technician B)

- **Evaluation of the test phase**

In the test phase the technician observed the realism of the representation of natural resource dynamics and natural resources associated uses.

"All (the actors relations in natural resource management represented in the RPG test) represent well the reality of natural resource uses." (Technician B)

The realistic representation made him reflect on his profession. As an agricultural and economic local technician he saw management opportunities for district development.

> "The game made me think of the possibility to create new pasture zones in the riparian zone and these new zones pressure on the forest." (Technician B)

In addition, he also emphasized the need to include "communities and their leaders in active natural resource management". He expressed his intention to include other actors in his individual planning and communicate to them about what he had learned.

> "There is a need to have communication and coordination between actors when it comes to natural resource management […] I have to involve actors in my professional planning of activities." (Technician B)

7.2.2.3. Evaluation of the design & test Technicians type C

- **Evaluation of the design phase**

From the three technicians who form this group only one district technician (technician C1) participated in the design phase. His general beliefs on natural resources were not different from those of the other two technicians who did not participate to the design phase. He, like them, underlines the need for more skilled technicians and infrastructures at the service level to manage natural resources, to raise communities' awareness of natural resource management, incentive coordination at the district level and to communicate with other actors for them to preserve the natural resources.

Table 12: Issues on natural resource management from Technicians C

Level of organization	Technical service	Community	District	Other (SWI donors, local entrepreneurs)*[3]
Technician 1 from SDPI	There is a lack of: consideration of local heterogeneity/ infrastructures/qualified technicians in natural resource management (NRM)	There is need to raise community awareness on NRM issues	There is a lack of qualified civil technicians and coordination of inter-services in NRM	There is a lack of information transfer between these actors and the district government on NRM issues
Technician 2 from SPDI	There is a lack of NR qualified technicians/need to raise communities' awareness on NRM issues	There is need to raise community awareness on NRM issues	No issues	No issues
Technician 3 from SDAE	There is a need for demonstration of NRM techniques/lack of NRM qualified technicians/ lack of infrastructures	There is need to raise community awareness on NRM issues	Need for coordination between services and planning of activities	There is a need to involve the others actors in preservation of NRM

Evaluating this technician's learning, more specifically associated to the design workshop, made him realize that local communities' development was strongly dependent on natural resource management.

> "Good management of natural resources benefits the proper community. The man and his cattle depend on good management of water and of the environment."
> (Technician C1)

His participation in the work did not make him think differently about his professional activities. He did not adopt different behavior after the design workshop.

[3]Donors such as drought reliefs, NGOs, and local entrepreneurs are from the Province of the District political elite (it is unclear what you mean with 'Province of the District political elite') and raise cattle or produce charcoal. For more information, please see chapter 2.

"I handle professional challenges everyday according to the situation and location […] my behavior has changed according to the compliance of the usual activities of my work." (Technician C1)

- **Evaluation of the test phase**

Two of the three technicians highlighted their understanding of natural resource management at the community level. The term "natural resource" was not specified with examples (e.g. land, water) by technicians in their questionnaires. It was, nevertheless, possible to observe that the game helped the technicians realize the relationship between natural resources and communities' food security. According to them, the depletion of natural resources was compromising food security for the farmer role.

"What I learned in relation to natural resources in the test was about the management of food. I learnt how to manage food so to secure the livelihood of a household. I learnt to manage time as well." (Technician C2)

"Food for my household was always missing at the end of the round and I needed to sell some goods to satisfy [this need]." (Technician C1)

The test made the technician C1 aware that his neighbors' activities could damage the natural resources he was exploiting for his livelihood. Both Technicians C1 and C2 recommended harmless activities such as agriculture or cattle grazing rather than charcoal exploitation to improve natural resource management.

I was worried about the intensive wood exploitation my neighbor was carrying out. […] There is a need to practice agriculture and cattle grazing." (Technician C1)

"What I found very interesting is the management of pasture [in the test]. I learned that a good pasture management could bring benefits." (Technician C2)

Personally, they thought it would be easy for them to communicate on natural resource management with colleagues. Technician C2 considered the game a fine support for communities to learn how to strategically benefit from their natural resources.

"We shall expose the actions we took in the test to the communities and their leaders so to improve their way of living." (Technician C2)

Technician C3 did not reflect much on the exercise. He kept saying he wanted to be a good professional. Later on, during the individual interviews he reflected on his playing farmer role with new livelihood strategies. This made him think of the need to increase inter-district services coordination.

R: 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 transportation. If the government gives me the transport, I can carry the seed and give it to the population. There should always be coordination between the government, communities and other institutions.

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

R: I found it very important in the game that there was an investor at the game table since I could borrow some money from him 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 was like a family, a group of people who I could work with. (Technician C3)

7.2.2.4. Evaluation of the implementation phase for type A, B, C

The RPG monitoring supported the development of new insights by the technicians of types, A, B and C. The technician A3, technician B and technician C1 monitored the sessions of the role playing game. The technician A2 played in the session of Tsocate. Through, the monitoring and playing, these four technicians contrasted their perception of the local complexity with the point of view of the consultative council's members. This process made them reflect on the learning of the consultative council's members.

The technicians recognized the difficulty for players to understand the game at first. They also understood 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 simulated world. But they acknowledged that after the first round, the players would project themselves into their role and situation and bring their reality into the game.

According to the technicians that monitored the RPG, the sessions' scenarios allowed the players to test the environmental and social responses to their livelihood strategies and/or the management of the natural resources. Through a feedback loop of their activities, the farmers could "bet" on productive infrastructure, such as motor-pumps. The three technicians' further interpretation of game learning was that this process, and its wide and faithful representation of reality, would allow the players to apply what they learned in their day-to-day routine. This learning is akin to experiential learning. According to the technicians, this tool supports the inhabitants' capacity to formulate better livelihood strategies and their accountability toward sustainable resource management within the context of Mabalane. Finally, four out of the six technicians underlined the importance of players' interactions and exchanges. Two interviewees insisted that the game revealed the importance of mutual help relationships between players as livelihood strategies. The two other players observed monetary exchanges, such as the trade of resources or equipment (e.g. plough), and job creation between players.

Furthermore, the monitoring or playing made the four technicians reflect on their own perception of planning: It concretized the technicians' perceptions of planning. Technicians A thought of inclusive planning processes. For example, the technician A3 confirmed through

the simulation his belief that CC members were able to choose and prioritize non-SWI infrastructures in a rational and informed way. He proposed a bottom-up participatory process in which each council starting, from the LCC to the DCC would select three types of non-SWI infrastructures. He was not considering SWIs because they are not perceived as being planned at the district level. The technician A2 valued the game as a tool to enhance understanding on a need for a more inclusive approach.

> R: What I found very important is to use this tool here, no talk, use the game, so that people can understand very relevant things while playing.
>
> I: Why?
>
> R: Because, people can more easily understood when they play. At the beginning they may not understand everything, the consequences of their actions, but in the second and third, rounds, they do. They recognize their reality, wonder about the game outcomes." (Technician A3)

Technician B considered the need to give a greater place for consultative councils' members to make their interest known in infrastructure planning. He observed a correspondence between the lack of inclusion 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 tax agent -who would have the responsibility of monitoring infrastructure development on behalf of the Local Consultative Council (LCC).

> "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 [the infrastructure] had not been constructed. There should be a person such as a fiscal agent for tax who could control the process of implementation, to see if it is done as planned." (Technician B)

The technician C1 who monitored the RPG sessions considered himself not to have learned much as a participant to the co-construction of the model and the monitoring of its simulations. He considered that the RPG aimed only at educating CC members. He added that the lack of representation of his own activities (the SDR activities) constrained his personal learning.

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

R: Let me think about it, I do not know how I can relate the exercise we did with my practice. The water sector was not represented much in the game; the game did not involve the community much. The person in charge of allocating the boreholes in the village was the SDR. He did so without the full consent of the villagers, without knowing if the village wanted a borehole or not. […]. The fact that there was not a direct relationship between the communities and the water infrastructures did not allow me learn things in the water sector. (Technician C1)

8. Analysis

8.1. The Consultative Council members' learning: An individual stance on local complexity

The FR, IR and SDR undertook a variety of individual activities using different sets of resources. In these exchanges the players kept a narrow perception of the system's complexity in acknowledging only direct interactions between the system's socio-ecological elements. For example, many became aware of the dependence of motor-pumps on uncertain water dynamics and the hydrogeology of their village. Similarly, they noticed the income that these new infrastructures could generate. However, few observed the indirect impact motor-pumps had on other natural resources dynamics, such as forest management. The same narrowing-down characterized the inter-player relationships. The players became aware of resource distribution among players and sometimes entered into bilateral relationships with others to exchange their natural resources, non-natural resources, or infrastructures in order to achieve their individual goals. They also rarely considered other players' roles in their interactions, limiting these interactions to the village level.

This narrow perspective on the social and ecological dynamics was confirmed by the players' post-session interviews. It could be argued that by not integrating others' roles into their individual strategies the players also did not consider the game as an opportunity to learn from the represented district services (SDR) and investors' (IR) interests and activities. This is not surprising in view of the current top-down and hierarchic mode of local governance in Mabalane. The game sessions could have been an opportunity, however, for consultative councils members to gain an understanding of the external actors and district services' interests and challenges along with farmers ones. Awareness of the other role-players and negotiation for natural resource management among multi-level actors needed to be tested for consultative council members within the game. Indifferent to their game role, however, the majority of the interviewees said they learned to test and formulate FR strategies from the simulations. Some used the RPG simulations to learn more about motor-pump functions and outcomes.

The players did not explicitly explain the reasons they did not learn much from the investor role and district roles. Nevertheless, many stated that they did not acknowledge the other

players' activities from the debriefing phase until the end of the RPG. In the debriefing phase, players also criticized the low level of interaction between the district services and leaders' roles when implementing the new SWI in a local context. The restricted interactions between farmers and public or private actors do not appear different from the described culture of Mabalane. A collective time of discussion, such as the debriefing phase and the individual interview, encouraged consultative council members to think more critically about interactions and strategies used by others. In fact, some players valued the ComMod process because it helped them to learn about possible ways of engaging in mutual relationships. Unfortunately, the role-playing game's aims to create a playful environment where consultative councils could interact more easily than in reality while learning from each role's objectives, challenges and constrains, was not fully achieved. The model has been evaluated in more precise terms in a later section.

Players' narrow perspectives on social and ecological dynamics are congruent with their experiential learning of the farmer role's livelihood strategies. This correlation is confirmed by the way players prioritize their individual role's interests over those of their public role in the simulated consultative councils. Although simulated consultative councils were set up at the end of each round to emphasize the exchange of player perspectives on the different role strategies and actions, players scarcely interacted. Some players expressed their livelihood difficulties, others offered advice, but the CCS did not foster intense discussions.

To conclude, both in the test and the stand-alone session, farmers at village level perceived system complexity in terms of the plurality and uncertainty of natural dynamics. The farmers used this type of learning to undertake individual adaptive planning. They focused on elementary interactions in the system rather than the subsequent ecological and social dynamics. Thus, they did not take advantage of the emergent properties of the socio-ecological system and overlooked the simulated consultative council as a reflection of their own consultative council's knowledge and role. In this pilot session, the players were concerned about understanding how to plan their strategies for the year to come. This point was confirmed by the technicians' analysis of what the players learned from the game.

This dominant perspective was reinforced by a member of the Ts presidency who tried to enhance discussions and decision-making on small water infrastructures in Tsocate's local consultative council by raising member's awareness and helping to integrate different perspectives during the planning process. This allowed the player to not only reflect on his first-order learning but also on questioning the underlying norms and values of the current planning process.

> "We were discussing issues in the simulated CC but we weren't searching for solutions. This is also what we miss in our consultative councils (talking about the LCC of Ts). [...] Instead we could search for solutions and explain them to the administrative post and, from there, the district services. From this process, the district services could evaluate our proposition feasibility and work with us." (IR, Ts)

Half of the technicians shared this player's awareness of the CC's potential for acknowledging local specificities in an integrative infrastructure planning.

8.2.A step toward a more integrative planning for technicians

Being involved in the initial phases of the participatory process, the technicians gained a different perspective. The participatory process helped the majority of the technicians to become aware of the emergence of natural resources, social interrelations and impacts of individual activities. Both during the design phase and the test phases, they observed the negative externalities of main district activities on natural resources availability and renewal. They were particularly conscious of the current pressure placed on native forests that charcoal production, even though only two of the seven were legally in charge of its regulations in reality.

> "So far, [the game] made us remembers to take care of and preserve natural resources."(Technician A2 attitude toward natural resources in the test phase)

Furthermore, their collective responses to the role-playing game show that they considered a wider range of collective strategies for managing natural resources than consultative council members.

But these collective responses were not representative of homogenous learning for the technicians. They questioned the origins of far-reaching phenomena and relations between local actors differently. The A technicians understood from the design phase onwards how actor and resource interactions could potentially damage natural resources and compromise local development. They took on leadership during the group work and were the first to reflect on social and ecological dynamics and player interactions. Therefore, they advocated increased awareness and integrated knowledge and interests on natural resource management within their professional realm and organizational level. They did not change their perspective on integrative planning right away, however.

In the design phase, the A1 &A2 technicians acknowledge the need for considering natural resources as a whole across every organizational level. Indirectly, they assumed that natural resource development were mutually dependent. They proposed, however, to tackle it in a fragmented manner at different organizational levels. They highlighted the need for new skilled and knowledgeable technicians in natural resource management, as well as the planning of small water infrastructures with lower impact on natural resources. Finally, they advocated community mobilization to raise awareness of natural resource conservation. This is a traditional disciplinary and hierarchic stance toward infrastructural planning. It views the impact on natural resources as a new public service without considering the complex nature of the natural resource management and how the interests and values of multi-level stakeholders interact, leading to "wicked problems" (see section 3.3). The A3 technician adopted an integrative planning stance from the design evaluation onwards. His attitude toward integrated planning could have come from acknowledging others' learning during the design and test

phases of the workshop or could have been acquired prior to the workshop. The A3 technician was the only Mabalane technician in charge of planning administration. Thus, his personal and professional background may have made him more willing to integrate other local actors' opinions in planning.

The interaction between technicians A1 & A2 during the test confirmed their general perspective on social and ecological dynamics and may have triggered a shift in their norms on planning. The role-playing game raised their awareness of the need to include actors from multiple levels in decision-making and planning. As a consequence, they also specified their intention to adopt integrative planning within their professional realm. One technician stated he would interact with others actors, such as NGOs and investors, and listen to communities and their leaders in order to make more informed decisions. The other technician viewed the game as a useful tool for communicating and for coordinating natural resource issues with different actors.

> "My behavior has already changed since I understand that natural resources need to be managed in a collective way, and that every actor has his importance in the management" (Technician A1 evaluating what he learned from the test phase)

In their professions, both the A1 & A2 technicians coordinate different people for the local development work. Technician A1 coordinates technicians from different fields in managing Limpopo National Park while technician A2 works as a community leader, planning and implementing policies in conjunction with the local consultative council. The mediating role they play in real life settings may have predisposed them to value the knowledge and interests of the local actors that have a stake in small water-infrastructure planning that impacts natural resources.

The relations between the actors' activities and natural resources were initially not as clear for technicians B and C. Their assessment of the current issues regarding natural resource management did not include nature/human interactions. This perception of local system dynamics was congruent with the traditional planning perspective.

In the simulated representation of Mabalane during the test phase and role-playing game, the B and C technicians' immersion led them to assess their contexts differently. In fact, playing the roles of farmers with their colleagues raised their awareness on the impact of both their and their neighbors' natural resource activities and household well being. After the test phase, technician B's views on planning remained paradoxical, varying from traditional to integrative. It seems that the participatory process guided his focus to more integrative planning. He did not completely understand the complex social and ecological dynamics, however. This is confirmed in his final interview, which showed that he wanted communities to participate in local planning to monitor infrastructure construction rather than to consider local knowledge and interests in the decision-making and planning. It is worth noting that technicians B and C are public officials from the district's technical services come from the province or capital city.

The C technicians believed that communities needed to revise and learn from local socio-ecological interactions. They had similar views on local complexity as the consultative council members, believing that the representation of local social and ecological dynamics in the ComMod process aims to improve local inhabitants' adaptive planning. They kept a traditional and top-down planning attitude throughout the process. Furthermore, they learned about complexity but did not revise their beliefs and norms in terms of infrastructural planning and its impact on natural resources. For example, one C technician recommended inter-district services coordination as a method of sharing material resources, such as transport, rather than a way to exchange knowledge and deliver a public service to do with natural resources.

In addition to learning about complexity, some technicians, regardless of their type, became interested in the visualization of complexity during the test phase. They learned from the dynamic representation of natural resources. Technician A1 clearly stated this, and reflected the views of others, who also learned from this presentation. For example, technician C2 valued the need to plan actions for a particular time-scale. From the spatial representation, technicians A3 and B learned to adapt their technical services according to the local specificities. The questionnaires and interviews did not allow a full assessment, but could answer whether these local specificities included both ecological and social dimensions. The willingness of some technicians to include local actors in their planning process seems to align with the consideration of social factors during the process of adapting their services.

To conclude, the technician's engagement with the participatory process helped them to realize, in different phases, the complexity of Mabalane's local context. They perceived the far-reaching impacts of their actions on natural resources and the livelihood of Mabalane's inhabitants. The test phase was crucial for raising their awareness, not only of natural resource depletion but also, the impact of natural resource mismanagement on community livelihoods. Thus, the two first co-construction phases allowed the technicians to understand human-nature interaction. The complexity of different actor's interactions was not understood by all technicians, however, and lead to different normative shifts in planning. Even though they could see how each of their actions extensively impacted natural resources and villager wellbeing, until the test phase most kept a top-down and traditional set of beliefs about planning. The A technicians may have triggered a shift in norms due to their professional and personal backgrounds. The B and C technicians never fully grasped the relation between socio-ecological dynamics and the normative shift toward integrative planning. For the C technicians, the role-playing game remained a tool that farmers could use to engage in more strategic individual or collective planning. The difference between technicians raises the question of what type of action-research would be best suited to changing the technicians' behavior toward a more integrated planning. For this reason, the action-research is analyzed in the following section.

8.3.Discussion and conclusion

8.3.1. The Evaluation of the action research

The co-construction of a prototype model with key local actors in Mabalane brought interesting outcomes. It raised the technicians and consultative members' awareness of the complex interactions of social and ecological elements in the context of Mabalane. Learning about this type of complexity helped both types of actors better understand planning. For half of the technicians and one of the CC members this was marked by a shift toward a more integrative planning. The others, including the majority of the consultative council members, underlined the challenge Mabalane inhabitants face in planning their livelihood strategies in accordance with the fluctuating and uncertain natural and social resource dynamics of the local context. The drawbacks and advantages of the research actions that were undertaken are discussed below. They help explain the results and suggest opportunities for further research.

8.3.2. Evaluation of the design and test phase

For the technicians, the learning about complexity was heterogeneous. For example, two of the district technicians (types A1 and A3) had already put what they learned into practice in their professional context, going beyond the reflective work, the study aimed at . One technician (C1), however, participated in all the participatory phases but did not feel interested in the learning process.

Regardless, there were commonalities in the way various phases of the participatory process influenced participant learning. The design phase was fundamental for helping them to understand the multiplicity of social actors and ecological resources in natural resource planning. The test offered the opportunity to observe the dynamic representation of these interactions and their subsequent impacts. Finally, the monitoring of RPG sessions helped some participants to imagine alternatives to the current planning mode, using practical references from the RPG. Two months were necessary to translate the information from the design phase into a playable draft of the role-playing game presented in the test phase. This time span seems to have benefited the A technicians' thinking, by giving them time to put into practice what they had learned during the design workshop. The participatory process offered the technicians, new meaningful insights within a set of complementary participatory process phases. Their shift in planning beliefs depended, in part, on their participation in earlier stage of the participatory process. It could be helpful to research the other factors that influenced their learning. Did any technicians already possess a particular awareness of the integrative approach? Did their level of literacy and their professional or personal background influence their reflection on social and ecological dynamics?

The A technicians' real-life mediation or coordination tasks may have favored their inclusion of other actors in their planning activities. If this hypothesis were confirmed, it would demonstrate our research did not consider the heterogeneity in the background of the technicians. It is possible that if the research action objective had been exclusively fostering the district technicians' thinking on integrative planning, pre-studies could have allowed more

elaborate questionnaires, facilitating the co-construction phases by taking their background heterogeneity into account.

Interestingly enough, in their reflection, few technicians identified the consultative councils as a potential place for integrative planning. Most of the technicians were committed to discussing and planning with local actors but did not identify particular institutions to normalize these interactions. This could be explained by a failure in the coordination of the co-construction phase to accurately show the relationships between the consultative councils and the complex social and ecological dynamics. The other possibility of this oversight is the conceivably incorrect assumption that consultative councils were appropriate multi-level institutions within which to embed the exchange of interests and knowledge among local actors. If so, it would be interesting to investigate the reasons that the technician did not view consultative councils as appropriate institutions for planning. If this view is confirmed, the ongoing research project could include a study on appropriate institutions for planning alongside an elaboration of integrative planning.

8.3.3. Evaluation of the RPG simulation

With the exception of one member, the consultative council's members retained a narrow perspective on complexity and planning. They were not expected to adopt a more integrative approach after the research because their level of participation in the participatory process seemed too low for a shift in planning norms. This did not prevent, however, the inclusion of windows of opportunity (including roles clear objectives and means and simulated planning spaces) that would stimulate a reflection on their role as member of a consultative council. Eventually, one of the consultative council's members became aware of the RPG potential for a more integrative planning process. The reason for divergent levels of learning among CC members should be further researched in order to identify whether the variation comes from RPG characteristics or external factors, such as player literacy or the Mabalane context (planning in a challenging environment). An evaluation of the RPG tool and implementation process could highlight new research paths toward understanding its role in stimulating integrative planning.

The CC members did not equally play, and learn from, their RPG roles. Leader, investor, and district roles were under-represented and under-observed, in comparison to the farmer role in the RPG. The choice to have one farmer from each village also play the leader role in the role-playing game did not reach expectations. The game was already difficult for participants to grasp, and was complicated by assigning a leader role with no predefined activities to the farmer role. For the next role-playing sessions, the players will not be assigned any combined roles. Furthermore, consultative council members had less knowledge on the Investor Role and District Services Role than expected and, unlike the farmer role, were not inspired by their roles. The interviews showed that half of the CC members were involved in farming activities. Furthermore, unlike the farmer role, the investor and the district services roles did not have pre-determined game objectives. The difficulty of playing unfamiliar roles, coupled with an unfamiliar representation of Mabalane system and many cards, may have challenged the player's knowledge exchange. The low number of RPG rounds could not compensate for

this. The players focused on the game's materiality and their roles' objectives and activities rather than interacting with each other and observing other players' activities.

Players were, however, able to bring their real-life experiences to the RPG play. With the help of the facilitator team, they interpreted their game activities and took ownership for their actions. They introduced local norms, such as water taxes, requested new infrastructures, such as small irrigation systems, and reproduced real collective interactions that included mutual help relationships and farmers associations. The realism of the game was nuanced by an emphasis on money exchange and trade. The players' comments revealed an economic orientation that may have been simplified by the game. The players stated that, in the game, they sold cattle to pay for food and to invest in infrastructure as plows and motor-pumps. The players viewed this as a new strategy because in Mabalane's real context, selling cattle is less usual. This result shows the limits of the game and its ability to represent certain cultural and social factors that determine real life choices and activities.

8.3.4. Further improvements of the participatory design and testing

The evaluations demonstrate that there is a place for greater reflection among actors, which can be stimulated by improving the action research. The research team identified the consultative councils as important associations in the game but this was not reflected by the technician group. Furthermore, it could have been interesting to explore institutional interactions during the design phase. The technicians did reflect on this, to some extent, with the questions in their individual questionnaires. The functional diagram described actor and resource interactions, with the most important ones at its center. After the exercise, it could have been asked how, when and where the major actors interact with each other within real-life contexts. The resources could have been extrapolated from the diagram in order to render the actors and their interactions more visible. An additional flipchart could have described the interaction types, as well as the place and time for yearly intervals. The description could focus on either the inland village or the riparian village, because both of them broadly share the same formal and informal institutions among multi-level actors. This description would help explain the interactions and information-exchange between the most important actors in the management of natural resources, whatever their institutional level. This reflection would have aided the identification of consultative councils and planning activities as central spaces for actor interactions.

Since participatory phases were complementary, it could have been valuable to reinforce the relationship between the design, test and implementation phases. It is possible that a greater exploration of the actors and resources, as well as the impacts of their interactions in the design phase, would have facilitated the technicians' understanding of these interactions in the test phase. The exploration of these interactions would have also provided legitimate indicators in the RPG simulations for monitoring the impacts and their sources.

Once the realism of the RPG was validated for the CC members, it could have been calibrated to exacerbate ecological and social impacts, allowing for CC members to see the indirect impact of their actions. Discussion places, such as simulated consultative councils, could also

have been reinforced in order to strengthen collective reflection on issues and to encourage collective planning (Box 11).

Box 11: Examples of increased reflection on planning in the RPG sessions:

Emphasis of ecological and social impacts:

Water resource impacts could be investigated by simulating arid climate scenarios with recurrent drought while maintaining the heterogeneity of water access between the inland and the riparian villages.

The calibration of the forest resources could be revised so that its status more quickly evolves from intact to deteriorated, to, ultimately, deforested.

In time, we could define collective indicators, such as deforested areas, total cattle heads, inland versus riverine-area water availability, number of farmers that did not reach food security, amount of charcoal taxes, and allocated SWI. Using these indicators, players could reflect upon, not only on their individual indicators, but also on the overall situation of their village and the district.

Emphasis on the relationship between actors and SWI management:

In order for players to understand or reproduce village-level management of the SWI, the challenges of frequent breakdown and repair could have included in the RPG. The game rules could offer players possibility of buying a new borehole part at the market. It would have been interesting to discuss the conditions of repair with the technicians and asking whether they would underline the need for transportation, technical knowledge or financial support. It would also be good to know what roles would be involved in this management.

Reinforcement of the CCS:

It is possible that facilitators could support reflection by stating, before the start of the CCS, that players should reintegrate their planning roles and discuss district and local planning. Following the example of PRONASAR, SWI programs could also be introduced. These programs would lead players to collectively decide on the allocation of boreholes in one village. In addition, mirroring real life, a discussion on the allocation of a constant fund for development could be introduced. This fund would not be explicitly called OIIL as participants should have the freedom to finance collective strategies with this fund.

Additionally, service district (SDR), investor (IR) and leader roles could also be reinforced. This could be done by detailing role objectives and choosing people who are more able to accurately perform the roles, for example, real actors. For the investor role, the possibility of hiring labor from the city rather than village households would have intensified his exploration of the forest while limiting local job opportunities. Both consequences would have threatened the farmer role's livelihood and may have challenged the top-down

institutions in forest management. It would have been interesting to observe whether exploration licenses would have still been disconnected from the village's natural resource management. This would have required a village leader to have an individual role with particular activities.

Finally, because the general research project aims to improve natural resource planning in order to support local development, it would be interesting to consider the need, expressed by CC members, for farmers to learn adaptive planning. The participatory process for collective planning could be combined with technical learning about individual livelihood planning. In addition, villagers could be provided with an opportunity to explore the constraints and benefit of using motor pumps in an integrated manner. This could be done using the companion modeling process, as with the Lam Dome Yai case study, in which rice farmers realized by participating, that they needed to be better organized in order to improve their farm's management of the drought risk. The technical knowledge they acquired from the dynamic representation of their system encouraged them to integrate the way they viewed their farm activities in relation to the labor shortage and irrigation canal opportunities. It also helped them to understand the relationship between the distribution of rainfall and the rice calendar, ultimately, leading to the revision of the agricultural calendar (Daré et al., 2014).

8.3.5. Conclusion for the global research project

In the continuation of the participatory planning process the players and technicians will be involved in a second round of simulations aiming at brainstorming local issues related to SWI and natural resource management with an improved version of the model. This phase will precede the construction of strategies to tackle the issue, the plan and, finally, the test using participatory and learning tools, such as the RPG. The results of this RPG prototype and test are appealing for the continuation of the research project. The realism of the RPG has been validated by the local planning actors. A number of small changes still need to be added, such as commercialization. When this is achieved, it can be used to test future strategies. Furthermore, both type of actors –the consultative council's members and the technicians – perceived the district's major impacts and issues. The technicians, however, had a more accurate vision of global interactions than consultative council members. Finally, the participation of the district's technicians, in particular, the technicians in charge of coordinating the district's various plans, raised their interest in the participatory method and helped them to adopt a different viewpoint on integrative planning. This will facilitate their commitment to the future research.

8.3.6. Evaluation of the action research in the broad scientific debate

- **What is the value of the work in the academic world?**

In academic planning science, there is a new paradigm on participatory planning that is based on the exchange of information and knowledge, and the integration of various stakeholders' norms and values in innovative planning, while taking into consideration the power bargaining and cultural aspects of developing countries(K. E. Davis, Ekboir, & Spielman,

2008; Ryan, 2011; V. Watson, 2012). The social learning and co-production approaches were developed as methods and tools to support participatory planning specifically adapted for development in Southern countries (Armitage, Berkes, Dale, Kocho-Schellenberg, & Patton, 2011; Blackmore, Ison, & Jiggins, 2007; Jiggins, van Slobbe, & Röling, 2007; Steyaert & Jiggins, 2007; V. Watson, 2012; Vanessa Watson, 2014). These methods and tools are in constant evolution. This research aimed to contribute to this field of study, focusing on the modeling of social and ecological dynamics in order to foster an exchange of knowledge and opinions among local actors. It has been shown that ComMod's participatory process of co-constructing a representation of local complexity, thereby illustrating social interactions based on natural resource access, brings new knowledge on planning to key local actors.

For the group that participated in the overall process, the change of beliefs on how the system works led some to choose integrative planning and operationalize it in their professional spheres, despite their hierarchical culture. Furthermore, the changes in technicians' beliefs and norms toward integrative planning and consultative councils in Mabalane were diverse and specific to each actor. This shows that the understanding of complexity was personalized by each actor and processed according to their set of beliefs about the system and other factors (see section7.2).It demonstrates that it is possible to guide local actors toward innovative planning while building on current local institutions, such as informal rules of interaction between government and leaders, and those between inhabitants from different villages and organizations, such as public administration services. It is particularly interesting for development approaches that foster a progressive strengthening of local government because it answers local issues with contextualized solutions.

- **What new question does it raise for the academic world?**

This research was an introduction to the ComMod participatory process for local planning actors. Therefore, it is important to evaluate the results of the global research project on planning to see if the reflections of participatory tools can bring actual changes to SWI planning. The research was conclusive within the context of Mabalane. Because of Mabalane's semi-arid climate, isolation, and the strong interdependence on its natural resources by the villagers, it is a very particular district. However, the problem of equitable and sustainable access to water is shared by other Mozambican districts. It could be of interest to study how this participatory process works in a district where social and ecological dynamics also exist on a macro level, such as land privatization by foreign companies for extensive irrigated rice production or a population that works in the town because the land is heavily affected by climate extreme events, such as floods and droughts. These global phenomena would necessitate the inclusion of actors working at levels other than district services and community representatives.

The context complexity could also increase with the inclusion of upper-level governance. In fact, the participatory process could be investigated at a provincial level. It would reflect reality in the sense that provincial levels work together with the local levels to improve water service delivery. With projects, such as PRONASAR, the province in is in charge of the national fund, setting contracts with drilling companies while the district government

manages them along with the community representatives. At an intermediate level, the willingness of the PNL technician to develop a new companion model in the overall buffer area of the PNL may be challenged. This area encompasses communities that belong to three different districts and are also under the governance of the PNL. This plural and multi-governance system offers opportunities for SWI management in natural resource conditions and simultaneously increases the social and ecological dynamics and interactions.

8.3.7. Reflection on research

I began my research with Carla, a master student from the Mozambique Forest Faculty, within a larger research project. Carla and I had complementary sets of knowledge. I knew the ComMod approach from previous experience and was formed in sociology while she was familiar with the local context from previous studies and brought an economic perspective to the research. Our teamwork facilitated the participatory process and iterative monitoring throughout the research. I did not have a very clear idea of the global research objective during my stay in Mozambique. Therefore, I needed to base my research on vague knowledge without compromising my colleague's research. The researcher leading the global research project had identified two axes of research that could be examined in this study. I investigated the technicians' awareness of the consequence of multi-level interactions for SWI adaptive management while Carla studied what the participants learned about natural resource management. Both of our studies were aimed at evaluating the overall participatory process.

Because of time constrains, we collaborated with the questionnaires and interview guides, sharing questions. We divided the interviews according to the guide. Upon my return from Mozambique, it was difficult to analyze my research results. Firstly, I had fewer results than expected because both Carla and I found it difficult to operationalize the concept of coordination in our respective interviews. The broad questions about multi-level interactions were too vague to be understood directly by the interviewees and I did not have enough knowledge on the real-life multi-level interactions to draw on specific examples. The limited number of interactions during the role-playing game sessions also did not facilitate this. I believe that extra time to dive into the literature, as well as an additional visit to Mabalane, would have helped the operationalization. Secondly, SWI management was rarely mentioned in the technician's questionnaires. Thirdly, I found it difficult to relate non-learning theories to the evaluation of the technicians' awareness. I decided, therefore, to use concepts from psychological sciences, such as planning behavior, coupling it with planning theories, such as integrative planning.

Despite this framework I could not relate my research interests to the global project and was, therefore, not able to justify this choice. What helped me to justify it was however, to understand the research literature on Mabalane as a context, the literature on ComMod scientific debates and, finally, my data by analyzing it in depth. It was easier to analyze the interviews I had personally conducted because my colleague had decided to temporarily stop her master's studies and could not be contacted during this time. I understood that the specific stance of my research required me to understand the overall research and my colleague's and

my own research, within a global context. I also wrote a conference article based on this analysis.

With this study, I enlarged my scope and included consultative council members in my research because they had engaged in the participatory process. In addition, I studied SWI management, in particular, within the broader concept of natural resource management. This was important because equitable and sustainable access to water via the SWI could not be disconnected from the management of other natural resources. Furthermore, I focused on the actors' perceptions of multi-level interactions. The framing of the learning process progressively shifted from local complexity to planning. To conclude, I believe the process was sometimes confusing but, nevertheless, interesting. I believe it would have been beneficial if I had read more on participatory processes, planning, scientific debate, and the context's local issues before going to the field. This knowledge would have helped me to facilitate and collect information in a more accurate way. Unexpected things always happen in the field, however. I would have adapted my research to that of my colleagues, for example, but she joined me one month after my arrival. Thus, this research illustrated the challenges that researchers face when working together on global research projects.

9. Literature

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10.List of Figures

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