Adaptación al cambio climático para el desarrollo local

SEVENTH FRAMEWORK PROGRAMME

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"Analysis of Socio-Ecological Dynamics"

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Acronyms

BMAAM: Bosque Modelo Araucarias de Alto Malleco

BMCh: Bosque Modelo Chiquitano

BMJ: Bosque Modelo Jujuy

CSO: Civil Society Organization

FCBC: *Fundacion para la Conservacion del Bosque Chiquitano*

MF: Model Forest, BM or *Bosque Modelo* in spanish

OSPC: Open Standards for the Practice of Conservation, EAPC in spanish

PARDI: Problematic-Actors-Resources-Dynamics-Interactions method

SES: Socio-EcoSystem

T2.4: task 2.4 of the EcoAdapt project

Executive summary

The analysis of socio-ecological dynamics (T2.4) is the last activity of the WP2 "Filling knowledge gaps about the context". This activity aims at developing information and knowledge about the dynamics and the functioning of the Socio-Ecological System (SES) in each of the project sites; exploring the interactions between human society and the ecosystem, defining the drivers that explain those dynamics and proposing some representations (conceptual models) which pave the way for further modelling, scenario building and simulation phase of the project (WP3).

Due to delays in the implementation in the other tasks of WP2; the field activities dedicated to the analysis of the SES were carried out in the project sites starting in April 2013. Nevertheless, thanks to a strong commitment of local teams and students; T2.4 was fulfilled in October 2013, which represents a very slight delay comparing with original schedule for September 2013.

T2.4 was implemented in 3 phases. The first phase consisted in the concerted definition of a methodology within a dialogue between the researcher team and each Model Forest (MF, *BM* in Spanish) team, a Civil Society Organization (CSO). This dialogue began during the workshop of Conception (May 2012) and led to choose as core method, the Problematic-Actors-Resources-Dynamics-Interactions (PARDI) method. It was adjusted according to the specific demand, situation and configuration of the project sites: the whole BMJ site in Argentina, the pilot BMCh site in Bolivia, and the two BMAAM sites in Chile. The second phase consisted in the implementation in each territory. After the definition and formulation of a shared problematic of the territory; actors and resources linked to this problematic were identified, mobilizing knowledge of MF staff and local stakeholders. Then, though specific workshops and/or interviews to direct and indirect actors of the SES, the interactions between actors and resources, as well as dynamics that affect these interactions were characterized systematically. Finally, a representation of the SES functioning was built by iteration within a dialogue between researchers, MF staff and local stakeholders. A set of integrated conceptual models and sub-models focusing on one part of the problematic or an issue, was built in each of the three territories. This active phase of field activities led to the redaction of three specific reports: Rixen et al., 2013; Aguilar et al., 2023; and Vilugrón et al., 2013, respectively for Jujuy MF, Chiquitano MF and Araucarias de Alto Malleco MF. The third phase consisted in a transversal analysis and synthesis of the three SES analysis conducted in parallel in the T.2.4. Deliverable 2.5 presents here this synthesis.

T2.4 systemic analysis generated four main results. First, it enabled to formulate a clear central problematic in each territory that facilitates: communication toward local population, actors' mobilization in the project process, and focus in the reflexion. Although the central key issue always deals with water security (i.e. Insuring availability and quality of water for multiple purposes), the formulation is different in each MF context, according to salient problems, the local expression of threats and causalities, and the orientation towards possible solutions already contemplated. Hence, in the Chiquitano MF (BMCh) and the Jujuy MF (BMJ), the problems of water availability and water quality are already tangible with more or less recurrence and leading to more or less tensions among actors, whereas in the Araucarias de Alto Malleco MF (BMAAM); the water problems are not so tangible yet, but are emerging out of the caveats of the legal framework.

The second main result is the identification of actors to be considered in the formulated central issue or problematic. Complementarily to Task 2.3 that mapped the stakeholders according to their relationships (socio-institutional networks, see Deliverable 2.4), Task 2.4 focuses on the actors, or categories of actors, that manage and interact directly with water and water-related resources. In particular, this task led to a further understanding and characterization of actors' practices and strategies. A particular attention has thus been paid to water end-users and to land users (i.e. various productive activities) as well as institutions. Systematically comparing or drawing parallels between the project sites, highlights both common and specific features of the SES, regarding actors' configuration in the different landscapes, and in water governance systems.

The third main result is a clarification of the resources that are at stake in each SES and the processes linking them together. Thus, the perception of the actors and the information available on these resources has been analysed. Moreover, the dynamics of these resources (hydrological system, forest-water relationship, infrastructure management) have been analysed in a comprehensive way. The difference of standpoints among local actors has been captured, as well as the uncertainties regarding ecological and technical functioning. The first insight is useful to fine-tune further dialogue activities, the second helps to further design complementary research.

The fourth and main result is the understanding of the SES functioning and its representation through conceptual models built participatively. These models represent in a systemic way, the main interactions between actors and resources, which allows to explain the endogenous processes contributing to the formulated problematic or central issue. In each MF site, specific sub models were first built according to different standpoints (Chile), parts of the problematic (Bolivia) or a parts of the watershed territory (Argentina). In BMCh, an integrated model of the dynamics in the Zapocó watershed has been built. It links land uses changes (deforestation process) with the issue of water quality for human consumption in rural areas and in the urban area of Conception town. In BMJ, the integrated model for the whole Perico-Manantiales watershed area focuses on sedimentation and erosion processes, while the 2 specific models for the respective two interrelated dam zone and irrigated zone, deal with all the processes affecting water availability and quality. In the BMAAM where the territory belongs to two neighbouring watersheds (Bio Bio river in Lonquimay commune, Imperial river in Curacautín commune), the model construction was led simultaneously in the two watersheds. For each site, two complementary sub models were developed to represent respectively water biophysical availability and legal accessibility.

Finally, the implementation of T2.4. strengthened the dialogue process with local stakeholders, through their participation to the model building and adjustment. The task contributed thus to fill gaps with useful information for the definition, in a next step of the project, of scenarios and adaptation plans to CC. It also contribute to strengthen a learning-by-sharing process between local stakeholders, including MF staff. Regarding methodology and approach, T2.4 allowed adapting, testing and revising, a beforehand selected method of participatory modelling. It revealed its relevance in different contexts to strengthen abstraction capacities of local stakeholders, paving the way for a more holistic and systemic thinking, that facilitates accurate, sound and innovative reflexion to define solutions and actions in the face of actual and future problems.

1. Introduction

The EcoAdapt project aims at supporting local organizations to develop strategies for Climate Change (CC) adaptation in 3 territories: the Chiquitano Model Forest (BMCh) in Bolivia, the Jujuy Model Forest (BMJ) in Argentina, the Model Forest of Araucarias de Alto Malleco (BMAAM) in Chile. The first phases of the project are dedicated to the analysis of local knowledge (WP1) and the filling of knowledge gaps (WP2). Four specific tasks have been designed to fill knowledge gaps: the analysis of knowledge and learning processes (T.2.1.), the development of assessment tools and methods appropriate to the context of decision (T.2.2.), the network analysis of actors (stakeholder mapping) (T.2.3.) and lastly the analysis of socio-ecological dynamics (T.2.4.).

In this EcoAdapt context, the specific objectives of the Task.2.4. "analysing dynamics of socio-ecological systems" are: to develop information and knowledge about the interaction between ecosystem and human society; to define the drivers that explain those evolutions and; to propose some representation (conceptual models) of the functioning of the Socio-Ecological System (SES) that pave the way for the following modelling and scenario building phase of the project (WP3).

This deliverable D2.5 presents the participatory modelling activities of the Task 2.4.: the methods and the results obtained in the 3 project territories. It synthesizes three T.2.4. specific reports developed in each Model Forest: Rixen et al, 2013 in the Argentinian BMJ; Aguilar et al, 2013 in the Bolivian BMCh; and Vilugrón et al, 2013 in the Chilean BMAAM.

This report is organized as follows. The first section presents the analytical framework and the participatory modelling methods of the T.2.4. The second section presents the results of the analysis in the different territories, and a synthesis of the different key findings. The third section proposes some transversal lessons learned with respects to methodology and approach. The fourth section discusses and puts in perspective the results of the analysis of the SES dynamics in the different project sites.

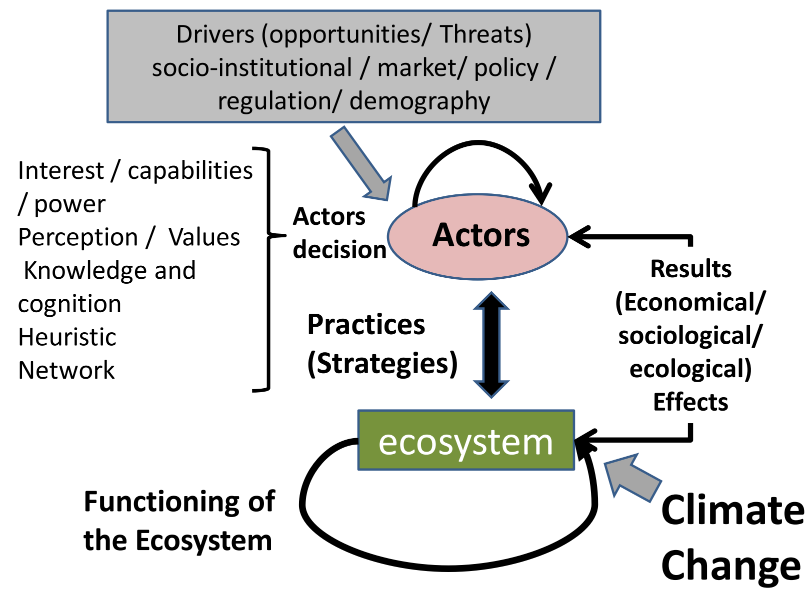
2. Concepts, Frameworks and Methods

The analysis of SES dynamics can be developed in very different ways. In the EcoAdapt project, the basic initial methodological principle was to articulate different concepts, frameworks and methods in a practical way associating the perspectives of both the academic and the MF teams. From a core analytical framework, proposed by researchers authoring this report and specifically designed for EcoAdapt T.2.4., different existing methods have been considered and articulated into a specific methodological process. Hereafter, we present the core general analytical framework, the main methods and tools used for participatory modelling in T.2.4. and finally the methodological steps developed in each project sites.

2.1. A core general analytical framework

To analyse the dynamics of Socio Ecosystems, we developed a specific core analytical framework (Le Coq and Fallot, 2012), linking dynamics of ecosystem to dynamics of actors (Figure 1). It explicitly puts the focus on the characterization of the interactions between human activities and ecosystem functioning through actors' practices that reveals actors' strategy. It considers the decision making process of the actors, with a comprehensive conception of actors' rationality, including interest and perception. It finally considers the main factors that affect the evolution the SES, differentiating human society drivers (socio-institutional, market, political, demographical), from climate specific drivers.

Figure 1: Analytical framework of the socio-ecological systems dynamics



Source: Le Coq and Fallot, 2012

2.2. PARDI in combination with complementary methodological tools

To put into practice this overall analytical framework, we decided to rely on existing methods that organize and facilitate the systemic analysis of these different elements. We especially consider that, with some adjustments, the ARDI (Actors Resources Dynamics Interactions) method developed by Etienne and colleagues (2011) could be used as the main methodological reference. In a complementary and articulated way accounting for the experience and skills of the MF staff or Civil Society Organizations (CSO: BMJ in Argentina, FCBC in Bolivia, BMAAM and SEPADE in Chile), other methodological tools were mobilized and partially used for more punctual contributions enriching the analysis. The Open Standards for the Practice of Conservation (OSPC) served in Bolivia (Salinas et al., 2013) and the Resilience Assessment approach provided guidelines to draw historical profiles in the three cases.

ARDI consists in a step-by-step method of participatory modelling. Each step corresponds to a specific objective. To better adjust the method to the research-action context, we added a preliminary step to the original ARDI method, the Problematic elicitation, thereby renaming the method PARDI. This initial P step aims to define the key problematic / issue that stakeholders share and want to tackle. Participatory definition and formulation of the Problematic, aims at facilitating the mobilization of the actors during the process, assuming that a SES modelling that does not focus on a common/shared issue, will not generate stakeholders' interest and might thus hinder participation.

The PARDI method basically consists in 5 steps corresponding to different fundamental questions and objectives (Fig 2) addressed during successive workshop sessions that gather the very actors involved in the issue to be addressed.

Figure 2: Steps and objectives of the PARDI method

P (problematic or issue)
Leading question:
- What are the main issue the stakeholders of the SES are facing?

Objectives:
- Define and formulate the issue as perceived by all stakeholders.
- Clarify the limits / border of the system in which the problematic/issue is taking place.

A (Actors)
Leading questions:
- What are the actors contributing to this issue?
- What are the actors that are dealing with the management of the resources at stake?

Objective:
- Iidentify the actors whose actions determine the problematic issue;

These actors can contribute directly or indirectly to the problematic and the resource.

R (Resources)
Leading question:
- What are the main resources at stake ¿ and that are linked with the resource at stake?

Objective:
- Identify the resources at stake and the resources that are interacting with the main resources at stake.
- For each resource, identify the main variable that describes the state of resource to take into account for actors' decisions

D (Dynamics)
Leading question:
- What are the main endogenous processes affecting the situation in relation with the issue?

Objective:

- Identify and describe the dynamics affecting the evolution of the SES

I: (Interactions)
Leading questions:
- How each actor is interacting with resources? How actors modify or mobilize the resources?
- For each resource, how the state of resource affects the actors?

Objective
- Identify and characterise the interactions between actors and resources

Source: authors, adapted from Etienne et al, 2011

To answer these questions and fulfill corresponding objectives, T2.4 draw on existing knowledge not only from earlier investigation and CSO's experience, but also from some T2.4 studies available on some specific aspects of socio-ecological dynamics[1]. These EcoAdapt studies gave rise to restitution meetings with the local population, providing the opportunity to start the PARDI process with field visits and local consultation.

However, organizing workshops and being very gradual (one step at a time), as recommended in the original method, appeared not to always be the best way to ensure participation and overcome practical difficulties in the analysis of socio-ecological dynamics. A general methodological process was developed to use PARDI in the framework of the EcoAdapt project (Figure 3), accounting that, in each of the three territories: 1) the MF organisation had already been working for several years, thereby gathering valuable information and knowledge, especially regarding issues, actors and resources, 2) previous tasks of the projects (especially T1.2, T2.1, T2.2, T 2.3) have already generated information and analysis, 3) some stakeholders solicited for these earlier tasks showed some tiredness in being consulted, 4) the organization of workshops and fieldwork faces cost and accessibility difficulties in contexts of poor transport infrastructure (BMCh) or adverse climate events (BMAAM).

The methodological adaptation mainly consisted in reducing the number of workshops and running two steps simultaneously, twice. First, the problematic was formulated in dialogue between MF staff and researcher team, on the basis on existing knowledge. The Actors and the Resources steps were conducted jointly in order to avoid confusion with task 2.3. actors network analysis. The Dynamics and the Interactions steps were also merged to jointly benefit from the generation process of new information with a series of interviews. Finally the construction of the model was done through an iteration of dialogues between the involved researchers, MF staff and local stakeholders.

[1] Other additional studies were also scheduled to take place within the time frame of T2.4. implementation (for more details, see Annexe). Nevertheless, due to time constraints, the results of these studies were not available to be integrated in the dinamic analysis presented in this report but will be integrated in the next step of the project (i.e. modelisation and scenario process).

Figure 3 : General methodological process of PARDI application in EcoAdapt project

	P -	AR-DI	PAR-D-I	PARDI
Objectives	Issue / Problematic definition	Actors and Resources identification	Dynamic and Interaction characterization	Synthesis, **conceptual model** building
Protocol	Ecoadapt Synthesis workshop (+ stakeholders' workshops)	Ecoadapt Synthesis workshop Bibliographical revision (including Ecoadapt materials)	-Workshops -Focus groups -Interviews -Secondary data	-Data analysis - Researcher / BM staff dialogue -Workshops (building or validation)
Main source of Information and knowledge	Mainly based on existing accumulated knowledge from BM and researchers		Mainly based on new information raised from stakeholders	

Source: authors

2.3. Steps and activities of T.2.4.

Task 2.4.was organized as follow:

- Step 1: Definition of methodological orientations

This first step of T2.4. consisted in developing an overall framework for SES analysis and in choosing a core methodology among the different methodological frameworks possible to analyse dynamics of SES, in a collaborative way between researcher and MF staff. This step was done during the Concepcion workshop in May 2012, where interest and limits of 4 methods were discussed. PARDI method was chosen as core method due to its ability to prepare Multi Agent Simulation modelling building planned in the following phase of the project[2]

- Step 2: Development of field research

To launch the field research activities, a generic approach was proposed based on PARDI method (Figure 3) during the EcoAdapt synthesis workshops held in April 2013 in each project

[2] For more detail, see Le Coq and Fallot (2012)

site, where a specific protocol was developed to adapt the generic approach to the local configuration. MF staff existing knowledge has been determinant, as well as its dialogue experience with stakeholders, and its specific interests and demands (Table 1).

In the Chiquitano Model Forest territory, in dialogue with the FCBC, we decided to integrate the resilience framework, as well as the Open Standard Methods (OSPC or *EAPC*)[3], as FCBC already used this method to build conceptual models. Regarding the protocol, a mix of workshops and individual interviews was used to maintain stakeholders' mobilization in an area distant from FCBC office and to capture specific information from stakeholders in a conflictive environment. The research was carried out by a master student, Teresa Aguilar, with the support of FCBC staff members, principally Nelson Pacheco, Mónica Vargas and Romy Cronenbold, under the supervision of the MF team' leader, Roberto Vides-Almonacid.

In Argentina, in coordination with BMJ, a specific socio-economic analysis of impact of climate change (extreme events – draught and flood) as well as a specific perception analysis was included. Regarding the protocol, a focus has been paid on interviews instead of workshops due to difficulties to organize local workshops. However, preliminary results were presented and validated in a final meeting with the stakeholders.The research was carried out with Annabel Rixen, student of Supagro, with the support of Cintia Ruiz of BMJ, under the local supervision of BMJ team coordinator Ralf Schillinger.

In Chile, the protocol focused on the application of PARDI. The research has been mainly developed though workshops as recommended in the original ARDI method. The research was carried out by Lorena Vilugrón, individual consultant related to the BMAAM, with the support of Diego Gonzalez, Claudio Sandoval and Washington Alvarado.
In each research site, one of the researchers involved in T.2.4 came to finalize the models and to help organizing restitutions and redaction of reports (A Fallot in BMCh in late august 2013, JF Le Coq in BMJ in early September 2013 and A Fallot in BMAAM in late September 2013). A specific report was developed in each research sites: in BMCh (Aguilar et al, 2013), in BMJ (Rixen et al, 2013), in BMAAM (Vilugrón et al, 2013).

[3] For more details on integration of EAPC and Resilience tools, see Aguilar et al, 2013.

Table 1: Process and research protocol in each Model Forest

Steps	BMCh	BMJ	BMAAM
P : issue/ problematic formulation	EcoAdapt synthesis workshop + Validation in 2 project local meetings (Santa Cruz and Concepcion)	EcoAdapt synthesis workshop (restitution T.2.2. and T2.3)	EcoAdapt synthesis workshop (restitution T.2.2 and T2.3) + Validation in local stakeholder forum (May 2013).
A and R: Actors and Resources characterization	Visit to communities and immersion in the local context (observation and key persons interviews)	Compilation MF staff knowledge, secondary data and research results from T.2.2 and T.2.4. + specific interviews on Water system functioning	Compilation of MF staff knowledge, secondary data and research results from T.2.2 and T.2.4. + 2 stakeholder workshops (Curacautín and Lonquimay in June 2013)
D and I: Dynamics and Interaction identification	32 Interviews including producers and institutions and direct observation in events and visits and field trips in communities	40 Interviews including producers and institutions, 1 focus groups, and direct observation in events and field trips	Field visits, individual stakeholder consultations and interviews + 2 stakeholder workshops (Curacautín and Lonquimay - 31/07 and 02/08/13)
Conceptual Models construction	Synthesis of D and I step, with integration of MF staff knowledge and dialogue with researchers + practical construction and validation of the model during a stakeholders'' workshop (26/08/2013)	Synthesis of D and I step, with MF Staff knowledge and dialogue with researchers Validation meeting in dam area (5th stakeholders forum 15/09/2013)	Synthesis of D and I steps, with MF Staff knowledge and dialogue with researchers + practical construction and validation of the model during a stakeholders'' workshops in Curacautín and Lonquimay (25 and 27/09/2013

Source: authors

- Step 3: Cross site synthesis

The synthesis was constructed after the 2.4. researchers had travelled to the project sites and participated to the stakeholder meetings where the conceptual models were discussed.
The synthesis basically consisted in drawing parallels between project sites in terms of T2.4 systemic analysis and thereby better characterizing the specificities of each site and the relevance of the analysis there.

Therefore, the present synthesis report (D2.5) not only gives an overview of the main results in each site, inviting to learn more through the reading of site specific reports (edited as EcoAdapt working papers), D2.5 also offer a deeper analysis out of the comparisons of water issue perceptions of local practices and of participation modalities to a sharing-by-learning process such as participatory modelling.

3. Results of the analysis of dynamics of socio-ecological systems

3.1. Problematic: the clarification and formulation of the key issue

In each project sites, the central problematic/issue was defined and formulated to represent the main interests of stakeholders. In all the MF, the issue is water security that is to say a water management issue facing the risk of water scarcity and water quality problems, either actual or in a short or medium term, in a context of multipurpose (often competing) water uses (Table 2).

Issue formulations are quite similar in the three sites, the main variation is related to 1) the nature of the issue, whether it focuses on water quality or quantity, and whether it also considers other resources, 2) the elements of context revealing perceptions of the main causes of the problems, and of where to orientate solutions or of guiding principles for the resolution of the problem (overall objective).

Hence, different levels of attention are given on the water quality issue (and the corresponding contamination problem), and to other resources. In all the MFs, the cause of the problem is perceived as a combination of actors' practices and institutional features. Regarding orientation, the MF puts more or less emphasis on the definition of the principles to solve the issue (e.g. equilibrium between environmental, economic and social balance of desired future).

Another difference between MFs is the degree of actual tensions on resources. Indeed, in the BMCh and the BMJ, the problem of water availability and water quality is already tangible with more or less recurrence (drought and flood) and leading to more or less tensions among actors, whereas in the BMAAM, the water availability and quality problems are not yet tangible, but are raising resulting from legal framework establishing private water rights with priority to land rights.

Table 2 : Problematic/issue in the 3 project sites and limits of the SES

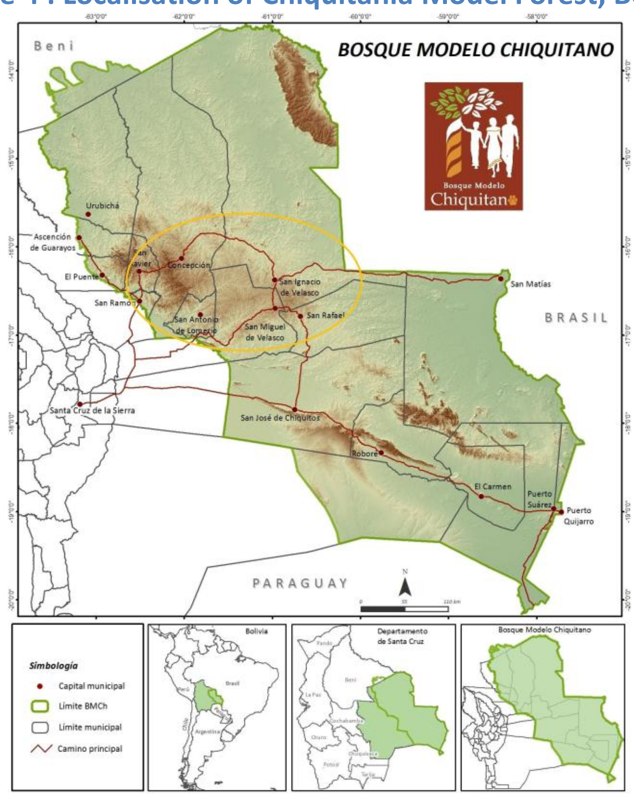
BMCh	**water security for consumption and production**
	How to insure the quality and the availability of the water for human consumption and production for a short and long-term, in a context of institutional weakness in water management, agricultural and animal husbandry expansion and demographical pressure, considered that the dry periods are more and more intense?
	"¿Cómo asegurar tanto calidad como disponibilidad del agua para consumo humano y producción a corto y largo plazo, en un contexto de debilidad institucional en la gestión del agua, expansión agropecuaria y presión demográfica, considerando que los períodos secos son cada vez más largos e intensos? "
BMJ	**water security in equitable and ecological friendly development**
	How to manage the water and the interrelated natural resources to achieve its availability present and future (in quantity and quality) in a equitable way for the different users (y avoid conflicts) in the perspective of a local development process in socio-environmental harmony and minimise the risk of destruction due to extreme events (to persons, economic activities, and infrastructure) in a context of increasing variability and uncertainties climactic (lack of water, excess, change of pattern) and superposition of norms, institutional disarticulation and lack of conscience in the Perico-Manantiales river watershed
	¨¿Cómo gestionar el agua y los recursos naturales vinculados para lograr su disponibilidad actual y futura (cualidad y cantidad) de manera equitativa para los diferentes usuarios (y evitar conflictos) en el marco de un desarrollo local en armonía socio-ambiental y minimizar los riesgos de daños por eventos extremos (persona, actividad económica, infraestructura) en un contexto de mayor variabilidad y incertidumbre climática (escasez, exceso, cambio de estado) y superposición de normas, desarticulados institucional y falta de conciencia en la cuenca del río Perico- Manantiales? "
BMAAM	**Water security for local development**
	How to insure the water availability for the local development in a short and mean term, in a context of increasing demand for the resource , reduction of precipitation of water and snow, and a restrictive legislation for the use and access of water ?
	" ?Cómo asegurar la disponibilidad de agua para el desarrollo local a corto y mediano plazo, en un contexto de mayor demanda por el recurso, disminución en las precipitaciones de agua y nieve, y una legislación restrictiva para el uso y acceso del agua?"

Sources: the authors, derived from Aguilar et al, 2013; Rixen et al, 2013; Vilugrón et al, 2013, Leclerc, 2013.

Along with the definition of the problematic, the limits of the SES to be considered were defined in order to be coherent with the key issue (relevancy) and compatible with implementation mean (modelling feasibility).

For BMCh, as the area of intervention of the FCBC is very large (more than 20 million hectares, Figure 4), it was decided in the early phase of the project to focus on a pilot site, with representative features of the region (growing urban water demand in quality and quantity, and deforestation problem in the upper part of the watershed). The selected site, the Zapocó watershed covers approximately 111.000 ha. An about 20% larger area was considered in the analysis, after integrating a buffer zone with the neighbouring local communities that may contribute to the water issue in Zapocó through land use decisions on the side border of the watershed (Figure 5).

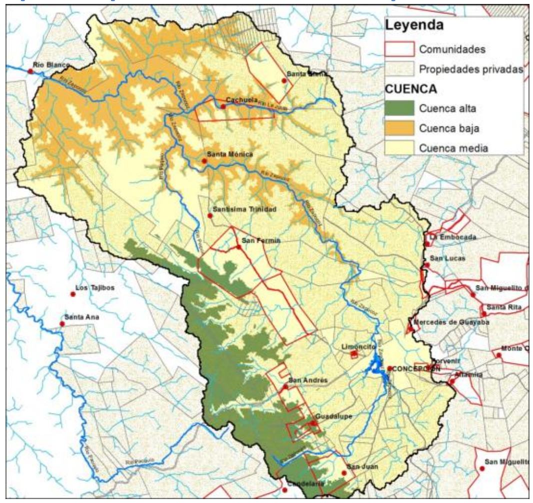
Figure 4 : Localisation of Chiquitania Model Forest, Bolivia



Source: www.bmchiquitano.com

In Zapocó, there is not much slope that clearly distinguishes the upper, the middle and the lower watersheds, respectively in green, light yellow and orange in the map below (Figure 5).

Figure 5 : Map of Zapocó watershed, Chiquitania Forest, Bolivia



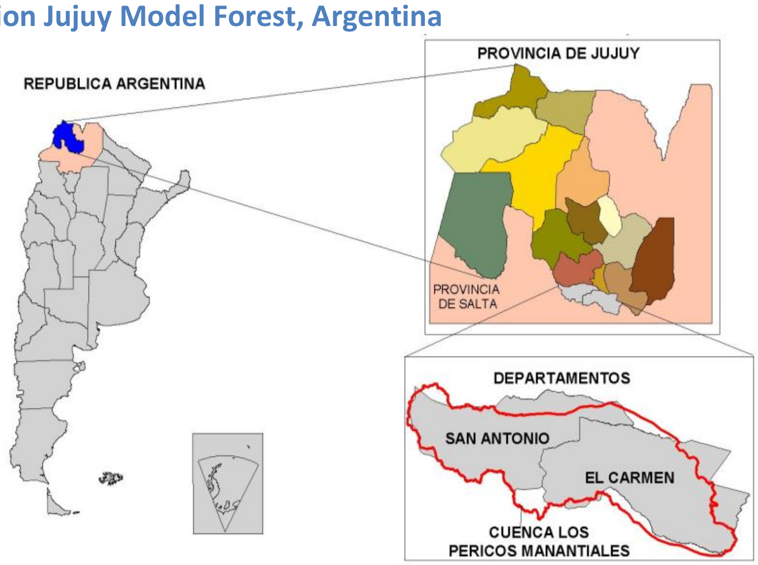
Source: FCBC, 2013

With respect to the water quality and availability issue, Zapocó territory is rather divided between:

- the urban area in Conception and around the town (two neighbour communities of Porvenir and Altamira) where water can be accessed through the urban distribution network;
- the rural area where water is procured from superficial water points (spring, stream, river) or wells with manual or motor pumps.

In BMJ, the whole area of intervention of the BMJ was considered, corresponding to the Perico-Manantiales watershed with approximately 130,000 ha (Figure 6).

Figure 6: Localisation Jujuy Model Forest, Argentina



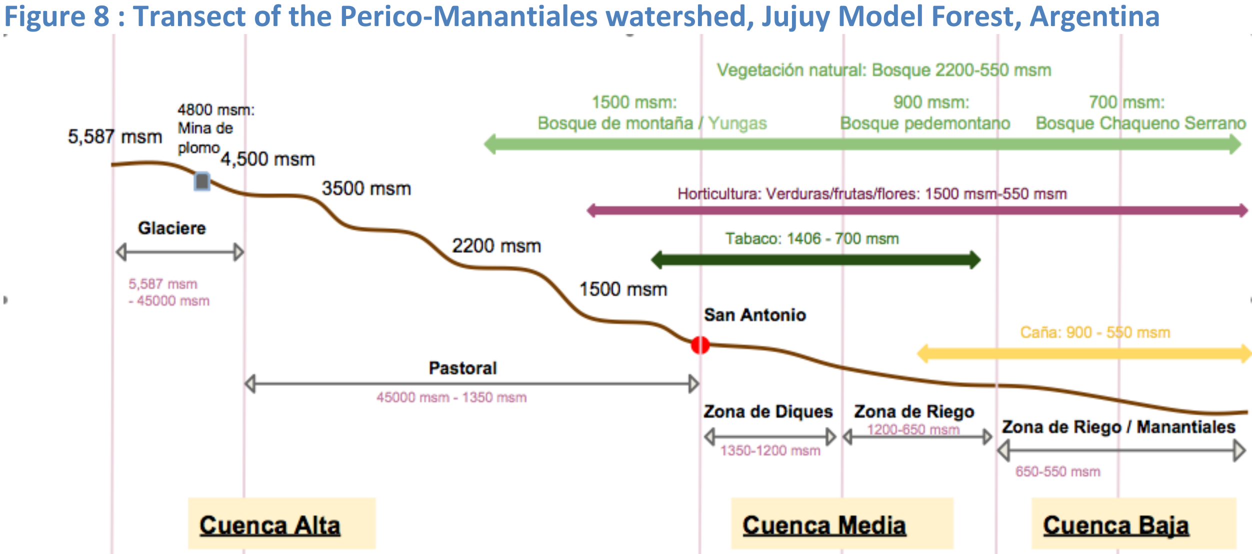
Source: BMJ, 2013

In Jujuy, the upper, middle and lower watersheds are clearly differentiated by their respective altitude levels and corresponding ecosystems (Figure 7 and Figure 8). According to a zoning of the area, specific sub problematics were defined and focussed on: 1) the issue of water contamination in the Dam zone (*zona de Diques*); 2) the issue of water availability and contamination in the lower area; 3) the erosion and sedimentation issues associated with flood risks for the whole watershed.

Figure 7 : Map of Perico-Manantiales watershed, in Jujuy Model Forest, Argentina

Source: Rixen et al, 2013

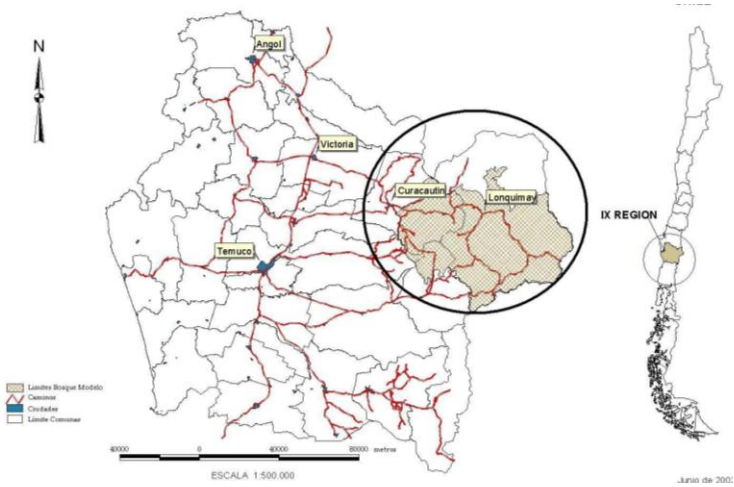
Figure 8 : Transect of the Perico-Manantiales watershed, Jujuy Model Forest, Argentina



Source: Rixen et al, 2013

In BMAAM, the delimitation of the area of reference for PARDI and conceptual model building was more complicated since BMAAM area of intervention is crossing over the upper parts of two large watersheds, the Bio Bio River and the Imperial River (Figure 10).

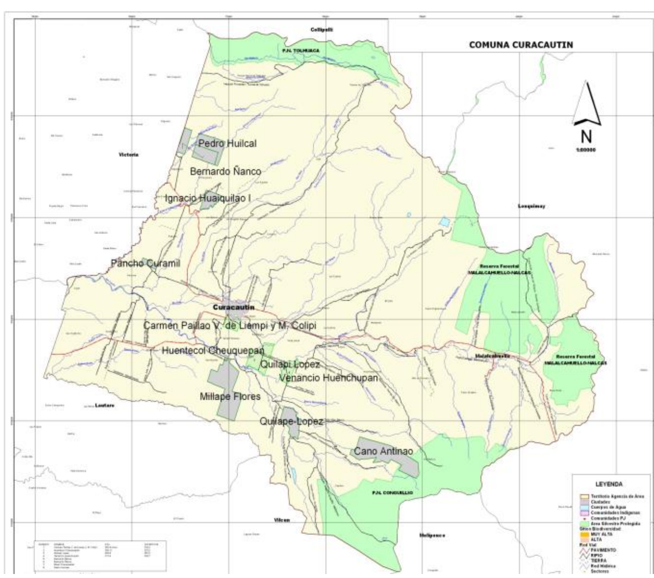
Figure 9 : Localisation of Araucaria Alto Malleco Model Forest, Chile

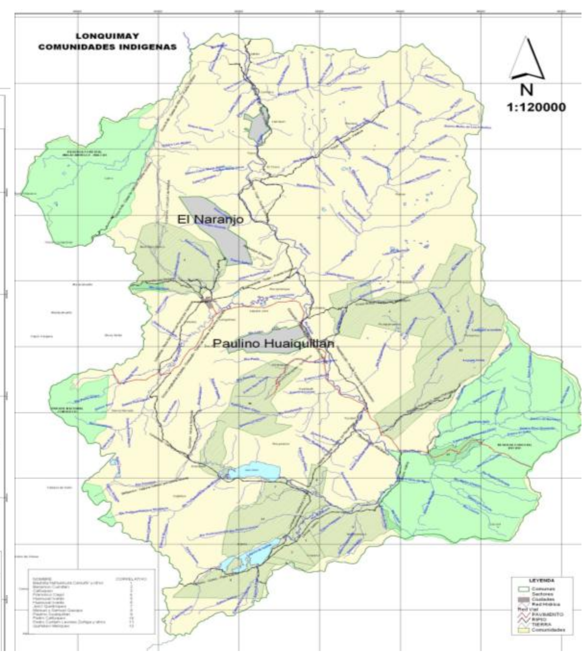


Source: Bosque Modelo Araucarias del Alto Malleco.

Although they cover a large area in total, both territories were considered for strategic coverage from BMAAM. Thus, the conceptual models have been developed twice and in parallel, with the same problematic and a few differences for some productive activities that take place in one territory and not the other.

Figure 10: Maps of Imperial river watershed in Curacautín (left) and of Bio Bio river watershed in Lonquimay (right).





Source: Vilugrón et al, 2013

3.2. The Actors

In each project site, a large list of actors was identified, who contribute to make the formulated problematic a central issue, for suffering water problems, benefitting from water services, intervening in their management, or several of these actions together.

Around 10 to 20 actors or actors categories were identified in each sites (Table 3). According to the specific problematic and purpose of each specific model, actors or groups of actors has been merged during the modelisation process, when they had basically the same action towards the water resource.

Differently from the actors considered in the socio-institutional analysis (T.2.3), actors considered in T2.4 are not necessarily institutions or represented by a formal or informal organization, but rather individuals or groups characterized by their actions towards water and related resources. The actors identified and considered in the analysis of SES (T2.4) are different from those identified by T2.3 also because of the difference of "entry points": the water security issue rather than the network of actors characterize by their cognitive relationships and availability to be "actors of change". These difference led to some confusion at the beginning of the T2.4 process. However, the result of the T2.4 shed light on some new actors and is very complementary to T2.3 results.

In the three cases, we can classify the actors according the same broad categories corresonding to their main functions: water users and polluters, water management and regulating bodies, other institutions acting indirectly. However, some differences can be highlighted between the project sites.

In the BMCh; water user / polluters are mainly rural and urban inhabitants and livestock farmers. Livestock farmers belong to one large action category with very different situations, namely those of large private farmers (*estanciero*) and community-organized subsistence farmers (*comunario*).
In the BMJ, water user / polluter are different according to area (dam area or irrigated area). In the irrigated area, the actors are mainly inhabitants and agricultural sectors organized according production orientation: tobacco, sugarcane, horticulture and animal husbandry.

In the BMAAM, as the water accessibility issue is mainly a legal one and not so much a biophysical one, a category of water owners (which are different from water users) has been added. This category can be broken down according the type of water rights the owner have: consumptive rights (rights to use water, such as for human consumption or agriculture purpose), or no consumptive rights (right to use the energy of water but the water should be returned to the ecosystem afterward, such as the case of hydroelectricity use of water). A category of actors in charge of regulating the water user right has also been added.

Table 3. Main actors contributing to the water security issue in project sites

BMCh	BMJ	BMAM
Water user/polluter - urban and rural inhabitants (consumers) - livestock farmers (*estanciero:* large scale private farmers and *comunario*: subsistence farmers, community organized) - Mine - Wood producers and transformers (*aserradero and carpinteria*) **Water management** - Conception Water cooperative (COSEPCO) - Municipality - OTB (inhabitant representative organization in rural or urban area) - water comity (rural area) **Other institutions / indirect actors** - INRA (agriculture land public regulators) - ABT (forest land public regulator)	**Water user/polluter** - Inhabitant in municipality or new quarter - Agricultural sectors : Tobacco producer (irrigation), Sugarcane producers , vegetable producers, cattle raiser - enterprises : Hidrocuyo, Agua de los Andes - in dam zone : clubs, restaurants, Motorsports, tourists **Other actors** - Moto drivers - Upstream cattle raiser - Gravel extraction enterprise **Water management/ distribution / regulation** - *Consorcio de Riego* (CRVP), -*Agua de los Andes* (drinking water distribution) - Hydraulic Direction (DRPH) - Dam zone manager (*Intendencia de Diques)* **Other institutions / indirect actors** - health services	**Water user/polluter** - Urban users - Rural users - Productive sector: tourism enterprise, agricultural producers (crop, livestock or forest), pisciculture (fish breeding), hydroelectricity **Other actors** - stone extraction enterprise **Water management / distribution** -Agua Auracanias (urban area) -APR comity (rural area) **Other institutions / indirect actors** -Direction of water facilities (DOH) -Sanitary service super intendancy service (SISS) **Water right owners (consumptive, no consumptive)** **Water rights regulation** -Water general direction (DGA) - Tribunal (*juzgado*)

Source: authors

3.3. The Resources

In each research sites, key resources involved in water security issue was identified (Table 4). Thus, in all research sites, the key central resources is water, which has been classified according to its origin or state (precipitation, running water, underground water), its location (upstream, downstream, in dam or micro dam, in irrigation system...) and its different qualities / states (natural water, treated for human consumption, waste water). The water is characterised by parameters such as quantity (described though variable such as water stocks in dam or water flows at different moment of the year in rivers or canal (*caudal*)), and quality (describe though variable such as biologic quality, chemical quality, sediment content, solid waste contamination content).

Following PARDI method, resources interacting directly or indirectly with key resource have been also identified. These resources can be biologic resources (such as cattle, fish, forest, crop land...) or key infrastructure resources (derivation canal, dam/micro dam, canal system, well, treatment facility...).

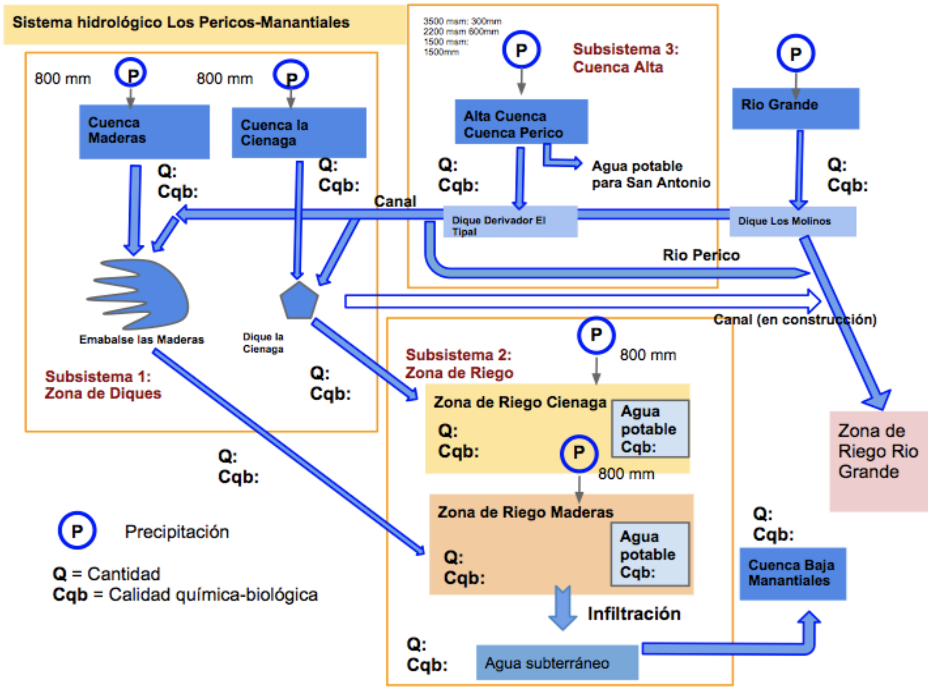
Table 4. Key resources in project sites

resource types	**BMCh**	**BMJ**	**BMAM**
		Water resources	
type of water	- superficial water (spring, stream, river) - subterranean water - waste water	- water of channel from river (*rio Grande and Perico*) - water in the dams (*La Cienaga, Las Maderas*) - water in irrigation system	- superficial water - subterranean water - waste water
criteria	- water flow - water quality (biologic, chemical, sediment)	- water discharge - water biologic quality - water chemical quality - sediment load - inorganic solid waste content	- water flow - water quality (biologic, chemical, sediment)
		Other resources	
biologic	- livestock - forest - crop land	- cattle - forest - crop land	- livestock - forest - crop land
infrastructure	- drinking point - micro dam - dam - well (*pozo, noria*) - water distribution infrastructure (bomb, tubes) - water treatment facility - sewage system* - waste water treatment facilities*	- derivation dam -channel - dams - water protection infrastructure - water distribution infrastructure (bomb, tubes) - water treatment facility	- drinking point - micro dam - well (*pozo, noria*) - water distribution infrastructure (bomb, tubes) - water treatment facility - sewage system* - waste water treatment facilities*

**: in construction*
Source: Authors

Further, the water system functioning was described in project sites according to available data. As in the case of BMJ (Figure 11), this representation enables to understand the dynamics of the resource and the key factors that may affect the state / characteristics of the water resource.

Figure 11. Functioning of water flow, case of Jujuy model forest



Source Rixen et al, 2013

3.4. Dynamics, Interactions, and Conceptual Model

The next step consisted in the identification of the dynamics that affects the SES and the characterisation of the interactions between actors and resource. This information has been organized and systematized in conceptual models according to sub issues or localizations (Table 5).

Table 5 : Conceptual model in the project sites and main sub issue addressed

BMCh	BMJ	BMAAM
Agricultural frontier model (issue of livestock extension leading to deforestation)	water quality in the dam area model (issue of waterwater quality)	water availability biophysical model (issue of water availability)
Rural water model (issue shared uses between human and livestock consumption)	water quantity model in the irrigation area model (issue of water scarcity)	water availability legal model (issue of legal water rights availability)
Urban water model (issue of institutional arrangement for water use, water infrastructure management and critical land use regulation)	erosion / sedimentation model (irrigation efficiency and flood risks issue)	

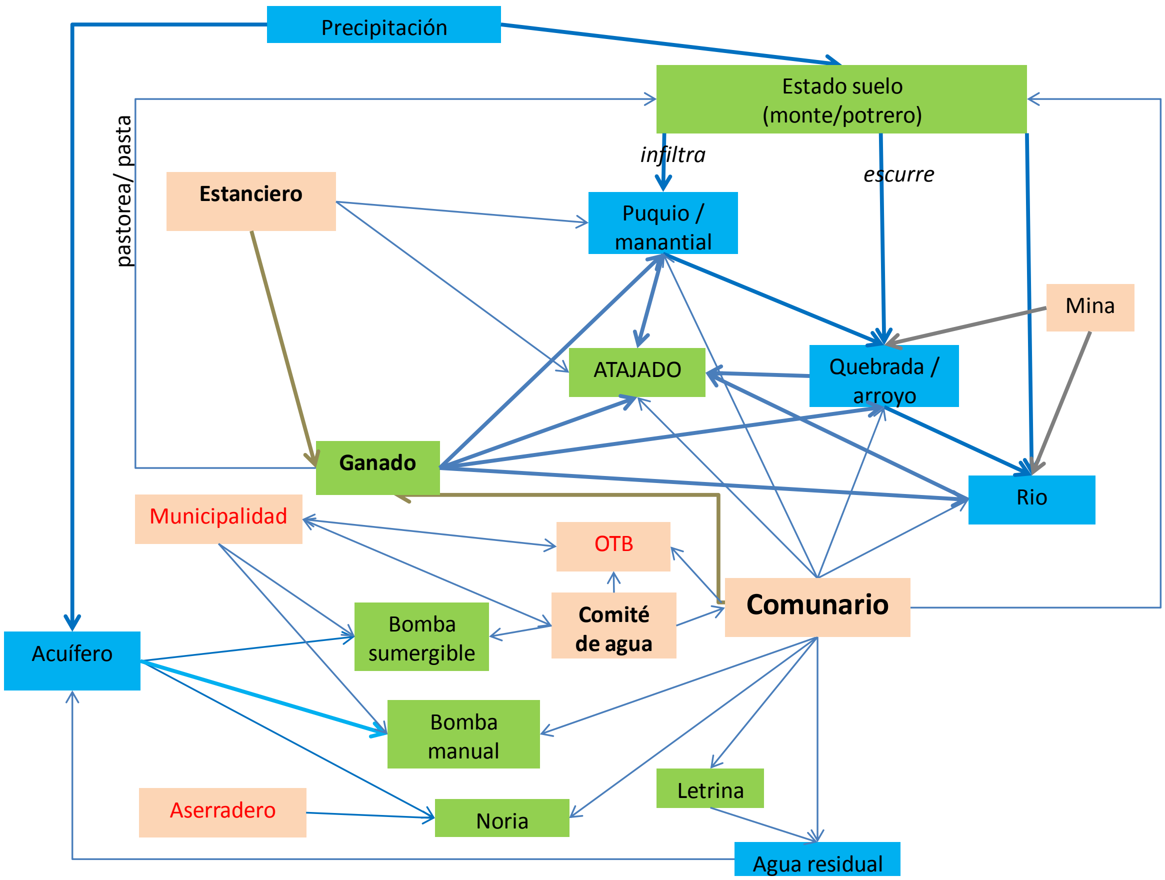
Source: Authors

1. Models of BMCh

In the BMCh, the analysis of socio-ecological dynamics around water security issue led us to successively represent:
- the dynamic context of cattle raising expansion and corresponding land use changes facilitated by unsustainable forest exploitation, all affecting water quality and availability through different processes, involving soil degradation, water extraction and contamination, lack of infrastructure and environmental monitoring;
- the water situation in rural areas where communities have little control of their water sources and face severe quality problems reinforced by lack of knowledge;
- the water situation in the urban area where the two principal institutions in charge of water security locally lack of regulating power on the activities that affect water quality.

<u>Agricultural Frontier</u>
The model representing the interactions that are taking place and explaining the dynamics of the agricultural frontier in Zapocó region (Figure 12) highlights the process of deforestation to raise cattle (*Ganado*) and to sell wood to wood processors (*Aserradero*). Deforestation is allowed and even encouraged by public institutions: 1) the public administeration in charge of agrarian reform (INRA) requires that landowners demonstrate the productive and social functions of their land or it might be confiscated and given to newcomers; 2) the forest authority that is in charge of controlling deforestation processes and that can not handle strong economic incentives in favour of illegal pastures extension and wood extraction. The model also evidence that with the development of livestock, the livestock farmers (*estanciero* or *comunario*) build micro-dams that affect water river, streams or springs, additionally to the erosion and sedimentation processes taking place after deforestation and overgrazing.

Figure 12. Conceptual model of agricultural frontier in Zapocó region



Source: Aguilar et al., 2013

Rural water

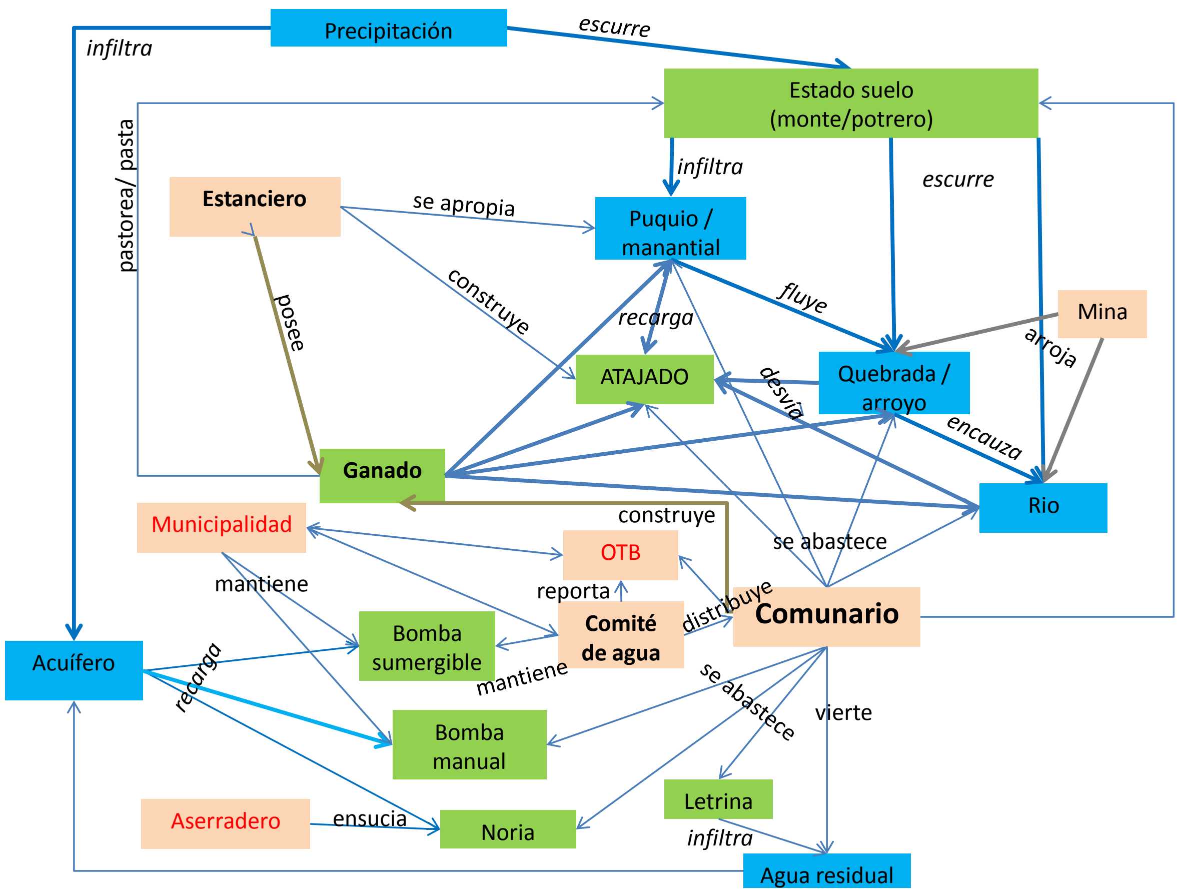
The model of rural water availability characterises the interactions that explain water availability in the rural area of the region of Zapocó (Figure 13). This model highlights the roles of different processes in availability:

- land uses (*estado de suelo*) whether forest *(bosque*) or pasture (*potrero*) affecting the dynamics of available water in springs, streams and rivers through infiltration, or run off;
- the diversity of water sources, either superficial or subterranean, first represented so as to be exhaustive of the possibilities in the Zapocó watershed, then adapted to the contrasted cases of two communities where substitution possibilities are analysed in case of pollution (mine) or disruption (destruction of a stream during wood extraction)
- the possible collective mobilisation of the subterranean water (*acuifero*) or superficial water, for which communities may have benefited from investments in water infrastructures (*atajado, bombas)*, but then go back to traditional unprotected water sources and sometimes share them with livestock, in case of problems with the

infrastructure such as deterioration (tanks), high operating costs (diesel motors), lack of knowledge to use them (chlorine dosage) or dysfunctional management;

- local water comity (*comité de agua*) conformed when water infrastructure were installed and relying on municipality to settle technical problems in providing water to rural inhabitants (*comunario*)
- severe health hazards because of the vicinity of latrines to precarious wells.

Figure 13 : Conceptual model of rural water availability in Zapocó region.



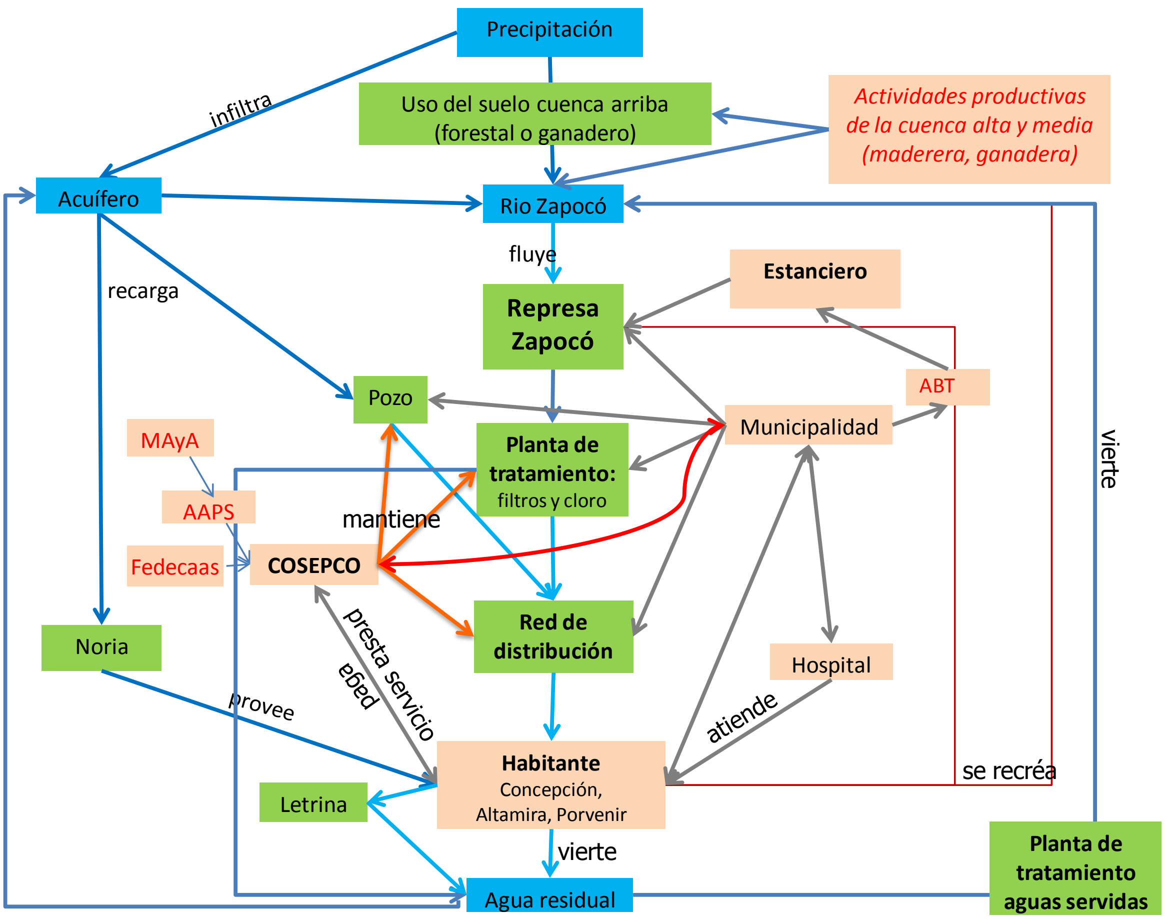
Source: Aguilar et al., 2013

Urban water

The conceptual model of water availability for the urban dwellers (Figure 14) characterizes interactions that affect availability and quality of water to Conception, Altamira and Porvenir inhabitants. It shows the influence on the system of the land use of the upper stage (that is described in the agricultural frontier model), the management of the Zapocó Dam and the water treatment facility by the COSEPCO, as well as the role of complementary sources of water extracted from the subterranean water sources (*noria*).

Variation in distributed water quality can be explained by the different origins of the water:
- the dam out of the river where the water may have been contaminated (livestock on riparian zones, leisure activities or bad practices on wastes) and is treated in an incomplete and archaic plant;
- two wells whose water is less exposed to pollution but not treated in one case.
Water quality is monitored by COSEPCO cooperative which however is not always informed about related health problems, reported by the hospital to the Municipality.
Municipality takes decision on infrastructure whose consequences in terms of maintenance fall back on the cooperative, and must therefore be covered by consumer water payments. In a context of demographic expansion, some inhabitants do not have access to the urban water services or suffer interruptions. Their alternative is digging a well, with the same possible health hazards as in rural comunities.

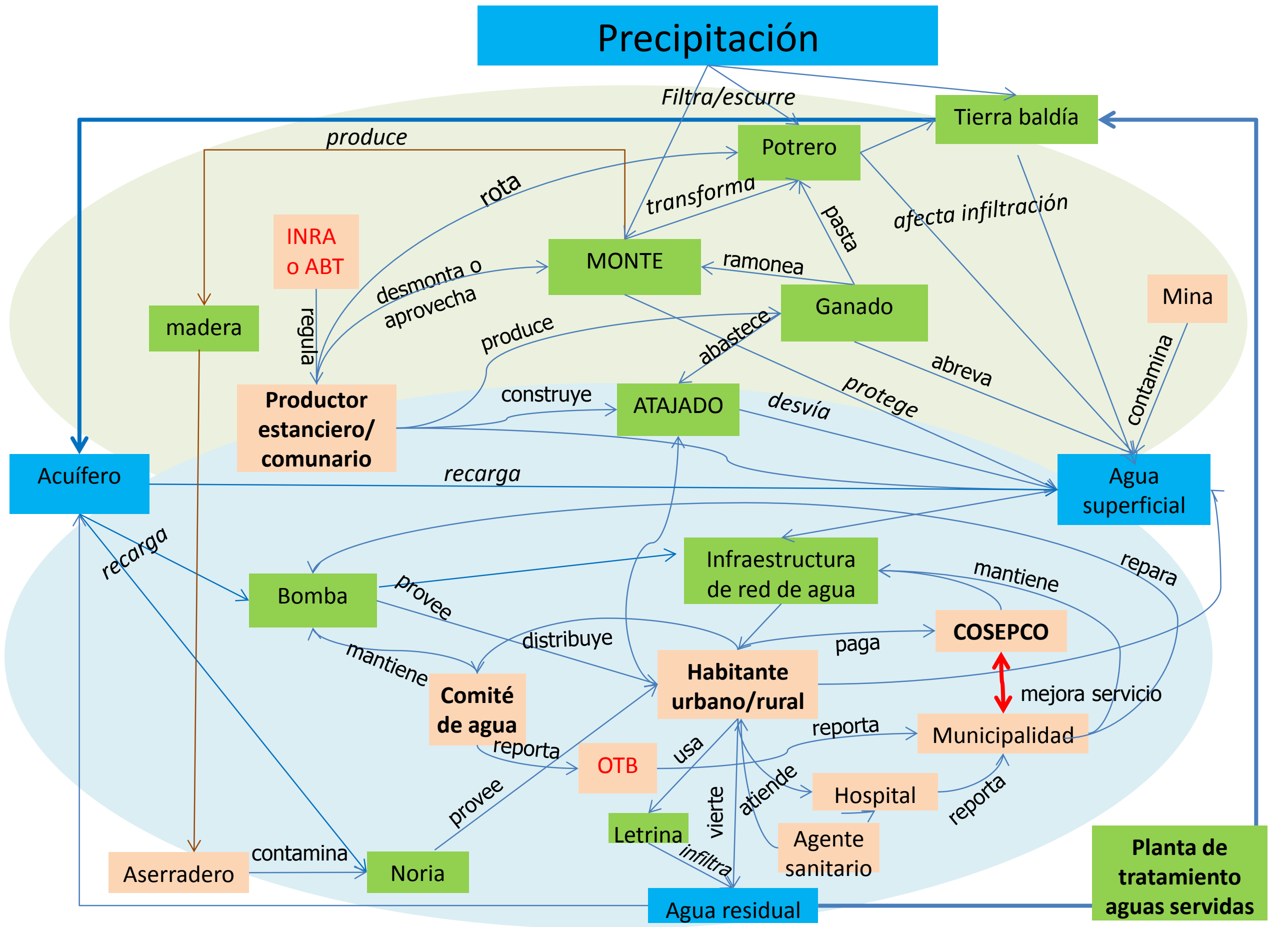
Figure 14 : conceptual model of urban water availability in Zapocó region



Source: Aguilar et al, 2013

Finally, an integrated model has been build (Figure 15). For its complexity, this model is less explicative than the others, its purpose is to visualize how all the processes and interactions analysed before are linked for belonging to the same watershed.

Figure 15 : Integrated conceptual model of water security and availability in Zapocó region



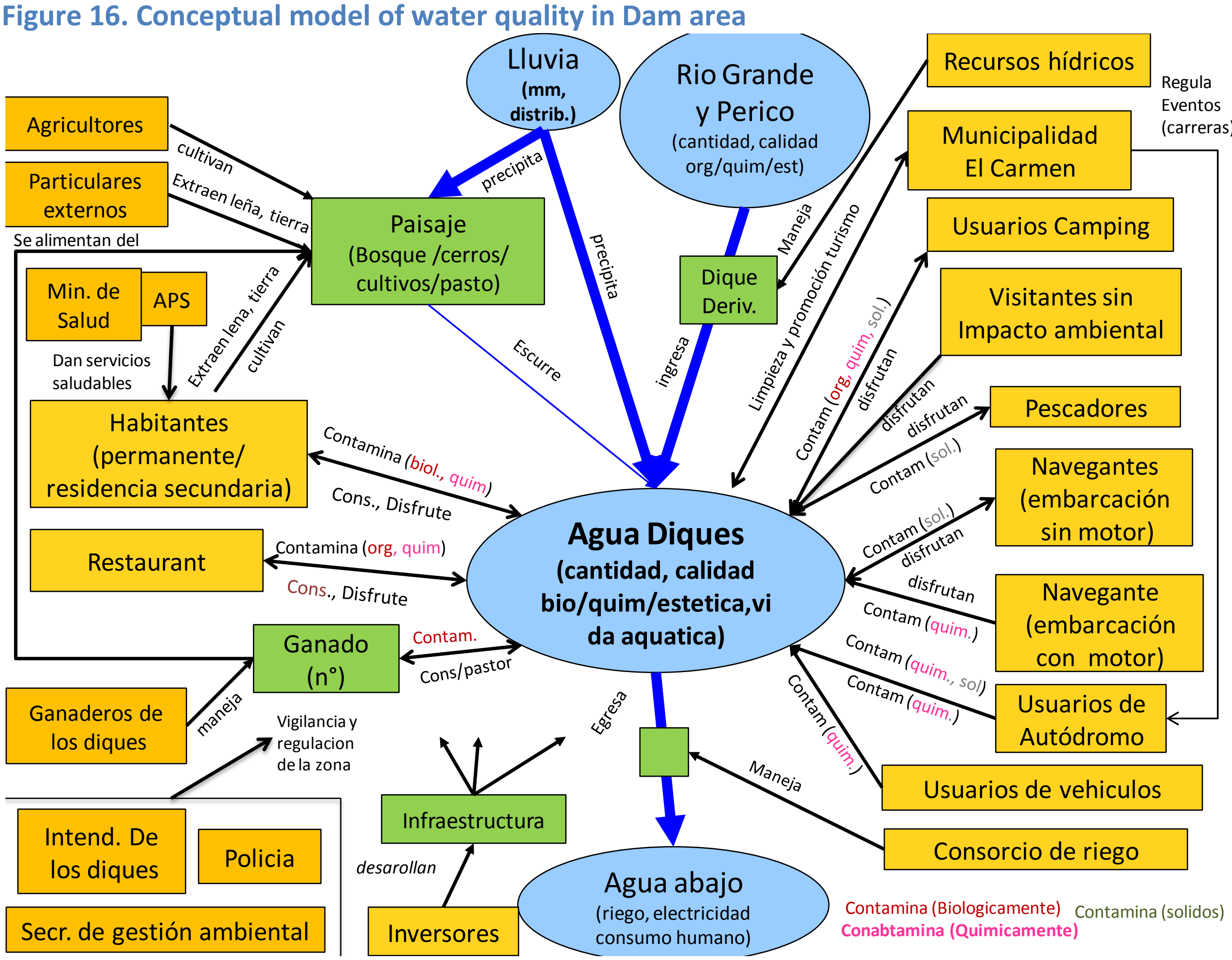
Source: Aguilar et al, 2013.

2. Model of BMJ

In BMJ, three main conceptual models were built, that enable thethe representation of the dynamics and interactions between actors and resource that explain : 1) on water quality (chemical, biologic and solid waste contamination issue) especially in the Dam area where water contamination is a specific issue for further local development, 2) on water availability in quantity especially in the irrigation areas where water scarcity is an stringent issue, and 3) on erosion and sedimentation which affect flood risks and irrigation efficiency.

The model of water quality in Dam area (Figure 16) presents all the contamination sources that dam area users are generating, according to types of contamination. It also shows the importance of regulation / enforcement on the overall system of public actors and downstream actors (Irrigation Water Consortium – CRC in Spanish).

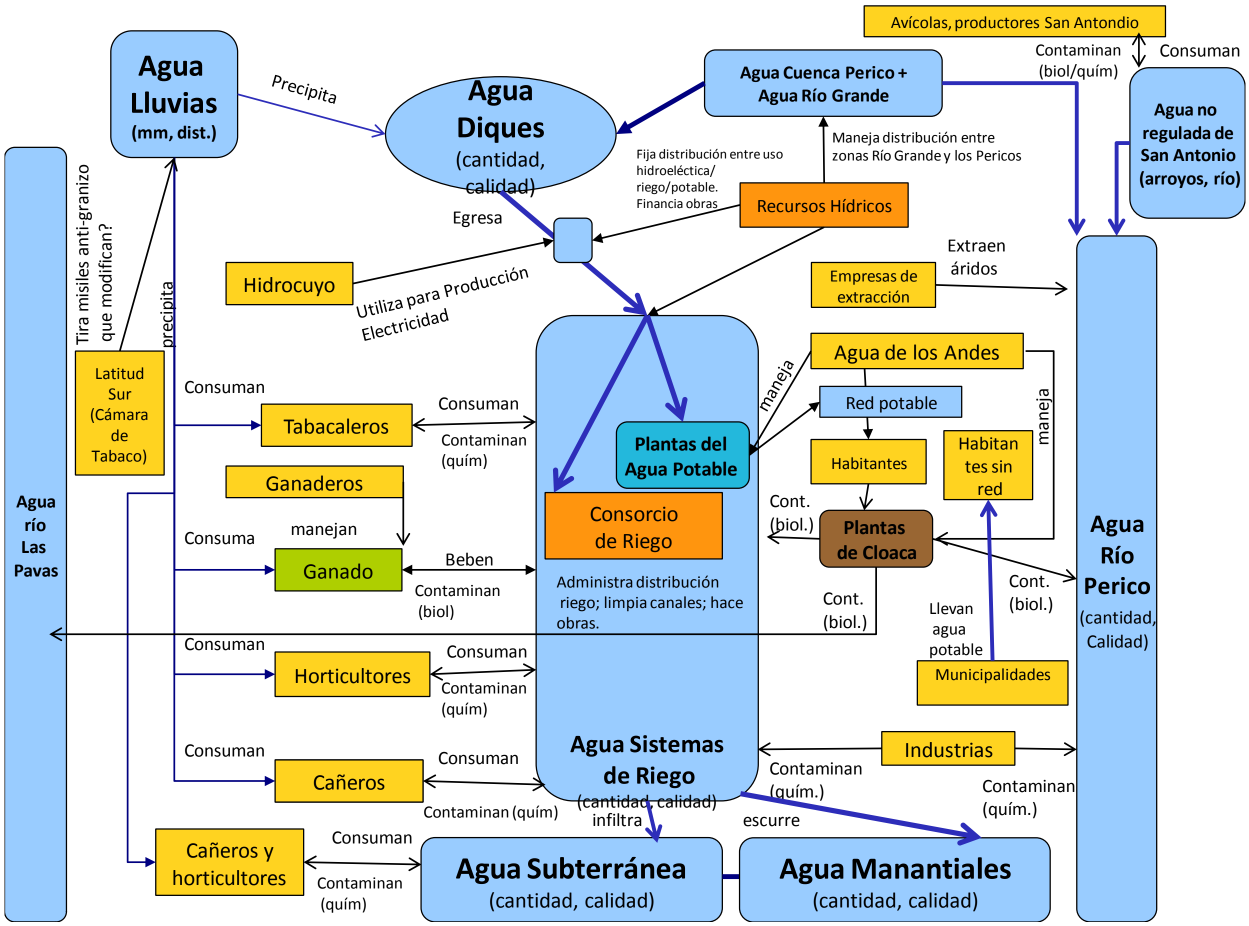
Figure 16. Conceptual model of water quality in Dam area



Source: Rixen et al, 2013

The model of water availability (Figure 17) is specially focused on the irrigation area where water scarcityis already present and competition for water is taking place between human consumption and agricultural production (and among agricultural production between sub sectors, such as tobacco, sugarcane and vegetable production). This model shows the competition between the 2 uses and the dependence from source of water from upstream watershed. It also shows interaction that led to contamination and degradation of water quality.

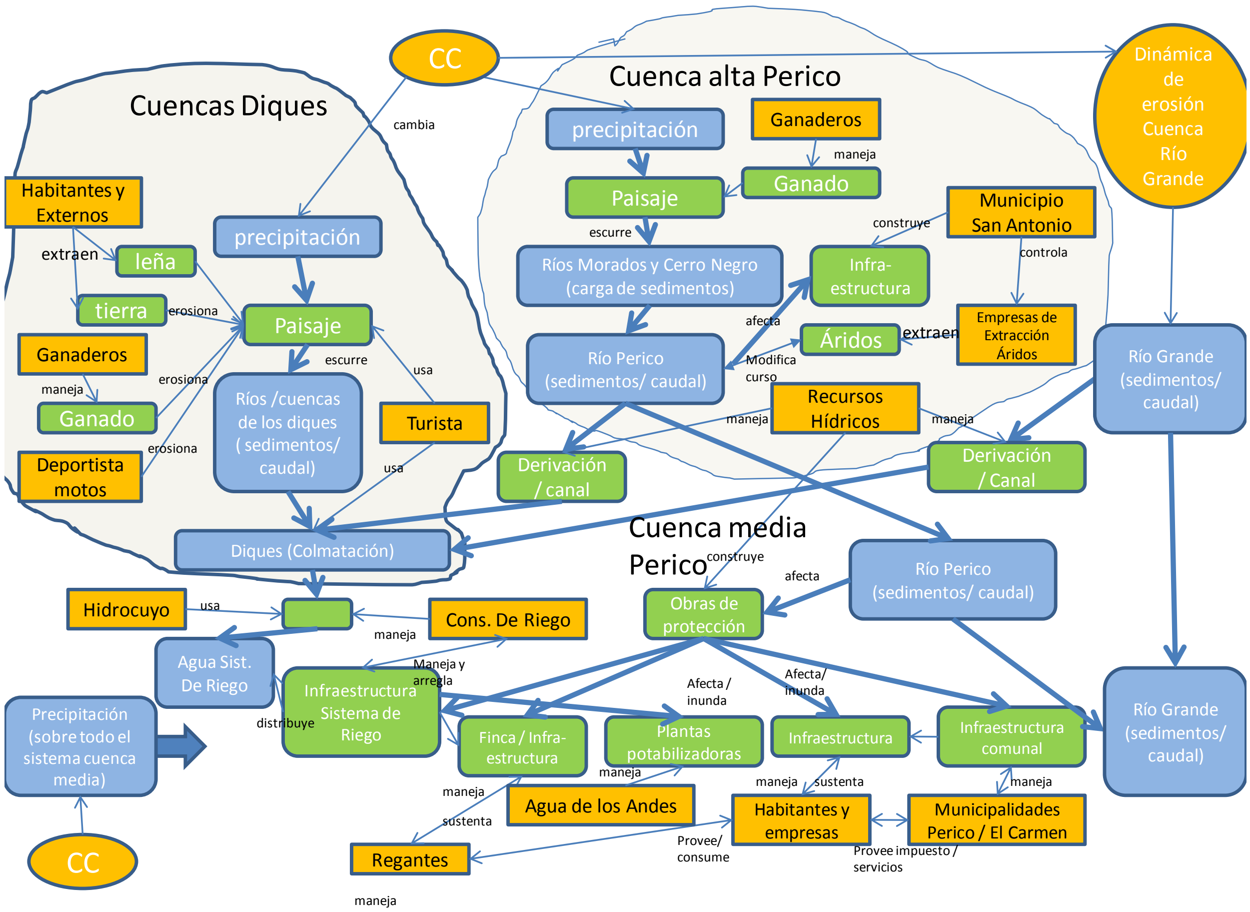
Figure 17. Conceptual model of water availability in irrigation area



Source: Rixen et al, 2013

The model of sedimentation/ erosion characterises the interaction between actors and resources that are affecting sedimentation and erosion process in the whole watershed (Figure 18). It characterise the role of each watershed parts (upper steam of dam zone area, upper stream of Perico river, and Grande River). It also highlights the role of control and management of protection infrastructure that may limit the problem of flooding and the effect on the activities of the population and productive sectors in the Perico downstream area.

Figure 18: Conceptual model of sedimentation / erosion in the Perico-Manantiales watershed



Source: Rixen et al, 2013

3. Model of BMAAM

In the BMAAM, water availability is not only a biophysical issue but also and above all a legal one given that water belongs to the owner of water rights when legally registered. The representation of corresponding dynamics and interactions was therefore done from two perspectives:
- the biophysical one where the PARDI model mainly illustrates the multiplicity of uses and the complementarity of superficial and underground sources;
- the legal one where the model disentangles undergoing regularization processes of water consumptive uses and new developments for the non consumptive use of water.

Given the similar situation of Curacautin and Lonquimay with regards to their common "water for development" problematic, the model structures are the same for both territories, the differences arise from differences in productive activities (aquiculture in Curacautin and not in Lonquimay) and in the origin of water for urban consumption (superficial in Curacautin, undeground in Lonquimay).

In each model there is a kind of double symmetry:
- around superficial water on the top and underground water on the bottom part of the model
- around domestic water consumption on the left and productive activities on the right of the model.

Graphically, the models were built with more emphasis on dynamics and their drivers than in the other sites, see the ovals in the next four figures, reflecting the need to rise awareness on issues to become more serious in the future.

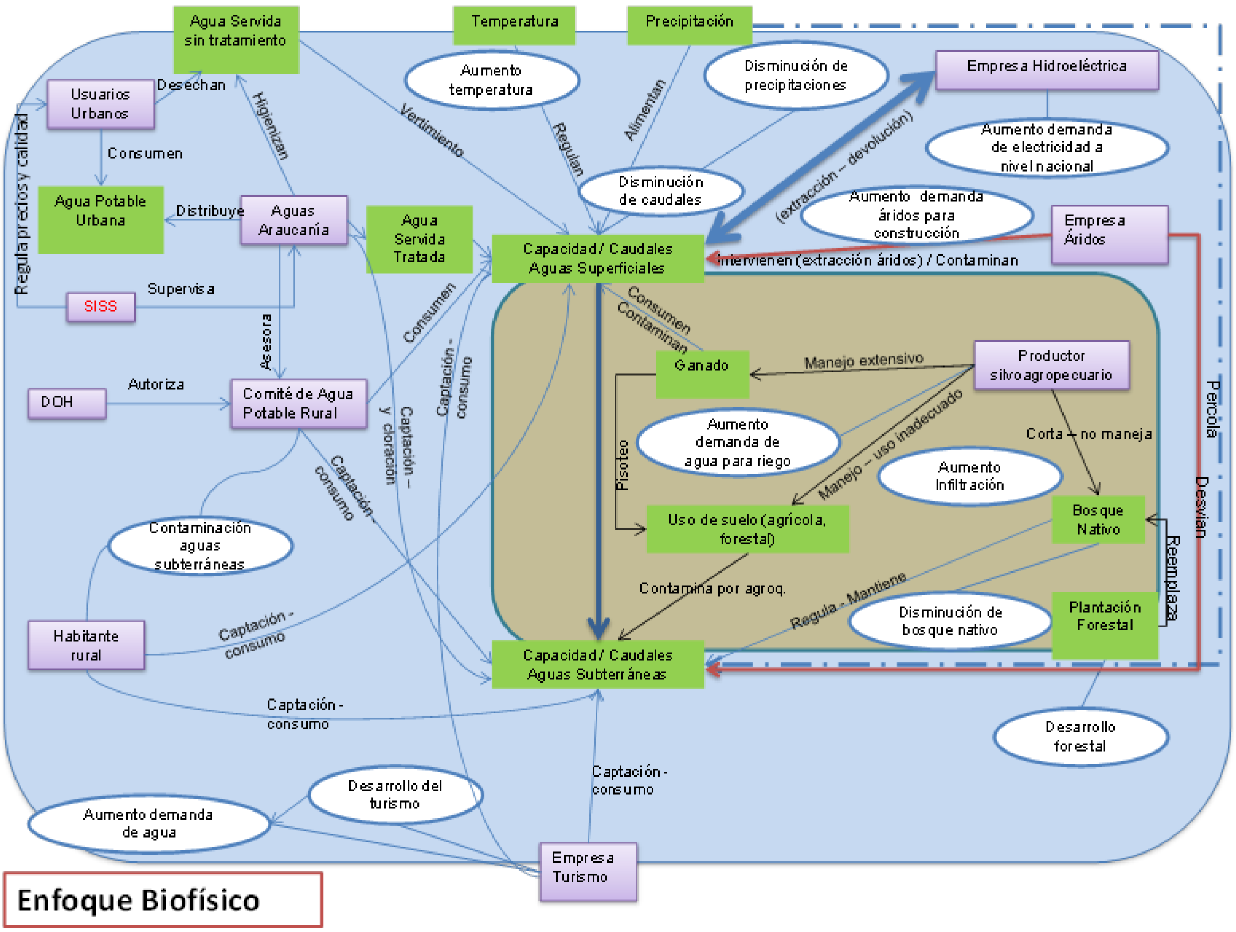
<u>Biophysical perspective in Lonquimay (Figure 19) and Curacautín (Figure 20)</u>

Water availability is determined by climatic variables (*temperatura, precipitacion*) affecting superficial water more directly than underground water.

Superficial waters are solicited and affected in their quality by different productive activities. Forestry plantations, cattle raising and crops consume water which it can also get from underground sources, and affect water quality in case of bad practices only. Stone extraction, aquiculture and hydroelectricity production use the superficial water (from the rivers) and return it downstream with uncertain impacts on its quality, its odour for instance in the case of aquiculture and the environment (waterbeds, native vegetation on the riparian zone…)
Regarding domestic consumption, the representation of urban water system just emphasizes the possibility that wastewater pollute downstream waters. For rural water provision, superficial sources represent the first option, complemented by underground water if necessary.

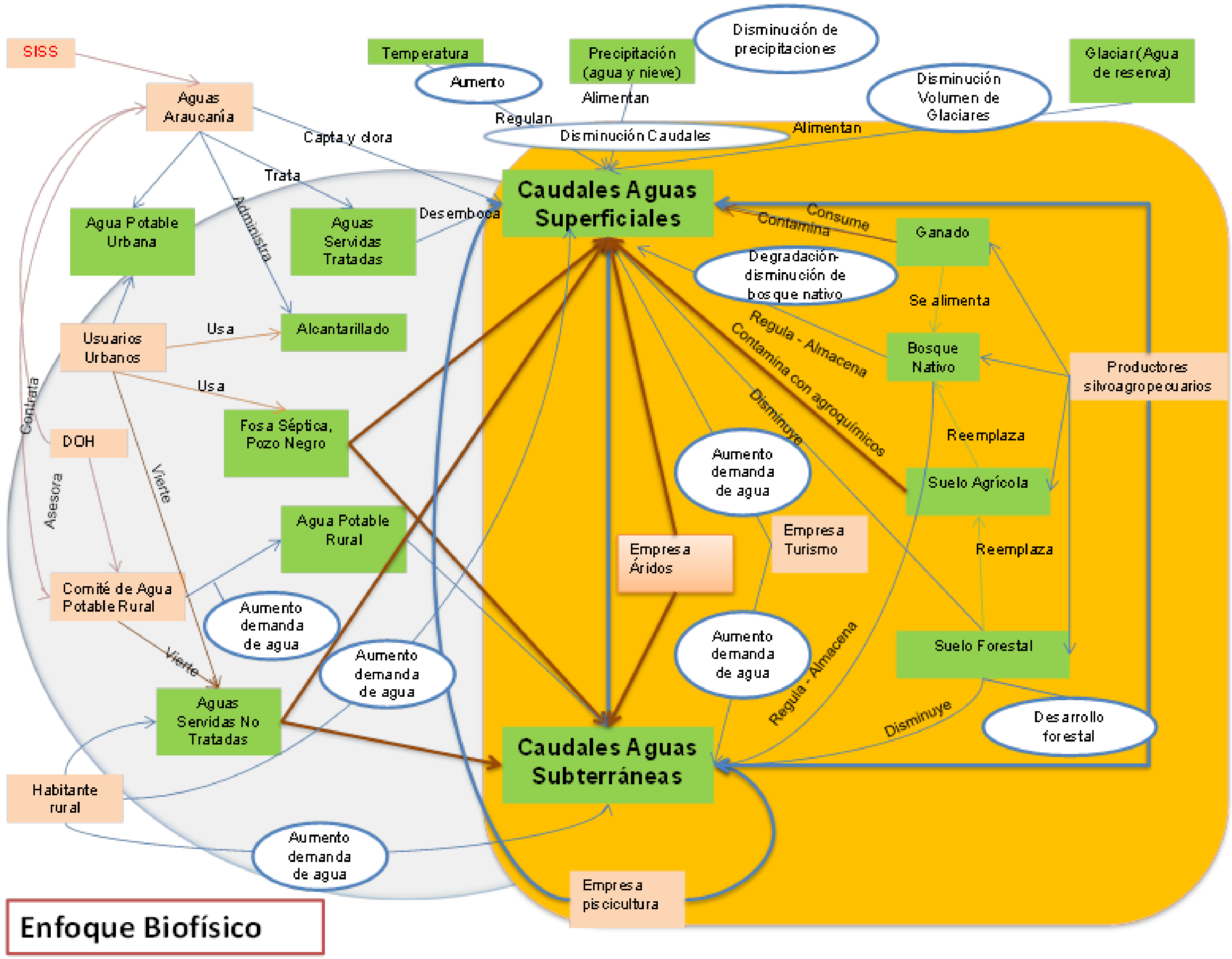
This necessity often arises from the lack of water rights, mainly for newcomers and for tourism developers.

Figure 19. Conceptual model of water biophysical availability in Bio Bio river upper watershed (commune of Lonquimay).



Source: Vilugrón et al, 2013.

Figure 20. Conceptual model of water biophysical availability in Cautín river upper watershed (commune of Curacautín).



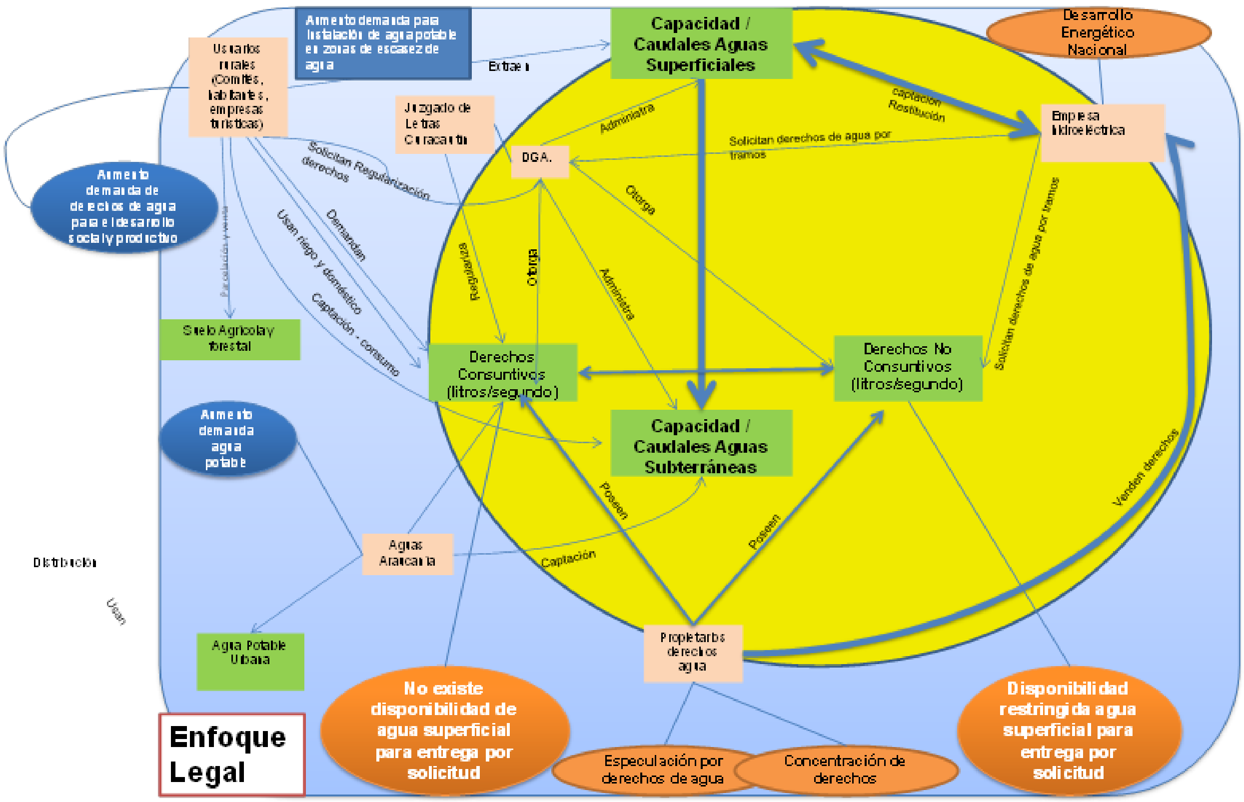
Longuimay (Figure 21) and Curacautín (Figure 22)

The legal models (Figure 21 and Figure 22) describe the characteristics that affect the access of water rights in each river and commune respectively Lonquimay and Curacautín. It illustrates the tension between water rights owners and water users, interested in consumptive uses or non consumptive uses.

Indeed, Water rights are of two types: consumptive and non consumptive. Since the 1981 water code, water rights have been attributed to the people soliciting them after a field verification that they correspond to biophysical availability, with an ecological margin corresponding to non attributable water, and that newly attributed water rights do not affect existing one in the same water flow.

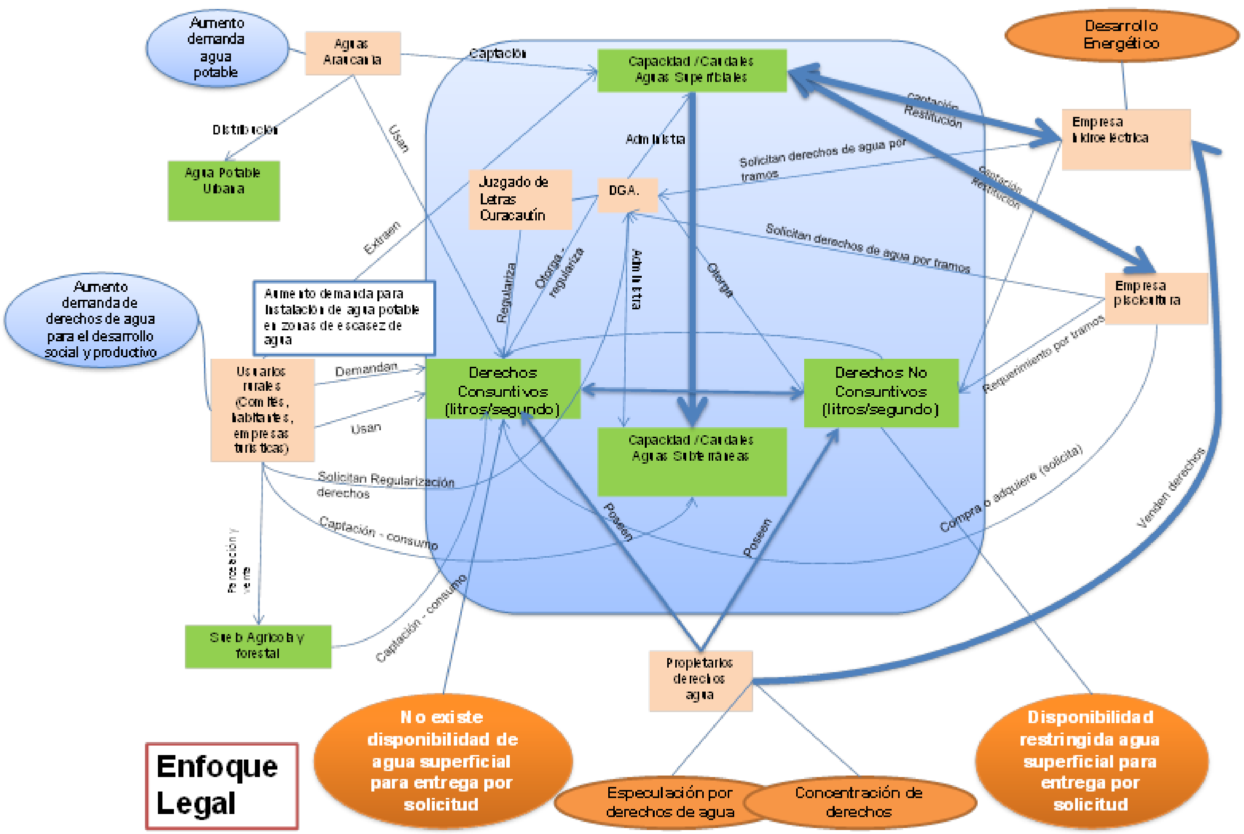
Nowadays, consumptive rights can be regularized to local users proving their presence before 1976, and are not available anymore for newcomers which can hardly buy them since owners expect their investment in water rights to become very profitable with hydroelectric projects.

Figure 21 : Conceptual model of water legal availability in Bio Bio river upper watershed (commune of Lonquimay)



Source: Vilugrón et al, 2013

Figure 22. Conceptual model of water legal availability in Cautín river upper watershed (commune of Curacautín).



Source: Vilugrón et al, 2013

4. Lessons learnt from the process

This section derives some lessons learnt from the implementation of the research process with the MF staff and local stakeholders. It especially focuses on lessons learnt regarding: 1) the learning process, 2) the adaptation of the approach to each specific situation, 3) information issues, and 4) the articulation of methods.

4.1. The learning process during the implementation process activities

In line with the general objective of EcoAdapt, an important factor to be considered in the implementation of the activities is the contribution to learning process, for which different lessons could be learnt.

Firstly, we can highlight the importance of cross site learning for researchers in the implementation of the process. Indeed, as the implementation on each site followed the same pattern (P – AR – DI - PARDI), the implementation of one step in a project site was useful to the other sites. Except for the initial step of the formulation of a shared problematic, the different steps of the process were implemented first in Bolivia, then in Argentina or Chile. Cross learning occurs at different steps of the implementation. At the beginning of the field research and the training on method dedicated to MF staff, a first lesson was derived in Bolivia where the difficulty to develop a full training during the Synthesis workshop emerged and was confirmed during Chile BMAAM synthesis Workshop. Thus in BMJ, the format of the training was adapted. At the stage of the model construction, the models developed in Argentina were mobilized to facilitate the early stage definition of the other models' construction. In particular, the final test of the model validation workshop format in Bolivia was used to define the Chilean workshop and adjust Argentinean Workshops. Moreover, in the overall approach for the building of the Model, raising from experience of the Argentina case, the pre-construction of the model based firstly on the interaction between local responsible of model building (student or consultant), MF staff and researcher was generalized to the project sites. This process of cross site learning that facilitates the fine-tuning of the process was facilitated through regular meeting between researchers in charge of monitoring and support of the task in each research site.

Secondly, we can highlight also an in-site learning process from MF staff and with local stakeholders according to a learning-by-sharing process. At the beginning of the implementation of the task, two main challenges were 1) to develop learning process on the method of conceptual model building (using PARDI method) and 2) develop sound models that enable further understanding of the region by MF staff and local stakeholders to set the base for scenario building (WP3). Working with teams that consist with 1 or 2 MF staff and a specific person in charge, facilitates the learning process about PARDI method in the MF staff, which alone cannot fully manage the method and if necessary use it for other issue. In many cases, the knowledge of the MF staff was already important but the main interest of the PARDI conceptual method were to integrate this knowledge (in the model), and to share the integrated knowledge with local stakeholders (case of BMJ), or to facilitate collective learning process during workshops (case of BMCh and BMAAM).

Although some evidence of learning process can be identified from experience, a more systematic measure of learning process during the implementation process of EcoAdapt could be achieved. A specific interview dedicated to MF staff and on Stakeholders' participant to workshop could help to grasp more specifically what they consider they have learned from the experience (at each step of the EcoAdapt Process). This has to be integrated in EcoAdapt M&E strategy.

4.2. One principle, different processes: Different forms of participatory modelling

As a key principle of the project, a participative approach has been a key principle for implementation of the T2.4. In particular, the shared decision between MF and research staff was to follow the principle of participatory modelling to get a fair level of ownership of the final outcome. However, the implementation of this principle was very different according to MF suggesting to revise and discuss the principle of participation and the local conditions that influence in the form of participatory building (Table 6).

Table 6. Characteristics of implementation context of T.2.4. and participatory forms adopted

	BMCh	BMJ	BMAAM
Characteristics of the implementation			
MF knowledge level	important but not specific territories	important knowledge (mainly technical)	limited knowledge
MF staff work habit	Workshop participatory	workshop (awareness raising)	workshop
MF position in the territory	far	inside	moderate far
MF staff number	moderate	limited	very limited
tension between stakeholders	potentially high	regular	regular
form of participation mobilized			
stakeholders workshop intensity and form	used for information elicitation and collective construction	used for validation mainly	systematic use of stakeholders workshops for elicitation and construction
type of participation	active	reactive	active

Source: Authors

In the Bolivian project site, the MF staffs have accumulated a large knowledge and information on the BMCh level, but were lacking of specific information on the local site (Zapocó Watershed). They are used to mobilize participatory methods for many purposes to diffuse information, or to elicit information, such as stakeholder workshops. At the beginning of the project, there were locally almost no information sharing and decision making stakeholders' forum in the specific local sites. In this project site, participatory principles have then been adjusted to this situation. A specific attention has been paid to strengthen the process of consolidation of a stakeholder forum (or platform) (*grupo impulsor*). A mix of workshops and interviews has been used to maintain information flow toward and from stakeholders, and creation of specific information.

In Argentina project site, MF staff is centred in the research site territory and have accumulated a large specific knowledge. The MF staff has work habits oriented to awareness raising workshops (diffusion, capacity building workshop) In this context, incorporation of stakeholders' knowledge has been done mainly indirectly by the MF staff and researcher though interviews. The collective stakeholders' workshop has been conducted in a more reactive way based on proposal made by MF / researcher staff.

In Chile project site, the MF staff number is more limited, the knowledge accumulated is more limited and not explicit. In this case, especially due to human resource limitation, stakeholders' workshops have been used systematically as the more efficient way to elicit information and share information with stakeholders.

Finally, we can conclude that:

- Modality of participatory co-construction need to be adjust to condition in a constant dialogue with MF staff
- The participatory process should be adapted taking into account three main factors of the context : the partners knowledge, experience/habit practice of participation and competencie.

4.3. The issue of information

As "filling the knowledge gaps" is the objective of EcoAdapt WP2, T2.4 should contribute to this objective. Implementing process of T2.4, including participatory modelling, allowed to draw some lessons regarding this issue.

First, in many cases much information already exists either at MF staff level or at institutional level, the conceptual model is more a way to structuring the information rather than filling the gaps.

Second, even if much information exists, their availability is an issue. Finally, access to information is time and energy consuming. In particular, in BMJ much effort has been put by MF staff and research to access existing data from organization or institutions, which resulted in frustration in many cases. In any case, it also reveals the lack of existing structures that are collecting and managing information potentially useful for grasping evolution of the SES.

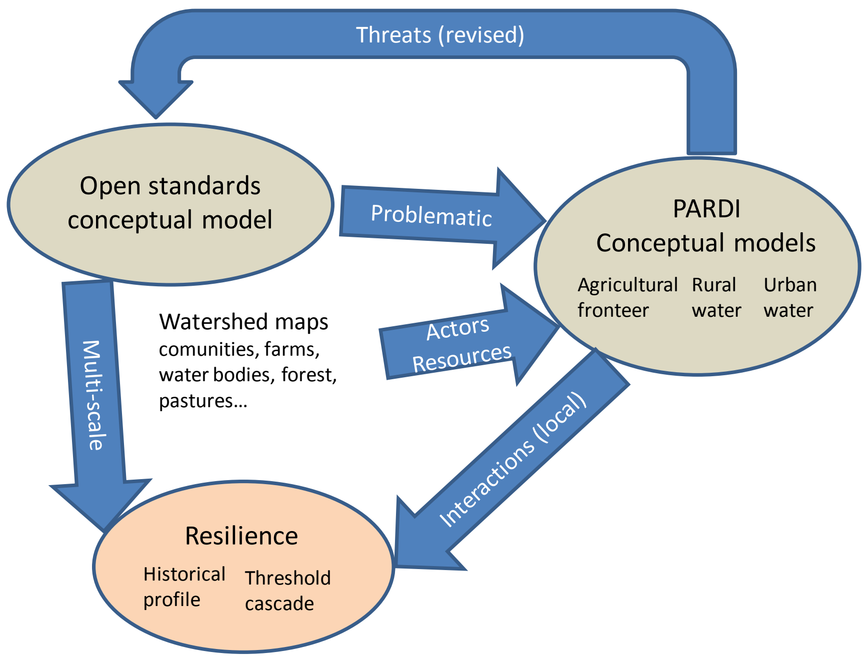
Third, the systematic approach of structuring information and building a conceptual models helps to identify further information gaps for further activities of the project. The information gaps could be on different types: on climate/hydrology, on interaction processes, on dynamics, on actors' activities and results.

4.5. Articulating methods

From the implementation process of Task 2.4 and the construction of conceptual models, we can derive lessons on the articulation of different methods. Two main "articulation" of methods have been explored: 1) OSPC, PARDI method and resilience framework, 2) Fuzzy conceptual model and PARDI conceptual models

The OSPC /PARDI / Resilience approach was one the methodological challenge of implementation in the BMCh where OSPC has been already used to characterize problems of the region. The integration of the different methods enables to facilitate the implementation of PARDI, and led to refine some elements analysed in the OSPC methods such as the threats. Both, PARDI and OSPC also contributed to provide elements of resilience framework (Figure 23).

Figure 23. Relationship between PARDI, OSPC and Resilience approach



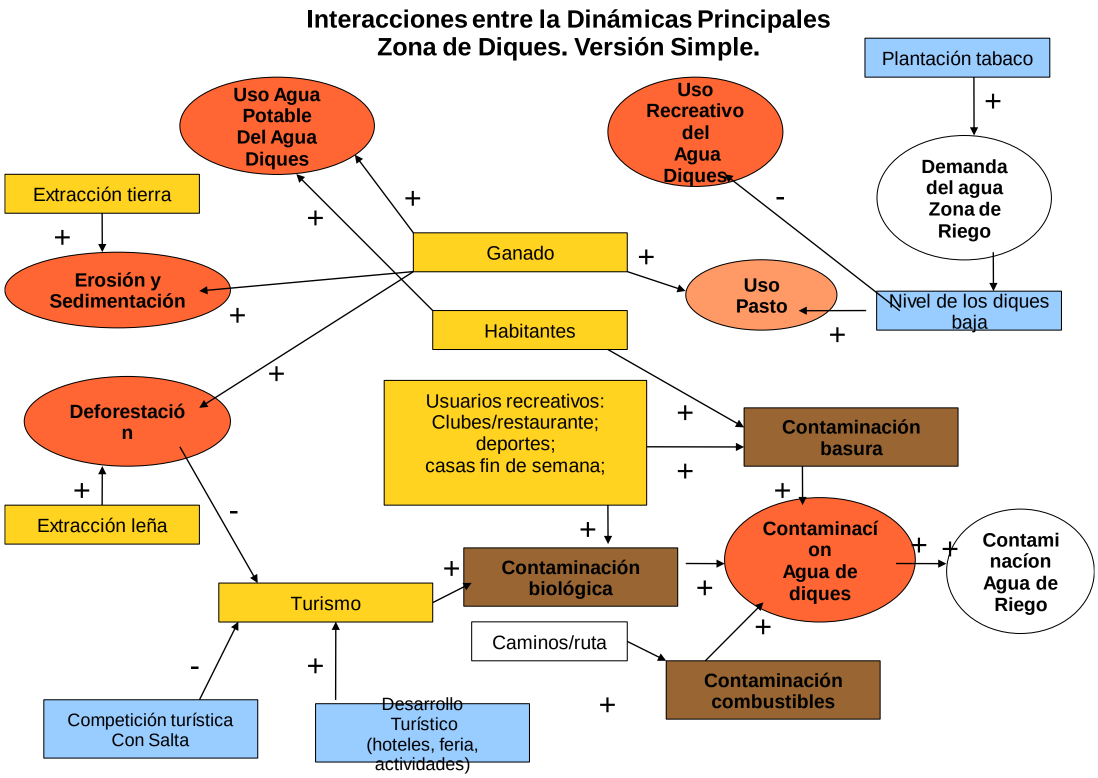
Source: Aguilar et al., 2013.

There are many ways to represent the interaction in SES as conceptual models. In T.2.4, especially in BMJ, two main types of representation have been built. During the process of conceptual model building, a mixed representation merging 1) actors oriented model (PARDI like) and 2) dynamic oriented model (Fuzzy Cognitive Mapping like) have been built (Figure 24).

The first one is a representation adapted to Agent-based modelling (Etienne et al, 2011). It focuses on actors heuristics about managing a resource, and pays less attention to linking external dynamics (such as deforestation, tourism development…)

The second one is derived from Fuzzy Cognitive Maps (Kok, 2008). It pays attention to the process and their interactions, but does not put emphasis on who is carrying out those processes.

Figure 24. Conceptual models mixed from PARDI and Fuzzy representation (a case in BMJ)



Source: Rixen et al, 2013

The process of implementation shows that

- information gathered to build Actors-based representation can be readily used to build process-based representation,
- both representations help to grasp the dynamics and catalyze reflection on the dynamics or actions that influence evolution of the SES.

5. Discussion

This section synthesizes results on dynamics of SES according to 1) the characterisation of the type of dynamics, 2) drivers of changes of the SES, and 3) spatial configuration of ressources and actors in territories.

5.1. Characterization of dynamic of SES or analysis of SES functioning

Using the PARDI method to analyse the dynamics of SES led to focus more on the functioning of SES (especially though the conceptual model building) than on a characterisation of the dynamics of SES.

To reduce these shortcomings, we developed historical analyses though time lines or historical profiles in the different project sites. Preliminary analysis of the long-term dynamics enables to characterize general dynamics types and specific situations.

BMCh is characterized by a dynamic of agricultural frontier driven by agriculture expansion. The level of intensification of the agriculture is limited (extensive cattle raising).

In BMJ, the SES is characterized by an intensification in the lower part of the watershed towards high value, labour and capital intensive crop (e.g. tobacco). The high artificialization of the ecosystem with important infrastructure (dam, irrigation system, missiles to reduce the risk of hail) to overcome the limits of ecosystem and reduce climatic risks. The system already exhibits signs of having reached the limit of current infrastructure level. Emergency for drought has been declared 2 times in the last 10 years, and the Jujuy region experiences a severe problem of water scarcity (*emergencia hidrica*) in 2013. However in comparison with the case of BMCh, the use of subterranean water is still very limited yet.

5.2. Drivers of changes, specific threats and Climate change variable

As stated in the general conceptual framework (Figure 1), dynamics of SES are not only driven by CC but also by other factors. In the project sites, differentdrivers of SES have been identified such as agricultural market demand and price of products, demography, etc. (Table 7). These drivers can evolve in a continuous way (such as gradual demographic increase), or create specific shocks (price crisis). Moreover, some specifics threats can be identified that could change drastically the structure of functioning of the SES, such as new infrastructures development (e.g. the new irrigation channel in Jujuy may increase drastically pressure on water availability, or the project for a new dam in BMAAM), or political changes that may affect the socio-system.

Thus, the relative importance of Climate Change as a key driver of local SES seems to be different according to the MF. In BMCh and BMJ, climate change variables (such as change of pattern of water precipitation) are leading or can lead to severe socio-economic problems in the area.

Table 7. Drivers of change in SES in project sites, specific threats and relative importance of CC in the system

	BMCh	BMJ	BMAM
Socio-economical drivers			
Market demand and price	meat and wood	sugar cane / tobacco	salmon
Demographic (pop growth rate)	strong (rapid immigration)	moderate (population increase)	moderate
Energy demand	very limited	moderate	strong potential increase
Climate change	important (recurrent draught in dry season)	Important (dry/flood) other climatic risks (hailstones, late ice period)	limited
Specific structural threats	no specific	in dam area : installation of large touristic investment in irrigated area: new channel to serve other irrigated areas	Dam construction perspective

Source: authors

5.3. Spatial configuration of ressources and actors in territories

The configuration of actors and resources distribution change the dynamic of SES and the possible orientation to respond to CC issue. In particular two factors, the asymmetries of resources and power between actors of the different parts of the watershed (upper, middle and lower parts) as well as the asymmetry among actors inside each part are key elements when building an adaptation strategy.

For example, in the BMJ, SES functioning and dynamics analysis shows that there is an important asymmetry between upper part of watershed (very low population density, no public or private representative organizations) and the lower part of watershed (high population density, economic and social activities and power ...). The power of actors of the upper part is very limited, as their direct influence on the lower part of watershed is inexistent. Thus, the local decisions are weighted on securing the situation of actors of the lower part of the watershed.

BMCh offers another configuration where upper, middle and lower part of the watershed are similar in terms of population density, but where powerful upstream actors have direct and important influence on the resource (though land use and micro dams). With clear economic and power asymmetries between actors of upper, middle and lower part of watersheds, the collective management of resources is more tricky and require important conciliation process (as any can imply on the others).

Further cross analysis of the configuration of the actors and resources distribution will provide interesting insights to the reflexion on the building process of adaption to CC and its implication regarding equity.

6. Conclusion and further steps

The analysis of the dynamics of SES enables formulate clearly a problematic that can mobilize local stakeholders to further develop collective action and collective reflexion on adaption to CC. Moreover, the important actors for using and managing water were identified and their decision rules on the way they interact with resources were evidenced. Conceptual models were built in each territory that enable to present the interaction between actors and resources, and further prepare scenario building and simulation modelling for designing an adaptation strategy. PARDI conceptual models will be translated to UML (Universal Modeling Language), as a start for specific Multi-agent models. In the BMJ case, fuzzy cognitive maps have been developed, which will be ported to iModeler for qualitative-quantitative modelling.

Regarding the methodological process, we have been able to test the application of the PARDI method in different sites, which benefited from cross sites learning process as well as learning-by-sharingamong the local stakeholders and the MF staff. Moreover, regarding the collaboration process in the project, these activities have strengthened the relationships between researchers' team and MF though the adjustment of the methodology and co-construction of models.

The process enabled to organize existing information and filling some information gaps, as well as to identify more clearly new information gaps. Further activities can be developed to further fill these gaps, to better understand and compare different situations accross project areas regarding dynamics and possible evolutions in a context of climate change.

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Annexe

Table: Complementary studies of T.2.4.

BMCh	BMJ	BMAAM
Impact study of agricultural and animal husbandry practices	Analysis of contamination in am zone	Historical analysis of the landscape
Inventory and systematization of analogous ecoregions	Study of climate variability	Historical study of river flows
Geospatial inventory of the sediment production	Actualization of irrigation datas	Recent climate evolution study
tipology of management and sediment production	Case study of policy in dam zone	Forest hydrology modelling
Hidrogeological study		

Source : POA 2013

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